Quaternary International 415 (2016) 336–343

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Altitudinal changes of summer air temperature trends in the Romanian Carpathians based on serially correlated models

Adina-Eliza Croitoru [a], Dorin Drignei [b, *], Doina Cristina Burada [c], Carmen Sofia Dragotă [d], Zoltan Imecs [e]

[a] Department of Physical and Technical Geography, Faculty of Geography, Babes-Bolyai University, 5-7, Clinicilor Street, 400006 Cluj-Napoca, Cluj, Romania
[b] Department of Mathematics and Statistics, Oakland University, Rochester, MI 48309, USA
[c] Oltenia Regional Meteorological Center, National Meteorological Administration, 3A, Brestei Street, Craiova, Dolj, Romania
[d] Institute of Geography, Romanian Academy, 023993 Bucharest, Romania
[e] Department of Hungarian Geography, Faculty of Geography, Babes-Bolyai University, 5-7, Clinicilor Street, 400006 Cluj-Napoca, Cluj, Romania

A R T I C L E I N F O

Article history:
Available online 28 June 2015

Keywords:
Climate
Temperature
Altitude
Change-point
Trend

A B S T R A C T

This paper investigates the relationship between altitude and summer temperature trends in the Romanian Carpathian Mountains. We considered 20 weather stations and three types of topography: summit, slope and depression. We used a change-point regression model with serially correlated errors and compared it with a mainstream literature change-point model with independent errors. For both models, we identified decreasing trends before the change-point and increasing trends afterwards for most summer temperature series. The model with serially correlated errors gives change-points and trends that are more variable for lower altitude and more similar with each other at higher altitudes. One of the possible factors explaining this behavior is that temperatures from some weather stations in depression areas may be influenced by human settlings and industrial activities, and this influence would dissipate with altitude. On the other hand, the model with independent errors shows no pattern in the variability of change points or trends. The cluster analysis also reveals that weather stations are best grouped by altitude.

1. Introduction

Detection of changes in mean air temperature is one of the important topics of climate research discussed over the past few decades. The air temperature exhibits cooling and warming trends at a global scale. An accurate characterization of these changes provides scientists and policy makers with the tools necessary for important decisions.

The higher mountain regions are the most exposed to large-scale climatic changes (Diaz and Bradley, 1997). These have important consequences in different socio-economic and environment fields: tourism economy, health of the human population living there, ecosystems, mountainous glaciers retreat, and water resources (Mountain Agenda, 1998; Beniston, 2003; Walther et al., 2005; Boisvenue and Running, 2006; EEA, 2008; Micu, 2009, 2012; Toreti et al., 2010; Croitoru et al., 2014). For example, in mountainous areas lower than 2500 m (as it is the case of Romanian Carpathians) the winter sport tourism may be negatively affected, but the favorable conditions for summer tourism may increase.

There are a few papers discussing climate changes in the Romanian Carpathians (Hauer et al., 2003; Micu, 2009; Busuioc et al., 2010) or the entire Carpathian Region (Bartholy and Pongracz, 2007; Birsan et al., 2014; Cheval et al., 2014), but most focused on single linear trend detection. We argue that change point analysis and trends detection before and after the change points are important because the single linear trends may underestimate the present warming through diminished slopes.

This paper is one in a recent series dedicated to changes in seasonal temperature in the Romanian Carpathians. Croitoru et al. (2012a) investigated changes in summer temperature trends at a limited number of summit stations, whereas Croitoru et al. (2014) showed that statistically significant changes in temperature trends exist for winter series. In this paper, we investigate changes in summer temperature trends at a larger number of weather

* Corresponding author.
E-mail addresses: croitoru@geografie.ubbcluj.ro, adina04@yahoo.com (A.-E. Croitoru), drignei@oakland.edu (D. Drignei), burada_cristina@yahoo.com (D.C. Burada), dragotacarmen@yahoo.co.uk (C.S. Dragotă), imecs@geografie.ubbcluj.ro (Z. Imecs).

http://dx.doi.org/10.1016/j.quaint.2015.05.075
1040-6182/

stations, representative for all altitudes and topography types (summit, mountain slope, and depression). We used a change-point regression model with serially correlated errors and compared its results with a mainstream literature change-point model with independent errors. Our findings reveal that the change-points and trends exhibit larger variability at lower altitudes than at higher altitudes. One of the possible explanations is that a low-altitude weather station may be located in a depression area influenced by human activities or not, and this influence would dissipate with higher altitude. This phenomenon is not observed in the results of the model with independent errors.

2. Materials and methods

2.1. Study area

The Romanian Carpathians cover about one third of Romania's territory (over 70,000 square kilometers), located in central and western parts of the country (Fig. 1). They interfere with the circulation of air masses, influencing the climate. During the summer they may be a partial obstacle for the hot and dry/wet southern air masses, originating in the Mediterranean Sea, in North Africa, or in Arabian Peninsula moving toward northern and northwestern regions. The Romanian Carpathians may also interfere with the wet western air masses originating in the Atlantic, moving more slowly toward Eastern and South-Eastern Europe.

2.2. Data

Summer air temperature data series calculated for 20 weather stations located in the Carpathian Mountains (Table 1) were used in this study. They are part of the Romanian national network of weather stations. We divided the weather stations by their location into three classes, based on topography type: summit, mountain slope, and depression. The weather stations chosen are representative for all three branches of the Romanian Carpathians: Eastern Carpathians (locations 1–4, 9 and 15–16), Southern Carpathians (5–6, 10–12, 14 and 17–18) and Western Carpathians (7–8, 13, and 19–20). Geographical coordinates are shown in Table 1. The absolute altitude above the Black Sea level of these stations ranges approximately from 560 m to more than 2500 m. While temperature data are available at each month of the year, in this study we have calculated and have focused on the summer season temperature, as representative for the warm period.

The data sets have been obtained from the Romanian National Meteorological Administration database and the earliest values recorded in that database are from January 1961. At that time, the national meteorological network was greatly reorganized and the measurements methodology changed considerably: until that moment, the daily mean temperature (background of the monthly mean temperature values used) was calculated from three values (measured at 8.00 h, 14.00 h and 20.00 h, local time). Nighttime measurements were not done before 1961. In January 1961, the 24/24 h measurements program began, and the mean daily temperature from that point on have been calculated using 4 values (at 00.00 h, 6.00 h, 12.00 h, and 18.00 h, UTC). In addition, most of the weather stations were set up in the late 1950s or in January 1961 (www.meteoromania.ro) and a few even later, in the early 1960s (Table 1). In this study, we decided to analyze temperature data recorded after January 1961 as they are considered more reliable. Most studies focusing on climate change detection conducted for the Romanian territory used only the datasets after January 1961 (e.g. Busuioc et al., 2010; Croitoru et al., 2012, 2014; Micu, 2012; Birsan et al., 2014; Cheval et al., 2014).

2.3. Methods

2.3.1. Statistical models for change-point analysis

Lund and Reeves (2002) and Toreti et al. (2010), among others, used the following statistical model for change-point analysis: $Y_t = \alpha_0 + \alpha_1 t + z_t$ for $1 \le t \le c$ and $Y_t = \beta_0 + \beta_1 t + z_t$ for $c < t \le n$. In these equations Y_t is the temperature at year t, which changes its

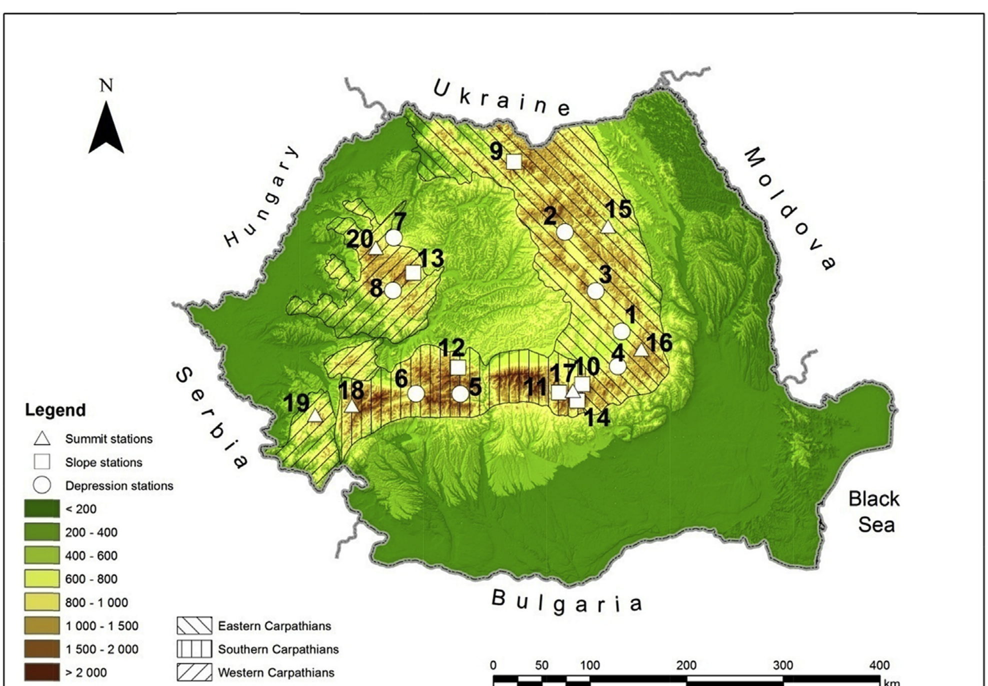

Fig. 1. Weather stations considered in this study.

Table 1
Location and main features of the weather stations.

Weather station	Latitude (°N)	Longitude (°E)	Height (m)	Period	Mean summer temperature (°C)	Carpathian branch
Depression stations						
Tg. Secuiesc (1)	45.99278	26.11500	569.0	1961–2007	17.0	Eastern
Toplita (2)	46.92639	25.36000	688.2	1961–2007	15.7	Eastern
MiercureaCiuc (3)	46.37139	25.77250	662.2	1961–2007	15.8	Eastern
IntorsuraBuzaului (4)	45.66833	26.05667	708.3	1961–2007	15.7	Eastern
Voineasa (5)	45.41111	23.96694	575.0	1961–2007	16.5	Southern
Petrosani (6)	45.40639	23.37667	599.0	1961–2007	16.7	Southern
Huedin (7)	46.85722	23.03250	561.3	1962–2007	16.7	Western
Campeni (8)	46.36389	23.04028	592.2	1963–2007	16.6	Western
Mountain slope stations						
Iezer (9)	47.58330	24.66670	1770.0	1961–2007	9.5	Eastern
Predeal (10)	45.50639	25.58361	1091.5	1961–2007	13.9	Southern
Fundata (11)	45.43139	25.27167	1383.0	1961–2007	13.1	Southern
Paltinis (12)	45.65722	23.93250	1454.3	1961–2007	12.6	Southern
Baisoara (13)	46.53556	23.31028	1356.0	1961–2007	13.2	Western
Sinaia-1500 (14)	45.35500	25.51417	1511.2	1961–2007	12.1	Southern
Summit stations						
Ceahlau-Toaca (15)	46.97750	25.95000	1897.0	1964–2007	8.9	Eastern
Lacauti (16)	45.82389	26.37556	1785.0	1961–2007	9.7	Eastern
Vf. Omu (17)	45.44583	25.45667	2504.0	1961–2007	5.0	Southern
Tarcu (18)	45.28111	22.53278	2180.0	1961–2007	7.2	Southern
Semenic (19)	45.18139	22.05583	1433.2	1961–2007	12.3	Western
Vladeasa-1800 (20)	46.75917	22.79417	1836.0	1961–2007	9.0	Western

trend at year c. The errors z_t are independent of mean zero and variance σ^2. In a compact, matrix form this model can be expressed as $\mathbf{Y} = \mathbf{X}\gamma + \mathbf{z}$, with $\mathbf{Y}$ the vector of temperatures, $\mathbf{z}$ the vector of errors and parameters $\gamma = (\alpha_0, \beta_0, \alpha_1, \beta_1)$. The following four vectors constitute the columns of regression matrix $\mathbf{X}$: the first two columns are 0 (before change), 1 (after change), and 1 (before change), 0 (after change) respectively; the last two columns are 0 (before change), t (after change), and t (before change), 0 (after change) respectively. The errors of this statistical model are assumed independent even though statistical time-dependence may exist, which may result in large-variance estimates of regression coefficients γ. Consequently, this may lead to classify trends as insignificant when actually they are significant, so in general this model is expected to report fewer statistically significant trends. A model with correct standard errors for trends will include serial correlation (e.g. ARMA processes, as in Brockwell and Davis, 2002). We used the R function 'arima' (R Development Core Team, 2009) to carry out the analysis that includes temporal (or serial) correlation. The orders of the ARMA models and the change points are obtained by minimizing the Akaike Information Criterion (AIC). Specifically, for each time series, we consider every time point as a potential change-point and compute the AIC measure. The actual change-point is the time point that makes the AIC measure as small as possible. Change-point models with correlated errors are still rarely used, although statistical models with space and/or time dependent errors are fairly common (e.g. Drignei et al., 2008; Drignei, 2009; among many others).

2.3.2. Hierarchical cluster analysis

Hierarchical cluster analysis (e.g. James et al., 2014) for annual temperature data series was also carried out to identify groups of similar stations. Thus, agglomerative (or bottom-up) hierarchical clustering based on Euclidean distance was calculated. Each sample is initially treated as its own cluster, and the method proceeds stepwise by systematically merging similar clusters. This procedure attempts to identify relatively homogeneous groups of weather stations based on temperature characteristics. Spatial cluster analysis using this method is very helpful in determining regional features, and it was successfully used for studying the temperature spatial distribution (Rebetez and Reinhard, 2008). To construct the vertical hierarchical tree plot, the R software was employed.

3. Results and discussion

3.1. Summer change-point analysis based on the serially correlated errors model

We have implemented the change-point model with ARMA correlated errors for the summer temperatures. In general, we found trends decreasing before the change point and increasing afterwards (Table 2, Figs. 2 and 3). The decreasing trends before the early 1980s as well as the increasing trends afterwards are strongly statistically significant for most locations (18 out of 20 weather stations in both cases). The trend is considered statistically insignificant if zero is within the margin of error (i.e. 1.96 standard deviations) from its estimated value. The boldface entries in Table 2 correspond to statistically significant trends. The statistical significance is strong if the trend estimate exceeds its margin of error by an order of magnitude, and mild otherwise.

Our findings are in line with those revealed for the entire European continent, where a cooling was detected until 1977, followed by 'an exceptionally strong, unprecedented warming' (Luterbacher et al., 2004), but the change points in the Romanian Carpathians occurred a few years later, especially at higher altitude. The change point in summer at higher altitudes occurred almost ten years later compared to the winter temperature change point (early 1970s) (Croitoru et al., 2014).

Considering the three topography classes, the steepest decrease before the change point was associated with the summit weather stations (as average value of all weather stations in this category), while the steepest increase after the change point was associated with the mountain slope stations followed closely by summit stations. The estimated regression slope was larger in absolute value before the change point (−0.310 … −1.013°C/decade) than afterwards (0.115 … 0.863°C/decade) (Table 3). The average positive regression slope after the change point is similar to the one detected for the Northern Italy, of 0.64°C(±0.193)/decade (Toreti

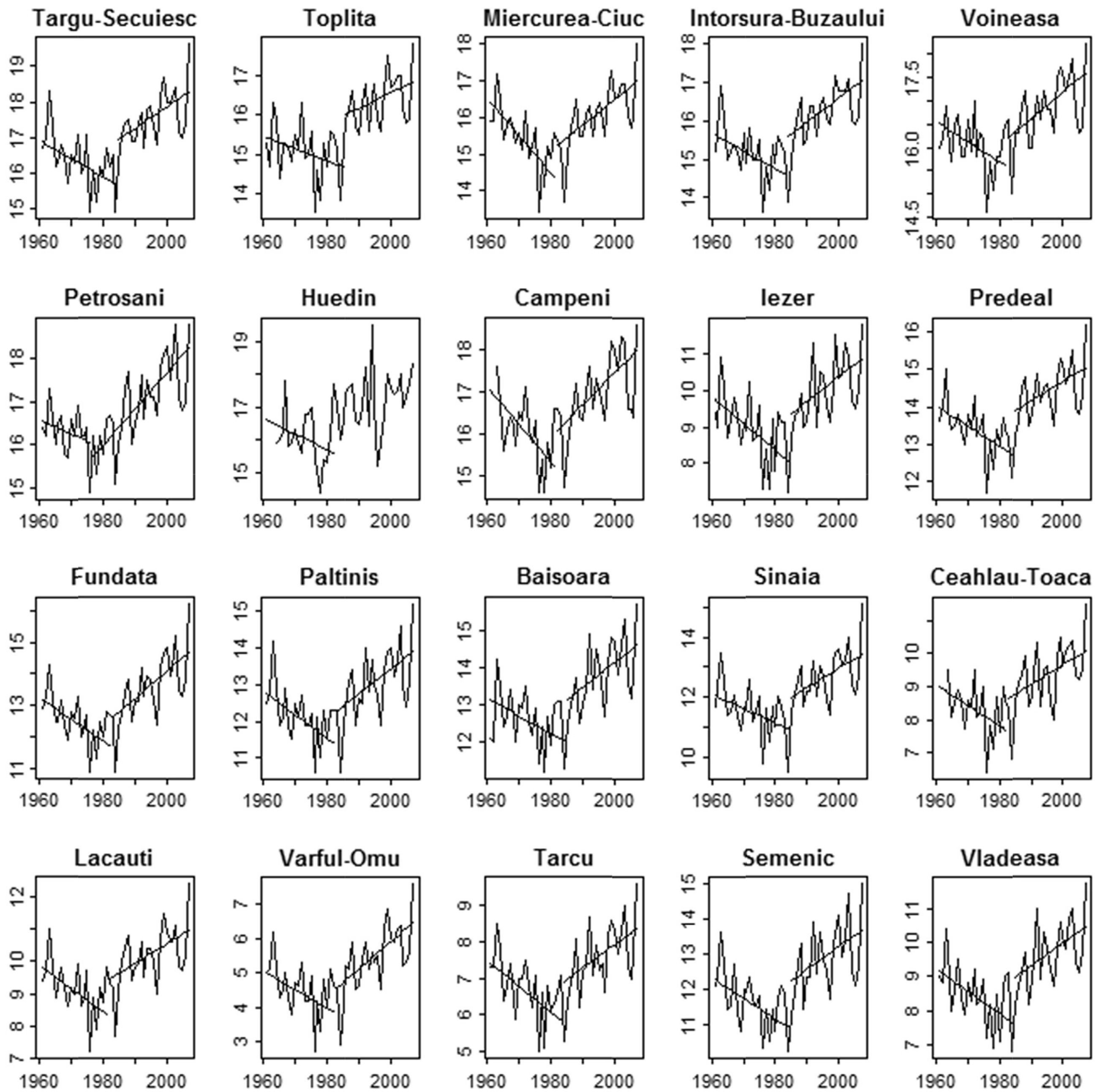

Fig. 2. Summer temperature trends over the period 1961–2007, for the change-point model with serially correlated errors (when the trend line is missing the slope was found statistically insignificant).

et al., 2010), but it is lower than the regression slope reported for summer in Europe after 1977 by Luterbacher et al. (2004), at a rate of 0.7°C (+/−0.2°C)/decade.

Compared to other European regions, the change points were found between 1981 and 1985 in the Romanian Carpathians for most stations, while for Northern Italy (including the Alps region) the common change point was 1981 (Toreti et al., 2010). A major methodological difference between our work and Toreti et al. (2010) is the inclusion of error correlations, which is reflected in the statistical significance of temperature trends. (Note that in the current paper we do not plot the regression lines of statistically insignificant slopes).

3.2. Summer change-point analysis when the model errors are independent

We have also implemented the change-point model with independent errors, and the results are presented in Table 2, Figs. 3 and 4. We noticed a larger variability among the change-points (1975–1985) regardless of altitude, although such variability is not justified climatologically due to the proximity of these weather stations relative to the European continent. This advocates for the choice of the model with serially correlated errors, which detects change-points much closer to each other, especially at higher altitude. According to the model with independent errors, almost half

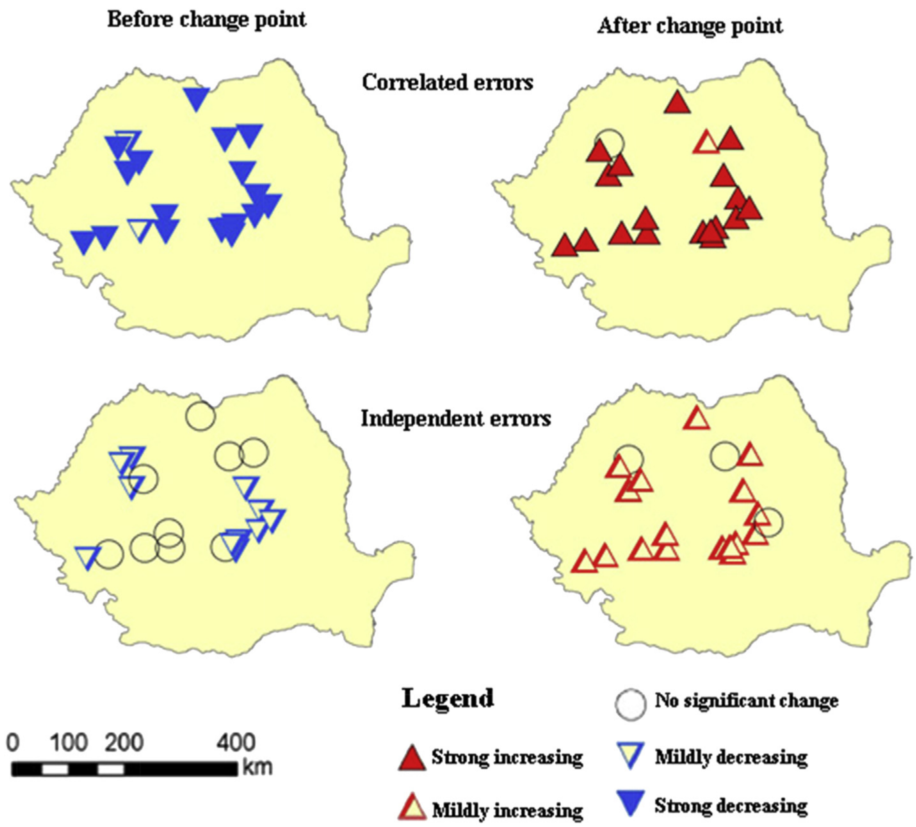

Fig. 3. Spatial distribution of the summer temperature trend in the Romanian Carpathians.

of the locations considered did not register significant changes before the change point, while 85% of them experienced mild increase afterwards. None of the weather stations, when analysed using the model with independent errors, recorded strongly significant increasing or decreasing trend of the summer season mean temperature.

3.3. Relationship between altitude and summer temperature trends

Fig. 5 shows plots of change-points and slopes of the regression models versus altitude, both for correlated and independent errors. When the errors are correlated, one can see higher variability of these values at lower altitude. While many factors may be

Table 2
Change points and slopes for summer data series.

Weather station	Correlated errors			Independent errors		
	C.p.Year	Slope before c.p.[a]	Slope after c.p.[a]	C.p.Year	Slope before c.p.[a]	Slope after c.p.[a]
Targu-Secuiesc	1984	**−0.500 (±0.049)**	**0.601 (±0.020)**	1985	**−0.517 (±0.347)**	**0.520 (±0.421)**
Toplita	1985	**−0.310 (±0.048)**	**0.397 (±0.112)**	1985	−0.267 (±0.349)	0.390 (±0.423)
Miercurea-Ciuc	1981	**−1.013 (±0.029)**	**0.694 (±0.002)**	1975	**−0.725 (±0.706)**	**0.801 (±0.226)**
Intorsura-Buzaului	1983	**−0.469 (±0.049)**	**0.635 (±0.012)**	1985	**−0.410 (±0.319)**	**0.477 (±0.386)**
Voineasa	1982	**−0.431 (±0.063)**	**0.572 (±0.015)**	1975	−0.043 (±0.641)	**0.644 (±0.205)**
Petrosani	1976	**−0.334 (±0.102)**	**0.833 (±0.003)**	1975	−0.161 (±0.690)	**0.776 (±0.221)**
Huedin	1982	**−0.482 (±0.232)**	0.115 (±0.199)	1981	**−0.591 (±0.580)**	0.253 (±0.421)
Campeni	1981	**−0.891 (±0.084)**	**0.768 (±0.007)**	1980	**−0.933 (±0.515)**	**0.625 (±0.328)**
Iezer	1984	**−0.737 (±0.050)**	**0.677 (±0.036)**	1975	−0.443 (±0.896)	**0.932 (±0.287)**
Predeal	1984	**−0.536 (±0.035)**	**0.516 (±0.010)**	1985	**−0.486 (±0.332)**	**0.452 (±0.402)**
Fundata	1982	**−0.684 (±0.045)**	**0.863 (±0.009)**	1975	−0.654 (±0.805)	**0.983 (±0.258)**
Paltinis	1982	**−0.640 (±0.050)**	**0.673 (±0.009)**	1975	−0.707 (±0.827)	**0.810 (±0.265)**
Baisoara	1984	**−0.461 (±0.049)**	**0.674 (±0.029)**	1975	−0.036 (±0.851)	**0.890 (±0.273)**
Sinaia	1984	**−0.489 (±0.047)**	**0.648 (±0.017)**	1984	**−0.624 (±0.432)**	**0.673 (±0.461)**
Ceahlau-Toaca	1981	**−0.829 (±0.084)**	**0.613 (±0.006)**	1975	−0.128 (±1.244)	**0.874 (±0.286)**
Lacauti	1981	**−0.719 (±0.053)**	**0.609 (±0.008)**	1985	**−0.453 (±0.391)**	0.411 (±0.473)
Varful-Omu	1982	**−0.530 (±0.030)**	**0.813 (±0.002)**	1985	**−0.503 (±0.370)**	**0.610 (±0.450)**
Tarcu	1983	**−0.722 (±0.008)**	**0.619 (±0.002)**	1975	−0.625 (±0.848)	**0.846 (±0.272)**
Semenic	1984	**−0.589 (±0.041)**	**0.655 (±0.015)**	1985	**−0.572 (±0.419)**	**0.597 (±0.508)**
Vladeasa	1984	**−0.659 (±0.082)**	**0.685 (±0.010)**	1980	**−0.951 (±0.584)**	**0.833 (±0.372)**

[a] Boldface indicates statistical significance.

Table 3
Summer temperature slopes based on altitudinal classes (correlated errors).

Station types	Before change point			After change point		
	Average slope	Maximum slope	Minimum slope	Average slope	Maximum slope	Minimum slope
General	−0.605	−0.310	−1.013	0.633	0.863	0.115
Depression weather stations	−0.554	−0.310	−1.013	0.577	0.833	0.115
Mountain slope stations	−0.591	−0.461	−0.737	0.675	0.863	0.516
Summit stations	−0.675	−0.530	−0.829	0.666	0.813	0.609

responsible for this variability, a possible explanation is that depression stations are located in areas with or without intense human activities, and this influence decreases as the altitude increases. This is not observed in the results of the model with independent errors.

We have also performed hierarchical cluster analysis using the summer temperature series. It reveals an association between altitude and summer temperatures. Specifically, we identified four main groups, as one can see in Fig. 6:

1. A high-elevation group, including four weather stations, located especially in Eastern and Western Carpathians with altitude between 1700 and 2000 m.
2. The second group gathers the two stations located over 2200 m.

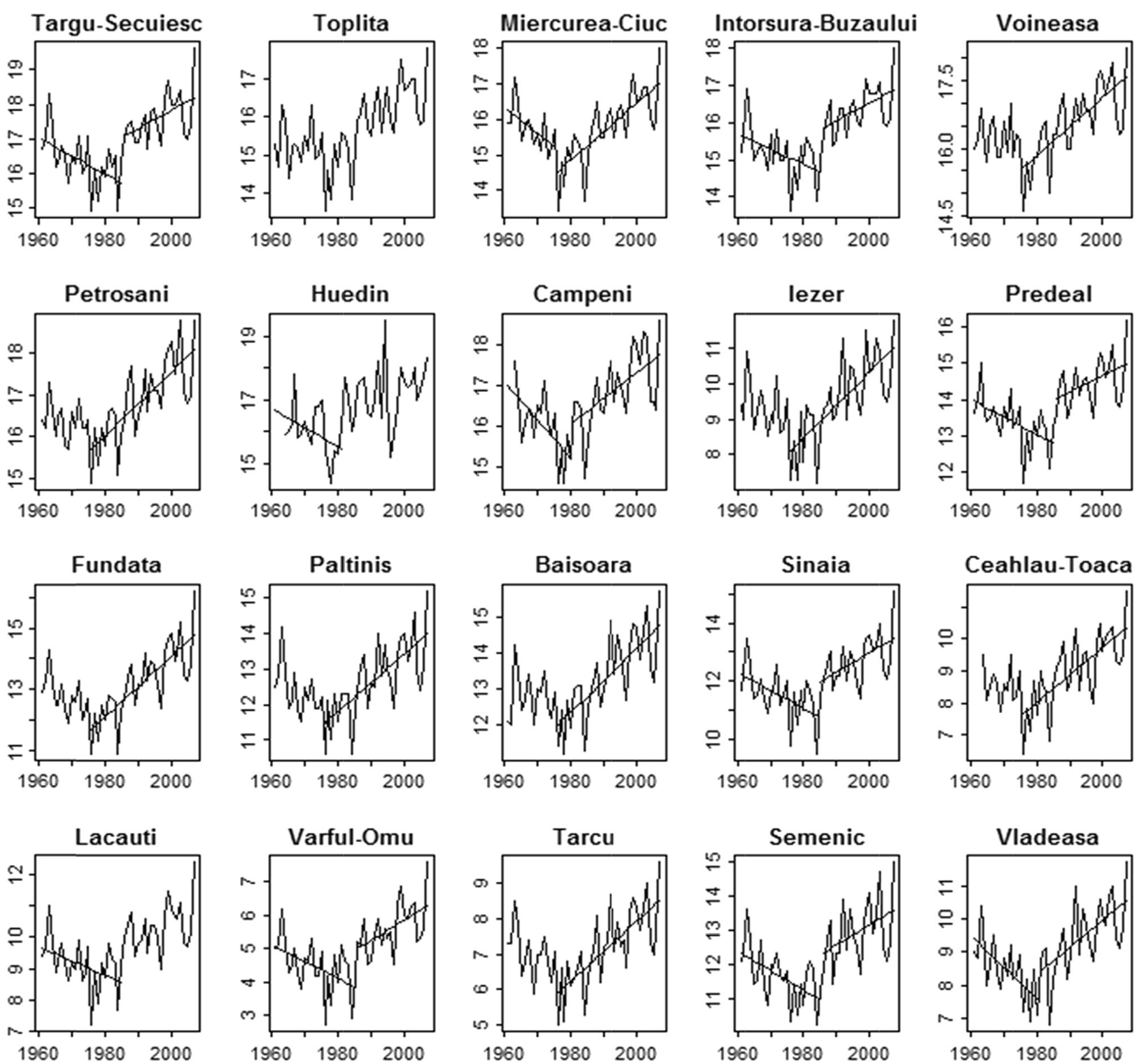

Fig. 4. Summer temperature trends over the period 1961–2007, for the change-point model with independent errors (when the trend line is missing the slope was found statistically insignificant).

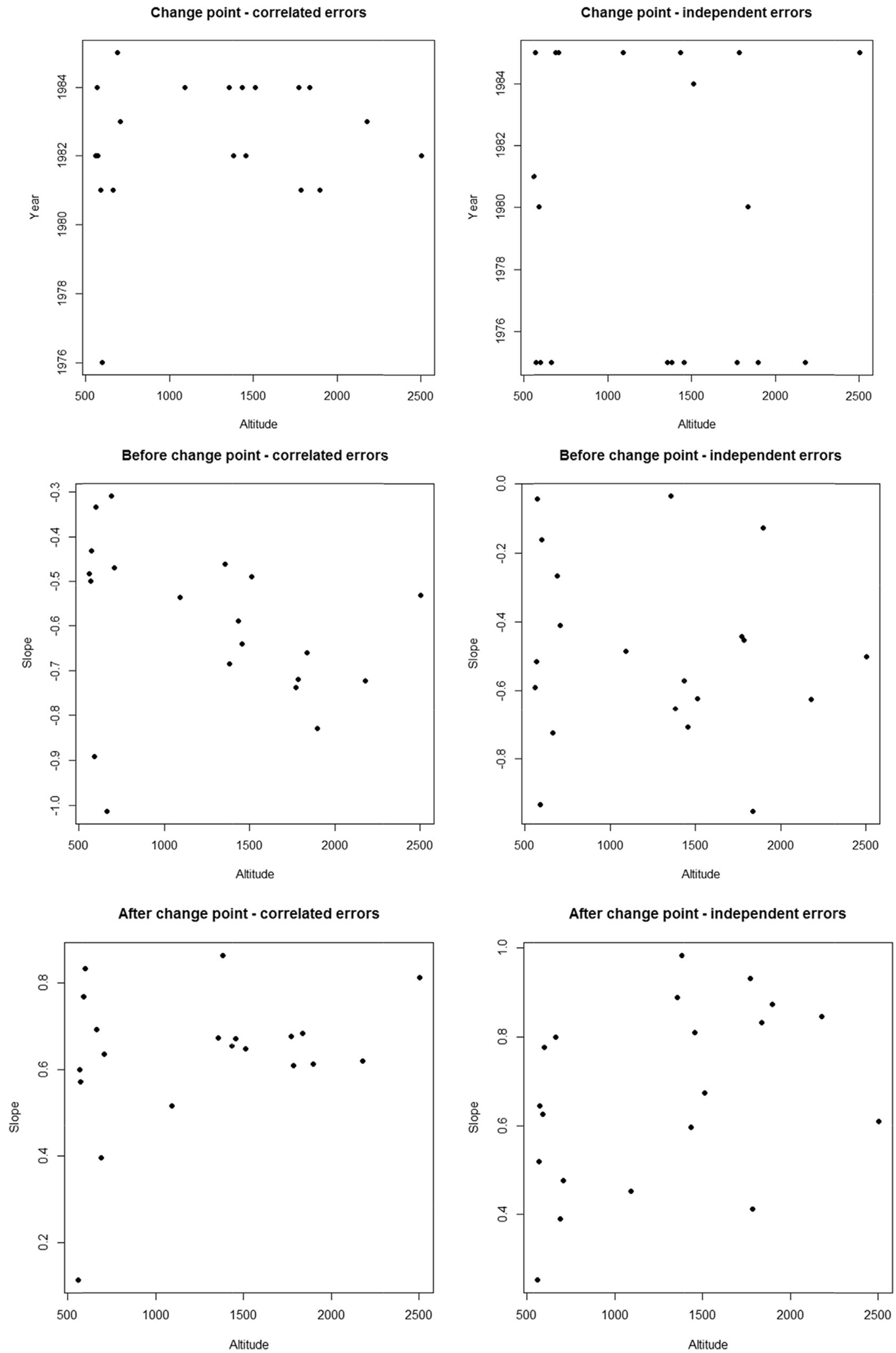

Fig. 5. Change points and regression slopes versus altitude, for models with correlated or independent errors.

3. The third group is formed by the weather stations located in depression with altitude lower than 1000 m.
4. The mountain-slope weather stations, with altitude of 1000–1500 m form the fourth group.

Generally, the groups are formed based on three types of topography, but there are two exceptions: the Iezer station (location 7), which establishes a better connection to the first group because of its altitude, while the Semenic weather station (location

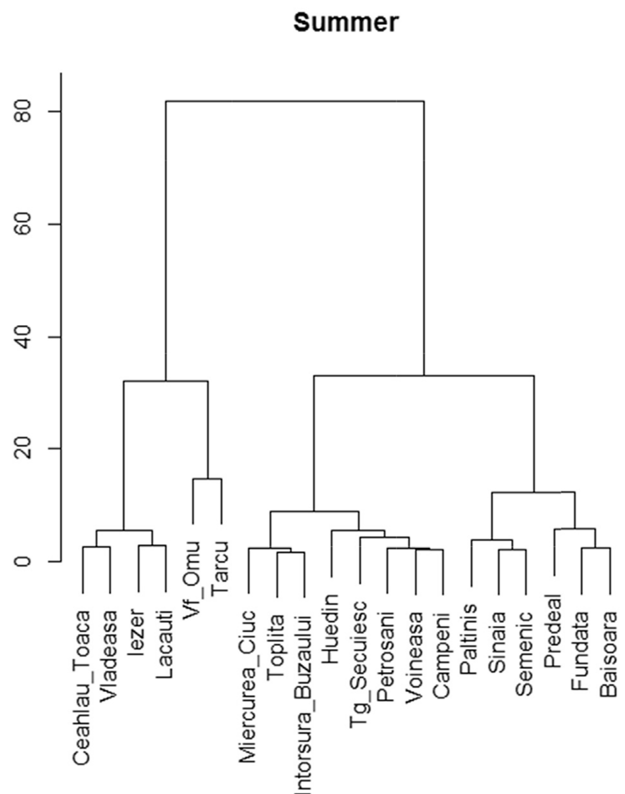

Fig. 6. Hierarchical cluster analysis.

19), which is a summit station, is more closely connected to the mountain-slope weather station group. Altitude is an important factor clustering the weather stations.

4. Conclusions

In this paper, we discussed a detailed analysis of the changes detected in summer temperature series in the Romanian Carpathians. The seasonal temperature series have been constructed from the monthly values of June, July and August.

Climatic changes are more 'visible' and homogenous with increasing altitude. The serially correlated errors model exhibits a strong decreasing before the change point and a strong increasing afterwards for the most weather stations considered while the independent errors model revealed only mildly decreasing and mildly increasing trends before and respectively after the change point for most locations. Moreover, based on the latter model, a larger variability among the change-points (1975–1985) regardless of altitude was found, which may not be explained by local factors, considering the proximity of the locations under study.

Based on the model with serially correlated errors, the summer temperature change-points as well as the regression slopes before and after the change-point are more variable at lower altitudes. This variability decreases with altitude. While this behavior may be due to many factors, such as general climatic features of the mountainous depressions, a reasonable explanation is the human presence and activities in some of the areas of lower altitude. More precisely, it consists of continuously increasing population and settlements in some lower areas, especially in the 1970s and 1980s, as well as an increase in industrial activities. The development of cities in the mountain regions was not uniform and simultaneous, and this situation led to variability in the intensity of temperature change. Although intuitive, such a phenomenon is not observed in the results from the model with independent errors. The hierarchical cluster analysis also revealed that altitude is an important factor grouping the weather stations based on summer temperature series.

Acknowledgements

The authors acknowledge the National Meteorological Administration for freely providing summer monthly temperature data. This paper was developed under the framework of research theme *Climate changes and their socio-economic and environmental impact in Romania* implemented by the Climate Research Group at Babes-Bolyai University, Faculty of Geography. We also thank the two anonymous reviewers for their suggestions, which helped us improve the quality of this paper.

References

Bartholy, J., Pongracz, R., 2007. Regional analysis of extreme temperature and precipitation indices for the Carpathian Basin from 1946 to 2001. Global and Planetary Change 57, 83–95.
Beniston, M., 2003. Climatic change in mountain regions: a review of possible impacts. Climatic Change 59, 5–31.
Birsan, M.V., Dumitrescu, A., Micu, D.M., Cheval, S., 2014. Changes in annual temperature extremes in the Carpathians since AD 1961. Natural Hazards 74, 1899–1910.
Boisvenue, C., Running, S.W., 2006. Impacts of climate change on natural forest productivity — evidence since the middle of the 20th century. Global Change Biology 12, 862–882.
Brockwell, P.J., Davis, R.A., 2002. Introduction to Time Series and Forecasting, second ed. Springer.
(in Romanian). In: Busuioc, A., Caian, M., Cheval, S., Bojariu, R., Boroneant, C., Baciu, M., Dumitrescu, A. (Eds.), 2010. Variabilitateasischimbareaclimei in Romania. Pro Universitaria, Bucharest.
Cheval, S., Birsan, M.V., Dumitrescu, A., 2014. Climate variability in the Carpathian Mountains Region over 1961–2010. Global and Planetary Change 118, 85–96.
Croitoru, A.E., Drignei, D., Holobaca, I.H., Dragota, C.S., 2012. Change-point analysis for serially-correlated summit temperatures in the Romanian Carpathians. Theoretical and Applied Climatology 108, 9–18.
Croitoru, A.E., Drignei, D., Dragotă, C.S., Imecs, Z., Burada, D.C., 2014. Sharper detection of winter temperature changes in the Romanian higher-elevations. Global and Planetary Change 122, 122–129.
Diaz, H.F., Bradley, R.S., 1997. Temperature variations during the last century at high elevation sites. Climatic Change 36, 253–279.
Drignei, D., 2009. A kriging approach to the analysis of climate model experiments. Journal of Agricultural Biological and Environmental Statistic 14, 99–114.
Drignei, D., Forest, C.E., Nychka, D., 2008. Parameter estimation for computationally intensive nonlinear regression with an application to climate modelling. Annals of Applied Statistics 2, 1217–1230.
EEA, 2008. Impacts of Europe's Changing Climate — 2008 Indicator Based Assessment. EEA. Report 4.
Hauer, E., Croitoru, A.E., Pavai, C., 2003. Tendintele si anomaliile extremelor termice si pluviometrice in regiunea de nord-vest a Romaniei. In: Sorocovschi, V. (Ed.), Riscuri si catastrofe. Casa Cartii de Stiinta, Cluj-Napoca, pp. 85–95.
James, G., Witten, D., Hastie, T., Tibshirani, R., 2014. An Introduction to Statistical Learning with Applications in R. Springer.
Lund, R., Reeves, J., 2002. Detection of undocumented changepoints: a revision of the two phase regression model. Journal of Climate 15, 2547–2554.
Luterbacher, J., Dietrich, D., Xoplaki, E., Grosjean, M., Wanner, H., 2004. European seasonal and annual temperature variability, trends, and extremes since 1500. Science 303, 1499–1503.
Micu, D., 2009. Snow pack in the Romanian Carpathians under changing climatic conditions. Meteorology and Atmospheric Physics 105, 1–16.
Micu, D., 2012. Cold waves in the Romanian Carpathians, an indicator of negative temperature extremes. In: Proceedings of the Conference Air and Water — Components of the Environment, 4Cluj University Press, pp. 97–104.
Mountain Agenda, 1998. Mountains of the World: Waters Towers for the 21st Century. Prepared for the United Nations Commission on Sustainable Development. Institute of Geography, University of Berne (Centre for Development and Environment and Group for Hydrology) and Swiss Agency for Development and Cooperation Paul Haupt, Bern, Switzerland.
R Development Core Team, 2009. R: a Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL. http://www.R-project.org (accessed 11.22.13.).
Rebetez, M., Reinhard, M., 2008. Monthly air temperature trends in Switzerland 1901–2000 and 1975–2004. Theoretical and Applied Climatology 91, 27–34.
Toreti, A., Desiato, F., Fioravanti, G., Perconti, W., 2010. Seasonal temperatures over Italy and their relationship with low-frequency atmospheric circulation patterns. Climatic Change 99, 211–227.
Walther, G.R., Beissner, S., Burga, C.A., 2005. Trends in upward shift of alpine plants. Journal of Vegetation Science 16, 541–548. www.meteoromania.ro (accessed 28.04.15.).