



ASSESSMENT OF A REAL-TIME FLOOD FORECASTING AT THE DOCE RIVER BASIN: SUMMER 2013 EVENT

A.J.S. Matos¹; E.G. Davis¹; A.J. Silva¹ I.S. Almeida¹ M.O. Candido¹
1. Geological Survey of Brazil (CPRM)

ABSTRACT: The Geological Survey of Brazil- CPRM manages a flood warning system in the Doce river basin, which is located in Southeastern Brazil between the states of Minas Gerais (MG) and Espírito Santo (ES). In summer of 2013 the worst flood that happened was on city of Colatina-ES. This town suffered the second greatest flood in the recorded history. It was observed that the active atmospheric events in this period were SACZ (South Atlantic Convergence Zone) and HCZ (Humidity Convergence Zone). The study of the rainfall in this basin has shown that in some places it rained four times more than expected, such as the region near the city of Rio Bananal, which registered an accumulated rainfall of 942mm for December 2013. The historical average (1977-2006), according to CPRM (2014), for this region is 206 mm of rain for the month of December, so it rained 457% of expected rainfall. The Rio Bananal monitoring station, located in this city, recorded a rainfall of 280mm in just one day. During this period, 79 hydrological warning bulletins were issued by CPRM. For the real time forecast in Colatina city was used a discharge-discharge model, which provides a pretty accurate level of the river with six hours in advance. The data used as input in the model comes from an automatic telemetric station. The Rio Doce basin system warning completes 17 years of operation in this rainy season of 2013/2014 and it has been crucial in the flood warning for cities monitored, minimizing the negative impacts of floods during critical events.

Key Words: Real-time forecasting, Flood , Doce River basin, CPRM

1. INTRODUCTION

CPRM (Companhia de Pesquisa de Recursos Minerais), the Brazilian geological survey company, monitors the Doce river basin, located in the country's southeast region, between Minas Gerais and Espírito Santo states. Flooding is frequent between December and March, throughout the rainy season in the Brazilian southeast. Thus, a partnership has been established in 1997 between CPRM and the national water resource authority (ANA – Agência Nacional de Águas), along with Minas Gerais meteorology and water resources institute (IGAM – Instituto Mineiro de Gestão das Águas), to operate a flood early warning system for the Doce river basin. The system provides forecasting on flood conditions to 15 municipalities¹ that have urban occupation by the main channel of the rivers Piranga, Piracicaba and Doce (CPRM, 2009).

The most recent flooding event, which took place in December 2013, reach Governador Valadares, Tumiritinga, Colatina and Linhares, at the middle and lower parts of the Doce river basin. The event, concentrating in the second half of December 2013, is one of the largest floods on record for the cities of Colatina and Linhares. The early warning system equipment and personnel were able to monitor all the flooding events in that period, of which we selected two to describe in more detail in this paper.

¹ Ponte Nova, Nova Era, Antônio Dias, Coronel Fabriciano, Timóteo, Ipatinga, Governador Valadares, Tumiritinga, Resplendor, Galiléia, Conselheiro Pena and Aimorés in Minas Gerais, and Baixo Guandu, Colatina e Linhares in Espírito Santo

2. DOCE RIVER BASIN PHYSICAL SETTING

The Doce river basin, in the Brazilian southeast, drains about 83,400 square kilometers, 86% of which in Minas Gerais state, and the remaining 14% in Espírito Santo. Figure 1 shows its location (CPRM, 2009).

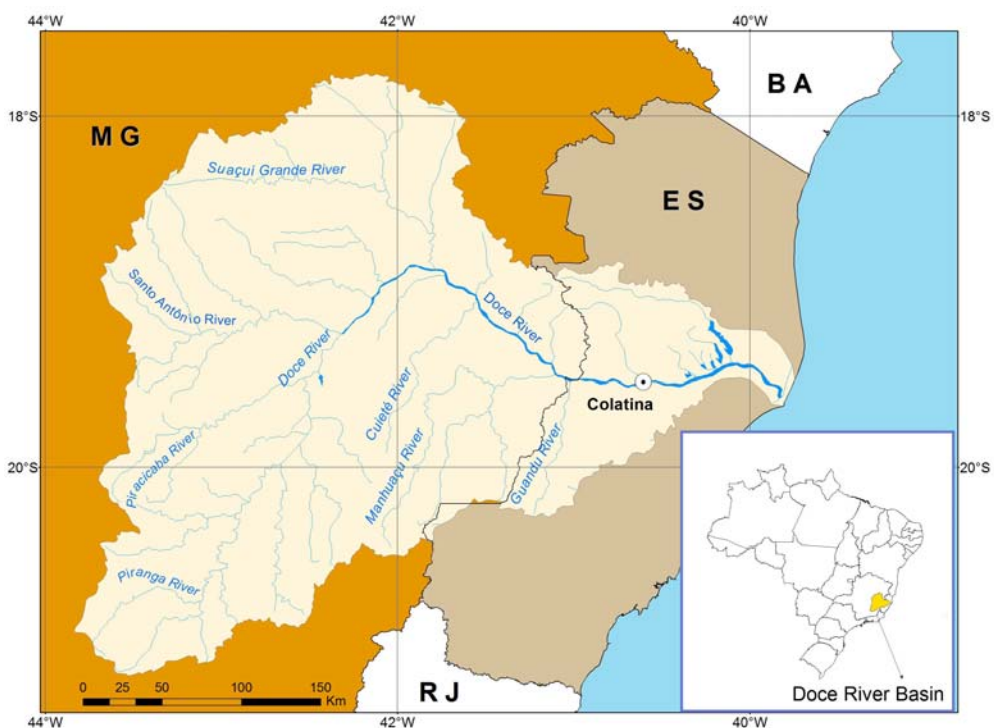


Figure 1 – Doce River Basin and Colatina city location

Doce river originates in the Mantiqueira and Espinhaço ranges, in Minas Gerais, and runs for 853 km towards the Atlantic, at the Regência settlement in Espírito Santo. Its main tributaries are, to the left, the rivers Carmo, Piracicaba, Santo Antônio, Corrente Grande, Suaçuí Grande, São José and Pancas, and to the right the rivers Casca, Matipó, Caratinga/Cuité, Manhuaçu, Guandu and Santa Joana (CPRM, 2009).

Colatina is one of the major cities of the state of Espírito Santo, situated on the banks of the Doce River. It has 120,677 inhabitants according to IBGE estimates for the year 2013.

3. THE FLOOD EARLY WARNING SYSTEM

The Doce basin flood early warning system operates 24 hours a day during the rainy season (December to March). Hydrometeorological data are collected from 45 stations throughout the basin. Such data are stored and analyzed, so that weather and water level forecasts can be produced and distributed to municipal authorities by e-mail. Such data and forecasts are also disseminated through a Web site. The system's team includes hydrology engineers, meteorologists, field teams and technicians that engage in a shift work schedule around the clock, including weekends and holidays. Figure 2 illustrates the system's operating steps.

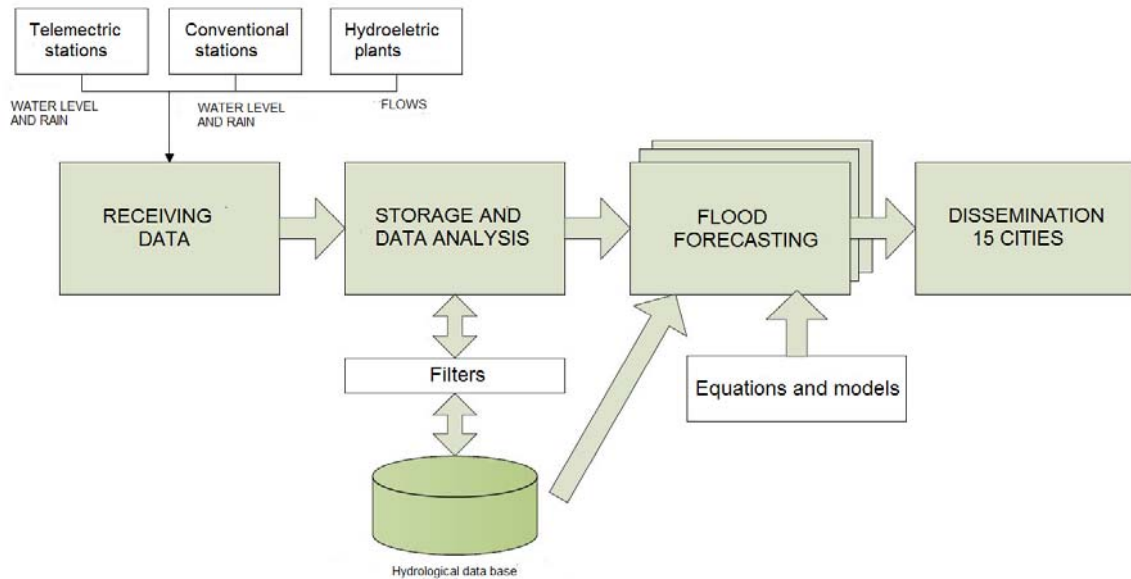


Figure 2 – Early warning system workflow

In some of the cities, deemed strategically important for the system, warning and flooding water levels were determined in the field. For the flooding level, topographic surveying determined the height at the city's lowest flooding point. Warning levels were then determined considering the water level rising times as measured in the January 1997 flood, obtained every 12 hours. The resulting warning level is set at least 40 centimeters below the flooding level (CPRM, 2003). The warning and flooding levels define the system's status. Normal operation occurs when water is below the warning level, and alert operation begins when warning levels are reached.

4. DEVELOPMENT

4.1 The rainy period 2013/2014

In the rainy period 2013/2014 the 24-hour operation of the flood warning system of Doce River basin started on November 25, 2013. Among the cities monitored, the flood event that occurred in December 2013, reached the cities of Governador Valadares, Tumiritinga, Colatina and Linhares.

In the Colatina city has been recorded two events where the river level has exceeded the flood level. In the first event, December 18 to 20, 2013, the river level rose about 2.6 meters above the flood level, where the first properties are achieved. The second event, December 21 to 28, 2013, was the second largest recorded in all available historical data series. In this event the river rose 4.0 meters above the flood level (Figure 3).

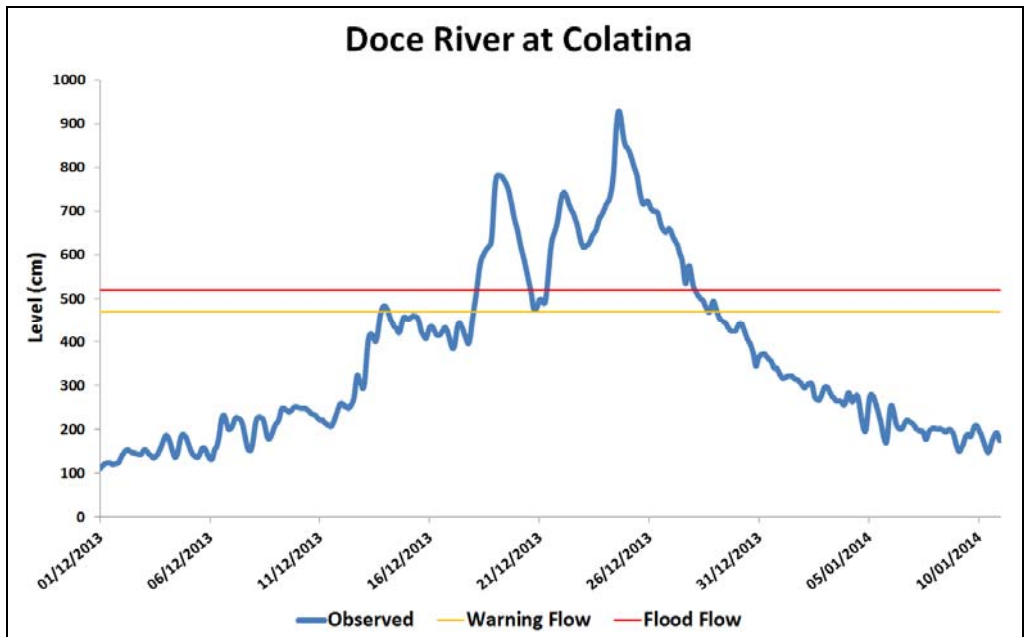


Figure 3 – River level at Colatina during the 2013/2014 flood event

During critical events, the CPRM staff has issued extraordinary bulletins with flood warnings. The hydrological forecasts performed used the data from the real-time automatic hydrological stations and the information collected from the HPP's (hydroelectric power plants) installed in the watershed. In addition to provide information via the web, the staff makes contact with the fire department and the Civil Defense. In December 2013, 93 boletins were issued.

In this period the Doce River in Colatina reached the 929 cm level and a discharge of 9196 m³/s. The recurrence interval for this event is greater than 70 years.

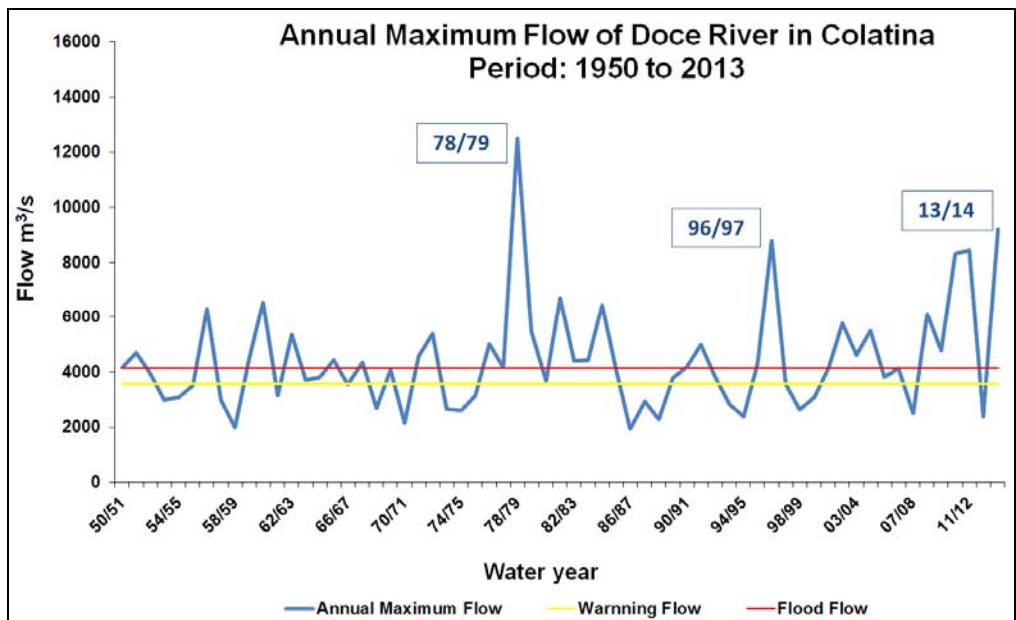


Figure 4 – Annual maximum flow of Doce River at Colatina based on historical data.

4.2 Analysis of weather systems

A system called HCZ (Humidity Convergence Zone) has configured on 12/11/2013, which initially has acted the southern state of Minas Gerais and the southern state of Rio de Janeiro and later shifted to the north acting on the state of Minas Gerais, northern Rio de Janeiro and southern Espírito Santo. On 12/18/2013 the HCZ intensified and turned into a SACZ (South Atlantic Convergence Zone), a system more intense than the previous, acting until 12/25/2013. After that, this moisture path, has returned again to be called HCZ until 12/27/2013 (CPTEC/INPE, 2014).

This moisture path acted between December 11 to 27, 2013, affecting mainly the eastern of the state of Minas Gerais state and the central area of Espírito Santo state. Can be seen in Figure 5 the SACZ over the eastern in the state of Minas Gerais and Espírito Santo. This area was the most affect by this event of flood.

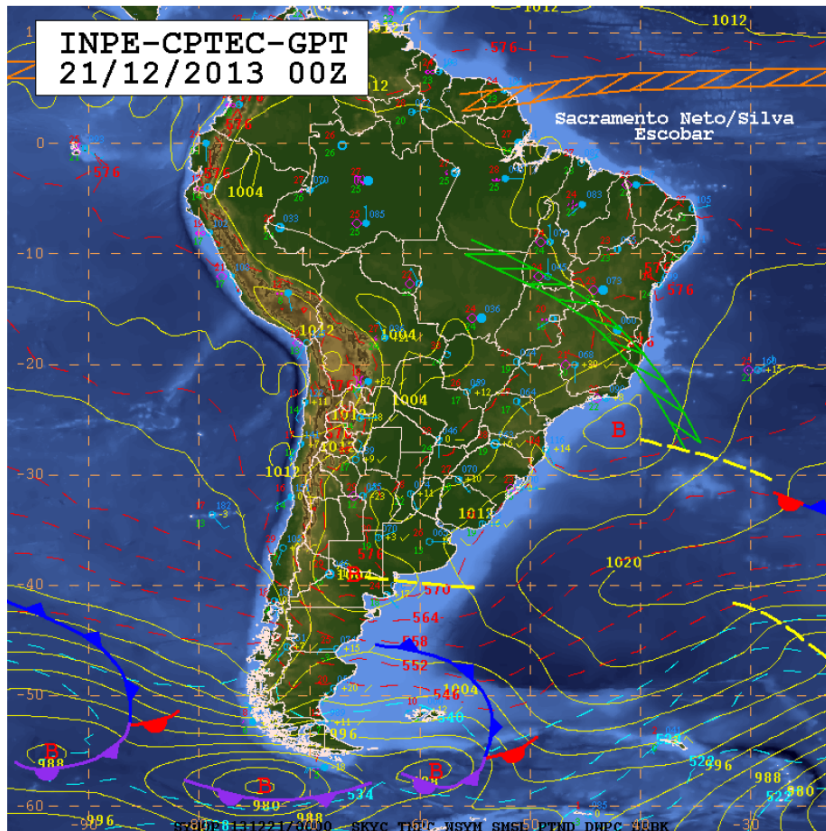


Figure 5 - Synoptic Analysis of the day 12/21/2013 (Fonte: INPE/CPTEC/GPT)

The infrared satellite image of the day 12/21/2013 at 0 hours (Figure 6) shows the cluster of clouds over the most affected region.

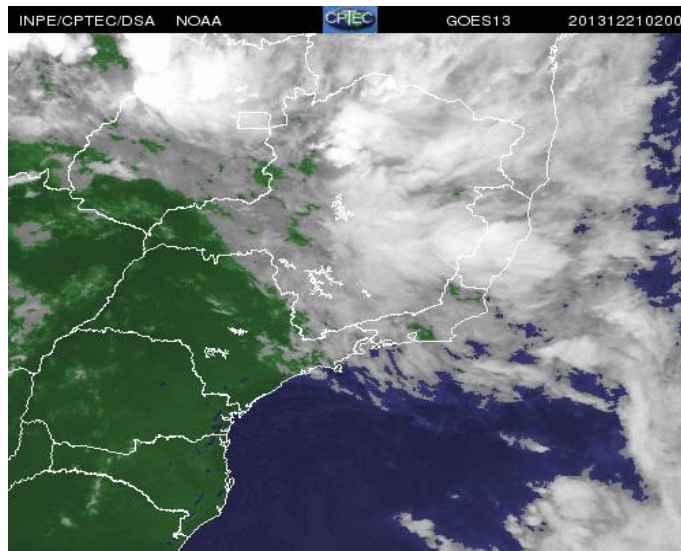


Figura 6- Weather Satellite Infrared Image - Dec 21th 2013 02:00Z - Southeastern Brazil (Source: INPE/CPTec/DSA)

4.3 Rainfall Analysis

Using the rainfall data of 176 gauge stations of Hydrometeorological Brazilian Network, operated by CPRM, were built maps of rainfall from the beginning of the rainy season for the hydrological year 2013/2014. The December 2013 rainfall map is shown in Figure 07.

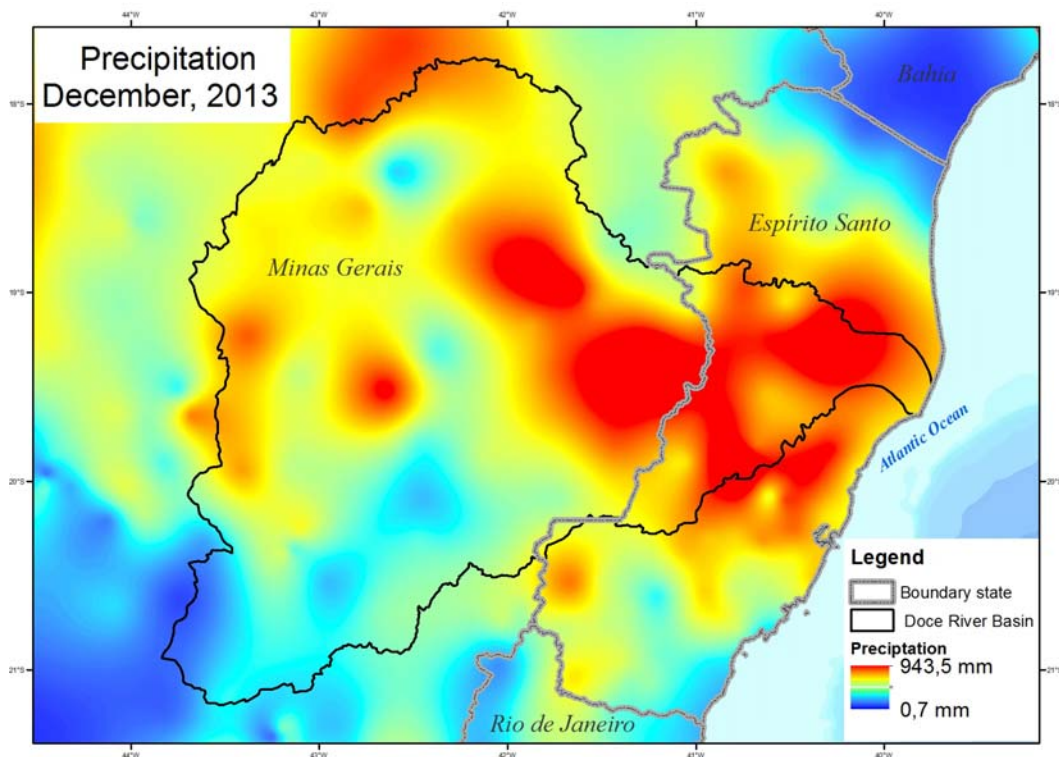


Figure 7 - Total rainfall in December 2013.

It can be observed that the greatest total rainfall recorded in the month of December 2013 occurred in the middle and lower part of the Doce River basin. In this region, the rains caused flooding and landslides in several districts of eastern Minas Gerais and Espírito Santo.

The comparison of historical average and total rainfall observed is shown in Figure 08. The anomaly precipitation in December 2013 exceeded the expected considering the eastern portion of Minas Gerais and central area of Espírito Santo, while in other regions the accumulated rainfall shows below the average.

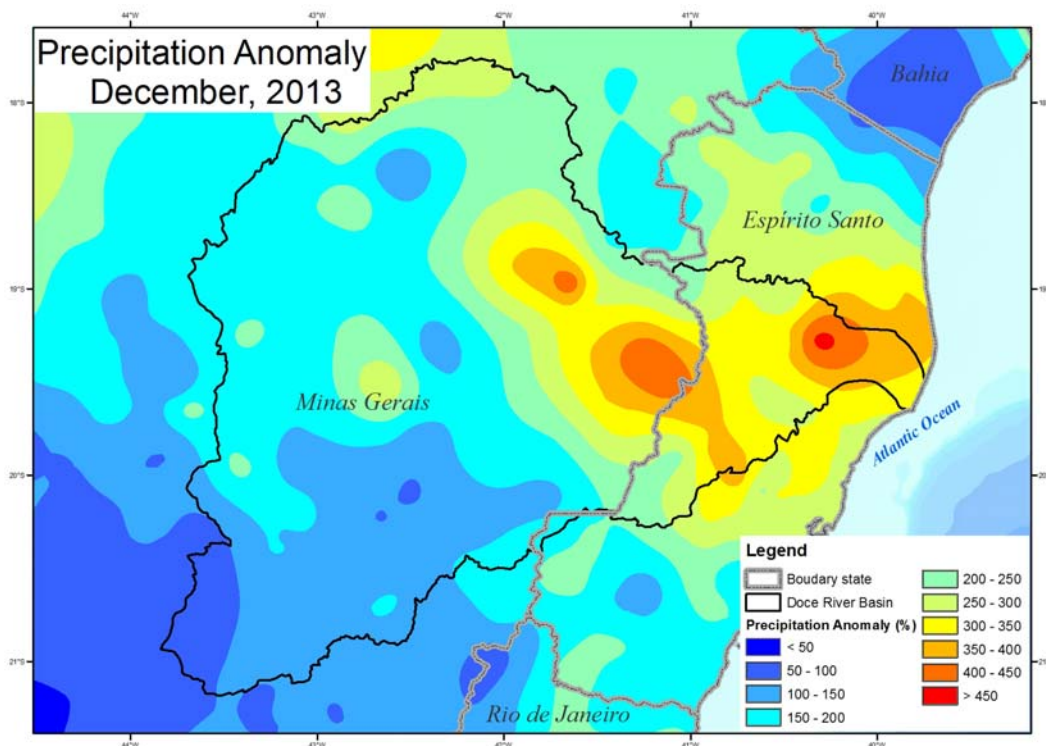


Figure 3 - Precipitation anomaly for December 2013, expressed in rainfall percentage in relation to the observed data of stations operated by CPRM and the historical average for December for 1977-2006 (Rainfall Atlas of Brazil, CPRM). The value of 100% represents that the observed precipitation is within the average of the time series.

In some basin areas has rained four times more than expected, as like around the region of Rio Bananal City, which registered a 942mm cumulative rainfall for the month. The historical average (1977-2006), according to CPRM (2014), for this region is 206 mm for December, so it rained 457% the expected. The Rio Bananal rain gauge, located in this city, recorded a rainfall of 280mm between 7am of December 16 to 7am of December 17.

In Caldeirão station was recorded, in four consecutive days, more than 90mm rainfall (126mm , 122mm , 93mm and 120mm) between 20 and 24 of December.

The highest rainfalls recorded were between 17 to 24 December. On 21 December 13 stations has recorded rainfalls above 100mm , five were above 150mm .

The highest rainfall values recorded for December were on Rio Bananal station, Resplendor Jusante and Caldeirão, with 942mm , 936mm and 909mm respectively.

5. CONCLUSION

The SACZ (South Atlantic Convergence Zone) was the weather system that caused significant accumulated rainfall, well above the historical average in the eastern portion of the state of Minas Gerais and central portion of the state of Espírito Santo. This system was the causative agent of the severe flooding that occurred in the town of Colatina and in other cities nearby.

The Warning System of the Doce River basin completed 17 years of operation in this rainy season of 2013/2014 and has been essential for the monitored cities, minimizing the negative impacts of floods during critical events.

6. REFERENCES

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