CLIMATE VARIABILITY
OF DROUGHT INDICES IN ROMANIA

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Indices de la variabilité du climat de sécheresse en Roumanie. La variabilité du climat de sécheresse en Roumanie a été étudiée en utilisant deux indices: un indice de sécheresse (DI), calculé en utilisant des dates de température et précipitation et l'indice *self calibrating Plamer Drought Severity Index* (sc-PDSI) calculé par Van der Schrier *et al.* (2006). L'indice de sécheresse (DI) a été calculé en utilisant des valeurs saisonnières de température et précipitation pour 25 stations de Roumanie dans la période 1951–2003. La comparaison entre l'indice DI pour la saison d'été à trois stations (Bucureşti, Sibiu, Târgu Mureş) et sc-PDSI pour la même saison en trois points de grille très proches des stations mentionnées indique une bonne concordance. Les deux indices caractérisent de la même manière les conditions d'humidité, seulement le signe est opposé parce que les valeurs positives de DI indiquent conditions de sécheresse tandis que pour sc-PDSI les valeurs négatives caractérisent une période de sécheresse. Les valeurs saisonnières de l'indice de sécheresse DI pour la période 1951–2003 ont été décomposées en fonctions empiriques ortogonales (EOF) et EOF tournées. On a analysé l'évolution dans le temps de la première composante principale pour chaque saison et la distribution spatiale de la première composante tournée. Pour le printemps et l'été, l'évolution dans le temps de la première composante principale indique une tendance vers sécheresse pour la période 1999–2003. L'investigation de la distribution spatiale de la première composante tournée de l'indice de sécheresse DI pour chaque saison a mis en évidence le fait que le printemps, l'automne et l'hiver la zone homogène pour l'indice de sécheresse est dans le sud-est de Roumanie. L'été, la zone homogène pour l'indice de sécheresse est dans le sud-ouest de Roumanie. Pour la période 1901–2002, les valeurs saisonnières en 99 points de grille sur le territoire de Roumanie ont été aussi filtrées par EOF et on a analysé l'évolution temporale de la première composante principale. Pour trouver les possibles points de changement climatique dans les séries de temps de l'indice DI pour chaque saison, on a estimé le rapport signal-bruit pour la première composante principale de l'indice DI. Les résultats significatifs du point de vue statistique indiquent le fait que l'année 1970 pour l'hiver et les années 1981, 1986 pour l'été sont des points de changement qui marquent la transition vers une période plus sèche, tandis que les années 1965, 1968, pour l'été et 1970, pour l'automne, sont des points de changements qui indiquent la transition vers une période plus humide.

Key words: Drought index, Empirical Orthogonal Functions, Romania.

1. INTRODUCTION

The Palmer Drought Severity Index (PDSI) is a measure of regional moisture availability that has been used extensively to study drought and wet spells in the United States, particularly as the primary indication of the severity and extent of droughts (Palmer, 1965; Heim, 2002), with applications in other parts of the world emerging in the past decade (Briffa *et al.*, 1994; Dai *et al.*, 1998; Dai *et al.*, 2004; Lloyd-Hughes and Saunders, 2002). The index is based on water supply and demand which is calculated using a rather complex water budget system based on historic records of precipitation and temperature and the soil characteristics of the site being considered. The quantities involved in the calculation are potential evapotranspiration, computed using Thornthwaite (1948) method; the amount of moisture required to bring the soil to field capacity; the amount of moisture that is lost from the soil to evapotranspiration and runoff. Detailed description how the PDSI is computed can be found in Alley (1984) and Karl (1986). Dai *et al.* (2004) investigated for PDSI at global scale over the period 1870–2002 the relationship with soil moisture and effects of surface warming. Akinremi *et al.* (1995) analyzed several drought indices in order to asses the validity of PDSI for characterizing drought on the Canadian prairies. Burke and Brown (2007) analyzed the uncertainty in the projection of future drought occurrence for four different indices (including PDSI) by using two model ensembles. Mareş *et al.* (1996) investigated the climate variability in Romania of a drought index calculated using the first EOF time component for the temperature and precipitation field (EOFDI). The study was achieved for seasonal and annual values over the period 1950–1993. For the summer time, the results obtained for EOF drought index have been compared with the ones for the Palmer Drought Severity Index. The authors noticed a good similarity between the two indices. By means of the canonical regression the influence upon EOFDI and PDSI of several factors including the atmospheric circulation at 500 hPa over the Atlantic-European sector, the solar activity, the Southern oscillation and SST from the Atlantic Ocean was tested. Mareş *et al.* (2002a, 2002b) tested the influence of NAO and ENSO upon PDSI for summer time over the 1891–1991 period and upon EOFDI over the 1951–1997 period using the correlation technique with different lags. Mareş *et al.* (2005) studied for the monthly, seasonal and annual time scale the drought index (DI) time series calculated by means of standardized anomalies of temperature and precipitation. An analysis of the internal structure of the DI time series was achieved, testing homogeneity and climate change points both for seasonal and annual values. The authors obtained for the wintertime a change point in DI in 1970–1971 related to an increase of the geopotential field after this date in Europe. This result is in accordance with Beniston (2005) who shows that a change occurred in the beginning of the 1970's in the North Atlantic Oscillation (NAO) index, a change reflected in the behavior of the maximum temperature in the Alps. Wells and Goddard (2004) presents a self calibrating PDSI (sc PDSI) which is more appropriate for geographical comparison of climates of diverse regions. The authors improve the performance of PDSI by automating the calculations Palmer made when he derived the empirical constants used in the PDSI algorithm. They achieve this by determining, for each location, the climatic characteristic weighting factor using data from only that location. Van der Schrier *et al.* (2006) calculated maps of monthly self-calibrating Palmer Drought Severity Index (sc-PDSI) for the period of 1901–2002 for Europe (35^0–70^0N, 10^0 W–60^0E) with a spatial resolution of $0.5^0 \times 0.5^0$. The authors analyzed summer moisture variability across Europe using the sc-PDSI. To compare sc-PDSI and PDSI values, a PDSI data set was produced based on the same input data as those of sc-PDSI. The authors pointed out that sc-PDSI provides a more realistic metric of relative periods of drought or excessive moisture supply. They observed that the percentage of months when the sc-PDSI indicates an extreme drought or an extreme wet spell is much less compared to the percentage of months classed as extreme when using the PDSI data.

The aim of this paper is to study the climate variability in Romania at the seasonal time scale of a drought index based only on temperature and precipitation values and of the sc-PDSI obtained from Van der Schrier *et al.*, 2006 (available online at http://www.cru.uea.ac.uk).

2. DATA AND METHODS

In order to study the variability of moisture conditions in Romania, two drought indices were used: a drought index (DI) calculated using temperature and precipitation data and the self-calibrating Palmer Drought Severity Index (sc-PDSI) calculated by Van der Schrier *et al.* (2006).

The drought index was calculated using the formula given by Ped (1975):

$$DI = \frac{\Delta T}{\sigma_T} - \frac{\Delta P}{\sigma_P}$$

Where $\Delta T, \Delta P$ are temperature and precipitation anomalies and σ_T, σ_P standard deviation for $\Delta T, \Delta P$ respectively. Depending on DI there is the following situation: $1 \le DI \le 2$ weak, $2 < DI < 3$ moderate, $DI \ge 3$ strong drought. The negative values of DI indicate a more or less intense wetness state.

The drought index was calculated for seasonal temperature and precipitation values in 25 stations from Romania for the period 1951–2003. In order to investigate the climate variability of the drought index the values of DI were filtered by decomposition in empirical orthogonal functions (EOF) and rotated EOF. The temporal evolution of the first EOF component and the spatial distribution of the first rotated EOF component for each season were analyzed.

In order to find possible climatic change points, the first EOF time series of DI for each season has been investigated using Pettitt (1979) and Mann Kendall procedure, described in Sneyers (1992). In addition, for increasing the confidence degree for the applied method, for every detected change point the signal-to-noise ratio was calculated. The quantification of signal-to-noise ratio $R_{S/N}$ has been achieved by means of procedures described in Mareş and Mareş (1994).

$$R_{S/N} = \frac{|X_S - X_A|}{\sigma_S + \sigma_A}$$

where $X_S, X_A, \sigma_B, \sigma_A$ represent averages and variances for several years before and after the reference year. Yamamoto (1986) considers that there is a climate jump when $R_{S/N} > 1$, but several authors such as Leith (1973), pointed out that climate changes are important when the signal-to-noise ratio is greater than 0.5.

3. RESULTS

For three grid points very close to the stations Bucharest, Sibiu and Târgu Mureş, the sc-PDSI seasonal values were calculated for the 1951–2003 period using the monthly sc-PDSI values obtained from Van der Schrier. Figures 1, 2 and 3 present the two indices for summer at Bucharest, Sibiu and Târgu Mureş. We can observe that the behavior of DI and sc-PDSI is similar, only the sign is opposite, because positive values of DI mean dryness while for sc-PDSI negative values determine a drought. Figure 4 presents the variance explained by the first 10 EOF components of DI for spring, summer, autumn and winter. It can be noted that except summer, the first EOF component explains about 70 % of the total variance. Figures 5, 6, 7 and 8 present the time evolution of the first principal component of DI for winter, spring, summer and autumn. Also the trends obtained by a 5 degree polynomial fitting are showed. For spring and summer it can be noted a tendency for dryness between 1999 and 2003, tendency that begun in 1986 especially for the summer time and can be very well observed by the signal-noise value from Table 1. For summer one can notice the period between 1970 and early 1980's with excess of moisture in Romania, in accordance with the results obtained by Van der Schrier for sc-PDSI regarding the European region.

Also, for the period 1901–2002, the sc-PDSI seasonal values in 99 points over Romania were filtered by empirical orthogonal functions (EOF) and the time evolution of the first principal component was investigated. Figure 9 presents the time evolution of the first principal component of DI and sc PDSI for summer for the period 1951–2002. The similarity of the two indices regarding the estimation of change points by considering both the curves inflexion in Fig. 9 and the change points presented in Table 1 is obvious. Figures 10, 11, 12 and 13 present the spatial distribution of the first rotated EOF component of DI for winter, spring, summer and autumn. We can observe that the homogeneous zones for the drought index in spring, autumn and winter are situated in the south-east part of Romania. In summer it can be noted that these homogeneous zones are situated in the south-west part of the country. Table 1 presents the change points for the first component series of DI for winter, spring, summer, and autumn. The bolded lines represent statistical significant results. The table contains the number of years before and after the change points, M_1, M_2 averages of the period before and after the change points, σ_1, σ_2 the standard deviation for the same period, S/N the ratio signal-to-noise calculated by procedure described in Mareş and Mareş (1994). For summer, the years 1965 and 1968 are change points indicating the transition to a wetter period while 1981 and 1986 represent change points marking the transition to a dryer period. For autumn and winter the year 1970 is a change point indicating the jump to a wetter period in autumn and to a dryer period in winter. The change points in summer (1981) and autumn (1970) are in agreement with the results obtained by Mareş *et al.* (1996) and Mareş *et al.* (2005).

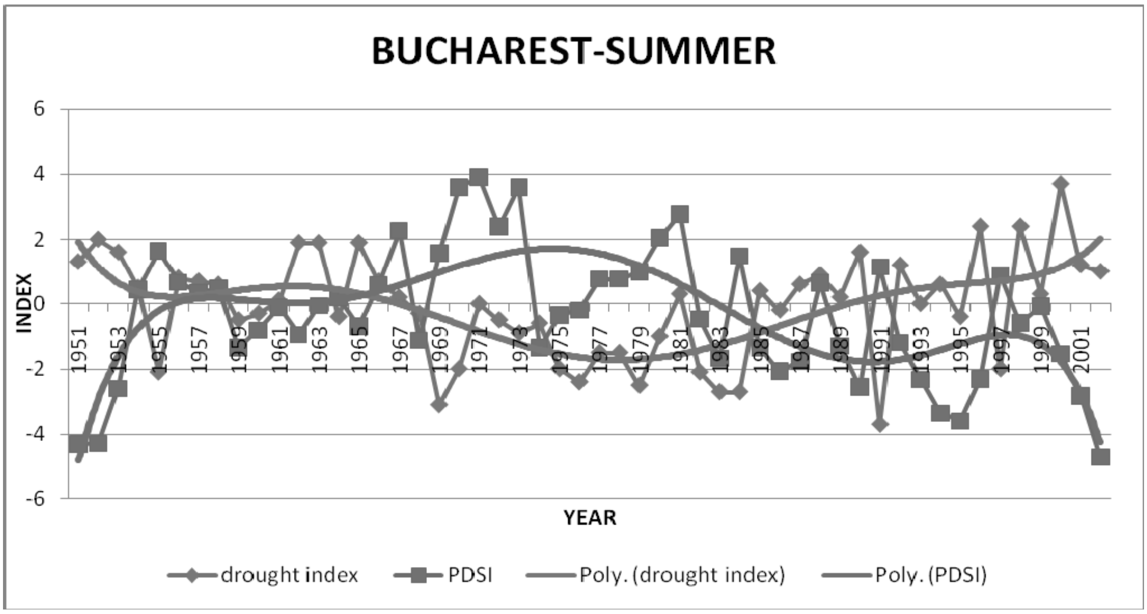

Fig.1 – Drought index and sc-PDSI index for summer, Bucharest.

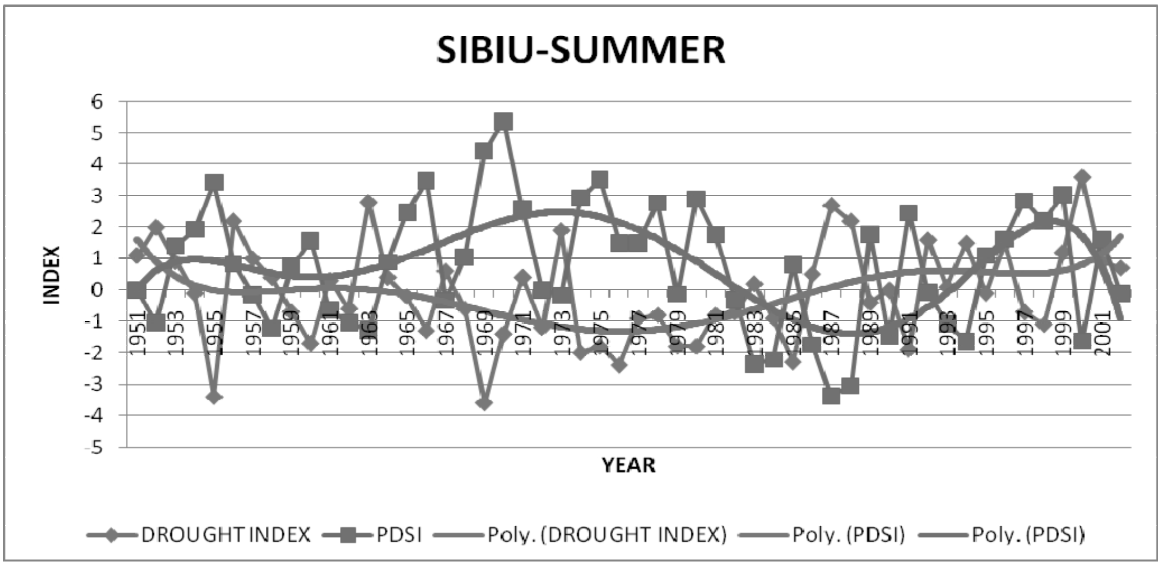

Fig. 2 – Drought index and sc-PDSI index for summer, Sibiu.

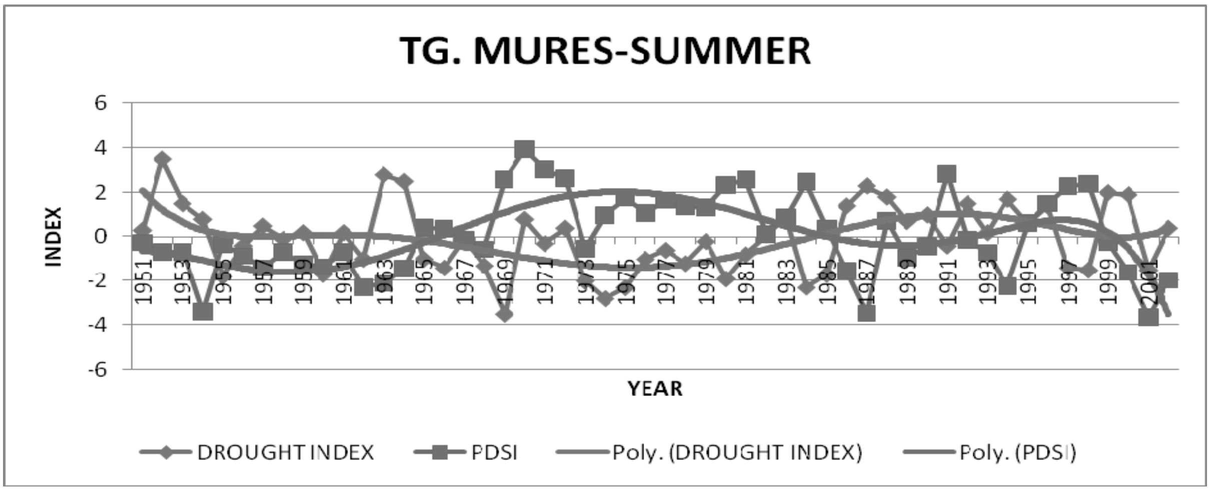

Fig. 3 – Drought index and sc-PDSI index for summer, Târgu Mureş.

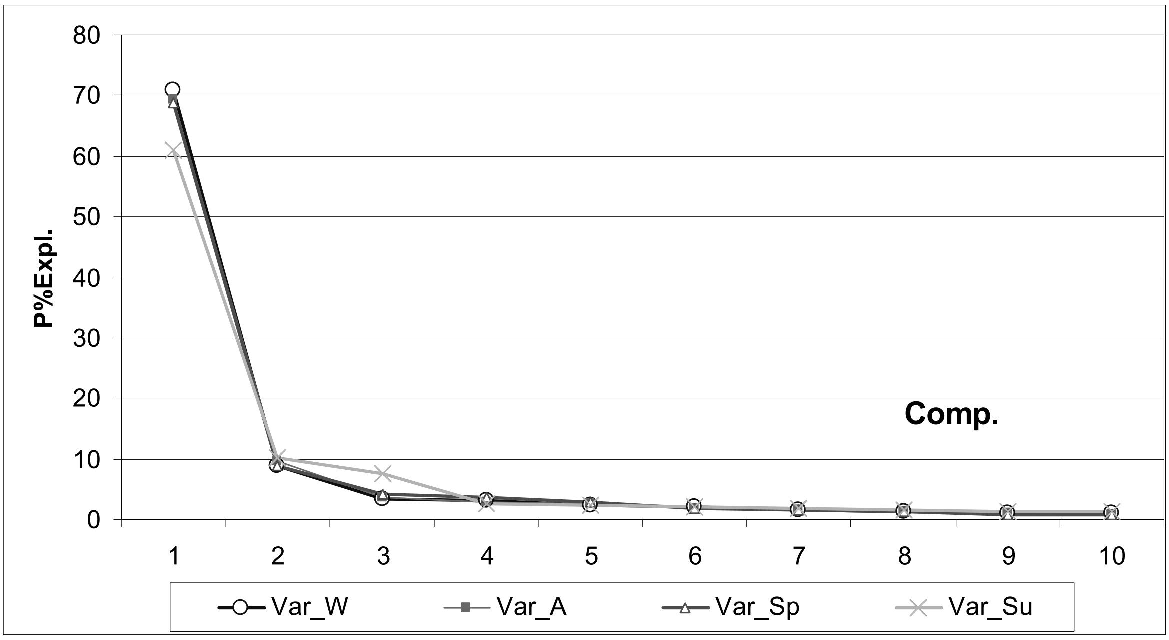

Fig. 4 – The variance explained by the first 10 EOF components of the drought index DI for Winter (W), Autumn (A), Spring (Sp) and Summer (Su).

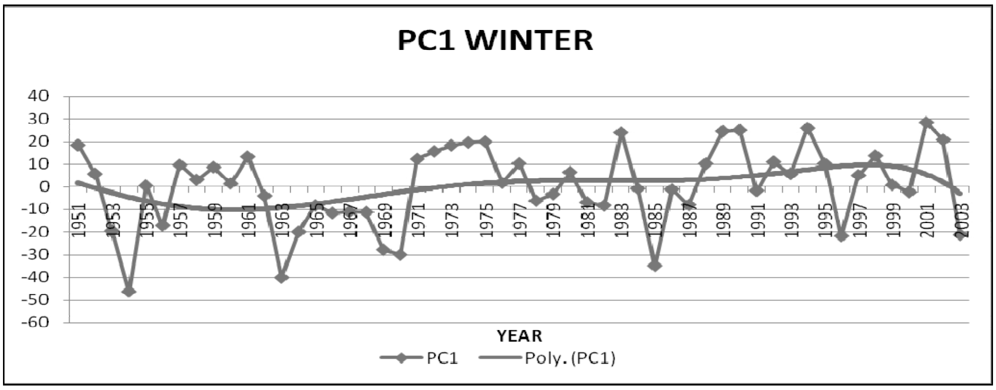

Fig. 5 – The first principal component of DI for Winter.

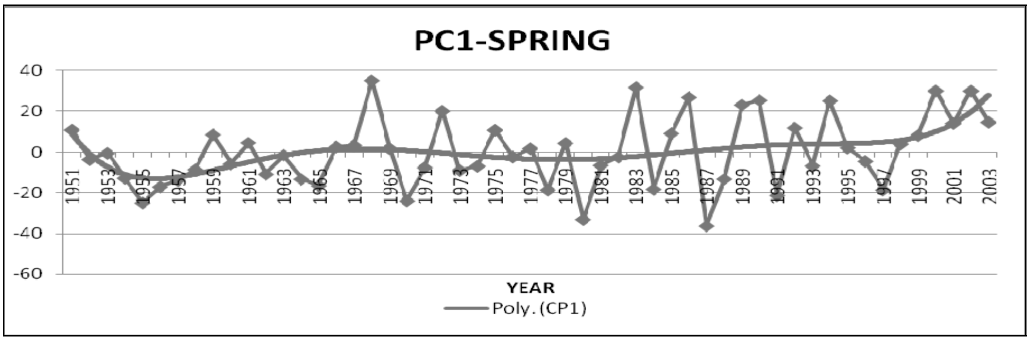

Fig. 6 – The first principal component of DI for Spring.

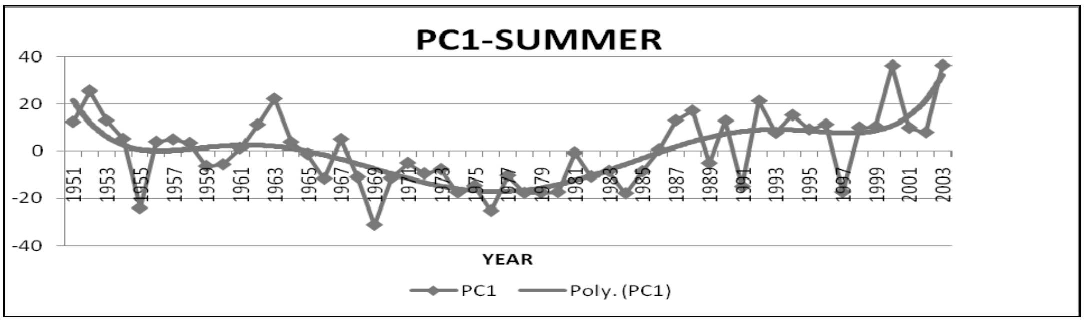

Fig. 7 – The first principal component of DI for Summer.

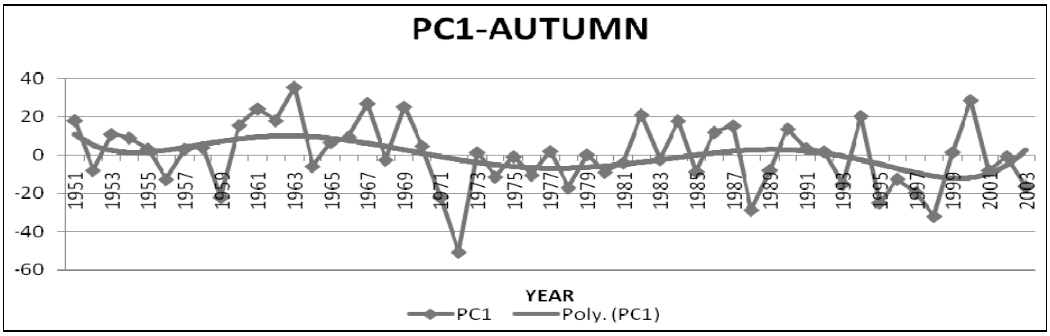

Fig. 8 – The first principal component of DI for Autumn.

Table 1

Change points for the first principal component of the drought index (DI) for Romania

	Nr.	*Change point*	*Year*	*M_1*	*M_2*	*σ_1*	*σ_1*	*S/N*
Winter	**1**	**1971**	**18**	**-10.884**	**5.442**	**16.452**	**14.983**	**0.519**
	2	**1970**	**10**	**-10.185**	**7.847**	**14.72**	**9.81**	**0.735**
Spring	1	1966	10	-9.083	2.085	9.487	15.095	0.454
	2	1988	14	-3.295	9.169	18.447	16.12	0.361
Summer	1	**1965**	**13**	**4.996**	**-12.511**	**11.928**	**9.068**	**0.834**
	2	**1986**	**15**	**-12.563**	**9.029**	**5.935**	**12.531**	**1.169**
	3	**1968**	**16**	**3.643**	**-13.665**	**11.576**	**7.252**	**0.919**
	4	**1981**	**21**	**-7.613**	**6.163**	**11.839**	**14.904**	**0.515**
Autumn	**1**	**1970**	**10**	**11.955**	**-11.299**	**16.183**	**14.466**	**0.759**

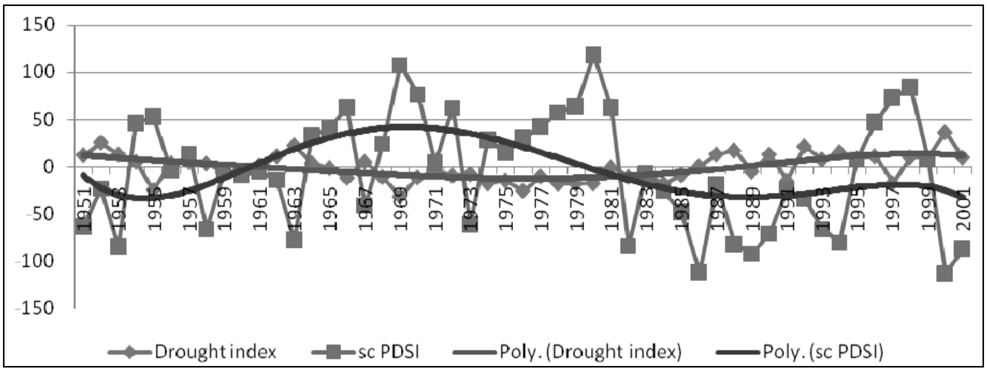

Fig. 9 – The first principal component for DI and sc-PDSI for Summer.

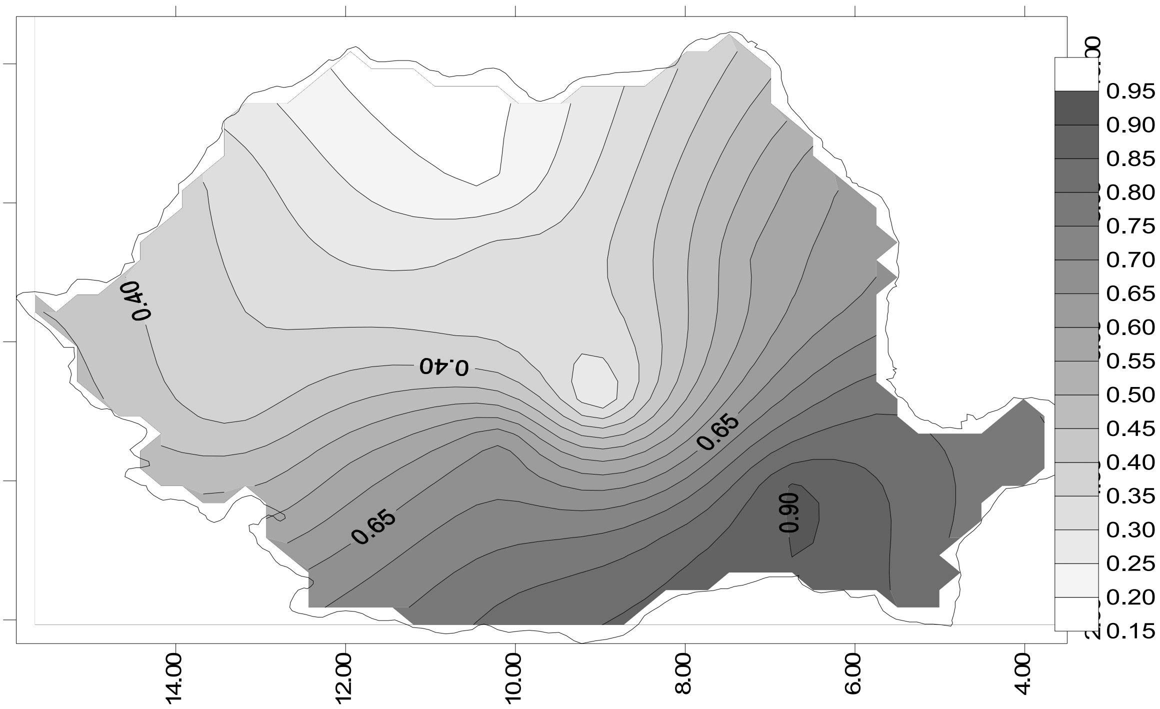

Fig.10 – Spatial distribution of the first rotated EOF vector of DI for Winter.

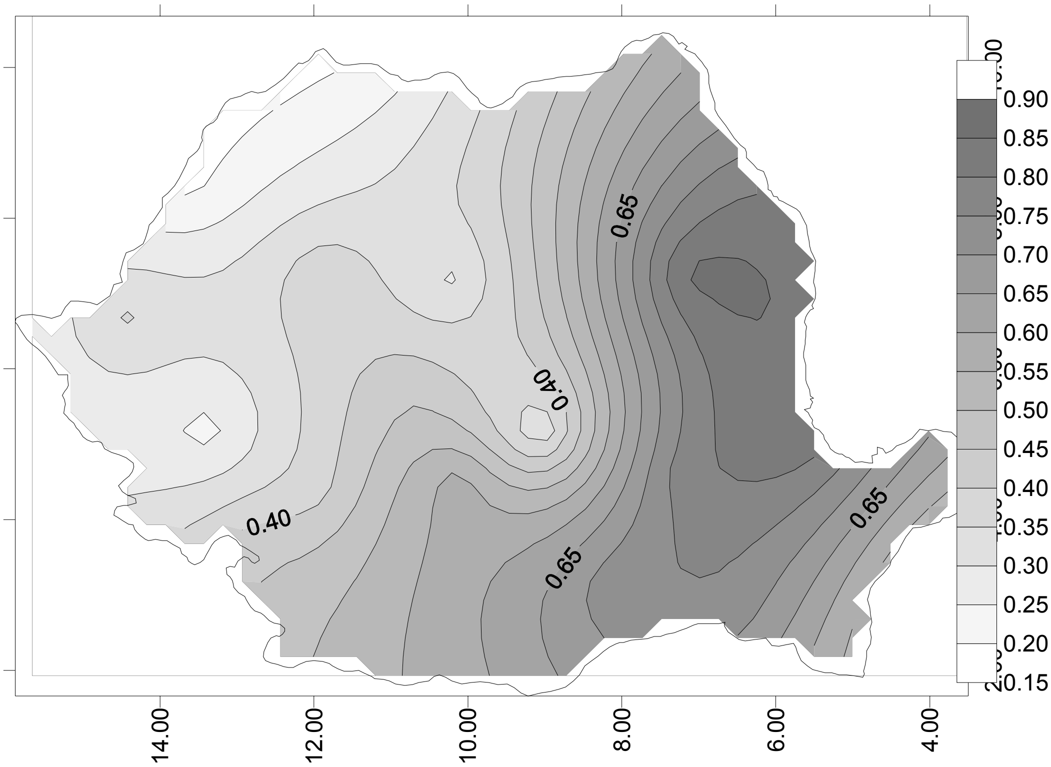

Fig. 11 – Spatial distribution of the first rotated EOF vector of DI for Spring.

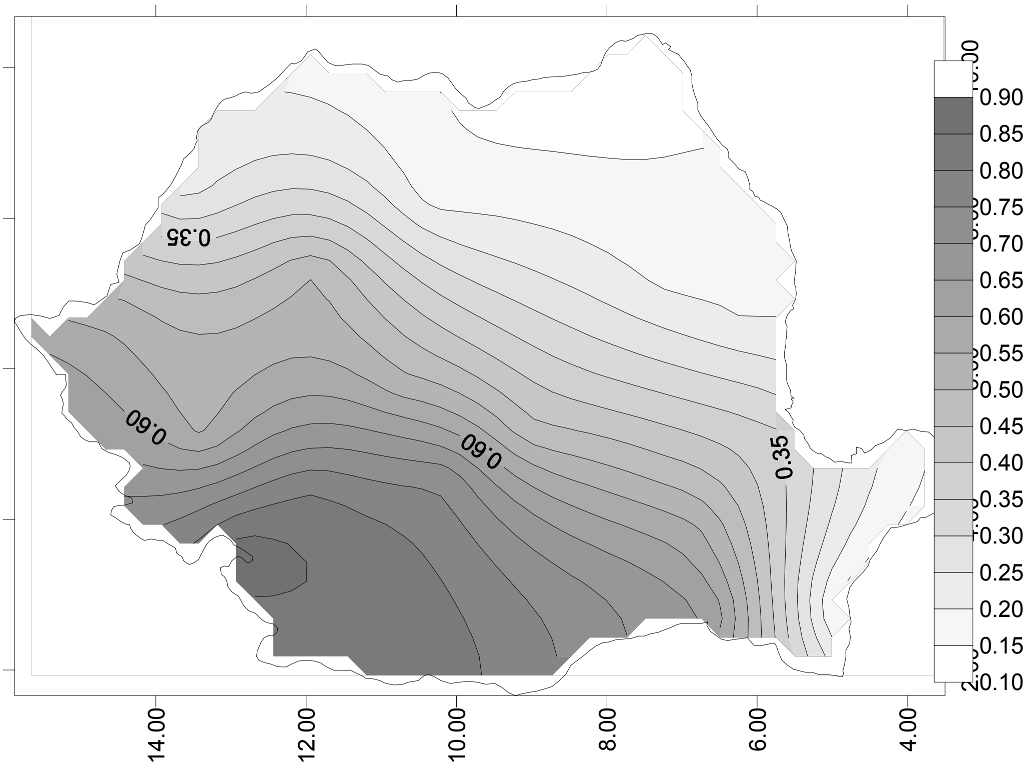

Fig. 12 – Spatial distribution of the first rotated EOF component for Summer.

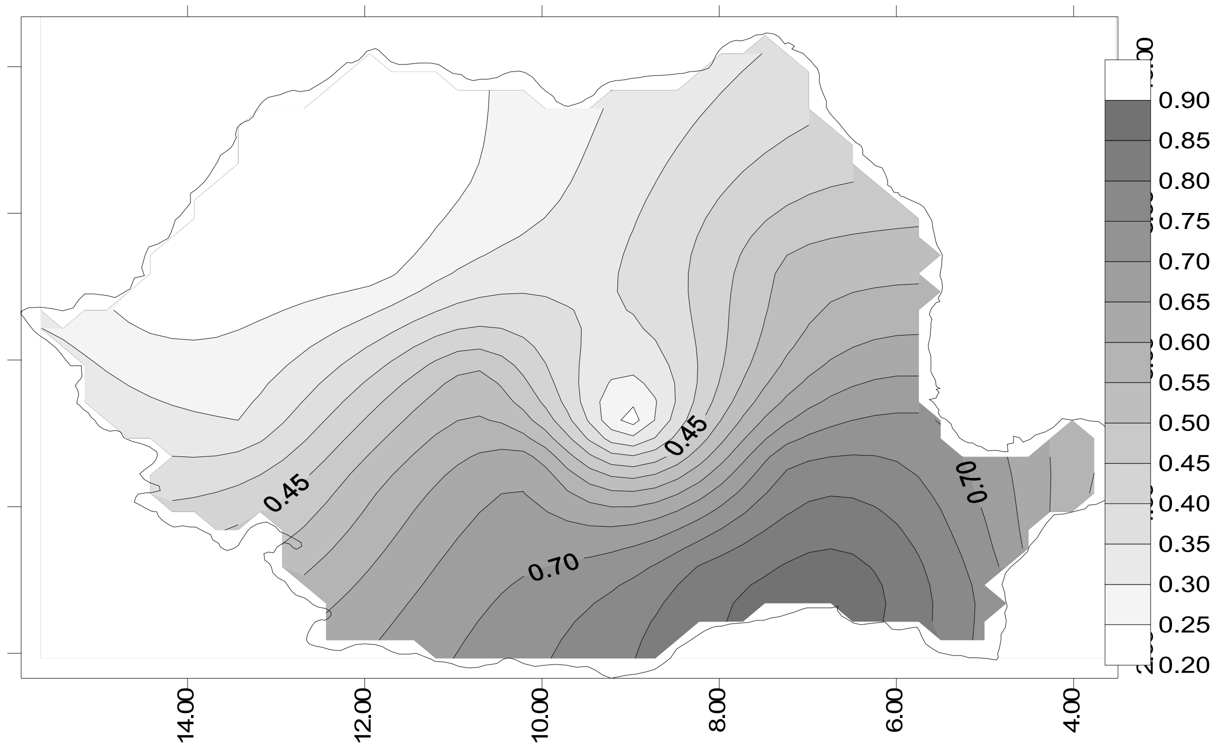

Fig. 13 – Spatial distribution of the first rotated EOF vector for Autumn.

4. CONCLUSIONS

Although the DI drought index is very simple to calculate, the study pointed out that it is similar with the sc-PDSI that has a rather complicated calculating procedure. The comparison between the DI and sc-PDSI seasonal values for the period 1951–2002 for three stations in Romania indicate a similar behavior, only the sign of the indices being opposite. The same similarity was obtained for the first temporal component EOF of DI and sc-PDSI for the same period. Analyzing the first temporal component of the DI for each season, a tendency for dryness in spring and summer between 1999 and 2002 could be observed. For summer, the period between 1970 and early 1980's appears as a persistent wet period, in concordance with the result obtained by Van der Schrier (2005) for sc-PDSI over the entire European region. The investigation of climatic change points was achieved by nonparametric statistical tests and for every detected point the signal-to-noise ratio was calculated. These methodologies were applied to the first temporal component series of the DI for each season. Several statistical significant change points: 1968, 1981 and 1986 for summer and 1970 for winter and autumn have been evidenced. The results will be used for studying climate changes in moisture availability in Romania by calculating DI from outputs of global models for climate changes using downscaling procedures.

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