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The extreme precipitation event of autumn 2024 in the Guaíba hydrographic region (RS)

El evento de precipitación extrema del otoño de 2024 en la región hidrográfica de Guaíba (RS)

O evento extremo de precipitação do outono de 2024 na região hidrográfica do Guaíba (RS)

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Abstract

In this article, we present the extreme precipitation event that occurred in the Guaíba Hydrographic Region (RHG) in the fall of 2024, from the perspective of geographic climatology. We initially discuss the concepts of climate extremes and the proposed analysis of the succession of three precipitation events in sequence. For this analysis, daily data from INMET and CEMADEN meteorological stations were organized. The three events were: the first, with 500mm, on average; followed by another with 200mm; and the last one of 100mm. The distribution of precipitation indicates an orographic effect and triggered mass movements on the slopes and extraordinary floods, especially in the Metropolitan Region of Porto Alegre, where the flood protection system collapsed, due to lack of maintenance.

Keywords: extreme event, precipitation; orographic effect.

Resumen

En este artículo, presentamos el evento de precipitación extrema ocurrido en la Región Hidrográfica de Guaíba (RHG) en el otoño de 2024, desde la perspectiva de la climatología geográfica. Inicialmente discutimos lo concepto de extremo climático y el análisis propuesto de la sucesión de tres eventos de precipitación en secuencia. Para este análisis se organizaron los datos diarios de las estaciones meteorológicas INMET y CEMADEN. Las tres pruebas fueron: la primera, con 500 mm, en promedio; seguido de otro con 200 mm; y el último de 100mm. La distribución de las precipitaciones indica un efecto orográfico y desencadenó movimientos de masa en las laderas e inundaciones extraordinarias, tanto en las subcuencas como en la Región Metropolitana de Porto Alegre, donde el sistema de protección contra inundaciones colapsó, por falta de mantenimiento.

Palabras clave: evento extremo, precipitación; efecto orográfico.

Resumo

Neste artigo apresentamos o evento extremo de precipitação ocorrido Região Hidrográfica do Guaíba (RHG) no outono de 2024, na perspectiva da climatologia geográfica. Discutimos, inicialmente, os conceitos de extremo climático e a proposta análise da sucessão de três eventos de precipitação em sequência. Para esta análise foram organizados dados diários de estações meteorológicas do INMET e do CEMADEN. Os três eventos foram: o primeiro, com 500mm, em média; seguido por outro com 200mm; e o último de 100mm. A distribuição da precipitação indica efeito orográfico e desencadeou movimentos de massa nas encostas e inundações extraordinárias, tanto nas sub bacias, como na Região Metropolitana de Porto Alegre, onde o sistema de proteção contra cheias colapsou, por falta de manutenção.

Palavras-chave: evento extremo, precipitação; efeito orográfico.

Introduction

In Rio Grande do Sul, although the climatological averages indicate only climate types with well-distributed rainfall throughout the year, there is significant interannual variability in the spatial-temporal distribution of rainfall. From 2020 to early 2023, the state experienced long periods of drought, so much so that it was included in the Brazil Drought Monitor. From June 2023 onwards, however, a series of extreme precipitation events occurred, some more localized, others more extensive. However, in terms of intensity and spatial scope, the precipitation that occurred in April and May 2024 was exceptional. Monteiro (1999) wrote that extreme events result from violent inputs into the geographic system that completely escape human control; at best, there may be prediction and states of alert for defense. He added that, however, catastrophic results never come exclusively from meteoric impact, that is, from atmospheric action. In geographic climatology, we learn from Monteiro (1999) how to analyze the atmospheric environment, which is made up of a series of atmospheric states over a place in their usual succession, as proposed by Maximilien Sorre. We understand from experience that atmospheric states oscillate, allow for deviations and produce accidents. Even the most serious, sometimes catastrophic, events should not be discarded from the geographer's climatological analysis, due to their local or regional impact and the chain reaction that follows them (Monteiro, 1991).

We also understand that rhythm is the geographic essence of climate, because "[...] the fundamental idea of climatic 'rhythm' is precisely that of being able to tune it to the other dynamics of other spheres: hydrological, geomorphological, biological processes [...]" (Monteiro, 1991, p.131). And, further, how this rhythm intertwines with the broader spectrum of local factors created by the major deviations introduced by the urban-industrial construct.

We adopted this theoretical-methodological proposition in this article to help understand the extreme event that occurred between the end of April and the month of May 2024 in Rio Grande do Sul.

The chosen spatial area was the Guaíba Hydrographic Region (RHG). This, established by State Law 10.350/1994, has an area of 84,763.54 km², corresponding to 30% of the territory of the state of Rio Grande do Sul, with 251 municipalities fully or partially included in it. It is divided into nine sub-basins: Vacaraí-Vacacaí Mirim, Alto Jacuí, Pardo, Baixo Jacuí, Taquari-Antas, Caí, Sinos, Gravataí and Lago Guaíba. We are aware that, despite the large extent of the extreme event, not all places in this extensive basin received precipitation of the same intensity. In the RHG, as intuitively learned, as a tacit idea held in the human mind and social memory, the time of year when rains cause floods "should be" September, early October, the socalled "São Miguel Flood", as it occurs around the date of September 29, which celebrates this saint. Also, these are the two months in which precipitation is slightly higher than in the others, according to climatological norms. However, the extreme event of widespread precipitation and flooding, which is a reference in this basin, the "Flood of 1941", also occurred in the months of April and May, as in 2024.

In this article, we present the spatial-temporal variation of precipitation in the RHG, which triggered the environmental disaster in the fall of 2024.

Materials and methods

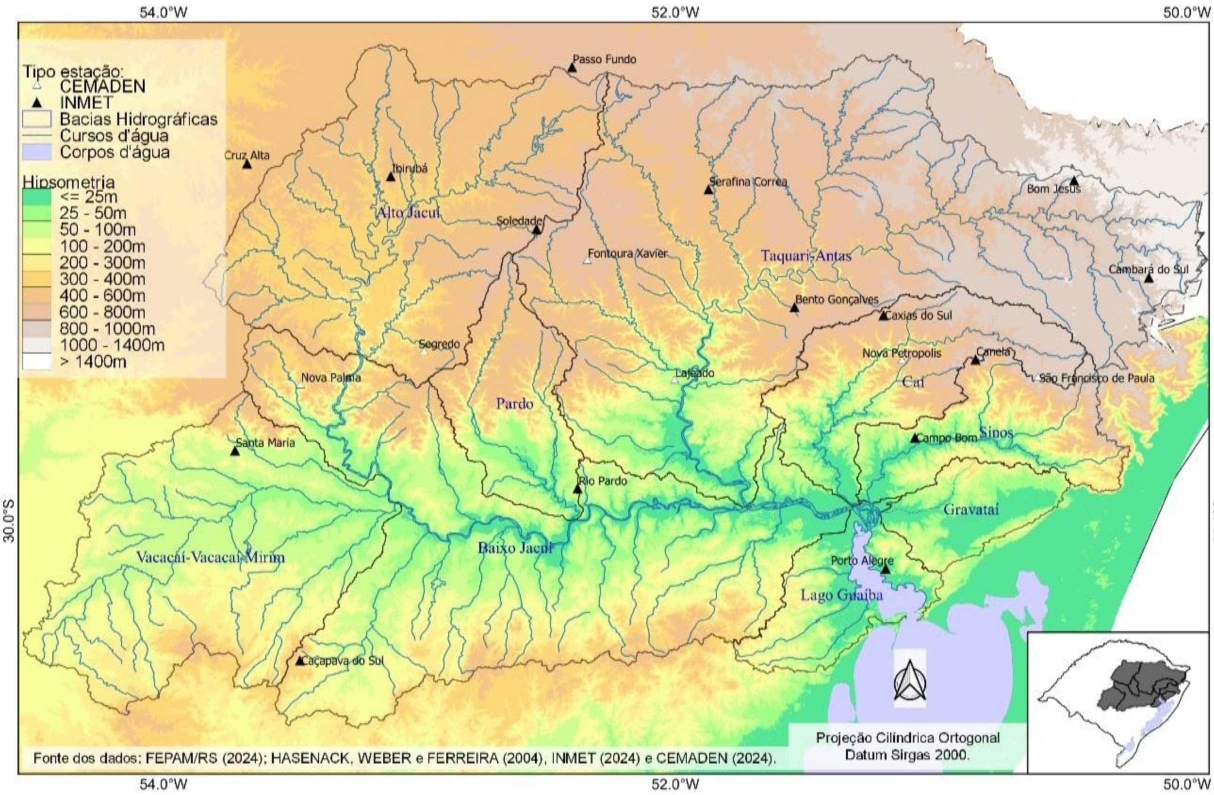
For the analysis, we organized daily data from meteorological stations from INMET and CEMADEN existing in the nine sub-basins that make up the Guaíba basin. As conventional stations record daily data at 9am local time (12TMG), for automatic stations (INMET and CEMADEN), hourly data between 12pm (TMG) on one day and 12TMG on the other were added. Therefore, even though most of the precipitation occurred the previous day, it was recorded at 9 am the following day. In this event, errors were found in the station records, both from INMET and CEMADEN, whose data had to be discarded.

In the catalog of meteorological stations from both bodies we obtained their geographical location. Based on this geometry, we imported the point spreadsheet into a project in QGIS (version 3.16), to which we also added the polygons of the RHG river basins and a digital elevation model in order to allow joint analysis of the data.

Results and discussion

To understand the impact caused by the concentrated precipitation in a short period of time in this Hydrographic Region, it was essential to characterize it from the point of view of its relief form and mode of occupation. Map 1 characterizes the relief of the different basins that form the RHG and the meteorological stations with records.

Map 1 - Hypsometry of the basins of the Guaíba Hydrographic Region and meteorological stations



Source: Collischonn (2024)

According to map 1, the RHG's altimetric amplitude is over 1,200 meters. The highest altitudes occur in the northeast, in the upstream portions of the Taquari-Antas rivers, where they are over 1,200 meters. Altitudes around the main channel of the Jacuí River are around 20 meters. The lowest altitudes, below 5 meters, occur around the Jacuí and Guaíba Deltas. Map 1 highlights the contribution area of each watercourse that drains into the Guaíba and Laguna dos Patos. The Taquari-Antas basin has the largest contribution area (31%), followed by the Basins: Lower Jacuí (20.4%), Upper Jacuí (16%), Vacacaí and Vacacaí Mirim (13.1%) and Caí (6%). The other basins contribute less than 5% each to the Hydrographic Region as a whole. Rivers were the main route of occupation of this territory, first by the bandeirantes in the 18th century, and later by the expansion of European colonization. For this reason, many cities developed from a landing stage on a promontory or terrace of a river. Currently, there are 251 municipalities that are fully or partially located in this territory and the urbanization rate, in general, is over 80%. The Guaíba Hydrographic

Region is the area with the highest population density in the state, housing 61% of the state's population, and is also the most industrialized.

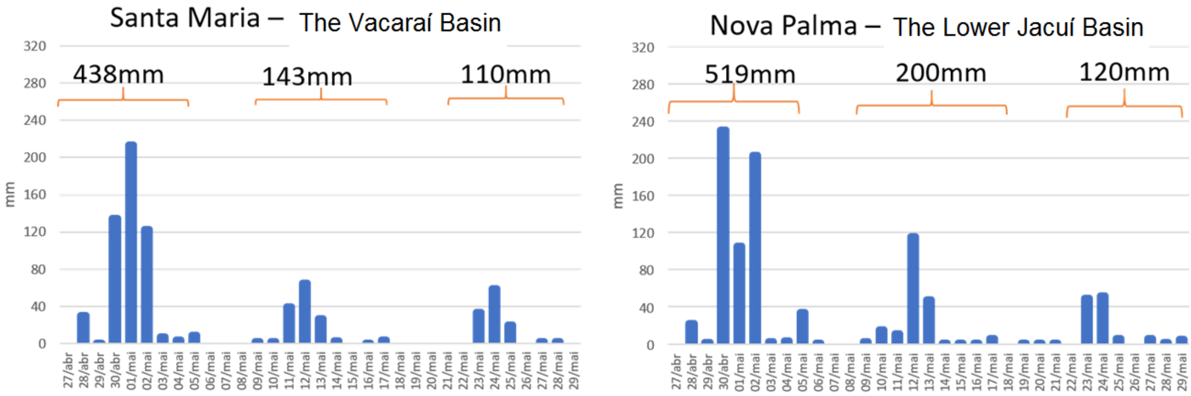
Three intense rainfall events occurred in all the basins that make up the RHG: the first, with the greatest intensity (500 mm on average), occurred from 04/27 to 05/05; the second (200 mm), from 05/09 to 05/14; and, finally, a third from 05/22 to 05/24 (~100 mm). According to a technical note from INPE meteorologists (2024), the combination of meteorological systems acting on different scales led to these occurrences. On a larger scale, the El Niño condition, of moderate to strong intensity, favored the occurrence of episodes of above-average precipitation in southern Brazil. In addition, the Tropical Atlantic Ocean was warmer in relation to its climatological normal, which increased the available moisture content. On a synoptic scale, the first and most significant precipitation event resulted from: 1) strong subtropical high pressure over the Brazilian Southeast and Central-West, which caused atmospheric blocking and contributed to the maintenance of a condition of high atmospheric instability over the RHG; 2) intense circulation associated with the Low-Level Jet, which transported hot and humid air from the Amazon region towards the RHG; 3) the presence of a long-wave trough, at mid-level, which favored the formation of low-pressure systems at the surface; 4) the advance and interaction of cold fronts with this warmer, more humid air mass, which contributed to episodes of severe storms, with records of gales, tornadoes, hail and heavy rains (significant volumes of rain in one hour), as well as high accumulated rainfall (INPE, 2024).

On May 5, ASAS gains reinforcement from polar air and the weather stabilizes for a few days; but the atmosphere close to the surface warms up again and, at the end of the 8th, a new front passes quickly over the east of the Region. In the following days, an unstable condition is established again with low-level jets bringing humidity from the Amazon region. The condition only changes, in a more generalized way in the Region, on May 19, with the action of a polar air mass. Finally, on May 22, the previous condition was reestablished, destabilizing the atmosphere until May 29, when an extratropical cyclone passed along the coast of Rio Grande do Sul.

Below, we present the chronology of these events in locations in the different Hydrographic Basins of the RHG.

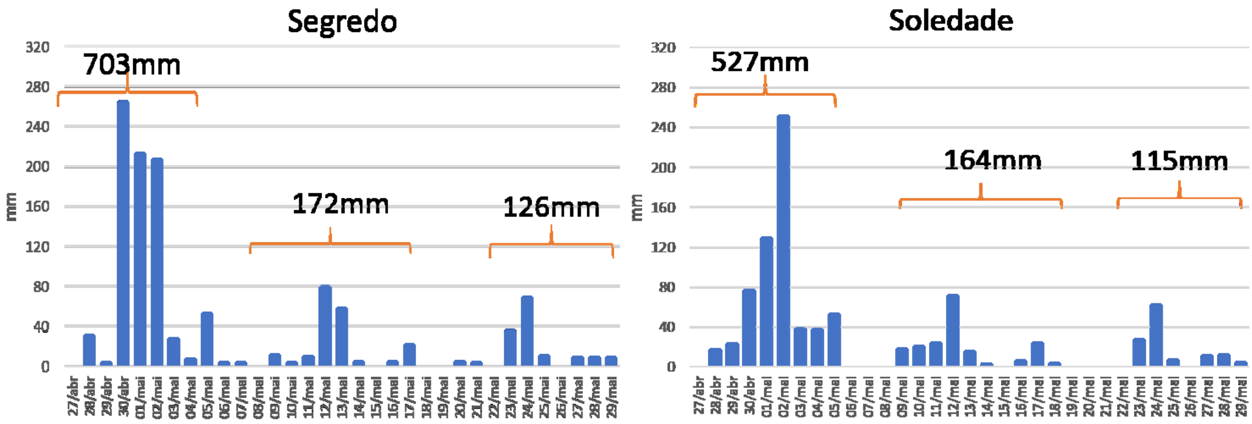
On April 27, severe storms occurred, with records of gales, tornadoes, and significant hail (between 4 cm and 6 cm) in several locations in Rio Grande do Sul, such as Venâncio Aires/RS, Barros Cassal/RS, Espumoso/RS, Santa Cruz do Sul/RS, Jacuizinho/RS, Passos de Torres/RS, and Passo do Sobrado/RS (Inpe, 2024). On April 29, significant rainfall volumes were recorded in a few hours, as well as the highest accumulated rainfall, in the Vacacai Basin – Vacacaí-Mirim, Alto Jacuí and Rio Pardo. These intense rains caused flash floods, flooding and landslides, loss of life and significant damage in these basins. In the following days, the rain continued to contribute to the occurrence of flooding in the lower courses of the Vacacaí, Vacacaí-Mirim, Pardo, Pardinho and Jacuí rivers. In Soledade, the rainfall from April 1 to 9 am on April 2 was 250 mm.

Graph 1 – Distribution of precipitation according to station records in the Vacacaí-Vacacaí Mirim and Lower Jacuí Basins.



Source: INMET (2024) and CEMADEN (2024). Organized by the author.

Graph 2 – Distribution of precipitation by station records in the Upper Jacuí Basin.



Source: INMET (2024) and CEMADEN (2024). Organized by the author.

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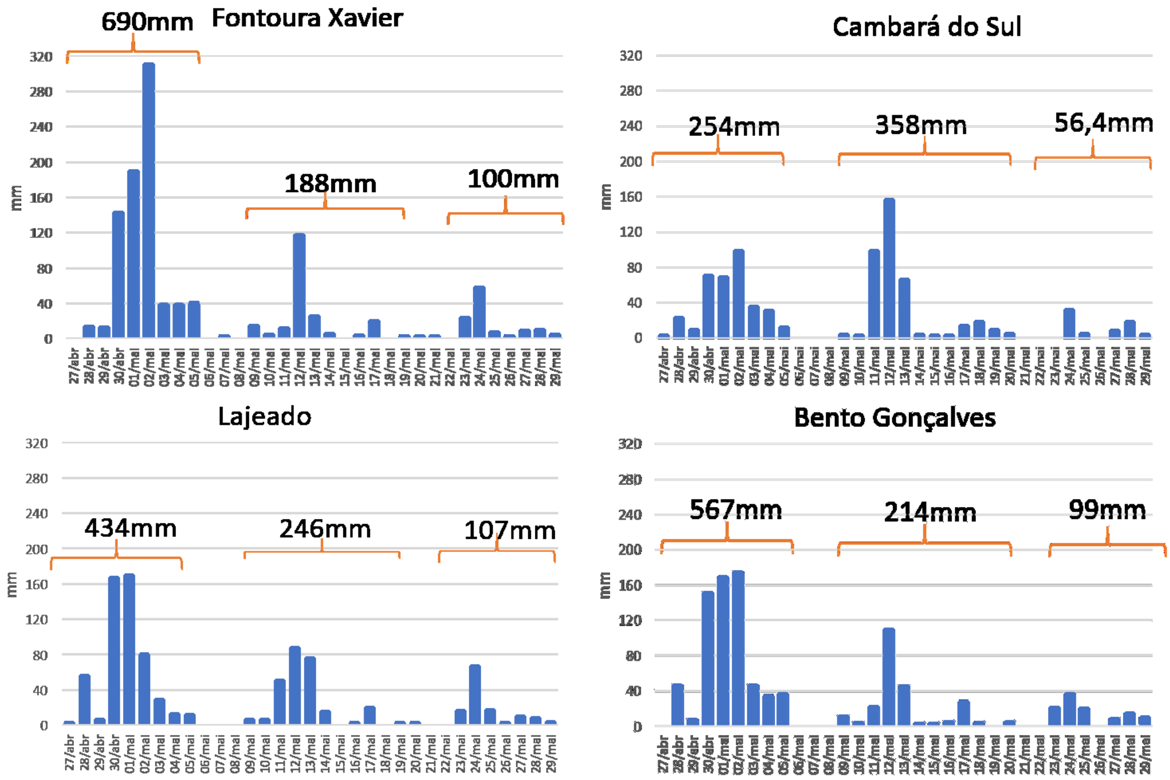
In the Taquari-Antas, Baixo Jacuí, Caí and Sinos basins, the precipitation volumes on 29/04 had also been significant (higher than the monthly average), but on the following days, 30/04 and 01/05, they exceeded any previous record. In Fontoura Xavier, the precipitation that occurred largely on the 1st and was recorded on the 2nd was 309 mm.

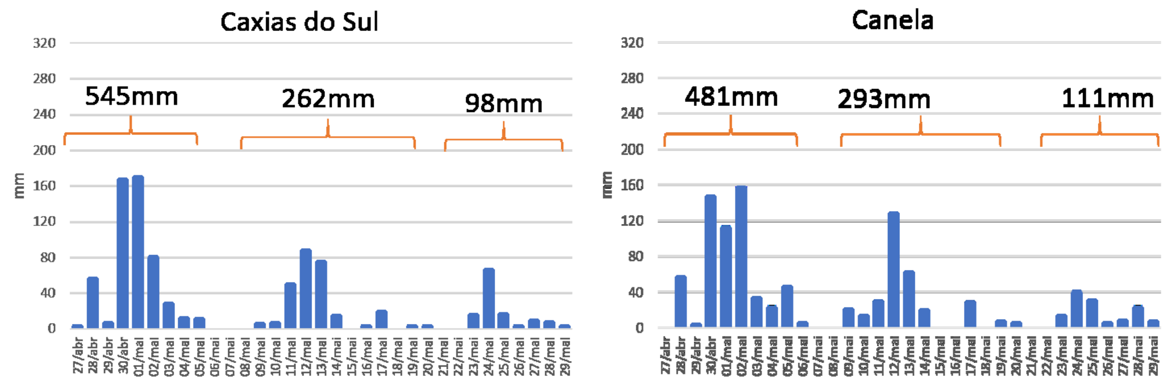
Graph 3 – Distribution of precipitation by station records in the Taquari-Antas Basin.



Source: INMET (2024) and CEMADEN (2024). Organized by the author.

In the eastern portion of the Caí basin (Canela), as well as in the eastern portion of the Taquari-Antas basin (Cambará do Sul) and in the Sinos basin (São Francisco de Paula), in the second event (10/05 to 17/05) greater precipitation was recorded than in the basins further west (graphs 3 and 4).

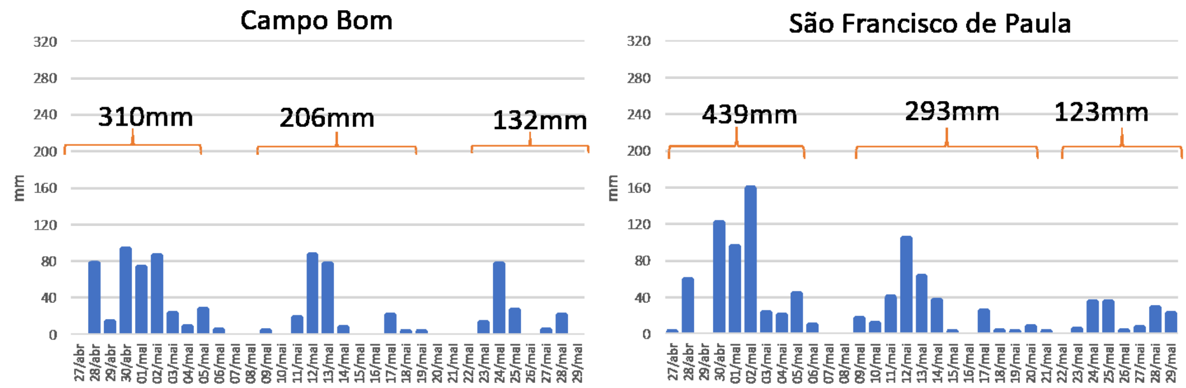
Graph 4 – Distribution of precipitation by station records in the Caí Basin.



Source: INMET (2024) and CEMADEN (2024). Organized by the author.

Most analyses, such as that of INPE (2024) previously cited, only considered the event that occurred between April 27 and May 2, which, in fact, was totally exceptional; however, the following event also recorded more than double the monthly climatological normal of most stations and, the last one, at least the monthly normal in a few days (graphs 1 to 6).

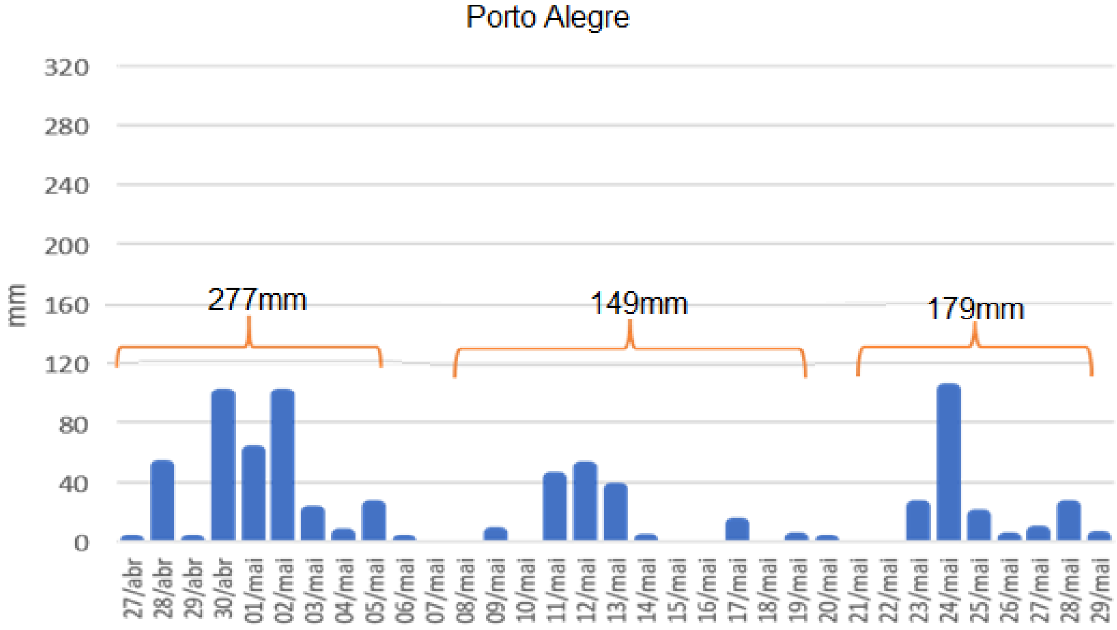
Graph 5 – Distribution of precipitation by station records in the Caí Basin.



Source: INMET (2024) and CEMADEN (2024). Organized by the author.

The persistence of heavy rains throughout the month of May also prolonged the duration of the floods and delayed the return to activities in downstream municipalities, such as Porto Alegre (graph 6), where precipitation, although extraordinary for the historical series, was less intense than in upstream locations.

Graph 6 – Distribution of precipitation in Porto Alegre in the Guaíba Lake Basin.



Source: INMET (2024) and CEMADEN (2024). Organized by the author.

Final Considerations

The rainfall in April and May 2024 in the RHG had extreme volumes at all meteorological stations, but with a different spatiotemporal distribution of precipitation between the sub-basins.

The conclusion we reached, when relating the position of the meteorological stations in the RHG with the distribution of daily precipitation data, is that, in addition to the atmospheric systems that combined to cause precipitation events, it is necessary to add the orographic factor to explain the high precipitation rates recorded in Santa Maria, Nova Palma, Segredo, Soledade, Fontoura Xavier, Bento Gonçalves, Caxias do Sul, Canela and São Francisco de Paula. As we have understood from Barry and Chorley (2013), the plateau escarpment contributed to the increase in precipitation: by forcing the turbulent rise of air due to surface friction (friction with the surface) causing convective instabilities, especially when funneling into valleys; because it slowed down the movement of disturbed systems of cyclonic origin.

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