Mediterranean Precipitation Variability 1948 - 1998 and its Links to the Atmospheric Circulation in the North- Atlantic- European Area

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Abstract

The paper addresses coupled variations of atmospheric circulation in the North-Atlantic-European domain and high-winter precipitation in different Mediterranean regions. CCA modes for the 1948 - 1998 period include a) patterns linked to the Mediterranean Oscillation accounting for large parts of Iberian rainfall variability, b) meridional circulation patterns predominantly responsible for rainfall variability around the Aegean region, and c) a large-scale north-south seesaw strongly linked with north-west African rainfall variability.

Introduction

The Mediterranean climate is characterized by distinct variabilities of precipitation on monthly, interannual and interdecadal time scales. This implies a particular vulnerability of the Mediterranean region to climate changes. Therefore a growing number of climate research studies in the last decades has focused on climate variability and change in the Mediterranean area.

Recent studies revealed non-uniform changes in precipitation during different seasons. In winter, widespread decreasing rainfall trends are indicated for the Western and Northern Mediterranean area since the 1980s (e.g. Goodess & Jones, 2002, Rodriguez-Puebla et al., 1998, Brunetti et al., 2002). Decreasing precipitation is also evident in major parts of the Eastern Mediterranean area (Kutiel et al., 1996, Xoplaki et al., 2000). Despite some regions with an opposite evolution (e.g. southern Israel, Ben-Gai et al., 1998), the majority of the Mediterranean area tends to decreasing winter precipitation.

Consistent with this widespread downward trend in precipitation a weakening and a decreasing number of cyclones as well as an increasing number of anticyclones in the Mediterranean area are indicated during the whole wet season from October to March (Maheras et al., 2001). Esteban-Parra et al. (1998) associate the dryer conditions in the western part with an intensification and dislocation of the Azores High. A recent trend towards rising pressure is well documented for most of the Mediterranean area (Brunetti et al., 2002, Reddaway et al., 1996). Maheras et al. (1999) and Goodess & Jones (2002) point to a connection of the observed precipitation decreases with the simultaneous positive mode of the North Atlantic Oscillation (NAO). Positive modes of the NAO are also associated with a reduction of atmospheric humidity over southern Europe and northwestern Africa (Halpert & Bell, 1997). This could partly account for decreasing precipitation, too. In addition, the so-called 'Mediterranean Oscillation' (MO) has to be addressed as a circulation pattern of utmost importance for Mediterranean precipitation characteristics. It represents a teleconnection pattern with opposite pressure and rainfall anomalies between the western and eastern Mediterranean area. The stronger positive mode of this pattern during the 1980s and 1990s contributes significantly to the observed pattern of recent precipitation changes (Maheras et al., 1999). This paper gives examples of large-scale circulation modes optimally linked with high-winter rainfall variability in different Mediterranean regions. This allows to put recent rainfall changes into the context of circulation dynamics.

Data and Statistical Procedure
Based on 0,5° x 0,5° gridded data for land areas (CRU05 dataset, New et al., 1999, 2000), Mediterranean precipitation regions are derived from s-mode principal component analysis (PCA, e.g. Serrano et al., 1999) for the period 1948 - 1998. North-Atlantic-European fields of geopotential heights (1000 and 500 hPa levels) from 70° W to 70° E and from 20° N to 70° N as well as specific humidity fields (30° W - 45° E and 25° N- 65° N), both with a 2,5° x 2,5° resolution (NCEP/NCAR Reanalysis), have been decomposed into so-called centres of variation (again applying s-mode PCA). All extracted PCA time coefficients of the large-scale variables were linked by means of Canonical Correlation Analysis (CCA; e.g. Barnett & Preisendorfer, 1987) to Mediterranean precipitation anomalies, separately for each precipitation region. This method identifies linear combinations of the large-scale circulation PCs which correlate best with respective linear combinations of the regional precipitation PCs. The scalars determining these linear combinations were transformed from the PCA space back to the physical space, yielding pairs of spatial patterns corresponding to a particular canonical mode.

Results and Discussion
CCA of regional precipitation and large-scale geopotential height fields reveals that large parts of high-winter precipitation variability in the western and central parts of the Mediterranean area are connected with a circulation mode characterized by opposite centers over south-western Europe and the subpolar zone, at the upper level with an additional center over the Eastern Mediterranean. Fig. 1 gives an example referring to Iberian precipitation.

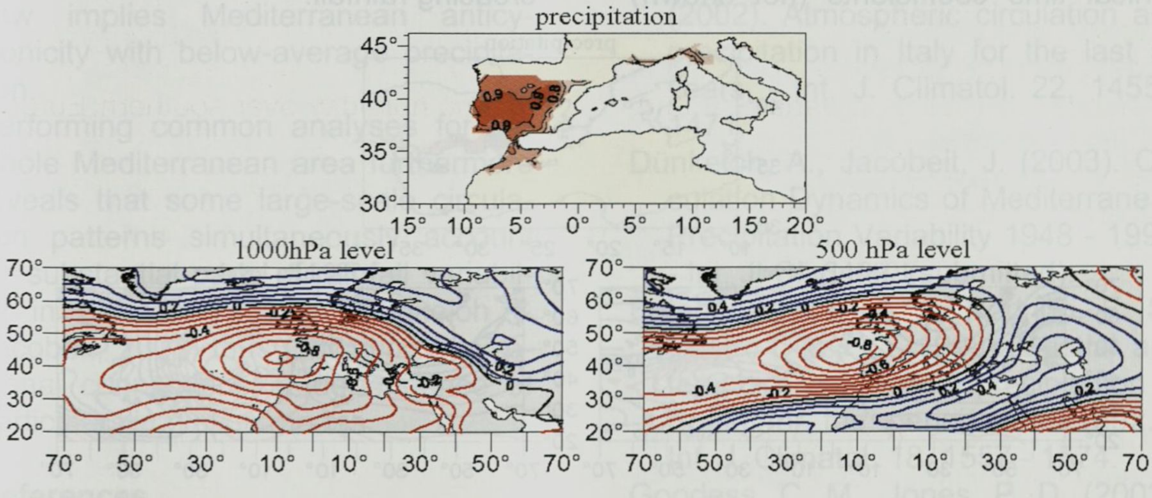

Fig. 1: Canonical correlation patterns for January and February 1948 - 1998 referring to geopotential heights at the 500 and 1000 hPa levels and to Iberian precipitation. Explained variance geopotential heights: 15.0 %; Explained variance precipitation: 64.4 %; canonical correlation coefficient r=0.94.

The depicted patterns can be assigned to the MO and also show the strongest link to circulation dynamics associated with the NAO. Simultaneously to wet conditions in the Western and Central Mediterranean region, below-normal precipitation occurs in some eastern parts (esp. the coastal areas of Libya, Egypt, the Levant and the southern Aegean Sea) as shown by Dünkeloh & Jacobeit (2003) in a similar study covering the whole Mediterranean domain within one particular analysis. Correlations of western and central Mediterranean precipitation with 1000 hPa specific humidity are positive over the whole Mediterranean and negative over northern Europe, implying that humidity can advance far east into the Mediterranean area with strong westerly airflow, whereas dry anticyclonic conditions prevail over northern Europe at the same time. In the reverse mode the pattern implies high pressure over the south-western region and an upper trough over the eastern Mediterranean leading to below-normal atmospheric humidity and precipitation in most parts of the Mediterranean region outside the eastern domain. The canonical time coefficients (not shown) reveal that this mode predominates since around 1980 in contrast to the 1960s when the positive mode (Fig. 1) prevailed. Precipitation variability of the central and especially of the northeastern Mediterranean regions is strongly linked to a pressure pattern with opposite centers over the central Mediterranean and over the adjacent regions to the west and to the east (Fig. 2). In terms of circulation dynamics this results in predominantly meridional circulations with a meridional trough (positive mode) extending from central Europe to North Africa. Thus, the Aegean region benefits from the frontal airflow downstream and the inserted humidity (see the precipitation pattern in Fig. 2). Due to advection of subpolar air masses on the rear of the trough, precipitation also increases on coasts exposed to N/NW within this northerly airflow (Algeria/Tunisia, Dünkeloh & Jacobeit, 2003). In the reverse mode, the Aegean region and most of the other central to northeastern parts receive below-normal rainfall due to anticyclonic conditions. This mode prevails since around 1988, contributing to the above-mentioned trends of decreasing rainfall.

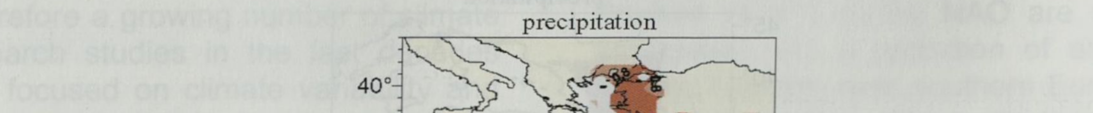

Fig. 2: Canonical correlation patterns for January and February 1948 - 1998 referring to geopotential heights at the 500 and 1000 hPa levels and to precipitation around the Aegean region. Explained variance geopotential heights: 9.6 %; Explained variance precipitation: 57.9 %; canonical correlation coefficient r=0.93.

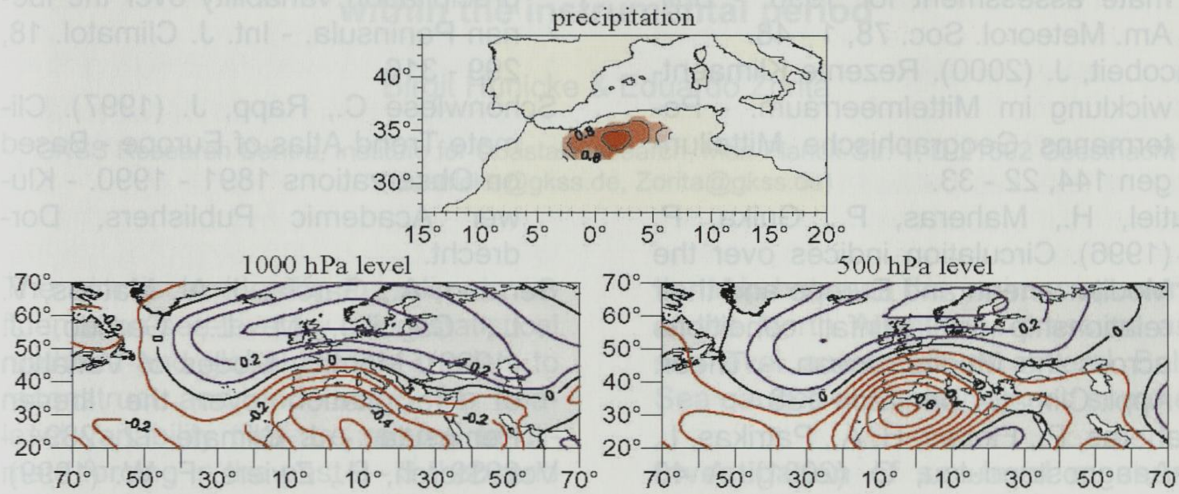

Fig. 3: Canonical correlation patterns for January and February 1948 - 1998 referring to geopotential heights at the 500 and 1000 hPa levels and to precipitation within the Maghreb region. Explained variance geopotential heights: 4.6 %; Explained variance precipitation: 63.8 %; canonical correlation coefficient r=0.83.

A third example refers to precipitation variability of the Maghreb region showing major pressure centers over Scandinavia and over western North Africa (Fig. 3). This implies enhanced blocking action in higher latitudes linked with cyclonic conditions to the south, consequently causing positive rainfall anomalies in western North Africa. The reverse mode of this north-south seesaw implies Mediterranean anticyclonicity with below-average precipitation.

Performing common analyses for the whole Mediterranean area furthermore reveals that some large-scale circulation patterns simultaneously account for substantial parts of rainfall variability in different regions (Dünkeloh & Jacobeit, 2003) thus indicating interregional connections in dependence of particular circulation modes.

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