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Spatial analysis of mean temperature trends in Spain over the period 1961–2006

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ABSTRACT

The spatial distribution of recent mean temperature trends over Spain during the period 1961–2006 at monthly, seasonal and annual time scale is carried out in this study by applying various statistical tools to data from 473 weather stations. The magnitude of trends was derived from the slopes of the linear trends using ordinary least-square fitting. The non-parametric Mann–Kendall test was used to determine the statistical significance of trends. Maps of surface temperature trends were generated by applying a geostatistical interpolation technique to visualize the detected tendencies. This study reveals that temperature has generally increased during all months and seasons of the year over the last four decades. More than 60% of whole Spain has evidenced significant positive trends in March, June, August, spring and summer. This percentage diminishes around 40% in April, May and December. Annual temperature has significantly risen in 100% of Spain of around 0.1–0.2 °C/decade according to the Fourth Assessment Report of the IPCC.

1. Introduction

Climate change over the last century is a subject of great interest that worries the scientific community as it could have a major impact on natural and social systems at local, regional and natural scales. As outlined by the IPCC Fourth Assessment Report (AR4) (IPCC, 2007) the global warming of the climate system is unequivocal as is now evident from observations of increases in global average air temperature. AR4 points out that "the 100 year linear trend (1906–2005) of 0.74 [0.56 to 0.92] °C is larger than corresponding trend of 0.6 [0.4 to 0.8] °C (1901–200) given in the Third Assessment Report (TAR)". AR4 also indicates that a warming of about 0.2 °C/decade would be expected for the next two decades. During the period 1901–2005 the linear trend of Northern Hemisphere annual land temperatures ranges from 0.072 ± 0.0226 °C/decade to 0.089 ± 0.025 °C/decade (IPCC, 2007).

Analysis of global temperatures is very important although it is equally of interest to study climate variations at lower scales (Harvey and Mills, 2001). Several authors have carried out temperature trend analysis at different spatial scales, for instance: Schönwiese and Rapp (1997), Parry (2000), Klein Tank et al. (2002), Klein Tank and Können (2003), Klein Tank et al. (2005), Luterbacher et al. (2004), and Moberg et al. (2006) for all Europe or Brunetti et al. (2000, 2004, 2006), Toreti and Desiato (2008), and Toreti et al. (2010) in Italy; Degirmendžić et al. (2004) in Poland; Rebetez and Reinhard (2008) in Switzerland; Wulfmeyer and Henning-Müller (2006) in Germany; Chaouche et al. (2010) in France; and Feidas et al. (2004) in Greece. Although there are local and regional differences most of Europe has experienced rising temperatures of about 0.8 °C during the 20th century (IPCC, 2001) showing similar patterns to the global or a hemispheric scale.

Many studies have focused on Spanish temperature over the last fifteen years at national, regional or local level: Esteban-Parra et al. (1995) in the northern Spanish Plateau; Brunet et al. (2001a), Serra et al. (2001), Sáenz et al. (2001), Sigró (2004), Cruz and Lage (2006), Salat and Pascual (2006) and Martínez et al. (2010) in the north of Spain; Morales et al. (2005) and del Río et al. (2005, 2007, 2009) in Castile and León; Piñol et al. (1998), Kutiel and Maheras (1998), Pausas (2004), Miró et al. (2006) and Capilla (2008) in eastern Spain; Galán et al. (2001) in the southern Plateau; Esteban-Parra et al. (1997), Castro-Díez et al. (2007) and Ordoñez (2008) in Andalusia; Homar et al. (2010) in the Balearic Islands or Oñate and Pou (1996); Parry (2000), Xoplaki et al. (2003, 2006), Prieto et al. (2004), Brunet et al. (2001b, 2005, 2006, 2007, 2009), Ileana and Castro-Díez. (2010) and Camuffo et al. (2010) for whole country. Although it is difficult to generalize the results reported by these authors, most of them coincide on the increase in temperature over the last decades.

Studies of spatial distribution of temperatures can be improved by using interpolation techniques which are commonly applied in Geographical Information Systems (GIS). One of the main objectives of using GIS in climatology is the construction of maps for highlighting spatial properties of climate data (Esteban et al., 2009). Different interpolation methods have been used to model the spatial distribution of temperature such us: inverse distance weighting, regression analysis, splines, kriging, polynomial interpolation, etc. Nevertheless

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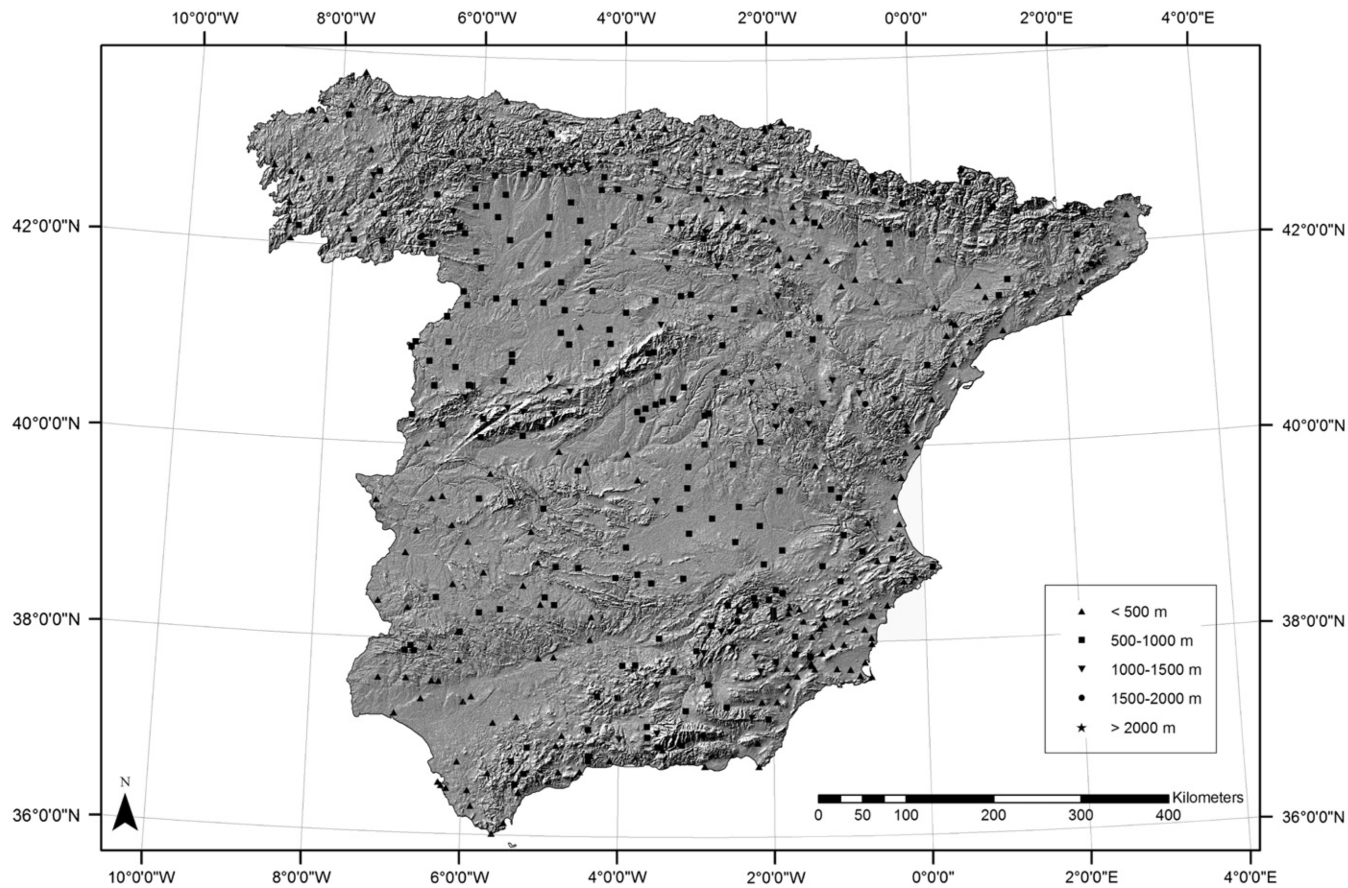


Fig. 1. Location of the meteorological stations in the study area grouped into five altitudinal ranges and digital terrain model (DTM) of Spain.

Collins and Bolstad (1996) pointed out that a regionalized variable such as temperature would be well disposed to kriging and cokriging. Kriging is a geostatistical method that uses known values and a semivariogram to predict the values at some unmeasured locations (Johnston et al., 2001). Many authors in the last fifteen years has preferred kriging as an interpolation technique for temperature data from all over the world (Courault and Monestiez, 1999; Sheikhhasan, 2006; Gómez et al., 2008; Irmak and Ranade, 2008; Cao et al., 2009; Tewolde et al., 2010. In Spain, this could be mentioned in the studies of Ninyerola et al. (2000), Vicente-Serrano et al. (2003), Almarza and Luna (2005), Luna et al. (2006), Attorre et al., 2007), and Benavides et al. (2007).

The aim of the present research is to contribute to the knowledge of the behavior of the mean temperature trends (sign and magnitude) occurred in Spain over the last decades on monthly, seasonal and annual resolution.

2. Study area

The study area comprises the continental Spain located in the southwest of Europe at 36°–44° N and between 10° W and 3° E. It spreads over 493,892 km^2 and occupies around 84% of the Iberian Peninsula. The major mountain systems distributed from west to east and starting from the north are: the Cantabrian Mountains (across northern Spain), Pyrenees (natural frontier with France), Central System, Iberian System (which extends from the eastern foothills of the Cantabrian Mountains to Betic System) and the previously mentioned Betic system (along the southern and eastern parts of Spain).

Table 1
Altitudinal ranges existing in the study area and number of meteorological stations included in each one.

	No. stations
<500 m	198
500–1000 m	202
1000–1500 m	59
1500–2000 m	13
>2000 m	1

Its location and the complex orography of the Iberian Peninsula determine a high variability in spatial distribution of temperature (Font Tullot, 2000) and make it particularly interesting from a climatic point of view (Ileana and Castro-Díez, 2010). The coldest month in the year is January while the hottest month is usually August in the Cantabrian coast, the Mediterranean and the Gulf of Cádiz (Capel, 2000). The Central Plateau and the Ebro and Guadalquivir depressions reach the highest temperature in July. The average annual temperature decreases from south to the north and from the coast towards inland (Capel, 1998). It is noteworthy that there is a difference of about 4 °C between northern and southern coast and of about 2 °C between the two plateaus (Font Tullot, 2000).

3. Data set and methods

3.1. Data set

Monthly mean temperature data records from 1961 to 2006 were analyzed in this study. The temperature series were at first collected from 478 Spanish weather stations provided by the Spanish Meteorological Agency. The selection of stations was carried out based on the homogeneity, length and completeness of records so that

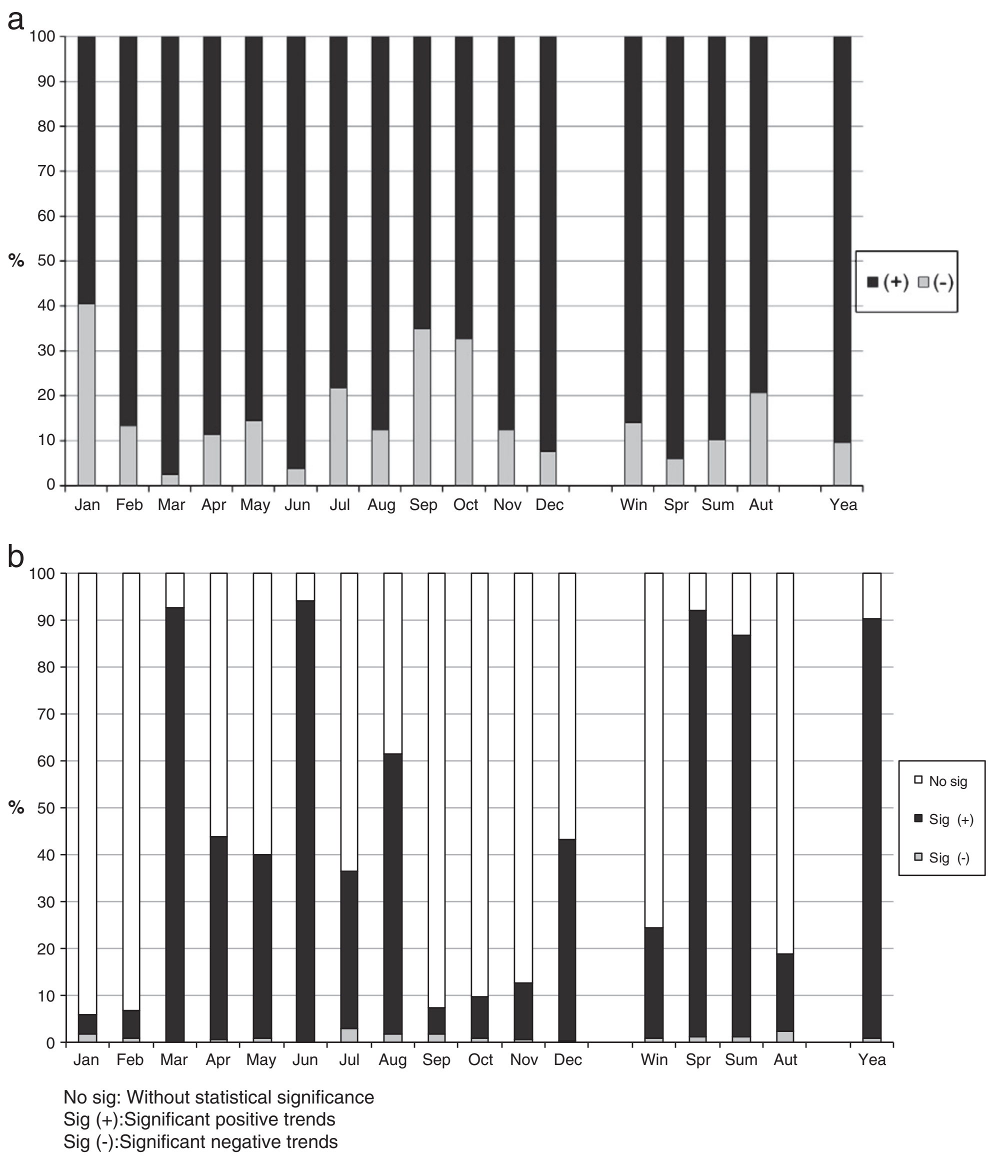


Fig. 2. a) Percentage of meteorological stations with positive and negative trends. b) Percentage of meteorological stations with significant positive and negative trends (95% confidence level).

most of the country was covered by the corresponding data. There were only selected weather stations with less than 3% of missing values in relation to the total data of the station for the whole study period. Missing data were substituted with the corresponding monthly value (Rodríguez-Puebla et al., 1998; Muñoz-Díaz and Rodrigo, 2006).

Seasonal and annual series were calculated for each station. Seasons were considered as follows: winter = December, January, and February; spring = March, April, and May; summer = June, July, and August; and autumn = September, October, and November.

The homogeneity of data was assessed to each of the weather stations using the Kruskal–Wallis test (Essenwanger, 1986) and Friedman and Kendall's tests. The homogeneity was not guaranteed by applying these tests for 5 stations. A total of 473 series were finally selected to carry out the later analysis which means that we worked with temperature data from station site every 1044 km^2 (Fig. 1). It represents, on average, a circle with a radius of approximately 32.3 km. The trustworthiness of the results is then guaranteed by the high density of weather stations over the study area.

Table 1 shows the meteorological stations included in each five altitudinal ranges delimited in the study area.

3.2. Methods

Trend analysis at monthly, seasonal and annual temporal resolution was carried out by applying linear and non-parametric models to each of the 473 temperature series. Yu and Neil (1993), Suppiah and Hennessy (1996) and Rodrigo and Trigo (2007) have pointed out that more information may be obtained from the combination of these techniques.

The slope of the regression line using the least squares method was used to obtain the magnitude of trends. These slopes were also utilized to generate the spatial distribution maps of temperature trends. The MAKESENS Microsoft Excel template developed by the Finnish Meteorological Institute (Salmi et al., 2002) was used to calculate the statistical significance of the tendencies. This software uses the non-parametric Mann–Kendall test (Sneyers, 1992).

Surface temperature maps were generated using geostatistical techniques. A previous exploratory data analysis was carried out in order to select the optimum geostatistical model. Firstly three interpolation techniques ordinary kriging, splines and cokriging were considered for that analysis. Nevertheless the cross-validation results revealed that ordinary kriging was the method that provided us the best results for the interpolation of our data. For a model that provides accurate predictions, the statistics of cross-validation should be as follows: the mean error should be close to 0, the root mean-square-error and average standard error should be as small as possible, and the root-mean-square standardized error should be close to 1 (Johnston et al., 2001). The spherical model was selected as the best function for modeling the empirical semivariogram in January, February, April, May, October, November, December, winter, summer, autumn and in annual time scale once the geostatistical analysis was carried out. The exponential model fitted well for the remaining months and seasons in the year. Anisotropy was considered in March, April, May, June, July, August, September, winter and spring.

ArcGis© 9.3 software was employed to generate temperature trend contour maps. Areas with significant trends at a confidence level of 95% were also superimposed on the contour maps.

4. Results and discussion

Fig. 2a and b shows respectively percentages of weather stations with positive and negative trends and their statistical significance at monthly, seasonal and annual timescales from 1961 to 2006. Fig. 3 illustrates the spatial distribution of temperature trends in the study period using ordinary kriging as interpolation technique. Percentages of the total territory with significant trends are represented in Fig. 4.

Figs. 2 and 3 show that positive trends have clearly prevailed against negative tendencies in Spain in the study period. This result points out that temperature in Spain is increasing over the last four decades.

At monthly resolution and taking into account the winter months, January and February have shown the lowest percentage of stations with positive significant trends (<7%). These stations have been mainly

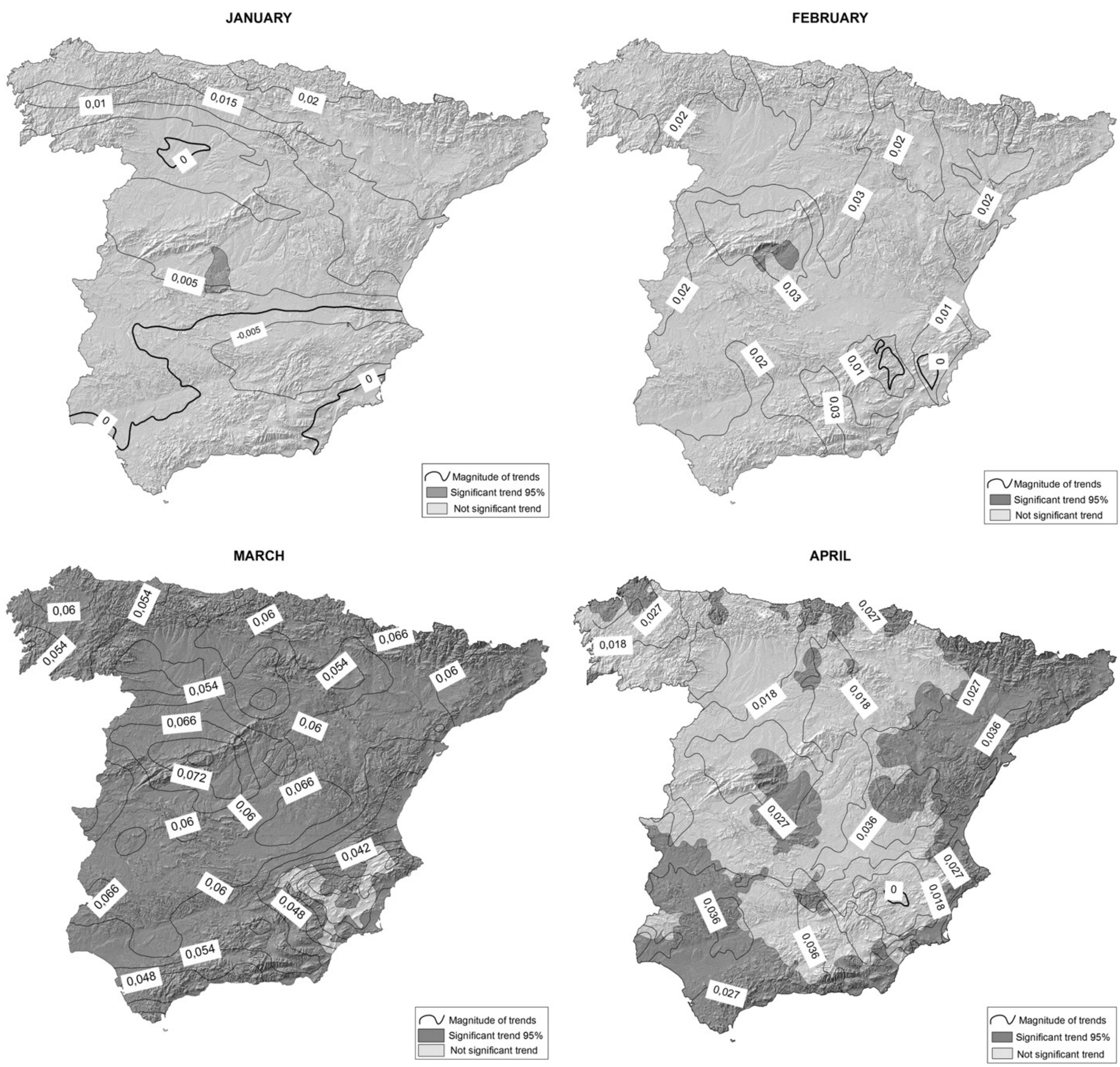


Fig. 3. Spatial distribution patterns of mean temperature trends (°C/year) on monthly, seasonal and annual timescale.

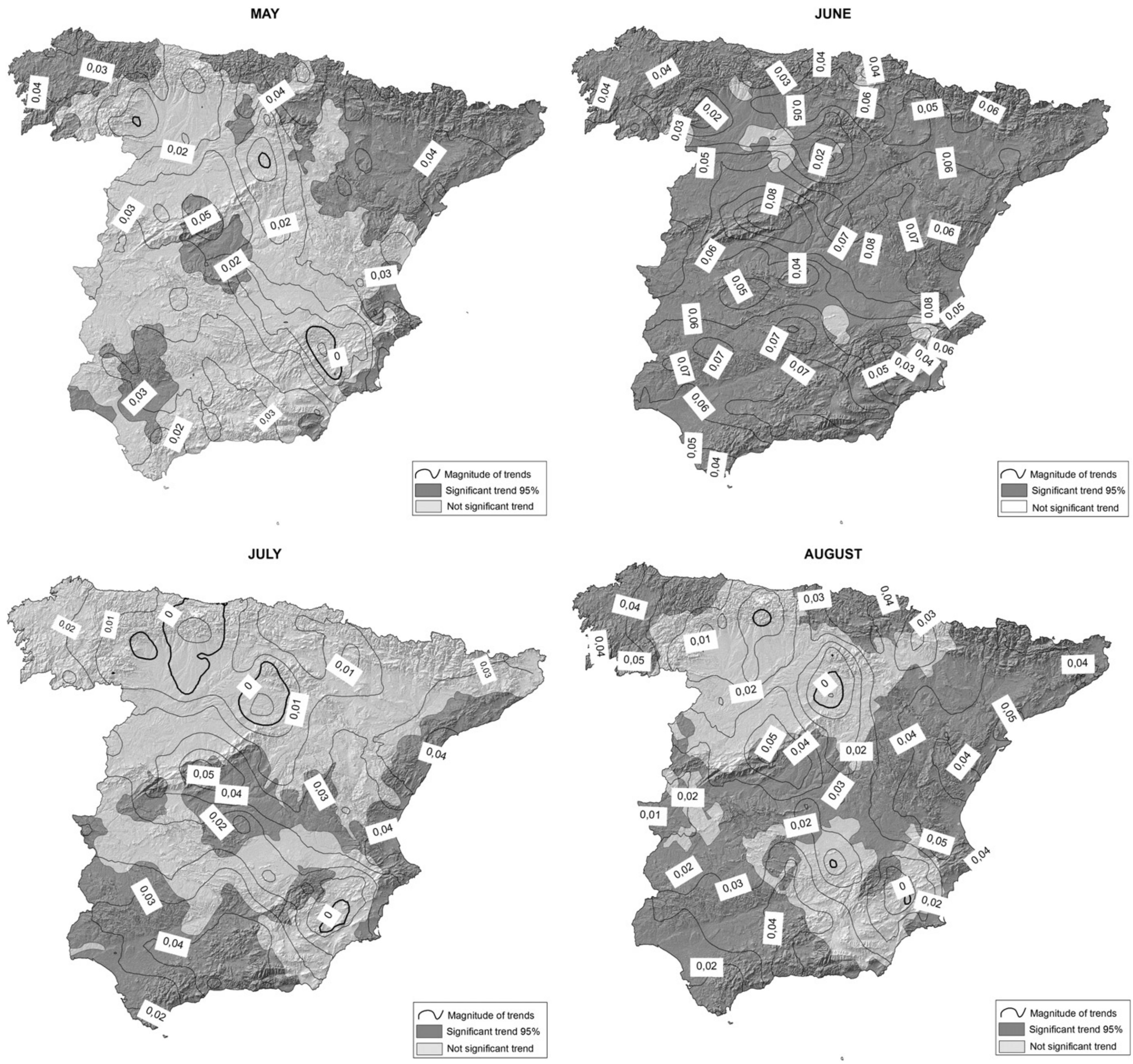
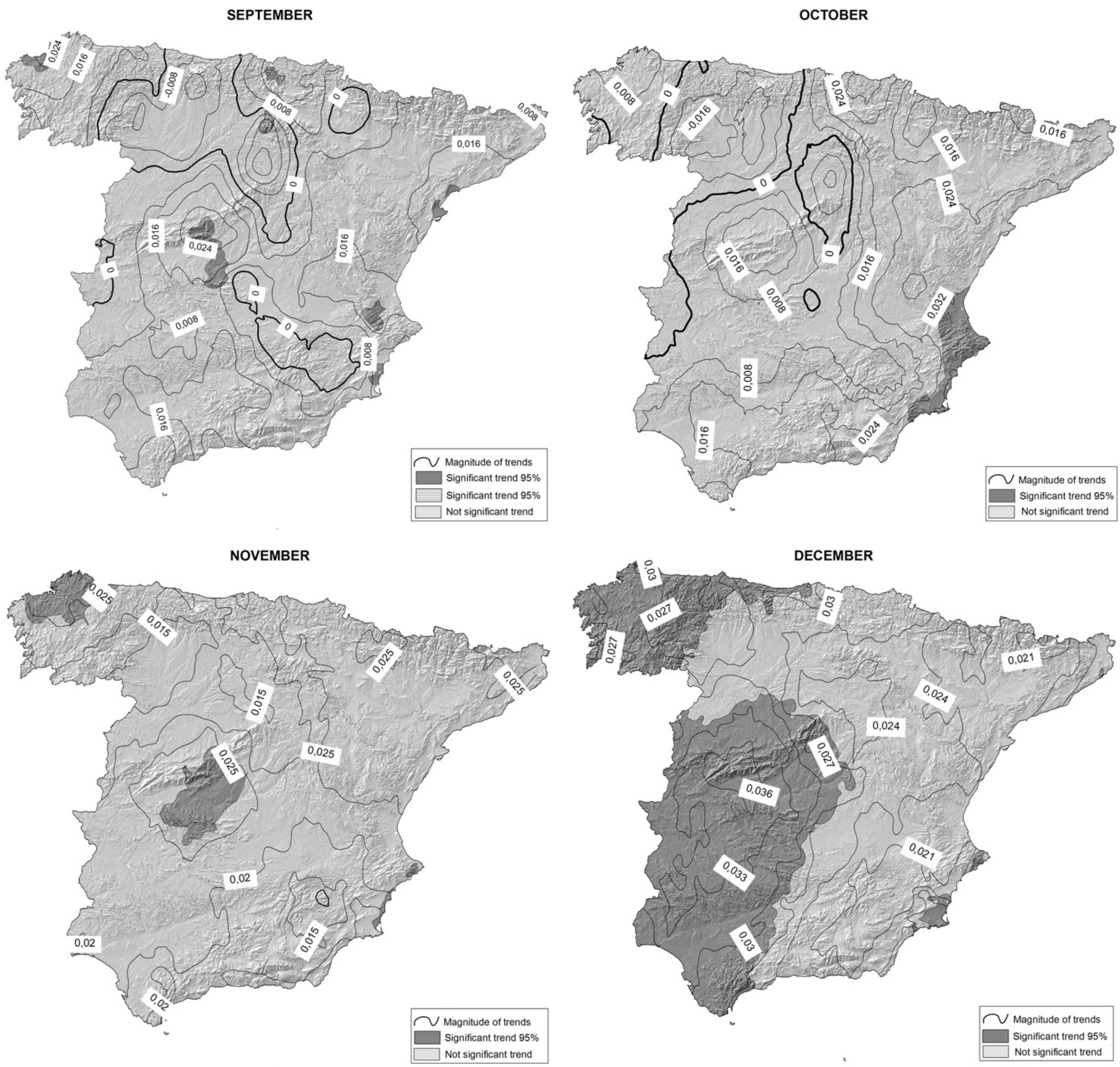


Fig. 3 (*continued*).

situated in small isolated areas in the center of Spain. Temperature has tended to increase in these territories of around 0.05 °C/decade in January and 0.3 °C/decade in February. 40% of the country has exhibited significant increases of temperature of 0.3 °C/decade on average in December. These areas have been mainly located in western parts of Spain. Positive tendencies in these months have been also found by Sigró (2004) for Catalonia, del Río et al. (2005, 2009) for Castile and León and Cruz and Lage (2006) for Galicia. The behavior of the winter season has been similar to that of December showing significant positive trends in western territories and representing more than 16% of Spain. The highest increases have been found in the northern parts with magnitudes of around 0.2 °C/decade. Statistically significant positive trends for whole Spain or for regional scales in this season have been reported by several authors: Morales et al. (2005) and del Río et al. (2005) for Castile and León; Cruz and Lage (2006) for Galicia, Brunet et al. (2001a, 2007) and Ileana and Castro-Díez (2010) for whole Spain. Our results are also in agreement with those mentioned for the Mediterranean Basin (Kutiel and Maheras, 1998; Brunet et al., 2001a; Sigró, 2004; Salat and Pascual, 2006; Capilla, 2008). Nevertheless we have noted that the Spanish temperature over the period 1961–2006 has tended to increase in general at a lower level than the results reported by some authors previously mentioned. Finally it is noteworthy that winter is not the season with the largest contribution to trends observed on annual basis. This result is in accord with that found by Morales et al. (2005), Brunet et al. (2007) and Capilla (2008).

Trends found in winter Spanish temperatures during the study period might be related to the behavior of some teleconnection patterns. Several authors have pointed out to that effect that the North Atlantic Oscillation (NAO) is one of the dominant atmospheric patterns on the temporal evolution of the winter temperature in



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the Northern Hemisphere and therefore in the Mediterranean area (Hurrell, 1995; Chmielewski and Rötzer, 2001; Pozo-Vázquez et al., 2001; Castro-Díez et al., 2002; Rodríguez-Puebla et al., 2002; Trigo et al., 2002; Linderholm et al., 2008; Folland et al., 2009; Rodríguez-Fonseca and Rodríguez-Puebla, 2010. NAO is characterized by a north–south level pressure dipolar pattern with one center located over Iceland and the one over Azores. During the positive phase of NAO (pressure higher than normal over the subtropics and lower than normal over high altitudes) occurs an intensified westerly flows that brings warm maritime air to Europe reducing polar breaks and leading to a warming of central and southern Europe and cooling of the Northwestern Atlantic sea (van Loon and Rogers, 1978; Rogers and Van Loon, 1979; Tomozeiu et al., 2002). Several studies have revealed a persistence of the positive phase of the NAO (Hurrell, 1996; Chmielewski and Rötzer, 2001; Hurrell et al., 2001; Serra et al., 2001; Cassou et al., 2004; Terray et al., 2004; Coppola et al., 2005; Beranova and Huth, 2007; Linderholm et al., 2008; López-Moreno et al., 2011) during the last few decades that could explain the warming across Europe since the early 1980s.

The increase of winter temperatures shown in this study might be also related to the East Atlantic (EA) pattern, which is the second prominent mode of low-frequency variability over the North Atlantic, and appears as a leading mode in all months (NOAA, 2011). The EA pattern is structurally similar to the NAO and consists of a north–south dipole of anomaly centers spanning the North Atlantic from east to west. The positive phase of the EA pattern occurring during much of 1977–2004 could have influenced on the warming across Europe during the last decades (NOAA, 2011). Sáenz et al. (2001) and Frías et al. (2005) also mentioned the influence of EA on the variability of the Iberian Peninsula temperature.

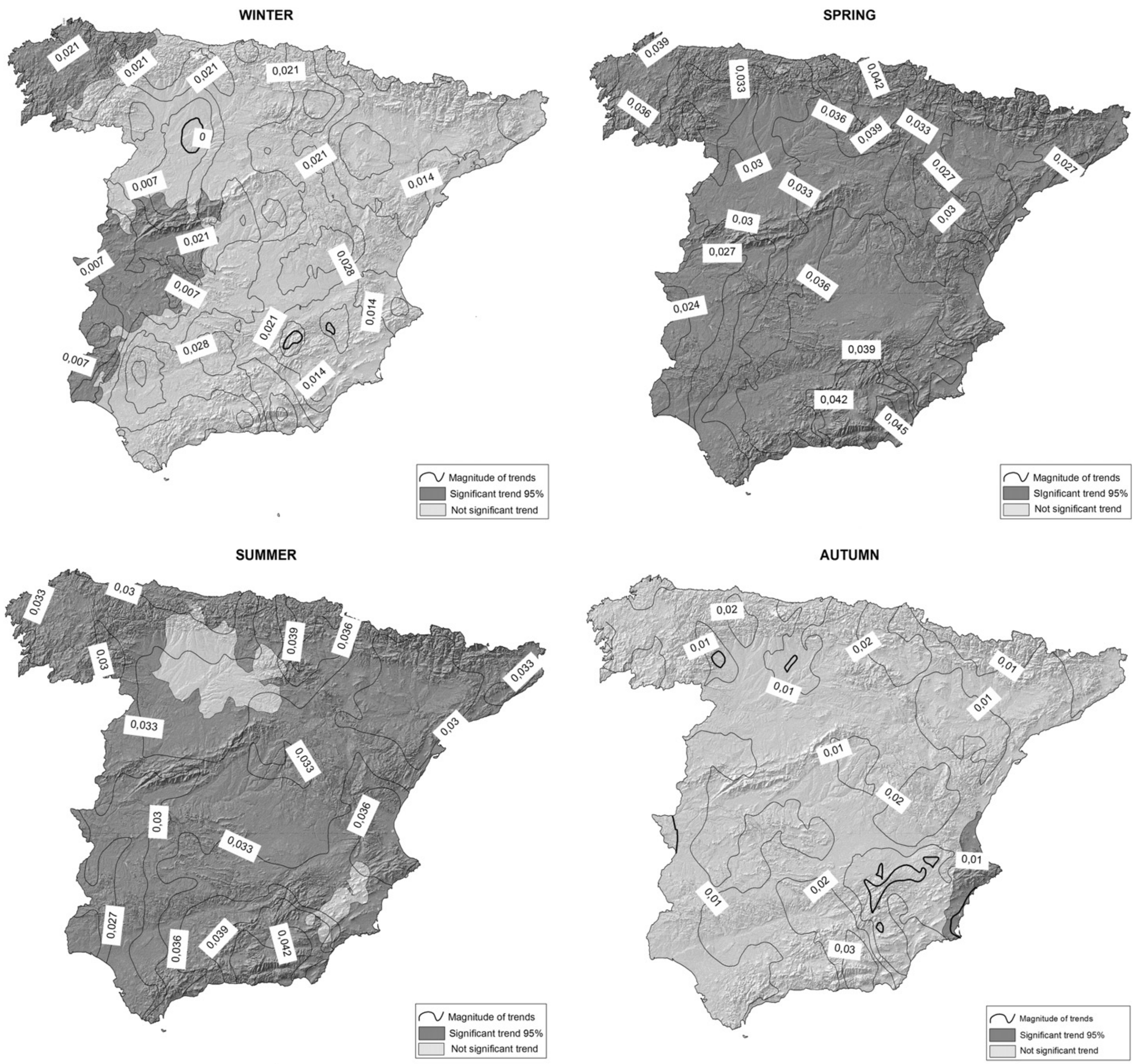

Fig. 3 (*continued*).

Analyzing months making up the spring season it can be seen that March was the second month of the year with the highest percentage of weather stations with positive significant trends (93%). It means that temperature has tended to significantly increase 0.34 °C/decade in more than 96% of whole Spain. The highest magnitudes of trends have been found in the center of the country and the lowest ones in the southeastern parts of Spain. Positive significant trends in this month have been also pointed out by Sigró (2004), del Río et al. (2005, 2009) and Cruz and Lage (2006). Trend analysis of April and May have revealed a similar pattern regarding to the location, percentage of meteorological stations with significant trends and magnitude of trends. Areas with increases of temperature have been situated in the east and southeast of Spain. Temperature has tended to increase in both months between 0.2 and 0.3 °C/decade. Sigró (2004) and Cruz and Lage (2006) have also found positive trends in these months. At seasonal resolution spring has been the season with the highest number of weather stations with statistical significance. Map prediction confirmed that temperature has tended to significantly increase in 100% of the country over the period 1961–2006 0.34 °C/decade on average. Rises of temperature in this season are in line with proposals of several authors: Kutiel and Maheras (1998), Brunet et al. (2001a,b, 2007), Sigró (2004), Morales et al. (2005), del Río et al. (2005, 2009), Cruz and Lage (2006), Salat and Pascual (2006), Capilla (2008) and Ileana and Castro-Díez (2010). Nevertheless it has been noted that magnitudes reported in this paper are generally lower than proposed by some of these authors. It is also noteworthy that spring has been the season with the largest contribution to trends observed on annual basis in this observation period. This fact has been highlighted by Brunet et al. (2001a) for the northeastern Spain, Morales et al. (2005) for Castile and León, Ordoñez (2008) for Andalusia and Brunet et al. (2007) for the whole Spain.

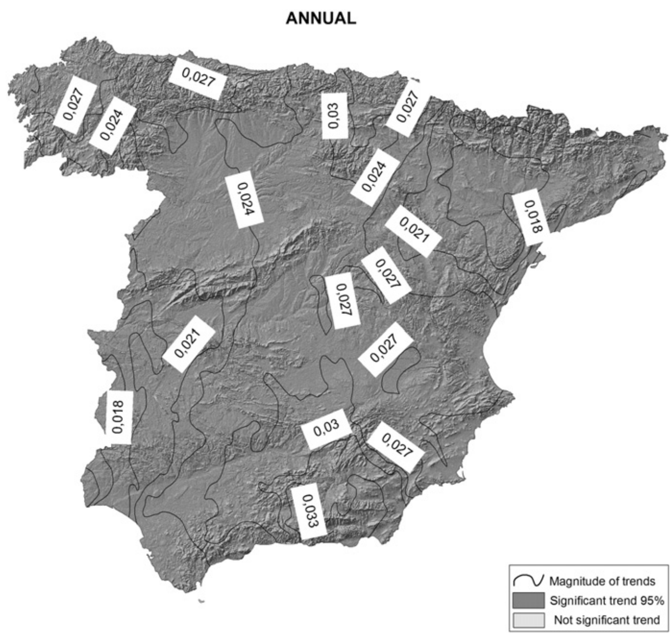

Fig. 3 (*continued*).

Positive trends found in spring in this paper might be also related to the North Atlantic Oscillation since its influence persists thorough the year although it is stronger in winter (Barnston and Livezey, 1987; Pozo-Vázquez et al., 2001). Chmielewski and Rötzer (2001) have pointed out that for the period 1969–1998 the positive phase of NAO clearly increased in early spring which has been associated with above-normal temperatures in Europe in these months. Hurrell et al. (2003) also found the influence of NAO is noticeable till April and Kakade and Dugam (2006) pointed out that during spring the positive phase of NAO is linked with the global continental warming. This result is in accordance with those pointed out by NOAA (2011).

Trend analysis of summer months has revealed that June has been the month of the year with the highest number of weather stations with significant positive trends (94%). It means that temperature has significantly increased in more than 97% of the whole Spain of around 0.5 °C/decade. The highest magnitude of trends in the year (up to 0.7–0.8 °C/decade) has been found in this month. Cruz and Lage (2006) and del Río et al. (2009) have also pointed out increases of temperature in June. Two main areas with positive significant trends covering about 32% of Spain have been noted in July: one in southwestern parts of the country and another one in the Mediterranean fringe extending to inner areas. An increase of temperature of 0.23 °C/decade on average has been found in these areas. The behavior pattern of August has been similar to July although it has been observed an increase in the percentage of km^2 with positive significant trends (63%) and the magnitude of trends has been also a little higher (0.35 °C/decade). Cruz and Lage (2006) and Miró et al. (2006) have also reported increases of temperature in both months. Taking into account the summer trend analysis it can be noted that this season has exhibited a behavior similar to spring although the percentage of square kilometers with statistical significance has been lower (92%) in the last one. Magnitude of trends has been also similar in both seasons (0.33 °C/decade). A number of recent studies have shown worldwide trends towards increasing summer temperatures. Rises in Spanish summer temperature have been also mentioned by Cruz and Lage (2006) for Galicia; Morales et al. (2005) for Castile and León; Sigró (2004), Xoplaki et al. (2003, 2006), Pausas (2004); Salat and Pascual (2006), Miró et al. (2006) and Capilla (2008) for the eastern territories; Brunet et al. (2001a,b, 2009) and Ileana and Castro-Díez (2010) for the whole of Spain.

Positive trends found in summer might be associated with blocking conditions, subsidence and stability over the Mediterranean and above-normal Mediterranean sea surfaces as Xoplaki et al. (2003, 2006) have concluded for the Mediterranean territories. On the other hand Mariotti and Dell'Aquila (2011) have also pointed out that Atlantic Multidecadal Oscillation (AMO) variability has contributed to the warmer conditions observed in the Mediterranean in June, July and August since the 1970s because of a progressive increase in the AMO index. It might be even possible that these increases are related to the summer North Atlantic Oscillation (SNAO), a pattern of variability which is the summertime parallel to the winter NAO (Folland et al., 2009). Although this pattern is less effective over southern Europe than in northern areas, studies of Yuan and Sun (2009) have found that from 1997 to 2002 the areas with significant negative correlations between SNAO and summer temperatures increased, extending to the most of the Mediterranean region. During that period the mean Northern Hemisphere land temperature showed a strongly accelerated warming trend.

Months conforming the autumn season have been characterized by having a low percentage of weather stations with positive significant trends. These stations have been located in isolated areas meaning 5% of the whole country. Only a small territory situated in the southeast of

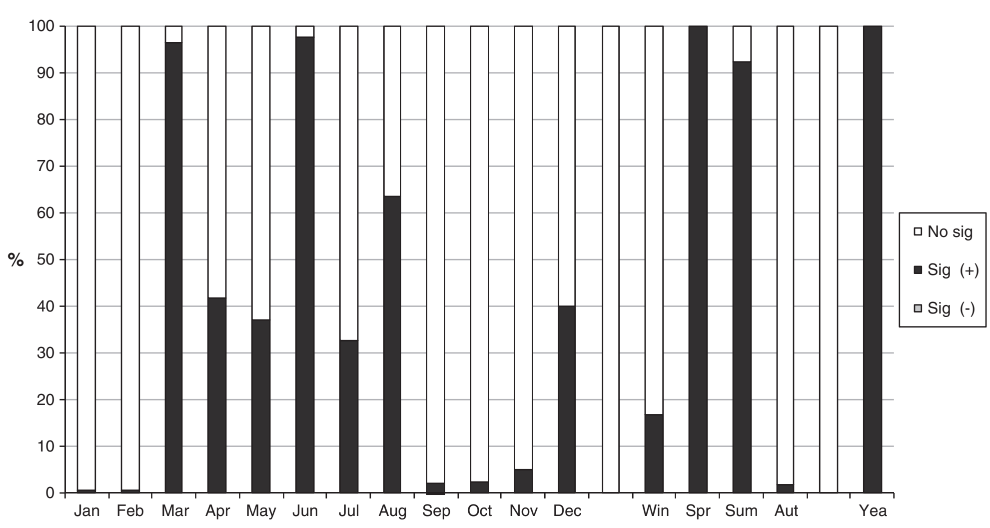

Fig. 4. Percentages of the whole Spain with negative and positive trends (95% confidence level).

Spain has shown significant increases in all three months. Positive trends in these periods have been found by Sigró (2004), del Río et al. (2005, 2009) and Cruz and Lage (2006). It is also noteworthy the existence of a small area with significant negative trends in September in the northwest of Spain. Autumn proved to be the season with the lowest percentage of weather stations with significant trends (16%) and with the lowest magnitudes (0.1 °C/decade). Several authors have propounded positive trends for different areas in this season: Kutiel and Maheras (1998), Brunet et al. (2001b, 2007, 2009), Morales et al. (2005), Cruz and Lage (2006), Salat and Pascual (2006), Capilla (2008) and Ileana and Castro-Díez (2010).

Increases of temperature in autumn might be also associated with the NAO and its positive phase. The low magnitudes of trends in this season could be related to the slight weakening of the southwesterly circulation during autumn (Tomozeiu et al., 2002).

Finally, it has been observed an annual trend towards a warmer climate with an estimated increase of 0.1–0.2 °C/decade for the whole country. This increase has been statistically significant in 100% of Spain. Our results are in accordance with what has been reported by several authors who have noted an increase between 0.1 and 0.4 °C/decade for the whole of the country or smaller territories (Kutiel and Maheras, 1998; Piñol et al., 1998; Parry, 2000; Brunet et al., 2001a,b; Klein Tank et al., 2002; Pausas, 2004; Sigró, 2004; Brunet et al., 2005; del Río et al., 2005; Morales et al., 2005; Cruz and Lage, 2006; Brunet et al., 2007; Castro-Díez et al., 2007; Brunet et al., 2009; del Río et al., 2009; Ileana and Castro-Díez, 2010). Summer and spring have been the seasons with the greatest contribution to annual trends. This result is in accord with those proposed by Morales et al. (2005) for Castile and León; Cruz and Lage (2006) for Galicia, Salat and Pascual (2006) for Catalonia, Capilla (2008) for Valencia and Brunet et al. (2007, 2009) for the whole Spain. As it has been mentioned for the seasonal trend analysis we believe that increases in annual mean temperature might be associated with the influence of different teleconnection patterns and mainly with the North Atlantic Oscillation since this pattern is recognized as the main mode of climate variability in the extratropical Northern Hemisphere (Hurrell, 1995; Hurrell et al., 2001, 2003; Gimeno et al., 2003; Sun et al., 2009).

5. Conclusions

Mean temperature data from 473 meteorological stations from 1961 to 2006 were considered in this study to analyze the most recent temperature trends in Spain and their spatial distribution using a range of statistical tools.

This study has revealed the following findings:

- Positive trends have clearly prevailed against negative ones in Spain over the last decades.
- Temperature has significantly increased in more than 60% of Spain in March, June, August, spring and summer. The highest magnitudes of trends have been found in June (0.5 °C/decade on average).
- Annual temperature has significantly increased of about 0.1–0.2 °C/decade in 100% of the country according to the AR4 of IPCC. Summer and spring have been the seasons with the largest contribution to annual trends.
- Increases observed in mean temperature in this paper might be related to the behavior of some teleconnection patterns and especially to the North Atlantic Oscillation (NAO) since several authors have associated its positive phase with recent warming across Europe.

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References

Almarza, C., Luna, C., 2005. Homogeneidad y variabilidad de la precipitación y la temperatura en zonas climáticamente homogéneas de la Península Ibérica. Available: http://www.ame-web.org/JORNADAS/C10-trabajo%20"Almarza%20y%20Luna.pdf [2010, August 15].

Attorre, F., Alfo, M., De Sanctis, M., Francesconi, F., Bruno, F., 2007. Comparison of interpolation methods for mapping climatic and bioclimatic variables at regional scale. International Journal of Climatology 27 (13), 1825–1843.

Barnston, G., Livezey, R.E., 1987. Classification, seasonality and low-frequency atmospheric circulation patterns. Monthly Weather Review 115, 1083–1126.

Benavides, R., Montes, F., Rubio, A., Osoro, K., 2007. Geostatistical modelling of air temperature in a mountainous region of Northern Spain. Agricultural and Forest Meteorology 146 (3–4), 173–188.

Beranova, R., Huth, R., 2007. Time variations of the relationships between the North Atlantic Oscillation and European winter temperature and precipitation. Studia Geophysica Et Geodaetica 51 (4), 575–590.

Brunet, M., Aguilar, E., Saladie, O., Sigro, J., Lopez, D., 2001a. The variations and trends of the surface air temperature in the Northeastern of Spain from middle nineteenth century onwards. Detecting and Modelling Regional Climate Change, pp. 81–93.

Brunet, M., Aguilar, E., Saladíe, O., Sigró, J., López, D., 2001b. The Spanish temperature series. Time variations and trends over the last 150 years. Geophysical Research Abstracts 3 GRA3 5333 76.

Brunet, M., Sigró, J., Saladie, O., Aguilar, E., Jones, P.D., Moberg, A., Walther, A., López, D., 2005. Spatial patterns of long-term spanish temperature change. Geophysical Research Abstracts 7, 04007.

Brunet, M., Saladie, O., Jones, P.D., Sigró, J., Aguilar, E., Moberg, A., Lister, D., Walther, A., López, D., Allmarza, C., 2006. The development of a new dataset of Spanish Daily Adjusted Temperature Series (SDATS) (1850–2003). International Journal of Climatology 26 (13), 1777–1802.

Brunet, M., Jones, P.D., Sigró, J., Saladie, O., Aguilar, E., Moberg, A., Della-Marta, P.M., Lister, D., Walther, A., Lopez, D., 2007. Temporal and spatial temperature variability and change over Spain during 1850–2005. Journal of Geophysical Research 112, 28–D12117.

Brunet, M., Casado, M.J., de Castro, M., Galán, P., López, J.A., Martín, J.M., Pastor, A., Petisco, E., Ramos, P., Ribalaygua, J., Rodríguez, E., Sanz, I., Torres, E., 2009. Generación de escenarios de cambio climático regionalizados para España. Agencia Estatal de Meteorología, Ministerio de Medio Ambiente. pp. 158.

Brunetti, M., Buffoni, L., Maugeri, M., Nanni, T., 2000. Trends of minimum and maximum daily temperatures in Italy from 1865 to 1996. Theoretical and Applied Climatology 66 (1), 49–60.

Brunetti, M., Buffoni, L., Mangianti, F., Maugeri, M., Nanni, T., 2004. Temperature, precipitation and extreme events during the last century in Italy. Global and Planetary Change 40 (1–2), 141–149.

Brunetti, M., Maugeri, M., Monti, F., Nannia, T., 2006. Temperature and precipitation variability in Italy in the last two centuries from homogenised instrumental time series. International Journal of Climatology 26 (3), 345–381.

Camuffo, D., Bertolin, C., Barriendos, M., Domínguez, F., Cocheo, C., Enzi, S., Sghedon, M., della Valle, A., Garnier, E., Alcoforado, M.J., Xoplaki, E., Luterbacher, J., Diodato, N., Maugeri, M., Nunes, M.F., Rodríguez, R., 2010. 500-year temperature reconstruction in the Mediterranean Basin by means of documentary data and instrumental observations. Climatic Change 101 (1–2), 169–199.

Cao, W.J., Hu, J.X., Yu, X.M., 2009. A study on temperature interpolation. Methods Based on GIS 17th International Conference on Geoinformatics George Mason Univ, Fairfax, pp. 1–5.

Capel, J.J., 1998. Ritmo anual de las temperaturas en España. Nimbus: Revista de meteorología, climatología y paisaje 1–2, 17–36.

Capel, J.J., 2000. El clima de la Península Ibérica. , p. 281. Ed. Ariel, Barcelona.

Capilla, C., 2008. Time series analysis and identification of trends in a Mediterranean urban area. Global and Planetary Change 63 (2–3), 275–281.

Cassou, C., Terray, L., Hurrell, J.W., Deser, C., 2004. North Atlantic winter climate regimes: spatial asymmetry, stationarity with time, and oceanic forcing. Journal of Climate 17 (5), 1055–1068.

Castro-Díez, Y., Pozo-Vázquez, D., Rodrigo, F.S., Esteban-Parra, M.J., 2002. NAO and winter temperature variability in southern Europe. Geophysical Research Letters 29 (8), 1160.

Castro-Díez, Y., Esteban-Parra, M.J., Staudt, M., Gámiz-Fortis, R., 2007. Temperature and precipitation changes in Andalusia in the Iberian Peninsula and Northern Hemisphere context. In: Sousa, A., García-Barrón, L., Jurado, V. (Eds.), Climate Change in Andalusia: Trends and Environmental Consequences. Consejería de Medio Ambiente, Junta de Andalucía, pp. 55–77.

Chaouche, K., Neppel, L., Dieulin, C., Pujol, N., Ladouche, B., Martin, E., Salas, D., Caballero, Y., 2010. Analyses of precipitation, temperature and evapotranspiration in a French Mediterranean region in the context of climate change. Comptes Rendus Geoscience 342 (3), 234–243.

Chmielewski, F.M., Rötzer, T., 2001. Response of tree phenology to climate change across Europe. Agricultural and Forest Meteorology 108 (2), 101–112.

Collins, F.C., Bolstad, P.V., 1996. A comparison of spatial interpolation techniques in temperature estimation. Proceedings of the Third International Environmental Modeling, National Center for Geographic Information Analysis (NCGIA) Santa Fe, New Mexico, 21–25 January.

Coppola, E., Kucharski, F., Giorgi, F., Molteni, F., 2005. Bimodality of the North Atlantic Oscillation in simulations with greenhouse gas forcing. Geophysical Research Letters 32 (23), L23709.

Courault, D., Monestiez, P., 1999. Spatial interpolation of air temperature according to atmospheric circulation patterns in southeast France. International Journal of Climatology 9, 365–378.

Cruz, R., Lage, A., 2006. Análisis de la evolución de la temperatura y precipitación en el periodo 1973–2004 en Galicia. In: Cuadrat, J.M., Saz, M.A., Vicente Serrano, S.M., Lanjeri, S., de Luis, M., González-Hidalgo, J.C. (Eds.), Clima, Sociedad y Medio Ambiente, Asociación Española de Cimatología serie A, nº5, Zaragoza, pp. 113–124.

Degirmendžić, J., Kozuchowski, K., Zmudzka, E., 2004. Changes of air temperature and precipitation in Poland in the period 1951–2000 and their relationship to atmospheric circulation. International Journal of Climatology 24 (3), 291–310.

del Río, S., Penas, A., Fraile, R., 2005. Analysis of recent climatic variations in Castile and Leon (Spain). Atmospheric Research 73 (1–2), 69–85.

del Río, S., Fraile, R., Herrero, L., Penas, A., 2007. Analysis of recent trends in mean maximum and minimum temperatures in a region of the NW of Spain (Castilla y León). Theoretical and Applied Climatology 90 (1), 1–12.

del Río, S., Herrero, L., Penas, A., 2009. Recent climatic trends in Castilla and León (Spain) and its possible influence on the potential natural vegetation. Acta Botanica Gallica 156 (4), 625–636.

Essenwanger, O.M., 1986. Elements of statistical analysis. World Survey of Climatology, vol.1B. Elsevier Science Publishing Company, INC, p. 424.

Esteban, P., Ninyerola, M., Prohom, M., 2009. Spatial modelling of air temperature and precipitation for Andorra (Pyrenees) from daily circulation patterns. Theoretical and Applied Climatology 96 (1–2), 43–56.

Esteban-Parra, M.J., Rodrigo, F.S., Castro-Díez, Y., 1995. Temperature trends and change points in the northern Spanish Plateau during the last 100 years. International Journal of Climatology 15 (9), 1031–1042.

Esteban-Parra, M.J., Rodrigo, F.S, Castro-Díez, Y., 1997. Estudio de las variaciones climáticas en Almería. In: Navarro, A., García-Rosell, L. (coord.). Recursos naturales y medio ambiente del Sureste peninsular. Instituto de Estudios Almerienses, Almería, pp. 489–501.

Feidas, H., Makrogiannis, T., Bora-Senta, E., 2004. Trend analysis of air temperature time series in Greece and their relationship with circulation using surface and satellite data: 1955–2001. Theoretical and Applied Climatology 79 (3), 185–208.

Folland, C., Knight, J., Linderholm, H.W., Fereday, D., Inison, S., Hurrell, J.W., 2009. The summer North Atlantic Oscillation: past, present, and future. Journal of Climate 22 (5), 1082–1103.

Font Tullot, I., 2000. Climatología de España y Portugal. Universidad de Salamanca, Salamanca, p. 428.

Frías, M.D., Fernández, J., Sáenz, J., Rodríguez-Puebla, C., 2005. Operational predictability of monthly average maximum temperature over the Iberian Peninsula using DEMETER simulations and downscaling. Tellus Series A—Dynamic Meteorology and Oceanography 57, 448–463.

Galán, E., Cañada, R., Fernández, F., Cervera, B., 2001. Annual temperatura evolution in the Southern Plateau of Spain from the construction of regional climatic time series. In: Brunet, M., López, D. (Eds.), Detecting and Modeling Regional Climate Change. Springer-Verlag, Berlim, pp. 119–131.

Gimeno, L., de la Torre, L., Nieto, R., García, R., Hernández, E., Ribera, P., 2003. Changes in the relationship NAO–Northern hemisphere temperature due to solar activity. Earth and Planetary Science Letters 206 (1–2), 15–20.

Gómez, J.D., Etchevers, J.D., Monterroso, A.I., Gay, C., Campo, J., Martínez, M., 2008. Spatial estimation of mean temperatura and precipitation in areas of scarce meteorological information. Atmósfera 21 (1), 35–56.

Harvey, D.I., Mills, T.C., 2001. Modelling global temperature trends using cointegration and smooth transition. Statistical Modelling 1, 143–159.

Homar, V., Ramis, C., Romero, R., Alonso, S., 2010. Recent trends in temperature and precipitation over the Balearic Islands (Spain). Climatic Change 98 (1–2), 199–211.

Hurrell, J.W., 1995. Decadal trends in the North-Atlantic Oscillation — regional temperatures and precipitation. Science 269 (5224), 676–679.

Hurrell, J.W., 1996. Influence of variations in extratropical wintertime teleconnections on Northern Hemisphere temperature. Geophysical Research Letters 23, 665–668.

Hurrell, J.W., Kushnir, Y., Visbeck, M., 2001. The North Atlantic Oscillation. Science 291, 603–605.

The North Atlantic Oscillation: climate significance and environmental impact. In: Hurrell, J.W., Kushnir, Y., Ottersen, G., Visbeck, M. (Eds.), Geophysical Monograph Series, 134, p. 279.

Ileana, B., Castro-Díez, Y., 2010. Tendencias atmosféricas en la Península Ibérica durante el periodo instrumental en el contexto de la variabilidad natural. In: Pérez Fiz, F., Boscolo, R. (Eds.), Clima es España: Pasado, presente y futuro: Informe de Evaluación del cambio climático regional, Red Temática CLIVAR-España, pp. 25–42.

IPCC, 2001. Climate Change 2001. Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. In: Watson, R.T., the Core Writing Team (Eds.), Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, p. 398.

IPCC, 2007. Climate change 2007: the physical science basis. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (Eds.), Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p. 135.

Irmak, A., Ranade, P.K., 2008. GIS Based Estimation of Spatial Distribution of Temperature and Evapotranspiration in Nebraska, American Society of Agricultural and Biological Engineers, St. Joseph, Michigan. Available: http://asae.frymulti.com/abstract.asp?aid=24955&t=2 [2010, August, 30].

Johnston, K., Ver Hoef, J.M., Krivoruchko, K., Lucas, N., 2001. Using ArcGis Geostatistical Analyst. ESRI, New York. 300 pp.

Kakade, S.B., Dugam, S.S., 2006. North Atlantic Oscillation and northern hemispheric warming. Indian Journal of Marine Sciences 35 (3), 205–209.

Klein Tank, A.M.G., Können, G.P., 2003. Trends in indices of daily temperature and precipitation extremes in Europe, 1946–99. Journal of Climate 16 (22), 3665–3680.

Klein Tank, A.M.G., Wijngaard, J.B., Können, G.P., Böhm, R., Demarée, G., Gocheva, A., Mileta, M., Pashiardis, S., Hejkrlik, L., Kern-Hansen, C., Heino, R., BesseMoulin, P., Müller-Westermeier, G., Tzanakou, M., Szalai, S., Pálsdóttir, T., Fitzgerald, D., Rubin, S., Capaldo, M., Maugeri, M., Leitass, A., Bukantis, A., Aberfeld, R., Van Engelen, A.F.V., Forland, E., Mietus, M., Coelho, F., Mares, C., Razuvaev, V., Nieplova, E., Cegnar, T., Antonio López, J., Dahlström, B., Moberg, A., Kirchhofer, W., Ceylan, A., Pachaliuk, O., Alexander, L.V., Petrovic, P., 2002. Daily dataset of 20th-century surface air temperature and precipitation series for the European climate assessment. International Journal of Climatology 22, 1441–1453.

Klein Tank, A.M.G., Können, G.P., Selten, F.M., 2005. Signals of anthropogenic influence on European warming as seen in the trends patterns of daily temperature variance. International Journal of Climatology 25, 1–16.

Kutiel, H., Maheras, P., 1998. Variations in the temperature regime across the Mediterranean during the last century and their relationship with circulation indices. Theoretical and Applied Climatology 61 (1–2), 39–53.

Linderholm, H.W., Folland, C.K., Hurrell, J.W., 2008. Reconstructing Summer North Atlantic Oscillation (SNAO) variability over the last five centuries. In: Elferts, D., Brumelis, G., Gärtner, H., Helle, G., Schieser, G. (Eds.), Tree Rings in Archaeology: Climatology and Ecology, 6, pp. 8–16.

López-Moreno, J.L., Vicente-Serrano, S.M., Morán-Tejeda, E., Lorenzo-Lacruz, J., Kenawy, A., Beniston, M., 2011. Effects of the North Atlantic Oscillation (NAO) on combined temperature and precipitation winter modes in the Mediterranean mountains: observed relationships and projections for the 21st century. Global and Planetary Change 77 (1-2), 62–76.

Luna, M.Y., Morata, A., Almarza, C., Martin, M.L., 2006. The use of GIS to evaluate and map extreme maximum and minimum temperatures in Spain. Meteorological Applications 13 (4), 385–392.

Luterbacher, J., Dietrich, D., Xoplaki, E., Grosjean, M., Wanner, H., 2004. European seasonal and annual temperature variability, trends, and extremes since 1500. Science 303, 1499–1503.

Mariotti, A., Dell'Aquila, A., 2011. Decadal climate variability in the Mediterranean region: roles of large-scale forcings and regional processes. Climate Dynamics. doi:10.1007/s00382-011-1056-7.

Martínez, M.D., Serra, C., Burgueño, A., Lana, X., 2010. Time trends of daily maximum and minimum temperatures in Catalonia (NE Spain) for the period 1975–2004. International Journal of Climatology 30, 267–290.

Miró, J.J., Estrela, M.J., Millán, M., 2006. Summer temperature trends in a Mediterranean area (Valencia region). International Journal of Climatology 26 (8), 1051–1073.

Moberg, A., Jones, P.D., Lister, D., Walther, A., Brunet, M., Jacobeit, J., Alexander, L.V., Della-Marta, P.M., Luterbacher, J., Yiou, P., Chen, D., Tank, A.M.G.K., Saladie, O., Sigro, J., Aguilar, E., Alexandersson, H., Almarza, C., Auer, I., Barriendos, M., Begert, M., Bergstrom, H., Bohm, R., Butler, C.J., Caesar, J., Drebs, A., Founda, D., Gerstengarbe, F.W., Micela, G., Maugeri, M., Osterle, H., Pandzic, K., Petrakis, M., Srnec, L., Tolasz, R., Tuomenvirta, H., Werner, P.C., Linderholm, H., Philipp, A., Wanner, H., Xoplaki, E., 2006. Indices for daily temperature and precipitation extremes in Europe analyzed for the period 1901–2000. Journal of Geophysical Research — Atmospheres 111 (D22), 1–25.

Morales, C.G., Ortega, M.T., Labajo, J.L., Piorno, A., 2005. Recent trends and temporal behavior of thermal variables in the region of Castilla – León (Spain). Atmosfera 18 (2), 71–90.

Muñoz-Díaz, D., Rodrigo, F.S., 2006. Seasonal rainfall variations in Spain (1912–2000) and their links to atmospheric circulation. Atmospheric Research 81 (1), 94–110.

Ninyerola, M., Pons, X., Roure, J.M., 2000. A methodological approach of climatological modelling of air temperature and precipitation through GIS techniques. International Journal of Climatology 20 (14), 1823–1841.

NOAA, 2011. National Weather Service. Climate Prediction Center. Available: http://www.cpc.ncep.noaa.gov/data/teledoc/ea.shtml Accesed 10 May 2011.

Oñate, J., Pou, A., 1996. Temperature variations in Spain since 1901: a preliminary analysis. International Journal of Climatology 16, 805–815.

Ordoñez, P., 2008. Análisis del estado del clima en Andalucía mediante índices climáticos atmosféricos. Congreso Nacional de Medio Ambiente, Cumbre del Desarrollo Sostenible, 1–5 Diciembre, Madrid.

Assessment of potential effects and adaptations for climate change in Europe. In: Parry, M.L. (Ed.), Summary and Conclusions. Jackson Environment Institute, University of East Aglia, Norwich, UK, p. 320.

Pausas, J.G., 2004. Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean basin). Climatic Change 63 (3), 337–350.

Piñol, J., Terradas, J., Lloret, F., 1998. Climate warming, wildfire hazard, and wildfire occurrence in coastal eastern Spain. Climatic Change 38 (3), 345–357.

Pozo-Vázquez, D., Esteban-Parra, M.J., Rodrigo, F.S., Castro-Díez, Y., 2001. A study of NAO variability and its possible non-linear influences on European surface temperature. Climate Dynamics 17 (9), 701–715.

Prieto, L., Herrera, R.G., Díaz, J., Hernández, E., del Teso, T., 2004. Minimum extreme temperatures over Peninsular Spain. Global and Planetary Change 44 (1–4), 59–71.

Rebetez, M., Reinhard, M., 2008. Monthly air temperature trends in Switzerland 1901–2000 and 1975–2004. Theoretical and Applied Climatology 91, 27–34.

Rodrigo, F.S., Trigo, R.M., 2007. Trends in daily rainfall in the Iberian Peninsula from 1951 to 2002. International Journal of Climatology 27 (4), 513–529.

Rodríguez-Fonseca, B., Rodríguez-Puebla, C., 2010. Teleconexiones climáticas en el entorno de la Península Ibérica. Predictabilidad y cambios esperados. In: Pérez, F.F., Boscolo, R. (Eds.), Clima en España: pasado, presente y futuro: Informe de evaluación del cambio climático regional. CLIVAR-España, pp. 1–85.

Rodríguez-Puebla, C., Encinas, A.H., Nieto, S., Garmendia, J., 1998. Spatial and temporal patterns of annual precipitation variability over the Iberian Peninsula. International Journal of Climatology 18 (3), 299–316.
Rodríguez-Puebla, C., García Casado, L.A., Frias, M.D., 2002. Trend and interannual variations in air temperature over the Iberian Peninsula. 13th. Symposium of Global Change and Climate Variations. 13–17 January 2002. Orlando, Florida. American Meteorological Society, Boston (USA), pp. 106–108.
Rogers, J.C., Van Loon, H., 1979. The seesaw in winter temperatures between Greenland and Northern Europe Part II: some oceanic and atmospheric effects in middle and high altitudes. Monthly Weather Review 107, 509–519.
Sáenz, J., Zubillaga, J., Rodríguez-Puebla, C., 2001. Interannual winter temperature variability in the north of the Iberian Peninsula. Climate Research 16 (3), 169–179.
Salat, J., Pascual, J., 2006. Principales tendencias climatológicas en el Mediterráneo noroccidental, a partir de más de 30 años de observaciones oceanográficas y meteorológicas en la costa catalana. In: Cuadrat, J.M., Saz, M.A., Vicente Serrano, S.M., Lanjeri, S., de Luis, M., González-Hidalgo, J.C. (Eds.), Clima, Sociedad y Medio Ambiente, Asociación Española de Cimatología serie A, nº5, Zaragoza, pp. 283–290.
Salmi, T., Maatta, A., Anttila, P., Ruoho-Airola, T., Amnell, T., 2002. Detecting trends of annual values of atmospheric pollutants by the Mann–Kendall test and sen's solpe stimates — the excel template application MAKESENS. Helsinki, Finnish Meteorological Institute Report No. 31. Helsinki, p. 35.
Schönwiese, C.D., Rapp, J., 1997. Climate Trend Atlas of Europe Based on Observations 1891–1990. Kulver Academic publishers, Dordrecht. 235 pp.
Serra, C., Burgueño, A., Lana, X., 2001. Analysis of maximum and minimum daily temperatures recorded at Fabra Observatory (Barcelona, NE Spain) in the period 1917–1998. International Journal of Climatology 21 (5), 617–636.
Sheikhhasan, H., 2006. A comparison of interpolation techniques for spatial data prediction. Ph. D. Thesis, Universiteit van Amsterdam, The Netherlands.
Sigró, F.J., 2004. Variabilidad espacio temporal de la temperatura del aire en Cataluña. Ph. D. Thesis, Universidad Rovira i Virgili, Barcelona.
Sneyers, R., 1992. On the use of statistical analysis for the objective determination on climatic change. Meteorologische Zeitschrift 1, 247–256.
Sun, J.Q., Wang, H.J., Yuan, W., 2009. Role of the tropical Atlantic sea surface temperature in the decadal change of the summer North Atlantic Oscillation. Journal of Geophysical Research—Atmospheres 114, D20110.
Suppiah, R., Hennessy, K.J., 1996. Trends in the intensity and frequency of heavy rainfall in tropical Australia and links with the Southern Oscillation. Australian Meteorological Magazine 45 (1), 1–17.
Terray, L., Demory, M.E., Deque, M., de Coetlogon, G., Maisonnave, E., 2004. Simulation of late-twenty-first-century changes in wintertime atmospheric circulation over Europe due to anthropogenic causes. Journal of Climate 17 (24), 4630–4635.
Tewolde, M., Beza, T., Costa, A.C., Painho, M., 2010. Comparison of different interpolation techniques to map temperature in the southern region of Eritrea. 13th AGILE International Conference on Geographic Information Science 2010, Guimarães, Portugal, pp. 1–5.
Tomozeiu, R., Busuioc, A., Stefan, S., 2002. Changes in seasonal mean maximum air temperature in Romania and their connection with large-scale circulation. International Journal of Climatology 22 (10), 1181–1196.
Toreti, A., Desiato, F., 2008. Temperature trend over Italy from 1961 to 2004. Theoretical and Applied Climatology 91 (1–4), 51–58.
Toreti, A., Desiato, F., Fioravanti, G., Perconti, W., 2010. Seasonal temperatures over Italy and their relationship with low-frequency atmospheric circulation patterns. Climatic Change 99 (1–2), 211–227.
Trigo, R.M., Osborn, T.J., Corte-Real, J.M., 2002. The North Atlantic Oscillation influence on Europe: climate impacts and associated physical mechanisms (vol 20, pg 9, 2002). Climate Research 20 (1), 9–17.
Van Loon, H., Rogers, J.C., 1978. The seesaw in winter temperatures between Greenland and Northern Europe Part I: general description. Monthly Weather Review 106, 296–310.
Vicente-Serrano, S.M., Saz-Sánchez, M.A., Cuadrat, J.M., 2003. Comparative analysis of interpolation methods in the middle Ebro Valley (Spain): application to annual precipitation and temperature. Climate Research 24 (2), 161–180.
Wulfmeyer, V., Henning-Müller, I., 2006. The climate station of the University of Hohenheim: analyses of air temperature and precipitation time series since 1878. International Journal of Climatology 26, 113–138.
Xoplaki, E., González-Rouco, J.F., Luterbacher, J., Wanner, H., 2003. Mediterranean summer air temperature variability and its connection to the large-scale atmospheric circulation and SSTs. Climate Dynamics 20 (7), 723–739.
Xoplaki, E., Luterbacher, J., González-Rouco, J.F., 2006. Mediterranean summer temperature and winter precipitation, large-scale dynamics, trends. Nuovo Cimento Della Societa Italiana Di Fisica C—Geophysics and Space Physics 29 (1), 45–54.
Yu, B., Neil, D.T., 1993. Long term variations in regional rainfall in the south-west of Western Australia and the difference between average and high intensity rainfalls. International Journal of Climatology 13, 77–88.
Yuan, W., Sun, J.Q., 2009. Enhancement of the summer North Atlantic Oscillation influence on Northern Hemisphere air temperature. Advances in Atmospheric Sciences 26 (6), 1209–1214.