The Role of Orientation on Air Temperature Variation in a Mountainous Region of Greece

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Abstract. The paper investigates the effect of orientation on the air temperature (T) which prevails at different slopes of Aenos mountainous region on Cephalonia Island, Greece. T data were recorded during the period 2014-2016 at sites of similar altitude in north-northwest (NNW) and south-southeast (SSE) facing slopes of the Aenos Mt. range. The analysis of T data showed that the SSE facing slopes of Mt. Aenos range were significantly warmer than those with NNW orientation. The findings of the study could be exploited for the planning of agrotourism and biodiversity conservation activities.

Key words: air temperature, Aenos, Cephalonia Island, agrotourism.

Introduction

Topography affects in a great degree the microclimate because the sun delivers different quantities of heat to sloping and flat ground during the day (Geiger, 2003; Barry and Chorley, 2003: 134-145; Liang et al., 2006: 268-277). At day time hours, temperature and distribution of solar radiation inside the air layer near the ground surface are influenced particularly by slope angle and orientation (Barry, 2008: 128). At night, the cold air currents move from the mountains or hills to the valleys independently of aspect, causing different microclimates according to the zone of altitude (Barry, 2008: 129; Whiteman 2000).

Mountains are considered as physical barriers to moving air currents, and T decreases as altitude increases because mainly of the adiabatic cooling (Whiteman, 2000; San and Zhag, 2016). The T exchange between high elevation regions of mountains and lowlands contributes to the mechanisms of cloud formation. Thus, the atmospheric structure could also be affected by the local topography (Barry and Chorley, 2003: 134-145; Shen et al., 2016: 14,006-14,017).

In complex mountain environments slope and aspect contributed more to surface air temperature variations than others topographic factors such as latitude and longitude (Sun and Zhag, 2016: 621-632). The south-facing slopes of mountains receive more solar radiation and so, appear warmer than the northern slopes (Geiger et al., 2003; Barry, 2008: 176). Additionally, on the east-facing slopes solar radiation changes from the northern and southern slopes according to the angle and the time of the year (Geiger et al., 2003). However, during the course of the day the air layers near the ground are strongly warmed and so, the west- and southwest-facing slopes receive great amounts of solar radiation (Seeman, 1979: 125-130). Therefore, the thermal mosaic occurring in the complex mountain environments offers in the creation of plant habitats with different thermal preferences (Sherrer et. al., 2011: 645-654). Taking into account the aforementioned analysis, the present work addresses the role of orientation on the monthly and seasonal T variations on a mountainous area of great tourism importance in Greece.

Materials and Methods

Study area

This research was carried out within the island of Cephalonia (Municipulity of Argostoli, Periphery of Ionian Islands) in the western part of Greece during the period 2014-2016. The highest mountain (Mt.) of the Ionian island group, Aenos, is situated in the southestern part of the Cephalonia island with a northwestern to southeastern orientation (Kamoutsis, 2015: 73-87). This mountain range and the parts of the greater mountainous areas constitute Aenos National Park with an area of 28,620 Km^2 covered mainly by the *Abies cephalonica* Loudon (cephalonian fir) forests, an endemic species in Greece. The Park has been characterized as a European Biogenetic Reserve in the European Ecologic Network of Special Zones of "Natura 2000" (Kamari et al., 2015: 259-318). Two sites were selected of Aenos mountain Mt. (Mt.) range with a great ecological importance due to presence of endemic plant species populations. The first site, NNWs (38º 11´ 38.9˝ N, 020º 36´ 55.0˝ E, alt. 816 m) in the area within the core of the National Park of Aenos was located on the north-northwest (NNW) facing slope of Aenos Mountain (Mt.) range and the second one, SSEs (38º 06´ 44.4˝ N, 020º 42´ 34.6˝ E, alt. 877 m) was located on the south-southeast (SSE) facing slope of the aforementioned Mt. in the wider area of Aenos National Park.

The aspect, the altitude, the latitude and longitude of each site were evaluated using a mobile Global Positioning System (Garmin e Trex Vista) and then cross-checked against 1: 65000 topographic maps. The climate of the Aenos Mt. regions is classified as "Mesomediterranean with small, dry period" according to the UNESCO-FAO bioclimatic classification (Mavrommatis, 1980; Chronopoulou-Sereli and Flocas, 2010: 573).

Field instrumentation and air temperature data analysis

In each site T data were recorded every 10 minutes with meteorological instruments equipped sensors and dataloggers (Hobo Pro v2, U23001, Onset computer Corporation, USA, accuracy ± 0.2 ºC over 0 ºC to 50 ºC) from January 1, 2014 to December 31, 2016. The instruments before their installation in the sites were tested in the laboratory against appropriate sensors for five days. Also, every three months, the instruments were tested *in situ* with reference sensors in their locations. The tests revealed no shift errors for any of the sensors. They were enclosed in appropriate shelters screened from precipitation and direct solar radiation and mounded under selected trees at the height of 1.5 m above ground surface (Flocas, 1997: 234). The shape of these shelters allowed acceptable air ventilation.

To explore the monthly and seasonal variability in temperature at each study region over the study sites the daily, monthly, seasonal and annual temperature values were calculated during the period of 2014-2016. In order to compare the mean monthly temperature (MMT, ºC) values for the period of the aforementioned years between the two examined sites, NNWs and SSEs, analysis of Student's t-tests (Matsoukis et al., 2018a: 100-106; Matsoukis et al., 2018b: 261-267) were performed. Statistical analysis was carried out using the MS Excel 2007 and IBM SPSS statistics 23 at the significance level $p \leq 0.05$.

Results and Discussion

The annual mean air temperature (AMT, ºC) on SSEs site was 13.2 ºC during the three-year period of 2014-16. Notably, the AMT on the NNWs was lower by 0.9 ºC than the respective value on SSEs.

The analysis of the variation of monthly mean temperature (MMT, ºC) during the studied reference period (2014-2016) on both studied orientations of the Aenos Mt. range at the study sites showed seasonality throughout the year with higher and lower values

in the summer and winter months, respectively. Particularly, the monthly course of the air temperature (T) showed that the coldest month is January with 5.6 ºC and 5.2 ºC in the SSEs and NNWs, respectively (Fig. 1). Also, the hottest months were July and August with 22.5 ºC and 21.1 ºC, respectively, at the aforementioned sites.

The seasonal distribution of MMT revealed that the mean value of T in summer fluctuated from 20.1 ºC in NNWs to 21.4 ºC in the SSEs sites. Also, during the winter, the mean values of T were 5.6 ºC and 6.2 ºC at those sites, respectively. During the transition seasons (autumn and spring) T took intermediate values, while it is noted that the autumn was warmer than in the spring at both studied sites.

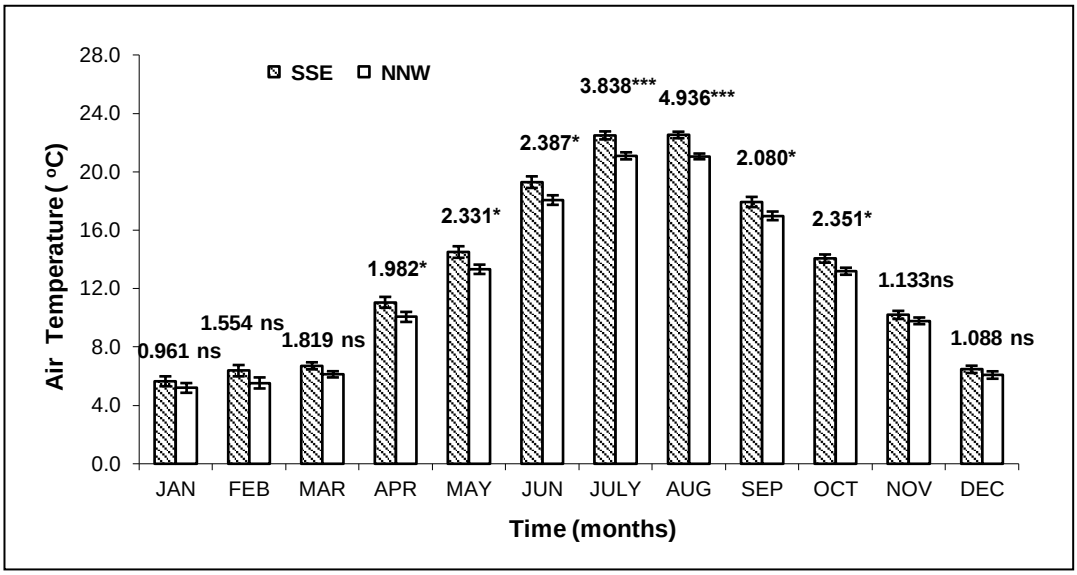

Fig. 1. Annual course of mean monthly temperature at the south-southeast (SSE) and north-northwest (NNW) facing slopes of Aenos mountain range in Cephalonia Island, Greece, during the period 2014-2016. In each column the vertical bar on it represents the standard error of the mean. ***, *: significant at $p \leq 0.001$ and $p \leq 0.05$, respectively. ns: not significant.

The comparisons of the MMT between the SSEs and NNWs sites, using the t-test technique, revealed significant changes during the period of April-October months (Fig. 1). Thus, SSE - facing slope was warmer than NNW during the aforementioned months period. It is well known that the T distribution over different slopes is influenced by the total amount of solar radiation received on their ground surfaces (Geiger et al., 2003). This parameter varies across the landscape because of the differing inclination and azimuth angles of mountain slopes as well as of the timing of sunrise and sunset, the day length, latitude and longitude. Generally, the total solar radiation amounts received in the southeast-facing slopes are higher than those of the northwest-facing slopes depending on the aforementioned topography parameters particularly, during the hot period of the year (Whiteman, 2000; Geiger et al., 2003). This results in different thermal conditions and, in general, to the variety of microclimates across the mountain slopes due to the complex terrain (Barry, 2008). However, there was an absence of the significance of MMT between two study sites during the rest period. So, we can suppose that “similar” thermal conditions dominated on the NNW and SSE - facing slopes of Aenos Mt. range in Cephalonia Island, Greece for each month of the cold period (from November to March). This fact could be attributed to the more frequent cloud cover and predominant precipitation in the mountainous zones compared to the lowland surrounding areas

(Barry, 2008: 177). For the rest of the period (April-October) where the cloud cover and precipitation are in general lower in Greece, in relation with the cold period (Chronopoulou-Sereli and Flocas, 2010: 75), significant changes of MMT were observed at the different orientation sites NNWs and SSEs of Aenos Mt. range.

Conclusion

In the present study significant air temperature changes were found at similar altitude sites with different orientation. Specifically, the south-southeast facing slopes of the Aenos mountainous range in Cephalonia Island, Greece were significantly warmer than those with north-northwest orientation during the April-October period. In this period, the visits from Greece and not only are extremely high in the National Park of Mt. Aenos. Having this in mind, the findings of this research could utilized for the planning of agrotourism activities that will improve in a high degree the economic development of the Cephalonia island. Also, useful information could be created from our findings regarding the biodiversity conservation in this important mountainous area in Greece.

Acknowledgement

Thanks are due to Dr. A. Chronopoulou-Sereli (Emeritus Professor, Agricultural University of Athens) and Dr. A. Matsoukis (Agricultural University of Athens) for their helpful comments.

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