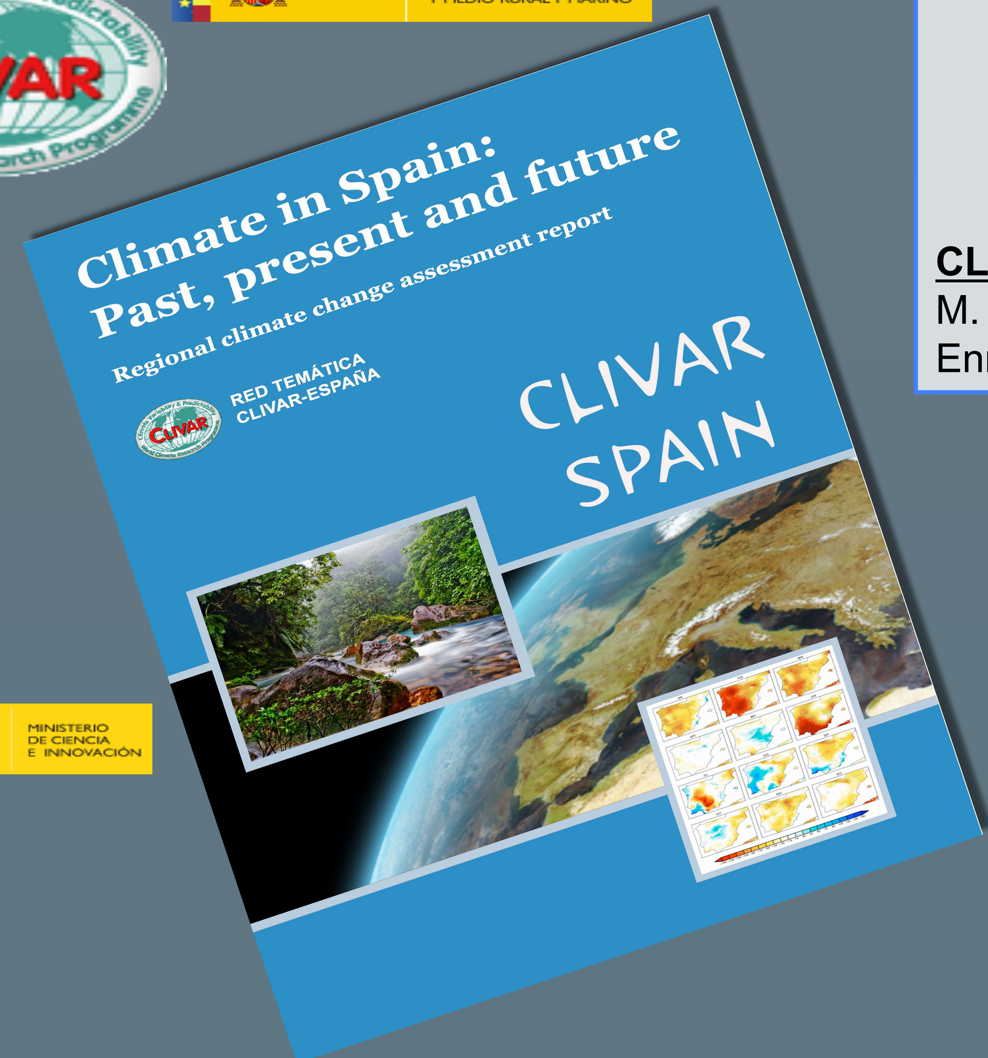
Current scientific knowledge of climate and climate change in the Iberian Peninsula (IP): the CLIVAR-Spain report

CLIVAR-SPAIN national committee: Ileana Bladé, Manola Brunet, Isabel Cacho, Yolanda Castro-Díez, Damiá Gomis, Penélope González-Sampériz, Alicia Lavín, M. Yolanda Luna, Gonzalo Mínguez-Macho, Fiz F. Pérez, Ernesto Rodríguez-Camino, Belén Rodríguez-Fonseca, Concepción Rodríguez-Puebla, Roberta Boscolo, Enrique Sánchez, Marcos G. Sotillo, Blas Valero-Garcés, Manuel Vargas-Yáñez.<zzz



Motivation for the report:

- IPCC reports need to be complemented with regional climate reports that assess the scientific knowledge of climate change in particular regions of the world. This is especially important for areas such as southern Europe and the Iberian Peninsula (IP) which have been signaled as very vulnerable to climate change. zzzzzzzzzzzzzz
- **"Climate in Spain: Past, Present and Future"** is a **collaboratively-build** (100 contributors) **assessment report** that reviews the existing evidence of changes in the climate of the IP (past and present), assesses our understanding of the physical processes associated with natural climate variability in this region and discusses projections from regional climate models.

Available at www.clivar.es and www.clivar.org/about/news.php

The Climate of the IP in the Past

- The climate of the IP was characterized by rapid climatic changes (on time scales ranging from decades to a few hundred years) that can be linked to variability in the North Atlantic circulation.
- During glacial and deglaciation times, relatively cold and arid conditions dominated the IP when the North Atlantic Meridional Overturning Circulation (AMOC) was weakened.
- The coldest and driest conditions did not occur during the Last Glacial Maximum (LGM) but during the so-called Heinrich events, when AMOC was severely reduced or even shut down (Fig. 1).
- During the Holocene (current interglacial), the IP evolved from more humid to more arid conditions, although the intensity and rate of this humidity shift varies spatially.
- Rapid temperature changes also occurred during the Holocene but their geographical extension is uncertain.

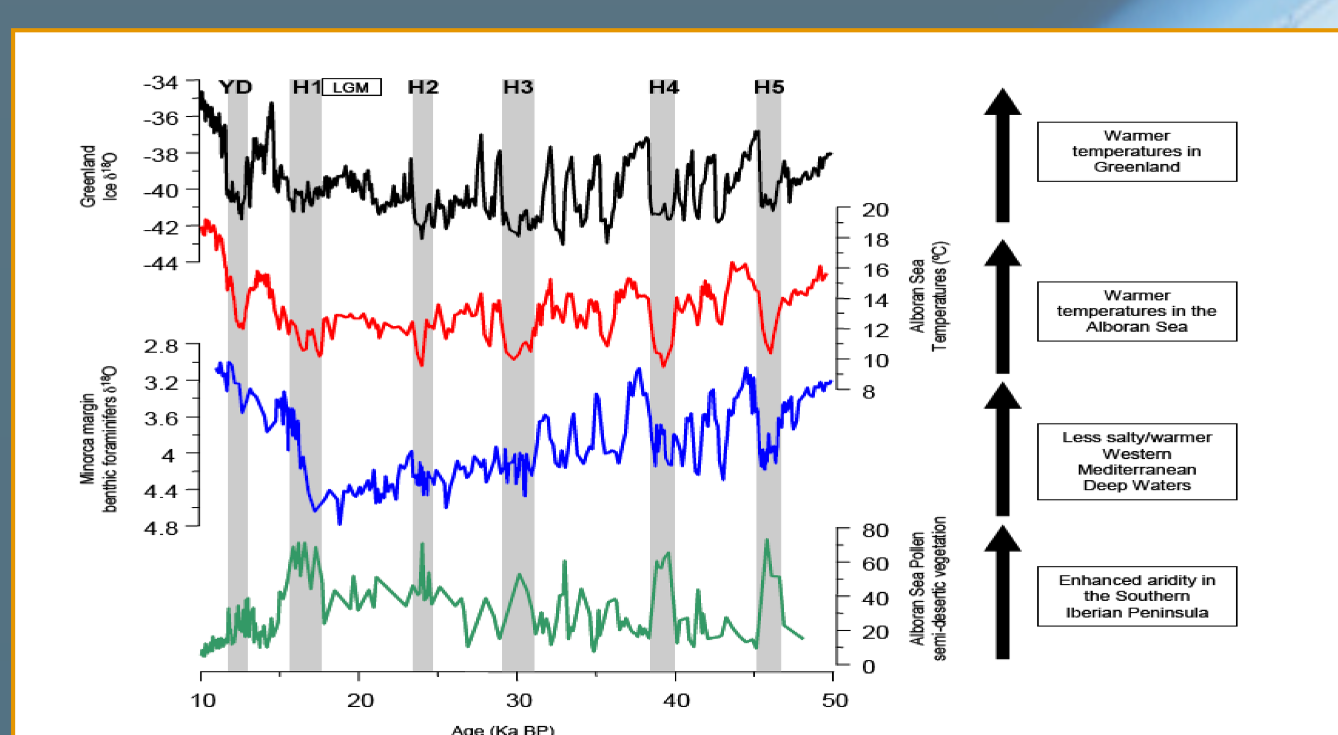


Figure 1: Paleoclimate records for the Iberian Peninsula and western Mediterranean Sea spanning most of the last glacial period and the deglaciation. The vertical grey bands highlight the position of the Heinrich and Younger Dryas events. LGM indicates the last glacial maximum.

The Current Climate of the IP: Teleconnections and Natural Variability Mechanisms

- The NH pattern of atmospheric variability that most influences the IP climate is the North Atlantic Oscillation (NAO), which is closely associated with rainfall and, to a lesser extent, wind, temperature and sea level variations, from interannual to decadal timescales.
- When the NAO is positive (negative), winter precipitation is greatly reduced (enhanced) in most of the IP, particularly in the southern half (Fig. 5).
- The past upward trend in the NAO accounts for some (~1/3) of the winter decrease in precipitation.
- Climate simulations for the 21st century project an upward NAO trend, which would result in a reduction of winter precipitation in the IP.
- The influence of ENSO on the IP is less clear but appears to be significant in autumn and spring for both temperature and precipitation.
- The influence of the NAO and ENSO on the IP climate has not been stationary.
- The NAO signal over Europe may be associated with different mechanisms, including an indirect influence from ENSO and forcing from the tropical Atlantic.

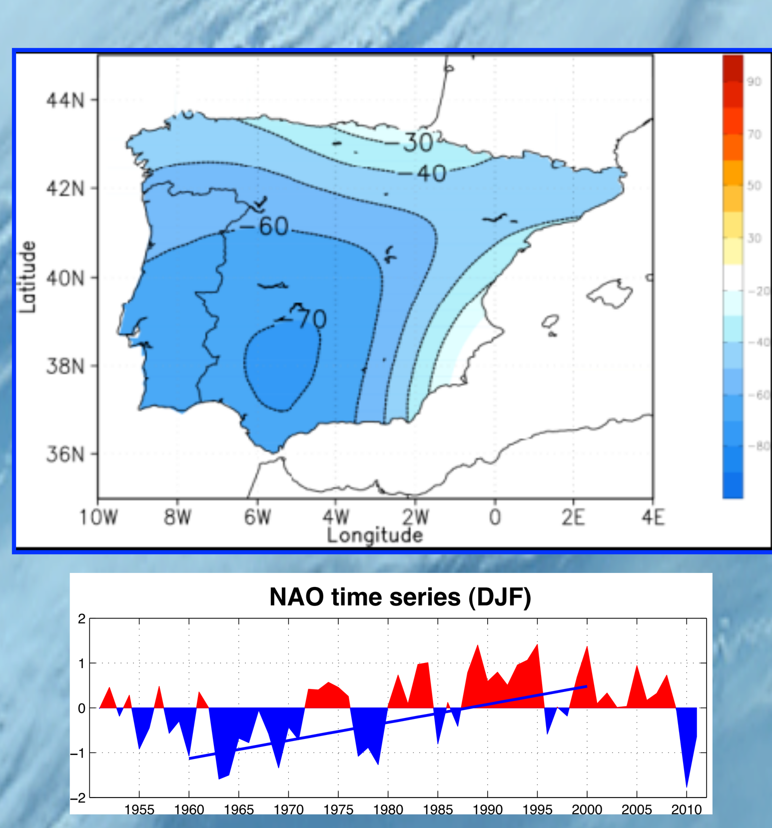


Figure 5. Correlation between precipitation and the NAO index for winter (DJF) and times series of the DJF NAO.

The Current Climate of the IP and Surrounding Seas: Observed Trends

Temperature:

- Progressive warming during the 20th century (Fig. 2), particularly prominent in the last three decades (1975–2005).
- The warming for the recent period is more pronounced in spring and summer.
- The rate of recent warming is close to 0.5ºC/decade (50% larger than the NH continental average and almost three times larger than the global average).

Precipitation:

- Annual precipitation in the last three decades has decreased compared to the 60s and 70s, mostly due to rainfall reductions in late winter (February-March; Fig. 3).
- The recent decrease in the IB is part of a large-scale pattern of reduced precipitation in the Mediterranean region, partly related to an upward NAO trend (Fig. 3).
- The first decade of the 21st century may have been the driest since 1950 (note: not so in the new, updated EOBS v5 data).
- The strong interannual variability and the lack of reliable early century data prevents a conclusive statement as to whether precipitation has decreased to a historical minimum.
- The pronounced decrease in summer precipitation projected by climate models for the end of the 21st century is not (yet) apparent in observations.

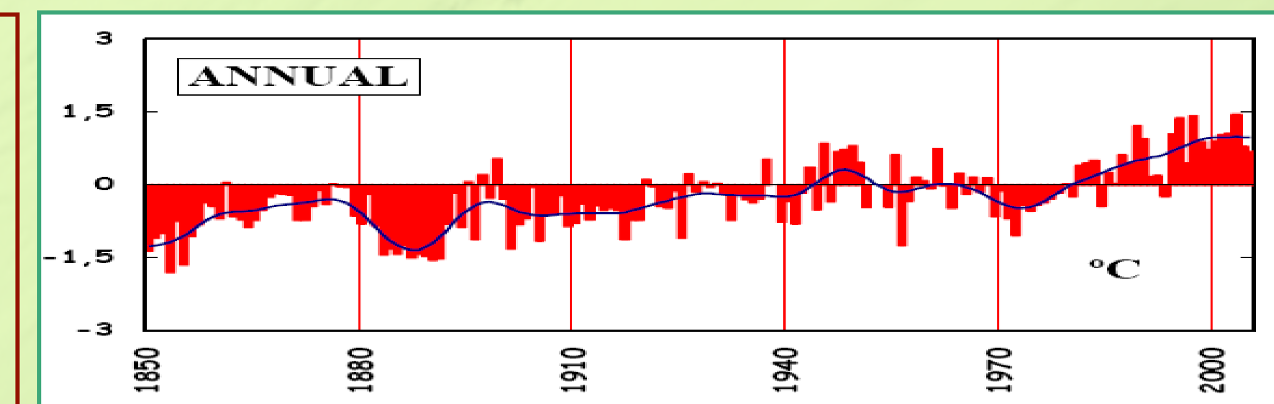


Figure 2. Annual variations in daily mean temperatures in Spain for the period 1850-2005, expressed as anomalies (in ºC) with respect to the 1961-1990 mean.

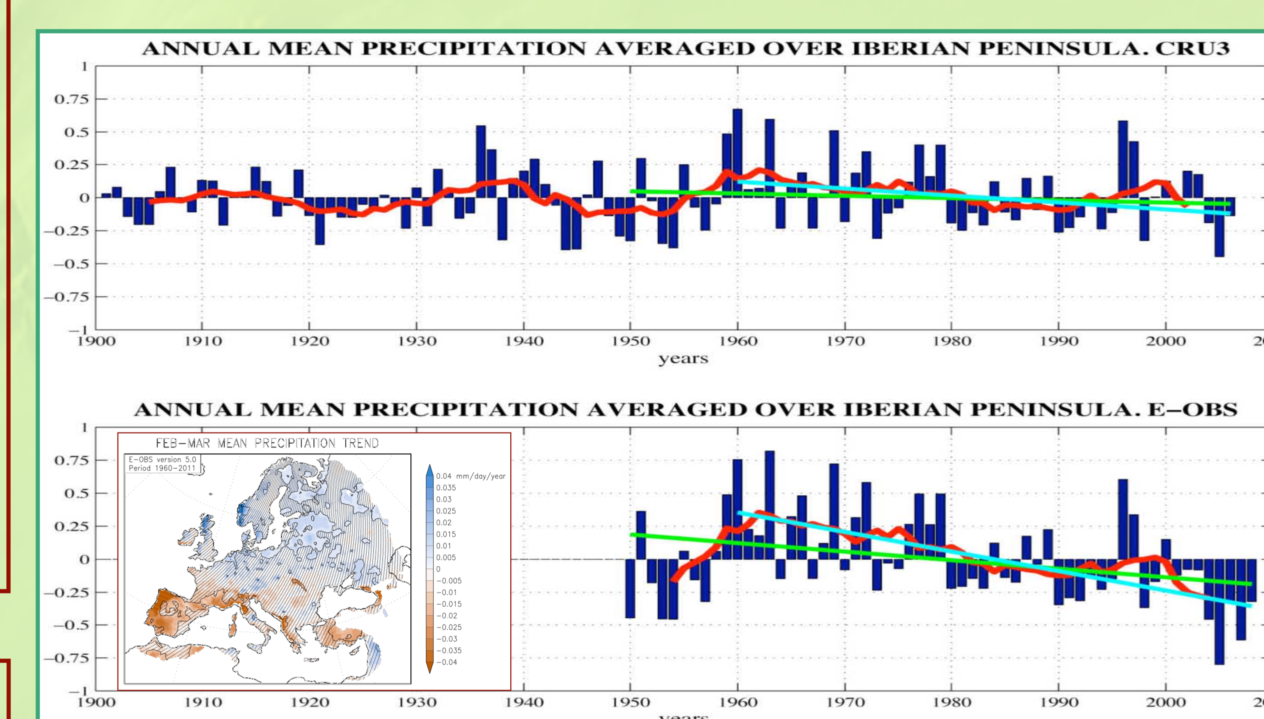


Figure. 3. Time series of annual mean precipitation anomalies (mm/day) over the IP (36ºN-43.5ºN, 10ºW-3ºE), based on the CRU and E-OBS datasets. The inset shows the spatial pattern of the February-March trend for the period 1960-2011.

Ocean Temperature and Salinity

- From 1985 to 2005, SST in the Bay of Biscay has increased by 0.12ºC/decade in the SW and by 0.35 ºC/decade in the NW. These values are consistent with the average increase of 0.19 ± 0.13ºC/decade estimated for the NH for the period 1979 to 2005 (IPCC).
- The warming has affected the entire water column. During the 90s the temperature of the upper 1000 m increased between 0.15ºC and 0.3ºC/decade.
- A decrease of 30% in the intensity of Atlantic upwelling since 1967 has been observed, which has decreased primary productivity and slowed down the renewal of coastal waters.
- In the western Mediterranean (Fig. 4), a temperature increase has been reported at deep layers, but with large uncertainty.
- Greater confidence exists for an overall increase in salinity, particularly at intermediate layers (~0.00013 psu/year), at least during the second half of the 20th century.

Sea Level:

- Atlantic coast: tide gauges have recorded a sustained sea level rise of around 1.4 mm/yr when the entire 20th century is considered and of more than 2 mm/yr during the second half of the century.
- Mediterranean coast: sea level records spanning the entire century indicate a rise of about 1.2 mm/yr (of the same order as the global mean). However, trends observed during the second half of the 20th century are weaker (0.3 - 0.7 mm/yr), becoming non-significant or even negative between the 1960s and the beginning of the 1990s.
- A pronounced increase in atmospheric pressure between the 1960s and the 1990s and a temperature increase weaker than the global mean may explain the different evolution of Mediterranean mean sea level compared to the open ocean.

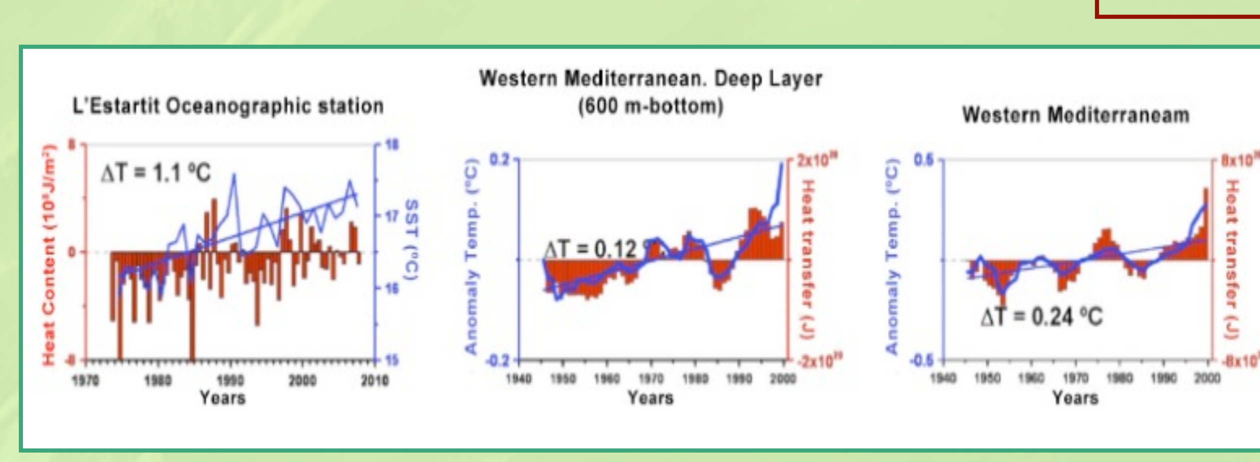


Figure. 4. Absorbed heat and SST at the Estartit station (Western Mediterranean) computed from the MEDATLAS data base.

The Climate of the IP in the Future: Anthropogenic Impacts

- Regional climate model projections for the end of the 21st century indicate pronounced increases in mean seasonal temperature (Fig. 6), larger in summer (6ºC in scenarios with the greatest anthropogenic impact) than in winter (2-3ºC).
- A decrease in precipitation throughout the entire year, again larger in summer than in winter, is also projected. On average, the models project increasingly arid conditions over most of the IP. With greater uncertainty, the models suggest an increase in extreme precipitation events, for both dry spells and intense precipitation episodes.
- An increase in extreme high-temperature events (>30ºC) is also predicted, particularly in the south of the IP.

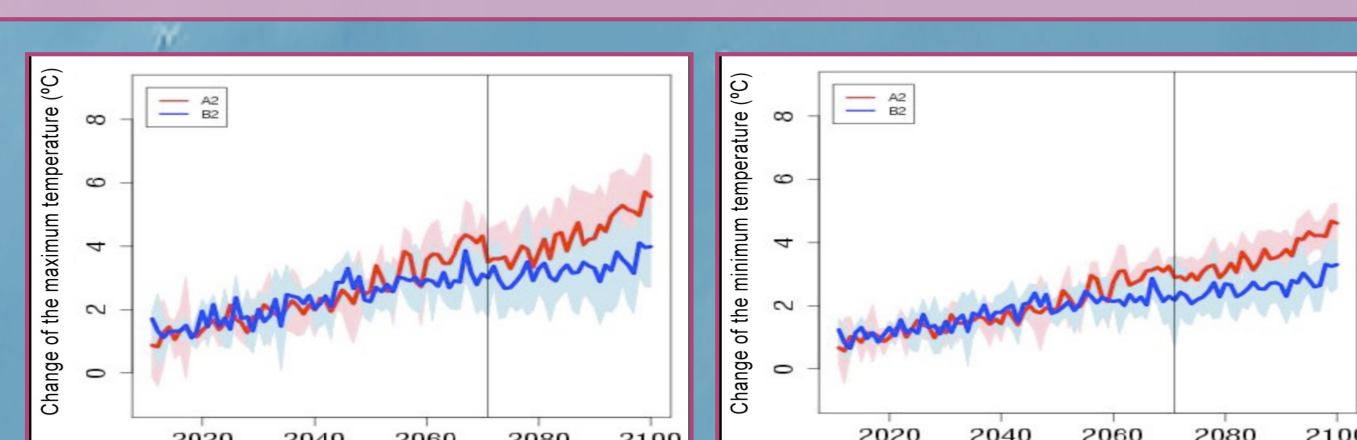


Figure 6. Annual maximum and minimum temperature change averaged over the entire IP during the 21st century for the A2 and B2 scenarios. Results are based on different downscaling techniques. The shaded area represents one standard deviation from the 10-year running-mean value (continuous lines).