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SPATIAL AND TEMPORAL ANALYSIS OF PRECIPITATION VARIABILITY IN THE SPANISH SECTOR OF DUERO BASIN (1961-2005)

Antonio Ceballos Barbancho
Departamento de Geografía, Universidad de Salamanca
ceballos@usal.es
Enrique Morán Tejeda
Juan Ignacio López Moreno
Instituto Pirenaico de Ecología, CSIC (Zaragoza)

Precipitation in Mediterranean areas has been historically characterized by high inter- and intra-annual variability. In a context of global warming, with more energy available in the atmosphere, it is likely that variability will enhance, giving to more frequent extreme events such as droughts and floods. Moreover, a redistribution of precipitation quantities across the globe is expected, with a projected decrease in precipitation for the Mediterranean countries. However, when studying recent trends in precipitation with observed data, not a robust signal towards more or less precipitation has been observed for these areas. Studies using high-quality climatic databases are necessary in order to understand with detail the spatial patterns of precipitation, and checking whether observed trends are spatially consistent. In this context, this works aims to analyze the trends in time of monthly and annual precipitation records in the Spanish sector of the Duero basin for the period 1961-2005. Moreover we seek to identify the spatial patterns of observed trends through the use of interpolation techniques over a dense network of precipitation series. The selection of a river basin to carry out this study enables further comparison between the evolution of precipitation and river flows.

The Duero basin is located in the north of the Iberian Peninsula, and drains water from a vast region (97,290 km^2) in Spain (81%) and Portugal (19%). The focus of this study was the Spanish part of the basin. The majority of the area comprises a large depression that is filled with Tertiary and Quaternary sediments and it is surrounded by various mountain systems with altitudes exceeding 2500 m surround the basin. Despite the large influence of Atlantic Ocean air masses, the dominant climatic conditions are Mediterranean, which are characterized by dry and hot summers. In addition, continental characteristics (large thermal oscillations) are evident in the central and southern sectors of the basin, and sub-Atlantic (more humid and temperate) characteristics are typical of the northern part.

Monthly precipitation data from 214 weather stations covering the period 1961-2005 were used for the analyses. The database was previously subjected to a strict procedure of data quality control, including correction of inhomogeneities, outliers, and filling of data gaps. Standard and widely accepted statistical procedures, including homogeneity tests, and liner regressions were used for this purpose. The high spatial density of weather stations used allowed us to spatially interpolate precipitation data and obtaining distributed maps. The interpolation technique was based on multiple regressions with geographical variables, including altitude, latitude and longitude, as independent variables, and precipitation as the dependent variable. The resulting maps allowed better interpretation of results in terms of spatial particularities, compared to maps with local information based on the location of weather stations. For detecting change in the precipitation records we plotted the series against time and calculated a moving-average of 5 years that enabled visualization of cycles. However, for a robust characterization of change in time a trend analysis was performed, using the Mann-Kendall test. The power of this non-parametric for detecting monotonic trends has been widely tested. The resulting *tau* coefficient and its statistical significance allowed us to identify trends in the precipitation series.

The interpolation of precipitation in space resulted in monthly and annual maps showing a distribution of precipitation highly dependent on topography, and in a lesser extent, in longitude and latitude. Thus, the higher values of precipitation are found in the mountainous areas, and in the north-west sector of the basin, while the inlands record the driest conditions. Moreover, a northwest-southeast gradient is observed for temporal variability of precipitation. These two features clearly indicate a trend towards Atlantic conditions in the northwest sector, and more Mediterranean conditions in the central and south-eastern parts of the basin. The intra-annual distribution of precipitation shows a great seasonality with a marked dry period from June to September, and moister conditions in winter, early spring and late autumn. These mean conditions are however subject to spatial differences, given the aforementioned gradients.

Results of the trend analyses show, above all, that precipitation in the Duero basin did not exhibit significant decrease or increase during the studied period. In the inter-annual basis, precipitation shows a high variable evolution, with a constant succession of dry and wet years. The moving-average technique allowed identifying cycles of increasing and decreasing precipitation, but in the long-term no statistically significant trend was observed. In the monthly basis, only precipitation in February showed a significant decreasing trend. This was more pronounced in the western half of the basin, indicating a likely decrease in the entrance of moist air masses from the Atlantic, which are responsible for precipitation in winter months. In contrast, precipitation in August and, in a lesser extent, October, displayed increasing trends across the territory. The aggregated results in a seasonally basis indicate that winter exhibited a slight tendency towards less precipitation, in autumn negative (although not significant) coefficients predominated, and spring and summer did not exhibit trends. A slight difference is observed in the spatial distribution of Mann-Kendall coefficients, with positive coefficients in the northern half of the basin, and dominantly negative coefficients in the southern half. However, the overall computation of trends showed that annual precipitation did not experienced significant trends during the studied period.

The results obtained in the Duero basin are in agreement with observations from other works that studied the same territory but at different spatial scale, and similar time periods. The most recent results of precipitation analyses in the Iberian Peninsula confirm the spatial variability of trends and the difficulty to find a homogeneous pattern of change for the whole territory. The absence of clear signals of change is in disagreement with most projection for future decades, which forecast dryer conditions in southern Europe as a consequence of global warming. For the Iberian Peninsula, however, it seems that this scenario is more likely to occur in the eastern half, where the Mediterranean conditions predominate. On the contrary projections for the Atlantic areas are subject to larger uncertainties. These observations highlight the need to take with cautions projections at large scales, as it is the case of water availability forecasts. For example, most projections forecast a decrease in water availability in southern Europe taking into account only likely evolution of precipitation. However, it has been demonstrated that the decrease of rivers flows in the Iberian Peninsula in recent decades is more related to other processes such as land-cover/forest growth.

To summarize, in this work we have demonstrated: i) a notable variability of precipitation in space and in the seasonal and inter-annual basis in the Duero basin; ii) the temporal trends in monthly and annual series, if existing, are not significant from the statistical point of view; iii) the distribution of trends in annual precipitation show a slight spatial pattern with positive coefficients in the north of the basin and negative coefficients in the south; iv) only the precipitation in February shows a significant (negative) trend in most of the territory. At the moment this scenario does not match with the previsions of decreasing precipitation for the 21st century.

This kind of results should encourage researchers to continue analyzing the behavior of precipitation in next decades to confirm the existence of trends and the suitability of projected evolution of precipitation.