EVOLUTION OF HYDRIC EXTREMES IN CATALUNYA DURING THE LAST 500 YEARS AND ITS REGIONAL MODELLING

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Abstract

The aim of the present thesis is to characterise the evolution of hydric extremes (floods and droughts) and the precipitation in Catalonia (NE Spain) for a period as longer as possible. This makes possible to provide a reference level for natural variability and to contextualise the current situation (last 30 years). The global warming due to the increase on GHGs will produce the hydrological cycle, precipitation and hydric extreme occurrence to change. The Mediterranean region will be one of the world most affected areas (IPCC, 2007). Some studies state the precipitation is decreasing in a great part of the Iberian peninsula, overall in the South and the Mediterranean zone (Esteban-Parra *et al.*, 1998; Romero *et al*., 1998; Alpert *et al.*, 2002; Goodess y Jones, 2002), but almost these studies are based on very short temporal series or a little number of them. There are also dynamical arguments to suppose a decrease on precipitation for all subtropical zones during the following decades, including the Mediterranean area (IPCC, 2007).

In this dissertation, the evolution of hydric extremes (basically floods) in Catalonia (1301–2005) have been analysed from different kinds of information: historical information providing from documentary sources, old instrumental series and meteorological models. The possible relationship between floods and precipitation with NAO, the relationship between floods and precipitation, as well as the weather types (SLP patterns) producing floods for historical periods of high occurrence on extreme events have been also analysed. Finally the results from recent (last 30 years) and past (last 500 years) regional simulations of precipitation and hydric extreme are presented.

The historical used information is formed by twelve flood chronologies with EXT floods (overflowing with light damages or without them) and CAT ones (overflowing with high damages or total destruction) for the 1301–2005 period. The series of hydric indices (combination of floods and pro pluvia rogation ceremonies) for Barcelona City during the 1521–1850 period is the other kind of documentary used data. The old instrumental information is formed by fourteen European daily pressure series for the 1780 1880 period and the precipitation series of Barcelona City (monthly resolution for 1786 2005 and daily for 1854 2005). Other precipitation series from AEMET during the period 1898 1998 (106 series) covering all Spain have been also used for having a wider spatially precipitation analysis during the 20th century using regional series (areal precipitation). The MM5 (limited-area model) is the meteorological model used for developing regionalised simulations. The simulations have been nesting and nudging to ERA40 Reanalyses

from ECMWF, as well as to ECHO-G climatic model, for different periods and resolutions: 1971–2000 (135–45–15 *km*) for the reanalyses (ERA40) and 1502–1989 (135–45 *km*) for the climatic model (ECHO-G).

The analysis of all used data and information allows to conclude the current observed variability (last 30 years: ~ 1981–2005), as well as during the 20th century, is not distinguishable respect to past anomalous periods in which there was a higher variability (high occurrence of floods and droughts). Nor it is stood out when analysing long pluviometric series from Catalonia and the rest of Spain. Concerning trends on hydric extremes, the difficulty on its analysis have to be commented, due to it is easy to confuse between increase on occurrence and increase on vulnerability. No statistical significant trend has been found for CAT floods. These floods are produced by the most extreme precipitation events, therefore they are not highly influenced by changes on vulnerability. However, the EXT floods present a significant increase, approximately placed during the last 150 years (~ 1850–2005), although this increase is greatly due to the increasing vulnerability of the zone by the occupation of flooding areas.

The analysed regional precipitation series do not show an important statistical significant long-term trend. In addition, the observed trends are very highly dependent on the length series and studied period. The observed trends can change its sign. Statistically significant trends are only found for spring in the CS region (–0,51 $mm \cdot yr^{-1}$) and for summer in BAL region (–0,28 $mm \cdot yr^{-1}$). The highest annual trend is observed for the NW region with a statistically significant increase on precipitation of +1,50 $mm \cdot yr^{-1}$. On the other hand, the only significant recent trend is a decrease on precipitation of −4.0 $mm \cdot yr^{-1}$ during the 1968–1997 period from the areal annual-mean precipitation series for the NE region of Iberian Peninsula (although it is comparable with prior short-term trend). Catalonia is located in this zone, however the long Barcelona City precipitation series (1786–2005) does not show any trend. Nor it is presented in the evolution of extreme precipitation for Barcelona City (1854–2005). It is only significant an increase on the total rainy days with appreciable precipitation (≥ 0.1 *mm*) linked to an increase on the light rainy days (≤ 1 *mm*).

Regarding the relationship between precipitation and floods, the comparison developed between floods recorded in Barcelona City and its daily precipitation series has shown the value of 50 *mm* as the daily precipitation threshold from which floods can take place. In addition this urban station shows the possibility of studying how the changes on vulnerability (occupation of flooding areas, improvements on drainage system...) influence on the change on flood frequency and overall on flash floods one. EXT floods as well as flash ones experimented an important increase at the middle of 19th century coinciding with the demolition of walls, which protected the city, and the occupation of flooding areas. These facts coincided with a flood increase in all Catalonia. However, the CAT floods do not show any trend and point towards a decrease during the last years thanks to the improvements on the city drainage system.

The relationship between NAO and areal precipitation during the 1898–1998 period for all Spain presents a variable correlation depending on seasons. The highest values are recorded in winter, with −0.7 for the CS region of Iberian peninsula and values below −0.5 in the NE, LEV and CN

regions of Spain. It is important to notice the NAO-precipitation correlation is not stationary within the 1898–1998 period with the highest values recorded on the last 30 years of considered series. The correlations obtained for this study are higher than the ones obtained by others authors. On the other side, the relationship between floods and circulation indices, like NAO, shows a light correlation. Therefore, it is ruled out a direct relationship between both variables. It is also light the relationship between floods and solar activity in Catalonia.

Concerning the weather types producing floods for an anomalous period, with high flood occurrence (1840–1870), we conclude these ones are similar to those identified during the 20th century by other authors, but its distribution within the year is different: an increase on floods recorded during spring. This last fact would be related to a major influence of snow melting (End of LIA). In addition, this period presents a greater percentage of CAT floods respect the actual period (1971–2000), with a percentage of 52% in front of current 18%. It is also shown a high occurrence of the weather type related to the synoptic situation which produces the heaviest precipitation and CAT floods in Catalonia (southern wind flux). Regarding atmospherical circulation during the 1840–1870 period, it seems not to have any significant anomaly which could explain the high flood occurrence, although the meridional circulation was predominant during this period.

The developed climatic simulations nesting and nudging the MM5 mesoscale model boundary conditions from a GCM (dynamical downscaling) have shown the importance of integration domain spatial resolution to reproduce the spatial distribution in Catalonia. Overall, it is important to reproduce the pluviometric maximum observed in the NE of the region. However, no differences are observed between resolutions when analysing precipitation temporal evolution. They have also shown as a good tool to reproduce the spatial precipitation patterns (annual, semi-annual, spring and summer), mean annual anomaly evolution as well as the evolution of extreme precipitation derived variables (number of days with precipitation > 50 *mm*) compared to the CAT flood evolution in Catalonia. The MM5 simulation nested and nudged to ERA40 Reanalyses boundary conditions (1971–2000) also allows to define weather types related to meteorological events producing floods that are consistent with those obtained from ERA40 (observed conditions). The MM5 simulation nested and nudged to ECHO-G atmosphere-ocean coupled model (1502–1989) produces a reliable multidecadal variability range in comparison with the observed one (areal precipitation for NE Iberian peninsula and Barcelona precipitation) for the last 100–200 years of the studied period. There is also an agreement between the evolution of simulated and observed (areal precipitation en Spain) values during 1898–1989 the period. This simulation also reproduces the CAT flood evolution from the end of the 16th century to the beginning of the 18th century. Due to this study it is necessary to develop a no forced simulation of climate to find whether the multidecadal internal variability within the model is essentially different (frequency and intensity) without forcings. Nesting and nudging MM5 to boundary conditions from a GCM will be a good tool to develop past or future regionalised climatic scenarios for all the prior commented variables. However, the seasonal and annual mean precipitation cycles, as well as the mean precipitation spatial distribution for winter and autumn, are not well reproduced by the simulation. Thus, the presented tool will be not useful to develop regionalised climatic scenarios.

Finally, in this thesis can been able to conclude the possible changes in precipitation due to the increase on GHGs have not been yet produced in Catalonia and the rest of Spain. This statement is possible to make due to an exhaustive analysis developed with hydric extreme and precipitation temporal series with a high temporal extension, higher than the great part of prior developed studies.