Rainfall in Azul and its relationship with the phenomenon el Niño Southern Oscillation (ENSO)

Precipitaciones en Azul y su relación con el fenómeno el Niño Oscilación Sur (ENOS)

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Originales: *Recepción:* 17/10/2016 - *Aceptación:* 29/03/2017

Abstract

The aim of this paper was to verify whether there is a correlation between rainfall conditions that occurred in Azul, Buenos Aires (Lat 36°45' S; 59°57' W and Long altitude 137 m), between 1950 - 2015, and thermal anomalies generated in ENSO episodes in its warm phases - El Niño (EN) and cold - La Niña (LN), using a monthly series and annual rainfall. The annual rainfall showed a slight positive trend in the case of EN and below the central tendency for LN; however, these differences were not significant at 5% probability. In the monthly scale very low values were found in the Pearson Index, where only for the process LN, and June (IP 0.5692), the linear relationship and t-Student analysis were slightly significant, 5%. Therefore, the existence of a change in the local rainfall regime in the years in which this process was present cannot be confirmed.

Keywords
rainfall • ENSO • interaction

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Resumen

El objetivo de este trabajo fue verificar la existencia de una correlación entre las condiciones pluviométricas que se presentaron en Azul, Pcia. de Buenos Aires (36°45' Lat. S; 59°57' Long. W y altitud: 137 m s. n. m.), entre los años 1950-2015, y las anomalías térmicas generadas en episodios del fenómeno ENOS, en sus fases cálida - El Niño (EN) y fría - La Niña (LN), empleándose una serie mensual y anual de precipitaciones. Las precipitaciones anuales mostraron que se manifiesta una leve tendencia positiva para el caso de EN e inferiores a la tendencia central para LN, no obstante dichas diferencias no resultaron significativas al 5% de probabilidad. En la escala mensual se encontraron valores muy bajos en el Índice de Pearson, donde solo para el proceso de LN, y para el mes de junio (IP de 0,5692), la relación lineal y el análisis de t-Student resultaron levemente significativas al 5%. Por lo observado no se puede afirmar la existencia de una modificación en el régimen pluviométrico local en los años en que se presentó dicho proceso.

Palabras clave

precipitaciones • fenómeno ENOS • interacción

Introduction

Since 1980 there has been a marked variation in the behavior of some meteorological phenomena in the centre-south of the province of Buenos Aires, as well as in other areas of the country (10), which translated in the rise of intensity and frequency of rainfall, droughts and storms, etc. These changes are not only observed locally but are modifying progressively the spatial pattern that characterized those phenomena covering all the continents, which makes it a global phenomenon.

Among those changes, one of the most important events of ocean-atmosphere interaction that takes place at an inter annual scale is known in the scientific field as El Niño- southern oscillation (ENSO), commonly called El Niño, is a natural and periodic climatic variation that consists in the oscillation between a warm phase (El Niño) and a cold phase (La Niña). These phases can be perceived by means of an abnormal warming or cooling of superficial temperature of the sea in the equatorial central and oriental Pacific Ocean. These marine thermal variations reach the north and south coasts of America and bring significant variations in the climatic patterns.

The forced deviation of the south east trade winds not only favours the entrance of warm and wet masses of wind from the Atlantic but it interacts in special situations with the "jet in low layers" which mobilizes air currents from the Pacific under the protection of strong convective effects generated by an unusual rise in the temperature of its water. This has caused to attribute it to the abnormalities in the circulation of the atmosphere that are recorded during the different ENSO cycles (9).

The positive anomalies in the surface temperatures generated in the Pacific are associated with the thermocline sinking and the reduction of the coastal emergence, whereas, the negative anomalies are associated to the thermocline rise and the strengthening of such emergence (8).

El Niño climatic episodes are known since long ago; however, in the last decades they have increased significantly; therefore, their impact has warned the world scientific community. Scientific analyses not only show a growing trend in the frequency, but also in the intensity of the extreme meteorological events in the last fifty years and it is likely that high temperatures, heat waves and heavy rainfalls will continue being more frequent in future which will be disastrous for mankind (5). Since the 1950 decade, lots of the changes observed have no precedents in the last decade to millennium.

The ocean and the atmosphere have warmed, the volumes of snow and ice have decreased, the sea level has risen and the concentrations of gases from global warming have increased (6).

The ENSO cycle is one of the main causes of regional climate variability. Its opposite phases, warm and cold, are associated with precipitation anomalies in many areas of the world, with different degrees of probability of occurrence according to region and time of year (11).

ENSO is a phenomenon of coupling between the ocean and the atmosphere manifested by variations throughout the climate system, affecting crop productivity in the Argentinean Pampean Region (14).

Although previous work on ENSO, precipitation and maize yields has been carried out, the results in the district of Azul are unclear. Fernandez Long *et al.* (2011) found a strong impact of the ENSO index on maize yield in the north and center of the Pampas region, while in the central-southeast of the province of Buenos Aires the impact was weak, showing a different behavior from that in the rest of the region, with negative correlation values. Previous work had also shown that the ENSO signal on the precipitation of the Pampean region weakened towards the south (1).

Although their causes have different origins El Niño Phenomenon (FEN) and the Phenomenon of Climatic Change (FCC) seem to be related at present.

The former shows an apparently cyclical chronology (3 and 7 years), whereas the FCC shows a continuous process. Nevertheless, it is possible to think that the FCC may generate a synergism exacerbating the FEN impacts. According to the World Meteorology Organization-OMM (16), the world meteorological patterns have been altered due to the climatic change that tends to warm the oceans and melt glaciers and warned. The atmospheric processes are affected by complex mechanisms of ocean-atmosphere interaction, where sea and atmosphere indices are used to detect and forecast ENSO. One of the most commonly used sea parameters to identify and quantify in a certain way the energy changes in that system ate the superficial sea temperature anomalies (ATSM). With this aim, the role that the different ocean areas with special characteristics play in those interaction mechanisms has been studied. Among these areas are those used for monitoring ENOS events known as El Niño 1+2 (0-10 S, 90-80 W), Niño 3 (5N-5S, 150-90W), Niño 4 (5N-5S, 160E-150W) and Niño 3, 4 (5N-5S), (170-120W).

The National Oceanic and Atmospheric Administration of the USA-NOAA (3), defined the El Niño Ocean Index (ONI) to identify the warming (El Niño) and cooling (La Niña) phenomena in the tropical Pacific.

The ONI is the mobile mean of three consecutive months of the ocean surface temperature anomaly in the sector 3, 4 that is situated between the parallels 5°N and 5° S and the meridians 120° W and 170° W. Currently, the world scientific community has agreed to adopt the "operational definition" given by NOAA in order to decide the presence of a Niño from the index Oni (2). This index is one of the greatest data bases that measures ENSO phenomenon. When that index is higher than +0.5°C throughout five consecutive months it is characterized as El Niño event and when it is lower than -0.5°C it is La Niña event.

The anomaly has a basis the period 1971-2000. The anomaly thresholds separate into weak (0.5 to 0.9°C), moderate (1.0 to 1.4°C), strong (1.5 to 1.9°C) and very strong (≥2.0°C). Therefore, in this paper the aim is to verify whether there is a correlation between the rainfalls in Azul between 1950-2015 and the thermal anomalies generated in the episodes of the ENSO phenomenon in its warm (El Niño) and cold (La Niña) phases.

Materials and methods

1)- Information considered to analyze the proposed objectives.

a)- The analysis of monthly rainfalls has been carried out in concordance with the latest modification (July 2015) of the classification proposed by the Climate Forecast Centre (CPC) of NOAA (3), correlating the mobile mean (MM) of three consecutive months the ocean surface temperature anomaly in the sector 3, 4 with the MM of three consecutive months of rainfall anomalies (AP) for each of the ENOS events (ec.1)

$$AP_i(\%) = \left(\frac{Pi - Mi}{Pi} \right) * 100 \qquad (1)$$

where:

Pi = expresses the rainfall behavior of a given month

Mi = the median for that month (series 1950-2015). This indicator that relates the MM of three months of the monthly rainfall series of each year, with the MM of the monthly rainfall medians for that series allows the obtention of a non-dimensional magnitude that avoids the distorting factor that seasonal variations in the intensity of this element generate.

The mentioned rainfall series corresponding to Azul was generated by the National Weather Service (1950-1990) and the Regional Agro-meteorology Centre (1991-2015) of Facultad de Agronomía -Universidad Nacional del Centro de la Provincia de Buenos Aires.

b)- Study zone: The district of Azul (36°13' to 37°26' Lat S and between 59°09' and 60°13' Long W) mainly corresponds to the Depressed Pampas physiography with a flat topography with little gradient placing it among the world regions with minimum morphogenetic potential (15). It has a humid mild climate without dry season with oceanic influence type Cfb (7) characteristic of the centre-east region of the province of Buenos Aires. The annual mean temperature for the centre zone of the district is 14.3°C, being 21°C the average record for the warmest month and 7.6°C for the coldest month.

The region has a regular rainfall patterns with a historic average for that town of 858.2 mm annually and a standard deviation of 189 mm with extreme values that show a minimum annual record of 487.8mm and a maximum of 1470.2 mm.

c)- Chronology of ENSO events in the period 1950-2015 according to the National Oceanic Atmospheric Administration (NOAA).

2)- In the analysis of correlation between the rainfall conditions given in Azul between 1950-2015, and the thermal anomalies generated on occasions when ENSO phenomenon episodes in their warm (El Niño) and cold (La Niña) phases were recorded, two types of variables were used:

2.1)- The independent formed by the element that defines the ENOS phenomenon

-The Anomalies of the Sea Surface Temperature (ATSM) in the equatorial Pacific, and

2.2)- A dependent variable formed by rainfall records:

-Monthly totals in relation with the median for the district in the period 1950/2015.

In the ENSO events, in their warm phase with values of ONI > +0.5°C as well as in the cold <0.5°C, a correlation analysis was applied. For that analysis, the Pearson correlation coefficient, which is obtained dividing the covariance of two variables by the product of their standard deviations, was used. Each model was statistically evaluated at significance level of 5% using the programme Statitix 8 (12).

In order to observe the number of years with values that escape the central trend for excess or for defect in the ENSO process, the difference was calculated separately for EN and LN events between each annual value with respect to the mean ± a standard deviation. For the warm phase, the data out of the range ±205.9mm were counted, and for the cold phase those that exceeded ±145.1mm. The statistic significance of the mean difference between annual rainfall totals corresponding to El Niño (EN) and La Niña (LN) processes was analyzed by means of the statistic *t*-Student with different variances (13).

Table 1. Pearson correlation coefficient (9).

Tabla 1. Coeficiente de correlación de Pearson (9).

Coefficient value	Meaning of the correlation (±)
Between ±0.90 y ±1	Very high
Between ±0.70 y ±0.89	High
Between ±0.50 y ±0.69	Moderate
Between ±0.30 y ±0.49	Low
Between 0 y ±0.29	Very low or no correlation

Results and discussion

For the case of EN there is s slight positive trend showing 19.2% of years with annual rainfall values higher than the central range (years: 1963, 1980, 1987, 1992 and 2002), whereas in two cases (7.7% , years: 1979 and 2005) there was a lower value to that central trend (figure 1, page 240).

A similar situation was verified for the LN process (figure 2, page 240), where for the years when that cold event was present in the series analyzed, 29.2% of years with rainfall values lower than the central trend (years: 1950, 1974, 1995, 2007, 2008, 2010 and 2011) and a value above (4.2%) of that number (year 1996) were found.

The annual rainfall means recorded during the processes of El Niño (EN) and La Niña (LN) are slightly above (36.5mm; 4.1%) and below (-49.1mm; -6.1%), respectively for those events (table 2, page 240) in relation to the mean (1950-2015).

In order to compare if those differences in the central trend of the EN and LN processes are significant *t*-Student (α=0.05) was applied, where the *t* observed (1.68) was lower than the critical *t* value (2.011) indicating the lack of significance and that those means are statistically the same to the 5% probability.

In order to understand the influence of the ENSO-EN and LN- process (between 1950-2015) at a monthly scale, a correlation analysis was used (table 3).

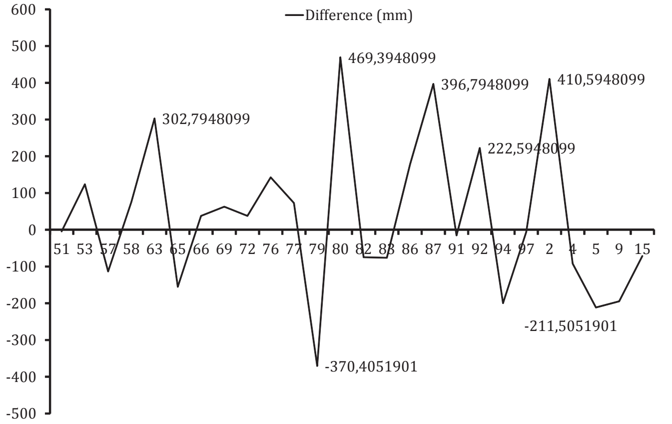

Figure 1. Difference of annual accumulated rainfall (mm) from the mean ± a standard deviation for the 26 years of EN in Azul for the period 1950-2015.

Figura 1. Diferencia de precipitación acumulada anual (mm), respecto de la media ± un desvío estándar para los 26 de años de EN en Azul, para el período 1950-2015.

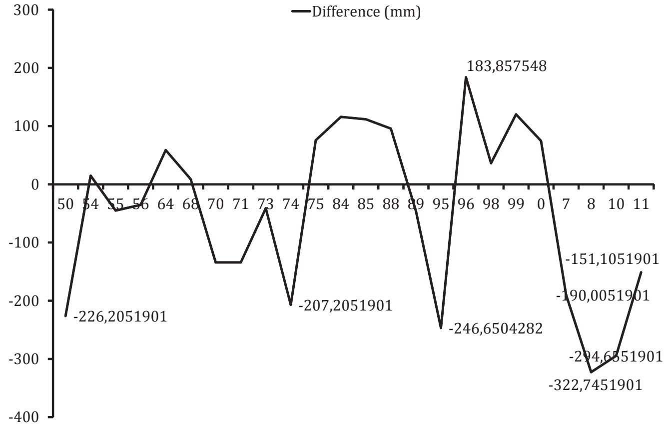

Figure 2. Difference of accumulated annual rainfall (mm) from the mean ± a standard deviation for the 24 years of LN in Azul for the period 1950-2015.

Figura 2. Diferencia de precipitación acumulada anual (mm) respecto de la media ± un desvío estándar para los 24 de años de LN en Azul, para el período 1950-2015.

Table 2. Annual rainfall means (PP) and their standard deviation (DE) during the processes of El Niño and La Niña with respect to the mean (1950-2015) for Azul.

Tabla 2. Promedios anuales de las precipitaciones (PP) y su desvío estándar (DE), durante los procesos de El Niño y La Niña, respecto de la media (1950-2015) para Azul.

Event	PP (mm)	Difference (mm)	DE (mm)
El Niño	894.8	36.5	205.9
La Niña	809.1	-49.1	145.9
Mean	858.2	-	189.0

The latter showed very low values (between 0 and ±0.29) in the Pearson Index (IP) (table 1, page 239) for the chronology of La Niña events in the months of January, February, April, July, August, September, October, November and December; whereas, in the spring-summer months (November, December and January), although they were of the same tenor, a negative correlation was observed, therefore the rainfalls showed an opposing behavior to that expected for being above the median.

The greater indices appeared for the coldest period of the year where March and May show an IP of 0.3878 and 0.3780, respectively, and were not significant at 5% probability. Only in June, (IP of 0.5692) the lineal relation was statistically significant at 5% with a P-*value* slightly below the 5% probability (table 3), where the analysis *t*-Student also was slightly significant according to the difference between the *t* observed (2.20) and the critical *t* (2.29).

A similar situation was reflected for the events of El Niño, where IP showed very low values for ten months of the year (January, February, March, May, June, August, September, October, November and December), with the highest values in April and July (0.4777 and 0.3080, respectively), but the results of the p-*value* and the verification with the *t*- Student analysis denote lack of correlation.

According to observation, an incidence of episodes of ENSO phenomenon on rainfalls for the district of Azul cannot be affirmed since no statistic evidence was found on the warm phase (EN), and where in the cold phase (LN) only in one month the Pearson Index was significant at 5% probability.

This is in line with the weakening observed by Barros and Silvestri (Number) in the influence of ENSO on precipitation towards the south of the Pampean region, and the low impact of the ENSO index on maize yield in the central-southeast of the province of Buenos Aires found by Fernandez Long *et al.* (2011).

Table 3. Pearson and P-value (Pv) Correlation Coefficients for rain and ONI for Azul.
Tabla 3. Coeficientes de Correlación de Pearson y P-*value* (Pv) para las lluvias y el ONI para Azul.

Month	EN	Pv	LN	Pv
January	0.2006	0.3474	-0.1342	0.5727
February	0.2119	0.3985	0.2919	0.2398
March	0.2693	0.3736	0.3878	0.0911
April	0.4777	0.1163	0.1867	0.5413
May	-0.0199	0.9536	0.3780	0.1827
June	0.1421	0.6280	**0.5692**[1]	**0.0423**
July	0.3080	0.2459	0.2262	0.4368
August	-0.1144	0.6849	0.1755	0.5156
September	-0.0607	0.8051	0.2067	0.4424
October	0.0261	0.9082	0.1037	0.6822
November	-0.0137	0.9506	-0.2192	0.3821
December	-0.0407	0.9000	-0.1966	0.4199

[1] Bold shows the only month in which the linear relationship was statistically significant at 5% for the ENSO processes present in the series analyzed (1950-2015).

[1] En negrita se indica el único mes cuando la relación lineal resultó estadísticamente significativa al 5%, para los procesos ENOS presentados en la serie analizada (1950-2015).

Conclusions

For the studied zone, very low to non-existent incidence of the ENSO phenomenon on the rainfalls for annual and monthly time scales was observed; therefore, in the light of statistic evidence and the long series analyzed, the existence of a modification in the local rainfall regime in the years in which that process was present in its warm phase as well as its cold phase, cannot be confirmed, therefore, an alteration in crop yields could not be expected either.

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