

# Regions of Occurrence of Natural Disasters by Sudden Flood and Drought on Rio Grande do Sul from Period 2003 to 2009

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**Abstract** This paper aims to carry out a mapping of natural disasters, droughts and gradual floods, occurring in Rio Grande do Sul (RS) state from period 2003 a 2009. Records of the events were obtained by State Civil Defense Authority to analyze the preferential period for these occurrences and the most affected areas. The results show that regarding the gradual floods, the areas of RS most affected were Depressão central (35%), the lowlands of Planalto Médio (18%), Alto Uruguai (14%), Encosta inferior do Nordeste (10%) and Missões (9%) regions. For the drought was observed that the Alto Uruguai region was the most affected (38% of the events), accompanied by Planalto Médio (19%), Missões (11%) and Depressão Central (11%) regions. The period between the finish of spring season and begin of the summer season were the preferential for the occurrences. Also was found that droughts and gradual floods did not occur only in years with presence of El Niño and La Niña climatic events. It's also occurred in periods without the influence of these phenomena (neutral years).

**Keywords** Natural Disasters, Droughts, Flood, mapping, Adverse Events

## 1. Introduction

According to the Civil Defense Glossary, Risk Studies and Disaster Medicine (2001), disasters are the result of processes (events) natural or anthropogenic (man-made) acting on a certain place, causing human damage, environmental / materials, and of economic and social losses. Natural disasters (ND) could be said to be the sum of natural events (NE) and the vulnerability of a place (V);  $ND = EN + V$ . Abrupt and gradual droughts and floods are among the natural disasters that occur most commonly in Brazil, especially in Rio Grande do Sul.

Data for Brazil from the Center for Research on the Epidemiology of Disasters at the Catholic University of Louvain, Belgium (EM-DAT), show that between 2000 and 2008 natural disasters such as floods, droughts, landslides, cold waves and extreme heat were responsible for the deaths of hundreds of people, achieving economic losses that exceeded four billion US dollars. These data show that natural disasters in Brazil tend to be associated with climate instability and are therefore have an atmospheric origin,

(Santos, 2007).

There is evidence that over the last few years the rainfall and extreme weather events have increased in intensity and frequency on a global basis. According to some researchers, this may be related consequence of human actions Such as rapid urbanization of cities, soil sealing, deforestation and silting of rivers, poor planning and use of watersheds, increased air pollution, etc.

According to the Intergovernmental Panel on Climate Change (IPCC, 2007a, b, Marengo et al, 2009), "... in many parts of South America, the frequency of precipitation events has increased, consistent with heating, and various regions, changes in temperature extremes have been observed over the last 50 years." Severe droughts events have been a recurrent event for much of the Brazilian population, especially in the densely populated South region which is highly dependent on the availability of water to feed its productive industries. Droughts can cause serious impacts on society and severely affect various economic spheres of the region such as agriculture and energy generation. The objective of the current study is to create a zoning for natural disasters, droughts and sudden floods that occurred in the state of Rio Grande do Sul (RS) between 2003 and 2009, based on notifications (instances) of the state civil defense.

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## 2. Methodology

Rio Grande do Sul (RS) is located in the extreme south of Brazil and adjoins Santa Catarina (SC) state to the north, Uruguay to the south, Argentina to the west, and the Atlantic Ocean to the east (Figure 1). Among the major weather systems that affect and determine the occurrence of natural disasters that State are cold fronts and mesoscale convective systems (MCS). At a larger scale (hundreds to thousands of kilometers), RS is influenced by ocean-atmosphere interactions such as El Niño and La Niña - which are characterized, respectively by heating and cooling of the waters of the equatorial Pacific Ocean, and which directly influence the frequency and severity of floods and severe drought in southern Brazil.

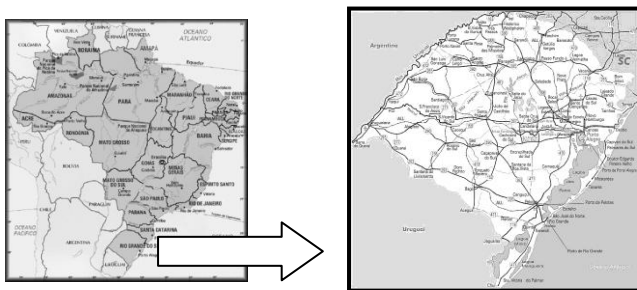


Figure 1. Map with Rio Grande do Sul (RS) state

For this study we used information on droughts and sudden floods between 2003 and 2009 in Rio Grande do Sul. Data were obtained from the RS State Department of Civil Defense, which collects and collates information from municipalities on the occurrence of adverse events (whose intensity can make the council decree Emergencies - SE).

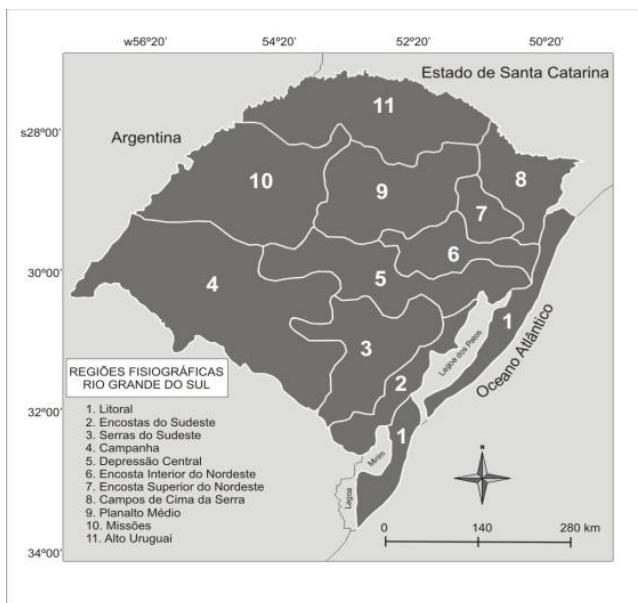


Figure 2. Physiographic regions of Rio Grande do Sul. Source: SEMA/RS

The data were organized and selected according to the types of events and the dates of occurrence, in order to analyse the monthly and annual frequencies, and the periods

in which they occurred. Likewise, the most affected regions and municipalities most affected during the study period were identified for each disaster event. In defining the zoning we used physiographic regions of the state, which were defined according to their geo-environmental characteristics (SEMA, 2010). A physiographic map of RS was constructed, which was used to rank the municipalities affected by drought and sudden flood events (Figure 2).

## 3. Results

The frequencies and the preferred regions of occurrence by sudden flood events (a) and dry (b) in Rio Grande do Sul, between 2003 and 2009 are showed in Figure 3. Among 1972 natural disaster occurred, the drought episodes caused the biggest problems, i.e., affected most municipalities (1292) to report emergency situation, such is the gravity of the situation.

### 3.1. Sudden Flood Events

Figure 3 shows the recorders of events that affected RS from years 2003 to 2009. It may be noted that these events occurred predominantly during spring season. The month of December showed the highest number of sudden flood events (54 events), after the months of September (19 events) and October (18 events), respectively (Figure 3b). The beginning period and finish of the seasons was based on dates: Autumn - March, 20<sup>th</sup> to June, 19<sup>th</sup>; Winter - June, 20<sup>th</sup> to September 20<sup>th</sup>; Spring - September 22<sup>th</sup> to December 20<sup>th</sup>; Summer - December, 21<sup>th</sup> to March, 19<sup>th</sup>.

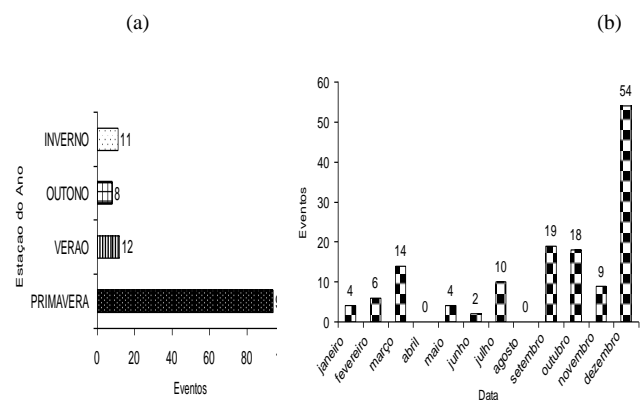
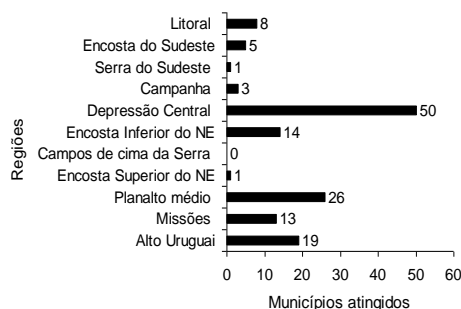


Figure 3

Figure 4 shows the spatial distribution of sudden flood events in Rio Grande do Sul. As opposed to what happened with drought events (presented later), sudden floods affected several regions of the state. Almost half of these episodes (50%) settled in the municipalities of Depressão Central, lower Northeast Hill and Hill southeast, which are characterized by slightly rough and inclined topography at altitudes lower 100 meters (Fortes, 1954). Other regions frequently affected by the floods were lower areas of the Planalto Médio (18%) and Alto Uruguai (14%).



**Figure 4.** Spatial distributions of sudden flood in Rio Grande do Sul state. Period 2003 a 2009

The annual distribution of sudden floods in Rio Grande do Sul is shown below (Figure 5), it appears that there is a higher incidence of these adverse events in the years 2003, 2007 and 2009 (86%), which represents almost all the episodes recorded in RS: 49 (2003), 31 (2007) and 40 (2009). The events of sudden floods were registered in both years of influence of ENOS phenomenon - El Niño/ La Niña events - and thermal neutrality years (2003, 2005 and 2008). For example, sudden floods (49) occurred in early 2003 (January, February and March) were influenced by the presence of El Niño (2002-2003), however, the events of end of this year (December) happened without the presence these phenomena (as shown in table 1).

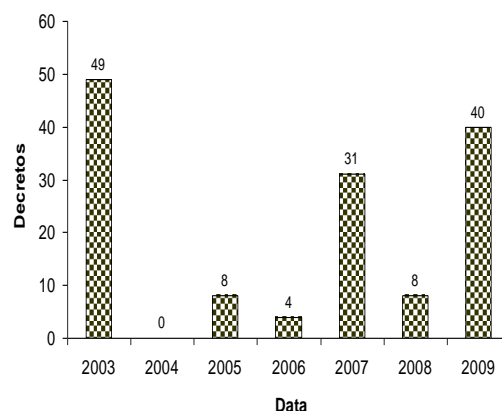
**Table 1.** Sea Superficial Temperatura (SST) Anomalies in the *Niño* 3.4 region (5°N-5°S, 120°-170°W). Recent Pacific warm (red) and cold (blue) episodes based on a threshold of  $\pm 0.5$  °C for the Oceanic Nino Index (ONI). Source: CPC/NOAA

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2002	-0.2	0.0	0.1	0.3	0.5	0.7	0.8	0.8	0.9	1.2	1.3	1.3
2003	1.1	0.8	0.4	0.0	-0.2	-0.1	0.2	0.4	0.4	0.4	0.4	0.3
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.8	0.7	0.7	0.7
2005	0.6	0.4	0.3	0.3	0.3	0.3	0.2	0.1	0.0	-0.2	-0.5	-0.8
2006	-0.9	-0.7	-0.5	-0.3	0.0	0.1	0.2	0.3	0.5	0.8	1.0	1.0
2007	0.7	0.3	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.8	-1.1	-1.2	-1.4
2008	-1.5	-1.5	-1.2	-0.9	-0.7	-0.5	-0.3	-0.2	-0.1	-0.2	-0.5	-0.7
2009	-0.8	-0.7	-0.5	-0.2	0.2	0.4	0.5	0.6	0.8	1.1	1.4	1.6
2010	1.6	1.3	1.0	0.6	0.1	-0.4	-0.9	-1.2	-1.4	-1.5	-1.5	-1.5

During year 2007, were recorded 31 notifications about sudden floods: 10 occurred in March and 18 in September. On March yet it was noticed in the RS the influence of El Niño phenomenon (moderate level; 2006-2007). According to Climamãise Bulletin (2007), this period seven frontal systems acted in Brazil (average is six systems). These were limited to southern Brazil, during first half of the month, causing high precipitation accumulated that exceeded the march climatological average. On September 18 events of sudden floods were recorded. This period already no had showed more under the influence of El Niño phenomenon. The SST of pacific equatorial ocean was close to normal gradually cooling and setting up a La Niña phenomena, that established in second half of year 2007 (2007-2008).

In year 2009 was recorded 40 sudden flood events: 32 occurred on December and 8 on November. During this

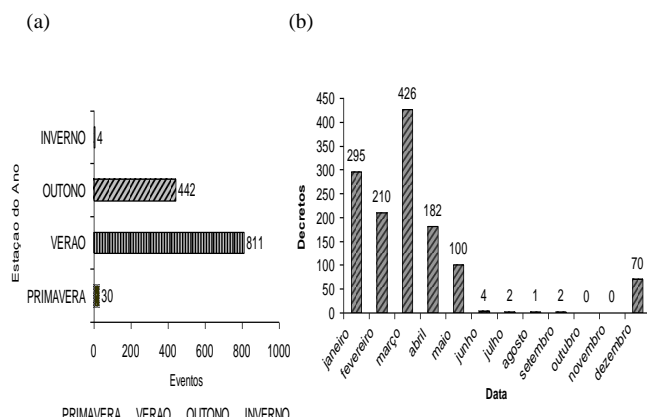
period the state was without influence of El Niño (2009-2010; weak) which total precipitated reached 500 mm in some cities of RS, above the climatological average (150 mm), for November. Data from the National Institute of Meteorology (INMET) showed that 19 municipalities accumulated precipitation extremely high, above 400 mm. In December, according to the INMET, the rainfall also was well above of the average, in most regions of the state (ex: Santa Maria, 311 mm; Uruguiana, 335 mm).



**Figure 5.** Municipalities in Rio Grande do Sul state with drought record, in the period 2003 a 2009

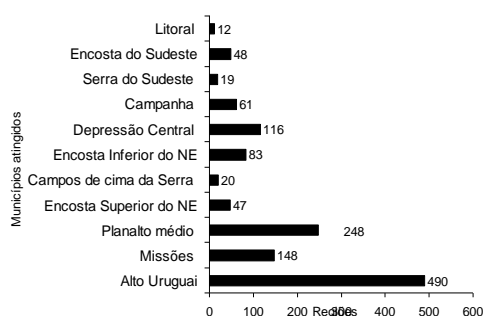
### 3.2. Drought Events

Figures 6, 7 and 8 show the episodes of drought that occurred in RS during the nine years of study. It is observed the distribution of these events throughout the seasons of the year, finding that the preferred station for its occurrence is summer (811 events) followed by autumn (442 events) - presenting the first (summer) almost twice the second (fall) - figure 6a. It may be noted as well (Figure 6b) that March was month in which the municipalities were have suffered most by drought (426), followed by months of January and February, with 295 and 210 recorded, respectively. Similarly to Sudden floods, the beginning period and finish of the seasons was: Autumn - March, 20<sup>th</sup> to June, 19<sup>th</sup>; Winter - June, 20<sup>th</sup> to September 20<sup>th</sup>; Spring - September 22<sup>th</sup> to December 20<sup>th</sup>; Summer - December, 21<sup>th</sup> to March, 19<sup>th</sup>.



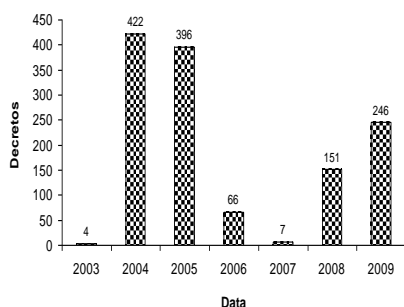
**Figure 6.** Frequency of drought occurrences in RS, according to season of the year (a) and months of the year (b) from 2003 to 2009

The spatial distribution of drought events in Rio Grande do Sul are presented in Figure 7. It is notable as evident disproportion (heterogeneity) of the municipalities affected by this type of natural disaster, an opposite to observed in sudden floods. The regions with the most occurrences were located in the northern portion of Rio Grande do Sul: the Alto Uruguai, Planalto Médio and Missões, which together account for approximately 70% of cases registered in the state, as opposed to regions localized in the southern half of RS, when few events for these weather adverse conditions were recorded (around 10%). The Alto Uruguay region had the highest frequency of droughts, representing 38% of all events occurred (in 1292), followed by regions Planalto Médio, where there were 19% and Missões region, which happened 11% episodes of drought.



**Figure 7.** Distribution of drought regions in Rio Grande do Sul in the period 2003 to 2009

Figure 8 shows the drought episodes occurred between 2003 and 2009. It is observed that the most intense episodes were the events 2004, 2005 and 2009, which affected several municipalities in the state: 422, 396 and 246 respectively. It should be noted, as shown in Table 1, the greatest damages caused to municipalities (by droughts) happened mainly in summer and autumn seasons. It is interesting to note also that during study period there were three occurrences of El Niño phenomenon (2004-2005; 2006-2007; 2009-2010), and only one La Niña occurrence (2007-2008), Table 1. Relationship these phenomena with more severe droughts, it is observed that most of drought events took place on years with presence of El Niño (low intensity) and also in neutral years (without presence of the phenomenon). Just over year 2008 the drought in Rio Grande do Sul were influenced by presence of La Niña event (2007/2008, of strong intensity).



**Figure 8.** Municipalities in Rio Grande do Sul with drought record, in the period 2003 to 2009

## 4. Conclusions

This study aimed to carry out zoning of natural disaster by droughts and sudden floods, in Rio Grande do Sul (RS) state, between years 2003 and 2009. Were analyzed the number of occurrences, the preferred regions and the more favorable period for them occurrences. Some conclusions can be showed:

### (i) Regarding the sudden floods:

The spatial distribution of the floods showed that about half of the episodes were established in RS municipalities of Depressão Central and Encosta Inferior do Nordeste e Sudeste regions. Other regions frequently affected by floods were the areas of Planalto Médio (18%) and the Alto Uruguay (14%).

Annual behavior of sudden floods between 2003-2009 showed a higher frequency of occurrence in the years 2003, 2007 and 2009: 49 municipalities affected in 2003, 31 in 2007 and 40 records in year 2009. Its emphasized year 2009 which presented (since the end year 2008) one of the worst sudden floods (if not most) already registered by gaúcho state (RS), with severe damage to summer agricultures (corn and soybeans). This time SST on Equatorial Pacific Ocean there was close to normal (neutral year). Since second half, temperature anomalies positive signs beginning to appear, setting a new El Niño event (2009-2010), causing severe accumulated precipitations over RS in late year 2009 and early 2010.

### (ii) Regarding the Drought:

The events recorded by the municipalities of Rio Grande do Sul was 1292, and the most affected regions were Alto Uruguay (490 events, 38%) Planalto Médio (248 events, 19%), Missões (148 events, 11%), the Depressão Central (116 events; 9%), Encosta Inferior do Nordeste (83 events; 6%) and Campanha regions (61 events; 5%). It is clear that northern half of state was region with the largest number of emergency situation decrees by drought (70%) and that suffered most from this type of adverse weather conditions. The hypothesis to be investigated (object of further study) is that factors such as topography of the region, morphological characteristics of soil, irregular distribution of rainfall during dry season (summer/fall), economic factors, etc., may contribute for high frequency these drought events in the region.

The most intense episodes occurred over years 2004, 2005 and 2009, and many municipalities affected: 422, 396 and 246, respectively. In the analysis of period (2003-2009) it was observed that most drought decrees occurred in the presence of years El Niño (weak) phenomenon. Only in 2008 the events were influenced by presence of La Niña phenomenon (2007/2008: strong).

The period with greatest occurrence of drought was the summer, followed by autumn, with records of 811 and 442 (municipalities affected), respectively. According to the emergency decrees, March was record the largest number of episodes (426), followed by January (295) and February

(210). It is believed that this fact is directly related to the summer agriculture (soy and corn) of these municipalities, that breaks in productivity (yield) of these crops would cause drastic losses in the economy of the municipalities - which are based (soy and corn) in the agricultural sector - leading them to enact Emergency Situation (SE) in order to help (financial) of state and federal agencies.

Also became evident that not only in years with the presence of El Niño and La Niña occurred in Rio Grande do Sul extreme weather situations, such as drought and sudden flood events. It was found that the years of thermal neutrality (with the absence of phenomena) are also important and deserve to be analyzed with better attention, especially with regard to the impact (event type) caused by them.

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