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The western Mediterranean climate: how will it respond to global warming?

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Abstract The paper discusses the newly produced temperature and precipitation series from instrumental observations in the Western Mediterranean (WM) area, dating back to 1654. The two series had a continuous swing and unstable coupling

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passing from correlation to anti-correlation. Only after 1950 are they permanently anti-correlated with increasing temperature and decreasing precipitation. It is not clear how long this coupling will persist. The analysis of the correlation between the Northern Hemisphere (NH) and the WM temperature anomalies and their trends shows a certain variability from 1850 to 1950; later a strong coupling between NH and WM. Results suggest that the WM climate is approaching a turning point that might locally oppose the adverse effects of Global Warming.

1 Introduction

Despite a steady increase in radiative forcing as a result of human activities is occurring, Knight et al. (2009) found that Global Warming (GW) has slowed in the last decade, and the anomaly record shows that no warming has been observed in the past 10 years. The stop of greenhouse warming has been proposed again in *Science* (Kerr 2009) to stimulate a wider discussion. This finding raised a doubt about the most negative GW predictions and several discussions within the scientific community.

Only long-term observations may provide an answer to this complex problem. A contribution can arise from the Western Mediterranean (WM) area (Fig. 1)

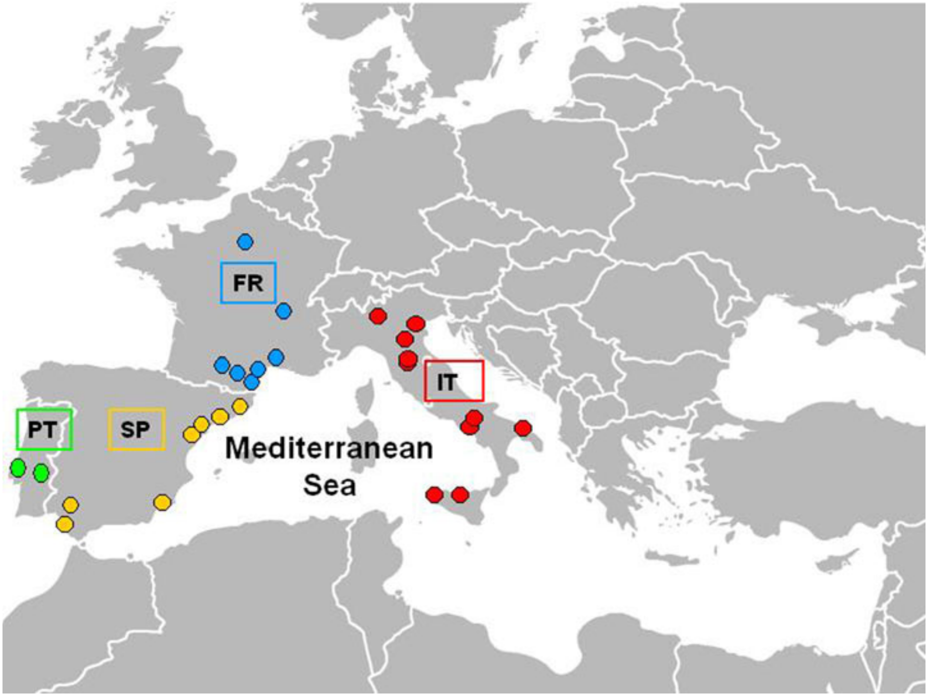


Fig. 1 Map of the Western Mediterranean area with the countries and the locations of the series of instrumental observations used in this paper. *PT*, *green* = Portugal; *SP*, *yellow* = Spain; *FR*, *cyan* = France; *IT*, *red* = Italy. *Dots* indicate station locations

that benefits from the longest series of daily instrumental observations since 1654, i.e. since the invention of the spirit-in-glass thermometer, first mentioned in 1641 and the creation of the first international meteorological network, active 1654–1670 (Targioni Tozzetti 1780). Unfortunately, similar long and reliable series are not available in other parts of the Mediterranean. The series used in this paper include newly produced long-term observations from Italy (1654–today), France (1676–today), Spain (1776–today) and Portugal (1816–today). Details about the above temperature series and how they have been produced are reported elsewhere (Camuffo et al. 2010).

This paper will discuss how temperature and precipitation have been coupled between them in the WM, and how WM is coupled with the Northern Hemisphere (NH).

2 Discussion and results

From the analysis of the long-term temperature and precipitation data, the WM climate appears to be characterized by continuous swings in both temperature and precipitation around the same level (Fig. 2) albeit with some variability in amplitude and phase lag. Although the maximum in the 1670–1730 period is based on a limited number of stations, it is however credible because the same behaviour is reproduced by independent stations in Italy and France, and tree rings as well.

The analysis of periodicity (Wavelet and Power Spectrum) points out 12.7, 26.5, 34.4 and 57.3-year periodicity for temperature (Camuffo et al. 2010) and a marked 90-year maximum for precipitation (Fig. 3).

The determination coefficient (R^2) between temperature and precipitation and their trends, i.e. their time derivatives, has been calculated over 5-year steps (Fig. 4). The result is that both the temperature and precipitation anomalies alternated correlation with anti-correlation periods; only after 1970 were both anomalies permanently anti-correlated. The same can be said for their time derivative that represents growing or decreasing trends. The 1970–today period has been characterized by an exceptionally long coupling between warm and dry weather in WM. A similar, but shorter coupling occurred between 1870 and 1900. The persistence of today's warm–dry coupling is totally unusual. It may be a change related to GW, or an unstable situation destined to have a short life.

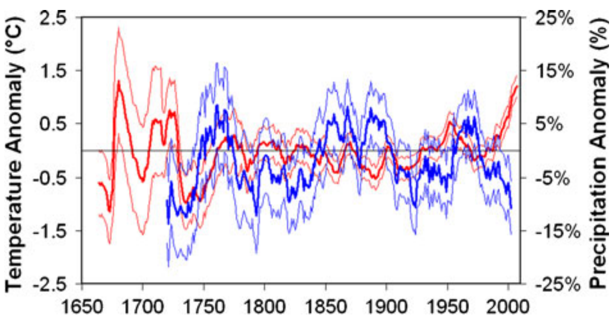


Fig. 2 Temperature (*red*) and precipitation (*blue*) anomalies calculated as difference from the 1961–1990 period in the Western Mediterranean area. *Thinner lines* represent the uncertainty band

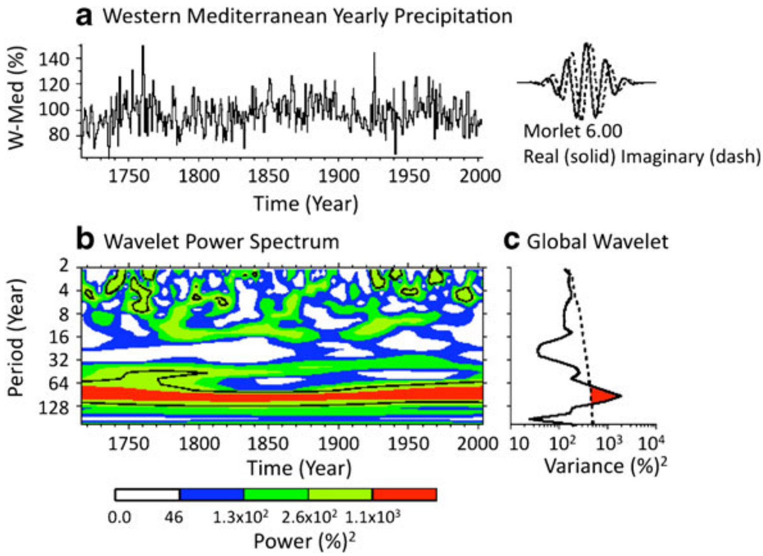


Fig. 3 Wavelet analysis for precipitation in the Western Mediterranean area

The WM is a very small part of the Northern Hemisphere (NH) and may respond in a different way to climate forcing. However, it is possible to see how much the WM and NH are related with each other taking advantage of the IPCC 2007 results (Le Treut et al. 2007). To this aim, the determination coefficient R^2 between WM and NH temperature anomaly series (Fig. 5) has been calculated over the 1850–2007 overlapping period. The same has been made with their trends (Fig. 5). The result is that the NH and WM temperature anomalies and their time derivatives have been prevalently correlated, but this correlation was often interrupted by lack of correlation or even anti-correlation. Only since 1950 a strong coupling was permanently kept between the NH and WM. The same for trends, but with weaker correlation.

It is also possible to calculate the spatial pattern of the NH–WM correlation, but for a shorter period in which sufficient reliable data are available, i.e. since

Fig. 4 Determination coefficient (R^2) between temperature (T) and precipitation (P) (*blue*) and their trends (*cyan*), i.e. their time derivatives dT/dt and dP/dt, in the Western Mediterranean area, calculated over 5-year steps

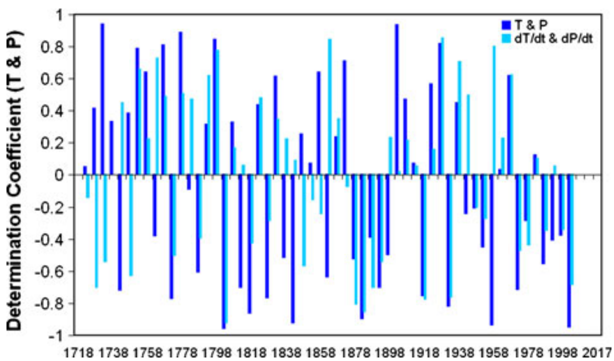
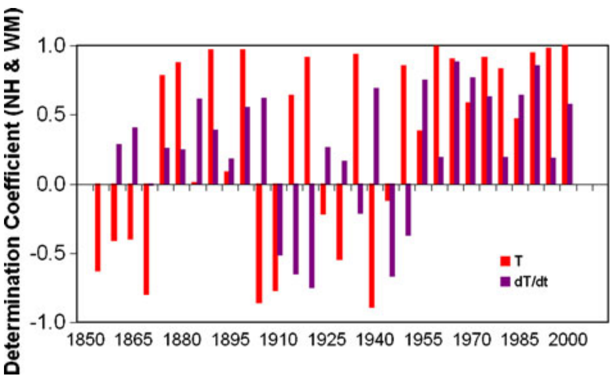


Fig. 5 Determination coefficient (R^2) between the temperature(T) anomalies (*red*) in the Western Mediterranean area and the Northern Hemisphere IPCC 2007 (Le Treut et al. 2007), calculated over 5-year steps. The same but for their time derivatives dT/dt (*violet*)



1850. A map of the NH–WM spatial correlation was calculated (Fig. 6) including temperature from web (Brohan et al. 2006; Van Oldenborgh et al. 2009) for the 1901–2006 overlapping period in which both NH and WM data are available. The result is that, in the NH and the WM, the temperature time derivatives have been prevalently correlated, but this correlation was often interrupted by lack of correlation or anti-correlation. Spatial coupling became strong and permanent after 1950. Before 1950, some unknown forcing triggered the Mediterranean to depart from the NH climate. This trigger has disappeared or has been overcome by other factors in the recent times. GW started in 1850, after the end of the Little Ice Age, but it has changed character since 1950.

3 Conclusions

The analysis of instrumental observations over 3.5 centuries in the Western Mediterranean area shows a continuous swing of both temperature and precipitation anomalies. The analysis of the correlation between temperature and precipitation shows

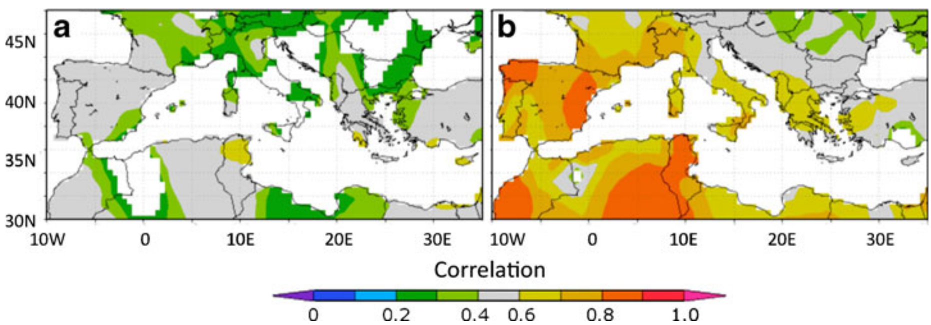


Fig. 6 Spatial correlation (p < 10%) between the annual mean temperature in the Mediterranean (CRU TS3) and the Northern Hemisphere (HadCRU T3NH) for the 1901–1969 period (**a**), and for the 1970–2006 period (**b**). Calculated after Royal Netherlands Meteorological Institute database and web-GIS Climate Explorer (Van Oldenborgh and Burgers 2005)

on the long-term period an unstable coupling, swinging between correlation and anti-correlation, except for the period after 1950, when an anti-correlation, i.e. warm associated with dry, persists.

Also the NH–WM coupling has been unstable, except for the 1950–today period. It is not clear whether the recent change in NH–WM coupling is reversible or irreversible. It is possible that the NH and WM coupling will return to swinging from correlation to anti-correlation.

It is possible that WM swings will return to operate, or combine with GW, locally leading to a more beneficial situation with less warming and more precipitation. In other words, if the reduced GW hypothesis is true, it is also possible that the WM climate is approaching a turning point that might locally oppose the adverse effects of GW. This hypothesis will be clarified in the future; however, further studies are needed to investigate WM forcing and oscillations.

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