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[Lecture]

Trend of air temperature at the meteorological station Vranje during the period 1949-2024

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Abstract: In this research, the temperature trends were analyzed at meteorological station Vranje for the period 1949-2024. The study aims to determine the trend in air temperature on annual, seasonal, and monthly levels and to determine the change point in the time series. The non-parametric Mann-Kendall test and Pettitt test were used. Based on the processed data and the obtained results, it can be concluded that the trend of annual, monthly and seasonal air temperatures is increasing. The air temperature increases annually by about 0.019°C ($\alpha=0.001$). A statistically significant trend was determined in July ($\alpha=0.1$) and in the summer period of the year ($\alpha=0.05$). A statistically significant trend of temperature increase occurred at the meteorological station Vranje after 1997. The results of air temperature trend research are of great scientific and practical importance for future urban and rural planning, but also for the projection of future trends and the creation of climate models.

Keywords: Air temperature trend, Vranje, Mann-Kendall, Pettitt test

Introduction

Climate change is the subject of numerous studies around the world. In recent years, anthropogenic influence has increasingly been included as the main factor in the positive trend of climate elements, although there is evidence of natural climate variability (Miletić et al., 2025). Ten years ago, estimates were that human influence led to an increase in global average air temperature of between 0.4° and 0.8°C

over the course of a century (Malinović-Milićević et al, 2014). Current estimates, for the period 2011-2020, are that global temperature increased by 1.1°C compared to the period 1850-1900, as a result of increased greenhouse gas emissions, but also inadequate land use, modern human lifestyles and the disproportionate ratio of energy production and consumption (IPCC, 2023). According to estimates by the National Aeronautics and Space Administration (NASA), rising temperatures will lead to an enhanced water cycle, which leads to increased evaporation. Increased evaporation further leads to more frequent and intense storms, but also contributes to the aridification of certain areas on land (Durlević et al., 2021). The increase in air temperature at the global level is reflected in all elements of the geographical envelope, and the consequences of climate change can be felt in many regions of the world through rising sea levels, melting glaciers, forest fires, and increasingly frequent and severe droughts. All of this significantly affects the living world, primarily human health and living in general, but also the social aspects of human activity (Sadhukhan et al., 2023).

Serbia is one of the countries that has faced significant changes in air temperature values over the past thirty years. As for the rest of the world, there are general forecasts for Serbia, which predict that the entire region of southern Europe will be affected by high temperatures and subsequent periods of drought. In almost all parts of Serbia, trends of increasing air temperature have been observed since 1949 and ending with 2020 (Sedlak et al., 2024). Some authors have linked atmospheric patterns over the Atlantic Ocean, such as the North Atlantic Oscillation (NAO), the East Atlantic Pattern (EA), with changes in temperature regimes in Serbia during winter and summer (Malinović-Milićević et al., 2015), while in the South Morava Valley the influence of the Mediterranean Oscillation has been analyzed (Miletić et al., 2025). Putniković (2025) linked the influence of atmospheric circulation types that are associated with the distribution of air masses with climatic conditions in Serbia.

This study aims to assess long-term temperature trends and to identify the transition year at the Vranje meteorological station, based on time series data covering the period 1949–2024, analyzed at annual, seasonal, and monthly scales. The results of this research can serve both local authorities and the highest state bodies as a clear insight into the trends of climate parameters, in order to take appropriate measures.

Methods and data

The study area includes data from meteorological station Vranje ($\varphi=42^{\circ}33'$, $\lambda=21^{\circ}55'$) in Southern Serbia, in subregion of Southern Pomoravlje. Station is located at an altitude of 432 meters. According to Köppen's climate classification, Vranje is located in the area of a moderately warm and humid climate with a warm summer (Cfb) (Milovanović et al., 2017). The climate of Vranje is characterized by great dryness, which resulted in the separation of a separate, Vranje climatic region. The longest drought period in Serbia was recorded in Vranje – 61 days (21.06.-21.08.1928) (Драгићевић и Филиповић, 2016). The weather conditions in Vranje during the summer are influenced by the activities of the Icelandic cyclone and the Azores anticyclone. Air masses from the northern part of the Atlantic, moving eastward and across the Adriatic Sea, pass through the territory of Serbia, along the Sava and Danube valleys, in late spring and early summer. During the summer, the southern part of Europe is exposed to the influence of anticyclonic air masses over the Azores Islands, which bring dry and warm weather. In the cold period of the year, Serbia is exposed to the influence of the Siberian anticyclone and cyclonic conditions over the Mediterranean (Gulf of Genoa) (Milovanović et al., 2017).

The data on annual and monthly air temperature values at the selected meteorological station were taken from the meteorological yearbooks of the Hydrometeorological Institute of the Republic of Serbia for the period 1949-2024 (<https://www.hidmet.gov.rs/>). The data on seasonal air temperature values are grouped in such a way

that December (from the previous calendar year), January and February belong to the winter season, March, April and May to the spring season, June, July and August to the summer season and September, October and November to the autumn. The winter of 1949 was not taken into account.

The research was conducted using non-parametric tests, the Mann-Kendall and Pettitt tests (Mann, 1945, Kendall, 1975). The Mann-Kendall test is used for the analysis, determination and decomposition of time series. This type of test has wide application in geographical research. The Mann-Kendall test is based on the correlation between the level of values of the series and their chronological order. The null hypothesis assumes that there is no trend in the selected series, and the alternative that there is a statistically significant trend (upward or downward). The Pettitt test is used to determine the year of transition, i.e. the period when significant changes in the trend of the analyzed parameters occurred (Sedlak et al, 2024; Tošić et al., 2025).

Results and discussion

During the observed period 1949-2024, the average temperature was 11.28°C. The maximum average annual temperature was recorded in 2024 and was 13.6°C, and the lowest 9.8°C in 1976. The annual trend of air temperature is constantly increasing (Figure 1). The trend value (z) is 4.075, while the Sen's estimate is 0.019. These results show that the air temperature is increasing by 0.019°C per year on average.

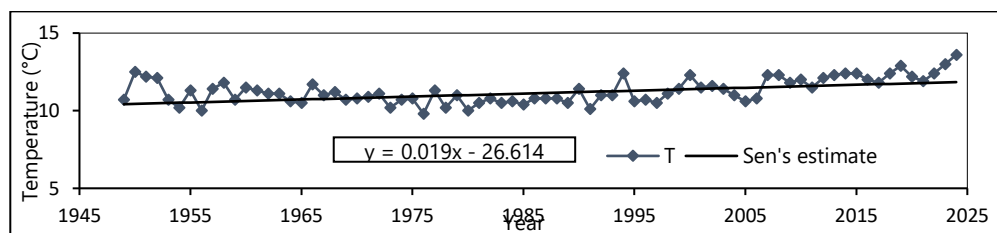


Figure 1. Result of Mann-Kendall test for annual air temperatures in Vranje for the period 1949-2024

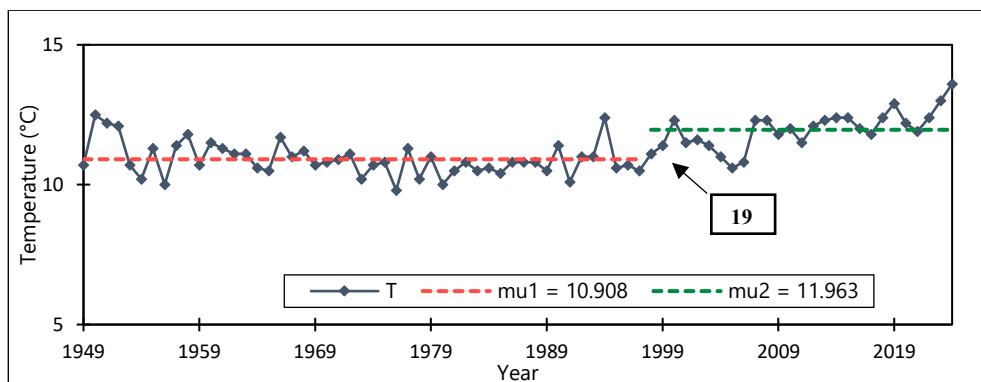


Figure 2. The transition year detected using the Pettitt test for annual air temperatures in Vranje for the period 1949-2024

By applying the Pettitt test (Figure 2), 1997 stands out as the year of significant change in annual air temperature. In the period 1949-1997, the average annual air temperature in Vranje was 10.91°C, and during the period 1997-2024, the average air temperature is 11.96°C, which is an increase of 1.05°C.

Table 1. Trend of seasonal air temperature values in Vranje (1949-2024) using the Mann-Kendall and Pettitt test

Season	Spring	Summer	Autumn	Winter
<i>b</i>	0.088**	0.130***	0.026	0.079*
<i>Y</i>	1998	1991	2007	2006

*Significance: * $\alpha=0.001$, ** $\alpha=0.01$, *** $\alpha=0.05$; *b* – Sen's slope, *Y* – transition year

At the seasonally level (Table 1), the most statistically significant trend was observed in the summer period of the year, then during spring and less significant during winter. Autumn is without statistical significance. The trend value during summer is 3.658, while the Sen's estimate is 0.130, i.e., summer temperatures, on average, increase by 0.130°C per year. Spring temperatures increase by 0.088°C per year, and winter temperatures by 0.079°C on average. The results of the Pettitt test coincide with the results of the Mann-Kendall test. Spring, summer, and winter again stood out as the seasons with significant changes.

The warmest months in Vranje are July and August with an average temperature of 21.6°C. The coldest month is January with an average temperature of -0.1°C and is the only month with a negative average air temperature. The highest July temperature was measured in 2012 at 25.4°C, and the lowest temperature was measured in January 2017 at -5.2°C.

Table 2. Trend of monthly air temperature values in Vranje (1949-2024) using the Mann-Kendall and Pettit test

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
<i>b</i>	0.133	0.300	0.583*	0.213*	0.210	0.140	0.293**	0.267*	0.100	0.050	-0.120	-0.190
<i>Y</i>	1993	2006	1973	1997	1993	1992	1992	1991	2010	1997	2007	2007

*Significance: * $\alpha=0.001$, ** $\alpha=0.01$, *** $\alpha=0.05$; *b* – Sen's slope, *Y* – transition year

At the monthly level (Table 2), several statistically significant changes in air temperature were observed, of which the July temperature was the most significant. A trend with lower statistical significance was recorded in March, April and August, while the other months did not show significant changes. The air temperature in July increases by 0.293°C per year, which is a trend with higher statistical significance. Air temperatures in March, April and August increase by 0.21-0.58°C per year and are less significant. A negative trend was observed during November and December, where the temperature decreased on average by 0.1-0.2°C per year, but without statistical significance. The result of the Pettitt test coincides with the results obtained by the Mann-Kendall test. For these months, 1991 (August) and 1992 (July) stand out as the years of change. The only deviation is observed in the February and June values. The years of change are 1992 (June) and 2006 (February), however, no significant statistical trend was observed.

A significant change in air temperature was observed at all levels in Vranje. The last decade of the 20th and the first decade of the 21st century stand out as periods of significant trend changes. The trend in air temperature can be explained by the movement of air masses,

but also by the influence of atmospheric patterns on the climate of Serbia.

Conclusions

The paper analyzes annual, seasonal and monthly air temperature trends at the Vranje meteorological station, using the Mann-Kendall and Pettitt tests, for the period 1949-2024. At the annual level, a significant increase in temperature was observed. At the monthly level, a significant trend was observed over four months, of which July temperatures stand out in particular. Observed seasonally, the most significant change is during the summer period, while greater significance is also observed during spring and winter. At all levels, temperature changes have been more intense over the last thirty-five years. Such air temperature trends in Vranje can be explained by the general movements of large air masses and patterns, which affect weather conditions in this part of Europe.

The results obtained may be significant for planning measures and regulations to protect or reduce the impact of climate change on human health and in general all spheres of social life and activity. In order to conduct a complete analysis, it is necessary to examine trends in other climate elements, such as precipitation, air pressure, humidity, and wind. In this way, it is possible to more precisely determine whether and how significant climate changes are.

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