Automatic classification of circulation types in Greece: methodology, description, frequency, variability and trend analysis

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With 9 Figures

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Summary

An automatic classification of circulation types is developed using spatial method of topology and geometry over a 40-year period (1958–1997) for Greece. The classification is based on MSLP and 500 hPa gridded data (NCEP reanalysis data at 00, 06, 12 and 18 and mean daily data, \( \varphi = 2.5^\circ \) and \( \lambda = 2.5^\circ \)) within the area of 20\(^\circ\)–65\(^\circ\) N and 20\(^\circ\) W–50\(^\circ\) E. At beginning, the adopted method is analysed. Then, the 20 circulation types (6 anticyclonic, 8 cyclonic, 2 mixed and 4 special types) are analysed and described. The frequency distributions of circulation types, on the seasonal and annual time scale, are analysed. Finally, the annual distribution and the annual trend of the circulation types are described.

The method is shown to be efficient in classification of circulation types in Greece, showing that the dramatic decreasing trend of precipitation in Greece – during the studied period – is in agreement with the strong decreasing trend of the frequency of the cyclonic types, on both for annual and seasonal time scales.

1. Introduction

Manual classification of atmospheric circulation has been widely reported in many studies over Europe, in spite of the fact that this technique relies on the researcher’s subjective interpretation (Lamb, 1972; Hess and Brezowsky, 1969; Maheras, 1988 and 1989; and Kassomenos et al., 1998).

The classification, which is based on computer calculations and analyses, is more or less objective approach and easier applied. According to Goodess and Palutikof (1998) there are two automated circulation classification schemes. The first scheme is based on existing circulation-type catalogues, such as: the Lamb Weather Types (LWTs (Lamb, 1972)) or the daily European Circulation patterns (Hess and Brezowsky, 1969). The second scheme is based on statistical grouping methods, including several correlation techniques (Yarnal, 1993), Principal Components Analysis and Cluster Analysis (Maheras, 1988; Bogardi et al., 1993; Yarnal, 1993; Matyasovszky et al., 1995; Beck and Jacobit, 1997) and Canonical Correlation Analysis (Luterbacher et al., 1998). Fuzzy rule and neural network based methods are also been developed (Bardossy et al., 1995; Michaelides and Pattichis, 1998). All these automatic and objective classifications posses limitations in the form of the data, the method used and the interpretation of the results (Kassomenos et al., 1998). However, an automatic classification of circulation, types “takes advantages of the large data handling capacity of modern computers, allowing the machine to determine statistically similar and significant synoptic grouping when based on standardized criteria and data, results can be replicated and studies can be compared” (Yarnal, 1993).

The objective of this work is to develop a new automatic classification scheme of daily circula-
tion types, which combines advantages of objective and manual classification methods, characterized thus as semi-objective method.

2. Methodology and data

The automatic classification of circulation types over Greece has been developed using spatial methods of topology and geometry (Roman, 1975), especially about the identification of high and low centres over the studied region and their effect in Greek area. This method considers almost all the criteria that applied to the empirical classification by Maheras (1982, 1988, 1989) except the criterion of cyclone’s trajectories. The empirical classification was made firstly for the period 1950–1975 in order to explain the geographical distribution of temperature and precipitation in Aegean Sea (Maheras, 1982). In later step the classification of circulation types was made for the period 1950–1985 in order to delimit seasons in Greece (Maheras, 1989). Finally this calendar expanded to 1990. It is obvious that there is a common period of 33 years (1958–1990) to the manual/objective classification scheme. This classification is based on MSLP and 500 hPa grided data (NCEP Reanalysis data at 00, 06, 12 and 18 h and daily mean, grided data (NCEP Reanalysis data at 00, 06, 12 and 18 h and daily mean, \( \varphi = 2.5^\circ, \lambda = 2.5^\circ \)) within the area of \( 20^\circ - 65^\circ \text{N} \) and \( 20^\circ \text{W} - 50^\circ \text{E} \), for the period 1958–1997. The method for automatic classification of the circulation types includes several steps, which are described as following: (Fig. 1)

First, we examine whether the hourly or mean daily pressure over Greece (for 8 grid points, \( 2.5^\circ \times 2.5^\circ \)) is anticyclonic or cyclonic, according to critical MSLP values reproduced during the empirical classification (Maheras, 1988, 1989).

The second step is to look for the centre of the high or low pressure, as it was determined at the first step. It is determined by the absolute highest or lowest value of pressure in the examined grid field (\( 20^\circ - 65^\circ \text{N} \) and \( 20^\circ \text{W} - 50^\circ \text{E} \)) i.e., when the pressure at the centre is greater or equal (for an anticyclonic centre) and less or equal (for a cyclonic centre) to each one of the 8 neighbouring grid point pressure values. The next approach is to check if there is a continuous decrease, or increase, of the pressure values, from the centre of the system towards Greece, for anticyclonic or cyclonic centres, respectively. The final step is to look for other regional or local centres. If one or more anticyclonic or cyclonic centres are indeed found and if all the conditions are similar to main centre, then the one located closer to Greece determines the final centre of the pressure system.

After locating the anticyclonic and cyclonic centre and before the classification of the anticyclonic and the cyclonic circulation types, a filter (third step) was applied. According to this, the minimum surface pressure gradient must be greater than 2.5 hPa/2.5\(^\circ\) for the anticyclonic fields and greater than 2.0 hPa/2.5\(^\circ\) for the cyclonic fields. They were checked in the four directions (east, west, north and south) with respect to the centre grid of the Greek area, (\( \varphi = 37.5^\circ, \lambda = 25^\circ \)). This way, all the anticyclonic and cyclonic fields with low-pressure gradient over the Greek area were pointed out. This is the classification of the MB circulation types. So, there are two MB circulation types: the MB1 (cyclonic) and MB2 (anticyclonic).

The fourth step constitutes the classification of the mixed types. This classification is the same as in the manual classification. For one type it includes all the cases, where the anticyclonic fields represent anticyclonic centres, being located at the west of the Greek area (southwest or northwest) and the cyclonic centres to the east of Greece (with high pressure gradient). The orientation of the isobars at the surface is meridional, from north to south. These conditions are classified to the Mt1 type. For the other, the anticyclonic fields represent anticyclonic centres, being located to the north, northwest, or northeast of the Greek area, with the cyclonic centre to the south, southeast, or southwest. The orientation of the isobars at the surface (with high pressure gradient) is zonal (from east to west), or semi-meridional (from northeast to southwest). Such conditions are classified as Mt2.

The fifth step is the classification of the anticyclonic circulation types. Each anticyclonic circulation type is determined according to the location of the anticyclonic centre (Fig. 2) and the conditions prevailing at the 500 hPa level (positive or negative geopotential height anomalies) over the Greek area.

- The first three anticyclonic types showing weak positive or negative geopotential height anomalies at the level of 500 hPa (A1, A2, A3).