Floods in Brazil

Abstract

In this work the higher flood events occurred in Brazil from 1979 to 2010 were determined in order to describe the atmospheric circulation patterns associated with them. An analysis was hold in the 23 extreme ones, according to the season (summer/winter) and the region where the event occurred. The main causes identified were the El Nino episodes, Madden-Julian Oscillation, ITCZ and SACZ, besides smaller scales systems. The events that were not related with these causes need further investigation.

Introduction

The South America lands are distributed along different latitudes, from above the equator to higher than 55ºS. The consequence is a vast diversity of climates due the presence of different atmospheric systems (Reboita et al., 2010). Brazil, with a large extension, shows it clearly as its lands cross low and high latitudes. It has numerous environments in each part of the country, leading to different weather conditions and precipitation patterns. As a result the frequency of flood events is fairly high, since they are distributed along the regions and also year round.

According to Reboita et al. (2010), these patterns can be classified in 8 different groups along South America, considering the graphs of monthly precipitation. Only the ones including Brazilian lands are going to be addressed in this work. Table 1 shows the patterns in each part of Brazil as well as the mechanisms involved in each one of them, as shown by Reboita et al.

Region	Features of Annual Precipitation Cycle	Atmospheric Systems Acting
South of Brazil	Precipitation mostly homogeneous during the year with high rainfall totals.	Frontal systems and cyclones from the Pacific Ocean; subtropical CVHL; IL; subtropical MCCs; atmospheric blocking; sea breeze; SACZ; SASA; eastern Andes LLJ.
Northwest to Southeast of Brazil	Maximum totals in summer and minimum in winter.	Trade winds; eastern Andes LLJ; SASA; convection due surface heating; BH; ITCZ; sea breeze; IL; tropical MCC; frontal systems; subtropical CVHL; cyclones.

North of the Northern region of Brazil and Northeast coast	Maximum rainfall in the first half of the year.	ITCZ; convection due surface heating; tropical MCC; trade winds; sea breeze; IL; tropical CVHL; SASA; frontal systems.
Northeastern Backlands of Brazil	Maximum rainfall in summer and minimum in winter with low totals.	ITCZ; tropical CVHL; frontal systems; SASA; descendent branch of zonal circulation with Amazon convection activity.

Table 1 - Precipitation patterns in Brazil. MCC: Mesoscale Convective Complex; SACZ: South Atlantic Convergence Zone; SASA: South Atlantic Subtropical Anticyclone; LLJ: Low Level Jet; BH: Bolivian High; ITCZ: Intertropical Convergence Zone; IL: Instability Lines; CVHL: Cyclone Vortices at High Levels.

Besides the mechanisms related above, Sugahara (2000) also emphasizes the influence of South Atlantic cyclones in the precipitation patterns. According to the author, these cyclones are strongly related with the high rainfall levels over the southeast of Brazil during summer months, resulting in the high cloudiness called as South Atlantic Convergence Zone.

However well described by these previous studies, these systems are considered climatologic conditions that can be extremely affected when large-scale anomalies occur in the atmosphere. The consequence can be a distinguished modification in the precipitation patterns (Calbete et al., 1998). For this reason, in addition to the regular atmospheric mechanisms, climate phenomena as El Nino/La Nina and MJO are also relevant when studying precipitation anomalies in Brazil.

Over a general view of the precipitation outlines described so far, and for the purposes of this work, the summer months (December to March) are considered as the wet season, while the winter months (May to August) are the dry season.

It is also important to highlight that Brazil is one of the countries with the highest amount of water resources in the world. According to Tolmasquim (2012), 81% of the Brazilian energy in 2010 was derived from hydropower, representing the most important part of the energy matrix. A consequence of this fact is that the supply of energy is closely connected with the water availability in the streams and, therefore with the levels of rainfall during the year. For this reason, the observation of the rivers streamflow is a suitable representation for events of excessive (or restrained) levels of precipitation, and it is one of the sources of data in this research.

It is quite clear that flood events can cause not only social but also economic and environmental damages. Unfortunately flood episodes cannot be avoided, as they are governed by systems beyond human reach. However, being prepared for those events is probably one of the best ways to reduce the harms. In order to better understand what has been causing floods in Brazil and, thus to prevent higher damages, this work analyzes the causes of the highest floods in the last decades. With this purpose, historical data regarding the levels of precipitation and streamflow of rivers along the country will be associated with flood occurrence during the past decades.

Data and Methods

The Flood Archive from the Dartmouth Flood Observatory (DFO) has registered the highest floods in the world since 1985, based in media and governmental information. This data is the starting point to determine the location and timing of the highest events in Brazil. From the respective location of these floods, data from ONS (National Operator of the Electrical System) from 1979 to 2010, containing the streamflow of the rivers, was used to analyze the magnitude of the flood. The day of the events (and days near) were said to be a flood event if the streamflow value was higher than the 99% percentile. Otherwise, a different station should be analyzed to identify the flood event. The days showing a streamflow equal or higher than this, for the period from 1979 to 2010, was also considered as a flood event.

Nevertheless, not all events mentioned by the DFO were identified by the streamflow values and therefore, data regarding rainfall was required. Thus, stations from INMET (National Institute of Meteorology) and ANA (National Water Agency) were chosen when close enough from the flooded location (both of them also considered from 1979 to 2010). The approach to determine the flood was the same as for ONS. This way, for each station, days with rainfall levels higher than the DFO flood was also considered as a flood event.

With this approach, the events were summarized in a list of 383 floods in 34 stations around Brazil shown in Figure 1.

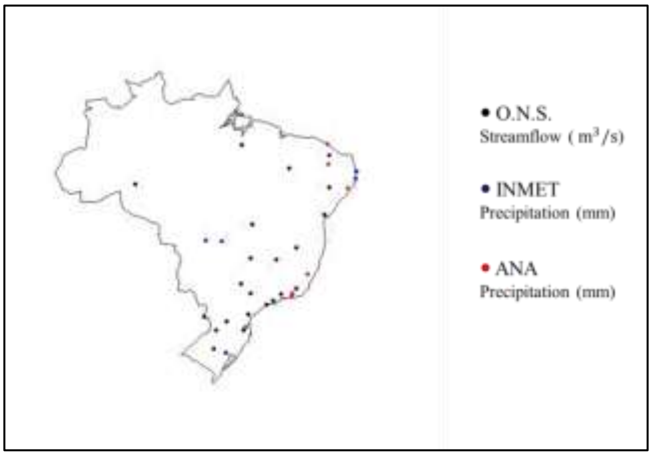

Figure 1 – Stations used in the analysis.

In order to simplify the analysis, the events were divided in summer and winter, as the wettest and driest seasons, respectively. Considering each season, the extreme events of each station were selected, resulting in a list of 20 events for summer and 3 for winter, with dates and location specified in Table 2. These are the events studied when analyzing the causes of the floods. The ones in bold are those mentioned by the DFO.

Season	Date	Region	Station	Source
Summer	03/feb/79	Southeast	Irapé	O.N.S.
	12/mar/79	Northeast	Itaparica	O.N.S.
	20/feb/80	Midwest	Serra da Mesa	O.N.S.
	03/mar/80	North	Tucuruí	O.N.S.
	17/mar/80	Midwest	Poxoreo	INMET
	13/dec/81	Southeast	Itamarati	ANA
	06/feb/83	Southeast	Promissão	O.N.S.
	02/feb/85	**Southeast**	**Ilha dos Pombos**	**O.N.S.**
	08/mar/87	Midwest	Aragarças	INMET
	24/dec/89	**Northeast**	**Pedra do Cavalo**	**O.N.S.**
	23/jan/92	Northeast	Açude Bonito	ANA
	10/jan/97	**Southeast**	**Três Marias**	**O.N.S.**
	25/dec/97	South	Triunfo	INMET
	18/jan/98	Southeast	Laranja da Terra	ANA
	20/dec/01	Midwest	Poxoreo	INMET
	23/jan/03	South	Triunfo	INMET
	07/mar/04	**Northeast**	**Fortaleza**	**ANA**
	05/jan/07	**Southeast**	**Ilha dos Pombos**	**O.N.S.**
	04/jan/10	South	Dona Francisca	O.N.S.
	05/jan/10	**Southeast**	**Funil**	**O.N.S.**
Winter	15/jun/82	South	Triunfo	INMET
	12/jul/83	South	Salto Pilão	O.N.S.
	08/aug/84	South	Foz do Chapecó	O.N.S.

Table 2 – List of extreme events for summer and winter.

From the dates listed above each flood was investigated in order to determine whether it was caused by regular atmospheric patterns or anomalous behavior. With this purpose, the events were grouped by region of occurrence. The comparison between the events was made evaluating anomalies in precipitation rate, sea surface temperature (SST) and outgoing longwave radiation (OLR). This study was based in the Daily Mean Composites from NOAA/ESRL website, http://www.esrl.noaa.gov/psd/data/composites/day/.

Results

1) Winter events

From Table 2 is easy to notice that the extreme events placed during winter months are restricted to the south region and besides, in the years from 1982 to 1984. The first two events are clearly connected with the 1982/1983 ENSO event, period on which the index showed an expressive positive anomaly. Moreover, as stated by Grimm et al., 2004, the higher occurrence of severe events during autumn/winter months is consistent with changes in seasonal rainfalls, which is a recurrent fact in years following an El Nino episode for this region of Brazil. The correlation of these floods with ENSO was also reported by Kousky and Cavalcanti, 1984.

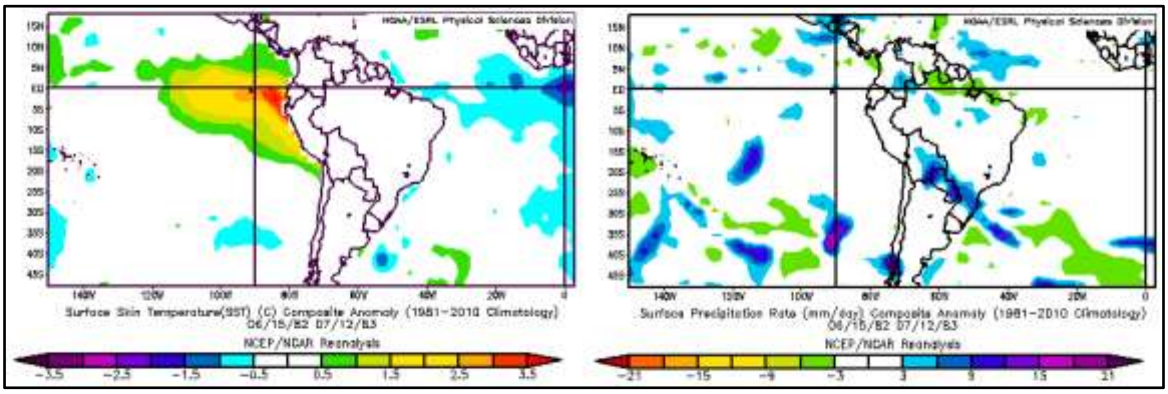

Figure 2 – 06/15/82 and 07/12/83 for SST (left) and precipitation rate (right).

The 1984 event however does not share the same features of the previous ones (Figure 3). From the OLR anomalies it can be seen that a massive cloudiness was originated in the south Atlantic, moving towards the south region of Brazil. As stated by Silva and Dias, 1998, around 3 days prior to the event a weak trough was identified over Argentina, sustaining western winds over Santa Catarina state. A few days later it was intensified and turned into a cyclone. This cyclone added to the anticyclone at East of the south region create appropriate conditions for the high rainfall levels (Figure 4).

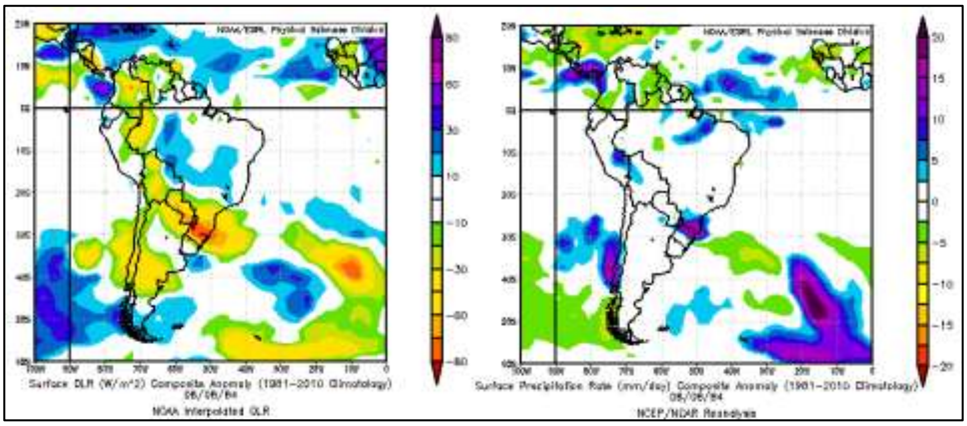

Figure 3 – 08/08/1984 for OLR (left) and precipitation rate (right).

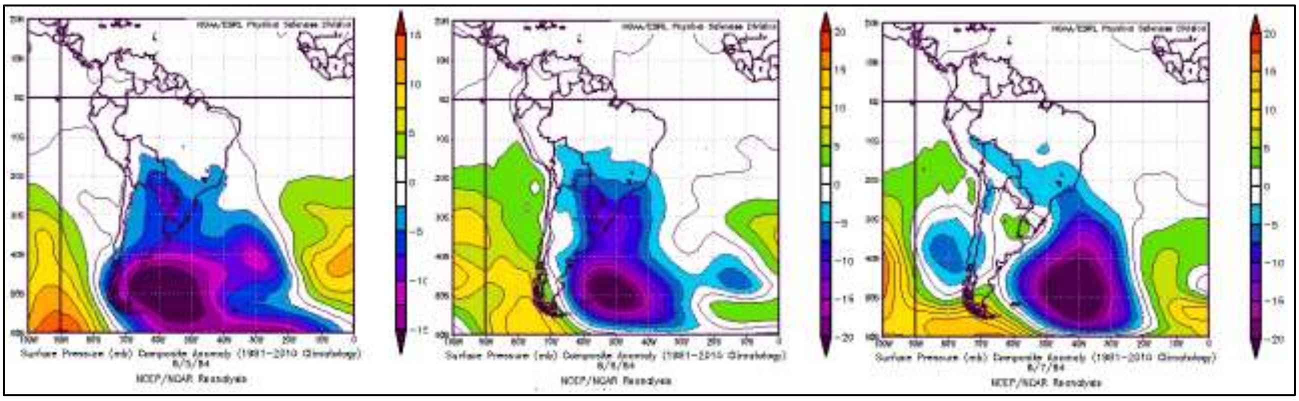

Figure 4 – 850mb pressure for 3 days prior to the 08/08/1984 event.

2) Summer events

When focusing on the Midwest region, it was possible to notice a relation between the period of the events and the MJO oscillation. When examining the index, its value was negative or turning into negative on the period of the events. This fact was similarly confirmed by Melo, 2006. The author also claims that this relation is more perceptible when the oscillation had an extreme behavior, however not exclusively associated to higher precipitation but also to extreme droughts. The event registered in the north region was included in this analysis due the proximity of the days.

For the Northeast region (Figure 5) a negative SST anomaly in the North and positive in the South of South Atlantic is evident, what favors the occurrence of precipitation in that region as said by Chaves, 1999. The author also states that the high OLR anomalies are due the cyclonic vortices at high levels (CVHL) usually formed in the tropical Atlantic during the summer months. The negative ORL anomaly also confirms the extreme precipitation in the Northeast verifying the influence of the ITCZ.

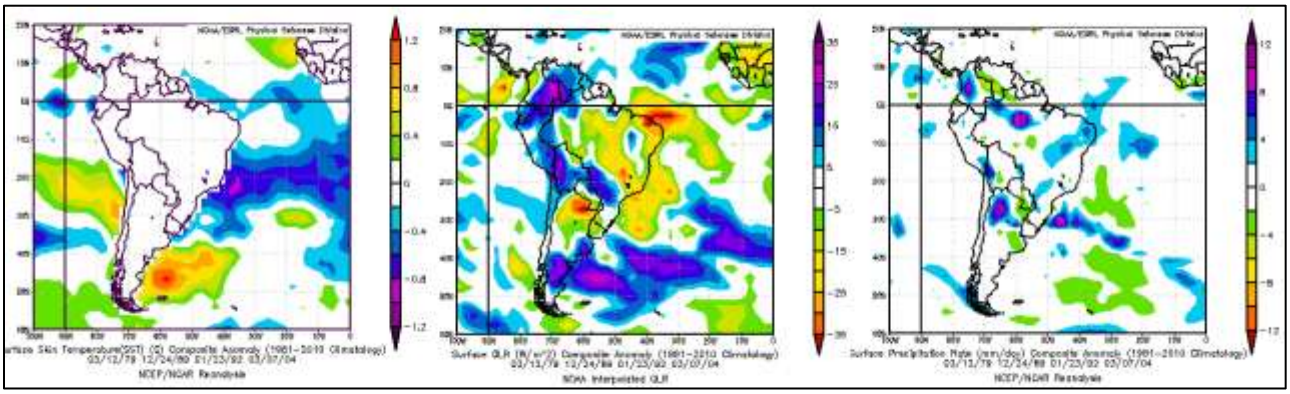

Figure 5 – 03/12/1979, 12/24/1989, 01/23/1992 and 03/07/2004 for SST (left), OLR (middle) and precipitation rate (right).

When analyzing the South region events, it is clear the influence of El Nino, which had considerable intensity for the years of 1997, 2003 and 2009. Figure 6 shows its presence with the SST anomalies and the OLR anomalies over Brazil. Moreover, this last one shows the Northeast/South dipole anomalies, typical of El Nino years (Cavalcanti, 1996) evidenced by droughts in the first and floods in the second.

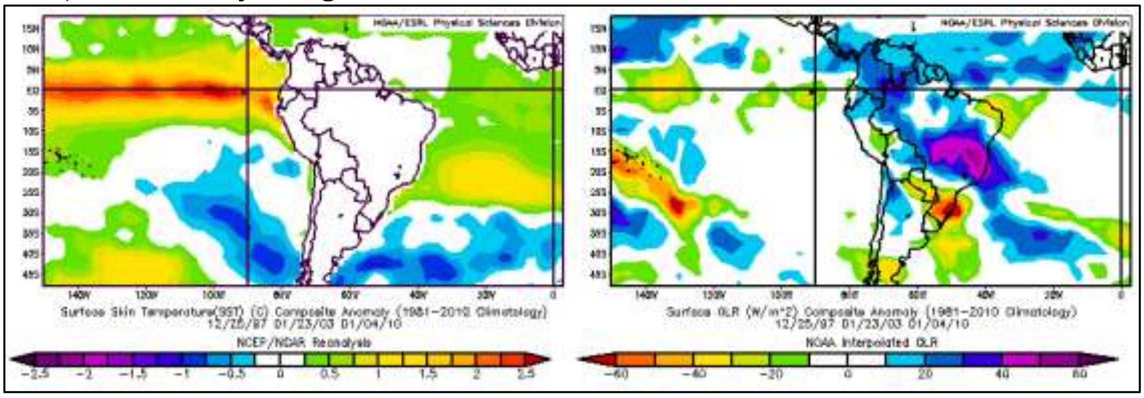

Figure 6 – 12/25/1997, 01/23/2003 and 01/04/2010 for SST (left) and OLR (right).

The Southeast events can be separated in two groups: the ones related with El Nino events (Figure 7) and the ones related with the South Atlantic Convergence Zone (Figure 8).

The El Nino (La Nina) is said to be responsible for a higher (lower) precipitation in the Mid/Southeast region, related with a colder (warmer) SST over the Atlantic caused by a higher (lower) cloudiness and therefore less (more) radiation can be absorbed (Grimm and Tedeschi, 2004).

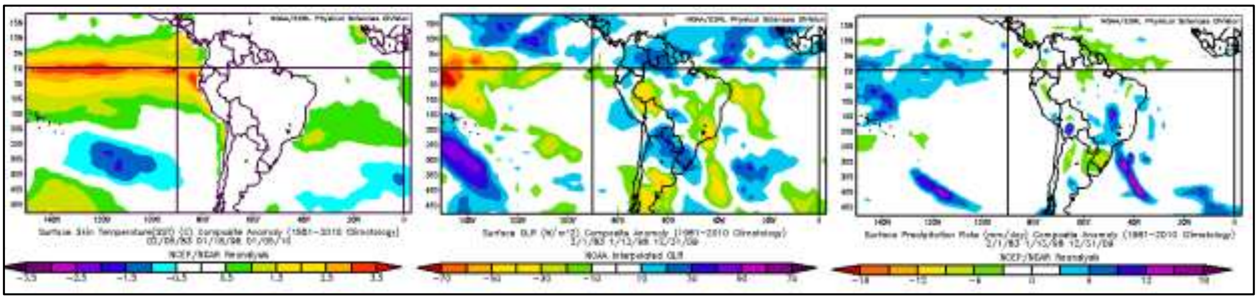

Figure 7 – 02/06/1983, 01/18/1998 and 01/05/2010 for SST (left), OLR (middle) and precipitation rate (right).

Figure 8 shows both the SACZ causing the high rainfall (OLR anomalies) and the association of these events with a negative SST anomaly. However these events are not related with El Nino episodes and, consequently it cannot be considered as a cause for these floods. Thus, further analysis should be made to investigate different reasons causing the intensification of these evidences.

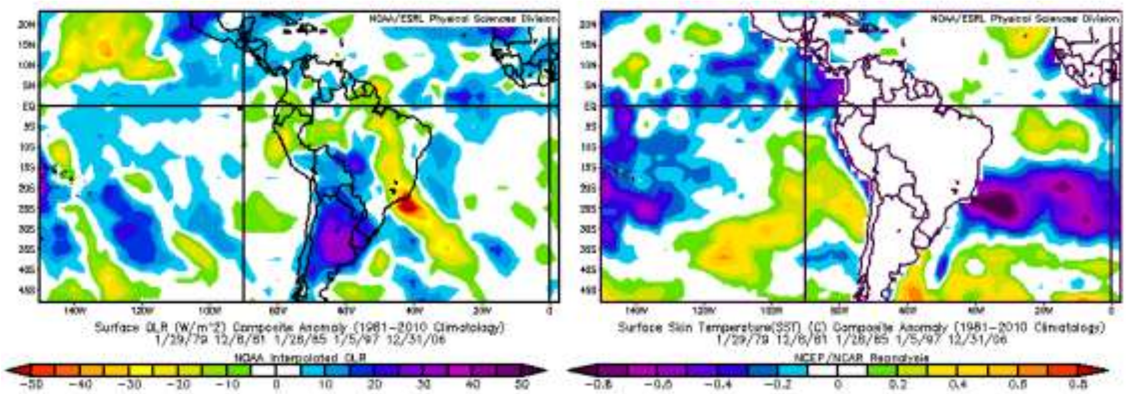

Figure 8 – 02/03/1979, 12/13/1981, 02/02/1985, 01/10/1997 and 01/05/2007 for OLR (left) and for SST (right), both for 5 days prior to the events.

Summary and Conclusions

In this work the highest flood events in Brazil from 1979 to 2010 were determined. The extreme ones were analyzed in order to reveal the atmospheric features involved with them. The approach chosen was to group these events by region, assuming that a pattern could be determined for events next to each other and for the same season (winter/summer).

For the unusual winter events, the main cause was related with El Nino episodes. Otherwise, it was a consequence of intensified, but usual, atmospheric circulation. The remaining question is what has caused this intensification.

The summer events had different causes according to each region. The South events could be identified as a reaction of El Nino events. The same was valid for some of the Southeast region events, when not related with the SACZ.

For the Midwest and North regions, the events were connected with the MJO, but not limited to it. The Northeast, in turn, had most of its events associated with the Atlantic Ocean behavior. It is important to notice that other usual systems, including small scale ones, might also have contributed with the high rainfall levels in these regions. As an example is the ITCZ in Northeast and convection complexes in North, besides other systems described in Table 1.

From this study, it can be seen that the causes for the flood events in Brazil have both local and global systems associated with them. Moreover, they are usually not limited to a specific location in the country, with more than one extreme event happening at the same time in different regions (Table 1). For January of 2010, for instance the South and Southeast events are both related with a distinguished El Nino episode. For March of 1980 however, the North and the Midwest events are probably a consequence of local features that ended showing the same consequence – an extreme rainfall event – however not specifically of the same cause.

Further analysis should be hold in order to determine small scale systems related with each one of the events and also to explain the intensification of the systems already identified.

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