INCT for Climate Change Phase 2
(INCT MC2)

Deslizamento de terra na Barra do Sahy, em São Sebastião. É o modelo da desigualdade que mata, não a chuva

Ref: FAPESP 2014/50848-9
CNPq 465501/2014-1
CAPES 88887.136402/2017-00
INCT-MCTI/CNPq/CAPES/FAPs 16/204

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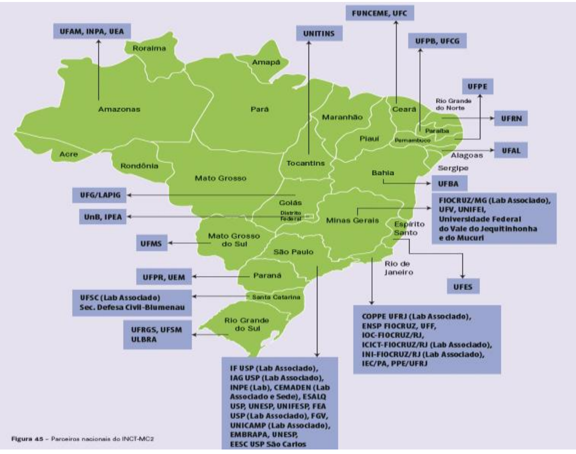
CEMADEN/MCTI

SUMMARY

1. Overview

The INCT for Climate Change Phase 2 (INCT MC2) aims to implement and develop a comprehensive network of interdisciplinary research on global change and sustainability, and is based on the cooperation between about 30 research groups from all regions of Brazil from various national international research groups, involving in its entirety over approximately 350 researchers, students and collaborators and establishing itself as one of the largest networks of environmental research developed in Brazil (Figure 1.1)



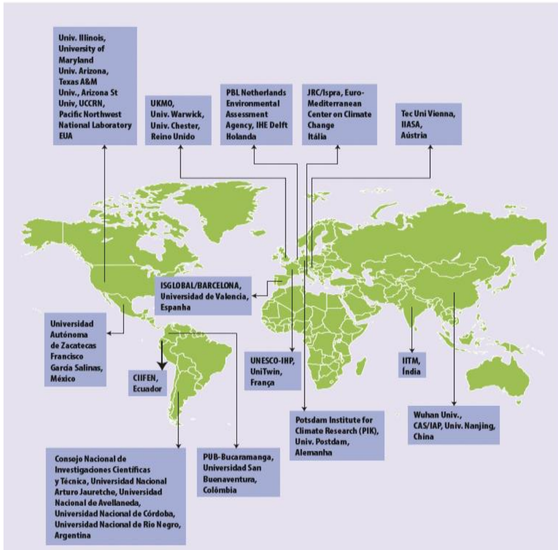


Figure 1.1. National and international partners of the INCT MC2

The program consists of six thematic lines (or subcomponents):

1. Food security;
2. Water security;
3. Energy security;
4. Health and climate change;
5. Natural disasters, impacts on physical infrastructure in urban areas and urban development;
6. Impacts on Brazilian ecosystems in view of changes in land use and biodiversity.

All these components are connected via 3 integrative themes or cross cutting themes:

7. Economy and impacts in key sectors;
8. Modelling the earth system and production of future climate scenarios to study vulnerability, impacts, adaptation and resilience;
9. Communication, dissemination of knowledge and education for sustainability.

Starting in Year 6, we have created a new phase of Integration and synthesis of the results of the 9 components, and the structure of the projects until the end of the project in 2025 is shown in Figure 1.2.

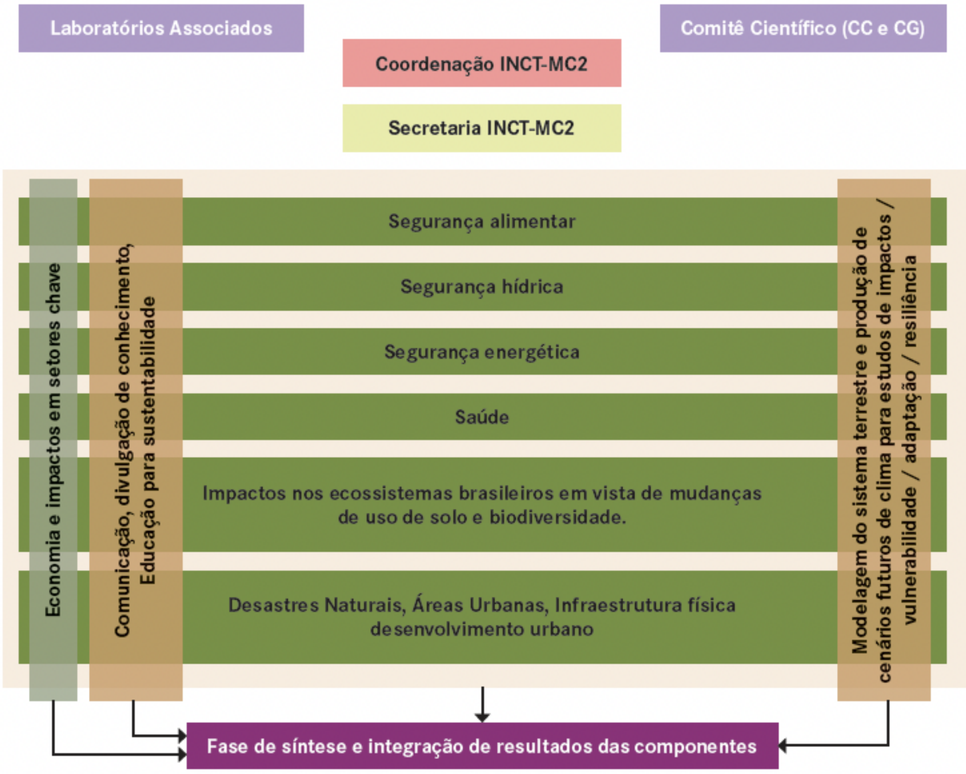


Figure 1.2. New structure of the INC MC2 since 2022.

So far, the scientific agenda of the INCT-MC2 was developed as planned, starting in 2017 and ending in 2025. This agenda provides scientific excellence in various areas of global environmental change and their implications for sustainable development. Emphasis on the impacts of climate change in agriculture, health, renewable energy, urban development and natural disasters such as central themes integrated into environmental modeling, the economics and communication of these impacts to the public, the scientific community and the academia, industry, business and government can contribute to maintaining excellence in activities in Science & Technology and Innovation as the axis of the sustainable environmental development, with character integrative and innovative.

Different from the Report of Year 1, where only FAPESP funded components were explained, in Years 2, 3, 4, 5 and now in year 6 we decided to include all components of the project, that include contributions of the UFMG and FIOCRUZ in MG, and partnerships with UFSC, UFRJ, IPEA, and other institutions outside of the State of Sao Paulo. This provides a better holistic view of the project and its components.

Perhaps one of the most important contributions of the INCT MC2 was the participation of several of the researchers of this project in the elaboration of the Scientific Report of Science Panel for the Amazon (SPA) and in the IPCC AR6 WG1 And 2. In response to these challenges and inspired by the Leticia Pact for the Amazon, a group of over 200 preeminent scientists from the region have untied to form the unprecedented. The Panel was convened by the United Nations Sustainable Development Solutions Network (SDSN), and provided a comprehensive, first-of-its-kind scientific assessment of the state of the Amazon, current trends, and recommendations for the long-term well-being of the ecosystem and its people. Its recommendations promote conservation as well as sustainable development of the region, with a vision of a standing forest, flowing rivers bioeconomy based on local and Indigenous knowledge, technology, and innovation. On March 2023 the SPA released their initial findings as well as a draft version of their full report for public consultation. The SDSN and the World Bank co-hosted a high-level dialogue in Belem, Pará to present these initial findings and foster conversations between scientists and policymakers to advance sustainable development pathways in the Amazon.

2. Objectives and aims

The objectives of the INCT MC2 have not changed:

- To implement and develop a comprehensive network of interdisciplinary research on global environmental change and sustainability
- To develop actions aimed at assessing adaptation to environmental changes and the transformation to sustainability, to reflect the vulnerabilities and resilience trajectories and propose ways in adapting to these changes, especially in relation to decision in the political sphere.
- To merge science with education from primary to the post-graduate levels.
- To provide an overview of issues related to sustainability and environmental-social-corporate responsibility, in order to facilitate the participation or even the implementation of activities in different areas of management of public and private institutions and their relationships with stakeholders.
- To maintain excellence in activities in Science & Technology & Innovation as the structural axis of sustainable environmental development, with an integrator and innovative character.
- To transfer knowledge using instruments that go beyond only scientific articles, but producing audio-visual material, web tools, and other outlets that allow the development of a scientific culture in society, improving the impact of Brazilian science and enabling increased international insertion of Brazil in environmental negotiations.
- To develop a research agenda in global change to identify and understand the current impacts of climate variability on natural and human systems in Brazil;
- To enhance and expand the scope of studies on global changes and their impacts on important sectors to the economy of Brazil.
- To engage and educate society, aiming to increase the resilience of these sectors.
- To sensitize the public perception of science and technology in relation to global change and impacts on society.
- To contribute prominently in the research and development of the National Plan on Climate Change and the National Adaptation Plan to Combat Drought and Desertification, in partnership with federal, state and international research programs on global change
- To produce publications and model data that can be used to provide scientific contributions to scientific panels, The Rede Clima, special reports of the Brazilian Panel of Climate Change and the Fifth National communication of Brazil to UNFCCC.

3 Coordination

Coordinator: Jose A. Marengo, Researcher, Level 1 B-CNPq classification, CEMADEN, Sao Paulo
Vice-Coordinator: Tercio Ambrizzi, Researcher, Level 1 A-CNPq classification, IAG USP, Sao Paulo

-Steering Committee

Name	Field of work	Institution	e-mail
Jose Antonio Marengo Orsini	Project's coordinator. Climate modelling, impacts and vulnerability assessments	CEMADEN	jose.marengo@cemaden.gov.br
Tercio Ambrizzi	Vice-coordinator, Climatology, climate studies, water security	IAG USP	ambrizzi@model.iag.usp.br
Paulo Nobre	Oceanic and coupled atmosphere-ocean modelling	CPTEC INPE	pnobre@cptec.inpe.br
Roberto Schaeffer	Energy and climate change	COPPE UFRJ	roberto@ppe.ufrj.br
Paulo Eduardo Artaxo Neto	Environmental physics, Amazonia, and climate change	IF USP	artaxo@if.usp.br
Eduardo Mario Mendiondo	Hydrology and water security	USP EESC	emm@sc.usp.br
Ulisses E C Confalonieri	Health and climate change	UFMG e FIOCRUZ	uconfalonieri@gmail.com efrangel@ioc.fiocruz.br
Eduardo Haddad	Economy of climate change	FEA USP	ehaddad@usp.br

All members of the Steering Committee (CG) are also coordinators of the Associated Laboratories. The Federal University of the Sate of Santa Catarina (UFSC) and the State University of Campinas (UNICAMP) are also Associated Laboratories. Associated Laboratories are those centers whose members are part of the CG but are not part of the group that is submitting the proposal. The progress of the Project is monitored by a Scientific Committee (CC), that is constituted by the coordinators of the sub components (themes) and from the cross cutting activities. We have meet virtually in March 2023 to see the progress of the project.

The transfer of knowledge to society must be developed from a system of investigation, management and experimentation information in the area of climate change, by means of:

• Theoretical strengthening of studies that support actions that invest in scientific communication and dissemination;
• The generation of analyzes of the relationships between sciences, technologies and society;
• The creation of new approaches methodologies that allow experimenting with social media and languages;
• The investigation of potentialities cultural artefacts (newspapers, magazines, movies, TV shows, works
art, blogs, videos, radio shows, podcasts, etc);
• The production and dissemination of information and quality materials that can serve as tools for public managers and civil society organizations in the evaluation, policy formulation and implementation public.

In this project, we want the community to science in global environmental change is heard, not only to legitimize what has already been decided by governments, but to influence the processes that are ongoing in public administration regarding environmental policies and major undertakings that may affect the environment.

The experience gained at the INCT-MC2 in the period 2017-2023 can be evaluated from the degree of interdisciplinary synergy in S&T and its continuity Social. Internally, the INCT-MC2 values this synergy in the integration between Subcomponents and Cross Axes. On the one hand, this synergy is accelerated in the Security Subcomponents Food, Water Security, Security Energy, Health, Impacts on Ecosystems Brazilians in view of changes in land use and Biodiversity, Natural Disasters, Analysis Integrated for Policy and Decision Making Public. Also, the synergy is strengthened in the Transversal Axes of Economy and impacts on highlighted sectors, Communication, Disclosure, Education and Modeling of the Earth System and Production of Future Scenarios. On the other hand, in the period 2020-2023, the INCTMC2 Subcomponents and Transversal Axes brought global recommendations for the federal, state and municipal levels in the Brazil.

The coordination of the components of the project have been updated:

CARGOS	COORDENADORES (INSTITUIÇÃO, ESTADO)	ATIVIDADES DESENVOLVIDAS NO PROJETO
Coordenador	J. Marengo (CEMADEN, SP)	Coordenação do projeto, modelagem climática, avaliações de impactos e vulnerabilidade, extremos, adaptação, líder do CG e CC. Sintese e Integração dos restados do projeto.
Vice-coordenador	T.Ambrizzi (IAG-USP, SP)	Vice-coordenador do projeto, climatologia, estudos climáticos, segurança hídrica, membro do CG e CC. Sintese e Integração dos restados do projeto.

SUBCOMPONENTES OU TEMAS INTEGRATIVOS/ TRANSVERSAIS	COORDENADORES (INSTITUIÇÃO, ESTADO)	ATIVIDADES DESENVOLVIDAS NO PROJETO
Segurança hídrica	E. Mendiondo (EESC-USP, SP)	Hidrologia, segurança hídrica, avaliações de risco, coordenador de subcomponente, membro do CG.
	S. Montenegro (UFPE, PE)	Modelagem hidrológica em áreas urbanas e rurais no semiárido brasileiro, coordenador de subcomponente.
Segurança alimentar	E. D. Assad (EMBRAPA, SP)	Segurança alimentar, modelagem agrícola, coordenador de subcomponente.
Segurança energética	R. Schaeffer (COPPE UFRJ, RJ)	Energia e mudanças climáticas, coordenador de subcomponente e membro do CG.
	E. B. Pereira (CCST-INPE, SP)	Energias renováveis, energia e mudanças climáticas. Cenários de energia eólica e potencial solar, coordenador de subcomponente.
	A. Szklo (COPPE-UFRJ, RJ)	Energia e mudanças climáticas, coordenador de subcomponente.
Saúde	U. Confalonieri (UFMG-FIOCRUZ, MG)	Saúde e mudanças climáticas, vulnerabilidade e saúde climática, coordenador de subcomponente, membro do CG.
	E. Rangel (FIOCRUZ, RJ)	Saúde e comunicação social, educação, coordenador de subcomponente.
Economia e impactos em setores-chave	E. Haddad (FEA-USP, SP),	Economia das mudanças climáticas, coordenador de tema integrativo, membro do CG.
	S. Margulis (IPEA, DF; Way Carbon, MG)	Economia das mudanças climáticas, coordenador de tema integrativo.
	J. Feres (IPEA, DF),	Economia das mudanças climáticas, coordenador de tema integrativo.

SUBCOMPONENTES OU TEMAS INTEGRATIVOS/ TRANSVERSAIS	COORDENADORES (INSTITUIÇÃO, ESTADO)	ATIVIDADES DESENVOLVIDAS NO PROJETO
Comunicação, difusão de conhecimento e educação para sustentabilidade	A. Amorim (UNICAMP, SP)	Linguagens, comunicação científica, coordenador de tema integrativo.
	S. Dias (UNICAMP, SP)	Educação – conhecimento e arte, coordenador de tema integrativo.
Modelagem do sistema terrestre e produção de cenários futuros de clima para estudos de vulnerabilidade, impactos, adaptação e resiliência	P. Nobre (CPTEC-INPE, SP)	Desenvolvimento de modelo oceânico e acoplado oceano-atmosfera, BESM – Brazilian Earth System Model, coordenador de tema integrativo, membro do CG.
	S. Chou (CPTEC-INPE, SP),	Modelagem climática regional, cenários futuros de mudanças climáticas de alta resolução, coordenador de tema integrativo.
Desastres naturais, áreas urbanas, infraestrutura física e desenvolvimento urbano	R. Alvalá (CEMADEN, SP)	Desastres naturais, avaliações de impactos e riscos, coordenador de tema integrativo.
	R. Rodrigues (UFSC, SC)	Desastres naturais, zonas costeiras, coordenador de tema integrativo.
	M. Barata (FIOCRUZ, RJ)	Mudanças climáticas e desenvolvimento urbano, cidades resilientes, coordenador de tema integrativo.
Impactos nos ecossistemas brasileiros frente às mudanças do uso da terra e à biodiversidade	P. Artaxo (IF-USP, SP)	Física ambiental, Amazônia, coordenador de tema integrativo, membro do CG.
	M. Bustamante (UNB, DF)	Inventários de emissões de gases de efeito estufa, estudos na região do Cerrado, coordenador de subcomponente.
FASE DE SINTESE E INTEGRACAO DE RESULTADOS	**COORDENADORES (INSTITUIÇÃO, ESTADO)**	**ATIVIDADES DESENVOLVIDAS NO PROJETO**
Síntese de resultados de integração entre componentes	J. Marengo (CEMADEN, SP) T. Ambrizzi (IAG-USP, SP) S. Viggiani (USP)	Preparação de dossiers e artigos de integração entre as diferentes componentes do projeto usando NEXUS+.

was created to support the integration of results from all the components of both the main themes as cross-cutting themes. this integration is being done using the NEXUS+ methodology used in the Fourth Communication of Brazil with the UNFCCC(4CN), always considering the relevance to the Sustainable Development Goals SDG-12 (sustainable agriculture), SDG-3 (ensure healthy living), SDG-7 (Clean energy and affordable: ensure access to cheap energy), SDG-11 (Sustainable Cities and Communities), SDG-13 (Action against global climate change), SDG-15 (Terrestrial Life: Protect, Restore, and Promote the sustainable use of terrestrial ecosystems), between others. By early 2023, hundreds of publications were generated by the collaboration between the various components of the INCT MC2, as well as such as numerous lectures, seminars, podcasts, interviews on social networks, in magazines and newspapers from Brazil and abroad, highlighting the theme of climate change and its characteristic transversal and integrative. so far 5 reports have already been generated and approved by the FAPESP and CNPq.

An extension of the project until 2025 will help to include topics that were not contemplated when the proposal was drafted in 2015 and which were gradually included in the current search schedule. For example, the theme of climatic extremes observed in Brazil and the another containing some reflections on the relationship between COVID-19 and climate change, were included, although it is still a controversial topic and still without a consensus in the community scientific about their associations.

Few online meetings too place among INCTs in 2020 and 2023. Recently, CNPq and some FAPs approved 60 new INCTs in 2023, and there are conversations with MCTIs to make the INCTs a regular programme from CNPq. This was discussed in the 75th annual meeting of the Brazilian Society of Science Progress (SBPC) that occurred in Curitiba, Parana, during 23-29 Juy 2023, The main topic of the Agenda was the current and future situation of INCTˆs/r INCTs.

4. New Development on the INCT MC2 after 2022

As for our INCT MC2, after our request for extension to 2025, FAPESP granted these fellowships:

São Paulo, 21 de março de 2023.

Ilmo(a). Sr(a).
Prof(a). Dr(a). JOSE ANTONIO MARENGO ORSINI

Em resposta a correspondência de V.Sa., datada de 16/12/2022, informamos que suas solicitações foram autorizadas, conforme abaixo:

- ADITIVO RECOMENDADO:
  6 quotas bolsa PD 12m;
  2 quotas bolsa TT-5 40h 24m;
  1 quota bolsa TT-4 40h 24m;
  1 quota bolsa TT-4A 40h 24m.

- VIGÊNCIA:
  De: 01/07/2027 a 30/06/2023
  Para: 01/07/2027 a 30/06/2025
  Compromissos de RC e PC: 30/06/2024 e 30/07/2025.

PARECER DAS COORDENAÇÕES

Prezado Professor, agradecemos seu pedido. Contudo considerando que o CNPQ concedeu aditivo de MP, MC, bolsas e que seu projeto ainda tem saldo de mais de um milhão não há justificativa para o aditivo solicitado. A Fapesp concede aditivo de pequeno valor para bolsas conforme descrito a seguir:
Recomenda-se a concessão de mais 6 cotas de 12 meses de bolsas de PD, duas cotas de bolsa TT5 de 24 meses, uma cota de bolsa TT4 de 24 meses e uma cota de bolsa TT4A de 24 meses.
Considerando as justificativas apresentadas e o fato da agência parceira ter concedido a prorrogação de vigência, recomenda-se aprovar os 24 meses adicionais em caráter excepcional.

Por favor, para qualquer consulta ou comunicação sobre esta correspondência, use exclusivamente os serviços do "Converse com a FAPESP" em www.fapesp.br/converse.

Certos da compreensão de V.Sa. quanto aos procedimentos desta Fundação, aproveitamos o ensejo para lhe expressar nossas saudações.

Atenciosamente,

Luiz Eugênio A. M. Mello
Diretor Científico

In addition, these PD fellowships were granted by FAPESP until June 2025, and the table shows them already distributed among the various components of the project.

Fellowships PD Granted	Number	Duration (Months)
Food security	1	12
Water security	1	12
Energy security	1	12
Natural disasters	1	12
Economy	1	12
Modeling	1	12
TOTAL	6	

Other type of fellowships were also granted buy FAPESP:

Fellowships TT Granted	Number	Duration (Months)
From the second half of 2022 a new component Food Security	0	0
Water Security	0	0
Energy Security	1 TTIVA	24
Natural disasters	1 TTV	24
Economy	0	0
Comunication	1 TTIV	24
Modeling	1 TTV	24

TOTAL		

5. Reports by component

In the following we focus on the reports from each sub component and crosscutting component, showing main results and activities developed in Year 4 of the project. We also include information on new team members coming into the project, explain some changes in the coordination of the components if that is the case and plans for Year 4. All information on scientific production and activities from each of the components (workshops, publications, participation in events, use of the BC and RT, fellowships [bolsas]) are listed in upcoming sections. The report is from activities developed by all components of the project.

5.1 Coordination

The two coordinators Jose Marengo and Tercio Ambrizzi have meet during year 4 in several occasions, some of these meetings took place USP, and other during other meetings and conferences where we both were there. We have changed the way the coordination works. For the administrative issues, CEMADEN hired Ms. Josiane Rosa, who is working part-time dedicated to this project. Ms Rosa helps the coordination with the procedures to indicate *bolsas* to CNPq, CAPES and FAPESP, with payments, meetings organization and air travel arrangements for participant scientists to meetings among INCT MC2 participants.

In addition to administrative activities, the coordinators together with their students, bolsistas and collaborators have developed a scientific agenda on investigation of observed climate variability and change, with focus on extremes in regions such Amazonia, Northeast Brazil, Pantanal and major cities, such as Sao Paulo. Some papers have been produced as well as reports in various journal, magazines and the Revista Pesquisa FAPESP. This is being done since the beginning of the project and constitutes a background fall all components. All these results are detailed in the reports by component.

In the following we report some of the major studies developed by the coordination. As mentioned in Year 4, the coordination works on some comprehensive e studies dealing with weather and climate extremes, providing some ground basis for the work of the components. From year 1-4 we have relayed on graduate students and bolsistas from INPE, USP and UNESP and from years 5 to 7 we will work with a bolsista that will work on the integration of results from all components. This shows that years 5-7 will be mainly integration of research results from years 1-4. The bolsistas will come from the extension approved by the CNPq for 2 more years of the project.

5.1.1 State of Climate for Latin America and Caribbean 2022 (WMO document lead by Jose A. Marengo and other representatives from the region)

The report was released during a WMO Regional Technical Conference for South American countries, organized by WMO in Havana, Cuba on July 2023.This is the third year that WMO has produced this annual regional report, which provides decision-makers more localized information to inform action. It is accompanied by an interactive Story Map (Figure 5.1)

Figure 5.1. State of the Climate in Latin America and the Caribbean 2021 (WMO 2022)

The report included some scientific results of the INCT MC2 for Brazil, and among the main results relevant to Brazil and South America, we can mention:

- **Rainfall**: In South America, below-normal rainfall was recorded in the central and southern regions of Chile (between 20% and 60% below normal) and in the central and south-western Andes of Peru and in Bolivia (between 30% and 50% below normal). As in 2021, below-normal rainfall was dominant over the Paraná–La Plata Basin in south-eastern Brazil, northern Argentina, Paraguay and Uruguay, suggesting a late onset and weak South American monsoon. Above-normal precipitation anomalies (10%–20%) dominated the semiarid region of north-eastern Brazil, southern Argentina, the northern coast of Peru, central and coastal Colombia, central South America and eastern Amazonia, French Guiana, Suriname and Guyana. Positive precipitation anomalies in south-east Brazil were related to heavy precipitation events concentrated in a few days. Some of the observed rainfall patterns were consistent with the typical rainfall patterns associated with La Niña conditions.
- **Extreme rainfall**:I n central South America, episodes of extreme rainfall triggered flooding and landslides that affected thousands of people. In the state of São Paulo, Brazil, at least 19 people died due to landslides and flooding after heavy rainfall on 28 January. Earlier, on 11 January, heavy rainfall of more than 200 mm in 24 hours led to flooding and landslides in Minas Gerais (Brazil), in which at least 15 people died. On 15 February, in Petropolis in the state of Rio de Janeiro, Brazil, 258 mm of rain fell in three hours (greater than the monthly average of 210 mm) and a total of 530 mm of rain was recorded in 24 hours, leading to more than 230 fatalities.32 Heavy rainfall occurred again on 20 March, 415 mm in 10 hours, leading to landslides and flooding. On 2–3 April, in Paraty and Angra dos Reis (about one hundred kilometres south-west of Petropolis), at least 16 people died after a record amount of rainfall, over 800 mm in 48 hours, triggered floods and landslides.
- **Floods**: Exceptionally heavy rains fell in the states of Pernambuco, Alagoas, and Paraíba (north-east Brazil). In Recife, in state of Pernambuco, the intense rainfall from 25 to 30 May, 551 mm (the monthly average is 411 mm), led to 130 deaths, impacted about 130 000 people, and caused the city to declare a state of emergency. In Rondônia, in western Brazilian Amazonia, heavy rain from early February increased the levels of rivers, causing flooding in the municipality of Cacoal.36 The Rio Negro at Manaus reached the severe flood level (29 m) in early May and 29.37 m by 23 May, the fourth highest level since 1903.
- **Drought**: The drought conditions in 2022 across the La Plata Basin in south-eastern South America were the worst since 1944. Below-normal rainfall was dominant in south-eastern Brazil, northern Argentina, Uruguay, Paraguay and eastern Bolivia, suggesting an early ending of the South American Monsoon. The third La Niña year in a row caused a prolonged period of drought conditions, mainly in south-eastern South America. In 2022, central Argentina recorded its driest year since records began in 1960.
- **Heat waves**: A large area centred around the central-northern part of Argentina, southern Bolivia, central Chile, and most of Paraguay and Uruguay experienced record-breaking temperatures during two consecutive heatwaves in late November and early December 2022. In Chile, forest fires caused significant damage to the flora and fauna after the burning of the Chilean Palm, a species native to the Valparaíso region.58 In the Bolivian Amazon, during the heatwave from 25 to 30 November, the city of Cobija recorded 37.7 °C on 28 November (the mean monthly maximum is 30.8 °C) The region is also experiencing a prolonged drought that started in 2019 and has worsened over the years. From 4 to 12 December, temperature records tumbled across Argentina,

as 24 weather stations recorded temperatures above 40 °C. Rivadavia station, located near the border with Bolivia and Paraguay, recorded a maximum temperature of 46 °C on 7 December.
-**Cold waves:** On 16 May, a subtropical storm over the South Atlantic favoured the intensification of an intense cold air surge that reached most of subtropical South America east of the Andes.65 In Brazil, a cold event from 16 to 23 May (the longest in 2022) affected most of the country, including western Amazonia; this event also affected Bolivia. On 18 May, the city of Sao Paulo recorded the third lowest temperature for the month of May in 32 years, 6.6 °C (the mean monthly minimum is 13.1 °C). In Gama (Brasilia), the minimum temperature reached 1.4 °C on 19 May, the lowest temperature recorded for May since 1963 (the mean monthly minimum is 15.6 °C). Cold events affected the Bolivian Altiplano from May to December, and the El Alto station recorded the lowest May temperature recorded in Bolivia in 24 years, 9.8 °C, on 23 May (the mean monthly minimum is -0.6 °C).
-**Impacts on agriculture**: Drought conditions in 2022 led to damages to agriculture and reduced crop yields, affecting global crop markets. In Brazil, a lack of rain and high temperatures were associated with large agricultural losses during the year. Brazil is one of the world's breadbaskets; agriculture amounts to nearly 7% of its annual gross domestic product (GDP). For the first quarter of 2022, there was a reduction of 5.2% in Brazil's agricultural production index compared to the first quarter of 2021. This was largely due to poor harvests of soy and corn associated with drought (it was the third consecutive dry year in parts of the country). Coffee yields were also affected and are expected to be the lowest since 2014; Brazil is the world's largest coffee bean producer.
-Impacts on water resources: The Paraná River, on which Argentina relies to export 80% of its agricultural products, was affected by low water flow due to the Paraná–La Plata Basin (LPB) drought. Levels of the Paraguay River at Ladario reached 64 cm below normal (the annual average level for 1900–2022 was about 280 cm). This situation can partially be attributed to dry conditions related to the La Niña event that started in 2020 and extended into 2022. In the LPB in 2022, the drop in hydropower productivity did not lead to an energy crisis but led countries to turn to less sustainable energy sources, such as thermoelectric sources, which use fossil fuels, making energy more expensive. The drought and associated low river flows caused problems for energy production at the hydroelectric plants in the region. Electricity production in the two binational power plants in the LPB – Yacyretá (Argentina and Paraguay) and Itaipú (Paraguay and Brazil) – has been drastically affected by the low levels of water. Itaipú has shown a steady decrease in water levels since 2018. A similar pattern has been seen for Yacyretá, although the decrease in hydropower generation began a little later than in Itaipú.

5.1.2 Hydrogeological disasters in the city of São Sebastião in the Northern Coast of the State of São Paulo in February 2023

On February 18th-19th, 2023, heavy rainfall affected the municipality of São Sebastião, on the coastal region of the state of São Paulo in southeast Brazil. Extreme rainfall of about 680 mm in less than 24 hours triggered multiple fatal and flash floods landslides in the city. This is perhaps the highest rainfall measured in all of Brazil in modern history. Therefore, the water-saturated soil led to deadly floods, debris flow, and landslides resulting in 65 casualties and damages. The meteorological situation was associated with a cold front crossing over a warmer subtropical South Atlantic off the coast of São Paulo. This was in addition to the orographic effect the Serra do Mar Mountain, causing an extreme and historic heavy precipitation event. This front remained stationary over the northern coast of areas of the State of São Paulo, and it rained continuously from around 19:00 on February 18th to 11:00 hours on February 19th. CEMADEN identified high and very high hydrological and geological risks, and alerts for those risks were submitted to emergency services at the municipal level with few days in advance. However, it looks like São Sebastião's population either was not warned of the upcoming disaster or if warned the population did not take any action because did not believe in the possibility of a disaster. This shows a need to improve perception of the imminence of a disaster. So, multi-hazard early warning systems are vital for adaptation and risk reduction in areas susceptible to disasters. Public policies must be implemented so lives can be saved. At the Vila Sahy in São Sebastião, extreme rainfall of more than 600 mm in less than 24 hours has triggered multiple fatal and flash floods landslides. This city reported most of the fatalities, 47 of the 65 deaths. Neighboring municipalities such as Ilhabela, Caraguatatuba, Bertioga, and Ubatuba were also heavily affected. These disasters destroyed infrastructure, leading to significant loss of life and destruction to the region.

The meteorological situation that led to heavy rainfall on February 18^{th}-19^{th}, 2023, was a cold front with a combination of various factors, such as warmer surface water in the subtropical South Atlantic off the coast of São Paulo and the orographic barrier represented by the Serra do Mar caused an extreme and historic heavy precipitation event. This front remained stationary over the NCSP and rained continuously from around 19:00 hours on February 18th to 11:00 on February 19th. According to rainfall data from the National Center for Monitoring and Early Warning of Natural Disasters CEMADEN, from February 18th -19 th, it rained 682 mm in Bertioga and 626 mm in São Sebastião. Such a rain amount is perhaps the highest single-day rainfall total in the country's recent history. The previous high rainfall event was in February 15 th 2022, when Petrópolis recorded 534 mm in 24 hours. It was the town of São Sebastião, 80 km north of Bertioga, where all but one of the deaths occurred. A high hydrogeological risk alert across the NCSP cities was issued 2 days before the tragedy. Late night of February 18, heavy rainfall impacted São Sebastião, and from the end of the night to the early morning of February 19, 2023, landslides, debris flow, and flashfloods impacted the region.

Figure 5.2 shows that rainfall in the NCSP, particularly between São Sebastião, Bertioga, and Guarujá, varied between 200 and 600 mm, and the most abundant rainfall occurred between February 18th -19th. Almost no rain on February 20, and some rain on February 21st -28th. The diurnal rainfall variability on February 18th-19th for stations in São Sebastião, Guarujá, and Bertioga shows that the highest rainfall volumes started to show up at 19:00 UTC (16:00 hours local time) and reached a maximum between 20:00 and 23:00 UTC hours (17:00 and 20:00 hours local time) on February 18 th (reaching between 60 and 140 mm) and continued until 11:00 UTC (08:00 hours local time) of February 19 th. In some stations, rainfall rose again between 02:00 and 09: UTC on February 19 th, in light blue from Sebastião. This means that in some stations, the abundant rainfall lasted almost 15 hours, from the afternoon of February 18 th to the late morning of February 19 th.

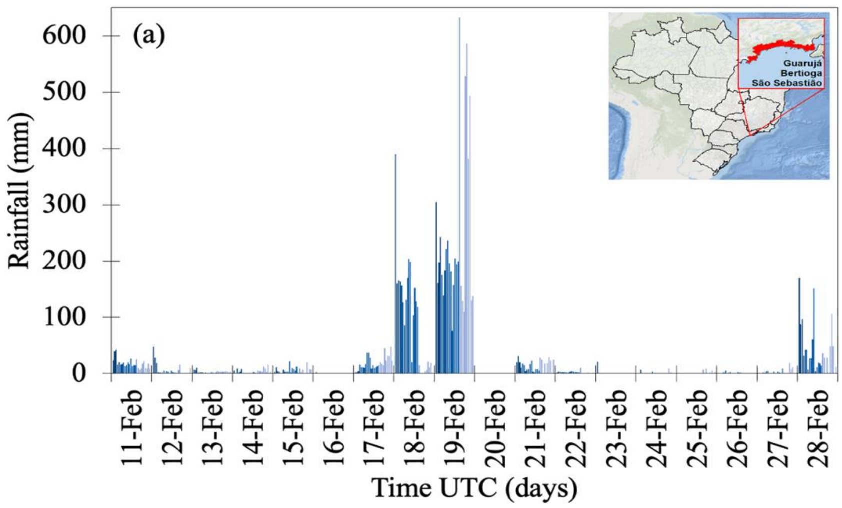


Figure 5.2. Daily variability of rainfall between February 11th-28th for the Sao Sebastiano, Bertioga and Guarujá region of the NCSP (see map on the upper right side of the panel). Units in mm/day.

Figure 5.3 shows accumulated monthly rainfall from February 2023 for the NCSP (Figure 8a), as well as accumulated daily 12:00 UTC to 12:00 UTC during February 18th -19th, 2023 (Figure 8b) from stations from the CEMADEN rainfall network. In February 2023, rainfall was well above average. The February climatology varies between 300 to 320 mm/month (www.ciiagro.org.br/boletins.html, last accessed on March 17, 2023). However, in February 2023, rainfall in São Sebastião varied between 640-850 mm/month, and in Bertioga and Guaruja, the accumulated varied between 210-1030 mm/month. Based on the diurnal behavior of rainfall from Figure 9b, the daily accumulated rainfall between 12:00 UTC to 12:00 UTC on February 18 th -19 th varied between 300-650 mm in Sao Sebastião and 150-680 mm/24h in Bertioga and Guarujá. In comparison, on February 17 th -18 th and 19 th -20 th , rainfall varied between 0-25 mm in Sao Sebastião and 5-20 mm in Bertioga and Guarujá.

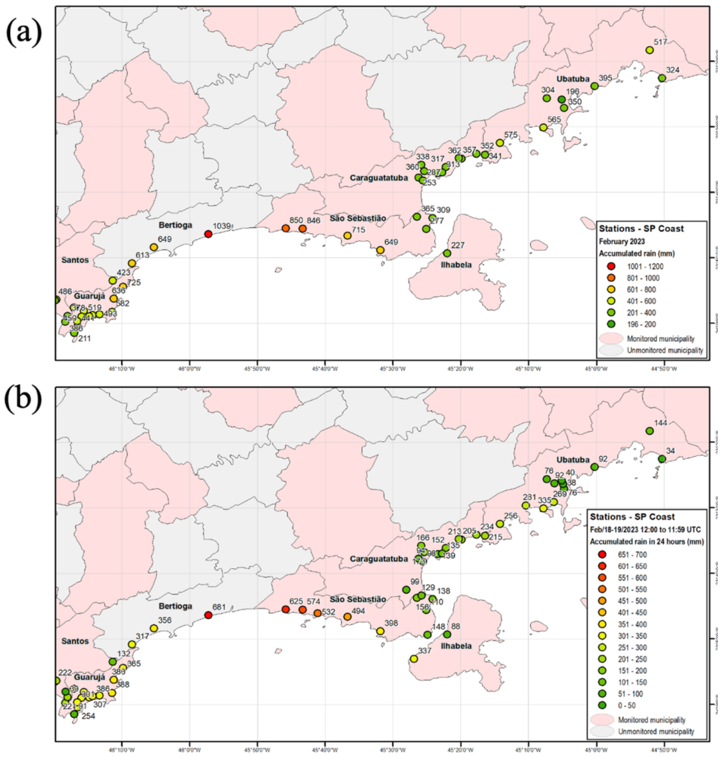


Figure 5.3. a) Accumulated monthly rainfall from February 2023, in mm/month for the NCSP; b) Accumulated 12:00 UTC to 12:00 UTC daily rainfall during February 18th-19th 2023 in mm/day for the NCSP. Circles in the map show location of CEMADEN's stations. Color scale is indicated with circles on the right side of each panel. Source of data CEMADEN.

The extreme rainfall event caused the widespread collapse of slopes that concentrated in a continuous strip of about 40km long and about 10km wide, notably involving the areas of high hills adjacent to the coastline of São Sebastião, including small islands and mountainous areas. The event was of great magnitude resulting in specific clusters of landslides and flows, which resulted in extraordinary volumes of mobilized material. The density of landslide scars (Figure 5.4) reveals the places where the event resulted in more severe impacts, highlighting the beaches of Barra de Boiçucanga (434 residences in risk areas), Camburi (608 residences), Baleia (185 residences), Barra do Sahy (162 residences) and Juquehy (575 residents) totaling 1964 residences most strongly affected by the event**.**

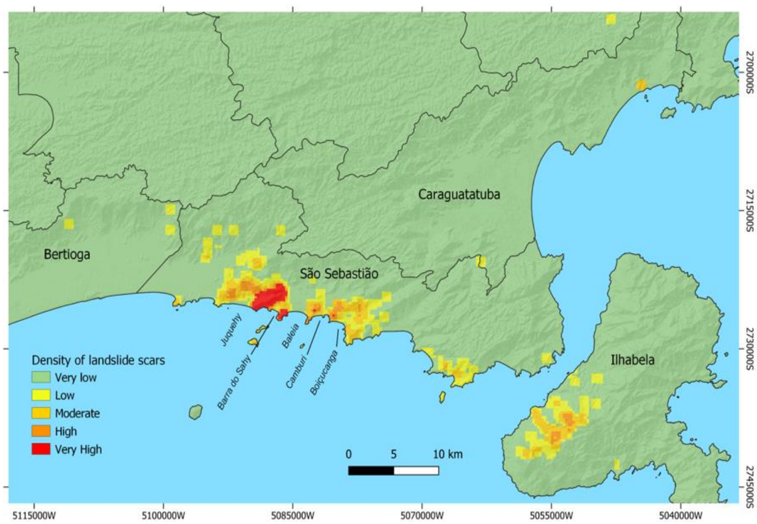


Figure 5.4. Landslides scar density from landslides triggered during the February 18th -19th , 2023 event, in São Paulo North Coast.

Disaster risk is notoriously a combination of climate and meteorological hazards, vulnerability, and people's exposure. The analysis of the critical rainfall thresholds with the observed data collaborated with consolidating the knowledge of the region's risk. The urban dynamics observed in areas susceptible to mass movement and flooding will continue to pressure occupation in geological and hydrological risk areas, requiring constant mapping to update the risk sectors. Urban control has the challenge of containing the advance of urban expansions over Atlantic Forest conserved slopes, especially where susceptibility can be considered medium or low on coastal hillsides, as in São Sebastião.

EWSs of mass movements and flooding can advance with the increase of automatic rain gauges associated with risk areas and, especially with investments in meteorological radar along the coastline and given the geographical character of the municipality, one can see the fundamental role of the action of protection and civil defense centers on each beach in the preventive and response actions against disasters. It is expected that an early warning triggers early action. In the case of fast-moving hazards, such as flash floods and landslides, this sometimes means evacuating and seeking appropriate shelter. In the case of São Sebastião and adjacent regions on the February 18^{th} -19^{th}, 2023 disaster, forecasts of alerts from high-risk hydrological and geological disasters were issued on time, and they reached the municipal Civil Defense offices. The local Civil Defense is responsible for interacting with the population and evacuating populations out of risk areas. Concerning Civil Defense activities, the primary needs, according to a recent study by, are related to financial support, structure, and capacity building. The disaster in São Sebastião shows the need for well-coordinated initiatives to support the Civil Defense of municipal governments, so vulnerable populations may be more resilient and can cope with disasters caused by extreme weather events. As in other regions of Brazil and the world, landslides and debris flow are exacerbated by inadequate infrastructure and poor planning, with many homes and buildings in high-risk areas vulnerable to these disasters. Therefore, multi-hazard early warning systems are essential for effective adaptation in areas at risk from weather and climate extremes, and this is being discussed in several panels and scientific networks.

5.1.3 Mesoscale convective systems over the Amazon basin in a changing climate under global warming.

Climate change is imminent and threatens the largest watershed in the world, the Amazon basin. As general circulation models may fail to represent cloud-scale phenomena, precipitation in a changing climate under global warming is still a factor of great uncertainty, especially in Tropical regions. In this study, long-term high-resolution simulations from a global cloud-resolving model under the scope of the Coupled Model Intercomparison Project (CMIP6) have analyzed the climate change impacts on the mesoscale convective systems (MCSs) over the Amazon basin. The authors generated a complete spatial, temporal, and statistical characterization of the MCSs for the past (1950–1960), present (2000–2010), and near-future (2040–2050). They found that MCSs are a critical mechanism for precipitation, especially in austral winter.

The simulations are consistent with the observed precipitation and MCSs patterns over the Amazon basin, indicating that MCSs are less frequent compared to the past and are expected to continuously decline in the near-future. Most decreases are projected from September to December, while an increase between June to August, mainly in the southern portion of the Amazon basin, as indicated in Figure 5.5. In addition, the investigation presented shows a great potential of using a global cloud-resolving model under the CMIP6 scope to investigate mesoscale systems in a warming climate.

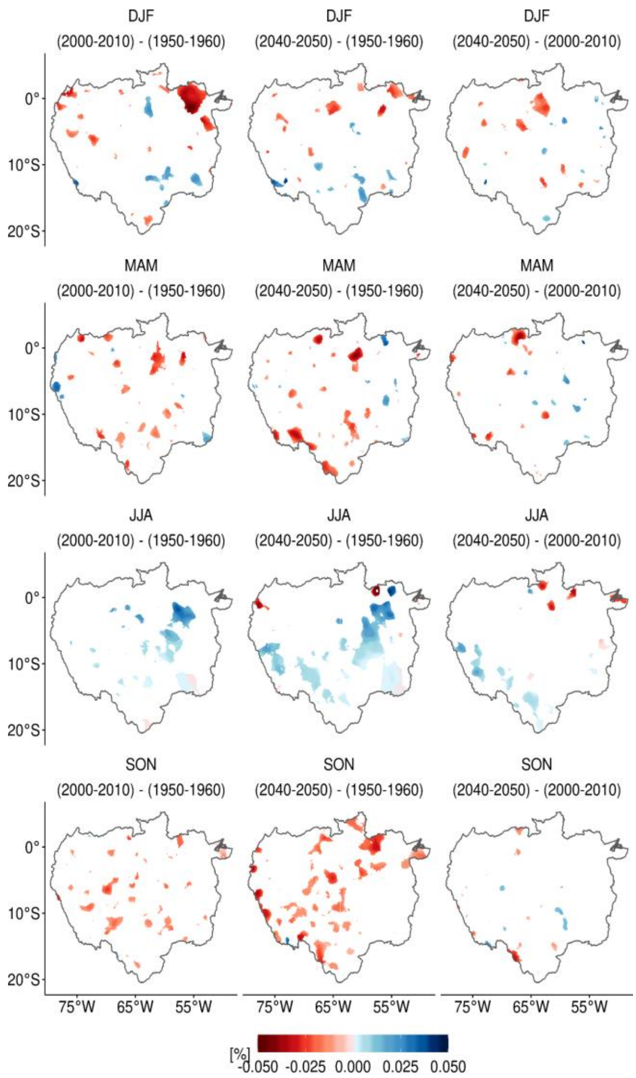


Figure 5.5 - Differences in the seasonal MCSs density over the Amazon basin between 2000-2010 and 1950-1960 (left panels), 2040-2050 and 1950-1960 (center panels), and 2040-2050 and 2000-2010 (right panels). All the lifespans were considered. Only statistically significant values above 95% were displayed.

5.2 Food security

This subcomponent is divided into three activities

- Activity 1 - Climate, agriculture and implications for food security
- Activity 2 - Economy, Climate and implications for food security
- Activity 3 - Climate, livestock and implications for food security

5.2.1 Activity 1 - Climate, agriculture and implications for food security

In this stage of the work, activities were developed to verify the evolution of the food supply, in terms of agricultural production, for some components of the basic basket, such as rice, beans, wheat and cassava. Subsequently, a projection was made of the possible increase in this food supply from the use of more sustainable practices.

5.2.1.1 Rice:

Rice is a staple o f the Brazilian diet and is present in food consumption in all regions of Brazil. The supply of this grain is projected to remain stable, following population growth, with a slight retraction near 2050 - just when population growth in Brazil is expected to slow down.

Projections indicate a production of 12.2 million tons in 2050 on an area of approximately 1.6 million hectares. Given the history of grain production and land use in Brazil, rice, along with beans,is expected to lose area relative to other crops such as soybeans and corn. Similarly, the smaller area is expected to be compensated by productivity gains, stabilizing production at around 1.6 million hectares. Figure 5.6 below illustrates the evolution of rice production until 2050.

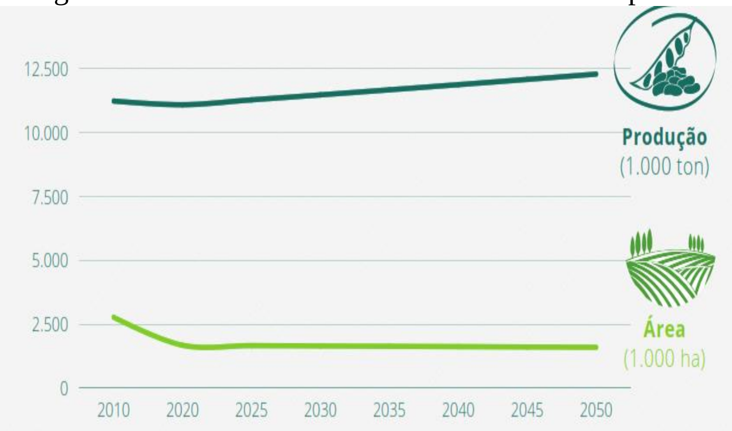


Figure 5.6: Evolution of rice production until 2050.   Source: IBGE, Municipal Agricultural Survey until 2020.

5.2.1.2 Beans

As in the case of rice, projections indicate a stability in bean consumption, with a slight retraction towards 2050, following the deceleration of population growth in Brazil.

Projections indicate a production of about 3 million tons on 2 million hectares in 2050. A reduction in area relative to other crops is expected due to pressure from soybean and maize expansion. This loss of area will be compensated by productivity gains through the expansion of the use of biological nitrogen fixation technology in legumes. Figure 5.7 shows the evolution of bean production for Brazil until the year 2050.

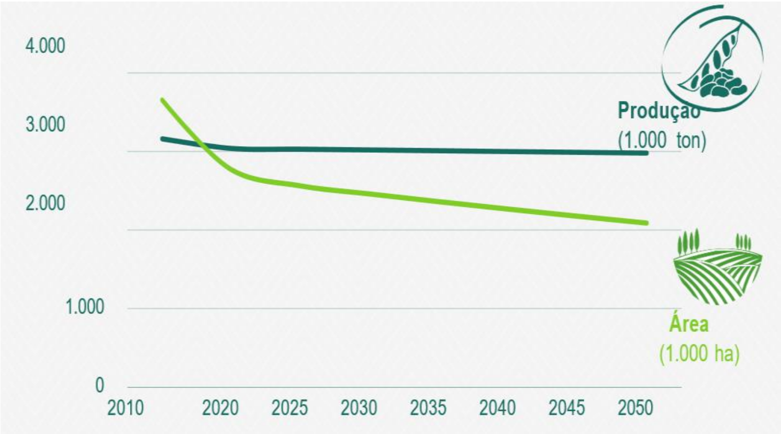


*Figure 5.7 Evolution of bean production in Brazil until the year 2050***.** *Source: IBGE, Municipal Agricultural Survey until 2020.*

5.2.1.3 Wheat

Wheat production was 6.3 million tons in 2020 using an area of 2.4 million hectares. International demand for wheat is projected to increase by 2050, driven by population growth and climate vulnerability of the crop in different regions of the world. Vigorous production growth via exports is projected, pressured by higher external demand until 2050.

Wheat is expected to gain area relative to other crops in regions where irrigation and the development of new cultivars have provided a significant increase in productivity. An area of up to 3.7 million hectares is projected by 2050. Figure 5.8 shows the evolution of wheat supply in Brazil until the year 2050.

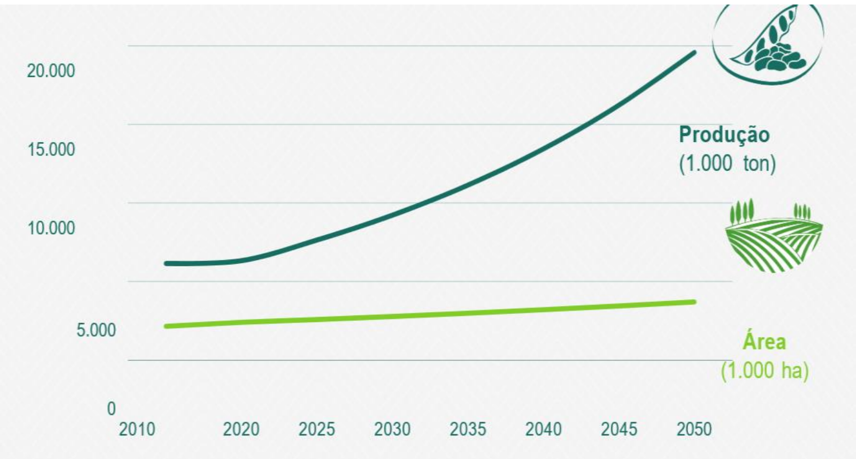


Figure 5.8. Evolution of wheat supply until 2050. Source: IBGE, Municipal Agricultural Survey until 2020. Due to the national and international situation, wheat is a crop whose projection indicates an increase in grain supply.

5.2.1.4 Cassava

Cassava production in 2020 was approximately 18 million tons on 1.2 million hectares. Cassava is widely used in the daily life of Brazilians, however historical data show that production has been losing space in the competition for land use with other crops. Several factors affecting both the supply side, such as price and climate variability, and the demand side, such as consumer income, for example, are contributing to this effect on cassava production.

Production is projected to be about 16.2 million tons by 2050 on an area of about 1 million hectares. By 2050, cassava will lose area relative to other cash crops. The reduction in cassava production reflects shrinking demand as households migrate to more attractive carbohydrate sources (rice and wheat derivatives, for example) with the expected increase in income. Figure 5.9 illustrates the evolution of cassava production until the year 2050.

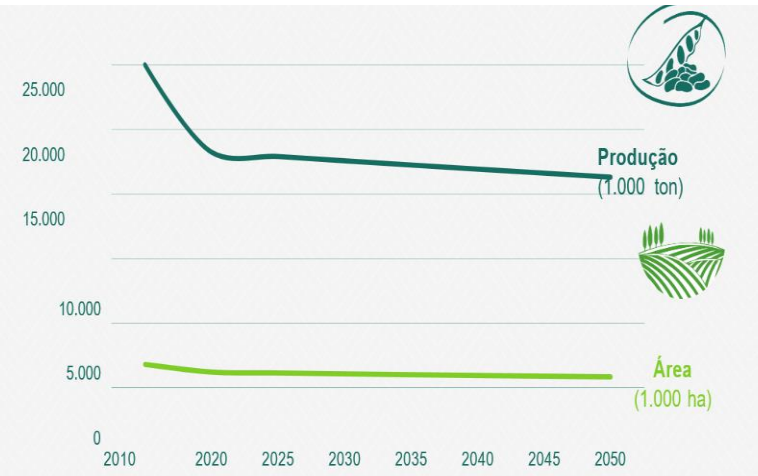


Figure 5.9 Evolution of cassava production until the year 2050. Source IBGE 2020

Analyzing the entire period and all crops, it is clear that there will be a retraction of the planted area mainly for rice, beans and cassava crops and a small increase in the corn area. This means that little by little these areas will be replaced by commodities such as soybeans and corn and this will certainly have an impact on food supply. Figure 5.10 illustrates the projection of planted areas until the year 2050 for various crops in Brazil.

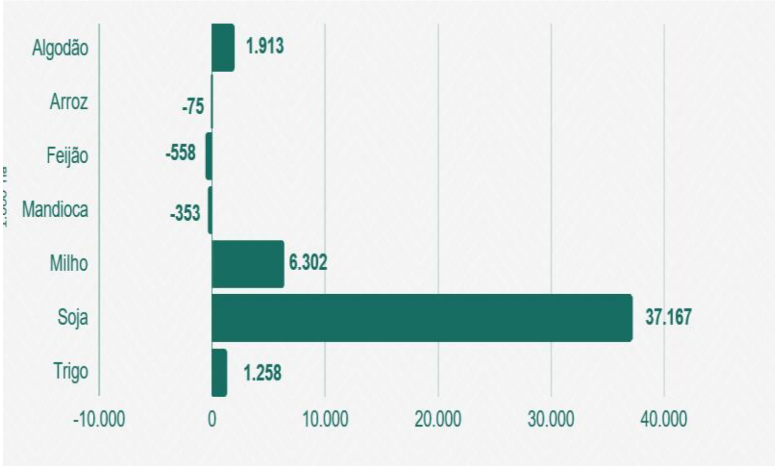


Figure 5.10. Variation of planted area for various crops in Brazil between the years 2021 and 2050. Bean, rice and cassava crops show a decrease in planted area when compared to soybean and corn.

Projections of the production and area of the main crops show that the planted area in Brazil is expected to exceed 100 million hectares by 2050. This expansion is concentrated in soybean, corn (second crop) and sugarcane (not shown in the figure above). Part of the increase in corn and cotton production is expected to be in soybean area. Some crops, such as rice, beans and cassava, are expected to lose area. Naturally, a part of the expansion of soybean, corn and sugarcane area should occur on new areas and substitution of other crops. This expansion may also occur in areas of degraded pasture. However, it is of utmost importance that there is an acceleration of the conversion of low or very low productivity pasture areas, due to lack of management, into crop areas or integrated production systems.

By 2050 there is a need to accommodate an expansion of about 45.6 million hectares in crop areas. This expansion is concentrated in an increase of 37 million hectares to the current soybean area and about 6 million hectares to the current corn area. Reducing the pressure for the extension of the area of crops in Brazil necessarily involves the expansion of techniques and technologies that increase land productivity without the need for new areas. The expansion of the high quality no-till system, associated with integrated production systems, can take grain productivity to a new level. In addition, the rapid advance of research, innovation and technology of new cultivars should expand the adoption of biological nitrogen fixation in legumes (beans) and grasses, contributing to the productivity of corn, rice and pasture areas.

A quick assessment of food consumption in Brazil, especially with regard to some items in the basic food basket, indicates that Brazilians are eating less. Table 1 shows the evolution of rice, beans, cassava and wheat consumption between 1985 and 2020. In all cases, consumption in KG/inhabitant fell. The most pronounced drop was in cassava, the staple of the diet in the North and Northeast regions.

Table 5.1. Per capita consumption of 4 items of the basic food basket in the last 35 years, in kg/inhabitant.

	Rice	**beans**	**cassava**	**wheat**
1985	**67**	**19**	**171**	**32**

1990	**74**	**16**	**159**	**37**
1995	**65**	**21**	**151**	**13**
2000	**67**	**16**	**120**	**14**
2005	**71**	**16**	**129**	**31**
2010	**65**	**18**	**125**	**31**
2015	**60**	**16**	**114**	**26**
2020	**49**	**14**	**83**	**26**

As temperatures and rainfall increase, the food production situation may be affected. In recent years, climate change has had a strong impact on soybean and maize production, reducing the harvest by more than 25 million tons.

5.2.2 Activity 2 - Economy, Climate and implications for food security

In activity 2 the results were indicated in the previous report (Year 5)

5.2.3 Activity 3 - Climate, livestock and implications for food security

Animal protein production in 2020 - beef, pork and chicken - was **27.9** million tons, of which 49% was chicken, 34% beef and 16% pork.

Total animal protein production is projected to grow to around 51.5 million tons in 2050. That is, an 84% growth compared to 2020.

Following the short-term downward trend, a slight decrease in beef production is expected until 2025 due to uncertainties regarding restrictions and sanitary barriers of the main export destinations. However, in the long term (2050), beef production is expected to grow to around 11.8 million tons. Several national (MAPA) and international (USDA) projections point to a sustained growth in international demand. Similarly, chicken production is projected to chicken production of 31.7 million tons in 2050, representing about 62% of total meat production in Brazil. Pork is expected to grow by 3.3 million tons by 2050 to a total of 7.9 million tons, or about 15% of total meat production (Figure 5.11).

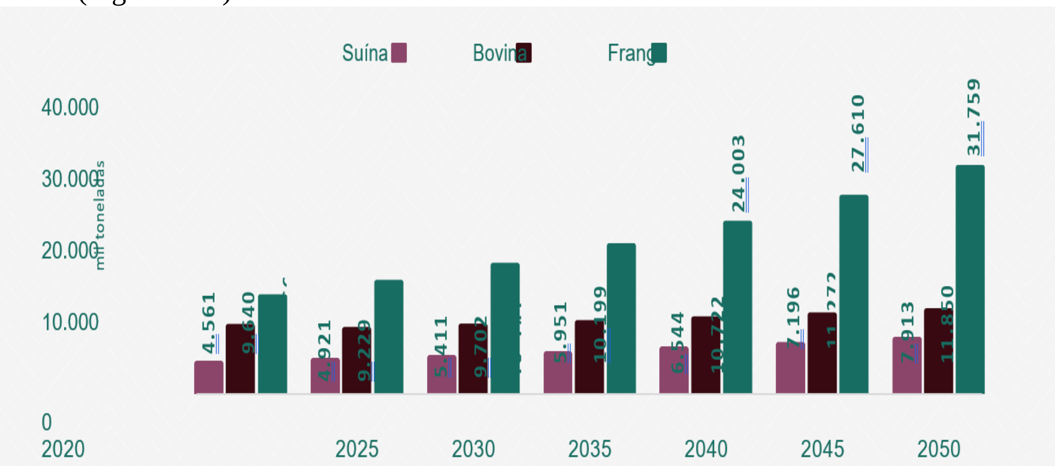


Figure 5.11: Evolution of animal protein supply up to the year 2050.

5.2.4 Some considerations:

To ensure food security for Brazilians and the country's growing relevance to the world supply, grain production in 2050 should reach approximately **535 million tons** in a planted area of about **111 million hectares**. These figures represent a growth of around **106% in production** and **71% in area** compared to 2021. This will require an increase in productivity, technological advances, wide adoption of modern practices and techniques such as no-till and integrated systems, an increase in the second crop area, reduction of the productivity differential between producers and regions, intensification of livestock, pasture recovery and better use of agricultural areas, among others. Public policies and actions by the private sector and the third sector must be improved and coordinated to this end, combining the availability of financial resources, investments in innovation, technical assistance and technology transfer, land security, environmental regularization, storage conditions and production outlets, and product and food quality control. All these efforts must also consider the improvement of the environmental and social sustainability of agriculture, integrating the objective of food security with the objectives of adapted and resilient systems and the reduction of greenhouse gas emissions.

5.2.5 Targets

Assessment of the vulnerability of food security due to changes in crops and pastures (such as new production systems and production intensification), until the year 2050.

The targets were achieved and described according to the results. The strongest impacts are related to the reduction of food supply, mainly rice, beans, cassava and wheat, and in some cases greater vulnerability of crops in the southern region, due to the effects of climate change, mainly water deficiencies, already described in the previous report.

5.3 Water security

5.3.1 Highlights:

With IPCC/AR6, UNESCO-IHP IX, UNEP WWQA, WMO Strategic Plan, IBPES and COP27, the 6th-yr INCTMC2 Water Security promoted “archetypes of participatory resilience” by “actors”, “models" and “datasets" with 2023-2032 HELPING Science Decade (see Figure 5.12 and Table 5.2):

1- Synergistic and Interdisciplinary Dialogue with new INCTs: i.e. the Nat. Observatory of Water Security & Adaptive Mgmt ("ONSEAdapta", SDG6) and “Fighting Hunger” (SDG 2),

2- EDI-driven (*Equity, Diversity & Inclusion*) affiliated research groups: namely “IEA/USP Planetary Health” (SDG 3), FAPESP Research, Dissemination & Innovation Center, “CEPIDs” (*CeMEAI-“Applied Maths for Industry"*, SDG 9) and Center for Research on Biodiversity Dynamics and Climate Change (SDG 15), FAPESP Eng. Res. Center (*C4AI-“Artificial Intelligence”*), FAPESP-Belmont Forum (*MADIS-“*Management of Disaster Risk and Societal Resilience*”*);

3- Educative Game-Changing Accelerators: with the INterdisciplinary CLimate INvestigation cEnter (INCLINE), the Center for Education and Research on Disasters (CEPED/USP), the UNESCO Chair on Urban Water (SDG 4) and Panta Rhei initiatives through new open tools, i.e. the Brazilian Ecohydrological Simulation Tool (BEST) and the HydroPol2D;

4- Participatory Serious Games: “Coevolutionary Amazon Health & Sanitation“ paradox (“CASH” Paradox), “BRazil’s Offset of Net-Zero Emissions toward GOals for Leveraging Development” (“*BRONZE-2-GOLD*”), and “Recycling Water Assets for Sustainable Habitats” (*ReWASH*), and Climate Justice, Equity, Diversity & Inclusion to Accelerate Water security and Adaptation Knowledge Exchange for Net-zero & Sustainability (“JEDI AWAKENS”);

5- New Demonstrative Pilot Projects (without Complementary Benefits): the FAPESP-NSFChina SDIC Flash Droughts Under Climate Change, the FACEPE-FAPESP Global change, sustainable development with WEFE viability and the IAHS New Scientific Decade HELPING;

6- FAIR data management: with CARE principles, through IAHS Panta Rhei benchmark dataset with socio-hydrological data of paired events of floods and droughts, the UNESCO-IHP-IX Operational Plan (2022-2029), IWA 'Earth Observation for water management' Community of Practice, Brazilian datasets (PNSH/ANA, CAMELS’BR & CABra);

7- New Centers of Global Change Climate Action e-Courses: in partnership with other UN Water Learning Centers, to boost interdisciplinary training using INCTMC2’s experiences through ABRHidro-Education Technical Comission, IAHS International Commission on Human-Water Feedbacks & WG History of Hydrology, and UNEP World Water Quality Alliance courses;

8- Social action: #OneDropOfScience #OneDoseOfResilience #BeFAIRwithCARE #GenerationRestoration.

Figure 5.12. Summary of highlights of the INCTMC2 Water Security subcomponent in the 2022/2023 period

Table 5.2. State of objectives and goals of INCTMC2-Water Security (from Marengo, 2014). Shaded cells represent new 2022/2023 workable topics appended for extension period until 2025.

10.2.3 Main objectives (page 34)	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
1. Identification of strategic river basins to systematize data collection of water supply and demand with hydro-climate models to evaluate indicators of water security for users.	👍	👍	👍	👍	👍	**New open models:** i.e. Brazilian Ecohydrological Simulation Tool (BEST) and the HydroPol2D		
2. Calibration and validation, spatially-distributed, of hydrological processes, i.e. rainfall- evapotranspiration, and runoff, under conditions of quasi-stationarity for several spatial scales, land	👍	👍	👍	👍	👍			
3. Simulation of calibrated models, coupling with climate models of medium-and long-term, for prospecting indicators of vulnerability and risk of hydrological extremes under future scenarios	👍	👍	👍	👍	👍	**FAIR data mgmt:** Panta Rhei benchmark dataset, socio-hydrological events of floods-droughts, UNESCO-IHP-IX Plan (2022-2029), IWA 'Earth Obs. Water Mgmt Comm. Practice, PNSH/ANA, CAMELS_BR & CABra,		
4. Evaluation of new adaptation strategies for water security for multiple uses under nonstationary conditions using classical and	👍	👍	👍	👍	👍			
5. Proposition of strategies for improving water security communication among stakeholders, scientific community, policymakers and vulnerable population to hydrological extremes		👍	👍	👍	👍			
1st Highlight for the 2023/2025 Period (extension): "Update New Understanding on Water Security" TASKS: new scenarios from C3S CORDEX (Diez-Tierra et al, 2022, AR6/IPCC, Pörtner et al, 2022); new resilient strategies (IPCC, 2022; Kreibich et al, 2022); new goals on water security & education (UNESCO-IHP-IX, 2022-2029); new water balance under change (Ballarin et al, 2022; Chagas et al, 2022); new demands for water security indices (ISH/ANA, 2022) and for the Nat. Water Resources Plan 2022-2040 (ANA, 2022); new models of water infrastructure (Macedo et al, 2022; Gomes Jr et al, 2022); new Act Project (PL) (Brasil, 4546/21; Sao Paulo, 146/22);								
2nd Highlight for the 2023/2025 Period (extension): " Accelerating scientific communication and science literacy to the wide audience of stakeholders TASKS: new tools for water security policies for the periods of 2022-2040, 2040-2060, 2060-2080 with: nation-wide and statewide enactments; indices of usage, efficiency and performance; climate modeling outputs, alert issuing and intraannual/interannual predictions; water resources pricing; water resources license; WASH tariffs; payment for ecosystem services (PES); river basin plans; GEE inventories; Ecologic-Economic Zoning e Strategic Environmental Assessment; Disaster Risk Reduction plans; Insurance and Climate Services.								
10.2.5 Expected Goals (page 36)						**New Reactive Serious Games:** "Coevolutionary Amazon Health & Sanitation" Paradox ("CASH" Paradox) **New Participatory Serious Games:** "BRazil's Offset of Net-Zero Emissions toward GOals for Leveraging Development" (*BRONZE-2-GOLD*), "Recycling Water Assets for Sustainable Habitats" (*ReWASH*) "Climate Justice, Equity, Diversity & Inclusion to Accelerate Water security and Adaptation Knowledge Exchange for Net-zero & Sustainability"(JEDI AWAKENS		
[1.] Strengthening information and databases for present and future climate-hydrology information in strategic basins under growing risks of hydrological extremes.	👍	👍	👍	👍	👍			
[2.] Consolidation of a cooperative research network from institutions of excellence in Brazil to evaluate the water security to the extremes of floods and droughts.	👍	👍	👍	👍	👍			
[3.] Promotion of adaptation strategy of climate-water-resilience for sustainable development in Braz. basins		👍	👍	👍	👍			
[4.] Providing technical tools for policies with strategies of adaptation to future changes aimed at mitigating hydrological vulnerability.		👍	👍	👍	👍			
3rd Highlight for the 2023/2025 Period (extension): INCTMC2 Water Security archetypes for "Actors", "Models" and "Datasets" engaged through Panta Rhei participatory-inquired research using serious games (reactive vs. participatory) and Social Campaigns #OneDropOfScience #OneDoseOfResilience #BeFAIRwithCARE #Generation-Restoration, and 2023-2032 HELPING (Hydrology Engaging Local People IN one Global world)								
[5.] New courses of water security in graduate programs, including interdisciplinary seminars and crosscutting training courses for public-and-private sectors.	👍	👍	👍	👍	👍	**New Global Change & Climate Action Courses:** ABRHidro Education Technical Commission and IAHS International Commission on Human-Water Feedbacks, WG History of Hydrology & UNEP WWQA		
[6.] Postgraduate Award of Brazilian researchers on the subject of water security with increased participation in national and international projects, and with public-private partnerships (PPPs).	👍	👍	👍	👍	👍			
[7.] Publication of research results in media accessible to interested parties, as well as in international journals of high impact and across disciplines.	👍	👍	👍	👍	👍	**New Demonstrative Pilot Projects** (without Complementary Benefits): the FAPESP-NSFChina SDIC Flash Droughts Under Climate Change, the FACEPE-FAPESP Global change, sustainable development with WEFE viability and the IAHS New Scientific Decade HELPING		
[8.] Expansion of participation of Brazilian researchers in international forums for innovation and solutions on water security.	👍	👍	👍	👍	👍			
New INCTs: "ONSEAdapta - Nat. Observatory for Water Security & Adaptive Mgmt." "Fighting Hunger & Food Security"								
[9.] Promotion of a science-to-policy network for the 2019-2035 Brazilian Water Resources Plan (ANA), under the legal framework (9.433/97, Braz. Wat. Res. Act; 12.187/09: the Braz. Climate Change Act; 12.608/12, Braz. Civil Defense Act; 14.026, New Sanitation Framework: 14.119. the Braz. Payment of Ecos.	👍	👍	👍	👍	👍			

5.3.2 Scientific and Management Actors (Science-For-Policy)

This part outlines a summary of activities developed by INCTMC2's water security (WS) affiliated institutions, i.e. UFPE, UFCG, USP, UFCG, UFRGS, CEMADEN, INPE, FUNCEME and EMBRAPA, with new affiliated institutions: UFMS, UFSC, UnB and ABRHidro, boosted through both the Latin American Unsolved Problems in Hydrology Workshop (Florianopolis-SC, 2023; Figure

5.13) and the Panta Rhei Symposium (Potsdam, 2023; Figure 5.14). Detailed information can be consulted in respective publications (see Section B). Highlights of the INCTMC's 6th year (2022/2023) were addressed in how Brazilian INCTMC2-WS' actions met global programs of UNDRR, UNFCCC, UN-Habitat, UNESCO-IHP-IX (2022-2029) and socio-hydrology initiatives of IAHS/Panta Rhei and IAHS/Unsolved Problems in Hydrology (UPH).

Figure 5.13. INCTMC2 Water Security in the Latin America's UPH, Florianópolis, 2023. Source:

UFSC

Figure 5.14. INCTMC2 Water Security in the Panta Rhei Symp., Potsdam, 2023. Source: GFZ,

https://iahs.info/News/news/panta-rhei-symposium/

The polycentric governance statement of the INCTMC2-WS subcomponent is: *"how new sustainable, resilient private-public partnerships promote targeted investment in climate services to strengthen community-based, hybrid early warning systems and decision support for water resources adaptation in climate-sensitive sectors and for most vulnerable people in the Tropics, through metrics and levels of indices[1], with flexible, adaptable and participatory mechanisms[2],* and *using resilience-driven (absorptive, adaptive, transformative) methods[3]".*

Hence, this 6th year of the INCTMC2-WS was consolidated through relevant research-into-policy networks with the IAHS Panta Rhei benchmark dataset with socio-hydrological data of paired events of floods and droughts, the UNESCO-IHP-IX Operational Plan (2022-2029), the IWA 'Earth

[1] Indices: *Nationally Determined Contributions of Parties (NDC) for UNFCCC, Nature's Contribution to People (NCP) for CDB & IPBES, and Digital Sequence Information" (DSI) for Natural Capital from CBD.*

[2] Mechanisms: - *Enhanced Transparency Framework (ETF), post-Paris 2015/UNFCCC, Monitoring, Report & Verification (MRV) on GHG from UNFCCC, Global Stocktake (GST) from UNFCCC, Sustainable Development Mechanism (SDM) of zero-net targets, Principles of Sustainable Insurance (PSI-UNEPFI) and Green Bonds, Waste Wise Cities from UN-Habitat, Water, Sanitation & Hygiene"(WASH) services from UN-Agenda 2030.*

[3] Methods: *Nature-based Solutions (NbS), Ecosystem-based Adaptation(EbA), Community-based Adaptation(CbA), Participatory Action Research (PAR)*

Observation for water management' Community of Practice, Brazilian open datasets on water security (PNSH/ANASB, CAMELS’BR & CABra).

Moreover, being Brazil a global player in natural capital has the INCTMC2 water security subcomponent decided to include the Intergovernmental Science-Policy Platform on Biodiversity & Ecosystem Services (IPBES) and the Convention of Biological Diversity (CBD) as programs for linking INCTMC2-WS’ science-for-policy goals.

5.3.2.1 Advances at Multiple Scales of Water Security

In this 2022/2023 period, research groups of INCTMC2-Water Security have gained advances like continental river flows’ datasets (A.1.1), sociohydrological datasets of paired events (floods and droughts, A.1.2), and datasets on droughts-and-floods change in Brazil (A.1.3).

5.3.3 Continental river flow datasets

In the period 2022/2023, the assessment of South American sediment fluxes under climate changes (Fagundes et al., 2023; Figure 5.15) and the assessment of climate change impact on flood discharge in South America and the influence of its main drivers (Brêda et al, 2023, Figure 5) are outlined for the INCTMC2 Water Security.

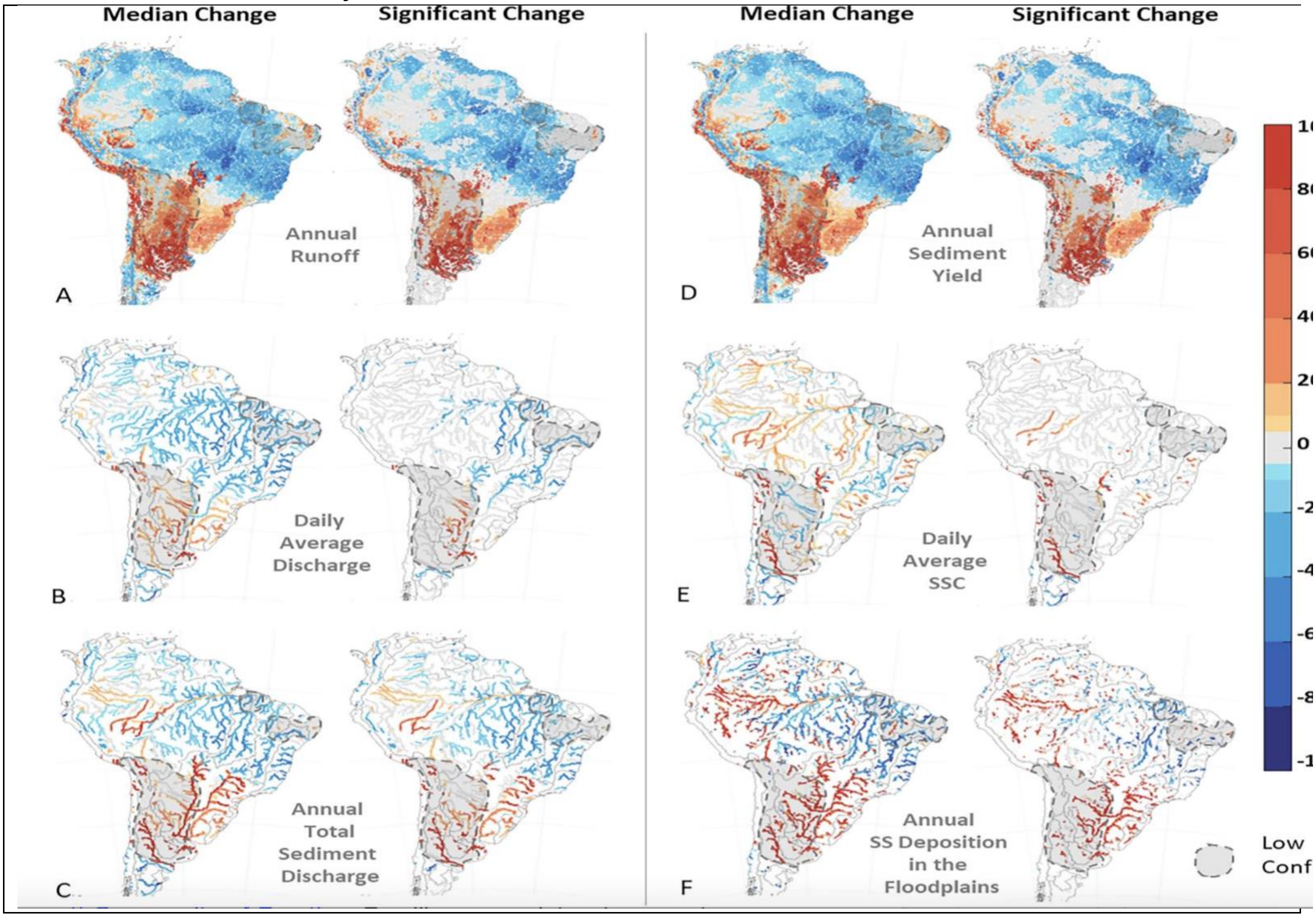


Figure 5.15. Projected impacts for South America due to climate change with the regional climate models Eta-BESM, Eta-CanESM2, Eta-HadGEM2-ES and Eta-MIROC5, considering the RCP 4.5 scenario for the period between 2021 and 2055, for the water and sediment variables: A) annual surface runoff; B) daily average discharge; C) annual total sediment discharge; D) annual sediment yield estimated using MUSLE equation; E) average daily suspended sediment concentration (SSC); and F) annual suspended sediment (SS) deposition in the floodplains. All values on the maps are presented as percentage values, estimated by comparing future projections (2021–2055) with past values (1961–1995). The median change was estimated from the comparison between the estimated

future and past values. The significant change was estimated considering that 3 or 4 models presented a statistical change of the mean at the significance level α = 10 % and 3 or 4 models showed an agreement of increase or decrease in the value of the variable studied. The low-confidence regions are those in which the hydrological-hydrodynamic model presented by Siqueira et al. (2018) showed low performance. Source: Fagundes et al (2023).

Fagundes et al (2023) highlighted that: (a) simulated sediment flows show contrast in northern (decrease) and southern (increase) South America (SA), (b) an increase in sediment transport >30 % might occur for the main South American basins, (c) the highest changes in sediment discharge may occur in Doce (−54 %) and Upper Paraná (409 %) rivers, (d) changes in water and sediment discharges can induce a new water composition in the Amazon basin, and (e) Future changes in sediment fluxes may greatly affect SA aquatic ecosystems. (Figure 5.16).

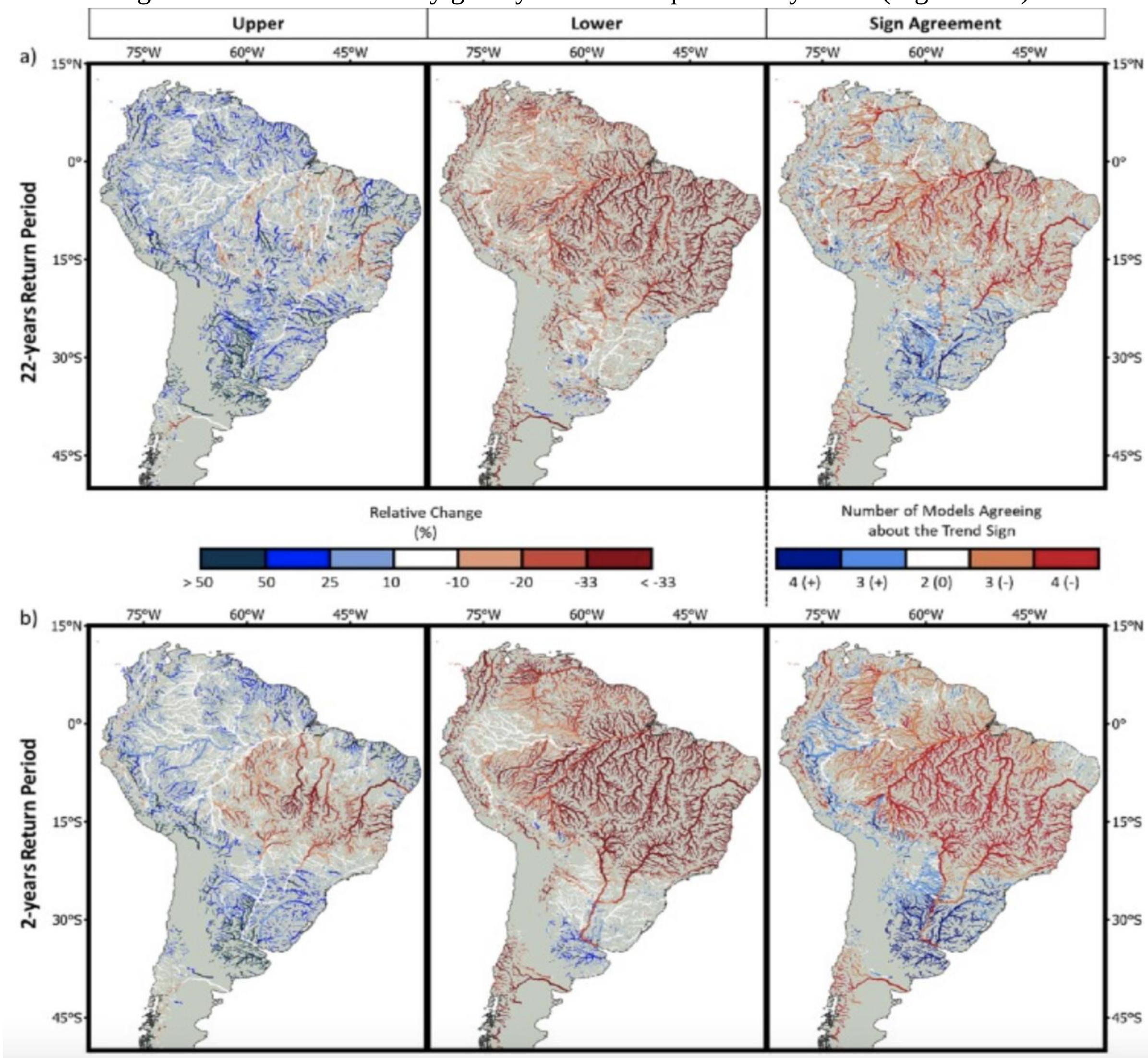


Figure 5.16. Relative change of flood discharge projections for the RCP4.5 scenario compared to the historical period. The left and center panels show the upper and lower limits related to the ensemble of 4 downscaled climate models, respectively, while the right panel indicates the agreement between these models regarding the change sign. Relative differences are shown for the second-highest (a) and median (b) annual maximum discharges from the future and historical periods. Source: Brêda et al (2023).

Otherwise, Brêda et al (2023) highlighted that (a) extreme rainfall events that lead to floods in large rivers are expected to decrease, (b) antecedent soil moisture is expected to be reduced in most of South America, and (c) soil moisture seems more impactful than precipitation regarding ordinary floods.

5.3.4 Sociohydrological datasets of paired events (floods and droughts)

When addressing South American datasets of paired events of floods and droughts (Figure 5.17, Upper Chart), several highlights are enhanced (Figure 6, Lower Chart). The dataset can be used by the scientific community for exploratory data analyses, e.g. focused on causal links between risk management; changes in hazard, exposure and vulnerability; and flood or drought impacts. The data can also be used for the development, calibration, and validation of socio-hydrological models. The dataset is available to the public through the GFZ Data Services (Kreibich et al., 2023, https://doi.org/10.5880/GFZ.4.4.2023.001).

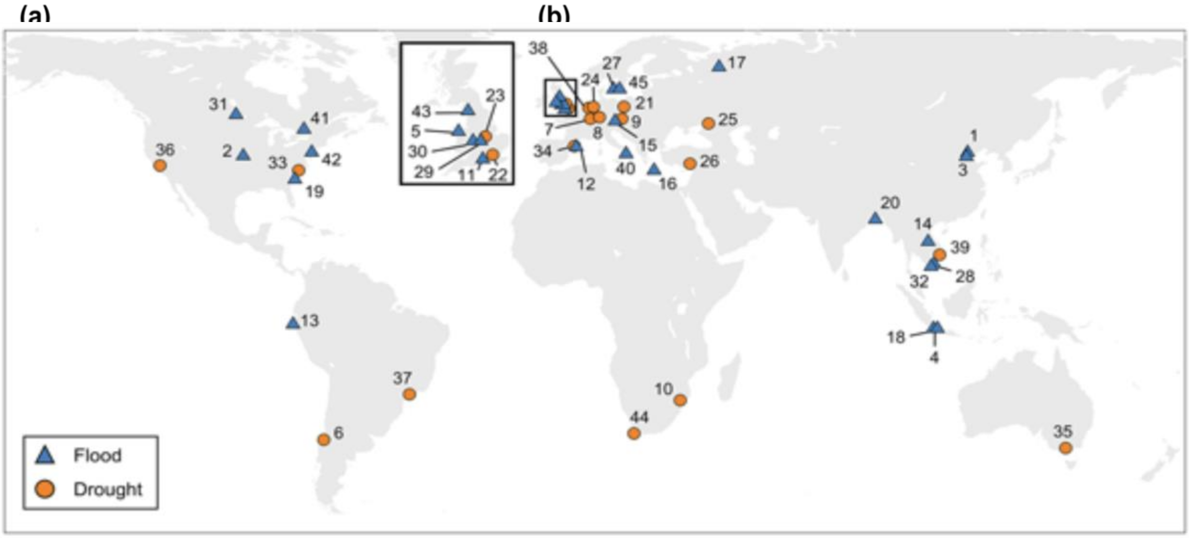


Figure 5.17. Upper Chart: Geographical distribution of paired events of floods and droughts. Lower Chart: Fraction of entries of each indicator for flood (a, left) and drought (b, right) paired events. Source: Kreibich et al (2023).

5.3.5 Datasets on droughts-and-floods change in Brazil

Chagas et al (2022) highlighted that accelerating water cycle has occurred in 29% of Brazilian territory (2.7 million km^2), with deceleration in 4% (0.4 million km^2), drying in 42% (3.9 million km^2); and wetting in 25% (2.4 million km^2). In parallel, Ballarin et al (2023) proposed Brazilian water security threatened by climate change and human (Figure 5.18, 5.19).

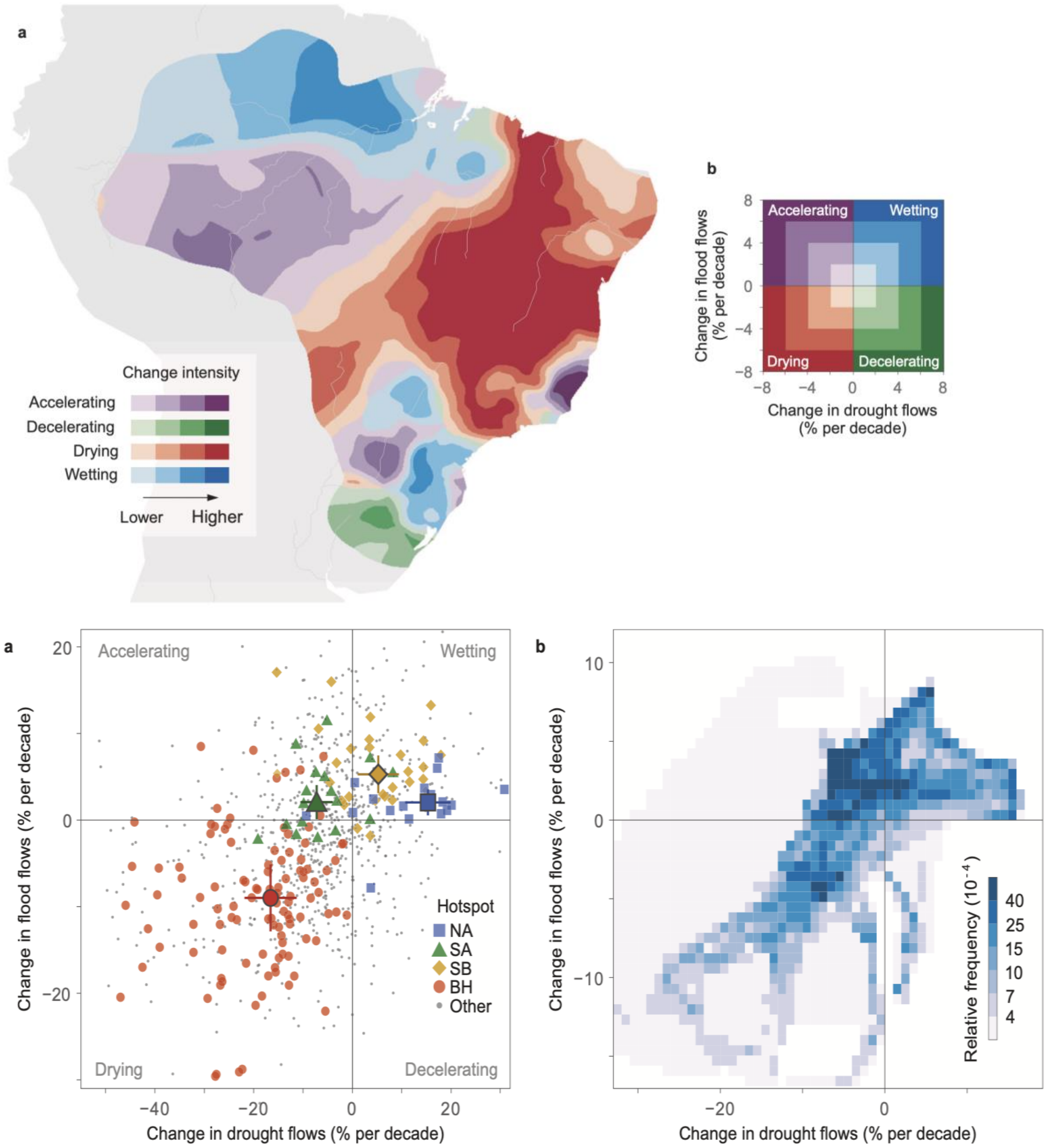


Figure 5.18. Upper Chart: Spatial distribution of the accelerating, decelerating, wetting, and drying streamflow trends in Brazil. a The location of the four quadrants of regional streamflow trends, with darker colors indicating larger change intensities. Lower Chart: Classification of streamflow trends into accelerating, decelerating, wetting, and drying quadrants. (a) Symbols without borders indicate flood and drought flow trends of n = 886 stations. Hotspots (Northern Amazonia – NA, Southern Amazonia – SA, Southern Brazil – SB, and Brazilian Highlands – BH) are indicated by colors. Symbols with borders represent the median trend of each hotspot, and the error bars indicate the median temporal uncertainty of the trend estimates. b Classification of regional trends, with darker colors indicating higher areal fraction per bin. Source: Chagas et al (2022).

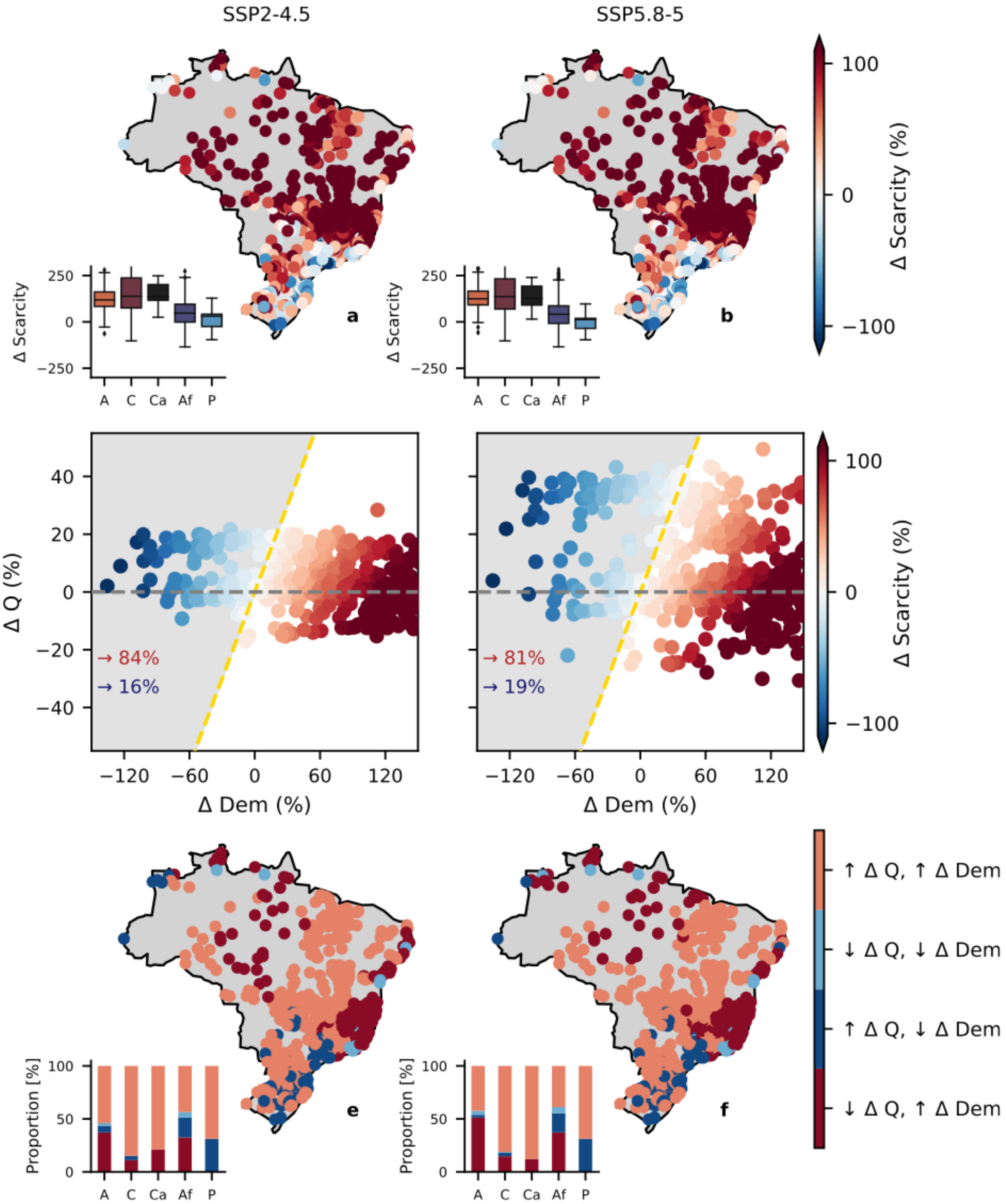
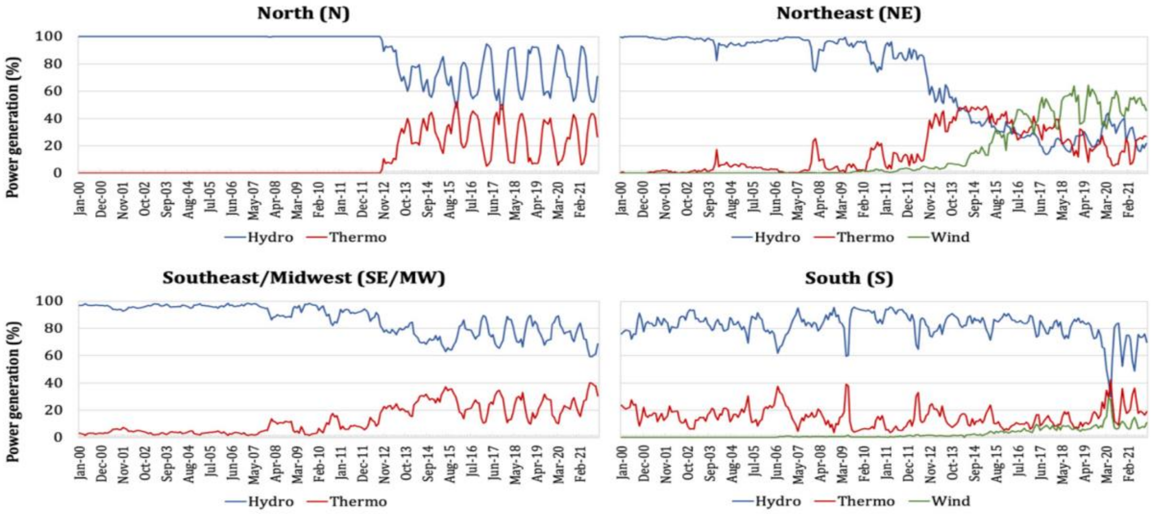


Figure 5.19. Water scarcity changes. (a and b) Projected relative changes in the long-term mean scarcity index in Brazil for the distant future (2070–2100) and historical period (1980–2010) under the SSP2-4.5 and SSP5-8.5 scenarios, respectively. Changes per Brazilian biome are displayed in traditional boxplots (A: Amazon, C: Cerrado, Ca: Caatinga, Af: Atlantic Forest, and P: Pampa). (c and d) Relationship between relative changes for the distant future (2070–2100) and historical period (1980–2010) in water availability (ΔQ), water demand (ΔDem), and in the water scarcity index (ΔScarcity) for the SSP2-4.5 and SSP5-8.5. A yellow, dashed line separates catchments with positive and negative changes in the scarcity index. A gray, dashed line separates catchments with positive and negative changes in water availability. Red (blue) numbers indicate the fraction of catchments whose water scarcity is expected to get worse (better). (e and f) Catchments classified in four different categorical classes according to their positive/negative changes in future water availability (ΔQ) and water demand (ΔDem). Categorical classes per biome are displayed on stretched bar plots. Source: Ballarin et al (2023).

5.3.6 Water-Energy Nexus and Storage Services under change

Acceleration processes have also affected water-energy nexus (see Figure 5.20) as highlighted by Cuartas et al (2022) and Tomasella et al (2023). Signals of land-use and climate change pointed by Ballarin et al (2023) and Chagas et al (2023) do justify freshwater storage services linked to climate services, especially for official list of dams and reservoirs in Brazil (see Figure 5.21).



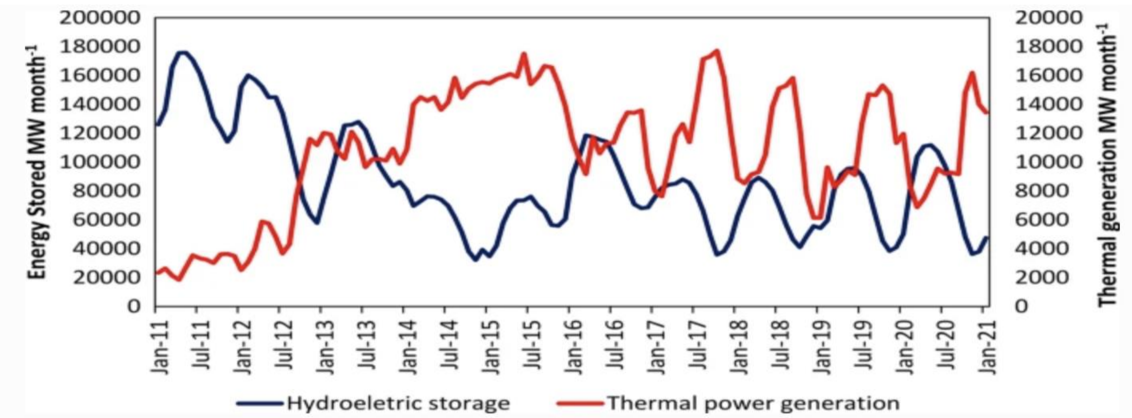
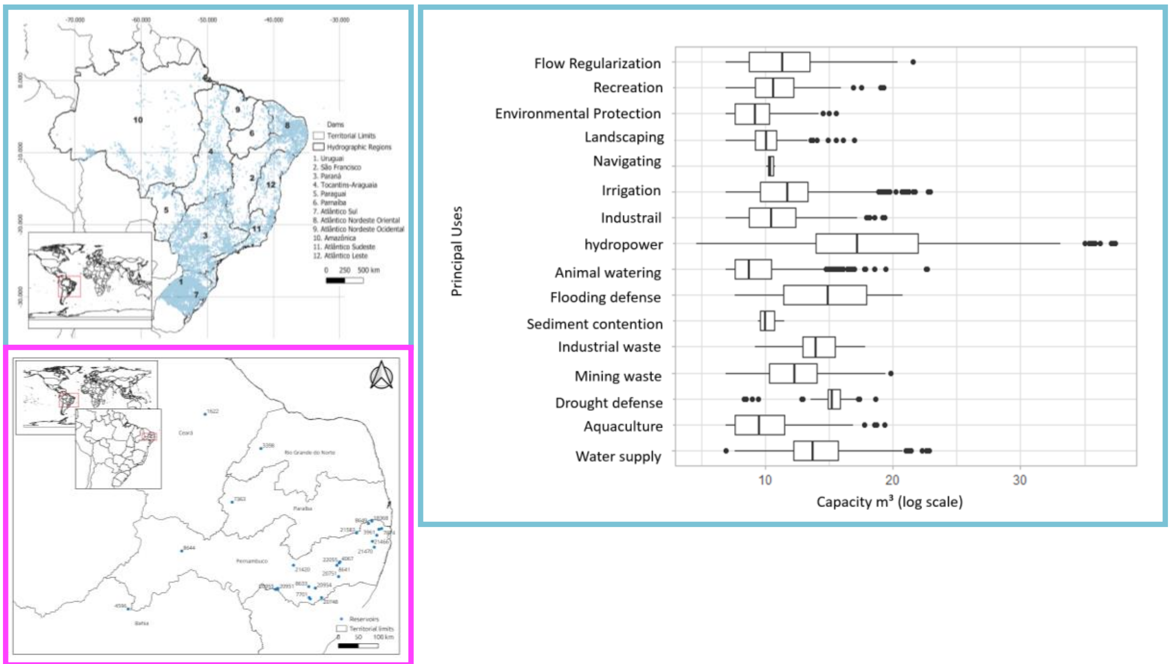


Figure 5.20. Upper Chart:Monthly electricity generation for Brazilian regions (Cuartas et al, 2022). Lower Chart: Stored energy in hydropower plants of the Center-West and Southwest of Brazil (blue line) and thermal power generation (red line) over the period 2011–2021. Source: ONS, adapted from



#	Reservoir	SNISB Code	State	Capacity (hm^3)	Lake Area (km^2)	Main demand	CO_2 Emissions (tCO_2/year)	Reforest Area (m^2)
1	Cantim	8644	PE	0.088	0.230	Flow regularization	3254.00	1907.36
2	Bolandim	7707	PE	0.120	0.980	Human supply	8766.00	5340.26
3	Barragem B	19063	PE	0.049	0.450	Recreation	5789.00	4527.85
4	Barragem 1	20951	PE	0.051	0.043	Irrigation	240.63	501.00
5	Barragem 2	20952	PE	0.006	0.003	Irrigation	240.63	501.00
6	Serra do Jardim	22055	PE	0.200	0.004	Human supply	70.06	110.00
7	Tamboril I	21420	PE	0.114	0.028	Human supply	2919.00	3625.45
8	Penedo Velho	3961	PE	0.234	0.089	Irrigation	8256.00	2563.35
9	Curtume	21466	PE	0.002	0.150	Industrial	22538.00	6526.58
10	Riacho da Palha	20748	PE	0.020	0.001	Human supply	486.21	955.00
11	Spray	18368	PE	0.020	0.030	Flow regularization	310.02	625.25
12	Sítio Timoteo	20954	PE	0.050	0.002	Irrigation	168.72	370.27
13	Mondé	8641	PE	0.110	0.040	Human supply	42.88	211.50
14	Sítio Queimada da Jurema	20955	PE	0.020	0.030	Irrigation	55.17	254.20
15	Bambu	3960	PE	0.020	0.003	Industrial	135.35	313.32
16	São Luiz	21470	PE	0.110	0.020	Industrial	9440.00	1318.00
17	Do Chau	8633	PE	0.110	0.010	Flow regularization	6340.00	880.00
18	Zenite	8660	PE	0.003	0.002	Human supply	5020.00	962.00
19	Riacho Escuro	21583	PE	0.037	0.010	Flow regularization	3126.00	1856.25
20	São Sebastião	20751	PE	0.250	0.013	Human supply	4504.00	865.00
21	Catú	7874	PE	0.018	0.004	Irrigation	3126.00	1802.14
22	Barragem A	4067	PE	0.013	0.216	Irrigation	254.00	600.00
23	Açude do Alemão	8649	PE	0.013	0.070	Flow regularization	536.00	950.00
24	Açude da Nação	7701	PE	0.263	0.110	Human supply	734.00	130.00
25	Reservatório Cedro	1622	CE	126	7.23	Human supply	5025.00	37.70
26	Barragem Santa Cruz do Apodi	3398	RN	648.846	31.95	Human supply	870.00	700.00
27	Eng. Ávidos	7363	PB	255.000	18,67	Human supply	680.00	539.07
28	Sobradinho	4596	BA	34160.00	3135.65	Hydroelectricity	2500.00	1000000.00

Tomasella et al (2023).

Figure 5.21. <u>Blue boxes</u>: geographical distribution of freshwater reservoirs in Brazil, with classification of principal purpose of existing freshwater reservoirs (total dataset: 22000 reservoirs, adapted from ANA/SNISB). <u>Pink boxes</u>: preliminary results of potential Green House Gas emissions of selected freshwater reservoirs in Northeast Brazil and their equivalent future forest areas around reservoirs needed to assimilate lake-originated carbon emissions, under existing land-uses and climate, and through BRONZE-2-GOLD approach ("Brazilian Offset for Net-Zero Emission toward Goals with Leveraging Development"). Further studies are expected for the combination with works of Ballarin et al (2023, climate change and land-use) and Chagas et al (2022). Source: Silva et al (2023, IUGG Berlin).

5.3.7 Water Security Insurance for multi-hazard and multi-risk pooling

For poor-gauged catchments, Benso et al (2023) addressed water security insurance mechanisms under change for both multi-hazard and multi-risks (Figure 5.22. By using "immediate-", "intermediate-" and "distant-scenario" changes has Gesualdo (2023) optimized premiums under climate change.

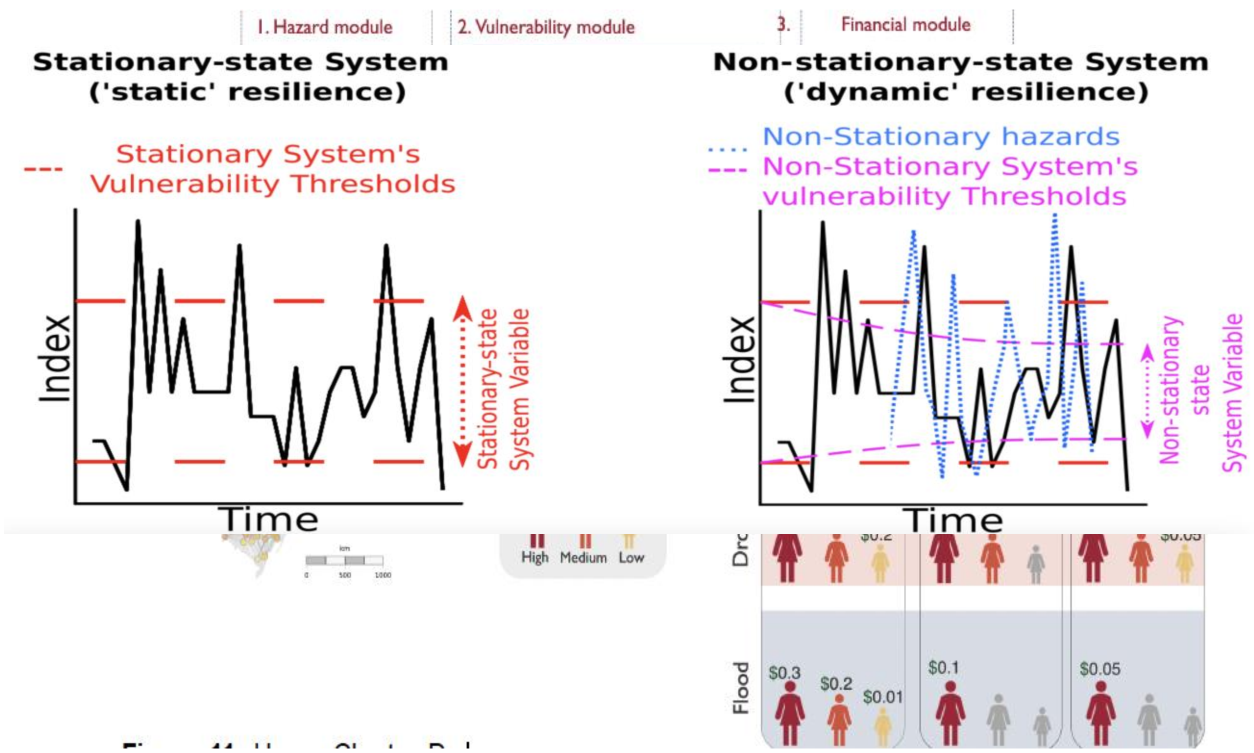


Figure 5.22. Upper Chart: Dynamic Water Insurance Under Change (Benso et al, 2023). Lower Chart: Dashboard (left) of drought risk pooling and insurance premium simulations (right) (Gesualdo, 2023)

5.3.8 Urban flash floods risk assessment under climate change

To assist small catchments draining to 40000 flood risk prone areas in Brazil, Castillo et al (2023) incorporated climate change scenarios to assess water security in the scale of human instability under urban flash-floods (Figure 5.23). Using the HydroPol2D model (Gomes Jr. et al, 2023), it is possible to map future flash-flood risk changes with distributed zoning and in poor-gauged areas.

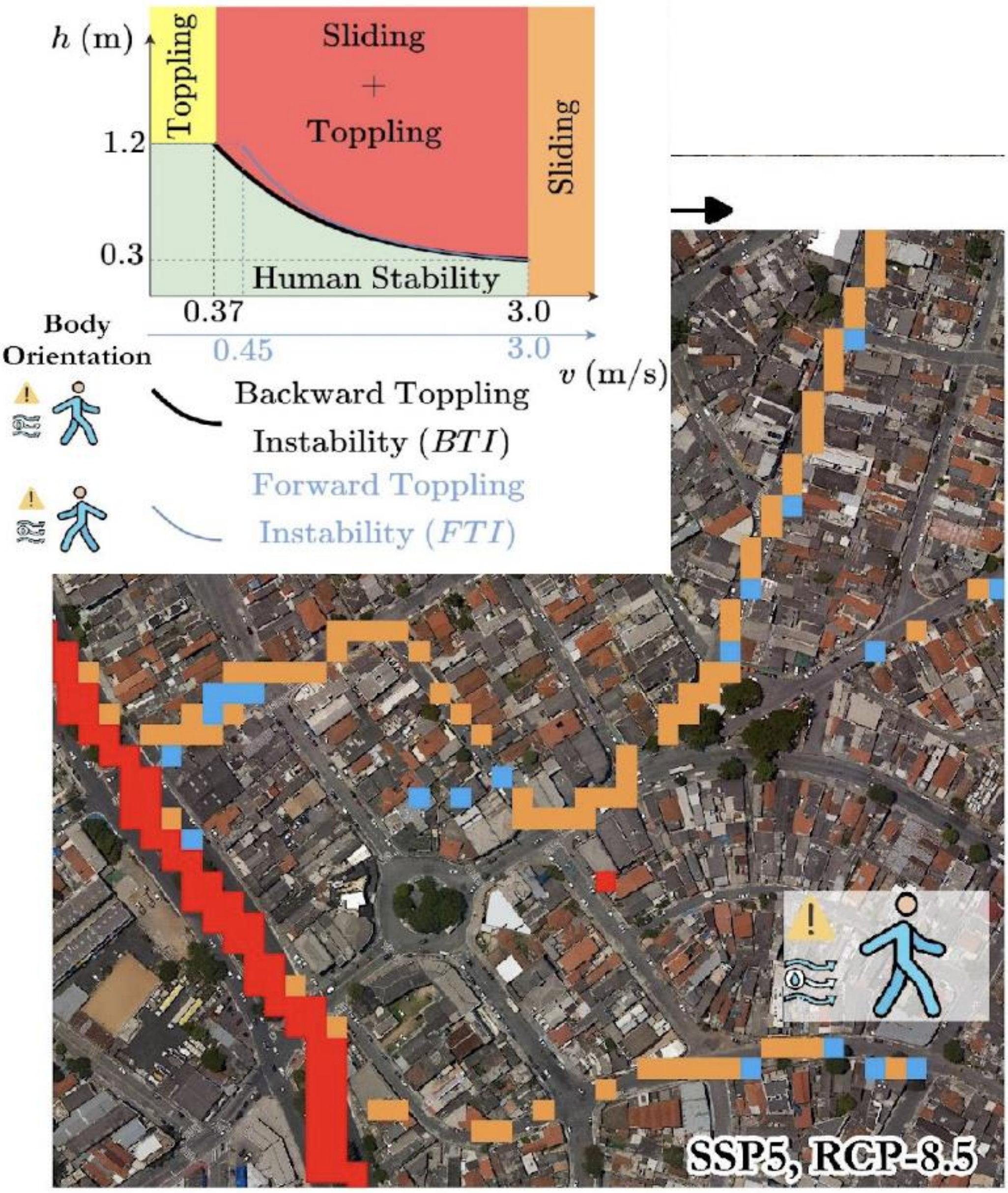
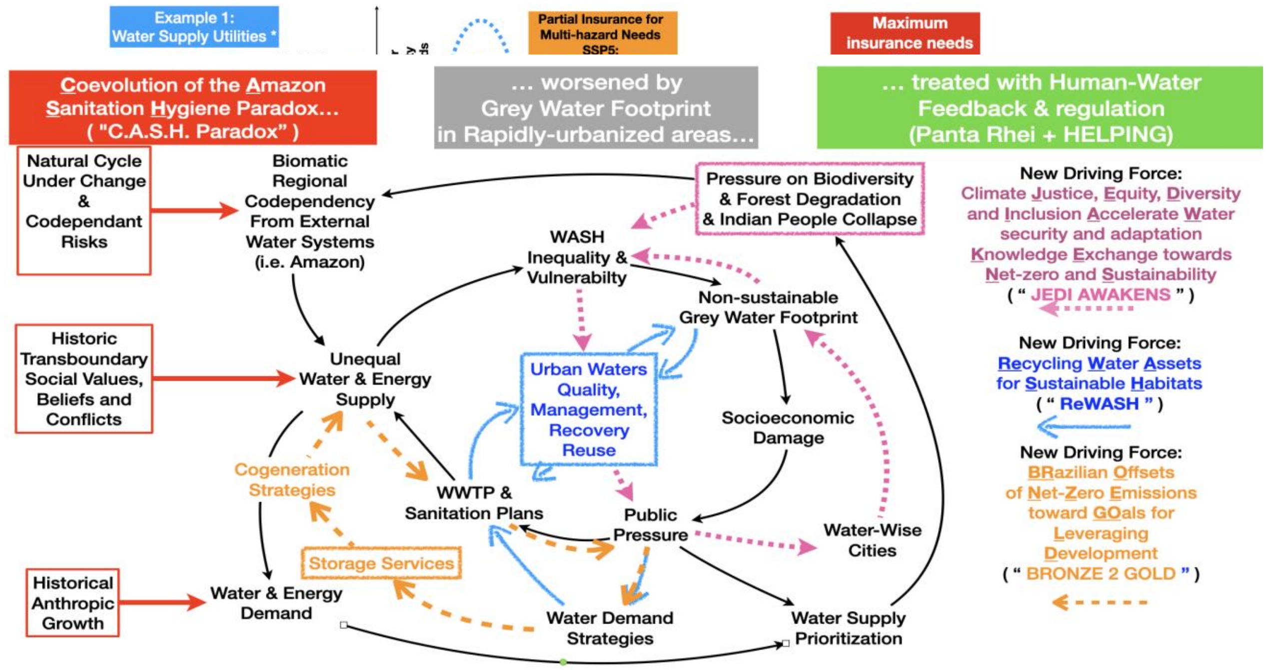


Figure 5.23. Example of urban flash-flood risk mapping for human instability under climate change using INCTMC2/HydroPol2D. Source: Castillo et al (2023)

5.3.9 New Water Security Models for Adaptation Under Change

Gomes Jr. et al (2023) presented a general fully-conceptual distributed water quality model (HydroPol2D) assisting not only DRR-frameworks but also long-term scenarios under change. On the one hand, HydroPol2D is open source code, friendly envisaged for coupling Climate-Impact Drivers (CID/IPCC) with INCTMC2's Water Security, thereby merging cascading risks with other subcomponents, i.e.: “Natural Disasters”, “Food Security”, “Integrated Modeling”, “Energy Security”, and "Education”. On the other hand, HydroPol2D is refined to handle new risk-transfer schemes under RCP x SSP's trials (see Figure 5.24, 5.25).



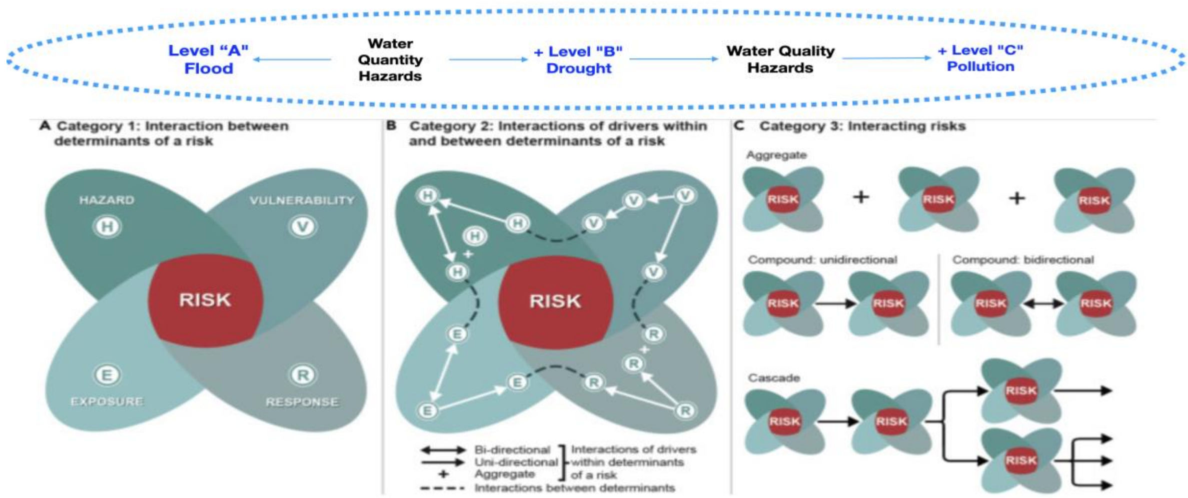


Figure 5.24. Upper chart: Example of Willingness To Pay as insurance scheme under INCTMC2's scenarios with different RCP x SSP coupled by simulation models of water quantity and quality, i.e. HydroPol2D, https://doi.org/10.1016/j.jhydrol.2023.129982. Lower chart: CID (Climate-Impact Drivers) of Water Security Hazards simulated with INCTMC2/HydroPol2D related to framework for complex climate change risk assessment, Simpson et al (2021), One Earth, https://doi.org/10.1016/j.oneear.2021.03.005. New "response" archetypes of strategies of adaptation to CID-water security extremes are presented in Figure 5.13.

Figure 5.25. Examples of new archetypes of climate-driven adaptation (IPCC/CID responses) of INCTMC2 Water Security subcomponent with main drivers (left, red lines), cascading IPCC-based risks (Pörtner et al, 2022) through reactive cycles (black lines) and proactive human-water feedbacks (colored lines). Adaptation strategies (i.e. "JEDI AWAKENS", "ReWASH", "BRONZE-2-GOLD") aim to: (1) mitigate pressure on biodiversity, forest degradation and Indian people collapse in Amazon-dependant areas (i.e. pink, dotted lines), (2) recycle urban waters in Brazilian megacities (blue lines) and (3) promote new freshwater storage services for ANA/SNISB dataset (orange, dotted lines). Source: Mendiondo et al, 2023, Panta Rhei Symp.& IUGG Berlin.

Furthermore, under a co-funded program between the Pernambuco's (FACEPE) and Sao Paulo's (FAPESP) agencies for research, they conducted a three-day SWAT+ short course, delivered in-person and via teleconference, at the University of Sao Paulo (USP) in Sao Carlos. This course was the kick-off of a long-term collaborative effort among the Brazilian Water Resources Association Technical Commission on Education ("ABRHidro-CT-Educacao"), the National Institute of Science & Technology National Observatory for Water Security and Adaptive Management ("INCT-ONSEAdapta"), funded by CNPq (Brazilian Research Council), and the UNESCO Chair on Urban Waters of USP.

This has led to discussions with Dr. Srini about developing a version of HAWQS, tentatively called "BEST" (Brazilian Ecohydrological Simulation Tool), that would cover all of Brazil. BEST will be a collaborative platform. Tentative plans include Dr. Srini providing a 10km x 10km SWAT model (initially uncalibrated) for the entire country. Brazilian researchers would be encouraged both to help calibrate the country-wide model and to contribute their more detailed, calibrated and validated SWAT models for other watersheds, starting with models of important Brazilian watersheds developed by the group. The Brazilian SWAT community would reach out to other universities and government agencies like EMBRAPA and ANA to contribute to this national effort.

5.4 Human health and climate change

The works were carried out along two complementary lines: A) application of models for projecting the distribution of parasitic disease vectors (different forms of leishmaniasis), depending on the climatic suitability for the proliferation of these vectors ("Distribution Potential"). In the last year of the project, the geographic scope of the analyzes will be expanded, initially restricted to the states of Minas Gerais and Rio de Janeiro. B) Retrospective analyzes of the effects of 5 geomagnetic factors on mortality from different causes (cardiovascular, neurological, autoimmune and infectious), in the South and Northeast regions of Brazil. In the final year, emphasis will be given to the effects of the Schumann Resonance phenomenon, due to the vast database of this parameter, existing for the study period (1996-2020).

5.4.1 Activities developed

According to the World Health Organization (2010, 2011) policies for surveillance and control of neglected diseases must be aligned with agendas committed to the assessment of climate and environmental changes. Thus, studies are being carried out with sandflies, insect vectors of leishmaniasis, an important disease in which Brazil has one of the highest numbers of cases (OPAS 2020, 2021).

In the first year, projections of the distribution of 04 vectors of American Cutaneous Leishmaniasis - ACL (*Bichromomyia flaviscutellata*, *Nyssomyia whitmani*, *Nyssomyia intermedia* and *Nyssomyia neivai*) were produced in scenarios of climate change in Brazil. In the following year, projections were made for other vector species *Psychodopygus wellcomei*, *Psychodopygus complex*, *Nyssomyia umbratilis*, *Migonemyia migonei*, *Lutzomyia longipalpis* and *Lutzomyia cruzi*, the latter two being vectors of American Visceral Leishmaniasis - AVL. In the third year, the results of the climate suitability scenarios of the vectors studied individually were analyzed, as well as their associations with the distribution of the respective ACL and AVL. In the fourth year, with the updating of the new scenarios of the Intergovernmental Panel on Climate Change (IPCC), the updating of the database related to the modeling of vectors was also started, so it was possible to calculate projections of the vector distribution associated with the variables socioeconomic conditions and the incidence of leishmaniasis, serving as a basis for calculating the vulnerability indexes of Brazilian municipalities. Such results, aggregated and analyzed by municipality, constitute important products to subsidize the National Leishmaniasis Control Program and the State and Municipal Health Secretariats of the country, aiming at a better planning of surveillance and control actions.

And in year 5, the municipal vulnerability in the State of Rio de Janeiro was analyzed for transmission of AVL (human and canine), as well as updating the record of *Lu. longipalpis*, an important vector of the disease, and its municipal classification. In the same year, the analysis of the spatial distribution of was studied *Ny*. *whitmani* in Brazil, in association with vegetation cover and the six Spatial Circuits of the LTA, which showed higher vector density in Dense Ombrophylous Forests, Seasonal Deciduous Forests, Seasonal Semideciduous Forests, Cerrado and Steppe. Finally, a systematic review of the climatic conditions that may affect the distribution of Covid-19 was started, in addition, the production of the modeling process to predict the distribution of Covid-19 under the effects of climatic conditions in the Brazilian territory.

In this year 6, the geographical distribution of was correlated *Ny*. *whitmani*, an important vector species of ACL in Brazil, and the population's vulnerability to the disease, through scenarios of environmental changes caused by land use. And to analyze future projections in relation to this vulnerability of the population in the face of climate change, it is necessary to understand how the dynamics of the disease occurs today in relation to the distribution of vectors in different ecological niches. Thus, an update of the municipal vulnerability for the transmission of AVL, ecological niche modeling and predicted geographic distribution of disease vectors in the state of Rio de Janeiro were carried out. Update of the vector distribution database (*Lu*. *longipalpis* and *Mg*. *migonei*) of AVL in the state, and creation of a thematic map of the spatial distribution of *Lu*. *longipalpis* and *Mg*. *migonei*, in the state of Minas Gerais, where about 70% of the cases of the disease in the Southeast Region are registered, as well as the production of maps related to vulnerability, municipal classification of the state and use and land cover in relation to these vectors.

With the current increase in global warming, it is believed that the results produced here can corroborate with the public power in the elaboration of strategic plans to mitigate the effects of global warming.

5.4.2 Analysis of the Spatial Distribution of *Nyssomyia whitmani*, Social Vulnerability and Risk Factors for American Cutaneous Leishmaniasis in Association with Vegetation Coverage in the Southeast Region

Vector-borne infectious diseases are exceptionally vulnerable to climate change as they depend on close relationships between microecological conditions, different parasite species, vectors and hosts that interact in complex transmission cycles. In Brazil, American Cutaneous Leishmaniasis (ACL) occurs in all Brazilian states, a disease sensitive to environmental factors, affected by changes in precipitation, temperature, humidity and land use. The study aims to correlate the geographic distribution of *Ny*. *whitmani*, to evaluate the vulnerability of the population to the occurrence of ATL in scenarios of environmental changes caused by land use. In order to evaluate the spatial distribution model of the vector and the surveillance and monitoring of ACL, in the municipalities of the states of the Southeast Region, databases were built with records of the occurrence of the vector, of the disease, associated with data on land use and cover (http://www.inpe.br).

These data were integrated into the Geographic Information System (GIS), a tool for investigating and forecasting environmental changes and creating thematic maps. Of the 1,667 municipalities in the states of the Southeast Region, *Ny. whitmani* was registered in 372 of them (Figure 5.26). Most of the vegetation cover in the Southeast Region is formed by the Atlantic Forest, which may undergo changes due to environmental and climate changes caused by the continuous process of environmental degradation. This favors the establishment of *Ny*. *whitmani* and the occurrence of human cases of ACL due to the strong association between the vector and the disease in areas with intermediate vegetation cover density. Future projections for ACL indicate the continuous process of expansion of the disease in the face of predicted climate changes and reinforce the wide geographic extension of this disease in Brazil. The use of geotechnology in assessing municipal vulnerability to ACL transmission is an important support product for the Brazilian Control Program.

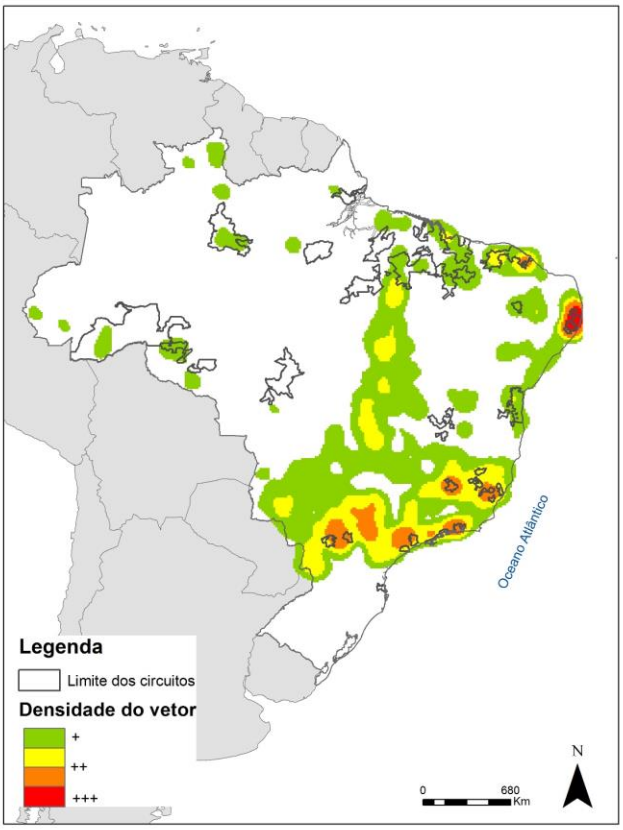


Figure 5.26. Spatial distribution of Nyssomyia whitmani in association with production areas and occurrence of ATL in Brazil, according to the Kernel technique.

5.4.3 Municipal vulnerability for transmission, ecological niche modeling and predicted geographic distribution of American Visceral Leishmaniasis vectors in the state of Rio de Janeiro, Brazil

Leishmaniases are sensitive to climate and environmental changes, the vectors are highly dependent on climate. The state of Rio de Janeiro (RJ) has a low number of cases of human American Visceral Leishmaniasis (AVL); and, paradoxically, a high number of infected dogs, human mortality, vector adaptation, urbanization and expansion of the disease. This study aims to identify vulnerable municipalities, map the spatial distribution of diseases, AVL vectors (*Lu*. *longipalpis* and *Mg*. *migonei*), and predict spatial distributions using ecological niche modeling based on climatic and environmental variables. The occurrence of vectors, human and canine cases of AVL were obtained from the National Information System for Notifiable Diseases in RJ and the literature; associated with uncorrelated bioclimatic variables: temperature, precipitation, altitude and Enhanced Vegetation Index. The models were based on algorithms: bioclim, logistic regression, random forest, maximum entropy and support vector machines; were executed in R and the final maps were drawn in QGIS. In the last three years in RJ, 48% of the municipalities registered transmission by AVL (human and/or canine) (Figure 5.27), 52% can be classified as vulnerable and 29% of this group receptive (where there is the presence of AVL vectors), no municipalities classified as non-vulnerable were found (Figure 5.28).

It is noteworthy that among the municipalities with human transmission, all were classified as sporadic transmission, except for the municipality of Rio de Janeiro, which is classified as having moderate transmission (Figure 5.29). The state has only 37% of municipalities with registration *Lu*. *longipalpis* and/or *Mg*. *migonei*, with a clear need for entomological studies in the region (Figure 5.30). The database included 42 records for *Lu*. *longipalpis* and 88 of *Mg*. *migonei*, present in 19 and 31 municipalities in RJ. *Lutzomyia longipalpis* and *Mg*. *migonei* are predicted to co-occur in the metropolitan region, coastal plain, parts of the green coast and south of the northern region. *Migonemyia migonei* is predicted to occur additionally in the middle Paraíba, Center-South, Northwest and south of the Costa Verde (Figure 5.31, 5.32, 5.33). After detection of the vector in vulnerable municipalities, the recommended control actions are health education, environmental management and canine investigation, aimed at early detection of AVL cases. These studies provide subsidies for surveillance and prevention campaigns and contribute to knowledge of the ecology and distribution of vectors in RJ, where the disease has shown increased transmission in urban areas in recent years.

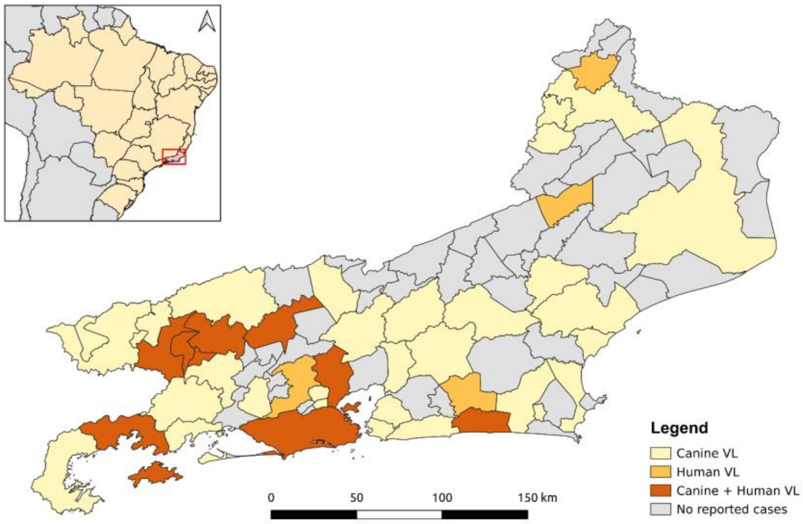


Figure 5.27. Distribution of human and canine cases of AVL in the state of Rio de Janeiro January, Brazil, in the period 2020 – 2022.

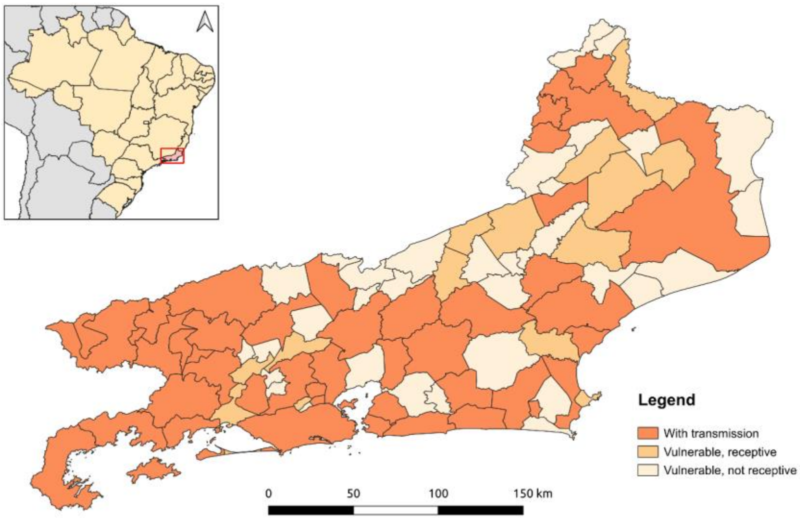


Figure 5.28. Distribution of AVL transmission and vulnerability in the state of Rio de Janeiro, Brazil, in the period 2020 – 2022.

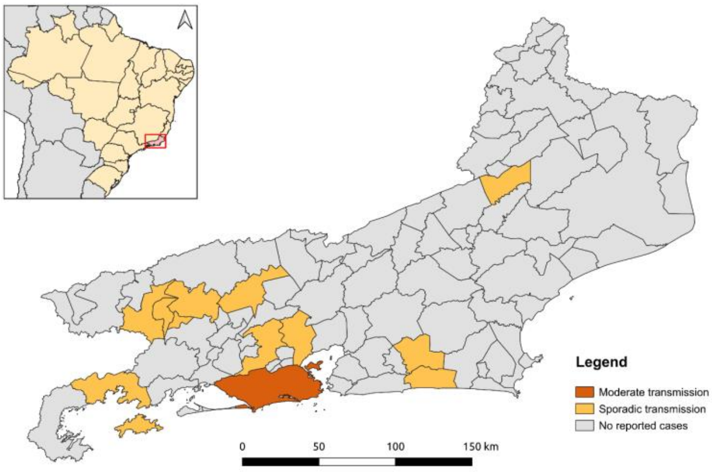


Figure 5.29. Distribution of AVL transmission classification in the state of Rio de Janeiro, Brazil, in the period 2020 – 2022.

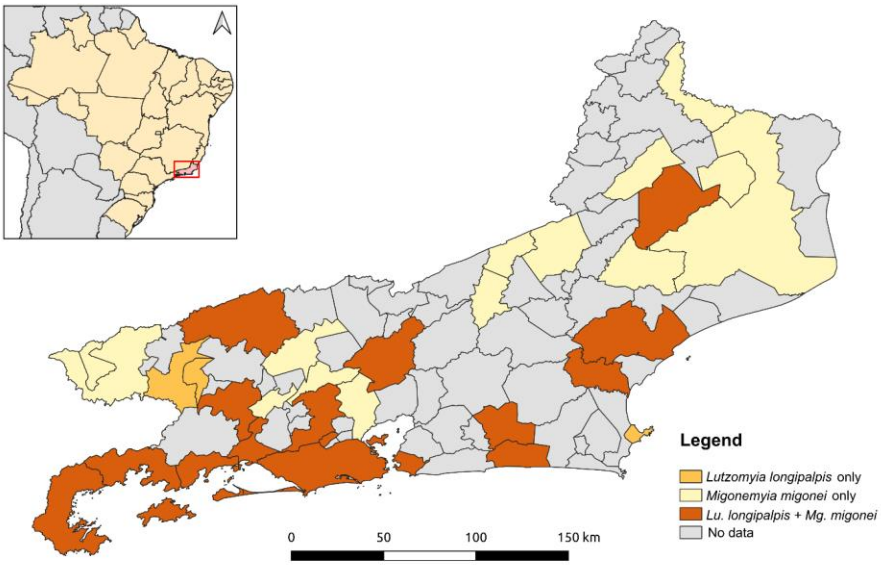


Figure 5.30. Distribution of AVL vector records in the state of Rio de Janeiro, Brazil, in the period 2020 – 2022.

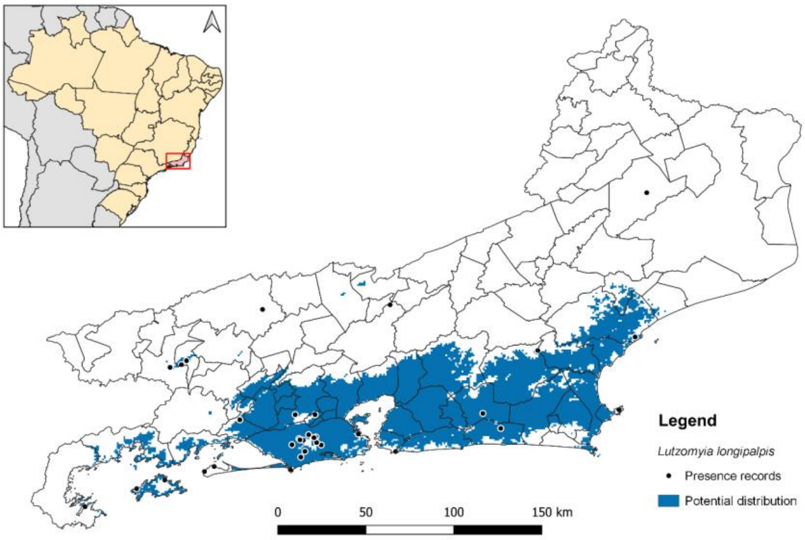


Figure 5.31. Potential distribution of Lutzomyia longipalpis records in the state of Rio de Janeiro, Brazil.

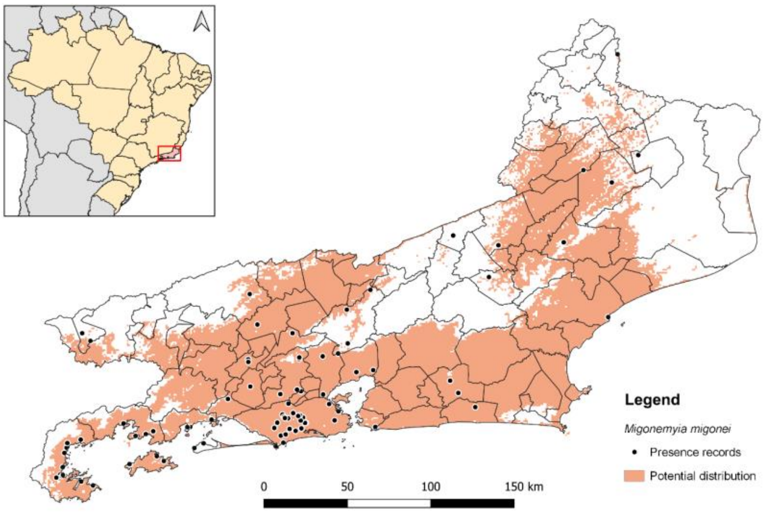


Figure 5.32. Potential distribution of Migonemyia migonei records in the state of Rio de Janeiro, Brazil.

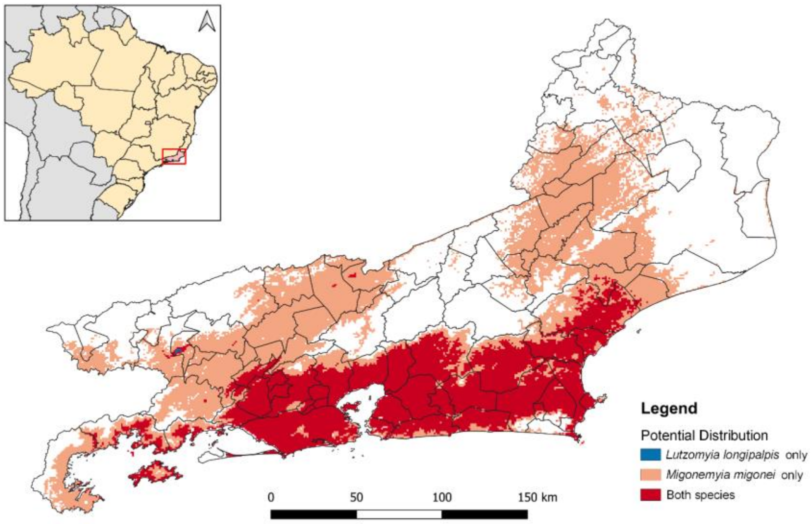


Figure 5.33. Potential distribution of AVL vector records in the state of Rio de Janeiro, Brazil.

5.4.4 Land use and land cover, spatial distribution of vectors, risk stratification and vulnerability of municipalities in the state of Minas Gerais, Brazil, in relation to American Visceral Leishmaniasis

The current distribution of cases and vectors of leishmaniasis are important to observe the panorama of sandflies, so that it is possible to analyze the climate and environmental changes that will be analyzed in the next stage of the project, to project the risks of contracting the disease with the impact on human health. The results may fill gaps in the current picture of the geographic distribution of vector species, the etiological agent that transmits American Visceral Leishmaniasis (AVL), as well as its adaptation to new environments, through the development of ecological niche models, enabling the production of probability maps of occurrence in different scenarios, study of the correlation between the increase in deforestation, rates of human cases of visceral leishmaniasis and the presence of vector species, observing possible areas of expansion of AVL. Thus, a first study was carried out to understand the profile of the disease and the vectors in the state with the highest number of cases in the Southeast Region, the state of Minas Gerais, which is composed of twelve administrative regions, North of Minas, Northwest of Minas, Jequitinhonha , Vale do Mucuru, Vale do Rio Doce, Central Mineira, Metropolitana de Belo Horizonte, West of Minas, Campos das Vertentes, Zona da Mata, South/Southwest of Minas, Triângulo Mineiro/Alta da Paranaíba. And of the 853 municipalities that make up the state, only 99 have records of AVL vectors, in 33 of them was found *Lutzomyia* *longipalpis*, at 37 *Migonemyia migonei* and in 29 both species were recorded. Of the twelve administrative regions that make up the State, there was no record of vectors only in Vale do Mucuri and *Lu*. *longipalpis* was present in all other regions, whereas *Mg*. *migonei* has not been registered in the Northwest of Minas Gerais. With regard to land use and cover (Figure 9), the largest artificial area is present in the Metropolitan region, in the municipality of Belo Horizonte and surroundings, and the meeting of the two vector species, in other regions an association of the species is observed *Lu*. *longipalpis* with large clusters of artificial areas.

Although only 99 municipalities have registered one of the vectors or both, there has been autochthonous notification of the disease in the last twenty years, in 384 municipalities in the State, and according to the historical record, the North and Northeast regions of Minas, Jequitinhonha, Central Mineira and Metropolitan Region of Belo Horizonte, recorded the highest notification of human cases and the same, however, there is a higher incidence in two municipalities, Belo Horizonte (with 20% of cases), in the Metropolitan Region and Montes Claros (with about 6 % of cases), in the North Region of Minas Gerais. It is important to highlight that in these municipalities the two vectors of the disease, *Lu*. *longipalpis* and *Mg*. *migonei*. In the stratification data from 2019 to 2021 (Figure 5.34), it was observed that the only municipality with a very intense transmission classification was Belo Horizonte, while Monte Claros and São João das Missões were classified as municipalities with intense transmission and Monte Azul, Presidente Juscelino, Sete Lagoas, Ipatinga, Juvenília, Ribeirão das Neves, Nacip Raydan, Comercinho and São João da Ponte with high transmission. In the Mucuri Valley, Northwest of Minas, Triângulo Mineiro/Alta da Paranaíba, Campos das Vertente and South/Southwest of Minas, there were some municipalities with low transmission and the Zona da Mata had no record.

As for the epidemiological classification for disease surveillance and control (Figure 5.35), the North and Northeast regions of Minas Gerais, Jequitinhonha, Central Mineira and Metropolitana de Belo Horizonte have a large part of the municipalities with transmission, and those that are not part of this classification, are vulnerable receptive or non-receptive, that is, no non-vulnerable municipality was found.

These results may subsidize the National Leishmaniasis Control Program; the State and Municipal Health Secretariats in Brazil, in the planning of surveillance and control actions; contribute to the promotion of health in underserved communities, in addition to international relevance, since many species of leishmaniasis vectors in Brazil are also distributed in neighboring countries (Figure 5.36).

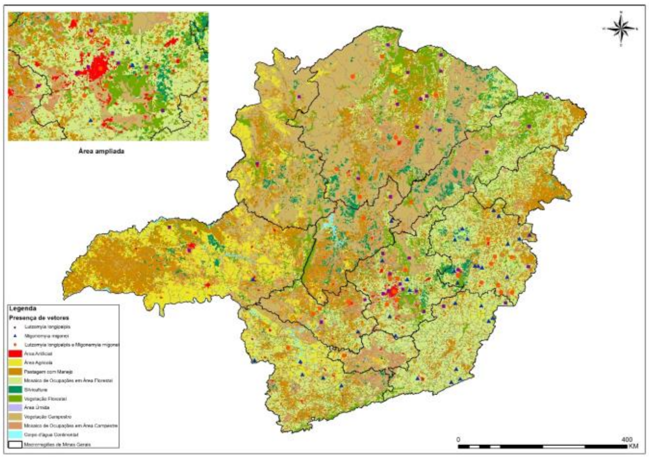


Figure 5.34. Map of land use and land cover associated with the encounter of Lutzomyia longipalpis and Migonemyia migonei, in the state of Minas Gerais, Brazil.

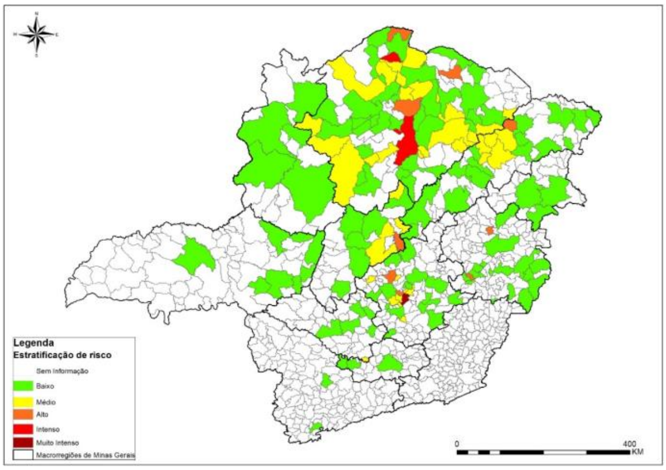


Figure 5.35. Risk stratification map for American Visceral Leishmaniasis, from 2019-2021, in the state of Minas Gerais, Brazil, from 2019 to 2022.

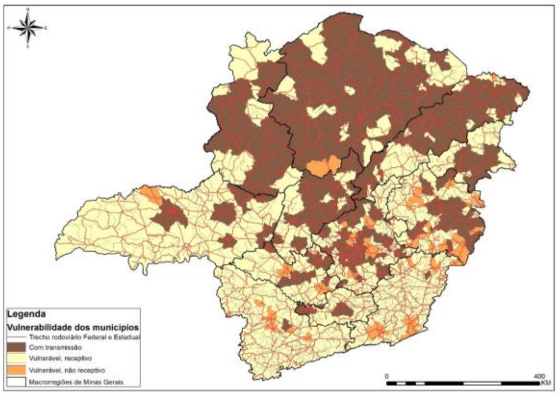


Figure 5.36. Vulnerability map of municipalities in the state of Minas Gerais, Brazil, from 2018 to 2022.

5.5 Energy security

This component aims to investigate how renewable energy resources respond to future climate considering the growing energy demand to achieve sustainable socio-economic development in a low-carbon economy, as well as Brazil's commitments made during climate conferences.

5.5.1. Activities carried out during the sixth year

a) Scientific and Administrative Activities developed in the 6th year (August 2022 to July 2023), together with information from meetings and working groups where the INCT may have been presented.

a.1) INTEGRATED ASSESSMENT MODELLING (IAM) FOCUSED ON THE ENERGY SECTOR

The Energy Security team has reduced research activities in the scope of INCT Mudanças Climáticas along with the 6th year due to the lack of grant support and scholarships for postdoctoral researchers. The researchers are planning activities for the next year and seeking funding for recent PhDs.

a.2) IMPACT OF ATMOSPHERIC AEROSOLS ON THE SPECTRAL FACTOR OF PHOTOVOLTAIC MODULES IN SÃO PAULO

Problem statement

Aerosols contribute to attenuating solar radiation through absorption and scattering processes. The absorption of solar radiation removes a photon from the solar radiation beam, while the scattering process changes the propagation direction of photons from the solar radiation beam. Studies on the impact of aerosols on the planet's radiative balance show that despite the emission of greenhouse gases intensifying the warming of the atmosphere, aerosols released into the atmosphere can contribute to its cooling since the radiative forcing of the atmosphere aerosol ranges from -0.85 to +0.15 $W.m^{-2}$ with an uncertainty of 1 $W.m^{-2}$. In addition, aerosol particles can also influence the atmospheric transmittance by indirect processes since they can act as droplet condensation nuclei and change the radiative properties of clouds, such as the droplet size distribution, cloud albedo and residence time in the atmosphere (SEKIGUCHI, 2003). The aerosol optical depth (AOD_{500nm}), Ångström coefficient (α), and the particles' absorption/scattering ratio (ω_o) data are fundamental to evaluating the impact of atmospheric aerosols on the surface solar irradiance (SSR).

Besides the SSR attenuation, the aerosol size distribution changes its spectral composition, particularly in urban areas where anthropic activities are the primary source of atmospheric aerosols (Mukherjee & Vinoj, 2020; Xia et al., 2021). The Ångström coefficient (α) is sensitive to atmospheric aerosol size distribution parameters so that low α values indicate the predominance of coarse-mode particulates. In contrast, high α values are associated with the presence of fine-mode particles, in general, produced by anthropogenic emissions related to fossil fuel burning. Urban aerosols typically have α values ranging from 1.2 to 2.5 (DUBOVIK et al., 2000). The spectral factor (SF) is a measure of the change in the solar radiation spectrum reaching the surface, and it can be evaluated from remote sensing data recorded during the routine operation of the PV power system.

It is increasingly important to understand the impact of aerosols on surface solar irradiance due to the rise in PV system-based power generation (NEHER et al., 2017; Gueymard & Kocifaj, 2022). SF analysis and its dependence on environmental aspects have been carried out in different regions worldwide for different PV technologies. Studies of this nature have great potential to contribute to PV power prediction studies, especially in large urban centers such as São Paulo, where the aerosol load tends to be more pronounced, especially in dry seasons, affecting PV module’s performance. However, such evaluations are scarce in Brazil.

This task investigated the seasonal regime of atmospheric aerosols in the largest Brazilian city and investigated the impact on photovoltaic (PV) power generation based on the spectral factor parameter. The metropolitan region of São Paulo has excellent potential for expansion of PV power generation, but it is subject to high concentrations of atmospheric aerosols, especially in the dry season (Castanho et al., 2001; Yamasoe et al., 2017; Yamasoe et al., 2021). The study used data from a PV power plant operating in the western neighborhood of São Paulo, where high-quality meteorological and atmospheric aerosol data are also available. Similar atmospheric conditions are expected in large and medium-sized urban areas in tropical climate regions exposed to aerosol emissions from industrial activities, high traffic load and cargo transportation, and biomass burning events in the neighborhood. So, the methodology and results can help numerical modeling improvement and support the Brazilian energy sector in planning solar power operations concerning designing and maintenance procedures to reduce energy losses.

The analysis of AERONET data pointed out the predominance of aerosols from urban sources and aerosols associated with biomass-burning events occurring in the Brazilian central region during the dry season between May and September. The meteorological conditions during the dry season explain the higher concentrations of aerosols in the atmosphere of São Paulo at this time of year.

Figure 5.37 and 5.38 shows the relationship between the daily variability of spectral factor and AOD_{500nm}, precipitable water (PW) during 2016 and 2017. The analyses demonstrated that the SF presented a reduction of up to 5% of the modules' expected performance from August to October when AOD_{500nm} and PW reached their highest values, above 0.7 and 2 cm, respectively (graphs d and e in both figures). According to the AERONET data, the optical properties of aerosols show high AOD_{500nm} values and a more significant variation of ωo and α from August to September due to the transport of aerosols from biomass burning events in Central areas of Brazil.

The PV system in São Paulo city showed seasonal performance losses of around 5% associated with atmospheric aerosols. The lowest SF occurred in August and September. The greater the number of particulates in the atmosphere, the greater the performance losses of PV systems and the generated power. The impact of aerosols is most significant when AOD_{500nm} higher than 0.2 are associated with precipitable water above 1.5. High values of precipitable water do not reduce the PV system's performance when the aerosols' optical depth is low, around 0.1.

In conclusion, the study contributes to the complex relationship between spectral factor patterns, optical aerosol properties, and atmospheric precipitable water. In addition, it contributed to understanding the impact on the PV power systems concerning the typical aerosol conditions in São Paulo metropolitan area, showing the relevance of monitoring aerosol optical data to feed numerical models developed to predict the power generation.

The research results were presented at the Brazilian Congress for Solar Energy. A paper is being prepared and will be submitted to a scientific journal with peer-reviewed editorial politics.

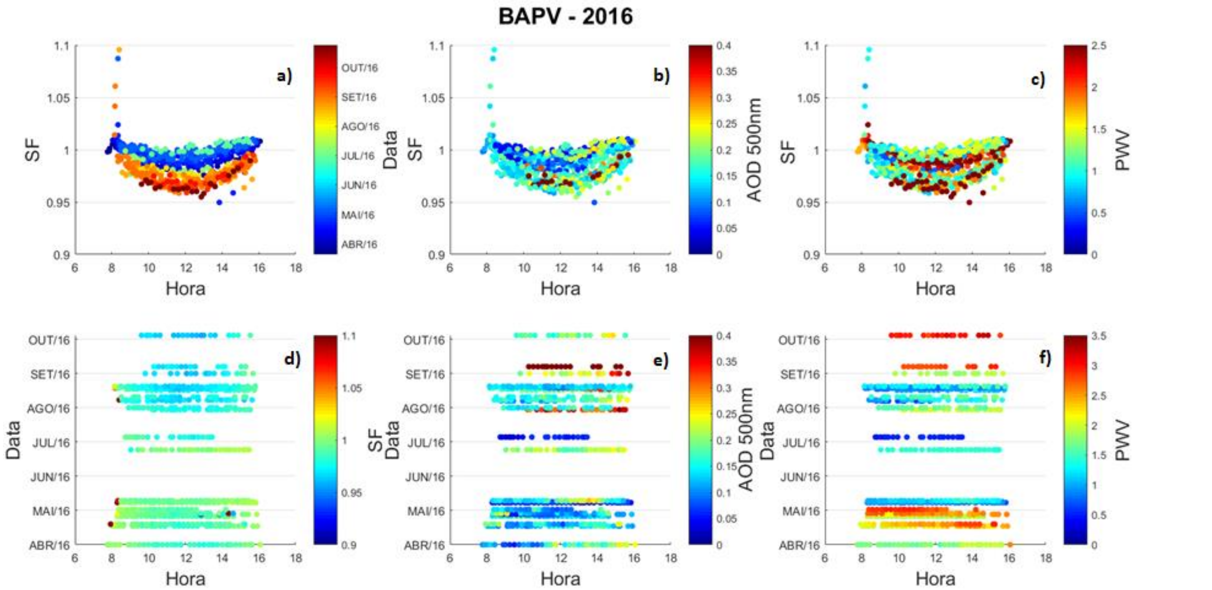


Figure 5.37. a) Daily variability of the SF of the BAPV system over 2016. b) Daily variability of the SF of the BAPV system as a function of the AOD 500nm in 2016. c) Daily variability of the SF of the BAPV system as a function of the PWV in 2016. d) Annual variability of the SF in the BAPV system in 2016. e) Annual variability of the AOD 500nm in 2016. f) Annual variability of the PWV in 2016.

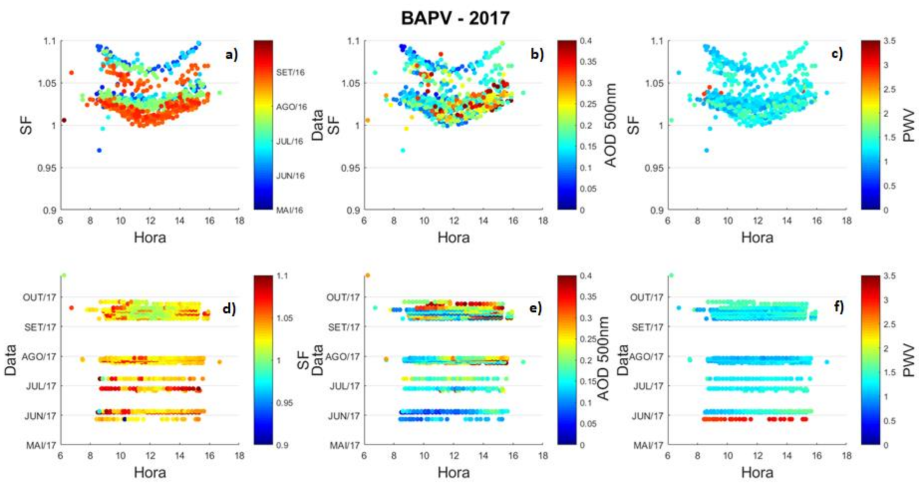


Figure 5.38. a) Daily variability of the SF of the BAPV system over 2017. b) Daily variability of the SF of the BAPV system as a function of the AOD 500nm in 2017. c) Daily variability of the SF of the BAPV system as a function of the PWV in 2017. d) Annual variability of the SF in the BAPV system in 2017. e) Annual variability of the AOD 500nm in 2017. f) Annual variability of the PWV in 2017.

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a.3) UPDATING THE SOLAR IRRADIANCE MAPPING BASED ON RADIATIVE TRANSFER MODEL BRASIL-SR USING GOES-16 IMAGERY (INPE, UNIFESP)

BRASIL-SR is a satellite-based model that estimates the downward surface solar irradiance developed by INPE. BRASIL-SR is a semi-empirical radiative transfer model that evaluates the atmospheric transmittance for two atmospheric conditions: cloudless and overcast with a very high cloud optical depth. The effective cloud cover index obtained from visible satellite imagery is used to interpolate between clear and cloudy sky conditions for transmittance assessment at any cloud coverage conditions. To calculate the clear sky transmittance, BRASIL-SR requires the following regional input data: longitude, latitude, altitude, surface temperature, relative humidity, total precipitable water vapor (PWV), total ozone in the column (O3), AOD in 550 nm and Ångström's exponent (AE), biome classification, and the Moderate Resolution Imaging Spectroradiometer (MODIS) bi-directional reflectance distribution functions (BRDF) kernel parameters. Additionally, local PWV, O3, AOD, and AE data can be optional input data for SSR assessment for specific locations. The SSR under cloudy sky conditions assumes the presence of Stratus clouds in two vertical layers of the atmosphere. The vertical profile of atmospheric gases, particulates, and the cloud-base height are calculated based on the standard atmosphere profiles. The effective cloud cover coefficient is obtained from statistical analysis of the GOES-16 imagery data.

This task aims to produce global horizontal irradiance (GHI) and direct normal irradiance (DNI) data for the 2017-2023 period and make it available for public access together with the current dataset available for 2005-2017 prepared for the Brazilian Atlas of Solar Energy using satellite imagery from former GOES satellites in operation. Public and private organizations in the energy sector use the current database, and they highly demand its update.

a.4) IMPACT EVALUATION OF FUTURE CLIMATE SCENARIOS IN SOLAR AND WIND ENERGY RESOURCE IRRADIANCE MAPPING BASED ON CMIP-6 MODELS

This task aimed to evaluate the time evolution and spatial pattern changes of solar and wind energy resource in the Brazilian territory until the end of the century. It used data from two Shared Socioeconomic Pathways, the SSP2-4.5, and SSP5-8.5, provided by forty CMIP6 climate models, including the multi-model ensemble. Robust statistical tests allowed to identify models that reproduce atmospheric patterns more assertively, building a smart ensemble to reduce uncertainties. The results for solar energy resource is concluded, while the final analysis for wind energy is running. The impact evaluation will bring valuable information to support energy entrepreneurs, governmental and nongovernmental organizations in planning the Brazilian energy sector, the electricity grid, and energy policy to build a national energy system resilient to future climate conditions. The geographical outcomes can also help design and develop public policies to promote environmental sustainability and social energy justice.

The results of the climate change impact on solar energy are presented below. This report is based on the paper content, which is in the final step of production (figures improvement and language revision). Figure 5.39 presents a schematic representation of the methodology adopted to evaluate the climate change factor for surface solar radiation (SSR) in the near-future (2015-2040), mid-of-century (2041-2070), and end-of-century (2071-2100) based on SSP2-4.5 and SSP5-8.5 scenarios proposed by IPCC for future climate.

The investigation used surface solar radiation (SSR) data available in three data repositories: the Coupled Model Intercomparison Project Phase 6 (CMIP6), ERA5 reanalysis provided by ECMWF (European Centre for Medium-Range Weather Forecasts), and Brazilian Solar Energy Atlas (BSR data). The CMIP6 provides the SSR data from forty global climate models used by the Intergovernmental Panel on Climate Change (IPCC) for a historical period (1980-2014) and for the future in three timeslices: 2015-2040, 2041-2070, and 2071-2100. Before using CMIP6 projections, it is critical to evaluate how representative their SSR outputs are of the observational patterns by comparing them with a reference (truth) database for the historical period.

Several studies suggest that the ERA5 reanalysis database fulfills the required features (long and continuous time coverage, hourly time resolution, and reliable ground data assimilation) to be the ground truth reference database (Avila-Diaz et al., 2020; Firpo et al., 2022). However, the ERA5 outputs for surface solar irradiation data overestimate the observational ground data throughout Brazilian territory due to specific regional issues not considered in its numerical radiative parameterization - as aerosols from biomass burning events in the Amazon and Central area of Brazil during the dry season and sub-grid shallow clouds that prevails in the tropical humid atmosphere over the continent. (Boiley e Wald, 2015; URRACA et al., 2018; Sianturi et al., 2020; Zuluaga et al., 2021).

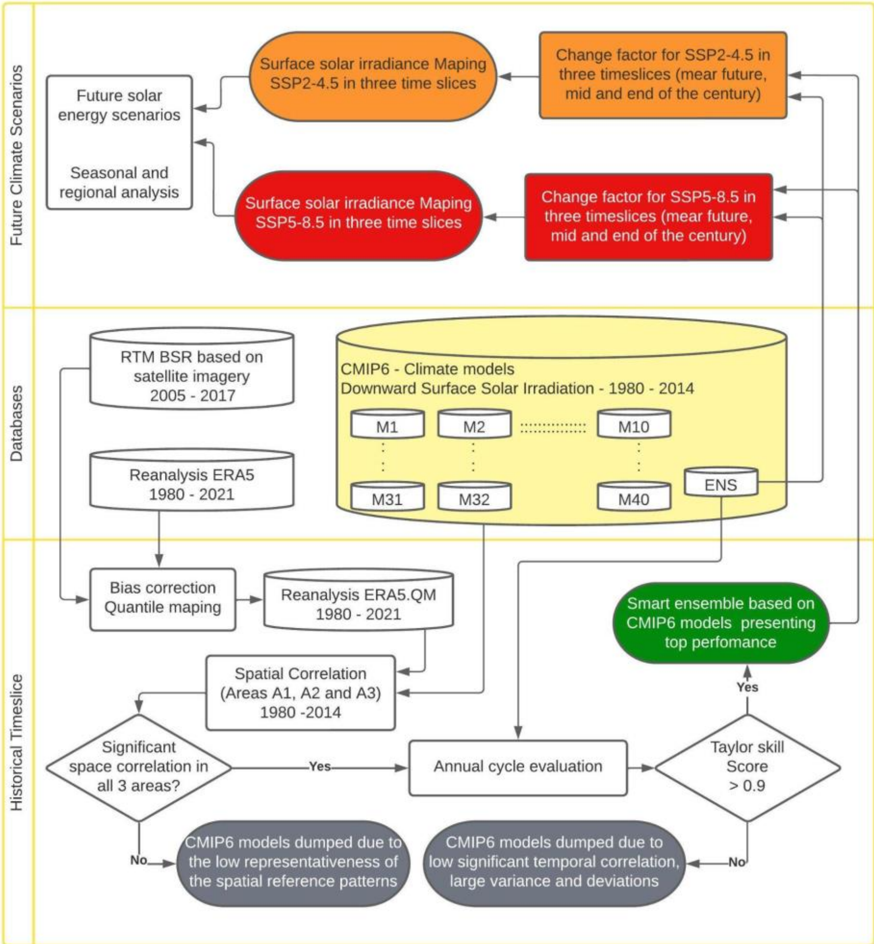


Figure 5.39. Diagram describing the procedure sequence used to investigate the future solar energy resource scenarios based on CMIP6 climate models.

Satellite-based SSR products have shorter time series than reanalysis datasets but present better accuracy (URRACA et al., 2018). Previous studies show that the Brazilian Solar Energy Atlas (BSR database) time series presents low bias throughout the Brazilian territory (Pereira et al., 2017). Nevertheless, its time coverage is shorter than required to serve as reference data for the performance evaluation of CMIP6 historical simulations. In order to meet the time coverage and confidence required for the reference database, we applied a bias correction method to the ERA5 database, assuming the BSR database as the reference truth.

Table 5.3 lists the forty Global Climate Models (GCM) from CMIP6 used in the study. The Table also provided the spatial resolution of each model. The criteria for model inclusion was the data availability of monthly Surface Downwelling Shortwave Radiation (SDSR) with a spatial resolution of up to 250 km. The CMIP6 data was downloaded from *https://esgf-node.llnl.gov/search/cmip6/* using an algorithm in Python. We used only the first member (realization1) of each GCM.

Table 5.3. CMIP6 models used in the study and their respective spatial resolution (sorted in alphabetical order).

ACCESS-CM2 [250 km]	M 01	ACCESS-ESM1-5 [250 km]	M02	AWI-CM-1-1-MR [100 km]	M03
BCC-CSM2-MR [100 km]	M 04	CAMS-CSM1-0 [100 km]	M05	CAS-ESM2-0 [100 km]	M06
M2 WACCM [100 km]	M 07	CIESM [100 km]	M08	CMCC-CM2-SR5 [100 km]	M09

CMCC-ESM2 [100 km]	M10	CNRM-CM6-1-HR [50 km]	M11	CNRM-CM6-1 [250 km]	M12
CNRM-ESM2-1 [250 km]	M13	EC-Earth3-CC [100 km]	M14	EC-Earth3-Veg-LR [250 km]	M15
EC-Earth3-Veg [100 km]	M16	EC-Earth3 [100 km]	M17	FGOALS-f3-L [100 km]	M18
FGOALS-g3 [250 km]	M19	FIO-ESM-2-0 [100 km]	M20	GFDL-CM4 [100 km]	M21
GFDL-ESM4 [100 km]	M22	GISS-E2-1-G [250 km]	M23	GISS-E2-1-H [250 km]	M24
HadGEM3-GC31-LL [250 km]	M25	IITM-ESM [100 km]	M26	INM-CM4-8 [100 km]	M27
INM-CM5-0 [100 km]	M28	IPSL-CM6A-LR [250 km]	M29	KACE-1-0-G [250 km]	M30
KIOST-ESM [250 km]	M31	MIROC6 [250 km]	M32	MPI-ESM1-2-HR [100 km]	M33
MPI-ESM1-2-LR [100 km]	M34	MRI-ESM2-0 [100 km]	M35	NESM3 [250 km]	M36
NorESM 2-LM [250 km]	M37	NorESM2-MM [100 km]	M38	TaiESM1 [100 km]	M39

CMIP6 models were evaluated concerning their ability to represent the SSR's spatial variability and intra-annual seasonality during the historical timeframe. Figure 5.40 shows the three target areas used to investigate the models' performance, comprising regions of great interest for the Brazilian energy sector:

●area A1 includes the semi-arid region in the Brazilian Northeast with the highest surface solar irradiation and the lowest seasonal variability (Pereira *et al.*, 2017);

●area A2 comprises the Southern region of Brazil, where the solar energy resource has the highest seasonal variability, but presents a high demand for distributed PV systems and could take advantage also from hybrid Wind-PV systems due to the high wind speed in the region (Amarante *et al.*, 2001); and

●area A3 covers the region that combines two advantages: a high surface solar irradiation and adjoining to the main electricity consumer centers with good coverage of the Brazilian interconnected electricity distribution system (SIN).

Sixteen out of the forty CMIP6 models provide SSR with a 250 km horizontal resolution, while only one has a 50 km resolution. Before evaluation, all CMIP6 models were interpolated (bilinear approach) to the same horizontal resolution of the ERA5.QM grid (around 27 km). The interpolation procedure was essential for a fair and unbiased comparison of the GCM models' achievements.

The performance evaluation of the models was carried out using data from 1980 to 2014, the intersection period between the ERA5 and CMIP6 databases. Both temporal and spatial statistical analysis were performed, as discussed in Lauer et al. (2017) for the three target areas based on the following parameters:

● Spatial correlation (Rs): the Pearson correlation calculated using the monthly average surface solar irradiation data from each grid point of the climate model (SSR_{Mx}, where Mx is the ID used for CMIP6 models listed in Table 1) and ERA.QM ($SSR_{ERA.QM}$);

● Annual cycle correlation (Rt): the Pearson correlation index obtained from the SSR_{Mx} and $SSR_{ERA.QM}$ time series of the monthly climatological averages;

● uRMSD: the unbiased root of mean squared deviations between the SSR_{Mx} and $SSR_{ERA.QM}$ monthly climatological averages;

● SD ratio: the average ratio between $SSRD_{Mx}$ and $SSRD_{ERA.QM}$ standard deviations in all three target areas.

The spatial correlation Rs allowed us to compare the skill of CMIP6 models in representing the mean spatial patterns of the SSR in the three target areas. In this sense, we select a subset of CMIP6 models with a significant spatial correlation (p-value < 0.05) for all twelve months in the three target areas.

The other three evaluation metrics (Rt, uRMSD, and SD ratio) were used to build the Taylor diagram, which summarizes how well the SSR data from CMIP6 models match the SSR climatology of the ERA5.QM. Based on the Taylor Skill Score (TSS) approach (Taylor, 2001), we to combine metrics and identify the CMIP6 models more representative of the SSR climatology accounting for important information regarding the variability in the CMIP6 simulations.

The CMIP6 models achieving TSS greater than 0.9 were combined to create a Smart Model Ensemble (SME) used in the impact assessment of future climate scenarios. For reference, the former multi-model ensemble (referred to as ENS from now on) was retained by averaging the SSR_{Mx} data provided by each of the forty CMIP6 models. The SME and ENS performances were also investigated based on the same statistical parameters applied to individual M_x models.

The "climate change factor" approach proposed by Navarro-Racines et al. (2015) was assumed to assess the impacts of future climate pathways SSP2-4.5 e SSP5.-8.5. The climate change factor (CCF) represents the percentage change in surface solar irradiation in future scenarios regarding the model's prediction for the historical timeslice (1980-2014).

CMIP6 model or ensemble and the subscript *timeslice* concerns the future climate scenario in evaluation. The CCF depends on the geographical location *[lat,lon]*, the month represented by *t*. The *SSP* is one of the future pathways for climate change (SSP2-4.5 or SSP5-8.5).

5.5.2 Results and Discussions

ERA5 SSR Bias Correction

The QM approach was developed using data from ERA5 and BSR databases from 2005 to 2015. The temporal correlation between ERA5 and BSR datasets is higher than 0.6, in line with the findings of URRACA *et al.* (2018). Then, the QM function was applied from 1980 to 2005 to extend the corrected ERA5 to the same period as the historical runs from CMIP6 models. Figure 5.40 shows the surface solar irradiance map assembled using the unbiased ERA5 data (referred to as ERA5.QM). From this point, it is used as a reference ground truth to evaluate the statistical deviations and spatial representativeness of SSR outputs provided by CMIP6 models.

Figure 5.41 demonstrates that the original ERA5 dataset has a moderate bias (up to 20W/m^2) in relation to the reference data (BSR), and after bias removal, it is reduced to within 5 W/m^2. The maximum monthly standard deviation differences were also reduced from 30 to 10 W/m^2 after the bias correction, as shown in Figure 5.42. ERA5 was overestimating SSR monthly variability in northern Brazil. The bias-corrected ERA5 database (ERA5.QM) shows improved confidence and extends for 34 years (1980-2014), key features to serve as a reference in performance evaluation of the CMIP6 climate models.

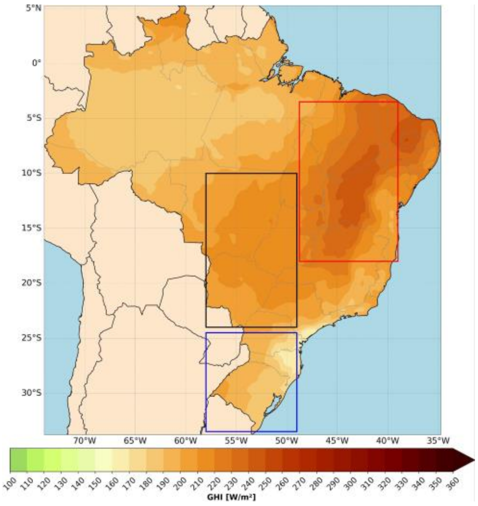


Figure 5.40. Map of the annual average of surface solar irradiance in Brazilian territory based on the debiased ERA5 data 1980-2014 (ERA5.QM). The rectangles indicate the target areas used in the performance evaluation of CMIP6 models: a) Area A1 delimited in a red rectangle, b) Area A2 in blue, and c) Area A3 in black.

5.5.3 **Evaluation of the CMIP6 Models in Historical Time-Slice**

The performance of CMIP6 models was evaluated for 1980-2014 by comparing their monthly climatological SSR averages with the ones obtained from ERA5.QM. Figure 6 is a panel showing the SSR climatology obtained from ERA5.QM dataset and the bias deviation of SSR simulations provided by the forty CMIP6 climate models. The ENS reproduces the SSR's spatial pattern over regions A1 and A3 with reduced bias. Nevertheless, the ENS overestimates (around 50 W/m^2) the climatological SSR in the Amazon region. These results agree with the findings described by Firpo *et al.* (2022), which show a negative bias for precipitation outputs of the CMIP6 models over the north of the Amazon region (Almazroui *et al.*, 2021; Ortega *et al.*, 2021).

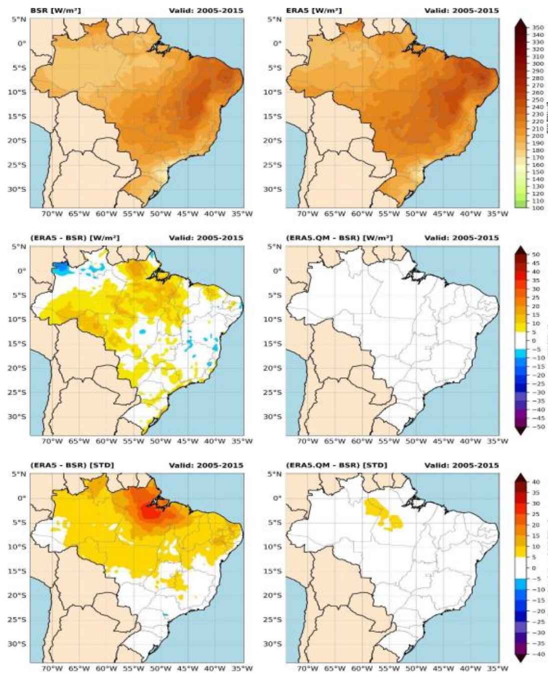


Figure 5.41 Annual mean of downward surface solar irradiation map prepared using BSR (left) and ERA5 (right) datasets; b) deviation map for SSRD in ERA5 (left) and ERA5.QM (right) regarding the BSR dataset; c) differences between standard deviation in ERA5 (left) and ERA5.QM (right) regarding the BSR dataset.

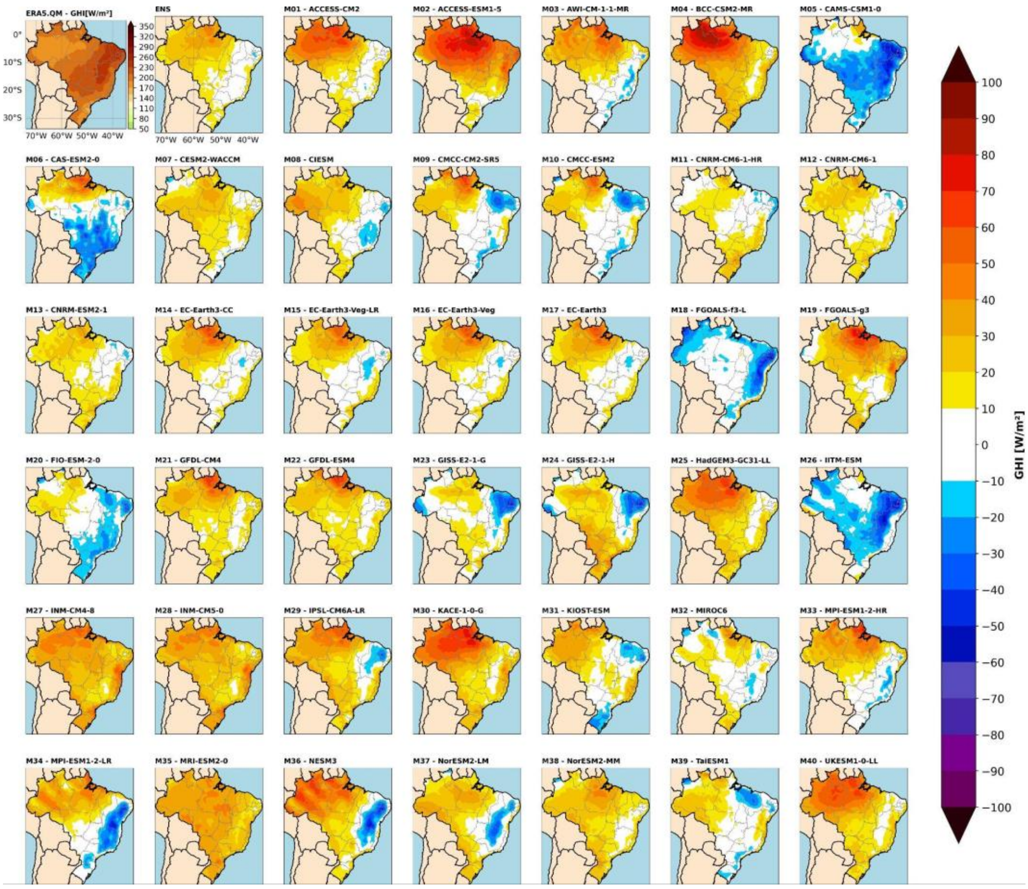


Figure 5.42. Panel comprising the downward surface solar irradiance map prepared from the ERA5.QM (left top line) and the bias deviation map for the ensemble (ENS) and forty CMIP6 climate models. The model identification is over each map.

The panel provides a comprehensive view of the diversity of SSR climatology data produced by CMIP6 models, including the alternation between positive and negative bias for specific geographical regions. Regarding the target area A1, for instance, the model ACCESS-ESM1-5 (M2) overestimates the SSR around 40-50 W/m^2, while the models M5, M18, M26 and M34 underestimate it around 40-50 W/m^2. Most models overestimate around 30 W/m^2 in area A2, while CAMS (M5), CAS-ESM (M6), and KIOS-T (M31) underestimate up to 20 W/m^2. The bias deviations in area A3 show a pattern similar to A2. In summary, Figure 5.43 highlights the need to identify the CMIP6 models providing the most reliable SSR data compared to the ERA5.QM dataset for the historical timeframe.

The first step in performance evaluation comprises the spatial correlation between climatological SSR provided by CMIP6 and ERA5.QM in the three target areas. Table 5.4 delivers visual information on the monthly spatial correlation results in the three target areas. The white lines indicate the 22 CMIP6 models and ensemble (ENS) presenting significant positive correlation ($p < 0.05$) in all twelve months for all three target areas. The models highlighted in grey did not proceed to the next evaluation steps. Most of the discarded models presented no-significant correlation in transition months between wet and dry seasons (April and October). Models M2, M26, M33, and M34 could not achieve a significant correlation during the austral summer season (from December to March). The ENS presented the best correlation index in the three target areas, supporting the benefit of working with model ensembles. The spatial correlation results (indexes and p-values) are available in the supplementary material.

Table 5.4. Results from spatial correlation analysis between SSR in ERA.QM and CMIP6 climate models and the ensemble (ENS). The "*" symbol represents the significant correlation ($p < 0.05$) in the sequence of target areas A1, A2, and A3. The "0" means no-significant correlation. Models highlighted in grey were removed from the next evaluation step.

MODEL ID.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
M01	***	***	***	***	***	***	***	***	***	**0	***	***
M02	***	**0	**0	***	***	***	***	***	***	**0	**0	**0
M03	***	***	***	***	***	***	***	***	***	***	***	***
M04	***	***	***	***	***	***	***	***	***	**0	***	***
M05	***	***	***	***	***	***	***	***	***	***	***	***
M06	***	***	***	***	***	***	***	***	***	**0	***	***
M07	***	***	***	***	***	***	***	***	***	**0	***	***
M08	***	***	***	***	***	***	***	***	***	***	***	***
M09	***	***	***	***	***	***	***	***	***	***	***	***
M10	***	***	***	***	***	***	***	***	***	***	***	***
M11	***	***	***	***	***	***	***	***	***	***	***	***
M12	***	***	***	***	***	***	***	***	***	***	***	***
M13	***	***	***	***	***	***	***	***	***	***	***	***
M14	***	***	0**	***	***	***	***	***	***	***	***	***
M15	***	***	0**	**0	***	***	***	***	***	***	***	***
M16	***	***	***	***	***	***	***	***	***	***	***	***
M17	***	***	***	***	***	***	***	***	***	***	***	***
M18	***	***	***	***	***	***	***	***	***	***	***	***
M19	***	***	***	***	***	***	***	***	***	***	***	***
M20	***	***	***	***	***	***	***	***	***	**0	***	**0
M21	***	***	***	***	***	***	***	***	***	***	***	***
M22	***	***	***	***	***	***	***	***	***	***	***	***
M23	***	***	***	***	***	***	***	***	***	***	***	***
M24	***	***	***	***	***	***	***	***	***	***	0**	***
M25	***	***	***	***	***	***	***	***	***	***	***	***
M26	0**	0**	0**	***	***	***	***	***	***	***	***	***
M27	***	***	***	**0	***	***	***	***	***	***	***	***
M28	***	***	***	***	***	***	***	***	***	***	***	***
M29	***	***	***	***	***	***	***	***	***	**0	***	***
M30	***	***	***	***	***	***	***	***	***	**0	***	***
M31	***	***	***	***	***	***	***	***	***	**0	**0	***
M32	***	***	***	***	***	***	***	***	***	***	***	***
M33	0**	***	0**	***	***	***	***	***	***	***	***	0**
M34	0**	0**	0**	***	***	***	***	***	***	**0	***	0**
M35	***	***	***	***	***	***	***	***	***	***	***	***
M36	***	***	0**	***	***	***	***	***	***	***	***	***
M37	***	***	***	***	***	***	***	***	***	**0	***	***
M38	***	***	***	***	***	***	***	***	***	***	***	***
M39	***	***	***	***	***	***	***	***	***	***	***	***
M40	***	***	***	***	***	***	***	***	***	***	***	***
ENS	***	***	***	***	***	***	***	***	***	***	***	***

The Taylor Skill Score was calculated in the sequence to determine how accurately the twenty-two CMIP6 models depict the seasonal changes in SSR within each target region. Figure 5.44 displays the Taylor diagram presenting the correlation index (r), unbiased root mean square deviation (uRMSD), and standard deviation (SD) ratio attained by the 22 models and the ensemble (ENS) compared to the ERA5QM dataset. The blue markers denote the models presenting the Taylor Skill Score (described in eq. 2) greater than 0.9. They represent the ten CMIP6 models (M_{ix}) and the ensemble ENS providing SSR climatology with the best spatial and time correlation, lowest deviations, and closer variability (SD) to the ERA5.QM data. Table lists the statistical parameters of them. The statistical parameters for all 22 CMIP6 models are listed in the supplementary material.

The ENS ensemble has the highest spatial correlation but performs poorly in other statistical measures listed in Table 5.4. M25 (IITM-ESM) is the top-performing model in the Taylor Skill Score, with the highest time correlation and lowest uRMSD.

The Smart Ensemble (SME) was prepared using the ten CMIP6 models in Table 3. The statistical parameters achieved by SME in the three target areas are also listed in Table 3. The SME showed spatial correlation equivalent to the ensemble ENS prepared with all 40 CMIP6 models. However, SME presented a superior result in the TSS analysis due to its higher temporal correlation, lower deviation (RMSD), and smaller variability (SD ratio) than ENS. The maps shown in Figure 8 indicate that the standard deviations of the SSR values among models from SME (around 15 - 27 W/m^2) are lower than the SD values obtained among models from ENS (20 - 30 W/m^2) in the whole Brazilian territory. The scattering among models is related to the uncertainty in ensemble mean, evidencing that the SME attained an expressive reduction in uncertainty while sustaining similar skill in reproducing SSR historical climatology.

Table 5.4. Results from spatial correlation analysis between SSR in ERA.QM and CMIP6 climate models and the ensemble (ENS). The “*” symbol represents the significant correlation ($p < 0.05$) in the sequence of target areas A1, A2, and A3. The “0” means no-significant correlation. Models highlighted in grey were removed from the next evaluation step.

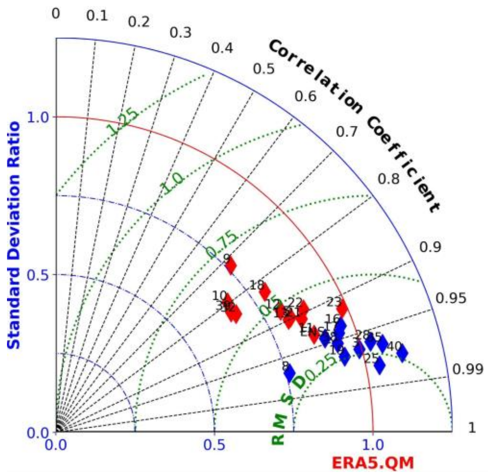


Figure 5.43. Taylor diagram comparing the statistical parameters (SD ratio, Pearson correlation, and RMSD) achieved by the CMIP6 models compared to the reference values represented by the ERA5QM database. The blue markers are the CMIP6 models with Taylor's Skill factor above 0.9.

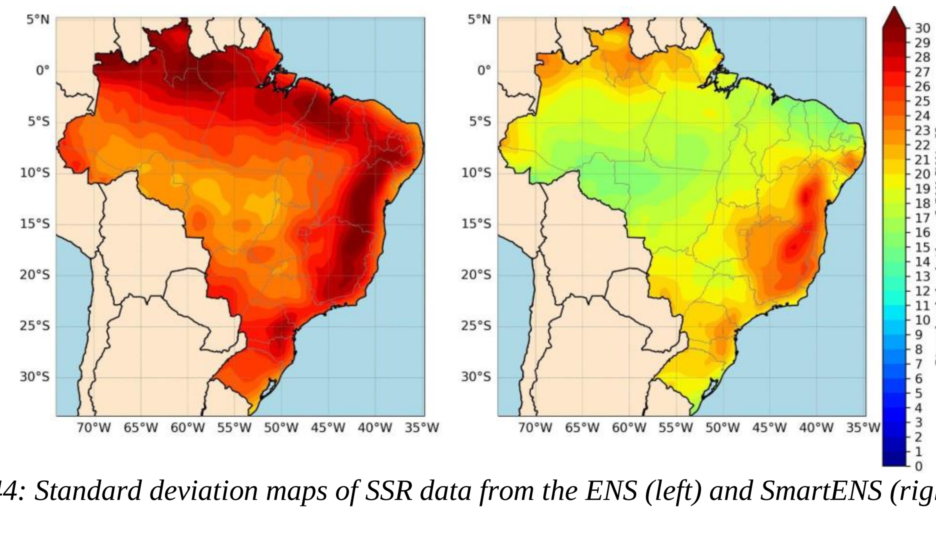


Figure 5.44: Standard deviation maps of SSR data from the ENS (left) and SmartENS (right).

Figure 5.45 displays the annual cycle of SSR in the three target areas, as determined by SME and the ERA5.QM dataset. The SSR deviations are generally below 20W/m^2, except in area A1 (red lines) from September through November. The high correlation coefficients (greater than 0.80) indicate that SME accurately represents the annual cycle of SSR for the three target areas.

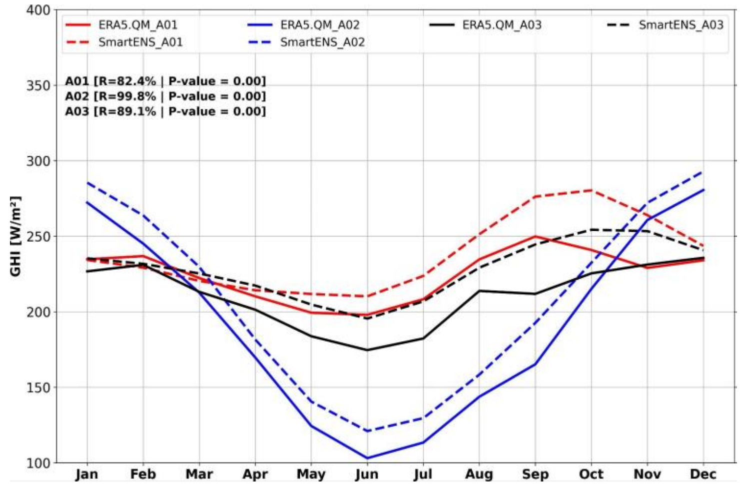


Figure 5.45. Annual cycle of SSR in the three target areas used in performance assessment of CMIP6 models. The line plot presents the SME outcomes (dotted lines) and the reference ERA5.QM dataset (solid lines) for the historical period.

Table 5.4. The statistical metrics achieved by ten CMIP6 models with the highest Taylor Skill Score. The last two lines list the metrics for ensembles ENS and SME. The statistical parameters are the average for the three target areas. The values in blue indicate the best performance regarding the specific metric

Models	Spatial Correlation	uRMSD (W/m^2)	Time Correlation	Standard Deviation (W/m^2)	Taylor Skill Score
M03	0.73	8.18	0.96	30.48	0.95
M08	0.83	9.91	0.97	23.35	0.90
M16	0.76	10.82	0.94	29.46	0.90
M17	0.75	10.19	0.94	29.07	0.91
M19	0.76	7.85	0.97	28.92	0.95
M25	0.79	**6.55**	**0.98**	32.02	**0.98**
M28	0.78	8.81	0.96	31.71	0.94
M35	0.81	8.65	0.96	32.77	0.95
M38	0.82	9.30	0.95	28.63	0.92
M40	0.81	8.20	0.97	34.41	0.96
ENS	**0.86**	**10.24**	**0.94**	**27.62**	**0.90**
SmartENS	**0.86**	**7.79**	**0.97**	**29.90**	**0.96**

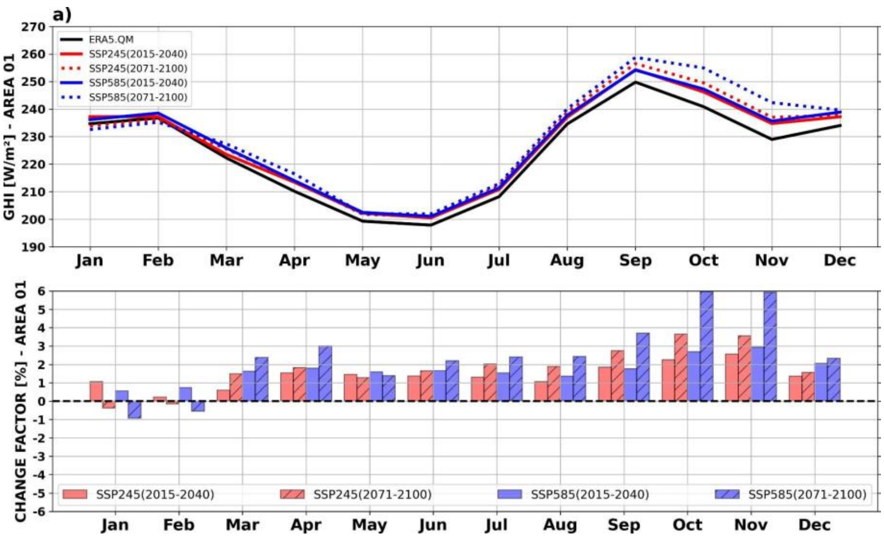
5.5.4 Impact Assessment on Solar Energy Resource

This topic presents the SSR prospects of changes in SSR for future scenarios in three timeslices: near-future (2015-2040), mid-term future (2041-2070), and end-of-century (2071-2100). For simplicity, some graphical results are presented only for the near-future and end-of-century. Complete plots and maps for the three timeslices and both climate scenarios (SSP2.45 and SSP5.85) are available at <data repository> for unrestricted access.

Figure 5.46 shows the seasonal variation of the change factor and SSR in the same target areas used earlier in the performance evaluation. In Area A1 (Figure 5.47), where the solar energy resource is the highest, the climate change factor (CCF) is positive throughout the year, except in January and February for the end-of-century timeslice. The highest CCF (up to 6% for SSP5-8.5 at the end-of-century) occurs in the austral Spring (from September to November), followed by the March-April (up to 3% for SSP5-8.5 at the end-of-century), both happens in transition periods between dry and wet seasons. Still, the CCF holds positive values around 1.5% in the near-future slice during the dry season from May to August in both future pathways but can get approximately 2.5% in SSP5-8.5 at the end-of-century timeslice. As a consequence of the CCF seasonal variation, the monthly mean SSR increases by more than 10 W/m^2 in the austral autumn and spring seasons in both scenarios and all timeslices. Such an increase in SSR agrees with the reduction in precipitation observed by Dantas et al. (2022) for the Brazilian Northeastern region, notably for the SSP5-8.5 scenario for the end of the century (2071-2100).

The seasonal CCF variation for the central region of Brazil (area A3, Figure 5.48) is similar to the Northeastern area A1. CCF assumes positive values throughout the year, with the highest CCFs in the wet season from October-March (3-5% in SSP5-8.5 and 2-3% in SSP2-4.5) at the 2071-2100 timeslice. The opposite seasonal pattern occurs in area A2 (Figure 5.48), where CCF gets negative values most of the year except for January and February, when CCF is around 0.5-1.0% in both scenarios and timeslices. The decrease in SSR is more intense during the April-August months achieving CCF around -4.5%(-2%) in SSP5-8.5 (SSP2-4.5) at the end-of-century.

Figure displays seasonal maps of the average CCF for the Brazilian territory's near-future (2015-2040) and end-of-century (2070-2100) timeframes. For summer in the near-future timeslice, the SSR is expected to increase by up to 3% in areas of the Amazon and Central Brazil, including Southeastern Brazil, closer to most of the electricity consumers.. At the end-of-century, the summer season shows a clear decrease of up to -2% (-4%) in SSR in the northern part of the Northeastern region under SSP2-4.5 (SSP5-8.5). On the other hand, it is expected to increase by up to 4% (6%) in the Amazon, Central, and Southeastern Brazilian regions under SSP2-4.5 (SSP5-8.5).



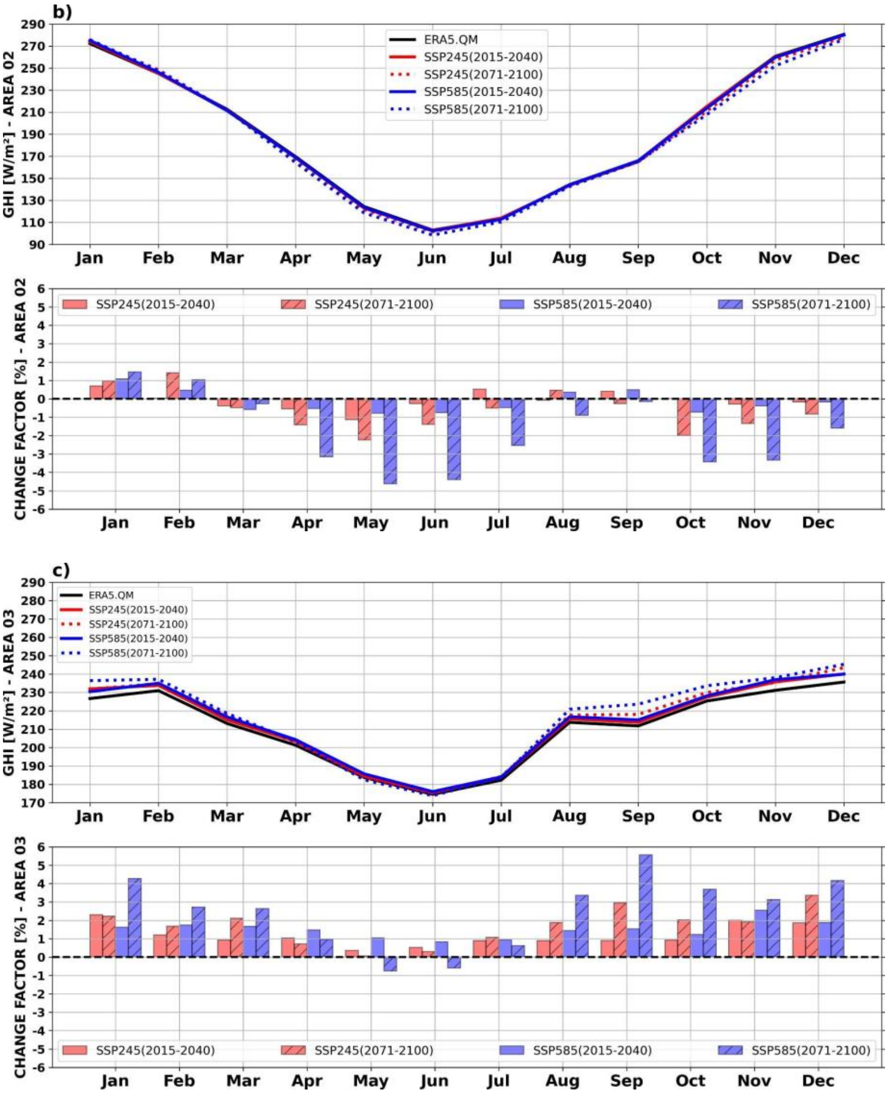


Figure 5.46. Seasonal variation of climate change factor (CCF) and surface solar irradiance (SSR) based on the outcomes from SME for SSP2-4.5 and SSP5-8.5 pathways. a) area A1; b) area A2 and; c) area A3.

For autumn in the near-future timeslice, the positive CCF (around 2%) is concentrated in Amazon and Northeastern Brazil under the SSP2-4.5 conditions. The same pattern can extend to the Southeastern region for the SSP5-8.5 pathway. Looking further to the end-of-the-century timeslice, a similar geographic pattern occurs with a maximum CCF of around 6% in a central area of the Amazon. However, there is a projected decrease in SSR for the Southern region, with CCF reaching -2% (-4%) in SSP2-4.5 (SSP5-8.5) pathways.

For the winter of 2015-2040 slice, the CCF maps depict a positive CCF (up to 3%) over the semiarid area of the Northeastern and part of the Southeastern Brazilian regions in SSP2-4.5. The pattern extends over the Central region of Brazil in SSP5-8.5. The geographical pattern also occurs in the 2071-2100 slice but with higher CCF values, reaching around 5% in parts of the Southeastern and Amazon regions. As happened in autumn, the SSR drops in the South of Brazil at the end-of-century slice in both climate scenarios reaching CCF values around -3% (-5%) in SSP2-4.5 (SSP5-8.5).

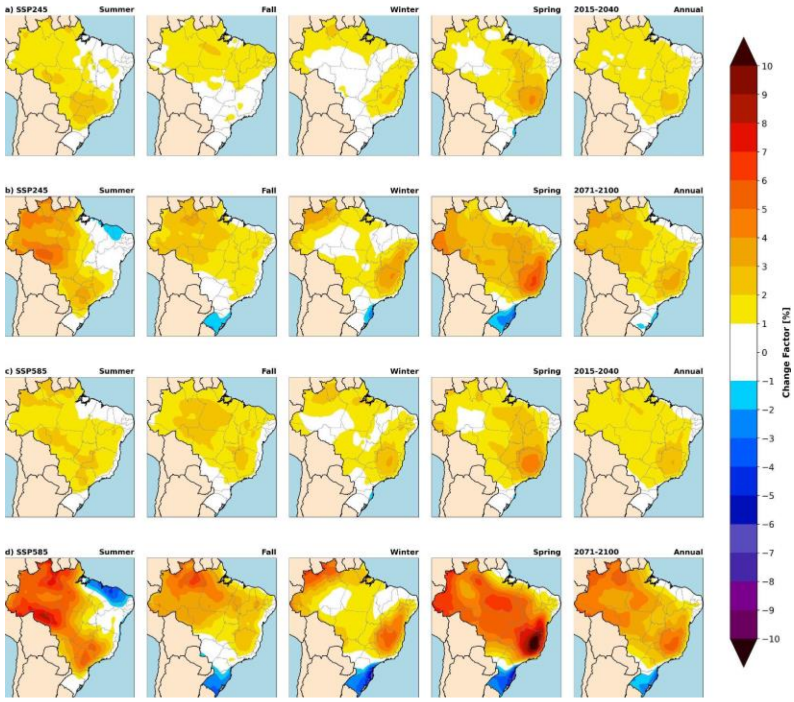


Figure 5.47. The change factor on seasonal SSR predicted by the SME in the SSP2-4.5 (first two lines) and SSP5-8.5 (last two lines) for the 2015-2040 (odd lines) and 2071-2100 (even lines) timeslices. The seasons are from left to right: summer; autumn; winter; spring, and annual mean.

During the spring, the positive CCF covers a vast portion of Brazil, stretching from the Western Amazon to the Atlantic coastal areas of the Northeastern and Southeastern regions. The semiarid region and northern part of the Southeastern region show the highest CCF values, around 4% (5%) in 2015-2040 and 6% (10%) in the end-of-century timeslice based on SSP2-4.5 (SSP5-8.5) scenarios. The Southeastern region encloses Brazilian largest cities and the higher amount of distributed PV systems, coincidentally where the highest increase in SSR is predicted.

Those amplified positive signals in SSR during spring over semi-arid and Central regions of Brazil (where most of the large-scale solar power plants are located) play an important role in the vulnerability of the Brazilian electrical system to climate change. The Brazilian Interconnected Electricity System (SIN) still relies mostly on hydropower and faces the more stringent operation at the end of the rainy season (September to November) when reservoirs are usually depleted and exposed to climate variability, implying in high risks. The tough electricity supply crisis in the past is unequivocal evidence (refs). In this sense, the higher solar resource levels during spring add resilience to the operation of the national electricity system in the future for both scenarios. Howbeit impacts on other renewable resources (wind, hydro) are expected and should be assessed altogether.

5.5.5 Case Studies for specific locations

Solar power generation has rapidly grown in most Brazilian metropolitan areas due to a decrease in the cost of photovoltaic systems and regulations that encourage distributed generation (ABSOLAR, 2023). In this context, we selected seven metropolitan areas of interest covering different climate regimes for evaluating the future impact on solar energy resource. Figure 5.48 shows the time evolution of the annual average of SSR from 1980 to the end of the century for these seven metropolitan areas according to SME models, including the linear regression line for the SSP2-4.5 and SSP5-8.5 pathways. Table 4 lists the trend slope and p-value for all locations and both climate pathways. All statistically significant trends are highlighted in bold blue numbers.

Two of the metropolitan areas (Fortaleza and Petrolina) are in the Northeastern region, which is the region with the highest surface solar irradiance in the Brazilian territory. Fortaleza is on the Atlantic coast close to the Equator, where wind energy resource is also vast all year long (Amarante *et al.*, 2001), and an installed capacity of around 2500 MW is already in operation (ANEEL, 2023). Hybrid wind-solar power plants are being considered a low-carbon alternative to reduce the intrinsic intermittence of solar and wind power generation. The advantages of hybrid power generation in the region is currently being assessed by the academy (Antunes Campos *et al.*, 2020; Santos *et al.*, 2020; Souza Nascimento *et al.*, 2022) and regulatory agencies (EPE, 2019; ANEEL, 2021) whilst the first plants are entering operation.

Petrolina is in the semiarid region where several large-scale PV plants are being deployed in lately. Additionally, it is at the border of one of the largest Brazilian hydropower reservoirs (Sobradinho 1050 GW), where previous studies indicated that floating photovoltaic power plants could improve water storage and management during extreme droughts periods and meet the water demands for other uses than power generation (Velloso *et al.*, 2019; Ferraz de Campos *et al.*, 2021).

Figure 10 indicates that climate change will impact the annual mean SSR in opposite ways in these two locations. Projections suggest that Petrolina will continuously increase SSR (170-270 Wh/m^2 per year) until the end of the century for SSP2 and SSP5 pathways (low significance). On the other hand, the CMIP6 models point out a significant negative trend (350-440 Wh/m^2 per year) on annual mean SSR in Fortaleza for both pathways. These results suggest an overall good resilience for solar energy resource in Brazil's Northeast region since most large-scale projects are developed in the semi-arid (interior) region. But the coastal region concentrates most of the population, and thus for the distributed PV systems on the northern coast, a certain level of reduction is expected. Nevertheless, those impacts are constrained to +/- 2% over the historical SSR level, which may not largely affect the sector's feasibility.

Brasilia and Belo Horizonte are important metropolitan areas in the central region of Brazil, both in terms of energy consumption and the national GDP. Solar power is rapidly expanding due to the region's abundant solar resources and reduced seasonal variation (Pereira *et al.*, 2017), key assets for large-scale photovoltaic power plants in Central region of Brazil. In addition, recent studies indicate that investments in photovoltaic power distributed generation (PVDG) have a payback period of approximately 3 to 5 years in the region (Antoniolli *et al.*, 2022), what explains the booming of those distributed PV systems all over Brazil in the last years . The CMIP6 projections suggest a positive trend for surface solar irradiation for both areas in the upcoming years, for both future scenarios. However, the trend slope is around twice higher in SSP5-8.5 (in the range of 600 to 800 Wh/m^2 per year) than in SSP2-4.5. It means roughly, up to 4% increase in solar energy resource in the more extreme scenario.

São Paulo, the largest metropolitan area in Brazil, has 37 cities with nearly 22 million inhabitants living in around 8000 km^2 in the Southeast. This area also has seen an exponential increase in PVDG since 2020 and holds the largest economical potential for those systems because it is the primary energy consumption center in the country. Figure 10 and Table 4 indicate that climate change will not particularly affect the annual mean SSR as the trend slope is small or zero and without statistical significance.

Porto Alegre is in the Brazilian Southern region, where SSR presents the largest seasonal variability (Pereira *et al.*, 2017). Such high variability is originated mostly due to the moderate latitude but is also affected by the climate dynamics in the region impaired by cold fronts coming from the South, low-level jets, subtropical mesoscale convective systems, and South Atlantic Convergence Zone. CMIP6 models predict a strong decreasing trend in the order of 610 Wh/m^2 per year under SSP5-8.5 for Porto Alegre. The decreasing trend is also present under SSP2-4.5 but it is not statistically significant. However, the South of Brazil has also a large wind energy potential, and hybrid wind-solar power generation can be an alternative to reduce the impact of climate change in the future SSR.

Finally, we selected Manaus to discuss the future SSR pattern in the Amazon region. Most of the Amazon region is not integrated into the Brazilian Interconnected Electricity Distribution System (referred to as SIN). Isolated power generation systems based on fossil fuel are spread out into the region, and their costs are financed by compulsory tax in the energy tariff paid by all electricity consumers in Brazil. Solar photovoltaic systems are the primary alternative to cut GHG emissions from such isolated power systems and to reduce the high taxes in electricity bills. The SSR data from SME shows the highest increasing trend for the Brazilian territory under both scenarios for Manaus.. In the more extreme scenario (SSP5-8.5) the SSR may increase up to 6%, bolstering the solar power option for this region (Table 5.5)

The future trends and spatial distribution of SSR in Brazilian territory emphasize the challenges in optimizing the benefits that solar power can add to the Brazilian energy matrix while remaining resolute in reducing GHG emissions to meet the Brazilian assumed commitments.

Table 5.5. Slopes of the SSR's trend line and respective p-value obtained for seven metropolitan areas of Brazil from the average of SME for two future scenarios (SSP2-4.5 and SSP5-8.5). Significant p-values at 5% are highlighted in blue.

Location	Historical timeframe		SSP2-4.5		SSP5-8.5	
	slope (Wh/m^2.year)	p-value	slope (Wh/m^2.year)	p-value	slope (Wh/m^2.year)	p-value
Petrolina	**789**	**0.25**	**175**	**0.44**	**263**	**0.22**
Fortaleza	**263**	**0.58**	**-350**	**0.01**	**-438**	**0.00**
Brasília	**438**	**0.39**	**236**	**0.05**	**613**	**0.00**
Belo Horizonte	**263**	**0.64**	**350**	**0.02**	**789**	**0.00**
São Paulo	**0.0**	**0.98**	**87**	**0.33**	**0.0**	**0.75**
Porto Alegre	**-263**	**0.66**	**-175**	**0.17**	**-613**	**0.00**
Manaus	**263**	**0.59**	**350**	**0.01**	**876**	**0.00**

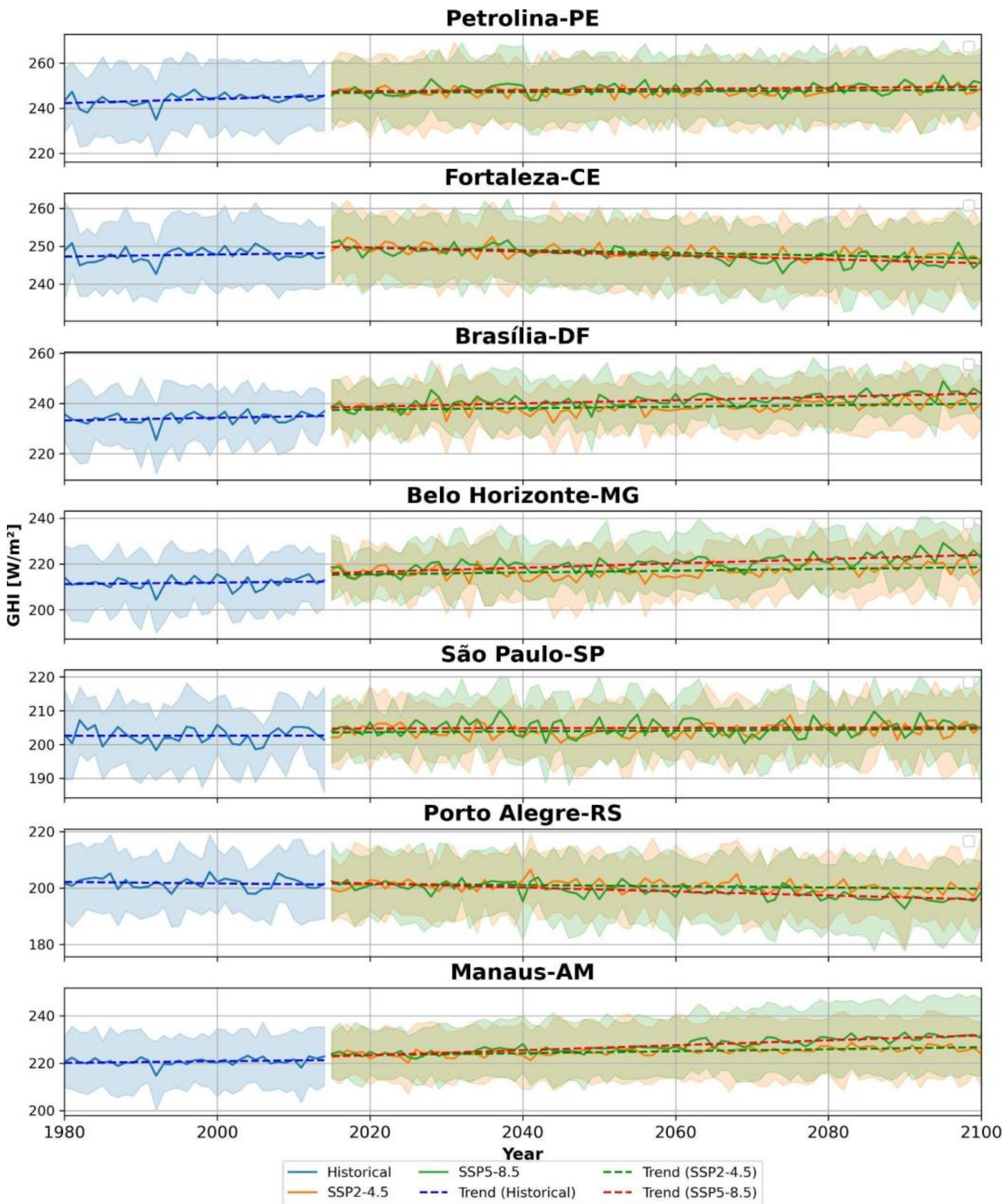


Figure 5.48. SSR time series and trends for seven metropolitan areas of Brazil generated from SME data for two future scenarios (SSP2-4.5 and SSP5-8.5).

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a.5) THE IMPACTS OF OFFSHORE WIND GENERATION ON THE STABILITY OF THE ELECTRICAL SYSTEM FOR THE PRESENT AND FUTURE CLIMATE

Several studies have estimated the potential for offshore wind generation on the coast of Brazil based on different databases and assumptions, indicating values between 400GW and 1300GW. On the other hand, there are no studies on the power generation variability in interconnected offshore wind plants in Brazil at various time scales. There are still questions about the stability gains that the integration of these plants can bring to the National Interconnected System (SIN). Therefore, it is understood that a thorough evaluation of this characteristic can reduce uncertainties in short and long-term energy planning, contributing to national energy security.

Several studies published in the last fifteen years address different aspects of Brazil's offshore wind potential and generation, including environmental, economic, technical, and climatological issues. Vinhoza et al. (2021) employed spatial multicriteria decision analysis based on data from the Brazilian Wind Potential Atlas 2013 (CEPEL), Bathymetry Project (CPRM), and geographic data (MMA) to identify offshore wind potential areas based on technical, social, economic, and environmental criteria. Other published articles have studied offshore potential using observational data (ocean buoys and satellites) and reanalysis of wind turbine altitudes ranging from 70 to 200 m as turbine heights have increased along with technological advancements in the sector.

Pimenta et al. (2008) used the logarithmic wind law to calculate offshore wind potential at 80 meters based on observed data from PIRATA buoys, oil platforms, QuikSCAT satellite scatterometer data, and bathymetry data from navigation charts. Silva et al. (2016) utilized Blended Sea Winds (BSW) data from 1987 to 2016, ETOPO5, and Digital Terrain Model (DTM) to estimate wind potential at heights of 70 and 100 meters using the logarithmic law as an extrapolation method. Galazzo et al. (2019) estimated offshore potential at heights of 80, 100, 125, 150, and 200 meters using the logarithmic law under neutral atmospheric conditions. Observed wind data were obtained from PIRATA, PNBOIA buoys, and scatterometers from MetOp A and B satellites, while bathymetry data were sourced from ETOPO1. The reanalysis models used were ERA5 (2000-2017) and Cross-Calibrated Multi-Platform (1988-2017).

As part of this research topic's methodology, ocean buoys data were used to evaluate wind data from the selected reanalysis dataset. Wind speed and direction data from 28 buoys from the projects PIRATA and the PNBOIA were evaluated, and from a total of 28 buoys, 21 (Table 5.6) had suitable data series for this study based on quality control testing.

Table 5.6 – Locations of Oceanic buoys with wind data acquisition systems in Brazilian coast

Lat	Lon	Period	Type
8N	38 O	01/1998 - 10/2018	PIRATA
4 N	38 O	03/2000 - 09/2019	PIRATA
0 N	35 O	01/1998 - 05/2020	PIRATA
8 S	30 O	08/2005 - 03/2023	PIRATA
14 S	32 O	08/2005 - 04/2023	PIRATA
19 S	34 O	09/2005 - 11/2018	PIRATA
3 S	32 O	06/2022 - 10/2022	PNBOIA
3 S	38 O	05/2018 - 11/2018	PNBOIA
8S	34 O	06/2016 - 09/2021	PNBOIA
16 S	37 O	07/2012 - 12/2016	PNBOIA
17 S	38 O	06/2021 - 11/2022	PNBOIA
19 S	39 O	10/2015 - 07/2017	PNBOIA
20 S	29 O	04/2021 - 08/2021	PNBOIA
22 S	42 O	06/2009 - 09/2013	PNBOIA

23 S	42 O	07/2016 - 10/2018	PNBOIA
23 S	43 O	09/2019 - 01/2020	PNBOIA
25 S	45 O	04/2011 - 12/2018	PNBOIA
27 S	47 O	04/2009 - 10/2019	PNBOIA
28 S	48 O	07/2022 - 10/2022	PNBOIA
31 S	49 O	04/2009 - 03/2019	PNBOIA
32 S	52 O	05/2002 - 10/2004	PNBOIA

A computational procedure was used for the quality assessment of observed wind data (wind speed and direction), air temperature, atmospheric pressure, and relative humidity. Quality control aims to minimize the possibility of biased results due to data inconsistency caused by poor sampling and database manipulation. It comprises three steps as follows:

a) Physical thresholds - the test check if observational data is in the range of physically possible values;
b) Relationship Tests - the test check if the relationship among observational data measured by different sensors are consistent;
c) Trend Tests - the test checks evaluates the time series behavior. Thus, all analyses and results generated in this study are based solely on the observational data classified as not suspicious by the data quality computational procedure. The suspicious data points are flagged according to criteria adapted from the Wind Resource Assessment Handbook (National Renewable Energy Laboratory - U.S. Department of Energy), Meteorological Monitoring Guidance for Regulatory Modeling Applications (EPA - Environmental Protection Agency), and the SONDA Network maintained by DIIAV/INPE. Figure 11 shows the time-series of observational data by the buoy located at the Equator and 35° West after data quality control. Figure 5.49 presents data series from a PIRATA buoy.

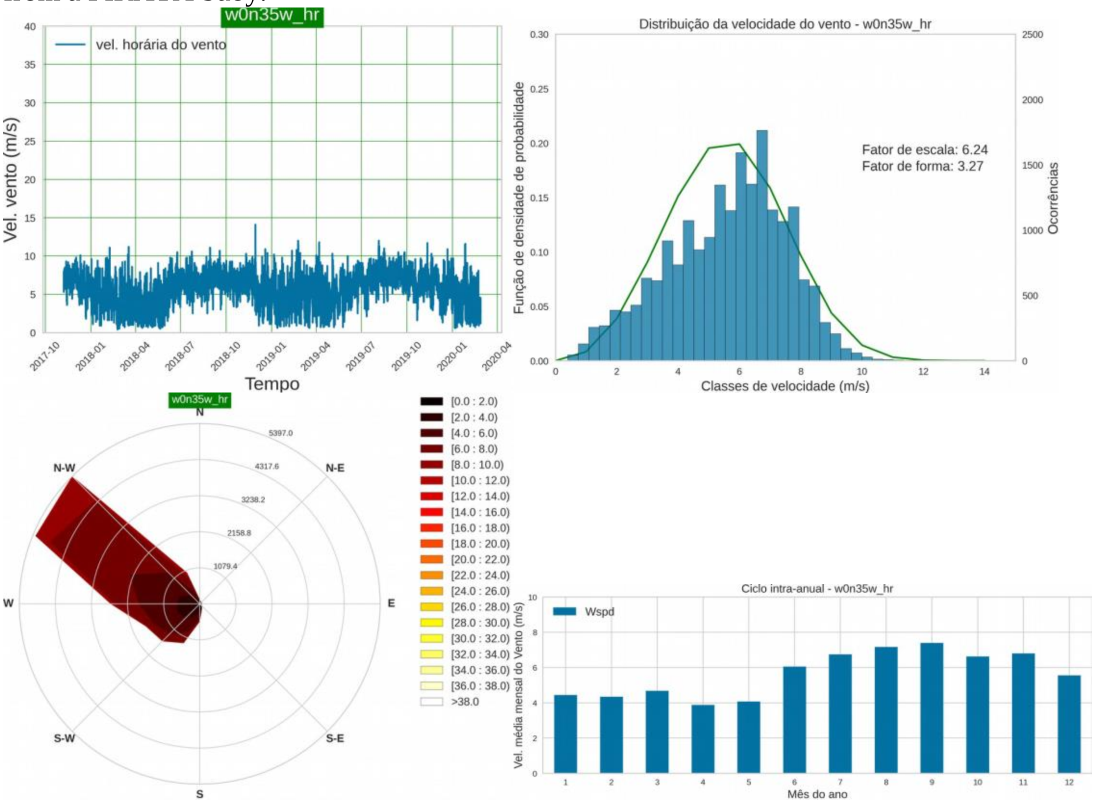

Figure 5.49– Wind data, Weibull analysis, Wind rose and intrannual cicle from buoy 0N35W - PIRATA project.

The same analysis was conducted for all buoys listed in Table 5, which will serve as the basis for data validation of numerical models (atmospheric reanalysis) and other intercomparisons, as outlined in the research project schedule. The a.5 task is in developing and a complete analysis will be presented in the next annual report.

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5.6 Natural disasters, impacts on physical infrastructure in urban areas and urban development

This section presents the main advances developed during the sixth year of activities, including interaction with another sub-project of the INCT-MC.

5.6.1 – Space-temporal characterization of drought in Brazil: trends assessment

Drought-related disasters are among the typologies that cause the greatest socio economic losses in Brazil. In recent years, drought has affected several regions of the country, compromising water and food security, especially in the most vulnerable communities. In this context, it is essential to identify areas where drought has been more frequent so that actions can be developed and implemented to mitigate the impacts caused by this phenomenon. This study aims to map Brazil's regions most affected by droughts considering the Integrated Drought Index on a 12-month scale (IDI-12) from 1982 to 2022. The IDI is an index developed for drought monitoring for short and medium-term (Cunha et al., 2019). Besides precipitation (SPI), the IDI includes information on vegetation response to water deficit (VHI). For frequency analysis, only events of severe, extreme, and exceptional categories were considered. In addition, the Mann-Kendall test was used for trend analysis (Kendall, 1975).

Droughts have been frequent in Brazil, causing significant impacts on several productive sectors. However, these impacts can vary considerably in different regions of the country, depending on local characteristics and particularities. According to IDI-12, the period from 2013 to 2022 was marked by the highest frequency of drought events in Brazil (Figure 5.50). During this period, approximately 7% of the country experienced severe to exceptional drought conditions for at least 50% of the time. The period between 2013 and 2020 is one of the analyzed periods with the highest drought occurrence. The regions that stand out frequently are the Northeast Region, the northern portion of the Southeast Region, and most of the Center-West and the south of the country. In addition, the trend analysis indicates that the Paraná River Basin showed a positive and significant trend of more intense drought events in the last almost 40 years (Figure 5.51). These results corroborate those obtained by Marengo et al. (2020) and Cuartas et al. (2022) in studies about the drought events in different regions of Brazil.

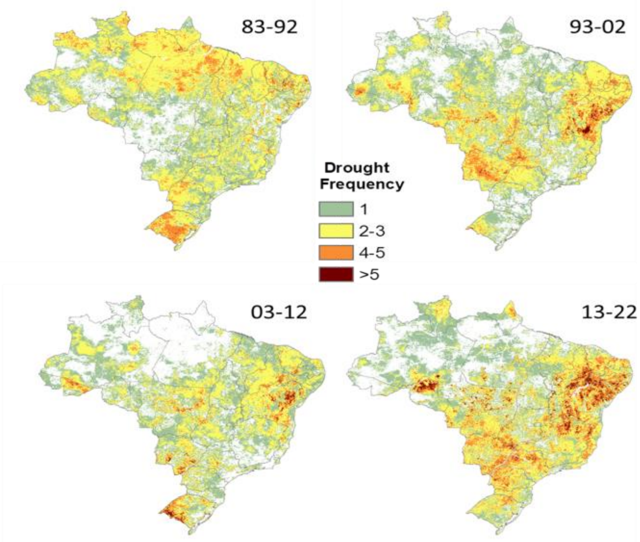


Figure 5.50 – Frequency of drought events in Brazil, from severe to exceptional categories.

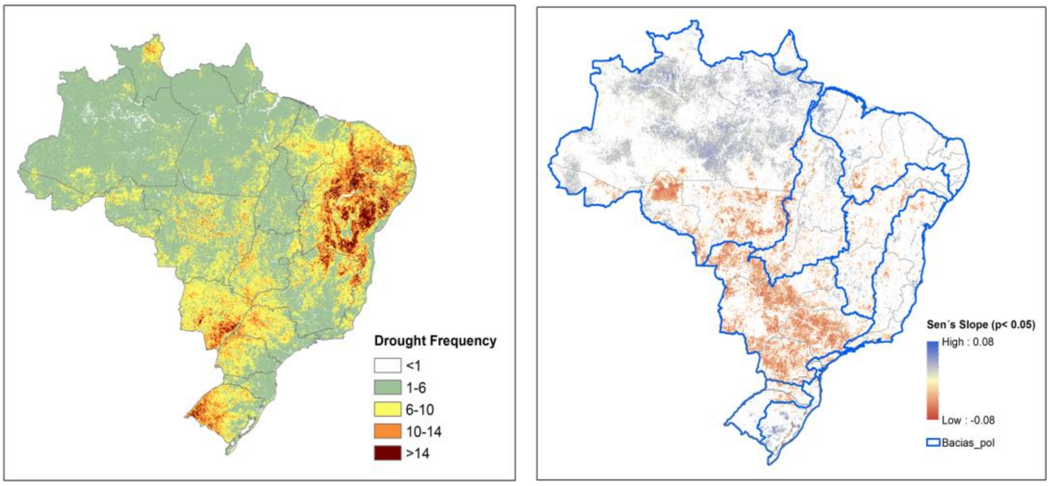


Figure 5.51 – Frequency of the severe to exceptional drought events between 1983 and 2022 (a); Sen's slope calculated using the Mann-Kendall test (b).

5.6.2 Monitoring Urban Drought

Wang et al. (2020) defined urban drought as a socioeconomic drought, while Zhang et al. (2019) emphasized its significance in relation to the Sustainable Development Goals of the 2030 Agenda, including "Sustainable Cities and Communities", and "Action against global climate change". The main drivers of urban drought include population growth, climate change, overexploitation of water resources, and inadequate water management practices. As in some countries, many cities continue to expand, understanding the vulnerability of urban drought becomes essential for identifying the most vulnerable municipalities and regions and implementing effective mitigation strategies, and ensuring the resilience of urban communities in the face of water scarcity challenges.

The first step of the present study consisted of a bibliographic review of vulnerability indicators to urban drought. For this study, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method was chosen which is systematic and replicable. The search tool used was the Web of Science (WOS) and the keywords: water, vulnerability, and urban, considering only the content in the abstract. In addition, some filters were applied: year of publication: between 2019 and 2023; document included: article, review article, conference article, early access, book chapter, data article, editorial material; and languages: Portuguese and English. The search returned 489 documents, and no article was removed in the first identification phase.

In the second step, the titles and abstracts of the 489 documents were analyzed, and the studies excluded themes, such as hydrology and hydraulics; underground water; water quality; seismic events; urban heat; floods and storms; cooperative management; and mining.

5.6.2.1 – Use of Artificial Intelligence for Reservoir Classification

An exploratory analysis with the Standard Precipitation Index (SPI) to estimate the situation of the reservoirs was carried out. The SPI has been widely used to characterize climatological extreme events. While positive extreme events have their most visible effect and consequences, a negative extreme does not necessarily mean a period of drought.

Drought events are defined when the SPI reaches values lower than -1 and end when the SPI is positive for two consecutive months. From the beginning and end of the drought event, it is also possible to estimate its duration, severity and intensity. The duration is the interval between the beginning and the end of the event, the severity is the sum of the SPIs during the drought event and the intensity is the ratio between the severity and the duration.

The first tests with the SPI aimed to analyze which scale of SPI best correlated with changes in the reservoir volume. For this, in addition to the SPI, information on severity and duration was used. Thus, for drought event months, severity and duration are equal to 0, and during drought events, duration and severity are progressive. For the calculation of the SPI, precipitation data from Merge (Rozante, 2010) were used and the methodology of McKee et al. (1993) was applied.

The analysis method used was regression and the models tested were: random forest, polynomial, radial basis function (rbf) and sigmoid. The choice of regression with AI was due to the ability to model complex and non-linear relationships between the input variables and the output variable, which allows capturing subtle patterns and interactions in the data which can be difficult to identify by traditional regression approaches linear, as is the case of this study. It is important to emphasize that AI regression presents challenges, such as the risk of overfitting (excessive adjustment) and the complexity in interpreting the results. Finally, two indices were selected as model fit indicators: the RSME (Root Mean Square Error) and the r^2 (coefficient of determination).

5.6.2.2 – Study Area

The reservoir chosen for the case study was Epitácio Pessoa, located in the Boqueirão in Paraíba municipality (Figure 5.52), with a maximum storage volume of 411.69 hm^3 and effective volume of 377.49 hm^3 (Vicente Serrano et al., 2012,). The reservoir supplies 25 municipal capitals and demands water use for: Urban Human Supply; Rural Human Supply; Animal Watering; and Irrigation (Vicente Serrano et al., 2012). Furthermore, the Brazilian National Water Agency (ANA) and the Executive Water Management Agency (AESA) define the reservoirs by their respective demand and the level of criticality of the stored volume. Although the AESA only considers it as a Critical Situation when the reservoir has a total volume below 5%, according to the ANA when the useful volume reaches 30.4%, the reservoir operates with restrictive demands. For this work, the following classification was considered based on the volume of the reservoir (%): 5% Critical Situation; 20% Observation; 27.9% Priority demands; 30.4% Restrictive Claims; and 35% or more, Total Demands.

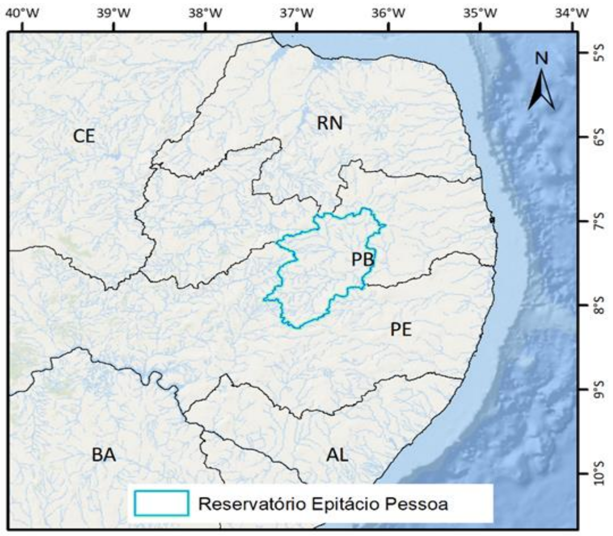


Figure 5.52 – Study Area.

5.6.2.3 – PRISMA Review: vulnerability index for urban water access

At the end of the exclusion process, 17 articles remained that fully met all the search criteria, and 14 were selected for a more refined and detailed analysis. Hence, from the results summarized so far, it is already possible to identify variables common to all studies, such as age group, gender, income, access to water, and the sewage system. In addition, other less common variables can collaborate with these work targets.

As the next steps, the 14 articles that are in a 'maybe' category will be analyzed. After finishing the vulnerability index review, the variables of the 'urban drought vulnerability' will be defined. In sequence, it will be time for data collection and preparation, which involves gathering data, data cleaning, handling missing values, normalization, and variable processing, such as calculations and aggregations. Finally, variable analysis and results visualization will be conducted to analyze the consistency of those steps.

2.2.4 – Epitácio Pessoa reservoir classification

The SPI 06 presented six drought events from May/2002 to Apr/2023: Nov/2007 to Apr/2008, Mar/2012 to Dec/2013, Apr/2015 to Nov/2015, Jul/2016 to Apr/2018, Oct/2018 to Mar/2019, and Jan/2012 to Jan/22 (Figure 5.53a). The event duration ranged from 6 to 22 months, and severity ranged from -3.06 to -29.78. SPI 12, on the other hand, presented two drought events: the first from May 2012 to May 2018, lasting 73 months, with a severity of -71.32, and a second event from March 2021 to December 2022, lasting 22 months, with a severity of -10.05 (Figure 5.53b). Finally, SPI 24 presented a drought event, starting in March 2013 and ending in April 2022, which lasted 86 months, with a severity of -81.53 (Figure 5.53c). The first drop in the percentage of water volume in the reservoir was also identified as negative SPI 06 and 12, between September and December 2003. The period of constant drop from February 2013 to zero in April 2017 was captured mainly by SPI 12 and 24. SPI 06, on the other hand, showed short periods of improvement (positive SPI) in this interval.

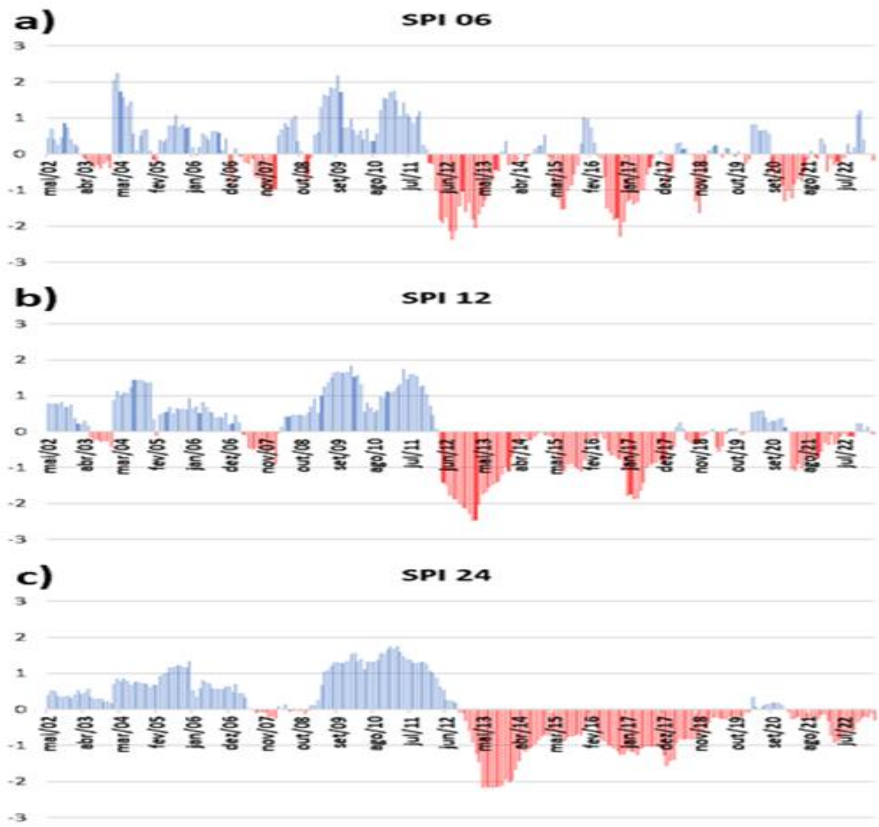


Figure 5.53 – SPI's 06, 12 and 24 time series.

Among all the models tested, the one that presented the best fit was the Random Forest regression (Table 5.7), which had an RMSE of [insert value] and an R2 of 0.85. According to Amaral (2023), one of the advantages of Random Forest is that it adapts well to non-linear data sets, and the scheme of testing several trees allows for a better fit and, therefore, a better result.

Table 5.7 – Methods and parameters of the AI used and their respective performances.

Method	RMSE	R^2	Parameters
Random Forest	127.15	0,85	Estimators = 100; Max Depth=4; Min Sample Split = 2; Random State=0
Polynomial – Ridge	495.15	0,49	Degree 3
SVM	294.49	0,62	Kernel=rbf; C=100; gamma=0,1; epsilon = 0,5
SVM	9847353848.0	-	Kernel = poly; gamma= auto; Graus= 2; epsilon=0.1, coef0=1

The Support Vector Machine (SVM) models did not show good results in this first analysis. Several configurations were tested for both the rbf kernel and the polynomial kernel; however, satisfactory results were not obtained. The final parameters used in the SVM models are shown in Table 1. The Ridge Polynomial model presented an r^2 = 0.49 (Table 5.7), which is much lower than that of the Random Forest.

As a result, the Random Forest was chosen as the best regression model for this work, and the degree of importance of each of the variables (x) of the regression was extracted. The variables SPI 24 and SPI 12 (Table 5.8) explain approximately 73% of the regression result, meaning they strongly influence the variation in the volume of water in the reservoir. The importance of the other variables was less than 0.09 (9%) each (Table 5.8).

In general, SPI 12 and 24 were promising for classifying the situation of the reservoir, with a kappa of 0.64 and good accuracy, mainly for the classes of total demand and Critical situation. The regression model and Random Forest classifier, in addition to being easy to apply, had good results, and also show promise for studies of this type. Finally, it is concluded that the remote sensing data, represented by the SPI, which is a precipitation index, has the potential to estimate the situation of the reservoir.

The next step is to test SPI at other scales and for different basin sizes. Furthermore, other indexes should be tested, such as SPEI, precipitation, and more. This step is predicted to start in January 2024.

Table 5.8 – Random forest feature importance.

Variable	**Feature Importance**
SPI06	0.087
Severity (SPI06)	0.002
Drought Duration (SPI06)	0.001
SPI12	0.198
Severity (SPI12)	0.011
Drought Duration (SPI12)	0.018
SPI24	0.568
Severity (SPI24)	0.058
Drought Duration (SPI24)	0.058

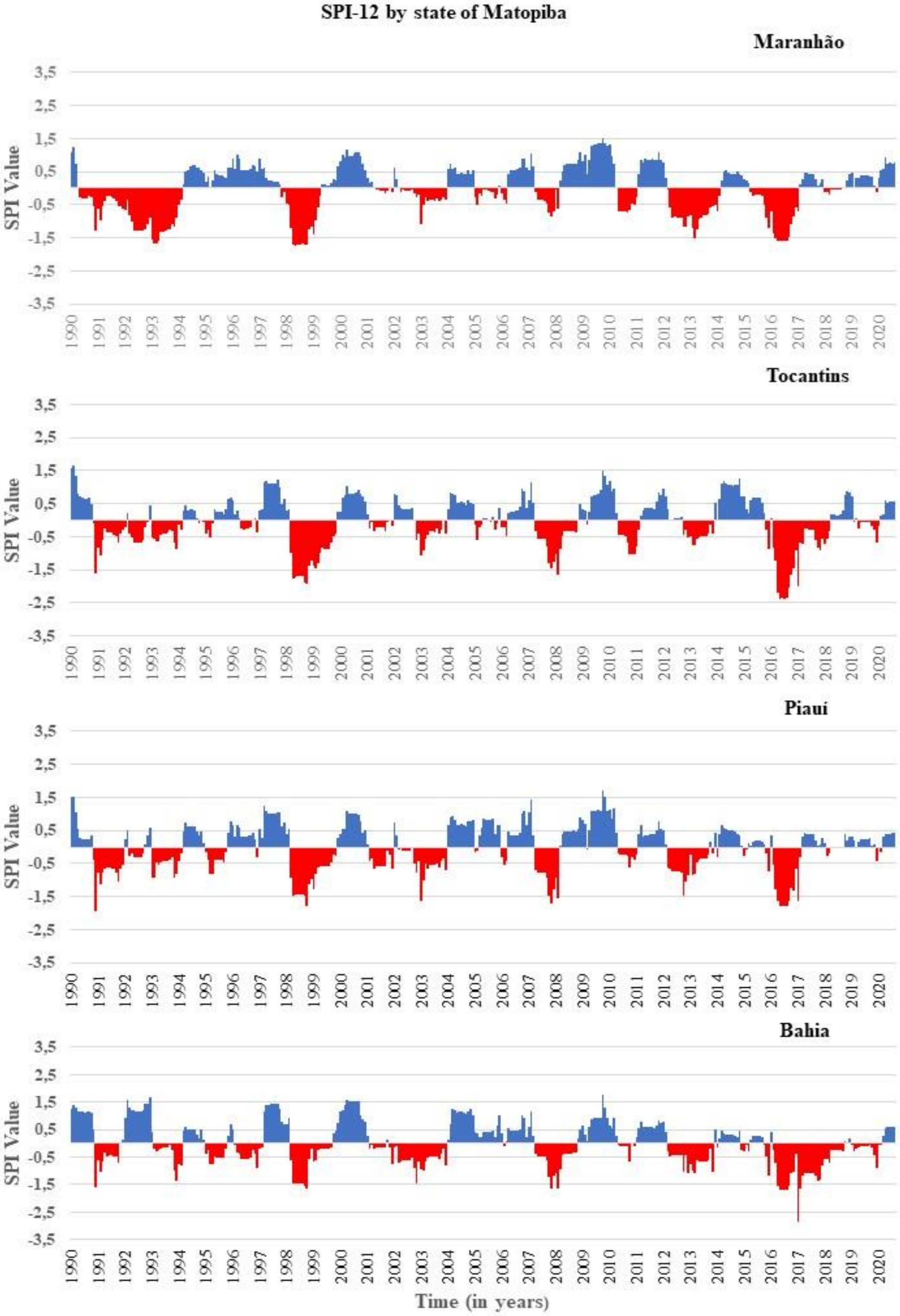
5.6.3 – Characterization of droughts and land use change in the Matopiba region, Brazil

The expansion of the agricultural frontier known as Matopiba, Brazil, is responsible for the intense land use transitions in the Cerrado biome. Anthropogenic and natural changes are interacting in a non-linear way, causing negative impacts on ecosystems and productive means, which puts at risk the region and Brazil, a country whose development is largely based on the use of natural resources. In the climate change scenario, the synergism between droughts, deforestation, and intensive land use exacerbates impacts once minimized by sustainable use. Based on this conception, this research aims to evaluate the patterns of droughts and changes in land use and land cover in order to characterize the region, since the interaction between climate and anthropic activities present unique spatial-temporal patterns.

Figure 5.54 presents the temporal evolution of the SPI and SPEI indices on a 12-month scale for each of the states included in Matopiba. It is worth noting that the SPI indicates drought events based only on precipitation deviation data; while the SPEI, in turn, indicates drought events enhanced by the effect of temperature. In general, both indices show the same drought events of higher intensity in different states. However, the drought events are more intense (more negative values) from the SPEI data.

According to both indices, the periods 1991-94, 1998-99, 2007-09 and 2015-20 presented the minimum values for the region. On the other hand, the years 1990, 1997, 2000, 2005, 2010, 2012, 2015 and 2019 presented the maximum values, characterizing more extreme rainfall events. It is observed, in addition, that in the evaluated period the dry events were more intense and frequent than the rainy ones, especially from the SPEI data.

Although the relationship between the results obtained by the indices is high, it is possible to show that the SPEI is more prominent in the analysis of droughts in the region, since it also considers the evaporative demand of the atmosphere. Because this is a predominantly agricultural region with savanna vegetation, water restriction is an important factor for the area's characteristic seasonality. Thus, this index allows the observation of the high conditions imposed not only by rainfall restriction, but also combines the effect of high temperatures, being a crucial element in the representation of extreme events in climate change scenarios.



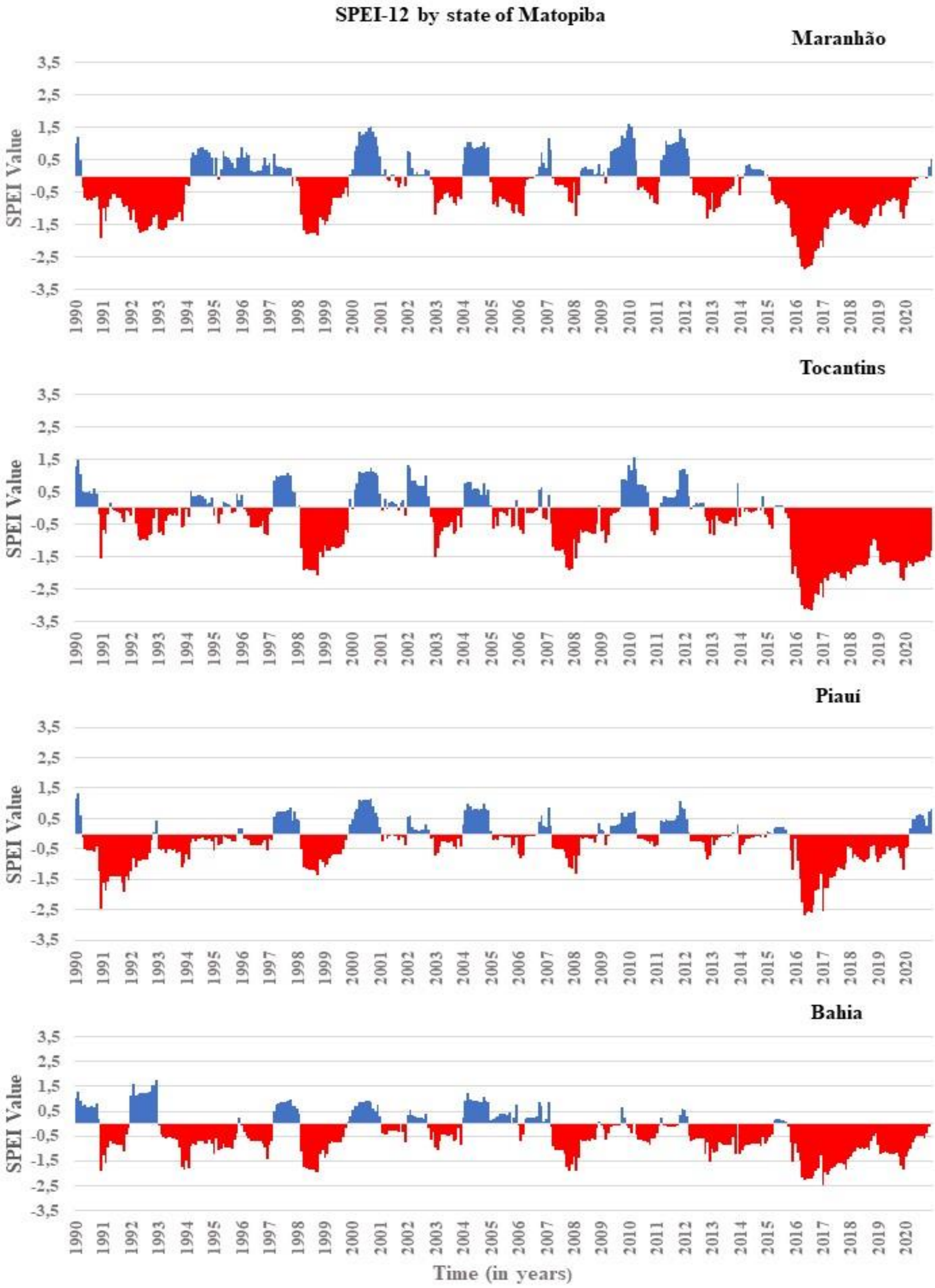


Figure 5.54 – Time evolution of SPI and SPEI indices, respectively, on the 12-month scale by Matopiba state.

Figure 5.55 shows the spatial distribution of drought recurrence from VHI and SPI-12 data between the years 1982 to 2020. From Figure 16, it is possible to observe that the recurrence of severe drought condition (VHI < 20 and SPI12 < -1.3)) is high in most of the territory of Matopiba. From the VHI data, the highest recurrence of severe drought is in the areas near the semi-arid, southeast of Matopiba, mainly in the Bahia region and the central portion of Maranhão. In relation to SPI-12, the data on recurrence of droughts are more spatially dispersed, that is, arranged in several areas of the territory. The energy conditions of the environment affect all the biochemical and biophysical processes that condition plant metabolism, such as water absorption, respiration, photosynthesis and water loss. The difference pointed out in Figure 5.56 in relation to the spatial pattern of drought occurrence obtained by the VHI and SPI may be because the VHI is an indicator of response to water deficit, whose dynamics is associated with the distribution of different types of vegetation. Thus, the drought recurrence map considering the ILV may indicate areas with vegetation less resilient to low water availability.

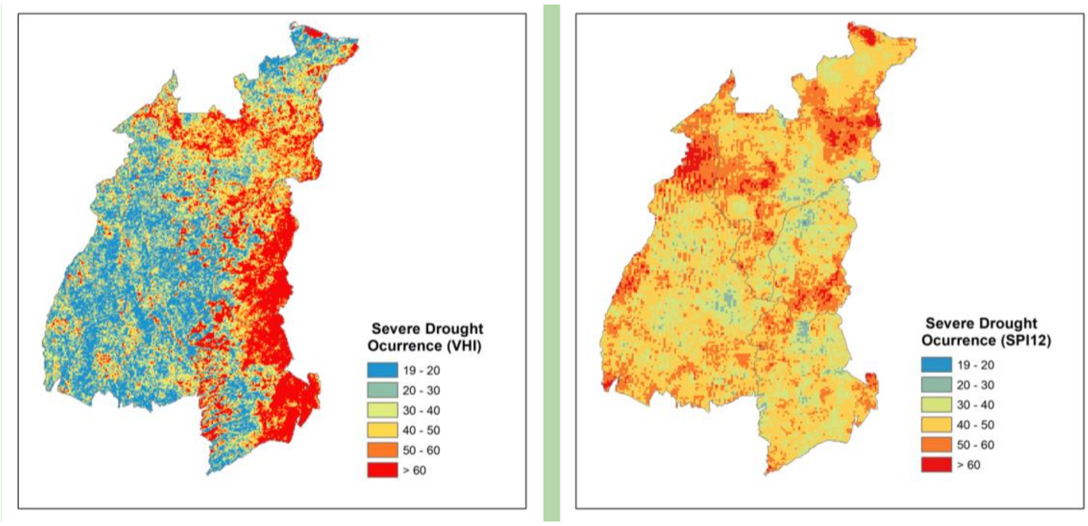


Figure 5.55 – Drought recurrence from VHI and SPI-12 data from 1982 to 2020.

The trends analysis showed positive trends for droughts, vegetation stress, temperature increase, and precipitation reduction (Table 5.9). In light of scientific evidence, anthropic activities and their global impacts on the environment characterize the need for risk reduction. Exacerbated impacts triggered by the lack of strategic management can compromise food security and agricultural development, and corroborate the rural exodus.

Table 5.9 – Results of the climate trend analysis in the different land use transitions using the Mann-Kendall (MK) method.

STATE	ID	LULC	SPEI		SPI		VHI		TMAX		TMIN	
			tau	P	tau	p	tau	P	tau	p	tau	p
MA	1	VEG-AGR	-0,208	<0.0001	-0,010	0,758	-0,243	<0.0001	0,433	<0.0001	0,439	<0.0001
	2	VEG-OTH	-0,161	<0,0001	-0,043	0,188	-0,158	<0,0001	0,393	<0,0001	0,453	<0,0001
	3	OTH-AGR	-0,117	<0,0001	-0,030	0,359	-0,09	0,005	0,366	<0.0001	0,475	<0.0001
TO	1	VEG-AGR	-0,224	<0,0001	0,038	0,247	-0,231	<0,0001	0,377	<0,0001	0,374	<0,0001
	2	VEG-OTH	-0,386	<0,0001	-0,083	0,012	-0,286	<0,0001	0,317	<0,0001	0,257	<0,0001
	3	OTH-AGR	-0,417	<0,0001	-0,103	0,002	0,024	0,461	0,322	<0,0001	0,383	<0,0001
PI	1	VEG-AGR	-0,211	<0,0001	0,009	0,791	-0,312	<0,0001	0,365	<0,0001	0,311	<0,0001
	2	VEG-OTH	-0,193	<0,0001	0,061	0,063	-0,29	<0,0001	0,332	<0,0001	0,233	<0,0001
	3	OTH-AGR	-0,227	<0,0001	-0,035	0,281	-0,191	<0,0001	0,365	<0,0001	0,26	<0,0001
BA	1	VEG-AGR	-0,456	<0,0001	-0,165	<0,0001	-0,058	0,071	0,244	<0,0001	0,244	<0,0001
	2	VEG-OTH	-0,42	<0,0001	-0,061	0,063	-0,081	0,012	0,233	<0,0001	0,137	<0,0001
	3	OTH-AGR	-0,491	<0,0001	-0,198	<0,0001	-0,21	<0,0001	0,282	<0,0001	0,32	<0,0001

5.6.4 – Analysis of extreme events, future projections under climate change and consequences for urban areas

Floods and droughts cause more damage worldwide than any other natural hazard, and their risks may be exacerbated by climate change and socio-economic activities. Often an increase in floods is aligned with a decrease in droughts as a result of more abundant rainfall, and the opposite is the case as rainfall becomes scarcer. However, some models suggest a joint increase in the severity of floods and droughts, a phenomenon referred to as the acceleration of the terrestrial component of the water cycle. This acceleration could lead to large compound impacts on global food production, ecosystem health, and infrastructure.

We analyse a comprehensive hydrometeorological, land cover and human water use data set in Brazil and show that water use and deforestation have amplified climate change effects on Brazilian streamflow extremes over the past four decades (Chagas et al. 2022). This region encompasses some of the world's largest basins with mounting concerns about changing floods and droughts. Our analysis is based on daily streamflow observations from 886 hydrometric stations for the period from 1980 to 2015. For each station, we compute the annual time series of the annual minimum 7-day streamflow as a measure of drought flows, mean daily streamflow as a measure of water availability, and annual maximum daily streamflow as a measure of flood flows. We quantify the trend magnitude of each time series (i.e., local trend) with the Theil-Sen slope estimator, the significance of each trend with the Mann-Kendall test and obtain regional trends by spatial interpolation with ordinary kriging.

While in the past, some of the drivers of streamflow change, such as climate and land management, have been analysed individually in South America, the results here show a clear, spatially coherent signal of streamflow changes that can be interpreted in terms of the compound effects of these drivers. Drying trends are the largest in central and northeastern Brazil (Figure 5.54). One possible explanation for the change is the southward shift of the South American Convergence Zone (SACZ), a major source of precipitation, which has moved away from central Brazil. The drying trends may also be related to a northward displacement of the Intertropical Convergence Zone (ITCZ), which has moved the equatorial precipitation band farther away from northeastern Brazil. Even though the average temperature has been increasing in central and northeastern Brazil over the past four decades, evaporation trends have been mostly not significant, possibly because of reduced precipitation water supply. An expansion of irrigated agriculture from 15 to 70 thousand km2 (i.e., by 367%) from 1980 to 2015 has led to a rapid growth of water abstraction, which in 2017 constituted 68% of the total Brazilian water use. Increases in crop productivity and water demands due to a drier climate have boosted agricultural water use even further. Water abstraction occurs mainly from May to September during the dry season in most of central and eastern Brazil, which is linked to a substantial reduction in drought flows.

The northward shift of the ITCZ that has contributed to the reduced precipitation in northeastern Brazil has also contributed to the wetting trends in northern Amazonia even though average temperature and evaporation have increased. On the other hand, the wetting trends in southern Brazil might be associated with stronger effects of the El Niño-Southern Oscillation climate mode and the strengthening and southwards shift of the SACZ. An acceleration of the terrestrial water cycle has occurred extensively in southern Amazonia due to both the northward shift of the ITCZ and deforestation. The latter can increase surface runoff which in turn decreases groundwater recharge, increasing floods and reducing the baseflow that maintains drought flows in the dry season.

In summary, we analyse streamflow data in major South American tropical river basins and show that water use and deforestation have amplified climate change effects on streamflow extremes over the past four decades. Drying (fewer floods and more droughts) is aligned with decreasing rainfall and increasing water use in agricultural zones and occurs in 42% of the study area. Acceleration (both more severe floods and droughts) is related to more extreme rainfall and deforestation and occurs in 29% of the study area, including southern Amazonia. If the observed changes of extreme streamflow continue into the future in an unabated way, they will have substantial impacts in South America and on the global scale, some of which are already manifesting themselves.

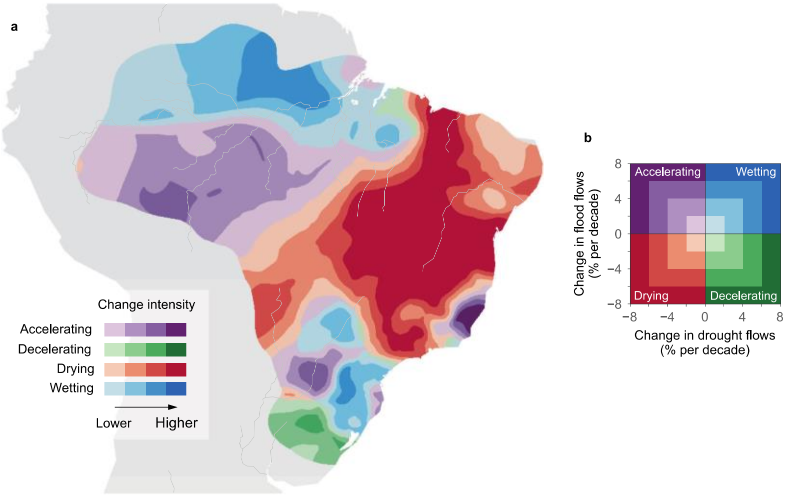


Figure 5.56 – Spatial distribution of the accelerating, decelerating, wetting, and drying streamflow trends in Brazil. (a) The location of the four quadrants of regional streamflow trends, with darker colours indicating larger change intensities. (b) Explanation of the colour code of a. Accelerating water cycle has occurred in 29% of the region (2.7million km^2); deceleration in 4% (0.4 million km^2); drying in 42% (3.9million km^2); and wetting in 25% (2.4million km^2).

5.6.5 – Quantitative analysis of rainfall events potentially landslide-triggering for Brazilian municipalities

This study aimed to provide a national-level database regarding precipitation events with the potential to trigger landslides to guide subsequent analyses concerning the climatic risks in Brazilian territory and, eventually, support decision-making related to disaster risk reduction actions and climate change adaptation measures. Thus, the study focuses on presenting a database with quantitative information on rainfall events that can potentially trigger landslides. The term "potential" is used because this type of information reflects only the climatic dimension related to the risk of landslides. It expresses the probability of heavy and/or intense rainfall events, which theoretically have a higher statistical relationship with landslides.

In the literature, the climatic dimension of “risk” is also referred to as "climatic hazard," expressing the probability of certain meteorological/climatic events occurring, considering different magnitudes, which can lead to other physical processes (in this case, landslides) that cause impacts on human and/or natural systems.

However, the risk of landslides depends fundamentally on other characteristics, especially the geological-geotechnical and geomorphological conditions (slope, hillside amplitude, soil thickness, soil type, mechanical properties, and lithology, among others), as well as the level of human interference at the local level. The combination of these features result in different levels of slope susceptibility, which can lead to mass movement when specific volumes of rainfall reach on the soil, infiltrate, and, once certain threshold conditions are exceeded, lead to its rupture, causing landslides (or other types of mass movements).

Thus, for a better representation of the climatic risk related to landslides, it is recommended that the information provided regarding the "climatic hazard" be combined with other dimensions that compose the risk. Besides susceptibility, these dimensions may also include the level of population exposure (the number of people living in areas with high and/or very high susceptibility), their vulnerabilities, and, depending on the approach, their capacity for coping and/or adapting to climate change.

5.6.5.1 – Observational precipitation data

The database used for quantifying rainfall events with the potential to trigger landslides was the CHIRPS (Climate Hazard Infrared Precipitation with Stations; Funk et al., 2015). This product is a collection of over 40 years of precipitation data covering nearly the entire globe, with daily temporal resolution from 1981 to the present, and a spatial resolution of 0.05° (approximately 5 km). This dataset incorporates climatological satellite-based precipitation estimates derived from Cold Cloud Duration (CDD) infrared observations, along with surface precipitation observations collected by rain gauges through an intelligent interpolation algorithm and be used for different purposes. Marengo et al. (2017) used CHIRPS data to analyze the characteristics of extreme precipitation events in the southeast region of Brazil and their relation to large-scale atmospheric circulation patterns, while Palharini et al. (2022) utilized various precipitation products, including CHIRPS, to identify and analyze extreme rainfall events in different regions of the country and how these extreme events are linked to natural disasters caused by flash floods and landslides. In addition to applications in evaluating extremes related to extreme rainfall, CHIRPS is also used to assess precipitation deficit events.

5.6.5.2 – Rainfall thresholds for landslides

In general terms, thresholds can be defined as pre-known values of rainfall volumes within a specific time window (1 hour, 6 hours, 24 hours, 48 hours, etc.) that, once surpassed, represent significant probabilities of landslides occurrence in a particular region. In Brazil, several studies have been conducted since the 1960s with the objective of finding thresholds related to landslide triggering. There are many thresholds for different Brazilian regions, but the method applied in this study accounted for events that historically exceeded the threshold of 50mm in 24 hours for all Brazilian municipalities. The choice of this specific threshold is based on several theoretical and empirical factors. Firstly, critical thresholds are not known for all Brazilian municipalities, necessitating an estimation that could represent, albeit preliminarily, the spatial variability of locations with a higher frequency of events potentially triggering landslides.

Although most Brazilian municipalities with a previous register of landslide-related disasters have operational thresholds higher than 50 mm/24h, there are several landslide occurrences recorded by CEMADEN (REINDESC - Records of Flood and Landslide Events from CEMADEN) in situations of rainfall around 50 mm, especially in cases where these rains were intense and concentrated in shorter periods (30 minutes, 1 hour, 2 hours, etc.). However, these events would not be possible to identify through the observed precipitation database (CHIRPS) because of its available temporal resolution (daily, values in 24 hours). This allegation is also supported by several studies, notably the one by Tatizana et. al (1987), which identifies this value (50mm) as the lower limit for triggering induced landslides (where there is human interference), provided that the rains are of high intensity (greater than 35 mm in 30 minutes). Furthermore, the observed precipitation database used as a reference typically has limitations that tend to underestimate the measured rainfall values in a large part of the Brazilian territory, except for the extreme South (Palharini et. al, 2022). For this reason, the good quality of results could be compromised if higher thresholds were used, as many potentially landslide-triggering events would not be accounted for in practice.

Therefore, it is understood that the number of days exceeding the value of 50 mm in 24 hours is a good representative to express the influence of the climatic dimension in the composition of the risk associated with landslides. As an additional contribution, the quantities of days exceeding higher thresholds, such as 100 mm and 150 mm in 24 hours, are also presented, but they were not used for the validation stage due to the limitations of CHIRPS data in estimating higher (extreme) rainfall values (i.e., high associated uncertainty).

5.6.5.3 – Quantification of events that exceeded the thresholds

In Figure 5.57 are presented the days with rainfall above 50mm. In Table 5.10 are shown results for 40 municipalities with the highest number of occurrences, under the column "Days with rainfall above

50mm," displaying the absolute values found in the historical series from 1992 to 2022. Additionally, the average per year (total divided by 30 years) is also provided. Finally, information about the number of days exceeding 100mm and 150mm is included.

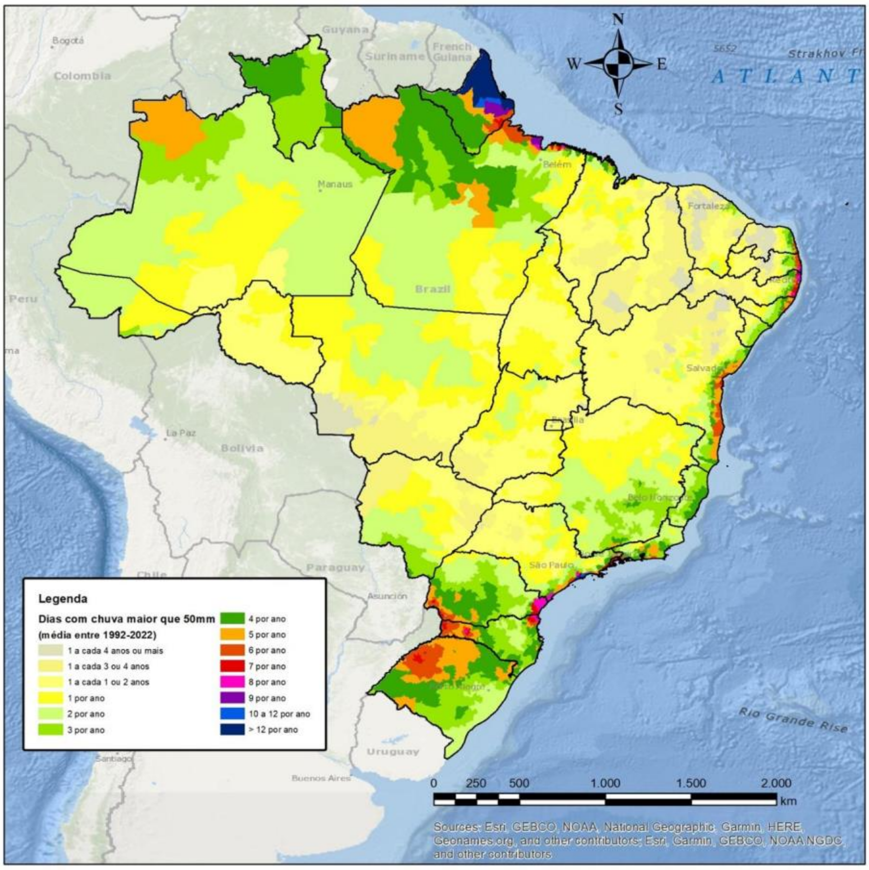


Figure 5.57 – Map of annual average of Quantity of days with rainfall above 50 mm for all Brazilian municipalities. Source of original rainfall data: CHIRPS.

Table 5.10 – List of 40 municipalities with the highest number of daily rainfalls above 50mm from 1992 to 2022. Source of original rainfall data: CHIRPS.

State	Municipality	Days with rainfall above 50mm (1991-2022)	Average days per yer with rainfall above 50mm	Days with rainfall above 100mm (1991-2022)	Days with rainfall above 150mm (1991-2022)
AP	Calçoene	510	17,0	62	12
AP	Oiapoque	423	14,1	53	12
AP	Amapá	394	13,1	37	6
SP	Cubatão	383	12,8	38	4
SP	Guarujá	379	12,6	40	6
SP	São Vicente	377	12,6	48	4
SP	Santos	374	12,5	39	3
SP	Bertioga	365	12,2	30	3
AP	Pracuúba	353	11,8	32	5
SP	Praia Grande	350	11,7	45	4
PB	Pitimbu	287	9,6	116	61
PB	Caaporã	287	9,6	100	56
SP	Mongaguá	286	9,5	36	2
PA	Soure	277	9,2	13	0
AP	Tartarugalzinho	276	9,2	17	2
SC	Itapoá	275	9,2	30	6
PE	Olinda	268	8,9	99	51
PE	Recife	261	8,7	98	55
PA	Salinópolis	261	8,7	16	2
AP	Cutias	258	8,6	11	1
PE	Goiana	256	8,5	90	48
PB	Cabedelo	252	8,4	97	52
PR	Paranaguá	252	8,4	28	4
PE	Ilha de Itamaracá	251	8,4	103	54
PR	Pontal do Paraná	251	8,4	31	4
PE	Tamandaré	249	8,3	94	48
SC	São Francisco do Sul	249	8,3	23	4
PE	Itapissuma	240	8,0	88	52
RJ	Angra Dos Reis	237	7,9	26	3
SP	Cananéia	236	7,9	24	3
PE	Rio Formoso	236	7,9	94	52
PA	São João de Pirabas	236	7,9	11	0
PB	Conde	235	7,8	87	46
PE	Paulista	234	7,8	99	48
SP	São Bernardo do Campo	234	7,8	17	2
PB	Alhandra	233	7,8	85	40
SC	Xanxerê	232	7,7	10	0

Data presented in Figure 5.58 and Table 5 indicate that certain regions of Brazil stand out for their high frequency of events exceeding 50 mm compared to others, such as the extreme North of Brazil, particularly the State of Amapá; part of the eastern Southeast region, especially the North Shore of São Paulo State and the Southern Coast of Rio de Janeiro State; the eastern portion of the Northeast of Brazil, particularly the coastal areas of Pernambuco and Paraíba States. Although some municipalities in the State of Amapá have recorded the highest quantities of intense rainfall events, this region does not have a high susceptibility to landslides, nor does it have a significant number of people exposed and vulnerable to this type of disaster. However, the results could be important to show the propensity of this region to be impacted by quick hydrological processes, like flash floods.

On the other hand, the coastal areas of the States of São Paulo and Rio de Janeiro are regions with many cities experiencing urban expansion towards the steep slopes of the Serra do Mar, creating high-risk scenarios. This combination of extreme “climatic hazard”, high local susceptibility, and a large population exposed and vulnerable is reflected in the recurring disasters during the last decades, highlighting the São Sebastião disaster in 2023, where the highest 24-hour rainfall in the history of Brazil was recorded in the neighboring municipality of Bertioga, SP. Other recent notable disasters have also occurred in Santos, SP; São Vicente, SP; Cubatão, SP; Guarujá, SP; and Angra dos Reis; RJ, which appear among the top 10 municipalities with the highest number of events in Table 5. Other areas with high recurrence of daily rainfall above 50mm include the western regions of the States of Santa Catarina and Paraná; the coastal strip between the northeastern part of Santa Catarina, the eastern of Paraná, the southern coast of São Paulo; and the entire southern coast of Bahia and the Recôncavo Baiano. All of these regions also have a history of landslide-related disasters and, together with the previously mentioned ones, constitute the most impacted regions in Brazil by landslides caused by intense rainfall. It is highlighted that the cities which not appear prominently in the results (both in Table 5 and in Figure 8), but have a considerable history of landslide-related disasters, are the cities located at Rio de Janeiro Mountain Region; cities in the Metropolitan Region of Belo Horizonte (MG); Vitória (ES), and Manaus (AM).

Although these areas do not have several occurrences of intense rainfall events recorded by CHIRPS, the results indicate that, on average, there are 4 rainfall events above 50 mm/24h per year, which represents an intermediate situation compared to all the results found for Brazil. Therefore, it is possible that the large number of previous disasters in these regions is more strongly linked to the high susceptibility of landslides and the high exposure of vulnerable population living in the slopes. In these cases, non-climatic conditioning factors are likely to be more representative in explaining the disasters registered in recent decades than the climate hazard. Another possibility is that the CHIRPS data may be underestimating the rainfall data, which requires further in-depth evaluations to test this hypothesis.

Additionally, analyses were also conducted in order to identify the trend during the evaluated period (1992-2022) in some Brazilian municipalities, aiming to provide preliminary information about ongoing climate change and their influence on the occurrence of intense rainfall events, particularly those exceeding 50 mm/24h. The cities chosen for these analyses were Blumenau, SC; São Paulo, SP; São Luís, MA; Salvador, BA; Maceió, AL; and Manaus, AM (Figure 9). The percentage increase values displayed on the figures, accompanied by an arrow, were calculated by dividing the value obtained from the trend line formula in 2022 (x=30) by the value in 1992 (x=0), suggesting the current average increment compared to the beginning of the historical series (1992). For instance, a value of +30% represents those in recent years, on average, there has been a 30% higher frequency of days with rainfall exceeding 50mm when comparing the data from the early 1990s. The arrows in yellow, orange, and red represent the intensity of discreet, moderate, and high increases, respectively.

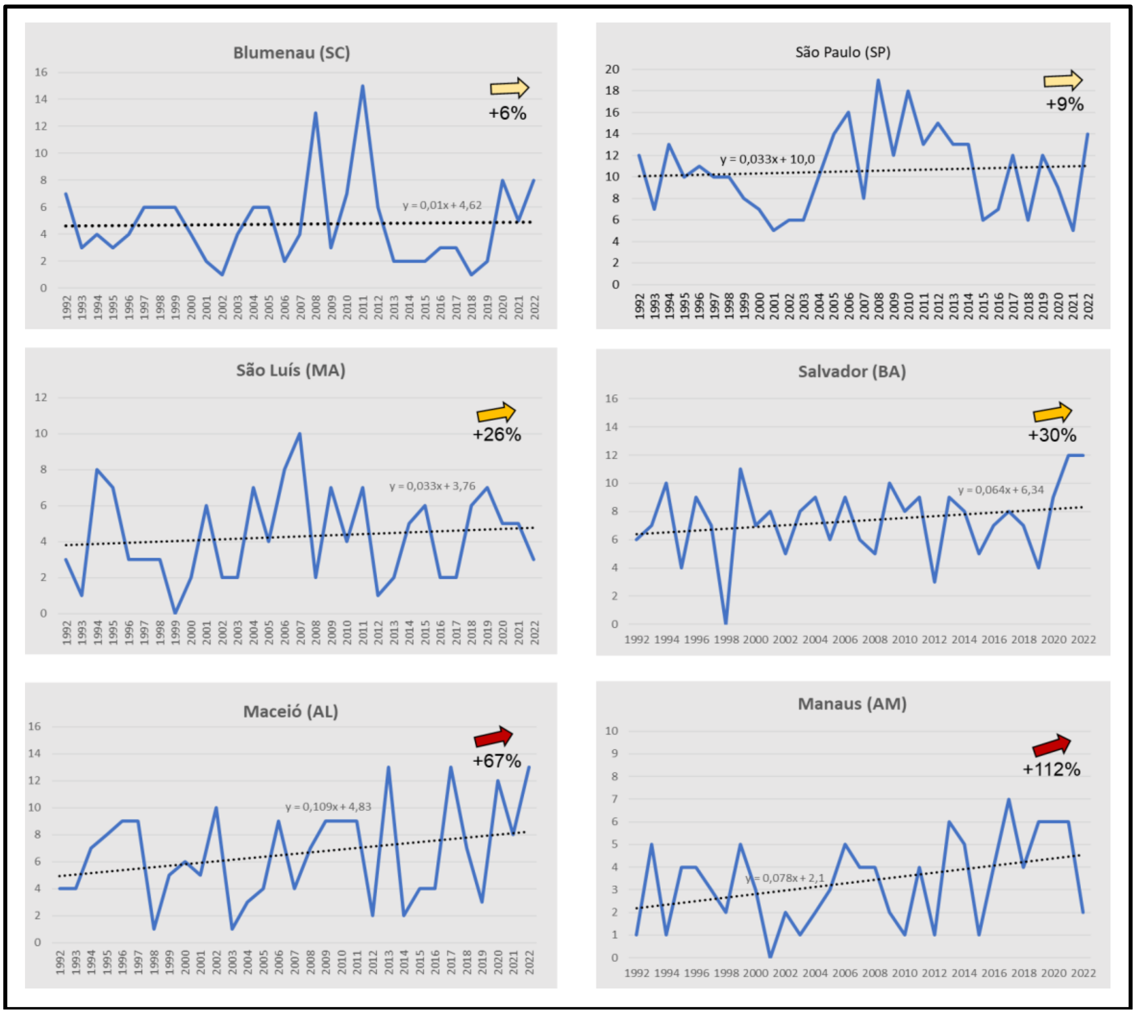


Figure 5.58 – Temporal distribution of the number of days above 50 mm from 1992-2022 and the linear trend line. The arrows in yellow, orange, and red represent the intensity of discreet, moderate, and high increasing, respectively.

The trend presented in Figure 5.59 indicates a pattern of increasing in daily rainfall events higher than 50mm. For Blumenau, SC and São Paulo, SP, the trend is discrete and there is little evidence of a systematic change in historical patterns of extreme events; however, in 2006 and 2011 two strong La Nina events occurred, which may be related to the increase in recorded extreme events. One of the explanations is that La Nina favors the passage of stronger cold fronts in these regions, which are responsible for causing massive and intense rainfall events, especially during the summer and in regions that are affected by the orographic effect. For the other cities, the trend of increasing in extreme events is more evident, although there is high interannual variability, which indicated that likely global climate changes may already be directly favoring the intensification of extreme rainfall events and requires special attention, given that these locations have complex scenarios of geohydrological risks established in their territories and a systematic increase in extreme rainfall events may indicate an exponential increase in economic and human losses.

5.6.6 – Urban planning and disaster risk: a case study in Pouso Alegre municipality

An effectiveness analysis of the current urban legal instruments concerning the risk management of floods-associated disasters was conducted, ie., an assessment of the possible gaps in municipal urban planning instruments that make risk management difficult or preventable was realized. Thus, a case study was carried out for the municipality of Pouso Alegre, MG (Figure 10), a city characterized by a history of flooding-related disasters.

The expansion of urban areas over the last few years has been distinguished by their disorderly growth, which has innumerable consequences for many cities worldwide. One of these consequences is the aggravation of exposure of the population to disaster risk due to the occupation without integrated planning of areas susceptible to flooding and other disasters that affect urban areas.

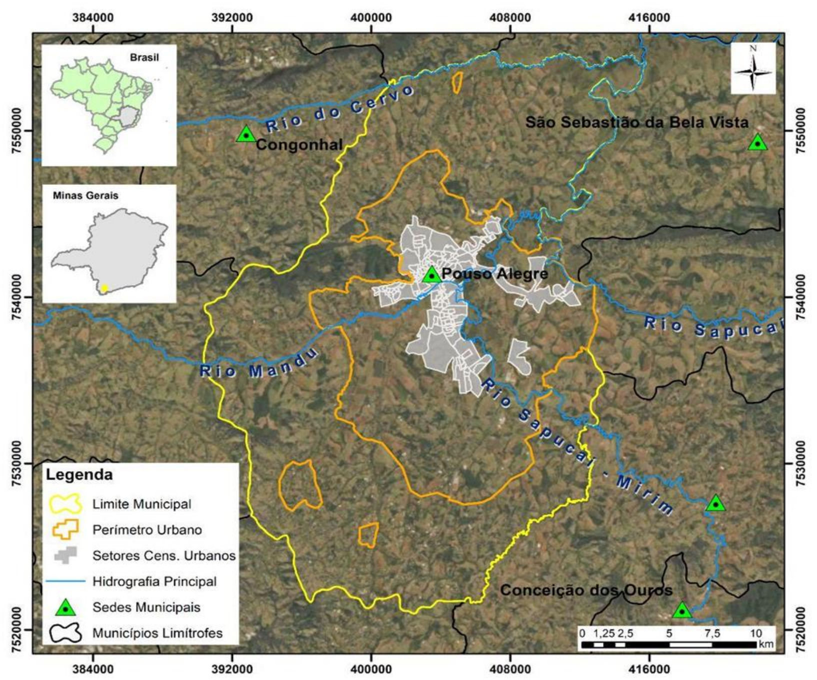


Figure 5.59 – Delimitation of the study area - Municipality of Pouso Alegre, MG.

In this study, the goal was to identify possible gaps in municipal urban planning instruments related to the risk management. As the first step, we assessed the recurrence of hydrometeorological events that caused impacts in Pouso Alegre, as well as the analysis of the social vulnerability of the population. For this, daily precipitation data were obtained through the Instituto Nacional de Meteorologia (INMET, https://bdmep.inmet.gov.br/) and from the HIDROWEB platform of the Agência Nacional de Águas e Saneamento Básico (ANA, https://www.snirh.gov.br/hidroweb/apresentacao), for the period from 1980 to 2021. Extreme indices, such as the monthly maximum 1-day precipitation amount (mm, RX1) and monthly maximum 5-day precipitation amount (mm, RX5) were calculated. In addition, the Mann-Kendall linear trend test (Mann, 1945; Kendall, 1975) was applied to assess any trend (positive or negative) in extreme rainfall events in Pouso Alegre.

According to the Rx5 (Figure 5.60), the observed maximum rainfall amount occurred in December 1999 (264 mm) and in January 2000 (304 mm). After these events, other smaller magnitude events were observed in February 2004 (181 mm), January 2005 (162 mm), January 2007 (177 mm), February 2009 (158 mm), January 2011 (183 mm), and January 2013 (186 mm).

From the Rx1, the daily rainfall accumulated in January 2000 (104 mm/24h), January 2011 (96 mm/24h), and January 2016 (103 mm/24h) stands out. It is noteworthy that, according to the linear trend test performed, despite a negative trend in the extreme rainfall events (Kendal's Tau = -0.015), these are not statistically significant (p-value = 0.629). Thus, according to the precipitation time series, there was no increasing trend in extreme rainfall in the municipality of Pouso Alegre.

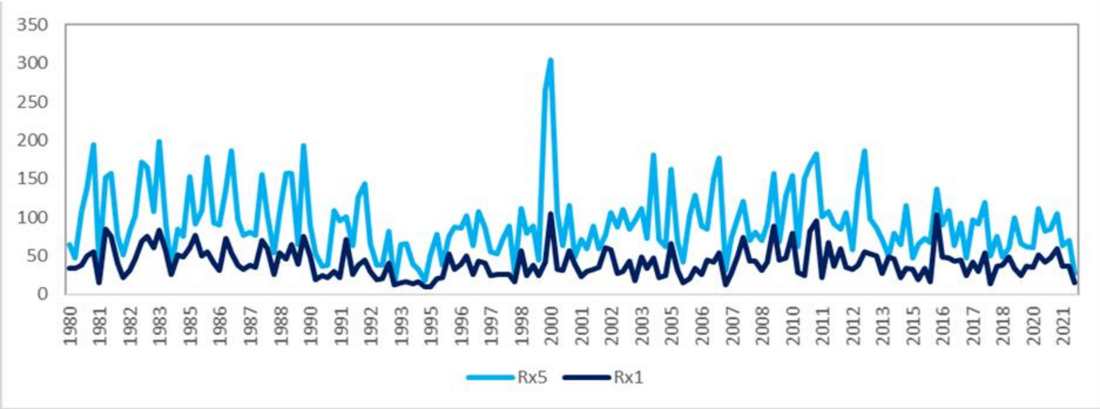


Figure 5.60 – Temporal evolution of Rx5 and Rx1 for Pouso Alegre.

From the Integrated Disaster Information System (S2iD), disasters related to extreme hydrometeorological events were reported in Pouso Alegre from 1997 onwards, with the last events listed in this source dating from 2016. We used this S2iD disaster data, complemented with a disaster dataset from the Situation Room of CEMADEN/MCTI, to develop a timeline (Figure 12) of events occurrence. In addition, Figure 5.61 also shows the moment of construction of flood control infrastructure, called "Dique 1" and "Dique 2".

The dikes are constructions carried out to dam the waters of the Sapucaí Mirim and Mandu rivers, whose flood areas go beyond the São Geraldo neighborhood. After constructing these structures, we can observe in Figure 5.62 that the frequency of flooding continued to be significant, even though there was no increasing trend in extreme rainfall events. As an emergency measure, given the continuity of events, the municipal government has been using suction pumps to remove the water that accumulates in the region, and, in January 2020, they had to be turned on to help drain the accumulated water in inhabited areas.

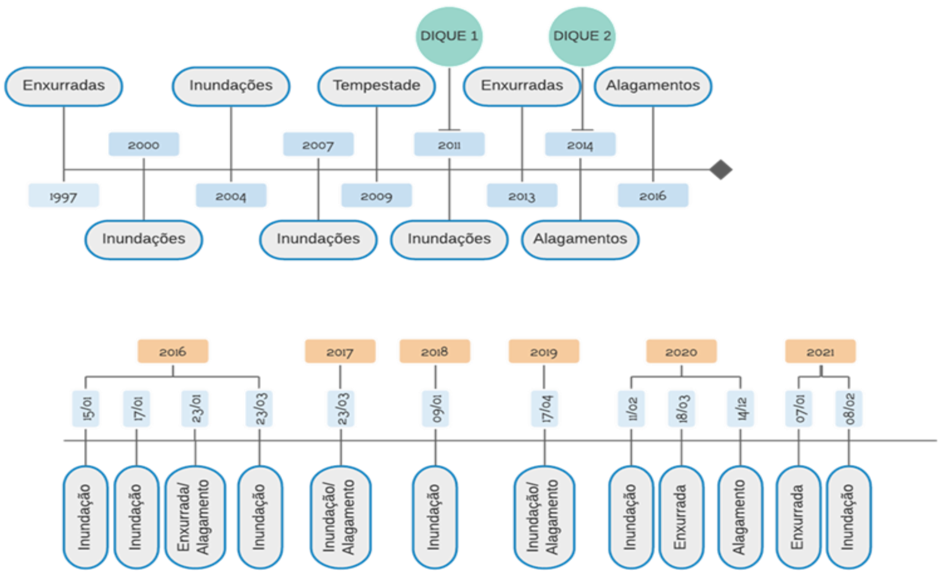


Figure 5.61 – Timeline of disaster occurrences related to flooding.

Once observed that the occurrence of disasters in the period analyzed does not increase in direct proportion to the extreme rainfall events, it can be inferred that other factors may be associated with the disaster occurrence. Among these, urban expansion is a relevant parameter capable of directly affecting the location and disaster occurrences over the years.

Figure 5.62 shows the evolution of the urbanized areas in Pouso Alegre, where the gray spots represent the area developed until 2000, the red areas show how much this area increased from 2001 to 2010, and the yellow ones until 2019.

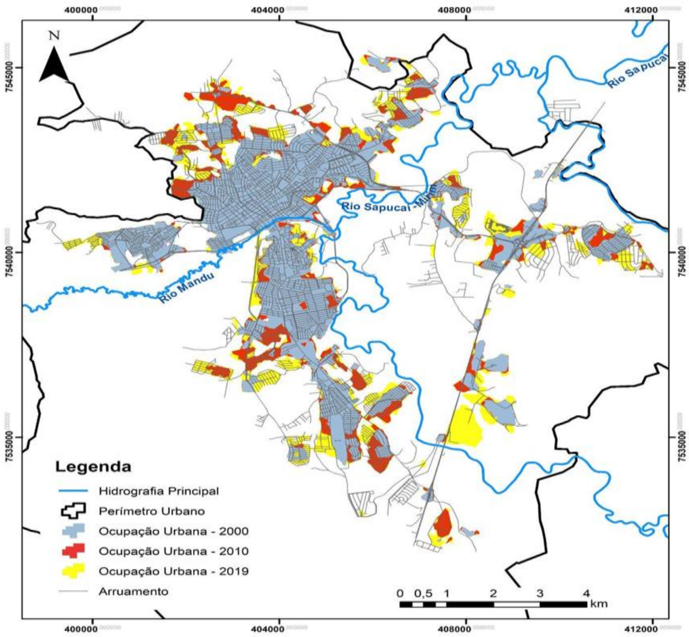


Figure 5.62 – Space-time evolution of urbanized regions in Pouso Alegre.

Figure 5.63 shows urban expansion and population growth over almost ten years. From the Figure, it is inferred that the increase of the urban region, which increased by 14.83 km^2 between 2000 and 2019, followed the growth of the population, which was 106,776 in 2000 and was estimated at 154,293 inhabitants in 2020.

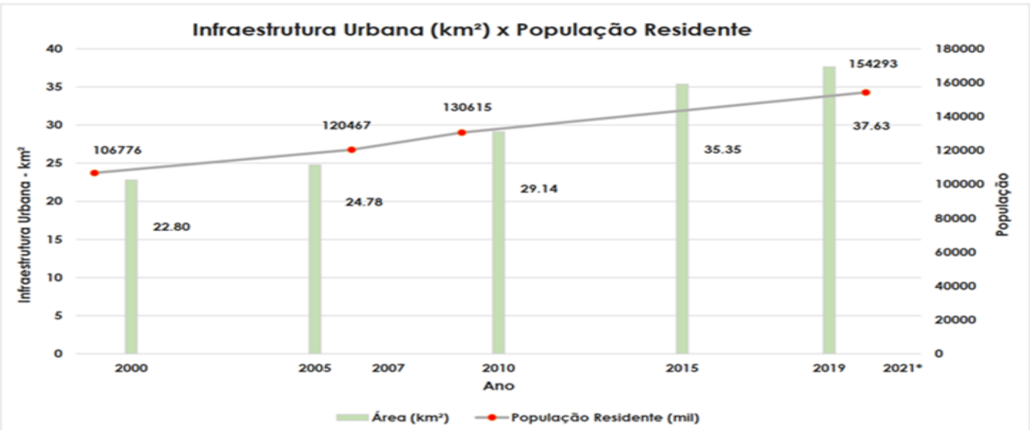


Figure 5.63 – Comparison of urban area expansion and population growth in the municipality of Pouso Alegre.

The urban expansion highlighted in Figure 14 was compared with flood occurrences (Figure 5.64) comprising the following periods: 1997 to 2005, 2010 to 2015, and 2015 to 2020. For 2004, 2007, and 2009, the exact locations of occurrences were not recorded, so these events are not present in Figure 5.64.

It can be observed that while some neighborhoods stopped recording occurrences, others, such as São Geraldo, Faisqueira, and Fosh II continued to present new records, being São Geraldo with the highest frequency of events in the period studied. It is noted that from 2016, events were registered in places with no records and outside the risk areas. It is worth mentioning that although it is possible to verify through communication media that the construction of the dikes was beneficial regarding the severity of the disasters reported, no records were found regarding the magnitude of these events. Therefore, an analysis in this regard became unfeasible.

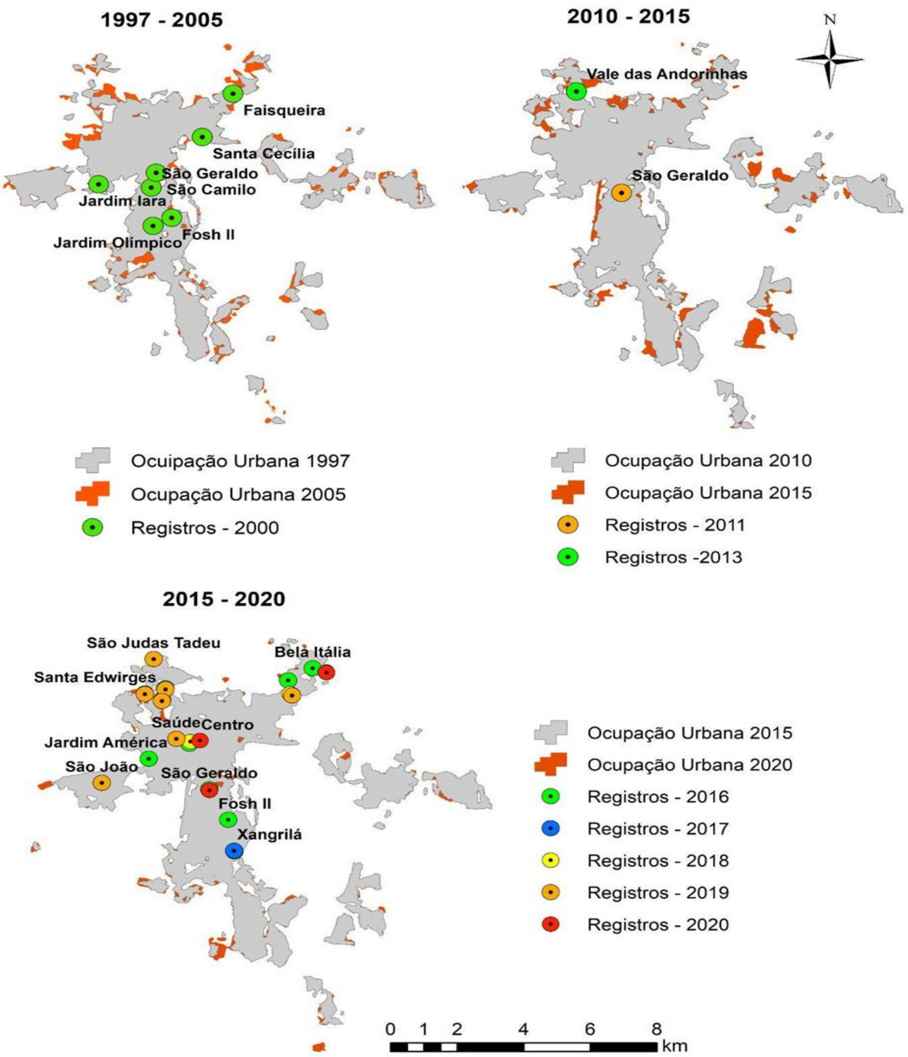


Figure 5.63 – Spatial distribution of floods occurrences in 1997/2005, 2010/2015, and 2015/2020.

5.6.3.1 – Effectiveness of legal planning instruments in the context of adaptive capacity

The municipality of Pouso Alegre proposed two master plans: the first, dating from 2008 (PDM-2008), and the second approved in August 2021 (PDM-2021). Although formulated after the flood in 2000, which is considered the event with the most significant impact on residents, the first master plan for the municipality superficially addresses Disaster Risk Management, outlining more strategies related to the control of occupation and population density, urban expansion, and the environment. Directly related to the disasters discussed here, the plan determines areas for resettlement of the population in regions of risk or environmental protection.

In the years following the approval of the PDM-2008, the municipality underwent significant economic development, opening companies and industries that became attractive to employers from other locations. With the consequent increase in population, disorderly growth and the drop in the quality of public services offered became notable and also reasons for discontent on the part of the population.

In the PDM-2021, the theme "disaster" was more frequently mentioned with the previous one, as well as including in its "Principles, Guidelines and Objectives" the control of urban expansion to avoid the occupation of risk areas and the urbanization of the precarious regions. In this context, territorial strategy guidelines were created based on the so-called "Macrozones" - ordering the urban and rural territory, and the "Transformation Structuring Axes" - composed of the road network, the water system, and the risk areas of the municipality.

Regarding the Master Plans analyzed here, great progress can be noted in the proposal of actions in order to disaster risk management when comparing both PDM-2008 and PDM-2021. It is highlighted that the risk management is widely discussed in the last one, and more strategies was included in terms of the real needs of the municipality.

However, despite the observed improvement, there need to be more measures related to education for risk perception and environmental education integrated, as well as an environmental policy from the perspective of the disaster. There is also a lack of consistent public policies to reduce the vulnerability focused on the population in risk areas.

Finally, the analysis carried out here demonstrates how comprehensive the circumstances that interfere with the occurrence of a disaster can be. Therefore, actions taken in this context must include strategies of a multidisciplinary nature, guided by perspectives from different fields of knowledge in an integrated manner, to minimize the disaster impacts on the population.

5.6.7 – Assessment of damage and loss from disasters caused by meteorological hazards

Advances were made to address two issues based on the preliminary results presented in the year five report on the disasters that occurred in the states of Bahia (BA), Espirito Santo (ES), Minas Gerais (MG), and Rio de Janeiro (RJ) during the summer season in that region (December 2021 and April 2022): (i) identify the historical behavior of occurrences caused by meteorological events in terms of the spatial distribution and intensity of impacts in these states, for which an impact index prototype was created; and (ii) identify possible correlations with meteorological phenomena on a global scale, for which a case study in Petrópolis was approached.

5.6.7.1 – Index composition: impact intensity proxy

The disaster impact intensity index prototype was created using data occurrence from the Digital Atlas of Disasters in Brazil (BRASIL, 2023), for the period from January 1991 to December 2022. Initially, disaster records related to meteorological threats (Table 5.11) occurred in the same states as the previous report (BA, ES, MG, and RJ) and in Pernambuco (PE), which was included in this report due to the disaster episodes discussed in the previous report also affected municipalities in that state.

Table 5.11 – Hazard typology (HT) selected for this study

COBRADE[i]	DESCRIPTION
13120	Cold Fronts/Convergence Zones (CF-CZ)
13211	Local/Convective Thunderstorm – Tornadoes (LCT-TOR)
13214	Local/Convective Thunderstorm – Heavy Rains (LCT-HR)

i Brazilian Coding of Disasters

Table 5.12 shows that about 60% of the municipalities in the region had at least one incidence recorded throughout the timeframe, with 99.1% of them being associated with a Local Convective Storm of the Intense Rain type (LCT-HR).

Table 5.12 – Proportion of municipalities with occurrences and Nº of protocols per HT

ST[i]	N° MP	MP-IMP[ii]	MP-IMP %	13120	13211	13214	TNP[iii]
BA	417	227	54.4	0	1	396	397
ES	78	51	65.4	3	1	138	142
MG	853	533	62.5	10	1	1135	1146
PE	185	82	44.3	0	0	118	118
RJ	92	74	80.4	3	0	282	285
TOTAL	1625	967	59.5	16	3	2069	2088

i: State; ii: Municipalities (MP) with impact data (IMP); iii: Total Number of Protocols (TNP) by ST

The following categories were examined in terms of impacts: number of events (NE), total human damage (HD), material damage (MD), public losses (PU), and private losses (PP) by kind of hazard and municipal resolution. The intensity proxy for each impact category was computed by normalizing the value corresponding to the municipality with respect to the sum of the values of all municipalities in the region with records of occurrence and for the three types of hazards. For example, in the municipality of Caraí, the proxy for the intensity of the impact in the category of public losses is determined as follows:

Input data

a. Public Losses by CF-CZ to Caraí = 90,235.55
b. Public Losses by CF-CZ to all municipalities (1625) = 23,583,920.5
c. Public Losses by LCT-TOR to Caraí = 0
d. Public Losses by LCT-TOR to all municipalities (1625) = 1,677,615.19
e. Public Losses by LCT-HR to Caraí: 295523.14
f. Public Losses by LCT-HR to all municipalities (1625) = 1,709,972,068
g. Total Public Losses (CF-CZ + LCT-TOR + LCT-HR) para Caraí = 385758.69
h. Total Public Losses to all municipalities (1625) = 1,735,233,604

Intermediate indices

a. $PU_{Caraí\ (CF\text{-}CZ)}$ = 90,235.55 / 23,583,920.5 = 0.0038261471769425;
b. $PU_{Caraí\ (LCT\text{-}TOR)}$ = 0;
c. $PU_{Caraí\ (LCT\text{-}HR)}$ = 295523.14 / 1,709,972,068 = 0.000172823373267966;
d. $PU_{Caraí\ (TOTAL)}$ = 385758.69 / 1,735,233,604 = 0,000222309371492651

The Caraí municipality's proxy index for the category public losses (INPU)

$INPU_{Caraí} = [PU_{Caraí\ (CF\text{-}CZ)} + PU_{Caraí\ (LCT\text{-}TOR)} + PU_{Caraí\ (LCT\text{-}HR)}] \div 3$ = 0,0000626251537969308

As shown in Figure 5.64, the outcome of this data processing shown on the region's map allows for identifying the spatial distribution of the intensity of damage and losses caused by meteorological events in the region.

Similarly, the proxy indexes for the following categories were calculated:

$INNE_{Municipality} = [PU_{Municipality\ (CF\text{-}CZ)} + PU_{Municipality\ (LCT\text{-}TOR)} + PU_{Municipality\ (LCT\text{-}HR)}] \div 3$
$INHD_{Municipality} = [PU_{Municipality\ (CF\text{-}CZ)} + PU_{Municipality\ (LCT\text{-}TOR)} + PU_{Municipality\ (LCT\text{-}HR)}] \div 3$
$INMD_{Municipality} = [PU_{Municipality\ (CF\text{-}CZ)} + PU_{Municipality\ (LCT\text{-}TOR)} + PU_{Municipality\ (LCT\text{-}HR)}] \div 3$
$INPP_{Municipality} = [PU_{Municipality\ (CF\text{-}CZ)} + PU_{Municipality\ (LCT\text{-}TOR)} + PU_{Municipality\ (LCT\text{-}HR)}] \div 3$

Finally, the index impact intensity proxy (IMP) and the weighted sum of proxies by category:

IMP = [INNE + INDH + INDM + INPU + INPP] ÷ 5 (Figure 17).

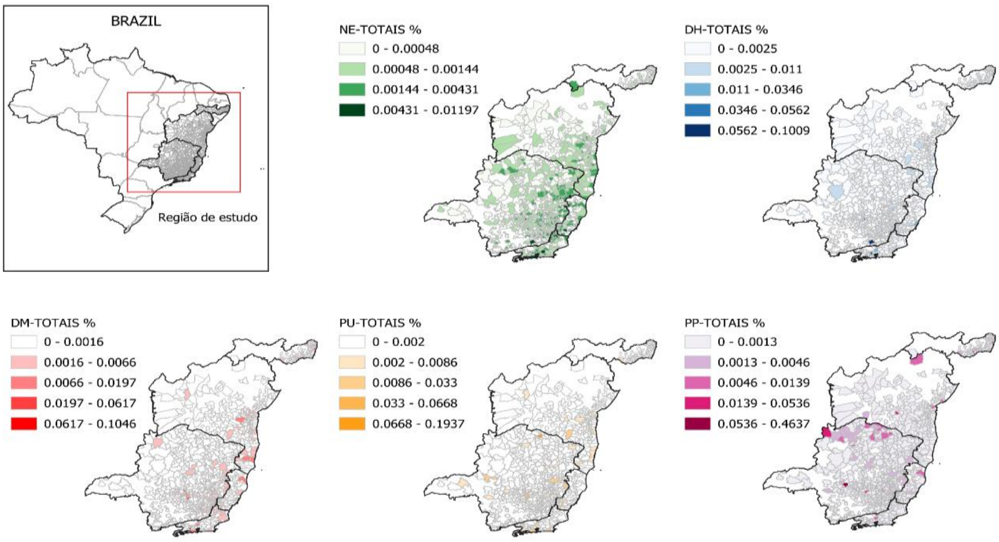


Figure 5.64– The severity of impacts connected to meteorological hazards in the research region: spatial distribution by category, number of events (NE), total human damage (HD), material damage (MD), public losses (PU), and private losses (PP).

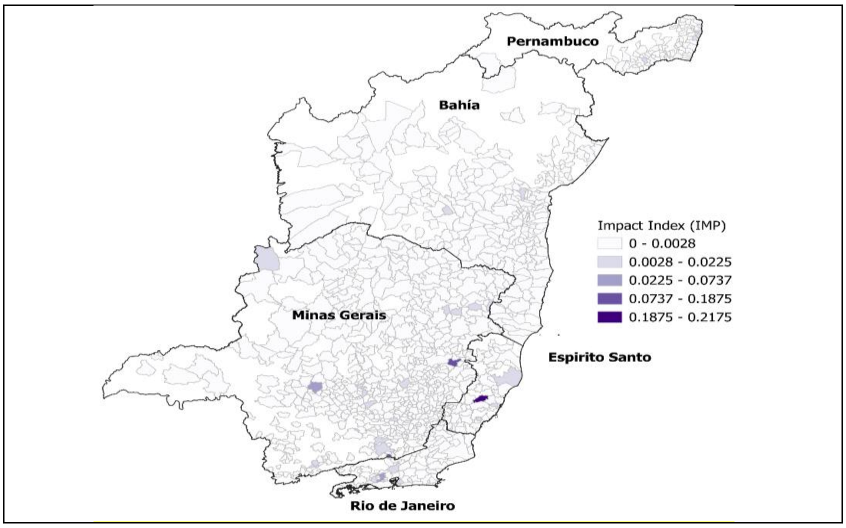


Figure 5.65 – The intensity distribution of impacts associated with meteorological hazards in the evaluated region, as measured by the Proxy Index, which groups all impact categories.

Table 5.13 summarizes the preliminary findings of this study. Among the 1625 municipalities with impact data in the region, 31 stood out, with 14 in the Number of Events (NE) category, five in the Human Damage (HD) category, four in the Material Damage (MD) category, two in the Public Losses category, and six in the Private Losses category (PP). Historically, the most expressive damage and loss categories for the region have been DH and PP. To continue this research, the incidences of meteorological disasters associated with the 31 municipalities included in this table will be thoroughly examined to comprehend the implications of these findings for these municipalities and the region.

Table 5.13 – Highlighted municipalities in the region in relation to the index impact intensity proxy (IMP)

State	Municipality Name	MAX[i] (%)	IMP-TYP[ii]
RJ	Nova Iguaçu	33.58	HD
MG	Galileia	31.59	PP
ES	Santa Maria de Jetibá	29.59	PP

MG	Simão Pereira	18.70	HD
MG	Bom Despacho	15.48	PP
BA	Ubaíra	11.16	NE
ES	Iconha	4.22	NE
MG	Pedro Leopoldo	3.49	MD
PE	Recife	3.46	HD
RJ	Seropédica	2.97	MD
MG	Juiz de Fora	2.74	HD
MG	Antônio Dias	2.18	NE
RJ	São Gonçalo	2.18	NE
MG	Maria da Fé	2.16	NE
MG	Caraí	2.15	NE
MG	Cristina	2.15	NE
MG	Bertópolis	2.13	NE
MG	Presidente Bernardes	2.12	NE
ES	Linhares	2.12	NE
MG	Águas Formosas	2.10	NE
RJ	Niterói	2.10	NE
MG	Tiradentes	2.08	NE
MG	Santos Dumont	2.08	NE
MG	Itabirito	2.07	PU
PE	Jaboatão dos Guararapes	2.06	MD
MG	Belo Horizonte	1.93	MD
BA	Dom Brasílio	1.79	PP
ES	Cariacica	1.63	HD
RJ	Petrópolis	1.12	PU
PE	São João	1.06	PP
MG	Buritis	0.85	PP

i Maximum value among the indices by impact category;
ii Category corresponding to the maximum value.

5.6.7.2 – An assessment of the damages and losses resulting from heavy rainfall in Petrópolis, RJ

This study aimed to find a correlation between extreme events that occurred in that municipality and climate change scenarios. Although no correlation was observed, we provide some results on identifying extreme events in this municipality using impact data. The historical record of disasters related to the municipality of Petrópolis shows that the types of hazards with the highest number of incidents between 2001 and 2022 are soil/or rock landslides, floods, and heavy rains. These events generally happen between October (the start of the rainy season) and April (the end of the rainy season) (Figure 5.66).

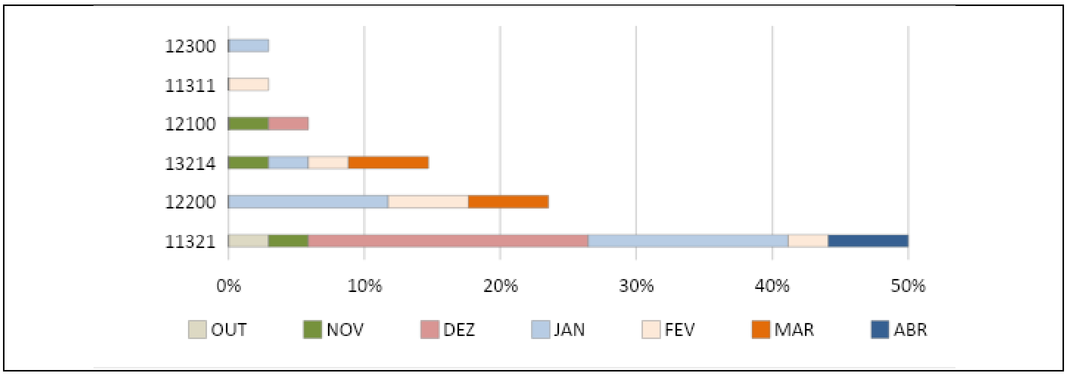


Figure 5.66 – Monthly distribution of disasters by typology in Petrópolis: 12300 flooding (1); 11311 blocks fall (1); 12100 flood (2); 13214 heavy rain (5); 12200 flood (8); 11321 landslides of soil and/or rock (17).

Human damage (DH) refers to the number of deaths, injuries, illnesses, homelessness, displaced people, missing people, and others affected; this last category involves all damages that do not fit into the other categories but represent 97% of the impacts on people in Petrópolis, as shown in Table 5.14. Landslides and/or landslides or rock are the leading cause of HD in Petrópolis, accounting for 45.6% of the total, followed by heavy rainfall (42.5%) and, to a lesser extent, floods (11.7%). Heavy rains had the greatest number of sick persons (200) and missing people (203); floods had the biggest number of homeless people (2921) and displaced people (8605); and landslides had the highest number of deaths (104), injured (530), and others impacted (364,701).

Table 5.14 – Human Damage (HD) by type of threat in the historic series of disaster occurrences affecting the municipality of Petrópolis from 2001 to 2022

COBRADE	**11321**	**12200**	**13214**	**12100**	**12300**	**11311**	**TOTAIS**	
Total Human Damages[i]	373,959	95,623	348,561	1,119	40	15	819,317	
%	45.6	11.7	42.5	0.1	0.1	0	100	100
Deaths	104	81	85	0	0	0	270	0.03
Injured	530	16	356	0	0	0	902	0.11
Sick	143	0	200	0	0	0	343	0.04
Homeless	2,287	2,921	1,629	0	0	0	6,837	0.83
Disposed	6,171	8,605	660	19	8	15	15,478	1.89
Disappeared [ii]	23	0	203	0	0	0	226	0.03
Others affected	364,701	84,000	345,428	1,100	32	0	795,261	97.06

i The unit of measurement for this variable is the number of Individuals; ii The number of missing people usualy turns into the number of deaths

The historical average of HD was raised between 2001 and 2022; this average was exceeded in 2005, 2013, and 2022. The HD was extreme last year, accounting for 40.64% of overall damage during the data period (Table 5.15). This conclusion contradicts previous research that suggests that the number of disaster-related deaths is decreasing (MORAES, 2022), which can be explained by the fact that these studies employ global databases that do not collect data on a local scale. Thus, the present research reinforces the need for comprehensive data on disasters-related damages and losses, as influencing political decisions for disaster risk management in territories should be based on detailed data from the territories themselves, rather than global data.

Table 5.15 – Annual Values of Human Damage (HD) in Petrópolis associated with the historical series of disasters

Year	2001	2003	2004	2005	2007	2008	2009	2010	2011	2013	2015	2016	2018	2022
Total Human Damage	5773	1957	3847	130056	738	46906	22336	58544	48239	152292	0	0	15695	332934
%	0,70	0,24	0,47	15,87	0,09	5,73	2,73	7,15	5,89	18,59	0,00	0,00	1,92	40,64
Deaths	38	17	0	0	5	9	7	3	71	34	0	0	3	83
Injured	143	320	1	0	7	16	10	0	0	49	0	0	4	352
Sick	143	0	0	0	0	0	0	0	0	0	0	0	0	200
Homeless	812	88	89	0	223	81	29	7	2805	1074	0	0	0	1629
Disposed	4375	20	544	56	335	1800	90	33	6363	1135	0	0	260	467
Disappeared	22	0	0	0	0	0	0	1	0	0	0	0	0	203
Others affected	240	1512	3213	130000	168	45000	22200	58500	39000	150000	0	0	15428	330000

The monetary values estimate of damages and losses (D&L) caused by flash floods in January 2011 accounted for 43% of Petrópolis' impact from 2001 to 2022. Adding the percentages from the previous years (2001, 2008, and 2016), flash floods accounted for 52% of the D&L in the municipality. In 2001, 2003, 2004, 2007, 2009, and 2013, soil and/or rock landslides were responsible for 33% of D&L. In 2016, 2018, and 2022, heavy rains provided 15% of D&L (Table 5.16). Flash floods, wet mass movements, and intense rains by local convective storms are extremely localized phenomena, with quick growth and huge destructive potential that are difficult to monitor for the purpose of sending a warning. They need communities to have a quick response capability to, above all, protect lives. Petrópolis is one of the 30 municipalities highlighted in Table 8, for having the highest impact index value for meteorological events in the region studied, in addition to having a very high percentage of human harm in its history of occurrences. This finding emphasizes the necessity of having impact-based risk indexes that can add value to warning systems for local communities, primarily to help them create self-protection mechanisms, such as people-centered warning systems.

This work is being resubmitted with the reviewers' suggestions and was recently pre-approved for publication in the journal Sustainability in Debate under the title “Identification of extreme precipitation events in the municipality of Petrópolis, RJ, and disasters triggered by rain”.

Table 5.16 – Monetary values of damages and losses in Petrópolis: the sum of material damages (MD), public (PU), and private (PP) losses

ANO	COBRADE	D&L US$	%
2001	11321	38,396,426.27	10
	12200	6,973,728.00	2
2003	11321	10,005,759.76	3
2004	11321	6,781,324.60	2
	12100	0.00	0
	12300	0.00	0
2005	11321	0,00	0
2007	11321	16,387,420.05	4
2008	12200	7,144,301.59	2
2009	11321	4,877,982.03	1
	12100	0.00	0
2010	11321	0.00	0
2011	12200	167,632,309.83	43

2013	11311	6,211.18	0
	11321	52,954,078.74	14
2015	12200	4,216.85	0
2016	12200	21,444,285.63	5
	13214	2,052,260.06	1
2018	12200	0.00	0
	13214	2,234,802.67	1
2022	13214	54,828,781.60	14
2001 - 2022	**TOTAL US$**	**391,723,888.85**	**100**

5.6.7.3 – Economic loss perceptions and assessment of vulnerability to complement the analysis of risk in the Itajai basin

The economic loss is the sum of the economic impacts which can be direct (the monetary value of the partial damage or destruction of an asset) and which can be indirect (reduction in expected revenue) UNDP (2014). Therefore, to know the economic impact of a disaster, it is necessary to have information that allows us to know both the monetary values of the assets that were impacted, and the consequences that the disaster generated in the economic life of the municipality. In Brazil, data on disasters are recorded in forms called FIDES (formerly AVADAN) that collect information from those actors who carry out the initial assessment of the damage, generally, members of the municipal Civil Defense and must be sent a few days after the disaster occurrence.

The disaster records FIDES and AVADAN were designed to collect information on damage and losses, however, much quantitative data does not exist or was not collected at the time of the disaster, but the field staff could identify the presence of damage, what leads to the fact that in many cases the spaces for ‘comments’ present in these forms included information on the perception and direct observation that it is possible to carry out in the place of the disaster. It can also identify who were the most affected people, which sectors, which services, and this is how it impacted the normal functioning of the municipality.

The study carried out was based on information from 144 forms from 24 municipalities of the Itajaí river basin (state of Santa Catarina) in the period 2010-2016, for which we took the forms that contained information in the field of comments, which reduced them to 103 events and 21 municipalities. Using the N-Vivo software made it possible to identify conceptual categories linked with damage and losses perceptions.

Each keyword was associated with a code to simplify processing, and exact matches, and derived words (plural, feminine, and masculine) were included. This first step allowed us to identify the most used words according to the type of event (see Figure 5.67). Specifically, it was possible to find a relationship between the narratives that can be considered subjective or qualitative of what happened in the place, with a formal description of causes and impact on people; on the other hand, we also found a perception of the losses derived from the disaster of public and private goods. Given that the qualitative study was based on the analysis of texts written under pressure and in stressful situations, the need to carry out a triangulation of the results and obtain a complementary narrative was seen, for this was carried out through focus groups and an online survey was applied to participants (Figure 5.68).

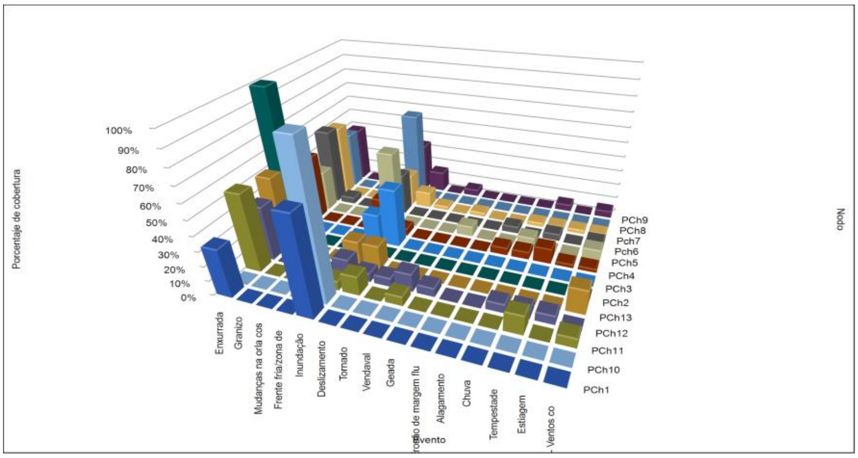


Figure 5.67 – Keywords by disaster type

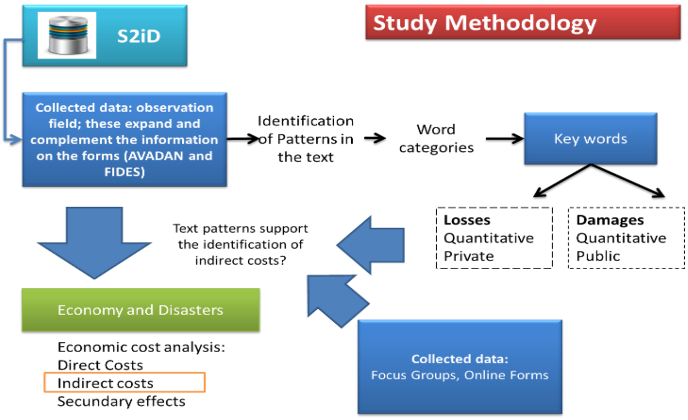


Figure 5.68 – Methodology of the qualitative analysis

Some preliminary findings allow us to identify that the formats had major changes when passing from them denominated AVADAN to FIDES, in some cases reducing the possibility of counting with detailed information. The first consequence was the increase in the use of the comment field to record this information (Figure 5.69), and a second consequence is that the new form does not allow the inclusion of detailed information as diverse as gender or age of people affected, kilometers of roads damage, type of crops. The reported economic impacts are centered on losses in the agricultural sector, damage to roads, the provision of energy services, and in education.

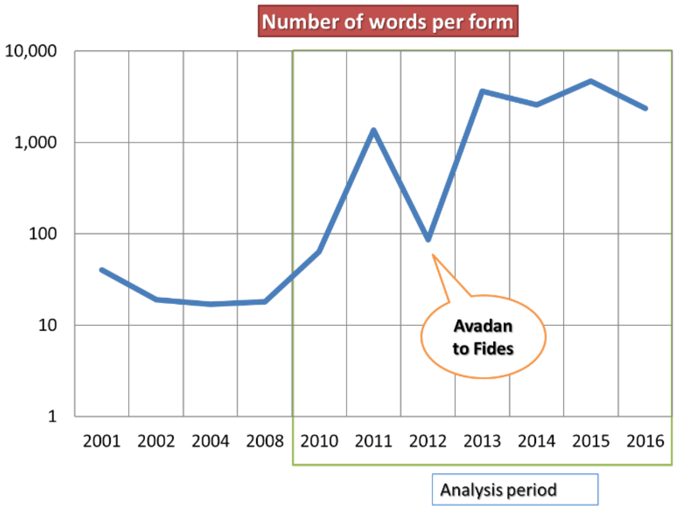


Figure 5.69 – Increase of word per form

5.6.8 – Vulnerability indicators to climate change for Brazilian cities - SISVUCLIMA - Blumenau, Santa Catarina

Throughout the period 2022-2023, efforts were put in order to improve the tool named SisVuClima – Blumenau, which was presented to the Secretary of Civil Defense of Blumenau and his team on March 10, 2023 and to the Secretary of Social Development of Blumenau and her team on May 16, 2023. Both meetings counted with professionals from other secretariats of Blumenau, aimed to learn about to use the tool.

The complexity of the vulnerability concept associated with the methodology adopted required a selection of potentially collectable data and reduction to a set of relevant indicators and criteria which allow to estimate the vulnerability, not neglecting the need to meet the conceptual requirements of a model, as well as to provide a viable measurement method for practical implementation at the desired scale.

However, the availability of measurable data that reflects qualitative or quantitative characteristics of the system under analysis is a critical matter for the municipal scale in Brazil, limiting the choice of variables that may compose the index. Thus, the tool used to support the assessment of the city's vulnerability is a matrix of indicators based on aggregated data at different scales: neighborhood and municipality, thereby expanding the capacity and variety of information that can be obtained and at the same time compatible with the limits of an urban area in the country. The matrix with the index, sub index and indicators proposed for Blumenau is presented in Table 5.16.

Table 5.16 – Description of the indices and indicators to operationalize the Index of Urban Vulnerability - UrVI in Blumenau.

Index	**Subindex**	**Indicator**	**Source**
Sensitivity	Natural environment	Green areas	Primary (based on data from Blumenau City Hall)
	Conditions of buildings	Households in subnormal agglomerates	IBGE
		Households in flood-prone areas	Primary (based on data from Blumenau City Hall)
	Water and sanitation	Sewage network	IBGE
		Waste collection service	IBGE
		Piped water	IBGE
	Urban mobility	Escape routes	Primary (based on data from Blumenau City Hall)
	Essential healthcare and educational services.	Health equipment in disaster-prone areas	Primary (based on data from Blumenau City Hall)
		Educational equipment in disaster-prone areas	Primary (based on data from Blumenau City Hall)

Adaptive capacity	Disaster-sensitive disease		City Health Department
	Vulnerable groups	Infant population	IBGE
		Elderly population	IBGE
	Poverty	Income below the poverty line	IBGE
		Literacy rate	IBGE
		Lack of access to assets	IBGE

The presented approach focuses on the application of a perspective of relative vulnerability assessment, that is, the comparison and interpretation of the vulnerability of different locations in the urban area. This is a useful strategy for estimating high or low vulnerabilities, due to the absence of precisely defined parameters to estimate when the vulnerability is increasing or decreasing. The variation of indicators and indices, between 0 and 1, allow this comparison, placing the analysis units from the conditions observed locally.

The UrVI contemplate a relative vulnerability assessment approach, comparing and interpreting vulnerability levels across different neighborhoods in the urban area. This strategy is useful for estimating high or low vulnerabilities since there are no specific parameters to determine when vulnerability is increasing or decreasing. By varying indicators and indices between 0 and 1, comparisons can be made, enabling analysis units to be positioned based on locally observed conditions. Therefore, indicators were suggested to assess vulnerability at different scales, considering the conditions of sensitivity and adaptive capacity of cities and its populations.

In addition to the identification of urban vulnerabilities, the indicators proposed should allow the visualization and communication of complex phenomena related to vulnerability reduction, so that they can be understood by policy makers, non-experts, and the general public. For these purposes, results may be used to generate thematic maps, allowing the representation of indices in the territory in a visual and intuitive way, and allowing managers to update indices as new data becomes available. This kind of tool has already been successfully applied in Brazil, i.e., the Climate Vulnerability System (SisVuClima) software was developed aiming to be used for national vulnerability assessment to subsidize the new National Adaptation Plan and has been implemented in six Brazilian states (about 1020 municipalities) with the participation of decision-makers and stakeholders (Dos Santos et al., 2019; Quintão et al., 2017; Vomaro et al., 2020).

5.6.8.1 – Analysis of the SisVuClima – Blumenau and its applicability for urban development considering climate risk

Some results generated by SisVuClima – Blumenau, as well as its evaluation and applicability to city planning considering climate risks are presented.

In Table 5.17 are presented the neighborhoods with higher values for the UrVi and their respective sub-indices. According to the methodology, the Velha Grande neighborhood is the most vulnerable among all the neighborhoods of Blumenau. The specific conditions of each neighborhood can be seen from the values of the sub-index. In Table 5.18 are included the least vulnerable neighborhoods, with Salto Weissbach as the one with a value of vulnerability equal 0. It should be noted that this does not mean that this neighborhood is not vulnerable, but has a relative vulnerability lower than the other neighborhoods. Figure 5.70 shows all the neighborhoods of Blumenau with their respective values of estimated UrVI.

Table 5.17 – Neighborhoods with higher values of UrVi and their respective sub-indices

Neighborhoods	Sensitivity Sub-index	Adaptive capacity Sub-index	Vulnerability Index
Progresso	0,722	0,948	0,831
Itoupava Central	0,728	1,000	0,867
Velha Grande	1,000	0,942	1,000

Table 5.18– Neighborhoods with lower values of UrVI and their respective sub-indices

Neighborhoods	Sensitivity Sub index	Adaptive capacity Sub index	Vulnerability Index
Salto Weissbach	0,333	0,000	0,000
Fortaleza Alta	0,000	0,358	0,015
Água verde	0,031	0,331	0,017
Jardim Blumenau	0,185	0,280	0,081

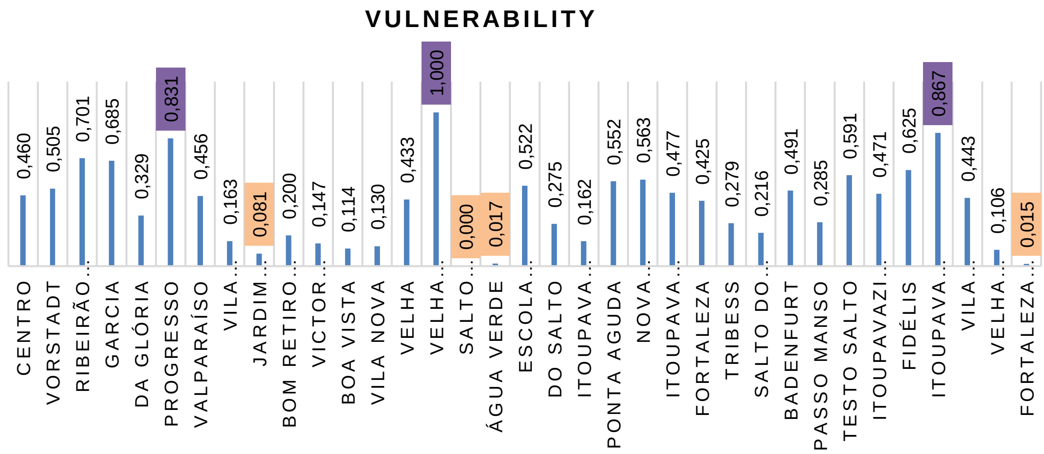


Figure 5.70 – Neighborhoods of Blumenau with their respective values of estimated UrVI.

The spatial arrangement of UrVI and their corresponding sensitivities and adaptive capacities indices, with emphasis on the most and least vulnerable neighborhoods between them, are shown in Figure 5.71. The white color corresponds to the index associated with least vulnerability of the neighborhood in relation to the other ones, while the darken colors correspond to the increase in vulnerability of the neighborhood in relation to the others. Neighborhoods in the central area to the south of Blumenau exhibited lower UrVI values, particularly Salto Weisbach (white). On the other hand, neighborhoods located at the city boundaries, specially to the North and South direction, are characterized by higher levels of urban vulnerability, with Velha Grande (brown) being the most concerning case. Figure 5.72 shows the neighborhoods more susceptible to flooding of 7 mm and 15 mm, respectively.

Urban Vulnerability Index Sensitivity Vulnerability Index Adaptive Capacity

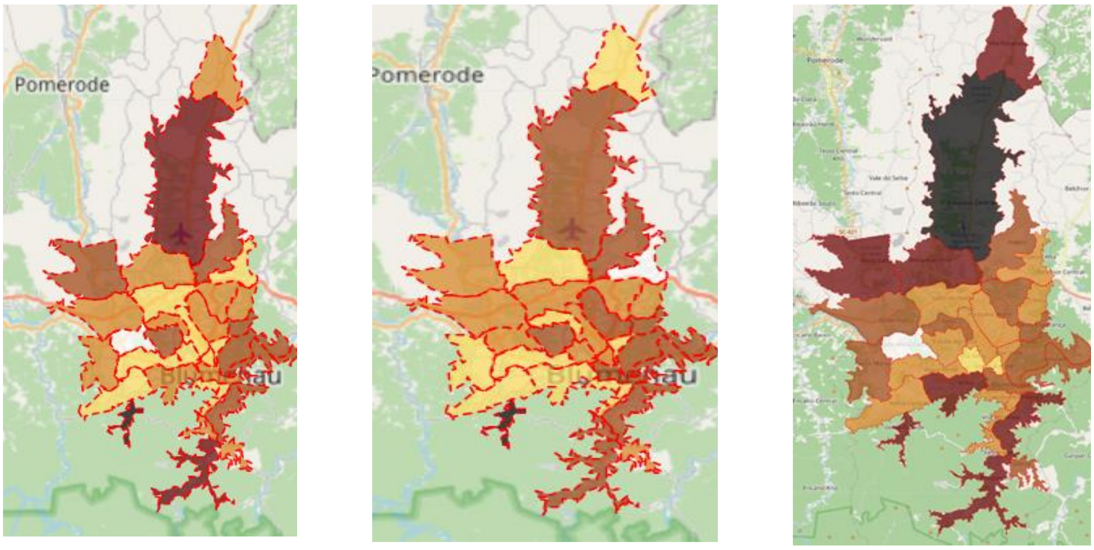


Figure 5.71 – Spatial distribution of the Urban Vulnerability Index (UrVI) and their corresponding Sensitivity and Adaptive Capacity indexes in Blumenau, SC.

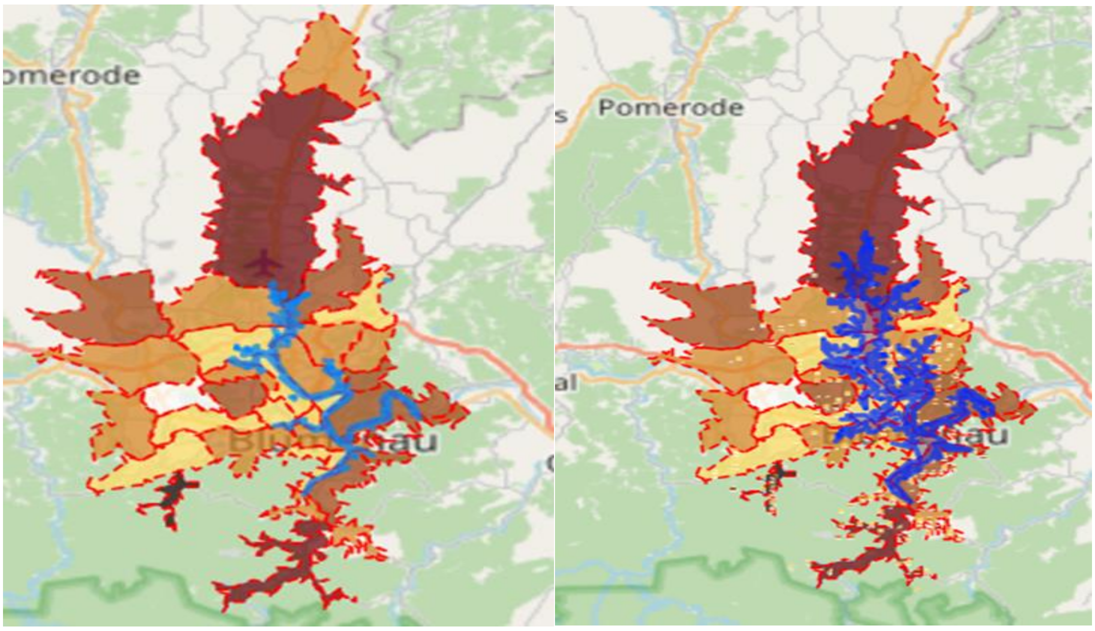


Figure 5.72 – Spatial distribution of the neighborhoods more susceptible to flooding of 7 mm and 15 mm, in Blumenau, SC.

Figure 5.73 presents the UrVI in all neighborhoods in city of Blumenau and the places more susceptible to disaster due to landslides, according to the risk index assessed under this project (FAPESP report, 2019).

From the results obtained with SISVUClima-Blumenau, it is observed that by directing the expansion of the city to the north or south parts, without considering the impacts related to floods, it is inferred that the municipality does not have a completely adequate infrastructure for the disaster risk management, as it is not prepared in terms of an escape route with easy access for the population in case of heavy rains. Furthermore, the occupation of the southern part of the city (e.g. Velha Grande) was not planned, as this area is susceptible to landslides.

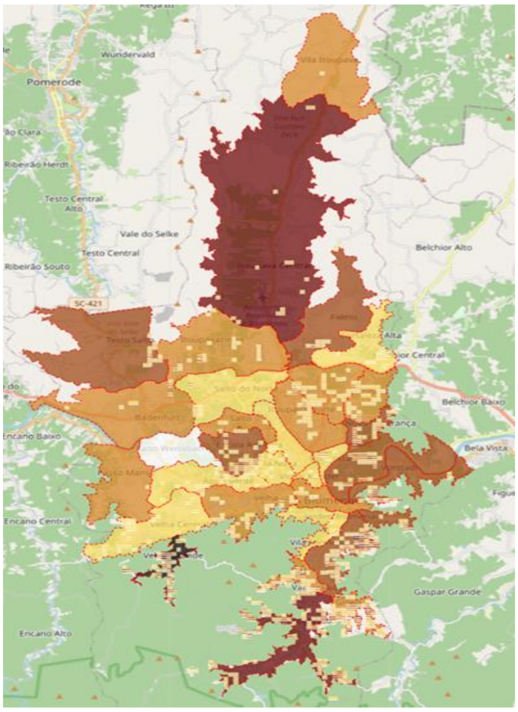


Figure 5.73– Spatial distribution of the UrVI through the city of Blumenau highlighting the places more susceptible to disaster due to landslides;

In Brazil, the issue of climate-related impacts and disasters stems from inadequate planning and territorial management, which fail to safeguard vulnerable areas and populations from occupying environmentally fragile spaces (Jacobi et al., 2013). This undermines the proactive nature that should underpin effective disaster risk management. From this perspective, the UrVI serves as an analytical tool that enables comprehensive and effective evaluation of risks, opportunities, and the socio-economic, environmental, and cultural implications of multisector strategies pertaining to the adaptation and mitigation of variability and climate change impacts. Considering the results of the UrVI, anticipatory measures can be implemented, facilitating the formulation of tailored adaptive actions, and establishing priorities for the most vulnerable areas compared to other ones within the intra-urban scale. Additionally, it assists in identifying the factors that contribute to variations in vulnerabilities at the specific local level.

The UrVI index combines diverse information across multiple sectors to assess the vulnerability of Blumenau's population in the urban context. This approach enabled a detailed analysis of urban vulnerabilities, from the broader level of sensitivity and adaptive capacity components down to the specific information that contributes to these indicators. Thus, it provided insights about who is vulnerable and where vulnerabilities are concentrated. In the case of Blumenau, the regions to the North and South of the city boundaries were the most critical areas evaluated by UrVI. These areas exhibited the highest sensitivities, particularly influenced by the sub-indexes of sanitation and urban mobility, and the poorest adaptive capacities, mainly in the sub-indexes of poverty and vulnerable groups.

The observed distribution pattern of the UrVI towards the northern and southern regions of Blumenau can be linked to the city's urban development process, as discussed by Ludwig (2020). By directing the expansion of the city to the north or south, without considering the impacts related to the floods, the municipality's infrastructure was not prepared so that the population has an easy escape route in case of heavy rains. Furthermore, the occupation of the south zone of the city (e.g. Velha Grande) was not planned, which is subject to landslides.

From the presented results, with the availability of the maps and the respective data tables, the managers of the different areas of the city can provide themselves with information to act together, in order to reduce the vulnerability of the population in the most critical areas.

With Sisvuclima, the city can provide itself with relevant information about the vulnerability in an intra-scale, which can be updated and/or object of construction of hypothetical scenarios, thus helping the integrated sectoral planning of the city in order to be more resilient to climate risks.

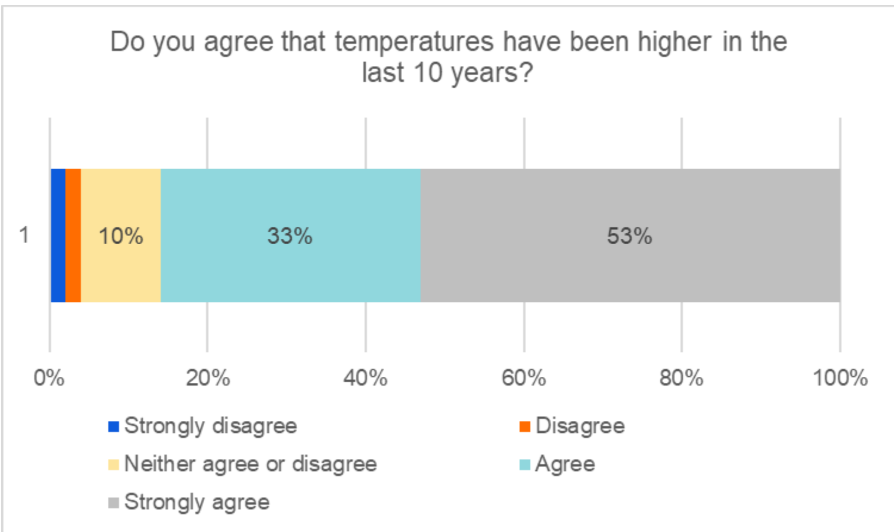
5.6.9 – Perception of climate risk and adaptation

A study to evaluate the perception of climate risk in the scope of municipal public management was conducted. The aim was to draw a status on the risk perception of municipal civil servants before SISVUCLIMA training. Thus, workers from the municipal government of Blumenau were invited to answer an online questionnaire consisting of 20 questions. The form addressed the (i) perception of climate change; (ii) changes in rainfall and temperature; (iii) access to information; (iv) impacts on professional performance, and (v) evaluation of the performance of public bodies. Participants also responded about the challenges faced by municipal management considering climate change scenarios.

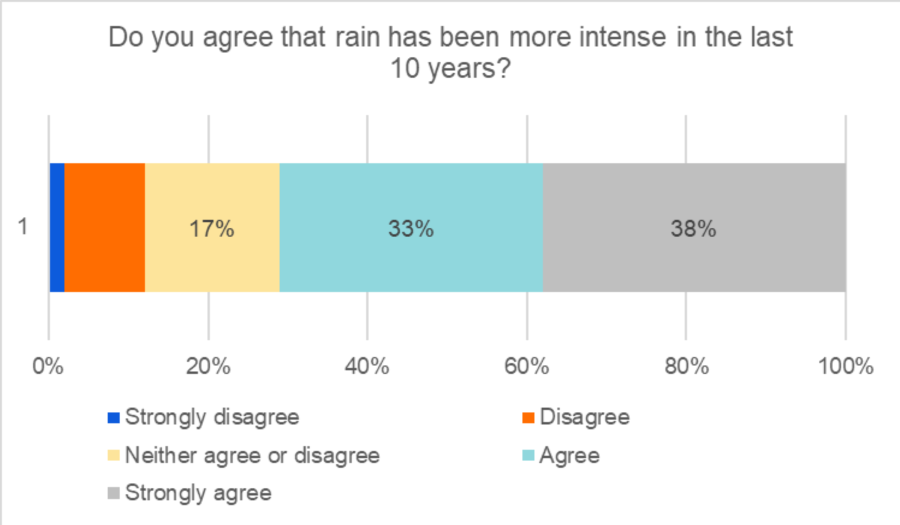
The form was answered by 81 municipal civil servants, from February to May 2023. The average age of the participants was 42 years old and the most respondents were women (62%). From the total number of participants, 52% had postgraduate degree, 36% higher education and 12% high school. The servants belong to the Secretariats of Social Development, Protection and Civil Defense, Urban Planning and Health. They act as administrative agents, civil defense agents, social workers, engineers, nurses, geologists, meteorologists and psychologists. Some of them were in management positions such as director, manager and secretary.

A brief summary of the main results of the study is presented below. Most of the participants (65%) completely agree that climate change is already happening and there was predominance (40%) of those who consider that the predictions are not exaggerated.

A result of the survey was highlighted: 38% agree that the rains have been more intense in the last 10 years and 32% partially agree. On the other hand, 53% agree that temperatures are higher and 33% partially agree (Figures 5.74). A research for studies on aspects related to changes in the pattern of rainfall and temperature will be conducted in view of the results described.



(a)



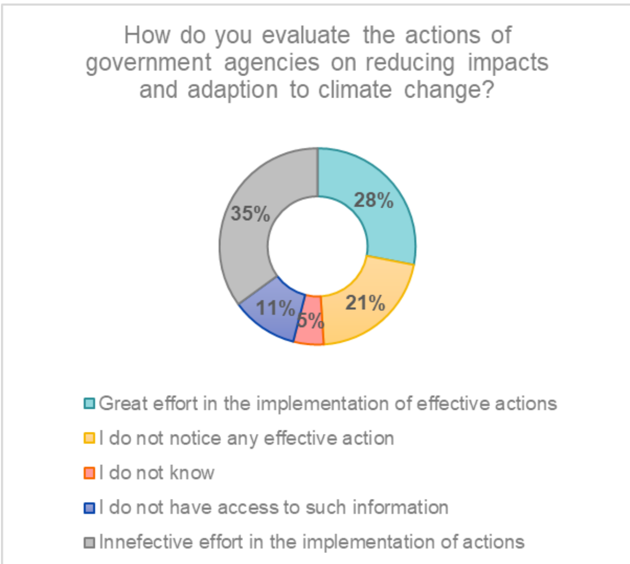
(b)

Figure 5.74 – Perception of the survey participants about the temperature (a) and rain (b) changes patterns.

From the perspective of professional performance, 57% of participants answered that they can understand information about climate change. Nonetheless, only 27% declared that they have enough information for their work. These data suggest that the means of disseminating scientific research results can be improved to reach different audiences, such as municipal technicians.

For the participants, the three sectors that will be most impacted by climate change in Blumenau are agriculture, biodiversity and water resources. Other sectors were also chosen by respondents, e.g. urban infrastructure (mobility, sanitation, energy, housing and telecommunications) and health. According to the participants, the most impoverished population will be the group most affected by climate change (80%), followed by farmers (12%).

Finally, respondents identified that the main challenges faced by municipal management to adapt to climate change are associated with occupations in areas at risk and water supply. Regarding the performance of government agencies in reducing the impacts of climate change, 35% answered that they identify little effort in the implementation of effective actions, while 28% perceive great effort in the implementation of effective actions (Figure 5.75).



Participants evaluation about the government actions on reducing and adaptation to Figure 5.75 – climate change.

5.7 Economy and impacts in key sectors

5.7.1 Introduction

The most important results achieved by the group during the sixth year of the project are related to continuing applications of different tools and databases developed in the first years of the project by various modeling initiatives related to some of the ongoing projects. Moreover, given the availability of more recent data for Brazil, a general municipality-level interregional input-output system was developed for 2019. Such a database was used, for instance, to calibrate (i) a model for the Brazilian Legal Amazon, (ii) a model focusing on the regional economies of Brazil's Northeast, with special attention to the Semi-arid, and (iii) a model for the Mantiqueira region. In the latter case, researchers have concluded the model integration with a hydrological model developed in collaboration with the subcomponent "Water Security". A study on "Water charge and conservation of natural areas: An ex-ante assessment of a policy proposal for the Mantiqueira region, Brazil" has been concluded showing that a proposed charge on water use can (under some conditions) achieve significant results in reforestation efforts and positive effects on Mantiqueira's GDP.

In our exploration of the Legal Amazon (LAM), which encompasses the Brazilian Amazon Basin and its adjacent Savannas (Cerrado), our research addresses a crucial yet often overlooked aspect: the regional characterization of resource demand within countries. Through meticulous examination, we unveil a groundbreaking insight – economic demand originating from the more developed Brazilian center-south region exerts a far more substantial influence on Amazonian deforestation than local or foreign export demand. This compelling finding prompts a reevaluation of prevailing paradigms, underscoring the significance of internal market forces that have been previously overshadowed by international trade considerations.

Finally, the regionalization method has been further tested and implemented in different countries, such as Angola, Chile, Colombia, Croatia, Greece, Iraq, Mexico, Morocco, Paraguay, and Ukraine. In this sixth year, the applications developed for Colombia were published as part of an edited volume by Springer Nature on "The Colombian Economy and its Regional Structural Challenges". The project with the Banco de la República is partially linked to our INCT and proposed to replicate some of the INCT-MC2 features in the Colombian case. Given the project's focus, we adapted one of its transversal themes ("economy and impacts on key sectors") to Colombia. During the fourth and fifth years, we addressed issues related to structural features of the Colombian regional system using the tools box developed in this project.

5.7.2 Summary of activities

The objective of the subcomponent remains the same:

"To provide policymakers and society in general with quantitative results of rating studies of the economic costs associated with impacts of climate change, to subsidize a more systematic way, the design of sectoral and global public policies aimed at reducing climate vulnerability."

Activities of Work Package # 1 (Integrated modeling) have focused on developing integrated modeling approaches to generate quantitative results associated with the impacts of climate change. We continued to focus on one of the areas that received more attention in years 1-5, namely, dealing with uncertainty in agriculture productivity and other physical models and the implications for economy-wide impacts.

We have also reinforced our efforts in two other key areas, developed since years 3-5, which include: (i) the water and economic modeling integration; and (ii) modeling uncertainty and risk assessment in the context of unexpected events. In the latter case, we have teamed up with colleagues from the Civil Engineering Department at UNAM (Mexico), led by Prof. Mario Ordaz, to devise alternative methodological approaches to integrate risk assessment models and CGE models. Using modeling of earthquakes in Chile, this partnership has advanced in bringing additional insights and understanding of the economic consequences of unscheduled events. We learn from this modeling experience and try to inform groups from the INCT better and elsewhere dealing with the economic impacts of sea-level rise and other climate-related effects. In this respect, a project with the World Bank ("Egypt's Sustainable Cities Review: Assessing the Impacts of Climate Shocks and Policy Reform in Egypt") has been initiated to examine the economic contribution of the cities to the overall regional Gross Domestic Product (GDP) based on climate change scenarios (i.e., RCP 4.5 and RCP 8.5), and how it varies under different climate shocks scenarios, such as extreme weather events (e.g., heat wave, drought, flash flood) or changes (e.g., sea level rise). A first joint paper entitled "Risk caused by the propagation of earthquake losses through the economy" has been published in *Nature Communications* (https://www.nature.com/articles/s41467-022-30504-3).

During the sixth year of INCT MC 2, the activities related to Work Package #2 continued to focus on two main themes: (i) development of land-use models for assessing the potential for cattle raising intensification in Brazil; and (ii) development of econometric models to assess adaptation to climate shocks through rural labor market reallocations.

We have also continued developing specific projects within the INCT Climate Change Project, complementing the funding received. In this context, the following projects funded by Fapesp should be mentioned: (i) "Urbanização e Mudanças Climáticas: Análises de Impacto na Região Metropolitana de São Paulo" (Doctorate, 2018/08833-5, granted); (ii) "Agricultural and Agro-Industrial Sustainability in Chile: Modeling the Impacts of Climate Change and Natural Disasters in an Integrated Framework" (CONICYT - Regular Research Project, 2018/08337-8, granted); (iii) "Fertility and Inequality: Evidence from Brazil " (Fellowship Abroad, 2018/06782-4, granted); (iv) "Uma Análise Espacial de Impacto da Acessibilidade à Água na Produção Agropecuária do Semiárido Brasileiro" (Scientific Initiation, 2018/11799-3, granted); (v) "The Economics of Low Carbon Markets – 2018" (Scientific Event Organization, 2018/17781-9, granted); (vi) "Assessing the Climate and Weather Effects in Brazil using Panel Data" (Fellowship Abroad, 2018/02081-1, granted); (vii) "The Economics of low Carbon Markets" – 2019 (Scientific Event Organization, 2019/13756-2, granted) (Figure 5.76)

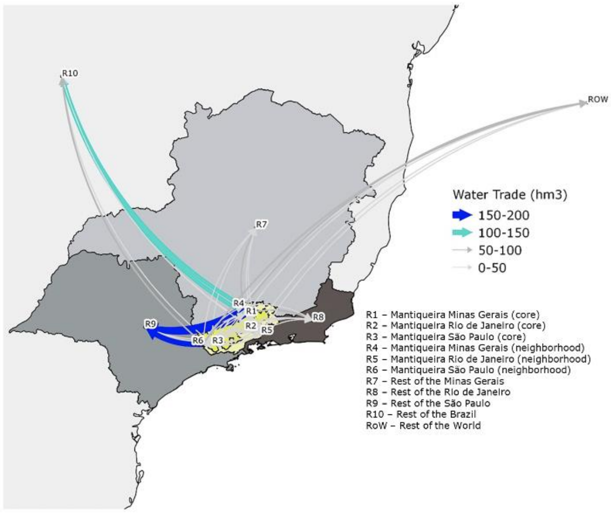
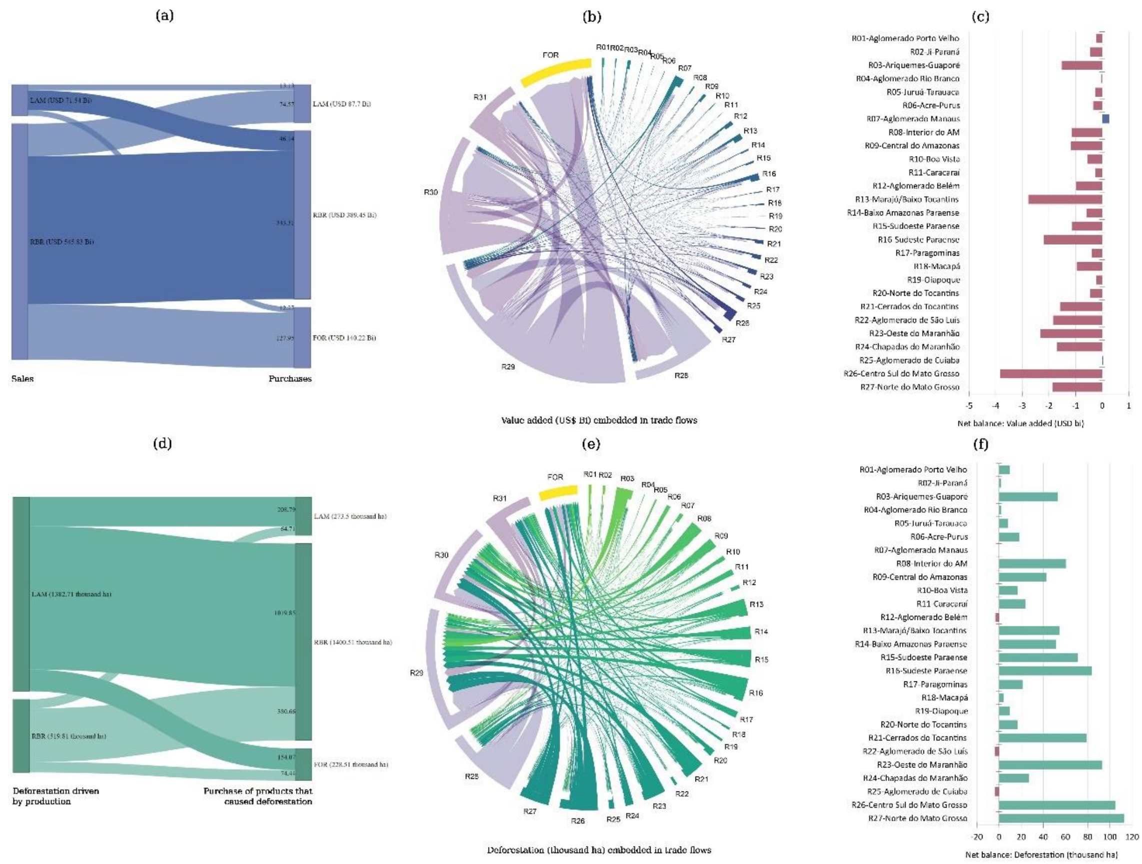


Figure 5.76. Virtual Water Flows from Mantiqueira Region

Figure 5.77a and b display the decomposition of LAM's GDP and deforestation driven by local (LAM) and external (RBR and FOR) demand. Analogous results are presented for a higher regional disaggregation in Figures (b) and (e). Results are presented in levels and percentage shares, identifying total GDP creation and total deforestation embedded in each bilateral trade flow. Finally, figures (c) and (f) present the balance of traded GDP and deforestation by region. The data correspond to the year 2015. Source: Authors' calculations using the IIOM-LAM



Note: LAM = Brazilian Legal Amazon; RBR = Rest of Brazil; FOR = Foreign markets. R01 – Aglomerado Porto Velho; R02 – Ji-Paraná; R03 – Ariquemes-Guaporé; R04 – Aglomerado Rio Branco; R05 – Juruá-Tarauacá; R06 – Acre-Purus; R07 – Aglomerado Manaus; R08 – Interior do Amazonas; R09 – Central do Amazonas; R10 – Boa Vista; R11 – Caracaraí; R12 – Aglomerado Belém; R13 – Marajó/Baixo Tocantins; R14 – Baixo Amazonas Paraense; R15 – Sudoeste Paraense; R16 – Sudeste Paraense; R17 – Paragominas; R18 – Macapá; R19 – Oiapoque; R20 – Norte do Tocantins; R21 – Cerrados do Tocantins; R22 – Aglomerado de São Luís; R23 – Oeste do Maranhão; R24 – Chapadas do Maranhão; R25 – Aglomerado de Cuiabá; R26 – Centro Sul do Mato Grosso; R27 – Norte do Mato Grosso; R28 – Restante do Nordeste; R29 – Sudeste; R30 – Sul; R31 – Restante do Centro-Oeste.

Figure 5.77 Decomposition of LAM's GDP and deforestation driven by local (LAM) and external (RBR and FOR) demand.

5.8 Modelling the earth system and production of future climate scenarios to study Vulnerability, Impacts and Adaptation

5.8.1 Development of the Brazilian Earth System Model – BESM

a.1.1.1 - BESM3.0.2 **-** (Global Atmos BAM1.2 sigma coupled to Global Ocean MOM6 via FMS coupler from NOAA/GFDL) version has been upgraded from the previous version of MOM6, incorporating both vertical Z and isopycnal coordinates, in addition to an improved marine sea ice model SIS2 and biogeochemistry model COBALT.

a.1.1.2 - BESM 3.0.2 **-** BESM 3.0.2 has been tested and debugging procedures 30 years (1981-2010) of November and December 1st initialized one year seasonal predictions, with ten member ensembles.

a.1.1.3 - BESM 3.0 - low level MPI programing has been upgraded for both the low resolution **T062L42** (i.e. 200 Km horizontal grid and 42 levels in the vertical) and the **T666L64** (i.e. 20 Km horizontal grid resolution and 64 levels in the vertical). Also, concurrent parallelism has been implemented for BESM3.0, with a combined effect of up to 30% increase in the efficiency of computation in the CPU machine CRAY XC-50 at INPE. (Figures 5.78, 5.79).

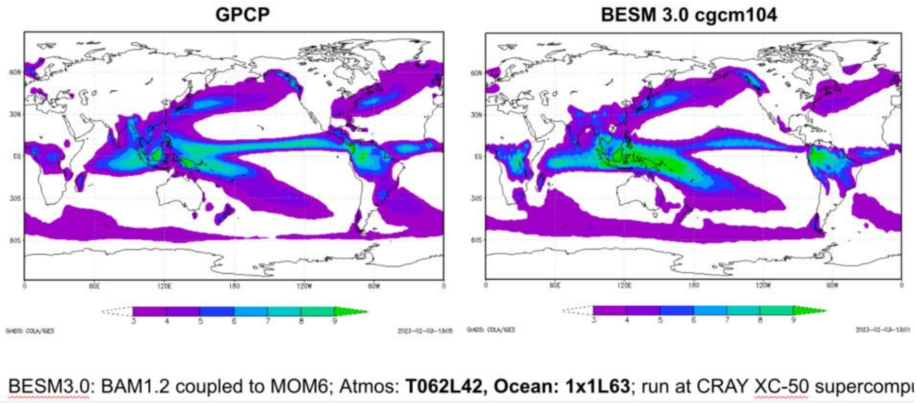


Figure 5.78- 30 years precipitation annual mean (a) Global Precipitation Climatology Project - GPCP; (b) BESM3.0 T062L42_atmos 1x1L63_Ocean 30 years run. Source: M.Baptista (2022, personal communication)

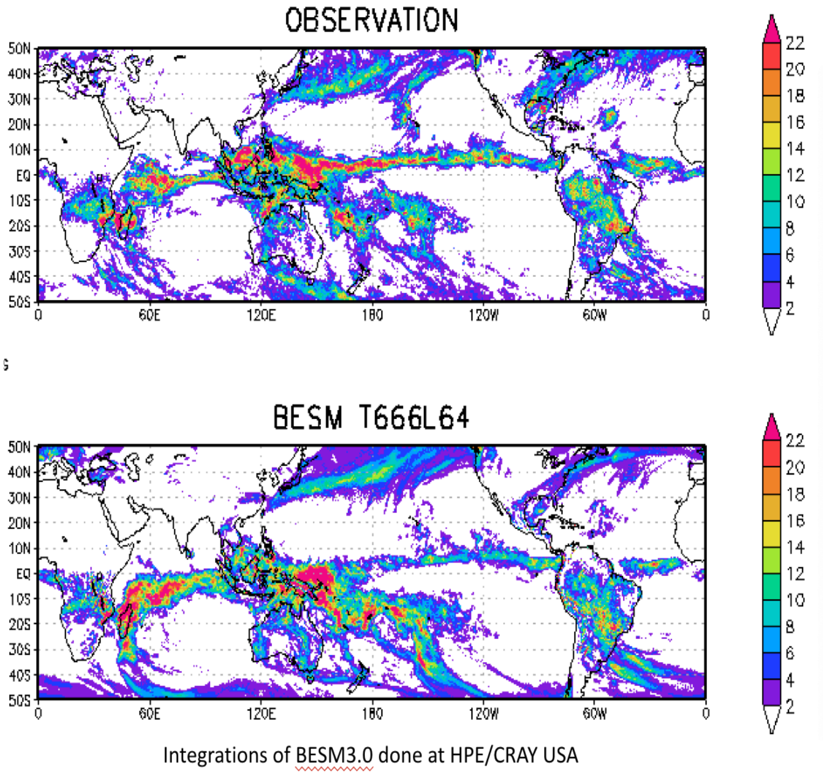


Figure 5.79 - Precipitation: (a) observation, (b) BESM 3.0 (T666L64_atmos- ¼ x ¼ L63_ocean) 10 day forecast, mm/day. Source: J.Tamaoki (2022, personal communication)

a.1.1.4 - MOM6 regional grid - MOM6 ocean model has been configured to run a regional grid over southwestern South Atlantic. Test runs of one year have been completed in a test-grid of ¼ x ¼ degree lat-lon (Figure 5.80)

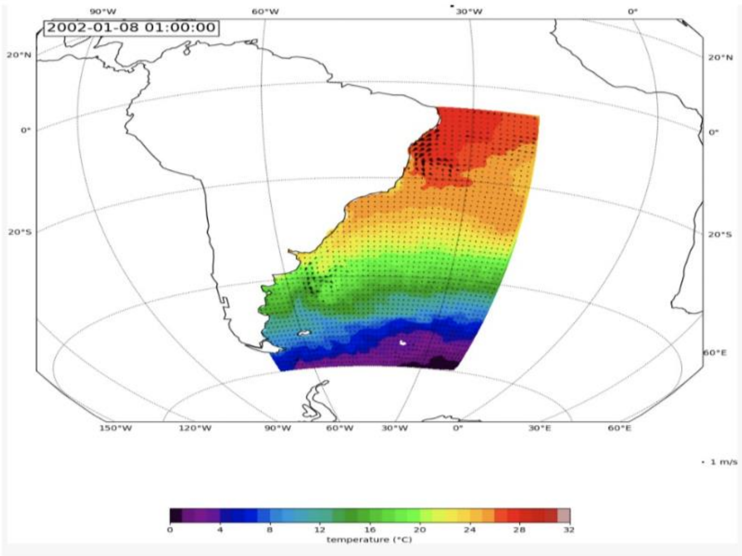


Figure 5.80 - MOM6 regional sea surface temperature simulation run at a ¼ x ¼ lat lon grid in the CRAY-XC50 at INPE. Source: Nicole Laureantis (2023 personal communication).

a.1.1.5 - BESM3.1 - Tests of hybrid vertical coordinate version of BESM (version 3.1) has been completed, with some improvements and bug corrections identified in the IBIS land model implementation of BAM2.

5.8.2 Development of the Regional Earth System Model – Contribution to INCT-MC2

a.2.1. Model development

a.2.1.1 **Eta version 1.4.2** has been compiled and tested at the Lovelace supercomputer of CENAPAD-SP (Centro Nacional de Processamento de Alto Desempenho em São Paulo). One of the main features of the v1.4.2 version is the ability to run the model on multiple temporal scales (time, subseasonal, and climate change) and different spatial resolutions, being able to use non-hydrostatic or hydrostatic mode. The model is able to perform long-term simulations in a reasonable time using only one computer node with 128 processors. The Eta model has been tested with boundary conditions from ERA5 reanalysis and conditions from CMIP6 global models such as BESM and EC-EARTH3. This version of the model is documented in Gomes et al. (2023).

a.2.1.2 **Land-surface - radiation interaction:** Improvements in the albedo

The Eta model's previous albedo map was based on climatological values. The new albedo depends on the model's vegetation type and with a monthly variation. In the tests for long-term runs with Eta at 20 km of horizontal resolution, the new albedo modified the interactions between the land surface and the radiative interaction; as a result, the 2-m temperature biases were reduced in some regions of the Amazon and northern Argentina (Figure 5.81).

a b,

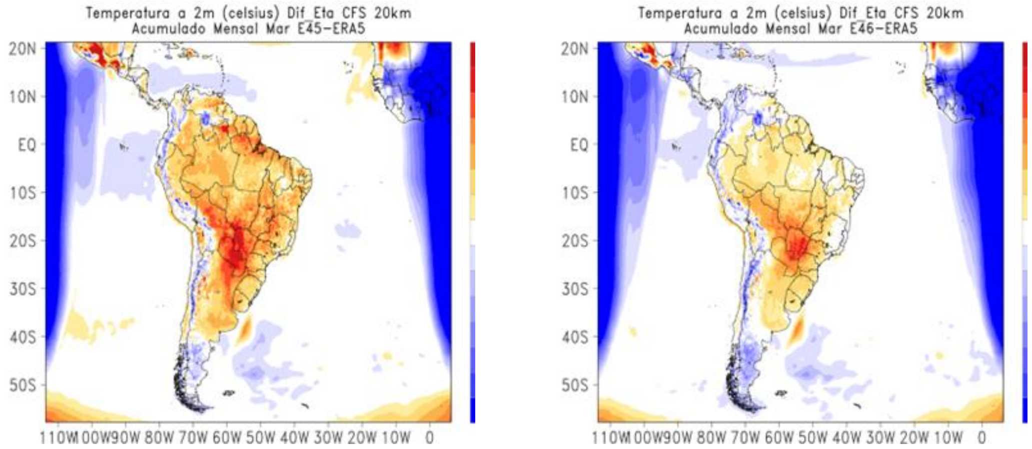


Figure 5.81 - 2-m temperature error (^oC) using climatological albedo (a) and vegetation-dependent albedo (b) forecast for March 2022. Discard the strong blue shading values, which are outside the model integration domain.

a.2.1.2 RRTMG **radiation scheme**

The Eta model's radiation package was updated to a newer code. The new radiation scheme introduced in the Eta model is the Rapid Radiation Transfer Model for GCM (RRTMG). The scheme was implemented in the Eta version 1.4.2 and tested in the cloudy sky, and an additional development is the inclusion of the deep convective cloud in the RRTMG scheme. This produced a further reduction in the positive bias of incident shortwave radiative flux at the surface, improvement in cloud cover, in the diurnal cycle of net radiation at the surface, and in temperature at 2 meters over land and sea. However, total precipitation was reduced. Further adjustments in precipitation are required. In a 10-year-long simulation, the model with the new modifications can reproduce the seasonal variability of radiation fluxes during the summer and winter compared to reanalysis data.

Several tests were carried out by modifying the convective and microphysics parameters in order to improve the radiation budget in the model and obtain a better version for climate change simulations. Figure 5.82 shows that the new RRTMG scheme in the Eta model improved the mean radiative fluxes and the mean 2-m temperature over land and sea.

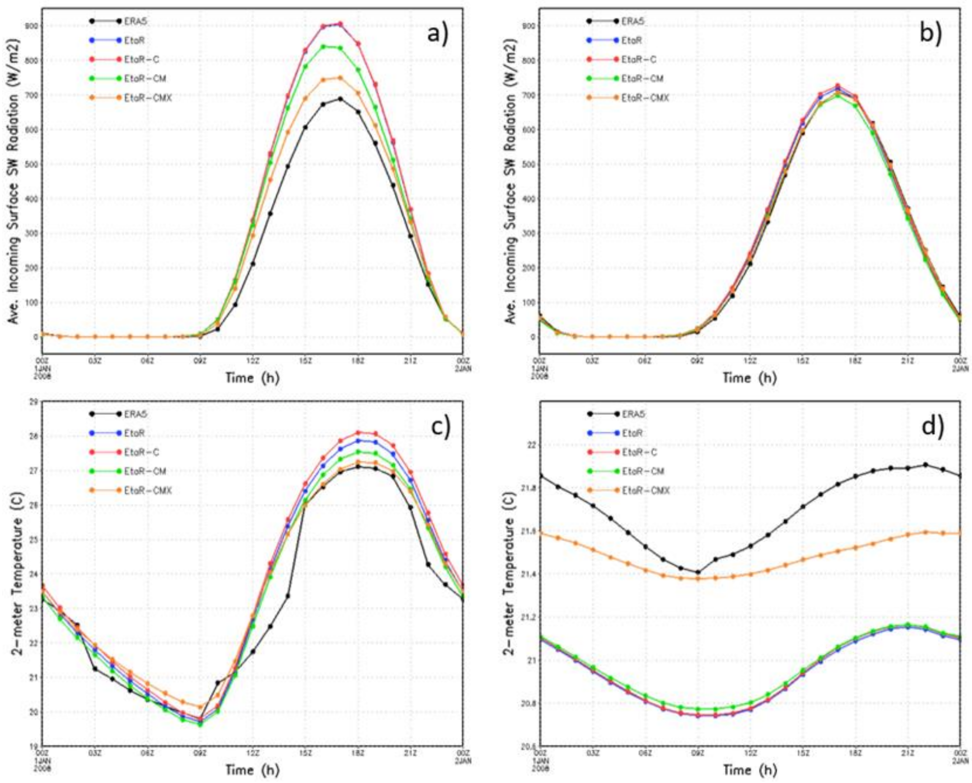


Figure 5.82. Mean diurnal cycle of solar radiation incident at the surface over a) land and b) sea and temperature at 2m over c) land and d) sea, for different numerical experiments and ERA5 reanalysis.

a.2.1.3 Coupling to regional ocean model: **Eta-MOM6**

The Eta model code has been modified as preparation for the coupling to the regional ocean model MOM6. Various steps are needed to achieve the coupled system. The regional model and the ocean model become routines and are both called by the coupler FMS (Flexible Modeling System). FMS is a software framework for controlling model runs and becomes the major driver of the coupled ocean-atmosphere modeling system. The development was based on modifying the Eta code according to the FMS coding rules, and a routine was constructed named ATMOS.f90. Tests were carried out to guarantee that the output was reproduced after each set of modifications. This activity is ongoing.

5.8.3 **Capacity building**

The newly developed version 1.4.2 was used for capacity building on climate modeling. training was provided during the VII Workshop in Numerical Modeling of Weather, Climate, and Climate Change using the Eta Model: Physical and Numerical Aspects (VII WorkEta, Figuyre 5..83) on 26-30 September 2022. This workshop consisted of an oral session with 19 invited lectures and participants' talks, and a hands-on session with model training, all activities done remotely. There were a total of 157 participants that joined at different times. The program, lectures, talks, and posters can be found at *http://www3.cptec.inpe.br/eta/programacao/*

Figure 5.83 - Snapshop of participants in the VII WorkEta.

5.9 Communication, dissemination of knowledge and education for sustainability.

5.9.1 General features

The transversal communication theme of the INCT MC2, from June 2022 to June 2023, featured several actions and productions by researchers from the Latin American Network for Scientific Dissemination and Climate Change, which brings together the participants of this subcomponent. Such activities and productions, in this period, addressed important aspects of communication and education related to climate change: the expansion of reflections and developments around the Anthropocene concept, based on problematizations arising from the humanities and arts (MARRAS, TADDEI, 2023; CANGI , 2023; DIAS, S.O; CANGI, A.; GONÇALVES, M.; AMORIM, A.., 2023; GARCIA, 2023; WUNDER, 2023; DIAS, 2022; DIAS 2023; SALES, DALMASO, RIGUE, 2023); the beginning of analyzes on the differences between Latin American and European experiences and approaches to the relationship between arts, sciences and communications in the face of the Anthropocene (DIAS, 2023; MURRIELLO, 2023; GARCIA, 2023; CANGI, 2023); the deepening of reflection on what it can be to give effective attention to the sciences in scientific dissemination practices and artistic practices (DIAS, 2022; DIAS, 2023); analyzes of interdisciplinarity in climate change research, focusing on the INCT MC Phase 2 (GUIVANT, FROMER, 2023); experiments in the field of climate change communication when plants, animals, clouds, stones, rivers, seas... are made partners and research and creation companies (DIAS, GUZZO, FONSECA, 2022; FONSECA, 2022; DIAS et al, 2022; ARANHA , 2022, 2023; ARANHA, DIAS, 2023; VILELA, 2022, 2023).

One of the important results of this year's work is the perception that communication in a new climate regime in a generic, universalizing, and abstract way, based on already given models, proves to be ineffective (GARCIA, 2023; DIAS, 2022, 2023). Therefore, it is important to analyze unique practices, assess how communicating systems work in different situations, how communicating problems linked to climate change are reinvented, dismantled, and how different outputs are produced by people and collectives in the various interactions with beings-things-forces-worlds (COTAIMICH, 2022; VIDAL et al., 2023; MURRIELLO, 2023; DIAS, GUZZO, FONSECA, 2022). In methodological terms, we sought to see and feel a multitude of ways of making climate change re-exist in photographic essays, performances, installations, drawings, paintings, book-objects, films, etc. (MURRIELLO, 2023; GARCIA, 2023; DIAS, GUZZO, FONSECA, 2022).

To get out of the usual, massified and dominant communicating systems, which, faced with a time of catastrophes, end up betting predominantly on issuing denouncements, repeating ready-made information, and characterizing worlds with no way out, researchers in this cross-cutting theme bet on storytelling as a way to make communicative possibilities flourish beyond the recognitive and representational regimes (DIAS, 2022; DIAS, GUZZO, FONSECA, 2022); as a possibility to allow people to feel existential metamorphoses and pluralisms (CANGI, GONÇALVES, 2023); and as a means of affecting people with other logics that cause disorder in the sensorium, opening potential for an expanded aesthetic of instability (CANGI, 2023) and that problematize monocultural and anthropocentric perspectives, increasing the capacity to act (DIAS, GUZZO, FONSECA , 2022).

The proposition and experimentation of artistic residencies were a novelty in this period in the project (ARANHA, DIAS, 2023). Residences are extremely relevant space-times for thinking about and experimenting with alliances between arts and sciences. It is where we can see how connections, inputs and outputs are created, where we distance ourselves from utilitarian perspectives and parameters and launch ourselves into creating new relationships (FONSECA, AMORIM, 2022). These experiences promote a transformation of laboratories into ateliers and ateliers into laboratories (FONSECA; KROEF, 2023; ARANHA, DIAS, 2023). A pilot artistic residency was developed within the scope of Labjor-Unicamp – entitled "Follow the frogs" (ARANHA, DIAS, 2023) - to experiment with the possibilities of bringing artists' studios and scientists' laboratories into the relationship. It was developed through partnerships between Labjor-Unicamp and the Institute of Arts at Unicamp, with the Laboratory of Natural History of Brazilian Amphibians (LaHNAB), at the Institute of Biology (IB) at Unicamp and with Ateliê Serafina. The residency involved selected artists and a group of students from the discipline "Art, science and technology" offered in the master's program at Labjor-IEL-Unicamp. As a result, eight works were produced, and an exhibition was held at the Plural space at Labjor-Unicamp. In the next two final years of this project, the idea is to carry out artistic residencies in partnership with the laboratories of INCT researchers. The first is already being considered in collaboration with the Water Resources sub-component, and the next will be with the Disasters and Economy sub-components. The analysis of the results of the residencies will be presented in the next reports.

In the field of publications, in addition to the articles and other texts published in the period and listed below, two contributions stand out. One is the participation of two researchers of the transversal theme, Marko Sinésio Monteiro and Renzo Taddei, in the book *A Critical Assessment of the Intergovernmental Panel on Climate Change*, published by Cambridge University Press, with a chapter on the theme of the so-called civic epistemologies. The concept refers to how communities of scientists and decision-makers from different countries incorporate and make sense of scientific information such as that produced by the IPCC. The other is the book *The Anthropocene: on ways of composing worlds*, edited by Renzo Taddei, coordinator of the transversal theme, and by Stelio Marras, professor at the University of São Paulo. The book deals with the implications of the Anthropocene concept for the humanities and social sciences, with contributions in the areas of anthropology, history, philosophy, ecofeminism, and the arts, and also brings a dialogue with two of the most outstanding thinkers linked to the traditional peoples of the country: the Indigenous leader Jerá Guarani and the Quilombola philosopher Antonio Bispo dos Santos.

5.9.2 Activities developed between June 2022 and June 2023

- We launched two ClimaCom Magazine dossiers with articles, essays, reviews, op-ed columns, news, interviews, reports, and artistic and cultural productions.

1) "Plant policies?" (December 2022, organized by Susana Dias, Marina Guzzo, and Fabiola Fonseca);

2) "Ciência.Vida.Educação" (May 2023, organized by Tiago Sales, Alice Dalmaso and Fernanda Rigue);

- We produced articles, summaries, expanded summaries, books, and presented papers at events based on research carried out individually or in groups.

- The project "Modes of Attention to the Earth: Arts and Science in the face of the Anthropocene" was approved at Unicamp's Ciência & Arte nas Férias - CAF, coordinated by Susana Dias and resulted in the offering of 4 workshops for 120 high school students from public schools in the city of Campinas.

- The project “Revista ClimaCom - arts, sciences, and communications in the face of the Anthropocene,” coordinated by Susana Dias, was approved in the BAS scientific initiation scholarship program at Unicamp, and we now have three scholarship holders - Rayane Barbosa, a Kaingang indigenous student from Faculty of Education at Unicamp, Leo Arantes Lazzerini from the Faculty of Applied Sciences at Unicamp and Priscila Cristina Dourado Salvadeo, from the Institute of Chemistry at Unicamp, who will work at ClimaCom magazine between June 2022 and July 2023;

- The project “Climate change, interdisciplinarity, and scientific communication” was developed by Julia Silvia Guivant (Responsible) and Antonio Carlos Amorim (FAPESP 2021/09683-0 Visiting researcher assistance, 3/1/22 to 02/28/23)

- The project “Perceive-make forest - alliances between arts, sciences, and communications in the face of the Anthropocene,” coordinated by Susana Dias, was approved by FAPESP.

- The project “Socio-climatic imaginaries and meta-cognitions: their roles in interdisciplinary research and scientific communication in a case study of the National Institute of Science and Technology for Climate Change (INCT-MC)” was approved with the participation of Julia Silvia Guivant and coordination of Renzo Taddei (CNPq-CNPQ Call Nº 26/2021);

- The “Pedagogies of the Image” project, coordinated by Gabriel Cid Garcia, was awarded two (2) scholarships for undergraduate students from the Institutional Program for Artistic and Cultural Initiation Scholarships - PIBIAC/PR-1/UFRJ, 2022.

- We produced a series of online seminars, “Latin American Variations in the face of the Anthropocene” and “Ecopoetics: education, art and the Anthropocene”, carried out with the participation of researchers from Brazil, Argentina, Colombia, and Mexico.

- The artistic residency “Seguir os sapos” was carried out in person in Campinas, and the organization of the artistic residency “Perceive-make Forest” began, which will take place online and in person in Manaus.

- In collaboration with the general coordination, we started construction of the INCT Climate Change Phase 2 website. It is expected to be online in the second half of 2023;

- We built the website of the Latin American Network for Scientific Dissemination and Climate Change that makes up this cross-cutting theme of INCT MC Phase 2 communication: https://www.rededcmc.labjor.unicamp.br/

- We edited the book “Modes of existing in the face of the Anthropocene,” with texts by José Marengo, Mário Mendiondo, Paulo Nobre, Donna Haraway, Natasha Myers, Ailton Krenak, among other researchers and artists. The book is being finalized for publication.

- We participated in the construction of the #AprenderParaPrevenir campaign, organized by Cemaden Educação (Figure 5.84). This edition of the campaign, the largest in its history, has the support of the Ministries of Education, Cities, Environment and Climate Change, and Integration and Regional Development, in addition to the National Water Agency, the Brazilian Red Cross, the Civil Defense, the Periphery Caravan and the Schools for the Climate movement. In this campaign edition, knowledge pills will be produced, together with the researchers from the INCT Climate Change, which will integrate the work materials with the participating schools.

Figure 5.84 . Poster for the 7th #AprenderParaPrevenir2023 Campaign, built in collaboration with the cross-cutting theme and which includes, in its planning, the elaboration of knowledge pills together with INCT-MC2 researchers.

5.10 Impacts on Brazilian ecosystems in view of changes in land use and biodiversity for sustainability

The ecosystems component of INCT-2 achieved significant advances in its scientific proposal in the last year. We managed to keep all ATTO Tower instruments in continuous operation until now. Despite the difficulties, we were able to continue the operation of the NASA/AERONET solar photometer network in the Amazon, with measurements of the optical properties of aerosols in 5 different locations: Manaus-ATTO, Manaus-Campina, Rio Branco, Ji Paraná, and Alta Floresta. A great success of this project was the assembly and operation of a new experimental site near the ATTO tower, the so-called Campina site, which has been in full operation since 2021. Radars, spectrometers, Lidars, and instrumentation for measuring aerosols and clouds in addition to radiation. It is a unique observational site in tropical regions of the planet, and this report describes some of the first results from this new experimental site. One of the highlights of this period was the CAFÉ-Brazil experiment. We brought the HALO plane to Brazil with resources from Max Planck and the German DLR. Several students actively participated in data collection and are working on data analysis for the experiment. We also carried out the experiment by boat on the Rio Negro, the FLOAT-Amazon. In this experiment, In this year of execution of our ecosystems component, we had a total of 25 scientific works published or submitted. Most of the works were published in journals with a high impact factor. In the last year, we had a total of 3 doctoral theses and master's dissertations. About six students are working on developing the project, including scientific initiation, master's, and doctoral degrees. Several students have completed their master's and doctorate, and their results are being discussed and presented in this report.

Below is a summary of the activities carried out in the CAFÉ-Brazil, FLOAT-Amazon, Campina, and ATTO tower experiments. We managed to keep the ATTO tower and the Campina site in full operation without interruptions in the measurements.

5.10.1 – Results from the CAFÉ-Brazil (*Chemistry of the Atmosphere Field Experiment – Brazil*) Experiment

In December 2022 and January 2023, this project carried out the experimental CAFÉ-Brazil campaign, as planned since the beginning of this project, and unable to be carried out in 2019 due to the COVID-19 pandemic. One of the objectives of this project is to integrate measurements of gases and aerosols in the Amazon using terrestrial, atmospheric, and remote sensing instruments. Very few large-scale measurements of gases and aerosols in the Amazon are made with aircraft, especially at high altitudes. The main objective of CAFE-Brazil is to understand the processes that produce high concentrations of aerosols in the upper atmosphere, to study the photochemistry of tropospheric oxidants that form secondary aerosols in the Amazon rainforest in polluted and clean regions, to validate satellite estimates and numerical prediction models weather, and understand the cloud-aerosol-precipitation interaction. The CAFE-Brazil experiment employed the research aircraft (HALO), which stands for High Altitude Long-Range Aircraft. It was headquartered in Manaus and carried out flights over the forest throughout the Amazon. The flights investigated sources of high concentrations of nanoparticles, how emissions of volatile compounds from the forest influence oxidation chemistry, and how this process relates to the formation of aerosols and their abundance at high altitudes. The HALO measurements were coordinated with measurements at the Amazon Tall Tower Observatory (ATTO), located near Manaus, in a remote location within the forest. Some instruments performing measurements at ATTO were replicated at HALO. In this way, it will be possible to relate the measurements at the ATTO and directly above the forest with the surface aerosol formation processes and sources of volatile compounds and the oxidation and aerosol processes in the upper atmosphere. In addition, the measurements provide a description of the atmospheric chemistry. They will serve as a basis for the adjustments of atmospheric and chemical models such as the WRF-Chem (Research and Weather Prediction Model coupled with Chemistry) and the measurements of several satellites that estimate aerosols and the optical thickness of the atmosphere.

The CAFÉ-Brasil experiment was planned for 2019, but due to COVID-19, the field campaign was transferred from 22/Dec to 23/January. The experiment has just been successfully completed, collecting 143 hours of data covering 85,000 km transects over the Amazon in December 2022 and January 2023. The collected dataset will be analyzed over the next 2 to 3 years, and the measurements will be integrated into the dataset for this project.

5.10.1.1 – The HALO DLR Gulfstream 550 aircraft

The Gulfstream 550 DLR aircraft was fully equipped with the instrumentation described in table 2.2.1. Figures 5.85 and 5.86show some of the images of the plane and its operation.

Figure 5.85. The HALO aircraft in Manaus.

Figure 5.86 – Photos of the HALO airplane and the Administration personnel in the Manaus airport.

5.10.1.2 – Instrumentation used during the CAFÉ-Brazil and research methods

The HALO (High-Altitude Long-Range Aircraft) aircraft is fully instrumented to measure greenhouse gases, aerosols, cloud condensation nuclei, and reactive trace gases. The aircraft has state-of-the-art instrumentation with very low detection limits and high precision. Table 5.19 below presents an overview of the instruments operated during the CAFÉ-Brasil experiment.

Table 5.19: Instruments in operation at the HALO plane during the CAFE-Brazil experiment.

Institute	Instrument	Species/Parameters
GU Frankfurt	CI-API-ToF MS	H_2SO_4, HOMs/ELVOCs, clusters
MPIC	HALO-CIMS	PAN/PAA, SO_2, $ClNO_2$, HCl
MPIC	HALO-MGC	NMVOC
MPIC	PTR-MS TOF	OVOC
MPIC	TRIHOP	Total Peroxides, H_2O_2, HCHO
MPIC	NOAH/ATTILA-CLD	NO, NO_2, CO, CH_4
MPIC	HORUS	OH/HO_2
MPIC	LIF-SO2	SO_2
MPIC	C-ToF-AMS	Aerosol composition (non-refractory)
MPIC	FASD (CPCs, UHSAS, OPC)	Aerosol number and size distribution
MPIC	CCN-Rack	CCN, BC, aerosol

	(CCNC, SP2, impactor)	impactor
KIT	FAIRO	O_3
FZ-Jülich	HALO-SR	Actinic Flux
DLR-FX	BAHAMAS	P, T, wind, humidity, TAS, aircraft position, altitude
DLR-FX	SHARC	H_2O mixing ratio (gas phase)

5.10.1.3 - Location of the base of operations and trajectory of the flights performed

The base of action was the airport of Manaus, AM. Manaus is located in the center of the Amazon basin, 3° south of the equator. Its location is ideal for carrying out measurements from aircraft above the Amazon region. Manaus International Airport provides several hangars suitable for HALO and support for aircraft and scientific groups to prepare instrumentation for research flights. The airport provided all operational logistics to carry out a HALO mission. The objective was to obtain samples of air masses originating from untouched and unpolluted regions of the Amazon to characterize the biogenic conditions without anthropic influence. The flights were performed from 150 meters above the ground to 14,000 meters above sea level, at the top of the troposphere. This is the first measurement of greenhouse gases at that altitude over the Amazon, and several reactive gases were measured for the first time in tropical forests (Figure 5.87).

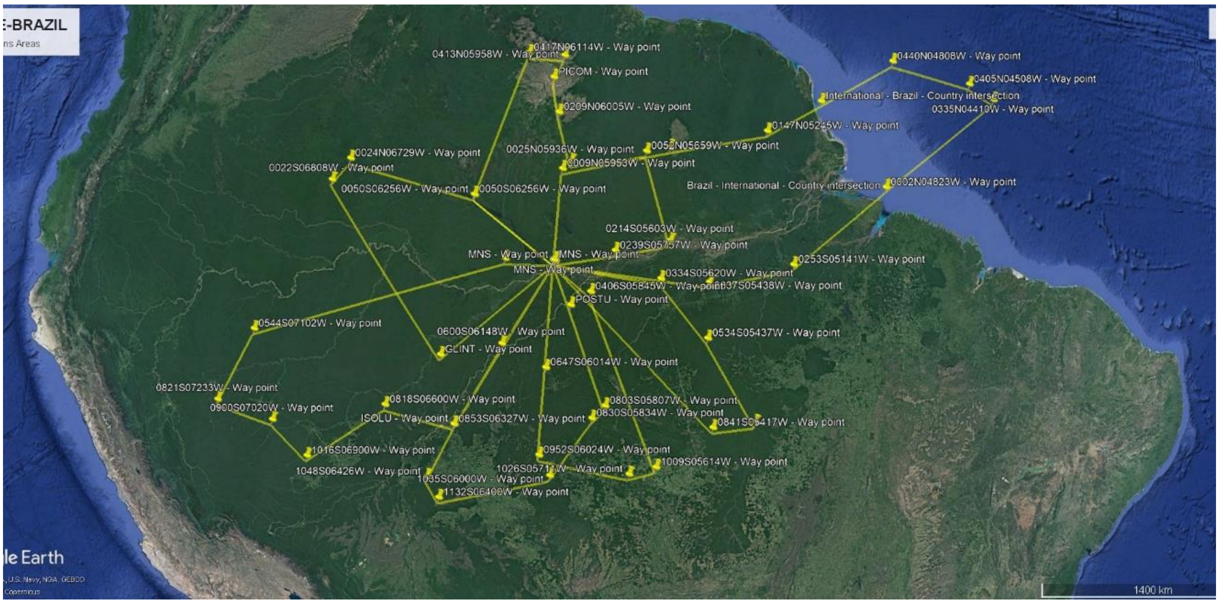


Figure 5.87 - Region covered by HALO flights within Brazilian territory, sampling most of the Amazon Rainforest. Many vertical profiles were made from 150 meters to 14,000 meters.

Each of these areas was explored on 20 flights. The area was fully measured according to the specific scientific objective of each mission. Figure 5.88 presents an example of the January 14 Flight.

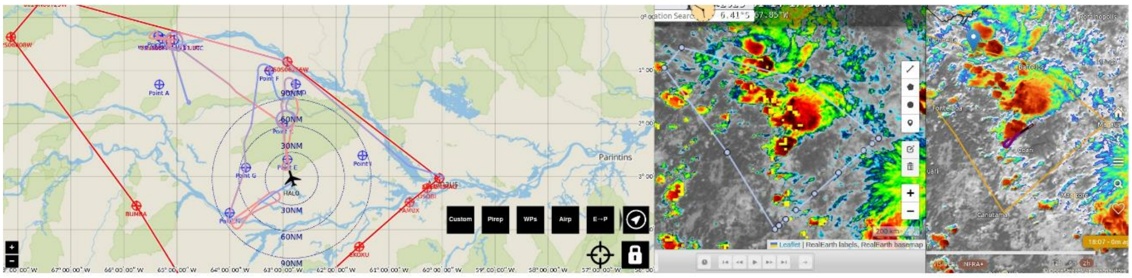


Figure 5.88 – Flight patterns for the January 14 experiment and cloud cover at that time, as sampled by the HALO plane.

Several instruments measured important information for understanding the relationship between convection/clouds and gas concentration. An example of the January 17 Flight is shown in Figure 5.89. This flight was over clouds and crossed cumuliform clouds. One can notice the increase of monoterpene within the updrafts of the cloud (at 1400 UTC). Updrafts were measured when the altitude is lower and the aircraft could penetrate the cloud.

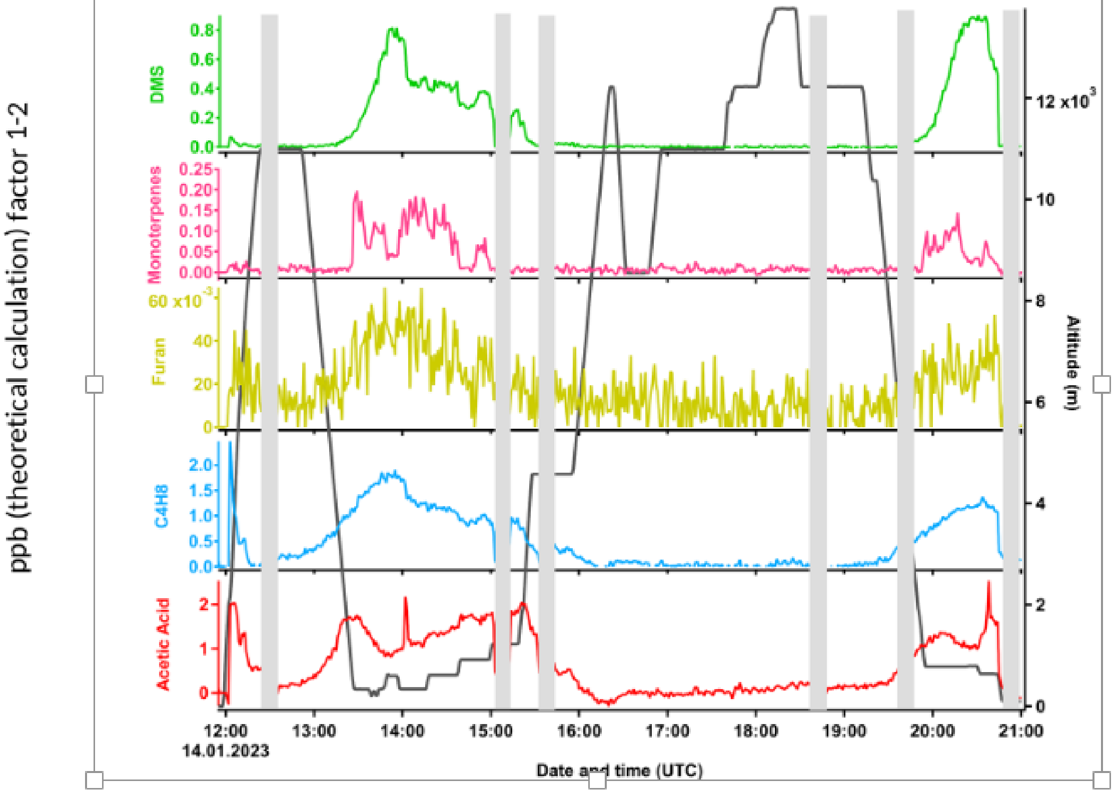


Figure 5.89 - Evolution of the trace gas concentration during the flight on January 17, 2023, measured using a PTR-MS.

5.10.2 – The boat campaign along the Rio Negro – the FLOAT-Amazon Experiment

As committed in the original proposal for this project, between January 10 and 21, 2023, an unprecedented experiment was carried out on the Rio Negro, aboard a research vessel (Figure 5.90). This experiment took place simultaneously with CAFE-Brazil, characterizing the properties of the atmosphere in a preserved and little scientifically explored region. The cruise consisted of a round trip from Manaus to São Gabriel da Cachoeira, in the extreme northwest of the state of Amazonas, covering a distance of approximately 800 km each way. Air and water samples were collected in this virtually untouched region of the Brazilian Amazon. The experiment was carried out in partnership with the State University of Amazonas (UEA) and collaborators from the Max Planck Institute, the University of California, and other researchers from IPEN and IAG-USP.

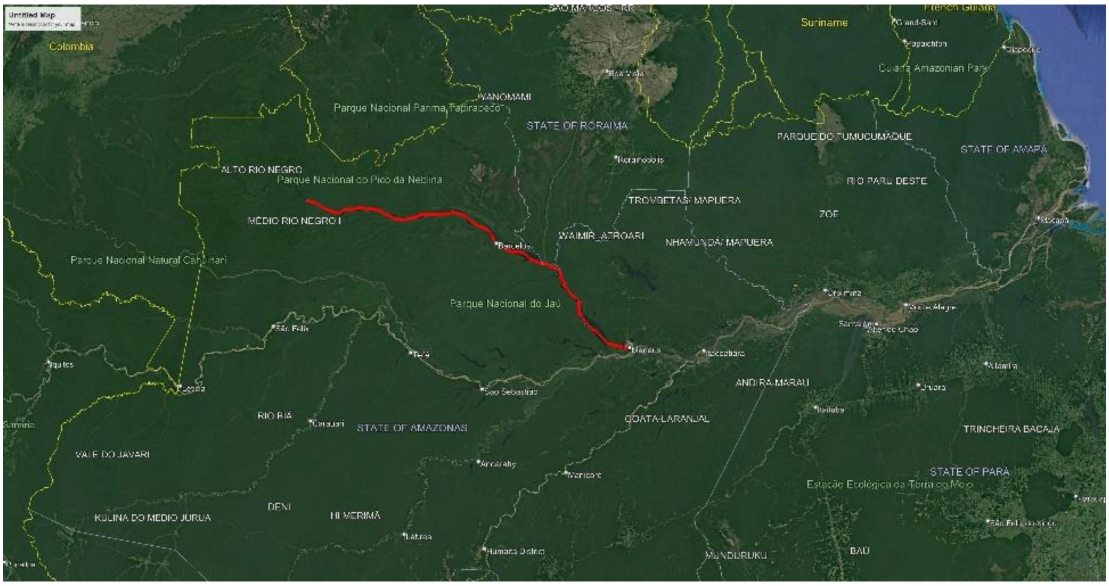


Figure 5.90 - Research ship and boat trajectory on the Rio Negro, from Manaus to São Gabriel da Cachoeira, in the Western Amazon.

State-of-the-art equipment was used (Table 2.1.1, Figure 5.91) to characterize physicochemical properties of aerosols, volatile organic compounds, and concentration of greenhouse gases, which will allow investigating dynamic processes involving biogenic emissions in this preserved region. In particular, unprecedented measurements of the isotopic fraction of CO_2 and CH_4 in the atmosphere and measurements of the flow of these gases between water and the atmosphere were carried out. This set of measurements will improve understanding of the contribution of different sources of greenhouse gases in the Amazon and investigate associations between biogenic aerosols and cloud properties.

Figure 5.91 – Instrumentation installed and operated on the research vessel for the FLOAT-CAFE-Brazil experiment.

Preliminary results show concentrations of gases and aerosols similar to those observed in the ATTO tower during the rainy season, after excluding any contamination periods. Excluding the periods of contamination when the ship was stationary or when there was a lull, the observed concentrations for gases and particles were comparable to background conditions in the Amazon: number of particles below 500 cm-3, NO2 <1.0 ppb and black carbon less than 1 ug/m3 (Figures 5.92 and 5.93).

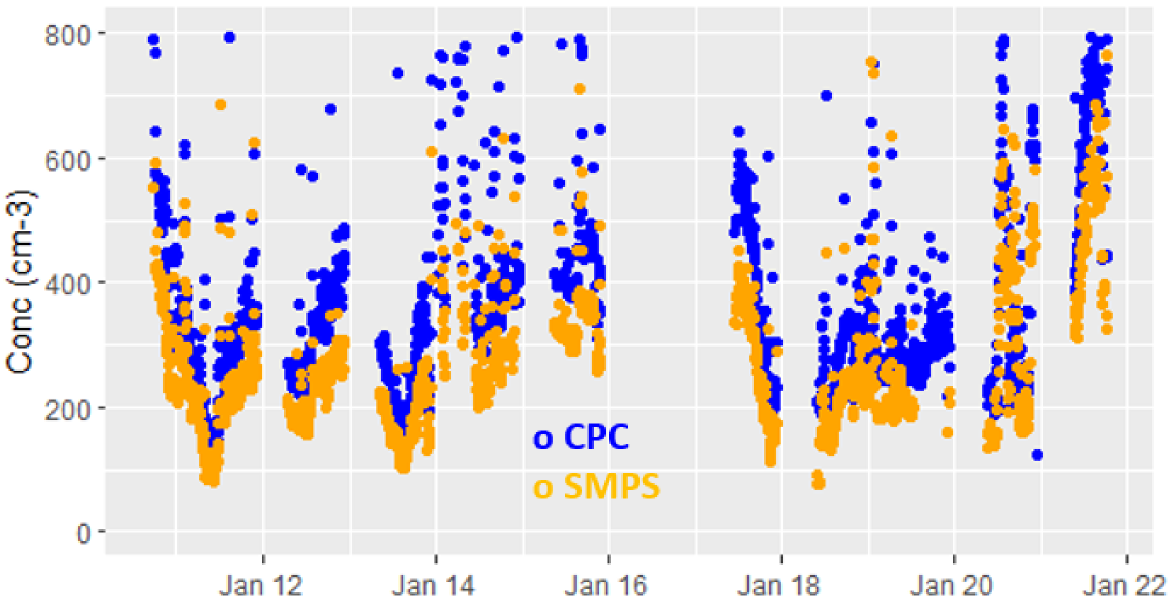


*Figure 5.92: Numerical concentration of particles meas*ured along the cruise from Manaus to São Gabriel *da Cachoeira on the Rio Negro.*

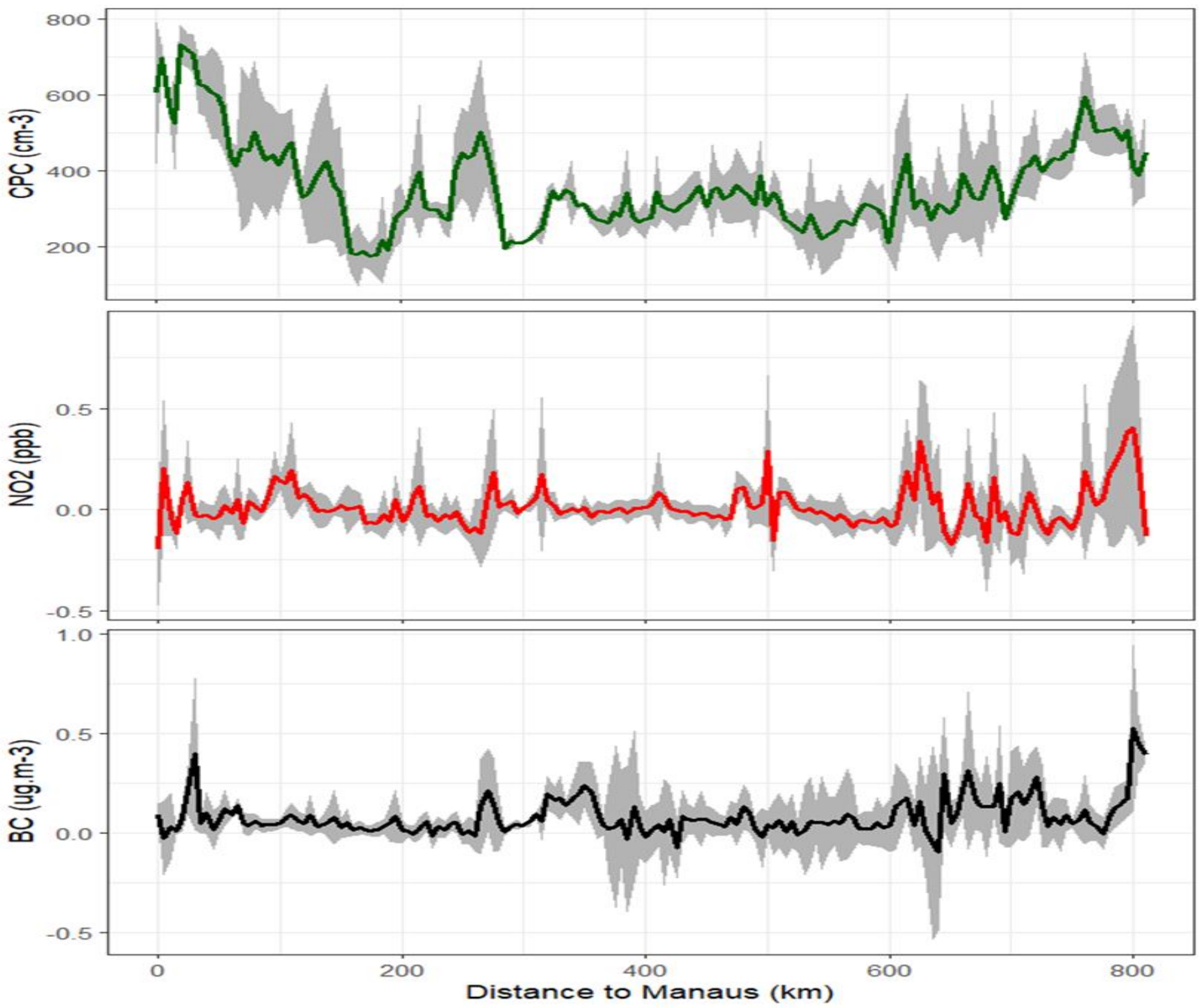


Figure 5.93 Numeric concentration of particles, NO2 and BC as a function of distance from Manaus, along the Rio Negro.

The average particle size distribution over the entire cruise (Figure 5.94) shows the prominence of the Aitken mode, indicating the influence of fresh particles, possibly of biogenic origin. On the other hand, the presence of the Hoppel minimum indicates that there may also be the influence of older particles, possibly processed in clouds. This size distribution format is consistent with what is observed during the rainy season in forest areas such as ATTO and ZF2. The correlation between the average diurnal cycle of O3 and the mass of submicrometric particles (Figure 5.95) reinforces the hypothesis of the production of secondary aerosols during the day. VOC data is being processed and will help to understand the dynamics of secondary aerosol production along the way.

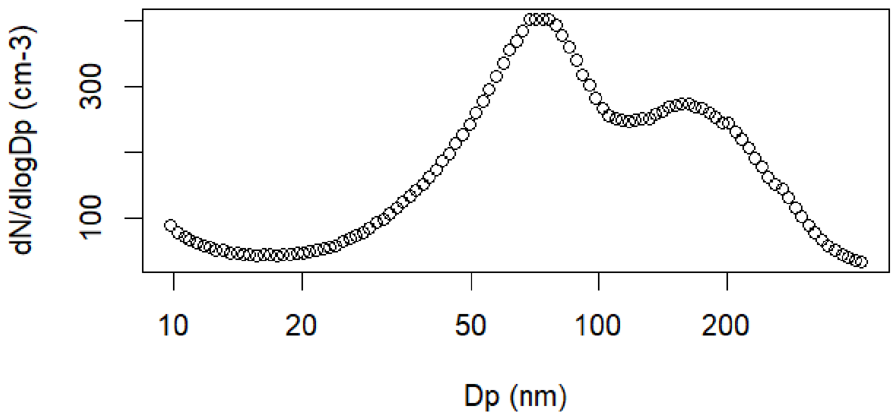


Figure 5.94: Mean particle size distribution in the Rio Negro.

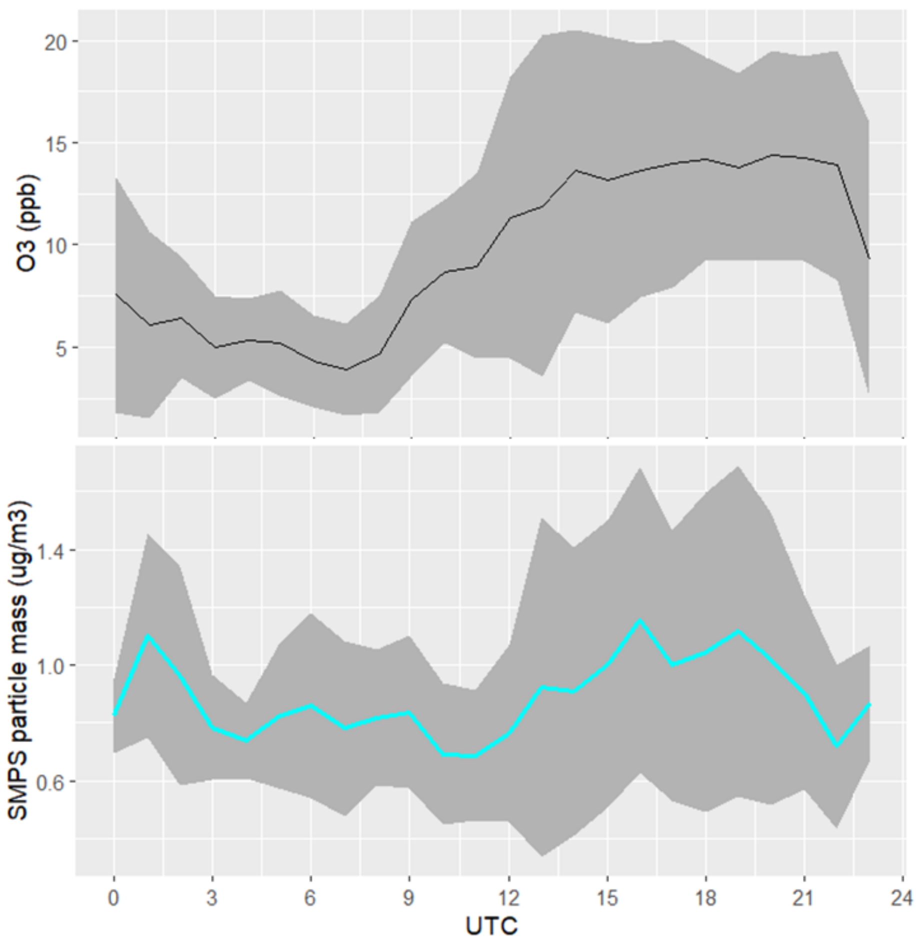


Figure 5.95. The mean diurnal cycle of O3 and mass of submicrometer particles observed along the cruise on the Rio Negro. Time in UTC corresponds to local time +4 h.

Finally, preliminary data from monitored greenhouse gases show CO2 concentrations typically between 400 and 440 ppm in contamination-free periods. CO2 concentrations showed a clear diurnal cycle, with high concentrations at night related to biogenic emissions (respiration) and boundary layer dynamics. Without a defined diurnal pattern, CH4 concentrations in the atmosphere varied between 1.88 and 1.92 ppm. Concentrations of CH4 dissolved in water were typically ten times higher than those observed in the atmosphere, suggesting that the river may act as a significant source of emissions. The isotopic ratio (□12C-CO2) was around -6 ‰, consistent with the atmospheric origin of CO2 molecules. On the other hand, during periods influenced by anthropogenic emissions near the port of Manaus, the isotopic ratio dropped to around -18 ‰. The data on greenhouse gases in the air and water are unprecedented for this region of the Amazon and are in the final processing stage (Figure 5.96).

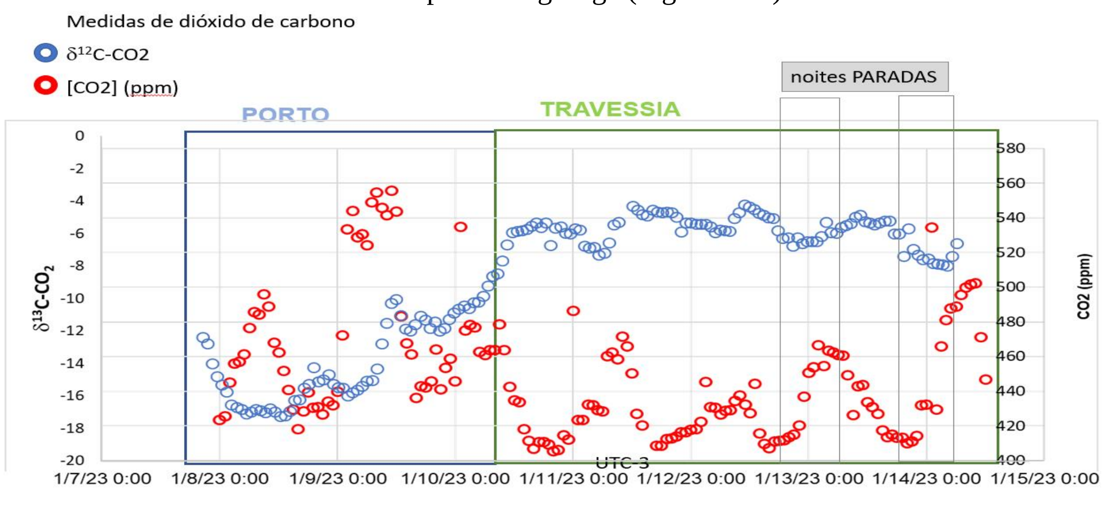


Figure 5.96: Time series of concentration and isotopic ratio of CO2 in the first days of the boat cruise of the FLAT-Café-Brazil experiment.

5.10.3 - Medidas sobre a composição orgânica e inorgânica do aerossol durante a campanha do FLOAT-Amazon.

There were no measurements of the aerosol's organic composition in the western Amazon region. We operate a Quadrupole Aerosol Chemical Speciation Monitor (Q-ACSM) for this. To complete the main species that make up the submicron particulate matter (PM1) data from the MultiAngle Absorption Photometer (MAAP) were used to estimate the black carbon equivalent, which will be called here just black carbon (BC).

To prevent the measurements from being contaminated by exhaust from the boat's engine and power generator, they were channeled to the bottom of the boat. However, depending on conditions such as wind direction and boat movement, contaminations are possible and observable through the sudden increase in gas concentrations (NO2) and typical diesel exhaust aerosols (BC). Therefore, the following results represent only PM1 concentrations without interference from this emission source (NO2< 2 ppb and BC<1 µg m-3).

On average, the concentration of PM1 was 0.89 µg m-3 with values ranging from 0.1 – 2.9 µg m-3, where the fraction of organic aerosols represents 85%, followed by BC (9%), sulfate (3%), ammonium (2%) and nitrate (1%), Figure 5.97. This composition, with a higher fraction of organics, was also observed in the ATTO tower (measured over 325m with the Q-ACSM, where organics represented 65% of the MP1, followed by 12% sulfate and 12% BC. However, the average concentration of MP1 was approximately half (0.4 µg m-3) of the measurement in the boat.

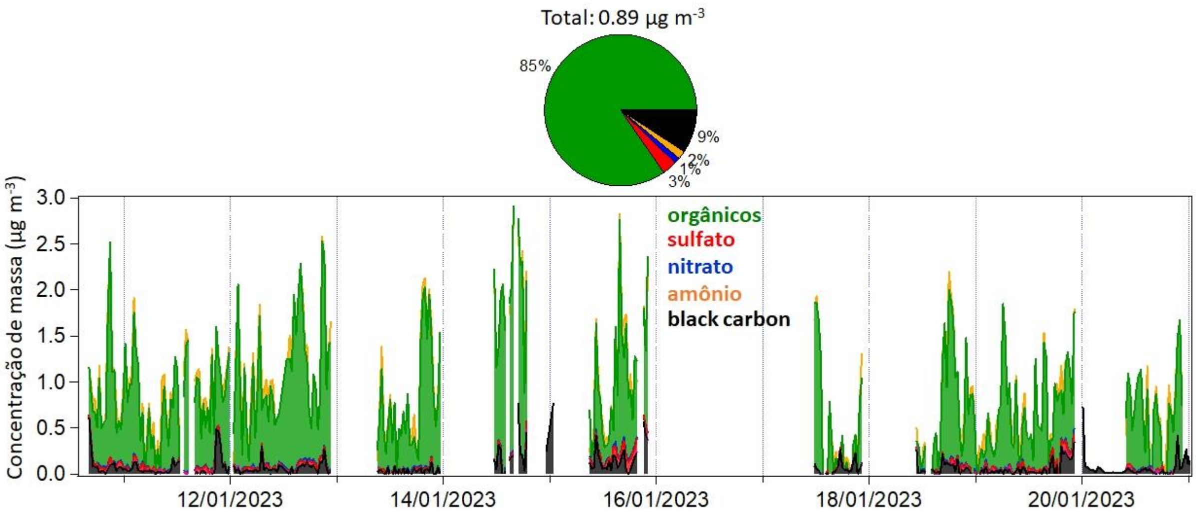


Figure 5.97 – Mass concentration of the main species that make up PM1: organics, sulfate, nitrate, ammonium, and BC measured during the period of the FLOAT experiment on the boat. The values presented correspond only to the period in which the boat was in motion.

The biggest difference in terms of mass concentration between the measurements of the boat and the ATTO tower is in the organics, Figure 5.98. In fact, the mass spectrum of aerosols measured during the FLOAT experiment shows a pattern of hydrocarbons, such as alkenes, cycloalkenes, and aromatics, quite different from the organic aerosols measured at ATTO. Another interesting aspect is related to the oxygenation of the molecules that make up the organic aerosols, while in ATTO, the aerosols present an aerosol character containing highly oxygenated molecules, indicated in Figure 5.99 by the black squares with high values of f44, a fragment marker of oxygenated molecules from organic aerosols. The aerosols measured during the FLOAT experiment, on the other hand, have lower f44 values, indicated by green circles, which are concentrated in the lower part of Figure 2.3.3, suggesting less oxygenated aerosols and, therefore, probably less processed in the atmosphere, that is, aerosols that were less time in contact with atmospheric oxidants, such as O3, OH and NO3 radicals.

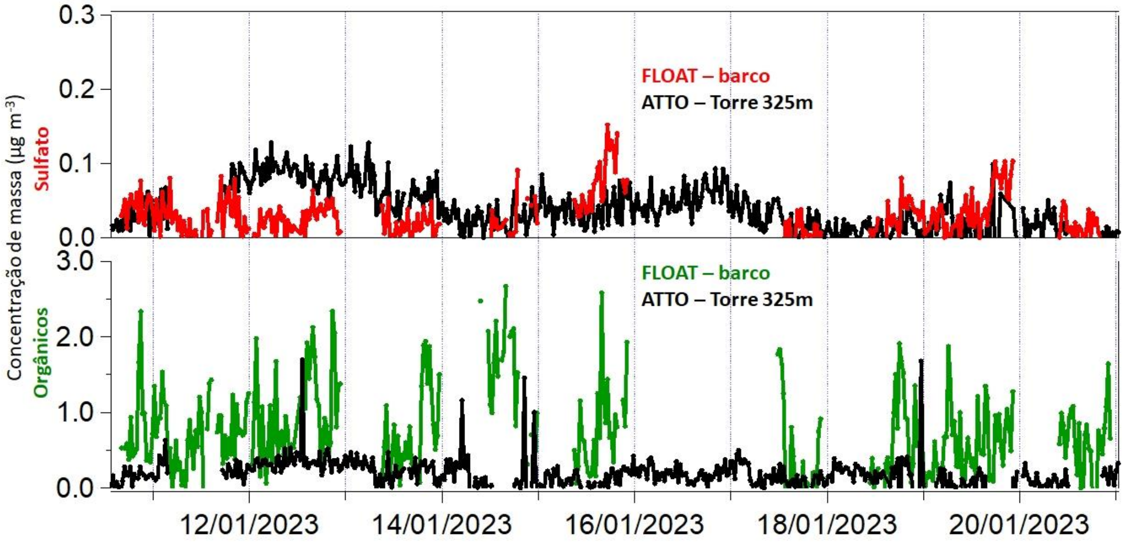


Figure 5.98 – Concentration of the main chemical species measured by the Q-ACSMs in the ATTO tower and in the FLOAT experiment (sulfate in the upper panel and organics in the lower panel).

The highest concentrations of organics during the FLAOT experiment may be related to distinct biogenic and anthropogenic sources. Among possible biogenic sources, emissions from the river itself can be mentioned, such as algae and other microorganisms, which, if present, can emit, under appropriate conditions, volatile organic compounds such as isoprene, monoterpenes, dimethyl sulfide and methanesulfonic acid. These gases, via chemical transformation processes can be converted in the atmosphere into secondary organic aerosols (AOS). Mass spectra are observed during the FLOAT experiment with the presence of fragments of biogenic molecules, such as, for example, isoprene-derived epoxy-diols, observed in mass fragment 82 (f82), however, it is observed that this quantity it is similar to that measured in the ATTO tower in the same period (Figure 5.100), which does not justify the two times higher mass concentration of organic aerosols found during the FLOAT experiment. Other biogenic fragments were not found.

Another possibility for the higher concentrations of organic aerosols during the FLOAT experiment is fugitive diesel emissions, i.e. evaporation of diesel-derived hydrocarbons from the power generator followed by rapid conversion to AOS via solar radiation, water, and atmospheric radicals. It is likely that the use of receptor models, such as positive matrix factorization (PMF) for example, will make it possible to separate the biogenic and anthropogenic organic fractions (Figure 5.101)

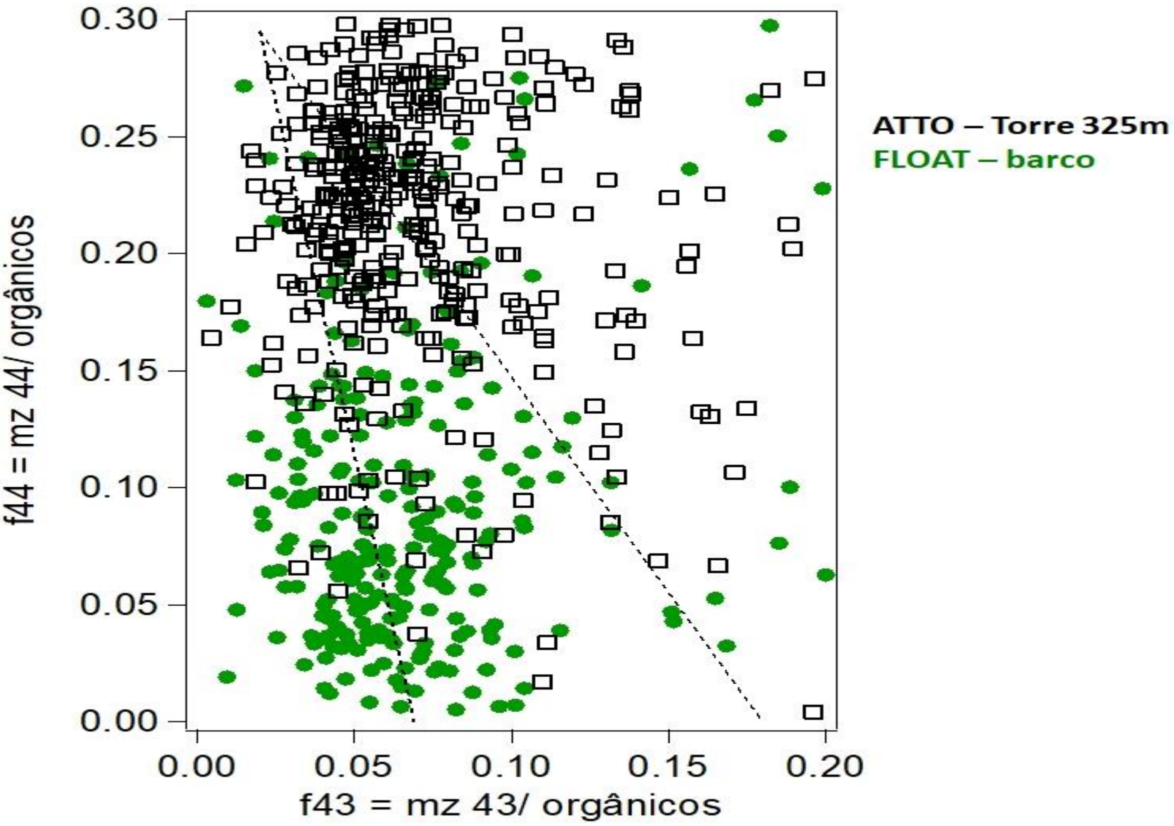


Figure 5.99 – Values of f44 and f43 measured in the FLOAT experiment (green circles) and in the ATTO tower (black squares) during the same period. The f44 fraction represents the abundance of fragments of more oxygenated molecules in organic aerosols, while the f43 represents less oxygenated fragments.

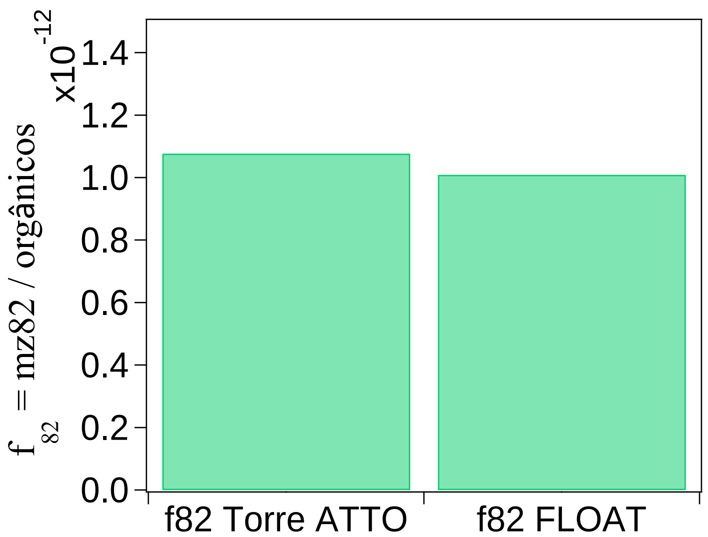


Figure 5.100 – Values of f82 for the ATTO tower and FLOAT experiment during the same period. These dimensionless values consist of the mass fragment 82 relative to the mass concentration of organics. This fragment is commonly found in organic aerosols derived from isoprene.

Figure 5.101 - Photos of the aerosol and gas inlets installed on the boat at the University of the State of Amazonas (UEA).

5.10.4 – Formation of new particles and vertical transport

Atmospheric aerosol particles are essential for cloud formation and precipitation, thus impacting the global energy balance and water cycle. However, the production of particles in pure environments such as the Amazon rainforest is still poorly understood. The formation of new particles can occur in the outflow at the tops of convective clouds and be transported downwards or they can form and grow from the oxidation of biogenic volatile organic compounds at low altitudes. In this study, we examine a comprehensive dataset of measurements of aerosols, trace gases, and meteorological parameters to assess the formation and growth of new particles in the Amazon rainforest. The results reveal that rainfall events are not only important for transporting particles through clouds but also for injecting ozone into the forest canopy. The concentration of near-ground particles increases with downdrafts, albeit modestly. However, another less frequent but more efficient process acts to increase the concentration of particles below 40 nm in size almost an hour after maximum precipitation. This phenomenon occurs due to downdrafts of ozone-rich air entering the canopy containing reactive organic species and consequently forming new particles. Especially on days when there was a high concentration of ozone the night before, these particles grow strongly in the early morning to form cloud condensation nuclei in the early afternoon.

On a planet that is changing its climate and a tropical forest being modified by land use, it is very important to understand the physicochemical processes that impact the evolution and formation of new particles in tropical forests. Furthermore, changes in the synoptic-scale circulation or El Nino/La Nina frequency will change long-range transport and downdraft, consequently changing Earth's rainfall pattern and radiation balance. Therefore, the ability to model these processes is key in forecasting tropical forest climate and analyzing feedback to global climate change. The Observatório da Torre Alta da Amazônia - ATTO has a new site for atmospheric physics measurements, the Campina site, equipped with radars, lidar, and ceilometers. These additional atmospheric measurements, combined with

measurements of reactive and non-reactive gases and particle size distribution, allow a complete view of physical-chemical processes and the analysis of the evolution and modulation of particle concentration. The main objective of this study is to show the physicochemical aspects of the growth of secondary aerosols or the formation of new particles, on the surface during rain events in the Central Amazonian forest in the rainy season, where the forest is closer to natural conditions. of a virgin forest without human influence.
We present below some of the results and the schematic conceptual model that describes the cycle of formation of new particulates.

Combining the particle size distribution with a wind radar profile, it was possible to assess how many particles are transported from upper levels to the surface during rain events. With the radar, it was possible to evaluate, during the wet period, the frequency of downdraft events and the total increase of nucleation particles of each downdraft. Two parameters were computed for each downdraft event: the time interval between the maximum downdraft and the maximum particle nucleation concentration and the additional effective increase in particle concentration associated with the downdraft event. Figure 5.102 shows the histogram of the distribution of the time interval between the two maximums and the total mean increase in particle concentrations. In most cases, approximately 30%, were associated with maximum particle concentration and almost simultaneous downdraft, reinforcing the hypothesis that downdraft is the main transport mechanism of particles from nucleation in the free atmosphere to the planetary boundary layer. However, these events contribute only to a small increase in the nucleation concentration of particles of the order of 10 cm-3. However, it can be noted that the maximum increase in concentration (6 times greater) occurs later, around one hour after the maximum rainfall intensity. These cases show a secondary increase in case frequency (15%). This result shows that different processes occur in the formation of new particles. These are the most frequent cases associated with vertical transport, but this process contributes to a very small increase in the concentration of nucleating particles. Growth after one hour is associated with a consistent increase in particle concentration below 40 nm. The reason for this increase may be associated with particles forming from a series of reactions forced by the increase in ozone concentration and oxidation reactions within the canopy of trees. The average concentration of ozone is higher when we have the maximum increase in nucleation particles, corroborating the proposal that ozone is a key element for the growth and formation of new particles in the Amazon.

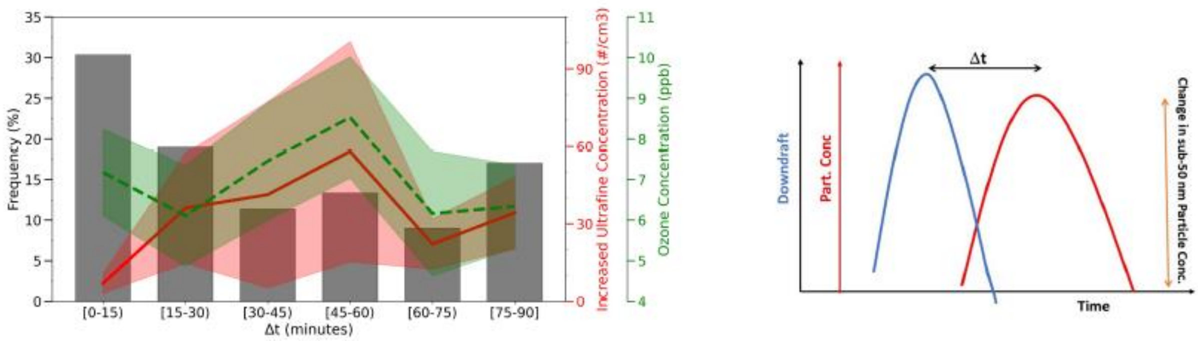


Figure 5.102. Histogram of the frequency of occurrence of the different time intervals between the maximum.

Figure 5.103 shows a schematic view of the processes that occur during rain events below the canopy of trees. Knowledge of this feedback mechanism between precipitation and gas concentration is very important on a planet with a changing climate. The formation of nucleation particles that later form cloud condensation nuclei may be related to rainfall events. One mechanism, the most frequent, albeit with a small impact on nucleating particle concentration, is associated with vertical particle advection from the upper troposphere. The second mechanism, less frequent but with much more impact on nucleation particle concentrations, is controlled by the high ozone content injected into the tree canopy by convective currents, followed by a chain of reactions within the tree canopy, producing organic particles and increasing the concentration of nucleating particles. The mechanism of the growth process in the morning is indirectly associated with convective clouds. At sunrise, during days followed by ozone-rich nights, photooxidation produces an intense growth process. A large amount of ozone injected into the tree canopy by rain is confined to the nocturnal boundary layer during the night, favoring aerosol oxidation and the oxidation of organic compounds at dawn. The aerosol particles near the canopy of trees are basically organic particles that grow into the Aitken mode throughout the day.

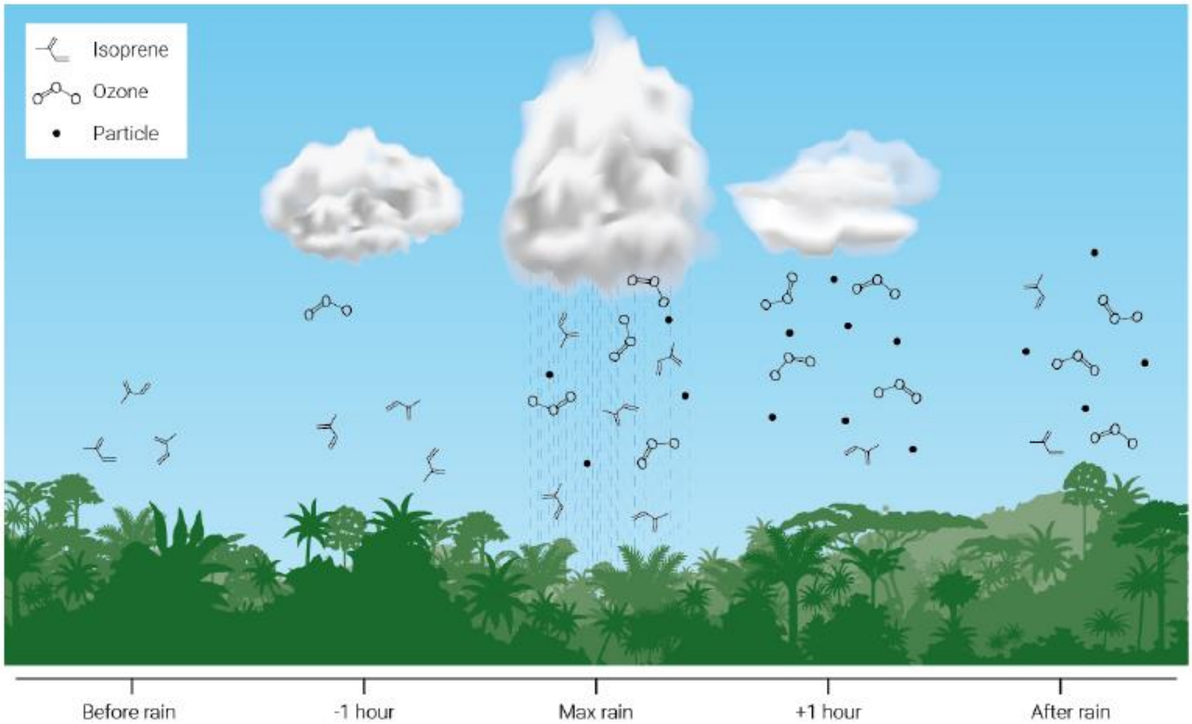


Figure 5.103. View of ozone, VOC (Isoprene-Monoterpenes), and particulate concentrations before and after the maximum rain rate.

This study combines different measurements collected on the ATTO website to study how meteorological events modify gas concentrations. A gas-concentration-analyzer measures the concentration of CO_2, CH_4, and CO; the Licor instrument measures the concentration of O_3, NO, and NO_2, and the PTR-ToF (Proton Transfer Reaction Mass Spectrometry - Time-Of-Flight) measures components volatile organics. Measurements were collected at the Instant Tower, a tower adjacent to the ATTO tower with 80m. Data were collected at different levels within and above the canopy of trees. The weather station at the top of the tower measured precipitation and various weather variables. Data collection covered the period from 2012 to 2020, although some instruments were collected in shorter periods. The 30-minute resolution data were combined to describe interannual, seasonal, and daily variability and relationships with precipitation. The gases were analyzed before, during, and after the rains.

This analysis provides a quantitative description of the variability of greenhouse gases, volatile organic compounds, and reactive gases, with height and meteorological forcings. CO_2 and CH_4 show an annual concentration increase with a well-established linear trend. However, CO, a reactive gas, does not have a well-established trend between years, and the variability is mainly associated with precipitation. CO concentration increases during dry years and decreases slightly during wet years. Regarding seasonal variability, CO_2 and CH_4 have the lowest variability throughout the year compared to the other gases analyzed. For CH_4, the maximum occurs in August, around two months after the maximum elevation of the Amazon River, and the minimum occurs at the same time as the minimum elevation of the river, around October/November. CO has a maximum concentration between the August/November season in the dry period when the boundary layer reaches the highest altitude, the average temperature is highest and the highest frequency of occurrence of fires. Nitrous oxide increases from January to October with a similar behavior with temperature. NO_2 has an almost unchanged behavior in concentration throughout the year until November, when it increases sharply. This is the period of maximum electrical activity in the region that is closely linked to NOx production. Ozone has the greatest seasonal amplitude, with a maximum during the dry season, the most polluted season, and a minimum during the rainy season. The anthropogenic effect of fires is stronger than the increase in ozone concentration produced by rainfall during the rainy season (Figure 5.104).

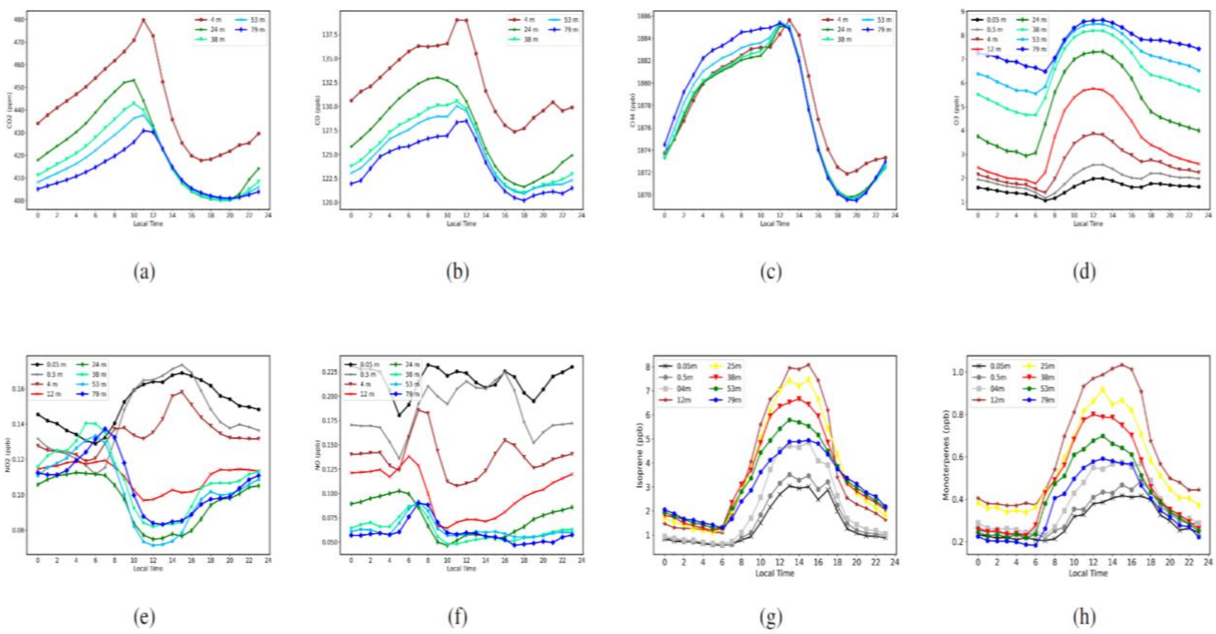


Figure 5.104 – Diurnal variability of CO2, CO, CH4, O3, NO2, NO, Isoprene and Monoterpene measured in ATTO at different heights.

The analysis of the diurnal cycle of these different gas concentrations allows us to detail the effect of climate on the modulation of the concentration of different gases (see Figure 2.10.3). During the night, CO2 is a highly stratified gas below the canopy of trees, the concentration increases linearly during the night, due to emission by trees, with a maximum concentration near the surface. In the afternoon, when the convective boundary layer is well developed, and precipitation begins, the CO2 concentration homogeneously decreases until late afternoon. The concentration of CO varies similarly with CO2, with almost the same vertical gradient. CH4 is less stratified than CO2, and peak concentrations occur about an hour later. CH4 is produced and accumulates overnight near the surface. When the convective boundary layer develops, surface flows intensify and CH4 rapidly diffuses to the upper levels. Normally, the soil is a CO sink due to methane oxidation. Solar radiation, one of the main forces of these gases, takes about two hours to reach the surface and may explain the phase difference between the decrease in concentration on the ground and just above the tree canopy. The ozone has a strong stratification with height during the day and presents a diurnal cycle with nocturnal minima and maximum during the day. Ozone concentration increases with sunrise, reaching a maximum in the early afternoon. The maximum concentrations are at the upper levels. Convective events bring in ozone-rich air, increasing concentration during the afternoon.

The variability of VOCs throughout the day makes it possible to establish the most important characteristic of the atmosphere associated with the sources and sinks of isoprene and monoterpenes. Measurements of isoprene within the canopy show the source of isoprene and monoterpenes in the tree canopy. The concentration at this level is about six times higher than at the surface. Isoprene concentration decreases from 2 pm LST until sunrise; overnight concentration is poorly stratified. This reduction in concentration is stronger during the day than at night, indicating that two processes are acting to reduce concentration. One is associated with solar radiation, and the other occurs mainly in the afternoon and is related to the process of rain formation. Maximum daily concentrations at 14 LST correspond to the moment of maximum temperature and boundary layer height. In the afternoon, around 4pm LST, there is a significant reduction in isoprene concentration below the canopy of trees, likely associated with oxidation and particulate formation during rain events. Monoterpenes vary during the day, similarly to isoprene, with greater stratification at night.

The composite analysis of the gas concentration before and after the rains, during the day, and at night, allows evaluating the variability of the concentration as a function of precipitation. CO2, CO, and CH4 decrease with rain, probably related to clean air injected into the boundary layer from the upper levels. Carbon dioxide and carbon monoxide are more stratified with height than CH4. An increase in ozone concentration is observed during precipitation events. The maximum occurs almost an hour later than the maximum precipitation. Nitric oxide shows less variability at higher levels than below the canopy of trees; the concentration is strongly reduced after maximum precipitation. On the other hand, Nitrogen Dioxide has an increase in concentration close to the surface, around one hour before the rain until around two hours after the maximum rain. The forest produces new particles after the occurrence of precipitation. The formation of new particles can be associated with a series of reactions that occur inside the canopy of trees involving NO, NO2, O3 and VOC gases. Figure 5.105 shows how monoterpenes and isoprene evolve during rain events, both day and night. During the day, when there is VOC production, rain reduces the VOC concentration, probably due to reduced temperature, radiation, and consumption to produce new particulates. At night, the effect is the opposite, rain increases the concentration of VOC on the surface. Since there are no sources at night, the increase in VOC may be due to VOC stored in the clouds and brought by the downdraft, by turbulence in the treetops which favors the release of monoterpene and the higher concentration in the residual boundary layer.

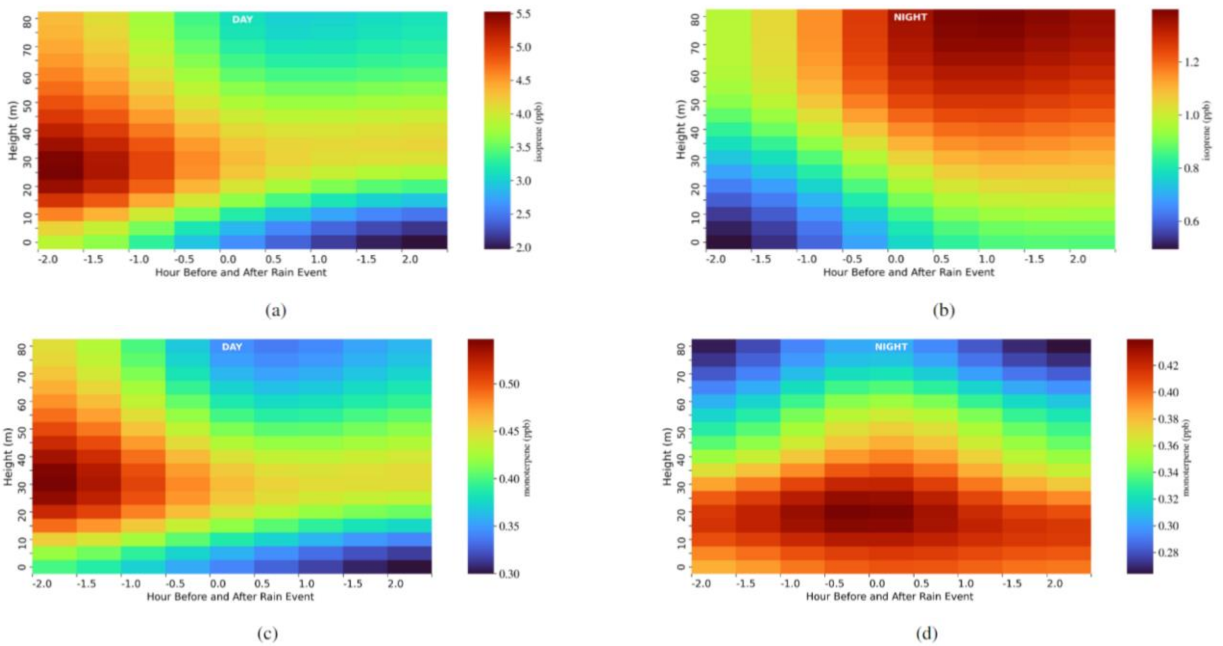


Figure 5.105. – Composite analysis of isoprene during the day (A), and night (B), monoterpenes during the day (C) and during the night (D), for two hours before the maximum rainfall rate until two hours after. A rainfall event was considered as an event within a 10-hour window with at least one moment with a rainfall rate greater than 0.5 mm.hr-1. The calculation was made for all cases from January 2018 to December 20.

5.10.5 The role of protected areas in water regulation in anthropized Cerrado basins

Changes in water regimes impact human societies aquatic and terrestrial ecosystems. Periods of prolonged drought, for example, stimulate the temporary transition of the electricity matrix to high-carbon sources, as burning fossil fuels and biomass is an alternative to preserve water in reservoirs, thus intensifying climate change. Other possible effects of drought are increased risk and severity of forest fires, deregulation of ecological interactions, for example, between plants and pollinators, and transition from perennial to intermittent rivers. On the other hand, increased precipitation or the concentration of precipitation in fewer, more intense events accentuates the transport of sediments and solutes into watercourses, potentially harming biodiversity and energy generation. Some of these impacts interact and even act in positive feedback, potentially intensifying over time.

The water security of ecosystems and human societies are, therefore intertwined. While some measures aimed at preserving water resources benefit both parties, such as pollution control, other measures to specifically ensure human water security, such as the transposition of rivers or the transition of the energy matrix, directly and indirectly, harm biodiversity. Therefore, water issues must be addressed in an integrated manner, considering human water security and environmental conservation.

The Cerrado is a remarkable example that food, energy, and water security are intrinsically connected. Here, we assessed the role of protected areas as a tool for conserving water ecosystem services locally based on hydrological modeling and spatial analysis.

Activities

A sub-basin of the Alto Jequitinhonha in Minas Gerais, was selected for the study. In addition to the presence of conservation units and the availability of a long historical series of flow and precipitation, we chose this basin because it is in a hotspot region for temperature increase due to land use transition patterns, as assessed by Rodrigues et al. (2022). In addition, the basin is also situated in a transition area between the Cerrado, the Caatinga, and the Atlantic Forest, which implies more site-specific conditions.

The Soil and Water Assessment Tool (SWAT) hydrological model was selected to assess water dynamics. It is well-established, in use since the 1990s, and has a large community of users in Brazil and worldwide who provide accessible and democratic support. SWAT was developed to "predict the impact of land management practices on water, sediment and agricultural chemical production in large, complex catchments with various soils; land uses and management conditions over a long period". Initially, the model separates the basin into sub-basins and hydrological units, aggregated areas in each sub-basin with a unique combination of slope, soil, cover, and management.

The driving force of the model is the water balance, and it operates in two phases: the land phase, which controls the amount of water, sediment, and chemicals moving from the land into the channels, and the routing phase, which assesses the transport of all these elements through the tributaries to the outlet.

Compilation and preparation of input data

Tables 5.20 and 5.21 describe the input maps and hydro-climatic data used by the model and their source and characterization.

Table5.20. Input Maps

Input	Source	Scale/Resolution
Relief	SRTM NASA v3	1 arc/seg (~30 m)
Land Use	MapBiomas 7.0 (2021)	30 m
Soils	IBGE (2021)	1:250.000

Table 5.21. Input data

Input	Source	Identification
Climate	CFSR e CFSv2	ds093.1 e ds094.1
Precipitation	ANA	1643037 – “Nova Esperança” 1643038 – “Juramento” 1743002 – “Vila Terra Branca - Jusante” 1843002 – “Gouveia” 1843003 – “Mendanha - Montante” 1843011 – “Serro”
Discharge	ANA	54010005 – “Vila Terra Branca Jusante”

In addition, in studies in the central Cerrado region, cover parameters were defined from a combination of values from Strauch & Volk (2013) and Ferrigo (2014). Soil parameters were compiled from the Embrapa database, the available water capacity map of the National Water and Sanitation Agency, and values obtained from the pedotransfer function of Saxton & Rawls (2006), when unavailable from other sources. It is important to note that, at this stage, a file of PronaSolos soil sampling points was combined with Embrapa profile characteristics files to obtain a more generalized overview of soil data from Brazil, more specifically from Minas Gerais, to reduce the model error. The script that was generated in the process will be published on GitHub.

Filling empty records

The filling of empty records was done from the Weather Generator, an extension of the SWAT model specifically used to generate statistics of the observed climate data and replace any unobserved data.

Simulation

The programs used for the simulation were: QGIS (version 3.16.16-Hannover) and QSWAT3 (version 1.6.3) (Python version 3.7). During the configuration of the model, the following values were set in order of execution:

i. "Stream threshold: 50,000 km2 (45 cells);
ii. "Merge small subbasins": 10% of the mean area;
iii. "Elevation bands": 0-8, 8-20, >20;
iv. Extra settings in .gw files as per Strauch & Volk (2013); and
v. "Warm-up period": 5 years.

Sensitivity analysis

The parameters were chosen based on the study by Silva and Christofaro (2017) of a sub-basin adjacent to this study in the Alto Jequitinhonha region.

Manual calibration

It was necessary to change some parameters manually to build a more realistic model before the automatic calibration. This was done following the indications of Abbaspour et al. 2015 to decrease the peak flow, and the values used in each parameter were:

i. CN2 * 0.9
ii. SOL_AWC * 1.1
iii. ESCO * 0.9

Calibration and validation

Calibration and validation of the model were performed semi-automatically using the SUFI-2 algorithm in the SWAT-CUP 2012 program (version 5.1.6.2). The period covered in each step was defined based on data availability and the indications of Klemeš (1986) - about 2/3 of the historical series for calibration (1980-2004, of which five years were for warming) and 1/3 for validation (2005-2021, of which five years were for warming), as indicated in Figure 5.107.

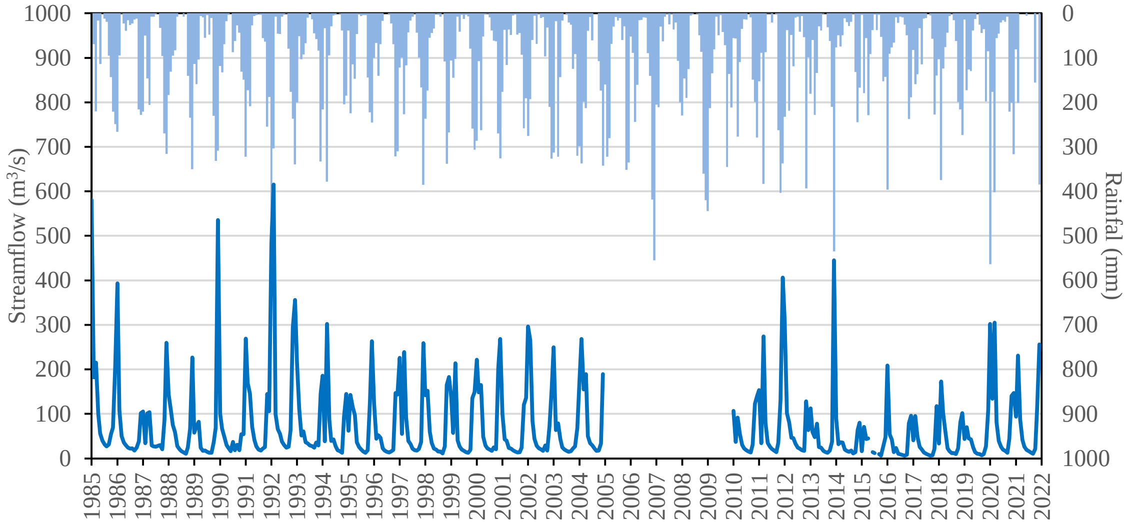


Figure 5.107. Precipitation and flow in the Alto Jequitinhonha sub-basin during the calibration and validation period (disregarding the years used for warming).

Partial results

The calibration of the model achieved very satisfactory statistics, as well as the validation, as seen in Table 5.22 and Figure 5.108. This result confirms the suitability of the input dataset used (including the soils refined in this work for the state of Minas Gerais) and increases confidence in the hydrological components that will be evaluated in the following stages of the project.

Table 5.22. Statistical values of calibration and validation iterations.

	Calibration	**Validation**
No. of simulations	1000	1000
No. of valid simulations	561	339
p-factor (valid simulations)	0.98	0.88
r-factor (valid simulations)	0.98	0.65
R2	0.87	0.86
NS	0.87[3]	0.86[3]
PBIAS	0.3[3]	-0.1[3]
Mean simulated (observed)	81.31 (81.53)	61.07(60.98)
Simulated standard deviation (observed)	92.79 (97.31)	72.51(76.03)

Legend: 0 Unsatisfactory; 1 Satisfactory; 2 Good; 3 Very good (Moriasi et al. 2007).

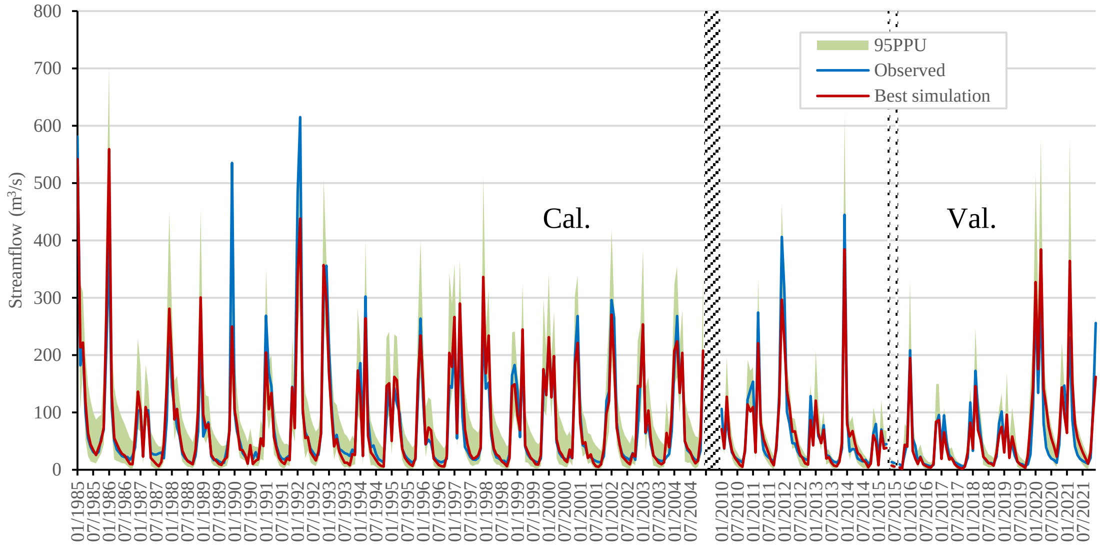


Figure 5.108: Observed and simulated flow in the model calibration and validation years. The hatched bars represent periods of data absence due to model warming or lack of observed records.

Final considerations

Once a suitable model has been achieved, the following steps will be to evaluate each hydrological component in the basin context, considering the different soil types, land use, and hydrological patterns observed over time. This will allow us to judge whether the configuration of protected areas in this basin also has a role in water cycle conservation compared to non-protected areas. In addition, it also opens up the opportunity to analyze more basins in other regions of the Cerrado. More specifically, it is planned to study a basin in the western region of the biome, where Rodrigues et al. (2022) identified hotspots of decreased evapotranspiration. Thus, considering all its heterogeneity, we will build an increasingly accurate picture of the biome.

5.11 Synthesis and integration phase

The production and supply of energy and food are the main sectors that can be affected by the increase in CO2 emissions and that eventually drive climate change globally. The water-energy-food sectors are vulnerable to climate variations and changes, and some adaptation measures can be very needed in the energy sector. For example, irrigation, that requires more energy than agriculture upland; desalination, which requires more energy than conventional water supply; It is increased use of groundwater storage and superficial, which may require more energy to additional pumping. This perspective is related to the approach of the Nexus+, with the availability of water at play a leading role in the relationship water-energy-food security. In addition production of water, energy and food is essential to achieve other development goals sustainable, such as health and wel being, reducing poverty, gender equality, economics and conservation of ecosystems and biodiversity.

In this way, many of the initiatives started and/or carried out from the National Plan of Adaptation - PNA have the potential to contribute to development, especially for the advancement of the goals and targets outlined in the 2030 Agenda, the called Sustainable Development Goals- ODS. The SDGs are part of a global agenda, with a set of goals for the development sustainable and a monitoring structure to be carried out through annual reports to the UN. The SDGs were formulated through a process participatory, including civil society, industry, private sector and local bodies, as part of the Agenda 2030 of the United Nations – UN for the period 2016-2030 and apply to all the countries. The 17 individual goals represent different elements of sustainability, demonstrating the complexity of each goal and its interdependencies.

According to the UNFCCC, the integration of the adaptation of the Paris Agreement (in the Brazilian case, the PNA) and the 2030 Agenda for Development (SDGs), with the Sendai Framework for Disaster Risk Reduction, must provide a basis for sustainable, low-income development carbon and climate resilient.

Objectives and Methodology

The first objective is the thematic integration of INCT-MC components: Food security; Water security; Energy security; Health and climate change; Natural disasters, impacts physical infrastructure in urban areas and urban Development; Impacts on ecosystems Brazilians due to changes in the use of land and biodiversity; Economy and impacts on key sectors; Earth system modeling and production of future climate scenarios for study vulnerability, impacts, adaptation and resilience; and communication, dissemination of knowledge and education for sustainability, considering the interrelationships, through content analysis, in a integrated and transversal perspective.

The second objective starts from the necessary integration with the SDGs, based on a cross-sectional analysis among the main themes of scientific production of each of the components and the SDGs, indicating possible synergies and trade-offs. For achieve both objectives, the production will be used scientific, materialized by articles published in the 2020-2023 period of each of the components, as well as investigation reports. must be consider that there are goals that the United Nations defined that they do not apply to Brazil.

Figure 5.109 shows a subjective view of how INCT-MC2 components fit into the ODS. While all components act on the ODS-13 on climate, some work on other SDGs directly or indirectly, whether in matters of water, agriculture, economy and poverty, health, cities or in more integrative themes such as, for example, Earth system modeling. This component generates future climate scenarios that can be applied in studies of impacts, vulnerability, adapting and building resilience to changes of climate. The climate change scenarios generated by the climate modeling component and scenarios of the INCT-MC2 could be listed in several SDGs.

For example, considering SDG-16 on peace, justice and effective institutions, climate extremes related to water stress can generate situations of dispute over water between states. That happened during the 2014-2016 drought and water crisis in Southeastern Brazil. The governors of Sao Paulo, Minas Gerais and Rio de Janeiro were "strange" in the dispute over the waters of the Paraíba do Sul river. Forecasts future persistent droughts over large areas of the country can become triggers for conflagrations regional/national and to avoid or resolve these situations we need effective institutions that they may act with peace and justice, considering Future scenarios of water availability and better plan the distribution and use of water.

The health component deals with “outcomes” (outcomes) and not exactly with strategies impact reduction. Therefore, this component has association with SDG-9 as a logical and necessary consequence of knowledge acquired on climate/health relationships. Even if this component does not work with “communication”, it provides the subsidies for others to do so. On the other hand, part of the research of this component has been mapping the impacts of disasters climate change in health, which highlights the relevance of SDG 5. The component of natural disasters and cities, SDG 14 and 15 are also relevant, when we think of coastal cities and solutions based in nature to urban centers.

The energy component has to do with SDG 11 which aims, by 2030, to reduce the environmental impact negative per capita of cities, including paying special attention to air quality, municipal and other waste management; by 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans for inclusion, resource efficiency, mitigation and adaptation to climate change, disaster resilience; and develop and implement, in accordance with the Sendai Landmark, Disaster Risk Reduction 2015-2030 and holistic risk management of disasters at all levels. This component energy also contemplates SDG-12 with the goal of by 2030, to achieve sustainable management and efficient use of natural resources; To encourage companies, especially large companies and transnational, to adopt sustainable practices and to integrate sustainability information in your reporting cycle; Support countries in development to strengthen their capacities science and technology to shift to standards more sustainable production and consumption (from energy resources).

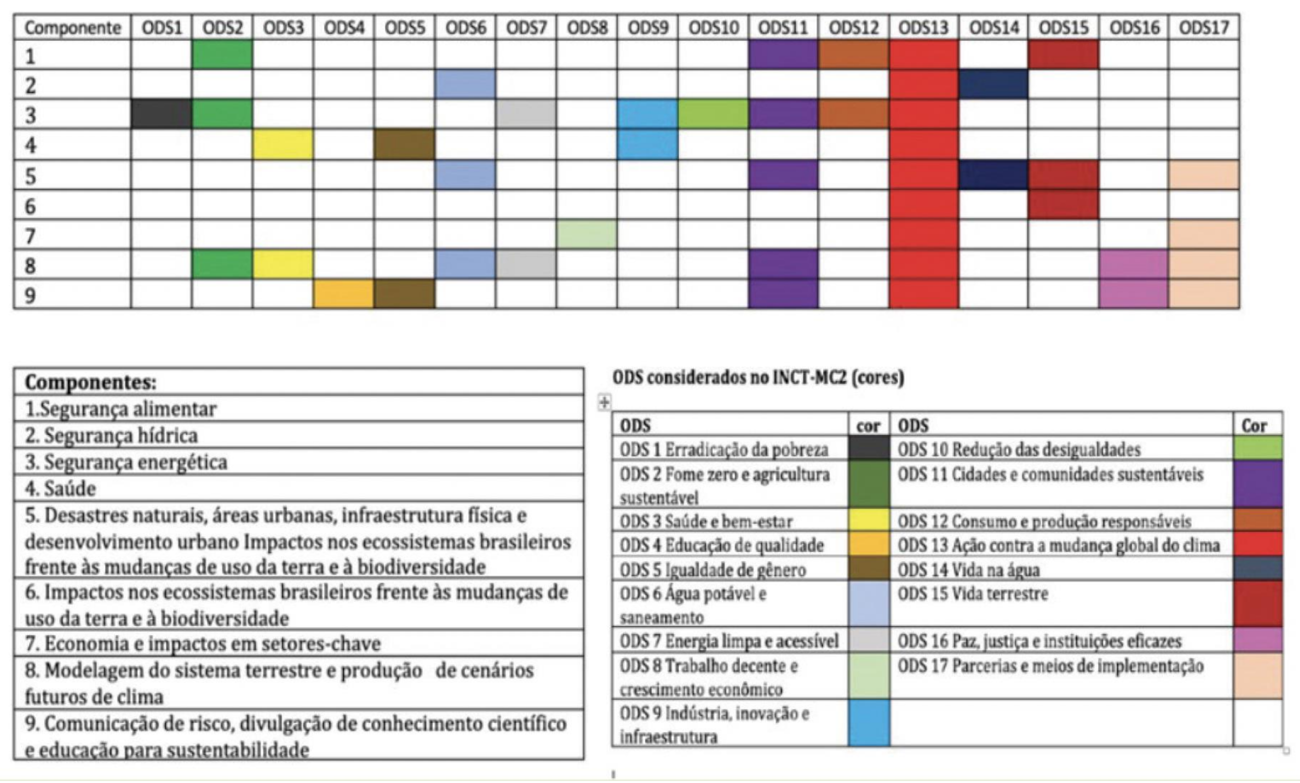


Figure 5.109. List of SDGs that are relevant to the different components of the INCT-MC2 project.

6. Integration among components of the project in Year 6

The experience gained at the INCT-MC2 in the period 2020-2023 can be evaluated from the degree of interdisciplinary synergy in S&T and its continuity Social. Internally, the INCT-MC2 values this synergy in the integration between Subcomponents and Cross Axes. On the one hand, this synergy is accelerated in the Security Subcomponents Food, Water Security, Security Energy, Health, Impacts on Ecosystems Brazilians in view of changes in land use and Biodiversity, Natural Disasters, Analysis Integrated for Policy and Decision Making Public. Also, the synergy is strengthened in the Transversal Axes of Economy and impacts on highlighted sectors, Communication, Disclosure, Education and Modeling of the Earth System and Production of Future Scenarios (Figure 5.110).

On the other hand, in the period 2020-2023, the INCTMC2 Subcomponents and Transversal Axes brought global recommendations for the federal, state and municipal levels in the Brazil. For example, the INCT-MC2 incorporated the intergovernmental S&T recommendations arising from IPCC/AR6, UNESCO-IHP IX 2022- 2029, UNEP WWQA/GEMS, WMO Strategic Plan, IBPES and Conferences of the Parties (COPs). Of this interdisciplinary synergy, the INCT-MC2 promoted these actions:

1- Synergy and Interdisciplinary Dialogue with other INCTs, eg. the INCT Observatory National Water Security and Adaptive Management (ONSadapta) and the INCT-Combate à Fome, supported by Nuclei of Research Support (NAPs) from INterdisciplinary CLimate Investigation cEnter (INCLINE), Center for Education and Research on Disasters (CEPED/USP) and the UNESCO Chair on Waters/USP, via campaigns of scientific popularization initiated by the INCT-MC2 entitled #UmaGotaDeSciencia #UmaDoseDeResiliencia.

2-New Interdisciplinary S&T Groups, via “EDI” principles (“Equality”, “Diversity” and “Inclusion”) promoted within the INCT-MC2, among them: from the “Institute of Advanced Studies” IEA/ USP Planetary Health”, from the FAPESP CEPID de Pesquisa project, Dissemination and Innovation of FAPESP (CeMEAI-“Applied Maths for Industry”), the Center for Research in Engineering on Intelligence Artificial Intelligence (C4AI-“Artificial Intelligence”), the FAPESPBelmont project Forum on Risk Management and Social Resilience (MADIS- “Management of Disaster Risk and Societal Resilience”);

3- Cooperation of Educational Accelerators (“Cooperative Game- Changer”) in the form of interdisciplinary alliances on themes inspired within the INCT-MC2 aiming at new related projects o various SDGs, e.g., “Coevolutionary Amazon Health & Sanitation“, or “C.A.S.H. Paradox, targeting Green Water Infrastructure/ Blue/Gray by 2035 (ca. BRL 190 billion), to be discussed in 2023 IUGG Berlin, the “BRazil’s Offset of Net-Zero Emissions toward GOals for Leveraging Development”- “BRONZE-2-GOLD”, where it will be presented a new renewable energy cogeneration matrix and multipurpose of the more than 22000 reservoirs of fresh water in the National Territory, with a total of 6.1 x 107 km3 storage, and the “Recycling Water Assets for Sustainable Habitats”, ReWASH, feasible to adapt in >40000 disaster risk areas in the National Territory;

4- New Demonstration Pilot Projects, highlighting nature interdisciplinary of INCT-MC2, e.g., the “FAPESP-NSFChina Sustainable Development International Cooperation ** Flash Droughts Under Climate Change, FACEPE-FAPESP ** Global change, sustainable development with WEFE viability and the IAHS proposal 2023-2032 New Scientific Decade (**: without BC FAPESP);

5- FAIR Data Management (Findable, Accessible, Interoperable, Reusable), with the cooperative use by the INCT-MC2 of various datasets on risk management resiliency provided by IAHS Panta Rhei benchmark dataset with socio-hydrological data of paired events of floods and droughts, the UNESCO-IHP-IX Operational Plan (2022-2029), the IWA ‘Earth Observation for water management’ Community of Practice, and databases in National Territory made available by PNSH/ANASB, CAMELS'BR and CABra;

6- New E-Learning Centers and Adaptation to Change Courses Climate in Brazil, via S&T partnerships established by the INCTMC2 for the 2023 UN Water Conference, with the support of ABRHidro-Technical Committee on Education and Chair UNESCO and UN Global Water Data Portal.

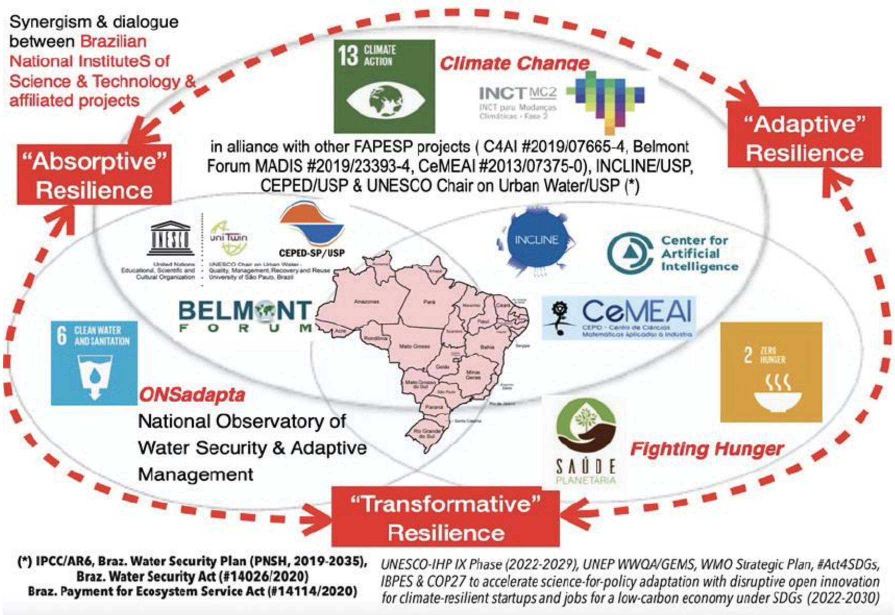


Figure 5.110 **-** *List of SDGs that are relevant to the different components of the INCT-MC2 project.*

7. Plans for Year 7 of the project

Plans for the seventh year include further approximation with researchers from the subcomponents natural disasters, water Security and human health, to further develop joint projects. The contribution of the INCT MC2 was fundamental for the development of the studies on impacts, vulnerabilities and adaptation for the upcoming 5th National Communication (5CN) to UNFCCC.

7.1. Human health

Continuing the studies in the Southeast Region, it will be analyzed in addition to the states of Minas Gerais and Rio de Janeiro, in which some important project data were obtained, the states of São Paulo and Espírito Santo, thus completing the states of the Southeast Region of Brazil, so the spatial distribution of will be analyzed *Lu. longipalpis* and *Mg. migonei* in three time frames (historical, current and future) considering climate change scenarios, where the results may fill gaps in relation to the geographic distribution of AVL vector species in the Region and their adaptation to new environments. For this, more maps of ecological niche models will be produced; probability maps of occurrence in different scenarios; study of the correlation between the increase in deforestation, rates of human cases of visceral leishmaniasis and the presence of sandflies, to observe the behavior of vectors and possible areas of expansion of American Visceral Leishmaniasis in these four states that make up the region. With these data, it will be possible to produce information that can indicate and show trends in the probability of occurrence of communicable diseases in future climatic conditions, contributing to the public power in the elaboration of strategic plans to mitigate the effects of global warming.

7.2 Food Security

-Smallholder livestock production and climate change adaptation: Economic impact, and implications for food security

Research on food and nutrition security in Brazil is mainly done on food quality and the nutritional status of the population and a little on the political, economic and social aspect. As a multidisciplinary area, investments are needed in bringing integration closer.

Animal protein plays an important role in addressing macro and micronutrient deficiencies in diets in many regions of the world. The target for 2050 is 435M tons of meat and dairy products from 843M tons. Modern animal production techniques have greatly improved the ability to provide protein for humans. Livestock farming is one of the contributors to climate change and also has impacts on biodiversity and freshwater depletion. In the particular case of small ruminants, they have been resilient in high environmental temperatures for a long time. However, there is no consensus on the most effective way to address climate change in small ruminant farming, whether intensive system with high performance animals or traditional system production with local breeds.

A preliminary analysis of small animal herds and rainfall in Brazil showed that there is no direct correlation, something like an association between longer droughts and fewer ruminants. However, physical geography and socioeconomic factors could explain the oscillation of the small animal population in the northeast region between 1960 and 1980. It is not yet clear whether there is a relationship between livestock numbers and severe famine events.

Targets

- EVALUATE the relationship between climatic variables (temperature increase and CO2 concentration), feed supply (quality of pasture and feed) with the growth of animal numbers over time.
- MEASURE the direct and indirect impact of climate change on livestock numbers (cattle and small ruminants) over time.

- EVALUATE the economic impacts on cattle and small ruminant livestock farming due t o changes in pasture availability, management techniques and technology, and their implications for family farmers and global food supply.
- MEASURE the impacts of climate change on global food security and Brazil's role as a global supplier of animal protein.

Objectives:

Assessing the direct and indirect socio-economic impacts of temperature and precipitation changes on the supply of food of animal origin;

Assess GHG emissions for small livestock and their contribution to Brazil's overall GHG emissions

Timetable

Activities	Survey and organization of small animal herd information	Organization, information on production systems for small	Definition and testing of models and protein supply in small animals	Analysis of the adaptation of production systems to climate change	Analysis and definition of food security impacts
1.0 month	X				
2.0 month		X	X		
3.0 mês		X	X		
4.0 mês		X	X		
5.0 mês			X		
6.0 mês				X	
8.0 mês				X	
9.0 mês				X	
10.0 mes				X	
11.0 mes					X
12.0 mes					X

7.3 Communications

- Three scholarship plans were produced and the selection processes will be carried out:
Social studies of science and technology and climate change (CNPq DTI-A scholarship holder)
ClimaCom: organization of webinars, publishing of communicative materials and maintenance of websites (CNPq DTI-C category grantee)
Journalistic and artistic dissemination of the INCT Climate Change (FAPESP category TT-4 scholarship holder)

- Two new ClimaCom dossiers will be launched with articles, essays, journalistic materials and artistic productions with the themes: “Disasters” and “Climate, territory and indigenous peoples”. The participation of researchers from the different components of the INCT in the journal will be encouraged by producing texts, interviews, participating in news, etc. The disaster dossier is being organized in a partnership between our transversal theme and researchers from the Disasters (Cemaden) and Water Security (USP) subcomponents.

- We will produce publications (for conferences, articles, books, etc.).

- Tatiana Plens Oliveira, under the guidance of Wenceslao Machado de Oliveira Júnior and Susana Oliveira Dias, will carry out the defense of her doctoral thesis - Body-solo-vivo: between lines of cultivation - which thinks about the relationships between the body, the land/Earth and the

Anthropocene.

- We will launch the book "Modes of existing in the face of the Anthropocene" with articles by INCT researchers and guest researchers and artists.

- We will launch the book-object "Company as a way of caring for the Earth", organized by Susana Dias, Bianca Santos, Marília Frade and Breno Filo, by the Editora do PPGArtes da UFPA in Belém.

- We will carry out three artistic residencies: two with the proposal "Perceive-make the forest", one in Manaus and another in Campinas, and one with the theme "Anticipating the disaster". The first will feature joint work with the laboratories of biologist David Lapola (Unicamp) and engineer Mário Mendiondo (USP). The second residency will be carried out in partnership with Cemaden.

7.4 Energy Security

Our project's energy security component focuses on analyzing the impacts of climate change on wind and solar resources. We have completed the analyses related to solar resources, but the analyses related to wind resources are still ongoing. We are starting to assess the frequency of climate extremes and their effects on the electricity sector, not just in terms of power deployment but also in potential damages to generation and transmission facilities and infrastructure. We are comparing data and models to achieve validation and robust trend analysis, and we plan to conclude in the next few months. These actions will also help to build future scenarios for the Earth system. We are also directing additional efforts toward analyzing offshore wind resources. We have already validated observational data acquired in oceanic buoys, and we are currently validating model data, which will allow us to revise offshore potential and compare power stability between the present and future using CMIP6 datasets.

The doctoral research project is starting at the Earth System Science program addressing the energy transition towards a low-carbon matrix, considering the integration of renewable sources. This project involves the joint work of the research team from the three institutions (INPE, UNIFESP, and COPPE-UFRJ) during the following years. As renewable energy resources are directly impacted by climate change, the study will help us understand and quantify the impacts on the electricity generation system and their consequences for Brazilian society, focusing on the transition and operation of the Brazilian energy system. We will consider data from CMIP6 models and assumptions currently adopted by the organizations responsible for Brazilian energy planning. We will recognize that the climate agenda is attaining importance in defining and developing public policies in Brazil and worldwide.

The energy security team from Unifesp, Unifei, and INPE are working together on data acquisition at the Furnas reservoir. Two data acquisition masts measure meteorological data (solar radiation, wind data, temperature at the surface, water surface temperature, and others) inside and outside the water reservoir to understand the breeze dynamic and the impact on the wind and floating PV energy. The research intends to understand the local climate impact on renewable energy resources and how hybrid power generation can improve water management and increase energy security.

We are also collaborating with the water security component on joint studies, particularly on the research project "Global changes and sustainable adaptations with water and energy viability and economic solvency" (FAPESP process 22/07521-5). The project focuses on coupling risk transfer mechanisms to ensure economic solvency under climate change, focusing on the water-energy-renewable and sustainable ecosystem nexus.

For the COPPE/AM team, improvements in the current models, especially regarding their capacity to encompass and represent the water-food-energy nexus are expected. Further, it is planned a study of different possible pathways of the energy system taking into account the impacts of COVID, using a scenario methodology in the IAM tools.

For the INPE team, the evaluation of CMIP6 climate change impacts on energy resources will continue, including a spatial and seasonal analysis of the models performance to develop a smart ensemble output. These outputs will produce distinct scenarios for solar and wind power resources over Brazilian territory.

7.5 Natural disasters

The next steps to be developed during year 7 of the subcomponent are detailed below.

3.1 – Develop a vulnerability index to assess the impact of urban drought in Brazil, considering two stages (i) proposition of an indicator of vulnerability to urban drought for the whole of

Brazil, based on socioeconomic and environmental data; (2) proposition of a methodology for monitoring the impact of urban drought based on climatological variables.

3.2 – Development of methodology for the assessment of compound drought-heat events over Brazil using an ensemble precipitation dataset and extreme heat indicators.

3.3 – Studies on economic loss and assessment of vulnerability for other municipalities and periods.

3.4 – Understand changes in the hydrological cycle of Brazil that will impact disasters in urban communities.

3.5 – Understand compound extreme events on land and in the ocean and determine their combined impacts on coastal urban communities, including on tourism, fisheries, aquaculture and human health.

3.6 – Projections of future precipitation that may affect the city of Blumenau using the CMIP5 and CMIP6 models. These evaluations will be used to plan, together with Blumenau Stakeholders, the adaptation strategies which should contribute to mitigate impacts from climate-related disasters in the city, and amplify its resilience to climate risks.

3.7 – Evaluating policymaker' risk perception from cities affected by landslides, floods and droughts.

a. Economy

Plans for the seventh year include continuing and further approximation with researchers from the subcomponents "Natural Disasters" and "Water Security" to develop joint projects further. Moreover, as pointed out in a previous report, the Fapesp granted a scholarship abroad for Paula Pereira Pereda to develop the project "Assessing the Climate and Weather Effects in Brazil using Panel Data" at Yale University, which has provided additional incentives to integration with other areas of the INCT, mainly related to health and agriculture. Prof. Paula Pereda has recently applied for a grant in Fapesp to further develop this initiative, inviting Prof. Jaqueline Oliveira, Associate Professor at Rhodes College (U.S.A.), to spend a year at USP to develop the project "Mudanças Climáticas: Como nos Adaptaremos?" (Project 2023/01015-3, under review).

There are two post-doc scholarships, already approved by Fapesp and CNPq, to be granted to researchers to develop projects integrating different subcomponents. The call for the Fapesp scholarship will focus on the development of a project related to water charge and insurance as strategies for adapting to climate change. The one for the CNPq will focus on the effects of climate shocks on socioeconomic indicators.

Ongoing projects with colleagues from Croatia ("Croatia's Tourism Sector: An Environmental Analysis Through an Interregional CGE Model"), Chile ("UPDATE OF THE INTERREGIONAL INPUT-OUTPUT TABLE OF CHILE AND INCORPORATION OF WATER RESOURCES"), Paraguay ("Systemic impacts of climate change in Paraguay from business agriculture"), and Morocco are to be further developed during the seventh year.

Finally, an array of recent FIPE projects allowed the discussion of the recent tax reform considering a "Green Tax Reform". We also plan to continue devoting time to integrating the land use findings with the computable general equilibrium model, as mentioned in the previous report.

b. Modelling

Internal discussions and actions toward the developing the Eta model coupled to MOM6 regional climate model were taken. The regional coupled Eta model shall enhance the capability of high resolution coupled downscaling over South America and the Tropical/South Atlantic Ocean.
- Due to the reduced availability of supercomputer power at INPE still in the year 6, the CMIP6 SSP's scenarios planned for year 6 of the project are postponed for the year 7. The climate scenarios shall encompass the period of 1985-2100, with BESM3.0, same for the RESM- Eta Model.
- Development of the Coupled Eta based model with MOM6 ocean model (RESM – Eta Model);
- Improve the coupling of the Radiation scheme in the RESM through tests and evaluation of the inclusion of aerosol (Eta Model)
- Coupling of the lake model FLake to the Eta Model
- Finish Coupling and evaluation of the dynamic vegetation + Carbon cycle in the RESM (Eta Model)
- Evaluation with the new model version of the Eta Model - continuation
- Generation of projections using new model version and new SSP's emission scenarios.

8. Development of the INCT MC2 web site

In 2023, the development of the INCT-MC2 website began, with the objective of organizing and gathering information and research results of the subcomponents, including the integration and synthesis work, which is being prepared by the general coordinator of the project. The site will also be a repository of publications authored by INCT-MC2 researchers.
The coordination of the INCT-MC2 was concerned with structuring the website in a professional manner, thus guaranteeing its functionality, usability and, consequently, greater engagement and interaction of the various stakeholders with the content made available. Thus, the design studio Magno Studio was hired, which created the design based on the guidelines and orientations of the coordinators of the components and of the scientific popularizer Ana Paula Soares, who had already worked on the website of the INCT-MC phase 1. The idea is that the website dialogues both with researchers in the area of climate change and related topics, as well as researchers from other areas and also the general public (decision makers, policy makers, educators, science communicators, the media, etc.).

The structure of the site and its contents were approved in July by the coordination and are in the programming phase, with launch expected by the end of August. The website will be hosted on the server of the National Center for Monitoring and Natural Disaster Alerts (CEMADEN), headquarters of this INCT, with the **URL: inctmc2.cemaden.gov.br** site structure.

In addition to the institutional sections, with names and information about the project, the INCT-MC2 website will feature short videos presented by the coordinators, specifically addressing each of the researches developed by the components. There will also be an area for the dissemination of opportunities (public notices, scholarships, etc.); agenda of events held by the INCT-MC2 or on topics of interest; publications (articles, books, book chapters, theses and dissertations and INCT-MC2 activity reports, as shown in Figure 5.111)

Figure 5.111. Structure of the website of the INCT MC2

9. Events organized by the INCT MC2 and its components with interaction among sub components of the project in Year 6 and when results of the project were presented

1. Encontro Academia –Indústria: CT&I para o Desenvolvimento do Brasil", a ser realizado no dia 24 de novembro, no SENAI CIMATEC, Salvador, BA,
2. 75th Encontro Anual da SBPC, Julho 2023, Curitiba, PR
3. O Agro do Futuro, Painel Riscos Climáticos no Agro, Parque Tecnológico São Jose dos Campos, SP, 2 Agosto 2023.
4. Visitas de lideres religiosos ao CEMADEN para conversar sobre temas de extremis, Amazonia, desastres e Mudanças Climáticas, organizado pela Iniciativa Inter-religiosa Pelas Florestas Tropicais – IRI Brasil, nas datas 30/05; 13/06; 27/06; 04/07; 25/07; 08/08; 29/08
5. Coordination meetings with the vice-coordinator and coordinator: 14-16 March 2023 at IAG USP; 6-7 October 2022 at FEA USP,
6. Seminário Internacional Emergência Climática: o que a universidade deve fazer para enfrentá-la JÁ! 14, 15 e 16 de Agosto de 2023 Local: Instituto de Economia da Unicamp
7. V Foro Latinoamericano y del Caribe de Vivienda y Hábitat a celebrarse en Bogotá del 31 de julio al 2 de agosto 2023.
8. 18º Congresso Internacional de Jornalismo Investigativo, que será realizado de 29 de junho a 02 de julho de 2023, na faculdade ESPM, na Vila Mariana, em São Paulo
9. Meeting of the Science Panel for the Amazon (SPA) to be held this March in Belem (Pará, Brazil). 8-10 March 2023
10. Aula Magna do Programa de Pós Graduação em Arquitetura e Urbanismo - PPGAU da Universidade Presbiteriana Mackenzie, 13 de setembro de 2022, São Paulo.
11. CONGREMET-Congreso Argentino de Meteoróologos, 7-11 Noviembre 2022, Buenos Aires, Argentina.
12. Reunión del Grupo Operativo de Monitoreo y Pronóstico focales del CRC-SAS/SISSA,

Servicio Meteorológico Nacional de Argentina, 1 y 2 de diciembre 2022, Buenos Aires, Argtentina.

13. Technical visit and 2 talks at the Droughts Team at the premises of JRC in Ispra, Italy, from 19th to 22nd September 2022.

14. **"DESAFIOS DASMUDANÇAS CLIMÁTICAS PARA O FUTUR), no** IX Seminário Internacional de Gestão do Risco deDesastres, 02 e 03 de março2023, Belo Horizonte MG

15. Reunión sobre estudos de la Amazonia y Transporte de humedad, 26-28 de diciembre 2022 en la sede de Conservación Amazónica – ACCA, Lima, Perú.

16. Visita de investigación e palestra sobre secas en el Laboratorio de Clima, Atmósfera y Océano (Climatoc-Lab) da Universidad de Valencia, Españ, 8-12 de mayo mayo de 2023.

17. AMORIM, A. C. R.; GARCIA, A. ; MOREIRA, M. A. ; MONTANEZ, M. S. ; WUNDER, A. ; Sebastian Alexi Wiedemann Caballero . Narrativas que inventam mundos outres - GIRO: Ciclo de conversas em torno das narrativas nas pesquisas e na formação. 2022. (Outro).

18. AMORIM, A. C. R.; NOVAES, M. P. . Ciclo de Seminários Estéticas Contemporâneas na América Latina e as Pulsões da Educação. 2022. (Outro).

19. ARANHA. N. Organização do "9° Encontro de Divulgação de Ciência e Cultura" promovido pelos alunos de Pós-Graduação em Divulgação Científica e Cultural do Laboratório de Estudos Avançados em Jornalismo (LABJOR), Universidade Estadual de Campinas (UNICAMP). 2022.

20. ARANHA, N. Organização do XXVI edição do Seminário de Teses em Andamento (SETA) realizado no Instituto de Estudos da Linguagem (IEL), da Universidade Estadual de Campinas (UNICAMP). 2022.

21. ARANHA, N. Organização do evento "Save the frogs" promovida pelo Laboratório de História Natural de Anfíbios Brasileiros (LaHNAB), na Unidade de Conservação ARIE Mata de Santa Genebra. 2023.

22. CANGI, A. Variações Latino-Americanas diante do Antropoceno 3. Poética de las piedras-Una Cartografía y Decolonizar el paisaje patagónico, com participação de Con Jeremías Castro (UNDAV) e Alejandro Miroli (UBA/UNDAV). 28/04/2023. Disponível em: https://www.youtube.com/watch?v=To8uxpN-vSQ&t=3s

23. CANGI, A. Variações Latino-americanas diante do Antropoceno 4 - Descolonización del paisaje patagônico, com Com Martín Bolaños (Undav) e Alejandra Adela González (Uba/Undav). 29/05/2023. Disponível em: https://www.youtube.com/watch?v=BQBf8oLaJE&t=3072s

24. DIAS, S. O; CANGI, A.; GONÇALVES, M; AMORIM, A.. 2o. Seminário do Ciclo "Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour" | com Santiago Arcila e Alyne Costa. YouTube da ClimaCom, 02/06/2023. Sobre os temas: "Gaia: uma figura (enfim profana) da natureza" e "O Antropoceno e a destruição (da imagem) do Globo".

25. DIAS, S. O; CANGI, A.; GONÇALVES, M; AMORIM, A.. 2o. Grupo de Estudos do Ciclo "Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour" | com Alik Wunder. YouTube da ClimaCom, 05/05/2023. Sobre os temas: "Sobre a instabilidade (da noção de) natureza" e "Como não (des)animar a natureza".

26. DIAS, S. O; CANGI, A.; GONÇALVES, M; AMORIM, A. 1o. Grupo de Estudos do Ciclo "Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour" | com Daniela Alvarez. YouTube da ClimaCom. 07/04/2023. Sobre os temas: "Sobre a instabilidade (da noção de) natureza" e "Como não (des)animar a natureza".

27. DIAS, S. O; CANGI, A.; GONÇALVES, M; AMORIM, A. 1o. Seminário do Ciclo "Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour" | com Michele Gonçalves, Susana Dias, Adrián Cangi e Carolina Cantarino. YouTube da ClimaCom. 03/03/2023. Sobre os temas: "Sobre a instabilidade (da noção de) natureza" e "Como não (des)animar a natureza"

28. DIAS, S. O. Variações Latino-Americanas diante do Antropoceno 1 - Artes y ciencias en la Patagônia, com Sandra Murriello, 2023.

29. DIAS, S. O. Variações Latino-Americanas diante do Antropoceno 2 - Pedagogias da

imagem: cineclubismo e educação, com Gabriel Cid Garcia e mediação de Teresita Ospina, 2023.

30. DIAS, S. II multiTão Pesquisas, no Laboratório de Estudos Avançados em Jornalismo (Labjor) da Universidade Estadual de Campinas, 2022.

31. DIAS, S. Seminário "Aprender com as nuvens: ontoepistemologias entre o céu e a terra", realizado no Labjor-Unicamp, dia 19 de setembro de 2022.

32. DIAS, S. Palestra "Una constelación de imágenes monstruosas" com Maia Gattás Vargas no Labjor-Unicamp. http://climacom.mudancasclimaticas.net.br/una-constelacion/.

33. GUZZO, M. Série de seminários: Antropoceno: arte, cuidado e invenção. 2023. (Encontro).

34. MURRIELLO, S. Organización muestra de arte-ciencia de *Tres a la deriva* y sesión F10: *The challenge of public communication of science in limnology and paleolimnology*. En: Congreso IAL-IPA. Lakes as memories of the territories. Bariloche, 27 de Noviembre al 1 de diciembre de 2022. Memorias IAL-IPA, p.81-90

35. QUEIROZ FILHO, Antonio Carlos. Webinário Internacional "Aulas Abertas do Rasuras" - Terceira Edição. (Sessão 1: sobre gamificação, vida urbana significativa e o aprender lúdico). 2023.

36. QUEIROZ FILHO, Antonio Carlos. Webinário Internacional "Aulas Abertas do Rasuras" - Terceira Edição. (Sessão 2: sobre linguagens artísticas e suas geo-grafias possíveis). 2023.

37. QUEIROZ FILHO, Antonio Carlos. Webinário Internacional "Aulas Abertas do Rasuras" - Segunda Edição. (Sobre inovação social urbana, design e práticas de interação, mídias locativas e engajamento participativo, coletivo e comunitário). 2022.

38. VIDAL, E. Charla – Taller Narrativas para pensar los conflictos socio-ambientales. El caso del Corredor Sierras Chicas: Mgter. Mariana Minervini (Docente FCC- Administración de Parques Nacionales) – Mgter. Luciana Nicola e Ing. Marcos Ferioli (Administración de Parques Nacionales), Rocío Juncos (Subsecretaría de Cultura SEU-UNC) y Claudia Rodríguez (Docente FCC). En la IV Bienal de Periodismo y Comunicación.Facultad de Cs de la Comunicación.Universidad Nacional de Cordoba. jun. 2023.

39. VIDAL, E. Taller de Lenguaje I y Producción Gráfica A. Taller de Lenguaje III y Producción Audiovisual - Ver para comprender. Desafíos del periodismo visual en la cobertura de la crisis climática-Presentación del portal Sonda Internacional. Pablo Tosco (Argentina) Mikel Konate (España), Lili Meyer (Australia) Modera: Elizabeth Vidal https:// sondainternacional.com. Disponible en https://www.youtube.com/watch?v=c9f-NCGfP5I En la IV Bienal de Periodismo y Comunicación.Facultad de Cs de la Comunicación.Universidad Nacional de Cordoba. jun. 2023.

40. MARTINS, FERNANDO RAMOS; MADELEINE S. G. CASAGRANDE, NILTON E. ROSÁRIO, GONÇALVES, ANDRÉ RODRIGUES ; COSTA, RODRIGO SANTOS ; LIMA, FRANCISCO J. L. ; PES, MARCELO P. ; PEREIRA, E. B. Congresso Brasileiro de Energia Solar, 2022, Florianópolis. Avaliação da irradiação solar com modelo BRASIL-SR em condições de céu claro – impacto de aerossóis na amazônia e cerrado.

41. BET, L. G. ; ROSARIO, N. M. E. ; ZILLES, R. ; MARTINS, FERNANDO RAMOS . ESTUDO SOBRE O IMPACTO DOS AEROSSÓIS ATMOSFÉRICOS NO FATOR ESPECTRAL DE MÓDULOS FOTOVOLTAICOS EM SÃO PAULO. In: Congresso Brasileiro de Energia Solar, 2022, Florianópolis. Anais do IX Congresso Brasileiro de Energia Solar. Florianópolis: Associação Brasileira de Energia Solar, 2022.

42. Workshop on Energy Transition hold by Brazilian Society of Geophysics. Virtual Event. Scientific Committee – Fernando Ramos Martins (INCT-Mudanças Climáticas) and partners from SBGF and Petrobras. Chair for the Third Session – Fernando Martins (Unifesp) and Marco Ianurberto (UNB).

43. Palestra proferida na Faculdade de Saúde Publica – USP – JUNHO 2022 – Titulo: Variabilidade Climática e suas mudanças: Passado, Presente e Futuro. Evento do Programa de Pós-Graduação da unidade.

44. Palestra proferida no IMECC – UNICAMP – JUNHO 2023 – Titulo: Variabilidade climática e impactos urbanos: Hoje e o Amanhã. Colóquio do IMECC-UNICAMP

45. Palestra proferida no IV Fórum de Meio Ambiente – Mudanças Climáticas – SETEMBRO 2022 – Título: Variabilidade Climática e seus Extremos: O Clima está mudando?
46. Palestra proferida na Escola Politécnica da USP – OUTUBRO 2022 – Título: Aquecimento Global, Variabilidade Climática e seus Extremos sobre o Brasil.
47. Palestra proferida no XIX Simpósio Brasileiro de Geografia Física Aplicada – NOVEMBRO 2022 – Título: Variabilidade Climática e seus Extremos: O Clima está mudando?
48. Debate sobre "avanços tecnológicos e inovações necessários à prevenção de desastres naturais em áreas urbanas ou turísticas". Audiência Pública da Comissão de Ciência e Tecnologia (CCT) do Senado Federal, 10/08/2022.
49. VI Seminário sobre Desastres Naturais. Eventos extremos de chuvas e escassez hídrica no presente e seus impactos no contexto de desastres. Coordenadoria Estadual e Proteção e Defesa Civil e ABJICA. Palácio dos Bandeirantes, São Paulo, 11/10/2022. https://www.abjica.org.br/vi-seminario-sobre-desastres-naturais-hibrido/
50. III END – Encontro Nacional de Desastres da ABHRidro. Eventos extremos e Sociedade sob a Perspectiva das Mudanças Climáticas. Niterói, RJ, 06-09/03/2023. Mesa Redonda 1: mudanças climáticas e Gestão Territorial: Como melhorar nossa adaptação aos riscos de desastres? 08/03/2023. Participantes: Ana Luiza Coelho Netto – UFRJ; Antonio Krishnamurti Beleño de Oliveira – PUC-Rio; Regina Célia dos Santos Alvalá – CEMADEN.
51. 1º Webinário Científico FNI-FAPESP. Palestra Temática sobre Monitoramento de Desastres Naturais – Sala 2. Online. 03/04/2023. (08h30 – 11h00). https://fapesp.br/15979/1a-webinario-cientifico-fni-fapesp
52. World Climate Research Program (WCRP) - Open Science Conference, Kigali, Rwanda, 23-27/10/2023.
53. ICTP/CLIVAR Summer School on Marine Heatwaves: Global Phenomena with Regional Impacts, Trieste, Italy, 24-29/07/2023.
54. Global Climate Observing System (GCOS) - 2nd Climate Observation Conference, Darmstadt, Germany, 17-19/10/2022.
55. NEREUS at FEAUSP hosts a weekly seminar, on Mondays, during the academic year. There were different presentations on topics related to the INCT-MC. The complete program with the names of the presenters and titles of the presentations can be accessed at (http://www.usp.br/nereus/?p=3989)
56. Workshop in 2022 focusing on "The Economy of Mantiqueira", involving different components of the INCT. The first part of the workshop took place in Itajubá (UNIFEI), where the focus was on discussions with local policymakers, and the second part took place in Gonçalves, MG, where the discussion was more technical. (https://unifei.edu.br/evento/seminario-internacional-a-economia-da-mantiqueira/)
57. Cuartas, L A (2023) HAND Model, a Topography Driven Wet Revolution in Land Surface Sciences, Union Lecture - IAHS, IUGG 2023, Berlin, https://www.iugg2023berlin.org/ union-lecturers/
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73. 19º Congresso Nacional de Meio ambiente: "Clima e Desastres Naturais". Chou Sin Chan. Poços de Caldas, 20 a 22/09/202
74. VII Workshop in Numerical Modeling of Weather, Climate and Climate Change using the Eta Model: Physical and Numerical Aspects (VII WorkEta
75. XIX Simpósio Brasileiro de Geografia Física Aplicada: "Passagens De Frentes Frias Extremas No Vale Do Itajaí No Clima Futuro". Priscila Tavares, Chou Sin Chan. Rio de Janeiro, 07 a 13/11/2022
76. VII Workshop em Modelagem Numérica de Tempo, Clima e Mudanças Climáticas utilizando o Modelo Eta: Aspectos Físicos e Numéricos (VII WorkEta): "Modelo Eta". Chou Sin Chan. Instituto Nacional de Pesquisas Espaciais, 26 a 30/09/202
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microfísica de nuvens”. Chou Sin Chan. Instituto Nacional de Pesquisas Espaciais, 26 a 30/09/2022

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80. VII Workshop em Modelagem Numérica de Tempo, Clima e Mudanças Climáticas utilizando o Modelo Eta: Aspectos Físicos e Numéricos (VII WorkEta): “Versão Unificada do Modelo Eta (all-scales version)”. Jorge Gomes. Instituto Nacional de Pesquisas Espaciais, 26 a 30/09/202
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10. List of publications

The papers published within the Year 6 of the INCT-MC2 included in the publication list reflects the activities of the subgroups that have funding other than FAPESP, as well as a continuous interdisciplinary work over the recent years.

1. MARENGO, JOSÉ A.; JIMENEZ, JUAN C. ; ESPINOZA, JHAN-CARLO ; CUNHA, ANA PAULA ; ARAGÃO, LUIZ E. O. . Increased climate pressure on the agricultural frontier in the Eastern Amazonia-Cerrado transition zone. Scientific R eports, v. 12, p. 457, 2022.
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11. Books and book chapters 2022-2023

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2. Marengo, J.A., Seluchi, M.E., Cunha, A.P. *et al.* Heavy rainfall associated with floods in southeastern Brazil in November–December 2021. *Nat Hazards* **116**, 3617–3644 (2023). https://doi.org/10.1007/s11069-023-05827-z
3. Nunes, L. , Gabriel, G. and Marengo, J. (2023) More Erratic and More Extreme: Trends in Precipitation in the State of São Paulo, Brazil. *American Journal of Climate Change*, **12**, 140-171. doi: 10.4236/ajcc.2023.121008.
4. GIRARDI, G.; OLIVEIRA JUNIOR, W. M.; NUNES, F. G. (Org.) . Pegadas das imagens na imaginação geográfica pesquisas, experimentações e práticas educativas. 1. ed. São Carlos: Pedro e João Editores, 2022. v. 1. 296p.
5. MARRAS, S.; TADDEI, R. O Antropoceno: sobre modos de compor mundos. São Paulo: Fino Traça Editora, 2022.
6. MURRIELO, S.; BARRIOS, G. (Comp.). “A 10 años de la erupción del Puyehue-Cordòn Caulle” Viedma: Editorial UNRN. (en prensa)
7. OLIVEIRA, A. G. (Org.) ; GIORDANI, A. (Org.) ; QUEIROZ FILHO, Antonio Carlos (Org.) ; TONETTO, E. P. (Org.) . Linguagens do desaprender: gestos intensivos e política dos afetos.. 1. ed. Porto Alegre: Evangraf, 2022. v. 1. 168p .
8. QUEIROZ FILHO, Antonio Carlos. Além do que a vista alcança: sobre paisagem como dobras de sentidos.. 1. ed. Vitória: Rasuras, 2022. v. 1. 171p .
9. FONSECA, F. S. R. Cartas ao outro: rasgos de um mundo em tempos de pandemia. 1. ed. São Paulo: Cobra coral edições, 2022. v. 1. 60p .
10. FONSECA, F. S. R. Eventos extremos. 1. ed. São Paulo: Cobra coral edições, 2022. v. 1. 58p .
11. VIDAL, Elizabeth; LOYOLA, María Inés; VIADA, Mónica María: MINERVINI, Mariana Andrea. Experiencias situadas en la enseñanza de la comunicación: el foco en el ambiente. ClimaCom – Ciência.Vida.Educação. [Online], Campinas, ano 10, n. 24, mai. 2023. Available from: http://climacom.mudancasclimaticas.net.br/experiencias-situadas/
12. CANGI, A. “Cosmopolíticas de los modos y maneras plurimodales”. In: Maria dos Remédios de Brito, Lindomberto Ferreira Alves e Dhemersson Warly Santos Costa. (Org.). Desejar o menor dos mundos, escrever corporeidades outras desde aí. 1ed.Belém: Programa de Pós-Graduação em Artes/UFPA, 2023, v. 1, p. 16-33.
13. DIAS, S. O.; BRITO, M. R. . "Fazer o papel falar" ou de como cultivar florestas em tempos de catástrofes. In: Maria dos Remédios de Brito, Lindomberto Ferreira Alves e Dhemersson Warly Santos Costa. (Org.). Desejar o menor dos mundos, escrever corporeidades outras desde aí. 1ed.Belém: Programa de Pós-Graduação em Artes/UFPA, 2023, v. 1, p. 85-103.
14. MIGUEL, J.; TADDEI, R.; MONTEIRO, M. Civic Epistemologies. In: PRYCK, Kari; HULME, M. (Org.). A Critical Assessment of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2022, p. 217-224. doi:10.1017/9781009082099.029
15. MIRANDA, Carlos Eduardo Albuquerque ; OLIVEIRA JUNIOR, WENCESLAO MACHADO . Comunidade de cinema com professores: uma experiência de encontro entre universidade e escola públicas. In: Gisele Girardi; Wenceslao Oliveira Junior; Flaviana Gasparotti Nunes. (Org.). Pegadas das imagens na imaginação geográfica pesquisas, experimentações e práticas educativas. 1ed.São Carlos: Pedro e João Editores, 2022, v. 1, p. 217-240.
16. MONTEIRO, Marko; ROTH, F.; SHELLEY-EGAN, C. Global Systems Resilience and Pandemic Disease: A Challenge for Governance. In: Leonard Hennen; Julia Hahn; Miltos Ladikas; Ralf Lindner; Walter Peissl; Rinie van Est. (Org.). Technology Assessment in a Globalized World Facing the Challenges of Transnational Technology Governance. 1ed.Cham: Springer, 2023, p. 203-220. https://doi.org/10.1007/978-3-031-10617-010

17. MONTEIRO, M. Guerras da Ciência. In: José Szwako; José Luiz Ratton. (Org.). Dicionário dos Negacionismos no Brasil. 1ed.Recife: CEPE, 2022, v. , p. 161-165.
18. MURRIELLO, S. y Pierucci, L., "Memorias del Puyehue-Cordón Caulle" (Capítulo 1) En: Murriello,S- y Barrios García,G. (Comp) A diez años de la última erupción del Puyehue-Cordón Caulle. Viedma: Editorial de la Universidad Nacional de Río Negro. (En prensa)
19. MURRIELLO, S. y Mariluan,A. (en prensa). Del silenciamiento a los procesos de visibilización de lenguas y sonidos. En: Malvestitti, M. y Farro,M. (comp.).Documentos inéditos en lenguas fuegopatagónicas (1880-1950) Viedma: Editorial de la Universidad Nacional de Río Negro.
20. QUEIROZ FILHO, Antonio Carlos; BORGES, R. H. M. F. . Estamos em aula: Geografias de afeto, encontro e devir.. In: Aldo Gonçalves de Oliveira; Ana Claudia Giordani; Ivaine Maria Tonini; Ludmila Losada da Fonseca; Suzana Campos. (Org.). Geografias e educação: singulares mãos docentes. 1ed.Rio de Janeiro: Letra Capital, 2023, v. 1, p. 387-411.
21. QUEIROZ FILHO, Antonio Carlos; BORGES, R. F. ; FERREIRA, G. C. . Agir em escala: corpo-imagem, linguagem-ensaio e experimentações de geo-grafias possíveis. In: Flaviana Gasparotti Nunes; Jones Dari Goettert; Juliana Grasiéli Bueno Mota. (Org.). Geografias e(m) Artes.. 1ed.Porto Alegre: TotalBooks, 2022, v. 1, p. 9-37.
22. OLIVEIRA JUNIOR, WENCESLAO MACHADO. Pelo espaço: desasfixiar pensamentos, desfigurar lugares em imagens. In: Aldo Gonçalves de Oliveira; Ana Giordani; Ivaine Tonini; Ludmila Losada da Fonseca; Suzana Campos. (Org.). Geografias e Educação: singulares mãos docentes. 1ed.Rio de Janeiro: Letra Capital, 2023, v. 1, p. 177-200.
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24. TADDEI, R. Alter geoengenharia. In: Danowski, D.; Viveiros de Castro, E.; Saldanha, R.. (Org.). Os Mil Nomes de Gaia - Do Antropoceno à Idade da Terra. 1ed.Rio de Janeiro: Machado, 2022, v. 1, p. 218-238.
25. TADDEI, R.; SHIRATORI, K. ; BULAMAH, R. C. . Decolonizing the Anthropocene. In: Callan, Hilary; Coleman, Simon. (Org.). The International Encyclopedia of Anthropology. 1ed.Londres: Wiley, 2022, v. 1, p. 1-12.
26. WIEDEMANN, S. ; AMARAL, S. R. F. ; OLIVEIRA JUNIOR, WENCESLAO MACHADO . Infancia y afectos in-comunes entre la mise-en-expérience y la mise-en-situation-école. Algunas notas sobre modos de experiencia cinematográficos en una escuela infantil en Campinas. In: Irene Depetris Chauvin; Natalia Taccetta. (Org.). PERFORMANCES AFECTIVAS - Artes y modos de lo común en América Latina. 1ed.Buenos Aires: EPUB, 2022, v. 1, p. 115-144.
27. ANJOS, K. L. ; ARAUJO, C. M. ; GALVÃO, C. O. . A injusDça socioambiental ante as emergências climáDcas em Campina Grande/PB. In: MIRANDA, L.I.B.; MORAES, D.A.. (Org.). Reforma urbana e direito à cidade: Paraíba. 1ed.Rio de Janeiro: Letra Capital, 2022, p. 133-149.
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29. PIREH, H.; FERRERO, G.; NAGABHATLA, N.; ARTHURSON, G.; ABDELAZIZ, Y. Z.; BHATIA, S.; FUREY, S. ; GALVÃO, C. O. . Water supply and sanitaDon for human se|lements. In: UNESCO. (Org.). The United NaDons World Water Development Report 2023: Partner-ships and CooperaDon for Water. 1ed.Paris: UNESCO, 2023, v. , p. 63-72. h"ps://unes-doc. unesco.org/ark:/48223/pf0000384655 RÊGO, Janiro Costa ;
30. ALBUQUERQUE, José Do Patrocínio Tomaz de ; PONTES FILHO, J. D. A. ; TSUYUGUCHI, B. B. ; Souza, T. J. ; GALVÃO, C. O. . Sustainable and resilient exploita-INCTMC2-FAPESP 2014/50849-9, Water Security, Highlights of the 6th Year – Contact. : Dr

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31. SOUZA FILHO, F. A.; REIS JR., D. S.; GALVÃO, C. O. (Orgs.) . Secas e cheias: modelagem e adaptação aos extremos hidrológicos no contexto da variablilidade e mudança do cli-ma. 1. ed. Fortaleza: Expressão Gráfica, 2022. v. 1. 1260p

12. Other activities and web sites of reports, art exhibitions and courses/seminars online and videos

Art workshops/Videos/Artistic productions

1. ALVAREZ, T. O. Mediadora do evento Variações Latino-Americanas diante do Antropoceno 2 - Pedagogias da imagem: cineclubismo e educação, com Gabriel Cid Garcia, 2023.
2. ARANHA, N. Apresentação oral “Comunicação e estudos multiespécies diante do Antropoceno: o caso dos sapos”, Seminário de Estéticas ampliadas da Universidad Nacional de Avellaneda. 2022.
3. ARANHA, N. Apresentação oral do trabalho intitulado “Comunicação e estudos multiespécies diante do Antropoceno – o caso do sapo cururu”, 9° Encontro de Divulgação de Ciência e Cultura”, promovido pelos alunos de Pós-Graduação em Divulgação Científica e Cultural do Laboratório de Estudos Avançados em Jornalismo (LABJOR), Universidade Estadual de Campinas (UNICAMP). 2022.
4. ARANHA, N. Apresentação oral do trabalho intitulado “Entre meios - Uma conexão de mundos com os sapos”, no evento multiTão Pesquisas, Laboratório de Estudos Avançados em Jornalismo (Labjor) da Universidade Estadual de Campinas.
5. ARANHA, N. Apresentação oral do trabalho intitulado “Comunicação e estudos multiespécies diante do Antropoceno: o caso do sapo cururu”, na área de Literatura, Artes e Comunicação, XXVI edição do Seminário de Teses em Andamento (SETA), Instituto de Estudos da Linguagem (IEL), da Universidade Estadual de Campinas (UNICAMP). 2022.
6. CANGI, A.. Apresentação no 1o. Seminário do Ciclo “Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour” com Adrián Cangi e Carolina Cantarino. YouTube da ClimaCom., 2023.
7. CANGI, A.; GONZÁLEZ, A. Mediadores do 2o. Grupo de Estudos do Ciclo “Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour” | com Alik Wunder. YouTube da ClimaCom, 05/05/2023. Sobre os temas: “Sobre a instabilidade (da noção de) natureza” e “Como não (des)animar a natureza”.
8. CANTARINO, C. Apresentação no 1o. Seminário do Ciclo “Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour” com Adrián Cangi e Carolina Cantarino. YouTube da ClimaCom., 2023.
9. DIAS, S. O . Mediadora do 1o. Seminário do Ciclo “Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour” com Adrián Cangi e Carolina Cantarino. YouTube da ClimaCom., 2023.
10. DIAS, S. O. Apresentação “ClimaCom e Bruno Latour” no 1o. Seminário do Ciclo “Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour”. YouTube da ClimaCom., 2023.
11. DIAS, S. O. Palestra na série de seminários: Antropoceno: arte, cuidado e invenção. Título da palestra: Companhia como modo de atenção à Terra. 2023. (Encontro).
12. DIAS, S. O. Palestra na disciplina: Naturezas, Culturas e Educação, na UFSC. Título da palestra: Espécies companheiras: desdobramentos de um conceito-prática. 2023. (Outra).
13. DIAS, S. O. Palestra “Como ser afetada por um rio?”, UFBA, 2023.
14. DIAS, S. Palestra “Percibir-hacer bosque: la aventura de entrar en conexión con un mundo todo vivo y vigorizar una anarquía ecológica”. Seminário de Estéticas ampliadas da Universidad Nacional de Avellaneda. 2022.

15. DIAS, S. Palestra. Fazer o papel falar ou de como cultivar de florestas em tempos de catástrofes. No 9o. Encontro de Divulgação de Ciência e Cultura - EDICC - organizado pelos estudantes do Labjor-Unicamp, 2022.
16. DIAS, S. O. Palestra "Perceber-fazer floresta do chamado a pensar o que pode a matéria papel diante do Antropoceno", UFPA. 2022. (Outra).
17. DIAS, Susana. Palestra proferida - "Alianças Vegetais: espécies companheiras de ensino diante do Antropoceno", no Instituto de Educação Matemática e Científica – IEMCI, da Universidade Federal do Pará no dia 06 de setembro de 2022.
18. DIAS, Susana. Palestra proferida - "Percibir-hacer bosque: la aventura de entrar en comunicación con un mundo entero vivo y dar vigor a una anarquía ecológica" no Curso de Postgrado Transdisciplinar: ARTES, CIENCIAS Y (DES) MONTAJE TRANSDISCIPLINAR. Cuerpo, salud, cuidados y equidad socio-ambiental-cultural y de géneros, no Espacio laboratorio de arte/s, performance/s, política, salud y subjetividad/es de la Facultad de Psicología de la Universidad Nacional de Córdoba- Argentina no dia 9 de setembro de 2022.
19. DIAS, Susana. Participação em mesa redonda. ''Pensar con imágenes - Crear con imágenes''. Universidad de San Buenaventura, Colômbia, 19 de outubro de 2020.
20. DIAS, S.; BRITO, M. R. de. Apresentação oral "A arte pública diante do Antropoceno: experimentações em "mesas de trabalhos"". IV Seminário Nacional GEAP, UFPA-Belém, 2022.
21. DIAS, S. Palestra "Rios, arte e comunicação" no Encontros no Labirinto - Diálogos transbordados, ecologias líquidas, corpos d`água, rios. Realização Labjor-Labirinto-multiTÃO. 2022.
22. DIAS, S.; OLIVEIRA, T. P. Oficina "Alinhavando nuvens e lençois freáticos - práticas de agroflorestar imagens" no evento "Aprender com as nuvens: ontoepistemologias entre o céu e a terra", realizado no Labjor-Unicamp, dia 19 de setembro de 2022.
23. GARCIA, G. C. Participante do encontro Variações Latino-Americanas diante do Antropoceno (ClimaCom/Fapesp), com a intervenção 'Pedagogias da imagem: cineclubismo e educação', online – 31/03/2023.
24. GARCIA, G. C. Mediação do 2º Seminário do Ciclo 'Ecopoéticas: educação, arte e Antropoceno - uma homenagem a Bruno Latour' (Unicamp/Rede DCMC/UFSC/Undav-Argentina/Fapesp), online - 02/06/2023.
25. GARCIA, G. C. Palestrante no evento 'Simondon e a educação' (Laboratório de Imaginário Social e Educação – Departamento de Fundamentos em Educação – Faculdade de Educação da UFRJ), apresentando a intervenção 'Desastre, individuação e nomadismo: aproximações metaestáveis da divulgação científica' – 20/10/2022.
26. GARCIA, G. C. Palestrante no ciclo de conferências 'Cinema, educação e sociedade' (Grupo de Estudos em Estéticas – GEPE/UFRB), apresentando a conferência: 'Nomadismo, ontologia e artifício: figurações do desastre no Antropoceno', 23/11/2022, online.
27. GARCIA, G. C. Ministrante na oficina 'Cineclubismo e cinema skholeiro', com Daniele Grazinoli, na Semana de Pedagogia 2022-2, evento da Faculdade de Educação da UFRJ – 26/10/2022.
28. GARCIA, G. C. Ministrante da 'Oficina de Produção de Podcasts e Divulgação Científica', com Bianca Pinheiro, na Semana de Pedagogia 2022-2, evento da Faculdade de Educação da UFRJ – 25/10/2022.
29. GUIVANT, JULIA S. Coordenação Mesa Redonda na 74 Reunião Anual da SBPC, 2022. (Congresso) A interdisciplinaridade e a mudança climática.
30. GUIVANT, JULIA S. Participação no debate As Humanidades ante o Antropoceno. 11/05/2023. Organização IEA/USP.
31. GUIVANT, JULIA S. Participação na Reunião de Coordenadores do INCT-MC Fase II - 09/06/2022 e 10/06/2022, realizada no FEA/USP (como parte das atividades de pesquisa).
32. GUIVANT, JULIA S. Palestra no dia 13/05/22 no Seminários de Doutorado Programa de Pós-Graduação em PCT – PPG-PCT/Departamento de Política Científica e Tecnológica – DPCT/IG/Unicamp. CT261 –Coordenação Prof. Dr. Marko Monteiro e Profa. Dra. Flavia Consoni. Tema: Interdisciplinaridade na pesquisa de mudança climática: desafios metodológicos.

33. MURRIELO, S. Expositora: *Artes y ciencias en la Patagonia.* VARIAÇÕES LATINOAMERICANAS DIANTE DO ANTROPOCENO - 1er encontro - Rede Latinoamericana de Divulgação Científica e Mudanças Climáticas. UNICAMP, Campinas , SP, Brasil // transmisión on line . 27 de Febrero de 2023
34. QUEIROZ FILHO, Antonio Carlos. Palestra "Bordar e compor - eco de afetos e reticências de possíveis". 2022.
35. TADDEI, R. Regional workshop in support of the development of the third World Ocean Assessment of the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, Including Socioeconomic Aspects. Panel on Indigenous, Traditional Knowledge Integration. Santos, 16 de maio de 2023.
36. TADDEI, R. Embodied Inaqualities of the Anthropocene Series (UCL/CIESAS/UFRGS). Title: Can the (Indigenous) Subaltern Speak (at the IPCC)?. Online, 23 de janeiro de 2023
37. TADDEI, R. Climate Science for Service Partnership Brazil Workshop. Title: The role of the social and behavioral sciences in disaster-related meteorological services. Online, 6 de junho de 2023.
38. TADDEI, R. Seminário Aprender com as nuvens - ontoepistemoilogias entre o céu e a terra. Trabalho: Pensando com as nuvens no sertão, na floresta e no laboratório. LabJor, Unicamp, 19 de setembro de 2022.
39. TADDEI, R. Campus Antropoceno Brasil. Apresentação na mesa “Escalas”. Casa de Cultura Mario Quintana, Porto Alegre, 8 de novembro de 2022.
40. TADDEI, R. Congresso Acadêmico Unifesp. Trabalho: “Democracia, sustentabilidade e políticas públicas”. Online, 27 de junho de 2022
41. TADDEI, R. Congresso Acadêmico Unifesp. Trabalho “Os conflitos envolvendo a pesca artesanal no litoral de São Paulo: a importância da transdisciplinaridade”. Online, 29 de junho de 2022.
42. TADDEI, R. Palestra no curso de Pós-Graduação em Cenografia, Pontifícia Universidade Católica do Rio de Janeiro. Título: “Sustentabilidade em cena”. Online, 9 de julho de 2022.
43. TADDEI, R. Emergencies, wellbeing and social justice in the Anthropocene (online) Seminar, Interdisciplinary Global Development Centre, York Environmental Sustainability Institute, York University. Title: Communicating risk and response. Online, 13 de julho de 2022.
44. TADDEI, R. Forum Permanente Especial Desafios da Sustentabilidade, Universidade Estadual de Campinas. Mesa: ODS 17. Campinas, Unicamp, 7 de junho de 2022.
45. TADDEI, R. Seminário Trajetórias do Ambientalismo Brasileiro, SESC Belenzinho. Mesa Territórios em disputa: novas lideranças e frentes de atuação. SESC Belenzinho, São Paulo, 29 de junho de 2022.
46. VARGAS, Maia Gattás. Palestra “Una constelación de imágenes monstruosas” no Labjor-Unicamp. http://climacom.mudancasclimaticas.net.br/una-constelacion/.
47. Bressiani, D., Montenegro, S. G., Galvincio, J., Fernandes, C., Mendiondo, E M. (2023) SWAT Course for Water Security and Adaptive Management Under Change, https://eesc.usp.br/noticias/comunicados_s.php?guid=curso-de-capacitacao-modelo-swatpara-seguranca-hidrica-e-gestao-adaptativa&termid=todos

Interviews, News and online magazines, dossiers, podcasts

1. DIAS, S. O.; GUZZO, M. ; FONSECA, F. (Orgs.). Dossiê 'Políticas vegetais'. 23. ed. Campinas: Labjor-Unicamp, 2022. 350p .
2. SALES, Tiago Amaral Sales; DALMASO, Alice Copetti; RIGUE, Fernanda Monteiro Rigue (Orgs). Dossiê ‘Ciência.Vida.Educação”. 23. Ed. Campinas: Labjor- Unicamp, 2023.
3. LIMA, D. C.; MARINI, M.; MONTEIRO, M. Diferenças, multiplicidades e desigualdades a partir da CTS. CTS em foco, p. 8 - 20, 01 jul. 2022. http://www.esocite.org.br/wp/wp-content/uploads/2021/01/CTS-v2-n3-1.pdf

4. MONTEIRO, M. Após anos de cortes, o que esperar da ciência na gestão Lula?. 2022. (Programa de rádio ou TV/Entrevista). https://www.terra.com.br/byte/apos-anos-de-cortes-o-que-esperar-da-ciencia-na-gestao-lula,7f599649f69530974b14a4e365b651a5b18cw94a.html
5. DIAS, Susana. Participação no Podcast Oxigênio #166 – Antropoceno: quando a humanidade é assunto da geologia. 19/05/2023
6. GUIVANT, JULIA S. Participação no Podcast Oxigênio #166 – Antropoceno: quando a humanidade é assunto da geologia. 19/05/2023
7. MONTEIRO, Marko. Participação no Podcast Oxigênio #166 – Antropoceno: quando a humanidade é assunto da geologia. 19/05/2023
8. QUEIROZ FILHO, Antonio Carlos. Áudio-aula: por que estudar linguagem é geográfico? (parte um). 2022 (Projeto de Extensão).
9. QUEIROZ FILHO, Antonio Carlos. Áudio-aula: por que estudar linguagem é geográfico? (parte dois). 2022 (Projeto de Extensão).
10. ARANHA, N.; DIAS, S. O. Organização da Residência artística “Seguir os sapos” em Campinas, desenvolvida em conjunto com a disciplina “Arte, ciência e tecnologia” do programa de Pós-graduação em Divulgação Científica e Cultural do (Labjor, Instituto de Estudos da Linguagem). 2023.
11. ARANHA, N.; BARBOSA, R.; DIAS, S. O. Oficina para estudantes Ciência & Arte nas Férias, intitulada “Entre-meios: uma conexão de mundos com os sapos”, Universidade Estadual de Campinas (UNICAMP). 2023.
12. ARANHA, N.; BARBOSA, R.; DIAS, S. O. Oficina para estudantes Ciência & Arte nas Férias, intitulada “Mesa de trabalho - Entre-meios: uma conexão de mundos com os sapos 2”, Universidade Estadual de Campinas (UNICAMP). 2023.
13. ARANHA, N.; BARBOSA, R.; DIAS, S. O. Oficina para estudantes Ciência & Arte nas Férias, intitulada “Mesa de trabalho - Entre-meios: uma conexão de mundos com os sapos 3”, Universidade Estadual de Campinas (UNICAMP). 2023.
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13. Summary Reports

Summary of scientific production 2022-2023 (Year 6)

Activity	quantity
Events organized by the INCT MC2 and its components with interaction among subcomponents of the project in Year 6	18
Participation in scientific events relevant to the INCT MC2 with accepted abstracts or presentations (with partial or total funding from the INCT MC2, or virtual participation)	86
List of publications	108
Books and book chapters	31
Other activities and web sites of reports, art exhibitions and courses/seminars online and videos	47
Interviews, News and online magazines Reports, pdcoasts	119

14. Fellowships (bolsas) granted by FAPESP and other funding agencies in Year 6 (including students)

-TT Fapesp
Iniciação científica BAS-Unicamp
-Title: Revista ClimaCom - artes, ciências e comunicações diante do Antropoceno
Student: Priscila Cristina Dourado Salvadeo
Adviser: Susana Dias
Scholarship source: Bolsa BAS Unicamp / Duração - 1 ano / Dedicação - 40 horas / Valor mensal R$ 678,00

-Title: Revista ClimaCom - artes, ciências e comunicações diante do Antropoceno
Student: Rayane Barbosa
Advisor: Susana Dias
Scholarship source: Bolsa BAS Unicamp / Duração - 1 ano / Dedicação - 40 horas / Valor mensal R$ 678,00

-Title: Revista ClimaCom - artes, ciências e comunicações diante do Antropoceno
Student: Leo Arantes Lazzerini

Adviser: Susana Dias
Scholarship source: Bolsa BAS Unicamp / Duração - 1 ano / Dedicação - 40 horas / Valor mensal R$ 678,00

-Scientific initiation CNPq
Title: Preservação Ambiental e Povos Migrantes: como artistas e jornalistas influenciam na visão social, a partir dos dados de pesquisa e características de imagens.
-Student: Pedro Battistella Sentinaro.
Adviser: Antonio Carlos Rodrigues de Amorim.
Scholarship source: Iniciação Científica (Graduando em Física) - Universidade Estadual de Campinas, Conselho Nacional de Desenvolvimento Científico e Tecnológico.

-Post-doctoral fellowships CNPq
Title: Mudanças climáticas e ideias para adiar o fim do mundo.
Researcher: Fabiola Simões Rodrigues da Fonseca.
Supervisor: Antonio Carlos Rodrigues de Amorim.
Fellowship source: Universidade Estadual de Campinas, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.

-Post-doctoral fellowships CONICET- Argentina
Title: Formas audiovisuales del paisaje en la Patagonia argentino-chilena (últimas décadas)
Researcher: Maia Gattas Vargas
Supervisor: Sandra Murriello
Fellowship source:CONICET- Argentina, 2022-2025

-Ph.D. CNPq
Title: Corpo-solo-vivo: entre linhas de cultivo
Student: Tatiana Plens Oliveira
Advisors: Wenceslao Machado de Oliveira Júnior and Susana Oliveira Dias
Scholarship source: Universidade Estadual de Campinas, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, 2019-2022

-Masters FAPESP
Title: Comunicação e estudos multiespécies diante do Antropoceno: o caso do sapo cururu.
Student: Natália Aranha de Azevedo
Advisor: Susana Oliveira Dias
Scholarship source: Mestrado (2023/03090-2), vigência: 01/04/2023 a 29/02/2024. Pós-graduação em Divulgação Científica e Cultural no Laboratório de Estudos Avançados em Jornalismo (Labjor) da Universidade Estadual de Campinas.

-Masters Capes
Title: A inadequação de uma terra/Terra viva: dimensão do feminino e as práticas diante da intrusão de Gaia
Student: Milena Bachir
Advisor: Susana Oliveira Dias
Scholarship source: Mestrado (2023/03090-2), vigência: 01/04/2023 a 29/02/2024. Pós-graduação em Divulgação Científica e Cultural no Laboratório de Estudos Avançados em Jornalismo (Labjor) da Universidade Estadual de Campinas.

-Doutorado Capes
Title: O Caminho Na Floresta: Aspectos Sociais, Ecônomicos e Ambientais dos Planos de Desenvolvimento da Amazônia Empregados na BR-319
Student: Juan Mattheus Gil Costa
Advisor: Marko Monteiro

Scholarship source: Doutorado. Início: 2021. Programa de pós-graduação Doutorado em Ambiente e Sociedade) - Universidade Estadual de Campinas. (Orientador).

Fernando Gonçalves Morais – Medidas de espessura ótica de aerossóis na Amazônia com a rede AERONET e o balanço radiativo. Em Co orientação com Eduardo Landulfo, IPEN. Nível Doutorado. Início em setembro de 2016. Orientador: Paulo Artaxo (IFUSP).
Itiara Mayra Barbosa de Albuquerque - Sensoriamento remoto de gases de efeito estufa e o balanço de carbono na Amazônia. Bolsista de mestrado IFUSP. Orientador Paulo Artaxo.
Rafael Valiati dos Santos. O perfil vertical de propriedades físico-químicas de aerossóis na torre ATTO, Amazônia Central. Bolsista de mestrado IFUSP. Orientador Paulo Artaxo.
Avila Benaya dos Santos Sousa – Análise da composição elementar de aerossóis na Amazônia. Bolsista de iniciação científica, IFUSP, orientação Paulo Artaxo.
Bruno Backes Meller – Mecanismos de formação e impactos de nanopartículas na atmosfera amazônica. Bolsista de doutorado FAPESP, início mar/2021. Processo 2020/15405-0. Orientador: Paulo Artaxo.

Marco Aurélio de Menezes Franco, Processos de geração, processamento e deposição de aerossóis medidos na torre ATTO, Amazonia central. Pós-doutorado, Supervisor: Luiz Augusto Machado.

Carolina Cristina Fernandes – número USP 8475144. Medidas para o Brasil implementar seus compromissos de redução de gases de efeito estufa e caminhar rumo a sustentabilidade. Bolsa de Pós Doc PRP-USP. Início: setembro de 2022.

Francisco José Lopes de Lima,, 2020/15754-4 FAPESP, MÉTODOS DE REFINAMENTO ESTATÍSTICO DE PROJEÇÕES CLIMÁTICAS PARA QUANTIFICAÇÃO DOS POTENCIAIS SOLAR E EÓLICO NO BRASIL, From 01/02/2021 To 31/01/2023

Fernando Vasconde de Arruda, Previsão de geração fotovoltaica utilizando modelo híbrido Autoencoder e LSTM. Mestrado

Francisco José Lopes de Lima, Métodos de Refinamento Estatístico de Projeções Climáticas para Quantificação dos Potenciais Solar e Eólico no Brasil, TT4-A

Marcelo Pizzuti Pes, Os impactos da geração eólica offshore na estabilidade do sistema elétrico para o clima presente e futuro, DTI-A

Guilherme Bággio Martins Machado, Qualificação e tratamento de dados ambientais para a análise de tendência de eventos climáticos extremos com impacto no setor elétrico, DTI-B

Elen Daiane Pelissaro. O PAPEL DO OCEANO ATLÂNTICO SUL E DO MODO ANULAR SUL NOS EXTREMOS DE PRECIPITAÇÃO NO SUL DO BRASIL SOB UMA PERSPECTIVA CLIMATOLÓGICA. 2022. Dissertação (Mestrado em Meteorologia) - Instituto de Astronomia Geofisica e Ciëncias Atmosféricas, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior. Orientador: Tercio Ambrizzi.

Iuri Valério Graciano Borges. SIMULAÇÃO NUMÉRICA REGIONAL EM ALTA RESOLUÇÃO DE EVENTOS EXTREMOS DE PRECIPITAÇÃO SOBRE O NORDESTE DO BRASIL. 2022. Dissertação (Mestrado em Meteorologia) - Instituto de Astronomia Geofisica e Ciëncias Atmosféricas, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior. Orientador: Tercio Ambrizzi.

Hugo Alves Braga. PROPAGAÇÃO DE ONDAS DE ROSSBY ATMOSFÉRICAS E A ZONA DE CONVEGÊNCIA DO ATLÂNTICO SUL. 2022. Tese (Doutorado em Meteorologia) -

Instituto de Astronomia Geofisica e Ciëncias Atmosféricas, Conselho Nacional de Desenvolvimento Científico e Tecnológico. Orientador: Tercio Ambrizzi.

MASTER – CAPES
PROCESS NUMBER: 88887.647768/2021-00
TITLE: Weakening of Coastal Upwelling Associated with Marine Heatwaves in the Western South Atlantic
NAME: Jhoseny de Souza Santos
PERIOD: 01/10/2021 to 31/01/2023
INSTITUTION: Universidade Federal de Santa Catarina

Paula Carvalho Pereda
"Assessing the climate and weather effects in Brazil using panel data"
Scholarships abroad - Research
Paula Carvalho Pereda
Link: https://bv.fapesp.br/en/bolsas/179293/assessing-the-climate-and-weather-effects-in-brazil-using-panel-data/

Michael Tulio Ramos de França
"Fertility and Inequality"
Scholarships abroad - Research Internship - Doctorate
Columbia University in the City of New York (United States)
Eduardo Amaral Haddad
Link: https://bv.fapesp.br/en/bolsas/177969/fertility-and-inequality/

Michael Tulio Ramos de França
"Fertility and inequality: evidence from Brazil"
Scholarships in Brazil - Doctorate
Eduardo Amaral Haddad
Link: https://bv.fapesp.br/en/bolsas/174909/fertility-and-inequality-evidence-from-brazil/

Eduardo Amaral Haddad
"Agricultural and agro-industrial sustainability in Chile: modeling the impacts of climate change and natural disasters in an integrated framework"
Regular Research Grants
Eduardo Amaral Haddad
Link: https://bv.fapesp.br/en/auxilios/102276/agricultural-and-agro-industrial-sustainability-in-chile-modeling-the-impacts-of-climate-change-and/

François Claude Prado Boris
"A spatial impact analysis of water accessibility on farming in the Brazilian semiarid"
Scholarships in Brazil - Scientific Initiation
Eduardo Amaral Haddad
Link: https://bv.fapesp.br/en/bolsas/181818/a-spacial-impact-analysis-of-water-accessibility-on-farming-in-the-brazilian-semiarid/

Karina Simone Sass
"Urbanization and climate change: impact evaluation in the Metropolitan Region of São Paulo"
Scholarships in Brazil - Doctorate

Eduardo Amaral Haddad
Link: https://bv.fapesp.br/en/bolsas/183721//

Inácio Fernandes de Araújo Junior
"Agricultural and agro-industrial sustainability in Chile: modeling the impacts of climate change and natural disasters in an integrated framework"
Scholarships in Brazil - Technical Training Program - Technical Training
Eduardo Amaral Haddad
Link: https://bv.fapesp.br/en/bolsas/184227/agricultural-and-agro-industrial-sustainability-in-chile-modeling-the-impacts-of-climate-change-and/

Inácio Fernandes de Araújo Junior
"Extreme events impact assessment: an integrated approach with computable general equilibrium and risk analysis"
Scholarships in Brazil - Post-Doctorate
Link: https://bv.fapesp.br/en/bolsas/202198/extreme-events-impact-assessment-an-integrated-approach-with-computable-general-equilibrium-and-risk/

Inácio Fernandes de Araújo Junior
"The impact assessment of extreme events: an integrated approach with computable general equilibrium and risk analysis"
Scholarships abroad - Research Internship - Post-doctor
Link: https://bv.fapesp.br/en/bolsas/210308/the-impact-assessment-of-extreme-events-an-integrated-approach-with-computable-general-equilibrium-a/

Eduarda Miller de Figueiredo
"Impact of gender diversity on several approaches"
Scholarships in Brazil – Doctorate
Link: https://bv.fapesp.br/en/bolsas/206701/impact-of-gender-diversity-on-several-approaches/

Carlos Roberto Azoni
"National crises, regional economic cycles and disparities"
Research Grants - Visiting Researcher Grant – International
Link: https://bv.fapesp.br/en/auxilios/112214/national-crises-regional-economic-cycles-and-disparities/

15. Students without fellowship

-Douglas Albuquerque Leite. Title: A inovação no setor brasileiro de saneamento básico diante das mudanças climáticas. Start: 2019. PhD (Doutorado em Política Científica e Tecnológica) - Universidade Estadual de Campinas.
-Felipe Mammoli. Title: Digitalizando o Mundo: Dados Digitais e suas Práticas no Observatório da Torre Alta da Amazônia (ATTO). Start: 2017. PhD (Doutorado em Política Científica e Tecnológica) - Universidade Estadual de Campinas, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.

16. Changes in Personnel

For the Communications component, there have been changes in the group, and it is currently constituted as follows:

- Prof. Dr. Renzo Romano Taddei (new coordinator, substituing Drn Antonio Amorim)–

Universidade Federal de São Paulo (UNIFESP)

- Profa. Dra. Susana Oliveira Dias - Laboratório de Estudos Avançados em Jornalismo (Labjor)/Núcleo de Desenvolvimento da Criatividade (Nudecri)/Universidade Estadual de Campinas (UNICAMP)

From the group of researchers, the following professors left: Claudia Pfeiffer and Cristiane Dias – Urban Studies Laboratory (Labeurb)/ Creativity Development Center (Nudecri)/ State University of Campinas (UNICAMP); Rafael Dias – Faculty of Applied Sciences (FCA)/ State University of Campinas (UNICAMP); Milena Serafim – Faculty of Applied Sciences (FCA)/ State University of Campinas (UNICAMP); Isaltina Maria de Azevedo de Mello Gomes – Federal University of Pernambuco (UFPE) and Francis Lacerda - Ecolume-Green Socioeconomics in the Caatinga Biome in the Face of Climate Change-CNPq 441227/2017-1-Agronomic Research Institute of Pernambuco/ IPA-Recife/PE (2017-2020).

Joined the team:

- Prof. Dr. Adrián Cangi – UBA/Undav - Argentina
- Profa. Dra. Alice Dalmaso - Labjor-Unicamp
- Prof. Dr. Sigifredo Esquivel Marins - UAZ - México
- Dra. Fabíola Fonseca - FE-Unicamp
- Profa. Dra. Gabriela di Giulio - USP
- Prof. Dr. Tiago Sales - Labjor-Unicamp
- Profa. Dra. Julia Silvia Guivant - UFSC-Labjor-Unicamp
- Profa. Dra. Lilian Maus - UFRGS
- A mestranda Milena Bachir - Labjor-Unicamp
- A mestranda Maia Gattas Vargas

In the Natural Disasters component, exclusion of a researcher in the CEMADEN team: Daniela de Azeredo França, and Insertion of the following researchers in the UFSC team: Vinicius B. P. Chagas

17. Financial report: Use of the RT and BC (summary)

Susana Oliveira Dias requested three days to participate in the IV Geap BR National Seminar, organized by the Grupo de Estudos de Arte Pública do Brasil, which took place on November 16, 17 and 18, 2023, at the Federal University of Pará. During the event, Susana presented the work “Public Art in the face of the Anthropocene: experiments on work tables,” written together with Maria dos Remedios de Brito (UFPA), and set up the artistic installation “Work table - Ways of attention to the Earth”, of his authorship. Participation in the event involved the presentation of the results of a work methodology in arts and communications that was developed within the scope of the INCT MC - Phase 2 called “Mesa de Trabalho”. The work was published in the proceedings of the event. Participation mobilized the writing of the book chapter “Making the paper talk, or how to cultivate forests in times of catastrophes”, also together with professor Maria dos Remédios de Brito, published in the book “Desire the smallest of worlds, write other corporeities from there”, organized by Remédios and Lindomberto Ferreira Alves and Dhemersson Warly Santos Costa Santos, which was published by Editora do PPGArtes da UFPA in 2023. The presentation also resulted in the creation of the book- object “Company as a way of caring for the Earth”, organized together with students Bianca Santos, Marília Frade, and Breno Filo, and which will be launched in 2023 by the Editora do PPGArtes da UFPA in Belém.

Renzo Romano Taddei participated in the annual meeting of 4S (Society for Social Studies of Science), in Cholula, Mexico, between December 5 and 10, 2022, for which he used project funds to purchase airfare, pay registration at the event and per diem. At the event, he presented work in the sessions “226: Anti-Encyclopedia-reconfiguring knowledge in academic practice” and “369: Dialogues on Interdisciplinarity and Climate Change: experiences from Brazil”.

Eduardo A. Haddad (PI) used part of the BC resources (per diem) to participate in an event in Ghana, from July 1 to 6, 2022, where he gave a talk on "Multisectoral and Multiregional Models in Disaster Impact Analysis", drawing on the INCT project results.

Resources from the CNPq project led by Paulo Nobre awarded funds from CNPq call for proposals 6/2020 allowed the hiring of one PostDoc researcher to develop the coupling of Eta-MOM6, with the support of members of the INCT-MC2 Modeling component. Paulo Nobre received a grant from the CNPq/MCTI/BRICS-STI No 04 call for proposals to develop a joint research with researchers from the Indian Institute of Tropical Meteorology - IITM in India, and the Chinese Academy of Sciences - CAS, in China, to develop high resolution earth system modeling aided by Artificial Intelligence algorithms to study the development of extreme climatic events in a warmer world. The RESM - Eta Model had received grant no.406591/2022-9 from CNPq. This supports generating new downscaling scenarios from BESM and EC-Earth climate models. .Further meetings between the components of INCT-MC2 toward joint articles production should be promoted.

18. Collaboration with other INCTs, projects and Research networks

This INCT MC2 works very closely with the Rede Clima, the Brazilian Panel on Climate Change PBMC, and the INCLINE program at USP. We are already interacting or plan to interact with these INCTs and projects due to common interests and collaboration:

Process 465680/2014-3
INCT da Criosfera
Coordinator: Jefferson Cardia Simões
UFRGS - Universidade Federal do Rio Grande do Sul

Process 465764 / 2014-2
INCT-Observatório Nacionalidade da Dinâmica da Água e do Carbono no Bioma Caatinga
Coordinator: Antônio Celso Antonino
UFPE-Universidade Federal de Pernambuco

Process: 465319/2014-9
INCT do Bioetanol
Coordinator: Marcos Silveira Buckeridge
USP - Universidade de São Paulo

Process: 2015/03804-9
INCT MacroAmb-Environmental Governance in São Paulo Macro Metropolis in a climate variability context
Coordinator: Pedro R. Jacobi
USP - Universidade de São Paulo

Process - CNPq nº 58/2022 (Novo INCT)
INCT Observatório Nacional de Segurança Hídrica e Gestão Adaptativa-ONSEAdapta, Coordinator: Suzana Montenegro
UFPE

UK-CSSP Climate Service Science Project
Newton Fund UK
CEMADEN, INPE, INPA, UKMO

RED-CLIMA (Red Española e Iberoamericana sobre Variabilidad Climática y Servicios Climáticos en Ecosistemas Terrestres y Marinos) Project, under Grant INCCLO0023 from the Consejo Superior de Investigaciones Científicas LINCGLOBAL CSIC from Spain.

Pantanal Research Network MCTI (Rede de Pesquisas do Pantanal do MCTI)

Approved Projects – complementary

DIAS, Susana. Perceber-fazer floresta: alianças entre artes, ciências e comunicações diante do Antropoceno. (Fapesp 2022/05981-9).

Approved Scholarships - complementary

DIAS, Susana. SAE-BAS-Unicamp. Valor aprovado em bolsas: R$ 50.400,00

Annexes

Ata Reunião: **Encontro INCTs – 75 Reunião Anual da SBPC**

Auditório 01 – Engenharia Química; 25-07-2023 18:30
Relatora: **Ana Paula de Carvalho Teixeira (INCT MIDAS UFMG)**

-Abertura Prof. Anderson Gomes
-Professor Jailson abriu a palavra para os participantes da reunião.
-Inicialmente cada representante dos diferentes e INCTs e outros participantes do encontro se apresentaram (nome, instituição ou INCTs).
Inicialmente, foi destacado a importância do retorno dos encontros no INCTs nas reuniões da SBPC! Especialmente para discutir o futuro, considerando a importância desse programa do CNPq e dos importantes projetos desenvolvidos nos INCTs.
O prof. destacou a prorrogação dos INCTs até 2024 e gostaria de escutar todos. O ideal seria ampliar a prorrogação até 2025 e talvez com mais uma liberação de recursos. Seria interessante termos uma avaliação de resultados, por exemplo, no final de 2024, e os que forem bem-sucedidos nessa avaliação poderiam ter os INCTs prorrogados, sem necessidade do envio de novos projetos para um novo edital. Essa é uma ideia e sugestão inicial do prof. Jailson. A idéia é que hoje todos discutam esse tema e outros para a criação da carta desse encontro de Curitiba para encaminhamento do CNPq.
-Fala do vice-coordenador INCT formação quântica (Luiz Davidovich): Problema hoje, esse INCT tem 120 pesquisadores. Se o recurso do INCT atual for dividido entre todos os pesquisadores, pode-se observar que o recurso para cada foi pequeno. O valor foi bom para estimular reuniões, mas não mudou o patamar de publicações no Brasil, em virtude da degradação dos equipamentos (equipamentos obsoletos e quebrados) que prejudica o desenvolvimento da pesquisa e formação de pessoas. Essa é uma questão importante. Pode-se aumentar o recurso para os INCts, temos que ter recursos substâncias para reforma dos laboratórios, manutenção dos equipamentos e estimulo para os estudantes. Algumas questões para se resolver: cursos de PG com vagas ociosas. Temos que pensar nisso, como os INCTs podem auxiliar nessas questões graves. Como podemos ajudar o Brasil a dar um salto na pesquisa científica. Finalmente para isso precisamos de recursos.
- Profa. Mariangela. INCT foi fundamental para a congregação de pessoas, criação de novos grupos (ex-alunos). O INCT passou por grandes dificuldades e foram pegos de surpresa por varias coisas. Ex: bolsas que eram do cNPq e foram para Capes. Vários assuntos que podem ser usados para justificar as perdas. Eles usaram as bolsas para auxiliar nas bolsas perdidas pelo programa de PG. Outra surpresa, muito do recurso não foi pelo CNPq e sim pela fundação regional que não permite que sejam comprados para outros estados. No caso deles, eles vão pedir prorrogação de todo o jeito. Finalmente, eles tem 13 produtos com registros, o INCT foi muito importante. Mas os INCTs tem falhas, por exemplo: comunicação com a sociedade. Então , a prorrogação até 2025 é importante para otimizar ainda mais essa cooperação entre INCTs e trabalhar em todos assuntos.
- Depoimento: olhando a história, até o final da década de 90 tínhamos uma dificuldade enorme de se fazer em colaboração interna. Era mais fácil colaborações externas que internas. Não se tinha mecanismo ou recurso para isso. Primeira iniciativa para isso foram os institutos do milênio que resolveram esses problemas e melhoraram muito a situação. Mas os INCTs têm um papel importante de integração nacional em ciências, que temos que resgatar e temos que manter. Todas as áreas necessitam de modernização. E cada rede tem suas características e as assimetrias aparecem quando criamos as redes. Os INCTS estão sendo um dos poucos mecanismos que temos hoje para corrigir a diferença que temos entre grupos de diferentes áreas. Então a proposta: ressaltar fortemente a importância do INCTs para essas redes, e para isso precisamos manter os INCTs e olhar muito para os recursos de capital. Ex: manter a estrutura

dos laboratórios (manutenção) e crias estruturas em centros novos). Manter custeio para integração, e estrutura de capital para manter o que está funcionando e auxiliar o fomento para os jovens que estão criando nesse momento seus grupos em lugares distantes. Isso tem que estar presentes nos programas INCts.

-Prof. Anderson: Gostaria de passar algumas informações para os participantes da reunião. Boa parte dos recursos nossos vem do FNDCTs. Esse conselho é importante para encaminhar o que tem que ser feito com esse recurso. 3,6 bilhões já existem e esse recurso vai estar disponível até 2025. A Finep irá cuidar desse recurso. Terá apoio para desenhar os termos de referência para a liberação de edital até o fim do ano. (infraestrutura de PeD, assegurar a expansão de PeD em cada estado; reduzir as assimetrias regionais, criar novos centros de PeD em diferentes áreas; desenvolvimento, ciências básicas e INCTs). Importante enviar para o prof. Jailson coisas importantes que podem ser incluídas nos próximos editais.

Depois terá um plano de ação até 2025 e depois a conferência vai olhar para esse plano para planejar os próximos 10 anos.

-Prof. Jailson: Essas informações são muito relevantes e importantes.

-Prof. Sergio Castelo: Gostaria de trazer uma questão de gestão. A maioria do recurso de custeio ficou nas FAPs. Agora que o recurso CNPq chegou. Mas um grande problema, a necessidade do coordenador ter que ir ao banco à todo momento e gerenciar o pagamento pelo pagamento via cartão. O grande problema é ter que ir ao banco toda vez para resolver os problemas, o pesquisador não tem tempo para isso. Ex de solução, o que a FAP de Pernambuco usa, que tem um sistema de gestão do cartão via internet. Prof. Sergio acha que essa questão deve constar na carta Curitiba. Citar a questão de segurança na carta.

-Prof. Jailson. A questão do CNPq em 2016, prof. Jailson fez várias reuniões com o Banco do Brasil para tentar resolver isso, mas não houve soluções.

-Prof. Marcos Pimenta: lembrar que o INCT teve duas fases. O INCT dele começou em 2009. Eram 60 no começo e com um orçamento maior que o da fase 2. E na época o dólar estava mais baixo e tinham uma cota muito boa de bolsa (70 bolsas de pos doc). Essa primeira fase que impulsionou o INCT, foi muito importante. Veio a segunda fase com menor recurso e com o dólar maior. O INCT incorporou novas pessoas (encontros de até 300 pessoas). É impressionante como tem sido observado pesquisadores jovens que relatam como o INCT foi importante para alavancar suas carreiras. Contudo, a fase 2 não tem dinheiro para investimento. Temos que tentar ver que a fase 2 foi muito precária. Nossa meta é voltar para o recuso da fase 1. E importante destacar, que não adianta prorrogar até 2025 sem novos recursos. Todo o recurso já está atrelado a gastos ate 2024. Temos que ser mais ambiciosos e pedir além da prorrogação até 2025 sem mais recursos. Não adianta muito prorrogação sem recursos adicionais. E muito importante pensar para voltar à fase 1 onde podíamos fazer investimento.

-Prof. Lazaro: o cartão de pesquisador não é bom. E é complicado o pesquisador ter que gastar mais de duas horas por semana em filas de banco. Sobre recursos, não podemos deixar passar o que aconteceu com a Capes, que confiscou bolsas. Ex: bolsas para os programas 3 e 4. Então vários grupos dentro do INCTs ficaram sem bolsas. Temos que chamar a Capes novamente para os INCTs.

-Prof. Adalberto Val: Os comentários são altamente importantes. Mas queria complementar. 1- duração dos INCTs é uma conotação politica extremamente importante. Ela reduz a instabilidade da pesquisa cientifica no Brasil. Muitos de nós sobrevivemos por causa dos INCTs. Precisamos pensar na estabilidade da pesquisa cientifica no Brasil. 2 – Fixação de recursos humanos. Estamos em uma situação dramática. Falta de aplicação para os programas de PG. Precisamos pensar na fixação de recursos humanos no país. Se o aluno não tem perspectiva de fixação, ele não faz PG. O valor da bolsa é complicado, mesmo com o aumento que tivemos, que não resolveu o problema de maneira geral. Precisamos pensar sobre isso. 3 – Redução das assimetrias. Não é so assimetria norte – sul. Mas também assimetria dentro doa estados. Precisamos pensar nisso. Ela n]ao vai ser feita pro decreto, mas ações conjuntas nossas. Ex: governança dos INCTs. É fundamental pensamos em uma equalização para isso. Quantos INCTS podem trabalhar em conjunto para diminuir as assimetrias. 4 – Acrescentar as questões das publicações. Pagamos caro para publicar atualmente. Precisamos pensar nisso. A ABC discutiu um pouco sobre a questão das publicações pagas, mas precisamos encontrart um

caminho para isso. 5 – Equívoco grande sobre as participações das FAPS. As Faps são do coordenador, e muitas Faps não aceitam investir em outros estados. Isso tem que ser resolvido.
-Prof. Sergio pediu a palavra de novo: Remanejamento de bolsas. Mão aceitou mais. A capes começou a influenciar nesse remanejamento. Isso impedia o uso do recuso, por exemplo para o Pos Doc. Vale a pena destacar isso na carta.
- Temos que talvez fazer uma carta específica para a Capes. Para ela voltar a recompor um pouco de bolsas que ela tinha de mestrado, doutorado e pos-doc. Lembrando o que aconteceu e o que pode ser feito nesse momento.
- Prof. Wagner UFF. Relato em relação ao cartão. INCT petróleo, relata o uso dos cartões filhotes. Isso facilita um pouco a utilização do cartão.
-Prof. Marcos Pimenta: As bolsas aumentaram o valor. Os nossos bolsistas vão ter aumento do valor da bolsa, só que teremos menos bolsa. Então podíamos pedir um suplemento para mantermos o número de bolsas que foram pedidas no começo.
- Professora: A conversão de dólar quando foi pedido os INCTS era muito diferente da atual, então precisávamos de uma correção em relação a isso.
- Prof. Roberto, instituto de conflitos. Relato sobre a importância dos INCTs para a pesquisa de excelência e aplicação desses resultados nas políticas publicas de várias áreas. Primeiro pedido: constar a ideia das políticas públicas e a importância dos INCTs dessas áreas para as políticas públicas. No caso das políticas públicas, eles sofreram muito com as mudanças dos governos. E nesse sentido, o último tempo do governo foi complexo. As oportunidades de aplicação foram menores. Os INCTS de políticas públicas são minorias, mas são muito importante, pois fazer ciência é fundamental, mas aplica-la também e a valorização do cidadão é muito importante e fundamental e tudo isso precisa ser discutido. Tem 67 livros desde 2017 que são importantes contribuições para essa discussão. Prof. Roberto quer apoiar todas as reivindicações, em especial em relação à Capes. O relacionamento com a Capes é fundamental pois ele cuida sobre a formação das pessoas e o mestrado e doutorado.
- Prof. Jesus Lubian: o CNPq diz que está abrindo uma nova política de distribuição de bolsas, mas é uma forma de mascarar o corte de bolsas. O número de bolsas CNPq não aumentou. O problema de bolsas é muito grave. Outro problema: os preços de todos os equipamentos aumentaram muito em relação ao início dos INCTs. Exemplo, valores dos computadores. A exigência de um novo recurso é imprescindível. Não adianta prorrogarmos o prazo de duração dos INCTs sem mais recursos. A segunda fase dos INCTs foi crítica. Merecemos uma segunda chance, mas uma segunda chance de qualidade, com bons recursos.

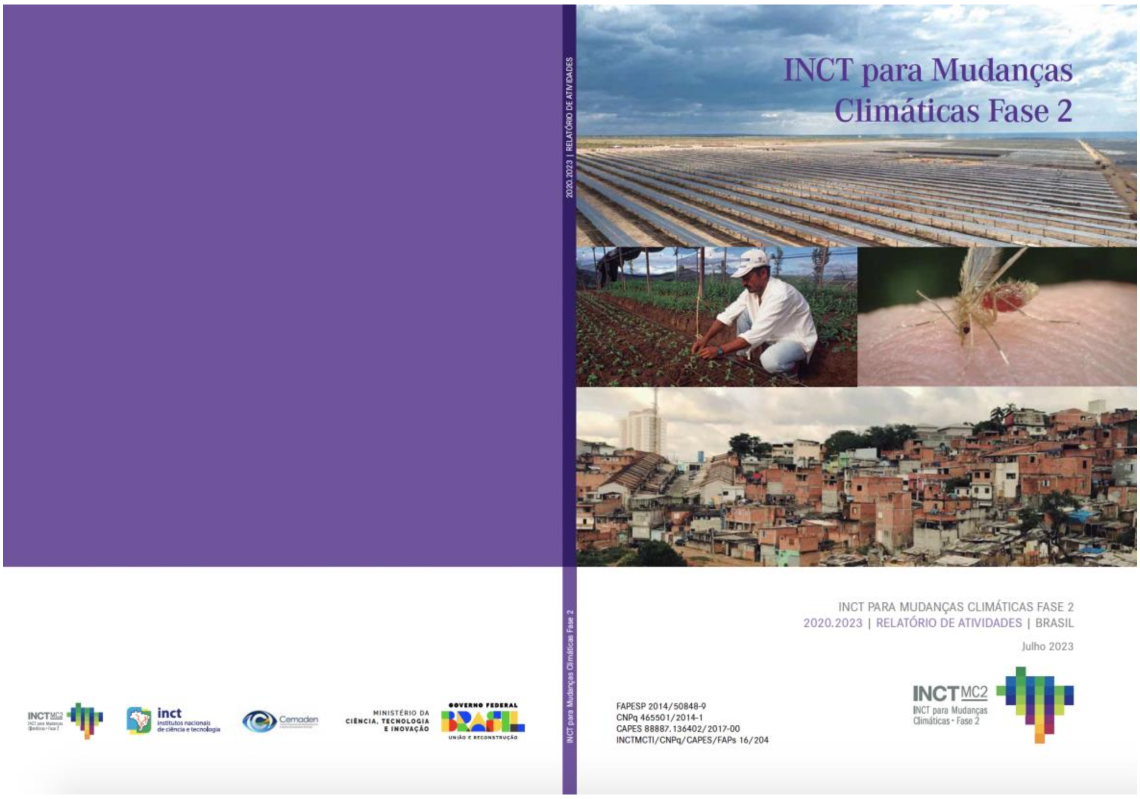
- Prof. Poderíamos propor uma politica bem objetiva: trazer a capes de volta, aumentar a fixação de alunos, e ampliar a integração entre os INCTS. Aproveitar que nossa ministra sabe de tudo isso. Reivindicar que q capes adicione recursos para o PNPD nos moldes antigos. Precisamos pensar nos estudantes. Quem sua os equipamentos são os estudantes. Bolsa de PNPD tem que atender a demanda de todos os programas, independente se usa equipamento ou não. Quem pode viajar e interagir com outros programas é a juventude, por isso precisamos focar neles. Pedirmos para a Capes voltar para os INCTs, especificamente para o PNPD e focar nos jovens que vão ter uma garantia por exemplo por cinco anos. Capes; aloque um recurso volumosos para os INCTS como PNPD (aumenta a interação, fixa as pessoas). Tem que ser recursos adicionais.
-Prof. Mariangela: gostaria de complementar. O CT Biotech . Indagou sobre o FNDCTs. Trazer pessoas para repatriação, mas ninguém quer voltar, Trocar repatriação por fixação de jovens. Temos que ter cuidado para esse dinheiro não ir para locais que não vai ser usado. Ele tem que ir para o CNPq e para locais que necessitam desse recurso.
- Prof. Jerson Lima: Muito importante a participação das FAPS e que pese todas as dificuldades de todos os estados, mas é muito importante. A Faperj teve um problema sério com os INCTs, no edital de 2014, mas foram feitas soluções para resolver isso depois. Apesar de todas as dificuldades, a Faperj conseguiu colocar todos os recursos que estavam propostos. É crucial a participação dos estados e tem que ter uma melhor flexibilização. Ex. compra para equipamentos para outros estados. O cartão realmente é um problema, há soluções possíveis. Jailson, está de parabéns pela reunião e ele assina embaixo de todas as sugestões. Talvez

olhando para o FNDCT, talvez ter um infra especifico para os INCTs que teriam um impacto muito grande. Um FNDCT específico para os INCTS.
-Prof. Faria: não vê com bons olhos ir até 2025, se não tiver aporte de custeio e bolsas.
-Fala final do prof. Jailosn: não é só prorrogar, tem que prorrogar com foco nesses problemas que aconteceram nos últimos anos.
Temos que pensar que temos novos 60 INCTs. Hoje temos quase 50 coordenadores aqui. Vamos preparar um texto escrito para o CNPq dizendo que precisamos conversar, mas sabendo o que queremos. Também precisamos entregar um texto para a prof. Mercedes. Temos uma outra discussão importante sobre o FNDCTS. Isso é muito importante. Precisamos de uma estratégia e essa é uma discussão da estratégia. Precisamos de uma estratégia. Se tivermos algo bem organizado para essas conversas, podemos ter bons resultados.

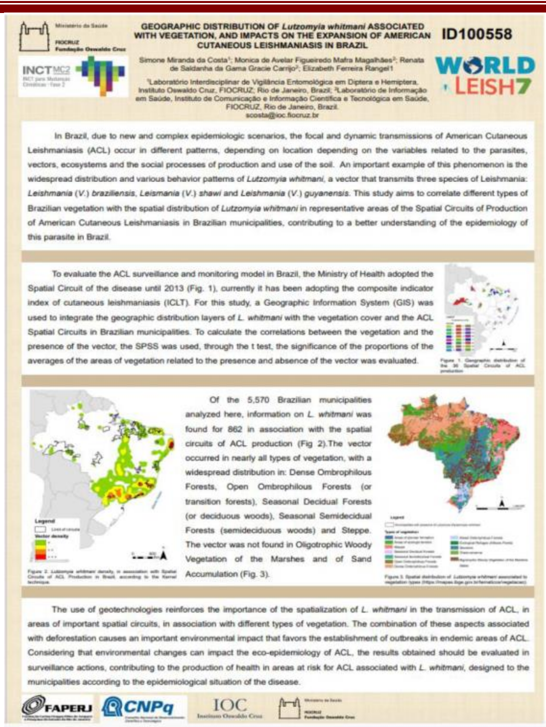
RESUMO:
1 - Carta especifica para a Capes
- Temos que talvez fazer uma carta específica para a Capes. Para ela voltar a recompor um pouco de bolsas que ela tinha de mestrado, doutorado e pós-doc. Lembrando o que aconteceu e o que pode ser feito nesse momento. Pedirmos para a Capes voltar para os INCTs, especificamente para o PNPD e focar nos jovens que vão ter uma garantia por exemplo por cinco anos. Capes; aloque um recurso volumosos para os INCTS como PNPD (aumenta a interação, fixa as pessoas). Tem que ser recursos adicionais.
2 – Carta específica sobre o encontro de Curitiba:
- Outra carta relacionada a essa reunião com alguns pontos específicos: prorrogação até 2025 , mas com recursos adicionais. Destaque da necessidade de recursos adicionais maior em especial em relação à defasagem em relação às bolsas, conversão do dólar e aumento do custo de insumos aumento equipamentos atualmente e valores necessários para publicações. Passar uma mensagem clara para o governo que temos que passar para outro patamar que o que temos hoje nos INCTs não é suficiente e não foi suficiente nos últimos anos.
Destacar a grande importância dos INCTs para o Brasil, exemplo, na área de políticas publicas, estabilidade das pesquisas, fixação de recursos humanos. Redução das assimetrias e outros
Foco na importância dos INCTs, bolsas com foco nos alunos e jovens pesquisadores, custeio, manutenção da infraestrutura. E falar dos problemas com o cartão.

Comentários finais:
Agradecemos profundamente a Professora Ana Paula pelo relato totalmente aderente ao que foi discutido com a presença de 48 Coordenadores(as) ou representantes. Destaco que a reunião foi transmitida por vídeo conferência. Comentários & sugestões das(os) Colegas serão de grande relevância para elaborarmos a **Carta de Curitiba**!!

Second INCT MC2 Report 2020-2023



Presentations of the INCT MC2 at meetings and conferences (presential and virtual)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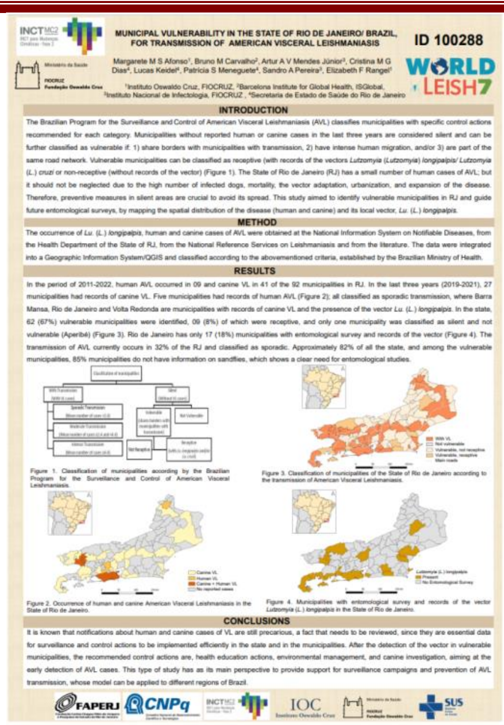
MUNICIPAL VULNERABILITY IN THE STATE OF RIO DE JANEIRO/ BRAZIL, FOR TRANSMISSION OF AMERICAN VISCERAL LEISHMANIASIS
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INTRODUCTION
METHOD
RESULTS
CONCLUSIONS
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Como as mudanças climáticas impactam na expansão dos flebotomíneos?
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Elizabeth Ferreira Rangel
Oswaldo Cruz Institute, FIOCRUZ/Rio de Janeiro, Brazil
Climate Change National Institute of Science and Technology/ Brazil
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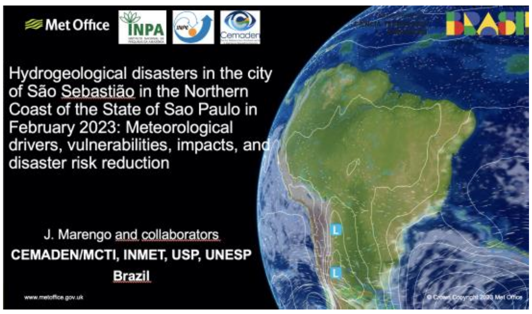
Impactos das Mudanças Climáticas na Saúde Humana: Leishmanioses
Elizabeth Rangel
Pesquisadora em Saúde Pública Instituto Oswaldo Cruz, FIOCRUZ
Pesquisadora do Instituto Nacional de Ciência e Tecnologia em Mudanças Climáticas (Coordenação do Subcomponente Saúde)
PÁTRIA AMADA BRASIL


Met Office
INPA
Cemaden
Hydrogeological disasters in the city of São Sebastião in the Northern Coast of the State of Sao Paulo in February 2023: Meteorological drivers, vulnerabilities, impacts, and disaster risk reduction
J. Marengo and collaborators
CEMADEN/MCTI, INMET, USP, UNESP
Brazil
www.metoffice.gov.uk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Eventos en la región y riesgo de desastres en um clima que esta cambiando: Impactos del Cambio Climático, El Nino, y deforestación de la Amazonia em LAC
Jose A. Marengo
R&D Director
jose.marengo@cemaden.gov.br
CEMADEN/São Paulo, Brazil
July 6 2023
WORLD METEOROLOGICAL ORGANIZATION
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XIV


18º CONGRESSO INTERNACIONAL DE JORNALISMO INVESTIGATIVO
ABRAJI
Por que é essencial falar sobre a emergência climática?
Jose A. Marengo
CEMADEN/São Paulo, Brasil
jose.marengo@cemaden.gov.br
São Paulo, 30 Junho 2023
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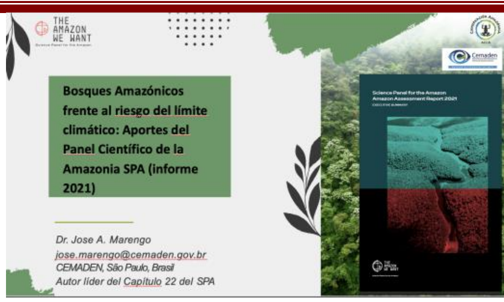
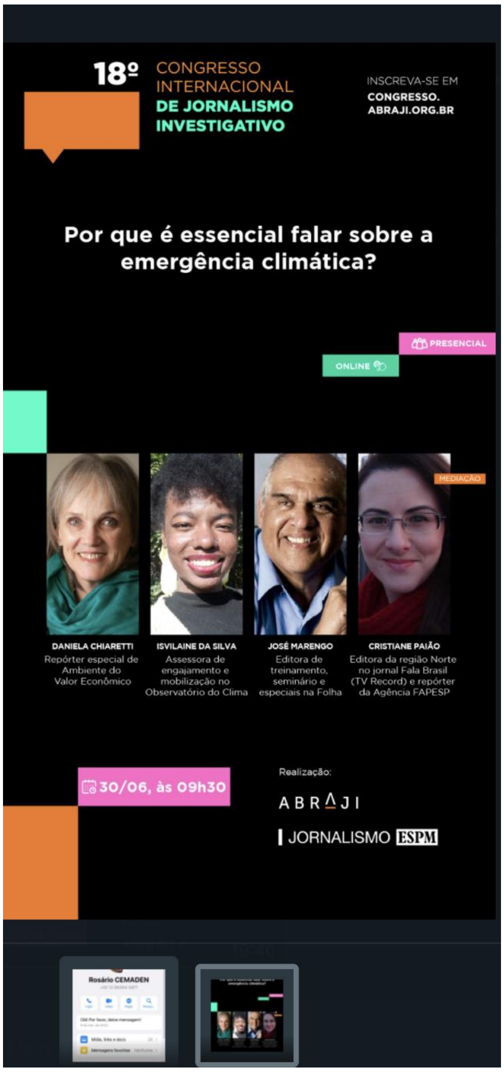
Desastres naturais e Mudanças Climáticas
Panorama dos eventos climáticos extremos: causas, consequências
e o que podemos fazer para reduzir seus impactos
INCT MC2
Jose A. Marengo
CEMADEN, SP
jose.marengo@cemaden.gov.br
Maio 2022


THE AMAZON WE WANT
Bosques Amazónicos frente al riesgo del límite climático: Aportes del Panel Científico de la Amazonia SPA (informe 2021)
Dr. Jose A. Marengo
jose.marengo@cemaden.gov.br
CEMADEN, São Paulo, Brasil
Autor líder del Capítulo 22 del SPA


G·STIC
THE AMAZON WE WANT
Science Panel for the Amazon
Presents at the G-STIC Conference
February 14th, 2023 • 13:30-14:45 (BRT)
Carlos Nobre
SPA Co-Chair
Paulette Bynoe
SPA Member
Luciana Gatti
SPA Member
Jose Marengo
SPA Member
Carlos Young
SPA Member
www.theamazonwewant.org


18º CONGRESSO INTERNACIONAL DE JORNALISMO INVESTIGATIVO
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Por que é essencial falar sobre a emergência climática?
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DANIELA CHIARETTI
Repórter especial de Ambiente do Valor Econômico
ISVILAINE DA SILVA
Assessora de engajamento e mobilização no Observatório do Clima
JOSÉ MARENGO
Editora de treinamento, seminário e especiais na Folha
CRISTIANE PAIÃO
Editora da região Norte no jornal Fala Brasil (TV Record) e repórter da Agência FAPESP
30/06, às 09h30
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THE AMAZON AND TROPICAL FORESTS:
ITS GLOBAL IMPLICATIONS AND NEEDED URGENT ACTIONS
EL AMAZONAS Y LOS BOSQUES TROPICALES: IMPLICACIONES GLOBALES Y ACCIONES URGENTES
Belmont Forum Collaborative Research Action
April 19, 2023 | 12:00 - 13:30 UYT / 15:00 - 16:30 UTC
English-Spanish interpretation
Interpretación español-inglés
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XXII Foro Regional de Perspectivas Climáticas del Oeste de Sudamérica
Santiago, Chile
27 al 31 de marzo de 2023
Revisión de los análisis de sequía de los reportes de estado del clima de 2020 y 2021 de la OMM en Latinoamérica y metodología CEMADEN
Cemaden
BRASIL
Jose A. Marengo
CEMADEN/MCTI
Sao Paulo, Brasil


Rede Clima
Mudanças Climáticas Globais no Brasil
Mesa redonda:
"Principais abordagens e análise:
6º Relatório do IPCC com foco nos desastres.
Medidas e políticas públicas implementadas."
29 de março
14h
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Moacyr Araújo
Coordenador Rede Clima e Vice-reitor UFPE
PARTICIPANTES
Armin Braun - Diretor do CENAD
(Centro Nacional de Gerenciamento de Riscos e Desastres)
Osvaldo Moraes - Diretor CEMADEN
(Centro Nacional de Monitoramento e Alertas de Desastres Naturais)
Suzana Montenegro - Diretora Presidente Apac
(Agência Pernambucana de Águas e Clima)


Desafios do Planejamento Urbano e Regional no Brasil e América Latina frente à emergência climática
Jose A. Marengo
CEMADEN/MCTIC
São José dos Campos, SP, Brazil
www.cemaden.gov.br
jose.marengo@cemaden.gov.br
VIII Seminário do PLUR
UNIVAP
São Jose dos Campos
Marco 2023


Variabilidade Climática, Mudanças Climáticas, Emergência Climática e desastres naturais
Jose A. Marengo
CEMADEN/MCTIC
São José dos Campos, SP, Brasil
www.cemaden.gov.br
jose.marengo@cemaden.gov.br
Dia Nacional da Conscientização sobre as Mudanças Climáticas.
16 Marco 2023


Cemaden
Variabilidade e mudanças climáticas e extremos hidro-meteorológicos que deflagram desastres naturais
Jose A. Marengo
CEMADEN,SP
jose.marengo@cemaden.gov.br
VII JORNADA DE GESTÃO E ANÁLISE AMBIENTAL: EMERGÊNCIA CLIMÁTICA: O FUTURO É AGORA!
3 a 6 de Outubro de 2022


VII Jornada de Gestão e Análise Ambiental
-Emergência Climática: O Futuro é agora-
03 - 06 Out 2022
MESA REDONDA:
MUDANÇAS CLIMÁTICAS
E RECURSOS HÍDRICOS
Prof. Dr. José Marengo (CEMADEN)
Prof. Dr. José Galizia Tundisi
(USP/UFSCar/IIEGA/IIE)
Moderador: Prof. Frederico Y. Hanai (UFSCar)


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"Modelo SWAT para Segurança Hídrica e Gestão Adaptativa"
Vagas Limitadas
Profa. Danielle Bressiani
UFPel
Instrutora
Informações e Inscrições:
29-31/05/2023, 14-17h
Presencial: USP São Carlos
Remoto Online: Instruções
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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO
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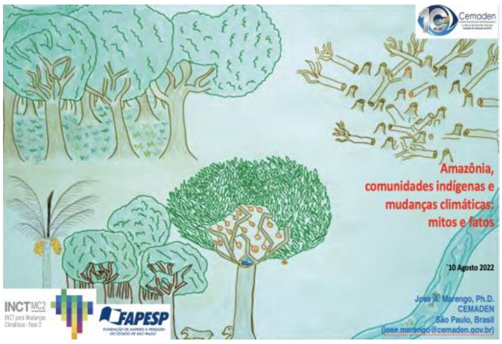
5o FORO LATINOAMERICANO Y DEL CARIBE DE VIVIENDA Y HÁBITAT:
"RESPONDER A LA CRISIS CLIMATICA Y SOCIAL"
Eje temático: Tendencias, desafios e impactos del cambio climático en la vivienda y los asentamientos.
Escenarios y proyecciones de los efectos del cambio Climático em America Latina y Caribe (LAC)
Jose A. Marengo
CEMADEN/São Paulo, Brazil
jose.marengo@cemaden.gov.br
Bogotá, Colombia 31 July 2023
UHPH
Hábitat para la Humanidad
V FORO LATINOAMERICANO Y DEL CARIBE DE VIVIENDA Y HÁBITAT


Cemaden
Amazônia, comunidades indígenas e mudanças climáticas: mitos e fatos
10 Agosto 2022
Jose A. Marengo, Ph.D.
CEMADEN
São Paulo, Brasil
jose.marengo@cemaden.gov.br
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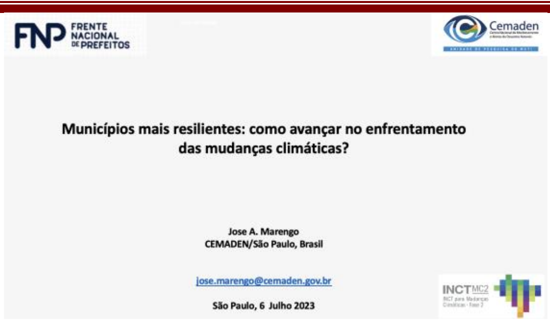
FNP FRENTE NACIONAL DE PREFEITOS
Cemaden
Municípios mais resilientes: como avançar no enfrentamento das mudanças climáticas?
Jose A. Marengo
CEMADEN/São Paulo, Brasil
jose.marengo@cemaden.gov.br
São Paulo, 6 Julho 2023
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VI CONGRESSO INTERNACIONAL DE RISCOS
Riscos e Conflitos Territoriais.
Das catástrofes naturais às tensões geopolíticas
Flash floods and landslides in the city of Recife, Northeast Brazil after heavy rain on May 25–28, 2022: Causes, impacts, and disaster preparedness
Jose A. Marengo
CEMADEN-Brazil
Jose.marengo@cemaden.gov.br
Cemaden
23 a 26 de maio de 2023
Faculdade de Letras da Universidade de Coimbra
Coimbra, Portugal
RISCOS


Secretaria Nacional de Povos e Comunidades Tradicionais e Desenvolvimento Rural Sustentável
marinasilvaoficial Ontem (27/07), a equipe do Departamento de Combate à Desertificação, da Secretaria Nacional de Povos e Comunidades Tradicionais e Desenvolvimento Rural Sustentável, do Ministério do Meio Ambiente, reuniu-se com pesquisadores do INPE, ANA, Cemaden, INSA e EMBRAPA Semiárido para discutir os instrumentos que orientam a ação política e a tomada de decisões no monitoramento das secas e da desertificação. Esse é mais um passo importante na retomada da Política Nacional de Combate à Desertificação e Mitigação dos Efeitos da Seca.
497 curtidas


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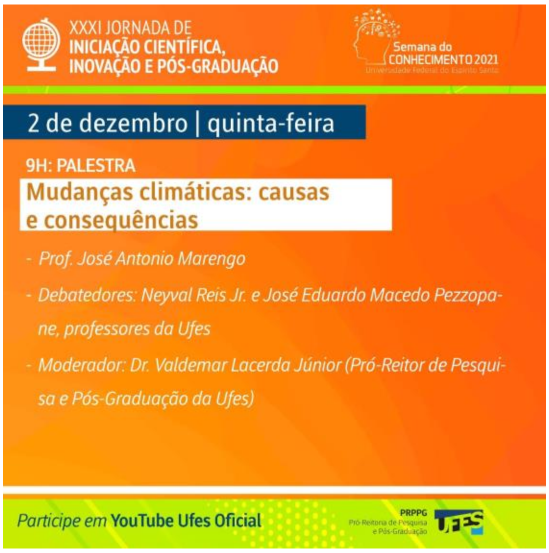
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL
Série de Debates "Ciência, Riscos e Desastres"
Mudanças climáticas, intensificação de desastres e formas de enfrentamento
14 de outubro, às 10h
(horário de Brasília)
Andréa Ventura
Professora da UFBA e coordenadora do Grupo de Pesquisa em Governança para Sustentabilidade e Gestão de Baixo Carbono
José Marengo
Coordenador Geral de Pesquisa e Desenvolvimento do Centro Nacional de Monitoramento e Alertas de Desastres Naturais
Transmissão pelo canal da Série de Debates
YouTube


XXXI JORNADA DE INICIAÇÃO CIENTÍFICA, INOVAÇÃO E PÓS-GRADUAÇÃO
Semana do CONHECIMENTO 2021
2 de dezembro | quinta-feira
9H: PALESTRA
Mudanças climáticas: causas e consequências
- Prof. José Antonio Marengo
- Debatedores: Neyval Reis Jr. e José Eduardo Macedo Pezzopane, professores da Ufes
- Moderador: Dr. Valdemar Lacerda Júnior (Pró-Reitor de Pesquisa e Pós-Graduação da Ufes)
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2 CONGRESO INTERNACIONAL
Preparing for Uncertainties of Climate Changes: A Framework for Vulnerability Reduction in the Tourism Industry
Erick da Silva Santos
José Antonio Marengo
Corresponding author: ericksantos@uft.edu.br
ORGANIZA:
Externado


PERU PESQUERO
CONDUCCIÓN:
ROCÍO VÁSQUEZ GOICOCHEA
Lic. Ciencias de la Comunicación
Mag. Cambio Climático
MARTES 11 DE JULIO
1:00 p.m. Perú
3:00 p.m. Brasil
ENTREVISTA
Dr. José Marengo Vásquez
Científico mundial y miembro del Grupo Intergubernamental de Expertos sobre el Cambio Climático (IPCC).
TEMA: "Impactos climáticos de El Niño en el Perú"
ENVIVO
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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL
Impact based Early Warning System at a Urban Scale:
The Brazilian Experience in DRR
Jose A. Marengo
CEMADEN/São Paulo, Brazil
jose.marengo@cemaden.gov.br
JRC, Ispra
September 2022
JRC


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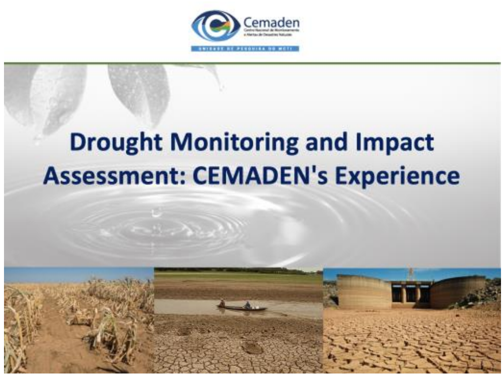
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL
GOVERNO FEDERAL
Drought Monitoring in Brazil
Jose A. Marengo
CEMADEN/São Paulo, Brazil
jose.marengo@cemaden.gov.br
JRC, Ispra
September 2022
Joint Research Centre
JRC


Cemaden
Drought Monitoring and Impact Assessment: CEMADEN's Experience


CSIC
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Cold Waves of Winter 2021 in central South America: Characteristics and impacts
J. Marengo (CEMADEN-Brazil) J. C. Espinoza (IRD CNRS-France), L. Bettolli (UBA-Argentina), A. P. Cunha (CEMADEN-Brazil), J. Molina-Carpio (UMSA-Bolivia), M. Skansi (SMNB-Argentina), K. Correa, (SENAMHI-Peru) A. M. Ramos (INMET-Brazil),R. Salinas (DMH-Paraguay) J.-P. Sierra (IRD CNRS-France)
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3 November 2022


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UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO"
O que a universidade deve fazer nos próximos cinco anos para apoiar a sociedade a começar o enfrentamento decisivo à emergência climática
Em foco: eventos extremos
Jose A. Marengo¹, Enner H, Alcântara²
¹CEMADEN
²UNESP-CEMADEN PG Desastres Naturais
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REUNIÃO DE AVALIAÇÃO E PREVISÃO DE IMPACTOS DE EXTREMOS DE ORIGEM HIDRO-GEO-CLIMÁTICO
Monitoramento das Condições de Seca em todo o Brasil
DIAGNÓSTICO: OUTUBRO/2022
JOSE A. MARENGO
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Heavy rainfall associated with natural disasters in South-eastern Brazil in November-December 2021: Meteorological context, trends in extremes and impacts.
J. A. Marengo, M. E. Seluchi, A.P. Cunha, L. A Cuartas, D. Goncalves, V. B. Sperling, A. M. Ramos, G. Dolif, S. Saito, F Bender, T. R. Lopes, R. C. Alvala, O L. Moraes
Jose A. Marengo
CEMADEN,SP
jose.marengo@cemaden.gov.br
CONGREMET
XIV Argentine Congress ofMeteorology (CONGREMET XIV)
7-11 November 2022
Buenos Airesd, Argentina
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AGROPOLO VALE
PARQUE TECNOLÓGICO São José dos Campos
O AGRO
DO FUTURO
Painel Riscos Climáticos no Agro
Jose A. Marengo
jose.marengo@cemaden.gov.br
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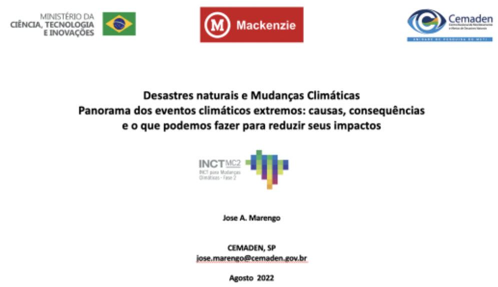
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Desastres naturais e Mudanças Climáticas
Panorama dos eventos climáticos extremos: causas, consequências e o que podemos fazer para reduzir seus impactos
INCT MC2
Jose A. Marengo
CEMADEN, SP
jose.marengo@cemaden.gov.br
Agosto 2022

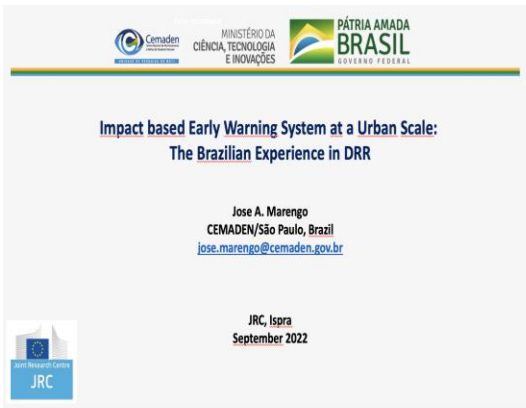

Variabilidade Climática e Impactos Urbanos: Hoje e o Amanhã
Tércio Ambrizzi
IEE/IAG- USP
Colóquios do IMECC-UNICAMP
Junho 2023
UNICAMP


V FÓRUM DE MEIO AMBIENTE
MUDANÇAS CLIMÁTICAS
Variabilidade climática e seus extremos: O Clima está Mudando?
Tércio Ambrizzi
Departamento de Ciências Atmosféricas
IAG/USP
Setembro 2022


Aquecimento Global, Variabilidade Climática e seus extremos sobre o Brasil
Tércio Ambrizzi
Instituto de Energia e Ambiente
IEE/USP
Outubro 2022


Pós Graduação
Faculdade de Saúde Pública
Variabilidade Climática e suas Mudanças: Passado, Presente e Futuro
Tércio Ambrizzi
Instituto de Energia e Ambiente - USP
Junho 2022
SAS-5700 INTERFACES AMBIENTE, SAÚDE E SUSTENTABILIDADE


VI CONGRESSO INTERNACIONAL DE RISCOS
Riscos e Conflitos Territoriais.
Das catástrofes naturais às tensões geopolíticas
ÍNDICE DE VULNERABILIDADE DAS POPULAÇÕES EM RISCO DE DESLIZAMENTOS DE TERRA NO CONTEXTO DO SISTEMA BRASILEIRO DE ALERTA PRECOCE
Regina C. S. Alvalá[1], Mariane C. de Assis Dias[1], Silvia M. Saito[1], Marcelo Seluchi[1]
Cláudio Stenner[2]
1.CEMADEN/MCTI; 2. IBGE
E-mailregina.alvala@cemaden.gov.br
23 a 26 de maio de 2023
Faculdade de Letras da Universidade de Coimbra
Coimbra, Portugal
RISCOS


MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL
Impact based Early Warning System at a Urban Scale:
The Brazilian Experience in DRR
Jose A. Marengo
CEMADEN/São Paulo, Brazil
jose.marengo@cemaden.gov.br
JRC, Ispra
September 2022
JRC


CSSP Brazil Annual Science Hybrid Workshop
Heavy rainfall associated with natural disasters in South-eastern Brazil in November-December 2021: Meteorological context, trends in extremes and impacts.
J. A. Marengo, M. E. Seluchi, A.P. Cunha, L. A Cuartas, D. Goncalves, V. B. Sperling, A. M. Ramos, G. Dolif, S. Saito, F Bender, T. R. Lopes, R. C. Alvala, O L. Moraes
CEMADEN/MCTI
28th-30th June 2022
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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
Cemaden
Cenários de Mudanças Climáticas e Impactos no Brasil:
Projeções de extremos de clima e desafios associados com o meio ambiente e sustentabilidade
September 01 - 03, 2022
Marina da Glória - Rio de Janeiro
Jose A. Marengo
CEMADEN, SP
jose.marengo@cemaden.gov.br
Setembro 2022


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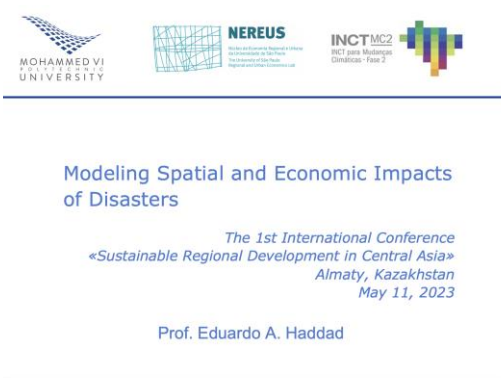
INCT para Mudanças Climáticas - Fase 2
Cajas de herramientas en modelos de equilibrio general multirregional y multisectorial para Paraguay
Laboratorio de Economía Regional y Urbana de la Universidad de Sao Paulo – NEREUS
San Lorenzo, Paraguay
09 de marzo de 2023
Eduardo Haddad Fernando Perobelli Inácio Araújo
Gustavo Castro Plinio Ramirez-Alvarez Raphael Fernandes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Modeling Spatial and Economic Impacts of Disasters
The 1st International Conference
«Sustainable Regional Development in Central Asia»
Almaty, Kazakhstan
May 11, 2023
Prof. Eduardo A. Haddad


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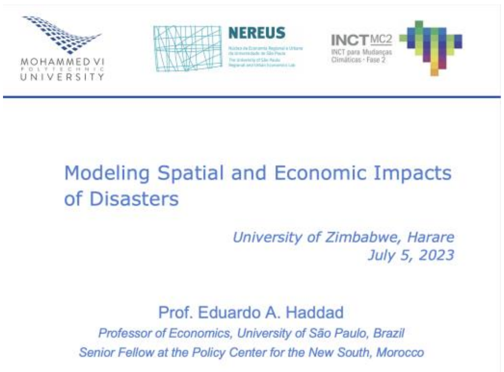
Multisectoral and Multi-regional Economic Modelling
FEBT Summer Scholl 2023
June 28, 2023
Split, Croatia
Prof. Eduardo A. Haddad
Professor of Economics, University of São Paulo, Brazil
Senior Fellow at the Policy Center for the New South, Morocco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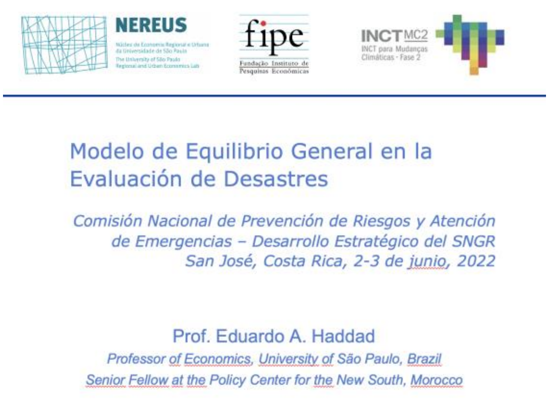
Modeling Spatial and Economic Impacts of Disasters
University of Zimbabwe, Harare
July 5, 2023
Prof. Eduardo A. Haddad
Professor of Economics, University of São Paulo, Brazil
Senior Fellow at the Policy Center for the New South, Morocco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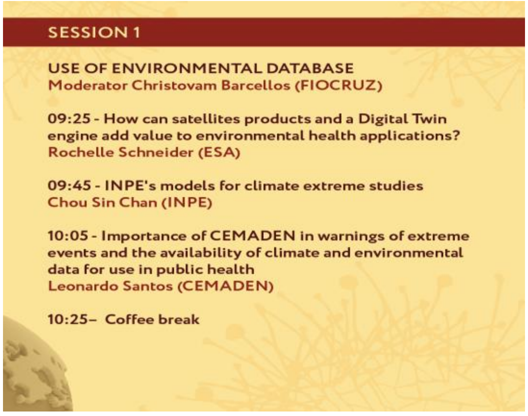
Modelo de Equilibrio General en la Evaluación de Desastres
Comisión Nacional de Prevención de Riesgos y Atención de Emergencias – Desarrollo Estratégico del SNGR
San José, Costa Rica, 2-3 de junio, 2022
Prof. Eduardo A. Haddad
Professor of Economics, University of São Paulo, Brazil
Senior Fellow at the Policy Center for the New South, Morocco


Mudanças Climáticas:
Soluções Baseadas na
Natureza
Paulo Nobre
Instituto Nacional de Pesquisas Espaciais - INPE
Aula Disciplina Mudança Climática
UFRPE, 28 de junho de 2023

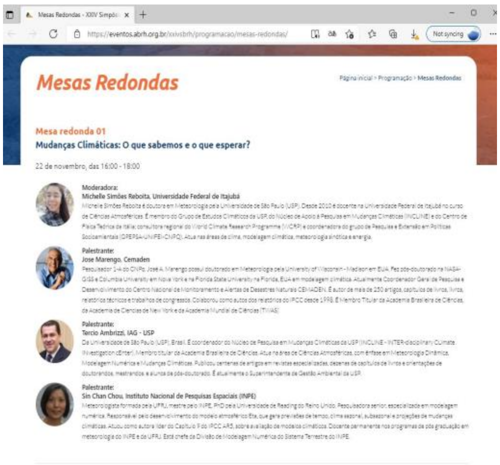

Mudanças Climáticas
o Gatilho/Seguro Amazônico
Paulo Nobre
Instituto Nacional de Pesquisas Espaciais - INPE
Seminário AMAZÔNIA 4.0
Manaus, 8 de agosto de 2022


II WORKSHOP
Environmental
Geospatial Data
and Health
MAY 4TH
8:30 TO 12:00
INSCRIPTION:
bit.ly/WorkshopEGDH
TRANSMISSION: Zoom Meetings
and youtube.com/cidacs.fiocruz
Ministério da Saúde
FIOCRUZ
Fundação Oswaldo Cruz
Instituto Gonçalo Moniz
cidacs
Centro de Integração de Dados e Conhecimentos para Saúde


SESSION 1
USE OF ENVIRONMENTAL DATABASE
Moderator Christovam Barcellos (FIOCRUZ)
09:25 - How can satellites products and a Digital Twin engine add value to environmental health applications?
Rochelle Schneider (ESA)
09:45 - INPE's models for climate extreme studies
Chou Sin Chan (INPE)
10:05 - Importance of CEMADEN in warnings of extreme events and the availability of climate and environmental data for use in public health
Leonardo Santos (CEMADEN)
10:25– Coffee break


WORKSHOP
Sensoriamento Remoto
& Agronegócio
PROGRAMA ESPACIAL BRASILEIRO
AEB
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL
GOVERNO FEDERAL
INFORMAÇÕES
Local: Auditório Roger Honiat - LIT, INPE, São José dos Campos-SP
Formato: Evento presencial com gravação de palestras
Data: 26/04 a 28/04
Carga horária: 2 dias de palestras (8h30-17h30) + 1 dia de visita
Número de participantes: até 30 pessoas


SisBaHiA
Sistema Base de Hidrodinâmica Ambiental
II Fórum
Laboratório SisBaHiA
USO DE MODELAGEM AMBIENTAL COMO FERRAMENTA DE SUPORTE A ANÁLISE DE MUDANÇAS CLIMÁTICAS E EVENTOS EXTREMOS
12 de abril • terça-feira
de 14:00 às 15:30
REALIZAÇÃO:
APOIO:
COPPE UFRJ
AECO
Palestrantes
SisBaHiA como ferramenta para análises de mudanças climáticas e eventos extremos
Paulo Cesar Colonna Rosman
Modelagem em escala local das mudanças climáticas
Sin Chan Chou
Efeito de fenômenos meteoceanograficos no nível d'água nas Lagoas de Jacarepaguá
Monica Frickmann Young Buckmann
Possibilidade metodológica do uso da Modelagem em análises de mudanças climáticas
Lidiane dos Santos Lima
Moderadora
Verônica Andrade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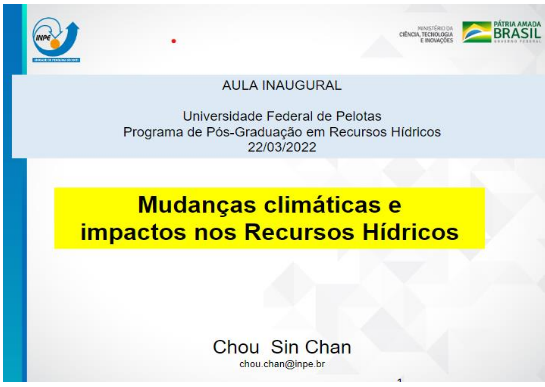
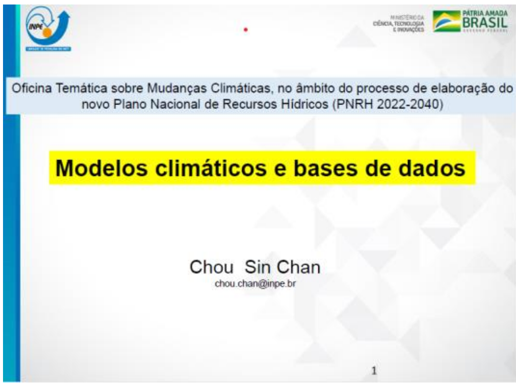
https://eventos.abrh.org.br/xxivsbrh/programacao/mesas-redondas/
Not syncing
Mesas Redondas
Página inicial > Programação > Mesas Redondas
Mesa redonda 01
Mudanças Climáticas: O que sabemos e o que esperar?
22 de novembro, das 16:00 - 18:00
Moderadora:
Michelle Simões Reboita, Universidade Federal de Itajubá
Palestrante:
Jose Marengo, Cemaden
Palestrante:
Tercio Ambrizzi, IAG - USP
Palestrante:
Sin Chan Chou, Instituto Nacional de Pesquisas Espaciais (INPE)


PÁTRIA AMADA BRASIL
Técnicas de análise das Mudanças Climáticas Globais
Chou Sin Chan
Teoria e Métodos da Climatologia
Pós-graduação em Geografia – UERJ
03/11/2021


Sin Chan Chou
Instituto Nacional de Pesquisas Espaciais
Ângela Livino
Empresa de Pesquisa Energética
Edson Sano
Embrapa Cerrados
Carlos Sanches
Netafim
inovagri
INOVAGRI
QUINTA FEIRA | JULHO 15 | 19h BRT
youtube.com/inovagri
Marcus Schmidt
Senninger Brasil
Lineu Rodrigues
Embrapa
MODERADOR
WEBINAR #18-2021
Tendências na Agricultura Irrigada Brasileira: Ambiente, Clima, Energia e Equipamentos


PÁTRIA AMADA BRASIL
AULA INAUGURAL
Universidade Federal de Pelotas
Programa de Pós-Graduação em Recursos Hídricos
22/03/2022
Mudanças climáticas e impactos nos Recursos Hídricos
Chou Sin Chan
chou.chan@inpe.br


PÁTRIA AMADA BRASIL
Oficina Temática sobre Mudanças Climáticas, no âmbito do processo de elaboração do novo Plano Nacional de Recursos Hídricos (PNRH 2022-2040)
Modelos climáticos e bases de dados
Chou Sin Chan
chou.chan@inpe.br


A dynamic resilience approach using multi-hazard index insurance design for extreme weather events and climate services
Marcos Roberto Benso*, Gabriela Chiquito Gesualdo, Greicelene Silva, Eduardo Mario Mendiondo
Contact: marcosbenso@usp.br
IUGG BERLIN 2023
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Acknowledgments
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CAPES


A PROPOSAL FOR A COLLABOR
BRAZILIAN ECOHYDROLOGICA
SIMULATION TOOL – BEST
UFPEL
USP
Universidade de São P
Apac
UNIVERSITY of GUELPH


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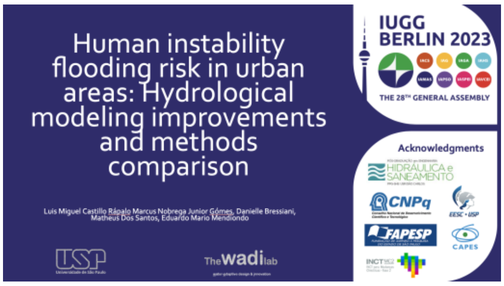
Human instability flooding risk in urban areas: Hydrological modeling improvements and methods comparison
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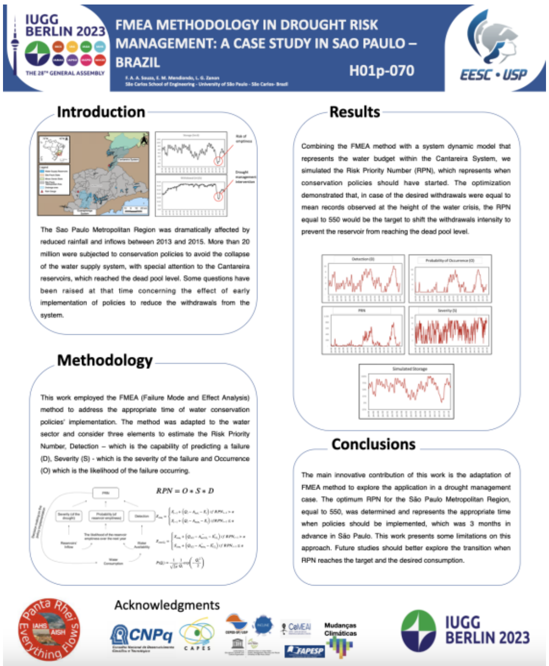
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FMEA METHODOLOGY IN DROUGHT RISK MANAGEMENT: A CASE STUDY IN SAO PAULO – BRAZIL
H01p-070
EESC • USP
Introduction
The Sao Paulo Metropolitan Region was dramatically affected by reduced rainfall and inflows between 2013 and 2015. More than 20 million were subjected to conservation policies to avoid the collapse of the water supply system, with special attention to the Cantareira reservoirs, which reached the dead pool level. Some questions have been raised at that time concerning the effect of early implementation of policies to reduce the withdrawals from the system.
Methodology
This work employed the FMEA (Failure Mode and Effect Analysis) method to address the appropriate time of water conservation policies' implementation. The method was adapted to the water sector and consider three elements to estimate the Risk Priority Number, Detection – which is the capability of predicting a failure (D), Severity (S) - which is the severity of the failure and Occurence (O) which is the likelihood of the failure occurring.
RPN = O * S * D
Results
Combining the FMEA method with a system dynamic model that represents the water budget within the Cantareira System, we simulated the Risk Priority Number (RPN), which represents when conservation policies should have started. The optimization demonstrated that, in case of the desired withdrawals were equal to mean records observed at the height of the water crisis, the RPN equal to 550 would be the target to shift the withdrawals intensity to prevent the reservoir from reaching the dead pool level.
Simulated Storage
Conclusions
The main innovative contribution of this work is the adaptation of FMEA method to explore the application in a drought management case. The optimum RPN for the São Paulo Metropolitan Region, equal to 550, was determined and represents the appropriate time when policies should be implemented, which was 3 months in advance in São Paulo. This work presents some limitations on this approach. Future studies should better explore the transition when RPN reaches the target and the desired consumption.
Acknowledgments
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Mudanças Climáticas
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Rapid Flood Predictions in Unseen Urban Catchments with Conditional Generative Adversarial Networks
Cesar do Lago, Marcio Giacomoni , Roberto Bentivoglio, Riccardo Taormina, Marcus Gomes Junior, Eduardo Mario Mendiondo
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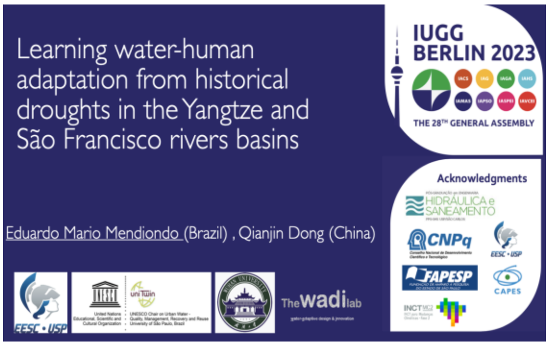
Learning water-human adaptation from historical droughts in the Yangtze and São Francisco rivers basins
Eduardo Mario Mendiondo (Brazil) , Qianjin Dong (China)
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Youth in the forefront
Online Youth Water Congress
"Emerging water challenges since COVID-19"
6 - 8 APRIL 2022
http://www.keody.auth.gr/youthcongress
Water-related disasters and climate change
Carlos Galvão
Federal University of Campina Grande, Brazil


GESTÃO DE RECURSOS HÍDRICOS EM CIDADES
Carlos de Oliveira Galvão
PPGECA
SEMINÁRIO NACIONAL
CIDADES INTELIGENTES, GESTÃO DE RECURSOS HÍDRICOS E PLANEJAMENTO


Assessment of risk pooling regions under spatially compounding Drought events in Brazil
Gabriela Gesualdo, Marcos Benso, Manuela Brunner & E. Mario Mendiondo
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IAHS Panta Rhei Symposium, Potsdam, Germany, 11 July 2023
GFZ
Grey Water Footprint of Rapidly-Urbanized Tropical Areas Worsened by the Coevolution of the Amazon-Sanitation-Hygiene Paradox
Eduardo Mario Mendiondo
FAPESP


Montpellier, 17 July, 2023
Recycling Water Assets for Sustainable Habitats: opportunities of urban physics to support the development of cities
Eduardo Mario Mendiondo
MUSE
MONTPELLIER UNIVERSITÉ D'EXCELLENCE
Univ Montpellier I-SITE Excellence Program


A combined mitigation and risk transfer solution for urban catchments: a proposal for an urban catchment
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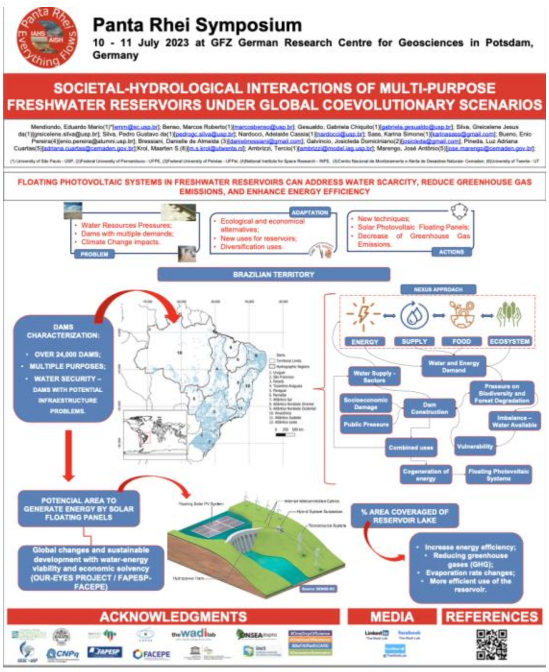
Fabricio Navarro , Marcos Benso, Marcus Nobrega, Milena Sousa, Enrico Pavan & Eduardo Mario Mendiondo


Panta Rhei Symposium
10 - 11 July 2023 at GFZ German Research Centre for Geosciences in Potsdam, Germany
SOCIETAL-HYDROLOGICAL INTERACTIONS OF MULTI-PURPOSE FRESHWATER RESERVOIRS UNDER GLOBAL COEVOLUTIONARY SCENARIOS
FLOATING PHOTOVOLTAIC SYSTEMS IN FRESHWATER RESERVOIRS CAN ADDRESS WATER SCARCITY, REDUCE GREENHOUSE GAS EMISSIONS, AND ENHANCE ENERGY EFFICIENCY
BRAZILIAN TERRITORY
NEXUS APPROACH
ENERGY
SUPPLY
FOOD
ECOSYSTEM
ACKNOWLEDGMENTS
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REFERENCES


On adaptive risk-transfer pathways of tropical freshwater reservoirs for multipurpose water-energy-food-ecosystem allocation using insurance mechanisms
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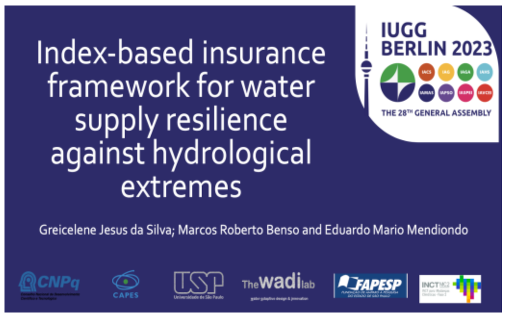
Pedro Gustavo Camara da Silva, Greicelene Jesus da Silva, Marcos Roberto Benso, Gabriela Chiquito Gesualdo, Josicleda Domiciniano Galvíncio, Danielle de Almeida Bressiani, Enio Pereira Bueno, Luz Adriana Cuartas Pineda, Maarten S. Krol, Karina Simone Sass, Adelaide Cassia Nardocci, Tercio Ambrizzi, José Antônio Marengo, Eduardo Mario Mendiondo


Index-based insurance framework for water supply resilience against hydrological extremes
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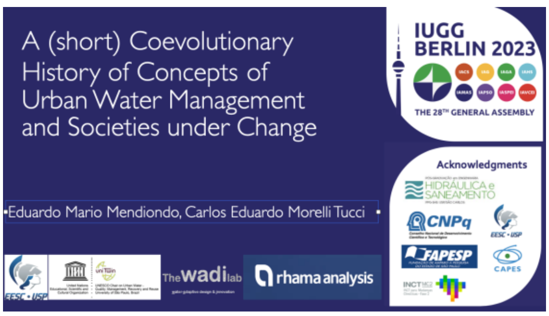
Greicelene Jesus da Silva; Marcos Roberto Benso and Eduardo Mario Mendiondo


A (short) Coevolutionary History of Concepts of Urban Water Management and Societies under Change
IUGG BERLIN 2023
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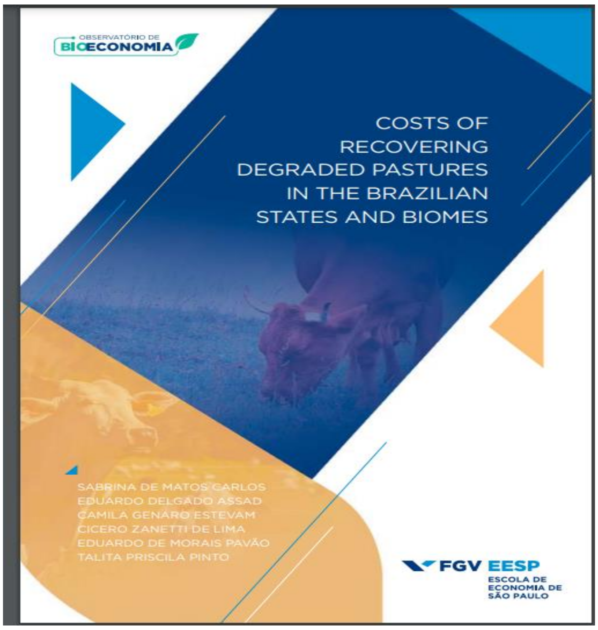
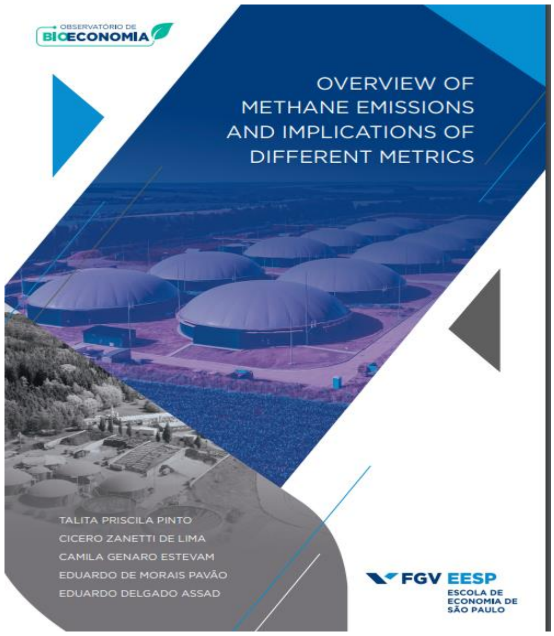
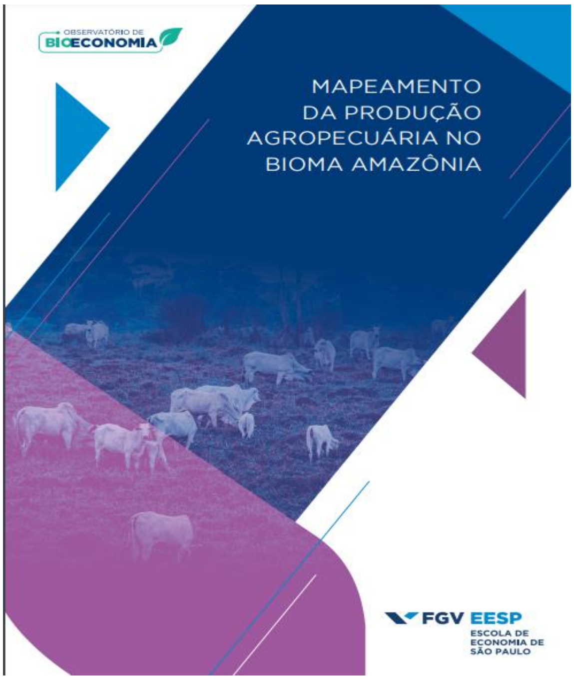
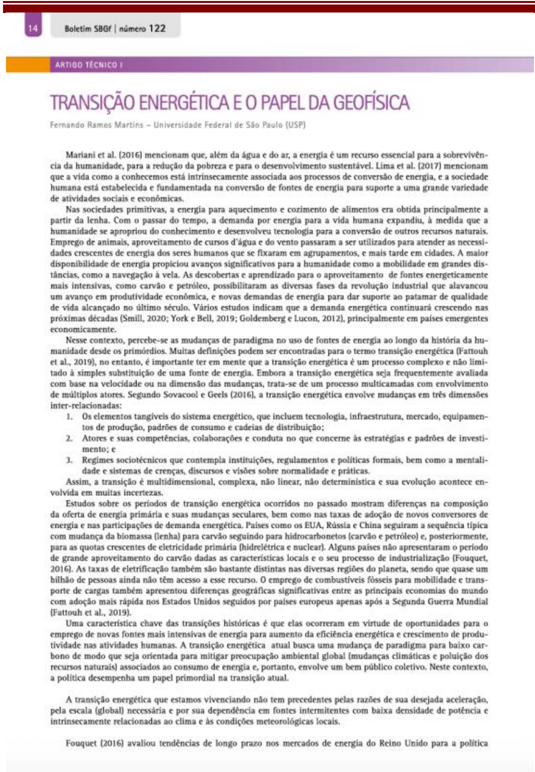
Acknowledgments
Eduardo Mario Mendiondo, Carlos Eduardo Morelli Tucci
rhama analysis

Reports, meetings, interviews, pod casts, and press communications where results of the INCT MC2 were mentioned









14 Boletim SBGf | número 122

ARTIGO TÉCNICO I

TRANSIÇÃO ENERGÉTICA E O PAPEL DA GEOFÍSICA

Fernando Ramos Martins – Universidade Federal de São Paulo (USP)

Mariani et al. (2016) mencionam que, além da água e do ar, a energia é um recurso essencial para a sobrevivência da humanidade, para a redução da pobreza e para o desenvolvimento sustentável. Lima et al. (2017) mencionam que a vida como a conhecemos está intrinsecamente associada aos processos de conversão de energia, e a sociedade humana está estabelecida e fundamentada na conversão de fontes de energia para suporte a uma grande variedade de atividades sociais e econômicas.

Nas sociedades primitivas, a energia para aquecimento e cozimento de alimentos era obtida principalmente a partir da lenha. Com o passar do tempo, a demanda por energia para a vida humana expandiu, à medida que a humanidade se apropriou do conhecimento e desenvolveu tecnologia para a conversão de outros recursos naturais. Emprego de animais, aproveitamento de cursos d'água e do vento passaram a ser utilizados para atender as necessidades crescentes de energia dos seres humanos que se fixaram em agrupamentos, e mais tarde em cidades. A maior disponibilidade de energia propiciou avanços significativos para a humanidade como a mobilidade em grandes distâncias, como a navegação à vela. As descobertas e aprendizado para o aproveitamento de fontes energeticamente mais intensivas, como carvão e petróleo, possibilitaram as diversas fases da revolução industrial que alavancou um avanço em produtividade econômica, e novas demandas de energia para dar suporte ao patamar de qualidade de vida alcançado no último século. Vários estudos indicam que a demanda energética continuará crescendo nas próximas décadas (Smill, 2020; York e Bell, 2019; Goldemberg e Lucon, 2012), principalmente em países emergentes economicamente.

Nesse contexto, percebe-se as mudanças de paradigma no uso de fontes de energia ao longo da história da humanidade desde os primórdios. Muitas definições podem ser encontradas para o termo transição energética (Fattouh et al., 2019), no entanto, é importante ter em mente que a transição energética é um processo complexo e não limitado à simples substituição de uma fonte de energia. Embora a transição energética seja frequentemente avaliada com base na velocidade ou na dimensão das mudanças, trata-se de um processo multicamadas com envolvimento de múltiplos atores. Segundo Sovacool e Geels (2016), a transição energética envolve mudanças em três dimensões inter-relacionadas:

1. Os elementos tangíveis do sistema energético, que incluem tecnologia, infraestrutura, mercado, equipamentos de produção, padrões de consumo e cadeias de distribuição;
2. Atores e suas competências, colaborações e conduta no que concerne às estratégias e padrões de investimento; e
3. Regimes sociotécnicos que contempla instituições, regulamentos e políticas formais, bem como a mentalidade e sistemas de crenças, discursos e visões sobre normalidade e práticas.

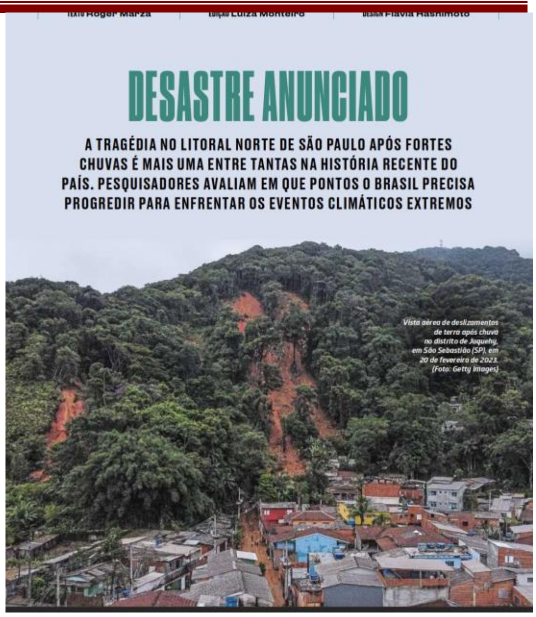
Assim, a transição é multidimensional, complexa, não linear, não determinística e sua evolução acontece envolvida em muitas incertezas.

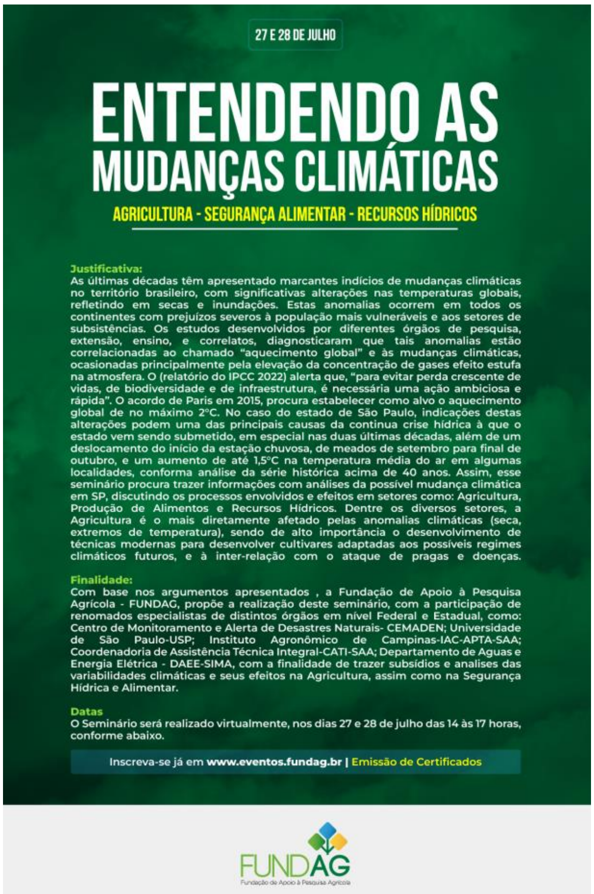
Estudos sobre os períodos de transição energética ocorridos no passado mostram diferenças na composição da oferta de energia primária e suas mudanças seculares, bem como nas taxas de adoção de novos conversores de energia e nas participações de demanda energética. Países como os EUA, Rússia e China seguiram a sequência típica com mudança da biomassa (lenha) para carvão seguindo para hidrocarbonetos (carvão e petróleo) e, posteriormente, para as quotas crescentes de eletricidade primária (hidrelétrica e nuclear). Alguns países não apresentaram o período de grande aproveitamento do carvão dadas as características locais e o seu processo de industrialização (Fouquet, 2016). As taxas de eletrificação também são bastante distintas nas diversas regiões do planeta, sendo que quase um bilhão de pessoas ainda não têm acesso a esse recurso. O emprego de combustíveis fósseis para mobilidade e transporte de cargas também apresentou diferenças geográficas significativas entre as principais economias do mundo com adoção mais rápida nos Estados Unidos seguidos por países europeus apenas após a Segunda Guerra Mundial (Fattouh et al., 2019).

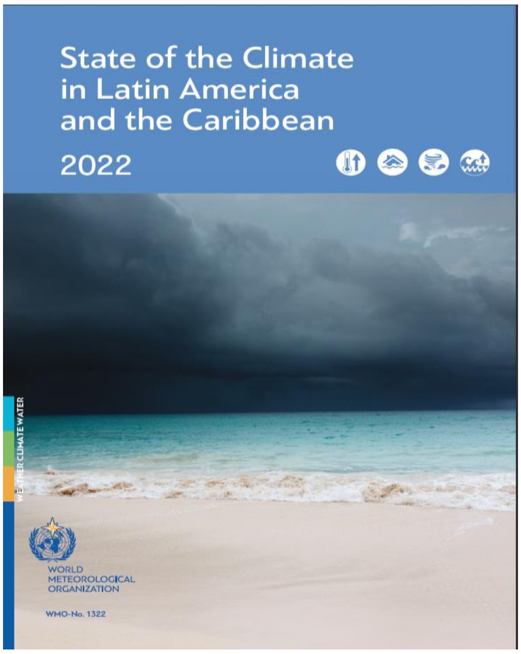
Uma característica chave das transições históricas é que elas ocorreram em virtude de oportunidades para o emprego de novas fontes mais intensivas de energia para aumento da eficiência energética e crescimento de produtividade nas atividades humanas. A transição energética atual busca uma mudança de paradigma para baixo carbono de modo que seja orientada para mitigar preocupação ambiental global (mudanças climáticas e poluição dos recursos naturais) associados ao consumo de energia e, portanto, envolve um bem público coletivo. Neste contexto, a política desempenha um papel primordial na transição atual.

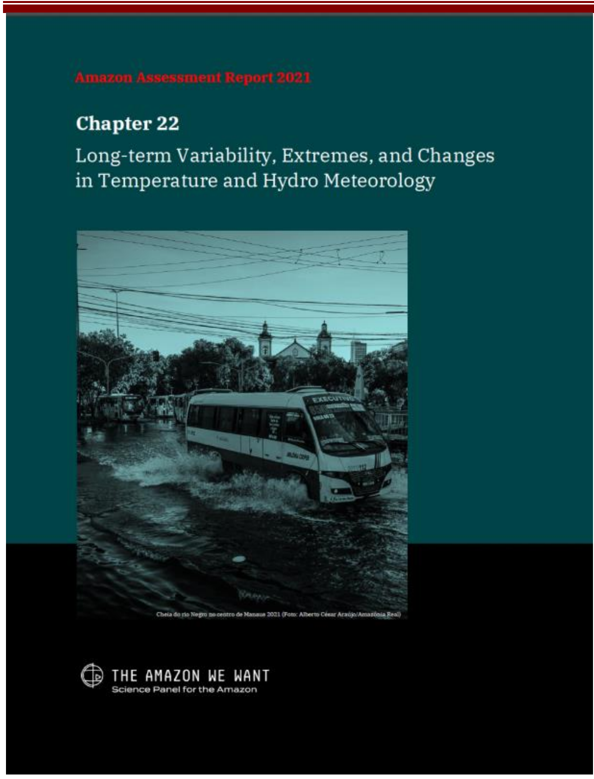
A transição energética que estamos vivenciando não tem precedentes pelas razões de sua desejada aceleração, pela escala (global) necessária e por sua dependência em fontes intermitentes com baixa densidade de potência e intrinsecamente relacionadas ao clima e às condições meteorológicas locais.

Fouquet (2016) avaliou tendências de longo prazo nos mercados de energia do Reino Unido para a política

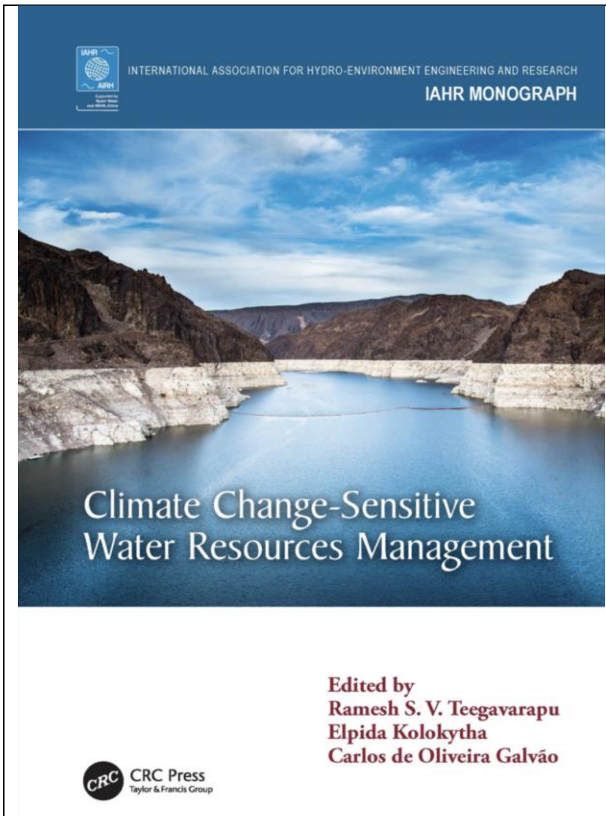




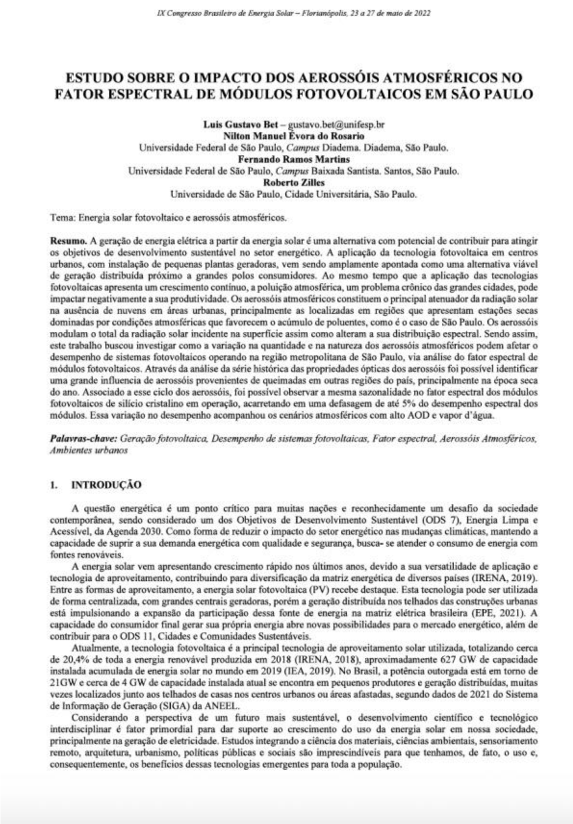



Amazon Assessment Report 2021
Chapter 22
Long-term Variability, Extremes, and Changes in Temperature and Hydro Meteorology
THE AMAZON WE WANT
Science Panel for the Amazon


Met Office
The Weather and Climate Science for Service Partnership Programme
Programme impact and achievements
2023


INTERNATIONAL ASSOCIATION FOR HYDRO-ENVIRONMENT ENGINEERING AND RESEARCH
IAHR MONOGRAPH
Climate Change-Sensitive Water Resources Management
Edited by
Ramesh S. V. Teegavarapu
Elpida Kolokytha
Carlos de Oliveira Galvão
CRC Press
Taylor & Francis Group

Some papers and other publications derived from the project



IX Congresso Brasileiro de Energia Solar – Florianópolis, 23 a 27 de maio de 2022

ESTUDO SOBRE O IMPACTO DOS AEROSSÓIS ATMOSFÉRICOS NO FATOR ESPECTRAL DE MÓDULOS FOTOVOLTAICOS EM SÃO PAULO

Luis Gustavo Bet – gustavo.bet@unifesp.br
Nilton Manuel Évora do Rosario
Universidade Federal de São Paulo, *Campus* Diadema. Diadema, São Paulo.
Fernando Ramos Martins
Universidade Federal de São Paulo, *Campus* Baixada Santista. Santos, São Paulo.
Roberto Zilles
Universidade de São Paulo, Cidade Universitária, São Paulo.

Tema: Energia solar fotovoltaico e aerossóis atmosféricos.

Resumo. A geração de energia elétrica a partir da energia solar é uma alternativa com potencial de contribuir para atingir os objetivos de desenvolvimento sustentável no setor energético. A aplicação da tecnologia fotovoltaica em centros urbanos, com instalação de pequenas plantas geradoras, vem sendo amplamente apontada como uma alternativa viável de geração distribuída próximo a grandes polos consumidores. Ao mesmo tempo que a aplicação das tecnologias fotovoltaicas apresenta um crescimento contínuo, a poluição atmosférica, um problema crônico das grandes cidades, pode impactar negativamente a sua produtividade. Os aerossóis atmosféricos constituem o principal atenuador da radiação solar na ausência de nuvens em áreas urbanas, principalmente as localizadas em regiões que apresentam estações secas dominadas por condições atmosféricas que favorecem o acúmulo de poluentes, como é o caso de São Paulo. Os aerossóis modulam o total da radiação solar incidente na superfície assim como alteram a sua distribuição espectral. Sendo assim, este trabalho buscou investigar como a variação na quantidade e na natureza dos aerossóis atmosféricos podem afetar o ...

IX Congresso Brasileiro de Energia Solar – Florianópolis, 23 a 27 de maio de 2022

Avaliação da irradiação solar utilizando modelo BRASIL-SR em condições de céu claro – estudo do impacto de aerossóis na Amazônia brasileira e no Cerrado

Madeleine Sánchez Gácita Casagrande – madeleine.gacita@unifesp.br
Fernando Ramos Martins – fernando.martins@unifesp.br
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Resumo. *As plumas de aerossol geradas durante a estação de queima de biomassa no Brasil sofrem transporte de longo alcance, resultando em grandes profundidades ópticas de aerossol em um domínio extenso do território brasileiro. Como consequência, a irradiância solar da superfície descendente, e em particular o componente direto, pode ser significativamente reduzida. Estimativas da irradiância solar incidente na superfície considerando a contribuição radiativa dos aerossóis de queima de biomassa são necessárias para apoiar o setor de energia solar do Brasil. Este trabalho apresenta resultados obtidos com a 2ª geração do modelo de transferência radiativa BRASIL-SR, desenvolvida para melhorar a representação do aerossol e reduzir as incertezas nas estimativas de irradiância solar de superfície em condições de céu sem nuvens. Dois experimentos numéricos permitiram avaliar a habilidade do modelo usando dados AOD observacionais ou regionais de reanálise do MERRA-2 em uma região frequentemente afetada por queimadas. Quatro locais de medição de solo forneceram dados para a alimentar o modelo e validar valores de GHI e DNI por ele ...*

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Variability index of solar resource based on data from surface and satellite

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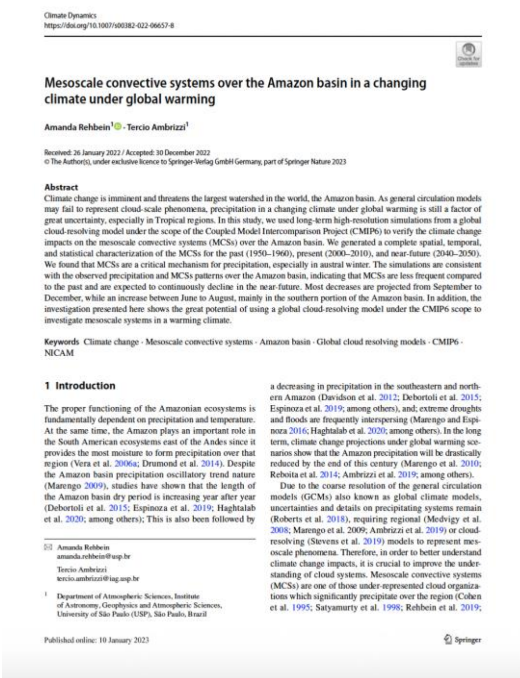
ARTICLE INFO

Keywords: Downward surface solar irradiance; Intra-day variability; Intermittency

ABSTRACT

Characterizing solar resource variability is paramount for its thermal and photovoltaic applications. Cloudiness is the main parameter that modulates both the intensity and frequency of variations in solar irradiance on the ground surface. This work introduces an objective index to quantify the temporal variability of the incoming solar irradiance on the surface, defined as Cloudless Percentage Days (CPD). This index accounts for the number of days classified as clear and stable (i.e., high clearness coefficient and decreased frequency of ramps of incoming solar irradiance). Two methods were developed to quantify CPD, the first based on ground measurements and the other based on satellite data. This work compares the results achieved with the two methods to understand their consistency. Monthly and annual maps were drawn for the Brazilian territory characterizing solar resource variability.



Climate Dynamics
https://doi.org/10.1007/s00382-022-06657-8

Mesoscale convective systems over the Amazon basin in a changing climate under global warming

Amanda Rehbein[1] · Tercio Ambrizzi[1]

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Abstract
Climate change is imminent and threatens the largest watershed in the world, the Amazon basin. As general circulation models may fail to represent cloud-scale phenomena, precipitation in a changing climate under global warming is still a factor of great uncertainty, especially in Tropical regions. In this study, we used long-term high-resolution simulations from a global cloud-resolving model under the scope of the Coupled Model Intercomparison Project (CMIP6) to verify the climate change impacts on the mesoscale convective systems (MCSs) over the Amazon basin. We generated a complete spatial, temporal, and statistical characterization of the MCSs for the past (1950–1960), present (2000–2010), and near-future (2040–2050). We found that MCSs are a critical mechanism for precipitation, especially in austral winter. ...

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Simulation of the effects of biomass burning in a mesoscale convective system in the central amazon

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ARTICLE INFO

Keywords:
Biomass burning
Downdrafts
Convective Systems
Amazonia

ABSTRACT

During the dry season of 2014, the formation of a mesoscale convective system (MCS) caused intense precipitation and strong winds in the central Amazon region. In this period, cases of MCS that occurred during the days when there were higher concentrations of CO were analyzed. Through this criterion, a case of MCS occurred on August 16th, 2014 was selected. We used the chemical-atmospheric model WRF-Chem to assess the influence of biomass burning aerosol on the intensity of precipitation, winds, vertical and horizontal transport associated with this convective system. We show that biomass burning aerosol reduces the strength of the mesoscale convective system, with less vertical and horizontal transport of carbon monoxide and ozone. In the absence of biomass burning aerosol downdrafts and precipitation rate are more intense, and cloud development up to 5 km is more developed, making the horizontal flow and vertical transport of ozone more intense, however, much more efficient in reducing the concentrations of other gases.

1. Introduction

The main contributors to the emission of aerosols in the Brazilian Amazon region are the biomass burning (BB), from deforestation and agricultural practices (Echalar et al., 1998; Martin et al., 2010; Reddington et al., 2015). The emission of BB aerosol in the Amazon atmosphere has many impacts on weather and climate through feedback with radiation and clouds (Ramanathan et al., 2001; Kaufman and Koren, 2006; Rosenfeld et al., 2008). Particles between 0.1 and 2 μm in diameter absorb visible light more strongly and transform electromagnetic energy into thermal energy, reducing incident solar energy reaching the surface (Charlson et al., 1992; Ackerman et al., 2000; Schwartz and Buseck, 2000).

Aerosol particles, including BB aerosol, can also act as cloud condensation nuclei (CCN) and ice nuclei (Roberts et al., 2001; Spracklen et al., 2011), and may also alter the reflectivity of the cloud (Albrecht, 1989; Jiang and Feingold, 2006). BB aerosol can also alter the onset of precipitation. For example, Andreae et al. (2004) observed that dense smoke from Amazon forest fires, rich in BB, reduced the size of cloud droplets and delayed the onset of precipitation in the region. It is known that delays in the onset of precipitation can increase the lifetime of clouds, allowing the strengthening of air updrafts and downdrafts and consequently increasing cloud cover (Albrecht, 1989; Koren et al., 2004). Furthermore, we know that in the Amazon region the organization of clouds often takes the form of mesoscale convective systems (MCS), which are responsible for a significant amount of precipitation in the region (Houze, 2004). Rehbein et al. (2017) carried out a study on the climatology of MCS in the Amazon for 14 years (2000 to 2013) and showed that these systems occur frequently, including during the dry season in central Amazonia, which occurs between August and December (Marengo et al., 2001). It is also known that during the presence of MCS, the occurrence of downdrafts is common, which play an important role in the dynamics of gas transport in the Amazonia (Betts, 2002; Gerken et al., 2016; Dias-Júnior et al., 2017; Melo et al., 2019; Bezerra et al., 2021). Betts (2002) confirmed the increase in the concentration of ozone (O_3) at the surface in the Amazon, generated by

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Atmospheric Chemistry and Physics

ACP Letters

Strong particle production and condensational growth in the upper troposphere sustained by biogenic VOCs from the canopy of the Amazon Basin

Yunfan Liu[1], Hang Su[2], Siwen Wang[1], Chao Wei[2], Wei Tao[2], Mira L. Pöhlker[2,6,7], Christopher Pöhlker[2], Bruna A. Holanda[2], Ovid O. Krüger[2], Thorsten Hoffmann[5], Manfred Wendisch[7], Paulo Artaxo[8], Ulrich Pöschl[2], Meinrat O. Andreae[3,4], and Yafang Cheng[1]

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Abstract. Nucleation and condensation associated with biogenic volatile organic compounds (BVOCs) are important aerosol formation pathways, yet their contribution to the upper-tropospheric aerosols remains inconclusive, hindering the understanding of aerosol climate effects. Here, we develop new schemes describing these organic aerosol formation processes in the WRF-Chem model and investigate their impact on the abundance of cloud condensation nuclei (CCN) in the upper troposphere (UT) over the Amazon Basin. We find that the new schemes significantly increase the simulated CCN number concentrations in the UT (e.g., up to $\sim 400\,cm^{-3}$ at 0.52 % supersaturation) and greatly improve the agreement with the aircraft observations. Organic condensation enhances the simulated CCN concentration by 90 % through promoting particle growth, while organic nucleation, by replenishing new particles, contributes an additional 14 %. Deep convection determines the rate of these organic aerosol formation processes in the UT through controlling the upward transport of biogenic precursors (i.e., BVOCs). This finding emphasizes the importance of the biosphere–atmosphere coupling in regulating upper-tropospheric aerosol concentrations over the tropical forest and calls for attention to its potential role in anthropogenic climate change.

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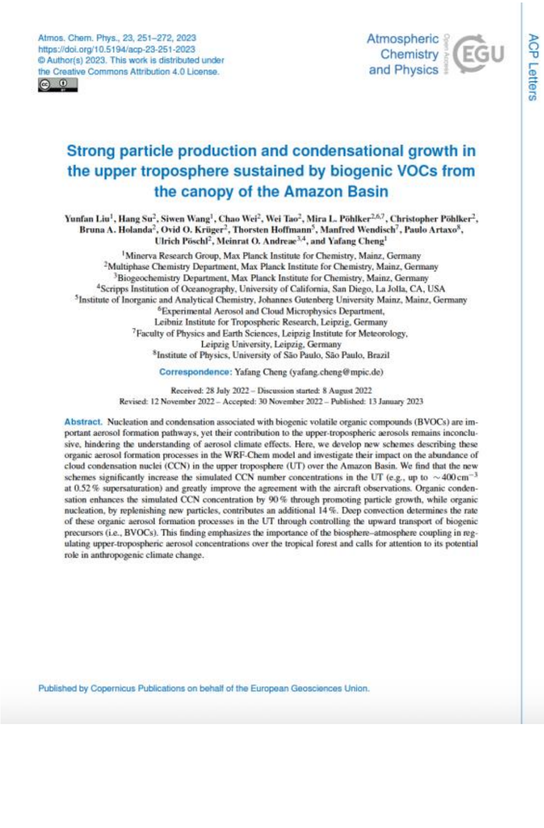

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Atmospheric Chemistry and Physics

ACP Letters

Strong particle production and condensational growth in the upper troposphere sustained by biogenic VOCs from the canopy of the Amazon Basin

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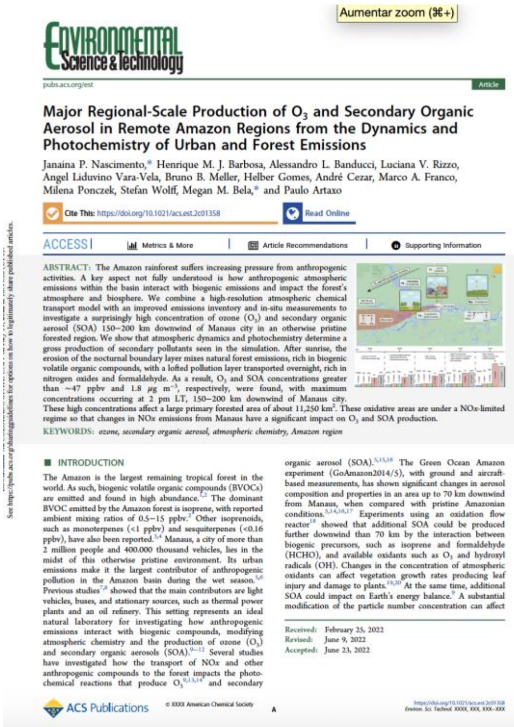

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Environmental Science & Technology

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Article

Major Regional-Scale Production of O_3 and Secondary Organic Aerosol in Remote Amazon Regions from the Dynamics and Photochemistry of Urban and Forest Emissions

Janaina P. Nascimento,* Henrique M. J. Barbosa, Alessandro L. Banducci, Luciana V. Rizzo, Angel Liduvino Vara-Vela, Bruno B. Meller, Helber Gomes, André Cezar, Marco A. Franco, Milena Ponczek, Stefan Wolff, Megan M. Bela,* and Paulo Artaxo

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ABSTRACT: The Amazon rainforest suffers increasing pressure from anthropogenic activities. A key aspect not fully understood is how anthropogenic atmospheric emissions within the basin interact with biogenic emissions and impact the forest's atmosphere and biosphere. We combine a high-resolution atmospheric chemical transport model with an improved emissions inventory and in-situ measurements to investigate a surprisingly high concentration of ozone (O_3) and secondary organic aerosol (SOA) 150–200 km downwind of Manaus city in an otherwise pristine forested region. We show that atmospheric dynamics and photochemistry determine a gross production of secondary pollutants seen in the simulation. After sunrise, the erosion of the nocturnal boundary layer mixes natural forest emissions, rich in biogenic volatile organic compounds, with a lofted pollution layer transported overnight, rich in nitrogen oxides and formaldehyde. As a result, O_3 and SOA concentrations greater than ~47 ppbv and 1.8 $\mu g\ m^{-3}$, respectively, were found, with maximum concentrations occurring at 2 pm LT, 150–200 km downwind of Manaus city. These high concentrations affect a large primary forested area of about 11,250 km^2. These oxidative areas are under a NOx-limited regime so that changes in NOx emissions from Manaus have a significant impact on O_3 and SOA production.

KEYWORDS: *ozone, secondary organic aerosol, atmospheric chemistry, Amazon region*

INTRODUCTION

The Amazon is the largest remaining tropical forest in the world. As such, biogenic volatile organic compounds (BVOCs) are emitted and found in high abundance.[1,2] The dominant BVOC emitted by the Amazon forest is isoprene, with reported ambient mixing ratios of 0.5–15 ppbv.[2] Other isoprenoids, such as monoterpenes (<1 ppbv) and sesquiterpenes (<0.16 ppbv), have also been reported.[3,4] Manaus, a city of more than 2 million people and 400.000 thousand vehicles, lies in the midst of this otherwise pristine environment. Its urban emissions make it the largest contributor of anthropogenic pollution in the Amazon basin during the wet season.[5,6] Previous studies[7,8] showed that the main contributors are light vehicles, buses, and stationary sources, such as thermal power plants and an oil refinery. This setting represents an ideal natural laboratory for investigating how anthropogenic emissions interact with biogenic compounds, modifying atmospheric chemistry and the production of ozone (O_3) and secondary organic aerosols (SOA).[9−12] Several studies have investigated how the transport of NOx and other anthropogenic compounds to the forest impacts the photochemical reactions that produce O_3[9,13,14] and secondary organic aerosol (SOA).[5,15,16] The Green Ocean Amazon experiment (GoAmazon2014/5), with ground and aircraft-based measurements, has shown significant changes in aerosol composition and properties in an area up to 70 km downwind from Manaus, when compared with pristine Amazonian conditions.[5,14,16,17] Experiments using an oxidation flow reactor[18] showed that additional SOA could be produced further downwind than 70 km by the interaction between biogenic precursors, such as isoprene and formaldehyde (HCHO), and available oxidants such as O_3 and hydroxyl radicals (OH). Changes in the concentration of atmospheric oxidants can affect vegetation growth rates producing leaf injury and damage to plants.[19,20] At the same time, additional SOA could impact on Earth's energy balance.[9] A substantial modification of the particle number concentration can affect

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African biomass burning affects aerosol cycling over the Amazon

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Smoke from vegetation fires affects air quality, atmospheric cycling, and the climate in the Amazon rain forest. A major unknown has remained the quantity of long-range transported smoke from Africa in relation to local and regional fire emissions. Here we quantify the abundance, seasonality, and properties of African smoke in central Amazonia. We show that it accounts for ~60% of the black carbon concentrations during the wet season and ~30% during the dry season. The African smoke influences aerosol-radiation interactions across the entire Amazon, with the strongest impact on the vulnerable eastern basin, a hot spot of climate and land use change. Our findings further suggest that the direct influence of African smoke has been historically relevant for soil fertilization, the carbon and water cycles, and, thus, the development of the Amazon forest ecosystem, even in the pre-industrial era.

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Geoscientific Model Development

Improvements to the representation of BVOC chemistry–climate interactions in UKCA (v11.5) with the CRI-Strat 2 mechanism: incorporation and evaluation

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Abstract. We present the first incorporation of the Common Representative Intermediates version 2.2 tropospheric chemistry mechanism, CRI v2.2, combined with stratospheric chemistry, into the global chemistry–climate United Kingdom Chemistry and Aerosols (UKCA) model to give the CRI-Strat 2 mechanism. A rigorous comparison of CRI-Strat 2 with the earlier version, CRI-Strat, is performed in UKCA in addition to an evaluation of three mechanisms, CRI-Strat 2, CRI-Strat and the standard UKCA chemical mechanism, StratTrop v1.0, against a wide array of surface and airborne chemical data.

CRI-Strat 2 comprises a state-of-the-art isoprene scheme, optimized against the Master Chemical Mechanism v3.3.1, which includes isoprene peroxy radical isomerization, HO_x recycling through the addition of photolabile hydroperoxy aldehydes (HPALDs), and isoprene epoxy diol (IEPOX) formation. CRI-Strat 2 also features updates to several rate constants for the inorganic chemistry, including the reactions of inorganic nitrogen and $O(^1D)$.

The update to the isoprene chemistry in CRI-Strat 2 increases OH over the lowest 500 m in tropical forested regions by 30 %–50 % relative to CRI-Strat, leading to an improvement in model–observation comparisons for surface OH and isoprene relative to CRI-Strat and StratTrop. Enhanced oxidants also cause a 25 % reduction in isoprene burden and an increase in oxidation fluxes of isoprene and other biogenic volatile organic compounds (BVOCs) at low altitudes with likely impacts on subsequent aerosol formation, atmospheric lifetime, and climate.

By contrast, updates to the rate constants of $O(^1D)$ with its main reactants relative to CRI-Strat reduces OH in much of the free troposphere, producing a 2 % increase in the methane lifetime, and increases the tropospheric ozone burden by 8 %, primarily from reduced loss via $O(^1D) + H_2O$.

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Optical properties and spectral dependence of aerosol light absorption over the Brazilian Pantanal

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Pantanal

ABSTRACT

Characterizing optical properties of aerosols, particularly the absorption processes, is fundamental for understanding the role of these particles in ecosystems as well as the climate, in general. Currently, changes in precipitation regimes in the southern Amazon basin have resulted in a considerable increase in biomass burning, whereby large amounts of aerosols and gases are emitted into the atmosphere. These increased emissions can impact the ecosystem, modifying mass and energy flows at the surface. This study, motivated by the need for more aerosol observations was the result of a long-term campaign carried out in the Brazilian Pantanal, which provided continuous in-situ measurements of aerosol optical properties between January 2017 and December 2019. From these data, optical properties of aerosols were quantified and analyzed seasonally. Corrected estimates for absorption coefficient (σ_{abs}) and Angstrom absorption exponent (α_{abs}) were utilized to characterize the spectral dependence of absorption by aerosols. With additional measurements of the scattering coefficient (σ_{scat}), it was possible to evaluate the single scattering albedo (ω_0). The mean values for σ_{abs}, σ_{scat}, ω_0 at 525 nm and α_{abs} 370–880 nm during the wet season were 0.66 ± 0.58 Mm^{-1}, 6.16 ± 5.75 Mm^{-1}, 0.90 ± 0.06 and 1.43 ± 0.49, respectively. These values, within measurement uncertainties, were similar to results found in the central Amazon. During the dry season, absorption and scattering increased approximately 88% and 86%, respectively, providing strong evidence for the contribution of local and regional emissions from biomass burning. The values of ω_0 did not reveal significant seasonal differences, however, a sharp reduction was observed, medians below 0.8, at the beginning of the burning period, which was associated with more recent local burnings and, therefore, greater absorption. The mean values evaluated for different spectral intervals reveal a strong contribution of brown carbon (BrC) during the dry season, with medians of 1.78 and 0.87 for the intervals of 370–590 nm and 590–880 nm, respectively. This work also quantified BC concentrations for the dry and wet seasons, obtaining mean values of 0.75 ± 0.83 and 0.12 ± 0.09 μgm^{-3}, respectively. In general, a striking similarity was encountered for aerosol optical properties between the Pantanal and the Central Amazon during the wet season. The results presented here characterize the background values for aerosol optical properties in the Pantanal, and the additional effects resulting from biomass burning emissions, therefore providing essential information to assess the effects these particles have on the ecosystem.

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Particulate matter fingerprints in biofuel impacted tunnels in South America's largest metropolitan area

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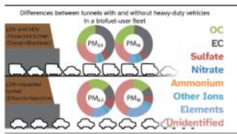
HIGHLIGHTS

- The biofuel used in a Brazilian megacity impacted chemical diagnostic ratios.
- Metal diagnostic ratios indicated the predominance of ethanol exhaust-related copper.
- The carbonaceous fraction EC3 was suggested as an HDV emission tracer.
- Higher proportions of carcinogenic PAHs were observed in the LDV-impacted tunnel.

GRAPHICAL ABSTRACT



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ABSTRACT

This study characterized the chemical composition of particulate matter (PM) from light- (LDV) and heavy-duty (HDV) vehicles based on two traffic tunnel samplings carried out in the megacity of São Paulo (Brazil), which has >7 million vehicles and intense biofuel use. The samples were collected with high-volume samplers and analyzed using chemical characterization techniques (ion and gas chromatography, thermal-optical analysis, and inductively coupled plasma mass spectroscopy). Chemical source profiles (%) were calculated based on the measurements performed inside and outside the tunnels. Identifying a high abundance of Fe and Cu for traffic-related PM in the LDV-impacted tunnel was possible, linked with the emission of vehicles powered by ethanol and gasohol (gasoline and ethanol blend). We calculated diagnostic ratios (*e.g.*, EC/Cu, Fe/Cu, pyrene/benzo[*a*]pyrene, pyrene/benzo[*b*]fluoranthene, and fluoranthene/benzo[*b*]fluoranthene) characteristic of fuel exhausts (diesel/biodiesel and ethanol/gasohol), allowing their use in the assessment of the temporal variation of the fuel type used in urban sites. Element diagnostic ratios (Cu/Sb and Fe/Cu) pointed to the predominance of LDVs exhaust-related copper and can differentiate LDVs exhaust from brake wear emissions. The carbonaceous fraction EC3 was suggested as an HDV emission tracer. A higher total polycyclic aromatic hydrocarbons (PAHs) fraction of traffic-related $PM_{2.5}$ was observed in the HDV-impacted tunnel, with a predominance of diesel-related pyrene and fluoranthene, as well as higher oxy-PAHs (*e.g.*, 9,10-anthraquinone,

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Measurement report

Measurement report: Long-range transport and the fate of dimethyl sulfide oxidation products in the free troposphere derived from observations at the high-altitude research station Chacaltaya (5240 m a.s.l.) in the Bolivian Andes

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Abstract. Dimethyl sulfide (DMS) is the primary natural contributor to the atmospheric sulfur burden. Observations concerning the fate of DMS oxidation products after long-range transport in the remote free troposphere are, however, sparse. Here we present quantitative chemical ionization mass spectrometric measurements of DMS and its oxidation products sulfuric acid (H_2SO_4), methanesulfonic acid (MSA), dimethylsulfoxide (DMSO), dimethylsulfone ($DMSO_2$), methanesulfinic acid (MSIA), methyl thioformate (MTF), methanesulfenic acid (MSEA, CH_3SOH), and a compound of the likely structure $CH_3S(O)_2OOH$ in the gas phase, as well as measurements of the sulfate and methanesulfonate aerosol mass fractions. The measurements were performed at the Global Atmosphere Watch (GAW) station Chacaltaya in the Bolivian Andes located at 5240 m above sea level (a.s.l.).

DMS and DMS oxidation products are brought to the Andean high-altitude station by Pacific air masses during the dry season after convective lifting over the remote Pacific ocean to 6000–8000 m a.s.l. and subsequent long-range transport in the free troposphere (FT). Most of the DMS reaching the station is already converted to the

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PLOS CLIMATE

OPINION

Tropical forests are crucial in regulating the climate on Earth

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Tropical forests are critically important for the global climate because of their impact on the radiation, hydrology, and biogeochemical cycles [1]. Tropical forests are large pools of global carbon, with about 360 Pg of carbon in forest vegetation, that with soil carbon adds up to 800 PgC, almost as much as is stored in the atmosphere [2]. In addition, forests are responsible for much of the carbon removal by terrestrial ecosystems, removing about 29% of annual CO_2 emissions or 15.6 Gigatons of CO_2 each year [3]. Tropical forests have a critical role in supporting biodiversity, storing carbon, regulating the water cycle, influencing the radiation balance via albedo, and having an important role in human well-being. Biogenic volatile organic compounds (BVOC) emitted by forests produces secondary organic aerosols (SOA) that are one of the main sources of cloud condensation nuclei (CCN), which are critical to nucleate cloud droplets [4]. Organic aerosols (OA) scatter solar radiation, cooling the surface and compensating for part of the heating produced by the greenhouse gases. When acting as CCN, OA increases cloud albedo, leading to additional biophysical cooling and increased diffuse radiation, which favors carbon uptake by the vegetation. Most of the aerosols over tropical forests are organic and, due to strong deep convection, are transported to the upper troposphere [5].

By the process of evapotranspiration, tropical forests provide water vapor to support cloud formation regionally as well as in interconnection with other parts of the globe. Deep convection is frequent due to the higher convective available potential energy (CAPE). The vertical distribution of latent heating released by convection over tropical forests impacts the Earth´s climate.

However, when forest cover and structure change due to land use and climate change forcings, shifts in biophysical processes occur, affecting ecosystem services related to water, carbon, and energy balances. While tropical forests contribute to climate regulation, global climate change is impacting forest ecosystems. Climate extremes are increasing significantly in tropical regions. Tropical forest temperatures are in sharp increase, in some regions, by more than 1.5˚C. In Southeast Amazônia, the dry season has expanded from four to five months during the past 50 years. Severe droughts have hit Amazonia three times since 2005. At the same time, since late 1990, nine extreme floods have occurred, the last one in 2021. Tropical forests have evolved under a relatively stable climate, and the increase in droughts and extensive floods could be enhancing tree mortality [1].

Recent findings show that climate change strongly impacts Amazonia's carbon balance, showing that non-deforested areas could soon become a carbon source for the atmosphere. Hubau et al., 2020 [6] compared Amazonian with African forests showing that Amazonia is decreasing the carbon uptake because of tree mortality, with no detectable multi-decadal trend

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Article

Relationship between Land Use and Spatial Variability of Atmospheric Brown Carbon and Black Carbon Aerosols in Amazonia

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Abstract: The aerosol radiative effect is an important source of uncertainty in estimating the anthropogenic impact of global climate change. One of the main open questions is the role of radiation absorption by aerosols and its relation to land use worldwide, particularly in the Amazon Rainforest. Using AERONET (Aerosol Robotic Network) long-term measurements of aerosol optical depth (AOD) at a wavelength of 500 nm and absorption AOD (AAOD) at wavelengths of 440, 675, and 870 nm, we estimated the fraction and seasonality of the black carbon (BC) and brown carbon (BrC) contributions to absorption at 440 nm. This was conducted at six Amazonian sites, from central Amazon (Manaus and the Amazon Tall Tower Observatory—ATTO) to the deforestation arc (Rio Branco, Cuiabá, Ji-Paraná, and Alta Floresta). In addition, land use and cover data from the MapBiomas collection 6.0 was used to access the land transformation from forest to agricultural areas on each site. The results showed, for the first time, important geographical and seasonal variability in the aerosol optical properties, particularly the BC and BrC contributions. We observed a clear separation between dry and wet seasons, with BrC consistently accounting for an average of approximately 12% of the aerosol AAOD at 440 nm in the deforestation arc. In central Amazon, the contribution of BrC was approximately 25%. A direct relationship between the reduction in forests and the increase in the area dedicated to agriculture was detected. Moreover, places with lower fractions of forest had a smaller fraction of BrC, and regions with higher fractions of agricultural areas presented higher fractions of BC. Therefore, significant changes in AOD and AAOD are likely related to land-use transformations and biomass burning emissions, mainly during the dry season. The effects of land use change could introduce differences in the radiative balance in the different Amazonian regions. The analyses presented in this study allow a better understanding of the role of aerosol emissions from the Amazon Rainforest that could have global impacts.

Keywords: AERONET; Amazon; brown carbon; black carbon; land use; remote sensing

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1. Introduction

When evaluating the impact of human activity on global climate change, the aerosol radiative effect is a significant source of uncertainty [1]. One of the main open questions is the role of radiation absorption by aerosols and their impacts on Earth's radiative balance [2]. Global climate models typically underestimate the large-scale radiative forcing of

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Tellus B
Chemical and Physical Meteorology

Tropical and Boreal Forest – Atmosphere Interactions: A Review

REVIEW ARTICLE

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Boreal forests; Tropical forests; Amazonia; biogenic emissions; fires; biomass burning; aerosol particles; climate effects

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ABSTRACT

This review presents how the boreal and the tropical forests affect the atmosphere, its chemical composition, its function, and further how that affects the climate and, in return, the ecosystems through feedback processes. Observations from key tower sites standing out due to their long-term comprehensive observations: The Amazon Tall

Weather and Climate Extremes

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Flash floods and landslides in the city of Recife, Northeast Brazil after heavy rain on May 25–28, 2022: Causes, impacts, and disaster preparedness

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ABSTRACT

From late May to early June 2022, 130 people died in catastrophic landslides and flash flood events triggered by exceptionally heavy rains in the states of Pernambuco, Alagoas, and Paraíba, along the coast of Northeast Brazil. Total rainfall in the city of Recife on May 25-30 was 551 mm, 140 mm higher than the average of the month of May. Rain was heaviest on May 25 and 28, with 100–200 mm and 151–250 mm, respectively. This coincided with easterly wave disturbances. May 28 saw the most rain, due to a significant cold front. Fourteen municipalities in the metropolitan region of Recife declared a state of emergency. According to the Civil Defense of Pernambuco state, the rain impacted 130,000 people there. Most of the heavy precipitation fell over areas with medium to very high geological vulnerability to landslides and extreme hydrological events. The loss of life and substantial economic impacts in Recife caused by the heavy precipitation of May 2022 and the disasters induced by it show that this city, like many others around the world, has limited capacity to cope with climate extremes. Urbanization has increased population density occupying hills and slopes of the city, contributing to the problem. To reduce the impact of such disasters, residents must be made aware of the risks of climate-related events, and they must be encouraged to heed alerts warning of natural disasters issued by state and federal institutions. Efficient monitoring of risk is also needed. Risk management will be viable only when everyone participates, which requires education and cultural change.

1. Introduction

Brazil has an estimated 3,000 km^2 of areas at risk for prevailing climate-related disasters. These areas were recently determined to have high and very high risk of landslides, floods, and flash floods. At least 825 municipalities are critically vulnerable to disasters (Alvalá et al., 2019; Assis Dias et al., 2020). Of the 8,266,566 people most at risk, around 75% are in areas susceptible to landslides or combined landslides and floods (Alvalá et al., 2019; Zachariah et al., 2022). This population faces considerable vulnerability (IBGE 2010). Recurring events in recent years underscore how urgent it is to mitigate the disaster risk (UN Office for Disaster Risk Reduction, 2019a, b).

Between January 1, 2013, and April 5, 2022, natural disasters caused US$ 67 billion in damages throughout Brazil (CNM 2022). From January to July 2022 alone, landslides, flash floods, and floods triggered by heavy precipitation events have left hundreds dead and missing in Brazil. The National Confederation of Municipalities (CNM 2022) estimates 503 deaths due to disasters related to heavy precipitation as of July 4, 2022. This is higher than the 290 deaths in all of 2021. From 2014 to 2018, fewer than 100 fatalities were caused by disasters triggered by heavy precipitation annually. After 2019, this number jumped to over 200 per year, with 2022 being the worst yet (as of July).

The city of Recife, capital of the state of Pernambuco, and 13 other municipalities, comprise the metropolitan region of Recife (MRR). Together, they form the fifth-largest population center in Brazil (Fig. 1). The MRR has an estimated population of 4,047,088 in 2020 (IBGE and CEMADEN, 2018), spread over a territory of 2,774 km^2. The population density is high, at 1,459 inhabitants/km^2 (https://www.citypopulation.

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A cold wave of winter 2021 in central South America: characteristics and impacts

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Abstract
During the austral winter (June–August) of 2021, the meteorological services of Brazil, Argentina, Peru, Paraguay, Bolivia, and Chile all issued forecasts for unusually cold conditions. Record-low minimum temperatures and cold spells were documented, including one strong cold wave episode that affected 5 countries. In this study, we define a *cold wave* as a period in which daily maximum and minimum air temperatures are below the corresponding climatological 10th percentile for three or more consecutive days. The intense cold wave event in the last week of June, 2021, resulted in record-breaking minimum daily temperatures in several places in central South America and Chile. Several locations had temperatures about 10 °C below average, central South America had freezing conditions, and southern Brazil even saw snow. The cold air surge was characterized by an intense upper-air trough located close to 35° S and 70° W. The southerly flow to the west of this trough brought very cold air northward into subtropical and tropical South America. A northward flow between the lower-level cyclonic and anticyclonic perturbations caused the intense southerly flow between the upper-level ridge and trough. This condition facilitated the inflow of near-surface cold air from southern Argentina into southeastern Brazil and tropical South America east of the Andes. In the city of São Paulo, the cold wave caused the death of 13 homeless people from hypothermia. Frost and snow across southern and southeastern Brazil caused significant damage to coffee, sugarcane, oranges, grapes, and other fruit and vegetable crops. Wine and coffee production fell, the latter by 30%, and prices of food and commodities in the region rose.

Keywords Cold waves · Minimum temperatures · Frost · Wave patterns · Coffee production

1 Introduction

Cold surges involve the incursion of cold and dry air masses from the southernmost part of the continent of South America toward low latitudes (e.g., Sulca et al. 2018). A cold wave is a meteorological event generally characterized by a sharp drop of air temperature to extremely low values near the surface, a steep rise of pressure, and higher wind speed, associated with hazardous weather. However, worldwide consensus on a clear and consistent definition for cold wave events does not yet exist (WMO 2015). *Cold waves* are usually defined as persistent extreme low-temperature events sustaining specified temperatures below a certain threshold over a minimum number of days (Radinović and Ćurić, 2014; Peterson et al. 2013). This minimum temperature threshold depends on the geographical region and time of year. In some cases, cooling corresponds with—or is reinforced

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ARTICLE

Perceptions About Climate Change in the Brazilian Civil Defense Sector

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Abstract Few studies have analyzed climate change perceptions in the disaster risk management sector. This research aimed to understand how civil defense experts are dealing with the climate change topic: what they learn and think about. An online survey was conducted between October and December 2021 with 1,063 participants from civil defense agencies in Brazil. The findings indicate: (1) most (80.6%) civil defense officers completely agreed that climate change will cause additional challenges to disaster risk management, while 10.1% stated that they are prepared to deal with it; (2) one quarter of the respondents (26.3%) completely agreed that they easily understand the information about climate change, but trust in the sources of information is a challenge—52.4% completely agreed and 40.5% partially agreed with information provided by scientists, but the levels of trust were reduced when referring to governments and press; and (3) about 30% of the respondents thought that civil defense work is associated with the Sustainable Development Goals (SDGs), despite SDGs 11 and 13 being related to disasters and climate change. The identification of civil defense' perceptions on climate change is an important step in seeking pathways for increasing capacity building to achieve disaster risk reduction and climate change adaptation.

Keywords Brazil · Capacity building · Disaster risk management · Emergency management · Risk governance · Risk perception

1 Introduction

Social sciences are essential to understand how people and societies perceive, comprehend, produce, and cope with environmental changes. However, this field of science has had a marginal role in carrying out research on climate change and in influencing climate change adaptation policy agenda (Victor 2015; Koehrsen et al. 2020; O'Reilly et al. 2020; Acselrad 2022), as is exemplified by recent literature reviews (Billi et al. 2019; Salmi and Fleury 2022; Zhong et al. 2022).

Social sciences refer to different fields of knowledge, such as history, cultural studies, political science, sociology, anthropology, and so on. Sociologists have used different approaches to study climate change, such as the sociology of loss (Elliott 2018), the drivers of climate change at macro-, meso-, and micro-scale levels and the implications for social justice (Dietz et al. 2020), environmental sociology (Lockie 2022), and sociology of social problems (Acselrad 2022). They have also been involved in multi- and interdisciplinary research through three main approaches: (1) coupled human-natural systems, such as sustainability science; (2) individual-level analysis; and (3) post-political framing of climate change (Weaver et al. 2014; Brulle and Dunlap 2015).

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Editorial: Climatic hazards and disaster risk reduction in South-Central America and the Caribbean

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KEYWORDS
climate change, disaster and climate risk reduction, floods, landslide, extreme rain events

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Editorial on the Research Topic
Climatic hazards and disaster risk reduction in South-Central America and the Caribbean

In this Research Topic collection, our objective is to show the state-of-the-art on disaster risk reduction initiatives in Central-South America and Caribbean regions. Countries in those regions are regularly affected by disasters of hydrometeorological origin. The year 2021 showed a record number of hurricanes that affected Central America and the Caribbean. It evidenced the increasing vulnerability of those areas to extreme events. At the same time, the Pantanal, Amazon, Central Chile, and the Parana-Plata basin are regions in South America that exhibited persistent drought conditions that increased the number of wildfires and affected natural and human systems (WMO, 2022). This WMO report shows that anticipatory actions are still limited in those regions and, in some countries, are almost non-existent, focusing more on disaster management (post-disaster). Discussions such as monitoring and early warning for hydrometeorological hazards, vulnerability assessment, and mapping are critical to addressing Target G of the Sendai Framework and SDG 13 related to climate action. Relevant disaster impact assessments are some subjects to be covered in this collection.

This collection includes five articles related to hazard and risk assessments in some countries in the region. Salgado and Nájera assess flood Early Warning Systems (EWS) for flash floods in Manizales, Colombia. The authors propose a duration-independent rainfall threshold for flash floods in the El Guamo stream basin in Manizales, Colombia. This basin with abrupt topography and small areas where floods are rapid and energy filled. This paper presents a systematic literature review of 19 case studies from 2016 to 2021 to compare and highlight complexities and differences in the methods used in rainfall threshold estimation in the El Guamo stream. While hydrodynamic models are solid in rainfall threshold estimation, probabilistic methods, including uncertainty analysis with utility functions, are valuable in improving decision-making in early warning systems.

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AVALIAÇÃO DAS SIMULAÇÕES DE TEMPERATURA E PRECIPITAÇÃO DE UM SUBCONJUNTO DE MODELOS DO CMIP6 PARA O BRASIL

Wesley de Souza Campos CORREA

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Neyval Costa REIS JUNIOR

José A. MARENGO

Sin Chan CHOU

Carlos NOBRE

RESUMO

Este artigo examina a capacidade do conjunto de 40 modelos climáticos do Coupled Model Intercomparison Projects Generation 6 - CMIP6, conjunto MOD, para simular a temperatura do ar e a precipitação médias do período de janeiro de 1985 a dezembro de 2014 em cada estado do Brasil. Apesar dos vieses nas simulações, o subconjunto do CMIP6 conseguiu simular satisfatoriamente o ciclo anual e sazonal da temperatura e precipitação, bem como captar a tendência das variáveis analisadas no Brasil. Em relação a temperatura do ar à superfície, o subconjunto do CMIP6 apresentou o melhor desempenho para as Regiões Sul e Sudeste do Brasil, com destaque para os estados do Paraná, Santa Catarina e São Paulo. O melhor desempenho para a precipitação, com o subconjunto do CMIP6 foi verificado sobre a Região Centro-Oeste. Em relação às tendências de aquecimento no período de 30 anos do estudo, 1985-2014, todos estados do Brasil apresentaram tendência de aquecimento, tanto para os dados do subconjunto do CMIP6, quanto para os dados observados. A precipitação na região Norte e Sudeste, não exibiu tendências claras para o período analisado, alguns estados apresentaram aumento e outros redução da precipitação. Nas Regiões Centro-Oeste e Nordeste todos estados apresentam tendência de redução da chuva. Na Região Sul, os três estados mostram tendência de aumento na chuva tanto no observado quanto no simulado. No entanto, além das incertezas inerentes a modelagem climática e vieses detectados, este estudo é relevante para indicar o comportamento dos modelos em simular o clima presente. A avaliação apresentada neste trabalho estabeleceu níveis de confiança no uso deste subconjunto de simulações de modelos para estudos do clima futuro, conforme detalhado no texto.

Palavras-chave: Modelagem; Modelos Climáticos Globais; IPCC; Mudanças climáticas.

ABSTRACT

EVALUATION OF TEMPERATURE AND PRECIPITATION SIMULATIONS OF A SUBSET OF CMIP6 MODELS FOR BRAZIL. This article examines the ability of 40 CMIP6 climate models to simulate the mean temperature and mean precipitation observed in each state in Brazil from January 1985 to December 2014. Despite the simulation biases, the CMIP6 was able to simulate the annual and seasonal behavior and capture the trend of the analyzed variables. For surface temperature, the subset of the CMIP6 showed the best performance for the South and Southeast Brazil regions,

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Article

Trends and Climate Elasticity of Streamflow in South-Eastern Brazil Basins

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Abstract: Trends in streamflow, rainfall and potential evapotranspiration (PET) time series, from 1970 to 2017, were assessed for five important hydrological basins in Southeastern Brazil. The concept of elasticity was also used to assess the streamflow sensitivity to changes in climate variables, for annual data and 5-, 10- and 20-year moving averages. Significant negative trends in streamflow and rainfall and significant increasing trend in PET were detected. For annual analysis, elasticity revealed that 1% decrease in rainfall resulted in 1.21–2.19% decrease in streamflow, while 1% increase in PET induced different reductions percentages in streamflow, ranging from 2.45% to 9.67%. When both PET and rainfall were computed to calculate the elasticity, results were positive for some basins. Elasticity analysis considering 20-year moving averages revealed that impacts on the streamflow were cumulative: 1% decrease in rainfall resulted in 1.83–4.75% decrease in streamflow, while 1% increase in PET induced 3.47–28.3% decrease in streamflow. This different temporal response may be associated with the hydrological memory of the basins. Streamflow appears to be more sensitive in less rainy basins. This study provides useful information to support strategic government decisions, especially when the security of water resources and drought mitigation are considered in face of climate change.

Keywords: runoff; precipitation; potential evapotranspiration; Pettitt test; sensitivity

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1. Introduction

A number of studies have reported streamflow reduction in several important basins throughout the world [1–5], putting enormous social, environmental and economic pressure on the world's population and leading to great insecurity when it comes to water, energy and food supply [6,7]. This phenomenon can be associated with the increase on frequency and intensity of extreme climatic events, such as heat waves and droughts [8], as well anthropogenic interferences in the climate via greenhouse gases emission and land use and cover modifications [9–11]. Both interferences together affect streamflow discharge and water resources management. In relation to climate variations, streamflow response is modified through changes in the precipitation regime and evaporation. To quantify these modifications is of considerable importance for a better understanding and

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Natural Hazards and Earth System Sciences EGU

Review article: Design and evaluation of weather index insurance for multi-hazard resilience and food insecurity

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Abstract. Ensuring food security against climate risks has been a growing challenge recently. Weather index insurance has been pointed out as a tool for increasing the financial resilience of food production. However, the multi-hazard insurance design needs to be better understood. This paper aims to review weather index insurance design for food security resilience, including the methodology for calculating natural hazards' indices, vulnerability assessment, and risk pricing. We searched for relevant research papers in the Scopus database using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) protocol. Initially, 364 peer-reviewed papers from 1 January 2010 to 19 February 2022 were screened for bibliometric analysis. Then, the 26 most relevant papers from the last 5 years were systematically analyzed. Our results demonstrate that despite a significant research effort on index insurance, most papers focused on food production. However, research considering other aspects of food security, such as transportation, storage, and distribution, is lacking. Most research focuses on droughts. Other hazards, such as extreme temperature variation, excessive rainfall, and wildfires, were poorly covered. Most studies considered only single-hazard risk, and the multi-hazard risk studies assumed independence between hazards, neglecting the synergy hypothesis between hazards. Lastly, we proposed a conceptual framework that illustrates design paths for a generalized weather index insurance design and evaluation. Solutions for addressing multi-hazard problems are considered. An illustrative example demonstrates the importance of testing the multi-hazard risk hypothesis for weather-based index insurance design for soybean production in Brazil.

1 Introduction

The increased frequency and magnitude of extreme weather and climate events have been evidenced in many regions of the globe, being widely attributed to climate change (IPCC, 2022). In recent years, extreme weather events have caused significant losses and damages in many climate-sensitive sectors, affecting urban and rural areas. Insurance is essential to provide economic sustainability to vulnerable sectors and to improve recovery from catastrophic climate events.

Insurance has been pointed out as a tool for safeguarding populations and properties from climate change (UNEP FI, 2012). Nevertheless, Kraehnert et al. (2021) argue that insurance itself is not an adaptation measure and depends on several characteristics and factors. Some relevant factors

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Novel Landslide Susceptibility Mapping Based on Multi-criteria Decision-Making in Ouro Preto, Brazil

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Accepted: 23 March 2023

Abstract

Weather-related disasters have caused widespread deaths and economic losses in developing countries, including Brazil. Frequent floods and landslides in Brazil are mostly climatic driven, often aggravated by human activities and poor environmental planning. In this paper, we aimed to map and discuss the susceptibility to landslides in the urban area of Ouro Preto, Brazil, a municipality with colonial and world heritage houses. We used data on precipitation, soil types, geology, digital elevation model (DEM), and land use and land cover (LULC) of high spatial resolution (1 m). The location of landslides in the urban perimeter was provided by the Civil Defense of Ouro Preto, and these were validated by fieldwork. A novel mathematical model based on multi-criteria decision-making (MCDA) and the Analytic Hierarchy Process (AHP) was used to map the susceptible areas to landslides. Results show that areas most affected by strong landslides were low-density vegetation (high susceptibility) and rocky outcrops (very high susceptibility). The largest areas susceptible to landslides are urban land use areas. Particularly, landslides that occurred in February 2022 in the region were related to intense soil saturation. With an average monthly rainfall of 122.60 mm, the uneven relief and edaphoclimatic characteristics had caused percolation of the surface runoff, naturally triggering landslides. This study supports mitigation efforts by local governments and decision-makers.

Keywords Vulnerability · Natural hazards · Heritage sites · AHP

Introduction

The report by the World Meteorological Organization and the United Nations Office for Disaster Risk Reduction shows that climate change and extreme events have caused an increase in disasters over the last 50 years. Importantly, from 1970 to 2019, (i), natural hazards accounted for 50% of all disasters, 45% of related deaths, and 74% of related economic losses; (ii) more than 11 thousand reported disasters have been attributed to weather events, with over 2 million deaths and US$3.47 trillion in losses; (iii) more than 91% of deaths occurred in developing countries; and (iv) economic losses have increased sevenfold in the 50-year period, from an average of US$49 million to a staggering US$383 million a day globally. In Brazil, extreme events and natural hazards, predominantly floods and landslides (Tominaga et al. 2009), are mostly climatic driven though their consequences are usually aggravated by human activities, coupled with a poor environmental planning (IPCC, Climate Change 2022, Alcântara et al. 2023). Landslide is defined as a mass movement of material, under the influence of gravity, such as rock or debris, down a slope and can happen suddenly or slowly over a period. Heavy rainfall and changes to the material's strength through weathering and erosion of the base of a slope are external factors that can lead to a landslide (Skilodimou et al. 2018).

Landslides reported during the rainy season of 2021/2022 in southeast Brazil were mostly caused by the

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RISK MANAGEMENT AND VULNERABILITY TO SEA LEVEL RISE IN BRAZIL, WITH EMPHASIS TO THE LEGACY OF THE METROPOLE PROJECT IN SANTOS

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ABSTRACT

Sea Level Rise (SLR) poses a range of threats to natural environments and built infrastructure in coastal zones around the world. Coastal cities in Brazil are vulnerable to the effects of SLR and to the intensity of storms that induce more storm surges and coastal inundation. Studies on vulnerability of coastal cities in Brazil have been developed by multidisciplinary and multinational collaboration between teams of natural and social scientists. Perhaps the best example is the METROPOLE Project (*An Integrated Framework to Analyze Local Decision Making and Adaptive Capacity to Large-Scale Environmental Change)*, a partnership between Brazil, United States and United Kingdom developed to evaluate how local government, stakeholders and citizens may decide about adaptation options related to SLR and extreme events projections. In this paper we show how some results of the METROPOLE project have been considered in the definition of public polices of climate change adaptation and for practical actions to increase resilience of Santos by reducing beach erosion, to reduce climate risk.

Keywords: Sea level rise; Climate change; Floods; Coastal erosion; Rainfall.

RESUMO

GESTÃO DE RISCO E VULNERABILIDADE À SUBIDA DO NÍVEL DO MAR NO BRASIL, COM ÊNFASE AO LEGADO DO PROJETO METRÓPOLE DE SANTOS. A elevação do nível do mar (SLR) representa uma série de ameaças aos ambientes naturais e à infraestrutura construída em zonas costeiras em todo o mundo. As cidades costeiras no Brasil são vulneráveis aos efeitos do SLR e à intensidade das tempestades que induzem mais ressacas e inundações costeiras. Estudos sobre vulnerabilidade de cidades costeiras no Brasil têm sido desenvolvidos por colaboração multidisciplinar e multinacional entre equipes de cientistas das ciências naturais e sociais. Talvez o melhor exemplo seja o Projeto METROPOLE (*Uma estrutura integrada para*

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Recent Hydrological Droughts in Brazil and Their Impact on Hydropower Generation

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Abstract: Brazil has endured the worst droughts in recorded history over the last decade, resulting in severe socioeconomic and environmental impacts. The country is heavily reliant on water resources, with 77.7% of water consumed for agriculture (irrigation and livestock), 9.7% for the industry, and 11.4% for human supply. Hydropower plants generate about 64% of all electricity consumed. The aim of this study was to improve the current state of knowledge regarding hydrological drought patterns in Brazil, hydrometeorological factors, and their effects on the country's hydroelectric power plants. The results show that since the drought occurred in 2014/2015 over the Southeast region of Brazil, several basins were sharply impacted and remain in a critical condition until now. Following that event, other regions have experienced droughts, with critical rainfall deficit and high temperatures, causing a pronounced impact on water availability in many of the studied basins. Most of the hydropower plants end the 2020–2021 rainy season by operating at a fraction of their total capacity, and thus the country's hydropower generation was under critical regime.

Keywords: hydrological drought; drought monitoring; hydrometeorological extreme; hydropower generation

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1. Introduction

Heat waves, heavy rain, drought and associated wildfires, and coastal flooding are examples of extreme weather events that pose risks to human health, livelihood, assets, and ecosystems. The 21st century begins with a considerable record of natural disasters associated with hydrometeorological and climatic extremes. These occurrences resulted in significant economic and environmental losses worldwide. Over 4.4 billion people were injured, homeless, displaced or in need of emergency assistance from 1998 to 2017. Floods, storms, droughts, heat waves, and other extreme weather events caused 91% of all disasters, according to the UNISDR and CRED report [1]. However, droughts can seriously harm a country's economic performance, causing widespread problems in various sectors. According to GAR [2], climate change increases the frequency, severity, and duration of droughts globally, requiring efforts to effectively respond to the significant risks posed by droughts. Future climate change scenarios are expected to cause considerably more

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Natural Hazards and Earth System Sciences

Deadly disasters in southeastern South America: flash floods and landslides of February 2022 in Petrópolis, Rio de Janeiro

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Abstract. On 15 February 2022, the city of Petrópolis in the highlands of the state of Rio de Janeiro, Brazil, received an unusually high volume of rain within 3 h (258 mm), generated by a strongly invigorated mesoscale convective system. It resulted in flash floods and subsequent landslides that caused the deadliest landslide disaster recorded in Petrópolis, with 231 fatalities. In this paper, we analyzed the root causes and the key triggering factors of this landslide disaster by assessing the spatial relationship of landslide occurrence with various environmental factors. Rainfall data were retrieved from 1977 to 2022 (a combination of ground weather stations and the Climate Hazards Group InfraRed Precipitation – CHIRPS). Remotely sensed data were used to map the landslide scars, soil moisture, terrain attributes, line-of-sight displacement (land surface deformation), and urban sprawling (1985–2020). The results showed that the average monthly rainfall for February 2022 was 200 mm, the heaviest recorded in Petrópolis since 1932. Heavy rainfall was also recorded mostly in regions where the landslide occurred, according to analyses of the rainfall spatial distribution. As for terrain, 23 % of slopes between 45–60° had landslide occurrences and east-facing slopes appeared to be the most conducive for landslides as they recorded landslide occurrences of about 9 % to 11 %. Regarding the soil moisture, higher variability was found in the lower altitude (842 m) where the residential area is concentrated. Based on our land deformation assessment, the area is geologically stable, and the landslide occurred only in the thin layer at the surface. Out of the 1700 buildings found in the region of interest, 1021 are on the slope between 20 to 45° and about 60 houses were directly affected by the landslides. As such, we conclude that the heavy rainfall was not the only cause responsible for the catastrophic event of 15 February 2022; a combination of unplanned urban growth on slopes between 45–60°, removal of vegetation, and the absence of inspection were also expressive driving forces of this disaster.

1 Introduction and background

The municipality of Petrópolis is nestled in the mountains, 68 km from the city of Rio de Janeiro. It presents a rugged relief with numerous cliffs, and it is populated by approximately 305 687 inhabitants. The city is predominantly

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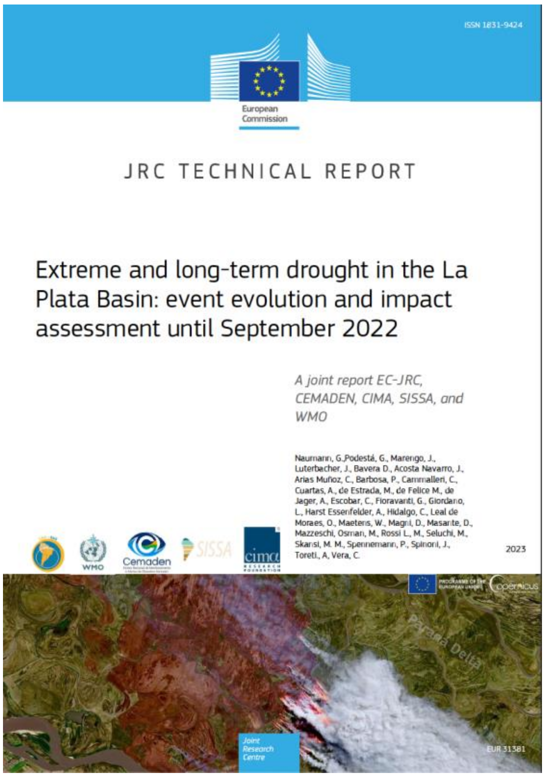

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JRC TECHNICAL REPORT

Extreme and long-term drought in the La Plata Basin: event evolution and impact assessment until September 2022

A joint report EC-JRC, CEMADEN, CIMA, SISSA, and WMO

Naumann, G.,Podestá, G., Marengo, J., Luterbacher, J., Bavera D., Acosta Navarro, J., Arias Muñoz, C., Barbosa, P., Cammalleri, C., Cuartas, A., de Estrada, M., de Felice M., de Jager, A., Escobar, C., Fioravanti, G., Giordano, L., Harst Essenfelder, A., Hidalgo, C., Leal de Moraes, O., Maetens, W., Magni, D., Masante, D., Mazzeschi, Osman, M., Rossi L., M., Seluchi, M., Skansi, M. M., Spennemann, P., Spinoni, J., Toreti., A, Vera, C.

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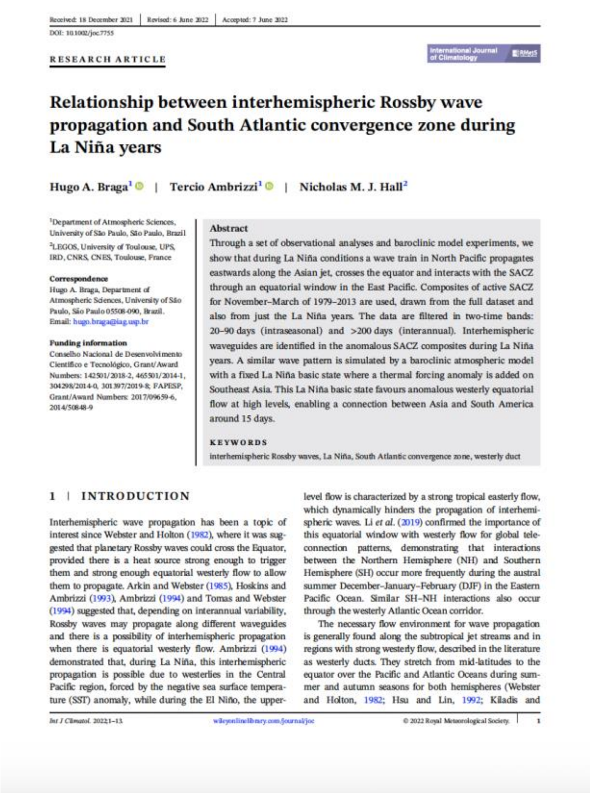

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RESEARCH ARTICLE

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Relationship between interhemispheric Rossby wave propagation and South Atlantic convergence zone during La Niña years

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Abstract
Through a set of observational analyses and baroclinic model experiments, we show that during La Niña conditions a wave train in North Pacific propagates eastwards along the Asian jet, crosses the equator and interacts with the SACZ through an equatorial window in the East Pacific. Composites of active SACZ for November–March of 1979–2013 are used, drawn from the full dataset and also from just the La Niña years. The data are filtered in two-time bands: 20–90 days (intraseasonal) and >200 days (interannual). Interhemispheric waveguides are identified in the anomalous SACZ composites during La Niña years. A similar wave pattern is simulated by a baroclinic atmospheric model with a fixed La Niña basic state where a thermal forcing anomaly is added on Southeast Asia. This La Niña basic state favours anomalous westerly equatorial flow at high levels, enabling a connection between Asia and South America around 15 days.

KEYWORDS
interhemispheric Rossby waves, La Niña, South Atlantic convergence zone, westerly duct

1 | INTRODUCTION

Interhemispheric wave propagation has been a topic of interest since Webster and Holton (1982), where it was suggested that planetary Rossby waves could cross the Equator, provided there is a heat source strong enough to trigger them and strong enough equatorial westerly flow to allow them to propagate. Arkin and Webster (1985), Hoskins and Ambrizzi (1993), Ambrizzi (1994) and Tomas and Webster (1994) suggested that, depending on interannual variability, Rossby waves may propagate along different waveguides and there is a possibility of interhemispheric propagation when there is equatorial westerly flow. Ambrizzi (1994) demonstrated that, during La Niña, this interhemispheric propagation is possible due to westerlies in the Central Pacific region, forced by the negative sea surface temperature (SST) anomaly, while during the El Niño, the upper-level flow is characterized by a strong tropical easterly flow, which dynamically hinders the propagation of interhemispheric waves. Li *et al.* (2019) confirmed the importance of this equatorial window with westerly flow for global teleconnection patterns, demonstrating that interactions between the Northern Hemisphere (NH) and Southern Hemisphere (SH) occur more frequently during the austral summer December–January–February (DJF) in the Eastern Pacific Ocean. Similar SH–NH interactions also occur through the westerly Atlantic Ocean corridor.

The necessary flow environment for wave propagation is generally found along the subtropical jet streams and in regions with strong westerly flow, described in the literature as westerly ducts. They stretch from mid-latitudes to the equator over the Pacific and Atlantic Oceans during summer and autumn seasons for both hemispheres (Webster and Holton, 1982; Hsu and Lin, 1992; Kiladis and

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GEOSCIENCES

Sea ice in the Weddell Sea and its relationship with the South Atlantic Subtropical High and precipitation in South America

CAMILA B. CARPENEDO, TÉRCIO AMBRIZZI & RAFAEL CESAR SILVA

Abstract: This study aims to evaluate the position and intensity of the South Atlantic Subtropical High (SASH), related to sea ice extent (SIE) retraction and expansion in the Weddell Sea, assessing precipitation in South America. We assess the difference between atmospheric fields related to SIE (four most intense retraction events minus four most intense expansion events) in February. To this end, we used NSIDC SIE, ERA-5 reanalysis, CHIRPS precipitation, ICOADS SST, ONI/SAM indexes (CPC/NOAA). In the following month, under neutral ENSO and SAM, we observed tropospheric warming in the Weddell Sea and cooling in the mid-latitudes South Atlantic. There is a weakening of both the Weddell Sea circumpolar low and the high pressures between tropical and subtropical latitudes, in addition to the equatorward shift of the Ferrel cell. Therefore, SASH weakens and contracts, resulting in a reduction of the tropical Atlantic moisture supply to South America and negative precipitation anomalies in the tropical region - similar to the suppression pattern of the South Atlantic Convergence Zone. Our results suggest that SIE retraction (expansion) in the Weddell Sea may contribute to the weakening (strengthening) of the SASH and an early-ending (longer-ending) or drier-ending (wetter-ending) rainy season in tropical South America.

Key words: sea ice, south atlantic subtropical high, weddell sea, south america, south american monsoon system.

INTRODUCTION

The South Atlantic Subtropical High (SASH) is a semi-permanent high-pressure system, typically located between 15°-45°S and 45°W-15°E (Mächel et al. 1998). This system is characterized by counterclockwise circulation (with calm winds at the center and more intense winds at the edge), subsidence (corresponding to the descending branch of the Hadley cell) and divergence in the low troposphere (He et al. 2017). In this way, evaporation exceeds precipitation in the SASH region, influencing the South American Monsoon System (Vera et al. 2006, Raia & Cavalcanti 2008, Arraut et al. 2012, He et al. 2017).

A Monsoon System is regarded as the reversion in the low-level wind direction between summer and winter, when the annual average is removed from the seasonal composition, associated with changes in thermal contrasts between continents and oceans, due to the difference in specific heat (Zhou & Lau 1998, Mechoso et al. 2005, Silva & Kousky 2012, Kitoh et al. 2020; and references therein). This difference in atmospheric circulation results in dry winters and rainy summers, typical of the tropical South America (Rao et al. 1996, Kousky & Ropelewski 1997, Grimm 2003, Gan et al. 2004). The exception occurs between the mouth of the Amazon River and the northern Northeast Brazil, where the

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GEOSCIENCES

Atmospheric blockings in Coupled Model Intercomparison Project Phase 5 models with different representations of Antarctic sea ice extent

CAMILA B. CARPENEDO & TÉRCIO AMBRIZZI

Abstract: This study investigated whether there are differences in the frequency and position of Southern Hemisphere atmospheric blockings between Coupled Model Intercomparison Project Phase 5 models with different representations of Antarctic sea ice extent in historical experiments. In the model with the greatest sea ice underestimation (Model for Interdisciplinary Research on Climate version 5) there is a weakening of the polar jet and an increase in 500-hPa height. These atmospheric conditions favor the predomination of simulated blocking frequency overestimations (autumn-winter), in relation to the observed (ERA-Interim). On the other hand, in the models with the greatest sea ice overestimations (Community Climate System Model version 4) and the better sea ice representation (Norwegian Earth System Model version 1) there is a strengthening of the polar jet and weaker positive differences in 500-hPa height in the Antarctic region. These atmospheric conditions favor a predominance of simulated blocking frequency underestimations (all seasons). All models present a good representation of the preferred blocking regions (South Pacific), although they do not represent the longitudinal location of the maximum frequency. In years of sea ice retraction (expansion), there is a predominance of a higher (lower) blocking frequency in the 60°S for all models and observed data.

Key words: Atmospheric blockings, sea ice, CMIP5, Antarctica.

INTRODUCTION

Prolonged episodes of extreme weather conditions such as droughts/floods (e.g., Trenberth & Guillemot 1995, Mo et al. 1997, Rodrigues & Woollings 2017) and heatwaves (e.g., Kalkstein et al. 1996, Karl & Knight 1997, Rodrigues & Woollings 2017) are often associated with periodic atmospheric flow anomalies (Dole 1986a, b, Higgins & Schubert 1994, 1996), which can last from a few days to weeks. Among these phenomena, atmospheric blockings are associated with extreme weather events due to their systematic and persistent nature, affecting the normal propagation of transient systems. A better understanding of the mechanisms that originate, maintain and dissipate such phenomena is of great importance for the success of short, mid- and long term predictions, considering that atmospheric blockings play an important role in atmospheric variability in various time scales (e.g., Rex 1950, Tsou & Smith 1990, Nakamura & Wallace 1993, Nakamura 1994, Nakamura et al. 1997, Lupo & Smith 1998, Luo et al. 2002, Nakamura & Fukamachi 2004, Tyrlis & Hoskins 2008, Rodrigues & Woollings 2017).

Among the mechanisms associated with atmospheric blockings, in the Northern Hemisphere orographic forcing is dominant

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Tropospheric pathways of the late-winter ENSO teleconnection to Europe

Bianca Mezzina[1,2,5] · Javier García-Serrano[2] · Tercio Ambrizzi[3] · Daniela Matei[4] · Elisa Manzini[4] · Ileana Bladé[2]

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Abstract
The late-winter signal associated with the El Niño-Southern Oscillation (ENSO) over the European continent is unsettled. Two main anomalous patterns of sea-level pressure (SLP) can be identified: a "wave-like" pattern with two opposite-signed anomalies over Europe, and a pattern showing a single anomaly ("semi-isolated"). In this work, potential paths of the tropospheric ENSO teleconnection to Europe and their role in favoring a more wave-like or semi-isolated pattern are explored. Outputs from historical runs of two versions of the MPI-ESM coupled model, which simulate these two types of patterns, are examined. A novel ray-tracing approach that accounts for zonal asymmetries in the background flow is used to test potential propagation paths in these simulations and in observations; three source regions are considered: the tropical Pacific, the North America/North Atlantic, and the tropical Atlantic. The semi-isolated pattern is suggested to be related to the well-known Rossby wave train emanating from the tropical Pacific, either via a split over northern North America or via reflection due to inhomogeneities in the background flow. The wave-like pattern, in turn, appears to be related to a secondary wave train emerging from the tropical Atlantic. The competition between these two pathways contributes to determining the actual surface response.

1 Introduction

El Niño-Southern Oscillation (ENSO) has been associated with a late-winter (January–March) signal in the North Atlantic-European (NAE) region, a "canonical" sea-level pressure (SLP) dipole between middle and high latitudes (e.g. Brönnimann 2007). The western part of this dipole, which is located over the North Atlantic, is robust and has been shown to be mostly driven by tropospheric processes (e.g. Mezzina et al. 2020, 2021a). In contrast, controversy still exists concerning the eastern part of the signal, located over the European continent, since disagreement is present in both observations (Fig. 1, top) and models (Fig. 1, bottom), also depending on the methodology and season used. In some cases, a "wave-like" pattern with two anomalies of alternating sign over Europe is present (Fig. 1a, e.g. Toniazzo and Scaife 2006; Hardiman et al. 2019). In others, a pattern with a single anomaly, negative for El Niño (e.g. Fraedrich and Müller 1992), is visible, sometimes appearing as an extension of the mid-latitude lobe of the canonical dipole (Fig. 1d, e), sometimes as a detached center (Fig. 1b, c, f); hereafter, we will refer to this pattern as "semi-isolated". The semi-isolated pattern is usually accompanied by an upper-level anomaly of the same sign over northern Europe (e.g. Blackmon et al. 1983; Brönnimann 2007; Brönnimann et al. 2007; García-Serrano et al. 2011; Mezzina et al. 2020), but the relationship between the lower-level and upper-level signatures has not been settled, nor their overall nature, robustness and dynamics.

It is well-known that the dominant feature of the ENSO teleconnection to the Northern Hemisphere (NH) extra-tropics is a large-scale tropospheric Rossby wave train emanating from the tropical Pacific and propagating at upper levels, with a first center of action over the Aleutian Low (cyclonic for El Niño), a second one of opposite sign over Canada, and

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Summer dry events on synoptic and intraseasonal timescales in the Southeast Region of Brazil

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RESUMEN

La ocurrencia de eventos secos en la región Sudeste de Brasil (SEB, por sus siglas en inglés) durante el verano (temporada de lluvias) se ha evidenciado en los últimos años, principalmente debido a eventos extremos previos en las temporadas 2013/14 y 2014/15. Los análisis de sequía se suelen realizar con datos mensuales. Aquí nuestra metodología aborda el tema con datos diarios para generar un análisis exhaustivo. Los eventos secos se evaluaron en diferentes subregiones de precipitación homogénea dentro del SEB, durante 37 temporadas diciembre-febrero (DJF, por sus siglas en inglés) y con dos escalas de tiempo diferentes de duración: sinóptica (5-9 días) e intraestacional (≥10 días). Se encontraron dos patrones dinámicos principales distintos para los eventos secos en las partes sur y centro-norte de SEB, respectivamente, pero no se identificaron diferencias importantes en las diferentes escalas de tiempo de ocurrencia. Los eventos del sur se caracterizaron por una cresta estacionaria que actuaba sobre todo el sur de América del Sur, lo que dificultó la aproximación de los sistemas transitorios al SEB del sur. Al mismo tiempo, este patrón mostró una configuración de Zona de Convergencia del Atlántico Sur (SACZ, por sus siglas en inglés) desplazada hacia el norte. En los eventos centro-norte, una alta presión centrada entre las regiones sur y sureste de Brasil se asoció con las condiciones de sequía. También se verificó un desplazamiento anómalo hacia el sur de los sistemas meteorológicos característico del verano sudamericano para estos eventos. Sobre el Atlántico Sur, se identificó una configuración de anomalía SST opuesta entre los eventos del sur y del centro-norte.

ABSTRACT

The occurrence of dry events in the Southeast Region of Brazil (SEB) during summer (rainfall season) has been in evidence in the last years, mainly due to previous extreme events in the 2013/14 and 2014/15 seasons. Drought analyses are usually carried out with monthly data. Here our methodology addresses the issue with daily data to generate a thorough analysis. Dry events were evaluated in different homogeneous precipitation sub-regions within the SEB, over 37 December-February (DJF) seasons and with two different timescales of duration: synoptic (5-9 days) and intraseasonal (≥10 days). Two main distinct dynamic patterns were found for dry events in southern and central-northern parts of SEB, respectively, but no significant differences were identified in the different timescales of occurrence. Southern events were characterized by a stationary ridge acting over the whole of southern South America, making the approximation of the transient system to southern SEB difficult. At the same time, this pattern showed a northern-shifted South Atlantic Convergence Zone (SACZ) configuration. In the central-northern events, a high pressure centered between Brazil's South and Southeast regions was associated with the dryness conditions. An anomalous southward shift of meteorological systems characteristic of the South American summer was also verified for these events. Over the South Atlantic, an opposite SST anomaly configuration was identified between southern and central-northern events.

Keywords: synoptic dry events, intraseasonal dry events, rainfall season.

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Article

Understanding the El Niño Southern Oscillation Effect on Cut-Off Lows as Simulated in Forced SST and Fully Coupled Experiments

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Abstract: In this study, we show that changes in the 250 hPa vorticity cut-off low (COL) activity may possibly be driven by sea surface temperature (SST) variations in the tropical Pacific. Using ERA5 reanalysis, the existence of different large-scale circulation patterns is identified that work to enhance the COL activity with a weakened jet stream, while COLs are suppressed with strengthened westerlies. The present-day simulations of AMIP-CMIP6 models reproduce realistic features of the El Niño Southern Oscillation (ENSO)–COL teleconnection, but biases exist, especially in coupled models. The differences are a priori due to the inability of the models to accurately predict the time-mean zonal flow, which may be in part due to systematic biases in the predicted SST. The underestimation of warm SST anomalies over the eastern Pacific is a common problem in CMIP3 and CMIP5 models and remains a major uncertainty in CMIP6. We find that a reduced bias in the predicted SST by coupled models is most likely to produce more skillful simulations in the Southern Hemisphere, but the same evidence does not hold for the Northern Hemisphere. The study suggests the potential for seasonal prediction of COLs and the benefits that would result using accurate initialization and consistent model coupling.

Keywords: cut-off low; sea surface temperature; ENSO; AMIP6; CMIP6; climate models

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1. Introduction

Cut-off low (COL) systems are synoptic-scale features characterized by a mid-upper-tropospheric cold low (depression) that has become completely detached from the main westerly flow. COLs have important implications for the local weather as they are typically associated with high rainfall and flooding in midlatitude and subtropical regions and also impact ozone concentrations due to stratosphere-troposphere exchange. Because of the importance of COLs in affecting the weather, understanding the characteristics of COLs and their variability is of particular interest for numerical weather and climate predictions. Many observational and numerical studies have investigated COLs from different perspectives [1–6]. Despite the recent advances in our understanding of COLs, the influence of teleconnection patterns on COLs and their predictability have received much less attention.

Given that El Niño Southern Oscillation (ENSO) is the dominant mode of interannual variability in the tropics and has significant impacts on the global climate, there is interest in how COLs might respond to changes in the tropical Pacific sea surface temperature (SST). There are compelling reasons to assume that the tropics might have a relevant influence on the COL activity. Many studies have shown that El Niño (La Niña) events can modify the Hadley circulation [7–9], affecting the subtropical eddy momentum flux and possibly the

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Mesoscale convective systems over the Amazon basin in a changing climate under global warming

Amanda Rehbein[1] · Tercio Ambrizzi[1]

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Abstract

Climate change is imminent and threatens the largest watershed in the world, the Amazon basin. As general circulation models may fail to represent cloud-scale phenomena, precipitation in a changing climate under global warming is still a factor of great uncertainty, especially in Tropical regions. In this study, we used long-term high-resolution simulations from a global cloud-resolving model under the scope of the Coupled Model Intercomparison Project (CMIP6) to verify the climate change impacts on the mesoscale convective systems (MCSs) over the Amazon basin. We generated a complete spatial, temporal, and statistical characterization of the MCSs for the past (1950–1960), present (2000–2010), and near-future (2040–2050). We found that MCSs are a critical mechanism for precipitation, especially in austral winter. The simulations are consistent with the observed precipitation and MCSs patterns over the Amazon basin, indicating that MCSs are less frequent compared to the past and are expected to continuously decline in the near-future. Most decreases are projected from September to December, while an increase between June to August, mainly in the southern portion of the Amazon basin. In addition, the investigation presented here shows the great potential of using a global cloud-resolving model under the CMIP6 scope to investigate mesoscale systems in a warming climate.

Keywords Climate change · Mesoscale convective systems · Amazon basin · Global cloud resolving models · CMIP6 · NICAM

1 Introduction

The proper functioning of the Amazonian ecosystems is fundamentally dependent on precipitation and temperature. At the same time, the Amazon plays an important role in the South American ecosystems east of the Andes since it provides the most moisture to form precipitation over that region (Vera et al. 2006a; Drumond et al. 2014). Despite the Amazon basin precipitation oscillatory trend nature (Marengo 2009), studies have shown that the length of the Amazon basin dry period is increasing year after year (Debortoli et al. 2015; Espinoza et al. 2019; Haghtalab et al. 2020; among others); This is also been followed by a decreasing in precipitation in the southeastern and northern Amazon (Davidson et al. 2012; Debortoli et al. 2015; Espinoza et al. 2019; among others), and; extreme droughts and floods are frequently interspersing (Marengo and Espinoza 2016; Haghtalab et al. 2020; among others). In the long term, climate change projections under global warming scenarios show that the Amazon precipitation will be drastically reduced by the end of this century (Marengo et al. 2010; Reboita et al. 2014; Ambrizzi et al. 2019; among others).

Due to the coarse resolution of the general circulation models (GCMs) also known as global climate models, uncertainties and details on precipitating systems remain (Roberts et al. 2018), requiring regional (Medvigy et al. 2008; Marengo et al. 2009; Ambrizzi et al. 2019) or cloud-resolving (Stevens et al. 2019) models to represent mesoscale phenomena. Therefore, in order to better understand climate change impacts, it is crucial to improve the understanding of cloud systems. Mesoscale convective systems (MCSs) are one of those under-represented cloud organizations which significantly precipitate over the region (Cohen et al. 1995; Satyamurty et al. 1998; Rehbein et al. 2019;

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Evaluating homogeneity and trends in extreme daily precipitation indices in a semiarid region of Brazil

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A regional investigation of precipitation extremes could help the local authorities to develop strategies against potential climatic disasters, especially in regions of large climate vulnerability. In this context, this study focused on the homogeneity and trend analysis of eleven extreme precipitation indices from a daily rainfall dataset of rain gauges of the state of Ceará, located in the north of Northeast Brazil, from 1974 to 2018 at annual and seasonal time scales. The data were first submitted to gap-filling and quality control processes. Homogeneity, trend, and correlation coefficient were performed subsequently. Homogeneity results showed that most of the precipitation series were classified as "useful." Significant break years in the series agreed well with moderate and very strong El Niño and La Niña events, suggesting a further investigation of this possible connection. Wet and dry day precipitation indices mainly indicated a decrease in the rainfall regime and an increase in dry days, mainly in the central-eastern, northwestern, and southern regions of the Ceará, especially during the annual time scale and the rainy season. The Locally Weighted Scatterplot Smoothing (LOWESS) curve showed changes in almost all series during the 1980s and 1990s, coinciding with the homogeneity breaks and years of severe droughts that strongly hit the region. Correlation coefficients were strong and significant between rainfall total index and the other precipitation indices.

KEYWORDS
precipitation, extreme indices, Northeast Brazil, data quality, homogeneity, trend analysis

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Article

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Climate and land management accelerate the Brazilian water cycle

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Increasing floods and droughts are raising concerns of an accelerating water cycle, however, the relative contributions to streamflow changes from climate and land management have not been assessed at the continental scale. We analyze streamflow data in major South American tropical river basins and show that water use and deforestation have amplified climate change effects on streamflow extremes over the past four decades. Drying (fewer floods and more droughts) is aligned with decreasing rainfall and increasing water use in agricultural zones and occurs in 42% of the study area. Acceleration (both more severe floods and droughts) is related to more extreme rainfall and deforestation and occurs in 29% of the study area, including southern Amazonia. The regionally accelerating water cycle may have adverse global impacts on carbon sequestration and food security.

Floods and droughts cause more damage worldwide than any other natural hazard[1,2] and their risks may be exacerbated by climate change and socio-economic activities[1,3,4]. Often an increase in floods is aligned with a decrease in droughts as a result of more abundant rainfall, and the opposite is the case as rainfall becomes scarcer[5,6]. However, some models suggest a joint increase in the severity of floods and droughts[1,7,8], a phenomenon referred to as acceleration of the terrestrial component of the water cycle. This acceleration could lead to large compound impacts[9] on global food production[10,11], ecosystem health[12,13], and infrastructure[8].

There are a number of processes that potentially cause an acceleration of the water cycle. In a warming climate, the moisture carrying capacity of the atmosphere is increased[14] enhancing extreme rainfall[15,16] which may increase streamflow during floods. Enhancement of rainfall seasonality[17] may decrease streamflow during hydrological droughts. Additionally, the global atmospheric and oceanic circulations are affected[7,14,18]. Weaker meridional pressure gradients in a warmer climate may lead to the amplification of stationary waves causing more persistent rainfall and drought periods[19] and rapid shifts between these two regimes[20-22]. Changes in monsoon patterns with increasing contrasts between land and sea surface temperature[7] can similarly increase floods and droughts. Land management can also accelerate the water cycle. Agricultural practices can reduce rainwater infiltration into the soil which increases overland flow and thus floods, and reduces groundwater recharge and thus low flows during droughts[23]. River engineering[8], urbanization[24], and groundwater pumping[25] can have similar effects on streamflow. While there is some evidence for the acceleration of the water cycle over the ocean[18], there is little such evidence over land[26,27] because of insufficient streamflow data and the confounding effects of the growing human interference in the terrestrial water cycle[8].

Here, we analyze a comprehensive hydrometeorological, land cover, and human water use data set in Brazil and show that water use and deforestation have amplified climate change effects on Brazilian streamflow extremes over the past four decades. This region encompasses some of the world's largest basins with mounting concerns of changing floods and droughts[6]. Our analysis is based on daily streamflow observations from 886 hydrometric stations (Supplementary Fig. 1) for the period from 1980 to 2015. For each station, we compute annual time series of annual minimum 7-day streamflow as a measure of drought flows, mean daily streamflow as a measure of water availability, and annual maximum daily streamflow as a measure of flood flows. We quantify the trend magnitude of each time series (i.e., local trend) with the Theil-Sen slope estimator, the significance of each trend with the Mann-Kendall test, and obtain regional trends by spatial interpolation with ordinary kriging.

For each basin, we consider three climate drivers of streamflow change, computed from daily meteorological data from 1980 to 2015:

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ORIGINAL PAPER

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Assessment of trends, variability and impacts of droughts across Brazil over the period 1980–2019

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Abstract

Drought indices are a numerical representation of drought conditions aimed to provide quantitative assessments of the magnitude, spatial extent, timing, and duration of drought events. Since the adverse effects of droughts vary according to the characteristics of the event, the socioeconomic vulnerabilities, exposed communities or environments, there is a profusion of drought indicators to assess drought impacts in different sectors. In this study, we evaluated the performance of two drought indices, the Standardized Precipitation Index—SPI and Standardized Precipitation Evapotranspiration Index—SPEI over Brazil derived from gridded meteorological information over the period 1980–2019. Firstly, we compared the gridded derived indices against the same indices derived from weather station data and available from a global dataset for time scales of 3, 6, 12, 24 months. Then we analyzed the spatio-temporal trends in SPI and SPEI time-series, which revealed statistically significant trends toward drier conditions across central Brazil for all time scales, though with more intensity for time scales of 12 months and larger. Trends were more significant in magnitude for SPEI than SPI, indicating an important role in the increase in evaporation, driven by increasingly higher temperatures. Finally, we demonstrated that climate signals are already having a disruptive effect on the country's energy security.

Keywords Drought trends · SPI · SPEI · Impacts

1 Introduction

Drought is a natural climatic event which affects all ecosystems, either in arid lands or rainforests (Dai 2011; Svoboda and Fuchs 2017; Wang et al. 2017). As a hazard, drought is primarily defined as a period in which precipitation is less than the long-term average, resulting in a water shortage. In the disaster context, drought takes place over densely populated

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DRAI: a risk-based drought monitoring and alerting system in Brazil

Raissa Zurli Bittencourt Bravo, Adriana Leiras, Fernando Luiz Cyrino Oliveira & Ana Paula Martins do Amaral Cunha

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Abstract

Drought is recognized as a devastating natural hazard, affecting human livelihood and causing a substantial economic impact. Consequently, experts and decision-makers concentrate on new approaches to reducing droughts' economic and social effects through studies that focus on the monitoring, prediction, and risk analysis of drought to inform drought preparedness strategies and mitigation measures. This study presents the Drought Risk Assessment Interface (DRAI), a drought early warning system applied to the Brazilian semiarid region based on a composite index of meteorological drought risk. The risk index has two components: hazard and vulnerability. The hazard component considers meteorological indicators, while the vulnerability component encompasses social variables. Based on the opinion of experts from several countries, we define the weight of each of these indicators in the risk index using the analytical hierarchy process. Then, we propose a standard for generating warnings in the DRAI. The warnings are associated with seven drought risk mitigation measures validated by local technicians. We conclude that DRAI is a valuable tool to academics and practitioners, such as Civil Defences that can act directly in risk mitigation actions.

Water Resources Research

Research Article

Brazilian Water Security Threatened by Climate Change and Human Behavior

André S. Ballarin, José Gescilam Sousa Mota Uchôa, Matheus S. dos Santos, André Almagro, Ianca P. Miranda, Pedro Gustavo C. da Silva ... See all authors

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Abstract

Water scarcity is a growing concern globally, with climate change and increasing population exacerbating the issue. Here, we introduce a new framework for assessing water availability in 708 Brazilian catchments that considers the effect of CO_2 concentrations on potential evapotranspiration, uses CMIP6 bias-corrected climate change simulations, and presumes an open water balance assumption, while considering the human-aspect by incorporating water demand projections. We note an average reduction of water security in 81% of the analyzed catchments by 2100. Among these catchments, 37% presented a reduction of future water availability, while 63% undergo a worse scenario due to an increase in human water use, which highlights the role of the human aspect in water security assessment. Our study shows important aspects for both advancing future water availability studies and for drawing a picture of the impacts of changes in climate and water use on Brazilian future water security that may be useful for water resources management practices and advancing hydrologic studies.

Key Points

- We introduce a new framework for assessing climate change and water use impacts on water availability in 708 Brazilian catchments
- We consider an open water balance, the effect of CO_2 concentrations on potential evapotranspiration, and water demand projections
- 81% of the catchments may experience reduced water security by 2100

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Research papers

A satellite-based approach to estimating spatially distributed groundwater recharge rates in a tropical wet sedimentary region despite cloudy conditions

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Abstract

Groundwater recharge (GWR) is one of the most challenging water fluxes to estimate, as it relies on observed data that are often limited in many developing countries. This study developed an innovative water budget method using satellite products for estimating the spatially distributed GWR at monthly and annual scales in tropical wet sedimentary regions despite cloudy conditions. The distinctive features proposed in this study include the capacity to address 1) evapotranspiration estimations in tropical wet regions frequently overlaid by substantial cloud cover; and 2) seasonal root-zone water storage estimations in sedimentary regions prone to monthly variations. The method also utilises satellite-based information of the precipitation and surface runoff. The GWR was estimated and validated for the hydrologically contrasting years 2016 and 2017 over a tropical wet sedimentary region located in North-eastern Brazil, which has substantial potential for groundwater abstraction. This study showed that applying a cloud-cleaning procedure based on monthly compositions of biophysical data enables the production of a reasonable proxy for evapotranspiration able to estimate groundwater by the water budget method. The resulting GWR rates were 219 (2016) and 302 (2017) mm yr^{-1}, showing good correlations (CC = 0.68 to 0.83) and slight underestimations (PBIAS = −13 to −9%) when compared with the referenced estimates obtained by the water table fluctuation method for 23 monitoring wells. Sensitivity analysis shows that water storage changes account for +19% to −22% of our monthly evaluation. The satellite-based approach consistently demonstrated that the consideration of cloud-cleaned evapotranspiration and root-zone soil water storage changes are essential for a proper estimation of spatially distributed GWR in tropical wet sedimentary regions because of their weather seasonality and cloudy conditions.

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Natural Hazards and Earth System Sciences
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Review article: Design and evaluation of weather index insurance for multi-hazard resilience and food insecurity

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Abstract. Ensuring food security against climate risks has been a growing challenge recently. Weather index insurance has been pointed out as a tool for increasing the financial resilience of food production. However, the multi-hazard insurance design needs to be better understood. This paper aims to review weather index insurance design for food security resilience, including the methodology for calculating natural hazards' indices, vulnerability assessment, and risk pricing. We searched for relevant research papers in the Scopus database using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) protocol. Initially, 364 peer-reviewed papers from 1 January 2010 to 19 February 2022 were screened for bibliometric analysis. Then, the 26 most relevant papers from the last 5 years were systematically analyzed. Our results demonstrate that despite a significant research effort on index insurance, most papers focused on food production. However, research considering other aspects of food security, such as transportation, storage, and distribution, is lacking. Most research focuses on droughts. Other hazards, such as extreme temperature variation, excessive rainfall, and wildfires, were poorly covered. Most studies considered only single-hazard risk, and the multi-hazard risk studies assumed independence between hazards, neglecting the synergy hypothesis between hazards. Lastly, we proposed a conceptual framework that illustrates design paths for a generalized weather index insurance design and evaluation. Solutions for addressing multi-hazard problems are considered. An illustrative example demonstrates the importance of testing the multi-hazard risk hypothesis for weather-based index insurance design for soybean production in Brazil.

1 Introduction

The increased frequency and magnitude of extreme weather and climate events have been evidenced in many regions of the globe, being widely attributed to climate change (IPCC, 2022). In recent years, extreme weather events have caused significant losses and damages in many climate-sensitive sectors, affecting urban and rural areas. Insurance is essential to provide economic sustainability to vulnerable sectors and to improve recovery from catastrophic climate events.

Insurance has been pointed out as a tool for safeguarding populations and properties from climate change (UNEP FI, 2012). Nevertheless, Kraehnert et al. (2021) argue that insurance itself is not an adaptation measure and depends on several characteristics and factors. Some relevant factors

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Socio-environmental monitoring and co-management strategies to favor groundwater recharge and sustainable use in southern metropolises: Toward a co-managed aquifer recharge model?

Guillaume Bertrand [1], Paul Cary [2], Lise Cary [3], Ricardo Hirata [4], Emmanuelle Petelet-Giraud [3], Marc Steinmann [1], Victor Coelho [5], Suzana Montenegro [6], Anderson Paiva [6], Cristiano Almeida [5]

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Abstract

In rapidly growing southern metropolises, climatic, anthropogenic and demographic pressures combined with centralized network deficiencies, favor individual initiatives to access freshwater, *e.g.*, illegal well settlements, pirate connection to the distribution network, rainwater harvesting, and storage in tanks. These strategies are amplified by extreme meteorological events (e.g., droughts) that also trigger cognitive mechanisms, such as denial, opportunism or a kind of "myopic" competition to access the resource without considering (knowing) collateral impacts. From these environmental and social dimensions, this review first evaluates the arguments for the integration of managed aquifer recharge (MAR) in socio-environmental observatories (SEO). SEO are structures concurrently monitoring natural, anthropogenic, and engineered processes but also relationships between stakeholders/managers and end-users. Second, in order to take advantage from the current private (and illegal) strategies, MAR implementation accompanied with a SEO structure is discussed to show how it promotes cognitive, social, economic, and governance conditions required for successful co-management.

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Research papers

Assessing climate change impact on flood discharge in South America and the influence of its main drivers

João Paulo L.F. Brêda, Rodrigo Cauduro Dias de Paiva, Vinícius Alencar Siqueira, Walter Collischonn

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Abstract

A warmer atmosphere is able to hold more water which consequently intensifies the hydrological cycle. The projected increase in extreme precipitation has been associated with greater floods; however, most recent studies have argued that the reduced soil moisture could be causing the opposite effect. We aim to understand how the hydrometeorological variables affect flood discharge and what the projections are for South America, a vulnerable continent that has been barely studied regarding flood trends. We used climate data from Eta simulations nested in 4 global climate models (BESM, CanESM2, HadGEM2-ES, MIROC5) as input for the MGB-SA hydrological model to yield flood discharge estimates. Then we were able to project the climate impacts on extreme precipitation, antecedent soil moisture, and flood discharge for large rivers (>1,000 km^2) and understand how these variables are related. Our results showed a strong sign that antecedent soil moisture is expected to be reduced in most of the continent except in Southeastern South America (SESA). On the other hand, there are mixed signs for rarer precipitation and a clear spatial pattern for 2-year precipitations (RP2), which is expected to increase on the SESA and west Amazon and decrease on Central South America (CSA). For basins>100,000 km^2, results indicate a negative change sign for 2-year precipitations, meaning that rainfall events that generate ordinary floods in large South American rivers are expected to decrease in the XXI century due to climate change. The change signs for flood discharge and extreme precipitation are spatially similar but more basins show a decrease for flooding than for rainfall. While only half of the South American basins are expected to present reduced 2-year precipitations, nearly 70 % of the rivers present a negative sign for 2-year floods, which can be attributed to the reduced antecedent soil moisture.

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Climate and land management accelerate the Brazilian water cycle

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Vinícius B. P. Chagas [1], Pedro L. B. Chaffe [2] & Günter Blöschl [3]

Increasing floods and droughts are raising concerns of an accelerating water cycle, however, the relative contributions to streamflow changes from climate and land management have not been assessed at the continental scale. We analyze streamflow data in major South American tropical river basins and show that water use and deforestation have amplified climate change effects on streamflow extremes over the past four decades. Drying (fewer floods and more droughts) is aligned with decreasing rainfall and increasing water use in agricultural zones and occurs in 42% of the study area. Acceleration (both more severe floods and droughts) is related to more extreme rainfall and deforestation and occurs in 29% of the study area, including southern Amazonia. The regionally accelerating water cycle may have adverse global impacts on carbon sequestration and food security.

water MDPI

Article

Recent Hydrological Droughts in Brazil and Their Impact on Hydropower Generation

Luz Adriana Cuartas [1,2,*], Ana Paula Martins do Amaral Cunha [1,2], Jessica Anastácia Alves [2], Larissa Milena Pinto Parra [2], Karinne Deusdará-Leal [1], Lidiane Cristina Oliveira Costa [1], Ruben Dario Molina [3], Diogo Amore [1], Elisangela Broedel [1], Marcelo Enrique Seluchi [1], Christopher Cunningham [1], Regina Célia dos Santos Alvalá [1,2] and José Antonio Marengo [1,2]

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Abstract: Brazil has endured the worst droughts in recorded history over the last decade, resulting in severe socioeconomic and environmental impacts. The country is heavily reliant on water resources, with 77.7% of water consumed for agriculture (irrigation and livestock), 9.7% for the industry, and 11.4% for human supply. Hydropower plants generate about 64% of all electricity consumed. The aim of this study was to improve the current state of knowledge regarding hydrological drought patterns in Brazil, hydrometeorological factors, and their effects on the country's hydroelectric power plants. The results show that since the drought occurred in 2014/2015 over the Southeast region of Brazil, several basins were sharply impacted and remain in a critical condition until now. Following that event, other regions have experienced droughts, with critical rainfall deficit and high temperatures, causing a pronounced impact on water availability in many of the studied basins. Most of the hydropower plants end the 2020–2021 rainy season by operating at a fraction of their total capacity, and thus the country's hydropower generation was under critical regime.

Keywords: hydrological drought; drought monitoring; hydrometeorological extreme; hydropower generation

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1. Introduction

Heat waves, heavy rain, drought and associated wildfires, and coastal flooding are examples of extreme weather events that pose risks to human health, livelihood, assets, and ecosystems. The 21st century begins with a considerable record of natural disasters associated with hydrometeorological and climatic extremes. These occurrences resulted in significant economic and environmental losses worldwide. Over 4.4 billion people were injured, homeless, displaced or in need of emergency assistance from 1998 to 2017. Floods, storms, droughts, heat waves, and other extreme weather events caused 91% of all disasters, according to the UNISDR and CRED report [1]. However, droughts can seriously harm a country's economic performance, causing widespread problems in various sectors. According to GAR [2], climate change increases the frequency, severity, and duration of droughts globally, requiring efforts to effectively respond to the significant risks posed by droughts. Future climate change scenarios are expected to cause considerably more

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An assessment of South American sediment fluxes under climate changes

Hugo de Oliveira Fagundes [a,*], Rodrigo Cauduro Dias de Paiva [a], João Paulo Lyra Fialho Brêda [b], Alice César Fassoni-Andrade [a,b], Pasquale Borrelli [c,d], Fernando Mainardi Fan [a]

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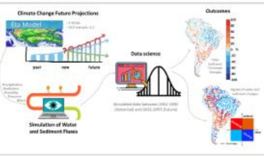
HIGHLIGHTS

- Simulated sediment flows show contrast in northern (decrease) and southern (increase) South America (SA).
- An increase in sediment transport >30 % might occur for the main South American basins.
- The highest changes in sediment discharge may occur in Doce (−54 %) and Upper Paraná (409 %) rivers.
- Changes in water and sediment discharges can induce a new water composition in the Amazon basin.
- Future changes in sediment fluxes may greatly affect SA aquatic ecosystems.

GRAPHICAL ABSTRACT



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ABSTRACT

Climate change can affect all levels of society and the planet. Recent studies have shown its effects on sediment fluxes in several locations worldwide, which can impact ecosystems and infrastructure such as reservoirs. In this study, we focused on simulating sediment fluxes using projections of future climate change for South America (SA), a continent with a high sediment transport rate to the oceans. Here, we used four climate change data yielded by the Eta Regional Climate Model: Eta-BESM, Eta-CanESM2, Eta-HadGEM2-ES, and Eta-MIROC5. In addition, it was evaluated the RCP4.5 greenhouse gas emissions scenario from CMIP5, which represents a moderate scenario. Climate change data between 1961 and 1995 (past) and 2021 and 2055 (future) were used to simulate and compare changes that may occur in water and sediment fluxes using the hydrological-hydrodynamic and sediment model MGB-SED AS. The Eta climate projections provided input data to MGB-SED AS model, such as precipitation, air surface temperature, incident solar radiation, relative humidity, wind speed, and atmospheric pressure. Our results showed sediment fluxes are expected to reduce (increase) in north-central (south-central) SA. While a sediment transport (QST) increase >30 % might occur, a 28 % decrease is expected to occur in the water discharge for the main SA basins. The most significant QST reductions were estimated for the Doce (−54 %), Tocantins (−49 %), and Xingu (−34 %) rivers, while the most significant increases were estimated for the Upper Paraná (409 %), Juruá (46 %), and Uruguay (40 %) rivers. We also observed that different climate change signals over large basins can impact the river water composition, which could lead to a new composition of the Amazon basin waters in the future, accompanied by a significant increase in sediment concentration.

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Modelling and assessment of sustainable urban drainage systems in dense precarious settlements subject to flash floods

Luma Gabriela Fonseca Alves, Carlos de Oliveira Galvão, Bervylly Lianne de Farias Santos, Eldson Fernandes de Oliveira and Demóstenes Andrade de Moraes

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ABSTRACT

In developing countries, dense, precarious and informal settlements are common. In the tropics, the occurrence of intense rainfall and the increased impervious surfaces have led to disastrous flash floods. Sustainable urban drainage systems (SUDS) are an alternative to enhance stormwater management and runoff control, providing benefits related to social and environmental domains. This study aims to ground the development of procedures for SUDS implementation to mitigate flooding, and to maximize urban benefits. We present a modelling framework of SUDS implementation, using the Storm Water Management Model (SWMM) to simulate various SUDS scenarios. An application to a small catchment in Brazil considered permeable pavements, bioretention systems, infiltration trenches and rainwater harvesting systems, introduced in both public and private areas. The results demonstrate that SUDS implemented in public spaces, although they may increase access to public facilities, do not completely avoid flooding in the denser parts of the catchment. In such cases, measures must be implemented in private lots due to the reduced amount of available public spaces. Such evidence shows that one of the key elements for flash flood management in consolidated dense and precarious urban settlements is the integration of SUDS measures with the engagement of local inhabitants in decision-making.

KEYWORDS
Brazil; SWMM; urban planning; urban design; flooding

MOTS CLÉS
Brésil ; SWMM ; aménagement urbain ; design urbain ; inondation urbaine

Modélisation et évaluation des systémes de drainage urbains durables dans des zones d'habitation denses et précaires sujets á des inondations

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Research papers

HydroPol2D — Distributed hydrodynamic and water quality model: Challenges and opportunities in poorly-gauged catchments

Marcus Nóbrega Gomes Jr. [a,b,*], César Ambrogi Ferreira do Lago [a], Luis Miguel Castillo Rápalo [a], Paulo Tarso S. Oliveira [c], Marcio Hofheinz Giacomoni [b], Eduardo Mario Mendiondo [a,d]

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Dataset link: https://github.com/marcusnobrega-eng/HydroPol2D

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Water quality model
Build-up and wash-off
Water Adaptive Design
Low impact development
Pollutant transport and fate

ABSTRACT

Floods are one of the deadliest natural hazards and are exacerbated by changes in land-use and climate. Urban development decreases infiltration by reducing pervious areas and increases the accumulation of pollutants during dry weather. It also decreases infiltration by reducing pervious areas and increases the accumulation of pollutants during dry periods. During rainy events, there is an increase in pollution concentrations and runoff that may be a source of water supply during drought periods. Modeling the quantity and quality dynamics of stormwater runoff requires a coupled hydrodynamic module capable of estimating the transport and fate of pollutants. In this paper, we evaluate the applicability of a distributed hydrodynamic model coupled with a water quality model (HydroPol2D). First, the model is compared to GSSHA and WCA2D in the V-Tilted catchment, and the limitation of the critical velocity of WCA2D is investigated. We also applied the model in a laboratory wooden board catchment, focusing on the validation of the numerical approach to simulate water quality dynamics. Then, we apply HydroPol2D in the Tijuco Preto catchment, in São Carlos - Brazil, and compare the modeled results with the full momentum solver of the HEC-RAS 2D. This catchment shares similar characteristics with many poorly-gauged and human-impacted catchments worldwide. The implementation of the model, the governing equations, and the estimation of input data are discussed, indicating the challenges and opportunities to scale HydroPol2D into the reality of data scarcity of larger poorly-gauged catchments. For a 1-yr return period of rainfall and antecedent dry days, and assuming an uncertainty of 40% in the water quality parameters, the results indicate that the maximum concentration of total suspended solids (TSS), the maximum load and the mass of the pollutant washed in 30% of the volume are, 456 ± 260 $mgL^{-1}km^{-2}$, 2.56±0.4 $kgs^{-1}km^{-2}$, and 89% ± 10%, respectively.

1. Introduction

The spatial scale is a determinant factor to decide which tools to apply in water resources problems such as flood management (Kreibich et al., 2022), flood modeling (Gomes Jr et al., 2023), and spatial analysis of pollutants transport (Yanxia et al., 2022). Solutions to these problems typically require numerical modeling, and the quality of these models usually depends on data availability and the actual state-of-the-art conceptual models used to express complex phenomena of the water cycle.

Hydrologic, hydrodynamic, and pollutant transport models are fundamental tools for decision-making about mitigating floods and poor water quality (Fan and Collischonn, 2014). In the literature, there are a variety of models that aid in the quantification of hydrodynamic processes at different temporal and spatial scales. At the watershed scale, where these phenomena are usually expressed on larger time scales (e.g., hourly or daily), the Large-Scale Hydrological Model (MGB-IPH) (Collischonn et al., 2007; De Paiva et al., 2013) and the

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Open Access Earth System Science Data

Panta Rhei benchmark dataset: socio-hydrological data of paired events of floods and droughts

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Journal of Hydrology
Volume 618, March 2023, 129276

Research papers

Generalizing rapid flood predictions to unseen urban catchments with conditional generative adversarial networks

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Abstract

Two-dimensional hydrodynamic models are computationally expensive. This drawback can limit their application to solving problems requiring real-time predictions or several simulation runs. Although the literature presented improvements in using Deep Learning as an alternative to hydrodynamic models, Artificial Neural Networks applications for flood prediction cannot satisfactorily predict floods for areas outside the training datasets with different boundary conditions. In this paper, we used a conditional generative adversarial network (cGAN) aiming to generalize flood predictions in catchments not included in the training process. The proposed method, called cGAN-Flood, uses two cGAN models to solve a rain-on-grid problem by first identifying wet cells and then estimating the water depths. The cGANs were trained using HEC-RAS outputs as ground truth. cGAN-Flood distributes a target flood volume (v_t) in a given catchment, which can be calculated via water balance from hydrological simulations. Our approach was trained on ten and tested on five urban catchments with distinct characteristics. The cGAN-Flood was compared to HEC-RAS for different rainfall magnitudes and surface roughness. We also compared our approach to the Weighted Cellular Automata 2D (WCA2D), a rapid flood model (RFM) used for rain-on-grid simulations. Our

GESTA Revista Eletrônica de Gestão e Tecnologias Ambientais (GESTA)

IMPACTO DAS MUDANÇAS CLIMÁTICAS EM CISTERNAS RURAIS DO NORDESTE BRASILEIRO

IMPACTS OF CLIMATE CHANGE IN RAINWATER CISTERNS IN THE NORTHEASTERN REGION OF BRAZIL

Marília Silva Dantas Rocha[a], Rodolfo Luiz Bezerra Nóbrega[b], Camilo Allysson Simões de Farias[a], Carlos de Oliveira Galvão[a]

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Resumo

O semiárido brasileiro é uma região caracterizada por uma alta variabilidade espacial e temporal do regime pluviométrico que, associada ao alto índice de evaporação, baixa capacidade de retenção de água no solo e alta demanda pela sociedade, provoca um desequilíbrio entre a oferta e demanda de água. Nas últimas duas décadas sistemas de aproveitamento de água de chuva (SAAC) têm sido implementados para uso domiciliar como alternativa para garantir suprimento de água à população rural da região. Mais de 600.000 famílias são usuárias dos SAAC provenientes de recursos e informações por programas sociais, como o Programa 1 Milhão de Cisternas (P1MC). Para que uma política de segurança hídrica possa ser bem implementada, é necessário que haja o monitoramento e estimativa de captação e armazenamento de água nesses sistemas já instalados a fim de conhecer as possíveis transformações em sua capacidade de prover água em decorrência das mudanças climáticas projetadas. Essas medidas auxiliam a tomada de decisões por parte de órgãos federais, estaduais e municipais de defesa civil, saúde e recursos hídricos, entre outros. Um dos maiores desafios, em face à variabilidade e às mudanças climáticas, é prever os impactos sobre o suprimento à demanda por água dessas famílias. Este artigo apresenta um estudo desses impactos no território do estado da Paraíba. Através de séries históricas de precipitação e das projeções climáticas simuladas por modelos de circulação global, foram criados cenários de mudanças climáticas e, ao submetê-los a um modelo de balanço hídrico dos SAAC, foi estimada a vulnerabilidade desses sistemas às possíveis mudanças no clima futuro. Constatou-se que a vulnerabilidade atual dos SAAC já é significativa e que as mudanças climáticas podem provocar impactos relevantes, que, por sua vez, podem ser mitigados com a adoção de medidas adaptativas baseadas nos resultados deste estudo.

Palavras chave: semiárido; água de chuva; recursos hídricos; abastecimento de água.

Abstract

The irregular water supply in the Brazilian semi-arid region is mainly due to its high spatial and temporal rainfall variability associated with high evaporation rates and low groundwater storage capacity. During the past two decades, rainwater harvesting systems (RHS) have been implemented for domestic use as an alternative to ensure water supply to the rural population in this region. Over 600,000 families use RHS implemented via resources from social programs, such as the 1 Million Cisterns Program (P1MC). To support a well-designed water security policy, it is necessary to monitor these RWS and project water supply scenarios to anticipate their vulnerability to future climate. These approaches will assist decision makers in federal, state and municipal agencies such as those responsible for the health, water supply, and civil defense of these populations. Our study shows the potential effects of climate change on water supply by RHS in the federal state of Paraíba, Brazil. We used observed time series of rainfall and climate projections from global circulation models as input for simulations with RHS water balance models. These outputs allowed us to assess the RHS

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Research article

Deforestation and fires in the Brazilian Amazon from 2001 to 2020: Impacts on rainfall variability and land surface temperature

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Abstract

Deforestation and fires in the Amazon are serious problems affecting climate, and land use and land cover (LULC) changes. In recent decades, the Amazon biome area has suffered constant fires and deforestation, causing severe environmental problems that considerably impact the land surface temperature (LST) and hydrological cycle. The Amazon biome lost a large forest area during this period. Thus, this study aims to analyze the deforestation and burned areas in the Amazon from 2001 to 2020, considering their impacts on rainfall variability and LST. This study used methods and procedures based on Google Earth Engine for analysis: (a) LULC evolution mapping, (b) vegetation cover change analysis using vegetation indices, (c) mapping of fires, (d) rainfall and LST analyses, and (e) analysis of climate influence and land cover on hydrological processes using the geographically weighted regression method. The results showed significant LULC changes and the main locations where fires occurred from 2001 to 2020. The years 2007 and 2010 had the most significant areas of fires in the Brazilian Amazon (233,401 km^2 and 247,562 km^2, respectively). The Pará and Mato Grosso states had the region's largest deforested areas (172,314 km^2 and 144,128 km^2, respectively). Deforestation accumulated in the 2016–2020 period is the greatest in the period analyzed (254,465 km^2), 92% higher than in the 2005–2010 period and 82% higher than in the 2001–2005 period. The study also showed that deforested areas have

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ORIGINAL PAPER

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Assessment of trends, variability and impacts of droughts across Brazil over the period 1980–2019

Javier Tomasella[1] · Ana Paula M. A. Cunha[1] · Paloma Angelina Simões[2] · Marcelo Zeri[1]

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Abstract

Drought indices are a numerical representation of drought conditions aimed to provide quantitative assessments of the magnitude, spatial extent, timing, and duration of drought events. Since the adverse effects of droughts vary according to the characteristics of the event, the socioeconomic vulnerabilities, exposed communities or environments, there is a profusion of drought indicators to assess drought impacts in different sectors. In this study, we evaluated the performance of two drought indices, the Standardized Precipitation Index—SPI and Standardized Precipitation Evapotranspiration Index—SPEI over Brazil derived from gridded meteorological information over the period 1980–2019. Firstly, we compared the gridded derived indices against the same indices derived from weather station data and available from a global dataset for time scales of 3, 6, 12, 24 months. Then we analyzed the spatio-temporal trends in SPI and SPEI time-series, which revealed statistically significant trends toward drier conditions across central Brazil for all time scales, though with more intensity for time scales of 12 months and larger. Trends were more significant in magnitude for SPEI than SPI, indicating an important role in the increase in evaporation, driven by increasingly higher temperatures. Finally, we demonstrated that climate signals are already having a disruptive effect on the country's energy security.

Keywords Drought trends · SPI · SPEI · Impacts

1 Introduction

Drought is a natural climatic event which affects all ecosystems, either in arid lands or rainforests (Dai 2011; Svoboda and Fuchs 2017; Wang et al. 2017). As a hazard, drought is primarily defined as a period in which precipitation is less than the long-term average, resulting in a water shortage. In the disaster context, drought takes place over densely populated

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Tropical cities research boundaries: a bibliometric analysis to bridge the gaps through multi-dimensional and cross-disciplinary features

José Gescilam S. M. Uchôa[1]*, Luis E. Bertotto[1], Matheus S. dos Santos[1], Alan Reis[1], Eduardo M. Mendiondo[1,2] and Edson C. Wendland[1]

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Tropical regions are known for their complex ecosystems and biodiversity, which play a vital role in regulating the global climate. However, researching tropical cities can be challenging due to the need for multi-disciplinary and multi-dimensional approaches. In this study, we conducted a bibliometric analysis to gain a structured understanding of the developments and characteristics of tropical cities research in the last decade. We identified the fundamental influences in tropical cities research, based on four major sub-topics: climate change, sustainable urbanization, protecting biodiversity, and urban resource management. We examined the connections between these themes and performed a systematic literature review on each. Our analysis provides a comprehensive trend analysis of tropical cities, both quantitatively and qualitatively. Our findings aim to provide a solid foundation for bridging the gaps for future crosscutting research.

KEYWORDS
tropical cities, interdisciplinary studies, climate change, sustainable urbanization, protecting biodiversity, urban resource management, bibliometric analysis, systematic literature review

1. Introduction

Tropical regions are home to ~42% of the world's population (Harding et al., 2016; Aghamohammadi et al., 2021), and with population growth and rapid urbanization, developing countries are predicted to experience nearly 95% of the global urban expansion in the coming decades (Akbari et al., 2015). As a result, tropical cities will face numerous challenges stemming from unplanned urban expansion and climate change. These challenges encompass a wide range of areas, including human health, productivity, urban planning, sanitation, resilience, and biodiversity. They are already manifesting as increased risks of heat stroke and disease transmission (e.g., Burkart et al., 2011; Coccolo et al., 2016; Lee J. M. et al., 2019), reduced human comfort due to high levels of thermal stress (e.g., Roth, 2007; Méndez-Lázaro et al., 2016; Ramsay et al., 2021), heightened energy consumption driven by increased cooling demand (e.g., Gamero-Salinas et al., 2021), decreased water availability and heightened pollution (e.g., Chow and Yusop, 2013; Pérez-Villalona et al., 2015; Silva et al., 2019), alterations in local flora and fauna distribution caused by inadvertent climate modification (e.g., Roth and Chow, 2012; Oh et al., 2018; Alue et al., 2022), air pollution

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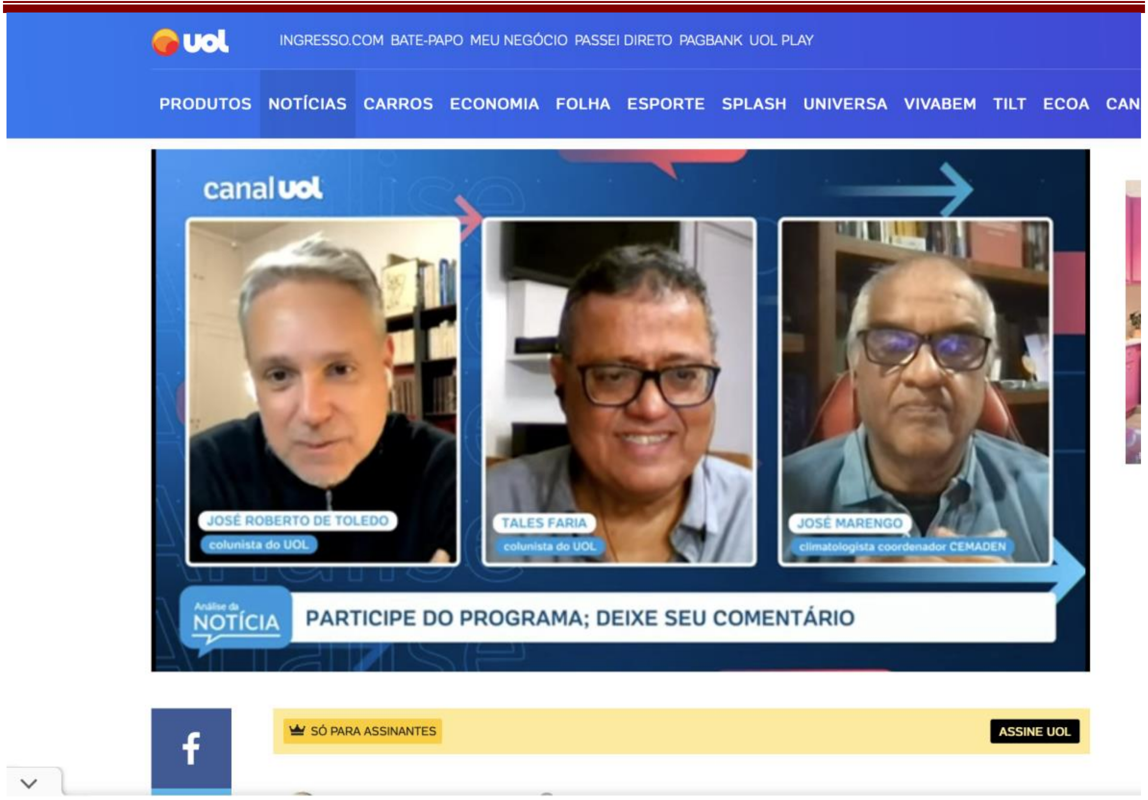
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PARTICIPE DO PROGRAMA; DEIXE SEU COMENTÁRIO
SÓ PARA ASSINANTES
ASSINE UOL

A6 | Valor | Quinta-feira, 23 de fevereiro de 2023

Brasil

Urbanismo Cerca de 4% da população sofrem com questões climáticas

Mais de 8 milhões vivem em áreas de risco, diz Cemaden

Daniela Chiaretti e Álvaro Fagundes
De São Paulo

Existem mais de 8.266.566 brasileiros vivendo em áreas de risco de deslizamento de terra e enxurradas no Brasil. Mais de 2,5 milhões vivem em áreas de alto risco e muita vulnerabilidade. Residem em 825 municípios considerados críticos a desastres. Com base nos dados do Censo de 2010 do IBGE, a cada 100 brasileiros, quatro estavam expostos a riscos de desastres climáticos no país. Na região Sudeste, a proporção é mais dramática — a cada 100 brasileiros, dez ameaçados.

Com dados populacionais atualizados, que devem surgir do novo censo que está sendo feito agora, esses números devem ser ainda mais dramáticos. A estimativa de pesquisadores é que hoje mais de 10 milhões de brasileiros vivem em áreas de risco.

Considerando que a população brasileira era de 190 milhões em 2010, o percentual que vivia em áreas de risco chegava a 4,3%. Nos 825 municípios foram avaliadas 27.660 áreas de risco.

Deslizamentos e inundações são os desastres naturais que mais matam no Brasil. Os dados acima são de uma série de estudos detalhados feitos por pesqui-

"O desastre não acontece na cidade inteira. Temos cidades grandes em que pode chover em determinadas regiões e nada vai acontecer. Queríamos saber onde estão as áreas de risco dentro desses municípios prioritários", diz Regina Célia dos Santos Alvalá, diretora substituta do Cemaden e coordenadora de relações institucionais e a pesquisadora a frente de várias destas análises.

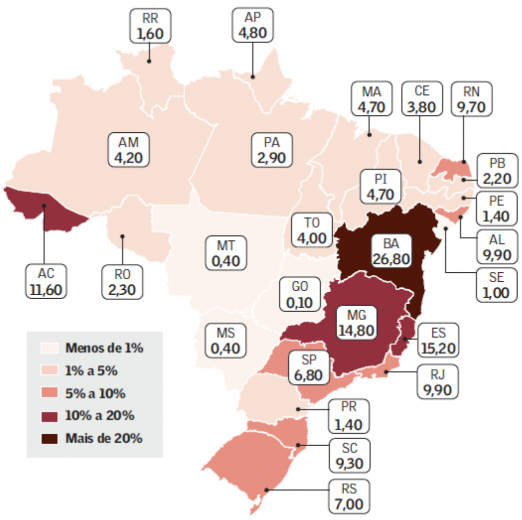
"Além do quantitativo mais preciso queríamos saber mais detalhes da população exposta — qual a idade e sexo, o grau de escolaridade e renda, quais as condições dos domicílios", diz Regina Alvalá. "Queríamos ter acesso às informações mais detalhadas que o IBGE coleta".

Os mais de 8,2 milhões de brasileiros expostos viviam em 1.290.537 domicílios e 17% dessas casas sem rede de esgoto ou fossas.

Os pesquisadores do Cemaden desenvolveram um índice de vulnerabilidade, ferramenta importante para apoiar a gestão de risco de desastres e reduzir as perdas de vidas. Utilizaram indicadores e cruzaram várias informações, como exposição física e capacidade de resposta da população, diz Regina Alvalá, que trabalha com a temática de desastre há 20 anos, inicialmente no Instituto Nacional de Pesquisas Espaciais (Inpe) e depois

Risco Brasil

Bahia tem população mais vulnerável a desastres naturais - em %



Municípios com maior número de moradores em áreas de risco a desastres naturais

Ranking	Cidade	População em área de risco, em mil pessoas	população em risco em relação ao total, em %
1	Salvador	1.216	45,5
2	São Paulo	674	6
3	Rio de Janeiro	445	7

A2 | Valor | Terça-feira, 28 de fevereiro de 2023

Brasil

Tentativa e erro na adaptação climática

Daniela Chiaretti

Em 2008, a prefeitura de Londres preparava a capital para o inevitável — os impactos climáticos. Em 2080 imaginava-se que o volume de água do Tâmisa poderia ter picos de água 40% maiores. Os planejadores mapearam estações de metrô, hospitais, aeroportos, mercados e escolas e estudaram o que aconteceria em cenários de enxurradas. A cidade tem uma barreira contra as enchentes do rio, mas que não é a prova de chuvas torrenciais repentinas, e o sistema de drenagem vitoriano também não dá conta se o volume de água for violento. Alguns estudos recentes indicam que 17% da cidade enfrenta risco médio ou alto de inundação.

Não precisou chegar 2080. Em julho de 2021 a cidade sucumbiu a dois dias de eventos climáticos extremos. Dois hospitais inundaram e recusaram pacientes que não estivessem em estado

coordenador-geral de pesquisa e desenvolvimento. "Se esses eventos serão mais frequentes e fortes no futuro, a população tem que ser treinada para respeitar o alerta, ser preparada para isso, sair de casa e ir a um lugar seguro, e não voltar", continua. "Tem que se criar a percepção cultural no Brasil de que o alerta de desastre existe para ser respeitado. Se o clima está mudando, não há outra forma. Não temos como combater isso. Temos que nos adaptar."

Nos Estados Unidos, quando há alerta de furacão, as pessoas sabem o que têm que fazer. Protegem portas e janelas, tentam evitar que seu patrimônio seja destruído, mas saem de casa. Vão para abrigos seguros. No caso de tornados, que são muitos mais rápidos, costumam buscar refúgio em espaços no subsolo até que o fenômeno vá embora. São treinados para agir assim. As sirenes disparam no Chile e no Japão quando tem um terremoto e há risco de tsunami. Em Lima, no Peru, todos têm uma pequena mochila na sala com cópia de documentos, uma água, alguma comida enlatada. "Quando há terremoto, saem todos com sua mochila, que tem o básico", conta Marengo, que é peruano, vive há muitos anos no Brasil, mas vê as mochilas sempre que visita os familiares. No Brasil, acredita, "há que haver uma melhor governança do sistema. Porque a cada ano vêm extremos de chuva ((o))eco

REPORTAGENS

"As mudanças climáticas já estão causando desastres", alerta Marengo aos candidatos das eleições de 2022

Ao ((o))eco, o coordenador do Cemaden fala da importância da educação e das políticas públicas para mitigarmos as mudanças climáticas

DÉBORA PINTO · 3 de outubro de 2022

Mudanças climáticas podem afetar finanças públicas dos países da América Latina e do Caribe

06 de outubro de 2022

Elton Alisson | Agência FAPESP – Os países da América Latina e do Caribe estão enfrentando graves crises socioeconômicas decorrentes de secas severas e eventos hidrometeorológicos, como chuvas intensas. O aumento da frequência e da intensidade desses eventos climáticos extremos pode colocar em risco o saldo fiscal – a diferença entre a arrecadação e os gastos públicos – dessas nações. Assim, elas podem ter dificuldade para tomar novos empréstimos que ajudem a gerenciar as consequências de futuros desastres naturais, avalia Graham Watkins, chefe da divisão de mudanças climáticas do Banco Interamericano de Desenvolvimento (BID).

Aumento na frequência e intensidade de eventos climáticos extremos coloca em risco o saldo fiscal e deve tornar mais difícil a tomada de empréstimos por nações da região para gerenciar as consequências de futuros desastres naturais, apontou economista do Banco Interamericano de Desenvolvimento em evento internacional (*foto: Portal Oficial do Governo do Estado do Alagoas*)

"Estamos diante de uma situação bastante séria. Os dados indicam que o número de desastres naturais na região triplicou em comparação com 50 anos atrás e eles estão afetando a produção agrícola, o fornecimento de energia e a saúde humana", afirma Watkins.

"Estimamos que os custos desses desastres climáticos que têm ocorrido na região já estejam em torno de US$ 3 bilhões anuais", disse Watkins em palestra durante a Cúpula sobre Desenvolvimento Sustentável na América Latina e Caribe, realizada nos dias 6,

Pós-doutorado em vulnerabilidade e redução de risco de desastres no Cemaden

18 de julho de 2023

Agência FAPESP – Uma oportunidade de pós-doutorado em vulnerabilidade e redução de risco de desastres com bolsa da FAPESP foi aberta pelo Projeto Temático "INCT 2014: INCT para Mudanças Climáticas (INCT-MC)". O prazo de inscrição acaba na quinta-feira (20/07).

Candidato deve ter doutorado obtido há menos de sete anos nas áreas de desastres, sensoriamento remoto ou ciências ambientais, com conhecimentos em desastres relacionados ao clima (*foto: Rovena Rosa/Agência Brasil*)

O trabalho será realizado no Centro Nacional de Monitoramento e Alerta de Desastres Naturais (Cemaden) em São José dos Campos (SP). A bolsa tem como objetivo a avaliação de dados históricos sobre os componentes do risco de desastres no Brasil.

O candidato deve ter doutorado obtido há menos de sete anos nas áreas de desastres, sensoriamento remoto ou ciências ambientais, com conhecimentos em desastres relacionados ao clima. É também exigida experiência de no mínimo cinco anos em pesquisa sobre redução do risco de desastres e educação para redução do risco de desastres no Brasil, com experiência em abordagem multidisciplinar. As experiências devem ser comprovadas por publicações.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Iedo Sá (Convidado)
Marcos Oliveira Santana
Afdrin (Convidado)
Regina Alvalá (Convidado)
Alexandre Henrique Bezerra Pires
Yriz Soares da Silva
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ECOLOGIA

As causas pouco lembradas das inundações (https://revistapesquisa.fapesp.br/as-causas-pouco-lembradas-das-inundacoes/)

Assoreamento de rios, ocupação de áreas de risco e precariedade das estruturas de atendimento a emergências ampliam o impacto das chuvas de verão, cada vez mais intensas

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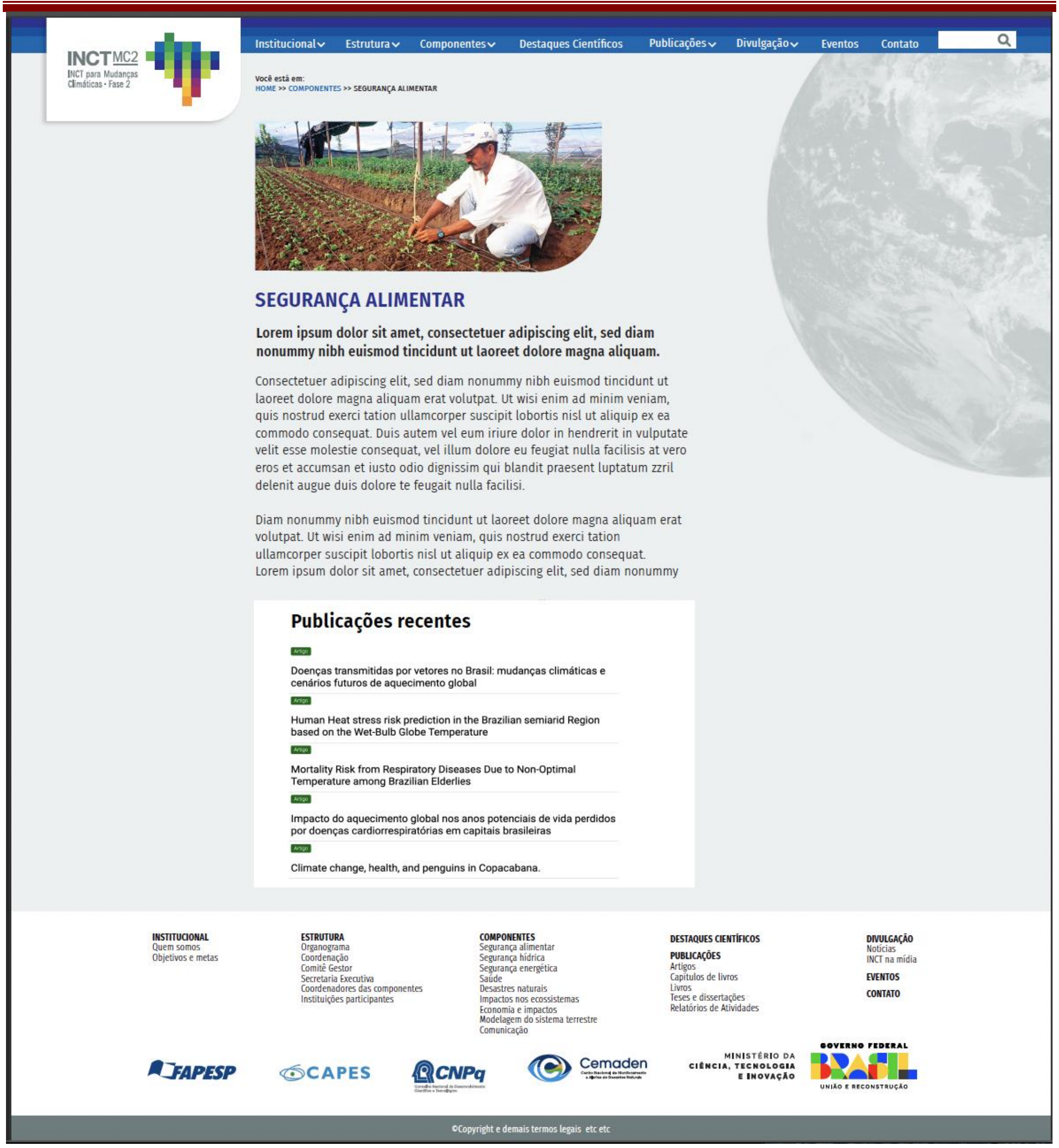
Levantamento do Centro Nacional de Monitoramento e Alerta de Desastres

Design of the web site of the Project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