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# Analysis of climate variability in semiarid region, Petrolândia, Pernambuco

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## Abstract

This study aims to analyze the temporal variability of precipitation in the city of Petrolândia - PE, which is located in the physiographic region Submedium São Francisco. Was used Rainfall Anomaly Index (RAI) to analysis of the variability of precipitation in the region. The highest monthly values of precipitation occurred between the months of December to April, with the highest rainfall in March, while that from August to October was the quarter of less rainfall. From the RAI noted that there was great variability between dry and rainy, with a total of 29 and 34 years, respectively. The RAI presented a amplitude of -4.2 to +6.8, with maxima occurring in, 1974 and 1985, being classified as extremely humid. While the smallest occurred in 1993 and 1998, being classified as very dry. It was found that implementation of the RAI worked as a fundamental tool for the study of seasonal rainfall, yet, through this monitoring and one can generate predictions about the climatological regional variation. For the region dry periods are considered to be more damaging to the economy than the flood periods, despite the damage caused by floods.

Keywords: climatology, river São Francisco, seasonality.

## 1. Introduction

The climate is one of the elements that characterizes the landscape and higher restlessness, currently promotes his change impacts on health, comfort and daily activities. In this context, the climatology in the urban space is presented as a research field essential to the management of cities, with a view to improving the quality of life of population, in this case, planning is fundamental, due to the fact that reduces the impacts and maximizes the positive aspects of climate change (Zanella and Moura, 2013).

The climatological analysis can also contribute as subsidy for implementation of public policies. For Santos et al. (2015) becomes important to develop regional policies, aimed at reducing, or even eliminate the adverse effects on hydrological systems, being indispensable the knowledge of environmental particularities of the area through monitoring and early identification of local climate peculiarities. Thus, providing adequate management of hydric resources.

The quantity of water of the watersheds is conditioned the action of various weather systems, thus it is necessary to implement adequate management, that considers the hydric resources for multiple uses, of which depends on the integrate operation and maintenance of human activities and the preservation of the environment (Santos et al., 2015).

In addition, important socio-economic activities such as agriculture, aquaculture and fisheries, are often subject to failures or successes of seasonal climate predictions, which can directly impact on reducing losses and increase of profits (Machado and Rocha, 2011). The influence of the occurrence of events of climatic phenomena, such as El Niño - Southern Oscillation (ENSO) is significant for the agricultural productivity of a region (Fisch and Valério, 2005).

According to Santos et al. (2014) this dependence on pluvial conditions is particularly observed in northeastern Brazil. According to Silva et al. (2010), this region is considered anomalous, characterized by irregularity spatio-temporal of precipitation, as well as the high potential evaporation due to high temperatures occurring during the year. Furthermore, as Gurjão et al. (2012) existing drought in Northeast Brazil are defined as natural characteristic climate, and its inevitable occurrence, but can cause heavy losses to society.

Several climatological studies directed at the variability and frequency of extreme precipitation events, as well as the dynamics of the hydrological regime in Northeastern Brazil (Araújo et al., 2007; Araújo et al., 2009; Macedo et al., 2011; Santos et al., 2011; Silva et al., 2011; Gurjão et al., 2012; Farias et al., 2014), have been fundamental to the management and planning of hydric resources. However, due to irregularities of significant rains in the semi-arid region, there is a need, based on the employment climate indices, in-depth knowledge of the events that characterize the extreme dry and rainy periods, thus presenting important climatological information of the area.

In this context, this study aimed to analyze climatic temporal variability in the city of Petrolândia - PE, located in the region of the Submedium São Francisco, as well as, identify the occurrence of phenomena of El Niño / La Niña from climatological data obtained by Pernambuco Agency for Water and Climates (APAC), utilizing the Rainfall Anomaly Index (RAI).

## 2. Materials and methods

### 2.1 Study Area

The Itaparica reservoir (Figure 1) is located along the São Francisco River in the physiographic division called the Submedium São Francisco, covering areas of the States of Bahia and Pernambuco, with an approximate area of 834 km² at the maximum level, storage capacity of 11 billion m³ of water with a maximum depth of 101m, average of 21 m, operating minimum quota of 299,0 m and maximum of 304,0 m, prevailing climate typically semiarid and Caatinga vegetation, with the presence of grazing and monocultures areas, which depend on irrigation projects (Melo, 2007).

Is located downstream of the hydroelectric complex of Paulo Afonso and Xingó, its watershed consists of the river São Francisco and intermittent rivers of seasonal flow in the rainy season. The reservoir is located in Petrolândia cities, Belém de São Francisco, Itacuruba and Floresta (Pernambuco), Rodelas and Gloria (Bahia).

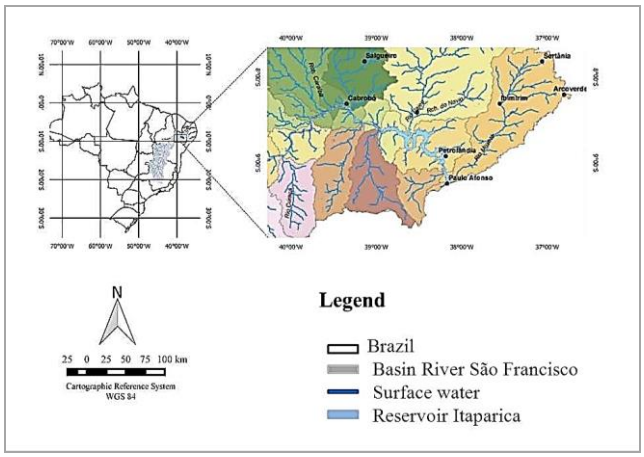


Figure 1 – Itaparica Reservoir: São Francisco River Basin. Fonte: Adaptado: Silva et al. (2014).

The region presents heterogeneous soil that indicate variable susceptibility to erosion, low pluviosity, high and intense solar radiation and average annual temperatures between 24 and 26 °C, with annual rainfall, ranging between 410 and 610mm (Melo, 2007). Displaying two seasonal seasons set: centralized rainfall season mainly in the months of May, June and July, and dry season between September and November, resulting in hydric deficit throughout the year.

The municipality of Petrolândia (Figure 2) is located in Mesoregion of the São Francisco Pernambucano, in the microregion Itaparica and region development Hinterland Itaparica, with geographical position determined by the parallel 09º 04' 08" E and 38º 18' 11" S, has limits to the west with the state of Bahia, east with Tacaratu,

north with Floresta and south with Jatoba, both in the state of Pernambuco (IBGE, 2010).

According to the Institute, has population of 32.492 inhabitants, population density of 30.75, IDH of 0.623, an area of 1056.595 km², with water treatment station system - ETA and sewage treatment station - ETE and demand urban 57 Lts/s water.

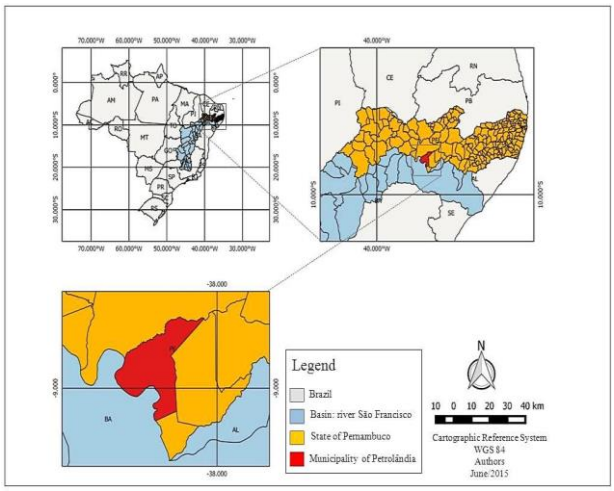


Figure 2 – Location of the municipality Petrolândia - PE.

2.2 Data and methodological procedures

The annual pluviometric data were provided by the Agency Pernambucana Water and Climate (APAC) for composition of climatology of the city of Petrolândia - PE, featuring dry and rainy periods.

These data were obtained through data gathering platform, number of code 49 of APAC, with geographical location -38.2164 (longitude) and -8.9742 (latitude), it was used a historical series of pluviometric data related period from 1940 - 2014, posteriorly, was calculated the monthly and annual averages of precipitation, using Microsoft Office statistical program.

It is noteworthy that throughout of the historical series data gaps were found, probably, there are failures in reading or station pluviometric equipment, however, some authors as Nikolova (2007), mentions that these gaps should not be filled, once the replacement values missing in the historical series can bring subjectivity to search.

2.3 Rainfall Anomaly Index (RAI)

Was used Rainfall Anomaly Index (RAI) developed by Rooy (1965) to analyze the variability of precipitation. According to Santos et al. (2011) for application of this index, it is recommended to use a historical series with data at least 30 years.

The application of the Rainfall Anomaly Index (RAI) contains a simple and effective calculation basis, allowing to monitoring the temporal variability of precipitation in the Petrolândia-PE region. Moreover, using this method it is possible to perform comparisons of current precipitation conditions related to the historical values (Freitas, 2005). The equations 1 and 2 (Rooy, 1965) for application of the RAI are presented below.

For Positive anomalies

$$RAI = 3. \left[\frac{A - \bar{A}}{M - \bar{A}}\right] \quad (1)$$

For Negative anomalies

$$RAI = -3. \left[\frac{A - \bar{A}}{X - \bar{A}}\right] \quad (2)$$

Where:

$A$ = annual precipitation measured (mm);

$\bar{A}$ = average annual precipitation of the historical series (mm);

$M$ = average of the ten highest annual precipitations of the historical series (mm);

$X$ = average of the ten lowest annual precipitations of the historical series (mm).

The values obtained from RAI were analyzed according to a new classification readapted by Araújo et al. (2009), thereby the years can be classified as dry or rainy. Table 1 presented the RAI intensity classes for the municipality studied.

For better assessment of the interannual variability of precipitation, were selected the years that presented extreme hydrological events and that did not exhibit gaps in the monthly series, in the existence of gaps, the employment of the monthly RAI becomes unfeasible to legitimize the data. Thus, specific analysis of the year allows to identify the intensity and durability of dry and rainfall periods that occurred in each month.

Table 1-Rainfall Anomaly Index intensity classes.

| Values of the RAI | Classification |
|---|---|
| **De 4 above** | Extremely humid |
| **2 to 4** | Very humid |
| **0 to 2** | Humid |
| **0 to -2** | Dry |
| **-2 to -4** | Very Dry |
| **De -4 below** | Extremely Dry |

## 3. Results and discussion

One can observe that in the municipality of Petrolândia the monthly mean from values higher of precipitation (above 40 mm) occurred during the months from December to April, with higher pluviometry in March, while the trimester of lowest pluviometry occurred from August to October, being lower than 20 mm (Figure 3). The observed data are in agreement with study of Silva et al. (2011) to physiographic region of the Submedium São Francisco, demonstrating for such a region the same rainy and dry periods, the rainfall season influenced by the meteorological system Intertropical Convergence Zone (ITCZ).

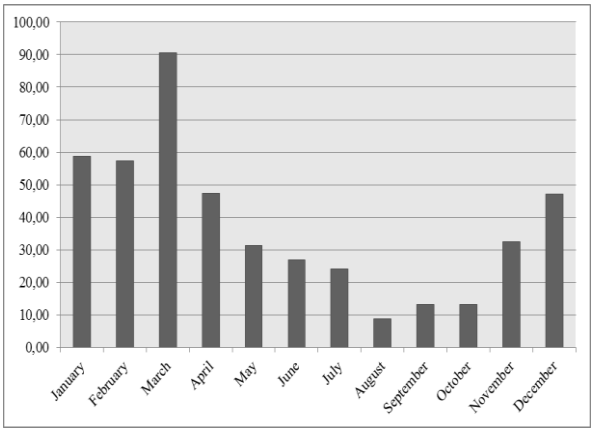


Figure 3 - Average monthly of precipitation on the historical series from 1940 to 2014 in the municipality of Petrolândia - PE.

The average annual of precipitation was 390 mm, is emphasized that on the historical series of pluviometry the years 1944, 1947, 1974, 1978, 1981 and 1985 stand out among the values above the annual average. Already the years of lowest pluviometry were 1946, 1955, 1956, 1987, 1990, 1993, 1998, 2007, 2013 and 2014, with annual total lower than 200 mm (Figure 4).

According to Silva et al. (2010) in a study on river basin Tapacurá, Paraiba, assessed on their results that the years 1978 and 1985 were also among the years of occurrence with precipitations above average (above 1,500 mm). These years of climatological standpoint are associated with episodes of the La Niña.

Based on the annual RAI, was observed that there was a great variability between dry and rainy years. Positive values represents rainy years, they had a total of 29 years, ranging between classes humid, very humid or extremely humid, already negative values presented a total of 34 dry years and were classified as dry, very dry or extremely dry. In figure 5 it is noticed that the amplitude RAI presented -4.2 to +6.8, with a maximum occurring in the years 1947; 1974; 1978 and 1985, being classified as extremely humid, with values above 4.0. While the minimum occurred in years (1946, 1955, 1956, 1987, 1990, 1993, 1998, 2007, 2013 and 2014) who obtained values below -2, or lower than 200 mm from the annual average classified as very dry.

Araújo et al. (2007) studying the climatology of Paraíba river basin also used the RAI and observed that the years 1993 and 1998 are among the negative values of precipitation for Taperoá region and upper Paraíba sub-basin, characterizing these as severely dry. And for positive values, the years 1974 and 1985 are among the rainiest, corroborating the results obtained.

The years 1993 and 1998 classified as very dry, can be justified for such facts. According to Macedo et al. (2011) that unlike the present study methodology, used the Standardized Precipitation Index (SPI), however, also found on the historical series these same years between the lower pluviometry. It is emphasized that these years were influenced by the El Niño phenomenon, which caused a significant decrease in rainfall regime in the region.

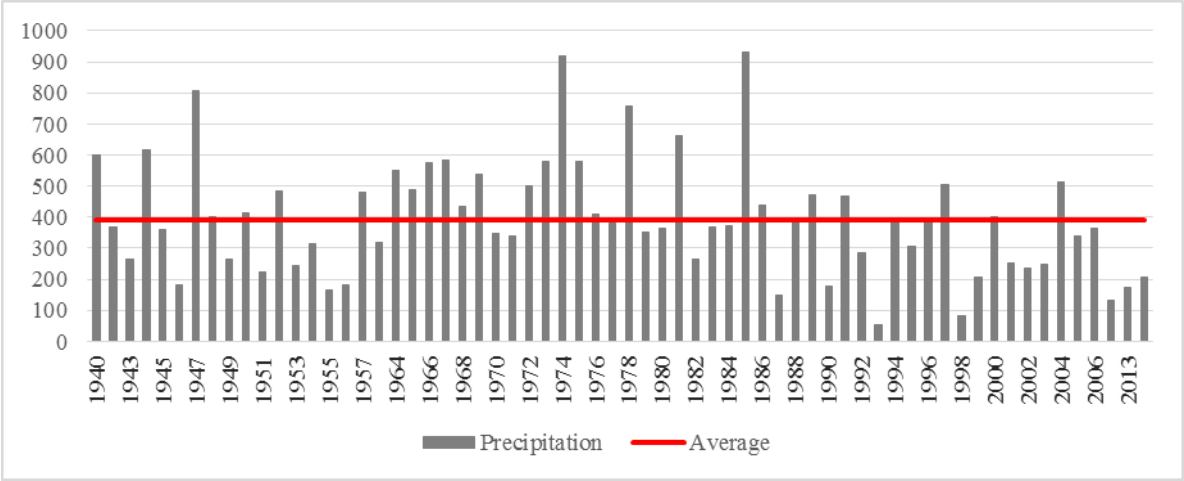


Figure 4 - Average annual of precipitation on the historical series from 1940 to 2014 in the municipality of Petrolândia - PE.

According to Macedo et al.; Santos et al.; Silva et al. (2011), the year 1985 is among the years there was the acting of the La Niña phenomenon. Ample documentation in the literature reveals that there is a relation between the episode of La Niña events and rainfall above of the climatological average in the Northeast region (Alves et al, 1997; Vianello et al, 2001).

For Santos et al. (2011) during this phenomenon the rains recorded in the Upper São Francisco are below the climatological average, differing from that found in this study (Submedium São Francisco), the authors characterized the phenomenon in that year as weak intensity.

Studies in Submedium São Francisco evidenced the association of El Niño - Southern Oscillation and Pacific Decadal Oscillation with probable decrease in the rains, where these remain in the hot phase of both events, and increase of precipitation in the cold phase of such events, showing that some regions of northeastern Brazil are more sensitive to aggregation of these phenomena (Silva et al, 2011).

Important to highlight that before year 1974 occurred 16 rainy years and 13 dry years, and subsequent to that, there were 12 rainy years and 21 dry years (Figure 5). So, the more humid period happened before 1974, and the driest period after.

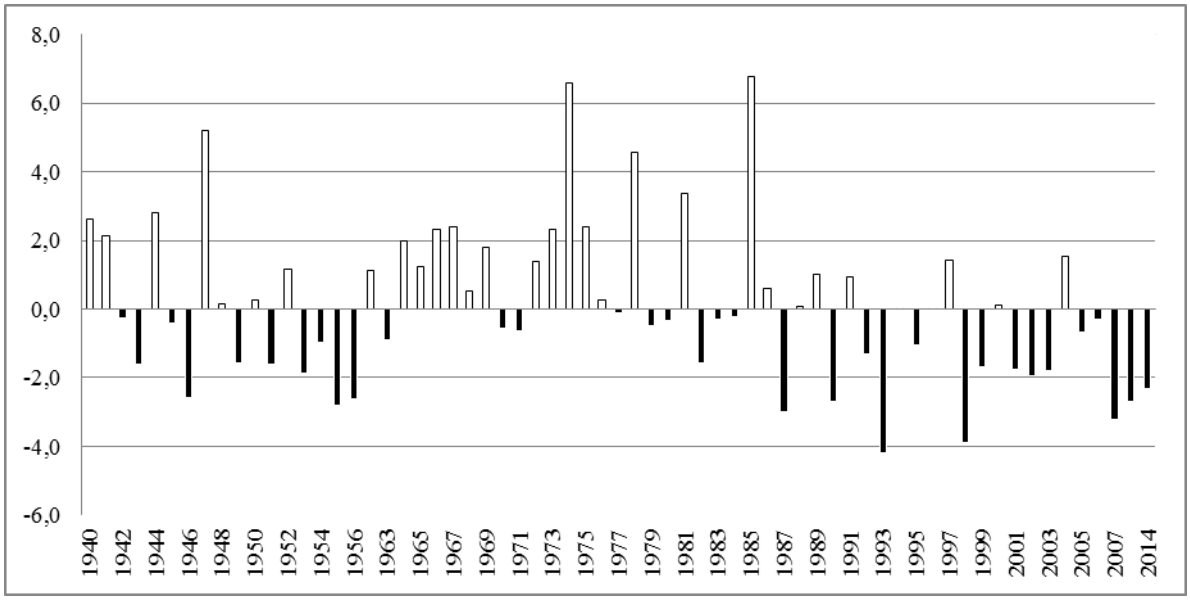


Figure 5 - Rain Anomaly Index (Annual / mm), related to the historical series from 1940 to 2014 in the municipality of Petrolândia - PE.

The same was observed by Silva et al. (2009) in a study conducted in the region of Lower Mundaú-AL (Mundaú River Basin), Northeast Region. The authors mention that this fact makes this year a 'inflection point' of a probable change in the local precipitation pattern. This "inflection point" was also observed by Araújo et al. (2007 and 2009).

Figure 6 represents the monthly RAI to the years 1974 and 1985, as previously mentioned, these were extremely rainy years. It should be noted, that for the year 1974, the monthly RAI presented that the months of March and May (rainy months) had negative values, however, have obtained a variation of -0.10 to -0.52, not very significant for dry period. Already the months of January and April were more representative for the humid period of said year.

Related to the year 1985, which obtained maximum occurrence value for rainy years in interannual pluviometric series. The month of February presented an expressive negative value in relation to other. However, for the humid period (December to April) the month of March has had greater prominence, followed by the month of April, which had a significant contribution to the annual total (Figure 6).

According Araujo et al. (2009) the month of March becomes more efficient in terms of pluviometry due acting of the Intertropical Convergence Zone (ITCZ) which reaches its maximum in March. Probably, this period was very important for the water supply of the region, and consequently for the economic sector, particularly the productivity of monocultures.

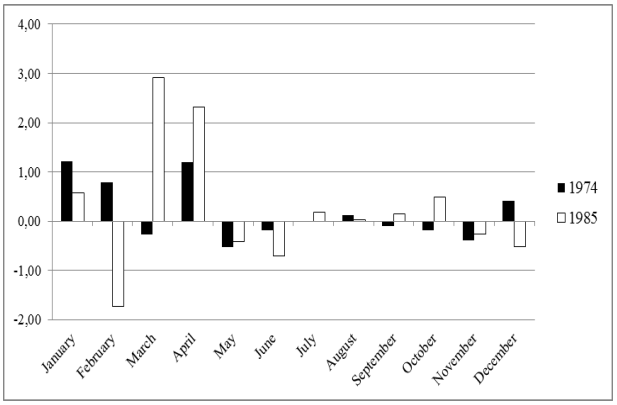


Figure 6 - Rainfall Anomaly Index (monthly / mm), referring to the rainy years (1974 and 1985) in the municipality of Petrolândia - PE.

## 4. Conclusions

The humid period in the city of Petrolândia-PE includes the months from December to April, being March the month of maximum contribution to the water supply in the basin River São Francisco in the region, however, the dry semester occurs between August to October, being August the driest month of the period. There was great variability in the interval between consecutive dry years intercalated with humid years, denoting disfavoring to water supply in the basin.

In the municipality of Petrolândia there was a higher incidence of dry periods with relative to humid periods in annual precipitation. Although the study of the seasonal distribution of rains in the region stating from Rainfall Anomaly Index (RAI) show changes in climatic regimes, however can not be affirm that these trends are related to global climate change, once approached an isolated place, demonstrating only the regional aspect.

The analyzes Rainfall Anomaly Index showed that the humid period occurred with maximum precipitation for the years 1974 and 1985. And for the dry period, are highlighted the years 1993 and 1998. In this study, verified that the Rain Anomaly Index functioned as a good instrument for the study of seasonal precipitation. Through this monitoring can generate predictions about the regional climatological variation.

Against of the exposed, prevention and mitigation measures can be planned in order to avoid the extreme events such as drought periods in the semiarid region, mainly for riverside populations, farmers, fishermen and fish farmers who live in the Petrolândia region. Measures such as the storage and utilization of rainwater can be adapted more effectively, maximizing their use in energy management, managing of social fisheries agricultural practices, since the hydrological regime of the semi-arid region in the basin of São Francisco river was intensely affected by the construction of hydroelectric plants.

For the city of Petrolândia the periods of drought are considered much more damaging to the economy than flood periods, despite the damage caused by flooding.

**References**


Alves, J.M.B., Souza, E.B., Repelli, C.A., Ferreira, N.S., 1997. Um estudo da variabilidade pluviométrica no setor leste do nordeste brasileiro e a influência do fenômeno El Nino/ Oscilação Sul. Revista Brasileira de Meteorologia 12, 25-40.

APAC. Agência Pernambucana de Águas e Clima, 2015. Available: http://www.apac.pe.gov.br. Access: may, 12, 2015.

Araújo, L.E.de, Silva, D.F.da, Moraes Neto, J.M., Sousa, F.A.S.de., 2007. Análise da variabilidade espaço - temporal da precipitação na Bacia do rio Paraíba usando IAC. Revista de Geografia 24, 47-59.

Araújo, L.E., Moraes Neto, J.M., Sousa, F.A.S., 2009. Classificação da precipitação anual e da quadra chuvosa da Bacia do rio Paraíba utilizando o Índice de Anomalia de Chuva (IAC). Revista Ambiente & Água 4, 93-100.

IBGE. Instituto Brasileiro de Geografia e Estatística, 2010. Cidades/Censo Demográfico. Available: http://cod.ibge.gov.br/32h5. Access: may, 12, 2015.

Farias, A.A.de, Souza, J.T.A., Sousa, F.A.S.de., 2014. Identificação e análise de secas severas e extremas no município de Taperoá - PB. Revista Brasileira de Geografia Física 7, 818-826.

Fisch, G., Valério, M.C., 2005. Variabilidade intra e interanual da precipitação em Taubaté-SP associado aos eventos El Niño e La Niña. Revista Biociência 11, 19-29.

Freitas, M.A.S., 2005. Um sistema de suporte à decisão para o monitoramento de secas meteorológicas em regiões semi-áridas. Revista Tecnologia 84-95.

Gurjão, C.D.S., Correia, M.F., Chaves Filho, J.B., Aragão, M.R.S., 2012. Influência do Enos (El Niño-Oscilação Sul) no regime hidrológico do rio São Francisco: uma análise em regiões com fortes pressões antrópicas. Revista Brasileira de Geografia Física 5, 774-790.

Machado, R.D., Da Rocha, R.P., 2011. Previsões climáticas sazonais sobre o Brasil: avaliação do regime aninhado no modelo global CPTEC/COLA. Revista Brasileira de Meteorologia 26, 121-136.

Macedo, M.J.H., Guedes, R.V.S., Sousa, F.A.S., 2011. Monitoramento e intensidade das secas e chuvas na cidade de Campina Grande/PB. Revista Brasileira de Climatologia 8, 105-117.

Melo, G.L.de, 2007. Estudo da qualidade da água do reservatório de Itaparica localizado na bacia do rio São Francisco. Thesis (Master). Recife, UFPE.

Nikolova, N., 2007. Regional climate change: precipitation variability in mountainous part of Bulgaria. Instituto Geográfico "Jovan Cvijic" SASA. Coleção de Pápeis 79-86.

Santos, E.P.dos, Correia, M.F., Aragão, M.R.S., Silva, F.D.S., 2011. Eventos extremos de chuva e alterações no regime hidrológico da Bacia Hidrográfica do rio São Francisco: uma aplicação do índice RAI (Rainfall Anomaly Index). Revista Engenharia Ambiental 8, 315-330.

Santos, P.V.dos, Santos, R.dos, Coutinho, M.D.L., 2013. Detecção de mudanças climáticas através de índices pluviométricos diários no Estado de Pernambuco. Revista Brasileira de Geografia Física 6, 713-731.

Santos, W.O., Silva, K.B.da, Coelho, D.C.L., Silva, K.M.P., Sobrinho, J.E., Silva, P.C.M.da, Batista, R.O., 2014. Variabilidade espacial e temporal das precipitações para a Microrregião de Pau dos Ferros-RN. Revista Brasileira de Geografia Física 7, 434-441.

Santos, E.C.A.dos, Araújo, L.E.de, Marcelino, A.dosS., 2015. Análise climática da Bacia hidrográfica do rio Mamanguape. Revista Brasileira de Engenharia Agrícola e Ambiental 19, 9-14.

Silva, D.F.da, Sousa, F.A.S., Kayano, M.T., 2009. Uso de IAC e ondeletas para análise da influência das multi-escalas temporais na precipitação da Bacia do Rio Mundaú. Revista de Engenharia Ambiental 6, 180-195.

Silva, R.M.da, Silva, L.P., Montenegro, S.M.G.L., Santos, C.A.G., 2010. Análise da variabilidade espaço-temporal e identificação do padrão da precipitação na Bacia do Rio Tapacurá, Pernambuco. Revista Sociedade & Natureza 22, 357-372.

Silva, D.F.da, Galvíncio, J.D., Nóbrega, R.S., 2011. Influência da variabilidade climática e da associação de fenômenos climáticos sobre sub-bacias do rio São Francisco. Revista Brasileira de Ciências Ambientais, 46-56.

Silva, M.T., Silva, V.P.R.da, Souza, E.P.de, Oliveira, V.G.de., 2014. Performance analysis of digital elevation models: a case study of

basin low middle São Francisco river. Journal of Hyperspectral Remote Sensing 4, 161-166.
Rooy, V.M.P., 1965. A rainfall anomaly index independent of time and space. Notos 14, 1-43.
Vianello, R.L., Ferreira, N.J., Oliveira, L.L., 2001. Meteorologia Fundamental. Edifapes, Erechin.
Zanella, M.E., Moura, M.O., 2013. O clima das cidades do nordeste brasileiro: contribuições no planejamento e gestão urbana. Revista da ANPEGE 9, 75-89.