Large-scale atmospheric circulation and the Mediterranean climate

The description of the large-scale circulation over the Mediterranean will focus on the two extreme seasons: summer and winter. For each season, first it will be given a brief description of its mean climate, and then attention will be moved to the main patterns of interannual variability and of their impacts on Euro-Mediterranean climate. It will be shown that the temporal variability of each of these patterns can be described using synthetic indices, and references will be given of the computational methods used to define them in the literature, of the possibility of using ready available indices time series, or of the possibility of constructing indices which describe particular aspects of local climate.

Finally, it will be shown the dependence of the results on the observational data set used, when evaluating the impacts on Mediterranean climate, especially for precipitation.

1- The Winter climate of the large-scale atmospheric circulation over the Mediterranean and main processes involved

The climatologies of T at 850 hPa (1961-2000 obtained using ERA40 data) and of total precipitation (1979-2006 obtained using GPCP data) show the main characteristics of the Euro-Mediterranean climate with respect of the surrounding regions.

On the one hand, in winter the temperature over the Eastern Atlantic and Europe is much milder with respect to North America or continental Asia (Siberia), thanks to the Gulf Stream heat transport. The atmospheric dynamical features contributing to define the Mediterranean climate are: the Atlantic Jet Stream and the presence of a diffluence over central Europe at the exit of the Atlantic Jet Stream. The variability of the intensity of these dynamical processes is the main reason underlying the interannual variability of Euro-Mediterranean climate.

The main modes of wintertime large-scale variability have been largely described in literature (Wallace and Gutzler, 1981; Barnston and Livezey, 1986; Rogers, 1990, Vautard, 1990; Michelangeli, et al, 1995). The following discussion is mostly based on the work of Pavan et al (2000a) and Pavan et al (2000b) updated so as to use the most recent observational data sets: as for the Z500, used to define the pattern for each mode of variability, it will be used monthly data from the ERA40 re-analysis data-sets for the period 1961-2001, extended to 2007 using the ECMWF operational analysis. The same source is used for the T850 monthly data used as a proxi of surface temperature, so as to evaluate the impacts. For precipitation the GPCP monthly precipitation data-set is used, covering the period from 1979 to 2007.

The main pattern of large-scale circulation variability having significant impacts on Euro-Mediterranean climate are the following: The North Atlantic Oscillation, the European blocking, the Eastern Atlantic pattern and the Scandinavian pattern.

The North Atlantic Oscillation, or NAO, is the single most important mode of interannual and interdecadal variability over the Euro-Atlantic region in winter. It has been extensively studied in the literature (Deser and Blackmon, 1993; Hurrell and van Loon, 1997; Stephenson et al, 1998; Wanner et al, 2001). It consists of a variation in intensity of the Atlantic Jet Stream associated with an oscillation of mass of the atmosphere between Greenland and the tropical Atlantic. It has been argued that the NAO is only a local North Atlantic tropospheric manifestation of the oscillation of intensity of the polar jet extending to the whole depth of the Atmosphere (Thompson and Wallace, 2000). The real thing is that no single dynamical process can be identified as the source of its variability. It has been shown that the decadal variability may be linked to a coupled ocean-atmospheric mode (Deser and Blackmon, 1993, Kushnir, 1994; Czaja and Frankignoul, 1999), but although many dynamical processes have been shown to play a role in the interannual variability of this pattern, none of them can explain its whole interannual variability. The variability of this pattern has been described using different synthetic indices, which can be mostly considered equivalent. All of them show the presence of an intense change in the index between the 1970ies and the 1990ies. The presence of this intense strength at the time was considered as a possible signature of a link between the NAO and climate change, although recent studies have shown that this hypothesis was unfunded. The impacts of a positive NAO anomaly are an increase in surface temperature over Northern Europe and a decrease of the same over South-Eastern Mediterranean, together with an increase of precipitation over Northern Europe and a decrease over the Mediterranean. Opposite impacts are expected in correspondence of negative NAO anomalies.

The European blocking pattern is a blocking high centred over Great Britain. A blocking as been defined as a positive SLP anomaly associated with a northern shift in the mid-latitude westerly jet and a non-null easterly flow over its southern flank, lasting continuously for more than 10 days. First studies of blocking were produced by Rex (1950), but later it has been the subject of many works in literature (Legras and Ghil, 1985; Shutts, 1986; Tibaldi and Molteni, 1990; Michelangeli and Vautard, 1998). It has been suggested that, once established, blocking is maintained via upscale cascade, thanks to the forcing of transients. Many studies have tried to investigate the possible relation between large-scale forcing and the variability of blocking frequency, but no ultimate result has been published. Several blocking indices have been proposed and it has been shown that they differ, capturing different aspects of the phenomenon (Doblas-Reyes et al, 2002). Impacts on Europe of blocking include a decrease in precipitation over Northern Europe, a decrease of temperature over Eastern Europe and the Mediterranean, and an increase of temperature over the British Isles.

The remaining two patterns have been documented in literature, but have attracted less attention than the two already mentioned. The first is the Eastern Atlantic pattern. This pattern, as described by the Z500 field, strongly projects on the zonal eddy component of the climatological flow, due to the co-location of the negative Z500 anomaly characterising it over the North Atlantic. Its index presents a weak but detectable trend in time. During the positive phase its impacts include an increase of precipitation over Portugal, a decrease of precipitation in Eastern Europe, and a substantial increase of temperature over Central Europe and the Mediterranean. The last, but not less important pattern is the Scandinavian pattern which plays an important role not only in winter, but also during autumn, when it becomes one of the first three modes of large-scale variability. Its pattern is characterised by a strong anomaly centred over the Scandinavian Peninsula. Its index presents a strong decadal variability. During the positive phase of this pattern, the impacts include a decrease in precipitation over the Scandinavian Peninsula and North-Eastern Europe, an increase in temperature over the Northern coast of the Scandinavian Peninsula, and a decrease in temperature both over the central-Western Mediterranean and over the region of the Caspian Sea.

2- The Winter climate of the large-scale atmospheric circulation over the Mediterranean and main processes involved

The mean field of T850 and precipitation over the Atlantic and Mediterranean region for summer have characteristics which are markedly different from the correspondent winter ones. First of all, the intense temperature gradient along the East coast of the North American continent and over the Atlantic is much weakened, thanks to the general warming over the polar region. This leads to a weakening and a substantial northern shift of the main Atlantic storm track. At the same time, an intense temperature gradient is established between the Northern African continent and the Mediterranean linked with the strong land-sea contrast between desert and sea. This temperature gradient is responsible for the presence of a very dry jet, impinging over the Atlas mountains (up to 4000m asl). Rodwell and Hoskins suggest that the orographic response to these mountains can be considered the cause of the zonal structure of the climatology over the Mediterranean. The summer is also the season of the Asian and the West African Monsoons. Rodwell and Hoskins (1996) have shown the importance of both Monsoons for the Mediterranean climate. In particular, it is suggested that the Asian Monsoon is responsible for the maintenance of the climatological subsidence present over the Eastern part of the Mediterranean, as can be seen from the climatological maps of ω at 500 hPa obtained using ERA40 data for the period 1961-2000.

The interannual variability is clearly linked to the variability of the main dynamical processes over described, namely the variability of Asian/Indian and West African Monsoon and the variability of the Atlantic jet stream.
The link between large-scale dynamics and the Mediterranean climate has been studied less frequently in literature. Two example are given: the mechanism suggested by Rodwell and Hoskins and the preliminary results on the summer heat wave over Central Europe (similar to that observed in 2003).

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