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Spatial Patterns of Long-term Spanish Temperature Change

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Introduction.

Long-term surface air temperature change over Spain has recently been assessed and documented by authors through the development of a new daily adjusted dataset of daily maximum, minimum and mean temperature (SDATS, "Spanish Daily Adjusted Temperature Series"). This dataset has been reconstructed with the 22 longest and reliable Spanish records for the period 1850-2003 in the framework of the EU-funded project EMULATE (**E**uropean and North Atlantic daily to **MUL**tidecadal clim**ATE** variability). Regional time series of daily mean temperatures, the Spanish Temperature Series (STS), have been constructed by averaging daily anomalies and then adding back the base-period mean. Regional warming is evident and highly significant (at 0.01 level) in these data (0.011 $\pm$ 0.002 ºC/year^{-1} for annual mean values), with the highest rates of warming from 1973 onwards (0.054 $\pm$ 0.015 ºC/year^{-1}), five times larger than the estimated over the entire period.

Here we analyse spatial patterns of long-term temperature change over Spain, by employing a subset of these data: daily mean temperature series during 1894-2003. A

Rotated Principal Component Analysis (RPCA) of the daily mean temperature series has been carried out on an annual and a seasonal basis, in order to characterise the most important spatial modes of variability of the Spanish long-term temperature change. The presentation will discuss these patterns and show many of the time series.

Analytical techniques and results.

The 22 daily adjusted records have been subjected to a RPCA, according to the VARIMAX criterion and using the 0.7 threshold of the Kaiser's rule (Kaiser, 1958; Richman, 1983), to summarize the inter-annual variability of daily mean temperature data during 1894-2003. Maps of REOFs loading factors and the associated score series have been produced. Linear trends of these time series have been fitted and the 95% confidence intervals of coefficient trends have also been estimated. The associated RPC time series have been studied to identify trends, anomalous warmer and cooler episodes and other interannual variations.

Three prominent patterns have been estimated from this analysis, which explain 89.5% of accumulative variance on annual basis: Northern Spain (NS), South-Western Spain (SWS) and South-Eastern Spain (SES). All three patterns' score series reach statistically significant (at 1% level) coefficient trends on this scale: 0.011 ± 0.0056 ºC/year^{-1} (NS), 0.010 ± 0.0057 ºC/year^{-1} (SWS) and 0.013 ± 0.0055 ºC/year^{-1} (SES) respectively. The SES region has contributed most to the entire Spanish warming during the analysed period.

On a seasonal scale, these patterns also explain the 90.6% of spring accumulative variance during the 110 years of the Spanish daily mean temperature dataset, 85.5% for summer and 89.3% for autumn. For winter a simple mode of spatial variability has emerged from the analysis, as only two patterns together explain the 87.3% of accumulative variance; these are the SWS pattern and a variant of the NS pattern, the North and North-Eastern Spain pattern (NNES). Winter warming has been more vigorously recorded over the SWS pattern (44.1% of the total variance and with the highest and significant (at 0.01 level) trendof its score series); meanwhile the NNES pattern explains the 43.2% of the variance, being its trend also statistically significant at the same level(Table I).

Table I. Seasonal coefficient trends and the 95% confidence intervals in parenthesis estimated from score series of the different Spanish spatial patterns emerged from RPCA (in ºC/year^{-1}). Bold (italic) indicates significance at 1% (5%) level.

For spring, the NS pattern explains 34.2% of the total variance, the SWS pattern 33% and SES pattern 23.4%. Trends of their associated score series are shown in Table I. In spring the highest coefficient trend is found in the SES pattern, being the area that

	NS	SWS	SES	NNES
Winter	-	**0.012** (±0.0056)	-	**0.010** (±0.0057)
Spring	**0.008** (±0.0058)	0.007 (±0.0059)	**0.009** (±0.0058)	-
Summer	**0.008** (±0.0058)	0.007 (±0.0059)	**0.011** (±0.0057)	-
Autumn	0.007(±0.0059)	0.006 (±0.0059)	**0.008** (±0.0058)	-

more vigorously has contributed to the entire Spanish warming during this season and period.

Spanish summer warming is explained by the SWS pattern (31.9%), followed by the SES pattern (27.7%) and NS pattern (25.9%). SES is again the pattern that reaches the highest coefficient trend, confirming the key role of this sub-region on the entire regional warming.

Finally, for autumn the NS pattern explains 35.9%, the SWS pattern 34.5% and the SES pattern 18.9%. The highest trend is again recorded over SES, being the spatial pattern that has contributed most to the Spanish entire warming for this season, followed by NS and SWS (Table I).

Conclusions

For the first time, authors have documented and analysed spatial patterns of long-term temperature variability over Spain (1894-2003). A significant and generalised increase in daily mean temperature has characterised the course of the 20^{th} century over entire Spain. The most remarkable feature is the strong and highly significant episode of rising temperatures that began in 1973 and is still lasting, in agreement with results found by Rodríguez-Puebla *et al*. (2001) who analysed a shorter period (1949-2000). Three spatial patterns of Spanish temperature variability have been estimated from a RPCA: The NS, SWS and SES patterns, which together explain 89.5% of accumulative variance on annual basis. Seasonally, two winter spatial patterns, SWS and NNES patterns (87.3%) have been estimated; meanwhile for the other seasons the same patterns as on the annual basis have been identified explaining 90.6% of the spring accumulative variance, 85.5% for summer and 89.3% for autumn.

The SES pattern, directly influenced by atmospheric and SST conditions over the Mediterranean Sea, has accounted for the largest rates of change in annual, spring, summer and autumn temperatures; meanwhile winter warming has been more contributed by SWS. Further analysis will be conducted in the near future in order to relate these spatial patterns to large-scale atmospheric anomalies and SST.

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