Progress in Detection and Projection of Climate Change in Spain since the 2010 CLIVAR-Spain regional climate change assessment report

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Introduction

The Iberian Peninsula region offers a challenging benchmark for climate variability studies for several reasons. It exhibits a wide variety of climatic regimes, ranging from wet Atlantic climates with annual precipitation around 2000 mm, to extensive semi-arid regions with severe hydrological stress, to even cold alpine environments in some isolated areas. This climatic diversity results from its latitudinal location at the northern edge of the subtropics, its complex topography punctuated by several important mountain chains, its peninsular nature, and the presence of two surrounding very different water masses: the Atlantic Ocean and the Mediterranean sea. The climate variety is reflected in large heterogeneities in the land-surface energy and water budgets and related exchanges with the atmosphere. Additionally, extreme events such as prolonged dry periods, heatwaves, heavy convective precipitation and floods are recurrent features. All these factors make comprehensive understanding and modelling of Iberian climate particularly challenging.

Like the rest of the Mediterranean region, and as stated in the last IPCC report (WG1AR5, Chapter 14, Christensen et al., 2013) the Iberian Peninsula is projected to be severely affected by large temperature increase and precipitation reduction, particularly in summer, and very likely more frequent heat waves. The prospect of strong negative impacts in an already vulnerable region emphasizes the need for thorough assessments of the current climate to better interpret climate projections, and increase our confidence in them.

Climate science developed slower in Spain if compared to some other European countries, but currently a large community of national researchers is involved in assessing the role of various processes, such as topography, natural modes of variability, teleconnections from the tropics, air-sea and land-sea interactions, in shaping those diverse regional climates and understanding how these may change under global warming. This task is aided by the existence of relatively long meteorological time-series and a dense network of stations — although regrettably not all data are publicly available to investigators.

Because many of the studies undertaken by the Spanish climate community fit in well with the main scientific objectives of the CLIVAR project, a network of scientists was created about 15 years ago with the goal of coordinating climate science in Spain, and increasing its international visibility. Roberta Boscolo at the time working for the International CLIVAR Project Office, was instrumental in promoting this effort. This led to the creation of the current CLIVAR-SPAIN scientific committee (www.clivar.es), that includes representatives from all the different fields related to CLIVAR science (meteorologists, atmospheric physicists, oceanographers and paleo scientists). The committee, with very little support from the national government, also strives to serve as a reference for the Spanish climate science community, a contact point with society and policy-makers, and a liaison with the international CLIVAR program.

The first tangible achievements of this committee were the organization of two national workshops in 2005 and 2009, both of which were followed by the publication of two assessment reports (available in English in the above webpage). While the first one, entitled "State of the art of the Spanish contribution to the Climate Variability and Predictability (CLIVAR) study", was intended to provide an overview of Spanish research groups involved in climate science, the second one, entitled "Climate in Spain: past, present and future. Regional climate change assessment report" was a comprehensive peer-reviewed regional climate assessment report, to which more than a hundred researchers contributed. It was the first coordinated effort to involve the entire Spanish climate community into a scientific endeavour to be made available nationally and internationally, as evidence of the vitality and relevance of Spanish climate science. We were proud to be able to present this report orally at the 18th session of the CLIVAR Scientific Steering Group in Paris (2011), and at the WCRP Open Science Conference held the same year in Denver via a cluster of posters.

After the publication of the last IPCC report in 2013, the CLIVAR-SPAIN committee decided that an update of that first regional assessment report was timely. With that in mind, a symposium was held in Tortosa in 2015 entitled "International Symposium CLIMATE-ES 2015: Progress on climate change detection and projections over Spain since the findings of the IPCC AR5" (http://www.climaes2015.urv.cat), with the support of various research institutions, including the Spanish Meteorological office (AEMET). The main goal of the symposium was to serve as a starting point for an updated assessment report. Subsequently, however, owing to lack of institutional funding, it was thought that a more viable option — and hopefully a more effective one — would be to present the results of the symposium via a special issue in CLIVAR Exchanges.

The following nine articles summarize the main findings presented at the Tortosa meeting. Each article deals with one of the topics of the symposium, namely: paleoclimate, climate time series, gridded datasets, atmospheric trends, teleconnections, oceanic variability, regional model assessment, regional atmospheric climate projections and oceanic projections (with projections for the Mediterranean and Atlantic treated separately). The structure resembles that of the first report but the emphasis is on updated results, advances in understanding, and new developments or research foci. The aim of this publication is to highlight the broad scope of ongoing national research focused on Spanish climate. For this reason, special attention has been paid to include as many research groups as possible, hoping that this issue may be used as a basis for finding Spanish scientists who specialize on particular topics.

Although the continued growth of Spanish climate science is evident, with an increasing number of contributions to international journals and individual participation in international projects and IPCC reports — a non-negligible feat in times of economic crisis and drastic science budget cuts —, we hope this special issue will also serve to demonstrate the capacity of the Spanish climate science community to work together in a coordinated effort. At the same time, we recognise that this special issue only partially describes national achievements of recent years.

We thank all the researchers that have contributed directly or indirectly to this issue, hoping that it will help to increase their international visibility and create awareness and recognition of their work. We also want to express our gratitude to all former members of the CLIVAR-SPAIN committee who, with their example and enthusiasm, paved the road and taught us that initiatives such as these are possible even without institutional support.

What follows is a brief summary of the main findings from each article.

1: Paleoclimate

The available marine and terrestrial climate reconstructions in the Iberian Peninsula for the last 2,000 years show the evidence of a complex spatial and temporal evolution for precipitation and temperature, with a pronounced spatial variability.

This replicates somehow the current climate variability in the Iberian Peninsula with a complex geography, led to a large presence of microclimates. However, the climate evolution of the Iberian Peninsula for the two last millennia can be divided in four main climate periods: the Roman Period, The Early Medieval Ages, the Medieval Climate Anomaly and the Little Ice Age, characterized by distinctive temperature and precipitation patterns. However, a larger effort must be conducted in order to obtain more robust and multiproxy climate reconstructions in areas where the geographical coverage is still low, such as the central Iberian Peninsula and northern marine areas. Furthermore, a better understanding of the decadal-to-centennial evolution of the main climate modes, specially the EA (Eastern Atlantic) and SCAND (Scandinavian), is of paramount importance, as well as their temporal interactions with each other, and with the total solar irradiance.

2-3: Instrumental reconstructions

In the last few years, a great effort has been carried out to improve the quality of the tools and atmospheric observations, including gridded datasets, 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. 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 in 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.

4-5: Atmospheric variability and trends

Observations from the last decades reveal that there is a warmer and drier scenario in comparison to past decades, a finding that is compatible with observations in other Mediterranean areas. In particular there has been a strong solar radiation increase from the 1980s, in agreement with an increase in the atmospheric evaporative demand, mainly in summer months. Temperatures have showed strong increases since the 1960s. Nevertheless, no noticeable changes in surface wind speed have been found. Strong decrease in relative humidity with no significant changes in absolute humidity has been identified. Although strong spatial and seasonal variability in precipitation trends have been found, it may be in relation to changes in the global teleconnections. Average annual precipitation over Spain has showed a moderate decrease in the past five decades. Regarding teleconnections, relevant research has been developed in the last decades regarding predictability of NAO (North Atlantic Oscillation), showing increased skill with tropics and stratosphere. Future scenarios project an enhancement of the NAO along the seasonal cycle, with impacts also in sea level and upwelling (see articles on oceanic downscalling in this issue). Nevertheless, the spatial pattern of NAO has been found to be non-stationary, and dependent on the influence that ENSO (El Niño – Southern Oscillation) and the slowly variant oceanic background exert on the atmospheric variability. The Pacific and Atlantic Oceans, and the Mediterranean, the stratosphere, and tropical convection have been found to modulate teleconnection patterns affecting Europe. Taking into account this information, a great progress has been made in recent decades on the development of applications on seasonal to decadal (s2d) and subseasonal to seasonal (s2s) forecast. The availability of results from the Climate system Historical Forecasting Project (CHFP), and the Coupled Model Intercomparison Project (CMIP5), together with very active investigations in both operational and research communities, have improved our abilities to make skilful predictions and future projections.

The Barcelona Supercomputing Center and AEMET are the most important institutions leading this progress, and a significant step forward is being done by the Spanish research community in the context of the climate services.

6: Oceanic observations

Results confirm the impacts of global heating on the Ocean at the Iberian regional scale.

This report highlights the importance of routine water monitoring. Unfortunately, many financial sources have a limited time span, typically 3-4 years. It is also true, however, that many of the monitoring efforts on which the report is based, and that are currently maintained by the IEO (Instituto Español de Oceanografía) and other institutions (ports, universities, etc...), started through specific scientific projects. This is the case of IEO Observing System, and the Espartel monitoring station. Other monitoring stations started as voluntary initiatives at very low cost, e.g. the Hydrochanges network or some of the oldest coastal recording stations (Aquarium in San Sebastián or L'Estartit station). In all cases, their usefulness to follow the evolution of climate change in the years to come has already been proven, as well as for the study of the biological resources and their dependence on the physico-chemical variables, which are all crucial aspects to implement the EU Marine Framework Strategy.

Nevertheless, a more coordinated strategy that considers the overall capability of the observation system to detect climate change signals would be very welcome.

7-8: Atmospheric downscaling: present climate features and climate change projections

Many studies analysing regional climate models (RCMs) in present climate conditions on the Iberian Peninsula have been published since 2010. EURO- and Med-CORDEX or ENSEMBLES and ESCENA national project are the main ones during this period. The main conclusion of these studies is that RCMs over the Iberian Peninsula provide very valuable information, proving that RCMs enhance local spatial distribution of climate variables, mainly due to a better representation of orographic and surface features. RCMs are largely able to capture precipitation regimes, temperature and wind variability as well as extreme events. However, substantial biases are still observed, hindering the direct applicability of RCM outputs in sectorial applications (hydrology, agriculture and energy, for instance). This opens a controversial issue about RCM bias correction, or adjustment, and its impact on the climate change signal. Related to statistical downscaling procedures (SDM), these methods are shown to be a spatially consistent alternative to standard bias correction methods, although the limitation for extreme values should be taken with caution in applications where this aspect is relevant. Among the benefits of SDMs, it could be highlighted that they are less computationally demanding than the RCMs and allow downscaling non-meteorological variables.

Related to climate change regional atmospheric projections, from the large ensemble of downscaling methods shown in this issue of Exchanges, and taking into account all several uncertainties indicated, some global statements can be made. For precipitation, there is a general trend to decreasing average precipitation in all seasons, with an average decrease of 30% for RCM estimates. Regarding temperature, the largest increases are expected in summer and autumn, reaching close to 3°C with respect to the 1971-2000 climatology in the upper end, and no less than 1°C in the most conservative estimates. Some relevant issues are worth to be mentioned for regional climate change impact studies applications. Several bias correction/adjustment methods have been developed in the past years, and several examples of specific usage and limitations which impacts studies over the region are shown. One current major focus of climate projections studies is the application of relevant climate change information for vulnerability, impact and adaptation research. Nevertheless, it is not already clear how to best proceed in order to select a subset of representative data for each particular study, since inconsistent or even conflicting information could be found. This is one of the key challenges considered in ongoing initiatives on climate change scientific research groups.

9: Oceanic downscaling: present climate features and climate change projections

A small reduction in the wave height and mean wave period has been found along both the Mediterranean and Atlantic coasts. In the Northeast Atlantic, sea level is projected to increase at a higher rate than the global mean value, although uncertainty is large. A temperature increase in the Atlantic is projected by all models although an AMOC (Atlantic Meridional Overturning Circulation) slowdown, also described in the article on Oceanic observations, may reduce heat advection towards the Northeast and modulate the warming. The projected general increase in upwelling will also affect the western margin of the Iberian Peninsula, counteracting the warming in a narrow band along the western Peninsula.

Concerning salinity, the increase in freshwater fluxes in high latitudes of the North Atlantic, and the increase in ice melting in Greenland, will likely result in a reduction in salinity in the Northeast Atlantic coast. Instead, evaporation-related freshwater loss will increase in the Mediterranean, causing an increase in salinity in this basin. However, injection of fresher waters from the Atlantic may partially counteract this process.

As for extreme events, although it is clear that the impact of marine storms will increase due to the general rise in the mean sea level, the evolution of storminess in southern Europe is not clear. Some results point towards a decrease in the overall number of storms but an increase in the most intense events, although the statistical significance of these changes is weak. The latest Intergovernmental Panel on Climate Change Assessment Report states that there is a high uncertainty associated with future winds and storms.

Concerning the sources of uncertainty of regional projections, the dominant factor in general is the Global Climate Model used to force the regional ocean model. Although temperature and sea-level scale linearly with increasing greenhouse gases concentrations, for salinity, storm surge and wind-waves the relation is not so robust.