Annual and seasonal air temperature and precipitation trends in the North of the Apuseni Mountains

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Abstract. This paper is focused on analyzing trends and variability in the time series of air mean temperatures and precipitation amounts at two representative meteorological stations (Băişoara and Vlădeasa 1800) located in the northern part of the Apuseni Mountains, using MAKESENS application (Mann-Kendall test for trend and Sen's slope estimator). The time series cover a relevant period of 54 years (1961-2014). The main results suggest an increase of mean air temperature, typical for summer, being consistent with the current global warming. The trends in precipitation are statistically insignificant, being positive in low and medium mountains areas and negative at high altitudes. According to the IPCC projections and predictions, a similar temperature and precipitation pattern trend is expected in the future in the study region. Also, an increase in extreme events (e.g. heavy rainfall) is expected. In this context, adaptation to climate change should be an important element of national, regional and local policies.

Key Words: climate change, warning trend, temperature evolution, precipitation variability.

Introduction. Climate change is one of the main long term drivers of economic, social and environmental change. Its impact is global with very different regional expressions (Kelemen et al 2009). Rising air temperature and changes in precipitation patterns are undeniable facts, which may have different impacts on various aspects of human life, especially on human settlements, agricultural products, energy consumption, etc. (Piticar & Ristoiu 2014). Since reducing greenhouse gas emissions in near future does not automatically imply a global warming attenuation, adaptation to climate change should be an important element of national policies (MESD 2008).

Global warming and its impact on the climate system are considered in The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change, 2013, as unequivocal. The globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85ºC, over the period 1880 to 2012 (IPCC 2013).

This scenario was almost the same for Europe. Thus, during the 20th century, Europe experienced an increase in average annual surface temperature of 0.8°C, with an increased rate of warming over time. Also, trends in the 20th century showed an increase in Northern Europe by 10-40% and decrease in some regions in Southern Europe by up to 20% in average annual precipitation. It is noted that the intensity of rainfall increased, even in some areas with decreased average annual precipitation (Kelemen et al 2009).

According to existing data and studies, in the past 100 years, the average annual air temperature increased by 0.8°C in Romania (MEWS 2015), being consistent with the observed global and European warning pattern. Similar trends in temperature were also reported in other studies (Busuioc et al 2008; Bîrsan 2012; Bojariu et al 2015; Dragota & Kucsicsa 2011; Piticar & Ristoiu 2012; Piticar & Ristoiu 2014), while the precipitation didn't show relevant trends (Bîrsan 2012; Bojariu et al 2015).

Based on recent studies, the mountain regions are particularly exposed to climate change and increased climatic variability (EC 2011; MESD 2008; Dragota & Kucsicsa 2011).

In this study, the north of the Apuseni Montains was chosen to analyze the trends and variability in the time series of air mean temperatures and precipitation amounts. This kind of study is an important step in estimating of future prediction and projections and offers a regional perspective, providing information for policy makers in helping them to take the most appropriate adaptation measures in the context of climate change and/or variability.

Database and Methods. Daily temperature and precipitation data (1961-2014 period) from two representative weather stations in the study region (Băişoara and Vlădeasa 1800) were used in order to perform this study (source of data: National Administration of Meteorology - Regional Meteorological Center Transilvania Nord) (Figure 1).

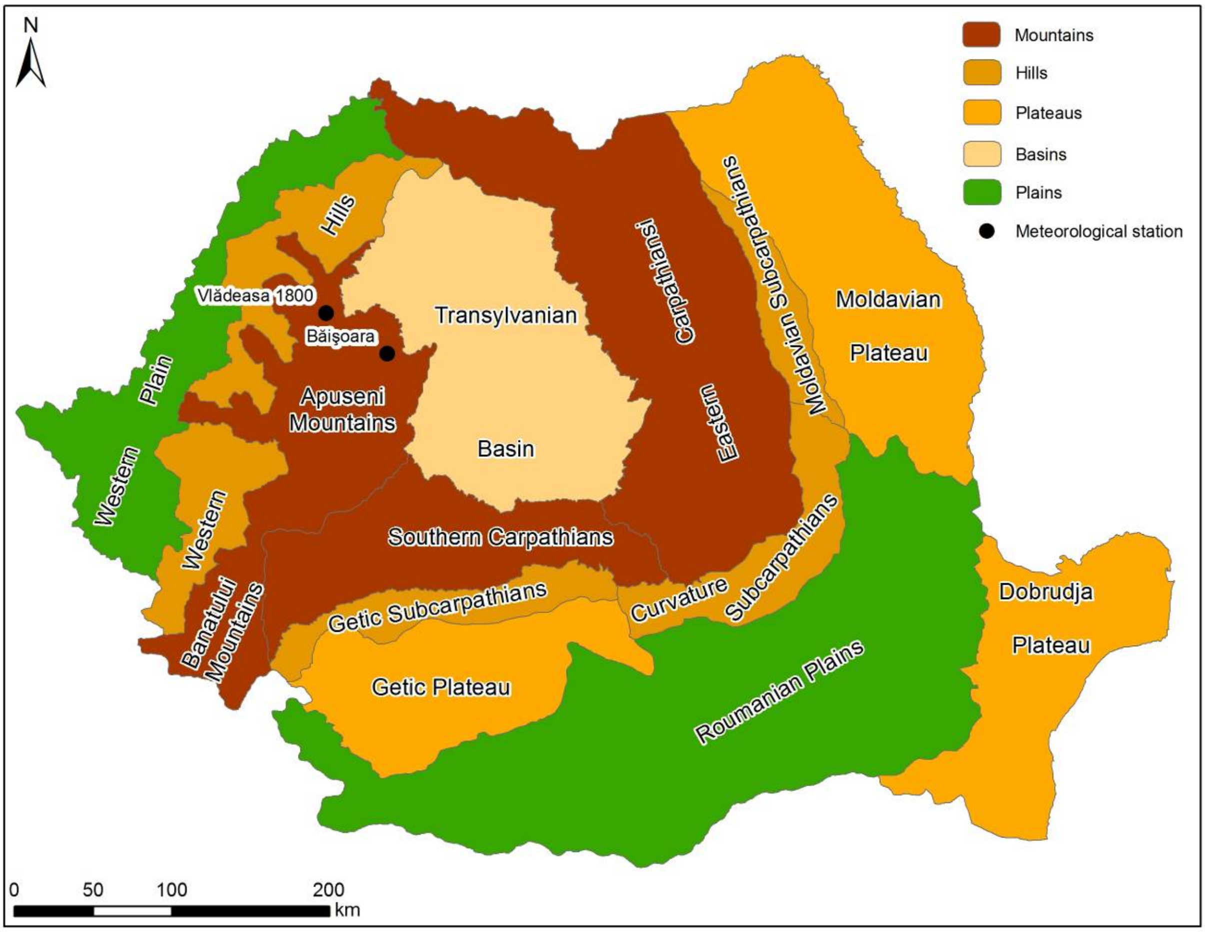

Figure 1. The location of the selected weather stations.

The research methodology followed the next steps:

- analysing daily data in order to detect any inhomogeneities and errors;
- computing annual and seasonal mean air temperatures and amount of precipitations;
- achieving trend graphs by using Microsoft Excel;
- applying MAKESENS methodology (Mann-Kendall test for trend and Sen's slope estimator), which is a non-parametric statistical method used to identify trends in the data series (Bîrsan 2012).

The Mann-Kendall test is applicable to the detection of a monotonic trend of a time series with no seasonal or other cycle. The Sen's method uses a linear model for the trend (Salmi et al 2002). These methods offer many advantages: missing values are allowed and data needed do not have to follow any particular distribution. In addition, single data errors of outliers do not significantly affect Sen's method.

In MAKESEN, the tested significance levels α are 0.001, 0.01, 0.05, and 0.1 (Piticar & Ristoiu 2014), which are corresponding to non-exceedance probabilities of 0.1%, 1%, 5% and 10%. In other words, a non-exceedance probabilities of 0.1% represents a chance in 1000 to not be true.

In this study, the trends are considered to be statistically significant on the $\alpha \leq 0.05$ (95% confidence level). Mann-Kendall test was applied to 10 time series (annual and seasonal mean air temperature and amount of precipitations), corresponding to each of two weather stations.

Results and Discussion

Temperature trends. In order to o study the temperature trend during the 1961-2014 period, the MAKESENS methodology was applied. The results show that the annual and seasonal mean air temperature presents a clear increasing trend for the north of the Apuseni Mountains.

Thus, linear trend line plotting indicates an increasing trend in the annual mean air temperature in the range of 0.29 to 0.30°C/decade, being statistically significant at 0.001 level (Table 1, Figure 2).

Table 1

Trends in annual and seasonal mean air temperature (1961-2014)

Weather station	*Altitude (m a.s.l.)*	*Temperature trend line slope (1961-2014) (ºC/decade)*				
		annual	*spring*	*summer*	*autumn*	*winter*
Vlădeasa 1800	1840	**0.29**	**0.29**	**0.50**	0.10	0.24
Băişoara	1356	**0.30**	**0.36**	**0.53**	0.11	0.23

* Values in bold are statistically significant on α ≤ 0.05

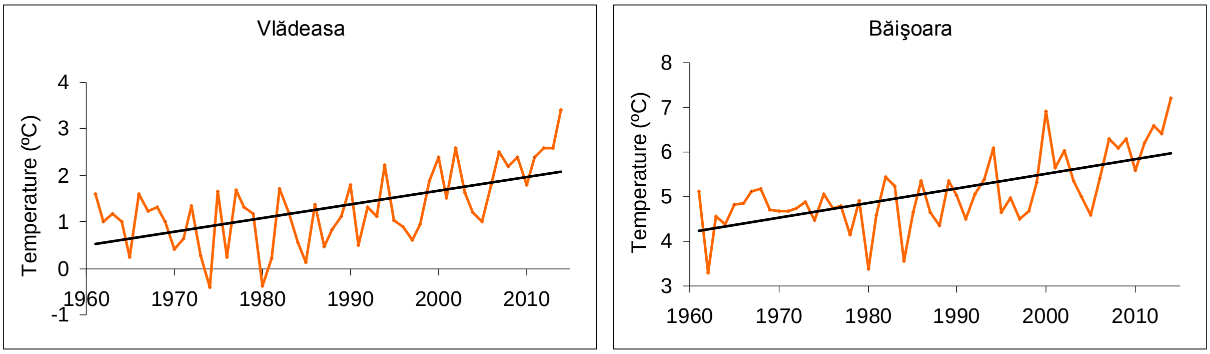

Figure 2. Graphs showing the trends in annual mean air temperature (1961-2014).

The Sen's slope estimator indicated discrepancies between the seasons. Thus, the highest positive slope of the trend line was typical for summer (0.50-0.53ºC/decade), with statistically significant level at 0.001.

A relevant warming has been identified also in spring, especially in low mountain areas (Băişoara station). Positive slopes also prevail in the case of winter and autumn seasons, but highlight only a slightly increasing slope. However, in these seasons, the statistical significance level is either very low or insignificant (0.1 in winter and ≤ 0.1 in autumn season) (Table 1, Figure 3).

These trends are consistent with those reported in other studies, especially for annual and summer values (Dragota & Kucsicsa 2011; Piticar & Ristoiu 2012; Piticar & Ristoiu 2014).

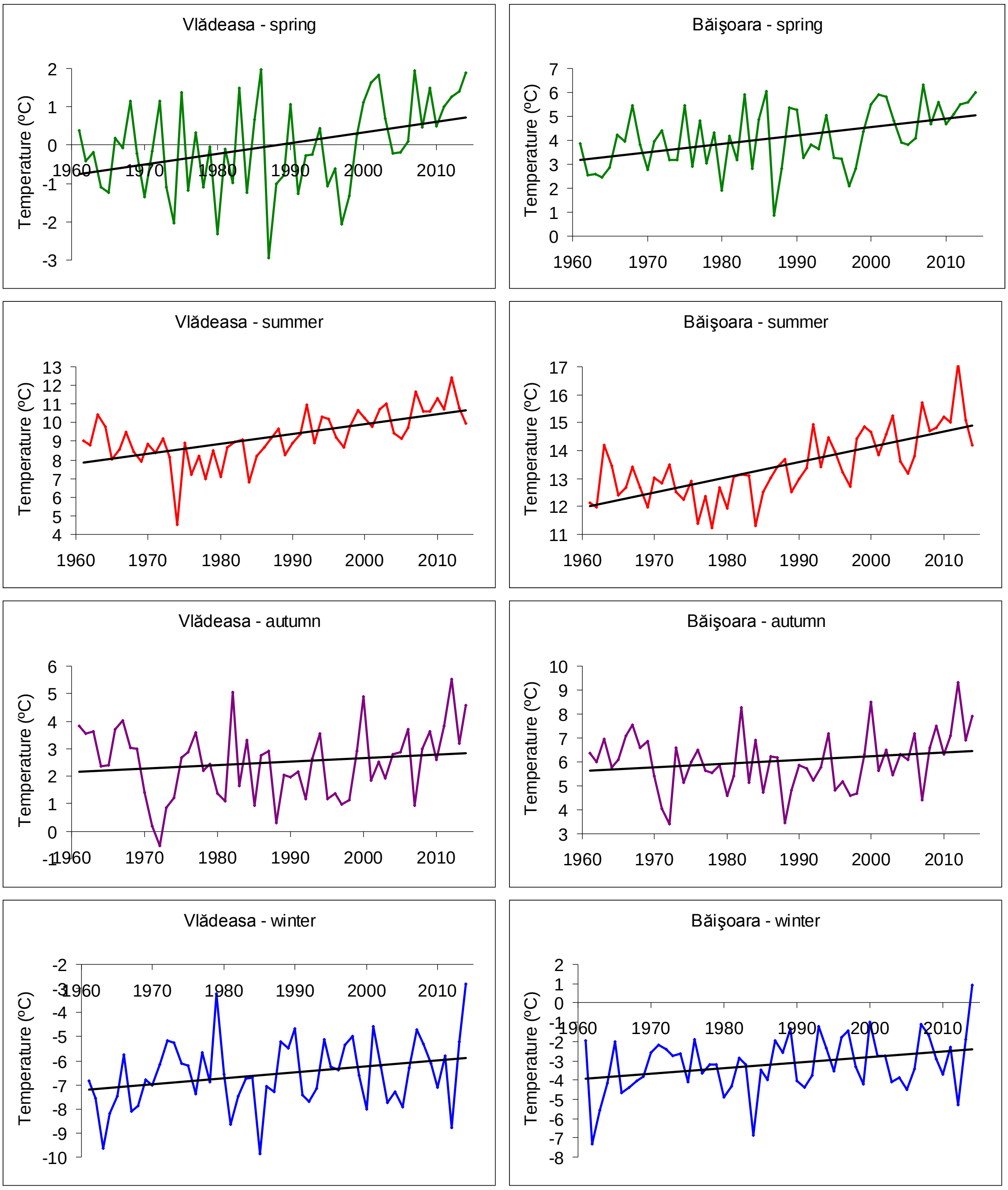

Figure 3. Trends in seasonal air mean temperature (1961-2014).

Precipitation variability. The trends in annual precipitation amounts indicates a decreasing trend for higher altitudes (-30 mm/decade at Vlădeasa 1800 station) and positive trend, in the medium and lower mountain areas (13 mm/decade at Băişoara). Similar negative trend and gradients for high altitude stations, in almost the same period, were also reported (Micu 2009; Dragotă & Kucsicsa 2011; Pinticar & Ristoiu 2014) (Table 2, Figures 4 and Figure 5). However, none of the time series results are statistically significant (α≥0.05).

Table 2

Variabilities in annual and seasonal precipitation amounts (1961-2014)

Weather station	*Altitude (m a.s.l.)*	*Precipitation trend slope (1961-2014) (mm/decade)*				
		annual	*spring*	*summer*	*autumn*	*winter*
Vlădeasa 1800	1840	-30	-5.5	-8.3	-2.4	-7.1
Băişoara	1356	13	0.1	3.9	7.3	-1.6

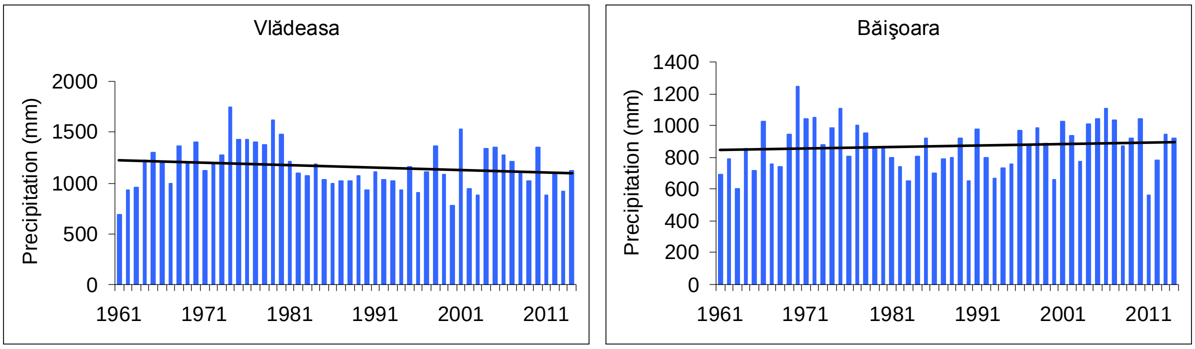

Figure 4. Changes in annual precipitation amounts (1961-2014).

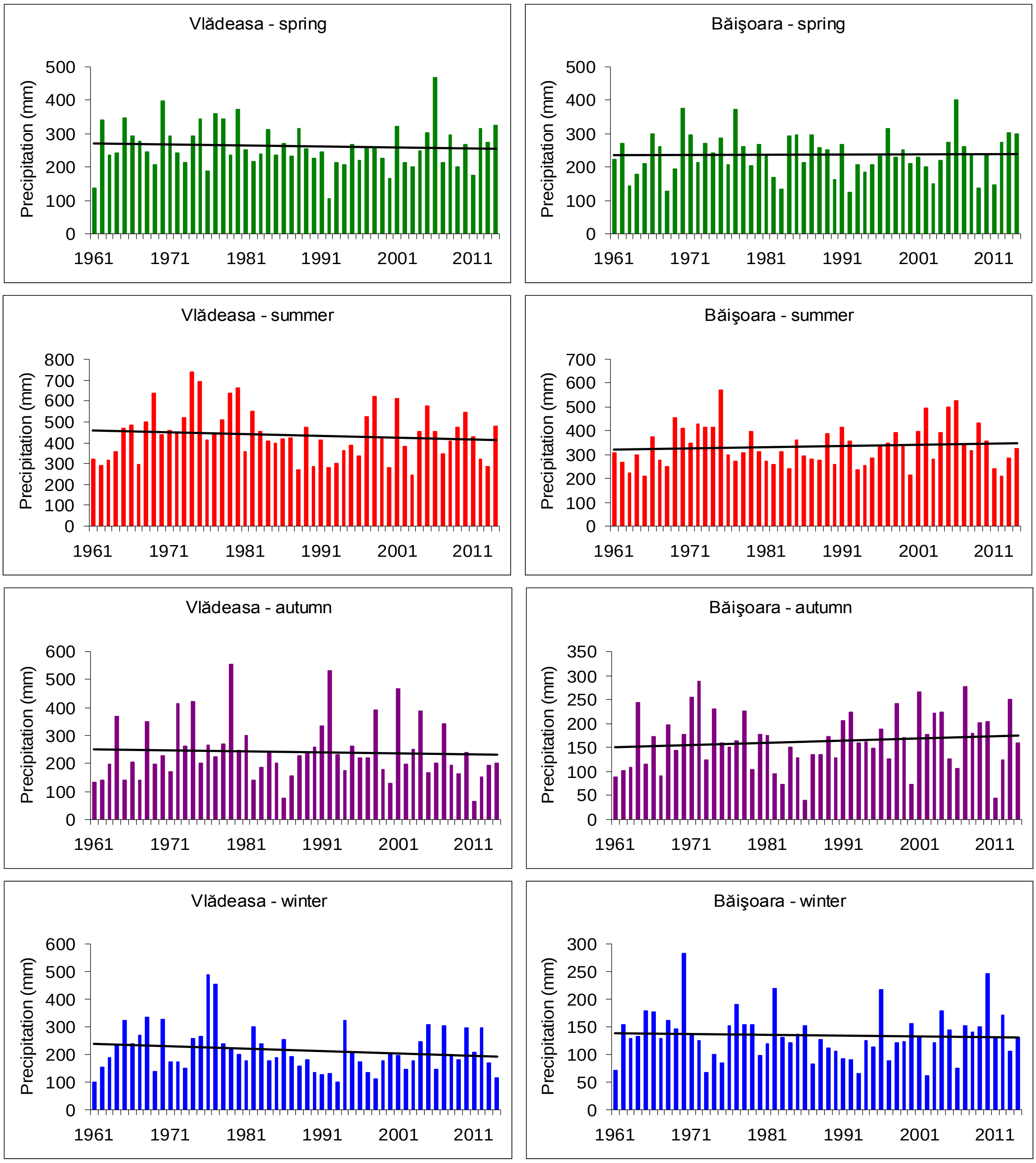

Figure 5. Changes in seasonal precipitation amounts (1961-2014).

Conclusions. The results of this study are consistent with other similar research performed across Central Europe and in Romania, showing an increase in air temperature and irrelevant changes in precipitation amounts. The MAKESENS application indicated that the most important increase in air temperature was specific to summer. According to the future projections and predictions, an increase in temperatures and evapotranspiration, especially in summer and light precipitation changes are expected in the study region. It is also expected to increase the frequency of heavy rainfall and intensity of precipitation and an abrupt decrease of snow thickness. These combinations will be reflected in flow and groundwater recharge pattern and water resources. In this context, by considering and applying the most appropriate adaptation measures, will be easier to deal with climate change and variability issues.

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