



Long-term Change in the Mean and Extreme State of Surface Air Temperature over Spain (1850-2003)

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Introduction

A new daily adjusted dataset composed of the 22 longest Spanish daily temperature records (daily maximum, minimum, mean temperatures and diurnal temperature range) has been reconstructed and generated in the framework of the European Community (EC)-funded project EMULATE (**E**uropean and **N**orth **A**tlantic daily to **M**ULTidecadal clim**A**TE variability), which began in November 2002 and will finish in October 2005. One of the objectives of EMULATE is to relate variations and trends in atmospheric circulation patterns to prominent extremes in temperature and precipitation. In this context and given the currently limited spatial coverage of the available daily time-resolution series in Spain, one of our initial aims was to locate, recover, digitise, quality control and adjust the longest and most reliable Spanish temperature and precipitation records, in order to initially develop a comprehensive analysis of long-term change in the mean and extreme state of Spanish climate.

This contribution aims to assess long-term (1850-2003) Spanish temperature change, by employing the new daily adjusted records of daily mean temperature. In this regard,

an assessment on long-term temperature variations and trends for further documenting and analysing the Spanish warming has been conducted by means of the creation of the Spanish Temperature Series (STS), which covers for the very first time the bulk of the Spanish instrumental era with a reasonably well resolved spatial coverage. An analysis on long-term changes in extreme temperatures occurrence has also been carried out to address quantitatively the nature of changes in the mean state of Spanish climate and document how long-term temperature change has been produced. The presentation will show of the major results.

Data, methods and results

A dataset integrating the 22 longest and reliable raw records of daily maximum and minimum temperatures has been generated by collecting data for the period 1850-2003 from different meteorological sources. Quality control tests, a relative homogeneity assessment on monthly basis (the Standard Normal Homogeneity Test developed by Alexandersson and Moberg, 1997) and the Vincent *et al.* (2002) scheme to interpolate monthly correction factors to daily basis have been followed and run to these raw data, in order to assure a credible reconstruction and assessment of long-term temperature variability and change over Spain. This new daily adjusted dataset, the so-called *Spanish Daily Adjusted Temperature Series* (SDATS), is composed of the adjusted 22 long records of daily maximum (Tmax), minimum (Tmin), mean (Tmean) temperatures and diurnal temperature range (DTR). Regional time series of daily mean temperatures for the period 1850-2003, the Spanish Temperature Series (STS), has been constructed by averaging daily anomalies and then adding back the base-period mean. A preliminary long-term extreme temperature change assessment has been conducted by employing the RCLimDex mechanism (Zhang and Yang, 2004) and by inspecting trends in percentile-based temperature indices (daily Tmax and Tmin 10th and 90th percentiles) that describe the number of “moderately extreme cold” days and nights and “moderately extreme warm” days and nights, respectively.

Regional warming is evident in these data over the entire period on annual and seasonal basis (Table I). Annual and seasonal trends and variations have been assessed, indicating a highly significant warming over the entire period. This warming has been widespread across the year, with winter reaching the largest seasonal rates of change and summer the lowest rates (even when estimated for the period 1850-2002 to leave out the very warm Spanish summer of 2003). Different episodes of rising and falling temperatures and intervals of anomalous warming (cooling) are shown as well. The most remarkable feature of the Spanish long-term temperature change has been the pronounced increase in temperature since 1973, which is still lasting. The analysis also confirm the existence of a mid-1940s’ warm phase and a mid-1970s cold phase, found out in previous work over Spain (Brunet *et al.* 2002) and on larger spatial scales

(Jones *et al.*, 1999). The coldest period in Spain was recorded, as well as worldwide (Jones and Moberg, 2003), during 1880-1894 (-1.4 °C average anomaly re 1961-1990 normal period). The most consistent and coherent temporal signal emerging from the calculated trends of the four extreme temperature indices selected indicates that Spanish warming has been mainly associated with a reduction (0.073 ± 0.015 days/year) in the number of “moderately extreme cold days” ($T_{\max} < 10^{th}$ percentile) and “moderately extreme cold nights” (0.065 ± 0.019 days/year); meanwhile trends of “moderately extreme warm days and nights” (T_{\max} and $T_{\min} > 90^{th}$ percentile) indicate that warm days and nights have increased at similar rates of 0.055 ± 0.012 days/year over the entire period.

Table I. Seasonal and annual temperature change fitted by a linear trend and in parenthesis the associated \pm standard errors for 95% confidence interval (in °C/year⁻¹) of the STS estimated over the entire period and several episodes of warming and cooling. Bold (italic) values indicates significance at 0.01 (0.05) levels.

Periods	Annual	Winter	Spring	Summer	Autum
1850-2003	0.011 (± 0.002)	0.013 (± 0.0031)	0.011 (± 0.0032)	0.01 (± 0.0028)	0.011 (± 0.0028)
1904-1929	0.03 (± 0.018)	0.031 (± 0.04)	0.032 (± 0.041)	0.028 (± 0.034)	0.035 (± 0.034)
1948-1973	-0.029 (± 0.025)	-0.011 (± 0.044)	-0.044 (± 0.037)	-0.034 (± 0.032)	-0.024 (± 0.032)
1973-2003	0.054 (± 0.015)	0.031 (± 0.033)	0.084 (± 0.022)	0.072 (± 0.031)	0.032 (± 0.031)
1973-2002	0.053 (± 0.016)	0.032 (± 0.036)	0.083 (± 0.024)	0.06 (± 0.03)	0.033 (± 0.031)

Conclusions

Clear and statistically significant evidences of annual and seasonal warming have been observed over Spain both throughout the entire period and, particularly, for the last episode of strong warming on the Spanish instrumental record, which began slightly earlier in Spain than on global and hemispherical scales (1973 versus 1977, this study versus Jones and Moberg, 2003). A shift of the reduced seasonal contrast in Spain over 1850-2003 has been found during this last warm phase, as summer trends increased at larger rates than winter ones, indicating an increasing in the seasonal contrast during this last very likely anthropogenically forced period. This claim is also true even when leaving out the hot summer of 2003 (Table I). Analyses looking for trends in extreme temperatures occurrence have evidenced significant (at 0.01 level) reductions of extremely cold days and nights and in lesser extent by increases in number of extremely warm nights and days in some seasons. This result is slightly different to the found on a global scale, where warm nights have increased at the largest rates (Frich *et al.* 2002). Further analysis relating change in the mean and extreme state of the Span-

ish thermal climate to prominent large-scale atmospheric anomalies and SSTs will be conducted.

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