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SPATIOTEMPORAL CHARACTERIZATION OF PRECIPITATION IN MATO GROSSO DO SUL: RAINFALL DISTRIBUTION AND ANOMALY(RAI) ANALYSIS FOR CLIMATE PHENOMENA

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ABSTRACT: This study examined the ENSO and Rainfall Anomaly Index in Mato Grosso do Sul state using rainfall data from 32 sites obtained from the National Water Agency through its web platform (www.hidroweb.ana.gov.br). Annual totals were compared with ENSO occurrence information at http://www.cpc.ncep.noaa.gov. Rainfall anomaly indices (RAI) were generated to qualitatively evaluate the series with ENSO. Some years considered in El Niño were classified as extremely wet by the RAI. La Niña's effect was confirmed by the RAI as extremely dry just in some particular years. Comparing the RAI obtained from the NOAA website information there is a reasonable correspondence between rainfall and the years under the action of the positive component of ENSO.

KEYWORDS: Mato Grosso do Sul, rainfall, RAI, El Niño, La Niña

CARACTERIZAÇÃO ESPAÇO-TEMPORAL DA PRECIPITAÇÃO DE MATO GROSSO DO SUL: DISTRIBUIÇÃO DA CHUVA E ANÁLISE DO ÍNDICE DE ANOMALIA DA CHUVA (RAI) PARA FENÔMENOS CLIMÁTICOS

RESUMO: Este estudo examinou o ENSO e o Índice de Anomalia de Chuva no estado de Mato Grosso do Sul usando dados de chuva de 32 locais obtidos da Agência Nacional de Águas por meio de sua plataforma web (www.hidroweb.ana.gov.br). Os totais anuais foram comparados com as informações de ocorrência do ENSO em http://www.cpc.ncep.noaa.gov. Índices de anomalia de precipitação (ACI) foram gerados para avaliar qualitativamente as séries com o ENSO. Alguns anos considerados em El Niño foram classificados como extremamente úmidos pelo IAC. O efeito de La Niña foi confirmado pelo IAC como anos extremamente secos, apenas em anos particulares. Comparando o IAC obtido das informações do site da NOAA, existe uma razoavel correspondência entre os anos sob a ação do componente positivo do ENSO.

PALAVRAS-CHAVE: Mato Grosso do Sul, chuvas, IAC, El Niño, La Niña

CARACTERIZACIÓN ESPACIO-TEMPORAL DE LA PRECIPITACIÓN DE MATO GROSSO DO SUL: DISTRIBUCIÓN DE LLUVIA Y ANÁLISIS DEL ÍNDICE DE ANOMALÍA DE LLUVIA (RAI) PARA FENÓMENOS CLIMÁTICOS

RESUMEN: Este estudio examinó el ENSO y el índice de anomalía de lluvia en el estado de Mato Grosso do Sul utilizando datos de lluvia de 32 sitios obtenidos de la Agencia Nacional del Agua a través de su plataforma web (www.hidroweb.ana.gov.br). Los totales anuales se compararon con la información de ocurrencia de ENSO en http://www.cpc.ncep.noaa.gov. Se generaron índices de anomalías de precipitación (ACI) para evaluar cualitativamente las series con ENSO. Algunos años considerados en El Niño fueron clasificados como extremadamente húmedos por el IAC. El efecto de La Niña fue confirmado por el IAC como años extremadamente secos, solo en años particulares. Comparando el IAC obtenido de la información del sitio web de NOAA, existe una razonable correspondencia entre los años bajo la acción del componente positivo de ENSO.

PALABRAS CLAVE: Mato Grosso Do Sul, Lluvia, IAC, El Niño, La Niña

1. INTRODUCTION

In recent years, studies on precipitation at regional and local scales have been responsible for a significant expansion of scientific works in the area of Meteorology and Climatology, especially those that seek to identify the influence of anomalies such as the El Niño-Southern Oscillation (ENSO) phenomenon (GRIMM et al. 1998, 2000; MOLION, 2005; MARENGO, 2007; STRECK et al., 2009, 2011; PAMPUCH and FERRAZ, 2012; SILVA et al., 2012, CHECHI and SANCHES, 2013; LYRA et al, 2017).

Among many others, one way to study rainfall is through the Rainfall Anomaly Index (RAI), which helps to monitor years of drought and excessive rainfall. This index allows comparisons of the rainfall regime of a given location from a series of historical data with current rainfall conditions and is also used to characterize the spatiotemporal variability of precipitation in the study region (ARAÚJO et al., 2007; MARCUZZO et al., 2011; SANCHES et al., 2014)]. Another advantage of RAI is that, unlike other indices, it only needs precipitation data and is easy to estimate. With that it contributes to studies that verify the impacts of global climate on the vulnerability of rainfall on the planet (ARAÚJO et al., 2009a; ALVES et al., 2016).

In the works by Araújo et al. (2007) and Araújo et al. (2009b) RAI was applied as a tool to analyze climatology in the geographic space of the Paraíba river basin, located in the southeastern part of the Taperoá and Alto Paraíba state and of the Médio and Baixo Paraíba sub-basins, and the influence on variability spatio-temporal rainfall in that region. When analyzing rainfall data from the first decades of the 20th century to the first years of the 21st century, the results reveal an inflection in the behavior of precipitation since the 1960s. After this period, there was a decrease in the frequency of dry years, however with a significant increase in its severity.

Similarities were found between the rainfall patterns of the Taperoá and Alto Paraíba sub-basins and the Médio and Baixo Paraíba sub-basins. An "inflection point" in the distribution of precipitation was found in the sub-basins of Taperoá and Alto Paraíba, in which consecutive dry years until the 1960s were observed. In the sub-basins of the Middle and Lower Paraíba, similarities were observed in the alternation of dry and rainy years throughout the IAC series.

Silva et al. (2009) applied the IAC seeking to identify the behavior of rainfall in the Mundaú River basin (between the States of Pernambuco and Alagoas) using precipitation data from 1955 to 1991 obtained from the National

Water Agency. The results showed that the year 1974 was considered as an "inflection point" with respect to rainfall in the basin. Before 1974, there was a predominance of rainy years over dry years. After 1974, dry years became more frequent than wet ones.

The work of Ewald (2010) sought to analyze the rainfall regime in the municipality of Marechal Cândido Rondon (PR) from 1965 to 2008 using statistical techniques and methods, seeking to correlate the ENOS events with the severity indices obtained through the IAC. Their analyzes showed strong relationships between the occurrence of the El Niño and La Niña phenomena with the wetter and drier years, respectively, and even though the IAC proved to be perfectly adequate for their analysis.

Seeking to use the IAC as a climatic indicator of rainfall variability in the micro-region of Gurupi (TO), Silva Junior et al., (2011) developed their analyzes using data between 1974 and 2006 from five rainfall stations belonging to ANA. The results pointed to the existence of great regional rainfall variability, registering events considered to be very dry for consecutive years between 1988 to 2003, especially in the municipality of Cariri do Tocantins. In Brejinho de Nazaré, the years 1976, 1984, 1990, 1991, 1998 and 2003 were considered by the IAC as Extremely Dry. However, 1980, 1984, 1985, 1989 and 2000 were considered Extremely Wet years after the application of the IAC.

Silva et al. (2012) sought to verify the influence of the ENOS phenomenon on the variability of rainfall in the metropolitan region of Fortaleza and in the Cariri region (interior of Ceará) using the IAC as an analysis tool. The authors observed that the association of the hot and cold phases of ENOS promoted, respectively, a decrease and an increase in rainfall for the Fortaleza region, demonstrating a strong correspondence between the events, differently from what was observed for the Cariri region of Ceará.

Studies have also shown that RAI can be used as a tool for the climatic monitoring of a given location (or region), monitoring and generating climatic prognosis and diagnostics.Marcuzzo et al. (2011) used the RAI as one of the resources to analyze the spatiotemporal and seasonal variation of rainfall in the state of Mato Grosso, with rainfall data between 1977 and 2006 showing that there were more negative events (dry years) than positive (wet years) in the period. Assis et al. (2015) report that the RAI developed by Rooy (1965) has good application for use in semiarid regions because of its ability to provide information on the occurrence, severity and impact of drought. In the São Francisco River basin, using data from 15 rainfall stations, it presented good response using this index, in which they observed that the occurrence of dry years is higher than that of rainy years in the region.

ENSO is a phenomenon of ocean-atmosphere interaction, associated with changes in the normal patterns of Sea Surface Temperature (SST) and trade winds in the Equatorial Pacific region between the Peruvian Coast and Australia (MORAES NETO et al., 2007), where, in the negative phase (La Niña), rainfall is generally below normal climatological values and, in the positive phase (El Niño), is generally above normal (GRIMM et al. 1998, 2000; BERLATO & FONTANA, 2003). In the case of Brazil, the ENSO phenomenon mainly influences the northern sector of the Northeast, eastern Amazon (in the tropical range) and the Southern region, resulting, respectively, in severe droughts with increased average temperatures, decreased risky precipitation. In Santa Catarina

(Southern Brazil), the occurrence of El Niño phenomenon was associated with the occurrence of positive precipitation anomalies (SÁ et al., 2018). However, in the case of the Midwest Region, where the state of Mato Grosso is located, there is no trend observed due to the low predictability for this region (BERLATO & FONTANA, 2003).

Marcuzzo and Oliveira (2012) correlated the variation of the maximum daily precipitation with the intensity of the El Niño (a) Index in the State of Mato Grosso do Sul. Data from 37 rainfall stations with 30 years of data and 55 stations with data ranging from 20 to 29 years were used, with all historical series ranging from 1977 to 2006. Monthly data on the intensity of El Niño and La Niña climate phenomena were obtained from the National Weather Service (NOAA), which was related to data of maximum daily precipitation in order to describe the course of precipitation evolution under the influence of the phenomena. From 1977 to 2006 the average monthly Niño (a) index ranged from -1.1°C to 1.3°C, variations considered moderate, with some variations considered strong in 1982 (2.3°C), 1983 (2.3°C), 1988 (-1.9°C), 1991 (1.6°C), 1992 (1.8°C), 1997 (2.5°C), 1998 (2.3°C), 1999/2000 (-1.6°C) and 2002 (1.5°C). In general, the extreme daily maximum rainfall each year increased in the El Niño episodes and little in the La Niña episodes and concluded that the El Niño and La Niña phenomena have evident effects on the precipitation of the state of Mato Grosso do Sul, however the El Niño phenomenon is more impactful than the La Niña phenomenon on the precipitation of the state of Mato Grosso do Sul.

The objective of the present work is to evaluate the influence of the ENSO phenomenon in rainfall over the state of Mato Grosso do Sul by applying the Rainfall Anomaly Index to the annual precipitation totals of 32 sites distributed within the state.

2. METHODOLOGY

2.1. STUDY AREA

The study area is the state of Mato Grosso do Sul (Fig. 1), which is located in the Midwest region of Brazil. The state has a total area of 357,145,534 km^2, covering 79 municipalities (IBGE, 2019), of which 32 have rainfall stations that were used in this study (Table 1).

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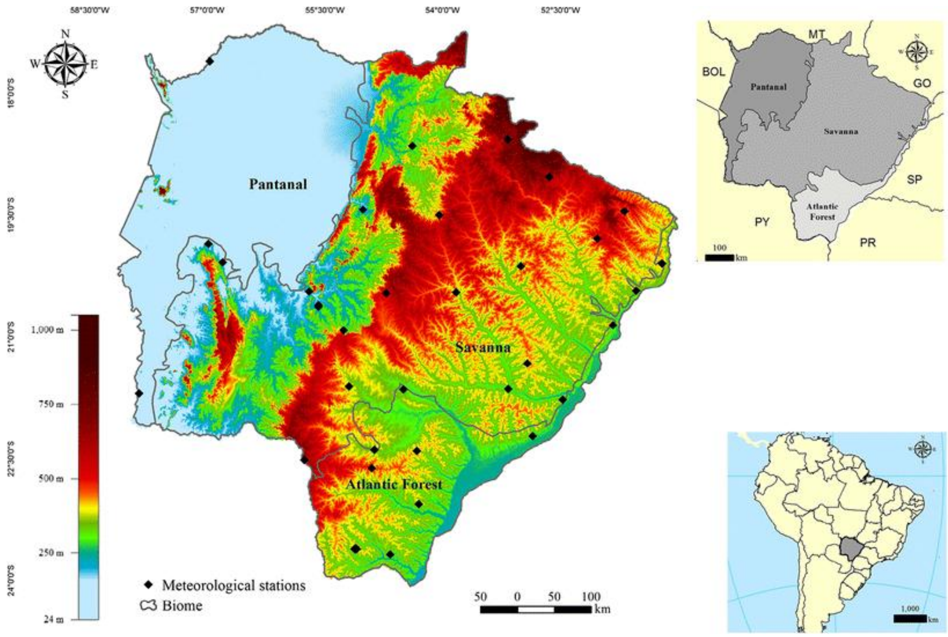

FIGURE 1 - Altitude map (m) for the state of Mato Grosso do Sul, separation between biomes (Savannah, Atlantic Forest and Pantanal) in the state and its location in Brazil and South America and location of meteorological stations. Source: Teodoro et al. (2015).

Table 1 - Altitude (m), latitude (°), longitude (°), and observation period of monthly precipitation for 32 municipalities in the state of Mato Grosso do Sul, Brazil.

Local	Latitude (°)	Longitude (°)	Altitude (m)	Period(years)
Água Clara	-20.50	-52.90	303	1975–2013
Amambai	-23.10	-55.00	480	1973–2013
Anastácio	-19.57	-56.20	106	1960–2000
Anaurilandia	-22.20	-52.70	284	1975–2013
Aparecida do Tabuado	-20.00	-51.10	375	1983–2013
Aquidauana	-22.47	-55.79	147	1960–2000
Bataguassu	-21.70	-52.40	329	1975–2013
Bodoquena	-19.90	-57.00	133	1954–2013
Caarapo	-22.60	-54.80	454	1973–2013
Camapua	-19.50	-55.00	404	1973–2013
Campo Grande	-20.40	-54.60	532	1975–2013
Chapadao do Sul	-18.80	-52.60	790	1983–2013
Corumba	-19.00	-57.60	118	1983–2013
Costa Rica	-18.50	-53.10	641	1983–2013
Coxim	-18.50	-54.70	238	1973–2013
Dourados	-22.20	-54.80	430	1973–2013
Gloria de Dourados	-22.40	-54.20	422	1973–2013
Iguatemi	-23.70	-54.60	333	1975–2013
Inocencia	-19.70	-52.00	502	1983–2013

Maracaju	-21.60	-55.10	384	1973–2013
Miranda	-20.24	-56.38	125	1960-2000
Inocência	-19,74	51.95	502	1960–2000
Navirai	-23.10	-53.10	366	1975–2013
Nova Andradina	-21.60	-53.10	271	1975–2013
Paranaiba	-19.70	-51.20	374	1983–2013
Ponta Pora	-22.50	-55.70	655	1973–2013
Porto Murtinho	-21.70	-57.90	90	1983–2013
Ribas do Rio Pardo	-20.50	-53.80	373	1975–2013
Rio Brilhante	-21.80	-54.60	312	1973–2013
Rio Negro	-19.40	-55.00	233	1975–2013
Santa Rita do Pardo	-21.30	-52.80	393	1975–2013
Selviria	-20.40	-51.40	348	1983–2013
Três Lagoas	-20.80	-51.70	319	1975–2013

Source: Autores (2020).

2.2. GEOGRAPHIC CHARACTERISTICS OF THE STUDY AREA

The state has several edaphoclimatic characteristics distributed among three biomes with peculiar climatic attributes: Savannah, Atlantic Forest and Pantanal; and altitudes range from 90 to 790 m (Fig. 1).

In the state, there are three major topographic units: (a) the western Pantanal, with a unique drainage network that spreads over a vast plain of moderate altitudes between 80 to 200 m; (b) in the center, a Divider Plateau (Serra de Maracaju) which extends in the Northeast - South-west (NE-SW) direction, separating the waters of the Paraguay and Paraná River basins, with altitudes ranging from 300 m (*Serra de Bodoquena*) to over 650 m (*Planalto do Amambaí*); and (c) in the eastern portion, the upper Paraná River, drained by large rivers of the sandstone-basalt plateau, with altitudes ranging between 200 and 250 m along the valley (ZAVATTINI, 2009).

The Savannah (or *Cerrado*) is the second largest biome in South America (SA) and covers 22% of the Brazilian territory. This biome is the source of three major watersheds of SA (Amazonas/Tocantins, São Francisco and Prata), resulting in high aquifer potential and great biodiversity (MMA, 2020). Because of its latitudinal position, the region is characterized by the transition between warm low latitude climates and temperate mid-latitude mesothermal climates (NIMER, 1989). In Mato Grosso do Sul, savanna is the dominant biome (BUENO et al, 2018). It is in this region that the highest elevations of the state are found, especially in the northwestern portion where there are points whose altitude reaches 1,000 m (Fig.1)

The Atlantic Forest is an environmental complex that includes mountain ranges, valleys and plateaus. It is also classified as a biodiversity hotspot and was once one of the richest and most varied sets of rainforest in SA, but is now recognized as the most uncharacterized Brazilian biome (FIORILLO & FERREIRA, 2013).The Pantanal biome covers 25% of the state of Mato Grosso do Sul, being an almost exclusive biome of Brazil, with an area of approximately 150.355 km^2

(PRAC, 2020). It is characterized by long-term flooding (due to low soil permeability) that occurs yearly on the lowlands and causes changes in the environment, wildlife and daily life of local populations (DOMINGUES et al., 2004). The climate of the Pantanal is ''Aw'' (Koppen classification), with annual rainfall between 1,000 and 2,000 mm, and two distinct seasons: dry (May to September) and rainy (October to April), being the rainy season responsible for over 80% of total annual precipitation (MESQUITA et al., 2013).

2.3. HISTORICAL SERIES OF MONTHLY AND ANNUAL PRECIPITATION

The historical series used in this work are the average monthly and annual rainfall data of 32 rainfall stations in the state of Mato Grosso do Sul (Fig. 1 and Table 1).

Data were obtained from the Brazilian National Water Agency's (ANA) hydro-meteorological database, available at the Hidroweb - Hydrological Information System portal (http://hidroweb.ana.gov.br/). As criteria for the use of data series, we considered only the use of consistent data, with a minimum of 15 years, there were no flaws in the historical series. To avoid discarding information, an equal data analysis period has not been established between stations.

The analysis of the occurrence of ENSO phenomena from 1989 to 2013 consisted of plotting the annual series totals by drawing their linear trend line and the standard deviation of the series and then compare the annual totals with the information about the occurrence of the ENSO phenomenon available on the National Weather Service Climate Prediction Center (NOAA) website (http://www.cpc.ncep.noaa.gov).

Another way to analyze the influence of the ENSO phenomenon on the annual rainfall of the series was by applying the Rainfall Anomaly Index (RAI) proposed by Rooy (1965) and adapted by Freitas (1998), in order to obtain positive and negative anomalies, respectively obtained from the following equations:

$$RAI+ = [(N-M)/(Mm\acute{a}x - M)] \quad (1)$$

and

$$RAI- = [(N-M)/(Mm\acute{i}n - M)] \quad (2)$$

N = observed precipitation of the year in which the RAI will be generated (mm); M = average annual rainfall of the historical series (mm); Mmax = average of the ten largest annual precipitation of the historical series (mm); and, Min = average of the ten lowest annual precipitation of the historical series (mm).

For the disposal of Meteorological stations in terms of RAI, the classification elaborated by Araújo et al. (2009b) for the longest dry and wet years within homogeneous groups was applied. The classification is made according to the values registered for the RAI, as shown in Table 2.

Table 2 - Rainfall level according to RAI.

Rainfall Anomaly Index (RAI)	Rainfall Rating
RAI≥4	Extremely rainy
RAI≥2 e RAI<4	Very rainy
RAI>0 e RAI<2	Rainy
RAI=0	No anomaly
RAI < 0 e RAI > -2	Dry
RAI≤ -2 e RAI > -4	Very dry
RAI ≤ -4	Extremely Dry

Source: Araújo et al. (2009).

The ENSO occurrence information was obtained from the database of the National Oceanic and Atmospheric Administration/Climate Prediction Center - NOAA/CPC (NOAA, 2015), for the years of analysis. The correlation (r) analysis was performed between the occurrence of ENSO and the RAI. The significance of the correlation coefficient was made, testing the null hypothesis (H0): true correlation is equal to 0, with significance level = 5%.Cluster analysis (CA) was performed using the WARD method. Ward's method was used in this work since it has been widely and successfully used in climatological studies resulting in satisfactory results (WARD, 1963; LYRA, OLIVEIRA-JUNIOR and ZERI, 2014; OLIVEIRA-JÚNIOR et al., 2017). Both the number of groups and the stations were subjectively determined by the dendrogram cross section. After obtaining the homogeneous groups, a climatology was elaborated for each region, in order to analyze separately the contribution of the meteorological variable. All Figures for the 32 stations are provided in supplementary material along with this study.

3. RESULTS AND DISCUSSION

3.1. MONTHLY RAINFALL ANALYSIS

The maps of the monthly average spatial distribution of rainfall in the state of Mato Grosso do Sul for the period 1998 to 2013 are shown in Fig. 2. The January and February rainfall distribution maps with the predominant continental equatorial air mass (hot and humid), show the highest rainfall in the north and northeast. It is also verified that the altimetric elevation of the area (*Serra da Bodoquena*) contributes to orographic rainfall in the southwest region of the Cerrado Sul-Mato-Grossense. For the months of March and April, rainfall maps show that the transition from summer to autumn causes a decrease in rainfall mainly in the northeast region, and orographic rainfall in the southwest of the state.

Between May and June, there is a downward propensity in rainfall in the northern part and a higher concentration of rainfall in the southern part of the state of Mato Grosso do Sul. This trend occurs due to the frontal rainfall that occurs with the advances of the Atlantic polar air mass over the continent at this time of year.

The distribution of rainfall in July and August, the winter period, shows a marked reduction in rainfall throughout the state of Mato Grosso, due to the arrival of polar air mass whose characteristic is to bring droughts to the central region of the country. The highest rainfall concentrations in this period are in the southern region, at latitude above 21 degrees, due to some incursions of the

Atlantic Tropical Air Mass that can bring some moisture to the region.

Rainfall maps for September and October, late winter and early spring show a significant increase in rainfall over previous months in the state. The increase in rainfall in September and October is due to the weakening of the Atlantic polar air mass due to the increase in solar energy influx in the southern hemisphere. In September the rains are concentrated more in the southern region and in October in the southeast region of the state. This phenomenon occurs due to the greater influence of the Atlantic Tropical Air Mass that acts mainly in the south of the region bringing moisture.

For the months of November and December, mid and late spring season, there is a tendency for rainfall to increase as a result of the increase in heat influx in the southern hemisphere in the final months of the year. The humid Continental Equatorial Air Mass gains strength and moves south increasing the amount of rainfall in the region. In November and December, precipitation becomes more concentrated in the northern region of the state due to the Continental Equatorial Air Mass, and also in the southwest region due to the high altitude of the *Serra da Bodoquena* (Fig. 2).

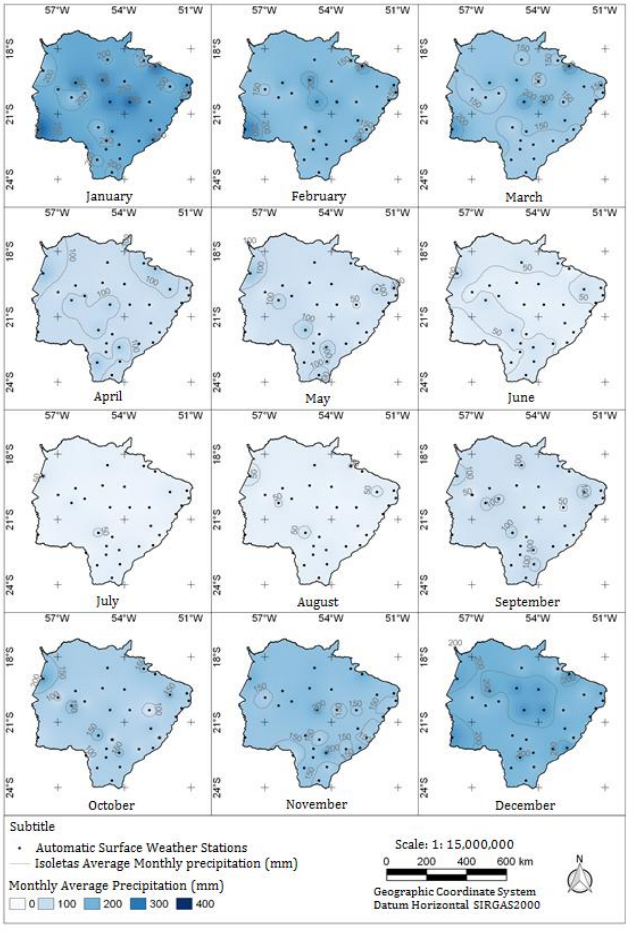

Figure 2 - Map of the monthly average spatial distribution of rainfall in the state of Mato Grosso do Sul.Source: Authors (2019).

3.2. REGIONS OF HOMOGENEOUS PRECIPITATION

Based on the CA technique, it was observed the formation of five homogeneous groups (50% similarity), defined later according to Keller Filho et al. (2005). Group 1 (G_1) formed by the municipalities or Meteorological stations : *Rio Pardo, Três Lagoas, Campo Grande, Bataguassu, Santa Rita do Pardo, New Andradina, Porto Murtinho, Aquidauana, Anastacio, Maracaju, Rio Brilhante, Anauriland, Caarapó* and *Dourados*, which revealed greater homogeneity of monthly precipitation considering all biomes. Group 2 (G_2) formed by the municipalities of *Gloria Dourados, Naviraí, Iguatemi, Amambai and Ponta Porã*, obtaining the highest average rainfall in the dry season and belonging to the Savana and Atlantic Forest biomes. Group 3 (G_3) was formed by the municipalities of *Aparecida do Taboado, Selviria, Miranda, Bodoquena* and *Corumbá*, which present lower average rainfall in the dry season and located in the Savannah and Pantanal biomes. Group 4 (G_4) was formed by the municipalities of *Camapuá, Agua, Clara, Coxim* and *Rio Negro*, which presented the highest average rainfall during the transition season, and belongs to a single biome (Savannah). Group 5 (G_5) formed by the municipalities of *Chapada do Sul, Costa Rica, Innocence* and *Paranaíba*, with the highest rainfall averages during in the rainy season, mainly in March and December, belonging only to the Savannah biome.

3.3. PRECIPITATION IN THE DRY AND WET PERIODS

The average rainfall of the wet period (Fig. 3) corresponds to the period from September to May. Rainfall maps for this period (Fig. 2) show a higher concentration of rainfall in the northern and southwest regions during the wet period. This distribution occurs due to the presence of the humid continental equatorial air mass, which provides rainfall mainly in the northern region, and the topography that provides significant rainfall in the southwest region.

The June to August quarter, characterized as a dry period (Fig. 3), presents maximum rainfall indexes of 349 mm for the total monthly averages. Rainfall is mainly concentrated in the southern region due to the incursions of the Atlantic Tropical Air Mass, which can bring some moisture to the region.

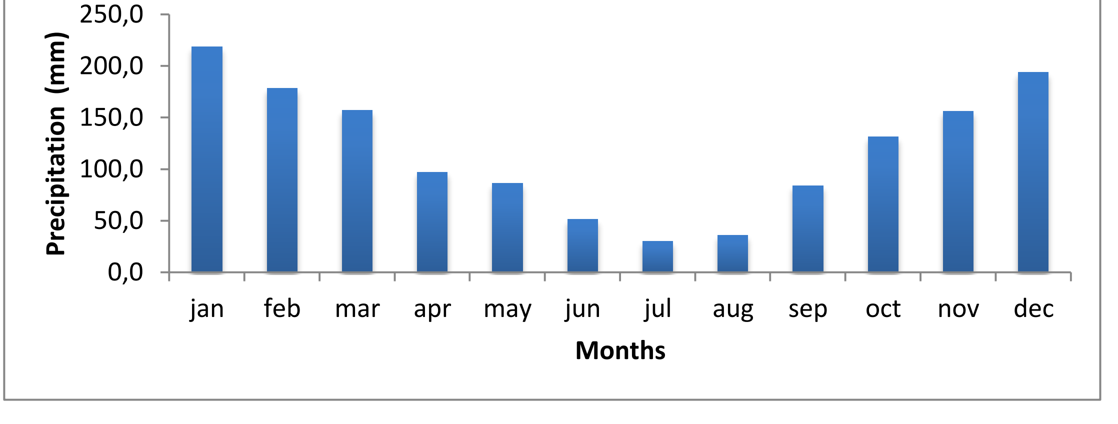

Figure 3 - Histogram of monthly average totals with precipitation (mm) seasonality for the state of Mato Grosso do Sul.

3.4. RAINFALL ANOMALY INDEX ANALYSIS

To understand the participation of ENSO phenomena in the annual precipitation totals of the presented series, the RAI developed by Rooy (1965) and adapted by Freitas (1998) was applied. The RAI classification is made following the values described in Table 2.

Figure 4 shows the estimated RAI for the series of each of the 32 rainfall stations, which allows us to classify the years according to the proposal of Freitas (1998) (Table 2), and thus obtain the framing of the years in Table 3.

In the analysis of the data from the historical series of more than 30 years (1978 to 2013), for the 32 studied and distributed rainfall seasons, it is observed the Rainfall Anomaly Indices for each location. According to Nimer (1989), this region has a certain climate uniformity with regard to atmospheric mechanisms (mainly the circulation of air masses), which makes regional thermal diversification due to geographical factors as altitude, latitude and longitude (continentality). The same author states that all static climatic factors, such as relief, act on the climate of a given region in interaction with regional atmospheric circulation systems, which demonstrates the importance of knowing the circulation systems acting on the region throughout the year to understand the climate dynamics of the study area.

Regarding the seasonal and spatial distribution of rainfall, Nimer (1989) states that these are very simple, as topography characteristics do not offer great barriers to atmospheric circulation systems, which define rainfall of the Brazilian Midwest Region.

However, these precipitations are not evenly distributed throughout the year. In almost every region, more than 70% of the total rainfall accumulated during the year is precipitated from November to March, and the November-January quarter is generally rainier..

During this quarter it rains on average 45% to 55% of the annual total. Contrariwise, winter is excessively dry and at this time of year the rains are very rare, with an average of 4 to 5 days of occurrence of this phenomenon per month, being even scarcer in the western sector of Mato Grosso do Sul, where at least one month does not even register a single day of rainfall. Therefore, drought happens more often in the winter quarter of June-July-August.

The distribution of annual and monthly rainfall averages in the region is uniform in space and time, since the highest and lowest total averages were measured in the municipalities, which leads us to believe that only topographic factors play no conditioning role in the spatial distribution of these variables. , since the atmospheric circulation conditions are practically the same for the whole portion of the state of Mato Grosso do Sul.

On a macro scale, the main air masses that influence the variation and seasonal distribution of rainfall in the region are Tropical Atlantic and Polar Atlantic (in winter) and Atlantic Tropical Mass (in summer). Thus, on a more localized range, spatial variations are responsible for factors such as topography and continentality, as well as being influenced by the predominant direction of air masses.

The rainy season (October to March/April) concentrates over 85% of annual rainfall, with December and January contributing more than 35% of annual rainfall. The dry season, which begins in April and extends to the beginning of October, is characterized by a significant reduction in rainfall. In the driest quarter of the year (June-August), rainfall represents, on average, less than 2% of the annual total.

During the dry season it is possible to observe long periods without rainfall and/or with insignificant rainfall, well below the daily evapotranspiration (Etp) and that does not change the dryness of the environment. These periods often exceed 100 days. During the analysis period, the average number of consecutive days in which prolonged dry spells occurred do not exceed 75 consecutive days.

It is also observed that the average days, in the years in which long dry periods occurred above the minimum research limit were 105 days, and the average days without significant rainfall (less than 2.5 mm) is 110 days and that Almost half of the years have a long period without rainfall exceeding 75 uninterrupted days. This period coincides with the season of the dry season, being more common in June, July and August, and may arrive until mid-September.

Following are graphs of the RAI and annual averages of the historical series of rainfall for the 32 locations analyzed in the state of Mato Grosso do Sul.

Table 3 - Classification of annual totals of the time series of the 32 series of rainfall data from the cities of MS, according to the RAI.

Percentage (%)	Ranking
5.7	Extremely wet
14.1	Very wet
32.4	Moist
3.4	No anomalies
5.7	Dry
17.2	Very dry
5.0	Extremely dry

Source: Authors (2019).

Table 3 shows that after the application of RAI, 5.7% of the years were considered extremely wet [RAI (4)]. In turn, classified as very wet (2 < RAI < 4) are 14.1% of years and between 0 <RAI <2, ie wet years, are 32.4%.

From the perspective of extremely dry years (RAI < - 4), there are 5.0% of the years. In the years classified by the RAI as very dry (-4 < RAI < -2) there are 17.2% and dry RAI (-2 <RAI <0) 5.7%. And finally, the years without anomalies correspond to 3.4%.

However, 1989 (strong La Niña), 2004, 2005 and 2006 (normal years) were classified by the RAI as "very dry" (-4.0 <RAI <-2.0). In 2004, 2005 and 2006, precipitation behavior should not be scarce, as they are under the neutrality of the ENSO phenomenon.

In the analyzed period, the highest ACI was 9.30 for the Iguatemi city in 1996, when rainfall varied from a maximum of 222 mm to a minimum of 72 mm. The lowest RAI value, -7.65, was for the Innocence city in 1991, which had a maximum rainfall of 174 mm and a minimum of 69 mm.

The analysis phase of the occurrence of ENSO phenomena was for the period 1989-2013. For this, the graphs of Figure 4 show the annual total precipitation along with its linear trend line and the standard deviation of the series.

In Figure 4, it is also possible to identify years that presented with precipitation within the standard deviation of the series, considered years with normal precipitation and which were under the influence of the ENSO phenomenon, both in its positive and negative phase.

The ENSO phenomenon classification in years with annual precipitation totals within the series standard deviation: 1999; 2000; 2001; 2007; 2008; 2010 and 2011 - La Niña and the years: 2002; 2005; 2007; 2009; 2010 - El Niño.

It is possible to notice that the adoption of the standard deviation of the series as a method of verifying the influence of ENSO in the annual precipitation totals for Mato Grosso do Sul, cannot represent, with great precision, the behavior of the phenomenon, especially in relation to the years with low volumes of annual precipitation (negative phase of the phenomenon).

Climate anomalies can last several months, especially in the tropical atmosphere, and are not only characterized by the lack or excess of some meteorological element, but also imply a change in their temporal and spatial distribution. The thermodynamic disturbances that occur in the atmosphere affect the climatic patterns of each region and, consequently, there is a direct dependence of the activities with the meteorological phenomena belonging to several spatial scales. On a global scale, the major influence is due to the climate variability mode of ENSO and its different phases/intensities (El Niño - EN; La Niña - LN), which are closely related to changes in climate, atmospheric circulation configurations and ocean-atmosphere interaction in the Pacific and Atlantic oceans (LIMBERGER and SILVA, 2016; LYRA et al., 2017), thus determining the anomalies of air temperature and mainly rainfall in various regions (GONZALEZ et al., 2013; GOIS et al., 2015; OLIVEIRA-JUNIOR et al., 2017).

ENSO can influence mainly the change in the regional rainfall regime, which may result in severe droughts or extreme rains, significantly interfering with human activities and alternations of rainy and dry periods. The characterization of ENSO phases and their influences in various Brazilian regions have been approached by several authors (MINUZZI et al., 2007; BRITTO et al., 2008; SILVA et al., 2009; REBOITA et al., 2010; GONZALEZ et al., 2013; MAIER et al., 2016).

For the state of MS there are occasional studies involving rainfall assessments, however, there are no reports to define the influence or not of the ENSO phenomenon in the region, even in the different hydrographic regions of the state.

El Niño and La Nina interferences in rainfall are known for most Brazilian regions, however, for the state of MS no definite interference patterns are observed throughout the cycles of these events. This information could support the prediction of climate variations due to the ENSO phenomenon and allow the adoption of techniques that minimize their effect on the current and future moment.

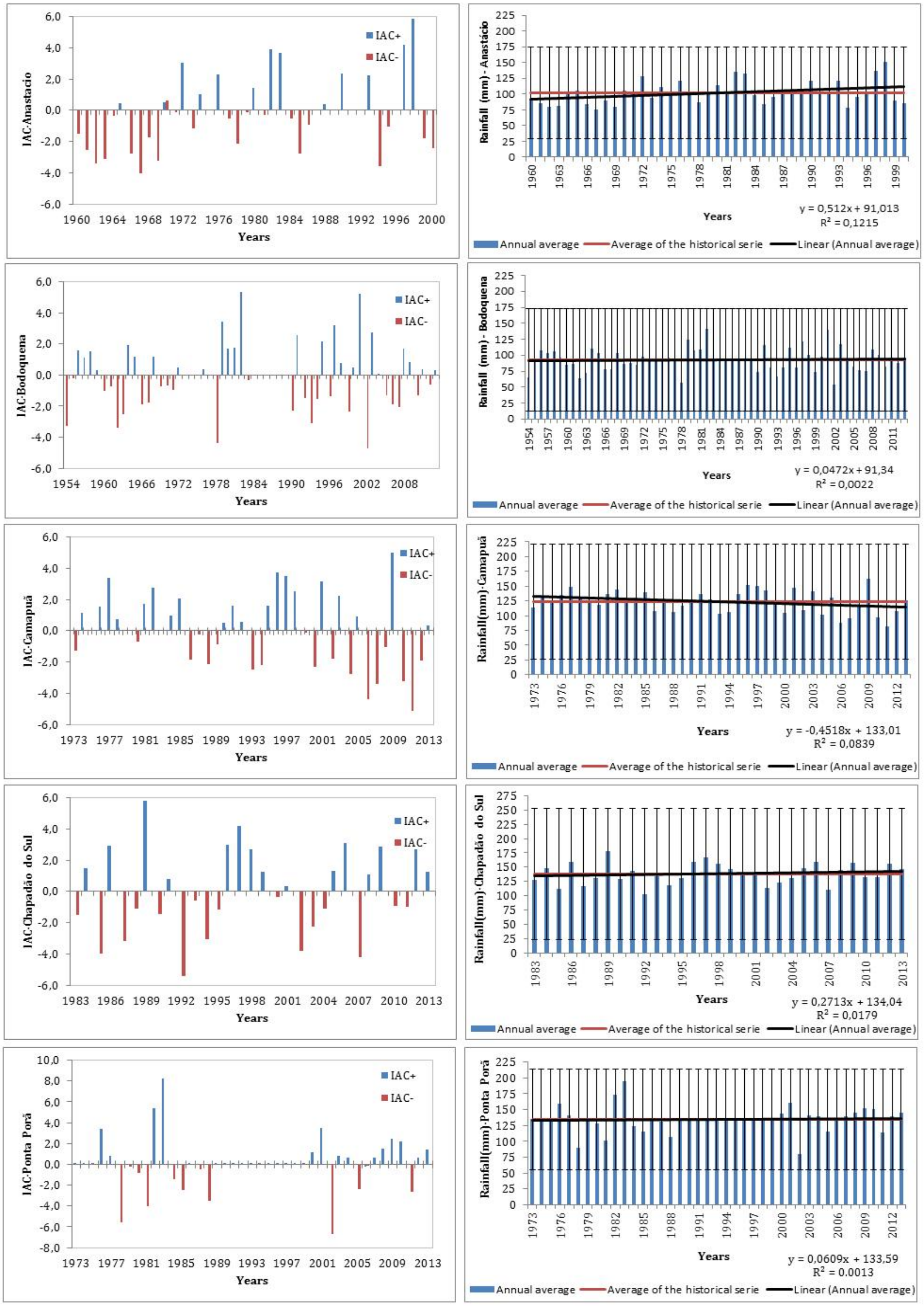

Figure 4 - Rainfall Anomaly Index RAI (RAI), annual averages of historical rainfall series over the years of the longest homogeneous historical series analyzed within each group in the state of Mato Grosso do Sul.

Source: National Water Agency (ANA, 2014); National Institute of Meteorology (INMET, 2014). Note: Precipitation data for RAI calculation.

The monthly average rainfall distribution (Figure 2) shows similarity in the reduction / increase between the three biomes and the possible influences of the El niño and La Nina phenomena. In general, the impacts of El niño and La Nina events are known to have spatial and temporal variability, and long periods with continuous anomalies consistent at the regional scale are not observed (GOIS et al., 2015).

According to Souza et al. (2013) total monthly and annual rainfall variations are due to the behavior of the regional atmospheric circulation throughout the year, together with local or regional geographic factors, the atmospheric systems acting in Mato Grosso do Sul are: Intertropical Convergence Zone (ICZ), Equatorial System, Continental Tropical System (STC), Atlantic Tropical System (STA), Atlantic Polar System (SPA) and South Atlantic Convergence Zone (SACZ).

The characterization of dry winters and rainy summers in the Midwest of Brazil derives from the stability generated by the influence of the subtropical anticyclone of the South Atlantic and small dorsals that form over the South American continental part. The rainy season is associated with the southward shift of the Intertropical Convergence Zone (ICZ, also known as CIT), following the apparent movement of the sun toward the Tropic of Capricorn (summer solsitium). Over the central portion of South America, the CIT advances further south than in the coastal regions, generating instability throughout central Brazil in the summer months. Due to the influence of the marine and equatorial tropical air mass, temperatures are elevated throughout the year. In winter, when the ICZ is shifted north, the region presents low or no precipitation (MENDONÇA and DANI-OLIVEIRA, 2007).

According to Souza et al. (2013) An important climatic factor that acts in the state of MS and changes rainfall levels is altitude, which allows differences in thermal and rainfall conditions between nearby locations (distances of less than 100 km from each other). However, it is noteworthy that, depending on the size of the evaluated watersheds, influences of vegetation type and latitude may also occur.

The Figure 5 shows the correlation (r) and the p-values for the correlation between ENSO and RAI+ and RAI -, for the Mato Grosso do Sul. The correlations range to -0.47 to 0.48, with 25% of the correlations being significant at 5% of error probability ($r \neq 0$). Terassi et al. (2018), verified the correlation of the standardized precipitation index with ENSO events and found low correlations (many not significant), as in this study. The weak correlation indicates little influence of El niño and La nina phenomena in the precipitation of Mato Grosso do Sul. The negative sign of the correlations was corresponding to the RAI – just in some cases, while the positive sign in correlation with RAI+ occurred in the most cases. However, here can often be a delay in the response of the precipitation index to the occurrence of ENSO, which may, in part, justify the relatively low correlations.

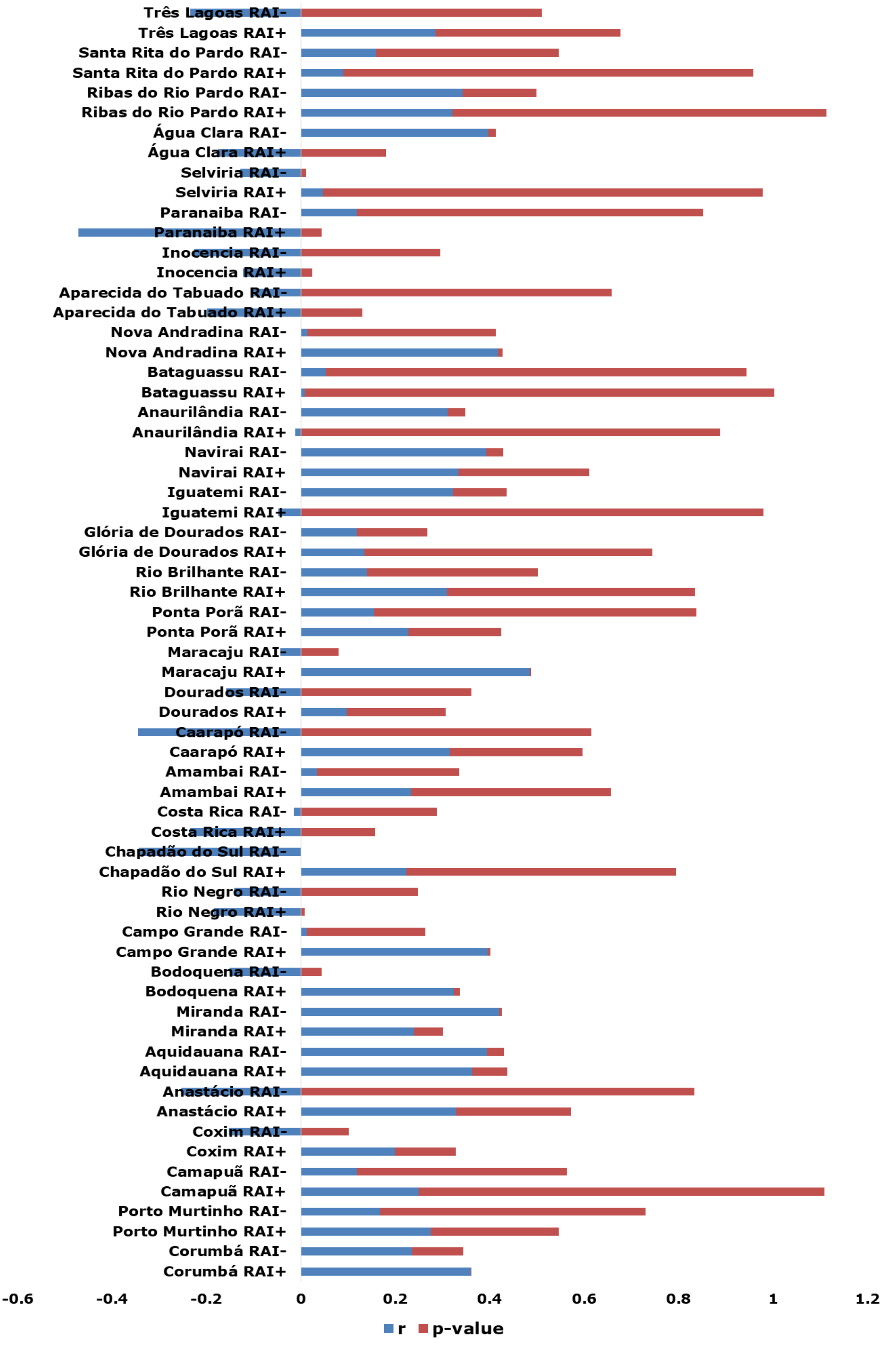

Figure 5 - Correlation between coefficient r and p-value for the ENSO occurrence and the rainfall anomaly index (RAI).

4. CONCLUSIONS

The rainfall maps of Mato Grosso do Sul, obtained from historical series, indicate that precipitation occurs more in the north and southwest of the state, due to the influence of the continental equatorial air mass coming from the north and the mass of the Tropical Atlantic Air from east, mainly through the southern region, in addition to the heavy rains that occur in the Serra da Bodoquena region. The dry season in the region is observed from April to September and the rainy season from October to March.

Correlations range from -0.47 to 0.48, with 25% of the correlations being significant at 5% probability of error ($r \neq 0$), the correlations of the standardized precipitation index with the ENSO events were low (many not significant)). The weak correlation indicates little influence of the El niño and La nina phenomena in the precipitation of Mato Grosso do Sul. The negative sign of the correlations corresponded to RAI - only in some cases, while the positive sign in the correlation with RAI + occurred in most cases

The results obtained in this study revealed that the RAI functioned as a tool for the annual study of the variation of precipitation in the state of Mato Grosso do Sul. It can also, through this monitoring, generate analyzes of the degree of accentuated or light regional rainfall and climatological changes. .

The highest absolute values of the RAI refer to positive anomalies. The stations, in all selected periods, were classified as "extremely rainy" and, in addition, the RAI was observed with a value greater than 9.0.

With the frequency information of the classes of rain anomaly indexes, it can be inferred that the dry season did not increase over time, nor was it possible to verify the weekly relationship between climatic anomalies (El Niño / La Niña) and RAI .

No precipitous changes in volume were found that could influence the climate drought. Aridity can be related to anthropogenic factors, mainly land use and occupation, which, together with low winter rains in the region, increase agricultural, hydrological and socioeconomic droughts.

As a future proposal, we will investigate the relational pattern between the effects of ENSO phases on the spatial distribution of rain and on drought patterns via Harmonic and Spectral Analysis (HSA) or using the Wavelet technique (WT).

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DATABASE DECLARATION / DATA AVAILABILITY: The weather database is in the public domain and available at: https://giovanni.gsfc.nasa.gov/giovanni/> and ftp://ana:agencia@ftp2.ana.gov.br/Upload/SGH/GEINF/PluMS.zip

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