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DRY SPELL EVENTS IN BRAZIL: HISTORICAL ANALYSIS IN YEARS OF CLIMATIC CONTRAST

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ABSTRACT

In South America, water in several regions is a strong limiting condition for socioeconomic development. More constant losses are observed in social and economic areas due to drought, for example, in the Northeast of Brazil (NEB) and Central West of Brazil (CWB), mainly in activities such as agriculture, animal husbandry, electricity distribution, water supply and tourism. The objective of this work is to investigate quantitatively and qualitatively the characteristics of 5-day dry spells in Brazil during the southern seasons and the relation of these drought events in normal years and climatic contrasts such as El Niño, La Niña in the tropical pacific for the period (1971-2005) with the aim of improving knowledge of the seasonal variation of rainfall in the country, with emphasis on the summer to enhance socioeconomic actions that depend on their variability with less risks. Data from the National Center Environment Prediction (NCEP) - Climate Prediction Center (CPC) of the National Ocean and Atmospheric Administration (NOAA) on Brazil, available at grid points (1° x 1°). The results show for the data observed (1971-2005) the variations of summer over Brazil for the southern and autumn seasons corresponding to the seasons with the highest rainfall in the Northeast and Central West of Brazil.

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INTRODUCTION

Man has always had to predict the climate, and now, technological evolution helps in this prediction. Observations and calculations are performed to study the atmosphere. Through statistical models, methods of data collection and mainly using physical concepts, scientists have developed models that can simulate weather and climate through physical and chemical processes that are some of the various tools used in meteorological studies. Even with heavy rains visible more often at the beginning of 2016, there are regions with a much lower rainfall index than other areas or regions of Brazil, such as the Brazilian Northeast (NEB) (Costa, 2008).

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Meteorological forecasts are of great importance characterized by the need to use rainwater in activities such as agriculture and water resources. Known for extreme droughts and dry spells of shares (periods of drought in the rainy season) (Carvalho *et al*, 2002) Brazil needs an excellent optimization of rational use of water resources (Silva & Rao, 2002). As for the dry spells, its characteristics must be investigated, in order to know its variabilities. The thermal variability of the tropical oceans has the characteristic of modifying the climatic variability of a continent. In the Pacific Ocean, the El Niño-Southern Oscillation (ENSO) phenomenon can negatively influence (positive) rainfall in NEB, for example, in El Nino and La Niña years via changes in Hadley cell positioning, which may decrease or increase the formation of clouds on the NEB, for example, altering the amount of rainfall of this region (Oliveira, 2001).

Studies that aim to investigate the variability of events associated with intra-seasonal precipitation, as is the case of summer variability, are necessary. South America is directly influenced in its climate and ecosystem by the thermal variability of the Pacific Atlantic Ocean and atmospheric systems with intra-seasonal performances such as the Madden and Julian Oscillation (Moly, 2002). Brazil is one of the areas affected by these thermal variations, and oscillations, marked by dry and full recurrent, the regions present great irregularity in the spatial and temporal distribution of rainfall.

In recent years new lines of research in dynamic observations and modeling have been developed at the most diverse timescales, aiming to minimize and better understand the influence of drought events on social and economic actions. For example, making comparisons and analyzes between the results of data collected by PCDs, Buoys and Remote Sensing are interesting to identify their differences in physical systems such as the thermal variations in the oceans in South America over the country. The objective of this work is to improve the knowledge of the seasonal variation of rainfall, with emphasis on summer and how they act on Brazil in the main rainy seasons of the year, autumn and summer, with emphasis on years of climatic contrast throughout the period from 1971 to 2005, in relation to the daily precipitation observations to potentiate socio-economic actions that depend on their variabilities with less risks. These types of studies that deepen the knowledge of these variabilities and their future projections are of great importance for predictions of climatic impacts in regions of South America and mainly in the NEB, being able to guide economic, social and political planning.

MATERIALS AND METHODS

For daily precipitation observed on Brazil, satellite data were used, mixed with rain gauge observations from the National Oceanic and Atmospheric Administration (NOAA), National Center Environment Prediction (NCEP) and Climate Prediction Center (CPC) database (Silva *et al*., 2008). This database was selected for the period from 1971 to 2005, accumulated daily totals of 24 hours, available in resolution of 1° x 1° grid points (latitude and longitude), each degree corresponds approximately 111 km, which is considered a detailed spatial resolution. For the analysis, the daily precipitation data were treated in Fortran programming language routines (IBM Mathematical Formula Translation System), mainly used in Computer Science and Numerical Analysis. The formal standard of the Fortran language used was Fortran 95 (ISO/IEC 1539-1: 1997), published in 1996, is aimed at the use of computers with advanced architectures.

The routines were created to indicate information about events of summer, which are periods of consecutive days with precipitation less than 2 mm or without precipitation (1971-2005). These events may be consecutive or interspersed with one or more days with precipitation greater than 2 mm. The dry spells events investigated by the routine were those of five days, analyzed separately during the four southern seasons divided in summer (December to February), autumn (March to May), winter (June to August) and spring (September to November) to all of Brazil, and also by the regions of the Brazilian territory that are divided by the Brazilian Institute of Geography and Statistics (IBGE). With this criterion, the Brazilian territory was divided into five regions: Brazilian Northeast (NEB), Brazilian Midwest (BMW), Brazilian North (BN), Brazilian Southeastern (SEB), Southern Brazil (SB). The five areas were delimited by the following coordinates: NEB (2 - 15°S, 34 - 49°W), BN (5°N - 10°S, 45 - 75°W), BMW (9 - 23°S, 46 - 60°W), SEB (15 - 24°S, 40 - 52°W), SB (22 - 34°S, 49 - 57°W). For the selection of these regions, criteria were used as similarities in physical, human, cultural, social and economic aspects. The analysis was done during all the years of the South American (SA) database in the Brazilian territory with emphasis in the NEB and BMW regions. The count of events was given by the sum of the number of events occurring at each grid point of 1° x 1°, and for the previously mentioned regions the counting of each event was done by the average precipitation of the grid points inserted in each one of them, for each season of the year. The output data of the Fortran routines compilations are provided in graphs and the count is illustrated by Figures generated by the GradS (Grid Analysisand Display System) software, which is an interactive tool used for manipulation and visualization of Earth science data that uses an environment of data of up to 4 dimensions: longitude, latitude, vertical level and time. Data from different sets can be graphically overlapped, with spatial and time registration joining different sets of data sets. Data can be displayed using a variety of graphic techniques printed on images.

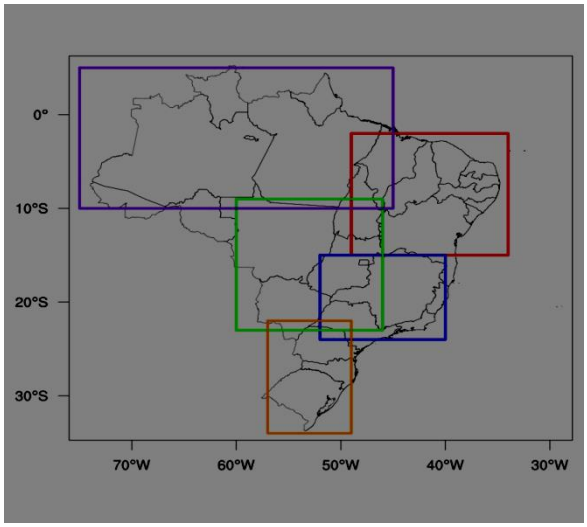

Figure 1. Study areas delimited by coordinates, NEB (red), BN (purple), BMW (green), SEB (blue), SB (yellow)

RESULTS

5-day dry spells events - interannual variability (1971 - 2005). The compilation of routines for the five-day summer events on AS with emphasis in Brazil provided information that is shown in the form of maps. The images show the predominance of events according to each season of the year and for some years of climatic contrasts in which El Niño, La Niña and Normal events occurred. Images were generated for each year individually between one thousand nine hundred and seventy-one, to two thousand and four, and for the four seasons. For the year one thousand nine hundred and eighty-three it was a year of climatic contrast of El Niño considered strong by the literature. One can see the high amount of summer events of up to five days (Figure 2). By the Figure presented, some impacts of the phenomenon El Niño Southern Oscillation (ENSO) are evident. In summer in El Niño years there are a greater number of five-day events, from the northern Amazon to the NEB; In the South Atlantic Convergence Zone (ZCAS) zone (Lopart, 2012), the most central and southern part of the

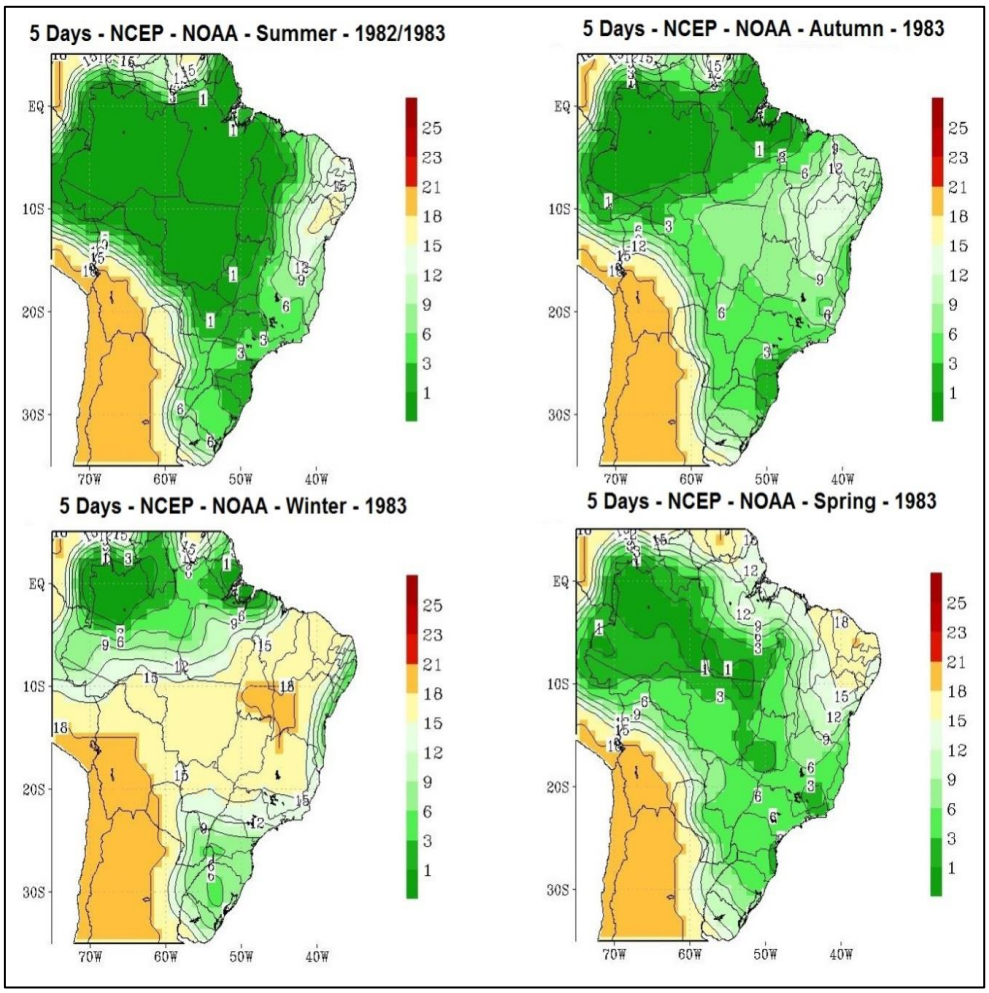

Figure 2. Number of five-day dry spells in Brazil during the seasons of the year in 1983

Amazon and the Midwest and Southeast regions of Brazil, the number of five-day dry spells is quite small compared to the NEB. In autumn, there is an increase in five-day summer events mainly in Central Brazil, leaving only the northern region outside these dry periods. Transported by atmospheric-oceanic teleconnections (via Walker-Hadley cells) the five-day events were evident in all seasons and regions; Although it is an intrassazonal characteristic of the precipitation, dry spells respond to this physical fortification between the Pacific Ocean and Atlantic. In the year one thousand nine hundred and eighty-nine, considered by the literature as a year of La Niña of strong intensity (CPTEC/INPE, 2017), we can see that the drought characteristics are less evident mainly on the Amazon (Figure 8).

In the region of ZCAS, the most central and southern part of Amazonia and central and western regions of Brazil, the number of five-day dry spells can be seen as similar to the El Niño years, except in the summer season. In the summer of the La Niña years, the region of increase of these events of summer does not extend much for the coast of the NEB and Amazon. In winter, we can see a small reduction in the number of events compared to the year one thousand nine hundred and eighty-three, the year of El Niño previously quoted, yet the central part of the NEB is badly hit by drought. It was evident a greater number of events in years of El Niño and a smaller number of events in years of La Niña as indicated in the literature, indicating the reduction (regularity of the increase) of the precipitation.

The year nineteen hundred and ninety-six, indicated by the literature as normal (year in which there were no El Niño and La Niña events) was chosen to demonstrate the behavior of five-day summer events. The literature also shows that the year one thousand nine hundred and ninety-six, despite being a normal year, was marked by a year of severe drought in the NEB (CPTEC/INPE, 2008). Figure 3 shows that in this year, a lower number of 5-day summer events predominated in the Amazon and the SACZ region in the summer and fall seasons, while in NEB and vicinity there was an increase in this number of events.

In the winter and spring seasons, higher numbers of five-day summer days (values greater than 15 events) are highlighted, mainly in winter, in Central Brazil, southern Brazil and NEB. In the spring season the con Figuration on the Amazon, and the region of operation of the ZCAS and NEB present a similar con Figuration. The construction of graphs was also performed for a better visualization of the count of the amount of events of five days by regions and seasons of the year. A routine in Fortran performed the analysis of the data showing the frequency of events during the period studied. The analyzes presented here are only for the autumn and summer seasons for the Brazilian Northeast (NEB) and Brazilian Midwest (BMW) areas. These areas were delimited by the following coordinates: NEB (2 - 15°S, 34 - 49°W) and BMW (9 - 23°S, 46 - 60°W). For the NEB (Figures 5 and 6) and for the COB (Figures 7 and 8) during the autumn and summer seasons it is possible to observe the behavior of the number of summer

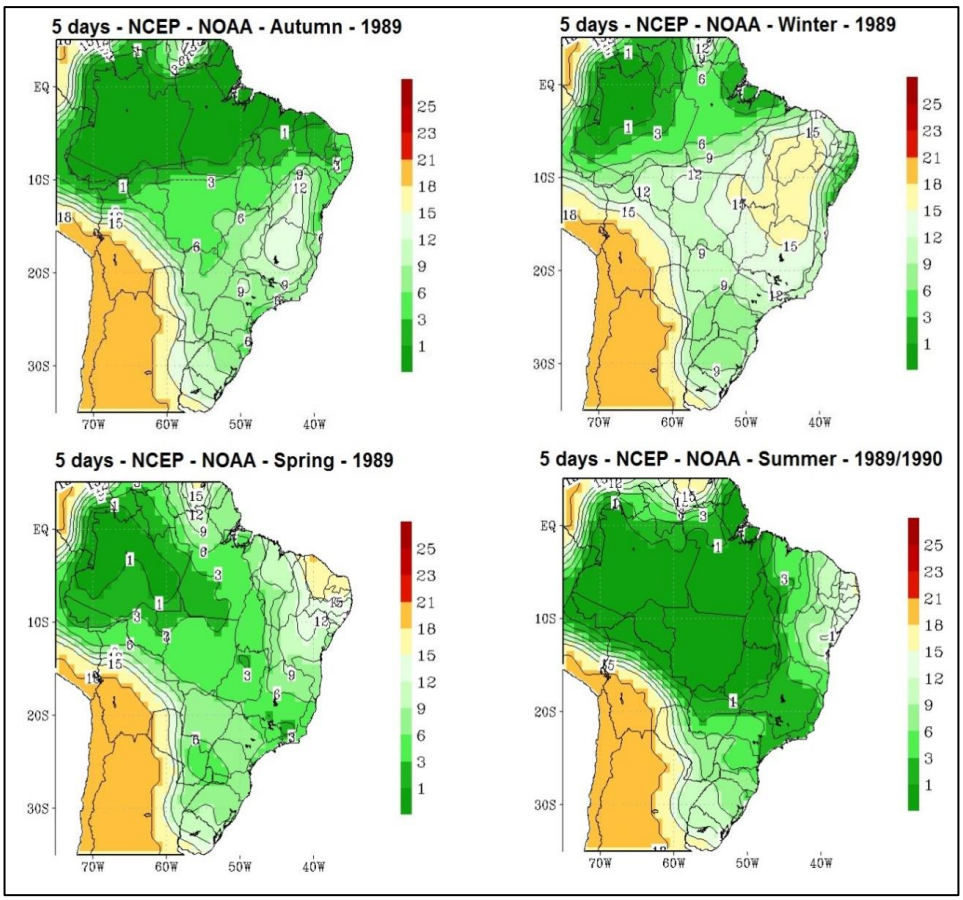

Figure 3. Number of five-day dry spells in Brazil during the seasons of the year in 1989

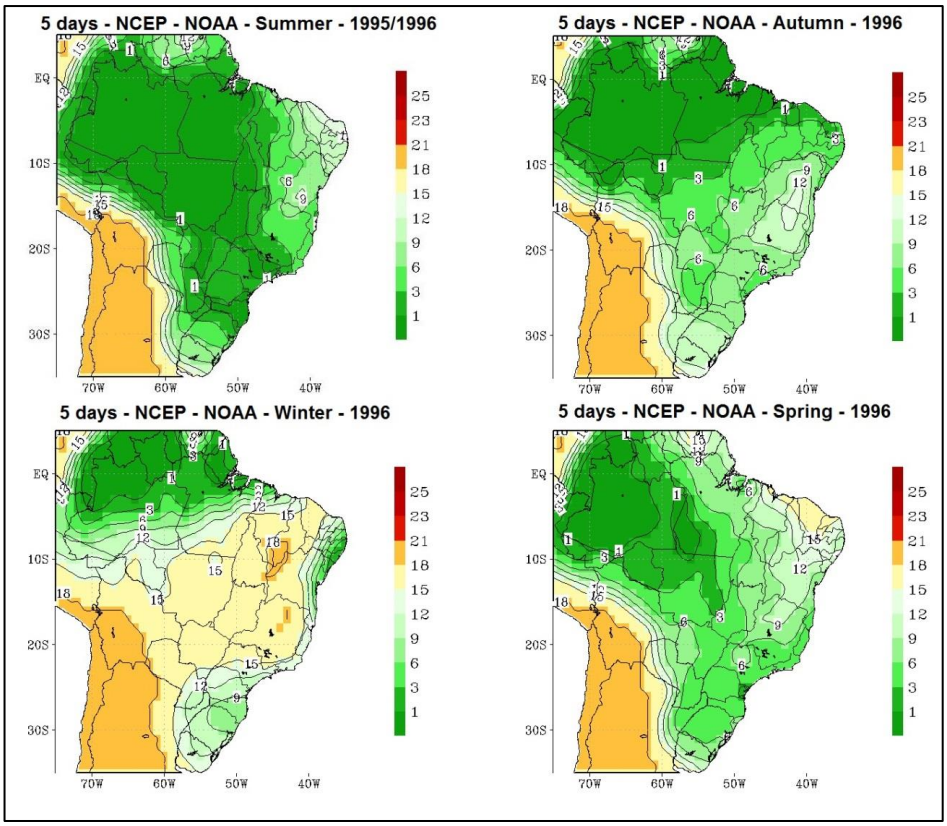

Figure 4. Number of five-day dry spells in Brazil during the seasons of the year in 1996

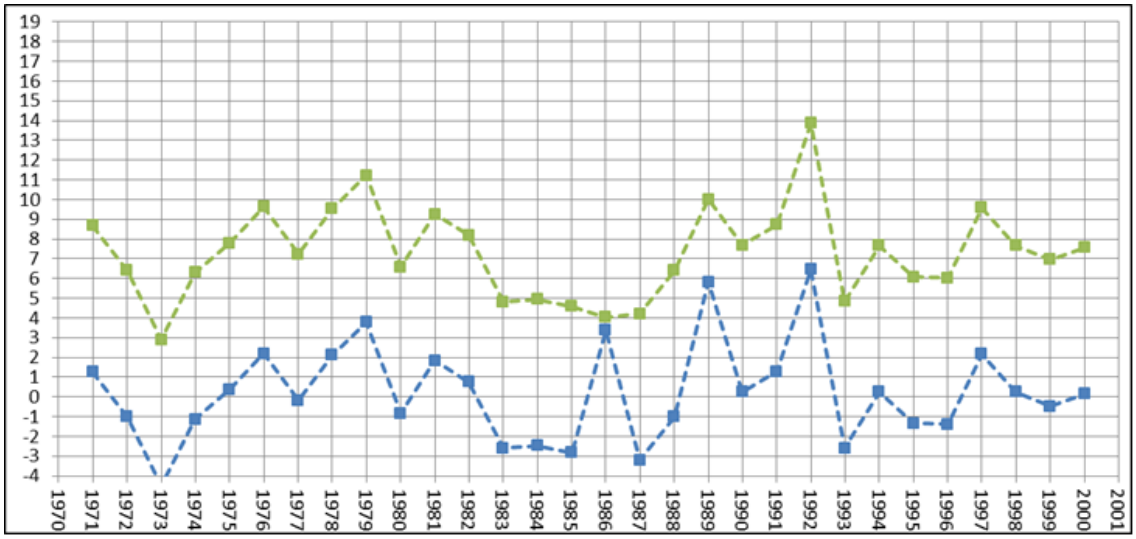

Figure 5- 5-day dry spells events and climate mean difference over NEB (2°S - 15°S, 34°W - 49°W) during autumns from 1971 to 2000. Blue Squares = Average climate difference 5 day events; Green Squares = 5 day events

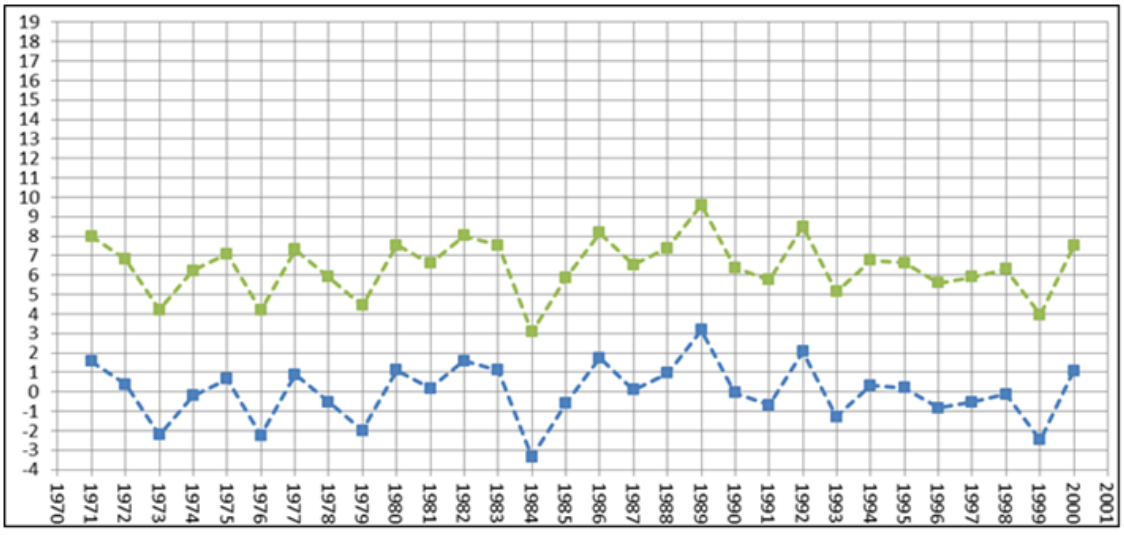

Figure 6- Events of 5-day dry spells and difference of the mean temperature over the NEB (2°S - 15°S, 34°W - 49°W) during the summers of 1971 to 2000. Blue Squares = Average climate difference 5 day events; Green Squares = 5 day events

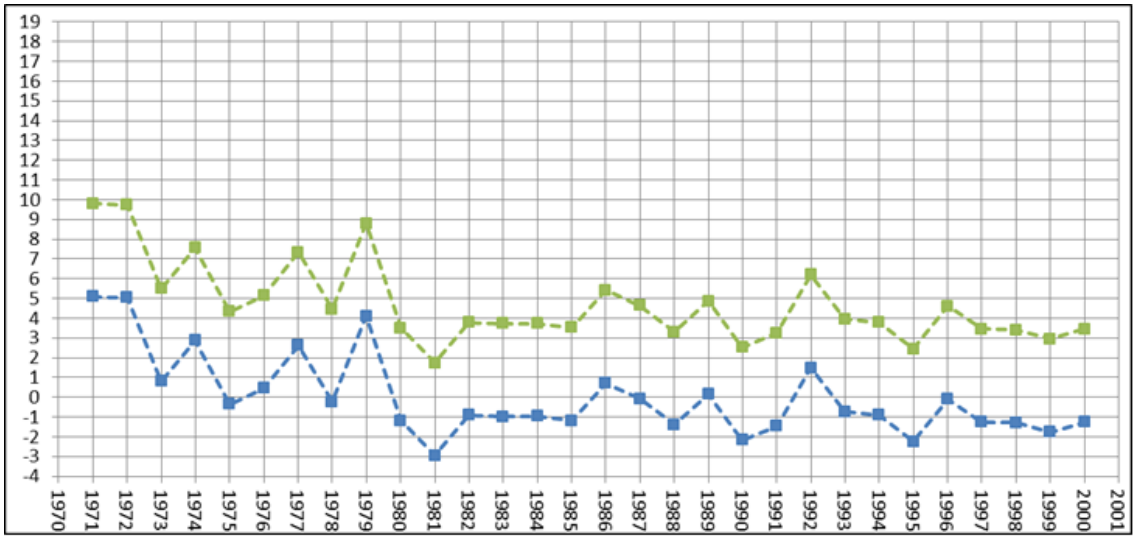

Figure 7 - Events of 5 - day dry spells and climate mean difference over BMW (9°S - 23°S, 46°W - 60°W) during autumns from 1971 to 2000. Blue Squares = Average climate difference 5 day events; Green Squares = 5 day events

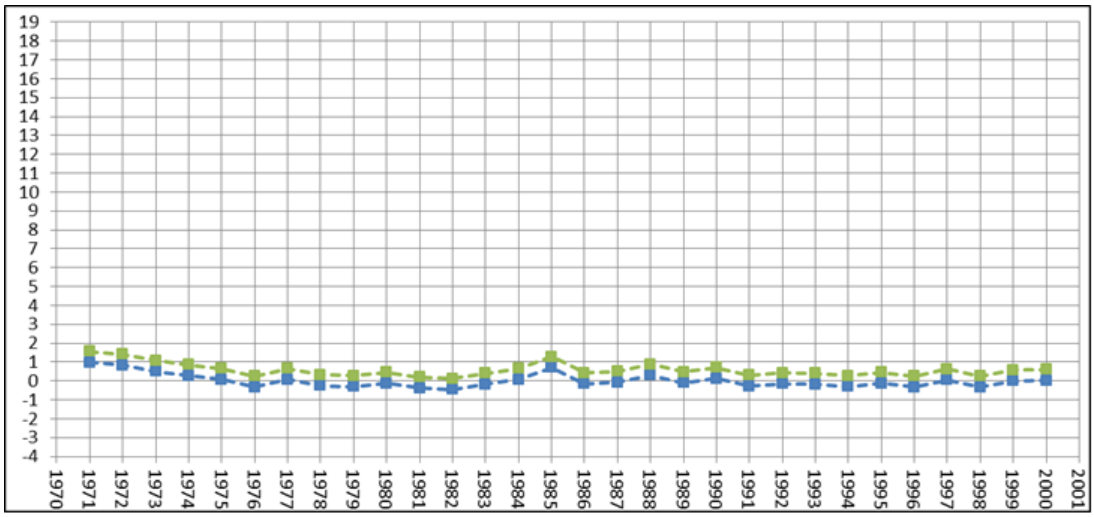

Figure 8 - 5 - day dry spells events and climate mean difference over BMW (9°S - 23°S, 46°W - 60°W) during the summers of 1971 to 2000. Blue Squares = Average climate difference 5 day events; Green Squares = 5 day events

events of five and ten days so that it is possible to find highlights in years of climatic contrast of both El Niño and La Niña. For the five-day events during the fall we can find variations of peaks and falls in a few years, the years with the highest peaks of events shown are the years of: 1976, 1978, 1979, 1989, 1992 and 1997. The years with the highest falls in the events were: 1973, 1983 to 1987 and 1993. The years of peaks cited coincide with the years of El Niño pointed by the literature as being years of strong intensity with the exception of the year 1989, which was a year of La Niña de strong intensity, and with some of the years cataloged as years of drought in the NEB.

Fall years are also categorized as El Niño years of high or moderate intensity, according to the literature. According to the graphs, during the fall, La Niña events have no influence on the five-day events on NEB, since El Niño has a strong influence on drought on the NEB during the fall season. During the summer of the NEB the five-day events (Figure 6) had considerable peaks in the years 1971, 1982, 1983, 1986, 1989 and 1992; and 1973, 1976, 1979, 1982, 1984, 1993 and 1999 years. As shown, some of the peak years coincide with El Niño years of strong intensity, with main highlight for the year 1983 and 1992 in the events of five days, but the years 1986 and 1987 were considered years of moderate intensity and the year 1971 is considered a normal year according to the literature.

The year of 1999 coincides with a year of La Niña of moderate intensity and the year of 1989 that was a year of La Niña of strong intensity gives the interpretation that years of La Niña does not have a well defined influence in the events of dry spells of five days on the NEB. For the COB in the fall season (Figures 7) peaks can be noted in the years 1971, 1972, 1974, 1977, 1979, 1986 and 1992; the most relevant peaks since the 80's correspond to La Niña years. The years with number of events below trend do not show trends because they are years of contrast, vary with years of contrast and normal years. Data show that dry spells in the COB region are influenced by El Niño during the fall, but also have inconsistencies, which may be a post-year recovery phase of contrast. In both Figures 7 and 21 a slight negative trend in the number of 5-day events over COB can also be observed over the years.

Final considerations

The results of the analysis of the data period from the NCEP-NOAA network for South America showed that the thermal variability of the tropical oceans has the capacity to change the climate variability of a continent and strong in the five - day drought events, was evident that these events act in all seasons and regions. Although it is an intra-seasonal characteristic of the precipitation, dry spells respond to this physical fortification between the Pacific Ocean and Atlantic. In the region of ZCAS, the most central and southern part of the Amazon and the regions of the west and southeast of Brazil, the number of five-day dry spells can be seen as similar to the El Niño years, except in the summer season. According to the data, during the fall, La Niña years have no influence on the five-day events on the NEB, unlike the El Niño years, which has a great influence on the drought on NEB mainly during the autumn, giving freedom to interpret that La Niña years do not have a well-defined influence on the five-day events on NEB. Dry spells in the COB region are influenced by El Niño during the fall, but also have years with inconsistencies, which may be a recovery phase after years of contrast.

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