DOI 10.2478/pesd-2014-0001 PESD, VOL. 8, no. 1, 2014

THE INFLUENCE OF EUROPEAN CLIMATE VARIABILITY MECHANISM ON AIR TEMPERATURES IN ROMANIA

Nicoleta Ionac[1], Monica Matei[2]

Key words: European climate variability, EOF analysis, non-parametric tests, maximum and minimum air-temperatures, Romania.

Abstract. The present paper investigates on the spatial and temporal variability of maximum and minimum air-temperatures in Romania and their connection to the European climate variability. The European climate variability is expressed by large scale parameters, which are roughly represented by the geopotential height at 500 hPa (H500) and air temperature at 850 hPa (T850). The Romanian data are represented by the time series at 22 weather stations, evenly distributed over the entire country's territory. The period that was taken into account was 1961-2010, for the summer and winter seasons. The method of empirical orthogonal functions (EOF) has been used, in order to analyze the connection between the temperature variability in Romania and the same variability at a larger scale, by taking into consideration the atmosphere circulation. The time series associated to the first two EOF patterns of local temperatures and large-scale anomalies were considered with regard to trends and shifts in their mean values. The non- Mann-Kendall and Pettitt parametric tests were used in this respect. The results showed a strong correlation between T850 parameter and minimum and maximum air temperatures in Romania. Also, the ample variance expressed by the first EOF configurations suggests a connection between local and large scale climate variability.

Introduction

To understand the mechanisms and physical processes that determine the global and regional climate and its variations, it is necessary to analyze the main characteristic structures of the climate system components. In this respect, it is noteworthy to mention the importance of conducting studies on climate variability analysis in order to identify the large scale mechanisms that may influence the

[1] Prof. PhD., University of Bucharest, ionac.nicoleta@gmail.com

[2] Ph.D. student, University of Bucharest, monicamatei06@gmail.com

regional or local climate. When it comes to presenting the climate variability based on observational data, the studies focus mainly on the analysis of temperature and precipitation variables, which are very important for human activities. As regards the Romanian territory, various studies were conducted, by using different methods or different number of meteorological stations and time periods (Busuioc and von Storch 1996; Boroneant et al., 2000; Busuioc et al., 2001). Generally, the main impact of climate change is related to the increase of mean air temperature values over land surfaces. From this point of view, the analysis of temperature variability is important to evaluate its growth rate for different time periods. Another important aspect is also related to the investigation of the frequency and magnitude of extreme events. For this, the present day weather conditions must be well understood both in terms of their common seasonal phenomena and extreme variations.

This study focuses on the spatial and temporal variability of maximum and minimum air-temperatures in Romania and their connections to the European climate variability. As it was already pointed out in the study conducted by Tomozeiu et al. (2002) it seems that the maximum air temperature in Romania is seasonally dependent on the various large-scale patterns of atmospheric circulations at European level. An analysis to detect the trend and shift points is therefore carried out by examining the data provided by 22 weather stations distributed all over Romania, over the 1961-2010.

The paper is structured as follows: section 1 describes the data and the methods that were used, while section 2 outlines the results. Section 3 summarizes the conclusions.

1. Data and methods

The observational data used in the present paper are represented by the 50 years' time series (1961-2010) of the seasonal means of maximum and minimum air temperatures during winter (December-February, DJF) and summer (June-August, JJA), at 22 weather stations evenly distributed all over the Romanian territory (Figure 1).

In order to analyze the spatial and temporal variability of observational data used in the study, two non-parametric tests were used. The trend of each time series was detected by applying the Mann–Kendall test (Sneyers, 1975), while the changes of the seasonal mean values of maximum and minimum air temperature were detected by means of the Pettitt test (Pettitt, 1979). These non-parametric tests have been used to verify the statistical assumptions in terms of the null hypothesis which does not depend on the distribution form. In practical examples, the positive values of the Mann-Kendall trend test greater than 1.97 shows an increasing trend, while the negative values lower than -1.97 reveal a decreasing trend. In both cases, the level of significance of 5% (0.05) is considered as being reasonable to obtain meaningful conclusions from a scientifically point of view (Busuioc et al., 2010). The Pettitt test detects the change points in the data series, by reporting the changes in time series average (Tomozeiu et al., 2000). More information about these tests can be found in Busuioc and von Storch (1996) and Busuioc et al. (2001).

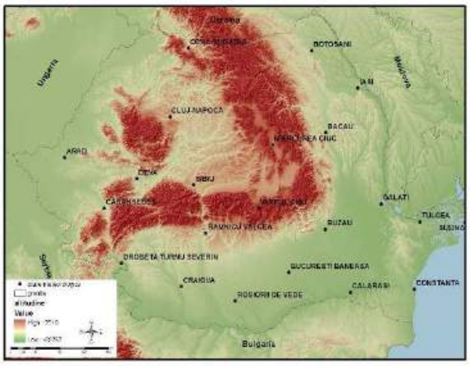


Fig. 1 – Geographical location of the weather stations used in the study

The EOF analysis (von Storch, 1995 and Wilks, 1995) has been used to investigate the spatial and temporal variability of the parameters under consideration. The analysis aims at finding possible relations between changes in large scale atmospheric circulation and seasonal mean values of air temperatures in Romania. For this, the first step of the EOF analysis is to split the temporal variance of original data sets into empirical eigenvectors (EOF's), associated with time series coefficients (PC's) which describe the evolution in time, of the spatial modes (Tomozeiu et al., 2002). It must also be pointed out that the EOF technique is applied to the anomalies calculated from the long-term mean of the data series. The Mann-Kendall and Pettitt tests are also applied to the PC series obtained in order to detect the possible reasons which could lead to changes in the seasonal mean of maximum and minimum air temperature values in Romania.

2. Results

2.1 The temporal and spatial variability of seasonal air temperatures in Romania

Below, we present the linear trends and the statistical significance for the seasonal mean values of maximum and minimum air-temperatures in Romania, as resulting from the non-parametric tests described above. Thus, Figure 2 show the linear trend for maximum air temperatures in the summer and winter seasons. The value distribution in the summer season reveals a significant warming at most of the stations, the highest values being recorded in the extra-Carpathian regions. Also, excepting the Sulina station, statistical significant trends were detected. Furthermore, the change point analysis performed by means of the Pettitt test revealed an upward shift in 1986, at most of the stations. In the winter season, significant values were detected at only 8 stations, the most pronounced values being identified in the South and South-East. The change point analysis shows an upward shift in the winter 1986/1987.

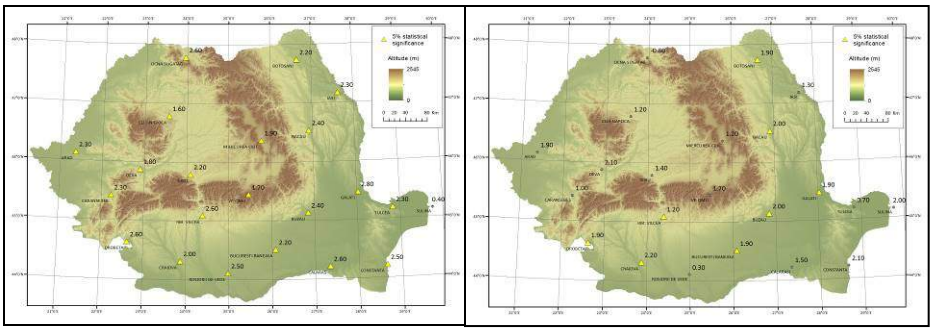


Fig. 2 - Linear trend (°C) of summer (left) and winter (right) maximum air temperature. Triangles mark the significant trends of 5%.

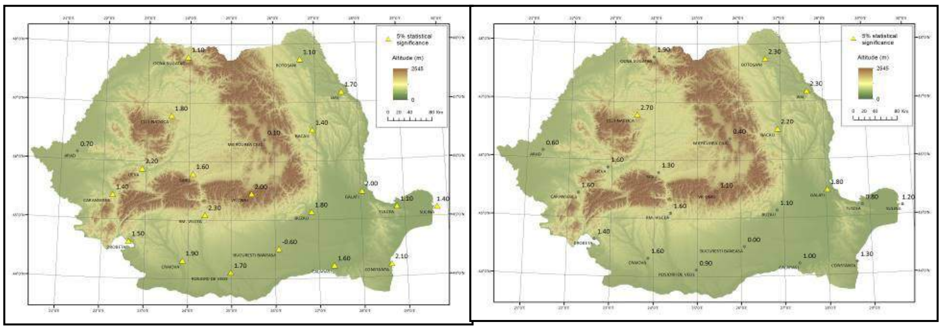
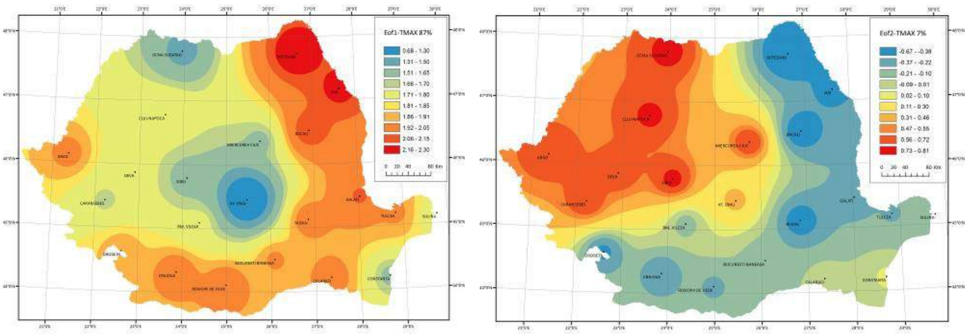


Fig. 3 - Linear trend (°C) of summer (left) and winter (right) minimum air temperature. Triangles mark the significant trends of 5%.

Concerning the analysis of the minimum air-temperature values, the results are shown in Figure 3. In summer, excepting the Arad and Miercurea Ciuc stations, statistical significant trends are detected, while in winter the signal is lower, a significant trend being detected only for Cluj Napoca, Bacau, Botosani, Iasi and Galati stations. The change point analysis revealed 1991 as a change point for the summer season at most of the stations, while the winter of 1986/1987 was pointed as an upward shift.

In order to identify the main characteristics of the spatial variability of seasonal mean maximum and minimum air temperatures in Romania, the EOF analysis was applied, by using the anomalies of summer and winter temperatures, as computed by subtracting the long-term means from the original values. In this respect, Figure 4 presents the first two EOF configurations for the **maximum air temperature** during the winter season. The first EOF configuration, with 87% explained variance, presents the same sign over the entire country, which may indicate that the temporal variability can be associated with a large-scale variability mechanism. As regards the spatial distribution of the displayed anomalies, maximum values can be found in the north and northeast part of the country. The second EOF pattern, with an explained variance of 7%, presents a dipolar structure, showing the influence of the Carpathian Mountains on the maximum air-temperature values distribution. Thus, the inner and outer Carpathian regions present opposite signs of variability.

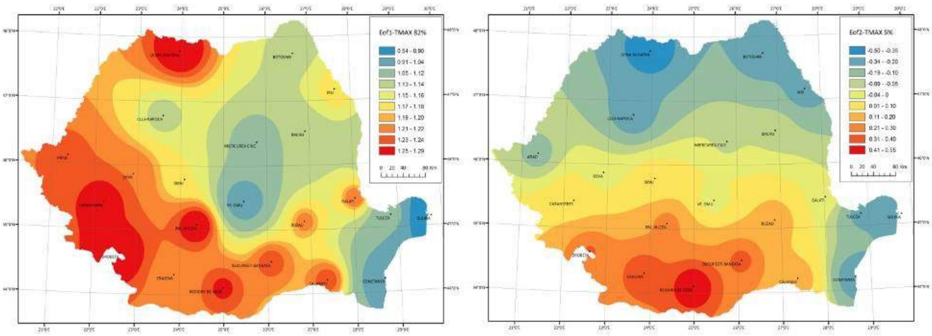


a. 87 % variance b. 7% variance

Fig. 4 - The first two EOF patterns of the mean maximum air temperature values during the winter season, in Romania

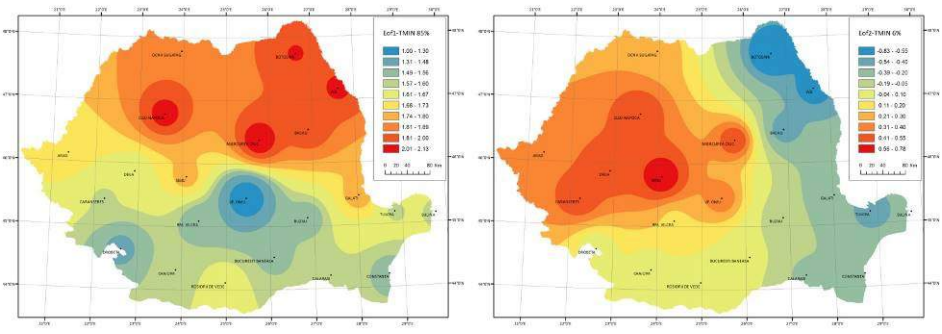
During the summer season, the first EOF analysis results for the mean maximum air temperature values are displayed in Figure 5. As in the case of the first EOF pattern for the winter season, the explained variance presents a high value (82%) in this case. The highest values (higher variability) are visible in the South and South-western parts of the country, while the lowest values are identified in the South-East.

The second EOF configuration shows a rather small explained variance (5%) and presents a dipolar structure between the inner and outer Carpathian regions, with different signs of variability.



a. 82 % variance b. 5% variance

Fig. 5 - The first two EOF patterns of the mean maximum air temperature during the summer season, in Romania

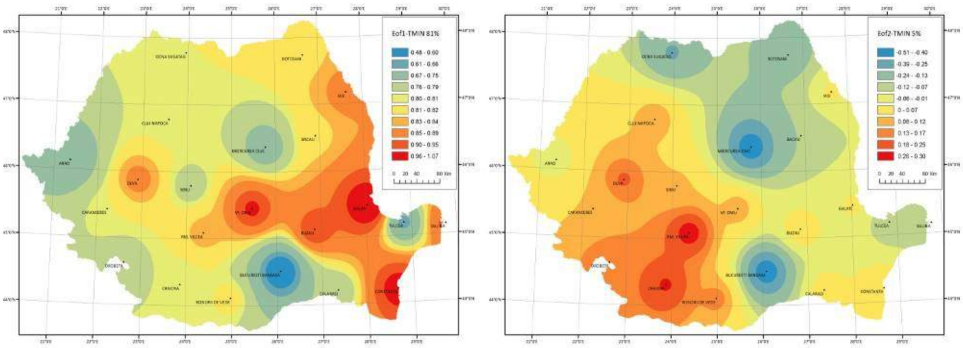


a. 85% variance. b. 6% variance

Fig. 6 - The first two EOF patterns of the mean minimum air temperature values during the winter season, in Romania

The EOF analysis performed for the **minimum air temperature** values in the winter season is presented in Figure 6. The first EOF configuration, with an explained variance of 85%, shows the same sign throughout the country, although higher anomaly values being recorded in the central Northern and North-eastern parts of the country. In case of the second EOF pattern, where the anomalies of opposite sign are shown, one may notice positive anomalies in the central and Western parts of the country, but with only 6% explained variance. Regarding the summer season, the EOF1 pattern shows an explained variance of

81% (Figure 7) and presents the most pronounced anomalies in the South-Eastern parts of Romania, whilst the EOF2 pattern (of 5% explained variance) reveals the most pronounced anomalies in the South-West. The Pettitt test applied to the PC series corresponding to the EOF analyses performed, shows shift points that are similar to those detected in the time series of each individual station.



a. 81% variance. b. 5% variance

Fig. 7 - The first two EOF patterns of the mean minimum air temperature values during the summer season, in Romania

2.2 Connection between Romanian air-temperatures and European large scale parameters

In order to find a physical mechanism that controls the climate variability in Romania, the large-scale climate variability was investigated by using the same method. Consequently, the EOF analysis was applied for both European H500 and T850 parameters in the winter and summer seasons, finally retaining the first two EOF configurations which explain more than 50% of the total variance. The first two wintertime EOF patterns over the 1961–2010 time periods for H500 parameter are presented in Figure 8. The first EOF model, which explains 34% of the total variance, exhibits a pronounced positive anomaly in central and western Europe, while the second EOF configuration (of 29% explained variance) shows a dipolar pattern, oriented from NW to the SE, composed of two structures: a structure centered in the North of the Atlantic Ocean, and another one, of opposite sign, centered in the Mediterranean Sea. For the first EOF configuration, the shift point detected was the winter of 1981/1982.

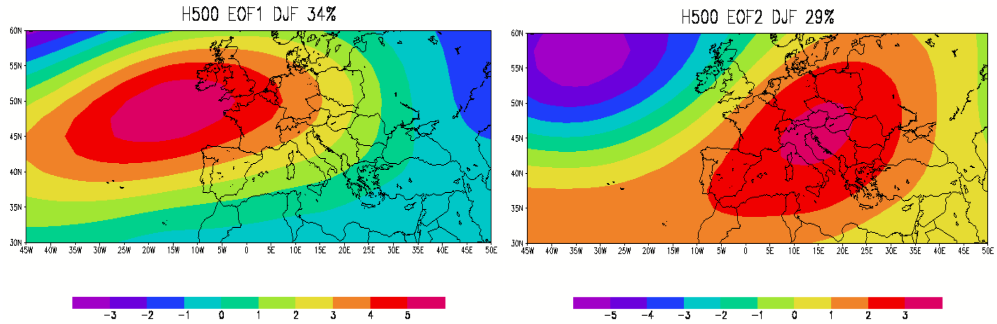


Fig. 8 - The pattern of the first and second H500 EOF configurations for the winter season

Figure 9 shows the first two EOF patterns for H500 in summer, featuring an explained variance of 31% (EOF1) and 19% (EOF2), respectively.

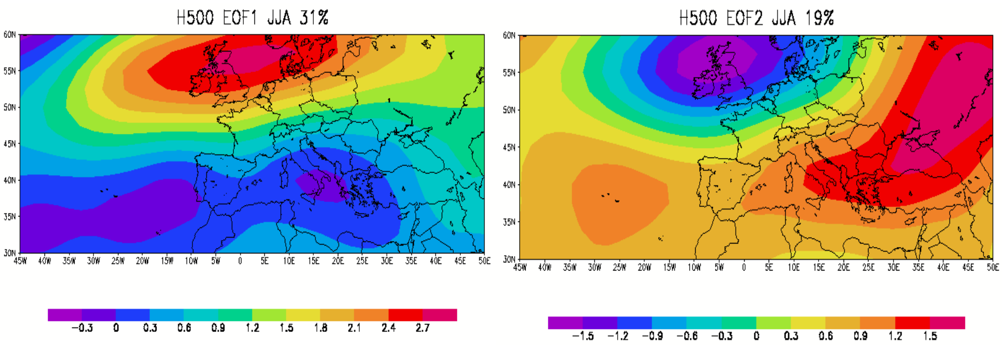


Fig. 9 - The pattern of the first and second H500 EOF configurations for the summer season

For the EOF1 structure, positive anomalies can be observed in north-western Europe, while the EOF2 configuration has a structure with three centers: a center of negative/positive anomalies centered in north-western Europe and two centers with opposite signs of anomalies (positive/negative) with the nucleus located in NE Europe and central North Atlantic. The Pettitt test revealed an upward shift of 1983 for the first EOF spatial pattern.

Regarding the EOF analysis for the T850 parameter during the winter season, the EOF1 configuration (Figure 10) shows a 47% explained variance, with pronounced anomalies in north-western Europe, while the EOF2 pattern reveals pronounced anomalies in Eastern Europe. The deviation from normal's for the Romanian territory is between 0.6-1.2 hPa, (EOF1) and 0.7-1.1 hPa, respectively (EOF2). In the summer season (Figure 11), the EOF1 configuration (of 39%

explained variance) shows the same variability in all the analyzed area, with a nucleus centered in north-eastern Europe. For Romania, there is a deviation from normal between 0.5 and 1 hPa. The EOF2 configuration (of 16% explained variance) presents a dipolar structure with the nucleus centered in north-eastern Europe and south-western Europe, respectively. The change point detected for the first EOF's are: 1989 (winter) and 1983 (summer).

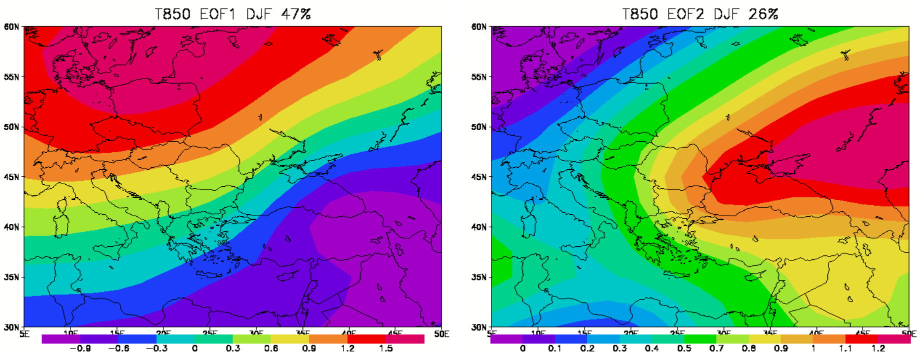


Fig. 10 - The pattern of the first (EOF1) and second (EOF2) T850 EOF configurationsfor the winter season

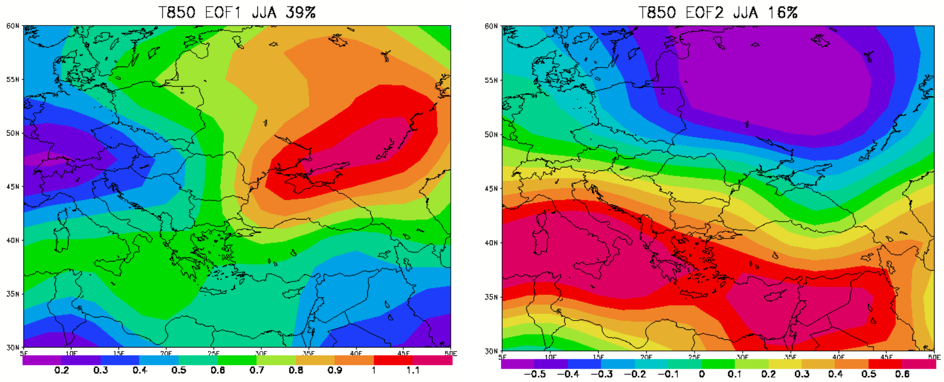


Fig. 11 - The pattern of the first (EOF1) and second (EOF2) T850 EOF configurations for the summer season

By taking into account the large explained variance of the first EOF configurations of the maximum and minimum air temperatures in Romania, below we also present the temporal series of the detected spatial variability. The changes in seasonal mean maximum and minimum temperature values in Romania can be explained by the changes in the first mode of the atmospheric circulation variability at European scale.

In this respect, Figure 12 presents the main component series of summer mean maximum temperatures in Romania, on one side, and the H500/T850 parameters in the same season, on the other side. One can notice that the positive anomalies of maximum air temperature can be associated to positive anomalies of the H500 and T850 parameters. On the other hand, the PC series of winter mean minimum temperatures in Romania and the H500/T850 time series are displayed in Figure 13. One may also notice that the influence of large scale parameters on the Romanian minimum air temperature regime is largely attenuated as compared to the summer season. As it was previously explained in various studies (Ion-Bordei, 2009, Busuioc et al., 2010), during the winter season, the temperature regime in Romania is much more influenced by the air circulation at surface level.

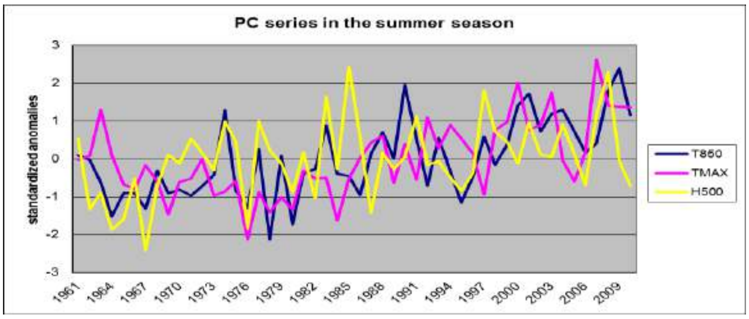


Fig. 12 - Temporal coefficients associated to the main modes of variability of H500/T850 anomalies and maximum air temperature anomalies in Romania

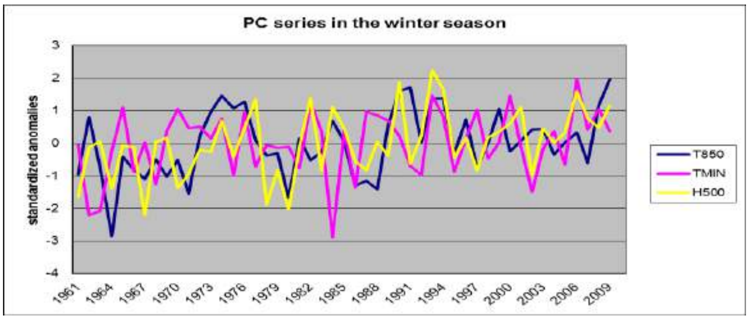


Fig. 13 - Temporal coefficients associated to the main modes of variability of H500/T850 anomalies and minimum air temperature anomalies in Romania

4. Conclusions

We may draw some interesting conclusions from this study with respect to the large scale mechanisms which control the changes in the seasonal mean maximum and minimum air-temperatures in Romania.

Primarily, the linear trend analysis performed for both maximum and minimum air-temperatures revealed positive trends both in summer and winter seasons. In the case of summer maximum temperatures, the highest values were identified in the South and South-East parts of the country. Regarding the analysis made for minimum air-temperatures in summer, a statistically significant trend was detected at most stations, while in winter, at only five stations.

The main characteristics of the spatial and temporal variability of the Romanian mean maximum and minimum air-temperatures were revealed by means of the EOF technique. The main modes of European climatic variability were also analyzed by applying the same method. Therefore, the PC series associated to the first EOF pattern of the H500 and T850 parameters and mean maximum and minimum temperature in Romania were analyzed by using the Pettitt and Mann–Kendall tests respectively, in order to detect their linear trend and shift points. The explained variance of the first EOF configurations for seasonal maximum and minimum temperature can lead us to the idea that the large scale mechanism is mainly responsible for the detected increasing trend. Also, the role of the Carpathian chain is revealed by the second EOF configuration, thus explaining the opposite variability between the inner and the outer Carpathian regions.

A significant warming trend was mostly detected in the summer season, while in winter the signal is lower. Regarding the EOF analysis performed for some European large scale parameters, in case of the geopotential height at 500 hPa, positive anomalies in both seasons were detected. Air-temperature at 850 hPa presents a much higher explained variance, with pronounced anomalies recorded above Romania. The analysis performed for the main component series of the EOF configurations also reveals the same linear trend mainly in the summer season. In other words, pronounced positive anomalies detected for maximum and minimum air temperatures in the summer season, can be associated to structures of positive anomalies for H500 and T850 parameters. In the winter season, it seems that the most pronounced influences are most probably related to other factors, like the intensification of the westerlies which is associated to the positive phase of the North Atlantic Oscillation (Busuioc et al., 2010, Dima and Stefan, 2008).

The temporal coefficients associated to the EOF technique performed for air-temperatures in Romania are in accordance with the trend analysis made for each station. The same situation is detected in the summer season but with different shift points detected (1986 for maximum temperature and 1991 for minimum temperature).

The results presented in this paper are in agreement with those presented by Tomozeiu et al., 2002, Busuioc and von Storch, 1996 and Busuioc et al., 2010, which analyzed the changes of the winter and summer precipitations in Romania and their relationship to the large scale circulation. This can lead to the idea that the large scale mechanism actually controls the temperature regime in Romania.

References

Boroneant (C.), Tomozeiu (R.), Rimbu (N.), 2000 - *EOF analysis of winter and summer precipitation in Romania*. Proceedings of the 3rd ECAC, October 16–20, 2000

Busuioc (A.), von Storch (H.), 1996 - *Changes in the winter precipitation in Romania its relation to the large scale circulation*. Tellus A 48: 538–552.

Busuioc (A.), Chen (D.), Hellström (C.), 2001 – *Temporal and spatial variability of precipitation in Sweden and its link with the large-scale atmospheric circulation.* IN: Tellus *53A*, vol.3, pp. 348-367.

Busuioc (A.), Caian (M.), Cheval (S.), Bojariu (R.), Boroneant (C.), Baciu (M.), Dumitrescu (A.), 2010 – *Variabilitatea si schimbarea climei in Romania*. 226 p. Edit. Pro Universitaria, Bucuresti.

Ion-Bordei (E.), 2009 - *Rolul lanţului alpino-carpatic în evoluţia ciclonilor mediteraneeni.* Ediţia a II-a, Edit. Printech, Bucureşti, 138 p.

Kalnay et al.,*The NCEP/NCAR 40-year reanalysis project*, Bull. Amer. Meteor. Soc., 77, 437-470, 1996.

Klein Tank (A.M.G.) et al., 2002 - *Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment.* Int. J. Climatol., 22, 1441-1453

Pettitt (A. N.), 1979 – *A nonparametric approach to the change-point problem*. IN: *Appl. Stat.*, vol. 28, pp.126-135.

Sneyers (R.), 1975. Sur l’analyse statistique des series d’observations. Note technique OMM, 143; 189 pp.

Tomozeiu, (R.), Busuioc (A.), Marletto (V.), Zinoni (F.), and Cacciamani (C.), (2000) - *Detection of changes in the summer precipitation time series of the region Emilia-Romagna, Italy,* J. Geophys. Res., 200, 193–200.

Tomozeiu, (R.), Busuioc (A.), Stefan (S.), 2002 – *Changes in seasonal mean maximum air temperature in Romania and their connection with large-scale circulation*, International Journal of Climatology 22:1181-1196.

von Storch (H.), 1995 - Spatial patterns. EOFs and CCA. Analysis of Climate Variability. Application of Statistical Techniques, Springer Verlag: 227–258.

Wilks (SD.), 1995 - *Statistical Methods in the Atmospheric Sciences*. Int.Geophysics Series, vol. 59. Academic Press: 467 pp.