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Homogenisation of Mean Air Temperature Time Series from Vojvodina (North Serbia)

Savić Stevan[A*], Milošević Dragan[B], Marković Vladimir[C], Kujundžić-Dačović Renata[B]

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Abstract

Standard Normal Homogeneity Test (SNHT) was applied for the detection of inhomogeneities in the time series of mean monthly air temperature data for 7 stations in Vojvodina Province (North Serbia) for the period 1949-2010. In time series of two stations missing data have been found, but gaps do not exceed 5% of dataset. These gaps have been filled in with values from the three best correlated neighbouring stations.

Seven series of the moving average multi-annual air temperature (48-month and 72-month span) have been investigated. For inhomogeneity detection of these time series AnClim software package has been used, while further analysis used various statistical and cartography methods. Reference series have been chosen from 4 to 6 stations, based on distance, similar altitudes and squared correlation coefficient higher than 0.9. SNHT has been applied for detecting abrupt homogeneity breaks. The critical level of the test was 95%.

Detected break points were compared to metadata records in order to diagnose causes of featured inhomogeneities. That type of information was crucial for applying calculated corrections of investigated series. After the homogenisation process, the adjustment values have been analysed. The breaks which are explained in metadata are related to the relocations of the stations and show mostly low correction values. Differences between average values of raw and homogenised monthly time series are mostly within range from 0 to 0.12°C. According to low difference data, the results present very similar linear trends of original and homogenised time series for all stations. Still, there are a substantial changes of spatial distribution paterns. The patterns for homogenised series seem more regular, due to successful application of homogenisation process, making the image of climate variations in Vojvodina more reliable.

Key words: homogenisation, SNHT, air temperature, metadata, Vojvodina, Serbia

Introduction

In modern time where phrases like "global warming" and "temperature increase" are everyday topics it is crucial to determine true temperature change. Unfortunatelly, long time series used for climate change analyses are influenced by inhomogenieties. They are caused by, for example, relocation of the meteorological station, the replacement of instruments or/and observers, changes in observation rules, changes in the environment of the meteorological station (planting or/and uprooting of trees and grass, the construction or redevelopment of the infrastructural objects, etc.), human errors in data processing, etc. (Jones et al., 1985; Karl and Williams, 1987; Gullett et al., 1990; Heino, 1994; Mobert and Alexandersson, 1997; Peterson et al., 1998; Tuomenvirta, 2001; Aguilar et al., 2003). If these inhomogenieties are not detected and treated adequately, results of climate analyses will be inaccurate.

[A] Climatology and Hydrology Research Centre, Faculty of Science, University of Novi Sad; Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia
[B] Department of Geography, Tourism and Hotel Management, Faculty of Science, University of Novi Sad; Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia
[C] Center for Spatial Information of Vojvodina Province, Faculty of Science, University of Novi Sad; Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia
* Corresponding author: Stevan Savić, e-mail: stevan.savic@dgt.uns.ac.rs

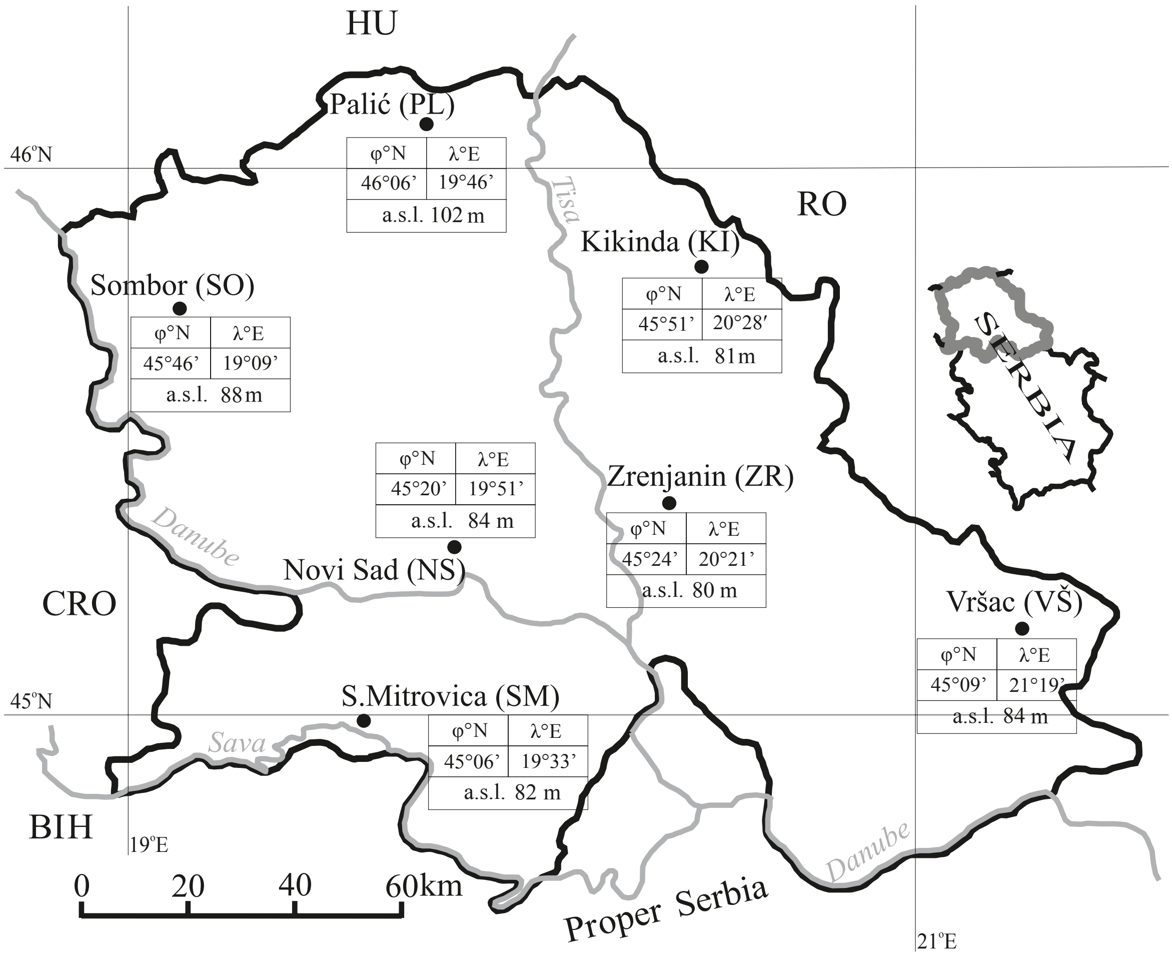

Figure 1. Geographical locations of meteorological stations in Vojvodina Province (North Serbia) and their coordinates

Climate time series are considered homogenoues only if their variability is related to regional weather and climate variability. Numerous statistical tests have been developed for detection of inhomogenieties in climatology time series records. There overview is given by Peterson et al. (1998) and Aguilar et al. (2003). In general, combination of statistical methods and methods relaying on metadata information (history of a station since its establishment to the present) is considered to be very effective in tracking down inhomogenieties.

Standard Normal Homogeneity Test - SNHT (Alexandersson, 1986) is used in many studies: Alexandersson and Moberg (1997), Moberg and Alexandersson (1997), Moberg and Bergstrom (1997), Peterson et al. (1998), Toumenvirta (2001), Wijngaard et al. (2003), Begert et al. (2005), Staudt et al. (2007), Pandžić and Likso (2009). In Serbia, this test was used in studies of Tošić (2004, 2005), Ducić et al. (2008), Savić (2009), Savić and Lazić (2009), Savić et al. (2010) and in this work.

In this article the main goal is to show importance of using homogenisation tools (in this case SNHT), in order to improve the quality of mean monthly air temperature time series. Therefore, we used various statistical and cartography methods to present differences between raw and homogenised time series and get more logical spatial average and trend value distribution paterns of homogenised series. Furthermore, the presented survey should brings out a significant contribution in understanding climate changes in Vojvodina, Serbia and Southeast Europe.

Data and methods

Testing on relative homogeneity of mean monthly air temperature in Vojvodina is analysed for 7 stations, more or less uniformly distributed over the territory (Figure 1). The period covered by this survey is from 1949 to 2010. The data have been provided by the Meteorological yearbooks of the Republic Hydrometeorological Service of Serbia. Since there was a small amount of data gaps (up to 5% of data), there was no significant bias of the final results. In time series of Palić (PL) and Sombor (SO) stations missing data have been found. Filling in the missing data of the time series was performed using the data from the three best correlated stations and applying a correction value.

Standard Normal Homogeneity Test (SNHT) was applied for detecting abrupt homogeneity breaks (Alexandersson 1986) of various climatology parameter time series. This survey brings out a small novelty in homogenisation approach. Instead of the raw monthly values, SNHT has been applied for detecting abrupt homogeneity breaks of mean monthly moving average air temperature data. Moving data windows used for the tests had 48-month and 72-month span. SNHT has been designed to remove the influence of the natural variation of weather and climate on a regional scale, i.e. for the detection of artificially caused abrupt breaks in the homogeneity of meteorological time series (Pandžić and Likso, 2009). The test is based upon the assumption that the difference between temperature series at a candidate station (the one being tested) and the reference series is fairly constant in time. Among 10 stations (three stations have been added in homogenisation test located in Proper Serbia – Belgrade, Veliko Gradište and Smederevska Palanka), reference series have been chosen from 4 to 6 stations, based on distance, similar altitude and squared correlation coefficient higher than 0.7 (Domonkos, 2006) with the test station. The critical level of this test was 95% (Khaliq and Ouarda, 2007). In practice, it may be difficult to determine beforehand which stations are homogeneous. Therefore, testing is usually done as an iterative procedure in which the homogeneity of the data is gradually improved by testing all series several times (Hanssen-Bauer and Førland, 1994; Tuomenvirta and Drebs, 1994; Mobert and Alexanderson, 1997; Tuomenvirta, 2001). For inhomogeneity detection of these 7 time series, AnClim software package has been used (Štěpánek, 2005). Detected break points were compared to metadata records in order to diagnose causes of featured inhomogeneities. That type of information was crucial for applying calculated corrections of investigated series.

In the further analysis, basic statistical and cartography methods have been used. The trends of mean monthly air temperature time series were detected with linear regression using the least squared method.

In the paper ArcGIS 9.2 software by ESRI company has been used. Maps were made in GCS_WGS_1984 Geographic Coordinate System, D_WGS_1984 Datum, with Prime Meridian Greenwich. The process of making isotherms maps of Vojvodina was done in following stages: collecting of material, database building, digitalization, development of Kriging model by 3D analyst tools.

Results and discussion

In total, 7 monthly air temperature time series from Vojvodina Province were tested. The analysis of homogeneity of mean temperature for the period 1949-2010 have discovered a number of break points that have been compared to the metadata information. Every break point has a time span for comparison to the metadata and a magnitude of change used as a correction value.

The station network in Vojvodina is dense enough, in order to get efficient homogeneity process. The stations are relatively equally distributed, i.e. the average distance between test and reference stations is about 50 to 100 km. The stations are on similar altitudes. The range of stations altitudes is only 52 m. Most of the stations are settled on 80 to 88 m.a.s.l. and only three stations are higher than 100 m.a.s.l. (Palić, Belgrade and Smederevska Palanka). Typical correlation coefficients of the mean monthly air temperature between candidate and reference stations range from 0.93 to 0.97. This enables the detection of relatively small breaks (Tuomenvirta, 2001).

All homogeneity break points must have a known or unknown cause. The following criteria for break point selection were:

- correction (adjusted) values over ±0.1°C (since smaller amounts of change would be meaningless comparing to measurement resolution)
- temporal matching to metadata information of the stations, and
- any break point with magnitudes over ±0.2°C, regardless of the metadata information (such break points were considered as from an unknown cause) (Savić et al., 2010).

In this research, homogeneity test and adjustments has been repeated three times on the entire lengths of records, following a test scheme where the time series of candidate and set of reference stations were successively improved. In the first circle of homogenisation test was detected all possible breaks at 7 stations from Vojvodina. These breaks were compared with metadata and defined the real non-homogeneity spots according to temporal matching. Following previous procedure, the adjustment process has been implemented on inhomogeneity time series. This process was done two times more. After the third circle of homogenisation test, amount of change on the detected breaks was less comparing to the first circle (less than ±0.2°C) or the break was not detected at all.

Homogeneity break points were not detected on NS and VŠ, while PL, SO, KI, ZR and SM had to be homogenised. Hence, SNHT has detected more than half (70%) of time series as non-

Table 1. *The results of homogeneity testing of the mean monthly air temperature time series for 7 stations in Vojvodina for the period 1949-2010*

weather station	abbr.	homogeneity break	amount of adjusted value (°C)	potential cause of inhomogeneity
Palić	PL	June 2000	0.06*	Work interruption of the station May-July 1999
Sombor	SO	August 1957 Jul 1969 May 1975	-0.21 -0.20 0.13	Relocation of the station, on December 1954 Relocation of the station, on January 1969 Relocation of the station, on April 1975
Novi Sad	NS	/	/	-
Kikinda	KI	May 1975	-0.03*	Relocation of the station, 1975
Zrenjanin	ZR	October 1954 July 1967	-0.18 -0.17	Relocation of the station, on October 1953 Relocation of the station, on January 1967
Vršac	VŠ	/	/	-
Sremska Mitrovica	SM	January 1986	-0.26	Relocation of the station, on January 1986

*Note: * - on PL and KI has been implemented adjustments according to obvious interruption in stations work, even adjusted values are less than ±0.1°C*

homogenuous (mostly caused by the relocation of the station), which is close to the results of some other similar analysis (Domonkos, 2006; Staudt et al., 2007; Pandžić and Likso, 2009). Applied adjustments of the series provided amount of correction magnitudes from ±0.03 to ±0.26°C (Table 1).

One of the product of the homogenisation process is differences of mean monthly air temperature values between raw and homogenised time series. The magnitude of differences is low with range from 0°C in NS, VŠ and PL to 0.12°C in SM. Even though, the mean temperature values of homogenised time series show better spatial tem-

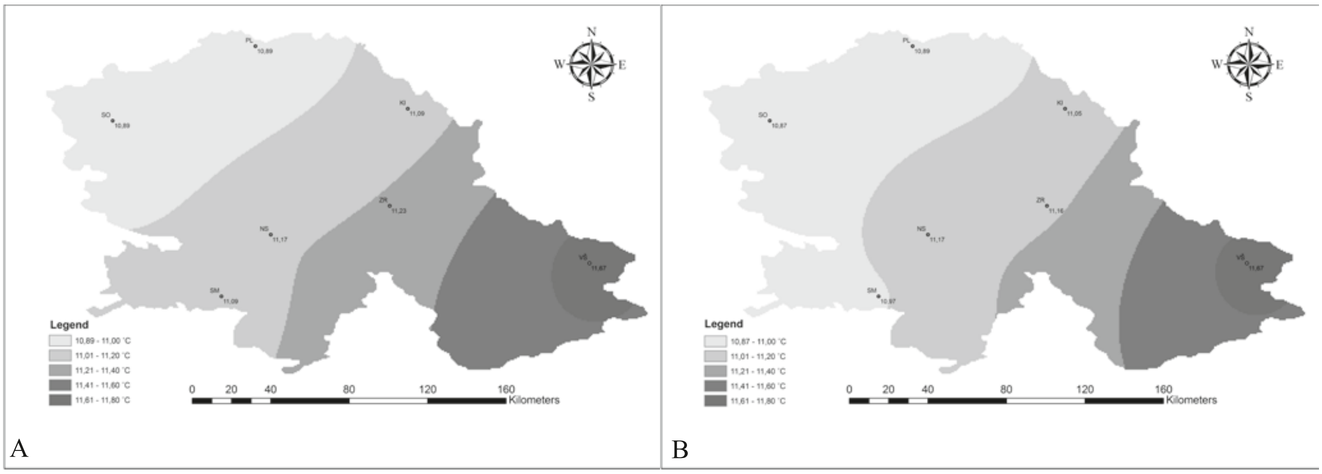

Figure 2. Spatial distribution of raw (A) and homogenised (B) mean monthly air temperature values for the period 1949-2010

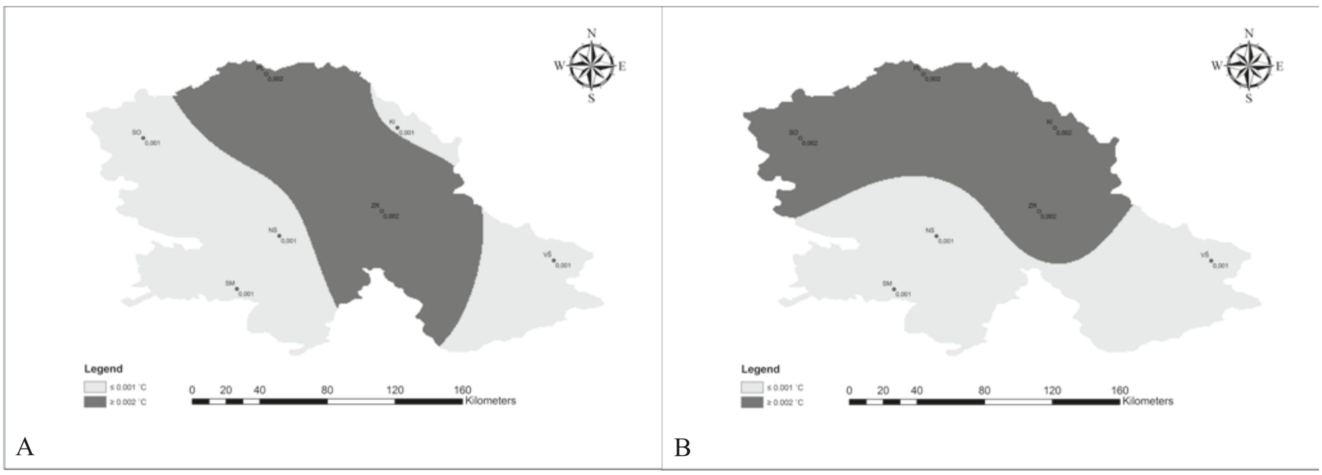

Figure 3. Spatial distribution of raw (A) and homogenised (B) trend values (°C/per year) for the period 1949-2010

perature distribution pattern in Vojvodina (Figure 2). Furthermore, analysis of linear trends provided minor differences between unhomogenised (original, raw) and homogenised mean temperature time series. The mangnitude of differences has from 0°C to 0.001°C/per year. Although these differences are rather small, spatial distributions of temperature trends show significant changes. The pattern featured in spatial distribution of temperature trends of homogenised series seem more regular than those of the non-homogenised series (Figure 3). Similar results of temperature trends spatial distribution in Serbia is given by Savić et al. (2010). This confirms the correctness of the homogenisation procedure, discovering the best possible image of temperature change over the territory of Vojvodina.

Conclusions

According to homogeneity analysis and results of moving average (48-monthly and 72-monthly) air temperature time series for Vojvodina, the main conclusions of this study are as follows:

- homogeneity assessment of the 7 time series of mean monthly air temperature for the period 1949-2010 shows inhomogeneities, generally due to relocations of weather stations. At the same time, the existance of eventually unexplained homogeneity break points indicate incompleteness of stations' metadata which is serious deficiency of meteorological station network in Serbia, as same as in other European contries;
- homogenisation test provided relatively low break point magnitudes and adjustment values (from ±0.03 to ±0.26°C), probably caused by small territory of Vojvodina Province, not too large distance among weather stations and the geographical area with a gentle relief, so generally, the climate is free from orographic effects. Furthermore, these stations are a group of higher-rank stations (main stations) which probably resulted in higher quality of observations;
- homogenisation process show relatively low differences of mean monthly (from 0 to 0.12°C) and trend (from 0 to 0.001°C/per year) air temperature values between raw and homogenised time series. Even though, spatial distribution of mean monthly temperature and trends of homogenised time series yields smoother and more logically pattern than of raw series;
- successful application of homogenisation process provide a solid ground for a variety of subsequent studies, with a considerably improved confidence, within the limits given by the initial data material, and therefore improve the perspectives for the analysis of regional temperature changes in Vojvodina (Serbia) and making the basis for the discussion of climate variations in the regional (Southeast Europe) or global context;
- further homogenisation assessments would be included other tests.

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