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The hunt for data: obstacles faced by researchers in the search for accurate information on precipitation in Brazil

Abstract

Precipitation data collection is a fundamental activity for understanding climate phenomena and making decisions in various areas, such as agriculture, water resources, and energy. However, collecting and analyzing this data in Brazil faces several challenges that affect the quality and reliability of the information. This article aims to analyze the challenges related to precipitation data collection in Brazil and present proposals to overcome them, contributing to improving the quality of information and the safety of the population. To achieve the proposed objective, the main factors presented in debates and discussions that occurred between master's and doctoral students, and researchers from government agencies in Brazil from 2021 to 2023 were monitored and recorded. The analysis of the challenges related to precipitation data collection in Brazil points to the lack of investment in the maintenance and monitoring of meteorological stations, the lack of observational data in certain regions of the country, the need to consider the spatial and temporal variability of the data, and the guarantee of the safety of the stations. To overcome these challenges, a joint effort is proposed by the government, the scientific community, and the general population with adequate investments in the maintenance and monitoring of meteorological stations, the adoption of more efficient solutions for data collection and analysis, the consideration of the spatial and temporal variability of the data, and the adoption of security measures for meteorological stations.

Keywords: precipitation, observed data, Brazil, meteorology, hydrology

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Abbreviations: ANA, national water agency; Cemaden - national center for monitoring and early warning of natural disasters; IFSC, federal institute of Santa Catarina; InMet, Brazilian meteorology institute; UFSC, federal university of Santa Catarina

Introduction

Observed precipitation data are collected through instruments and measurement techniques to record the amount of precipitation that occurs in a specific location and time period. This data includes information about the amount of rain, snow, hail, or other forms of precipitation that fall in a specific area. Generally, this data can be collected by rain gauges, weather stations, weather radars, satellites, and other sources of weather and climate measurement, and is used by meteorologists, hydrologists, and other professionals in Brazil and around the world to understand climate patterns, predict future weather conditions, monitor water levels, and manage water resources. Most of the time, observed precipitation data can be found in various sources or databases from government meteorological agencies, research institutes, universities, and international organizations. However, the availability and accessibility of this data may vary according to the region and country where it is collected.[1] In some countries, such as Brazil, observed precipitation data are collected and made available in a centralized manner by the government, which at first glance may make them easily accessible to researchers and professionals. However, many researchers face significant challenges in obtaining observed precipitation data to support their research, and as a result, many studies end up using reanalysis data generated by hydro-meteorological modeling. These data are produced through numerical weather prediction models that are retrospectively run on previous periods. The models use direct observations, such as data collected by weather stations and satellites, as well as other indirect data sources, such as soil temperature and atmospheric pressure data, to estimate past weather conditions.

Although these data present a more homogeneous spatial and temporal resolution and are available for a longer period of time, it is important to remember that they are an approximation of real data and may contain uncertainties that need to be considered in hydro-meteorological analyses.[2] For example, errors in model calibration, data assimilation, or representation of physical processes in the atmosphere may occur, which can affect the accuracy and reliability of research based on this type of data. It is important for researchers to be aware of these limitations and uncertainties when using hydro-meteorological reanalysis data in such studies and whenever possible, seek the use of real and validated observable data for their research. This article presents some of the main factors that are considered obstacles, in the Brazilian context, to obtaining observed precipitation data, which are of fundamental importance for conducting studies related to hydro-meteorology. The factors presented in this article were the result of debates and discussions that took place from 2021 to 2023 among master's and doctoral students, and researchers from Brazilian government agencies.

Material and methods

The methodology used in the article involved a review of discussions among master's and doctoral students and researchers from government agencies in Brazil. The article is based on a qualitative analysis of the challenges faced by researchers and emphasizes the importance of being aware of the limitations and uncertainties associated with different sources of data. The methodology employed in this scientific article utilized the hypothetical-deductive method with a qualitative approach, through a historical-organizational case

study. The researcher observed the debates among professionals from the institutions responsible for data collection and the researchers, master's and doctoral students who utilize this data for their research. The hypothetical-deductive approach aims to develop and test hypotheses based on theoretical foundations. In this study, hypotheses or research questions related to the historical and organizational aspects of a specific case were formulated. If the premises are true, the conclusion will also be true. The qualitative methodology focuses on understanding and interpreting phenomena from a subjective and contextual perspective. In this study, it involved the collection and analysis of non-numerical data such as interviews, documents, and observations. Observation was used to gain in-depth insights into the case under investigation, particularly regarding the debates among professionals and researchers who deal with precipitation data and face challenges in data collection. The case study design allows for a detailed analysis of a specific phenomenon within its real context, specifically addressing the difficulty in obtaining observable precipitation data. In this study, the focus is on a specific historical and organizational case involving government entities responsible for the observational network and researchers. This enables a comprehensive analysis of its unique characteristics, developments over time, and its impact on the organization. By combining the hypothetical-deductive, qualitative, and historical-organizational case study approaches, this research seeks to explore and understand the complex relationships, dynamics, and influences within a specific case. The aim is to provide a rich and detailed account of the historical and organizational factors at play, shedding light on patterns, trends, and unique insights that contribute to the existing body of knowledge.

Results and discussion

Obtaining observed precipitation data is a fundamental aspect for conducting studies related to hydrometeorology, especially in Brazil, where limiting factors are still present. One of the most significant obstacles is the low density of rain gauges throughout the country, which, combined with Brazil's complex topography, can create challenges in interpretation, especially with data obtained from radar, which is considered an important source of accurate information about precipitation. Although radar data can provide high-resolution precipitation measurements, their interpretation can be affected by natural obstacles, such as mountains, which can interfere with data accuracy.

After the debate among research institutions, industry professionals, and researchers, significant results were presented regarding the Observational Network of Brazil. The data reveals the availability of various types of stations and equipment used to collect meteorological and hydrological information across the country. Among the highlights, 9 meteorological radars were identified, playing a crucial role in detecting and monitoring precipitation at high resolution. Additionally, there is a total of 3,375 automatic rain gauges, devices that allow for continuous and accurate collection of rainfall data. Furthermore, there are 1,375 semi-automatic rain gauges, providing valuable information on precipitation.

Regarding hydrological stations, Brazil has 301 units closely monitoring water levels in rivers, reservoirs, and other water sources. For geotechnical purposes, 137 stations have been registered, responsible for collecting essential data for studies related to soil behavior and geotechnical stability. Considering the semi-arid characteristic of some regions, 650 specific stations have been deployed to monitor the climatic conditions in these environments. Additionally, there are 100 agricultural stations, focused on obtaining data related to agriculture and its impact on the environment. Lastly, the 550 Acqua stations stand out, providing information on water quality and the monitoring of water resources in different regions of Brazil. These results reflect significant advancements in observation and data collection infrastructure in Brazil (Figure 1). According to the National Center for Monitoring and Early Warning of Natural Disasters - Cemaden (2022), the exclusive use of radars is not sufficient to issue alerts quickly, and it is necessary to equip municipalities with more effective devices, such as rain gauges. In comparison, Japan, for example, has 20 weather radars and has a network of 17,000 rain gauges. In contrast, in Brazil, there are only 4.750 rain gauges, even with a decades-old culture and an established network, the country still presents this diagnosis, which makes it essential to increase the number of rain gauges in the country.

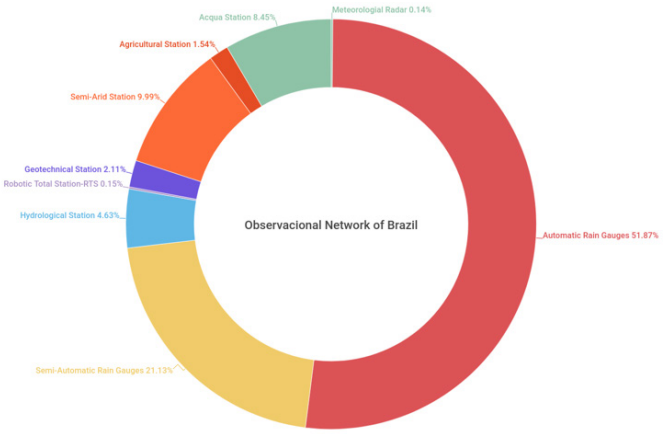

Figure 1 Survey of the observational network in Brazil that collects precipitation data.

Source: Cemaden, 2022.

Similarly, the Brazilian Meteorological Institute – InMet[3] states that the absence of effective maintenance programs for observation equipment and meteorological stations concerns the scientific community. According to data from this agency, among the 767-equipment distributed by the institution throughout Brazil, 210 are unusable due to technical problems and result in increased damage to various sectors, with a significant focus on agriculture. Additionally, many rain gauges in Brazil are poorly maintained, which can lead to quality and maintenance problems such as obstructions, malfunctioning, and inaccurate readings. Government agencies such as Cemaden and the National Water Agency – ANA[4] acknowledge that the lack of adequate maintenance and operation of rain gauges can have a significant impact on the development of research and obtaining accurate observed data. In the analysis and reports of these institutions, almost half of the rain gauges installed in Brazilian cities are inoperative due to lack of maintenance, which makes it difficult to historically monitor precipitation by areas of the municipality and impairs medium and long-term planning to reduce damages caused by storms. The absence of accurate data can also affect the effectiveness of climate and hydrometeorology-related research and predictions. Rain gauges are equipment used by meteorologists and professionals who work in disaster response, such as the Fire Department and Civil Defense, to understand the intensity of a particular rain and minimize response time. Without access to this data, the ability to effectively respond to natural disasters is reduced. Knowledge of precipitation thresholds capable of increasing the possibility of disasters, such as landslides and floods, is an important tool to assist in disaster risk management and, consequently, to reduce socioeconomic losses during events related to landslides on slopes and during periods of heavy rainfall.[5]

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Closely related to equipment maintenance, the quality of data collected by meteorological stations can also be compromised and can represent substantial obstacles in using such data in research. Technical problems, such as sensor failures, can lead to errors in measuring precipitation. Interference in measurement, such as the presence of obstacles near the meteorological station, can distort the collected data. The effects of the wind, such as the dispersion of rain droplets, can also affect precipitation measurement, and human errors, such as instrument calibration failures, can compromise the quality of the collected data and cause researchers to use observed data with temporal gaps.[6] To solve these problems, it is necessary to invest in proper maintenance and monitoring programs that ensure proper operation and calibration of equipment. The availability of trained technical labor and sufficient financial resources are also fundamental to guarantee the proper maintenance of weather stations. In addition, it is important that there is awareness-raising work by the authorities responsible for maintaining these stations so that the population understands the importance of these instruments in collecting accurate data on precipitation and, consequently, in the safety of the population.

One of the challenges faced by researchers working with climate analysis and modeling in Brazil is the limitation of historical precipitation data, which are often only available for a few decades, limiting the ability to identify long-term trends and make accurate predictions for the future.[7] The limited availability of historical precipitation data is a problem that can negatively affect the quality of analyses of temporal and spatial variability of hydrometeorological processes. Additionally, the climate characterization of a given region may be impaired by the lack of reliable historical data. According to Wanderley, Amorim, and Carvalho[8] the use of series with gaps can lead to erroneous conclusions, presenting different patterns than those observed in the absence of faults. This can compromise the analyses of temporal and spatial variability of hydrometeorological processes, as well as affect the climate characterization of a given region. Long-term trend analysis is fundamental for climate modeling and for the development of public policies aimed at minimizing the effects of climate change. However, the lack of historical precipitation data can limit the accuracy of these analyses and, consequently, the effectiveness of climate-related public policies.

Some areas may have experienced significant climate and precipitation changes over time, but these changes may not be detected if historical records are not available, which can lead to inaccurate data interpretations and make it difficult to make informed decisions about water resource management and adaptation to climate change. Techniques used to fill precipitation data gaps can generate more consistent series needed for more detailed studies of possible climate changes and their implications for economic, social, and environmental sectors. They can also enable the incorporation of climate change in water resource planning processes, along with other sectoral policies, taking into account possible impacts that changes in rainy season patterns can cause at local and global levels.[9] Studies by Brubacher et al.[10] state that despite faults in extensive series harming studies related to urban and rural planning, to monitor extreme events that may impact society and assist in urban drainage projects aimed at reducing risks inherent to flooding and inundation, and engineering works such as dam sizing, methods for filling gaps such as weighting from Simple or Multiple Linear Regression, mathematical models based on machine learning, such as Artificial Neural Networks, spatial interpolators for gap filling (Inverse Distance, Natural Neighbor, Kriging), can help researchers mitigate these faults and contribute to the correction of missing data.

Another factor pointed out by the entities responsible for data collection and the Brazilian scientific community as a challenge in obtaining observable precipitation data is related to the destruction of weather stations, which causes great concern to this sector. Often, the population does not understand the importance of these instruments and confuses them with other types of monitoring technology, such as speed control radars or surveillance cameras. This can lead to the vandalism or destruction of weather stations by individuals associated with crime or simply by people who do not understand the purpose of the equipment or do not agree with the state's supervision of individual conduct in modern society.[11] Security measures can be taken to prevent the vandalism of meteorological stations, such as the installation of fences or placing the stations in safer and more difficult-to-access locations. In summary, the lack of maintenance, monitoring, and vandalism of meteorological stations are challenges that affect the collection of precipitation data and, consequently, the reliability of climate forecasts and the safety of the population. It is important that adequate investments are made in the maintenance and monitoring of these stations, as well as in awareness and security measures, to ensure the accuracy of the collected data and thus contribute to making more informed decisions regarding the safety of the population.

Conclusion

From the analysis of the challenges related to precipitation data collection in Brazil, it is possible to identify a series of obstacles that affect the quality and reliability of this information. The first challenge is the lack of investment in maintenance and monitoring of meteorological stations, which can lead to data loss and inaccuracy in weather predictions. It is crucial that there is a joint effort from the government, scientific community, and general population to ensure proper maintenance of these stations, in order to minimize the effects of the lack of investment. Another relevant challenge concerns the lack of observational precipitation data in certain regions of the country. In this case, it is necessary to seek solutions that allow for more efficient information collection, such as the use of satellites and other advanced monitoring technologies. However, it is important that these solutions are implemented in an integrated and coordinated manner, in order to ensure the accuracy and reliability of the collected information. Additionally, the importance of considering the spatial and temporal variability of precipitation data is highlighted, in order to identify patterns and trends that can help to better understand climate phenomena and their implications for the population. In this sense, it is necessary to invest in models and analysis techniques that allow for the exploration of the complexity of this data, taking into account regional differences and seasonal variations. Likewise, it is necessary to ensure the security of meteorological stations, avoiding vandalism and destruction by the population. Awareness and security measures should be adopted, such as the installation of fences and the choice of safer and more difficult-to-access locations for station installation. Only then will it be possible to ensure the collection of reliable data and the safety of the population. In summary, the debate among stakeholders indicates that precipitation data collection in Brazil faces a series of challenges that need to be overcome to ensure the quality and reliability of information. It is crucial to have adequate investment in maintenance and monitoring of meteorological stations, as well as in the adoption of more efficient data collection and analysis solutions. The consideration of spatial and temporal variability of data and the assurance of station security are also crucial aspects for the success of this endeavor. Only with a joint and coordinated effort will it be possible to overcome these challenges and advance in the understanding of climate phenomena, contributing to more assertive decision-making and the safety of the population.

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Conflicts of interest

I declare that there is no conflict of interest.

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