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A report on the experience of risk communication by volunteer researchers during the 2024 climate disaster in Rio Grande do Sul, Brazil

Um relato sobre a experiência da comunicação de riscos por pesquisadores voluntários durante o desastre climático de 2024 no Rio Grande do Sul, Brasil

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Abstract: The climate disaster of April and May 2024 in Rio Grande do Sul occurred in a context of climate change, which has been intensifying extreme events in the region. Caused by extraordinary rainfall, the crisis exposed structural and risk management failures, highlighting the urgent need for effective communication. This article presents a chronology of the disaster and a report on the voluntary actions of researchers in producing and disseminating basic information, including Guaíba water level forecasts, risk maps, technical support in the Taquari Valley, shelter monitoring, sanitation information, and the Repositório de Mapas (Maps Repository). Pioneering analyzes of the flood impacts enabled a rapid understanding of the event. The report highlights challenges such as technological limitations, coordination issues with public management, and the absence of a strong institutional system. The lack of watershed agencies compromises integrated water resource management and long-term disaster response. The event reinforces the need for substantial investments in water governance, monitoring infrastructure, and adaptation strategies to strengthen society's resilience.

Keywords: Rio Grande do Sul; disasters; climate adaptation; risk communication; disaster risk reduction.

Resumo: O desastre climático de abril e maio de 2024 no Rio Grande do Sul ocorreu em um contexto de mudanças climáticas, que vêm intensificando eventos extremos na região. A crise causada por chuvas extraordinárias expôs falhas estruturais e de gestão de riscos, evidenciando a urgência de comunicação eficaz. Este artigo apresenta uma cronologia do desastre e um relato das ações voluntárias de pesquisadores na produção e disseminação de informações essenciais, incluindo previsão do nível do Guaíba, mapas de risco, suporte técnico no Vale do Taquari, monitoramento de abrigos, informações sobre saneamento e o Repositório de Mapas. Análises pioneiras sobre os impactos das inundações foram cruciais para a compreensão rápida do evento. O relato destaca desafios como limitações tecnológicas, dificuldades de articulação com a gestão pública e a ausência de um sistema institucional robusto. A inexistência de agências de bacias hidrográficas compromete a gestão integrada dos recursos hídricos e a resposta a desastres no longo prazo. O evento reforça a necessidade de investimentos substanciais em

governança hídrica, infraestrutura de monitoramento e estratégias de adaptação para fortalecer a resiliência da sociedade.

Palavras-chave: Rio Grande do Sul; desastres; adaptação climática; comunicação de riscos; redução de riscos de desastres.

1. Introduction

The disaster that occurred in Rio Grande do Sul between April and May 2024 confirmed that Brazil is definitively facing the consequences of climate change. The United Nations (UN) defines a disaster as a "serious disruption in the functioning of a community or society due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to human, material, economic and environmental losses" (United Nations [UN], 2016, p. 13). Based on this definition, we can affirm that Rio Grande do Sul suffered an unprecedented disaster, caused by both extraordinary rainfall and the institutional inability to deal with its effects. Floods devastated cities in several valleys, and the flood protection system of the Porto Alegre Metropolitan Region collapsed (Collischonn et al., 2025). Approximately 900,000 people were directly affected, many depending on improvised rescues due to the lack of emergency action plans. A total of 183 deaths were confirmed, and the event affected the entire Patos Lagoon basin, impacting cities such as Pelotas and Rio Grande. Some analyses classify it as the biggest climate disaster in Brazilian history (Marengo et al., 2024).

The situation in Rio Grande do Sul is part of a broader context, as 2024 was the hottest year on record, with a global average temperature of 15.1°C (Copernicus, 2025). This latest result follows that of 2023, which recorded an average of 14.9°C. For the first time, the threshold of 1.5°C above the pre-industrial average of 13.5°C (1850-1900) was exceeded, anticipating the most pessimistic projections of the latest report from the Intergovernmental Panel on Climate Change (IPCC, 2021). In 2023, for example, the World Meteorological Organization (WMO, 2023) predicted that this threshold would occur between 2028 and 2035. Although El Niño influenced the 2023 and 2024 climate, the sequence of successive records in the last fifty years suggests that climate change may be accelerating.

Climate change is increasing the frequency of extreme rainfall events, especially in humid regions (Donat et al., 2016; Donat et al., 2019). Thus, if climate change is accelerating, the risks associated with these events should also increase. The World Economic Forum (WEF, 2024) classifies extreme weather events as the second most serious global risk in the short term and the first in the long term. In 2023 and 2024, such events were widespread, including hurricanes in North America, flash floods in Europe and South Korea, heat waves in East Africa, wildfires in Canada, droughts in the Amazon, and extreme rainfall in Africa and southern Brazil. Since vulnerability is uneven across different scales of the planet, their impacts are expected to be relatively more significant in communities that have contributed little to global warming. For example, mortality from these events in the last decade was approximately 15 times higher in the Global South (IPCC, 2023). In the Porto Alegre Metropolitan Region, the populations most affected in 2024 were, disproportionately, the poor and black populations, a fact that emphasizes the problem of environmental justice in this context (Acselrad, 2010; Observatório das Metrópoles, 2024).

The extreme events in Brazil between 2023 and 2024, such as intense rainfall and severe droughts, were not surprising as these patterns had already been projected at least a decade ago. The 2013 IPCC report indicated variations of up to 20% in rainfall in the Southern region by the end of the century, contrasting with similar reductions in the Northern region (IPCC, 2013). The Brazil 2040 study, coordinated by the Instituto Nacional de Pesquisas Espaciais (INPE, National Institute for Space Research), confirmed this projection with regional climate models (Secretaria de Assuntos Estratégicos da Presidência da República [SAE], 2015). The most recent IPCC report pointed out that, upon exceeding 1.5ºC above pre-industrial levels (which occurred in 2024), there would be a change of at least 10% in the rainfall regime, showing an upward trend in the South and Southeast and a downward trend in the North, Midwest and Northeast (IPCC, 2021). Marengo et al. (2021) reinforced the high risk of floods and landslides in the South. Brêda et al. (2023) emphasized that variations in precipitation impact river flows in South America, while empirical data from river gauging stations (1980-2015), by Chagas et al. (2022), demonstrated an increase in peak flood flows in southern Brazil.

Similar to many other researchers, we witnessed the disaster in Rio Grande do Sul firsthand. The events of April and May 2024 profoundly shook our lives and are beyond a mere case study. Most of us were displaced, mainly due to the collapse of power and sanitation in Porto Alegre. We all have friends and family who had to deal with flooded houses. We worked tirelessly, improvising ways to provide relevant information during the crisis. From this mobilization emerged a collaborative network among researchers, students, and alumni, mainly from the Universidade Federal do Rio Grande do Sul (UFRGS). The most emblematic result was the launch of the Repositório de Mapas (Maps Repository) on May 10, 2024, centralizing risk data on the university's homepage.

This article contributes to the technical-scientific community by documenting and analyzing voluntary actions in the production of risk information during the crisis. Based on current data, extreme events in Rio Grande do Sul are likely to recur, possibly with even greater intensity. However, the very definition of disaster ensures that such events are not unavoidable – thus, society and institutions can and should develop the capacity to adapt to and respond to climate risks. Therefore, specialized communication is essential in risk reduction, which encompasses all phases of disaster management.

Communication – a symbolic, technical, and social process – is a structuring element of collective life, responsible for mediating between knowledge, perception, and action (Rüdiger, 2010). In the context of emergencies, communication becomes even more central, as it not only shares information but also structures meanings and decisions in critical times. Specifically, risk communication is the area dedicated to informing, alerting, and guiding populations and institutions about imminent threats and protective measures. It is a practice that articulates multiple actors – specialists, managers, the community – in an attempt to reduce vulnerabilities and increase resilience (Rodríguez & Puga, 2017; Loose & Girardi, 2018). The Maps Repository and other actions reported in this article are part of this perspective, which aim to make technical knowledge accessible and understandable to diverse audiences, including in situations of collapse of formal communication channels.

Before delving into the details, it is necessary to contextualize its preliminary events dating back to 2023. Between September 4th and 5th, 2023, extreme rainfall caused a disastrous flood in the Taquari River. Given the situation of the technology and knowledge available, the disaster could certainly have been less severe. Motivated by this, some authors published a Technical Note on September 11th, through the Instituto de Pesquisa Hidráulica (IPH-UFRGS,2023), highlighting this gap and suggesting urgent actions. In November of that year, further rainfall raised the level of Lake Guaíba, which reached 3.46 m at Cais Mauá, becoming the highest level recorded after only the 1941 flood (4.75 m). The episode exposed flaws in Porto Alegre's flood protection, leading authors from IPH-UFRGS to publish a flood risk map based on Müller Neto et al. (2019). Widely publicized in the press, the study received the headline: *Without a protection system, Guaíba would flood the airport, the Public Market, and stadiums* (Freitas, 2023). A few months later, the 2024 disaster materialized the technical forecast established during the preceding year. The new flood surpassed the 1941 record, reaching 5.37 m at Cais Mauá. From then on, the network of researchers expanded and culminated in the creation of the Maps Repository, a key portal for disseminating information during the crisis.

The next section presents the methods adopted. The third section provides an overview of the April and May 2024 disaster, with a chronology of the hydrological processes. Following these, we provide accounts of the actions of different research teams during the crisis. The last section establishes concluding remarks, addressing the future challenges posed by the intensification of climate change and the urgent need for climate adaptation, including the technical capacity building of institutions in Rio Grande do Sul.

2. Methodology

The method used to establish a comprehensive account initially involved the hydrological and political contextualization of the May 2024 disaster in Rio Grande do Sul, followed by the systematization of the interpretations from the researchers involved.

Researchers carried out a literature review in the main national and international scientific journals, searching for recent articles and studies on the event to reconstruct the hydrological chronology. Moreover, data from the Sistema Nacional de Informações sobre Recursos Hídricos (SNIR, National Water Resources Information System) were analyzed to interpret the results in light of publicly available empirical evidence. Simultaneously, journalistic sources and news reports were consulted to understand the political decisions made throughout the disaster, albeit with less depth than the hydrological analysis. This approach allowed for contextualizing the researchers' actions, highlighting how their activities were directly linked to the evolution of hydrological processes in Rio Grande do Sul.

Following the creation of this groundwork, the second stage consisted of articulating and harmonizing the reports from seven research groups that worked simultaneously during the disaster, totaling eighteen primary researchers, who co-authored the report. To ensure consistency in the systematization of information, each group answered a standardized set of five questions:

(1) What was the objective of the activity? Explain why it was necessary to develop this activity in the context of the disaster.

(2) When was the activity developed? Outline the activities necessary in the chronology of events.

(3) How were the actions carried out? Provide details about the technical or operational methods, the communication tools used, etc.

(4) What were the outcomes achieved? Give details about the results obtained, including technical specifications and the advantages and limitations of the findings.

(5) What was the relevance of this work to society? Demonstrate how the chain of decisions affected the outcome in the context of the disaster.

The feedback was collected, analyzed, and compared to identify common patterns and specific characteristics of the responses. This process allowed for structuring a unified report, highlighting the relationship between the different approaches adopted by the researchers and the hydrological and political context in which they were embedded.

3. Results: the chronology of the disaster in Rio Grande do Sul

Setting up a chronology requires,defining a starting point, but this can lead to an infinite regression. If climate change intensifies the hydrological cycle, it could be seen as the ultimate cause of the disaster, although its origin dates back to the Industrial Revolution and the use of fossil fuels. The same reasoning applies to vulnerability in Rio Grande do Sul: the occupation of riverbanks has roots in European colonization, while institutional fragility reflects decades of insufficient investment in disaster management. Between 2012 and 2023, the Federal Government failed to assign more than a third of the resources intended for the Programa de Gestão de Riscos e Desastres Risk and Disaster Management Program) (Accioly, 2024; Nobre et al., 2024; Altino, 2025), while state and municipal agencies were reduced or eliminated, such as the Metroplan and the Departamento de Drenagem de Águas Pluviais (Rainwater Drainage Department). The absence of river basin agencies exacerbates the inability to promote water security, a problem already accentuated by the extinction of the Departamento Nacional de Obras de Saneamento (DNOS, National Department of Sanitation Works) in 1990. In the long term, the conception of a liberal and austere state, predominant in Rio Grande do Sul since the beginning of the 20th century, consolidated a governance model averse to technical state institutions, following the tradition of Assis Brasil, who opposed politicians such as Júlio de Castilhos, Getúlio Vargas, and Leonel Brizola, supporters of a technical and interventionist state.

It is evident that the results from the interplay of hydrological and political processes on multiple scales, combining an extreme hydrological event with low state capacity,rendered institutions unable to face the crisis. We do not intend to establish a political chronology, but three episodes illustrate this fragility. On May 2, 2024, the Porto Alegre City Hall installed a shelter in the *Pepsi On Stage* warehouse*,* an area at high risk of flooding, ignoring risk maps, such as the one published in November 2023. Only after the publication of another map on May 3 the media began advocating for the transfer of sheltered individuals to safe locations, to protect them from being affected by the flood (Jacobsen, 2024; Sul21, 2024).

On May 6, the state's digital infrastructure was paralyzed for 21 days, a collapse that could have been avoided if there had been early security at the Usina do Gasômeter (Gasometer Power Plant) (Redel, 2024; Secretaria de Planejamento, Governança e Gestão do Rio Grande do Sul, 2024). On the other hand, the technical success in draining the Menino Deus polder, made possible by the installation of a generator, contradicts the notion of the catastrophe's inevitability, suggesting that adequate planning would have reduced the impacts of the flood.

The chronology of the hydrological component, in turn, could be initiated on April 26, 2024, with the formation of an atmospheric blocking

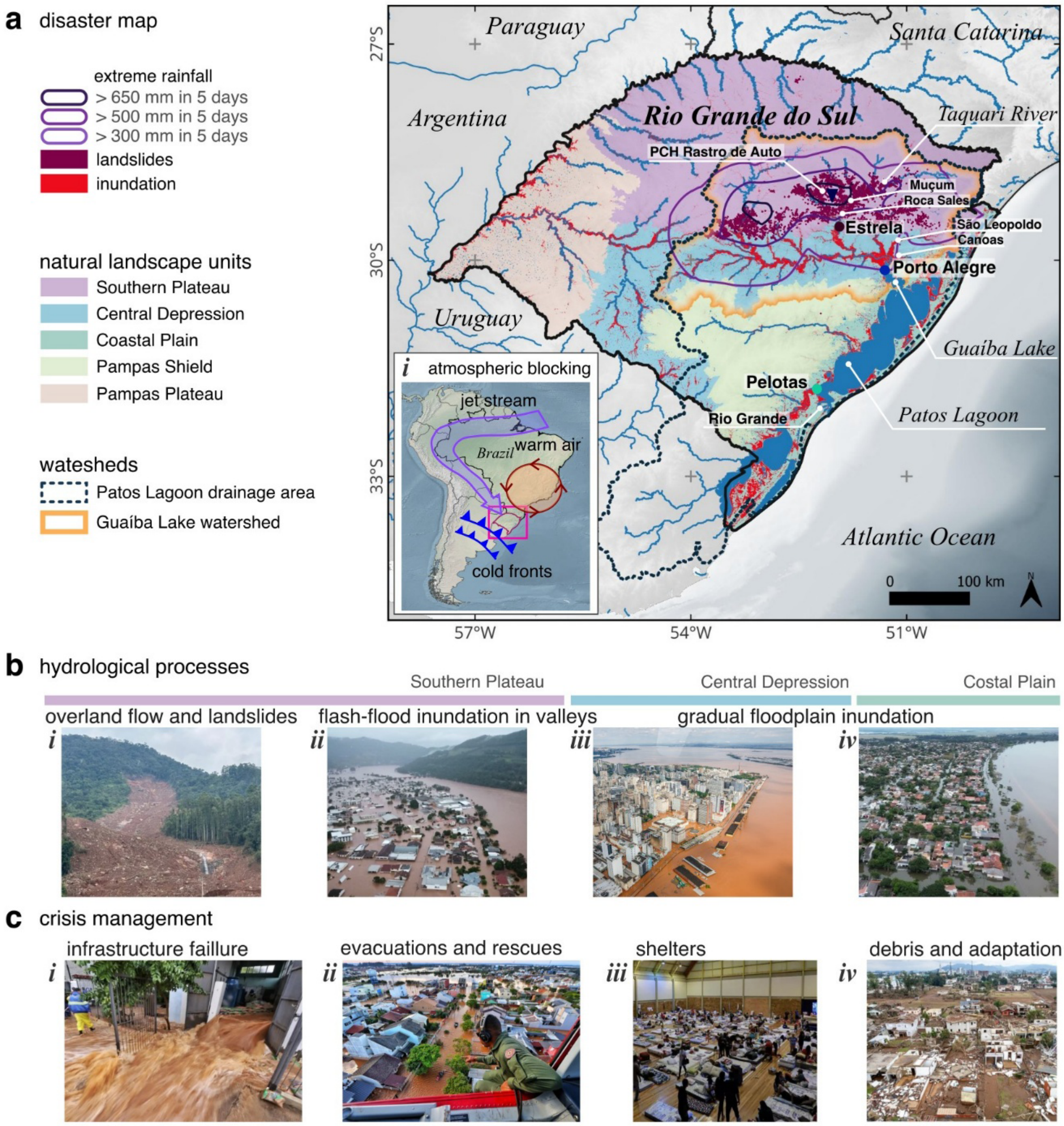


Figure 1
Overview of the 2024 disaster in RS. (a) Extent of the event. (b) Hydrological processes: flash floods/landslides (i); rapid flooding in valleys (ii); gradual flooding in lowlands (iii, iv). (c) Crisis triggered: infrastructure failures (i); rescues (ii); shelters (iii); waste and adaptation (iv).
Source: bi) Firefighters; b-ii) Bruno Zilio; b-iii) Ricardo Stuckert; b-iv) FlyCameraPelotas; ci, ii) Lauro Alves; c-iii) Porto Alegre City Hall; c-iv) Gustavo Mansur.
Data: Collischonn et al. (2025).

event over South America (Figure 1a, detail i). According to Marengo et al. (2024), an anomalous mass of warm air over southeastern Brazil prevented the entry of cold fronts, while the subtropical jet stream brought moisture from the Amazon, sustaining rainfall in Rio Grande do Sul. Reboita et al. (2024) complement this analysis with precipitation and remote sensing data, detailing the action of atmospheric systems at multiple scales. On a large scale, a heat anomaly in the western Indian Ocean produced a Rossby wave, originating an anomalous anticyclone over southeastern Brazil, which intensified the subtropical jet stream and favored the formation of deep clouds. At the mesoscale, the jet stream east of the Andes delivered heat and moisture, interacting with cold fronts between April 26 and May 5, giving rise to convective systems with intense rainfall and electrical discharges.

With the atmospheric blocking that formed on April 26, intense rainfall persisted in Rio Grande do Sul for ten days, until May 6, when the cold front dissipated. The most critical period was from April 28 to May 2, with accumulations above 100 mm in almost the entire state, except in the south and west (Reboita et al., 2024; Marengo et al., 2024). During this period, half of the territory recorded rainfall exceeding 300 mm, especially in the central-east, where accumulations reached 650 mm in five days – four times the historical average for May (140–160 mm). Collischonn et al. (2024) confirm this distribution of rainfall data, demonstrating that the event surpassed all Brazilian records between 1961 and 2022 for areas of 2,000 to 100,000 km² and durations of 3 to 14 days. Figure 2a shows the daily series from the Rastro de Auto Barramento Small Hydroelectric Power Plant (PCH) station (ANA 86743800), at the epicenter of the rains in the Taquari River basin, showing an escalation from April 29, with a peak of 267 mm on May 1 and other events in the second week.

The unexpected rainfall was concentrated on the escarpment of the Southern Plateau, a region of steep slopes, deep valleys, and shallow, highly clayey soils of the Serra Geral Formation, with a storage capacity of up to 200 mm (Chagas et al., 2020; Paiva et al., 2024). Data from the SMAP satellite indicate that these soils reached saturation between April 29 and May 1, with moisture increasing from 0.4 to 0.53 by volume and remaining high throughout the month, a clear sign of saturation (Reboita et al., 2024).

Between April 29 and May 1, soil saturation on the escarpment of the Southern Plateau reached a critical threshold, triggering flash floods and widespread mass movements, extensively documented in real time by the population. Flash floods are characterized by the water rapid slopes, triggered by both the intense rainfall and soil saturation (Dunne, 1983). Mass movements result from the interaction between slope, soil type, and water content. Collischonn et al. (2025) identified translational landslides as the most frequent, as well as incomplete slope failures.

The use of orbital imagery from May 6 and 7 confirms that these processes occurred before those dates (Andrades-Filho & Mexias, 2024, Paula, 2024; National Aeronautics and Space Administration [NASA], 2024). The distribution of landslide scars coincides with the focus of intense rainfall (Figure 1a). Egas et al. (2024) show that the frequency of landslides in-

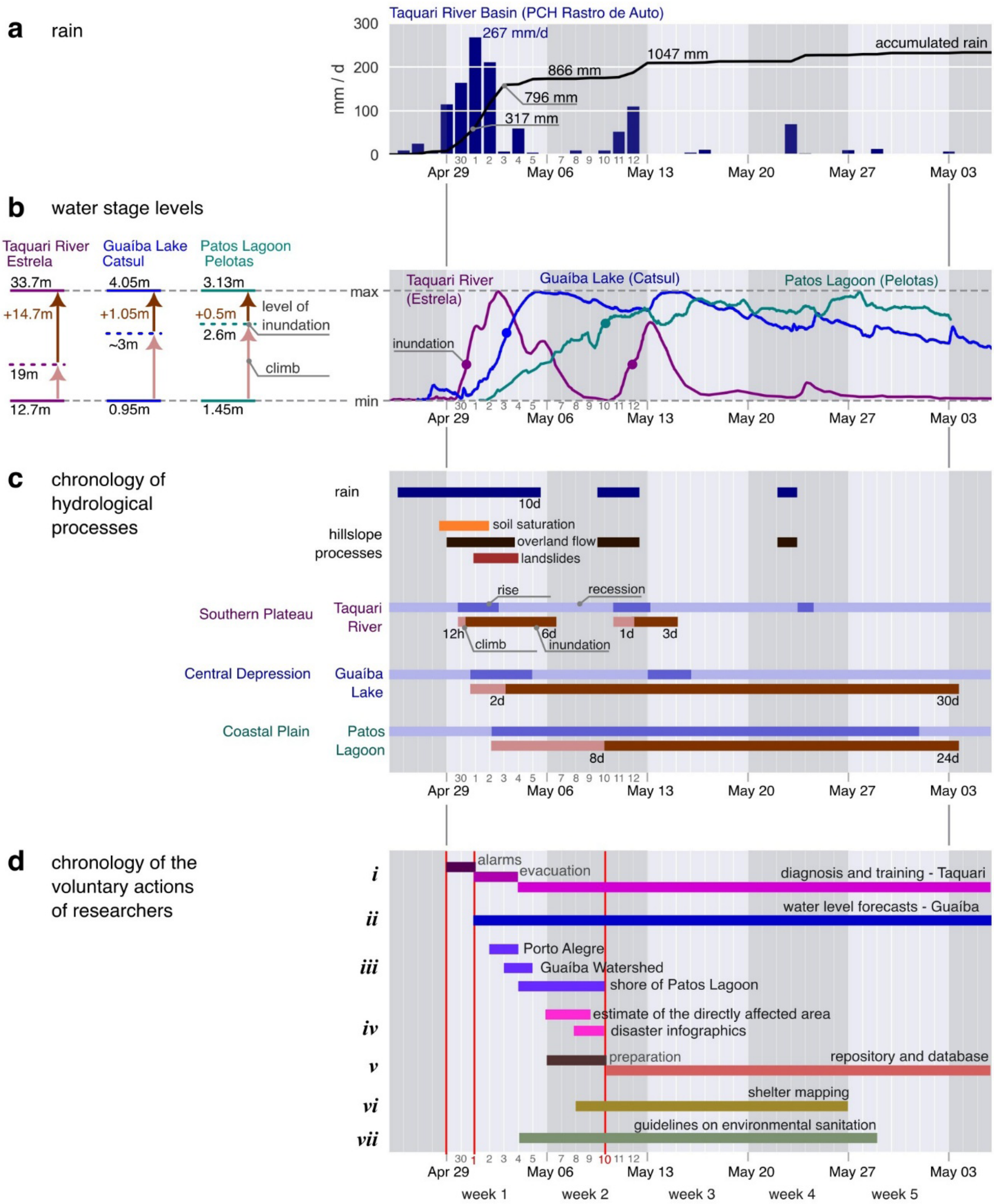


Figure 2
Hydrological component of the disaster. (a) Rainfall in the Taquari River Basin. (b) Floods from the Southern Plateau to the Coastal Plain, with normalized water levels. (c) Chronology of the disaster, highlighting the rapid evolution in the valleys and slower progression in the Central Depression and Coastal Plain. (d) Voluntary actions of researchers: support in the Taquari Valley (i); bulletins (ii); risk maps (iii); impact estimates (iv); maps repository (v); shelter mapping (vi); sanitary guidelines (vii). Source data: station 86743800; gauges 86879300, 87242000, 88810100 (Agência Nacional de Águas e Saneamento Básico [ANA], 2023).

creased from the threshold of 200 mm of accumulated rainfall, indicating widespread soil saturation from April 30 onwards.

The flash floods on the slopes of the Southern Plateau then converged into the valleys, causing floods in the rivers that flow into the Central Depression, the Coastal Plain, and the Atlantic Ocean. This dynamic explains the extreme event that affected mountain towns, the Porto Alegre Metropolitan Region, and the Patos Lagoon coastline. The flooding patterns were dictated by the topography: in the Southern Plateau, narrow valleys and high slopes produced rapid floods – as in the Taquari River; the Coastal Plain favored slow runoff, influenced by differential flows and winds; and in the Central Depression, such as Lake Guaíba, the floods were rapid due to the contribution of mountain rivers, but the recession was slow due to the connection with the lagoon system. In all cases, the floods surpassed levels to the point of causing inundations and severe impacts on society. Studies indicate that the floods and rainfall were extreme, exceeding the 100-year recurrence rate (Marengo et al., 2024; Collischonn et al., 2025).

To illustrate these processes, we focus on three water level readings: Estrela (Taquari River, station nr. 86879300), Catsul Terminal (Guaíba Lake, nr. 87242000), and Pelotas Port (Patos Lagoon, nr. 88810100). Figure 2b shows the normalized levels, while Figure 2c presents a Gantt chart with the evolution of hydrological processes. In the Taquari River, the main flood occurred between April 30 and May 3, crossing the flood threshold in 12 hours on May 1st, reaching 14.7 m/s with complete recession on May 10. Recurrent rains caused another four-day flood in the second week. In Guaíba Lake, the level remained high for 30 days after the initial rapid flood that occurred between May 1 and 5, with another three-day flood and recession until the end of July. In the Patos Lagoon, the flood began on May 2, lasted 25 days, and receded until August. Silveira et al. (2024) point out that the backwater in the Jacuí Delta delayed drainage to Lake Guaíba, creating gradients of up to 15 cm/km. Laipelt et al. (2025) stressed the influence of winds on the recession.

The succession of hydrological processes (Figure 1b) exposed the institutional fragility of Rio Grande do Sul, reflecting inadequate urban planning, lack of maintenance of protective structures, and improvised emergency response (Figure 1c). The escalation of the disaster is evidenced by the state declarations of calamity: 46 municipalities on May 13, 78 on May 21, and 95 at the end of the month (Giaccom & Rorato, 2024). The rapid flooding in lower valley areas made it difficult to evacuate quickly, resulting in casualties and complex rescues; and slowed recession exacerbated the humanitarian crisis in the Metropolitan Region. The failure of protective structures surprised the population and increased the need for shelters and rescues (Collischonn et al., 2025). In sanitation, the drinking water supply was progressively restored thanks to the efforts of technical staff, who prevented a complete social collapse in the region. In the Coastal Plain, the gradual flooding with a delay of several days allowed for more organized evacuations, aided by the exchange of information with the affected regions.

4. Results: report on the voluntary actions of researchers

This section introduces an account of the response to the crisis, initially focusing on the voluntary actions that these authors and researchers carried out. Although a complete survey of what was done on the institutional side is still unavailable, we aim to document our experience and contribution, preserving the memory of these initiatives, something that becomes important in the context of potential future events. Some of these actions involved direct contact with decision-makers, while others occurred autonomously, with dissemination being done through indirect channels or mediated by messages, without a formal structured articulation. The initiatives described are organized in Figure 2d, using a Gantt chart that complements the chronology of hydrological processes. Table 1 presents a list of the developed applications mentioned in the reports.

4.1. Technical support and citizen communication in the Taquari River basin

Technical support in the Taquari River basin was structured in three phases: before the event (alerts), during the calamity (evacuations and rescues), and after the flood (diagnosis and training). Actions included hydrological forecasts, communication about flood levels, technical support to Civil Defense, restoration of monitoring after the collapse of automatic stations, and coordination between the government, the Public Prosecutor's Office, research institutions, and volunteer technicians for the recognition of risk areas and communication to the citizens. The central objective was to ensure clear communication with the population, mitigate misinformation, and recover hydrological monitoring capacity.

The alerts began on April 29 with monitoring of rainfall and initial forecast of flood levels. On May 1st, they were intensified due to the rapid rise of the river, leading to recommendations to evacuate vulnerable areas before nightfall, when power and communication failures worsened.

The critical phase of rescues and evacuations began in the early morning of May 2, when the Taquari River reached unprecedented levels and destroyed vast areas. Power outages, internet downtime, and disruptions to monitoring systems hindered rescue efforts. Volunteer teams relayed distress calls via *WhatsApp* to the Fire Department, while the Universidade do Vale do Taquari (Univates) used a local radio station to update forecasts. Historical records of floods in Lajeado, taken every 30 minutes and transmitted via radio to downstream municipalities, were crucial for manual measurements of the river level. The strategy combined hydrology, communication, and geotechnologies, including mathematical models fed by

Table 1 List of digital applications mentioned in the reports. Initiatives from other colleagues are listed in the Maps Repository. Source: the authors.

Initiative	Authorship	Application	Scope	Link
Maps Repository	General	*ArcGIS Story Map*	Rio Grande do Sul	https://storymaps.arcgis.com/stories/a81d69f4bccf42989609e3fe64d8ef48
Flooding and Shelters in Porto Alegre	IPH-UFRGS; FAU-UFRGS	*Google My Maps*	Porto Alegre Metropolitan Region	https://www.google.com/maps/d/viewer?mid=1F2r9aE2ikmUPdplswcceL57m57tfWlQ&ll=-30.100918274494354%2C-51.170058&z=11
Floods in the Porto Alegre Metropolitan Region	HGE (IPH-UFRGS)	*Google My Maps*	Porto Alegre Metropolitan Region	https://www.google.com/maps/d/viewer?mid=1yioyl2lr5xZOg3fV8i9OZV2t-5Jfa18&ll=-29.92606691379669 2%2C-51.151168200099455&z=10
Water sources and protection system	NESA (IPH-UFRGS)	*Google My Maps*	Porto Alegre Metropolitan Region	https://www.google.com/maps/d/viewer?mid=1XCT-eGo39ygiVlLHE6EjxZHY45E2TqA&ll=-30.0018588313984%2C-51.12253004999999&z=11
Areas prone to mass movements	GPDEN (IPH-UFRGS)	*Google My Maps*	Taquari River Valley	https://www.google.com/maps/d/viewer?mid=1VKA9oe_jDTmeUCetNHGx2rDmDBYAnTI
Satellite images	HGE (IPH-UFRGS)	*Google Earth Engine Apps*	Guaíba Lake Hydrographic Region	https://ee-leolaipelt.projects.earthengine.app/view/enchentes2024imagens
Flood simulation (HEC-RAS)	HGE (IPH-UFRGS)	*Google My Maps*	Guaíba Lake Hydrographic Region	https://www.google.com/maps/d/viewer?mid=1ZzfSX_tPoDATywh1GptSdw5FDO9FVuU&ll=-29.77261939982494%2C-52.25107549999999&z=8
Criticality model – Rio Grande	LABModel (IGEO-UFRGS)	*Google My Maps*	Southern Zone and Coastal Plain	https://www.google.com/maps/d/viewer?mid=1ygr-fX5zL8vg56c9a9n8rr2cyM01GL4&g_ep=CAISDTYuMTEzLjAuNTcwMjAYACDdYipILDk0MjE2NDAxLDQ3MDcxNzA0LDQ3MDY5NTA4LDk0MjE4NjQxLDk0MjAzMDE5LDQ3MDg0MzA0LDk0MjA4NDU4LDk0MjA4NDQ3QgJCUg%3D%3D&g_st=iw&ll=-32.151358942296255%2C-52.11889260313629&z=14
Phased system – Rio Grande	LABModel (IGEO-UFRGS)	R Shiny	Southern Zone and Coastal Plain	http://inundacaorg.riogrande.ifrs.edu.br/
Citizen Map – Floods and Landslides	GPDEN (IPH-UFRGS)	*Google My Maps*	Rio Grande do Sul	https://www.google.com/maps/d/viewer?mid=1jWiyVwY3JPyQUVaBSRbCjp_QOIRxalQ&usp=sharing
Level forecast bulletins	HGE (IPH-UFRGS)	Several	Porto Alegre	https://storymaps.arcgis.com/stories/a81d69f4bccf42989609e3fe64d8ef48#n-d90jUJ
Database of flood data for the Guaíba Lake Hydrographic Region in May 2024.	General	Zenodo	Guaíba Lake Hydrographic Region	https://doi.org/10.5281/zenodo.11164049
Database of flooding in the Lagoa dos Patos region in May 2024	LABModel (IGEO-UFRGS)	*Open Science Framework*	Southern Zone and Coastal Plain	https://osf.io/9wr5c/

real-time stations. An emergency channel via *WhatsApp* allowed for the overlaying of over 200 locations sent via *Google Earth Pro* onto risk layers, guiding families on contingency measures. *WhatsApp groups* facilitated coordination between Civil Defense, the Public Prosecutor's Office, and universities allowing swift and coordinated decision-making.

Figure 3
Participatory mapping of points along the extent of the flood and mass movements, conducted in the Taquari River valley and other regions. In a) sending of geolocated points via *WhatsApp;* in b*) Google My Maps* application with the results obtained.

In the aftermath of the flood, volunteers participated in training sessions and expanded a citizen science project initiated in 2023, recording flood levels and mass movement scars, resulting in a citizen map (Figure 3). A total of 634 points were mapped, primarily of flooding and landslides, in regions such as the Taquari and Rio Pardo Valleys, the Metropolitan Region of Porto Alegre, and the Central region of Rio Grande do Sul. With more than 23,000 views already, the map has received significant attention in the international press specializing in climate coverage. The team also worked with the Civil Defense of Lajeado and the Serviço Geológico do Brasil (SGB, Geological Survey of Brazil), measuring the maximum flood levels in Lajeado, Estrela, and Cruzeiro do Sul. Following receding waters, the points were surveyed using GPS-RTK to produce public data on the flood occurrences of May 2024.

Technical support actions had significant social impacts, guiding crucial decisions before, during, and after the disaster. Alerts underpinned mandatory evacuations to at-risk areas. The emergency georeferencing system optimized rescue efforts, prioritizing the most vulnerable areas. In the post-disaster period, the maps created provided input for modifying master plans and risk management strategies. Despite challenges, such as the dependence on electricity for data transmission during the crisis, engagement in citizen communication resulted in a robust database on flood levels and landslide scars, currently analyzed by researchers from the Grupo de Pesquisa sobre Desastres Naturais (GPDEN – IPH/UFRGS, Natural Disaster Research Group) and Univates.

4.2. Guaíba Lake Level Forecast

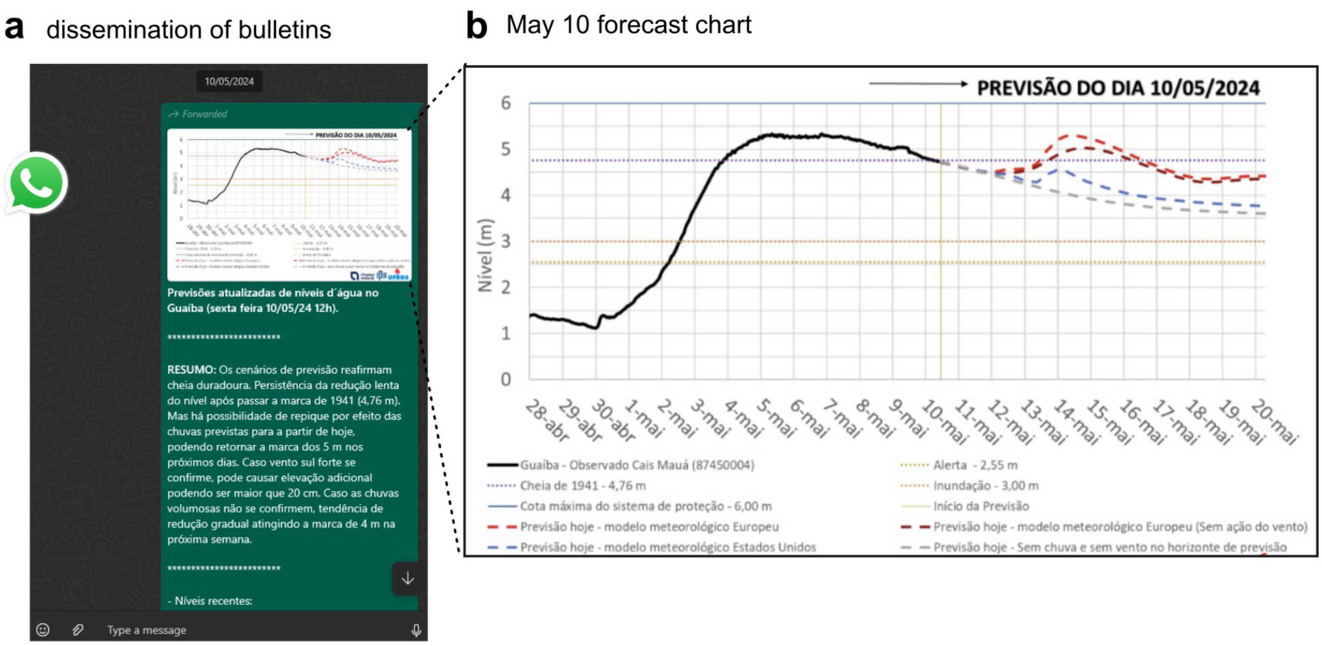
Given the already reported extreme rainfall, the Grupo de Pesquisa de Hidrologia de Grande Escala (he, Large-Scale Hydrology Group) team (IPH-UFRGS) began, on May 1st, 2024, forecasting the levels of Guaíba Lake (also known as Guaíba River), aiming to monitor the flood and to assess whether the 6-meter overflow level of the Porto Alegre flood protection system would be exceeded. This initiative was based on experience gained during the floods of September and November 2023, when this system was first trialed as part of a research project. At this point, with the imminent arrival of large flows in the most populated region of Rio Grande do Sul, it was necessary to predict the duration of the flood and its potential impacts.

The first forecast, made on the evening of May 1st, indicated that the Guaíba Lake level could exceed 5 meters. This information was shared via *WhatsApp* among technical contacts, including the Sala de Situação do Governo Estadual (State Government's Situation Room). Given this exceptional forecast, which surpassed the record flood level of 1941 (4.75 meters), the team began issuing daily bulletins as from May 2, including communicators and journalists to broaden the reach. Thus, the bulletins were disseminated through social networks, the press, and later incorporated into the IPH-UFRGS website and the Maps Repository. As illustrated in Figure 4, the bulletins continued being distributed until July 11th, when the event was receding.

The water level forecasts were developed based on hydrological and hydrodynamic models, combined with rainfall and river flow data, satellite and radar imagery. The process included evaluating previous forecasts and the most recent meteorological conditions, processed in the MGB (inflow rates) and HEC-RAS (Guaíba Lake levels) models. The bulletins described

Figure 4

Example of forecasts and communication of forecasts made by the IPH-UFRGS team for the Guaíba Lake levels during the 2024 flood: a) dissemination via WhatsApp of the forecast for May 10th, and detail b) shows a zoom of the forecast, where the forecast of the second peak of the flood is shown in advance.



the recent behavior of Guaíba Lake, including water and rainfall levels in the basin, meteorological and water height forecasts, as well as broad recommendations. The team's technical interpretation was fundamental in dealing with model uncertainties and observational flaws.

Each bulletin detailed the levels observed until the previous day, and four different scenarios for the following 10 days. The first scenario assumed stability without additional rain or wind, while the others combined forecasts from the ECMWF and GFS models. Beyond the numerical values shown in the graphs, it was necessary to contextualize the results with a more detailed description so they could be understood both by managers and the public.

The forecasts had a direct impact on assessing what was to come in Porto Alegre, anticipating by three days that the Guaíba Lake would exceed 5 meters, but would not reach 6 meters. The second peak of the flood was predicted eight days in advance, improving preparedness to deal with the crisis. Small variations in levels were monitored to avoid unnecessary alarms. The estimate indicated a receding below the flood level between the end of May and the beginning of June, helping to gauge expectations about the duration of the public calamity that had ensued.

The experience of the team involved corroborated that hydrological forecasts cannot rely solely on models and observational data – human intelligence is needed to supervise and disseminate the results. The uncertainties of the models, the flaws in the measurements, and the complexity of decisions in the emergency situation required specialized interpretation and constant debate to validate the results before issuing each bulletin. The case made it clear that, in situations like this, investing in a significant and qualified body of experts in the field of modeling, capable of debating and critically interpreting the functioning of the models, is as indispensable as improving warning and forecasting technologies to protect lives and properties.

4.3. Hydrological risk maps

Starting on May 2, teams began developing hydrological risk maps, complementing level predictions with the spatial distribution of flooding (Figure 5). In Porto Alegre and the Guaíba basin, initiatives operated independently, while in the coastal plain, particularly in Rio Grande, development occurred in close cooperation with municipal managers, ensuring alignment with civil defense operations.

In Porto Alegre, the mapping aimed to anticipate impacts in case of failure of the flood protection system. Bulletins indicated that the Guaíba Lake would exceed its historical water level, leading to the simulation of hydrostatic scenarios of up to 7.00 m. Widely disseminated from May 3, the map, created in QGIS and available on *Google My Maps,* became a desirable public consultation tool, reaching 14 million views by the end of 2024. Its

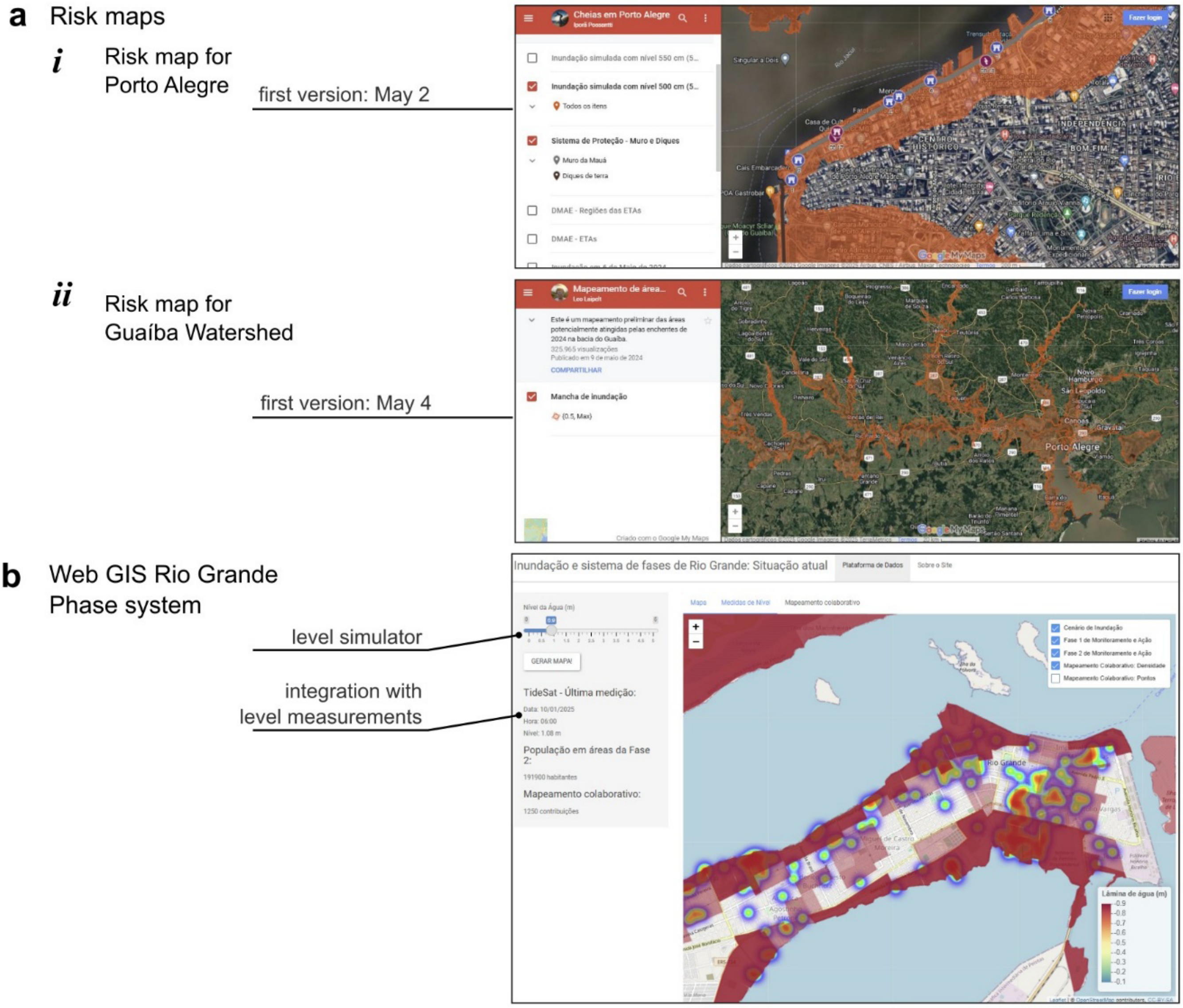


Figure 5

Flood risk maps developed on the eve of the flood and released preventively. In a) risk maps for Porto Alegre and the Guaíba Lake basin and in b) phased system for Rio Grande.

update incorporated observed data, layers on Estações de Bombeamento de Águas Pluviais (EBAPs, Rainwater Pumping Stations) and Estações de Tratamento de Água e Esgoto Plants (ETAs, Water and Sewage Treatment), as well as information on shelters and donations. Easy access allowed the population and managers to make strategic decisions, avoiding errors such as the installation of shelters in high-risk areas.

In the Guaíba Lake basin, the analysis expanded the forecast to municipalities in the Metropolitan Region, contributing to the planning of displacements and the definition of safe zones. Produced on May 3 and released on May 4, the map used the HEC-RAS model to simulate the progression of the flood based on the projected elevation of the Guaíba Lake. The segmentation of the vector layers ensured better detail on the *Google My Maps* platform. However, the release of an alert polygon by the Civil Defense of Rio Grande do Sul, without correspondence to the area actually flooded, caused confusion among the population. Nevertheless, the predictive map correctly anticipated impacts in Canoas and São Leopoldo, proving its value in emergency planning.

Unlike previous approaches, in Rio Grande, the modeling integrated a Phased System of Preventive and Emergency Actions, developed alongside municipal management officials. Initiated on May 4 and formalized on May 6, the system used topography and real-time data to improve the flood response. Besides being available via *Google My Maps,* a web-based GIS application was developed in *R Shiny,* hosted at the Instituto Federal do Rio Grande, allowing for greater detail and interactive functionalities. The mapping was based on a 1-meter resolution digital terrain model (DTM), processed from LIDAR data from the City Hall, with real-time integration of the *TideSat sensor,* which provided dynamic readings of the water level. The web-based GIS also incorporated a participatory form, allowing the submission of georeferenced records by the population. The platform consolidated multiple data sources, including responses from participatory mapping and census sectors from IBGE 2022, ensuring more effective municipal management.

4.4. Pioneering analyses on the impact of flooding

A diagnostic phase of the disaster initiated on May 6. A team of researchers mapped the flood area in the Guaíba Lake basin and created the first public infographics about the disaster (Figure 6), summarizing its impacts in a didactic and accessible way for the general public. This is important for broadening the comprehension on the scope of the phenomenon experienced in Rio Grande do Sul. The analysis focused on this basin, which concentrated the most severe effects at that time, while other regions of the

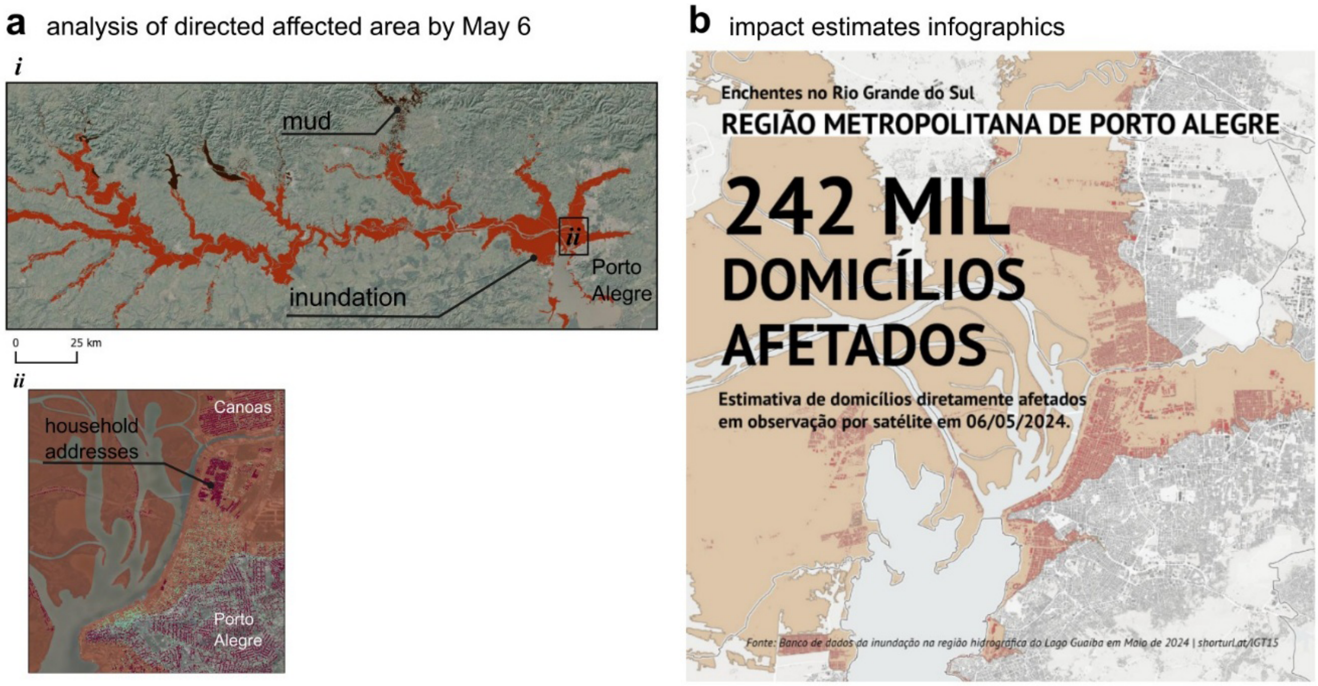


Figure 6

Pioneering analyses on the impact of the flood. In a) estimate of the area directly affected on May 6, 2024: flood map (i) and cross-referencing with the address database (ii). In b) infographics with impact estimates.

state, such as the shores of the Patos Lagoon and the Uruguay River basin, had not yet been affected with such intensity.

The first satellite images were obtained by Sentinel-2 on May 6 and 8, 2024, when weather conditions allowed observation of the impacted area. The images were processed in *Google Earth Engine* to generate flood and mud masks. The Normalized Difference Water Index (NDWI) was applied to detect areas still flooded, and the Bare Soil Index (BSI) to identify mud in dry locations. Manual refinement was then performed to correct inconsistencies, especially in urbanized areas, using natural color images via *Earth Engine Apps*. This initial delimitation was subsequently improved by another team with high-resolution images from *Planet satellites* (scenes from May 7 and 9), *Skysat,* and *WorldView,* in addition to field data and flood level interpolation, improving the representation of the affected area.

On May 9 and 10, the team involved produced infographics highlighting the extent of the flooding, the affected population, and the households impacted. This was made possible by cross-referencing the flooded area with data from the 2022 Demographic Census (Instituto Brasileiro de Geografia e Estatística – IBGE, Brazilian Institute of Geography and Statistics) and the Cadastro Nacional de Endereços para Fins Estatísticos (CNEFE, National Address Registry). Sampling at municipal level facilitated the production of bar graphs, ordering the most affected municipalities in both absolute and relative terms.

The widespread dissemination of infographics and maps starting on May 10 made information about the disaster accessible to managers, researchers, and the public. The pioneering publication of this information established a benchmark for subsequent analyses and contributed to a clear understanding of the massive magnitude of the event.

4.5. Maps Repository and Database

Perhaps the culmination of all the actions was the development of the Maps Repository[1], which was created to centralize and organize the various initiatives developed in parallel during the disaster, facilitating access to spatial information produced by different researchers. From the first days of the crisis, interactive maps, technical notes, and complementary analyses were made available for Porto Alegre, the Guaíba Lake basin, and the shores of Patos Lagoon. Initially structured for internal use, the list of these products was organized into a public platform to systematically expand its reach. Access to the *ArcGIS Story Maps* platform was used, provided by the UFRGS institutional license.

The website began production on May 6, 2024, concurrently with the initial analyses of the flood. Initially, it consisted of an internal compilation of links to maps and technical materials. As mapping initiatives expanded,

1 Available at: https://storymaps.arcgis.com/stories/a81d69f4bccf42989609e3fe64d8ef48

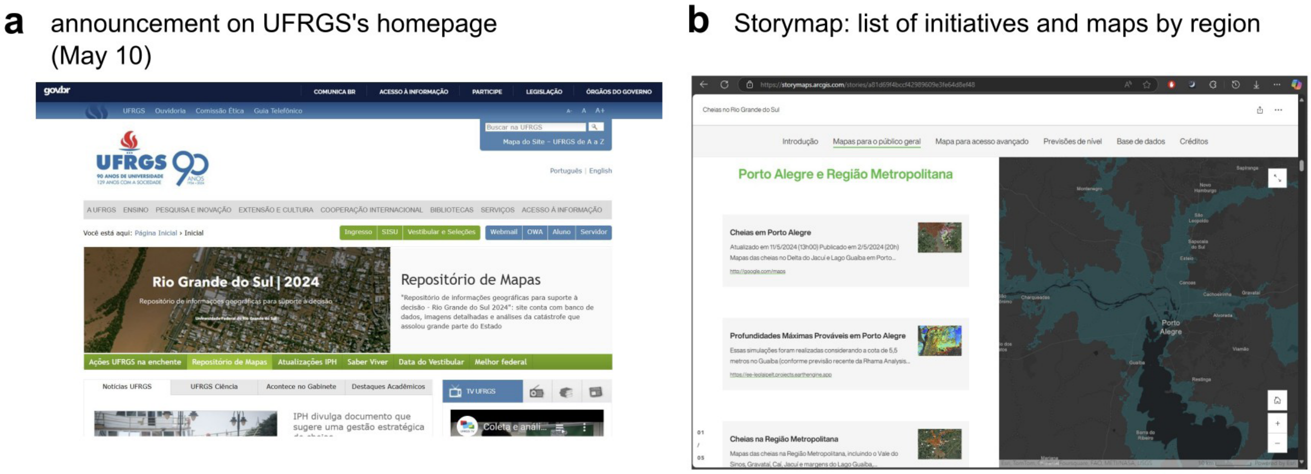


Figure 7

Maps repository created with the ArcGIS Story Map application. In a) portal promotion. In b) main website items: introduction and impact estimate (i); list of initiatives and maps by region (ii).

the need for a consolidated portal led to the official launch of the website on May 10, accompanied by a press interview with UFRGS. The platform gathered voluntary and institutional contributions, and became a unique repository for consulting spatial information about the disaster during the crisis, linked to the University's homepage (Figure 7a).

The website's structure was organized into specific sections (Figure 7b). The first emphasized pioneering infographics and initial analyses of the flood. Following this, a section compiled interactive maps organized by region, including a simplified *web GIS* with layers relevant for technical analysis. The website also stored forecasts of the Guaíba Lake level up to May 20 and provided direct links to public databases on Zenodo (focused on the Guaíba Lake basin) and the Open Science Framework (focused on the Patos Lagoon shoreline). The Zenodo database, containing the most relevant disaster data, resulted in over 18,000 downloads in the following months.

Despite the rapid implementation, some operational limitations were identified. Initially, only one researcher had administrative access to the website, which restricted the frequency of updates. To overcome this restriction, a password was temporarily shared among the team until the system was set up for multiple editors. Furthermore, the inclusion of new maps and authors required constant adjustments to the platform's maintenance.

The data available on Zenodo have been widely used in external analyses, enabling independent studies on the impacts of the flood. The Instituto de Pesquisa Econômica Aplicada (IPEA, Institute for Applied Economic Research), for example, used the published flood map to cross-reference with socioeconomic data and support preliminary estimates the required assistance for the Ministério do Desenvolvimento Social (MDS, Ministry of Social Development). Furthermore, the open availability of the data facilitated the replication of results, the production of technical reports, academic research, and data-driven journalistic reports, consolidating the repository as a reference for studies on the disaster.

4.6. Mapping and monitoring of shelters

The Grupo de Trabalho sobre Abrigos (WG, Shelters Working Group) was created to organize and geolocate information about the emergency shelter locations structured during the 2024 disaster. Composed of approximately 30 volunteer researchers from institutions such as the World Resources Institute (WRI) Brazil, the Mãos – Arquitetura, Terra e Território (Technopolitical Laboratory Hands Architecture Earth Territory), and PROPUR/UFRGS, the group maintained continuous monitoring of the shelter network, filling the gap left by the lack of a unified database. Given the diversity of emergency initiatives and the rapidly changing demands, it became urgent to systematize information on addresses, capacity, volunteer needs, and priority items to optimize the distribution of resources and support to the displaced population.

Activities began in early May 2024 with a small group of researchers and expanded with the creation of a *WhatsApp group* on May 8. From May 9 onwards, part of the team began working in person at the Parque de Ciência e Tecnologia (PUCRS) (TECNOPUC, Science and Technology Park), where other groups, such as Ajuda/RS and SOS/RS (later Bonanza), were also organizing data on the floods. The process started focusing on Porto Alegre, expanding to the Metropolitan Region and, subsequently, to inland cities with a large concentration of displaced people, such as Pelotas and Caxias do Sul. Throughout the month, the Working Group released 10 updates of interactive maps on *Google My Maps,* consolidating the only public and structured database of shelters during the crisis (Figure 8). The effort continued until May 27, when the continuous update structure was finalized. Although activities began remotely, in-person meetings became central to integrate efforts with other initiatives.

The structuring of the information involved compiling diverse sources, manually geolocating the shelters, continuously updating needs, and categorizing services. The institutions responsible for each shelter were identified, data available on the internet were cross-referenced, and information was systematized in the Maps Repository. One of the challenges was the inconsistency of existing databases, with duplicate names, incomplete addresses, and discrepancies. To solve this, a unique identification code based on geographic coordinates was adopted, ensuring greater accuracy. Furthermore, the shelters were categorized into shelters for people, shelters for animals, donation centers, soup kitchens, and multi-functional spaces.

The data compiled by the working group resulted in a database with 1,110 initial records, of which 920 were validated for external publication. The team periodically updated an interactive map on *Google My Maps* and produced reports on the distribution of shelters, organizing the information by type of service, capacity, need for volunteers, and items available or lacking. The dynamic movement of shelters – with creation, deactivation,

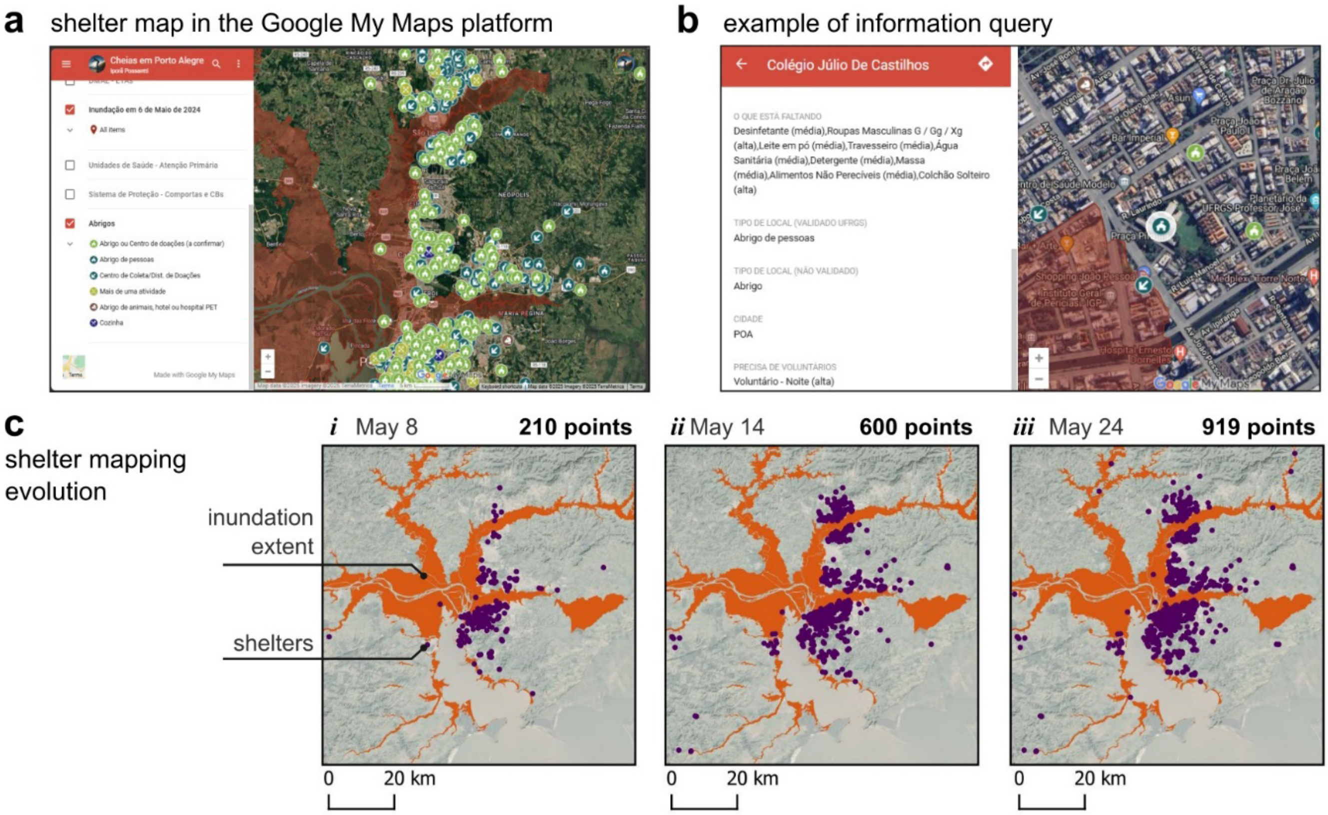


Figure 8

Mapping and monitoring of shelters and donation collection points during the crisis. In a) interactive map on the *Google My Maps* platform . In b) example of querying information about the mapped point, such as the list of items that were missing at the shelter and whether they need volunteers. In c) evolution of the mapping throughout the month of May, reaching 919 mapped points, including other cities in the State.

or change of function – required continuous monitoring and direct contact with administrators and volunteers to maintain data accuracy.

The database has a wide-reaching effect, aiding in resource allocation and disaster response. The data was integrated into platforms such as Vivo and *Waze,* facilitating the distribution of donations. The interactive map garnered millions of views, becoming a reference for volunteers, social organizations, and public managers. Furthermore, the database was incorporated by initiatives such as Ajuda/RS and SOS/RS, reducing duplication and improving shelter management. Despite attempts at collaboration with the Porto Alegre City Hall, the municipal administration did not integrate the data into its system. Similar proposals from the state government and Civil Defense to create a easily reachable map during the period of greatest need failed to move forward.

The work of the Shelter Task Force demonstrated the importance of data organization in disaster scenarios, allowing for more efficient management of shelter spaces. The consolidation of information in a structured database and the consistent release of interactive maps increased the transparency of the process and strengthened the humanitarian response, ensuring that resources reached those who needed them most.

4.7. Public utility information in sanitation

The dissemination of technical information on hygiene and sanitation was a key point during the 2024 disaster. The actions were conducted by the Núcleo de Estudos em Saneamento Ambiental (NESA, Center for Studies in Environmental Sanitation) (IPH-UFRGS), involving professors, technicians, and students. Initially focused on emergency actions, the materials ensured safe measures in responding to the crisis. As the situation worsened, the scope was expanded to include recovery. The vulnerability of the water and sanitation infrastructure had already been highlighted in 2023, after extreme events compromised water supply and sewage treatment in Rio Grande do Sul. The flood of May 2024 and the imminent failure of the flood protection system accentuated the risk of water supply interruption and overload of drainage and waste systems. Thus, the production and dissemination of information on water supply, waste management, and hygiene was vital to mitigate impacts and guide the population and managers.

Activities began in 2023 with the publication of the *Technical Note on Sanitation in Hydrological Disaster Situations – Floods*. As forecasts indicated that the Guaíba Lake would surpass historical records in the 2024 floods, the group anticipated emergency measures to maintain the Water Treatment Plants (WTPs) of Porto Alegre. Between May 4 and 6, the *IPH-UFRGS Note to the Community* was structured and launched on May 7, with proposals to avoid the shutdown of the WTPs and warnings about the risks of water scarcity. Simultaneously, NESA's Instagram launched a campaign with guidelines on water conservation, emergency sanitation, and disease prevention (Figure 9b). Between May 9 and 11, guidelines on waste management and environmental hygiene were disseminated. On May 13, the document *Strategies and care during and after floods*, aimed at the population and emergency shelters, was consolidated and published. Throughout the month, new content addressed food safety and the proper use of personal protection equipment (PPE) for cleaning.

Furthermore, starting on May 6, with the collapse of the supply systems, a map was implemented on *Google My Maps* platform to identify alternative sources of drinking water in the Porto Alegre Metropolitan Region (Figure 9a). The map classified the sources by safety for consumption (blue: potable; red: treatment required) and included information on

Figure 9
Interactive map of drinking water sources on *Google My Maps* (a) and social media posts with information on environmental sanitation, including water quality measurements and guidance on post-flood waste management (b).

a potable water sources map in Google My Maps application

b public service information on social media (Instagram)

the operation of the pumping stations (EBAP), the status of the protection systems (walls, dikes and sluice gates) and the operation of the water treatment plants.

The team produced and disseminated informational materials based on the Technical Note and on national and international references, such as documents from the Fundação Nacional de Saúde (Funasa, National Health Foundation), the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and the Environmental Protection Agency (EPA). During the flood, the content was widely disseminated via NESA social media, the IPH-UFRGS website, and local and national media outlets. Collaboration with the Secretaria de Estado do Meio Ambiente e Infraestrutura do Rio Grande do Sul, the Fire Department, and the VIGIDESASTRES program ensured that the information reached managers, rescue teams, and the general public.

The main achievement was consolidating information on sanitation in disasters, a topic rarely addressed in Brazil. The material served as a reference for managers, technicians, and the affected population. In May, views on NESA's social media grew by 5,022% compared to the previous month, reaching 28,000 accounts and increasing followers by 26.3%. Aside from online dissemination, professors participated in interviews on radio, newspapers, and TV, expanding the reach of the information. The material was used by hospitals, schools, government agencies, and humanitarian organizations, assisting in the formulation of strategies to minimize the health crisis.

5. Final considerations

Based on the report presented, our volunteer actions were primary to communicate risks during the 2024 disaster in Rio Grande do Sul, filling technical gaps and highlighting the lack of governance for events of this magnitude. Beyond contributing to the emergency response, this article aims to preserve the collective memory of Brazil's largest climate disaster, given the growing possibility of the recurrence of extreme events. Although it does not cover all the actions taken, many of which recorded in the Maps Repository, we hope that this experience will help improve society's capacity to react.

The crisis called attention to the strategic role of communication, understood not only as the transmission of data, but as a process that connects individuals, contexts, and meanings amidst urgency. In an environment marked by institutional failures and the collapse of formal networks, risk communication proved to be as critical as physical infrastructure. It was necessary to quickly translate technical knowledge into clear guidelines and ensure access to qualified information for diverse audiences.

The event reaffirms that disasters are not inevitable but are a result of the interaction between natural processes and social vulnerabilities. Southern Brazil faces a scenario of more frequent and intense floods (Collischonn et al., 2025), aggravated by infrastructure failures, forecasting difficulties, and challenges in emergency response. Between 2012 and 2023, the Federal Government failed to apply more than a third of the resources allocated to the Risk and Disaster Management Program (Accioly, 2024; Nobre et al., 2024). Our experience has shown that, despite the prevalence of artificial intelligence, critical human interpretation remains irreplaceable, as evidenced in the forecasting of water levels in Porto Alegre. The integration of information has also proven vital, as exemplified by the Phase System in Rio Grande, reinforcing that water level forecasts, real-time monitoring, and risk maps need to be accessible to the population to avoid operational errors.

The chronology of the disaster reflected the geographical diversity of the territory: rapid responses in the mountainous valleys, slow-recession flooding in the Central Depression, and a gradual advance in the Coastal Plain. This differentiated dynamic demands planning tailored to each context. Measures such as floodplain zoning, associated with conservation units and revisions of master plans, can restrict occupation in susceptible areas, enabling dignified housing alternatives. Mitigation requires adequate infrastructure and a management model with clear responsibilities and sustainable operating and monitoring mechanisms. Preparedness requires reliable warning systems, operated by technical teams trained to interpret models and communicate risks effectively, while recovery should be guided by the logic of resilient reconstruction.

The implementation of these measures requires strengthening water governance. The Sistema Estadual de Recursos Hídricos (SERH) needs to coordinate actions between the state, municipalities, and the federal government, as well as to create and consolidate basin committees and agencies. The absence of these agencies in Rio Grande do Sul compromises risk and disaster management. Experiences in other states show that their operation expands the availability of technical information and enables planning instruments (Pavão et al., 2013; Costa et al., 2018). Furthermore, the technical and executive support of these entities accelerates the implementation of key infrastructure projects, ensuring that investments are directed to initiatives with greater impact and financial sustainability (Marques, 2024). Institutional strengthening, coupled with qualified and integrated communication, is a prerequisite for the lasting success of any adaptation and response measure.

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