P2.23 TEMPERATURE EXTREMES VARIABILITY IN THE SOUTH OF SOUTH AMERICA IN RELATION TO ATLANTIC SST AND THE SOUTHERN ANNULAR MODE

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Abstract

The objective of this research is to study the main variability modes of the frequency of extreme temperatures in the south of South America (Argentina), their relation to the Atlantic sea surface temperatures and the Southern Annular Mode. Observational data and reanalysis data were used for this propose over the 1964-2003 period. A wavelet analysis showed that the main variability mode found at a seasonal scale was an 8-year wave signal present in spring that remains active until the 90's. It was noticeable in the analysis of cold nights, Atlantic SSTs, and the Southern Annular Mode (SAM). A cross-wavelet analysis among them reflected this signal as a common variability mode, with the positive phase of the SAM congruent with warmest condition in the coastal zones of the Atlantic Ocean and lower cases of cold nights at the reference meteorological stations analyzed. Although longer series are desirable for low frequency variability analysis, the results agree with previous studies that take into account an 8-year periodicity of the baroclinic waves at the Southern Hemisphere, supporting the relevance of the 8-year signal.
Key words: cold/warm nights/days - Variability Modes – Wavelets - Southern Hemisphere – Argentina

1. Introduction

A few years ago, due to the joint effort made by the scientific community from different countries, several workshops were held to collect climatological information on a daily basis; the objective was to carry out a strict quality control and to generate indices that could be used to analyze extreme events. These meetings were coordinated by the Team on Climate Change Detection, Monitoring and Indices (ETCCDMI), a group established by the WMO that developed a comprehensive list of indices meaningful over continental to global regions (Karl et al, 1999, Peterson et al, 2001).

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One of the meetings dealt with the analysis of trends to extreme temperatures in South America (Vincent et al, 2005). According to this analysis, the indices of minimum temperature showed the highest variation in the 1960-2000 period, with an increase in the percentage of warm nights and a decrease in the percentage of cold nights in many of the stations studied. Others works related with these indices can be found at Alexander et al (2006) and Aguilar et al. (2006), among others.

Many of the previous works analyzed trends of the indices related with the frequencies of extreme temperature, but the temporal variability is quite complex. Climate series may exhibit jumps, periodic and quasi-periodic events that do not necessarily last over long periods but are present for a sequence of years and then disappear or remain as weak signals in the system. In this work these signals (at multiples scales) are analyzed in extreme temperature indices using a wavelet transform (Torrence and Compo, 1998). Atlantic SSTs, and the SAM index are also examined in order to capture coherent patterns, with common variability modes physically consistent. Cross wavelets were used for this purpose (Grinsted et al, 2004). In section 2 the data and methodology used in this study are presented. Sections 3 deal with different variability scales of the indices studied at a seasonal scale for the series of frequency of extreme temperatures on surface and sea surface temperature respectively, seeking common variability modes. In section 4, the SAM is examined in relation with the common variability modes previously shown at Temperature indices and Atlantic SSTs. In the last section, the most relevant conclusions are presented.

2. Data and methodology

The extreme temperatures indices analyzed in this work were obtained by taking into consideration a database of daily maximum and minimum temperatures of 40 stations all over Argentina (fig. 1), which have been subjected to a quality control for the 1959-1998 period (Rusticucci and Barrucand, 2001) and then extended up to 2003. Taking this information into account, 4 indices of extreme temperatures were generated:

- TN10 ("cold nights"): percentage of days with minimum temperatures lower than the 10th percentile
- ·TN90 ("warm nights"): percentage of days with minimum temperatures higher than the 90th percentile
- ·TX10 ("cold days"): percentage of days with maximum temperatures lower than the 10th percentile
- ·TX90 ("warm days"): percentage of days with maximum temperatures higher than the 90th percentile

The indices, calculated for each month and each year, are defined following the ETCCDMI's recommendations, are consistent with those used in the study by Vincent et al. (2005) and are similar to the indices used in studies about other regions: The percentiles used were calculated for the 1961-1990 reference period. They are defined on a daily basis, with a 5-day window centered on each calendar day.

Based on the results from Rusticucci et al. (2003) that find the Atlantic zones of highest correlation with the seasonal temperature from several stations of Argentina, three Atlantic Ocean "boxes" were considered (fig. 1), with a width between 5° and 12° longitude and 6° and 10° latitude: they are centered at approximately 30°S-48°W (SST30), 36°S-50°W (SST36) and 46°S-62°W (SST46). When choosing the boxes, the influence of the Brazil and Falklands current and the confluence between both respectively was also taken into account (Schmitz, 1996 and references therein).

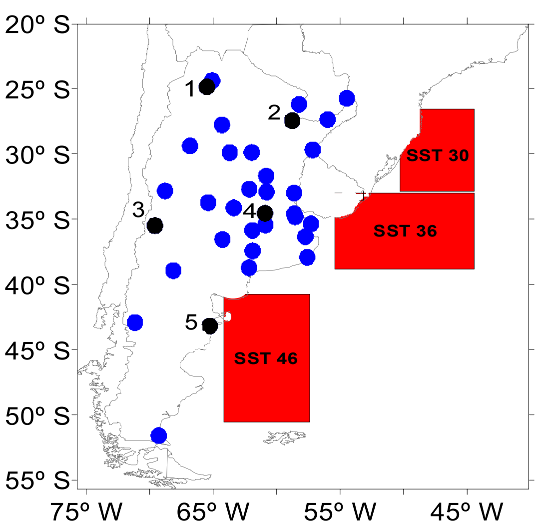

Figure 1: Stations used in the study. Some reference stations are highlighted: 1 Salta; 2 Corrientes; 3 Malargüe; 4 Junín; 5 Trelew. The rectangles represent ocean zones in which the SST were averaged-

A wavelet transform was applied to study the different variability scales of the different series and the cross-wavelet was calculated to analyze the common variability modes (adapted from Grinsted et al., 2004). This methodology was applied to some stations that were selected according to the homogeneity results previously found (Barrucand et al., 2006) and the "quality" of the series, considering those that did not show any missing data (the stations are highlighted in Fig. 1). A seasonal scale were considered, taking into account summer (Dec-Jan-Feb), autumn (Mar-Apr-May), winter (Jun-Jul-Aug) and spring (Sep-Oct-Nov). The period considered was 1964-2003 since the previous years showed a higher number of missing data.

Finally, the variability of the Southern Annular Mode (SAM) was analyzed in relation to the common modes previously found at Atlantic SSTs indices and extreme temperatures frequencies.

3.Variability modes of extreme temperatures and Atlantic SSTs

In a previous study (Barrucand et al, 2006), different variability modes of the temperature indices were analyzed. A noticeable 8-year signal was found, specially at cold nights in spring. Atlantic SSTs series appear to be affected by this mode too. In order to make a consistent study on the variability scales between the mentioned series, the cross-wavelet spectrum was calculated.(fig 2). It shows a common 8-year signal between SST30 and cold nights. The results for SST36 are similar. As can be seen, the series are in anti-phase, so that the temperature increase in the ocean regions is associated with a decrease in the cold events in spring.. However, as evidenced by the wavelet analysis of each of the series (not shown) and the cross-wavelet, there is no such a relation in the late 80's, which could imply a change in the relations within the system, or simply that the mode became inactive then.

The 8-year wave modulation that was so clearly seen at the four reference stations at central and north of Argentina does not appear in the Patagonian stations, except for a signal in the cross-wavelet with SST30 –in phase– that appears after 1990. Although this signal is mostly outside the cone of influence, it also indicates that there may be a change in the climate system at the beginning of the 90's.

This possible change or potential jump in the climate system was early mentioned in Zhang et al. (1997) and is being observed by different studies and meteorological variables. Some examples can be found in Huth and Canziani (2003), that find changes in the Antarctic polar vortex and in Malanca et al. (2005), that find a change in the ozone fields at middle latitudes, both observed at the beginning of the 90's.

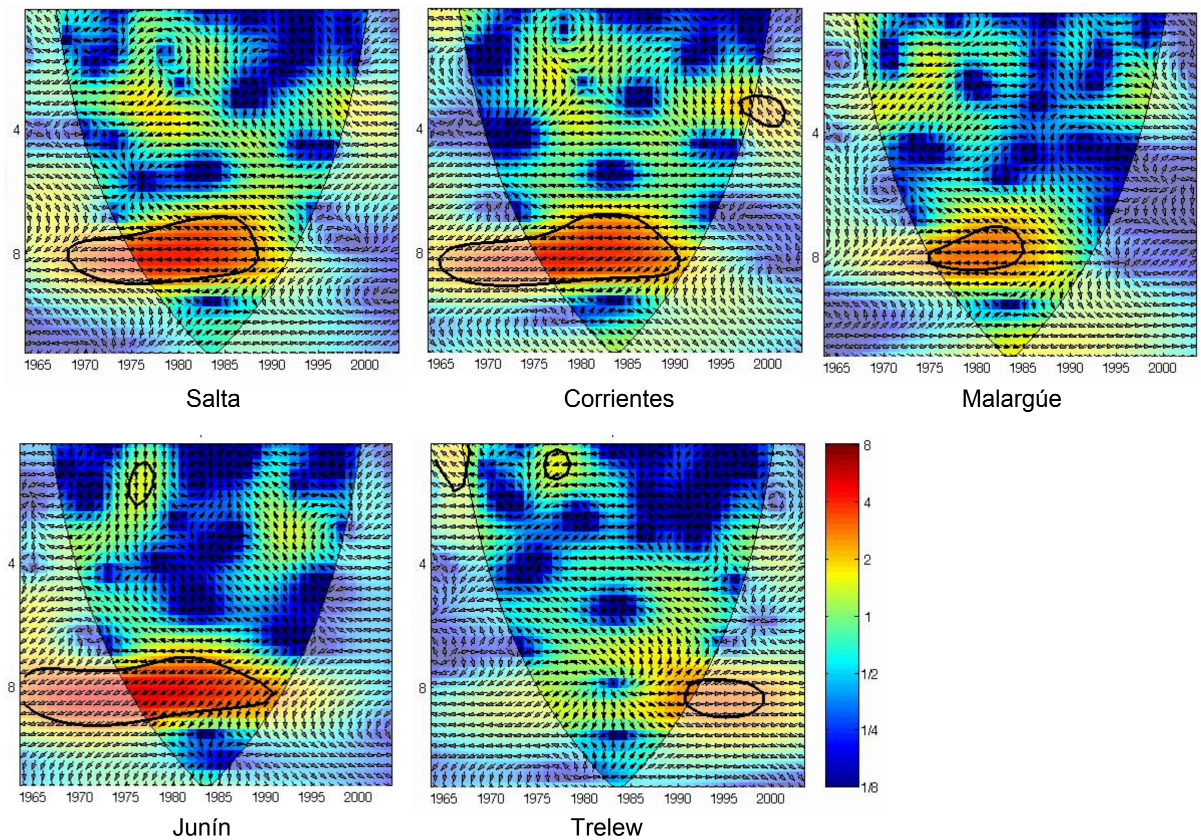

Figure 2: Cross-wavelet transform between some reference series TN10 and the standardized series SST30 (spring). The arrows indicate the phase relation between the series analyzed. as a thick contour (with in-phase pointing right, anti-phase pointing left, and SST leading TN10 by 90º pointing straight down). The thick contours encloses regions of greater than 95% confidence (red noise assumption).

The association with the southern ocean region (SST46) turned out to be different from the one corresponding to SST30 and SST36. The 8-year wave appears in the cross-wavelet with the Patagonian station –in anti-phase– from the 90's onwards.

The analysis was performed for the other three extreme indices. The 8-year wave signal is also reflected on many cases, but with a changing phase, so the physical relation becomes more complex.

4. Common variability modes with the SAM

The important signal detected both in the surface temperature indices and in the Atlantic's SST encouraged further research in order to seek possible forcing mechanisms that could modulate the observed variability. The fact that the 8-year signal was more strongly shown in the series of cold events frequency, encouraged the analysis of some index representative of middle and high latitudes. In this context, the SAM turns out to be an appropriate index for evaluating potential patterns modulating the variability observed.

The main variability mode in the Southern Hemisphere atmospheric circulation that is dominant in the extratropical regions and the high latitudes has a symmetric or "annular" zonal structure, with anomalies of opposite signs between the Antarctica and middle latitudes. It can be observed in several atmospheric fields, such as surface pressure, geopotential height, surface temperature and zonal wind (Thompson and Wallace, 2000).

Many of the studies that have discussed this variability mode found an important positive trend of the index. While the NCEP data indicates a more significant trend during winter, Marshall (2003) using the observational data, shows that the highest trend occurs in summer, and no trend is observed in spring.

In this work the SAM index is defined as Marshall (2003), that considers a zonal average of pressure at sea level at 40ºS and 65ºS based on six stations close to each of the latitudes. A wavelet analysis showed that the 8-year signal is clear in the spring SAM index (figure 3). It is possible to see that in the late 80's-beginning of the 90's, there appears another significant signal of a higher frequency. It is possible to see that in the late 80's-beginning of the 90's, there appears another significant signal of a higher frequency.

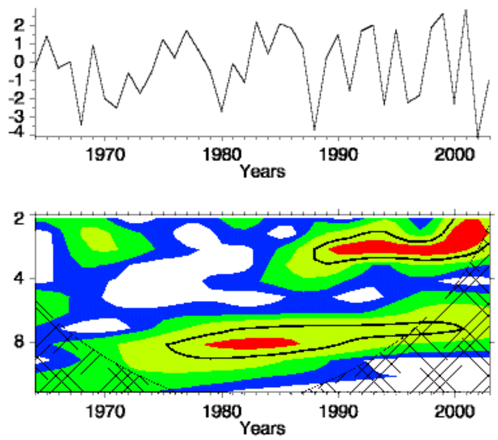

Figure 3: SAM index (spring) spring and the local Wavelet Power Spectrum [Period (years) vs. time (years)]. The contour levels are chosen so that the 75% (red), 50% (light green), 25% (green), 5% (blue) of wavelet power is above each level. The thick contour encloses regions of greater than 90% confidence for a white-noise process. The cross-hatched region is the cone of influence, where zero padding has reduced the variance.

A cross-wavelet analysis between SAM, Atlantic SSTs and the cold nights index reaffirmed this signal as a common variability mode. It appears consistently for the SST30 (fig. 4) and SST36 (not shown) zone and in-phase (higher values of the SAM index associated with higher ocean temperatures). On the contrary, the SST46 zone does not show consistency with the SAM

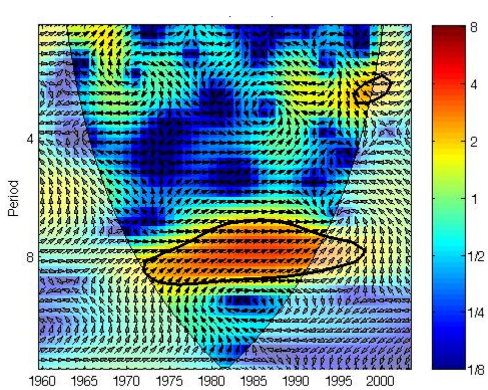

Figure 4: idem. Fig 2 but for SAM and SST30

The 8-year signal appears consistently for the cross-wavelet between SAM and cold nights, with and anti-phase relationship An example is presented at figure 5

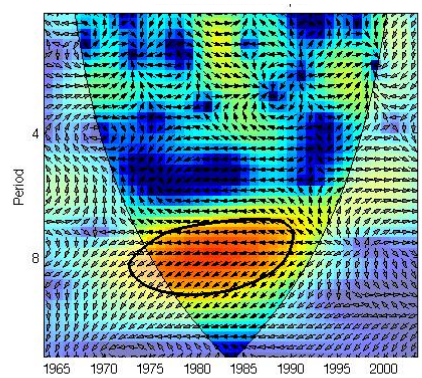

Figure 5: idem fig.2, but for cross-wavelet between SAM and cold nights (spring) of Salta station

It should be noted that in the cases of the positive SAM index, there is a higher relative pressure on the south of South America with respect to the one seen for cases with negative SAM. (figure 6), which would be associated with a lower number of cyclones for the first case, lower number of cold events and consequently, warmer conditions These results agree with Gillet et al (2006), who analyzed regional impacts of the Southern Annular Mode over the whole of the Southern Hemisphere. They found a positive association between the positive phase of the SAM and the temperature anomalies of the Southern South America, although not significant for stations located at subtropical latitudes.

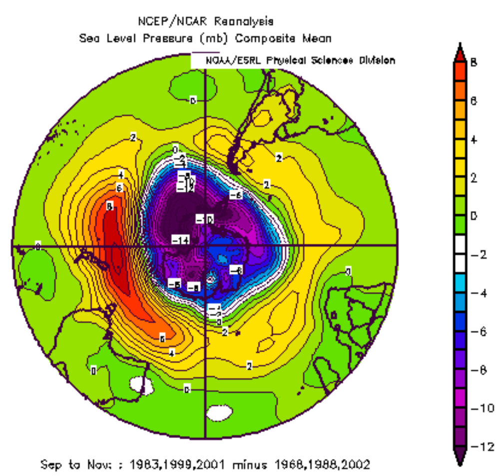

Figure 6: Composites of Sea Level Pressure of 3 cases with positive minus 3 cases with negative SAM. Spring. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.cdc.noaa.gov/".

5 Discussion and concluding remarks

Previous results provided some evidence about an 8-year signal as a significant variability mode of temperature indices of Argentine stations and Atlantic SSTs. A cross wavelet analysis showed this signal as a common variability mode in spring. It was more significantly observed in the frequency of cold extremes, with an increase of Atlantic SSTs linked with a decrease of cold events. The SAM index was also analyzed, and a congruent 8-year signal was found. The three variables/ indices were taken by different databases. This fact provides a stronger result. Even more, the present study is not the unique that makes a reference to such signal. Rao et al (2003) studied the interannual variations of storm tracks in the Southern Hemisphere and their connections with the Antartic Oscillation. They analyzed dominant periodicities of the baroclinic waves for the period January 1974 - December 2000 and they found a dominant 8.33 year periodicity in October, something congruent with the 8-year signal that is been mentioned here. Certainly, we need longer series for a better analysis of low frequency variability and further analysis must be done in order to understand the propagation path of the signal. Nevertheless, the fact that the 8-year wave signal has been found in different variables coming from different sources of information and other studies as Rao et al (2003), permit us to infer that it is a real part of the climate variability and the results can contribute to a better understanding of the main variability modes present in the Southern Hemisphere

Acknowledgments: This research work has been supported by the following grants: ANPCyT - PICT 05 38273, UBA X135 and UBAX234.

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