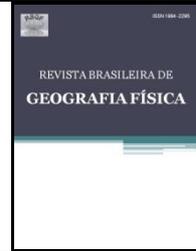




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## Meteorological Systems Influences Rainfall in Seropédica

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### ABSTRACT

Rainfall data from 2001-2011 from Seropédica were related to synoptic systems and El Niño Southern Oscillation episodes (ENSO). Evaluation was divided into average, monthly, seasonal and annual. Synoptic data are from Climanalise from 1996 to 2012. Descriptive statistics and non-parametric tests (Mann-Kendall (MK), Pettitt and Sen Method ( $S_e$ )) were applied to time series from Climanalise. The identified average characteristics showed high interannual and intraseasonal variability of synoptic systems, followed by the interaction between local and mesoscale systems in the rainfall regime. Seasonally, spring (38.06%) and summer (30.35%) were higher than autumn (20.91%) and winter (10.68%). The highest average accumulated monthly was observed in the joint occurrence of SACZ/ MCZ and FS from November to January period, followed by the influence of ENSO episodes in Seropédica. FS occurrences decreased in 2005, while in 2003 there was an increased SACZ/MCZ. MK test results considering  $\alpha = 5\%$  showed that there is Significant Increasing Trend (SIT) in SACZ/MCZ ( $Z > 2.25$ ) and Significant Decreasing Trend (SDT) of FS ( $Z < 3.68$ ) in Rio de Janeiro. Statistical identified trends and critical periods of synoptic systems.

Keywords: ENSO, Synoptic Systems, non-parametric tests.

## Sistemas Meteorológicos Influenciam a Chuva em Seropédica

### RESUMO

Dados pluviométricos de 2001-2011 de Seropédica foram correlacionados com os sistemas sinóticos e os episódios de El Niño-Oscilação Sul (ENOS). A avaliação foi dividida em: média, mensal, sazonal e anual. Os dados sinóticos são provenientes da Climanalise de 1996 a 2012. Foi aplicada uma estatística descritiva e os testes não paramétricos (Mann-Kendall (MK), Pettitt e Método de Sen ( $S_e$ )) a série temporal da Climanalise. As características médias identificadas mostraram alta variabilidade interanual e intrasazonal dos sistemas sinóticos, seguido da interação entre os sistemas locais e de mesoescala no regime de chuva. Sazonalmente, a primavera (38,06%) e o verão (30,35%) foram superiores ao outono (20,91%) e o inverno (10,68%). Os maiores acumulados mensais médios foram observados na ocorrência conjunta de ZCAS/ZCOU e SF nos meses de novembro a janeiro, seguido da influência dos episódios de ENOS em Seropédica. Os casos de SF diminuíram em 2005, enquanto 2003 houve um aumento de ZCAS/ZCOU. Os resultados do teste MK, considerando-se  $\alpha = 5\%$  mostraram que há Tendência Significativa de Aumento (TSA) de ZCAS/ZCOU ( $Z > 2.25$ ) e Tendência Significativa de Redução (TSR) de SF ( $Z < 3.68$ ) no Rio de Janeiro. A estatística identificou as tendências e os períodos críticos dos sistemas sinóticos.

Palavras chaves: ENOS, Sistemas Sinóticos, testes não paramétricos.

### Introduction

Among the meteorological variables, rainfall is the most important in the socioeconomic development of a region, numerous researchers and scholars (Moraes et al.,

2005; Lyra et al., 2014; Kamruzzaman et al., 2016) claim that is essential the knowledge about it in the development of agricultural, trade, industry, tourism, power generation and urban

drainage planning. Because of its importance, several methodologies have been developed in recent decades in order to characterize (intensity, duration, frequency and trend) and understand the impacts produced by it in various regions of Brazil (Moraes et al., 2005; Dereczynski et al., 2009; Ferrari et al., 2012; Lyra et al., 2014; Teodoro et al., 2017) and world (Yue et al., 2003; Westra et al., 2013; Ahmed et al., 2014). However, few studies were conducted exclusively in the Fluminense Lowland, Rio de Janeiro (André et al., 2008; Oliveira Júnior et al., 2014; Brito et al., 2016; Sobral et al., 2018), mainly in the municipality of Seropédica involving the average characterization of rainfall as the meteorological systems and trend evaluation.

Several approaches have been taken in the analysis of spatio-temporal variability of rainfall and identification of meteorological systems responsible for these patterns, especially in the Metropolitan Region of Rio de Janeiro (MRRJ) and in the State of Rio de Janeiro (SRJ) (André et al., 2008; Zeri et al., 2011; Oliveira Júnior et al., 2014; Brito et al., 2016). For this purpose statistical and mathematical techniques are used, such as principal component analysis (PCA), cluster analysis (CA), Fourier Transform (FT), Harmonic and Spectral Analysis (HSA), probability distributions and Wavelet technique, GIS tools (Geographic Information System), Remote Sensing products (RS) and Atmospheric Modeling (MA) to assist in weather and climate analysis (André et al., 2008; Zeri et al., 2011; Lyra et al., 2014; Oliveira Júnior et al., 2014; Lyra et al., 2017).

The mainly meteorological systems that act in MRRJ range from synoptic to local scale and are classified as producers and inhibitors of rainfall. The main ones are: Frontal System (FS), Mesoscale Convective Complexes (MCC), South Atlantic Convergence Zone (SACZ), South Atlantic Subtropical High (SASH), Atmospheric Blocking (AB), breezes systems (bay/lake, valley/mountain and sea/land), orography rainfall and convective storms (Dereczynski et al., 2009;

Reboita et al., 2010; Cataldi et al., 2010; Brito et al., 2016; Sulca et al., 2016; Sun et al., 2017). Currently, the Group of Weather Forecast (GWF) suggests the definition of Moisture Convergence Zone (MCZ) when to configure the following weather conditions: i) Similar to SACZ, but lasting only three days and from the fourth day can be characterized as SACZ; ii) When SACZ begins to dissipate, but an organized cloud band can still be identified. In the latter case, it is noted that convergence at 850 hPa shows two preferred areas: one toward SACZ and another to north of Argentina, Paraguay and west of the South of Brazil by the presence of Low Level Jet (LLJ) (Montini et al., 2019). This latter pattern may be associated with the approximation to a front or a trough in the middle troposphere. In some episodes may occur simultaneously both moisture convergence regions, and the one directed to the south of Brazil or Argentina does not generate cloudiness. This situation coincides with the transition for MCZ (Climanálise, 2013; Oliveira Júnior et al., 2014).

Such systems previously mentioned cause variable rainfall intensity, depending on the location and topography of the region, and or inhibit or cause severe dry spells in the SRJ. The presence of massifs existing in MRRJ (Pedra Branca, Tijuca and Gericinó) provide a barrier to the air displacement in the lower levels of the atmosphere and result in changes in the circulation structure and own local weather conditions, or in adjacent regions along with the bays of Sepetiba and Guanabara interfering in rainfall regimes (Zeri et al., 2011; Oliveira Júnior et al., 2014). Seasonal and annual patterns of weather systems that act in RMRJ can be influenced by climate variability modes, such as El Niño - Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) (Cataldi et al., 2010; Brito et al., 2016). On the context, the study aims to assess the rainfall regime in Seropédica-RJ in various time scales and its relations with synoptic systems producers of rainfall and the ENSO signal based on descriptive statistics and non-parametric tests.

## Material and Methods

### Study Area

The municipality of Seropédica is located at 22° 44' 38''S and 43° 42' 27''W, at 26 m of altitude, (Figure 1), with approximately 266.55 km<sup>2</sup>. Although considered politically as part of the RMRJ geographically it is situated in an area of the coastal plain called Baixada Fluminense de Sepetiba. Limited to the south by Atlantic Ocean, this has as internal limits the Serra do Mar to the

west (W) and Northwest (NW), the massifs Pedra Branca to east (E), the Serra da Mantiqueira to Northeast (NE) and the North (N) and Northeast (NE) a succession of small height hills that incorporate the landscape called Mar de Morros (Gasparin et al., 2013). According to the Köppen classification, the climate is "Aw", with rainfall concentrated between November and March,

average annual rainfall of 1.213 mm and average annual temperature of 23.9 °C (Oliveira Júnior et

al., 2013).

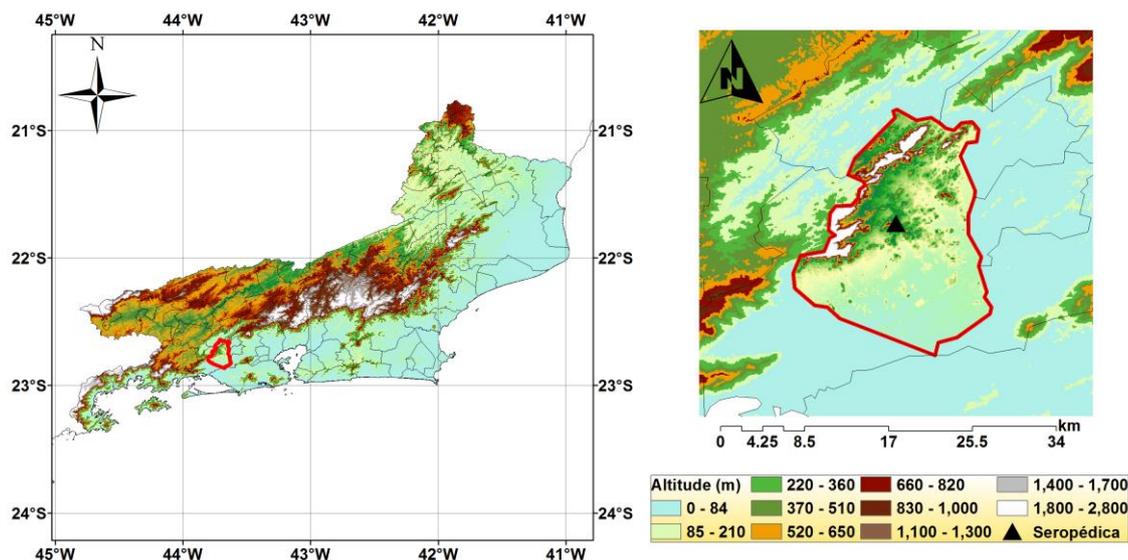


Figure 1. Altimetry Map (m) of the State of Rio de Janeiro highlighting the elevation (m) of the municipality of Seropédica.

### Rainfall Series

Rainfall hourly data for the period 2001-2011, belonging to Automatic Surface Weather Station (EMAS) from Seropédica, called Agricultural Ecology (AE), located at 22° 45' 28"S and 43° 41' 5"W and with 34 m of altitude, provided by National Institute of Meteorology (INMET) were converted into monthly data accumulated. The time series was evaluated on the seasonal scale (summer - December/January/February (DJF), autumn - March/April/May (MAM), winter - June/July/August (JJA), and spring - September/October/November (SON), monthly, annual and average, and at last, associated to ENOS events (El Niño, La Niña and Neutral), and the main synoptic systems producers of rainfall (FS, SACZ and MCZ). Subsequently, we applied descriptive statistics and non-parametric tests available in the literature (Mann-Kendall (MK), Pettitt and Sen Method ( $S_e$ )). It is noteworthy that the remaining gaps in decadal time series were filled with data from climatological normals obtained from INMET and 3B43 version product from Tropical Rainfall Measuring Mission satellite (TRMM) (Oliveira Júnior et al., 2014).

### Synoptic Data and ENSO

Climanálise data are referred to the passage and action of FS and SACZ and MCZ positioning during the period 1996-2012 in SRJ. According to the literature, these synoptic systems occur more frequently compared to others (André et al., 2008; Dereczynski et al., 2009; Cataldi et

al., 2010; Zeri et al., 2011; Oliveira Júnior et al., 2014). Data were extracted with the aid of occurrence frequency diagram of synoptic systems in the SRJ and in the reports obtained from Climanalise newsletters (Climanalise, 2013).

ENSO occurrence information was obtained from the database National Oceanic and Atmospheric Administration/Climate Prediction Center - NOAA/CPC (NOAA-CPC, 2015). In Table 1 are shown El Niño, La Niña and Neutral events from 2001 to 2011, classified as hot (red) and cold (blue) based on a threshold  $\pm 5^\circ\text{C}$  of the sea surface temperature (SST) (NOAA-CPC, 2015).

### Non-parametric Tests

MK test is the method that locates and detects the starting point for trend. It is suitable for analyzing climate changes in weather series, hot spots obtained from environmental satellites and vegetation indices (Gois et al. 2016; Caúla et al. 2016).

Groppo et al. (2005) describes the MK test as a  $x_i$  time series of  $n$  terms ( $1 \leq i \leq n$ ); its statistical can be set to a time series  $x = x_1, x_i, x_j, \dots, x_n$  defined by:

$$S = \sum_{j=i+1}^n \text{sgn}(x_j - x_i) \quad (1)$$

Wherein  $x_j$  are the estimated values sequence data,  $n$  is the length of the time series and the  $S$  signal given by Eq. 2.

$$S = \begin{cases} \text{sgn}(x) = 1 & \text{for } (x_j - x_i) > 0 \\ \text{sgn}(x) = 0 & \text{for } (x_j - x_i) = 0 \\ \text{sgn}(x) = -1 & \text{for } (x_j - x_i) < 0 \end{cases} \quad (2)$$

Table 1. Years and months of ENSO events (El Niño, La Niña and Neutral), between 2001 and 2011.

ENSO	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2001	-0.7	-0.6	-0.5	-0.3	-0.2	-0.1	0	-0.1	-0.1	-0.2	-0.3	-0.3
2002	-0.2	-0.1	0.1	0.2	0.4	0.7	0.8	0.9	1	1.2	1.3	1.1
2003	0.9	0.6	0.4	0	-0.2	-0.1	0.1	0.2	0.3	0.4	0.4	0.4
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.5	0.5	0.4	0.2	0.1	0	0	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.2	0	0.1	0.2	0.3	0.5	0.8	0.9	1
2007	0.7	0.3	0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.2	-1.3
2008	-1.4	-1.3	-1.1	-0.9	-0.7	-0.5	-0.3	-0.2	-0.2	-0.3	-0.5	-0.7
2009	-0.8	-0.7	-0.4	-0.1	0.2	0.4	0.5	0.6	0.7	1	1.2	1.3
2010	1.3	1.1	0.8	0.5	0	-0.4	-0.8	-1.1	-1.3	-1.4	-1.3	-1.4
2011	-1.3	-1.1	-0.8	-0.6	-0.3	-0.2	-0.3	-0.5	-0.7	-0.9	-0.9	-0.8

Source: National Oceanic and Atmospheric Administration/Climate Prediction Center.

For time series  $x_1, x_2, x_3, \dots, x_n$  with large numbers of terms ( $n > 4$ ) under the null hypothesis  $H_0$  of absence trend,  $S$  has a normal distribution with zero mean and unit variance. The  $S$  variance is defined by the following equation:

$$Var(S) = \frac{n(n-1)(2n+5)}{18} \quad (3)$$

And with repetitions of data, the variance is:

$$Var(S) = \frac{1}{18} \left[ n(n-1)(2n+5) - \sum_{p=1}^g t_p(t_p-1)(2t_p+5) \right] \quad (4)$$

Wherein  $n$  is the number of observations;  $t_p$  is the number of observations with equal values into given group  $p_{th}$  and  $g$  is the number of groups containing equal values in the data series into a given group  $p$ . The second term represents an adjustment for censored data.

Statistical significance of  $S$  was tested for the null hypothesis using a two-tailed test, which in turn may be rejected for high values in the MK statistic, which is defined by:

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & \text{for } S > 0 \\ 0 & \text{for } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & \text{for } S < 0 \end{cases} \quad (5)$$

Based on  $Z_{MK}$  statistics, we made the decision on to accept or reject the null hypothesis  $H_0$ , in other words,  $H_0$  hypothesis is accepted when the time series has absence of trend, or  $p\text{-valor} > \alpha$ , and rejected in favor of the alternative hypothesis  $H_1$  when there is a tendency to  $p\text{-valor} < \alpha$  in the time series, we adopted a 5% significance level for this study, in short.

The results will be analyzed according to the  $Z$  statistical signal, which indicates that positive values ( $Z > 0$ ) show an increasing trend and negative values a decreasing trend ( $Z < 0$ ). To obtain the estimate of the magnitude of increasing or decreasing trend for FS, SACZ and MCZ, according to Gois et al. (2016) the slope can be estimated by calculating the slope minimum square (B). However, this value calculated by linear regression (Gilbert, 1983; Yue et al., 2003; Ferrari et al., 2012; Ahmed et al., 2014) can deviate from the true value of slope inclination in the presence of outliers in the data, and thus the  $S_e$  nonparametric method (1968) modified by Hirsch et al. (1984) was used and applied in this study.

Table 2. Classification of  $Z_{MK}$  Trend into confidence interval from -1.96 to +1.96.

Categories	Scales
Significant Increasing Trend-SIT	$Z_{MK} > +1.96$
Non Significant Increasing Trend-NSIT	$Z_{MK} < +1.96$
Without Trend-WT	$Z_{MK} = 0$
Non Significant Decreasing Trend-NSDT	$Z_{MK} > -1.96$
Significant Decreasing Trend-SDT	$Z_{MK} < -1.96$

Pettitt test (1979) is a nonparametric test that enables identifying the year of occurrence of abrupt change in historical series. In practice, it uses a version of the Mann-Whitney test, which verifies whether two samples  $X_1, \dots, X_t$  e  $X_{t+1}, \dots, X_T$  belongs to the same population. The  $U_{i,T}$  statistic performs a counting the number of times that a member from the 1st sample is greater than the 2nd member according to the Eq. 6:

$$U_{i,T} = U_{i-1,T} + \sum_{j=1}^T \text{sgn}(x_i - x_j) \text{ for } t = 2, \dots, T \tag{6}$$

Wherein;  $\text{sgn}(x) = 1$  for  $x > 0$ ;  $\text{sgn}(x) = 0$  for  $x = 0$ ;  $\text{sgn}(x) = -1$  for  $x < 0$ .

The  $U_{i,T}$  statistic is calculated for the values  $1 < t < T$ , and thus the  $k(t)$  statistic of the Pettitt test that corresponds to the maximum in absolute value of  $U_{i,T}$  is estimated as the year in which the change occurs, according to the Eq. 7:

$$k(t) = \text{Max}_{1 < t < T} |U_{i,T}| \tag{7}$$

It locates the point where there are abrupt changes in the average time series, and its significance can be calculated as follows:

$$p \cong 2 \exp\{-6k(t)^2 / (T^3 + T^2)\} \tag{8}$$

Abrupt changes is  $t$ , where occurs the maximum  $k(t)$ . Critical values of  $k$  can be calculated as follows:

$$k_{crit} = \pm \sqrt{\frac{\ln(p/2)(T^3 + T^2)}{6}} \tag{9}$$

**Results and Discussion**

Average rainfall over the period was 1091 mm (Figure 2a), below of the climatological normal (1274 mm) evaluated for the municipality of Seropédica-RJ according to INMET – (Sobral et al., 2018). In the series there was an increase in accumulated annual rainfall between 2001 (La Niña) and 2003 - (Neutral / El Niño), from 2004

there is a significant decrease, especially in 2005 and 2006, corresponding to Neutral / El Niño cycle. From 2007 to 2011 occurred alternating La Niña, Neutro and El Niño cycles (Table 1), and therefore it is considered rainy years in relation to period average (Figure 2a).

The high variability in total annual cumulative rainfall possibly is associated with the occurrence of ENSO cycles that directly interfere on rain-producing systems (FS, SACZ and MCZ) in the SRJ (Silva e Dereczynski, 2014; Oliveira Júnior et al., 2014; Brito et al., 2016; Sun et al., 2017; Sobral et al., 2018). Moreover, it can do not rule out the influence of mesoscale and local systems that contribute to this variability in the rainfall regime in the municipality of Seropédica (Oliveira Júnior et al., 2013; Gasparin et al., 2013; Sobral et al., 2018; Rocha et al., 2019).

On the seasonal analysis, the highest average cumulative rainfall occurs on spring season with values upper 313.78 mm (38.06%) influenced by increase of the frequency of synoptic systems (FS and SACZ/MCZ) in the Southeast Region (Ferreira et al., 2004; Reboita et al., 2010; Brito et al., 2016; Sun et al., 2017), as well as mesoscale and local systems. On this case, the rain-producing process in local scale is influenced by breeze circulation systems, sea/land (Bay of Sepetiba) and valley/mountain (region topography) (Oliveira Júnior et al., 2012; Gasparini et al., 2013; Sobral et al., 2018).

The winter season (JJA) presents the lowest average accumulated rainfall in Seropédica, with values below 80 mm (10.68%) - (Figure 2b). In the autumn (MAM) occurred a significant decrease corresponding to 20.91%, with absolute values of 265 mm. This is due to non-occurrence of SACZ and MCZ episodes, followed by great variability in SF performance at this station in the SRJ (Brito et al., 2016; Lyra et al, 2017; Sobral et al., 2018) both reduces of the local effect systems (local convection and sea/land and valley/mountain breezes circulations) in the municipality (Oliveira Júnior et al., 2014). The

process of absence or inhibiting of FS, SACZ, and MCZ episodes favor the reduction on the average accumulated rainfall values, similar to the results found by André et al. (2008), Brito et al. (2016) and Lyra et al. (2017).

The average monthly rainfall was below normal climatological, except during winter season, followed by May and September months.

The highest (lowest) accumulated rainfall occurs during summer and spring (winter) season, greater than 100 mm (below 30 mm) (Figure 2c). This pattern of highest accumulated rainfall is associated with joint occurrence SACZ and FS episodes, especially in the summer and spring (Brito et al., 2016; Sun et al., 2017).

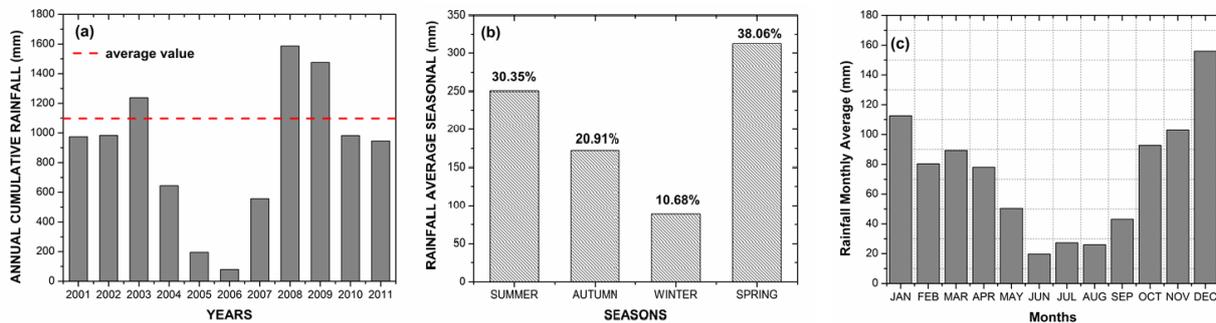


Figure 2. Accumulated annual (mm) (a) and seasonal (mm) (b) rainfall and its respective percentage and the average monthly (c) in the municipality of Seropédica-RJ from 2001-2011.

Regarding the rain-producing systems, there was a significant increase in SACZ/MCZ episodes after 2003 due to the change in the phenomenon characterization, according to Climanálise (Oliveira Júnior et al., 2014). More than 80% of SACZ events occur with the presence of a trough or subtropical front over the Atlantic Ocean in the Southeast Region (Climanálise, 2013; Brito et al., 2016; Sun et al., 2017). Cloudiness band associated with SACZ is not always well defined and homogeneous. This behavior is similar to the ITCZ (Intertropical Convergence Zone) or FS, meaning that systems can be present with weak activity. Moisture flux at 850 hPa appears well established, directed from the Amazon region to the ocean, going through Midwest and Southeast of Brazil. Bolivian High (BH) and the Northeast trough (CNE) or Northeast Vortex - NEV appear well defined only in cases of classic SACZ. However, not always these systems appear well characterized over a SACZ event (Sulca et al., 2016; Sun et al., 2017).

Usually the BH appears, although it unconfigures in various situations, the NEV may not appear in SACZ cases (Sulca et al., 2016). Moisture Convergence Zone at low levels, caused by presence of the aforementioned characteristics, should persist for at least four days to characterize the SACZ (Sulca et al., 2016; Sun et al., 2017). FS events had great variability during the study period, especially in rainy years (Brito et al., 2016; Sulca et al., 2016; Sun et al., 2017). According to Fedorova and Carvalho (2000) and Ferreira et al. (2004), FS are observed more

frequently in El Niño years than in La Niña years corroborating the results found for the SRJ, especially in the temporal variability of rainfall in Seropédica.

Overall, it was observed a strong influence of the synoptic, mesoscale and local systems which in turn interact as complex terrain that surrounds Seropédica in the rainfall distribution. Seasonally, the spring and summer had the highest percentage occurrences of rainfall compared to the autumn and winter (Moraes et al., 2004; Brito et al., 2016; Sun et al., 2017; Sobral et al., 2018). Results obtained by Moraes et al. (2004) show that the displacement of convective cells follows two main paths: Southwest - Northeast (FS and local systems) and North - South (convective cells originated from Serrana region moving in situations of dominant circulations of North-South) and corroborate the results obtained in this study. The highest accumulated rainfall was found, regardless of the year, particularly associated with ENSO episodes and its impact on synoptic and local systems (Oliveira-Júnior et al., 2018; Schossler et al., 2018).

In 2001 (Figure 3a), from November to February (spring and summer) occurred increased the SACZ activity (5 episodes) and consequently the average rainfall values increased (Figure 3a), followed by high FS variability during the cycle 2000/2001 (La Niña), especially in winter (JJA). Opposite situation occurred in 2002 (Figure 3b), when 4 episodes of SACZ were observed (December and February), and again high

variability of SF during 2002-2003 cycle (Neutral/El Niño), which resulted in increased

annual accumulated rainfall (Figure 2a).

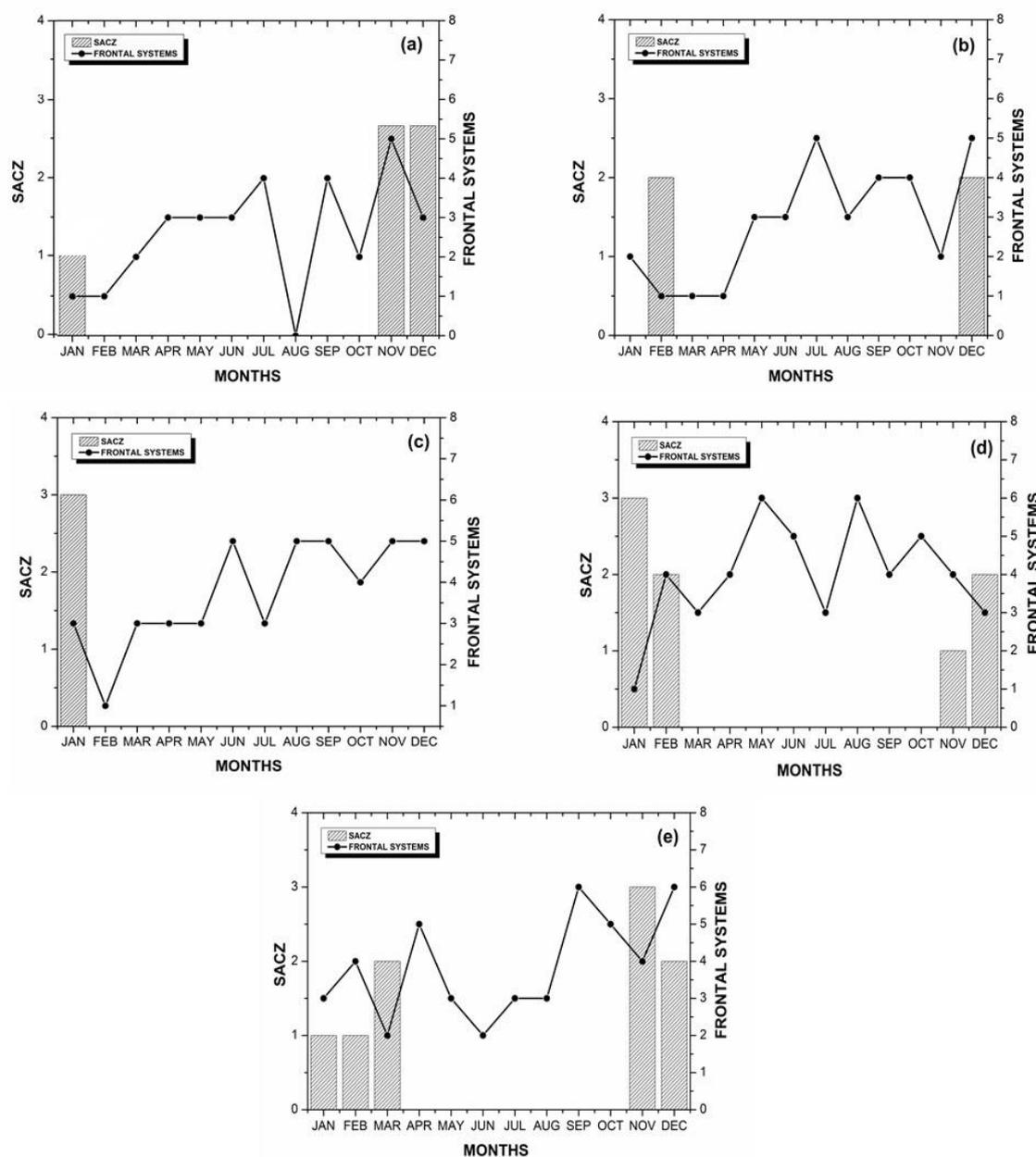


Figure 3. Monthly totals of SACZ/MCZ and FS episodes in 2001 (a), 2002 (b), 2003 (c), 2004 (d) and 2005 (e) in the State of Rio de Janeiro. Source: Climanálise (2013).

In 2003 (Figure 3c), the three episodes of SACZ (only in January) associated with increase constant of FS during year possibly influenced the larger accumulated rainfall in the summer, during March and October / November (late spring) and smaller in JJA (winter) and September (early spring) (Figure 2c). Unlike 2004 (Figure 3d), it is verified an increases on number of SACZ/MCZ, but there was a reduction in the accumulated annual rainfall. (Figure 2), corroborating the results obtained by Ferreira et al. (2004) and Oliveira Júnior et al. (2014). In both studies, it was shown that regardless of the El Niño

category, the amount of SACZ / MCZ is highly variable, but without additional rainfall. At last, in 2005 (Figure 3e), there was the greatest SACZ/MCZ episodes compared to previous years, followed by high FS variability in 2004/2005 cycle (Neutral/El Niño). There was a significant annual decrease in accumulated rainfall values. It is noteworthy that 2005 contradicts all the results of the previous cycles, justified by duration of the El Niño cycles, which began in the quarter (JJA) 2004 and ended the quarter (MAM) 2005 and the event magnitude (Table 1).

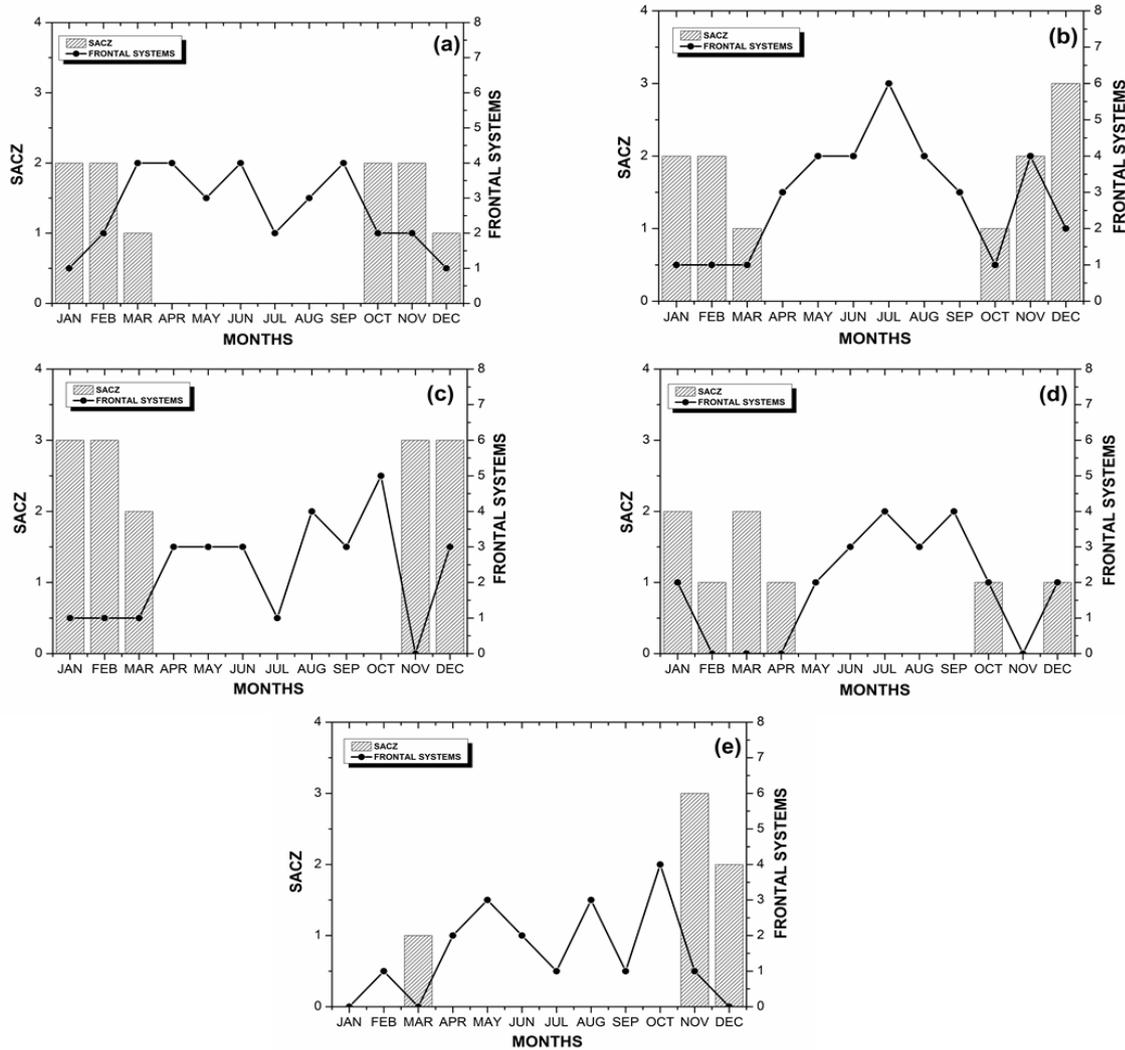


Figure 4. Monthly totals of SACZ/MCZ and FS episodes in 2006 (a), 2007 (b), 2008 (c), 2009 (d) and 2010 (e) in the State of Rio de Janeiro. Source: Climanálise (2013).

In 2006 (Figure 4a), there were ten SACZ/MCZ episodes. However, the high FS variability between autumn and winter, decreasing in the spring and summer, resulted in the lowest accumulated annual rainfall. In 2007 (Figure 4b), there were eleven SACZ/MCZ episodes affects on higher accumulated rainfall in October (late spring) to December (early summer) and the lowest between June (early winter) until September (early spring) (Figure 2c). In 2008 (Figure 4c), it is observed fourteen SACZ/MCZ episodes with a significant increase compared to other years and high FS variability over the year, resulting on increased accumulated rainfall years in Seropédica, RJ. As opposed, in 2009 (Figure 4d) occurred significant reduction of SACZ/MCZ episodes for only eight. These higher monthly

accumulated were directly reflected in the annual accumulated 2008/2009 compared to the other years of the series (Figure 4).

Trend analysis by MK test (ZMK) for SACZ/MCZ and FS episodes showed that  $H_0$  is accepted. There is a significant increasing trend (SIT) of SACZ/MCZ episodes in the SRJ for  $Z > 0$  and  $p\text{-value} > 0.05$  probability (Table 2). Comparatively, the SF showed significant decreased trends (SDT), for  $Z < 0$  and  $p\text{-value} < 0.05$ , followed by values of Se magnitude of approximately  $0.523 \text{ number of cases}\cdot\text{year}^{-1}$  and  $-1.583 \text{ number of cases}\cdot\text{year}^{-1}$ , respectively. Subsequently, years of abrupt changes were 2003 and 2005 both changes were detected by the Pettitt test (Table 3).

Table 3. Statistical analysis of the annual rainfall trend by non-parametric tests Mann-Kendall, Sen Method (Se) and determining the year of change by Pettitt tests from 1996 to 2011, considering the significance level at 5%.

Location	Episodios	Z	Z <sub>MK</sub>	P-Value	S <sub>e</sub> (n° of cases.year <sup>-1</sup> )	Pettitt
State of Rio de Janeiro	SACZ/MCZ	2.45	0.46	0.014	0.523	2003
	FS	-2.75	-0.52	0.006	-1.583	2005

### Conclusions

Decadal evaluation of rainfall patterns of the municipality of Seropédica is mainly characterized by the synoptic systems, but we do not rule out the influence of variability mode ENSO due a short database. The highest accumulated monthly rainfall occurred in periods of joint occurrence of SACZ/MCZ and FS, during November to January months.

MK test shows a significant increasing trend (SIT) of SACZ/MCZ events, followed by the significant decreasing trend (SDT) in the case of FS for time series in the SRJ. From this statistical approach, it is possible to characterize and identify trends, critical periods of producers of rainfall systems in the SRJ and particularly for the municipality of Seropédica.

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