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Looking for periodicities in the hail intensity in the Andes region

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RESUMEN

Para construir una serie de intensidades de granizo en el área de Mendoza (Argentina), se emplearon fuentes documentales y técnicas de caracterización. Cuando se analizaron las series temporales, mediante el Análisis Sigular del Expectro (SSA), y el Método de Máxima Entropía, encontramos oscilaciones decadales con periodos de aproximadamente 20 años y oscilaciones interanuales de alrededor de 4 a 9 años.

Además cuando la variación por tendencia de los datos se eliminó, se puso de manifiesto una oscilación de frecuencia de cerca de 72 años.

ABSTRACT

Documental sources and categorization techniques were used to construct a series of the annual hail intensity in Mendoza area (Argentina). When the temporal series by means of Singular Spectrum Analysis (SSA) and the Maximum Entropy Method (MEM) was analyzed, we found interdecadal oscillations of periods of about 20 years and interannual oscillations of about 4 and 9 years. In addition when detrented-data were used a low frequency oscillation of about 72 years also appears.

1. Introduction

To characterize interannual variability in the climate system is a major topic in climate research. This permits us to distinguish between natural variability and anthropogenic climate change. Most of the studies of climate change have been done using as variable surface temperature because of long record of instrumental measures, the good possibilities of reconstructing historical measures and the physical meaning of temperature (related to internal energy). It is well-known that the global surface temperature presents variability on timescales of a century or less together with a secular trend since 1930. If we consider a single way of analyzing this variability such as Singular Spectrum Analysis (SSA) (Broomhead and King, 1986; Vautard and Ghil, 1989) and a single set of data such as time series of annually-averaged temperatures from 1854 to 1988 produced by the Climatic Research Unit of the University of East Anglia (Jones *et al.*, 1986), three main timescales of oscillations have been found. Ghil and Vautard (1991) identified interannual oscillations with periods of 5-6 years, probably related to ENSO phenomenon and interdecadal oscillations with periods of 21 and 16 years probably related to changes in the extratropical ocean circulation. Schlesinger and Ramankutty (1994) identified an oscillation of period 65-70 years using the same series but detrented. This finding does not have the general consensus. So Yiou *et al.* (1996) consider that this oscillation could be an artifact generated by the general trend in the data set.

Fewer studies have been done using other climatic variables. By using the same techniques, Prieto *et al.* (1999) found similar periodicities in the annual number of hail-days in the Andes region and in a later work (Prieto *et al.*, 2000) in the number of annual snow days in the Andes region. The objective of this article is to find these oscillations in other climatic variables not related to the number of events but to the intensity of them. Thus we have analyzed the intensity of the hail events in the Andes region using categorization techniques to quantify qualitative information from historical newspapers.

2. Data

Data consist on the annual series of accumulated values of hail intensity on Mendoza area, Argentina (Fig. 1), placed between 32°S and 37°S latitude and between 67°W and 70°W longitude. The main sources for the reconstruction were the daily meteorological reports from the *Los Andes* newspaper during the period 1887-1987. They show a high degree of continuity providing a homogeneous and relatively objective information,

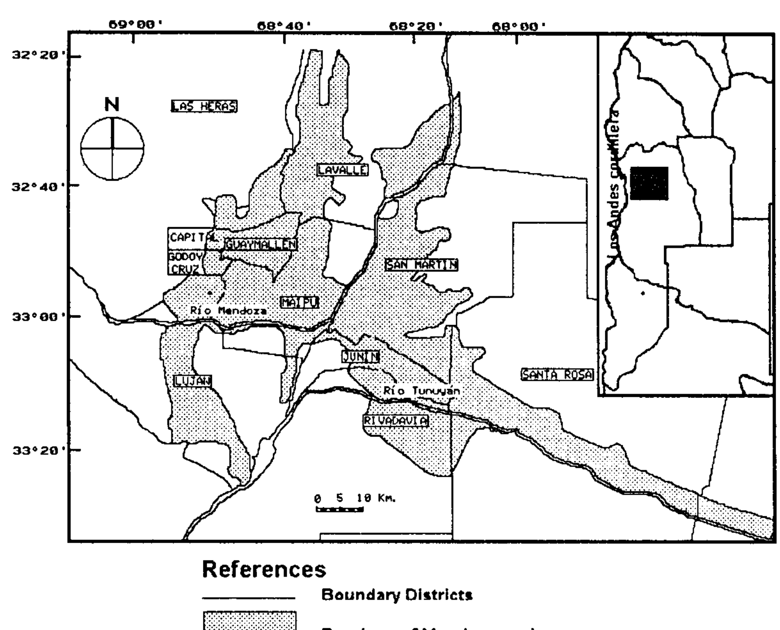

Fig. 1. Map of the Mendoza area.

because the meteorological information is limited to those events which are of interest for the public; mostly reproducing official reports. Another source of homogeneity is the fact that the spatial coverage of the information has been kept constant throughout the whole period of study; it has always referred to the province of Mendoza. From every report data related to hail occurrence were extracted. This information was recorded textually to apply to the meteorological message the content analysis technique. This was used to verify the validity of the recorded information and get a collection of homogeneous data. Changes in the linguistic expressions were analyzed and reduced to a present day equivalent scale. This allowed a further quantification of the series. A great variety of meteorological terms related to hail were identified; after analyzing their equivalence they were grouped into twelve indicators (Table 1).

1 granizo	(hail)
2 piedra	(stone)
3 manga de piedra	(stone storm)
4 manga de granizo	(hail storm)
5 tempestad de lluvia y piedra	(rain and stone tempest)
6 lluvia y manga de piedra	(rain with stone storm)
7 tempestad de lluvia y granizo	(rain and hail tempest)
8 lluvia y manga de granizo	(rain with hail storm)
9 lluvia y piedra	(rain and stone)
10 tempestad de lluvia y manga de granizo	(rain tempest with hail storm)
11 lluvia y granizo	(rain and hail)
12 tempestad de lluvia y manga de piedra	(rain tempest with stone storm)

Table I.

A quantitative scale of every phenomenon was also obtained, with three categories: light, moderate and abundant. Daily values of 1, 2 and 3 were assigned respectively to each one of the three categories (light, moderate and abundant). Accumulated annual values of hail intensity was then constructed using the number of hail days weighted with the daily intensity values. Full details of the reconstruction method can be found in Prieto *et al.* (1995).

3. Method

To analyze the temporal series we have combined two methods. Singular Spectrum analysis (SSA) is designed to extract as much information as possible from short, noisy time series without prior knowledge of the dynamics underlying the series (Broomhead and King, 1986; Vautard and Ghil, 1989). The method is a form of principal component (PC) analysis applied to lag-corrections structures of time series. SSA is particularly successful in isolating periodic components and trends. It composes time series into oscillatory, trending and noise components and provides reconstructed components (RCs). To analyze the period of the RCs a method of spectral analysis has to be used. In this article Maximum Entropy Method (MEM) is used (Burg, 1967). MEM differs from other spectral methods by its representation of noisy oscillatory signals as autoregressive processes, rather than as a sum of sinusoids. The advantage is that it is very efficient for detecting frequency lines of stationary time series. The disadvantage is that for high number of autoregressive terms MEM often include spurious peaks. Due to the fact that we analyze RCs (with low noise) this is not a big problem. A comprehensive description of both methods, SSA and MEM, can be found in the review by Yiou *et al.* (1996).

4. Results

Figure 2 shows the accumulated values of hail intensity. From this series we cannot infer any clear oscillation without the help of powerful mathematical tools. That is why we use SSA to investigate the oscillatory component. SSA considers M lagged copies of a central time series sampled at equal intervals and calculates the eigenvalues and eigenvectors of their covariance matrix. By analogy with nomenclature from other climatic analysis the eigenvectors are usually called empirical orthogonal functions (EOFs) and the coefficients involved in the expansion of each lagged copy of the temporal series, principal components (PC).

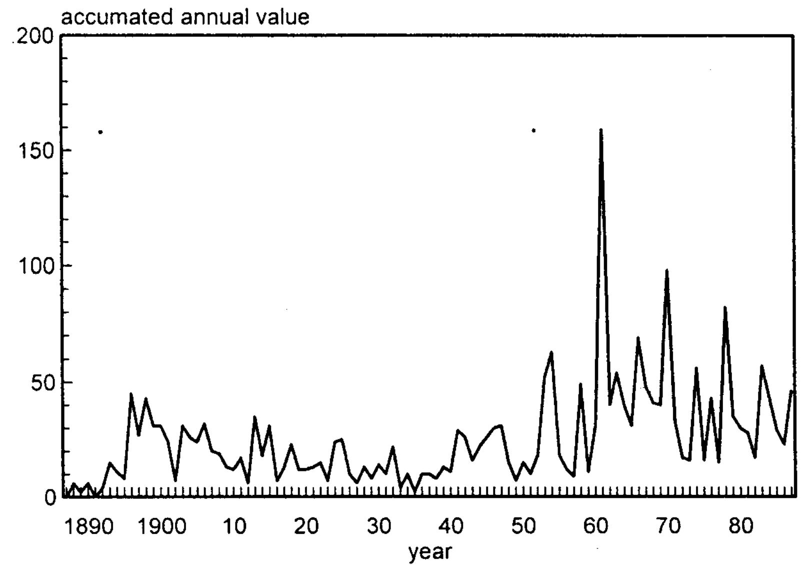

Fig. 2. Accumulated annual values of hail intensity from 1887 to 1987.

The first 4 eighenvalues account for 48.44% of the total variance. The first eigenvalues accounts for 26.8% of the variance and the following three together for 21.64% of the variance. The first reconstructed component PC1 (Fig. 3), represents a positive trend together with a very low frequency oscillation. To know the period of this oscillation, the power spectrum of the RC was calculated by the MEM. Results do not show

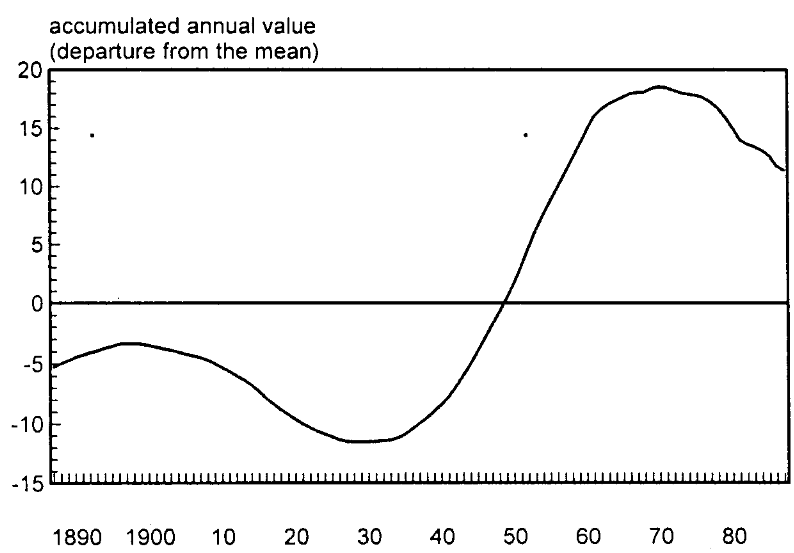

Fig. 3. Reconstructed series from the PC-1 (Trend plus very low frequency oscillation).

any significant oscillation before removing the trend, however after removal of the trend an oscillation with period of 72 years is obtained. This result is in agreement with the finding by Schlesinger and Ramankutty (1994) of an oscillation in the global system of low frequency when trend is removed.

The second reconstructed series using PC 2 (Fig. 4) represent an oscillation with period 20 years that is concordant with the bidecadal oscillation of the global surface temperature (Ghil and Vautard, 1991).

The decadal oscillation of the global surface temperature (Ghil and Vautard, 1991) of period about 9 years is also present in the intensity of hail-days by means of the PC 3. MEM of the reconstructed series (Fig. 5) revealed a period of 9 years.

Finally PC 4 represents an oscillation of period 4-5 years (Fig. 6) that is also related with an oscillation in the global temperature of period 4.8 years related to ENSO phenomenon (Ghil and Vautard, 1991).

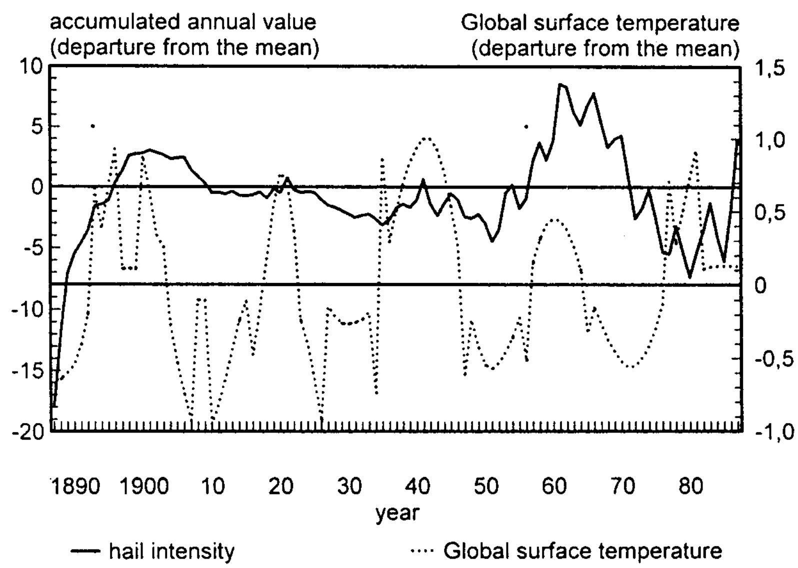

Fig. 4. Reconstructed series from the PC-2 (Decadal oscillation).

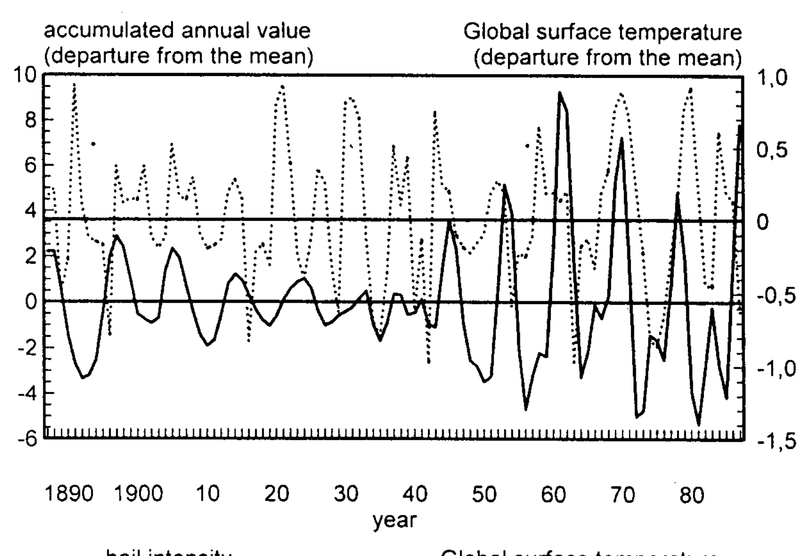

Fig. 5. Reconstructed series from the PC-3 (Bidecadal oscillation).

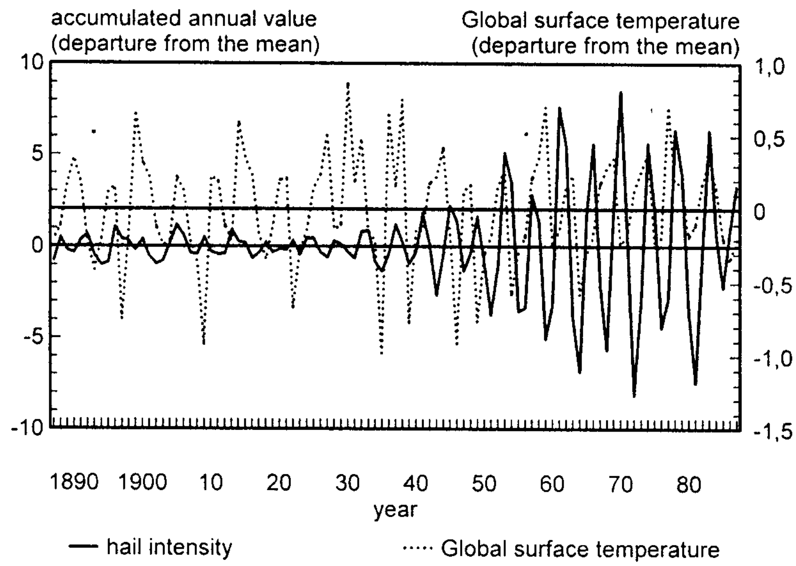

Fig. 6. Reconstructed series from the PC-4 (Interannual oscillation).

5. Concluding remarks

Two main remarks can be done from the present study. First, documental sources and the techniques employed to treat them are an excellent data bank to study interannual variability in the climate system and secondly, the oscillation of the global surface temperature are also present in other variables related to temperature such as convective activity and ways of precipitations related to it.

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