# Seasonal Air Temperature Variability and Trends in a Mountainous Forest Ecosystem of Central Greece

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**Abstract.** During the last decades, a progressive increase of temperature in Mediterranean region was recorded. This change effect both natural ecosystems and human activities. In this study, the variability and trends of mean air temperature in the University Forest of Pertouli (Central Pindus, Greece) was evaluated. To this end, long-term (1961-2019) time series for air temperature from a mountainous meteorological station were collected and analyzed. The seasonal data were subjected to Mann-Kendall test to assess the possible upward or downward statistical significant trends and in case of a significant trend to detect approximately its time of occurrence. Additionally, least square method was used to estimate the trend magnitude. The results showed warming trends in all seasons which they found statistical significant. Finally, the magnitude trend since 1961 (58 years period) is approximately + 1.4ºC, +1.1 ºC, +1.3 ºC and 1.2 for the winter, autumn, spring and summer mean air temperature.

**Keywords:** climate change; temperature; Mann-Kendall; least square method; trend.

## 1 Introduction

Air temperature is an important climatic component and it is governed by many factors, including incoming solar radiation, humidity and altitude. In addition, it present seasonal and diurnal variations and highly influence hydrological cycle (Mavromatis and Stathis, 2011, Myronidis et al., 2012, Myronidis et al., 2018), tourism decision making (Endler and Matzarakis, 2011, Matzarakis and Nastos, 2011,) and vegetation distribution (Wason et al., 2017, Kamoutsis et al., 2018, Macek et al., 2019).

Climatological studies showed that global average surface temperature increased by about 0.85 °C between 1880 and 2012, while the current rate of warming over the past 60 years (1951-2012) is 0.12 °C per decade (IPCC, 2013). The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC,


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2013) emphasizes that the Mediterranean basin is expected to become warmer and dryer until the end of the 21th century, while future warming will possibly be larger than the global mean (Giorgi and Lionello, 2008). Climate changes compounded with trends of rural abandonment will highly influence natural ecosystems within the Mediterranean basin. It is also reported that are likely to diminish forested areas that will be replaced by shrub lands (Resco de Dios et al., 2007).

The trend analysis of air temperature time series indicated a positive trend in the western Mediterranean and a negative trend in the eastern Mediterranean for the period 1950-1990 (Sahsamanoglou and Makrogiannis, 1992, Parker et al., 1994). Many papers have been published dealing with the temperatures trend analysis in Greece. An overall cooling trend was detected in winter air temperature for the period 1951-1993 (Proedrou, 1997). The same cooling trend was also noted for the mean annual and summer values, although a reverse warming trend was detected around the mid-1970s at several stations. Also, according to Feidas et al. (2004) cooling trend was mentioned for winter, whereas warming signal detected in summer for the period (1955-2001). In addition, a more recent research by Feidas (2017) updated with the 12-year period 2002–2013 found that the warming signal detected previously only in summer has now intensified and spread in other seasons. A cooling trend was also found by Nastos et al. (2011) for mean annual air temperature (1951-2007) in the wider region of Greece. A pronounced cooling trend from the beginning of the 1950s up to the mid-1970s was exhibited. It then remained at low levels until the beginning of the 1990s, and then increased up to 2000, when a turning-point is clear although the temperature remained at high levels. Another study conducted by Mamara et al. (2016), examining the mean air temperature (1960-2004), highlighted a statistically significant negative trend during 1960–1976 and a positive one during 1977–2004.

However, there are limited studies analyzing seasonal trends considering data from mountainous meteorological stations (Proutsos et al., 2010). This is due to difficulties of installation and maintenance of meteorological instruments, especially at the high altitude of the mountainous regions.

The object of this study is to analyze variability and detect trends in long term (1961-2019) seasonal air temperature time-series based on data from a mountainous meteorological station located in Central Greece.

## 2 Material and Methods

Observations of daily mean air temperature ($^{o}$C) for the period 1961-2019 were collected, from a mountainous meteorological station (1180 m.a.s.l) located in the University Forest of Pertouli, over the mountainous range of Pindus (Central Greece) (Fig.1). The rights for the management of Pertouli forest was assigned to the Aristotle University of Thessaloniki in 1934 for educational and research purposes. It covers an area of 3.290 ha and consists mainly of pure fir stands (Abies borisii-regis). Moreover, the region has great environmental importance as belongs to the European nature conservation network Natura 2000 according to the criteria of Directive

92/43/EEC and specifically includes the Site of Community Importance (SCI) with code GR1440002, namely "Kerketio Oros (Koziakas)".

The data series are complete, i.e. have no missing values. Double mass method and two parametric statistical tests (Student's t and Chi-Square test) were applied so as to adjust any heterogeneity of the temperature data, while the details of these methods can be obtained from WMO (1986). The latter tests demonstrated that the temperatures data were indeed homogeneous.

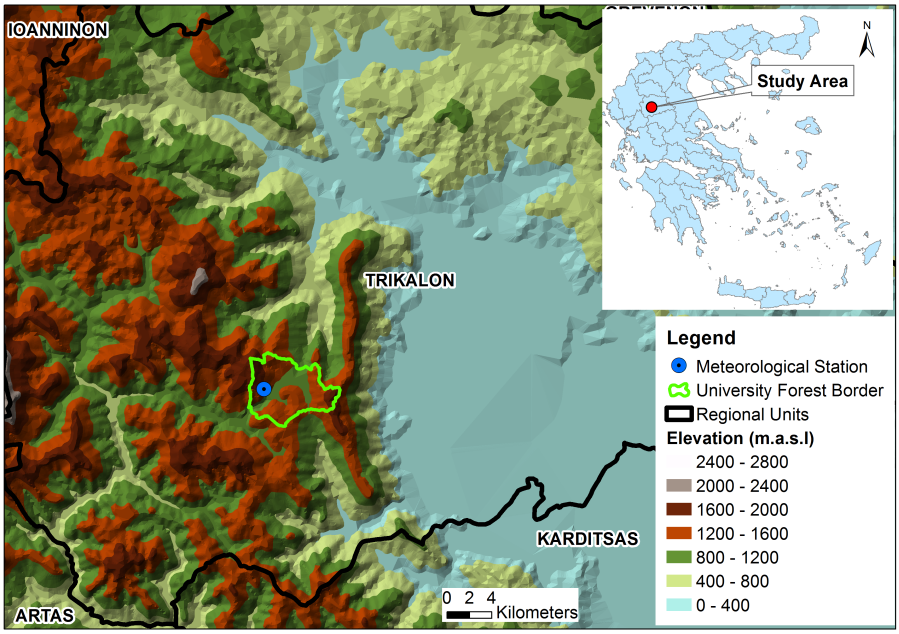


**Fig. 1.** Location map of the study area.

Trend analysis was performed on seasonal time scale. Therefore, time series of air temperature were subjected to a non-parametric Mann-Kendall test, as it has been proposed by Sneyers (1990) so as to detect any trend over the examined period. A lengthy description of the methodology and its computation can be found in the literature (e.g. Feidas et al., 2004 Myronidis et al., 2012). The sequential form of the Mann–Kendall test, consisting of the application of the test to all the series starting with the first term and ending with the $i_{th}$ term (and the reverse), was also used for a progressive analysis of the series. In the absence of any trend, the obtained graphical representation of the direct ($u_t$) and the backward ($u_{t'}$) series with this method produced curves that overlap several times. However, in the case of a significant trend (5 % level $|u_t|>1.96$), the intersection of the curves enabled one to detect approximately its time of occurrence. Furthermore, trend magnitudes were computed based on least square method.

## 3 Results

The air temperature in the University Forest of Pertouli varied greatly between seasons as shown in the following figure (Fig.2). It is noteworthy that mean temperature range is 17.1 ºC, for the examined period (1961-2019). As depicted, mean air temperature is equal to 0.8 ºC (-1.7 ºC to 3.4 ºC) in winter, 9.9 ºC (6.7 ºC to 11.8 ºC) in autumn, 7.7 ºC (4.7 ºC to 9.8 ºC) in spring and 17.9 (15.3 to 20.2) in summer.

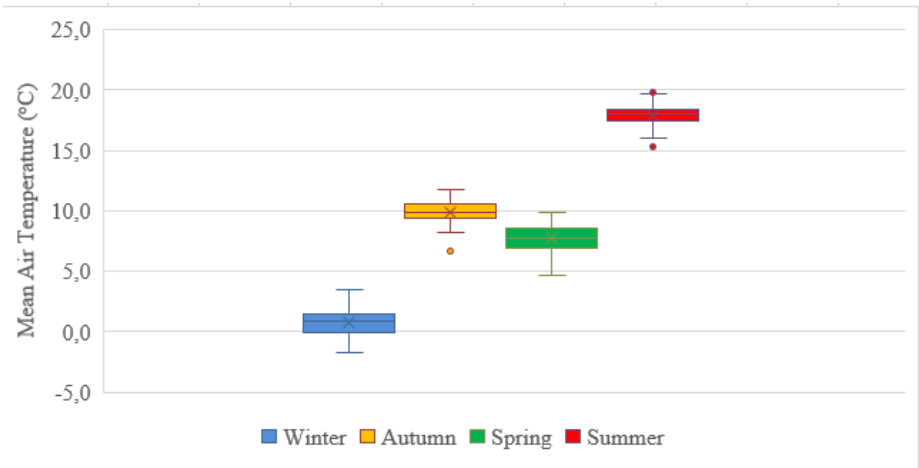


**Fig. 2.** Seasonal variability of mean air temperature.

Regarding the results of the Mann- Kendall test, statistically significant (at the 95% level of significance) warming trends were detected on seasonal air temperatures. The beginning of the change starts in the early of 1980s for winter, at the end of 1990s for autumn and spring and in the early of 1990s for summer (Fig 3).

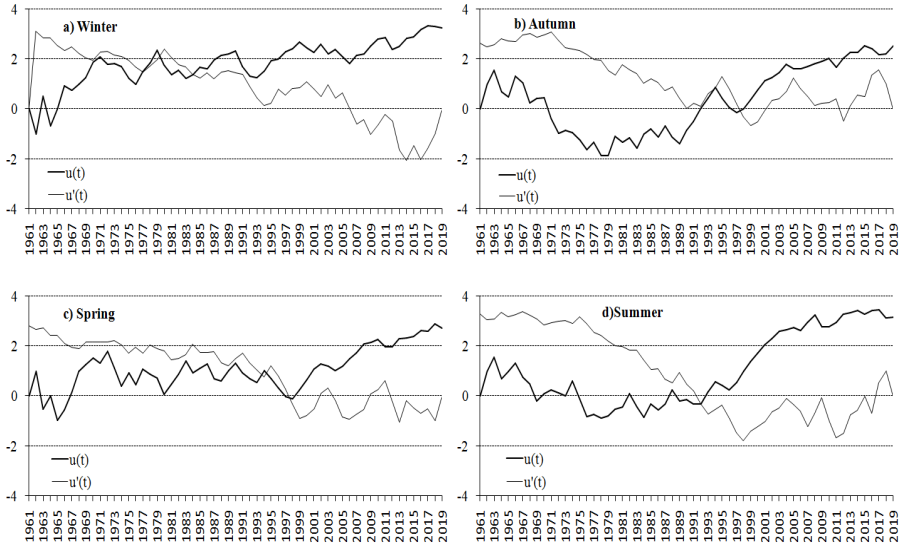


**Fig. 3.** Graphical representation of the series u(t) and the retrograde series u'(t) of the sequential version of Mann-Kendall test in a) winter, b) autumn, c) spring and d) summer.

Moreover, the least square method was used to compute trend magnitude. It was found that the magnitude of the trend is approximately + 1.4°C, +1.1 °C, +1.3 °C and 1.2 in winter, autumn, spring and summer mean air temperature respectively, since 1961.

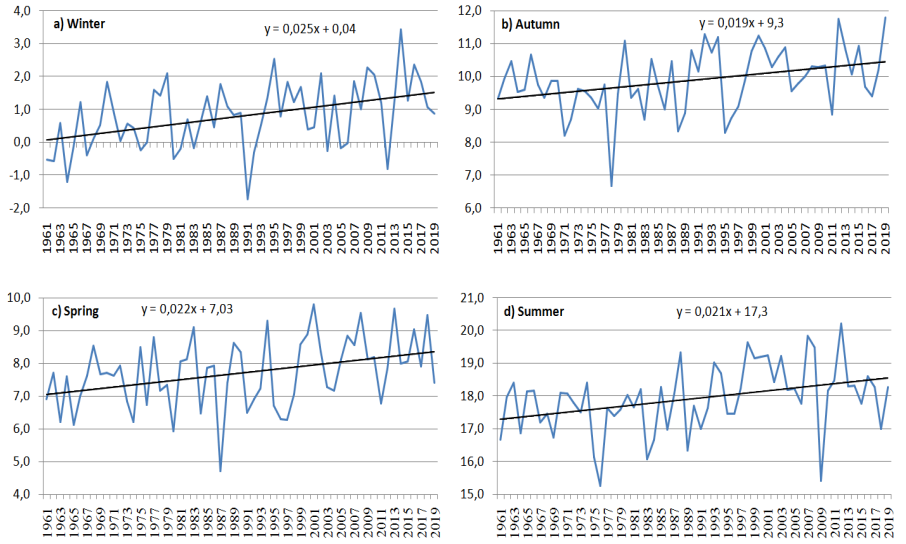


**Fig. 4.** Trend analysis of air temperature time series in a) winter, b) autumn, c) spring and d) summer.

## 4 Conclusions

In this study, variability and trends of seasonal air temperatures in the University Forest of Pertouli (Central Greece) for the period 1961-2019 were analyzed. Trend analysis was based on a combination of two statistical tests.

The mean air temperature presents great variability and ranges from 0.8 °C (winter) to 17.9 °C (summer). The results of the Mann-Kendal test highlighted statistically significant warming trends in all seasons. Also, it was found that mean temperature non-stationarity starts to occur in the early of 1980s for winter, at the end of 1990s for autumn and spring and in the early of 1990s for summer. The trends magnitude of mean air temperature during the last 58 year, using least square method, computed to + 1.4°C for winter +1.1 °C for autumn, +1.3 °C for spring and 1.2 for summer. The warming in the study area is higher than the average in Greece (Feidas, 2017). Also, the future climate condition is expected to be warmer until the end of the 21$^{th}$ century

To this end, water availability, forest growth and snow cover period will be highly influenced. The effects are not only environmental but also economic, as the reduction of snow cover period will result in limitation of the operational days of ski center resort in the area.

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## References

1. De Dios, V. R., Fischer, C. and Colinas, C. (2007) Climate change effects on Mediterranean forests and preventive measures. New forests, 33(1), p.29-40.
2. Endler, C. and Matzarakis, A. (2011) Climate and tourism in the Black Forest during the warm season. International journal of biometeorology, 55(2), p.173-186.

3. Feidas, H., Makrogiannis, T. and Bora-Senta, E. (2004) Trend analysis of air temperature time series in Greece and their relationship with circulation using surface and satellite data: 1955–2001. Theoretical and Applied Climatology, 79(3-4), p.185-208.
4. Feidas, H. (2017). Trend analysis of air temperature time series in Greece and their relationship with circulation using surface and satellite data: recent trends and an update to 2013. Theoretical and Applied Climatology, 129(3-4), p.1383-1406.
5. Giorgi, F. and Lionello, P. (2008) Climate change projections for the Mediterranean region. Global and Planetary Change, 63(2-3), p. 90-104.
6. IPCC. Climate Change (2013) The Physical Science Basis. Contribution of working group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, UK.
7. Kamoutsis, A., Chronopoulos, K., and Matsoukis, A. (2017) Altitude and Canopy Cover Effects on Air Temperature in a Mountainous Region of Ionian Islands, Greece. Current World Environment, 13(3), p.292.
8. Macek, M., Kopecký, M. and Wild, J. (2019) Maximum air temperature controlled by landscape topography affects plant species composition in temperate forests. Landscape Ecology, 34(11), p.2541-2556.
9. Mamara, A., Argiriou, A. A., & Anadranistakis, M. (2016). Recent trend analysis of mean air temperature in Greece based on homogenized data. Theoretical and Applied Climatology, 126(3-4), 543-573.
10. Mavromatis, T. and Stathis, D. (2011) Response of the water balance in Greece to temperature and precipitation trends. Theoretical and Applied Climatology, 104(1-2), p.13-24.
11. Matzarakis, A. and Nastos, P. (2011) Analysis of tourism potential for Crete Island, Greece. Global Nest Journal, 13(2), p.141-149.
12. Myronidis, D., Stathis, D., Ioannou, K. and Fotakis, D. (2012) An integration of statistics temporal methods to track the effect of drought in a shallow Mediterranean Lake. Water Resources Management, 26(15), p.4587-4605.
13. Myronidis, D., Ioannou, K., Fotakis, D. and Dörflinger, G. (2018) Streamflow and hydrological drought trend analysis and forecasting in Cyprus. Water resources management, 32(5), p.1759-1776.
14. Nastos, P. T., Philandras, C. M., Founda, D. and Zerefos, C. S. (2011) Air temperature trends related to changes in atmospheric circulation in the wider area of Greece. International journal of remote sensing, 32(3), p.737-750.
15. Parker, D. E., Jones, P. D., Folland, C. K., and Bevan, A. (1994) Interdecadal changes of surface temperature since the late nineteenth century. Journal of Geophysical Research: Atmospheres, 99(D7), p.14373-14399.
16. Proedrou, M., Theoharatos, G., and Cartalis, C. (1997) Variations and trends in annual and seasonal air temperatures in Greece determined from ground and satellite measurements. Theoretical and Applied Climatology, 57(1-2), p.65-78.

17. Sahsamanoglou, H. S. and Makrogiannis, T. J. (1992) Temperature trends over the Mediterranean region, 1950–88. Theoretical and Applied Climatology, 45(3), p.183-192.
18. Sneyers, R. (1990) On the statistical analysis of series of observation.WMO Techn. Note, No 143, Geneva, p.192.
19. Wason, J. W., Dovciak, M., Beier, C. M. and Battles, J. J. (2017) Tree growth is more sensitive than species distributions to recent changes in climate and acidic deposition in the northeastern United States. Journal of applied ecology, 54(6), p.1648-1657.
20. WMO. (1986) Guidelines on the Quality Control of Surface Climatological Data. Geneva. WCP-85.