Observed atmospheric trends in the Iberian Peninsula

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State of the Art

Bladé and Castro-Diez (2010) provided a comprehensive review on climate trends in the Iberian Peninsula during the instrumental period, with a special focus on precipitation and air temperature. According to that review, Spain witnessed a general air temperature increase during the 20th century. That increase was more pronounced during the last decades of the 20th century, a finding that is consistent with other regions of Europe. The review of Bladé and Castro-Diez (2010) indicated a strong spatial, seasonal and inter-annual variability of precipitation over Spain, with a general negative trend between 1960 and 2010. Nevertheless, the authors did not include any updates on variability and changes of other essential atmospheric variables (e.g. relative humidity, wind speed, drought and atmospheric evaporative demand). Vicente-Serrano et al. (2017) published an update revision of the recent peer-reviewed articles that analysed changes in temperature and precipitation but also in solar radiation, near-surface wind speed, surface humidity and evapotranspiration. This article presents a summary of that study.

Changes in solar radiation

Sánchez-Lorenzo et al. (2013) showed a significant upward trend between 1985 and 2010 on the order of 3.9 $Wm^{-2} decade^{-1}$. Similar significant increases were observed in the mean seasonal series, with the highest rate of increase during summer (6.5 $Wm^{-2} decade^{-1}$) (Figure 1). Mateos et al. (2014) quantified the contribution of clouds and aerosols to "brightening" processes in Spain, indicating that clouds are the key factor responsible for explaining "brightening" trends, as they explain approximately 75% of the solar radiation changes.

Air temperature change

Del Río et al. (2011) analysed the evolution of mean air temperature using 473 meteorological stations between 1961 and 2006, and showed dominant positive trends, mainly in spring and summer months, suggesting an annual increase between 0.1 and 0.2°C $decade^{-1}$, which was statistically significant in the entire peninsular Spain. Del Río et al. (2012) analysed the evolution of maximum and minimum air temperatures for the same period and found an identical rate of increase (0.3°C $decade^{-1}$) for maximum and minimum temperatures, particularly in summer and spring months. The average of increase in maximum temperature was 0.37°C and 0.43°C $decade^{-1}$ during summer and spring, respectively. For minimum temperature, the warming rate was 0.34°C (summer) and 0.41°C $decade^{-1}$ (spring). Gonzalez-Hidalgo et al. (2015a; b)

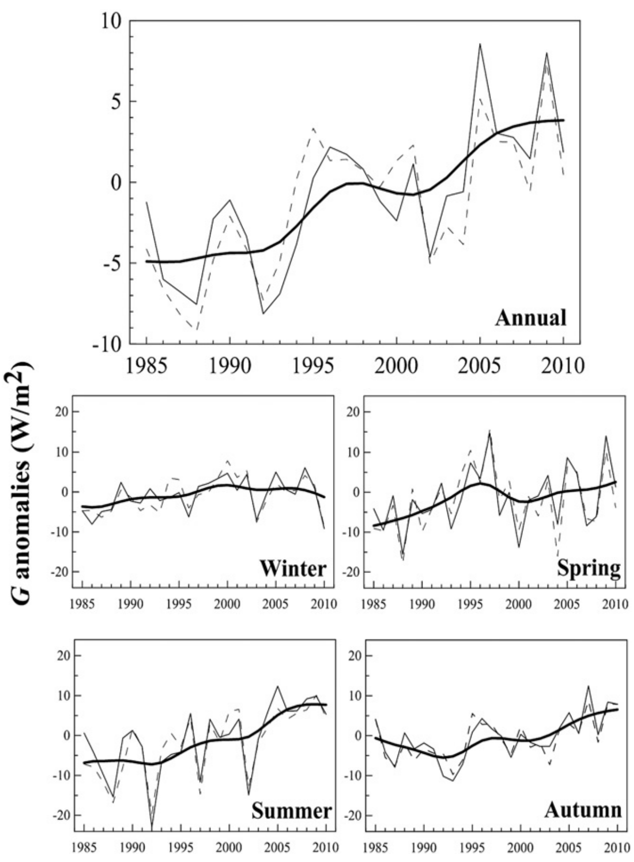

Figure 1: Mean annual and seasonal global radiation series (thin line) from 1985 to 2010 from the network of stations in Spain, plotted together with a 13-year Gaussian low-pass filter (thick line). The series are expressed as anomalies from the 1991–2010 mean. Dashed lines show the mean global radiation series obtained using the subset of 5 stations with collocated diffuse radiation records (From Sánchez-Lorenzo et al., 2013)

showed that maximum temperature has risen in late winter/early spring and summer, while minimum temperature has increased in summer, spring and autumn, especially in southern regions of Spain. Moreover, they showed that trends in the daily temperature range had a clear north–south gradient during summer, with positive trends in the north and negative trends in the south. The overall signal in maximum temperature showed a positive trend over more than 75% of land, and the strongest signal was detected in June, in which 87% of land exhibited a statistically significant positive trend (Figure 2).

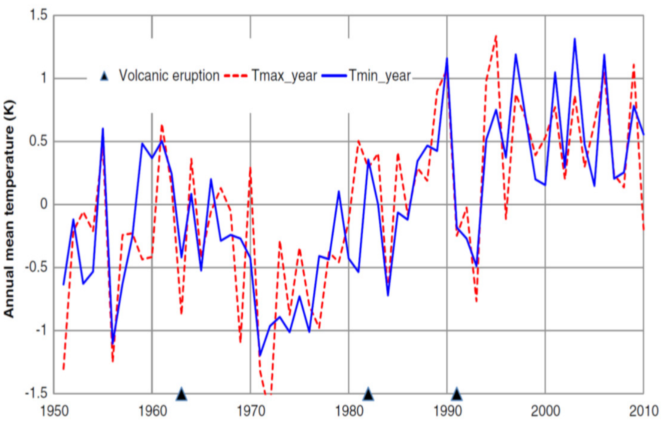

Figure 2: Annual mean of Tmax and Tmin value (1951–2010). Anomalies to base line period 1951–2010. Red line: Tmax; blue line: Tmin; triangles: volcanic eruptions (From González-Hidalgo et al., 2015b)

Regarding changes in daily temperatures over Spain, Rodríguez-Puebla et al. (2010) analysed changes in warm days and cold nights and indicated that warm days increased by 1.1% of decade^{-1} on average, while cold nights exhibited a decrease on the order of -1.3% decade^{-1}. The increase in the frequency of warm temperature extremes was continuous during the past two decades. Sánchez-Lorenzo et al. (2012) confirmed that the average frequency of tropical nights showed a continuous increase since the beginning of the 1970s, with the most extreme values recorded during the 2000s.

Changes in surface winds

Azorín-Molina et al. (2014) showed a generally slight downward trend for the period 1961–2011 (-0.016 ms^{-1} decade^{-1}). However, they found seasonal differences, with a declining trend in winter and spring and an increasing trend in summer and autumn. Over Spain, wind “stilling” affected almost 77.8% of the stations in winter and 66.7% in spring. Nonetheless, roughly 40% of the declining trends were statistically significant. On the contrary, increasing tendency appeared in 51.9% of the stations in summer and 57.4% in autumn.

Changes in surface humidity

Vicente-Serrano et al. (2014) showed a large decrease in relative humidity over mainland Spain from 1961 to 2011, which was more pronounced in spring and summer (-1.02% and -1.56% decade-1, respectively). On average, the decrease was on the order of -5.1% at the annual scale between 1961 and 2011. In contrast, there was no overall change in the specific humidity in this period, except in spring that exhibited an increase (Figure 3).

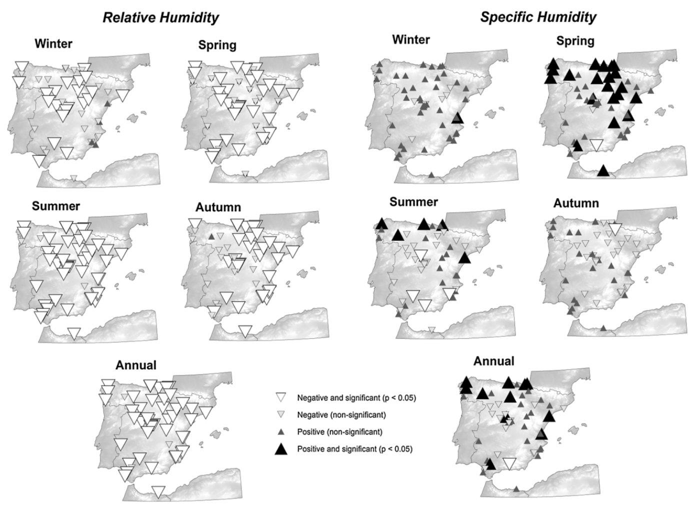

Figure 3: Spatial distribution of seasonal and annual trends in relative and specific humidity in Spain (1961–2011) (From Vicente-Serrano et al., 2014)

Changes in precipitation

González-Hidalgo et al. (2011) showed that monthly precipitation trends have high monthly variability, with coherent spatial trend patterns in March, June (both with a general and significant negative trend) and October (general positive trends). More localized trend patterns were noted in July, February and April. Del Río et al. (2011b) revealed a decrease in rainfall in more than 28% of the Spanish territory during summer and winter between 1961 and 2006. Although regional patterns of rainfall changes are complex, regional series over the whole Spain showed a precipitation decrease in winter and at the annual scale (Rodríguez-Puebla and Nieto, 2010; Vicente-Serrano et al., 2014). Gallego et al. (2011) analysed trends in frequency indices of daily precipitation during the last century (1903–2003), using data from 27 stations in Portugal and Spain, and found that the total number of rainy days and light (≥0.2 and <0.25 mm) rainfall increased at many observatories over the Iberian Peninsula for all seasons. Acero et al. (2011) who used a peaks-over-threshold approach showed that for a 2-yr return period yielded a large proportion of negative trends for the considered seasons: 58% for winter, 63% for spring, and 69% for autumn. Nevertheless, the parametric approach also revealed an increase in the area with positive trends for a 20-yr return level, relative to a 2-yr return period. This feature could give indications on certain increase of intense precipitation events. On the contrary, Rodrigo (2010) showed that the trend of the probability of daily rainfall less than the 5th percentile is positive but in contrast, the probability of daily rainfall higher than the 95th percentile is negative, which would suggest a decrease of rainfall intensity during this period.

The atmospheric evaporative demand (AED)

Vicente-Serrano et al. (2014b) found a strong increase (24.4 mm decade^{-1}) in the magnitude of AED at the annual scale across Spain, with the main increase in summer (12 mm decade^{-1}). This increase was mainly explained by the decrease in relative humidity and the increase in maximum temperature since the 1960s, particularly during summer months.

Concluding remarks

Although recent climate trends are determined by the used datasets and mostly the selected periods for analysis, it is possible to draw some concluding remarks for the different variables:

1. there is a strong solar radiation increase from the 1980s;
2. temperatures showed strong increases (around +0.3°C decade^{-1}) since the 1960s, which were stronger in summer months;
3. there are no noticeable changes in surface wind speed, with a slight downward trend recorded but not statistically significant;
4. strong decrease in relative humidity was recorded (-5% between 1961 and 2011). In contrast, no changes in absolute humidity were identified;
5. there is a strong spatial and seasonal variability in precipitation trends, maybe in relation with change in atmospheric teleconnections and the influence of ENSO (see Rodriguez et al., this issue), although average annual precipitation over Spain showed a moderate decrease in the past five decades;
6. the atmospheric evaporative demand increased in the past five decades (+24.4 mm decade^{-1}), mainly in summer months. Overall, the recent climate trends observed for Spain clearly suggest a warmer and drier scenario in comparison to past decades. This finding is compatible with observations in other Mediterranean areas, where there is a tendency toward a climate scenario characterized by lower water availability (García-Ruiz et al., 2011).

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