A SEVERE CONVECTIVE EPISODE TRIGGERED BY ACCUMULATED PRECIPITATION IN THE COAST OF PARANÁ STATE, BRAZIL

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I. INTRODUCTION

Paraná State, Southern Brazil is a prone area to severe weather events, such as intense precipitation, lightning activity, hail and tornadoes: from 1980 to 2006 the state registered 2,446 natural disasters, 71% of which caused by precipitation (IPMet, Banco de Dados, Desastres Naturais). In addition, Paraná is amongst the Brazilian states that register more tornadoes and the risk to such phenomenon next to the coast is considered high: between 12 and 15% per year (Candido, 2012).

However, March of 2011 will be sadly remembered by population who lives next to the Paranaguá Bay: an unusual combination of meteorological conditions favoured the intensification of rainfall along the cost of Paraná State and harshly impacted the area, in special two towns: Antonina and Morretes (Figure 1).

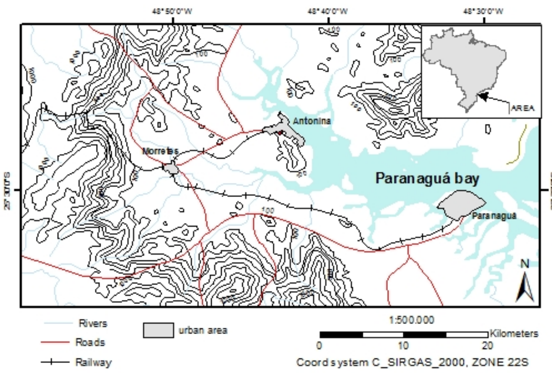

FIG. 1: Affected area (Morretes and Antonina)

Source: J. de Lima Picanço

Although previous flooding, mud flow and debris-flow events have occurred throughout the region, residents declared the episode was the major disaster caused by precipitation ever. Nonetheless, Vieira dos Santos (1951) described two similar events in 1796 and 1846: the author mentioned that the waters of Paranagua Bay became red due to the massive presence of fine sediments, fact also observed in this recent episode (Figure 2).

FIG 2: Sediments carried to Paranaguá Bay changed the colour of the water

Source: Renato E. Lima (UFPR)

The severity of the event of March 2011 can be attested by the high accumulated rainfall concentrated in a relatively short period, the extension of the affected area, and the associated impacts, among them land degradation in watersheds and severe disruption in road network, water supply, electricity and telecommunication systems. The area remained isolated by road access for a couple of days due to the collapse of various bridges and it was estimated that 16 million people were affected, as the region is an important connection of Southern Brazil to the rest of the country. Operations of Paranaguá Port, one of the most important of Brazil, were also affected.

The event left 4 people death, another 221 injured, 2 persons missed and around 33,000 displaced; in addition, partial economic losses were around US$63 million. Major damages forced the government to declare the state of calamity in Antonina and Morretes and state of emergency in Paranaguá and Guaratuba - other affected towns (Civil Defense, State of Paraná). Figures 3a, 3b and 3c illustrate the extension of the devastation.

FIG 3a, 3b and 3c: General outlook of impacts in Antonina and Morretes, Paraná State

Sources: Jefferson de L. Picanço (IG-UNICAMP) and Renato E. Lima (UFPR)

II. PRESENTATION OF RESEARCH

The Paranaguá Bay is a flat narrow zone in the western side of Serra do Mar Escarpment. Precipitation in the area is mainly associated with convective activity especially during summer, cold fronts and cyclones that can develop in the region due to the presence of cyclonic vortices or troughs at high levels, mesoscale convective systems and local circulation such as breezes. Severe weather episodes, in particular, are largely connected with extra-tropical cyclones, mesoscale convective systems, upper level jets and frontal systems (Beneti et al., 2013).

March of 2011 registered a quite heavy episode of mass movements and floods triggered by concentrated precipitation. The largest impacts occurred on 11th. March, but the accumulated rainfall of the precedent days contributed to the severity of the event: from Table 1 one can see that 3 locations registered accumulated above 600mm in 12 days only.

	1-10 March (mm)	11 March (mm)
Paranaguá	230,0	84,0
Marumbi	411,8	164,0
Antonina	263,0	98,6
Morretes	386,0	230,6
BR277 km35	384,6	236,8
BR277 km41	391,6	213,6
BR277 km48	384,8	199,0
Guaricana	292,8	137,8
Salto do Meio	306,4	155,2

TABLE 1: Accumulated precipitation from 1-11 March 2011 for selected stations in the coast of Paraná state.

Source: SIMEPAR

III. RESULTS AND CONCLUSIONS

By Figure 4, which illustrates the monthly accumulated totals for 2011 in Paranaguá station compared to the normal period of 1961-1990, one can confirm that precipitation volumes were above the average from January to March, especially in March. The role of accumulated volumes in triggering mass movements was discussed by Guidicini and Iwasa (1977), Nunes et al (1989) and Guzzetti et al (2007), among others.

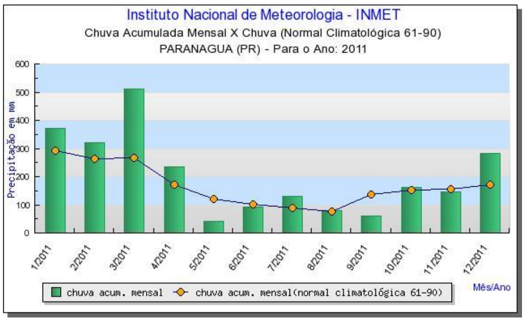

FIG 4: Monthly totals of 2011 in comparison to the normal of 1961-1990 period for Paranaguá station

Source: INMET

The event was connected to a convective activity associated with an eastward instability which remained in the coast and a trough with high gradient and considerable instability at different levels. Strong differential thermal advection contributed to the increase of instability over the location; the intense pressure gradient in the Atlantic Ocean associated with the subtropical anticyclone generated strong winds which promoted the transport of moisture from the ocean to the continent and thus a vast cloud cover remained in the area and contributed for the heavy and continuous precipitation (Figure 5).

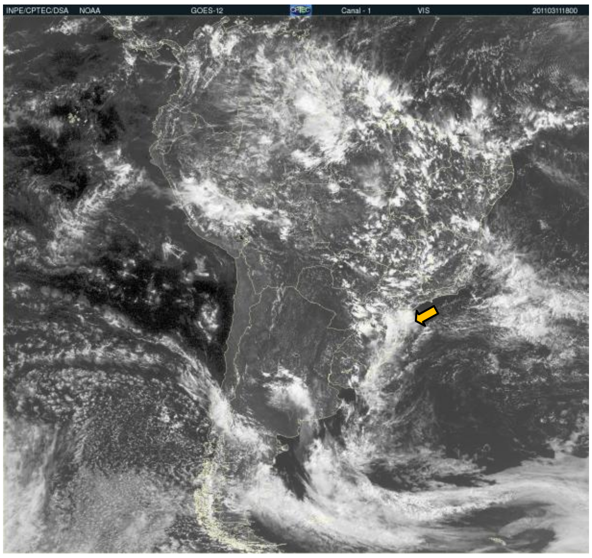

FIG.5: Visible satellite imagery showing a vast cloud cover in Paranaguá Bay, 11 March at 18UTC.

Source: CPTEC

Top cloud temperatures were not too low (Figure 6) and values of CAPE were not very high, but temperatures were close to the dew point due to the high instability and associated humidity.

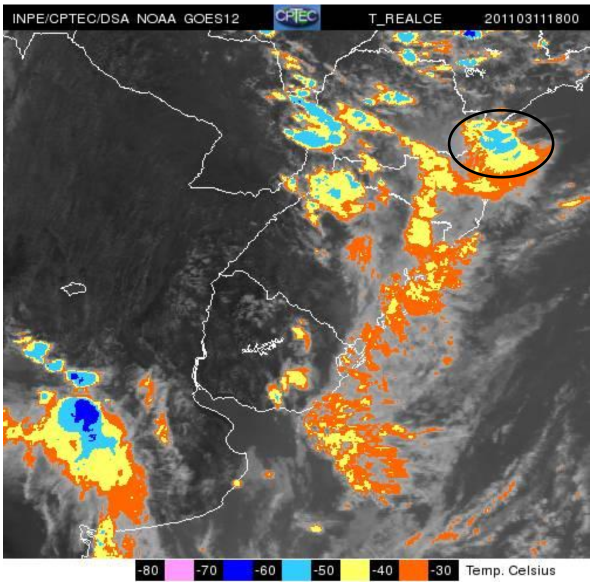

FIG 6: Cloud top temperature on 11 March 2011 at 18UTC.

Source: CPTEC

The consequences of the instability were massive landslides and floods. The process initiated as translational slides in the steepest slopes of the area with different material according to the litotypes such as soil, debris (soil with pieces of rock), large trees and rocks. Huge volumes of coarse and fine sediments were deposited in different locations, such as the base of slopes and channels and part of the material reached the Paranaguá Bay, which promoted in turn major floods in the lower areas. Rotational and translational slides of earth and rock were observed, as well as mud flows, which are very slippery.

Due to the inherent atmospheric and geomorphological characteristics of the region, similar episodes are expected to hit the area in the future. Therefore, a set of measures for avoiding imminent disasters must be put into effect, including the establishment of rainfall thresholds, i.e., totals of precipitation that when exceeded can provoke landslides and/or floods, efficient warning systems based on the potential of rainfall expected, continuous evaluation of the regolith (result of rock weathering) as well as regulation of the land use.

Risk evaluation is central for reducing the negative effects of landslides and requires the understanding of the ways in which previous episodes occurred (assessment of landslide density and temporal and spatial recurrence). Notwithstanding, scenarios of climate change shows that both frequency and intensity of heavy rainfall indices are on increase in Southern Brazil and climate change is expected to augment the variability of rainfall episodes (Marengo, no date), which may lead to even more intense and frequent disasters. In addition, the area is under constant pressure due to its locational advantages, linking Paranaguá Port and the Southern Region of Brazil to the rest of country. Therefore, there is a tendency to decrease the threshold stability of the area and all these aspects must be considered.

IV. ACKNOWLEDGMENTS

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