Atmospheric Climatic observations and instrumental reconstructions over the Iberian Peninsula I: development of high-quality climatic time series.

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Introduction

Observational series are the basis for climate variability studies. They provide the raw material used to analyse local climates, build gridded products to assess regional or global climates and their changes, and calibrate global climate models. Great efforts have been made in the last decades to increase the number and quality of the climate measurements, but the technologies and observing practices have suffered relevant changes since the beginning of the instrumental era (mid-19th century) which, jointly with relocations and changes in the surrounding of the observatories, altered the properties of the observational records. Therefore, statistical methodologies must be applied to the raw series in order to homogenize them, i.e., to identify and remove the artificial biases from the real climatic signal. International initiatives have grown in the last decades to improve homogenization methods, develop new techniques or adapt the existing ones to new variables. For example, in the years 2007-2011 the COST Action ES0601 "Advances in homogenisation methods of climate series: an integrated approach (HOME)" put together the main European research groups to "achieve a general method for homogenizing climate and environmental datasets" (Venema et al., 2012). Further improvements of these techniques have reached enough skill to reliably remove most significant biases in the monthly series.

However, daily series have much more variability than their monthly aggregates, hence limiting the power of detection of inhomogeneities. Therefore, more refined statistical methods are needed, including the study of parallel measurements to provide corrections based on metrological studies (MeteoMet project: Merlone et al., 2015) or on models simulating the physics of the phenomena producing biases (Auchmann and Brönnimann, 2012).

Development of high-quality time series

In order to study climate variability, climatologists would like to have long-term observational series, free of errors and inhomogeneities. Therefore, efforts are needed to obtain longer time series, particularly via digitalization of data in weather books (data rescue), and careful attention must be paid to control their quality and homogeneity.

Data Rescue (DARE)

Data rescue involves a great deal of work: discovering observations in old documents (logs, paper strips and climate summaries), scanning or photographing them, inventorying, and digitizing data. Yet the scarcity of staff in many National Meteorological Services prevents these tasks from progressing at the desired speed. Apart from limited data rescue activities in several universities and governmental institutions, it is worth mentioning the efforts on early instrumental data recovery conducted under framework of the Salvà-Sinobas project (Domínguez-Castro et al., 2014), which digitized more than 100,000 meteorological observations made between 1780 and 1850, a period in which only two series were previously available. This data set contains measurements of air temperature, atmospheric pressure, wind direction and weather state from 16 sites in mainland Spain and Balearic Islands, most of them at a daily resolution. García et al. (2014) reconstructed the 1933-2013 global solar radiation time series from the Izaña Atmospheric Observatory (Tenerife, Canary Is.).

On-going projects are currently recovering and digitizing monthly values of precipitation and average extreme temperatures prior to 1950. There are other isolated data rescue efforts focused on particular stations, as those completing the series of Maò (Carreras, 2009), Barcelona (Prohom et al., 2016) and Oviedo (Mora and González, 2017).

Quality control and homogenization

The quality control of observations is a multi-phase task since it must be performed from the first time data are registered to their final storage in the operational database. Moreover, climatologists normally apply further quality controls before analysing the series, checking their spatial and internal consistency. These procedures are often implemented in the same software used to detect and correct inhomogeneities.

As after the successful COST Action ES0601, several homogenization packages have improved their performance, and with new ones emerging, additional comparisons of their skill must be undertaken. One of these efforts is being financed by the Spanish Ministry of Economy and Competitiveness through the project MULTITEST, which aims at improving the comparative tests made by Guijarro (2011). Their results are available at http://www.climatol.eu/MULTITEST/index.html

Some international projects are currently trying to take advantage of current homogenization methodologies to build a global air temperature dataset with an unprecedented quality and density of stations, especially the International Surface Temperature Initiative (http://www.surfacetemperatures.org/).

One of the main concerns about series homogeneity is related to the changes from manual to automatic stations. As these are difficult to detect with relative homogenization methods when all or most of the instruments in a network are replaced in a short period of time, the Parallel Observations Science Team (POST) is compiling a database with parallel measurements, in order to assess the impact of this overall instrumental changes (http://www.surfacetemperatures.org/databank/parallel_measurements).

Among the first efforts to build a quality controlled and homogenized long dataset was the compilation of SDATS (Brunet et al., 2006), which contains 22 Spanish timeseries of daily air temperatures (mean, maximum and minimum) from 1850 to 2005. This dataset has recently been reassessed and updated to 2014. In addition to preparing datasets in gridded format (see Herrera et al. in this volume), quality control and homogenization tasks have also been undertaken as a previous step in several climate variability studies:

- Vicente-Serrano et al. (2010) constructed a daily precipitation database for Northeast Spain using data from 3106 stations along 1901-2002. Data gaps were filled using values from nearest neighbor stations, and the homogeneity of the series was checked using the Standard Normal Homogeneity Test (SNHT; Alexandersson, 1986) with the help of the AnClim package (Štepánek, 2008a).
- In the same area, El Kenawy et al. (2011 and 2013) compiled daily extreme air temperature data from 1583 stations spanning portions of the 1900-2006 period. After filling missing data by linear regression, the series homogeneity was assessed by applying SNHT, Two-Phase regression and the Vincent tests.
- González-Hidalgo et al. (2011 and 2015) built monthly precipitation (MOPREDAS, 1951-2010) and maximum and minimum temperature (MOTEDAS, 1949-2005) databases by using all available series (6821 and 1358 respectively) with a minimum of 10 years of observations in mainland Spain. Their homogenization was performed by means of the AnClim and ProclimDB software (Štepánek, 2008a, b).
- Luna et al. (2012) built a dataset integrated by 66 long monthly precipitation series, covering mainland Spain and the Balearic Islands, which was homogenized with the Climatol package (Guijarro, 2013a) using all available Spanish precipitation series as references.
- Martín et al. (2012) studied 36 selected stations from Tenerife (Canary Islands), using AnClim to homogenize them, while Máyer et al. (2017) selected 23 Canary precipitation series to study the trends of the Concentration Index.

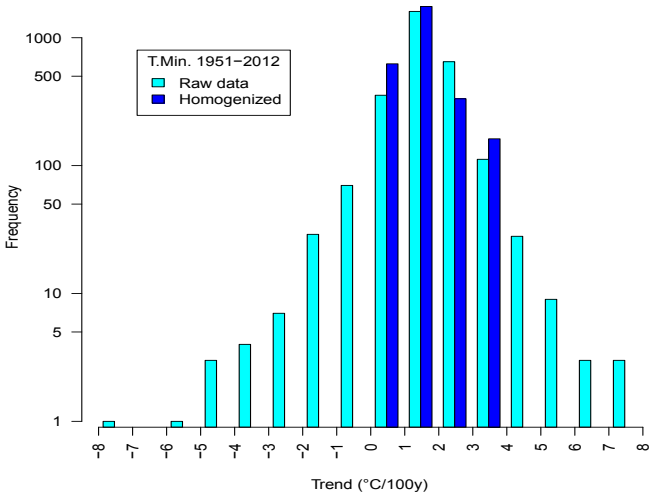

Figure 1: Trends of the Spanish minimum air temperatures before and after the homogenization of their series. Inhomogeneities in the raw observational data result in an abnormally high dispersion of the computed trends.

- Guijarro (2013b) homogenized mean maximum and minimum monthly air temperatures from 2856 Spanish series (including the Balearic and Canary archipelagos) with at least 10 years of observations by means of the Climatol package. An illustrative example of the benefits of the homogenization procedures before any variability test is made can be seen in Figure 1.
- Cuadrat et al. (2013) homogenized 49 long series of daily extreme temperatures using SNHT with the support of the ProClimDB software, to study the evolution of heat and cold waves in Spain.

- Sánchez-Lorenzo et al. (2013) developed a new dataset of surface solar radiation in Spain based on the longest series with records since the 1980s. Thirteen monthly series were selected, and their homogeneity was assessed by means of the SNHT. A similar approach was performed to study changes in cloudiness since the mid-19th century by considering 39 long-term Spanish series (Sanchez-Lorenzo et al., 2012).
- Sánchez-Lorenzo et al. (2014) built a dataset of evaporation in Spain based on long-term series of Piché and pan measurements. Piché evaporation data were gathered from 58 stations, beginning in the 1960s, while pan evaporation data from 21 observatories begin in 1984. This dataset was homogenized by means of the HOMER software.
- Azorin-Molina et al. (2014) compiled monthly wind speed series recorded at 67 stations across Spain and Portugal for 1961-2011, and applied the SNHT using the AnClim package with MM5 simulation output series as references.
- Azorin-Molina et al. (2016) assessed the variability of daily peak wind gusts of 80 series from Spain and Portugal for 1961-2014, also using MM5 outputs as references to homogenize them, this time by applying the Climatol package (Guijarro, 2013a).
- A recent PhD thesis (Serrano, 2017) compiles a new reconstruction of daily Spanish precipitation for the period 1951-2015.

Ongoing research within the MeteoMet project is being performed, and the Spanish IMPACTRON network is working towards improving our understanding of the impact of transitions such as (i) manual to automatic observation, (ii) relocations from cities to airports, and (iii) changes in thermometric screen types, on air temperature series.

Conclusion

Climatological studies developed in Spain along the last years have improved previous efforts focused on the production of quality controlled and homogeneous datasets, and have addressed the study of new climatic variables. These studies will need to be extended to other climatic variables and be updated regularly to include new incoming data. At the same time, forthcoming efforts will focus in the homogenization of daily series, which will allow a more refined assessment of the past and current climate variability, and at the same time will be useful to provide better future climate projections through downscaling of RCM forecasts.

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