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The Rhythm of the Rains in Non-Standard Years (2007 and 2008) in the Preto River Hydrographic Basin - Southeastern Brazil

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Abstract: *The climate manifests itself both as time and space and so, following contradictions and movements, each of its elements will have their own rhythms, habits and exceptionalities. In turn, the interactions between them and society are part of a dialectical reality that need to be recognized, because changes in the regime of weather typologies directly or indirectly affect people's lives, bringing disruption to a population that is not prepared to deal with such weather, bringing disorders to a population that is not prepared to address such inclement weather. In this context, the present study aimed to study the rhythm of rainfall recorded in the Rio Negro hydrographic basin, located in the Southeastern region of Brazil, through the proposal and construction of graphs for years that were considered exceptional for the region, in its annual and daily sequencing. The results indicated that the rains behaved differently in dry and humid years, with regional or local geography and atmospheric systems being the main factors responsible for such variations.*

Keywords: *Rain rhythm; Climate risks; Regional climate.*

1. INTRODUCTION

Climate is a factor that directly or indirectly influences people's lives. Rain, an important element that characterizes the climatic dynamics of a region, can facilitate or limit human activities, because it is fundamental for food production and direct water consumption. It is also connected to physical hazards such as the susceptibility of a society to extreme events (floods and landslides) in such a way that it can be beneficial or harmful according to the regimen in which they occur.

Therefore, in order to make the most of the rain as a resource, or to reduce the impacts of its irregularities, it is fundamental to have studies that understand how the rhythms occur. This is especially true in a country like Brazil, which has numerous climatic types [1], has weak laws governing human occupation of areas considered as risky, and urban centers with concentrated population density and high rates of soil waterproofing.

According to Monteiro, who creates and incorporates the rhythm paradigm in geographic climatology and is considered the father of Brazilian climatic epistemology, *"é a sequência que conduz ao ritmo e é o ritmo a essência da análise dinâmica"* [2] (p. 10 – Author’s translation: “It is the sequence that guides the rhythm and rhythm is the essence of dynamic analysis”). To understand the sequence of regular intervals and to consider the exceptions of the climatic typologies, which is proposed in the rhythm’s study, would be the basis for a total and complex understanding of the regional distribution of rainfall.

Based on genetic and dynamic fundamentals, as well as on sequencing of time and the concern for the interconnections and interdependencies of the most diverse phenomena, there is a perspective that has its antecedents linked to the School of Bergen, recommended by the norwegian Vilhelm Bjerknes and that comes to Brazil with the works of Max Sorre [3]. It has as presuppositions the relations, thermos-hydrodynamic concepts and the construction of synoptic letters, which allows a better understanding of atmospheric phenomena, once it takes into account the air masses’ origin, frequency and trajectory. According to Mendonça and Danni-Oliveira [4] and Sant′Anna Neto [5], this paradigmatic change in meteorology had a strong repercussion on Brazilian geography and pioneering works, like as those of

Adalberto Serra and Leandro Ratisbona ("Air masses in South America" – translation by article authors) which stand out for innovation according to the dynamics of the air masses and later those of Edmon Nimer [1] with his study of the South American atmospheric circulation, as well as those of Monteiro [2] with his paradigm of rhythm and urban climate, that became the basis of Brazilian climatology.

In this context, it is proposed in this manuscript to study the daily sequencing and annual rainfall dynamics in non-standard years[2,6], one dry and one humid year, adapting a consolidated theoretical-methodological basis of Brazilian climatology, which is the rhythmic analysis proposed by the geographer Carlos Augusto de Figueiredo Monteiro [2, 6] having the Rio Preto River hydro graphic basin (Southeastern region of Brazil) as the territorial unit of research and proposing the creation of graphs for the rhythmic analysis. That graphs would favor the understanding of the genesis

and repercussion of the rains in the region, bringing a spatial-temporal detailing of these and allowing that the rhythm of the rains in non-standard years and the extreme events that occurred to be identified.

The justification for choosing this theoretical-methodological base for a research is given by the fact that it is already consolidated in Brazilian climatology [7], being researched in several regions of the country, interfaces with distinct temporalities, and adapted to the needs and realities of each research.

2. Materials and Methods

In this topic, it will be presented the methodology that was used to create rainfall rhythm charts, in years with exceptional characteristics for the meteorology series studied (2007, 2008), using geoprocessing for the elaboration of the cartographic products of spatial analysis and having a watershed of regional dimensions as a unit of study

2.1. Study Area

A hydrographic basin of the Rio Preto is located in the area of the forest zone Mineira, known as "Zona da Mata Mineira" and adjacent Fluminense lands, in the northwest of the State of Rio de Janeiro and in the southeast of the State of Minas Gerais, a center-west of the sea mountain range, known as "Serra do Mar" or Mar Ridge. It encompasses 37 municipalities, nine of which belong to the state of Rio de Janeiro and 28 belong to the state of Minas Gerais. It occupies an area of about 8,593 km² and it has a population of about 5,259,067 inhabitants [8]. It is a sub basin of Rio Paraíba do Sul River, which belongs to the hydrographic region of the Southeast Atlantic watershed [9] and has three main rivers as its tributaries: the Paraibuna River, the Peixe River and the Cágado River.

As emphasized by Nimer (1979) and Cavalcanti (2009) is a basin that is located in a region of climatic transition. It is influenced by tropicality and presents an energy input higher than the highest latitudes. This latitudinal position implies a climatic reality defined by the influences of dynamic and static factors [1, 10] where frequently oppositions occurs between extratropical and tropical systems. The dynamic factors are represented by their own dynamics of the atmosphere, while the static factors are the relief morphology and the position in relation to the ocean, which together compose this regional climate.

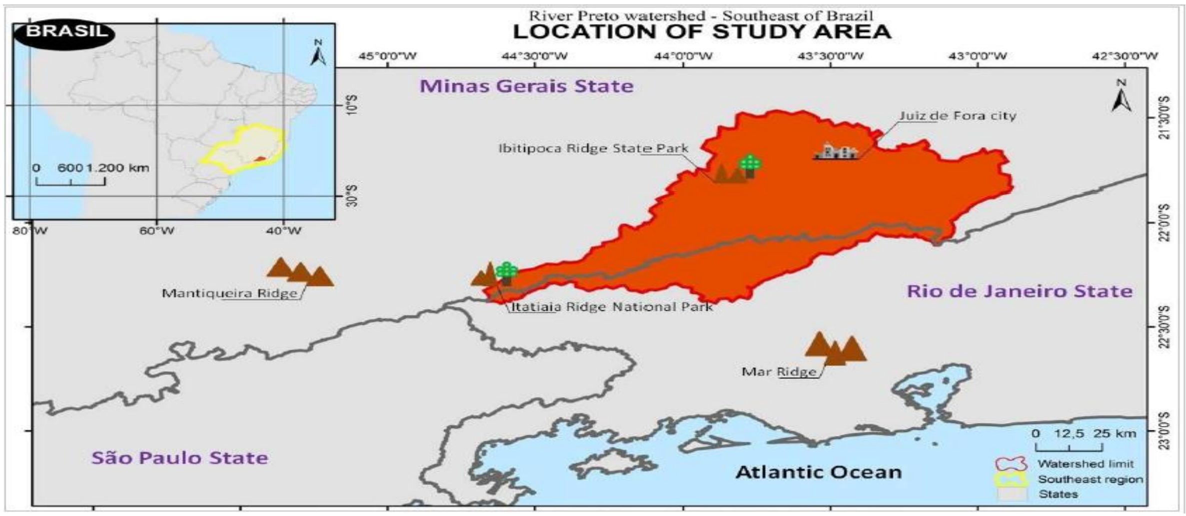

Fig1. *Location Study Area.*

In zonal terms, it is primarily the geographical position that brings a climatic characterization to a hydrographic basin. Thus, the radiation balance in the studied area is higher than in the highest latitudes because it depends largely on the solar height [1]. This bahavior makes the processes of evaporation and evapotranspiration more active, that is already accentuated in the region by the existence of liquid surfaces, creating preconditions for rainfall (CONTI, 1989).

The seasonality of the climatic elements is well marked and it largely follows the translation movement. Both the radiation balance and precipitation indicate the existence of two distinct seasons, one that runs from October to March (warmer, rainy and radiated), and one that runs from April to September (cooler and drier). The annual average rainfall is about 1536 mm in the watershed (ANA, Hidroweb), but there are points near Itatiaia ridge where there were registered totals above 3500 mm (1983). The annual average thermal amplitude is in the range of 5thC [1]. The local water availability is also important to accentuate these contrasts, especially with the formation of convective rains in the summer.

The predominant action is the air masses origination on the ocean and a small action of that continental origin can be observed. When these air masses follow their trajectories they influence the types of weather because they carry characteristics of their origin place, that cause strong regional climate changes and are able to generate certain instability in the places where they pass [1]. That systems influences the climate dynamics in differents regions because they are linked to the distance from the oceans and their own modelling relief, forming different climate types.

The area studied is characterized by the frequency and predominance action of the Atlantic Tropical Mass and by the Atlantic Polar Mass and its cold fronts, that normally modify the temperature and can cause precipitation. The South Atlantic Convergence Zone (ZCAS), a great provider of humidity, is one of the factors responsible for rainfall in late spring and summer [11].

On a local scale, that is the morphology and morphostructure of the relief tied to the land cover patterns the main differentiators of climate units in the study area. Regarding the relief model, it is important to emphasize that both the slope and the altimetric variations and orientation of its slopes influence the regional and local climate of the basin the distribution of radiation on a local scale is influenced by topography, terrain shapes, the orientation and inclination of relief slopes. The temperature is influenced by the coverage pattern of the land and by the topographical situation where the site is located.

It is located in the *"Domínio Morfoclimático dos Mares de Morro Florestados"* [12], which is characterized by a concave-convex sequence with an active relief varying between 300 meters and 2700 meters (near the Itatiaia ridge). The mountain ranges are part of Mantiqueira Ridge and Mar Ridge. This type of relief is the main factor of spatial differentiation of the types of weather that can be found in the studied area. The spatialization of the synoptic processes in the watershed is mainly conditioned by the orographic effect that topographic variations (both regional and local) exert on the direction, velocity, and intensity of the air masses during the course followed by the atmospheric systems.

Associated with the occupation of the valley of Paraíba do Sul River, it presents a history of the land use beginning at the end of the 17th century by the *Coffee Cycle* and later by its decline at the end of the 19th century through the substitution of coffee-related activities for livestock, extensive and dairy activities. This territory were configured following each historical-economic process and today as main economic activities the agriculture and industry. Based on aerial photos, it is verified that, with regard to the use and coverage that has been given to land, it presents a vast area of anthropic interventions with some fragments of native vegetation witch correspond to the areas with the highest altimetric dimensions.

2.2. Technical Procedures

The research is based on the propositions of Monteiro, who defend as a technique of rhythmic analysis the composition of a graph of simultaneous representation of the climatic elements in their daily variation, which enables the graphical representation of the sequence of the different meteorological systems involved in the secondary circulation [13]. Its serial analysis occurs sequentially, paying attention to the irregularities that represent the different degrees of proximity of the habitual rhythm. It would work with standard years and it didn't fix on the 30 years of The World Meteorological Organization or the climatological normal calculations, but in standard years for a determined data series.

From these propositions, it was concluded that the annual and daily scales would be the most adequate for this study, because they would be representative of the regional climatic reality. The methodological choice of the year was based on standard classification procedures (dry, humid and usual [2,13] and on statistical techniques which are common use methodologies in Brazilian climatology [14, 15], from the meteorological series between 1975 and 2014 recorded in stations located in points distributed by the study area (Figure 2). From these it became possible to group years with common characteristics, allowing visualizing those that present similarity in the annual totals of precipitation, either by the habitualities, or by the exceptionalities. The techniques used were: standard deviation, quantile, Sturges formula and box plot.

Analysis during the choice of these standard years demonstrated that there would be years represented by positive or negative anomalies in annual precipitation totals and that the statistical classification of these annual totals in wet, moist tendencies, dry and dry-tending, would show that there are correlations between them and the general atmospheric dynamics. Then, after the construction of the worksheets with the years that could be studied, it was decided to choose a dry year (2007) and a wet year (2008) for the climatology of the studied area, because they would represent the inconsistencies that exist, allowing understanding the daily rhythm of the rains in years with positive and negative anomalies.

Having chosen the year and considering that the rains genesis is bounded to the regional atmospheric circulation, we proceeded to the analysis stage of the surface synoptic charts. The survey was carried out daily by analysing the Navy′s Synoptic Letters, according to Monteiro′s [2] rhythmic analysis methodology, for the 12 o′clock time, which is considered ideal time, since the 00 o′clock time would represent the day before or after. These letters are based on atmospheric pressure fields and they allow observation of frontal systems, air masses, ZCAS as well as their dynamics and trajectories, which allows us to gauge the typologies of time that prevailed in the studied days.

In order to ensure greater precision in the data and because the study area has regional dimensions, it was decided to consider as having influenced in the time and / or formation of daily rains all the mechanisms that were in operation within a quadrant (Figure 2) covering as geographical coordinates – 15°S, -30°S, -30°W, and -50°W. The choice of this spatial delimitation for analysis was made to facilitate the observation of the movement of the atmosphere sequence in the watershed and bordering regions.

In possession of the synoptic letters and in consultation with the monthly climate of *CLIMANALISE* bulletin, the analysis and tabulation were started in order to create the rhythm letter. Spreadsheets were created inserting as much information as possible because they would subsidize a later correlation with the rains in the region. It also used surface information, meteorological elements, precipitation and air temperature, in order to verify and justify which atmospheric system was in operation that day. The air temperature was used. The maximum, minimum and daily amplitude, found on the campus of the Federal University of Juiz de Fora (Juiz de Fora city, Minas Gerais State). Such information would confirm the arrival, the beginning and performance of a new air mass because they have thermal characteristics that distinguish them. So, the maximum and minimum volumes of precipitation found in the watershed (per day) were used, and the rainfall of 12h, 18h and 24h of Federal University of Juiz de Fora was used to to resolve doubts regarding the working masses.

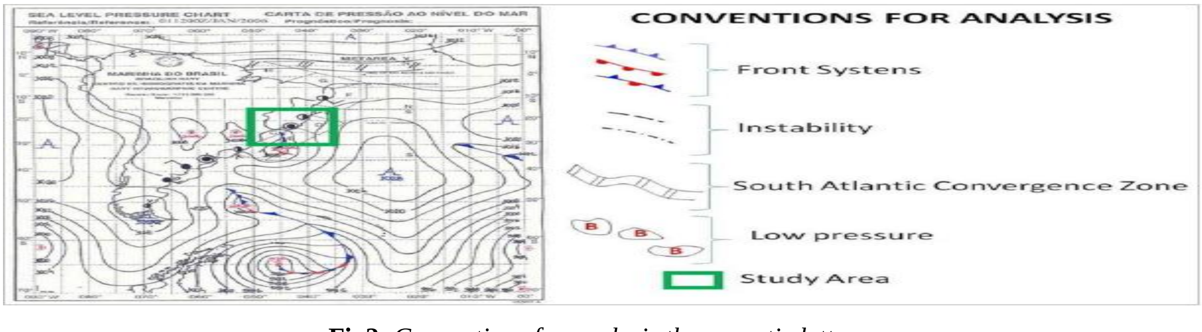

Fig2. *Conventions for analysis the synoptic letters.*

It is worth noting that there is heterogeneity in the temporal-spatial distribution of the meteorological elements in the studied area and that, therefore, care was taken to use surface data to verify how air masses take into account their geographical position. Besides that, in order to facilitate the understanding and visualization of the relationship between the working systems and the occurrence of rainfall per day, after the synoptic analysis it was chosen to collect daily precipitation totals recorded in test stations (Figure 3).

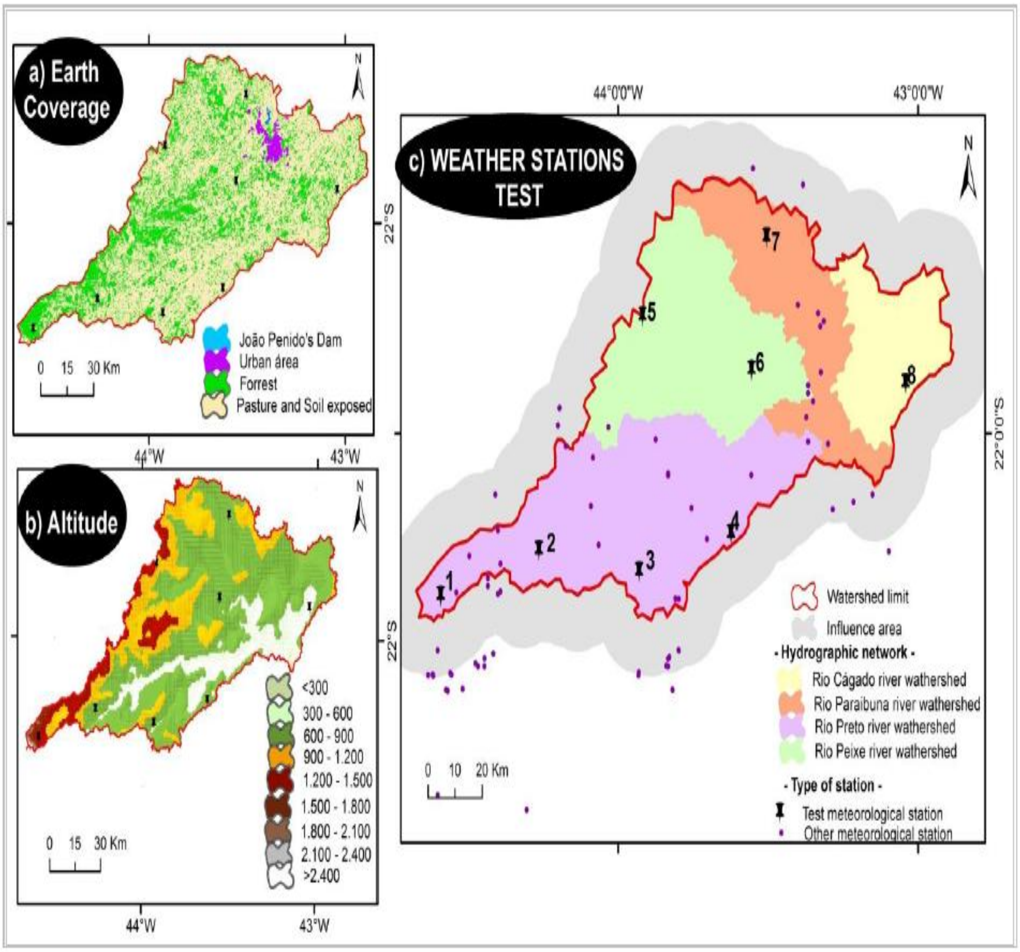

Fig3. ***a*** *and* ***b****): Characteristics of the many different environment [20, 21]; c) Location test weather stations[8, 9].*

This choice was justified by the fact that we understand that there is a relationship between air masses, fronts, and lines of instability and the formation of rains in the region. They could also influence the characteristics of the site where the watershed is located, which could justify a heterogeneous distribution of precipitation. We also understood that there would be some similarity between points located in proximity, and that they would represent the pattern that followed the rains in that location.

When we use surface data from stations located in points with different characteristics, we open a range of options that not only generalize and have a direct and generalized relationship between the working system and the presence of rainfall. Thereby, it is possible to observe whither the rains recorded on that day would be from the atmospheric systems or if they would be related to the local orography.

After the data collection of rain and the synoptic analysis, the construction of the rhythm graphic of the time types sequencing was started. The construction took place in image editing softwares (Phothoshop, PowerPoint 2010), entering manually the information collected and organized into spreadsheets. The elaboration and disposition the informations was based on the elements' criteria to have a map/cartographic product. The option to construct a circle graphic was an attempt to represent the dynamics of the informations because this geometric figure illustrates the idea of movement, highlighted by the dynamic climatology. The choice to construct just one clipboard allowed both the annual regimen and the daily sequencing of weather types to be fully displayed and visualized.

We inserted media reports that emphasized the repercussion of extreme rainfall events that occurred during the periods studied. Thus, it would be easy to observe and correlate which atmospheric systems could be responsible for the irregularities of the analysed years. Then, considering that there are terminological divergences in the conception of what would be an extreme event and that it varies from region to region, we made a calculation to determine which days presented high total precipitation for the study area. Two static techniques (P85 and above than 50 mm) were used according to the methodologies cited [16, 17]. It is understood that the insertion of such information would be useful to facilitate the visualization of which precipitation systems and totals were the ones that mostly influence the eventualities in the study area.

3. Result and Discussion

The explanation of the results obtained will be divided in two parts. In the first one, the rhythm graphs will be described and analysed, as well as the quantification of the days influenced by each system and its correlations with the rainfall genesis in in these. In the second one, we will discuss the theme of the extreme precipitation events that occurred in in these and their impacts and repercussions. The choice to work in this way followed a perspective of starting from the whole, represented by the interannual variation of the rains and the totality of extreme events that were registered in the studied period, highlighting events that were exceptional for the climatology of the region.

3.1. Atmospheric System: Actuation

In relation to the two years chosen for the studies of the climate rhythms, 2007 (dry) and 2008 (humid), it was verified that in these years the events of *El Niño* and *La Niña* framed into the categories of low and moderate intensity. Thus, the total annual variation of the precipitation in relation to the average series, for each test point, was between 567 and 539 mm for the dry year (2007) in Taboas (point 4) and 1314.2 mm in Torreões (Point 6) for the rainy year (2008).

About the atmospheric systems that were in acting during the studied period (Figures 4 and 6), it was verified that the main mechanisms that acted in the study area were the South Atlantic Convergence Zone (ZCAS), the Instability Lines (LI), the Frontal Systems (Fronts), the Atlantic Polar Mass (mPa) and the Atlantic Tropical Mass (mTa), with the predominance of the last one (table 1).

Table1. *Main atmospheric systems influencing study area.*

ATMOSPHERIC SYSTEMS INFLUENCING STUDY AREA		
Mechanism	**Origin**	**Characteristic**
mTa	- Fixed semi anticyclone of the South Atlantic	- High temperature - Too much moisture (limited to surface layer) - Homogeneous and stable
mPa	- Atlantic polar anticyclones - Antarctica and Fixed-Wave	- Initially dry, cold and stable - During its trajectory it absorbs heat and humidity and becomes unstable - Declination of temperature
ZCAS	- The mechanisms that originate and maintain the ZCAS are not fully defined - Northwest - Southeast orientation cloudiness band	- Interactions between frontal systems and tropical convection - Occurs in the summer in South America
LI	- Areas of barometric depression - Between the states of Pará and Amazonas	- Air in convergence - A series of aligned Cumulonimbus clouds that move evenly - Causes severe weather such as: hail, storms, high winds, others; a type of atmospheric disturbance
Fronts	- Displacement of air masses	- Important atmospheric disturbance - Increases the temperature when arrives and causes it to fall when it is acting - It can causes more intense rains. If it's stationary causes calm and continuous rains - It can cause rains in the region

Source: *Adapted from Nimer [1]; Hidroweb- National Water Agency (http://www.snirh.gov.br/hidro web/- Access to data: December/2015).*

Observing the literature, we found the works of Borsato and Mendonça [18] who concluded that for Caparaó (south-eastern region of Brazil) the mTa operated between 31.9% and 51.3% between the years of 2002 and 2010. Monteiro [2] (p. 122) also verified *"a participação da Massa Tropical Atlântica normalmente predominante, ultrapassando 50%"* (Author's translation: "the participation of the Atlantic Tropical Mass [is] normally predominant, exceeding 50%") when he proposes a climatic classification for the state of São Paulo.

The year of 2008 drew attention because of the effects of the South Atlantic Convergence Zone, which was present in 19% of the days (or 70 days), more than twice as many days in relation to the other year which it acted on 8% of the days (30 days). This fact justifies the greatest precipitation volume in that year, since under the action of the ZCAS every day there was rain. The performance of the Atlantic Polar Mass also deserves attention during the year of 2008 because it was active only 10% of the days, which is a significant decrease compared to 2007 (23% of the days). Frontal systems were less accounted for this year.

The number of rainy days in those years helped to predict what was expected. The rainy year (2008) presented the river watershed with the highest number of rainy days (347 days), while in the dry year (2007) the rainfall was recorded in 322 days. On days of frontal systems passage, it was observed that the rainy year (2008) had more prominence because 94% of days with fronts presented precipitation records.

The daily precipitation totals that were considered as high total are those higher than 50mm, since according to the quantis technique (p85), the low magnitude events such as those of 0.4mm, that would be practically a minimum of precipitation considered as day of rainfall, would also enter the totals considered as exceptional rainfall (table 2). It is worth noting that in Table 1 the information for 2006 was also included because this is a year considered to be usual for the climatology of the region [19], and that being habitual and being temporarily close to the studied years, would serve as a basis for possible comparisons with the exceptional years (2007, 2008).

The year of 2008 (rainy) presented as a month with less presence of rain the month of July (6,8 mm in Point 2) and the dry year (2007) presented the month of August as the one that registered the lowest precipitation values (Maximum of 7,8 mm for Point 5).

It was also observed that in the rainy year (2008), besides registering high monthly totals, which reached 582.5 mm monthly (November), presented a rainy period that extends and also includes the months of April and September. It also contributes to the high precipitation totals registered this year. The dry (2007) and humid (2008) years presented homogeneity regarding the monthly spatial distribution of rainfall.

Table2. *Totals considered as exceptionalities in the rainfall per month- Percentile P85.*

Totals considered as exceptionalities in the rainfall per month - P85.

Mounth / Test Station	January			February			March			April			May		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
1 Agulhas Negras Farm	9,6	17,0	29,6	16,4	9,1	20,0	24,2	0,8	25,1	5,7	7,1	7,7	5,7	17,0	1,8
2 Zelinda	7,2	19,5	14,6	28,8	3,6	25,7	11,6	0,0	10,8	0,2	8,5	8,8	0,2	19,5	0,0
3 Conservatória	6,5	13,3	12,7	14,6	0,0	18,5	4,5	0,4	4,8	0,0	0,0	11,8	0,0	13,3	0,0
4 Taboas	9,1	9,2	6,6	11,2	0,1	20,0	0,9	0,0	4,0	0,0	0,0	7,4	0,0	9,2	0,0
5 Conceição do Ibitipoca	2,8	24,9	10,9	8,9	1,1	15,1	6,8	2,3	8,8	0,0	0,3	4,6	0,0	24,9	0,0
6 Torreões	8,7	28,9	19,4	12,2	0,0	26,3	3,2	0,0	23,1	0,0	0,0	2,6	0,0	28,9	0,0
7 Chapeu D'Uvas	13,9	23,0	13,4	8,7	0,0	14,8	14,2	0,7	2,6	0,0	0,0	7,8	0,0	23,0	0,0
8 Estevão Pinto	2,0	23,8	10,3	9,5	0,9	7,2	8,0	1,7	9,0	1,9	0,0	3,4	1,9	23,8	0,0

Mounth / Test Station	September			October			November			December		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
1 Agulhas Negras Farm	5,6	0,8	5,5	11,9	3,1	9,4	24,5	8,8	29,6	21,7	19,5	29,6
2 Zelinda	0,8	0,0	0,8	4,5	0,0	2,5	17,4	2,1	14,6	9,1	6,6	14,6
3 Conservatória	1,7	0,0	0,5	4,6	0,6	3,2	9,4	9,9	12,7	6,9	11,4	12,7
4 Taboas	0,3	0,0	0,0	1,6	1,0	3,1	5,5	6,7	6,6	5,7	6,4	6,6
5 Conceição do Ibitipoca	2,9	0,0	1,2	4,1	4,7	4,8	25,4	7,1	10,9	9,8	7,9	10,9
6 Torreões	0,0	0,0	0,0	2,2	6,0	8,0	5,8	6,1	19,4	19,8	0,0	19,4
7 Chapeu D'Uvas	0,0	0,0	0,0	3,6	4,1	1,4	20,2	9,1	13,4	10,6	7,5	13,4
8 Estevão Pinto	0,0	0,0	0,0	1,4	2,0	4,6	14,1	5,1	10,3	10,7	8,1	10,3

Source: *Hidroweb - National Water Agency (http://www.snirh.gov.br/hidroweb/ - Access to data: December/ 2015).*

3.2. Atmospheric System: Influences in the Rain' Genesis

Then, for us to have conscience that inside the annual cycles are exceptions and that intense episodes of rains can bring disruption to the population directly or indirectly linked to it, we chose to give a detailed description of the daily sequencing of the rains that occurred in the analysed period, highlighting the exceptionalities that were found. The year of 2007, which was considered a dry year, presented the month of January quite rainy (figure 4). The days 2, 3, 4, 5, 16, 17 and 22 were under the influence of the Convergence Zone of the South Atlantic and it was registered high precipitation totals for almost all pluviometric stations. On day 4 was registered 96.8mm at the station located in Santos Dumont and on day 16, also at Santos Dumont station, 93.8mm. In Resende, on January 22, 115mm were recorded. In this month also the days under the performance of mTa, mPa and frontal systems presented high daily precipitation totals

Searching in the literature it was verified that January 2007 was classified as one of the five rainier months of the last 46 years also in other locations in the Southeast and Center-West regions of Brazil [CLIMANALISE BULLETIN, January 2007]. In this month, we have already observed the weakening of the *El Niño* episode [CLIMANALISE BULLETIN, January 2007] but in terms of repercussion in society, were found in various media reports on what the rains of days between 5 and 25, brought from disorder to the population. Electronic sites such as *"Gazeta do Povo", "UOL", "G1", "Terra", "Eletrobrás/Eletrosul"* and *"Diário da grande ABC"* are some examples (figure 4) of media that reported the physical and human destruction that the irregularities of these rains brought to the studied area.

The first half of the month of February 2007 was also marked by the presence of rainfall. In this month the effects of the ZCAS and Instability Line are noteworthy. In this month, no such high precipitation was found (compared to the previous month), with the maximum recorded for the month on day 12, 83.6 mm in Vargem Alegre. In terms of the spatial distribution of these rains, there is an arrival and performance of the cold front on February 11, and on day 12 a greater homogeneity in the rains for the basin. From February 17th to March 19th, Tropical Mass Atlantic was observed, which presented high temperatures and low humidity values [CLIMANALISE BULLETIN, March 2007] in a way that few rains that occurred in these days were convective rains. It is noteworthy that there wasn't precipitation in the first fortnight of March and that from day 20 was the arrival of fronts and convection air movements that caused precipitation in the study area.

The systems responsible for the rains recorded in April were basically mPa and frontal systems, which is expected for the dry season of the region. The days 5 and 6 recorded the highest precipitation total of the month, 60.5 mm and 63.4 mm respectively, and they were under the operation of mPa. The months from May to August of 2007 were typical of winter with a reduction or almost nonexistence of precipitation. When they happened they were related to frontal systems and mPa.

The rainy season started at the end of September but the precipitation was reduced in this month. Only the days 23 and 24, which were days with the passage of a frontal system, we could observed high precipitation values, which reached 53.3 mm and 48.9 mm in Zelinda on the respective days. In the other days, in which some precipitation was registered (which were few), the relation that is made is that in this there was the performance of the mPa, frontal systems or convective activity. The first half of October was practically rainless. At only a few points, a convective activity eventually led to precipitation. This is justified by the fact that this month *"continuou sob a influência do intenso escoamento Anticiclônico que atuou sobre grande parte do setor leste da América do Sul em setembro passado"* [CLIMANALISE BULLETIN, October 2007] (Tradução dos autores: "Continued under the influence of the intense Anticyclonic outflow that acted on much of the eastern sector of South America last September").

On the other hand, from the 18th, when was observed the arrival of a front and mainly between the days 22 and 26, when was observed the instability line and the South Atlantic Convergence Zone, there were positive anomalies in the precipitations. The highest recorded daily total for the month was 104.5mm in Visconde de Mauá on the 25th. Also days 22, 23 and 30 deserve attention because they recorded values above 50mm. In the first two days, the reason was the activity of the LI and the last of a frontal system. As to the spatial distribution, it was verified that these values were registered to the southwest of the study area (Visconde de Mauá, Zelinda and Santa Isabel do Rio Preto, respectively).

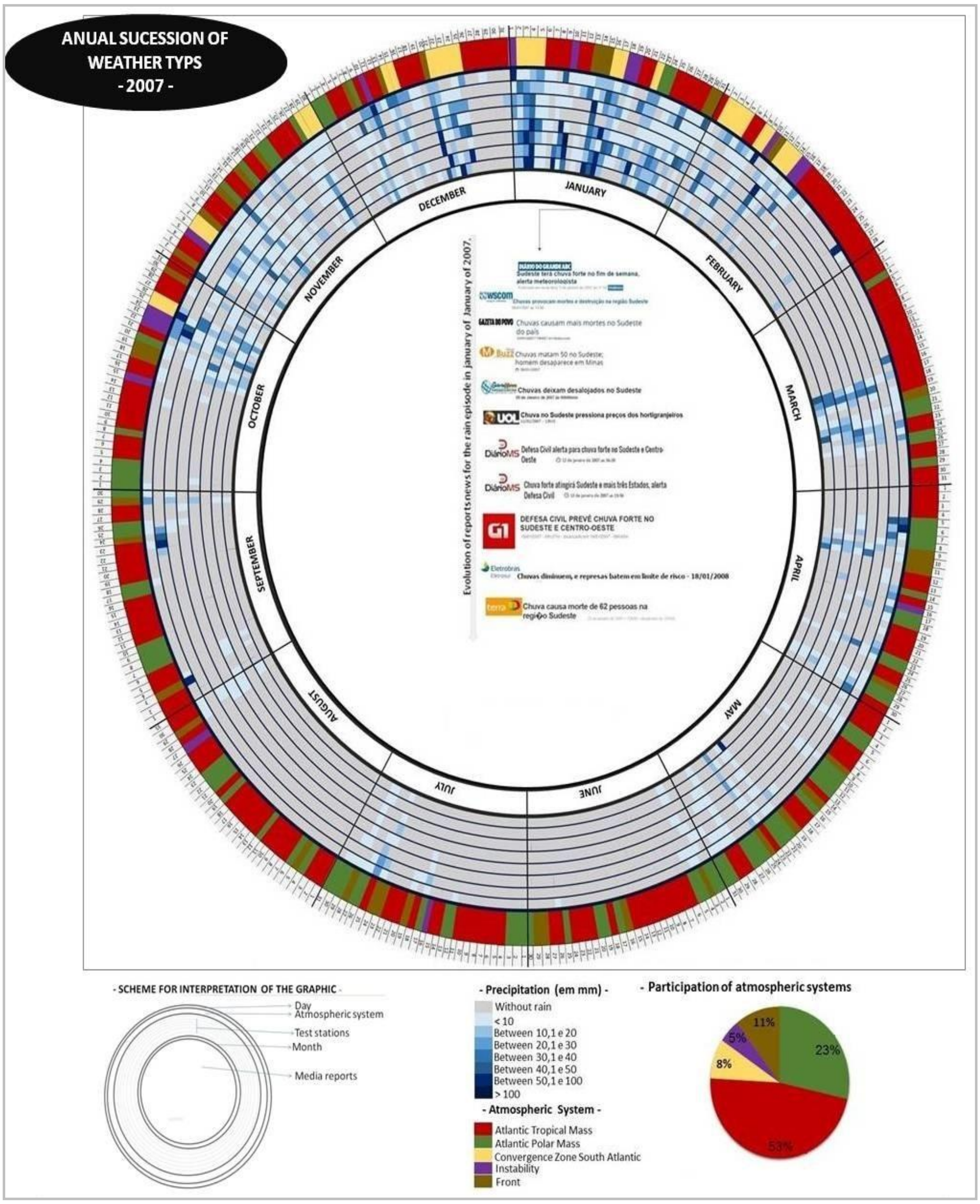

Fig.4. *Figure of the rains rhythm and type of atmospheric system for the year 2007 [2, 22, 23, 24].*

November had a precipitation pattern that followed the performance of the atmospheric systems, which showed the intensification of the La Niña phenomenon in the equatorial region of the Pacific Ocean [CLIMANALISE BULLETIN, November 2007]. It is necessary to highlight that the performance of ZCAS in this month was lower than expected and it was acting for only 5 days. The highest values recorded in the month were on the 4th day in Moura Brasil (81.4mm), on the 8th Ponte do Costa (75.7mm) and Fumaça (73.3mm), on the 9th day in São Gabriel Farm (90mm), on the 16th in Resende (94mm) and on the 20th in Santa Isabel do Rio Preto (69.5mm). The month of December (2007) also registered precipitations below expectation by the climatology for the month [CLIMANALISE BULLETIN, December 2007]; however, some days had significant volumes of precipitation. The 10th day of December was under the action of LI and it was registered 70.3mm in Santa Isabel do Rio Preto.

The year of 2008 (figure 6) begian under the performance of mTa and the presence of convective rains in the southwest portion of the study area. However, it is from the 5th that the presence of more intense rains is verified when we observed two days with frontal systems and the formation of the ZCAS. The 6th presented a maximum of 78.6 mm of precipitation for the weather station in Torreões given the passage of the frontal system. The 7th registered a 62mm precipitation in Santos Dumont and 9th registered a total of 82.3mm for the Concervatória station due to the ZCAS. This month still had high precipitation on days 10 (103.5 mm in Ponte do Costa), 14 (82.1 in Fumaça), 16 (191.1 mm in Inhagape and 91.7 mm in Itatiaia National Park) and 30 (90.4mm in Itatiaia National Park). It is noteworthy that on the 15th an LI was observed, which may also have influenced the rains of the 14th and 16th.

The month of February began with an LI, which may have favored the formation of ZCAS between on days 2 and 8. On such days, high precipitation totals were recorded (between 107.5 mm on the 3rd day in Ponte do Costa and 40.7mm in Sobraji on the 8th day). Also at the end of the month, another episode of ZCAS recorded high totals resulting in the maximum precipitation of the month registered (114.5mm) in Taboas. Thus, it was verified that the month of February presented typical characteristics of summer.

In March two rainy periods were observed. The first period was between days 5 and 17, where a total of 110.9 mm was registered in Visconde de Mauá. On March 16, 110.6 mm of precipitation was registered in Agulhas Negras Farm during ZCAS activity. These points are located in the highest region of the hydrographic basin (figure 2). On March 11 it was possible to observe the arrival of a cold front in the study area. The second rainy season of the month started on March 24 and it runs until March 29. On such days, the LI was active and values such as 137.5 mm were recorded in the Funil Barramento on day 24 and 75.8 mm in Estevão Pinto on day 28.

The month of April still presented characteristics of summer as emphasized by the Climanálise Bulletin, (April of 2008) ″*as chuvas continuaram acima da média histórica na maior parte do Brasil*" (Author's translation: "the rains continued above the historical average in the greater part of Brazil″). In this month, it was observed that the frontal systems work is what justifies the rainfall genesis, as is the case on days 4, 5, 6, 8, 9, 15, 16, 21, 22 and 23. Among these days the record of precipitation was 136.4 mm on April 22 in Manoel Duarte. In an attempt to justify the recording of a high precipitation value in April (something atypical), it was observed in analysis of the synoptic chart (figure 5) for days 21, 22 and 23, that a cold front was exactly on the studied area, which may have been the cause.

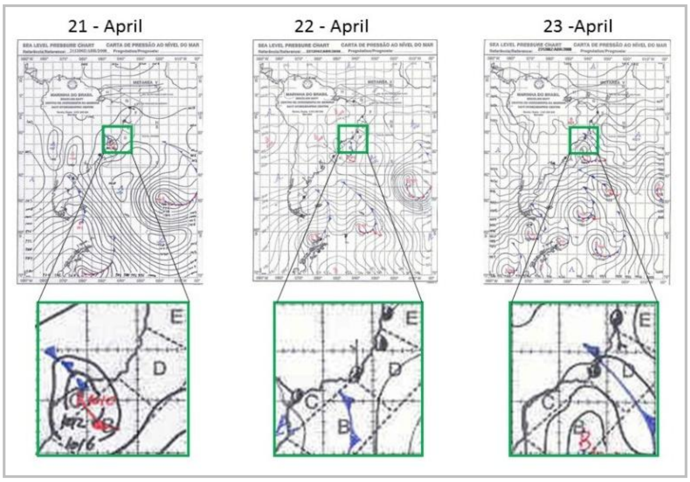

Fig5. *Activity of a frontal system* - *April 21th to 23th, 2008. Source: Brazilian Marine website (https:// www. mar.mil.br/dhn/chm/meteo/prev/cartas/cartas.htm - Access to data: November – 2015).*

In May, the driest season began and extended through the months of June and July. The few days in which rainfall totals exceeded 10mm, for example on May 3 and June 26, the presence of LI could be noted. The rainy season of 2008 began in August and already registered precipitation volumes that reached 52.3 mm per day at São Gabriel Farm. From these days until the 22nd, the active system was mTa and the stability didn't bring rain to the studied area. Between the 23th and 31th, frontal systems and the mPa were the cause of registered rains.

The maximum precipitation recorded for the month of September was 42.2mm on day 28 for the Pentagna station; on this day there was a frontal system passage. Also 16th and 27th, which were under the action of the fronts, registered precipitation totals considered high when compared to the other days of the month. 37.6mm of precipitation were recorded in Santos Dumont on September 16 and 35.3mm in Ponte do Costa on September 27. It is noteworthy that in the second fortnight of the month, the activity of frontal systems was more frequent and lasting, and this is what caused the rains that occurred in this period.

The month of October 2008 was marked by eight days of LI activity. In these, as expected, high precipitation values were recorded. On day 2, Torreões registered 93.2mm of rainfall, corresponding to the highest value found for the month. In this month, different from 2007, the presence of the ZCAS wasn't verified. Other days, like the 3rd (47.2 mm in Conceição do Ibitipoca), 15th (43.4 mm in the Conservatory), 18th (49.3 mm in Juiz de Fora), 19th (43.3 mm in Campolide) and 30th (46.6mm in Pedra Selada) are shown to illustrate the fact that in the rainy season several mechanisms may be responsible for the excess rainfall, as in these cases where mPa, convection and LI are possible causes. Therefore, it is worth highlighting the importance of the dynamics of atmospheric systems knowledge in each region.

November of 2008 was marked by the activity of the ZCAS during 21 days, by the LI during four days, and by the frontal systems during three days. In this month, daily totals reached 89.1mm Sobraji on 7th, 163.2mm in Torreões on 13th, 72.5mm in UEL Santa Cecilia Takada D′Agua, 74.2mm in Pentagna, 82.2 on 28th in Fumaça, 62.3mm in the Ponte do Costa on the 29th, and 67.5mm in Mirantão on the 30th. This month is a good example of how the rains spatial distribution may be irregular in the studied area under the same system. Several points presented the highest totals recorded on different days, making it uncertain if the atmospheric system or the site conditions are responsible for the rainfall genesis in the region.

In December, *"a atuação da Zona de Convergência do Atlântico Sul (ZCAS) continuou favorecendo a ocorrência de totais pluviométricos acima da média histórica em grande parte da Região Sudeste"* [CLIMANALISE BULLETIN, December 2008] (Author's translation: "The performance of the South Atlantic Convergence Zone (ZCAS) continued to favor the occurrence of rainfall totals above the historical average in much of the Southeast Region") for the studied area.

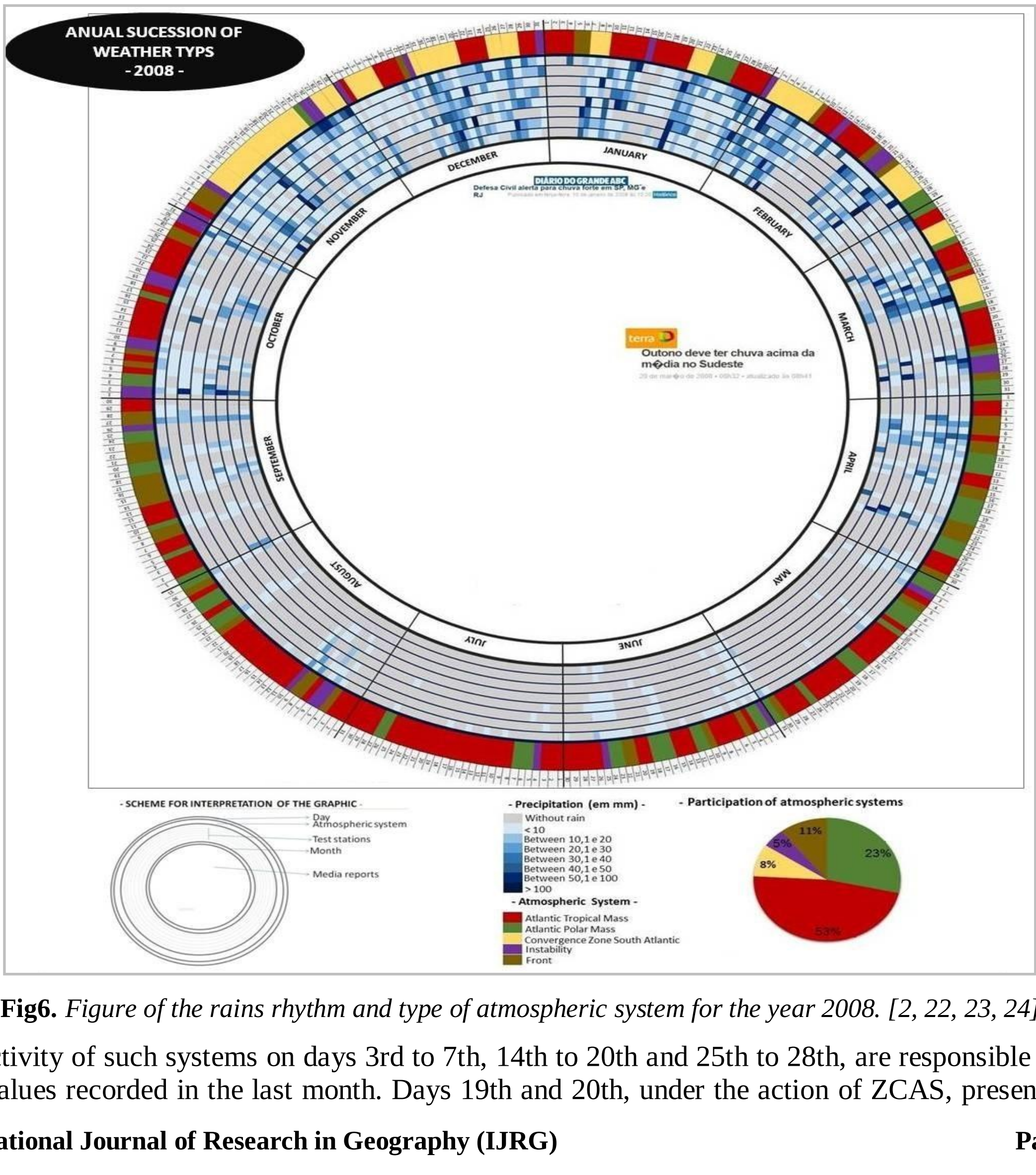

Fig6. *Figure of the rains rhythm and type of atmospheric system for the year 2008. [2, 22, 23, 24]*

The activity of such systems on days 3rd to 7th, 14th to 20th and 25th to 28th, are responsible for the high values recorded in the last month. Days 19th and 20th, under the action of ZCAS, presented the highest total precipitation. Note that day 23th presented the highest recorded volume among the three years (301 mm in Pedreira Pacau).

In terms of repercussions of the annual anomalies and rainfall irregularities, it was observed that in both years the total deviations from the series average weren't so significant that great disturbances were reported because generally the exceptions that are most prominent. In January of 2007, the large number of deaths that were recorded caught attention. This year, even though it was considered dry, presented a month of January where the rains were concentrated and above the climatological averages for the region. It is worth mentioning that eight years have passed and therefore the number of reports available has not been significant.

After this explanation of rainfall sequencing and its correlations with the systems that were in activity, we can mention that following the characteristics of each locality, an event can be considered as extreme or not, because a population is accustomed to a certain total of rain and certain climatic dynamics. When an event like the one of January 2007 occurs, an extreme event of intense rainfall, it results in greater disturbances. This example illustrates the exceptionalities that could be found in other areas.

A correlation between the events considered extreme during the two years studied (2007 and 2008) confirmed one of the initial hypotheses of this study, which would be related in most of the days to the passage of cold fronts or Instability lines, or to the formation of convective rains on days of tropical Atlantic mass.

4. Conclusion

The technical procedures that were used to create the rhythm chart and the cartographic products allowed for the daily observation and interannual sequencing of the rains and illustrated well the anomalies that were recorded in the studied period.

The rains rhythm between the non-standard years (2007, 2008) was characterized mainly by the large-scale atmospheric variations, which caused abnormal events by having a their own interannual dynamics and which, when in summation (total annual rainfall) produced these years with positive and negative rainfall anomalies. In this yearly scale, emphasis was placed on ZACS, which was the main responsible system for registering positive anomalies during 2008, and of mPa, which conversely, operated on a few days in that year (10% of the days, while 2007 acted in 23% of the days).

These systems acting in the study area, when interacting with the surface created climatic typologies that were spatially and temporally distinguished, also creating seasonal or daily variations represented by the extreme events of rain. These events were concentrated in January 2007 for the dry year and didn't focus on the rainy year, and could be recorded in the months of November, December, January, February and March.

Considering the fact that the hydrographic basin of the Rio Preto presents a territorial dimension in the order of regional magnitude, it ended up presenting in its perimeter rural and urban areas, like in the case of the municipality of Juiz de Fora, which is an effective central city for the *Mata mineira* zone. In this way, by understanding the climatic dynamics that occur in it, we are contributing both to the proper management of the resources of its rural areas and to the territorial management of the cities that are located therein.

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CONFLICTS OF INTEREST

This manuscript is result of the research project conducted by Daiane Evangelista de Oliveira (D.E.O) as part of her masters dissertation financed by the National Council of Scientific and Technological Development (CNPq) and developed at de Laboratory of Climatology and Environmental Analysis (LABCAA-UFJF) of Federal University of Juiz de Fora (UFJF). Cássia de Castro Martins Ferreira (C.C.M.F.) guiding and Débora Couto de Assis (D.C.A.) and worked together. The work was conducted under the guidance of C.C.M.F. and D.C.A. provided assistance in the analyses. The manuscript was prepared by D.E.O. and all authors read and approve the final version.

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