Climatic observations and instrumental reconstructions: development of high-quality climatic gridded products

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Introduction

Observations, studies of feedback processes, and model simulations are the basis of our knowledge and understanding of the climate system, as has been shown by the Working Group I of IPCC's Fifth Assessment Report (IPCC, 2013). In order to improve and adapt observational datasets to the actual needs of the scientific and impact studies communities, as well as to the needs of policy makers, many international programs have been setup to collect data and information used to study climate (e.g. Copernicus, formerly GMES: Global Monitoring for Environment and Security), and to provide climate services (e.g. Copernicus and GFCS: Global Framework for Climate Services). The main focus of some of these projects is to prepare and deliver climate information that meet users' needs (WMO, 2011). Within these initiatives, a set of Essential Climate Variables (ECVs) (GCOS, 2010a; Bojinski et al., 2014) have been identified, based on their relevance to characterize the climate system and its changes, feasibility and cost effectiveness. Also, guidance and best practices have been defined to obtain and support the generation of long-term, high-quality and traceable ECV datasets (GCOS, 2010b).

In this framework, several projects have grown in the last decade to improve the temporal and spatial coverage of our observational networks (e.g. EURO4M or UERRA Projects), process the raw measurements to isolate the climatic signal (e.g. Action Cost HOME or MeteoMet), develop products (e.g. gridded datasets) useful for the different communities, and include them in the assimilation process of the reanalysis products (e.g. UERRA Project). Despite the improvement of our observations and the development of very high quality observational datasets (see Guijarro et al., this volume, for more details), high-resolution gridded observational products that capture the temporal and spatial diversity of climatic variables are increasingly demanded by the climate analysis and impact communities. Several products have been developed within the activities of different national (e.g. Portugal: Belo-Pereira et al., 2011; Romania: Birsan and Dumitrescu, 2014; Dumitrescu and Birsan, 2015; the Alpine region: Isotta et al., 2014; or Germany: HYRAS precipitation database, Rauthe, 2013) or international (e.g. E-OBS, Haylock et al., 2008; van den Besselaar et al., 2011) projects by applying some interpolation process to the raw observations.

This work describes the main advances and initiatives since the previous CLIVAR-Spain assessment (Pérez and Boscolo, 2010) on the development of climatic gridded products emphasising the studies affecting the Iberian Peninsula.

Development of gridded datasets

As described in the previous section, the high-quality observational datasets usually comprise of a limited number of time series non-homogeneously distributed, locally representative and, in most cases, spanning different time periods. However, datasets with different features are needed for different purposes, and some post-processing is needed to build adequate products. High-resolution gridded datasets built from quality controlled observational datasets are increasingly demanded for climate analysis and the impacts communities, and several products have been developed in the last few years in response to this demand (e.g. E-OBS in Europe or MOPREDAS, MOTEDAS, SAFRAN or Spain02, among others, in Spain).

Due to the high climatic variability and complex relief of Spain, the available international products (e.g. E-OBS, WATCH or WFDEI) are not able to reproduce properly the different Spanish climate regimes (Herrera et al., 2012; Herrera et al., 2015; Bedia et al., 2013). Many regional and national gridded datasets have been built in the last decade using different approaches according to the needs of the scientific and impact communities, leading to a wide range of products which will be summarized in this section.

Focusing on the spatial resolution, Ninyerola et al. (2007) developed a dataset with a 200-m spatial resolution for the Iberian Peninsula of monthly and annual climatologies of precipitation, radiation and temperatures, which has been extensively used in ecological modelling. Gonzalo et al. (2010) built a similar dataset to develop the phytoclimatic diagnosis of the Peninsular Spain, but using different interpolation method and explicative variables, and with lower spatial resolution (1 km).

At a regional scale, Vicente-Serrano et al. (2003, 2007 and 2010) built climatic maps of monthly precipitation, temperatures and fog in the Ebro Valley and Aragón at a 1 km spatial resolution, considering several interpolation methods. Garzón-Machado et al. (2014) built a climatophilous potential natural vegetation map with a spatial resolution of 25 m for La Palma Island, in the Canary Islands. Ruiz-Arias et al. (2011, 2015 and 2016) developed solar radiation gridded datasets for Andalusia (1km) and Peninsular Spain and Balearic Islands (10km), using this one to assess the solar radiation of the WRF Model. However, the aim of most of these studies was comparison between different interpolation methods and, as a result, most of these datasets are distributed only under request.

Despite the very high spatial resolution of the previous datasets, time series of monthly, daily or intra-daily data are necessary in many cases (e.g. for trend analysis). In this sense, González-Hidalgo et al. (2011 and 2015) developed monthly datasets of precipitation (MOPREDAS) and temperatures (MOTEDAS) for mainland Spain to be used for trend analysis, model validation and downscaling purposes, covering 1945-2005 and 1951-2010, respectively. Both datasets have a spatial resolution of 0.1º, and have made use of a dense observational network of 2670 stations for precipitation and 1358 for temperature from the Spanish Meteorological Agency (AEMET).

Herrera et al. (2011, 2012 and 2016) developed a series of high-resolution daily precipitation and temperature gridded datasets (Spain02) for the peninsular Spain and the Balearic Islands. To this aim, 2756 and 250 quality-controlled stations from the Spanish Meteorological Agency (AEMET) were used to build the different existing versions. In particular, version v2 (0.2º regular grid) is a gridded dataset with local representativeness, appropriate to local and extreme events analysis (Herrera et al., 2012), whilst version v4 includes three different resolutions matching Euro-CORDEX grids (0.11º, 0.22º and 0.44º in rotated coordinates). This version provides areal representative (AA) values (by averaging from an auxiliary 0.01º grid) in products AA-2D, AA-3D and AA-OK, following the notation used in Herrera et al. 2016, and it is an appropriate product to validate regional climate models (RCM). Point representative values are still provided in version v4 in product OK (Ordinary Kriging). Version v3 was built considering quality controlled stations with long time series of precipitation (at least 40 years with at most 10% of missing data per year) in order to obtain an appropriate dataset for trend analysis. The different versions of Spain02 are freely distributed for research purposes at the AEMET climate services portal. Version v2 is the reference dataset used in the development of the scenarios for the national program for regional climate change (PNACC-2012). Version v4 is one of the national gridded datasets considered in the framework of the COST Action VALUE (http://www.value-cost.eu/) used to validate regional climate models of Euro-CORDEX, the European branch of the CORDEX initiative.

In addition to the Spanish gridded datasets, Belo-Pereira et al. (2011) developed a dataset for Portugal (PT02) using 400 quality-controlled stations, and with the same interpolation technique and grid used in version v2 of Spain02. This has led the development of two equivalent datasets for a common period (1951-2003) that have been combined in recent studies to obtain the dataset IB02, a precipitation gridded dataset of daily precipitation for the Iberian Peninsula (Ramos et al., 2016; Sousa et al., 2016).

Recently, an extension of the SAFRAN analysis (Durand et al., 1993; 1999) has been applied to the mainland Spain and the Balearic Islands (Quintana-Seguí et al., 2016; 2017), leading to an hourly high-resolution (5 km) gridded dataset based on daily precipitation, and six-hourly temperature, wind speed, relative humidity and cloudiness. SAFRAN also provides modelled incoming visible and infra-red radiation. This way, it provides all the necessary variables to force, for instance, a Land-Surface Model (LSM) or any other physically based distributed hydrological model. The product covers the period 1979-2014, and is available for research purposes from the Mistrals-HyMex database (Quintana-Seguí, 2015).

On a regional scale, several high spatial resolution (~1 km) daily datasets have been developed in the last years within regional projects or specific analysis/needs of some research groups. Militino et al. (2015) defined and validated a spatio-temporal interpolation method to obtain a precipitation grid with a resolution of 1 km covering the Navarra region. Within the regional project "Escenarios Regionales Probabilísticos de Cambio Climático en Cantabria: Termopluviometría", Gutierrez et al. (2010) built a similar product for Cantabria, including precipitation and temperature, which was used to project the future climate change scenarios for the region by means of statistical downscaling. Miró Pérez et al. (2015) combined statistical downscaling and spatial interpolation to obtain a very-high resolution grid of daily maximum and minimum temperatures for the Valencia region considering ~300 stations from different institutions (AEMET, CEAM, SIAR and IIG) covering the period 1948-2011. This dataset is referred as SDSITVC in Miró et al. (2016), where it is proposed as a tool for estimating bioclimatic change already occurred in mountainous areas.

Summary and conclusions

In the last few years, a great effort has been carried out to improve the quality of the tools and products used to analyse the climatic system from different points of view. In this sense, several initiatives and projects have emerged aiming to rescue and digitalize existing observational data, with special attention to regions with a poor spatial and/or temporal coverage, and to develop adequate tools and methods to elaborate high-quality datasets for climate analysis.

The Spanish climatological community is involved in most of the current projects and initiatives related to the development of several tools and products (e.g., Climatol package for data analysis and homogenization, or the gridded datasets MOPREDAS, SAFRAN or Spain02), which are being presently used by the international community in many studies, and extending the analysis on data assimilation methods to different models, variables and processes.

In particular, as has been reflected in this article, several regional and national gridded products have been developed in the last years for research purposes covering a wide range of applications, resolutions, variables and time periods. However, the main shortcoming that should be pointed out is that most of the high-quality datasets developed at a local, regional or national scale in Spain are rarely shared with the climatological community, leading to redundant analysis in many cases. On the other hand, there are not adequate intercomparison analyses between the different datasets developed. Finally, recent changes made by the Spanish Meteorological Agency regarding its open data policy, along with the improvements of new or existing tools, could allow the publication of new and updated gridded climatological products in the near future.

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