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The influence of El Niño and La Niña phenomena in Brazil: The case of the rainfall distribution of the municipality of Vitória da Conquista in the state of Bahia

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Tiago Pereira Santos
Graduated in Geography from the State University of Southwest Bahia, Vitória da Conquista, Brazil.
Specialization in geography at the State University of Southwest Bahia (UESB)
Address: Universidade Estadual do Sudoeste da Bahia - Campus Vitória da Conquista/BA. Estrada do Bem Querer, Km 04 - Vitória da Conquista - Bahia, Brazil. Sector: Department of Geography.
E-mail: tiagosinger@gmail.com

Marcelo Araújo da Nóbrega
Geographer and PhD in Botany (Phytogeography) from the University of São Paulo (USP).
Full Professor of the Department of Geography of the State University of Southwest Bahia (UESB), Address: State University of Southwest Bahia - Campus Vitória da Conquista/BA Estrada do Bem Querer, Km 04 - Vitória da Conquista - Bahia, Brazil. Sector: Department of Geography.
E-mail: maraujonobrega@gmail.com

ABSTRACT
This study refers to the anomalies in local and global atmospheric dynamics from episodes of El Niño and La Niña phenomena. The intention of this research is to investigate whether there is an influence of these phenomena on the rainfall distribution of the municipality of Vitória da Conquista. The methodology used in this work was carried out through the comparison of rainfall data of the periods of occurrence of El Niño and La Niña through the website of NOAA - National Oceanic and Atmospheric Administration between the years 1982 to 2016 and through data from the National Institute of Meteorology (INMET) in order to verify possible anomalies in the rainfall distribution. Through this investigation it was possible to perceive that both the El Niño phenomenon and the La Niña influence the distribution of rainfall in order to intensify the rainfall irregularity in the municipality, that is, the largest volumes of rain are concentrated in a few months during the year, promoting long periods of drought and at the same time, large volumes of rain in short periods of time. It was also found that there is another oceanic-atmospheric phenomenon that influences the region that the Atlantic Dipole, also capable of intensifying the rainfall irregularity of the municipality of Vitória da Conquista.

Keywords: El Niño, La Niña, Rainfall distribution, Vitória da Conquista-Bahia, Brazil.

1 INTRODUCTION

This work is relevant, because the study of the relationship between the phenomena of El Niño and La Niña teleconnections on the rainfall distribution of the municipality of Vitória da Conquista is still unknown, thus requiring a more in-depth analysis of these data, that is, it is necessary to verify the monthly precipitation data of the years of occurrence of these phenomena, in this case the influence on the rainfall distribution, in order to elucidate with greater clarity how they influence the atmospheric dynamics of Vitória da Conquista.

It is very important to have knowledge of the influence of the phenomena of teleconnections on the rainfall history of the municipality, especially in the case of El Niño and La Niña phenomena, since they alter the climatic rhythm in several parts of the world, evidencing the relevance in studying

and understanding these changes in weather and climate. These phenomena compromise human activities causing great disturbances to society, due to long periods of drought or the reverse, when large volumes of precipitation occur in a short period of time, such a situation can cause house collapses, strong floods, in short, serious damage to society in general.

It is interesting to note that in the understanding of the Climate in a given place it is necessary to study the variability and anomalies of the climatic variable, that is, the variation of the climatic conditions around the climatological average, in addition to the extreme fluctuation of an element of a climatological series, with marked deviations from the observed pattern of variability (Sena, Morais Neto and Lucena, 2017). That is, it is important to compare the history of precipitation of the municipality with the occurrences of El Niño and La Niña phenomena, having as a parameter the climatological normal, in order to verify possible anomalies.

The phenomena of teleconnections are distant actions related to simultaneous climate changes that occur between the atmospheric circulation and the surface temperature of the oceans, causing anomalies in the oceanic-atmospheric system of a certain region of the planet, causing changes in the weather and climate of other parts of the world. There are several phenomena of teleconnections and the best known of them are the El Niño and La Niña phenomena that in activity alter the climatic rhythm of several parts of the world, including Brazil. However, there are other patterns, as reported by the *Climate Prediction Center (*NCEP/NOAA) that can have control over weather and climate in areas far from the centers that originate them, including in the opposite hemisphere (SANTOS, 2011).

El Niño and La Niña are large-scale phenomena that feature temperature anomalies of the surface of the Pacific Ocean, which occur simultaneously with the atmosphere. These phenomena affect the atmospheric circulation, mainly determining anomalies in the field of rainfall in several regions of the globe (Freire, Lima and Cavalcante 2011).

El Niño is the unusual warming of the Equatorial Pacific Ocean that, in line with the weakening of trade winds in the same region, tends to cause changes in atmospheric circulation. In El Niño years there is a change in position of the ascending branch of the Walker cell in the Equatorial Pacific that moves to the Eastern Equatorial Pacific. Two descending branches are then formed, one of them over the Atlantic and Northeast of Brazil (Freire, Lima and Cavalcante 2011).

La Niña is a phenomenon that is characterized by being the opposite of El Niño, that is, it is the cooling of the waters of the Equatorial Pacific Ocean, for this reason it is known as cold episode (Oliveira, 2001). In activity, the strengthening of the South Pacific Subtropical High occurs, allowing the transport of cold surface ocean waters with greater ease to the Central-West Equatorial Pacific, thus strengthening the Walker cell.

> The phases of the ODP (Pacific Decennial Oscillation) are defined as positive when there is an increase in Pacific Ocean temperatures and negative when there is an anomalous decrease in these temperatures. Such variations are related to factors such as marine currents,

> volcanisms on the ocean floor and, especially, solar activity. Thus, due to the fact that the Pacific Ocean occupies about one third of the Earth's surface, variations in the ODP directly influence the climate of the continents (Costa, Becker and Brito, p.3, 2013).

Because they are global phenomena, El Niño and La Niña have proven influence on atmospheric dynamics and relationship with the occurrence of extreme events, given that such phenomena occur in the largest ocean on the planet, hence the importance of monitoring and specific studies of the influence of the ENSO phenomenon on important meteorological variables such as: precipitation, temperature and wind of a given place.

> The observance and spatial contextualization of extreme events are of great relevance for understanding the dynamics of natural and social processes on the territory. Despite contributing on a macroscale to the study of climatic events, the use of annual averages of precipitation data presents methodological barriers to understanding the dynamics of the local climate. The simple interpretation of the averages does not evidence, therefore, the gradation of the impacts that such indices promote in the cities (Oliveira, Junior, Nóbrega and Girão, p.2, 2011).

Given this, it is evident the importance of an in-depth analysis of the climatic data of a given environment, given that a climatological study is very complex and therefore requires greater rigor with the data to be worked, in order to obtain a satisfactory and safe result. Therefore, this article aims to work the monthly precipitation data in the years of El Niño and La Niña, verifying the influence of these phenomena on the climate of the municipality of Vitória da Conquista.

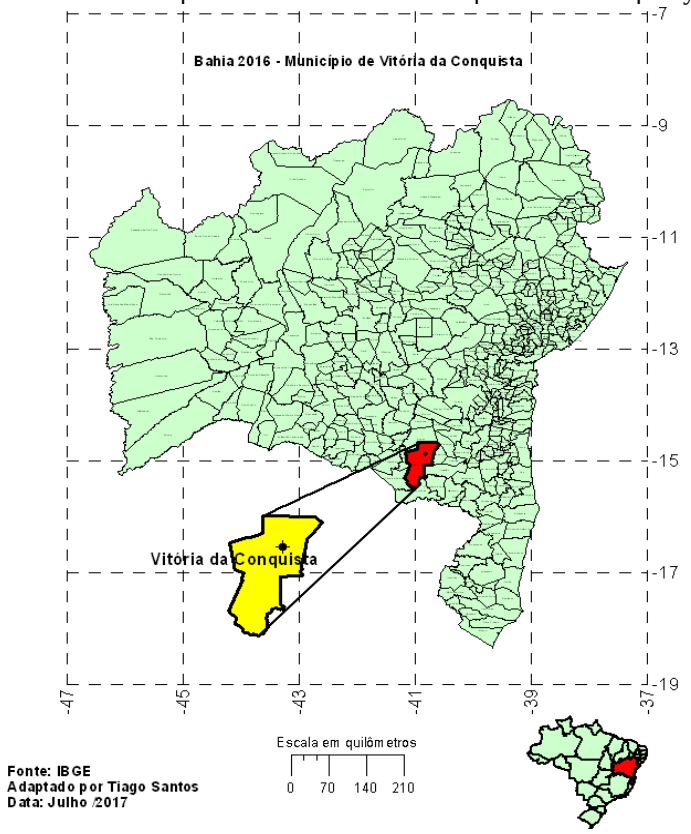
> Modern man is affected by weather and climate in the same way as his ancestors. But unlike the ancients, modern man does not want to live at the mercy of meteorological weather. He now wants to manage or even plan the control of weather conditions. For this purpose, man needs to be able to understand atmospheric phenomena so that he can predict, modify or control them when possible (AYOADE, 2003, P.7).

Throughout human history, man has constantly sought to understand the complexity of weather and climate and the tendency is that the constant scientific studies in progress, certainly, will be increasingly developed in the future, mainly because of the technological advances and innovations that will arise in the field of climatological research and with this, will favor a better understanding of atmospheric dynamics as well as the interaction of teleconnection phenomena with atmospheric phenomena, thus allowing greater efficiency in short- to long-term weather forecasts.

2 MATERIAL AND METHODS

The municipality of Vitória da Conquista is located between the geographical coordinates of 14º 30' and 15º 30' south latitude and 40º 30' and 41º 10' longitude W and occupies an area of 3,743 km² (Figure 1). It consists of the headquarters city, Vitória da Conquista and the districts of: José Gonçalves, São Sebastião, Pradoso, Bate Pé, Iguá, Dantilândia, Cabeceira da Jibóia, Veredinha, Inhobim, Cercadinho and São João da Vitória.

Figure 1. Vitória da Conquista – Bahia: Location map of the municipality – 2017



Source: IBGE/Adapted by Tiago Santos

The climate of the municipality of Vitória da Conquista is influenced by three atmospheric systems throughout the year and varies in intensity according to the season. In autumn and winter, the Atlantic Tropical mass together with the trade winds coming from the South Atlantic Ocean (Atlantic Polar mass), carry cold and humid winds providing low temperatures and weak rain. Part of the municipality be situated on the Planalto dos Geraisinhos, as well as, the city of Vitória da Conquista making this city one of the coldest in all of Bahia.

In spring and summer, the main atmospheric system to influence the region is the Continental Equatorial mass that has as its characteristic the transport of a lot of heat and humidity over the municipality, causing the formation of convective clouds, that is, conditions conducive to the occurrence of torrential rains and with this, filling the cold water dams I and II that supply the city of Vitória da Conquista.

The average annual rainfall of the municipality is 734 mm with dry season from May to September. In this period there are usually orographic rains, mainly in the months of May to August and it is considered a dry season because of the fact that the lowest precipitation rates recorded annually occur.

3 METHODOLOGICAL PROCEDURES

To carry out this scientific article, initially a research was carried out on climatological works related to the phenomena of El Niño *and* La Niña *teleconnections in order to understand the relationship between these ocean-atmospheric phenomena with the climatic dynamics of the Brazilian territory, mainly over the northeast region.*

In this study, an analysis of rainfall data of episodes of El Niño and *La Niña phenomena between the years* 1982 to 2016 was carried out, separating in this period the episodes of moderate and strong intensities, observing the rainfall distribution in the years of occurrence of these phenomena having as reference the climatological normal of the municipality of Vitória da Conquista.

To carry out this research, total, mean and rainfall standard deviation graphs were produced, with the objective of characterizing the climatic dynamics of the municipality in relation to the occurrence of these phenomena of teleconnections, observing if there are anomalies in the annual precipitation cycle and thus making an interpretation of these climatological data.

In the process, graphs were made with the annual precipitation (January to December) in years of *El Niño* and *La Niña episodes,* making the comparison with the graph of climatological normal of the municipality, verifying the influence of these phenomena on the rainfall distribution. It was also carried out the observation through research of the occurrence of the atmospheric phenomenon South Atlantic Convergence Zone (SACZ) in periods *of El Niño and La Niña*, verifying if there is the highest occurrence of this phenomenon during the year, since the SACZ cause greater volumes of rain over the municipality, being very important for the supply of water reservoirs and also of the water tables of Vitória da Conquista and region.

4 RESULTS AND DISCUSSION

With reference to the episodes of El Niño and La Niña phenomena between the years *1982 to 2016 (34 years) of moderate to strong intensities extracted from* the National Oceanic and Atmospheric Administration *(NOAA), there were in all, in this period, not counting the events of low intensity, 6 episodes of the* El Niño phenomenon , 4 of strong intensity and 2 moderate episodes. The *La Niña* phenomenon presented in this period 4 episodes, 3 of strong intensity and 1 moderate, not counting the occurrences of weak intensity (Figure 2).

Figure 2. Years of occurrence and intensities of *El Niño* and *La Niña*: 1982 to 2016.

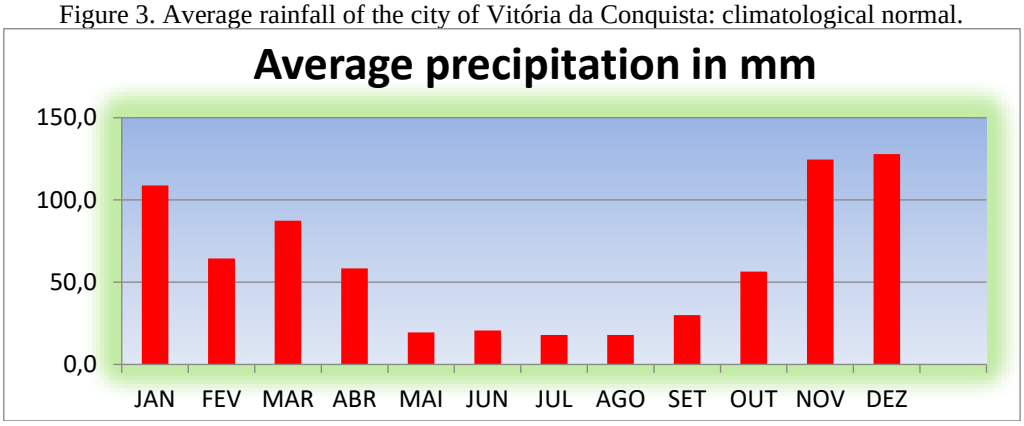
YEARS OF EL NIÑO OCCURRENCE	
YEARS	INTENSITY
1982/1983	**STRONG**
1986/1988	**MODERATE**
1990/1992	**STRONG**
1997/1998	**STRONG**
2002/2003	**MODERATE**
2015/2016	**STRONG**
YEARS OF LA NIÑA OCCURRENCE	
YEARS	INTENSITY
1988/1989	**STRONG**
1998/2001	**MODERATE**
2007/2008	**STRONG**
2010/2011	**STRONG**

Source: NOAA

After verifying the years of occurrence of these phenomena of teleconnections, it was observed the behavior of the monthly precipitation of the municipality of Vitória da Conquista before these episodes of anomalies of the temperature of the surface waters in the Eastern Pacific Ocean, since these changes influence on the atmospheric dynamics in almost the entire planet.

The reference to verify the influence of these phenomena on the monthly precipitation of the municipality was the data of the climatological normal of Vitória da Conquista, such graph presents the average of the monthly precipitation based on the accumulation of data in a period of 30 years (Figure 3).

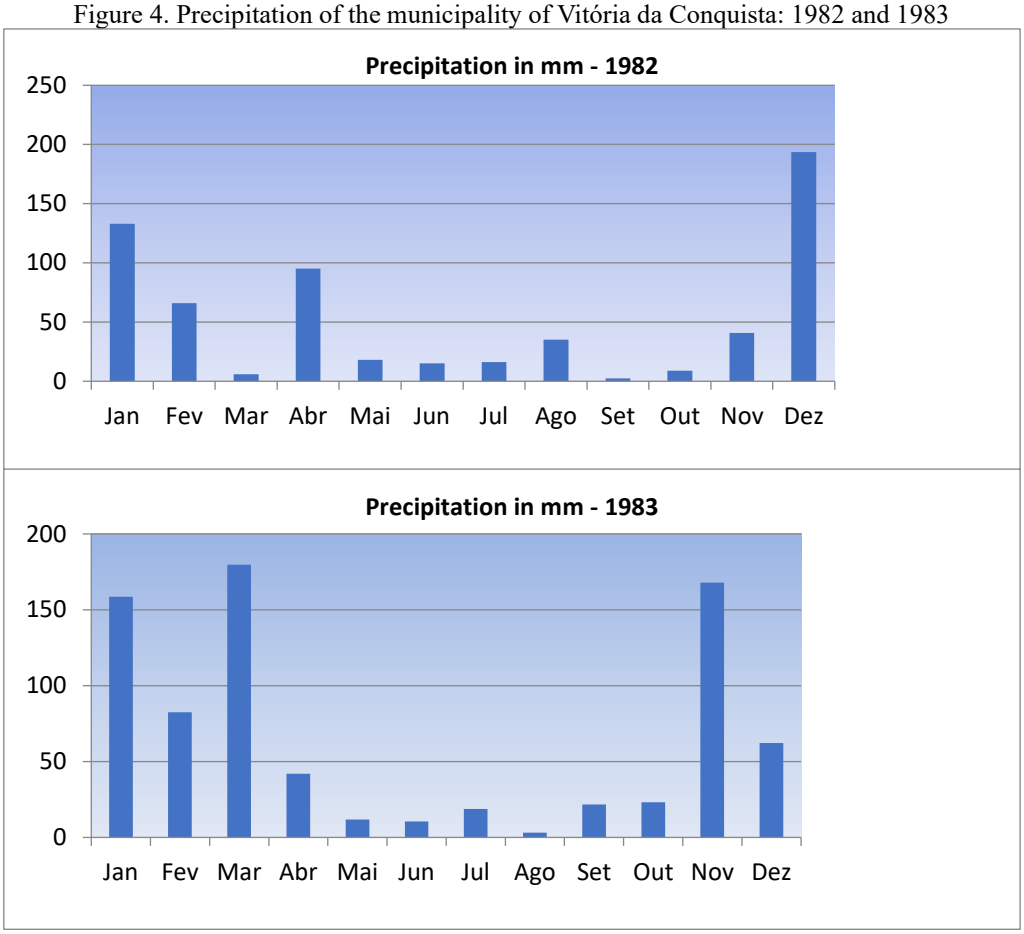
Figure 3. Average rainfall of the city of Vitória da Conquista: climatological normal.



Source: INMET (1961 to 1990)

Based on the climatological normal of the city, with a total annual rainfall of 740 mm, the monthly precipitation of the years of occurrence of the *El Niño* and *La Niña* phenomena was verified in order to verify the influence of these ocean-atmospheric phenomena. First, we will present the precipitation data of the *El Niño phenomenon of the years 1982 and* 1983, which was very strong, considered the strongest and most devastating of the twentieth century (Figure 4).

Figure 4. Precipitation of the municipality of Vitória da Conquista: 1982 and 1983

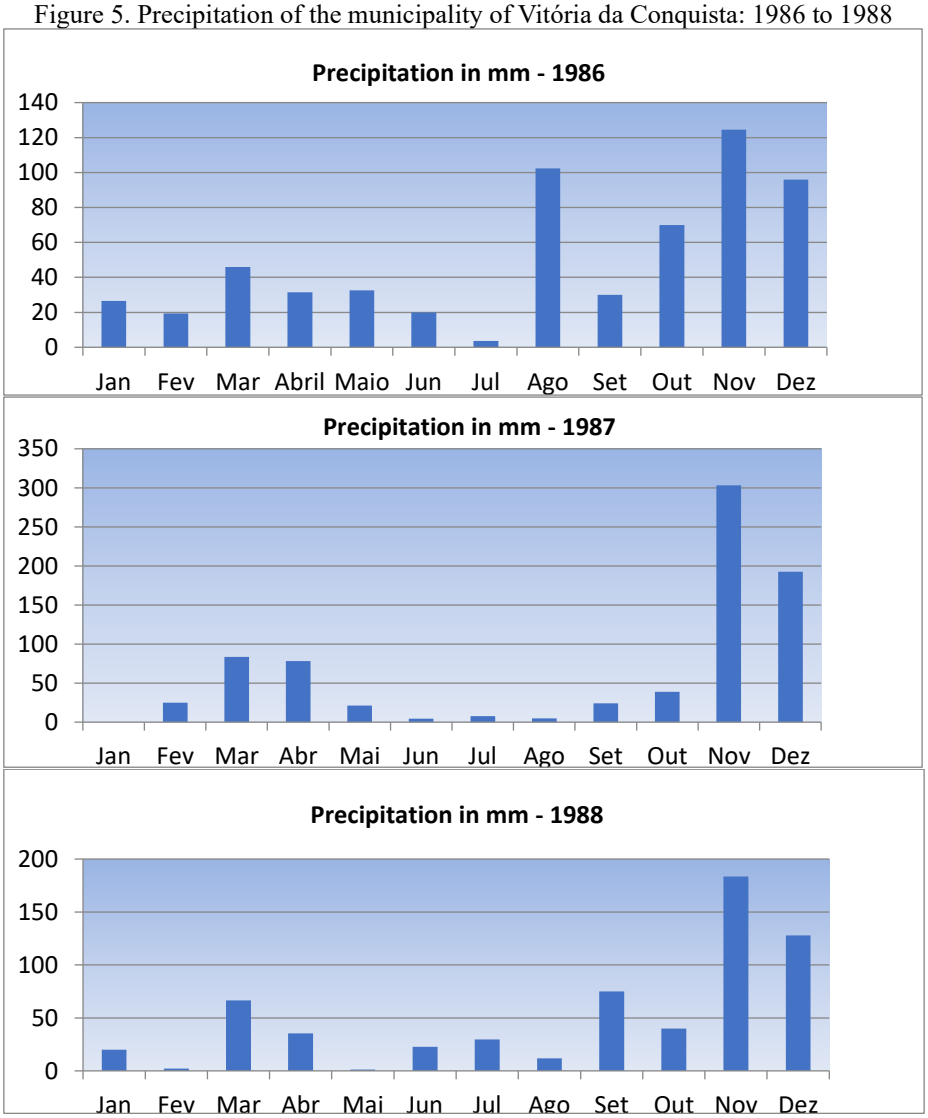


Source: INMET

Checking the precipitation of the two years, it is possible to notice that in 1982 there is a greater concentration of rainfall in the months of January, February, April and December, that is, in this year the *El Niño* phenomenon caused a greater irregularity in the rainy cycle, although the rainfall irregularity in the municipality is common, in this period it was much more pronounced. In 1983, the rains were concentrated in the months of January, February, March and November, evidencing a higher concentration of rainfall in these months. In summary, the year 1982 rained below average, that is, a year considered dry and of concentration of rainfall in short periods and 1983 was a year of rainfall slightly above average and also with a high concentration of rainfall, evidencing that El *Niño* caused a greater irregularity in the rainfall distribution.

In the years 1986 to 1988 there was an episode of *the El Niño* phenomenon of moderate intensity (Figure 5).

Figure 5. Precipitation of the municipality of Vitória da Conquista: 1986 to 1988

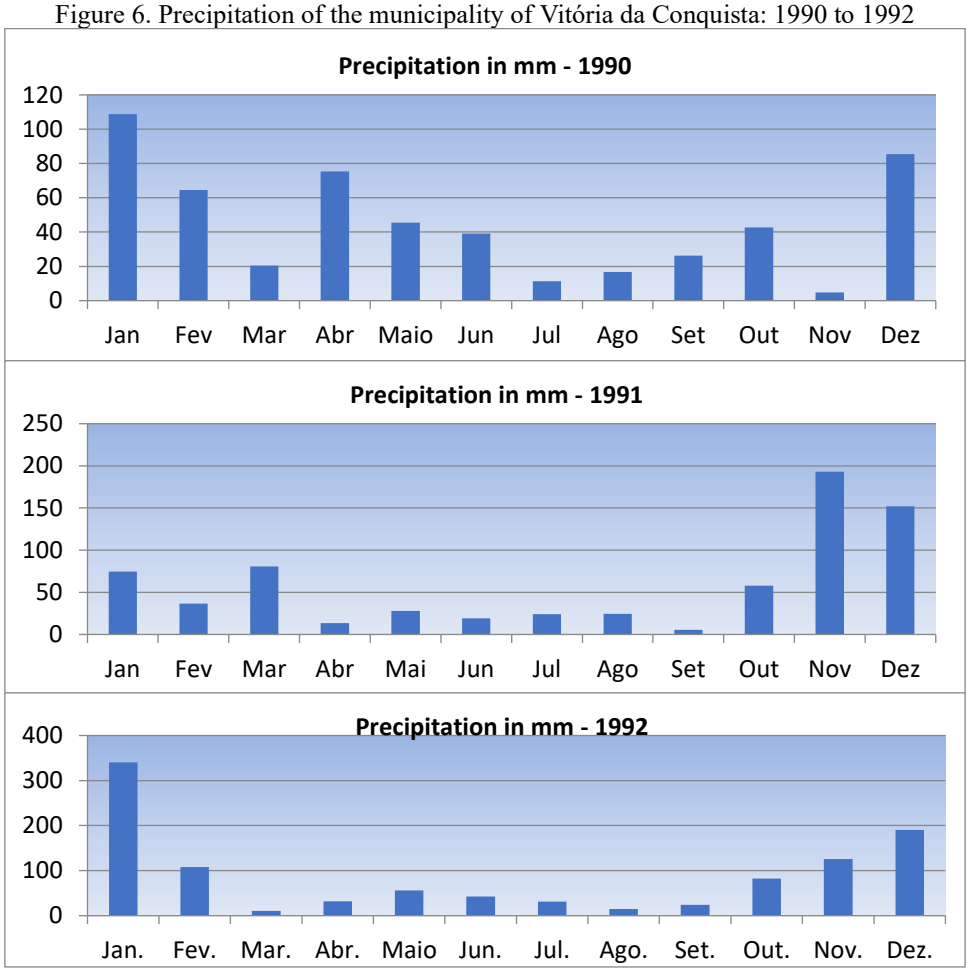


Source: INMET

In 1986, the data for the months of June, September and November are not available in the INMET or BDMEP database, in which case the climatological average of these periods must be used. In that year, the rains were concentrated in the months of August, October, November and December, that is, there was a very irregular rainfall distribution and with total precipitation below average (602.3mm). The year 1987 was a year of distribution of rainfall practically concentrated between the months of November and December, with precipitation well above the average in these two months, evidencing the influence of *El Niño* in the intensification of the rainfall irregularity of the municipality, and the total precipitation was slightly above the average (784.1 mm). And the year 1988 presented the concentration of rainfall in the months of March, September, November and December, and the December data were not found in the INMET database, using the climatological average of this period. This year also presents a greater intensification of rainfall irregularity, with total precipitation below average (dry year).

In the years 1990 to 1992, there was an episode of the *El Niño* phenomenon of strong intensity (Figure 6).

Figure 6. Precipitation of the municipality of Vitória da Conquista: 1990 to 1992

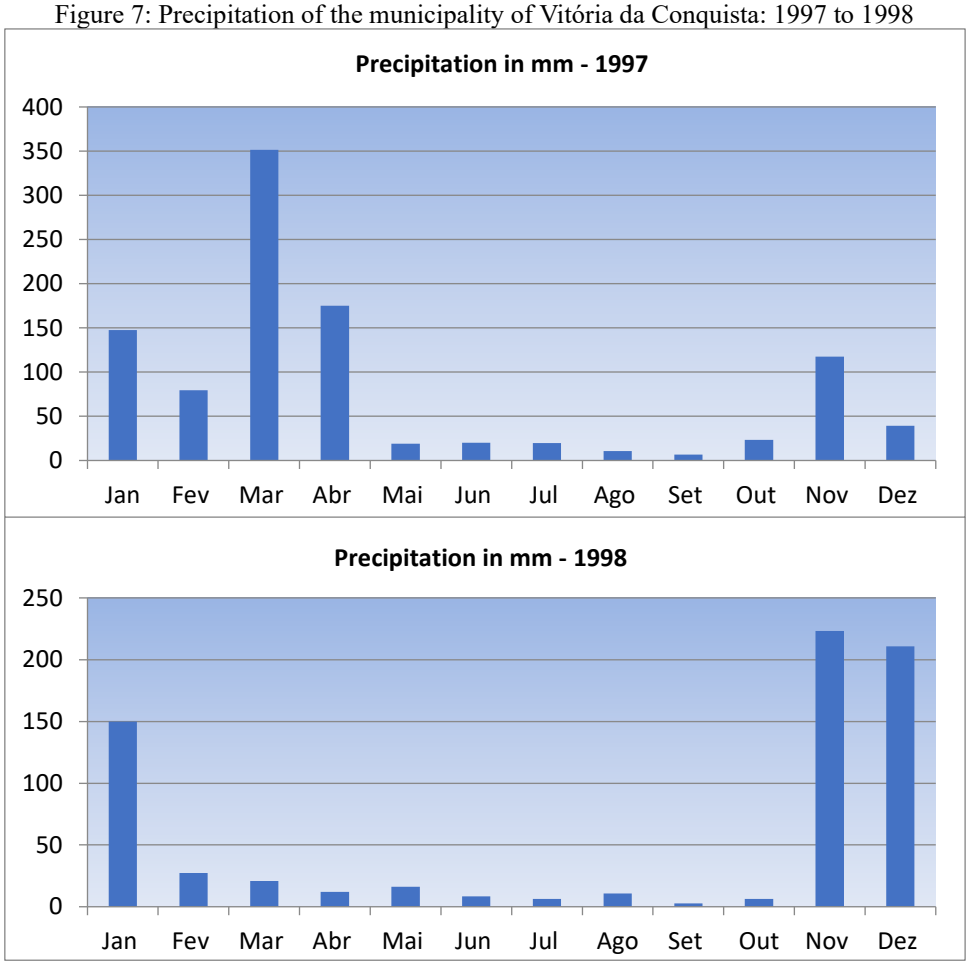


Source: INMET

In 1990, precipitation data for the months of January and February are not available in the INMET database, and average precipitation is used. It is verified that the rains were concentrated in the months of January, February, April and December, and it is not possible to evaluate whether there was an intensification of the rainfall irregularity due to the use of the averages of the data of January and February. The year 1991 presents the concentration of rainfall in the months of January, March, November and December, with the remainder of the year dry, evidencing a greater irregularity of rainfall during the year. And the year 1992 presents a large volume of rainfall in the months of January, February, October, November and December, with a total rainfall of 1058.4 mm, that is, a very rainy year and rainfall distribution considered normal.

In 1997 and 1998 there was an *El Niño* of strong intensity, one of the most intense ever recorded, following the precipitation data in Vitória da Conquista in this period (Figure 7).

Figure 7: Precipitation of the municipality of Vitória da Conquista: 1997 to 1998

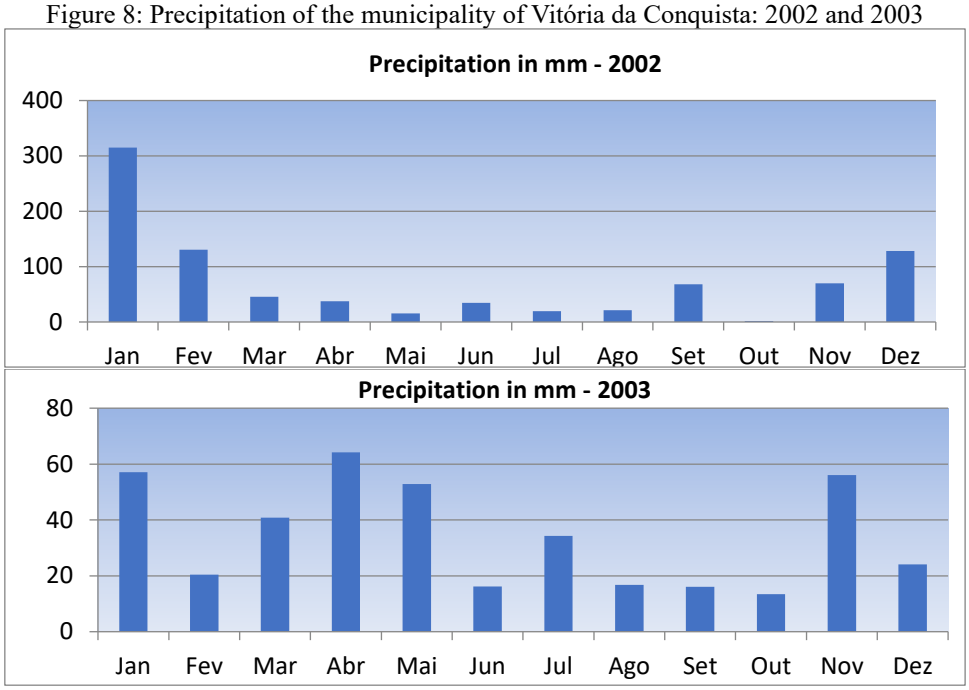


Source: INMET

In the year 1997, the rains were concentrated in the months of January, February, March, April and November, considered a normal rainfall distribution, however, in the month of March it rained 4 times the expected for this period, that is, a rainfall total much above normal in a short time, the total precipitation in that year was 1009.3 mm, considered a very rainy year. The year 1998 presents a great irregularity in the rainfall distribution, evidencing the influence of *El Niño on the* concentration of rainfall in a few months. In that year the rains were concentrated in January, November and December, with the rest of the year very dry. The total rainfall in 1998 was 694.4 mm, considered normal.

In 2002 and 2003, a moderate-intensity *El Niño* episode occurred (Figure 8).

Figure 8: Precipitation of the municipality of Vitória da Conquista: 2002 and 2003

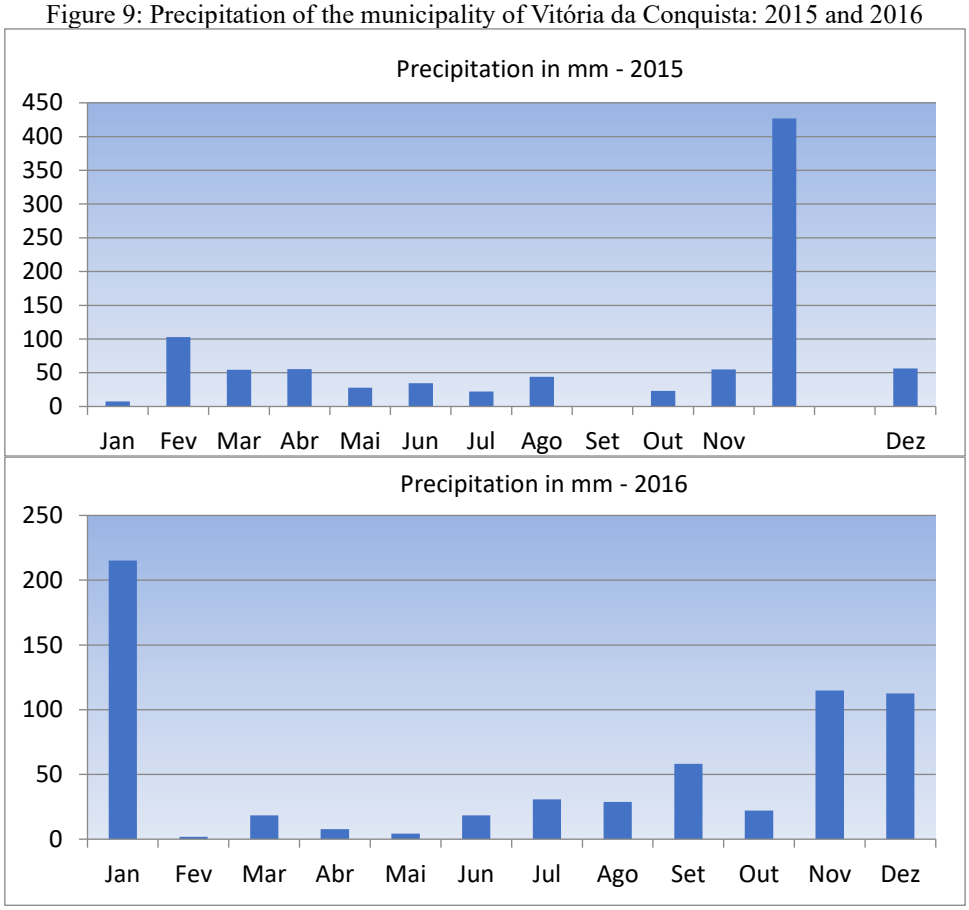


Source: INMET

In the year 2002, the rains are concentrated in the months of January, February, September, November and December, with a large volume of precipitation in the month of January. This year presents the rainfall distribution considered normal in relation to the climatological normal of the municipality, with total precipitation above the average (887.7 mm). In 2003 the rains were concentrated in the months of January, April, May and November, considered a rainfall distribution also normal, however, the year was very dry, with total precipitation of 412.3 mm. In summary, *the El Niño* phenomenon in this period had no influence on the rainfall distribution of the municipality.

In the years 2015 to 2016, the most intense *El Niño* phenomenon of the twenty-first century occurred and one of the strongest since the records were made (Figure 9).

Figure 9: Precipitation of the municipality of Vitória da Conquista: 2015 and 2016



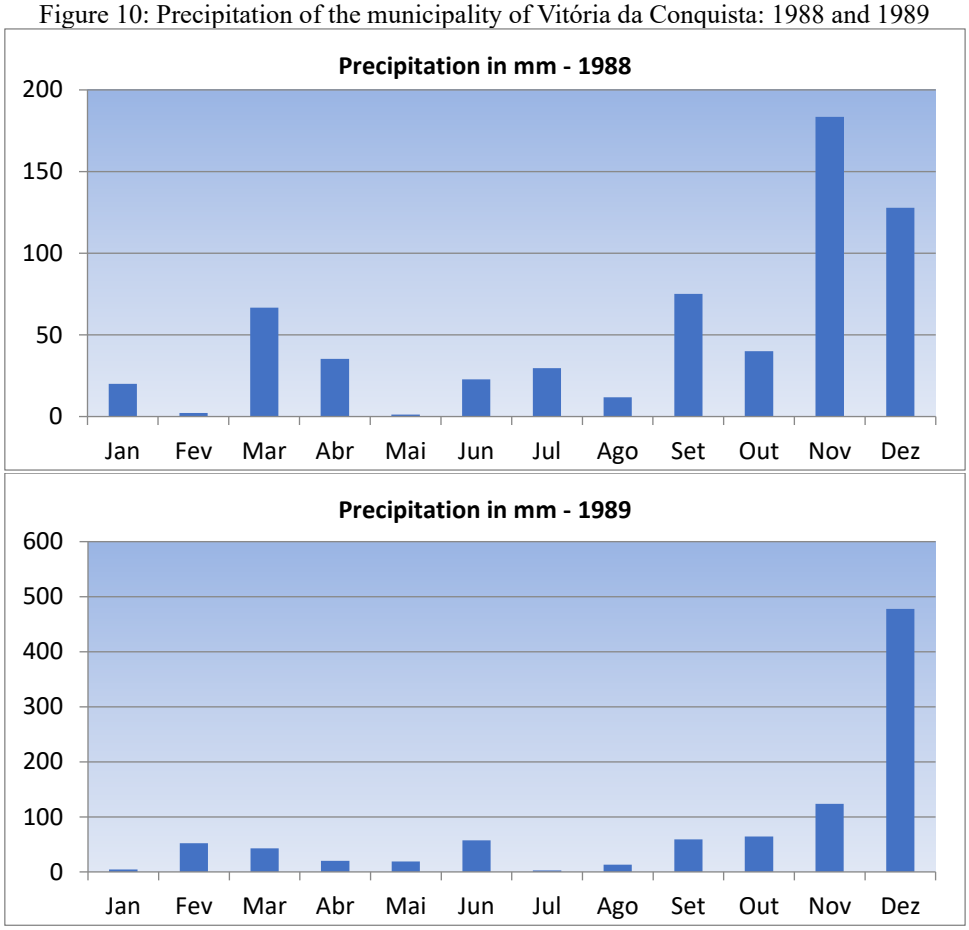
Source: INMET

In the year 2015 the rains were concentrated in the months of February, March, April, November and December, having its rainfall distribution considered normal, since the total precipitation was far below the average, that is, it was a very dry year. In 2016, the rainfall distribution was extremely irregular, with rainfall concentrated only in the months of January, November and December, evidencing the influence of the *El Niño* phenomenon on the greater rainfall irregularity of the municipality that year. The total rainfall was 689.1 mm considered a dry year.

Subsequently, the influence of the inverse phenomenon to *El Niño, that is, the* La Niña phenomenon, was verified. This phenomenon is generally favorable for the occurrence of above-average rainfall in the semi-arid Northeast, allowing the formation of convective clouds more frequently over the interior of the Northeast region.

First, the years 1988 and 1989 were verified, which was a period of *La Niña* phenomenon of strong intensity (Figure 10).

Figure 10: Precipitation of the municipality of Vitória da Conquista: 1988 and 1989

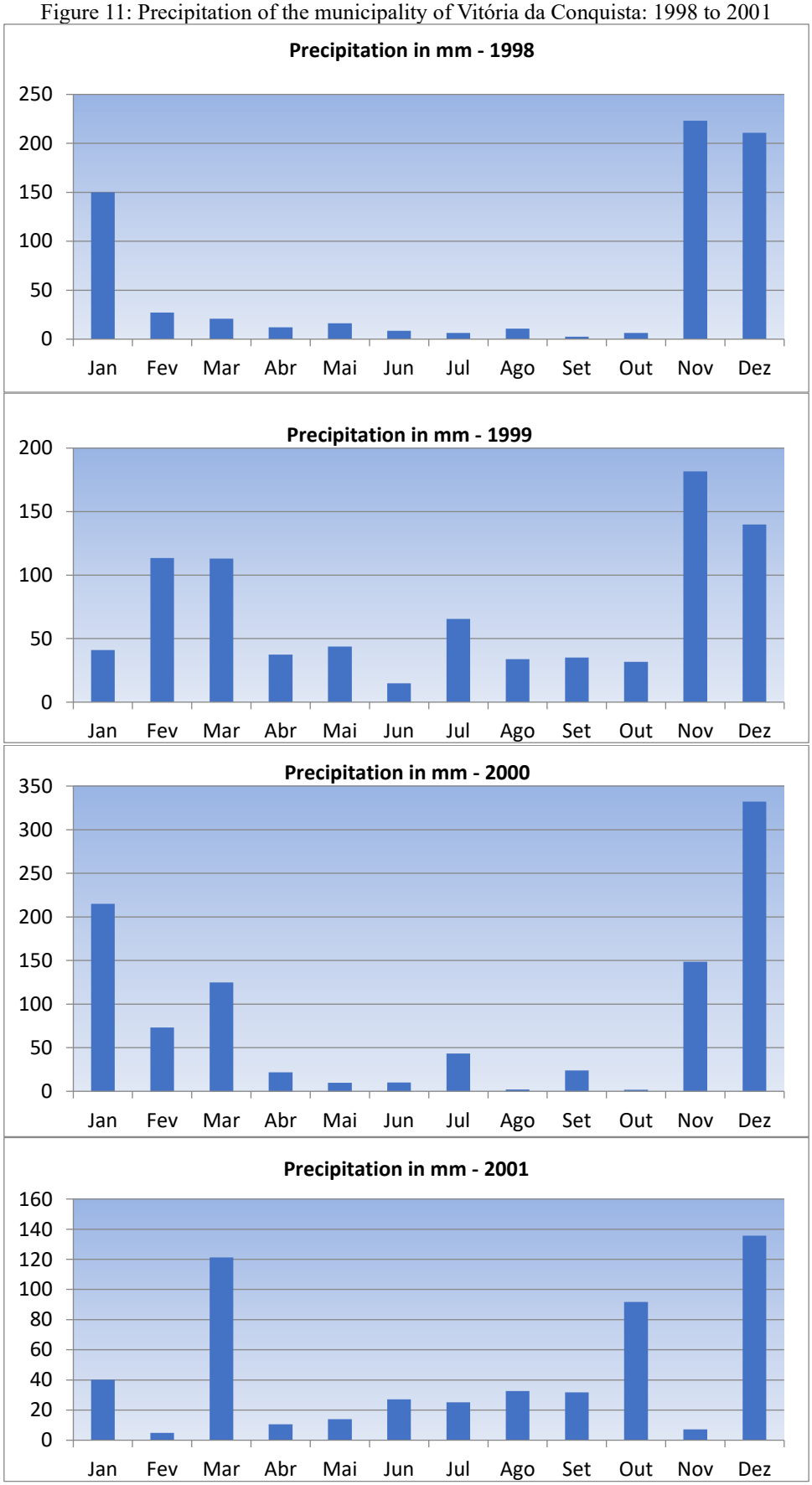


Source: INMET

In 1988, the rains were concentrated in the months of March, September, November and December, that is, the *La Niña* phenomenon influenced in order to promote a greater irregularity in the rainfall distribution of the municipality, concentrating the rains mainly in the months of November and December. The total rainfall in that year was 615.9 mm, considered a dry year. Already the year 1989, the rains were concentrated practically only in the months of November and December, the *La Niña* phenomenon promoted, in this period, a large rainfall volume in the month of December, registering only in that month the value of 477.8 mm, equivalent to almost 4 times the amount of rainfall expected for this month, that is, there was a very clear accentuation of the rainfall irregularity in that year that recorded a total rainfall of 936.3 mm, considered a very rainy year.

In the years 1998 to 2001, there was a long period of *La Niña*, since this phenomenon usually lasts for 2 to 3 years. This *La Niña* episode was of moderate intensity (Figure 11).

Figure 11: Precipitation of the municipality of Vitória da Conquista: 1998 to 2001



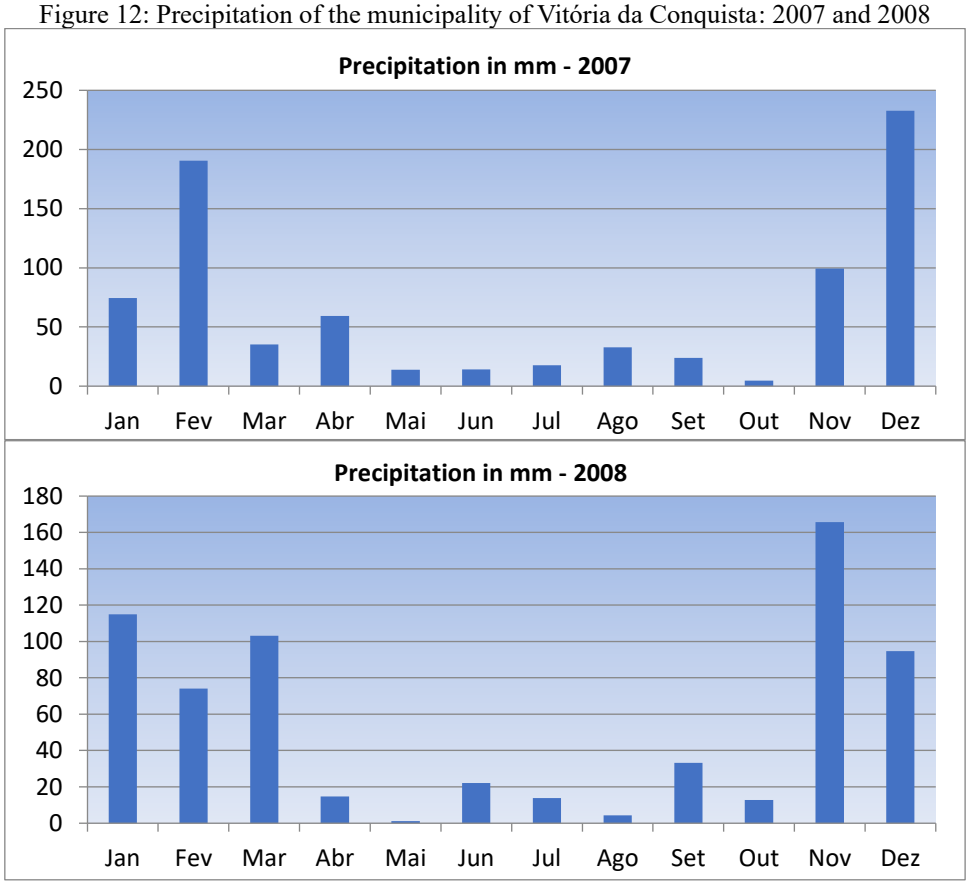
Source: INMET

In 1998 the rains were concentrated in the months of January, November and December, with a clear intensification of the rainfall irregularity in this period. The total rainfall in that year was 694.4

mm, considered close to the climatological average. The year 1999 presents a concentration of rainfall in the months of February, March, November and December, that is, the rainfall distribution was quite irregular with the total precipitation of 850.9 mm, considered a rainy year. In the year 2000 the rains were concentrated in the months of January, February, March, November and December, considered a year of normal rainfall distribution for the climatological pattern of the municipality, with a total precipitation of 1006.4 mm, considered a very rainy year. And the year 2001 presents a concentration of rainfall in the months of March, October and December, considered quite irregular, evidencing the influence *of La Niña* in the intensification of the rainfall irregularity of the municipality of Vitória da Conquista. The total rainfall in that year was 541.7 mm.

In the years 2007 and 2008 there was an episode of the *La Niña* phenomenon of strong intensity (Figure 12).

Figure 12: Precipitation of the municipality of Vitória da Conquista: 2007 and 2008

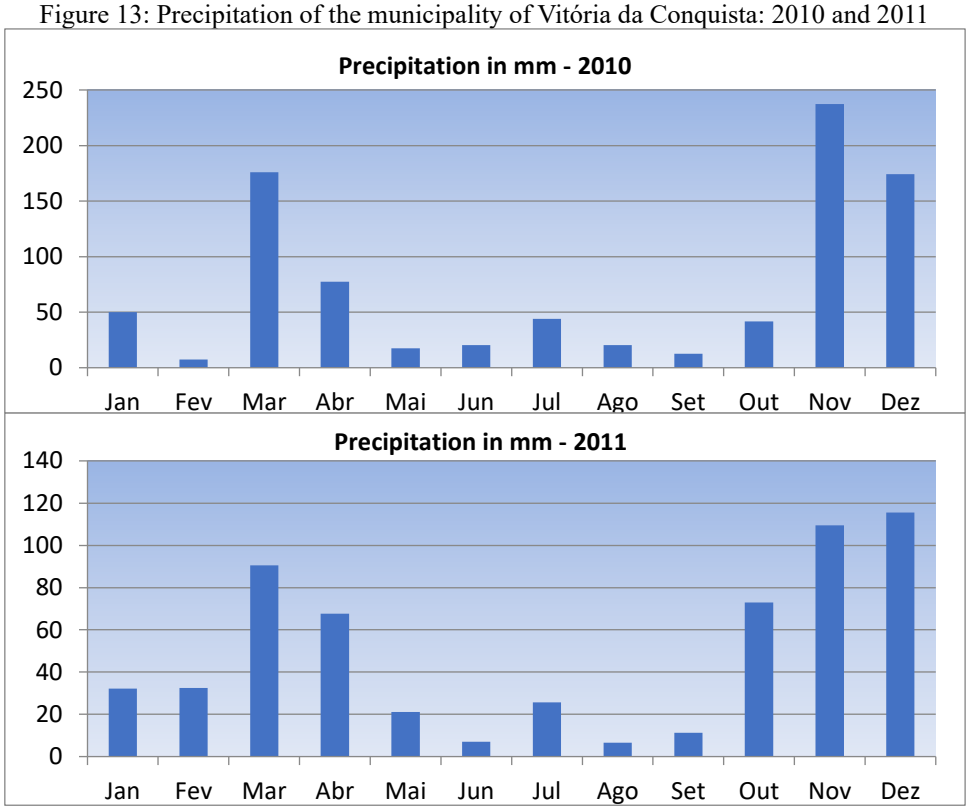


Source: INMET

In the year 2007 the rains were concentrated in the months February, November and December, evidencing an irregularity above normal, the total precipitation was 798.8 mm, considered a little above the climatological average. And in 2008 the rains were concentrated in the months of January, February, March, November and December, evidencing a rainfall distribution considered normal. Total rainfall that year was 654.6 mm, slightly below the climatological average.

In the years 2010 and 2011 there was a *La Niña* phenomenon of strong intensity (Figure 13).

Figure 13: Precipitation of the municipality of Vitória da Conquista: 2010 and 2011

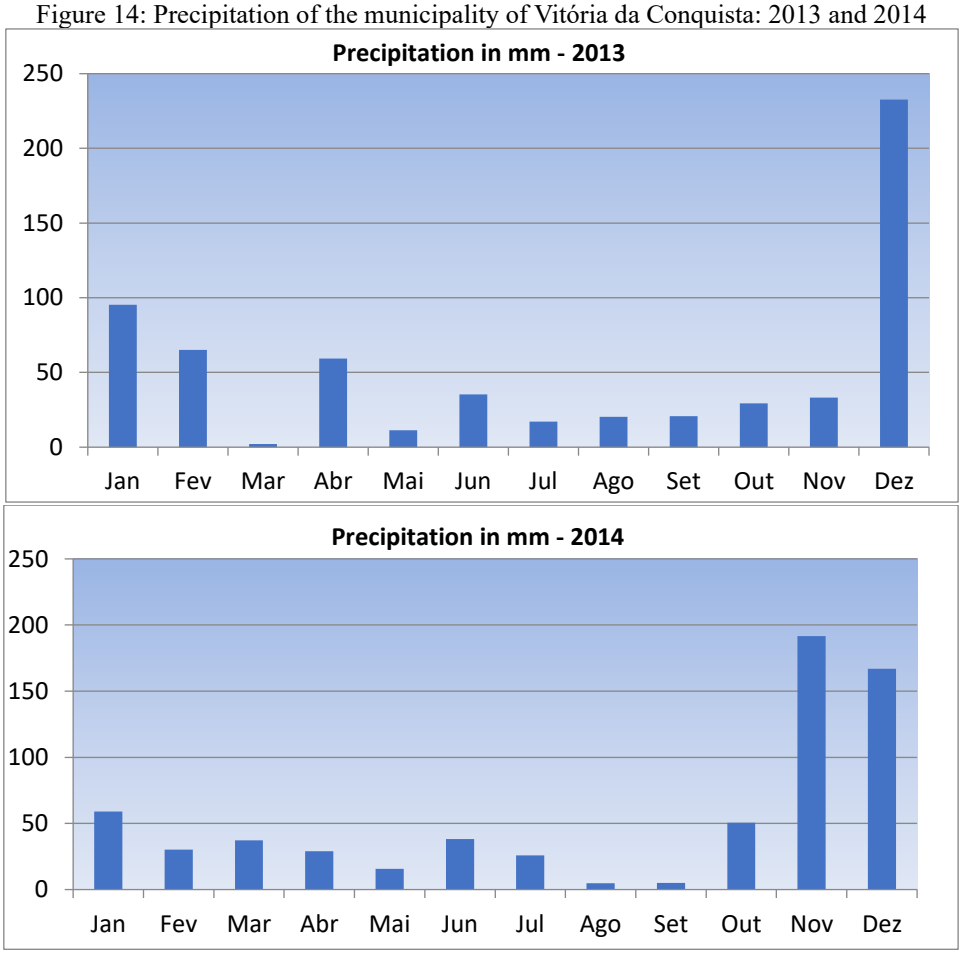


Source: INMET

In the year 2010 the rains were concentrated in the months of March, April, November and December, with a rainfall irregularity considered accentuated. The total rainfall in that year was 878.5 mm, considered a rainy year. And in the year 2011 the rains occurred in greater volume in the months of March, April, October, November and December, being considered a normal rainfall distribution. In that year it rained a total of 592.4 mm, considered a relatively dry year.

In the years 2013 and 2014 neither of the two Ocean-atmospheric phenomena occurred, that is, a period of climate neutrality (Figure 14).

Figure 14: Precipitation of the municipality of Vitória da Conquista: 2013 and 2014



Source: INMET

In 2013 the rains were concentrated in the months of January, February, April and December, with above average rainfall in the month of December, presenting an irregularity in the rainfall distribution. The total rainfall in that year was 622.1 mm, considered a dry year. And in the year 2014 the rains were concentrated in January, October, November and December, also presenting irregularity in the rainfall distribution, with above average rainfall in the months of November and December. The total rainfall in that year was 654 mm, considered a relatively dry year. It was found with this that there is the influence of another Ocean-atmospheric phenomenon in the precipitation of the municipality that is the Dipole of the Atlantic, such phenomenon also exerts influence on the climate of the semi-arid northeastern region:

> The Atlantic Dipole is an anomalous change in seawater temperature in the tropical Atlantic Ocean. This phenomenon changes the meridional circulation of the atmosphere (Hadley) and inhibits or increases the formation of clouds over the Northeast of Brazil and some African countries, decreasing or increasing precipitation (ARAGÃO, 1998, p. 841).

The Atlantic Dipole influenced this period of climate neutrality of the El Niño and La Niña phenomena in *order to intensify the rainfall irregularity and also reduce the volume of precipitation for several months in a row, that is, it is not only the* El Niño *and La Niña* phenomena that influence

the region under study, there are other variables such as the Atlantic Dipole, evidencing the climatological complexity that exists in the studies of this geographical theme.

5 FINAL CONSIDERATIONS

Climatology is undoubtedly a very complex science and considered recent in comparison with other sciences. What explains this complexity is the way in which the climate is dynamic and involves a series of physical-natural factors for its understanding. One of these factors is the phenomena of teleconnections, involving a complex interaction between the oceans and the Earth's atmosphere, interfering directly on the behavior of temperature, humidity and especially precipitation throughout the planet, hence the importance of the present study.

It was found that both the El Niño phenomenon and the *La Niña* phenomenon influence the rainfall distribution of Vitória da Conquista in order to intensify the irregularity of rainfall during the years of these two phenomena, to the point of concentrating most of the rainfall volumes in only 3 months of the year, as occurred in 1998, 2001 and 2002, for example. In 38.4% of the years studied, the rains were concentrated in greater volume in millimeters per m^3 in only 4 months during the year and the normal is 7 months according to the graph of the climatological normal of the municipality of Vitória da Conquista. In another 38.4% of the years, the rains were concentrated in greater volume in only 5 months of the year. With this, it was evident that although the rainfall irregularity of the historical data of the municipality is considered normal, in episodes of the *El Niño* and *La Níña* phenomena this irregularity becomes to be more intensified, that is, the rains are concentrated in a few months during the year, causing most of the year to be very dry.

It was also found that in years of climate neutrality, that is, when the El Niño *and* La Niña *phenomena do not occur, there is the influence of another teleconnection phenomenon influencing the precipitation of the municipality that is the Atlantic Dipole, possibly also capable of intensifying the rainfall irregularity of the municipality of Vitória da Conquista.*

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