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Natural Disasters in Southeastern Brazil Associated with the South Atlantic Convergence Zone

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Abstract

This study analyzed rains in southeastern Brazil associated with the South Atlantic Convergence Zone (SACZ), which resulted in several disasters over the study area. The study period was from 1976 to 2010 and data were obtained from the National Water Agency (ANA) and Department of Water and Energy (DAEE) of the state of São Paulo. Outgoing Longwave Radiation (OLR) data were also used to analyze SACZ, which is an important dynamics influencing spring and summer in this region. A close relationship between SACZ intensity and economic and life losses in the study area was observed.

Introduction

The Southeastern region of Brazil, corresponding to approximately 11 % of the Brazilian territory, has an area of 924,512 square kilometers. The states included in this region are Rio de Janeiro, Minas Gerais, São Paulo and Espírito Santo. It includes the following river basin districts: São Francisco, Atlântico East, Atlântico Southeast and Paraná.

The southeastern region is characterized by the transition between warm climates of low latitude and mesothermic climates of intermediate latitudes. The latitudinal variability, the proximity to the sea (continentality), the topography and the role of tropical and extratropical systems of intermediate latitudes provide the region a climate diversity not seen in any other region of the country.

Regionally, it also marks the transition between permanently wet regimes of Southern Brazil and alternately wet and dry climates of Central Brazil. These characteristics influence the temporal and spatial variations of temperature, precipitation and wind. The latitudinal position favors a broad exposure to solar radiation. However, local factors such as topography and proximity to the sea provide relevant temperature fluctuation in relatively close places (Brazilian Yearbook of Natural Disasters, 2012).

The Southeastern region of Brazil is characterized by the influence of the South Atlantic Convergence Zone (SACZ), the main phenomena influencing the rainfall regimen by the Upper Tropospheric Cyclonic Vortex (UTCV) and by inverted troughs, which act mainly in the winter, providing moderate weather conditions especially in São Paulo and by the prefrontal instability lines generated from the association of dynamic factors of large-scale and mesoscale features. It is the region of heterogeneous spatial and temporal behavior. The Brazilian semiarid region includes northern states of Minas Gerais and Espírito Santo, while the states of Rio de Janeiro and São Paulo show the highest total rainfalls in the country. The hydrological regime in the region is well marked. There are periods of drought concentrated in the months from June to September and expressive rains over the months from November to March, peaking in December and January. It is a region of large number of hydrological disasters, with well marked seasonality. Especially with regard to flooding, this region shows the highest number of affected people in the country, possibly because it is the most populated region, and human damage, in absolute numbers, is also the most expressive, Cavalcanti, et al. 2009.

The atmospheric dynamics, responsible for numerous meteorological and climatological processes such as drought, heavy rains and storms, is also inducer of geological processes such as mass movements, erosion and hydrological processes such as torrents and floods.

The modernization and diversification of industrial production (initiated in the second half of the twentieth century and intensified from the 1970s, with the internationalization of the economy) promoted an intense displacement of rural populations to cities (CARVALHO and PRANDINI, 1998).

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Data from the XII IBGE Census (2010), in 1950, only 40 % of 51,941,767 Brazilians lived in cities. Under moderate growth pressure, these cities had their best land occupied. Visibly problematic land remained unoccupied (CARVALHO and PRANDINI, 1998). Twenty years later, the absolute population would show an increase of 82%. The urban area, in turn, began to concentrate 55 % of the population. Currently, there are 190,755,799 (twice as 1970) and urban centers account for approximately 84 % of this total in various land and housing conditions.

This rapid urbanization led to an uncontrolled growth of cities in areas often with geological and geomorphological conditions unfavorable to occupation (TOMINAGA, 2007), coinciding with a significant increase in the frequency and intensity of natural disasters around the globe (EM-DAT, 2009).

A theme present in the everyday life of society today, natural disasters are severe disturbances caused by natural phenomena of great magnitude, capable of generating large human, material, economic or environmental losses, which impact exceeds the capacity of the affected community or society to cope with their own resources (UNISDR, 2009). Severe natural phenomena are strongly influenced by regional characteristics and when they occur in places where humans live, result in losses and damages, (KOBIYAMA et al., 2006). To be included in the database of emergency events (EM-DAT), it must present at least one of the following criteria: 10 or more killed, 100 or more affected, declaration of emergency and need for international aid (SAITO et al. 2009; MARCELINO et al. 2006).

Usually, sudden and unexpected, disasters can be distinguished from each other as to their genesis as hydrometeorological, exogenous or of external dynamics (snow avalanches, forest fires, floods, mass movements, extreme temperatures and heat waves, storms, tornadoes, hurricanes and droughts). Those of internal dynamics (endogenous or geophysical) are earthquakes, tsunamis and volcanism (ALCÁNTARA-AYALA, 2002; MARCELINO, 2003; TOMINAGA, 2009). Their intensity depends mainly on the interaction between the magnitude of the adverse event and the degree of vulnerability of the affected receiver system (CASTRO, 1999).

In theory, anyone can be victim of a natural disaster (TOMINAGA, 2007). In practice, the poorer are the most vulnerable, because income disparity prevents their access to urban areas within geotechnical safety standards, whose cost of location goes beyond the economic and financial reality of this portion of the population (PERDORMO, 2010). With no alternatives, these people build fragile dwellings in more densely populated areas and on land with greater susceptibility to hazards. Several studies have reported a sharp increase in the number of these events on all continents, especially in developing countries and their adverse effects: increasing numbers of victims and financial amounts needed to rescue the population and reconstruction of affected areas. This fact can be attributed to population growth, socio-spatial segregation, accumulation of fixed capital in dangerous areas, technological advances in communications and global climate change (MARCELINO et al. 2006).

The aim of this study was to analyze some disasters caused by heavy rains in the Southeastern region of Brazil based on data of precipitation and outgoing longwave radiation.

Material and Method

To analyze the incident rainfall over the southeastern region of Brazil, data from 183 rainfall stations (Figure 1) within 34 years (1976-2010), obtained from the Hydrological Information System, National Water Agency (ANA) and also database of the Department of Water and Energy (DAEE), under the Water Resources Management System (SIGRH) of the State of São Paulo were obtained.

To observe the occurrence of intense convective activity over South America and especially in the Southeastern region of Brazil, outgoing longwave radiation (OLR) information was used, which is part of sets of meteorological data provided by the National Oceanic & Atmosphere Administration (NOAA) and provided by the Physical Sciences Division of the Earth System Research Laboratory, Boulder, Colorado.

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The variability of the geographical distribution of convective processes over South America and southeastern Brazil was analyzed through daily OLR data, which covered an area bounded between 35ºS to 10ºN (19 points in latitude) and 80ºW to 30ºW (21 points in longitude available for certain SACZ episodes) previously identified by Quadro (1994) and CLIMANÁLISE (1990-2011).

The daily OLR values correspond to radiometric measurements in the spectral range from 10.5 to 12.5 μm between downward and upward (means of two satellite passes per day) obtained for each grid point with spatial resolution of 2 5^o - 2.5^o degrees by the AVHRR/NOAA sensor (WALISER and ZHOU, 1997). This variable is widely used to indicate the formation of convective clouds over territory located in the tropical region through satellite measurements (LIEBMANN and SMITH, 1996). These clouds are associated with much more vigorous height, which makes their tops to stand at altitudes near the tropopause. The higher the top of a cloud, the lower the emission of long waves, so, OLR can be used as an indicator of precipitation (FERREIRA and GURGEL, 2002).

Reports of collections of "Folha de São Paulo" and "O Estado de São Paulo" newspapers and publications from the Bulletin of Climate Monitoring and Analysis (CLIMANÁLISE), National Institute for Space Research (INPE) helped establishing a relationship between rainfall and the occurrence of natural disasters.

Newspaper articles, also corresponding to the period of SACZ influence, allowed us inferring about the magnitude of events (especially the most affected localities and the number of deaths and homeless).

The SACZ episodes analyzed in this study correspond to events previously identified by Quadro (1994) between 1980 and 1989 and Climanálise publications (1990-2011). From these dates and OLR data, contour lines were plotted with the use of the Surfer 8.0 software, which represented the SACZ position and areas of convective activity. Darker shades indicate higher intensity of convection processes (lower OLR values), whereas lighter shades refers to lower intensity. White shades, usually located at north and south of the convective field are related to subsidence of the atmospheric circulation and represented by the absence of this process.

The intensity of these episodes was defined based on OLR gradients (values lower than 240 W/m^2) over the South American territory and southeastern Brazil; comparison with visual analysis of satellite images (when available) consistent with the duration of these phenomena (at least four days); data from rainfall stations located in the area of influence of the convective field; reports of collections of "Folha de São Paulo" and "O Estado de São Paulo" newspapers and publications from CLIMANÁLISE, (KOUSKY, 1988; QUADRO, 1994; FERREIRA and GURGEL, 2002; FERREIRA et al. 2004;. CARVALHO et al. 2004; SILVA, 2006).

Among 109 episodes analyzed, 39 disaster situations were selected. The presence of areas of cloudiness indicates association of this band with the occurrence of homeless and displaced people (897,319), victimizing other 2,826 approximately. The selection of these 39 episodes followed criteria of the Emergency Disasters Database (EM-DAT), created with the help of the Belgian Government by the Université Catholique de Louvain, Brussels and maintained by the Centre for Research on the Epidemiology of Disaster (CRED), linked to the World Health Organization (WHO), or 10 or more killed; 100 or more affected and declaration of emergency (GUHA-SAPIR et al. 2012).

Discussion of Results

The southeastern region of Brazil has rainfall pattern with two distinct seasons: dry season (April-August) and wet season (September-March). The high rainfall volumes recorded during spring-summer arise primarily from the effect of the South Atlantic Convergence Zone and localized heating zones.

The spatial variability of rainfall can be observed in the contour maps (Figures 2-3). Darker shades indicate an increase in the intensity of this phenomenon (SACZ), whereas lighter shades refer to smaller rainfall intensities. Figure 2 shows that the highest average rainfall (over 1,400 mm) are in the southeastern region of the study area, which covers the mid-eastern state of São Paulo (SP), mid-southern state of Minas Gerais (MG) and the mountainous regions and coastal plains of the state of Rio de Janeiro (RJ).

The lowest averages, in turn, occur in western state of São Paulo (1,300 mm) and northeastern state of Minas Gerais (800 mm).

The largest deviations in relation to the yearly average (Figure 3) occurred in the mid-eastern portion (over 290 mm). These values result from the influence of a more rough relief and greater proximity to the Atlantic Ocean, while in western São Paulo, Vale do Jequitinhonha and Mucuri (MG), deviations were below 270 mm.

Tables 1 and 2 show a large variability of geographical positions of the convection process over the study area (transience that predominated over the following states: Minas Gerais, São Paulo and Rio de Janeiro). In relation to the consequences, significant increase in the number of affected people throughout the study period, especially in the last decade, was identified.

There was influence of SACZ on 21 occasions between 1980 and 1989. Tables 1 and 2 show the 11 most significant episodes in number of fatalities and homeless, respectively.

Table 1 - Number of deaths in Southeastern Brazil according to state due to SACZ events between 1980 and 1989.

SACZ	MG	SP	RJ	ES	Total
January 1980	11	1	6	-	18
February 1980	-	23	-	-	23
December 1980	16	2	-	-	18
December 1981	4	6	60	-	70
January 1982	12	-	16	-	28
January 1983	86	5	-	-	91
January 1985	64	3	17	34	118
February 1985	-	2	27	-	29
January 1987	17	21	1	-	39
February 1987	-	85	1	-	86
February 1988	-	1	201	-	202

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Table 2 - Number of homeless in Southeastern Brazil according to state due to SACZ events between 1980 and 1989**.**

SACZ	MG	SP	RJ	ES	Total
January 1980	9.427	10.000	-	2.400	21.827
February 1980	12.000	2.500	-	-	14.500
December 1980	1.146	100	-	13.500	14.746
January 1981	500	6.000	2.000	-	8.500
December 1981	4.395	700	5.000	-	10.095
January 1982	3.918	-	3.000	-	6.918
February 1983	-	10.579	-	-	10.579
January 1985	63.335	5.141	21.000	10.631	100.107
January 1987	4.266	200	600	-	5.066
February 1987	-	20.681	-	-	20.681
February 1988	-	5.000	8.524	-	13.524

The analysis of Tables 1 and 2 shows that the state of Rio de Janeiro and Minas Gerais were the most affected by rainfall. Both showed, respectively, the highest number of deaths (329) and homeless (101,987).

The effect of SACZ between January 23 and February 6, 1985 helped to intensify rains in the Northern, Northeastern, Midwestern and Southeastern regions of Brazil. According to Figure 4, it is possible to verify the presence of convective cloud bands from southwestern Colombia to the Atlantic Ocean coast of states of Espírito Santo and Rio de Janeiro. Low OLR values (lower than 210 W/m^2) are an important indicator of the occurrence of deep convection over the study area.

Compared with other events of this phenomenon during this decade, it was the episode that left the highest number of affected people (100,107) and second highest number of fatalities (118).

Northern Brazil, Vale do Mucuri and Vale do Rio Doce and Zona da Mata, state of Minas Gerais accounted for approximately 63 % of affected people (63,335). Losses across the state came to R$ 1 trillion. Heavy rains have destroyed 1,300 houses, 110 bridges, two schools and damaged 2,600 homes, 4 public buildings, 20 bridges in 141 municipalities of Minas Gerais (O

ESTADO DE SÃO PAULO, 1985, p. 32). Of the 56 deaths recorded since the beginning of the rainy season in the state of Espírito Santo, 34 were in this event, which is much higher than the statistics for the next two decades: 1990-1999 (5) and 2000-2010 (31). In the city of São Paulo, at the eve of its 431st anniversary, fifteen straight hours of rain were enough to cause two deaths due to landslides and left 1,141 homeless. The most affected regions were Itaquera (East Zone) and São Miguel Paulista (North Zone). In Guarulhos, precipitation reached 106 mm. It was the heaviest rain that occurred in a 24-hour period since 1949 (FOLHA, 1985). In northern state of Rio de Janeiro, more than 20,000 people were left homeless as a result of rains and flood of Carangola and Muriaé rivers.

Between January 31 and February 14, 1988, again the influence of SACZ contributed to intensify rains in the Northern, Midwestern and Southeastern regions of Brazil (Figure 5).

Figure 5 shows an area of intense convective activity (OLR values lower than 200 W/m^2) at northwestern-southeastern direction, which went from western state of Rondônia to the Atlantic Ocean through the coasts of Rio de Janeiro and São Paulo. However, deep convections were restricted to the state of Rio de Janeiro. The incidence of high rainfall volumes on the coastal lowlands, state capital and mountainous region, especially between February 03 and 07, 1988, left at least 201 dead.

Only in Petrópolis, 165 people died buried and about 4,000 were left homeless due to thunderstorms. According to information from a document sent to the federal government by the Company of Public Works of the State of Rio de Janeiro (EMOP), the possibility of large floods occurring in the city of Petrópolis (FOLHA, 1988, p. A16) was predicted 20 years ago.

Between 1990 and 1999, there were 16 episodes of SACZ. Tables 3 and 4 show the 10 most significant convergence zones. Compared with the last decade, there has been a reduction in the number of fatalities in all states. However, the number of people who lost or left their homes remained higher, especially in Minas Gerais and Rio de Janeiro. Through the analysis of Table 4, it could be inferred that the presence of convective bands over the study area was more effective during the month of January (six episodes), when 243 deaths were recorded (55%). Of these, 114 (26%) occurred only in episode of 1997.

Table 3 - Number of deaths in southeastern Brazil according to state due to SACZ events between 1990 and 1999**.**

SACZ	MG	SP	RJ	ES	Total
January 1990	13	-	-	-	13
January 1991	27	2	29	4	62
January 1992	18	4	7	-	29
February 1993	9	1	-	-	10
February 1995	2	43	8	-	53
December1995	30	3	-	-	33
January 1996	-	21	3	1	25
February 1996	-	22	66	-	88
January 1997	84	23	7	-	114
February 1998	-	3	7	-	10

Table 4 shows the magnitude of episodes of January, in which 182,514 homeless (77 %) were recorded. The states that had the highest number of victims in this period were MG (129,695) and RJ (67,727).

The highest number of deaths and homeless were observed in 1991 and 1997, when convective cloudiness areas remained semi-stationary over the study area.

The SACZ configuration from January 10 to 18, 1991 (Figure 6) contributed to the formation of convective clouds over a wide area of the South American continent from eastern Peru to coastlines of Rio de Janeiro and Espírito Santo (OLR values lower than 200 W/m^2). Rainfalls on the capital of SP and MG were the highest recorded during the months of January for the last 60 and 50 years, respectively. According to data from the 7th District of Meteorology, rain gauges at Mirante de Santana (Northern SP) recorded 106.4 mm of rainfall within 24 hours.

Table 4 - Number of homeless in southeastern Brazil according to state due to SACZ events between 1990 and 1999.

SACZ	MG	SP	RJ	ES	Total
January 1990	42.000	5.032	-	-	47.032

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January 1991	30.000	1.000	6.569	1.500	39.069
January 1992	9.323	1.630	4.338	-	15.291
February 1995	-	12.500	-	-	12.500
December1995	4.750	2.080	-	-	6.830
January 1996	-	2.043	-	500	2.543
February 1996	-	520	4.000	-	4.520
January 1997	43.622	5.797	20.470	6.160	76.049
February 1998	-	1.420	32.350	-	33.370
January 1999	-	2.530	-	-	2.530

In MG, rainfalls over the metropolitan region of Belo Horizonte, Vale do Rio Doce, Zona da Mata and southern region for over a week caused 27 deaths and left about 30 thousand homeless. The cities of Passa Quatro, Itamonte and Itanhandu declared state of public calamity. In Itajubá, the shopping mall was flooded by the Sapucai River and eight thousand people were left homeless (O ESTADO DE SÃO PAULO, 1991).

The mountainous region of Rio de Janeiro was again affected by heavy rainfalls three years later. Only on January 17, 21 people died and 450 were left homeless in the municipalities of Nova Friburgo, Teresopolis and Petropolis.

In January 1997, SACZ influenced two periods: January 02 - 08 and January 20 - 29. According to Climanálise (1997), positive rainfall anomalies over the northern state of São Paulo and Southeastern state of Minas Gerais were observed, with values of up to 200 mm above the climatological average. This increase in rainfall volumes is the result of intense convective activity (OLR values lower than 220 W / m^2). It was the heaviest rain in Belo Horizonte since 1978. It rained 355 mm up to 10 a.m. on Sunday (January 05, 1997) in Belo Horizonte, where the average rainfall in January is 290 mm.

At the end of the event, the state of MG recorded 76 deaths, 42,807 homeless and 4,844 isolated people, 179 municipalities affected, 541 landslides and 15,992 residences were flooded or affected by landslides. In the state of Rio de Janeiro, approximately 16,420 people were homeless, according to the Civil Defense.

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In the second SACZ episode (January 20 to 29, 1997) areas of convective cloudiness covered a wide area of the Brazilian territory since the western Amazon to northeastern state of Santa Catarina. GOES-8 image (Figure 7.1) shows the predominance of convective processes more southerly in the southeastern region, on the border between states of São Paulo and Paraná. As a result of the influence of SACZ between days 20 and 24 (Figures 7.1 and 7.2), the increase in rainfall volumes caused the worst flooding in 50 years at the Vale do Ribeira region. At some points, the level of the Ribeira do Iguape River rose 14.5 meters, as in the city of Eldorado, the most affected by heavy rains.

Between 2000 and 2011, there were 23 episodes of SACZ. Tables 5 and 6 show the 17 most significant. Compared with past decades, there has been significant increase in all states both in the number of deaths and homeless. The most emblematic case occurred in January 2011 in the mountainous region of the state of Rio de Janeiro, which was named by the Geological Service of Rio de Janeiro of "mega-disaster of the mountainous region" (SPINELLI, 2011). This decade was also characterized by repeated SACZ configurations in the same month.

Tables 5 and 6 show that the states of Rio de Janeiro and Minas Gerais were again the most affected by heavy rains. Both showed, respectively, the highest number of deaths (1,344) and homeless (235,872).

Table 5 - Number of deaths in southeastern Brazil according to state due to SACZ events between 2000 and 2011.

SACZ	MG	SP	RJ	ES	Total
January 2000	14	15	13	-	42
December 2000	5	2	-	7	14
December 2001	1	-	60	-	61
February 2002	23	-	-	-	23
December 2002	1	-	34	-	35
January 2003	45	10	35	3	93
January 2004	15	16	11	9	51
December 2005	9	-	4	-	13
January 2006	-	7	16	-	23
December 2006	5	-	3	4	12
January 2007	4	3	30	-	37
February 2008	9	1	10	-	20

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December 2008	10	-	3	2	15
January 2009	4	-	8	1	13
December 2009	1	28	2	1	32
December 2010	12	1	-	4	17
January 2011	1	15	1115	-	1131

Table 6 - Number of homeless in southeastern Brazil according to state due to SACZ events between 2000 and 2011.

SACZ	MG	SP	RJ	ES	Total
January 2000	81.530	15.852	9.700	-	107.082
December 2000	400	220	-	5.000	5.620
December 2001	495	2.000	1.806	-	4.301
February 2002	2.000	3.325	-	-	5.325
December 2002	1.200	140	1.500	-	2.840
January 2003	13.699	1.200	2.200	4.931	22.030
January 2004	10.263	2.727	4.141	-	17.131
December 2005	-	-	-	1.499	1.499
January 2006	-	780	-	-	780
December 2006	6.982	-	-	2.058	9.040
January 2007	-	327	13.491	-	13.818
February 2008	2.800	3.550	2.350	-	8.700
December 2008	10.500	-	30.036	5.343	45.879
January 2009	92.660	-	12.000	4.700	109.360
December 2009	2.023	1.960	183	3.831	7.997
December 2010	11.320	11.441	-	7.300	30.061
January 2011	-	5.321	34.268	-	39.589

It could be inferred through the analysis of Tables 5 and 6 that the presence of convective bands over the study area was very effective both in the months of December (eight episodes) and January (seven episodes). It is likely that the records for January (1,390 deaths and 309,790 homeless) are linked to high rainfall volumes arising from these convergence zones.

In 2004, the influence of SACZ between January 10 and 20 (the second event in that month) helped to intensify rains in the Northern, Midwestern, Northeastern and Southeastern regions of Brazil. Figure 8 shows an area of intense convective activity, extending from southwest Amazon to the Atlantic Ocean through the coastline of Bahia and Espírito Santo.

During the first half of January, the actions of frontal systems, the configuration of three SACZ episodes and the development of areas of instability favored rains in almost the entire Southeastern region (CLIMANÁLISE, 2004).

In the first thirteen days of the year, rainfalls caused a balance of 30 deaths: 13 in São Paulo, 9 in Minas Gerais and 8 in the Espírito Santo (GUIMARÃES and CHAVES, 2004). Three days later, 11 more victims were registered in Rio de Janeiro, where the most serious cases occurred in Northern state of Rio de Janeiro (municipality of Santo Antônio de Pádua) and District of Xerém in Duque de Caxias (Baixada Fluminense). Two women, one man and one boy died dragged by the current of the Pomba River, which overflowed in Santo Antônio de Pádua. In Xerém a slope sliding buried a man and his two daughters. Only in the state capital, since the beginning of the year, it rained 344 mm, or 56.4 % more than the expected 220 mm for the entire month.

The SACZ configuration between December 04 and 08, 2009 favored the formation of convective clouds (OLR values lower than 210 W/m^2) since southern Colombia to the Atlantic Ocean through the coastline of Espírito Santo. The association between frontal systems and thermal convection generated intense rainfalls that initially affected the southern region of the study area (mainly on the metropolitan areas of São Paulo and Campinas).

In the rural area of Pinhalzinho, state of São Paulo, a couple died buried. In the capital, a thunderstorm of 40 minutes caused 218 km of traffic jams, left without electricity neighborhoods of Paraíso (South), São Mateus (East), Bom Retiro (downtown) and Itaim Bibi (West), Congonhas airport closed for 15 minutes and buried five people: an adult in São Rafael Park (East SP) and four children in Itapecirica da Serra (BENITES et al. 2009).

The influence of SACZ between January 11 and 15, 2011 intensified rainfalls in the Northern, Midwestern and Southeastern regions of Brazil. Figure 9 shows an area of intense convective activity (OLR values lower than 200 W/m^2), which extends from the southern Amazon to the Atlantic Ocean along the coast of Rio de Janeiro.

The organization of deep convections over the states of São Paulo and Rio de Janeiro between the evening of Monday (January 10, 2011) and the early hours of Wednesday (January 12, 2011) contributed to increased rainfall, consequently to the occurrence of landslides and floods. The heavy rain that fell during the night and early morning of that day on the metropolitan areas of São Paulo, Sorocaba and Vale do Paraíba caused 14 deaths, three in Maua, three in São Paulo, one in Embu Guaçu, one in Mogi das Cruzes, one in Iperó and five in São José dos Campos.

Concluding Remarks

By comparing maps, data and reports can show that the summer period is the most favorable to the occurrence of natural disasters such as landslides and floods, especially during the month of January, when there were more SACZ configurations (16 episodes).

The permanence of this meteorological phenomenon for several days interferes in rainfall volumes of different locations under the influence of convective cloudiness bands. Therefore, the amount of accumulated rain due to its presence (four days or more) is an important parameter to anticipate the possibility of a catastrophic event and thus save lives.

Episodes in which convective processes covered the entire study area were emphasized (January 1985, 1991, 1997, 2004, and December 2009), as well as those in which high number of fatal victims and homeless were observed (February 1988 and January 2011). During these episodes, there was recurrence of floods and landslides in certain areas such as the coastal lowlands, mountainous regions, metropolitan region of Rio de Janeiro, northeastern and northern state of Rio de Janeiro, southern and southeastern state of Minas Gerais, Zona da Mata, metropolitan region of Belo Horizonte, Vale do Rio Doce and Mucuri; metropolitan region of São Paulo, Northern Coast, Vale do Ribeira, Vale do Paraíba; Northwestern regions, Mid-southern region of Espírito Santo.

The use of newspaper reports was essential both to establish the relationship between rainfall and the occurrence of natural disasters as to differentiate episodes in terms of magnitude (number of deaths and homeless) and spatial extent (most affected locations). This information also revealed the

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inability of municipal administrations and the government unpreparedness in relation to existing risk situations in various cities in the study area.

The size of tragedies could be minimized with the implementation of a preventive plan involving the entire southeastern region of the country to act not only in the rainy season; better use of budget funds; greater flexibility in emergency transfers; adoption of preventive measures and performance of structural works; hiring specialized professionals; investment in equipment, infrastructure and human resources for Civil Defense, maintenance of teams (avoiding the diversion of functions of employees linked to municipal administration); combat and surveillance of illegal occupation of slopes and floodplains; mapping of risk zones and also housing policies of social character.

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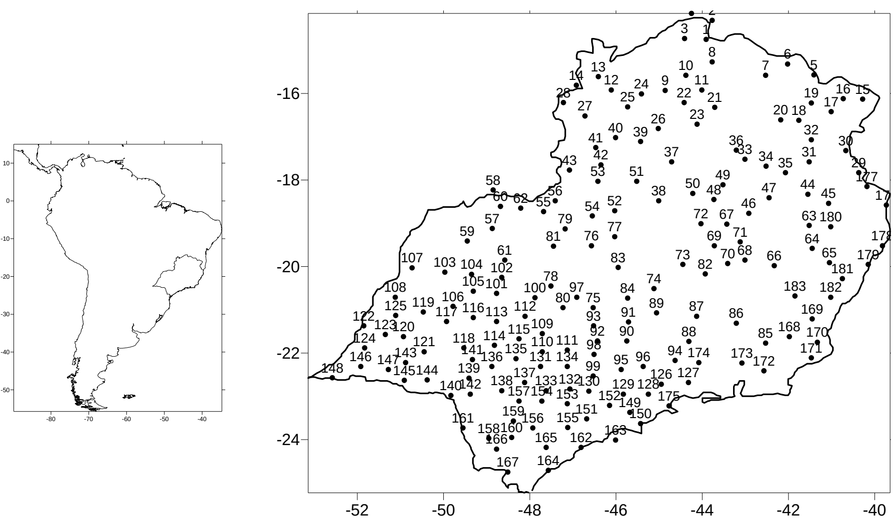

Figure 1 - Spatial distribution of rainfall stations in the study area.

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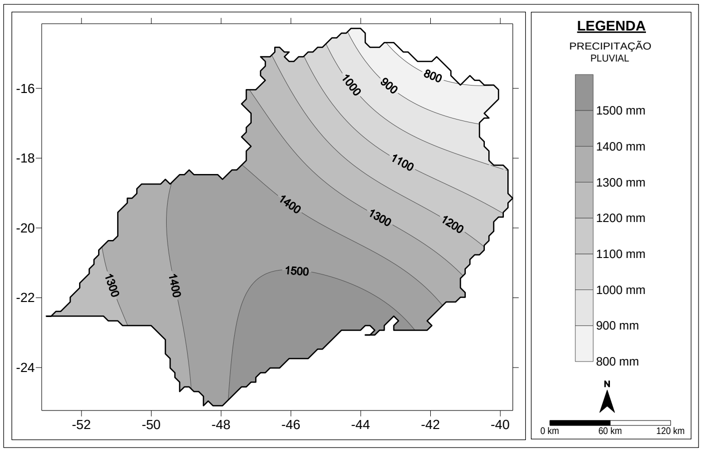

Figure 2 - Contour lines of the average incident rainfall over the study area.

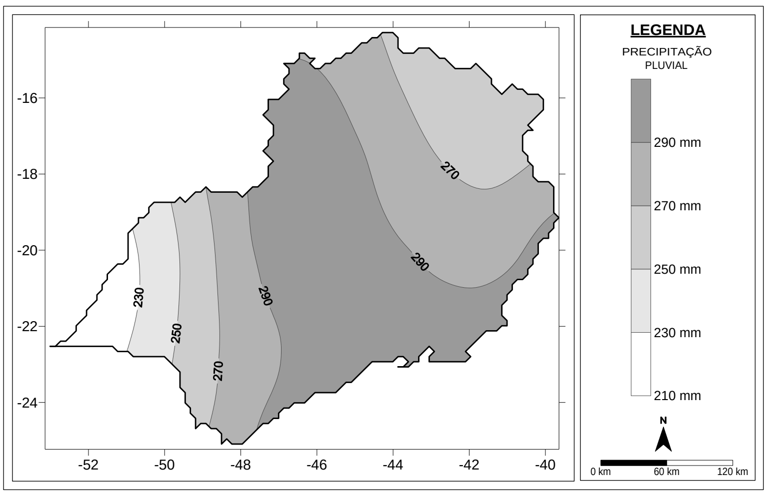

Figure 3 - Contour lines of the standard deviation of incident rainfall over the study area.

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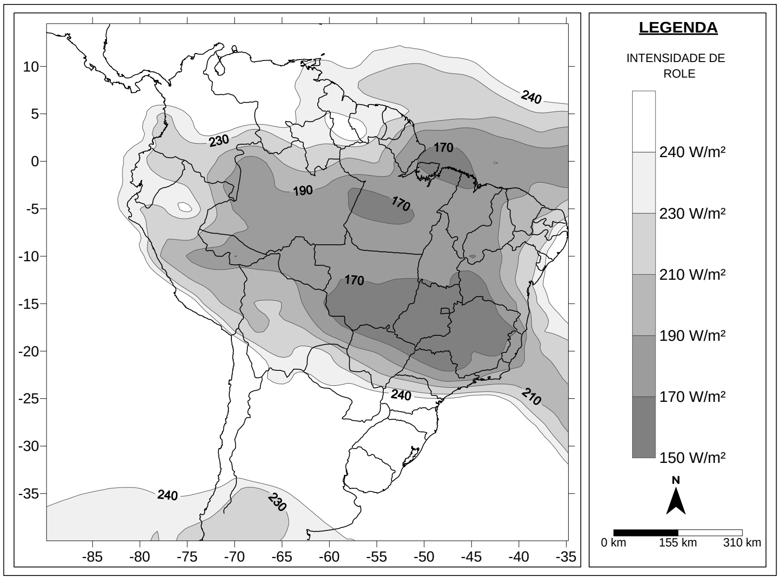

Figure 4 - Average OLR field (values lower than 240 W/m ^{2}) between January 23 and February 6, 1985.

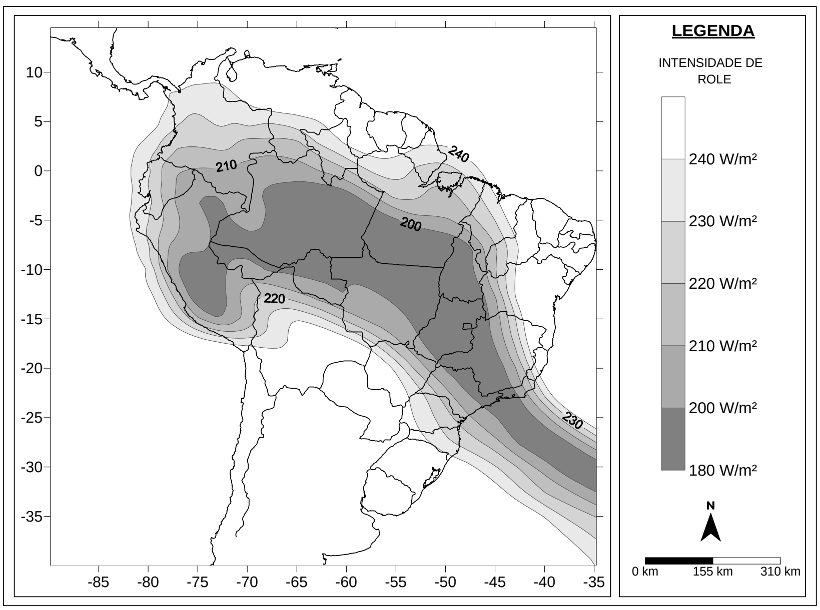

Figure 5 - Average OLR field (values lower than 240 W/m ^{2}) between January 31 and February 14, 1988.

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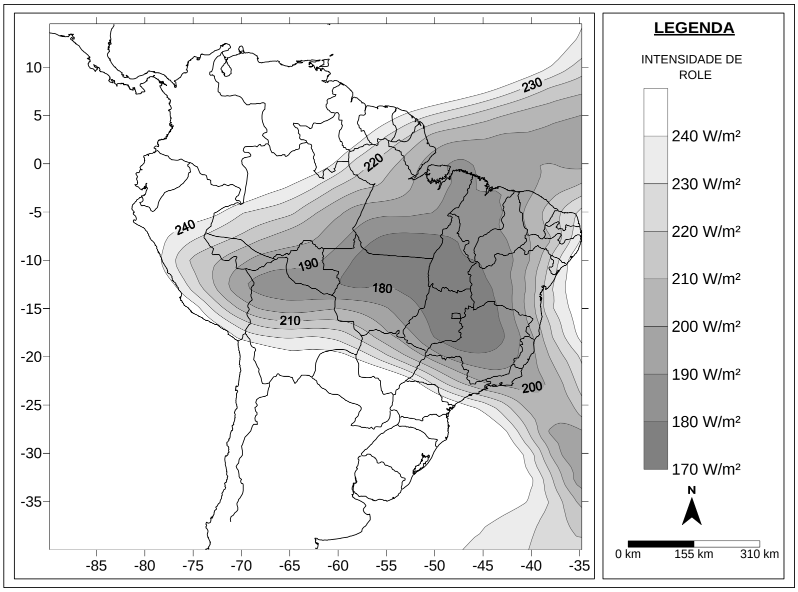

Figure 6 - Average OLR field between January 10 to 18, 1991.

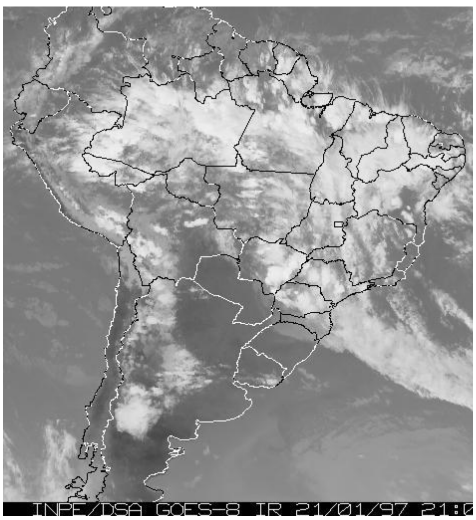

Figure 7.1 - SACZ organization on January 21, 1997.

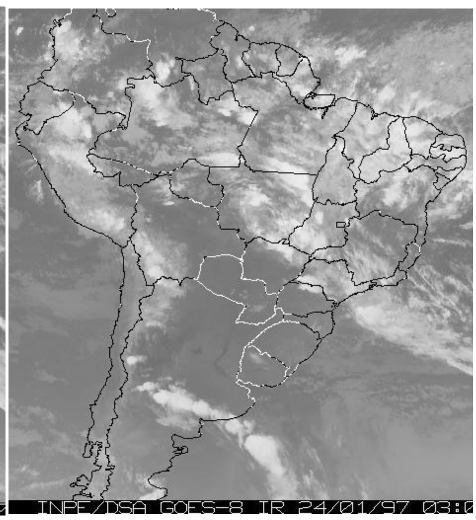

Figure 7.2- SACZ dissipation on January 24, 1997.

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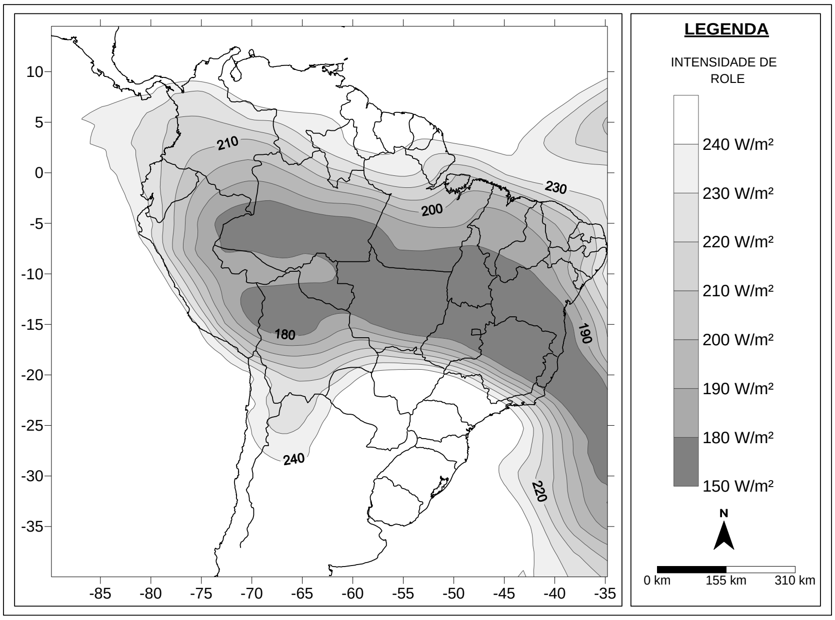
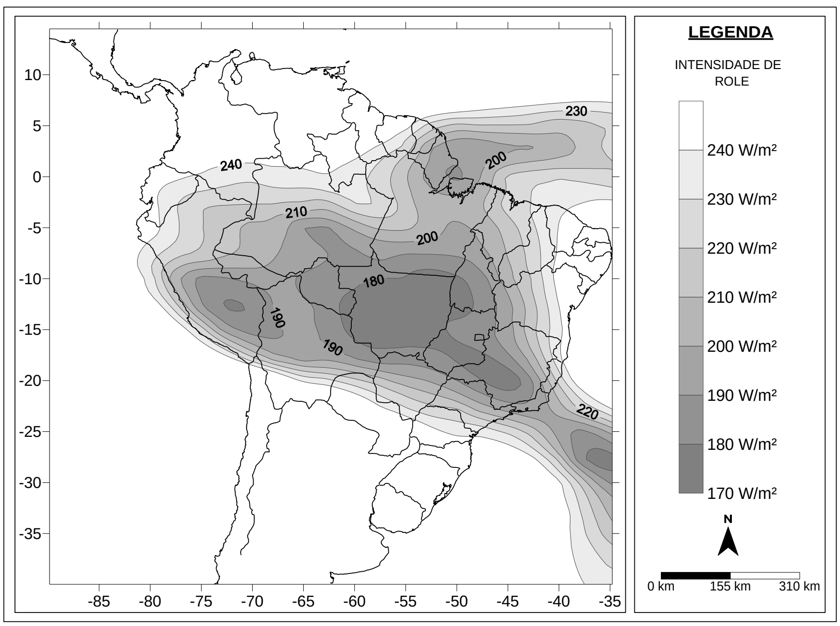


Figure 8 - Average OLR field (values lower than 240 W/m ^{2}) between January 10 and 20, 2004.



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590 Figure 9 - Average OLR field (values lower than 240 W/m^2) between January 11 and
591 15, 2011.