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Atmospheric processes leading to droughty periods in Romania

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Abstract The study of climate variability is important for a better understanding of the hydrological and atmospheric processes that lead to droughty periods in Romania. The variability of the seasonal and annual precipitation at Romanian raingauge stations is examined for characteristics of droughty periods in the atmospheric processes. The discharge series were statistically analysed to complete the image of the water resources behaviour in Romania. The changes identified in the time series of data by means of statistical methods, using Canonical Correlation Analysis, were shown to be correlated with the large atmospheric circulation.

INTRODUCTION

The drought phenomenon on the Balkan part of Europe is a specific feature of the geographical conditions. This phenomenon, although without a strict cyclicity, shows a repeatability at 15–25 year intervals with a persistency of about 12–15 years, and short term interruptions of about 1–3 years with rainfalls above the normal values (Adler *et al.*, 1998). These interruptions do not modify the general features of the droughty periods. Three long intervals with droughty and excessively droughty periods during the last century can be mentioned: 1894–1905, 1942–1953, and 1981–1995 (Adler *et al.*, 1998). Winter and summer water resources characteristics were studied in an effort to identify the large-scale conditions inducing the variability. It is well known that atmospheric circulation and climate are linked. But the regional climate is generated by the simultaneous action of the various processes at local, regional and global scales. The knowledge of the relative contribution of these processes is important for explaining the regional climate variability. In this paper the relationship between simultaneous variability of seasonal precipitation in Romania and large-scale atmospheric circulation is empirically examined by Canonical Correlation Analysis (CCA) (von Storch, 1995; Busuioc & von Storch, 1996). The conclusions are extended to the discharge series trying to explain the characteristics of the variability of water resources in the Carpathian region.

The results are presented mainly for the winter and summer seasons for which the climate signals of water resources series (precipitation and discharge) are significant.

DATA AND METHODS

Data used in this paper are the time series of annual, monthly and winter precipitation at 14 meteorological stations, the seasonal mean sea level pressure in the period 1901–1996 and discharges at 40 gauging stations during 1921–1996. The large-scale circulation is represented by the sea level pressure (SLP) field for the area between 30–55°N and 5–55°E. The monthly SLP data have been obtained from the National Centre for Atmospheric Research (USA) with a resolution of 5° × 5°.

The most affected periods (i.e. season, and the most representative months in seasons) of water deficits or of high flow were identified. An excessive droughty period was defined as one where less than half of normal water resources were produced. Using monthly data, both the excessive droughty periods and the synoptical conditions which induced them in Romania, were identified.

To see if any changes in water resources "regimes" were produced, the concept of "change points" was applied. Firstly, Pettitt's statistic (Pettitt, 1979) was used, not as a confirmatory tool but only as an exploratory tool for the determination of the possible regime change. To overcome the inhomogeneity problem we search for simultaneous change points in dynamically related time series: discharges as an integrator of precipitation in the basin, precipitation and large-scale circulation. Canonical Correlation Analysis (CCA) has been used to identify the regional characteristics of the spatial patterns of SLP and of the precipitation in Romania. The time series associated to the most significant CCA pairs of precipitation and sea level pressure to detect "change points" were analysed. It was found that systematic and physically plausible changes of the mean state happen simultaneously in the both parameters. Thus the changes in the mean precipitation are real and not due to inhomogeneities; this aspect was reflected in discharge time series too.

DROUGHTY ASPECTS IN WATER RESOURCES TIME SERIES AND RELATED SYNOPTIC CONDITIONS

The annual precipitation trend observed at the meteorological stations in areas of interest did not always emphasise a decreasing tendency, although large areas are affected by such a phenomenon. The analysis of water resources was extended to river discharges. The tendency of the mean annual discharges was extracted. A concordance with the annual precipitation registered in each basin can be observed.

The analysis of the time series data shows that the trends are statistically significant in only few cases, at a 5% level of significance adopted for the Mann test, in the central part of the Carpathian arc. Nevertheless, a slight tendency towards a decrease was detected within all the time series from gauging stations located in the southern and southeastern side of the Carpathian region, due to the very low amounts of precipitation during the last 16 years. During the period 1982–1996 the annual precipitation amounts were more than 50–70% below the monthly and annual normal values (Adler *et al.*, 1998). Most of the annual series of precipitation and discharges in the area of interest emphasised in general a decreasing trend that does not characterize the repartition of water resources during all the seasons. The most affected season by deficits was the winter with large deficits after 1970 and especially during in the 1981–1995 period.

Pettitt's statistics derived from all precipitation data showed a downward change point at about 1969/1970 for several stations. The shifts are in the order of –9 to –66 mm for the 1969/1970–1994 period. It can be noted that if a new splitting of the precipitation time series is done in 1970, another downward change point is found in 1981. This shows the fact that after 1970 the precipitation is continuously decreasing, but more evidently after 1981, inducing an important decrease in water resources.

The influence of the physico-geographical conditions of each basin were reflected in the starting point of the droughty period (the downward point), which can vary with some years, depending on the inertia of the basin to the deficits in precipitation. Although in most cases the downward change point in precipitation was registered in 1969–1970, only in a few cases, in high mountains (Fagaras), the downward point of the discharge time series was simultaneous. In the other areas, the inertia of the hydrological basins was important due mainly to groundwater resources, which sustain the surface runoff through the base flow. In all cases water resources are diminishing after 1981 (downward change points), most significantly in the south and the middle of the Carpathian. Some discrepancy in the simultaneousness of the change points in winter series of data of precipitation and discharges is due to the snowmelt phenomenon.

The deficits during summer periods were registered around 1940–1941, when a very droughty period was registered for the eastern part of Romania. For the western part, the ninth decade of the century was the driest (1981 is the most significant downward change point).

Four main synoptic conditions were identified which lead to droughty aspects in Romanian water resources time series. The first is: anticyclone in central Europe,

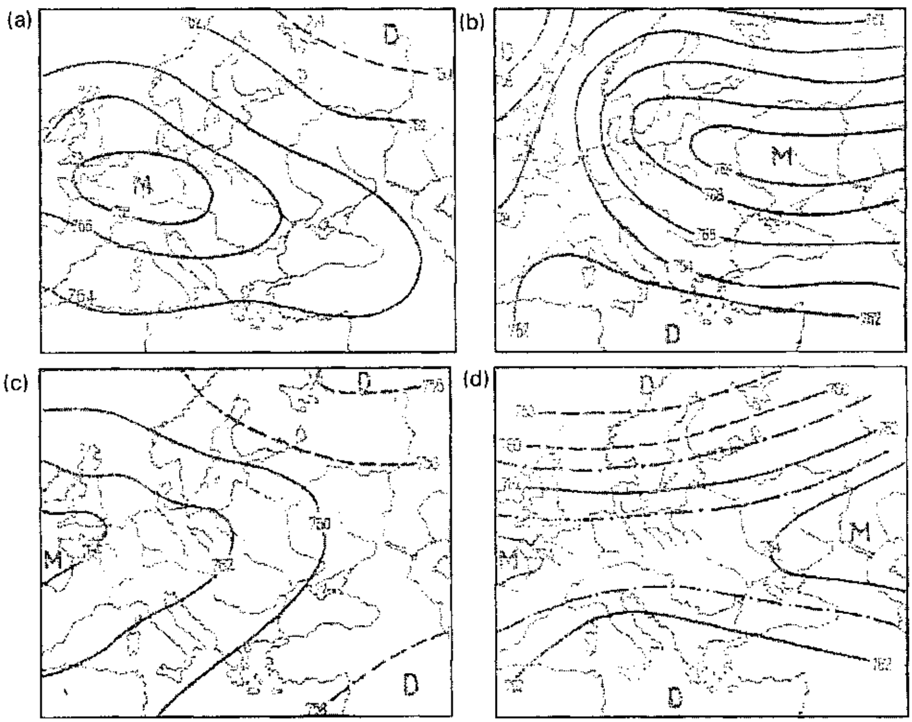

Fig. 1 The most frequent synoptic situations inducing deficits in Romanian water resources time series (precipitation and discharges).

(covering Romania) and Iceland depression extended in eastern Europe (Fig. 1(a)). The second shows a synoptic situation with anticyclones in eastern Europe, northeast or southeast (covering Romania) and low pressure from the northern Atlantic Ocean to western Europe and the Mediterranean Sea (Fig. 1(b)). The third synoptic situation (Fig. 1(c) contains an anticyclonic ridge covering the area from the North Atlantic to central Europe (and Romania) and low pressure in the extreme northeast and southeast of the continent. The fourth synoptic situation contains situations with high pressure in central Europe and the Balkan regions induced by Euroasiatic and Azoric anticyclones and low pressure in the Arctic Ocean and in southern Europe (Fig. 1(d)).

The first synoptic situation is specific for the cold period (September–March) with an exception in May 1947. The frequency of all cases is 21.3%. The second takes place from September to May, with high frequency during autumn (65% of all cases) and in winter (20%) with 21.5% frequency of all cases. The third synoptic situation is mainly found during summer and spring time, the maximum frequency being in July (51%), but with a low total frequency of cases 12.4%. The fourth type has a maximum frequency of 43.8%. This situation is most frequent in autumn, August–September (30% of the total cases—159), but the possible period is from August to May.

CONNECTION BETWEEN SEASONAL WATER RESOURCES AND LARGE-SCALE CIRCULATION

To verify the regional seasonal synoptic characteristics, Canonical Correlation Analysis (CCA) was applied.

For the *winter season* the first CCA pair exhibits a correlation between precipitation and SLP coefficient time series of 0.84. The patterns for both variables represent a link that is very reasonable from the physical point of view: low pressure over the Europe and Mediterranean basin guides maritime air and precipitating weather systems into Romania, such that above normal precipitation is recorded (Fig. 2). The time coefficients associated to these patterns have an upward change-point at about 1933 (Fig. 3). The link is strong and therefore we can assert that changes in the Romanian winter precipitation are due to changes in the large-scale circulation. For more details see Busuioc & von Storch (1996). The patterns of the second CCA pair associates the northwesterly flow over Romania to positive precipitation anomalies in the intra-Carpathian region, the highest being in the northwest (Fig. 3(b)).

During the *summer season*, the first CCA pair associates (with a maximum correlation of 0.70) the anticyclone structure with the centre over the Black Sea to below normal precipitation in Romania (Fig. 4). The time coefficients corresponding to these patterns have a simultaneous downward change point at about 1941 that is consistent with same change points in the centre of the country and the Black Sea littoral. The second CCA pair associates the zonal circulation over Romania to below normal precipitation in the intra-Carpathian region and above normal precipitation in the extra-Carpathian region. The eastern zonal circulation became more frequent after 1961 which could explain the upward change points at about 1968 in the northeastern part of the country (Fig. 5). Also, some short-lived convective weather systems could be responsible for the positive precipitation anomalies from the extra-Carpathian region.

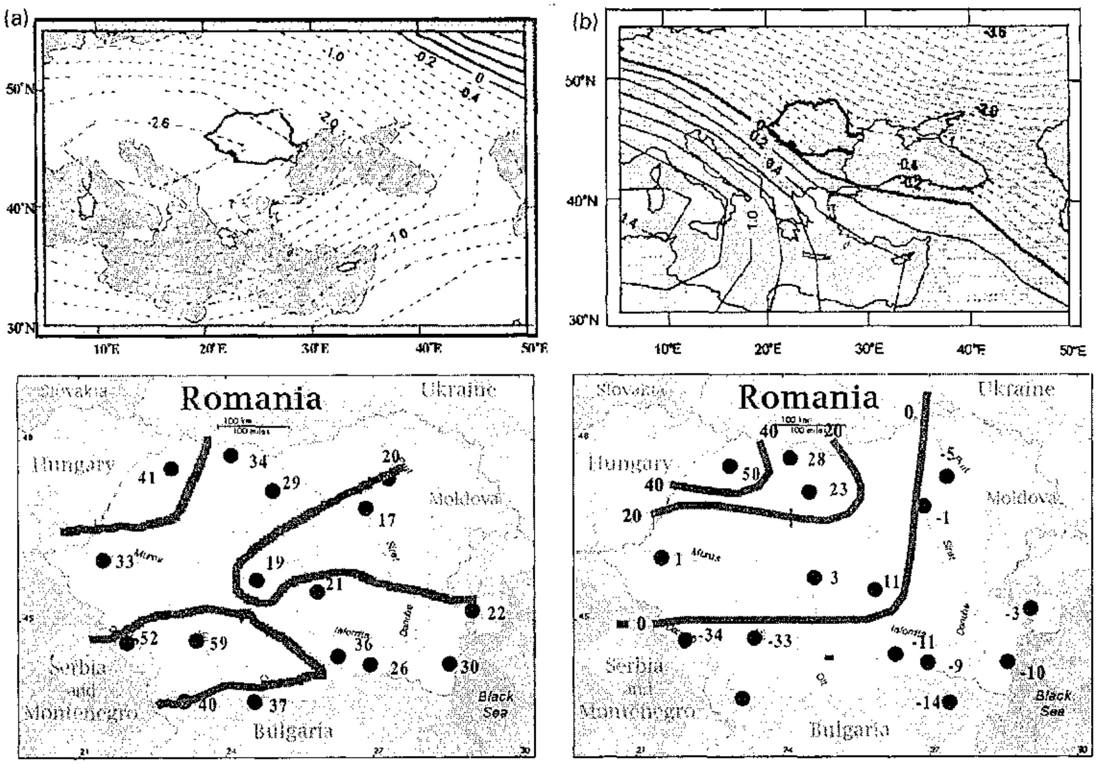

Fig. 2 The patterns of (a) the first and (b) the second canonical pair of the winter mean sea level pressure (Mb) and total winter precipitation (mm). (Romania is marked by a heavy line in the area; continuous lines mark positive values and dashed lines negative values for winter times.)

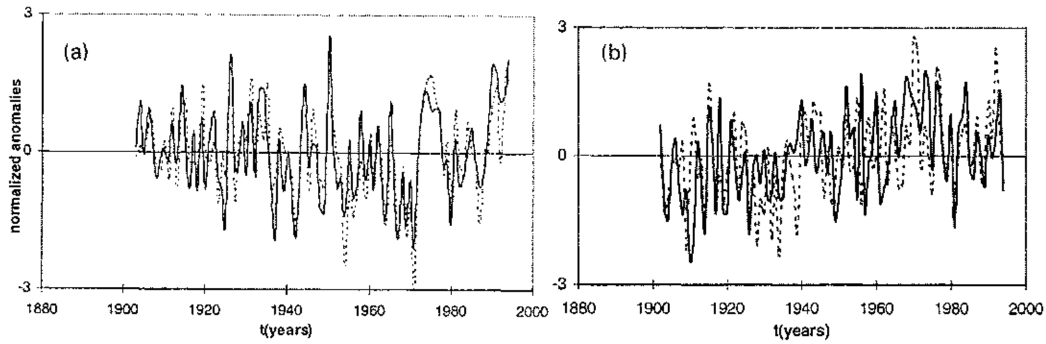

Fig. 3 (a) The first and (b) the second canonical correlation time coefficient analysis patterns of the sea level pressure anomalies (continuous line) and precipitation anomalies (dashed line) for summer times.

CONCLUSIONS

Two main periods of deficits were identified in Romania after 1940–1942, mainly in the summer season with comparable intensities and affected areas—namely 1941–

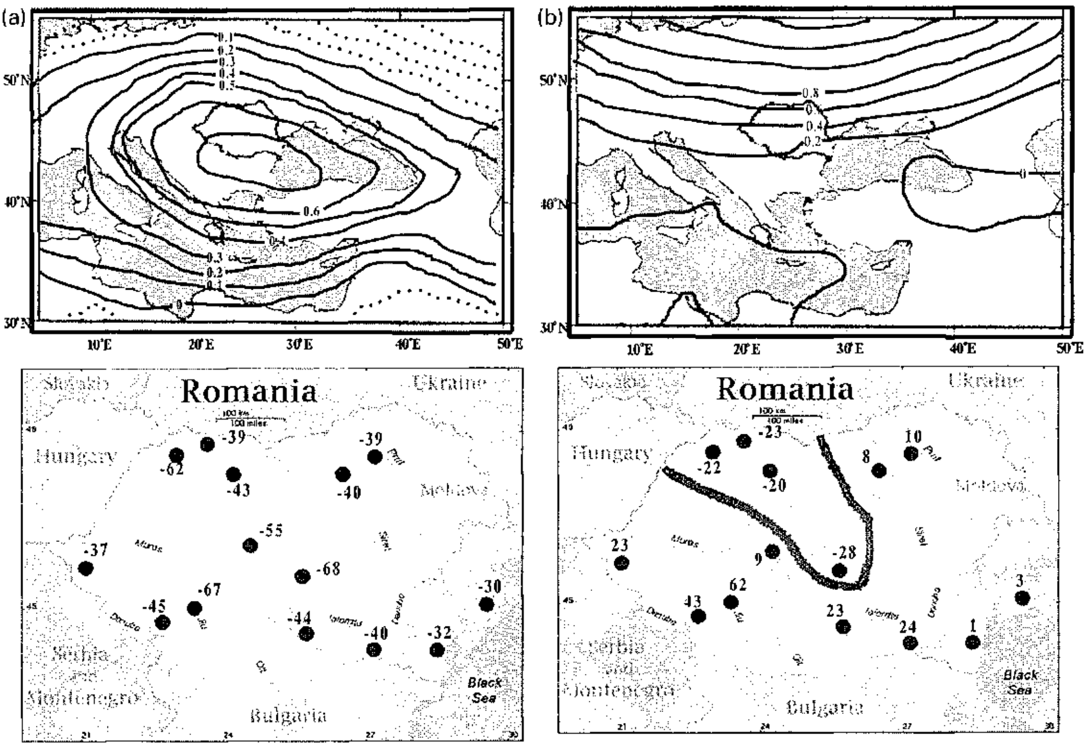

Fig. 4 The patterns of (a) the first and (b) the second canonical pair of the summer mean sea level pressure (Mb) and total winter precipitation (mm). (Romania is marked by a heavy line in the area; continuous lines mark positive values and dashed lines negative values for summer times.)

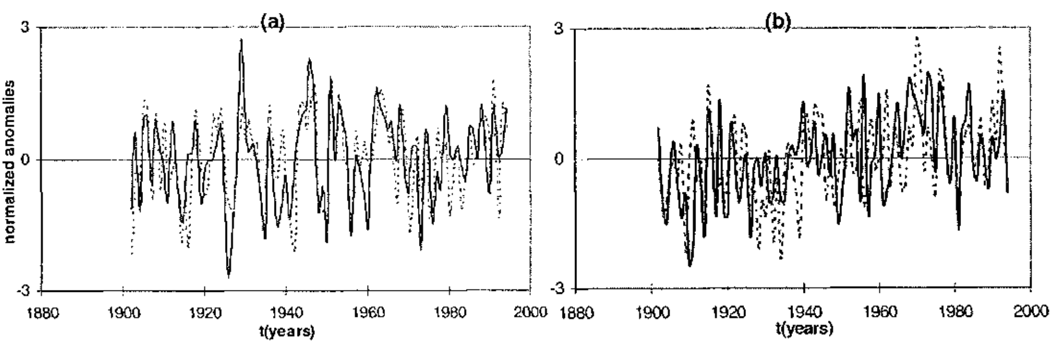

Fig. 5 (a) The first and (b) the second canonical correlation time coefficients analysis patterns of the sea level pressure anomalies (continuous line) and precipitation anomalies (dashed line) for winter times.

1953 and 1981–1995. A comparable decrease in available water resources in the eastern part of Europe was evident only after 1981.

A decrease in available water resources was recorded since 1969–1970, mainly during the winter in connection with the decreasing frequency of the Mediterranean southwesterly circulation.

The interrelation between precipitation and available resources of water in rivers during winter is not always evident as the restitution of the snow layer taking place during the spring as well as in the winter time affects the seasonal precipitation–discharge balance.

The river discharges were affected mainly after 1981. The inertia of the hydrological response to decreasing precipitation caused by groundwater storage plays an important role in delaying the effects on river discharge.

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