POSSIBLE INFLUENCES OF PACIFIC DECADAL OSCILLATION IN THE TEN DAY BASED RATIO BETWEEN ACTUAL AND POTENTIAL EVAPOTRANSPIRATION IN THE REGION OF CAMPINAS, SÃO PAULO STATE, BRAZIL ([1])

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ABSTRACT

Considering the importance of the ratio between the actual and potential evapotranspiration (AE/PE) for agricultural purposes, the present study estimated the 10-day based AE/PE, aiming to evaluate possible influences of the Pacific Decadal Oscillation (PDO), on temporal variability series, in the region of Campinas, São Paulo State, Brazil. The shapes of the beta probability density function of the AE/PE series for four periods (two in the cold PDO phase and two in the warm PDO phase) do not show differences between the PDO phases. In this sense, the use of "average periods" to obtain a standard climatology for agrometeorological purposes (such as the climate normal of the 1961-1990 period, which encompasses sixteen years of the cold PDO phase and fourteen years of the warm PDO phase) should not result in significant errors in the region of Campinas, SP. However, considering academic/scientific purposes, the analyses of the autocorrelation functions of the residual AE/PE series for the four periods show differences in the persistence between the two phases of the PDO.

Key words: climate normal, sea surface temperature.

RESUMO

POSSÍVEL INFLUÊNCIA DA OSCILAÇÃO DECADAL DO PACÍFICO NA RAZÃO DECENDIAL ENTRE A EVAPOTRANSPIRAÇÃO REAL E POTENCIAL NA REGIÃO DE CAMPINAS (SP), BRASIL

Tendo em vista a importância agrícola da razão entre a evapotranspiração real e potencial (ETR/ETP), estimou-se esta relação (em escala decendial), a fim de verificar possíveis influências da Oscilação Decadal do Pacífico (PDO) sobre a variabilidade temporal desse parâmetro agrometeorológico na região de Campinas, Estado de São Paulo, Brasil. Pelas formas da função de densidade de probabilidade Beta das séries de ETR/ETP para quatro períodos (dois na fase fria, e dois na fase quente) não se observam diferenças significativas (influência) entre as fases da PDO. Nesse aspecto, sob o ponto de vista agrometeorológico, o uso de um determinado "período médio" (tal como a normal climatológica de 1961-1990, que compreende dezesseis anos da fase fria e catorze da fase quente), para caracterização de séries temporais de ETR/ETP, não deve resultar em grandes erros. No entanto, sob o enfoque científico/acadêmico, diferentes "graus de persistência" das séries de anomalias de ETR/ETP foram observados nas duas fases da PDO. Nas fases frias, foram detectados maiores graus de persistência; sugere-se, assim, que a variabilidade temporal da ETR/ETP na região de Campinas pode estar relacionada à variabilidade de longo prazo da temperatura da superfície dos oceanos tropicais.

Palavras-chave: normal climatológica, temperatura da superfície do mar.

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1. INTRODUCTION

The water deficiency during crop cycles is responsible for approximately 56% of the Brazilian yield breaks. Droughts limit the photosynthesis process by promoting the closing of the stomata. Based on this relationship, several crop simulation models (CSM) estimate yield break using the ratio between actual evapotranspiration and potential evapotranspiration (AE/PE) to quantify the water factor influence on the final crop production. Moraes et al. (1998) developed agrometeorological models to estimate soybean productivity in the region of Ribeirão Preto-SP. Ortolani et al. (1998) developed an agrometeorological model to evaluate the seasonal development of a rubber tree plantation. Camargo and Hubbard (1999) developed a drought index for a sorghum crop. Piccini et al., (1999) developed and tested productivity break estimate models for coffee. The FAO model proposed by Doorenbos and Kassam (1994) relates the cultures yield break to the AE/PE series. In this sense, one can also mention the agroclimatic zoning based on the AE/PE series done with the objective of quantifying, or trying to reduce, the crops water deficit risk in a given region. In this case, the AE/PE series should be estimated over a period of at least thirty years. The choice of this long period is usually based on the availability of the data and on the possibility of using the period called "The Current Climatic Normal" (1961 to 1990). So, it becomes evident that low-frequency large-scale meteorological phenomena are almost never adopted for agrometeorological purposes.

The ocean plays an important role in the climate variations due to its strong coupling with the atmosphere through dynamic and thermodynamic processes. This coupling is the main factor in modulating the climate variability in the interannual to decadal scales. The ocean/atmosphere coupling depends crucially on the sea surface temperature (SST), which controls sensible and latent heat exchanges. Therefore, variations in the SST field, mainly in the tropical oceans, reflect directly on the climate variability (Voituriez and Jacques, 2000). In this context, the tropical Pacific, due to its extension, plays a dominant role in the climate variability.

Several studies pointed out a mode of the SST variability in the Pacific, similar to the El Niño/ Southern Oscillation (ENSO), but with a multi-decadal scale variation (Mantua et al., 1997; Zhang et al., 1997; 1998), hereinafter referred to as the Pacific Decadal Oscillation (PDO). The global anomaly patterns of the SST, sea level pressure (SLP) and wind stress fields for the PDO and ENSO modes are quite similar. However, the SST pattern for the PDO is less equatorially confined in the eastern Pacific and shows significant structure in the extratropical North Pacific (e.g., Zhang et al., 1997). Mantua et al. (1997), using SST and SLP data for the period 1900-1995, found that the PDO oscillations with the 50-70 years periodicity defined the cold PDO regime during the 1900-1924 and 1947-1976 sub-periods, and the warm PDO regime during the 1925-1946 period, and from 1977 to the middle of the 1990's.

As for the South American climate variability, only more recently has it been interpreted in the context of the PDO effects (Andreoli and Kayano, 2005; Kayano and Andreoli, 2007). These papers showed that the PDO creates a background for the ENSO teleconnections for the South American precipitation, acting constructively (destructively) when the ENSO and the PDO are in the same (opposite) phase. This relationship, between the PDO and the South American climate variability, may emphasize the importance of considering low-frequency large-scale meteorological phenomena on the choice of average periods to obtain a standard climatology for agrometeorological purposes, such as agroclimatic zoning.

Operating since 1886, the Agronomic Institute of Campinas in the State of São Paulo, is one of the pioneer research centers in Brazil recording meteorological data. It has been recording daily data on air temperature and rainfall since 1890 and is one of the longest meteorological series in the country. Therefore, considering the importance of the AE/PE ratio for agricultural studies and the availability of long meteorological data series of the Agronomic Institute, the present work examines possible influences of the PDO in this series and evaluates the "need" of considering low-frequency large-scale meteorological phenomenon on the "choice" of "average periods" to obtain a standard climatology for agrometeorological purposes.

2. MATERIAL AND METHODS

The data used here consist of the daily precipitation and air temperature series representative of the weather station of the city of Campinas-SP (22º54'S; 47º05'W; 669 m), available at the Agronomic Institute (IAC).

According to the international Köeppen classification, the climate of the region is Cwa. The average temperature of the hottest month is higher than or equal to 22 ºC, the average temperature of the coldest month is lower than 18 ºC and the average precipitation of the driest month is lower than 30mm.

The climatological water balance models of Thornthwaite (1948) and Thornthwaite and Mather (1955) were used here to estimate the PE and AE values, respectively, for every 10-day interval of the 1900-1998 period. These 10-day intervals are established in such a way that every month contains three 10-day intervals, and one year totalizes thirty-six 10-day intervals. So, the last 10-day interval for the months with 31 days has in fact 11 days, while for February it has 8, or 9 for leap year, days. After that, the 10-day AE/PE series was divided into four non-overlapping sub-periods encompassing the PDO phases defined by Mantua et al. (1997): 1900 – 1924 (cold phase – CP1), 1925-1946 (warm phase - WP1), 1947-1976 (cold phase – CP2) and, 1977-1998 (warm phase - WP2). The sub-period between 1961 and 1990 (N) was also evaluated.

The frequencies of occurrences of AE/PE values ware obtained by estimating the beta probability density function (BPDF) and its parameters (p and q) for each sub-period, separately. In order to evaluate the PDO influences in the frequencies of occurrences of the AE/PE values, the results for the CP1, WP1, CP2, WP2, sub-periods were compared. According to Wilks (2006), for a variable x, the BPDF distribution is given by:

$$f(x)=\left[\frac{\Gamma(p+q)}{\Gamma(p)+\Gamma(q)}\right]x^{(p-1)}(1-x)^{(q-1)} \quad 0=x=1 \quad \text{p and q>0} \quad (1)$$

The BPDF is a very flexible function, taking many different shapes depending on the values of its two parameters. In general, for p =1, the probability is concentrated near zero, and for q =1, the probability is concentrated near 1. If both parameters are less than one the distribution has a U-shape. For p > 1 and q > 1, the distribution has a single mode, with the largest probability shifted to the right for p>q, and the largest probability shifted to the left for q > p. The distribution is symmetric for p = q. The Beta distribution parameters were fitted using the method of moments.

The Kolmogorov-Smirnov (KS) test was used to evaluate the AE/PE temporal distribution degree of adherence to the BPDF. According to Assis et al. (1996), the test can be applied to evaluate if the temporal series values can be considered as coming from a population with a pre-set theoretical distribution, under the null hypothesis, H_0. The test is defined as:

$$\text{Dmax} = \text{Max} \mid F'(x) - F(x) \mid \quad (2)$$

$$F(x) = Fa/(n+1) \quad (3)$$

where, Max is the largest absolute value among the established frequency classes in the test; Dmax is the calculated value of the Kolmogorov-Smirnov test; F'(x) is the theoretical probability distribution function; F(x) is the empirical probability distribution function; Fa is the cumulative distribution function of each class; and n is the number of pre-established classes.

For a pre-established significance level, 5% in this study, if Dmax is larger than or equal to the critical value, the null hypothesis (H_0) that the data comes from a population with beta distribution is rejected. The KS test is applied in all 10-day intervals of CP1, WP1, CP2 and WP2.

Considering that the analysis based on the probability density function gives only the frequencies of occurrence of AE/PE values, number of the same AE/PE value occurring in the series, the autocorrelation function of AE/PE is also obtained for each sub-period. Prior to the autocorrelation function calculations, residual or anomaly AE/PE time series were obtained by removing the median of each thirty-six 10-day intervals. This means that the annual cycle of each series has been removed. The autocorrelation function allows to evaluate the persistence of the residual AE/PE values. The linear tendency of the series was also removed. These calculations are done separately for each sub-period. The computations of the autocorrelation coefficients (r_k) follow standard equations, as described in Wilks (2006). The standard error of r_k, is calculated assuming a white noise process for the series which is given by:

$$SE(r_k) = \{(1/N) * [(N-k)/(N+2)]\} \quad (4)$$

3. RESULTS AND DISCUSSION

The variability of the weather conditions in Campinas and surrounding areas is characterized by the dynamics of regional atmospheric circulation associated to the diversified relief of the region. Both tropical and polar origin systems act in the region. While, the tropical Atlantic systems are the most important in terms of frequency of occurrence, the polar systems, with prominence for the polar Atlantic systems, command the regional climatic variability (Monteiro, 1973; Nunes, 1997).

In terms of water balance variables, according to Ortolani and Camargo (1987), from October to March precipitation exceeds evapotranspiration; from April to September after they reach balanced values, evapotranspiration becomes larger than rainfall, usually resulting in periods with water deficiency in the region of Campinas. Blain et al. (2007) found that the for 10-day interval AE/PE distribution is strongly shifted to the right indicating that, even during the dry season, maximum AE/PE values can be expected.

Table 1 shows the Dmax values of KS test for each thirty-six 10-day intervals of CP1, WP1, CP2 and WP2. The Dmax values are considerably lower than the critical value of 0.254, which shows that the empirical distribution can be fitted to the BPDF for the pre-established significance level.

Table 1. Dmax values of KS test for the thirty-six 10-day intervals of the1925-1946 (WP1), 1947-1976 (CP2), 1977-1998 (WP2), and 1900-1924 (CP1) sub-periods. Campinas São Paulo State

Ten day	WP1	CP2	WP2	CP1	Ten day	WP1	CP2	WP2	CP1
1	0.043	0.029	0.049	0.033	19	0.055	0.054	0.115	0.075
2	0.043	0.013	0.043	0.019	20	0.053	0.131	0.059	0.106
3	0.043	0.022	0.043	0.014	21	0.081	0.125	0.121	0.106
4	0.043	0.038	0.048	0.055	22	0.064	0.050	0.100	0.036
5	0.043	0.026	0.060	0.042	23	0.066	0.056	0.115	0.055
6	0.043	0.045	0.043	0.046	24	0.102	0.059	0.126	0.060
7	0.057	0.014	0.043	0.038	25	0.083	0.050	0.055	0.048
8	0.043	0.059	0.043	0.052	26	0.043	0.057	0.043	0.063
9	0.043	0.058	0.067	0.050	27	0.103	0.043	0.055	0.020
10	0.060	0.032	0.108	0.028	28	0.043	0.059	0.043	0.027
11	0.081	0.161	0.043	0.099	29	0.043	0.048	0.043	0.054
12	0.071	0.127	0.043	0.088	30	0.045	0.068	0.095	0.051
13	0.043	0.080	0.049	0.082	31	0.055	0.029	0.048	0.042
14	0.048	0.095	0.043	0.044	32	0.052	0.025	0.043	0.021
15	0.092	0.035	0.079	0.068	33	0.043	0.033	0.045	0.030
16	0.073	0.074	0.095	0.077	34	0.043	0.018	0.043	0.034
17	0.043	0.042	0.094	0.100	35	0.045	0.029	0.043	0.027
18	0.055	0.042	0.097	0.077	36	0.043	0.033	0.052	0.026

Table 2 shows the p and q beta distribution parameters of each thirty-six 10-day intervals of the sub-periods CP1, WP1, CP2 and WP2. It is noticeable in Table 2 that the AE/PE series follow the climate pattern of the region, during the four analyzed sub-periods (Table 2). In general, from April to August, q parameter values increase, evidencing a displacement to the left of the distributions. In other words, the number of cases for which the ETR reaches the potential values decreases. The dry period has its apex in August when the lowest probabilities of AE/PE =1 are observed. After this month, the q parameter values begin to decrease with the smallest values being observed from December to February.

As mentioned by Blain et al. (2007), a very important point that should be taken into account by comparing variations of p and q parameters values among different periods (CP1, WP1, CP2 and WP2) is the subjectivity in the definition of the terms "climate" and, consequently, "changes in climate patterns". This subjectivity is present in every statistical analysis related to these themes. In the present analysis, the BPDF shapes and parameters allowed to detect differences in the frequency of the occurrence, probability density, of the AE/PE values among different historical periods. However, to determine if such differences are due to the "changes in climate patterns" is very difficult.

It should also be considered that the region of Campinas is in a tropical/subtropical transition area, suffering influence of both tropical and polar air masses systems. In this case, the separation between variability and climatic alteration becomes even more subjective. Following Katz (1993), here the definition adopted was that "changes in climate patterns" in the expected frequency of occurrence of AE/PE series should result in a transformation on the graphic representation, which means a change in the distribution shape.

Using the p and q parameters values presented in Table 2, the distribution shapes of the AE/PE values in the region of Campinas, SP of the first 10-day interval for the months when the precipitation exceeds the evapotranspiration (October to March) are shown in Figure 1, and for the other months, in Figure 2.

Table 2. Values of p and q beta distribution parameters of each thirty-six 10-day intervals for the 1925-1946, 1947-1976, and 1977-1998 sub-periods. Campinas, São Paulo State

Mth	TenDay	1900/1924		1925/1946		1947 /1976		1977/1998	
		q	p	q	p	q	p	q	p
Jan	1	0.14	8.51	0.06	1.50	0.14	2.98	0.13	4.49
Jan	2	0.10	8.55	0.14	5.98	0.09	3.01	0.17	6.42
Jan	3	0.04	32.81	0.29	8.24	0.28	9.68	0.13	3.32
Feb	4	0.08	8.23	0.15	4.37	0.13	5.30	0.13	3.16
Feb	5	0.26	9.26	0.26	9.19	0.14	4.04	0.24	3.30
Feb	6	0.11	4.95	0.15	2.53	0.22	4.35	0.30	3.78
Mar	7	0.20	7.80	0.22	8.51	0.26	5.50	0.23	7.22
Mar	8	0.20	5.49	0.20	4.70	0.28	3.87	0.18	2.02
Mar	9	0.37	3.22	0.32	3.68	0.25	5.57	0.27	2.48
Apr	10	0.34	3.18	0.59	4.21	0.16	2.14	0.25	2.64
Apr	11	0.72	3.91	0.48	2.04	0.91	7.63	0.41	3.88
Apr	12	0.54	2.21	0.72	2.42	0.64	2.67	0.41	2.10
May	13	0.35	1.46	0.39	1.13	0.47	2.32	0.28	1.37
May	14	0.53	2.60	0.42	1.46	0.43	1.67	0.12	0.95
May	15	0.42	1.88	0.49	1.24	0.48	1.47	0.30	2.24
Jun	16	0.34	1.64	0.34	1.29	0.40	1.59	0.53	3.34
Jun	17	0.30	1.59	0.33	0.88	0.35	1.14	0.52	2.35
Jun	18	0.38	1.59	0.44	1.10	0.48	1.34	0.73	3.50
Jul	19	0.33	1.19	0.75	1.57	0.27	1.05	1.05	2.97
Jul	20	0.40	1.18	0.41	1.03	0.65	1.39	0.75	1.82
Jul	21	0.64	1.43	0.56	0.94	0.71	1.26	0.81	2.06
Aug	22	0.35	1.09	0.47	0.93	0.59	1.10	1.73	2.77
Aug	23	0.28	0.81	0.92	1.56	1.10	1.40	1.01	1.52
Aug	24	0.72	2.05	0.45	0.84	0.66	0.94	0.48	0.90
Sep	25	0.66	1.70	0.54	1.13	0.40	0.62	0.35	0.73
Sep	26	0.41	1.03	0.21	0.81	0.40	0.50	0.27	0.90
Sep	27	0.15	0.82	0.34	1.08	0.31	0.65	0.13	0.49
Oct	28	0.34	2.08	0.14	0.50	0.29	0.82	0.26	0.97
Oct	29	0.13	0.95	0.18	1.25	0.13	0.93	0.15	0.82
Oct	30	0.15	0.92	0.16	1.31	0.17	2.38	0.33	1.67
Nov	31	0.11	1.30	0.17	2.23	0.20	1.33	0.43	2.23
Nov	32	0.05	1.21	0.16	6.22	0.09	0.97	0.11	1.30
Nov	33	0.28	3.89	0.17	8.09	0.18	1.69	0.13	1.56
Dec	34	0.14	5.07	0.07	2.82	0.05	1.67	0.18	2.05
Dec	35	0.12	2.88	0.15	5.35	0.13	4.36	0.06	2.33
Dec	36	0.08	9.01	0.07	2.35	0.10	2.59	0.14	5.39

Comparisons among the probability density of the AE/PE series for the first 10-day intervals for the months from October to March during the CP1, WP1, CP2 and WP2 sub-periods (Figure 1) did not evidence the PDO influence in the AE/PE series shapes. In November, for instance, the two largest frequencies of the AE/PE=1 occurrence were found during CP1 and WP1, while the smallest one, during WP2. In December, the BPDF shapes are very similar during the WP1, CP1 and CP2 sub-periods. During WP2, an increase on the frequency of occurrence of AE/PE values of 0.7, 0.8 and 0.9 and a reduction in the occurrence of the AE/PE =1 cases was observed. From January to March, the density function shapes were very similar during the four analyzed sub-periods.

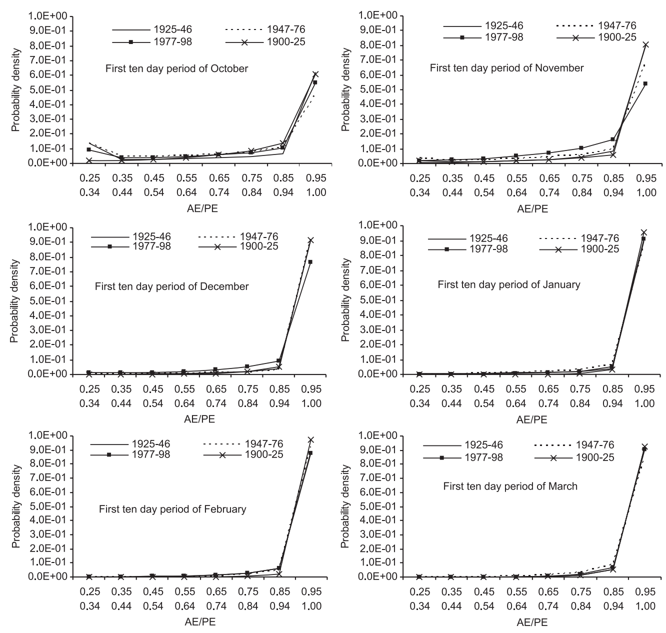

Figure 1. Probability density of the AE/PE series in Campinas, São Paulo State, of the first 10-day period for the months from October to March. The horizontal axis represents all the possible AE/PE values between 0.25 to 0.34, 0.35 to 0.44, 0,45 to 0.54, 0.55 to 0.64, 0.65 to 0.74, 0.75 to 0.84, 0.85 to 0.94, and 0.95 to 1.00.

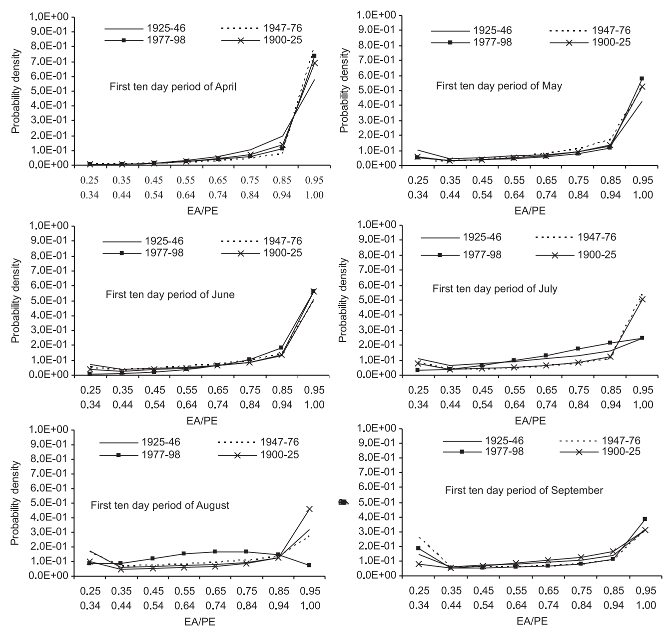

Figure 2. Probability density of the AE/PE series in Campinas, São Paulo State, of the first 10-day period for the months from April to September. The horizontal axis represents all the possible AE/PE values between 0.25 to 0.34, 0.35 to 0.44, 0,45 to 0.54, 0.55 to 0.64, 0.65 to 0.74, 0.75 to 0.84, 0.85 to 0.94, and 0.95 to 1.00.

Inspections of Figure 2 and Table 2, did not evidence, once again, the PDO influence over the AE/PE series shapes. In May of the WP2, CP1 and CP2 sub-periods, the BPDF shapes were very similar. The beta distribution curves were almost coincident in June of the four analyzed sub-periods. In August, differences in the graphic shape of the AE/PE series during WP2 were noticed. Unlike what was observed in the other analyzed sub-periods, the maximum AE/PE value (AE/PE= 1) did not present the largest absolute frequency during August of WP2. This indicates the intensification of the water deficiency during the first 10-day intervals in August during the 1977-1998 period. A more detailed analysis of August curves indicates an increase in the probability density for the AE/PE values of 0.5, 0.6, 0.7 and 0.8, and a decrease of probability density for the maximum AE/PE value during WP2, relative to the other sub-periods. However, the features of the August curve of the WP2 sub-period should not be attributed to the PDO because the curve of the other warm period (WP1) did not show the same features. Further investigation, in order to evaluate the causes of this feature, such as an increase of the urbanization level of the city of Campinas, should be subject of future studies.

In order to evaluate the use of the current climate normal (1961-1990) to obtain a standard climatology for agrometeorological purposes (such as agroclimatic zoning), Table 3 shows the p and q beta distribution parameters of each thirty-six 10-day intervals of the sub-period 1961-1990.

The values of the beta distribution parameters of the 1961-1990 period, of each thirty-six 10-day intervals, were similar to those observed in the other periods analyzed (CP1, WP1, CP2 and WP2).

The autocorrelation functions of the residual AE/PE for lag 1 to 36 for, CP1, WP1, CP2 and WP2 sub-periods are shown in Figures 3, 4, 5 and 6, respectively.

The autocorrelation function of residual AE/PE values for the CP1 sub-period shows significant positive r_k values from lag 1 to 11 (Figure 3). This yields a long persistence of the sign of the residual AE/PE from the first 10-day interval of January to the second 10-day interval of April. Other significant r_k were noticed in lags 29, 30 and 33 to 36.

The autocorrelation function of residual AE/PE values for the WP1 sub-period showed positive r_k values above the white noise limit from lag 1 to 8 (Figure 4). This implies a persistence of the sign of the residual AE/PE for the period spanning January to the second 10-day interval of March, which overlaps the wet season in Campinas. Significant r_k values are also noted for lag 24, positive, and for lags 32 and 33, both negative.

Table 3. Values of p and q beta distribution parameters of each thirty-six 10-day intervals for the 1961-1990 sub-period. Campinas, São Paulo State

Ten day	q	p	Ten day	q	p	Ten day	q	p
1	0.08	3.46	13	0.31	1.60	25	0.26	0.59
2	0.13	3.36	14	0.31	1.28	26	0.37	0.59
3	0.09	3.40	15	0.41	1.42	27	0.16	0.51
4	0.13	3.53	16	0.42	1.71	28	0.22	0.82
5	0.24	3.78	17	0.44	1.55	29	0.16	0.96
6	0.26	3.27	18	0.53	1.61	30	0.25	1.78
7	0.28	8.53	19	0.49	1.40	31	0.19	1.58
8	0.30	2.57	20	0.49	1.24	32	0.11	1.13
9	0.25	2.76	21	0.61	1.37	33	0.13	2.00
10	0.24	1.99	22	0.61	1.21	34	0.09	2.52
11	0.62	4.78	23	0.93	1.55	35	0.11	3.02
12	0.59	2.15	24	0.57	1.01	36	0.08	3.13

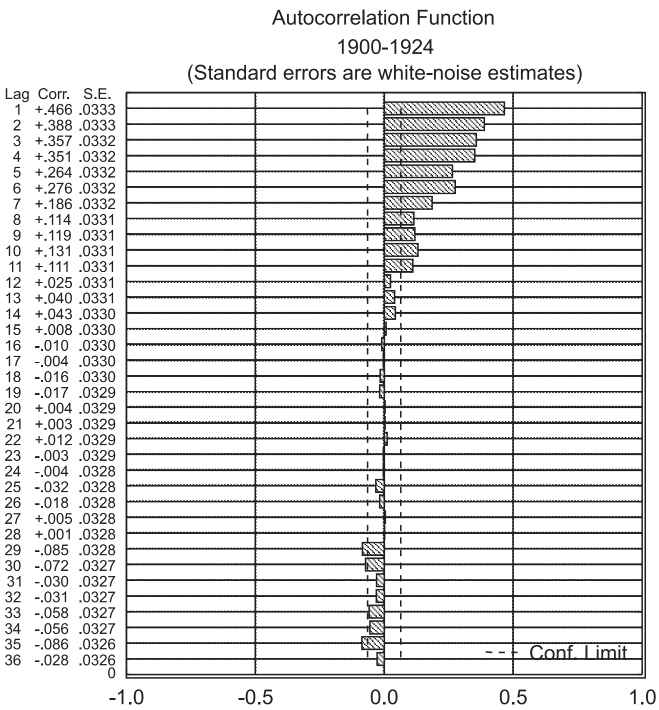

Figure 3. Autocorrelation function of the residual AE/PE series in Campinas, São Paulo State, for the 1900-1924 sub period.

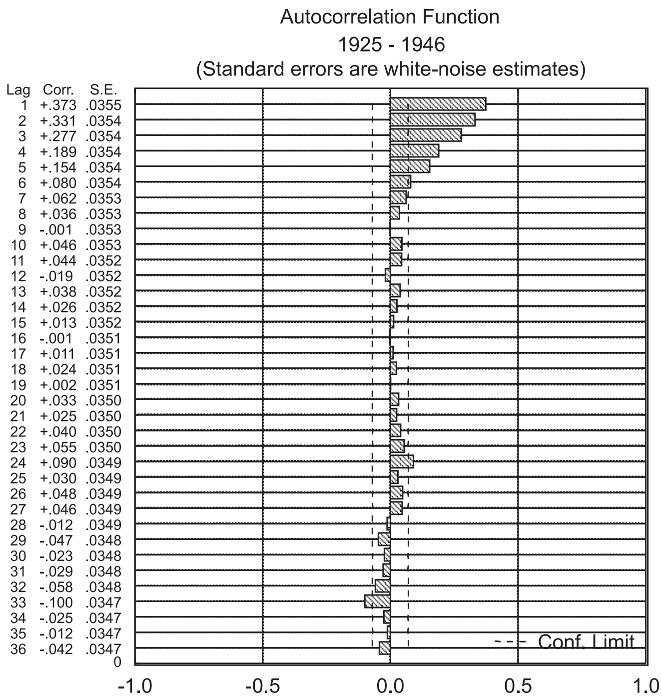

Figure 4. Autocorrelation function of the residual AE/PE series in Campinas São Paulo State, for the 1925-1946 sub-period.

The autocorrelation function of residual AE/PE values for the CP2 sub-period shows significant positive r_k values from lag 1 to 14 (Figure 5). As it has been observed during CP1, this yields a long persistence of the sign of the residual AE/PE from the first 10-day interval of January to the second 10-day interval of May. This period includes the last three months of the wet season and most of the two first months of the dry season in Campinas.

The autocorrelation function of residual AE/PE values for the WP2 sub-period showed significant positive r_k values from lag 1 to 3 (Figure 6). This implies a persistence of the sign of the residual AE/PE during the three 10-day intervals of January. Significant negative r_k values were noticed in lags 6 and 7. This implies a sign reversal of the residual AE/PE relative to the first two 10-day intervals of January.

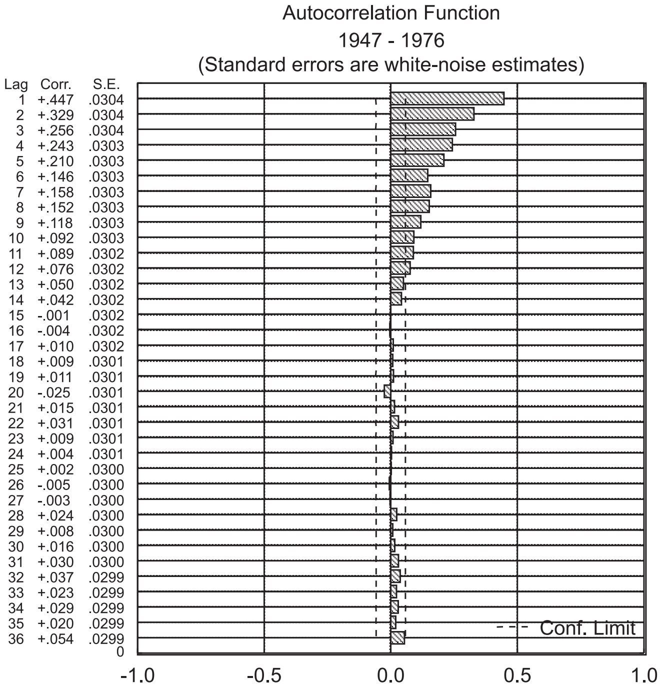

Figure 5. Autocorrelation function of the residual AE/PE series in Campinas, São Paulo State, for the 1947-1976 sub-period.

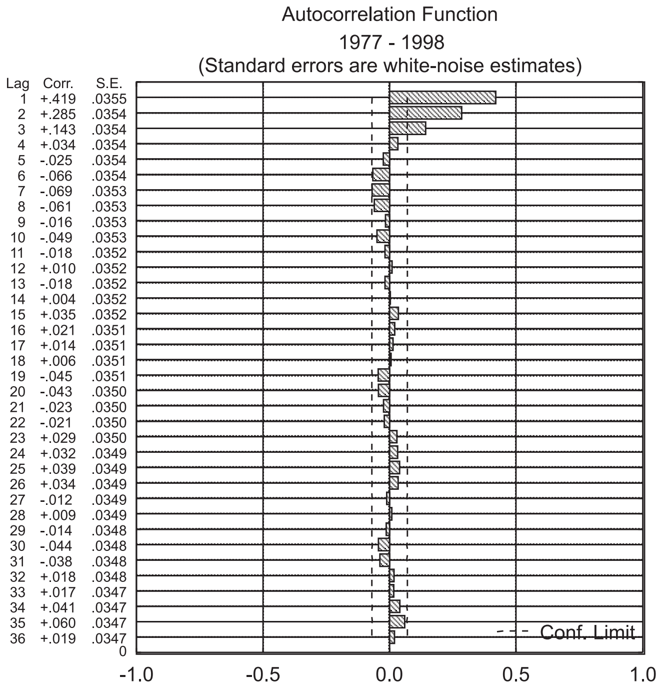

Figure 6. Autocorrelation function of the residual AE/PE series in Campinas, São Paulo State, for the 1977-1998 sub-period.

Comparing Figures 3, 4, 5 and 6, one can observe a quite different persistence level of the sign of the residual AE/PE observed during CP1, WP1, CP2 and WP2. It can also be noted that the largest persistence levels of the sign of the residual AE/PE are observed for CP1 and CP2 sub-periods. This might indicate that the temporal dynamics of the AE/PE values is, in some way, related to the PDO phases.

4. CONCLUSIONS

1. Considering the agrometeorological purposes, which are usually based on the frequency of occurrence of agrometeorological variables, the analyses of the shape of the beta probability density function of the AE/PE series for the four periods analyzed did not show differences between the warm and cold phases of the PDO. In this sense, the use of "average periods" to obtain a standard climatology for agrometeorological purposes, such as climate normal of the 1961-1990 period, which encompasses sixteen years of the cold PDO phase and fourteen years of the warm PDO phase, should not result in significant errors in the region of Campinas, São Paulo State.

2. Considering academic/scientific purposes, the analyses of the autocorrelation functions of the residual AE/PE series for the four periods show differences in the persistence between the two phases of the PDO. For the WP1 and WP2, the persistences of the residual AE/PE were 7 and 3 10-day intervals, respectively. For the CP1 and CP2 sub-periods, the autocorrelation functions showed larger persistence of the residual AE/PE, which were 11 and 14 10-day intervals, respectively. Therefore, the residual AE/PE series show larger persistence during the cold PDO phase than during the warm PDO phase. It is likely that such a long persistence is related to direct or indirect influence of low-frequency large-scale meteorological phenomena as the PDO.

REFERENCES

ANDREOLI, R.V.; KAYANO, M.T. ENSO - related rainfall anomalies in South America and associated circulation features during warm and cold Pacific decadal oscillation regimes. International Journal of Climatology, v. 25, p.2071-2030, 2005.

ASSIS, F.N.; ARRUDA, H.V.; PEREIRA, A.R. Aplicações de estatística à climatologia. Pelotas: Universitária, Universidade Federal de Pelotas, 1996.

BLAIN, G.C.; CAMARGO, M.B.P.; PEREIRA, A.R. Detection of possible alterations (trends) in the ten day period ratio between actual and potential evapotranspiration during the years 1890 to 2005 in the region of Campinas-SP-Brazil. In: CONGRESSO BRASILEIRO DE AGROMETEOROLOGIA, 15., Aracajú. Anais... Sociedade Brasileira de Agrometeorologia, 2007. (CDROM).

CAMARGO, M.B.P.; HUBBARD, K.G. Drought sensitivity indices for a sorghum crop. Journal of Production Agriculture, v.12, p.312-316, 1999.

DOORENBOS, J.; KASSAM, A.H. Efeito da água no rendimento das culturas. Tradução de GHEYI, H. et al. Campina Grande: Universidade Federal da Paraíba, 1994.

KATZ, R.W. Towards a statistical paradigm for climate change. Climate Research, v.2, p.167-175, 1993.

KAYANO, M.T.; ANDREOLI, R.V. Relations of South American summer rainfall interannual variations with the Pacific Decadal Oscillation. International Journal of Climatology, v.27, p.531-540, 1997.

MANTUA, N.J.; HARE, S.R.; ZHANG, Y.; WALLACE, J.M.; FRANCIS, R.C. A Pacific interdecadalclimate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society, v. 78, p.1069-1079, 1997.

MONTEIRO, C.A.F. A dinâmica climática e as chuvas no Estado de São Paulo: estudo geográfico sob forma de Atlas. São Paulo: Universidade de São Paulo, 1973.

MORAES, A.V.C.; CAMARGO, M.B.P.; MASCARENHAS, H.A.A.; MIRANDA, M.A.C.; PEREIRA, J.C.V.A. Teste e análise de modelos agrometeorológicos de estimativa de produtividade para a cultura da soja na região de Ribeirão Preto (SP). Bragantia, v.57, p.393-406, 1998.

NUNES, L.H. Distribuição espaço-temporal da pluviosidade no Estado de São Paulo: variabilidade, tendências, processos intervenientes. São Paulo: Universidade Estadual de São Paulo, 1997.

ORTOLANI, A.A.; CAMARGO, M.B.P. Influência dos fatores climáticos na produção. In: CASTRO, P.R.C. et al. Ecofisiologia da produção agrícola. Piracicaba: Potafos, 1987. p. 71-81.

ORTOLANI, A.A.; SENTELHAS, P.C.; CAMARGO, M.B.P.; PEZZOPANE, J.E.M.; GONÇALVES, P. S. Agrometeorological model for a seasonal ruber tree field. Indian Journal Of Natural Rubber Research, v.11, p.8-14, 1998.

PICCINI, A.G.; CAMARGO, M.B.P.; ORTOLANI, A.A.; FAZUOLI L.C.; GALLO, P.B. Desenvolvimento e teste de modelos agrometeorologicos para a estimativa de produtividade do cafeeiro. Bragantia, v.58, p.171-178, 1999.

THORNTHWAITE, C.W. An appoach toward a rational classification. Geographical Review, v.38, p.55-94, 1948.

THORNTHWAITE, C.W.; MATHER, J.R. The water balance. Centerton: Drexel Institute of Technology - Laboratory of Climatology, 1955. 104p. (Publications in Climatology, v.8, n.1)

VOITURIEZ, B.; JACQUES, G. El Niño Fact and Fiction. Paris: United Nations Educational, Scientific and Cultural Organization, 2000. 128p.

WILKS, D.S. Statistical methods in the atmospheric sciences. 2,Ed. San Diego, Academic Press, 2006.

ZHANG, Y.; WALLACE, J.M.; BATTISTI, D. ENSO-like interdecadal variability: 1900-93. Journal of Climate, v.10, p.1004-1020, 1997.

ZHANG, Y.; NORRIS, J.; WALLACE, J.M. Seasonality of large-scale atmosphere-ocean interaction over the North Pacific. Journal of Climate, v.11, p.2473-2481, 1998.