

HEAVY RAINFALL ASSOCIATED WITH NATURAL DISASTERS IN SOUTHEASTERN BRAZIL IN NOVEMBER-DECEMBER 2021: METEOROLOGICAL CONTEXT, TRENDS IN EXTREMES AND IMPACTS

Jose A. Marengo¹, Marcelo E. Seluchi¹, Ana Paula Cunha¹, Luz Adriana Cuartas¹,
Demerval Goncalves¹, Vinicius B. Sperling¹, Andrea M. Ramos², Giovanni Dolif¹, Silvia
Saito¹, Fabiani Bender¹, Tarcio Rocha Lopes³, Regina C. Alvala¹, Osvaldo L. Moraes¹

jose.marengo@cemaden.gov.br. Corresponding author

¹National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN), São Paulo, Brazil

²National Institute of Meteorology (INMET), Brasilia, Brazil

³Maringá State University, Environmental Department (UEM), Paraná, Brazil

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1) INTRODUCTION

Weather and climate-related disasters such as droughts, floods, landslides, storms are the main patterns of natural events in long-term weather cycles which are potentially affected by climate change. In addition, population clustering in vulnerable areas and unsustainable land use in urban and rural regions have increased vulnerability to natural disasters. Moreover, an accelerated urbanization process occurred at a chaotic and unplanned pace, and the outcome of a misdirected urban land use policy and an increasing frequency of weather extremes could not be worse. Flash floods, floods, and landslides represent 70% of natural disasters at the national level and 90% in the Southeast region of Brazil. This region that includes the states of São Paulo, Rio de Janeiro, Minas Gerais, and Espírito Santo, shows the highest total mortality rates due to natural disasters. The biggest cities are the metropolitan regions of São Paulo and Rio de Janeiro. From 2015 to 2019, the states in southeastern Brazil have experienced 1373 events of extreme rainfall (events with precipitation above 50 mm/hour). Of those, 730 occurred in the state of Sao Paulo (EM-DAT 2019). Therefore, a combination of heavy rainfall and high population density living in vulnerable areas is a killer recipe for natural disasters, resulting in fatalities and displaced people (Ramires and Mello-Thery 2018).

From November 2021 to the end of December 2021, heavy rainfall affected the southern region of the State of Bahia (SBA) and the northern section of the state of Minas Gerais (NMG), causing widespread floods and resulting in a relatively lower number of casualties compared to the intensity of the event. Heavy rainfall has caused significant flooding and river overflow since November 2021. In Bahia, 17 municipalities reported emergency state due to a dam collapse followed by flooding on December 23th and after. The SBA and NMG regions suffered by the end of 2021 from the consequences of the floods: houses, schools, hospitals, and other infrastructures have been destroyed and damaged, along with other losses and fatalities among the population, and 600 houses were destroyed by the flood. Therefore, this paper provides a comprehensive analysis of the observed meteorological and hydrological features of the November-December 2021 heavy rains that affected the vulnerable areas of SBA and NMG.

2) THE WEATHER-RELATED DISASTERS OF SBA AND NMG IN NOVEMBER-DECEMBER 2021

Rainfall peaks in December-January in NMG and SBA maximum occurs in March-April. So, the SBA's heavy rainfall events in November and December 2021 were atypical in terms of timing and intensity. In December 2021 rainfall anomalies show more than 200 mm above average. From December 22th to 29th, some atmospheric trough episodes occurred in the coast of the state of Bahia, in addition to the convergence of moisture in the middle and lower layers coming from Amazonia and evaporation from a warmer tropical South Atlantic off the coast of the State of Bahia provided more rainfall to SBA.

For both NMG and SBA, the wettest period was 22th-26th, and for NMG, it was also very wet on 27th-29th. These were the periods were the ones that experienced floods and landslides with the higher number of fatalities among the population. The circulation fields show a favorable meteorological situation for intense convection and upward vertical motion moisture convergence along the SACZ on 22th-29th December, in a moister atmosphere with extensive contents precipitable water-saturated soil. The overall meteorological situation was embedded in a rather barotropic pattern, including a wide, warm anticyclonic circulation over southern South America and cyclonic circulation over Southeastern South America and the region under study with an almost vertical structure placed at high latitudes and an intense cold cyclone located on the Atlantic Ocean east of the southern region of Brazil. Due to the barotropic nature of the general situation, different forcings were acting for several days, yielding significant humidity anomalies allied to continuous vertical movement and large areas of low-level convergence, which are fundamental factors to cause persistent and abundant precipitation. In addition, low-level 850 hPa circulation northwesterly wind anomalies allowed persistent anomalous moisture transport from the Amazon to the region of interest. This flow contributed to strong precipitable water anomalies, upward motion, strong convection, heavy rainfall in the region and wet soil (Marengo et al 2022).

4) IMPACTS

In December 2021, while rainfall was alternating between the two regions in November and December, it was during the last week of December when the most abundant rainfall affected the SBA-NMG region. Unfortunately, more disasters occurred due to soil saturation from previous intense rainfall events that triggered the floods and landslides that left fatalities and substantial economic damage in the region. The impacts recorded in Minas Gerais and Bahia highlight the pre-existing conditions of vulnerability related to socioeconomic, structural, and institutional aspects. Floods destroyed and damaged houses, schools, hospitals, and other infrastructure in November and December 2021 in the southern region of Bahia and the northern part of the State of Minas Gerais. The total affected population is estimated to be 815,597, with 101,256 people in need, 517 people injured, and more than 90,000 displaced in approximately 277 Municipalities (Web Relief 2022). During that period, the heavy rains in southern Bahia continued to claim victims across the state, two dams broke due to the storms, and dozens of cities are still entirely flooded. In addition, rescue and relief operations have been highly complex and time-consuming due to flooding on roads and the continuation of rains in the region. Furthermore, sanitary conditions were severely compromised with the risk of disease outbreaks; schools were used as shelters jeopardizing safe return to education (Web Relief 2022, UNICEF 2022).

The Ministry of Economy estimated losses due to disasters in Bahia and the Minas Gerais States from October 1st to January 17th, 2022, of the order of 15.4 billion Reais (about 3.1 US billion). Housing and infrastructure on the floodplains reveal the high exposure of people and assets. It is essential to highlight that the affected areas are formal and non-formal occupations authorized by the local governments to be occupied. It is also noteworthy that the rains severely

affected rural areas, especially for small producers and traditional populations. In addition to the destruction of plantations, many houses were also affected.

5) CONCLUSIONS AND RECOMMENDATIONS

Due to its higher population density and hundreds of thousands of households sitting on unstable slopes, Southeast Brazil has the highest total mortality rates. Although extreme rainfall frequently occurs in this region during the wet summer season, these events can affect thousands of residents and leave financial loss through the cascading effects of flooding and landslides. The number of deaths consequence of this disaster in December 2021 was relatively lower if compared with the heavy precipitation amount concentrated in a few days. In January 2011 in the highlands of Rio de Janeiro, it rained 460 mm (climatology for January: 230 mm), and the heavy rainfall sparked flash flooding and mudslides across the highlands, devastating mountain towns, and the floods and landslides claimed the lives of 916 people and left 35 000 people homeless. In December 2021, heavy rains have triggered deadly floods and landslides across much of Brazil, threatening to delay harvests and briefly forcing the suspension of mining operations in the state of Minas Gerais, just north of Rio. The heavy rainfall in southern Bahia and northern Minas Gerais on 22nd -29th December 2021 led to floods and landslides that took the lives of 33 people, and rainfall and rained 500 mm in 48 hours that period, being the January climatology of 200 mm.

The above situations show that compared to January 2011 in Rio de Janeiro, in the recent extremes of heavy precipitation in 2020-2022, while the rainfall amount was much higher, the number of deaths was lower. This fact could be partly attributed to the accuracy of weather forecasts and the occurrence of intense SACZ with days in. The recent disasters in 2021 and 2022 claimed fewer lives than 2011 because CEMADEN had informed the Civil Defense well in advance of the risk of landslides and flash floods and then acted at the municipal Civil Defenses. Without it, the number of deaths would be many times higher. In addition, after 2011 and after CEMADEN's implementation, the monitoring of risk conditions was improved by deploying the CEMADEN's network in risk areas in Brazil. With that, it was possible to measure rainfall at the municipal level better providing a better picture of the meteorological/hydrological situation so extreme heavy rainfall could be identified and monitored. As a result, the risk of disasters was better predicted. This was not the reality in 2011.

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