TRENDS IN WINTER TEMPERATURES IN THE SECOND HALF OF THE 16th CENTURY IN THE CENTRAL SYSTEM MOUNTAIN RANGE OF SPAIN

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I. INTRODUCTION

The final aim of this research is to contribute to the body of knowledge about climate prior to the instrumental era through the interpretation of mainly handwritten documents, which are kept in diverse archives.

To achieve these objectives, information about all kinds of news with meteorological significance was used (Table 1, Figures 1 and 2), found in the following types of documents: 1) public documents e.g. accords, agreements, orders or royal dispositions that contain references to natural events when they result in damage to goods or persons. 2) Private correspondence, especially personal letters, where spontaneous remarks about many circumstances, especially weather, are included. 3) Reports on the state of royal forests and game, usually addressed to the monarch, containing references to weather and environment, which was vital to the justification of problems that occurred or actions that were taken.

II. METHODOLOGY

To translate qualitative information to numerical amounts, points were given according to the following criteria:

1) Significance of the source. 2) Relationship between the meteorological event described and the geographic area where it occurred. 3) Explanation of what occurred, taking into account the meaning of what is described and how it is expressed. 4) Objective damage caused by or the main consequences of the meteorological event.

The series obtained, made by taking into account episodes indicating cold and mild temperatures, is called winter thermicity, with a positive number as the result of a year with a mild winter and a negative number for years with cold winters. Higher absolute numbers indicate more intensely cold or mild winters.

In order to compare the 1550-1590 WCI values with current winter values, the data from this series was transformed into anomalies with respect to a reference series. The method proposed by Brázdil et al. (2005) was used for the climate reconstruction of the data series based on documentary evidence.

The reference series used is the mean winter monthly temperature from 1961 to 1990 (INM, 1996) from the Puerto de Navacerrada observatory, located at an altitude of 1887 m, 40º 47´ 35" latitude and 04º 00´40" longitude, in the center of the area under study.

The transformation was performed by taking the following steps: 1) Prepare the series through the assignment of an ordinal index ranging from +4 and -4, which was applied to the winter thermicity series and to the reference series. 2) Convert the ordinal indices from the winter thermicity series into termperatures, based on the regression coefficients of the reference series, where Y= ordinal index and X= temperatures. 3) Verification with the 1952-1960 series from the reference station. 4) Obtain the series of historical anomalies.

Significant trends in the anomaly series were sought using the Mann-Kendall no parametric test (Sneyers, 1975) and the Student's t-test on average differences. The rate of change in winter temperatures was determined through linear regression models against time with an adjustment for minimum squared.

III. TEMPERATURE RECONSTRUCION

The series begins with some cold winters between 1550 and 1552 and continues with mild winters between 1553 and 1557. Cold temperatures progressively intensify, becoming especially intense in the first half of the decade of the 1570s. The last few years of the century show no significant cold events.

The transference equation to convert the indices as defined into temperatures was carried out through data described in Section II (Table 3). The adjustment of the series reconstructed at the reference average (-0.4 º C) provides the series of historical anomalies. Its annual distribution curve is shown in Figure 3. The average of the series of anomalies is 0.6 º C below the reference series and shows high interannual variability.

IV. INFLUENCES ON FOREST DEGRADATION

Data with information about this deterioration indicate the existence of excess often illegal logging as well as widespread impoverishment of timber mass, especially in the pine and oak forests in the northern sierra.

Deterioration in forest mass increased as of the second half of the 80s, after an accumulation of numerous years of cold temperatures. Although forest mass deterioration could also be caused by periods of drought or specific forest mass destruction due to extreme precipitation, to date, no clear connection has been established between those events and forest deterioration.

VI. CONCLUSIONS

The comparison of winter temperature data with a current reference series (1961-1990) made it possible to define a drop of temperatures which occurred between 1550 and 1599 and to determine the internal variability of that time period. Although both series include events of high cold intensity, what differentiates the series of anomalies from the reference series is the concentration of high intensity events in a limited number of consecutive years. According to available data from 1564 to 1587, temperatures dropped > -1 º C with respect to the reference series average.

The series of anomalies are subdivided into these groups of years: 1550-1563, 1564-1575, and 1588-1599. The decrease in temperatures that occurred between 1564 and 1587 was preceded by several years of winters that were alternately mild and cold (1550-1563), and followed by several years of contained thermal decreases (1588-1599).

The decrease in winter temperatures described is considered to be the primary cause of the deterioration of the forests reflected in the documents consulted, although the potential influence of periods of drought should also be assessed. The drop in temperatures may have affected the organization and structure of plant communities.

This work proves that a cold climate crisis existed. Its main phase with a severe drop in temperatures took place between 1564 and 1587, continuing with decreasing intensity until the late 16th century. According to various publications consulted, this crisis corresponded to the Little Ice Age. Although this cold oscillation has not been completely defined chronologically in Spain, the data presented in this article may help to identify its time period as well as the characteristics of the thermal decrease it caused and the spatial distribution of its effects.