Present and future projections of human-bioclimatic conditions over Peloponnese, based on regional climate model simulations

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The Peloponnese peninsula is the southernmost part of mainland Greece, characterized by a mountainous interior and deeply indented coasts. Such a region is of great interest due to the mosaic of microclimates appeared and thus, it constitutes a famous touristic destination. The objective of this study is to quantify the present and future human-bioclimatic conditions over Peloponnese, based on simulations by the RAMCO-2 (KNMI) regional climate model, concerning the near future 2031-2050 and the far future 2071-2100 with respect to the reference period 1961-1990, under A1B scenario. The assessment of human-bioclimatic conditions is carried out in terms of the Physiologically Equivalent Temperature (PET), which is one of the most popular physiological thermal indices derived from the human energy balance. The estimation of PET is based on gridded data sets of air temperature, relative humidity, wind speed and global solar radiation. The results interpret the spatial distribution of strong heat stress (PET>35^{o}C), strong cold stress (PET<8^{o}C) along with thermal comfort (18^{o}C<PET<23^{o}C) over Peloponnese, for the near and far future with respect to the reference period

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1 Introduction

Climate change on regional and local scale is of great concern that it would be a key factor in redesigning the touristic preferences with respect to traditional destinations, especially in the Mediterranean region, which is projected to appear high vulnerability due to extreme climatic conditions, such as heat waves and droughts (IPCC 2007). Weather and climate are important factors for tourism decision making (de Freitas 2003, Didaskalou et al. 2004). Besides, as the environmental impact is very extensive, the attempt to promote off-peak tourism to traditional or other destinations represents one way of reducing the pressure on the environment (Didaskalou and Nastos 2003). On the other hand, an extension or a shift of tourism period would be beneficial concerning the resilience and adaptation to global warming. The assessment of climatic tourism potential can be performed by facets of climate in tourism (thermal, aesthetical and physical facet) (de Freitas 2003). The thermal facet of climate is based on a complex thermal index, e.g., Physiologically Equivalent Temperature (PET), which is based on the human energy balance, while the other two facets, the aesthetical and physical, can be interpreted by simple and easy extracted parameters and factors, combined in a Climate-Tourism-Information-Scheme, which includes the most relevant and reliable parameters and tourism-climatological factors (Matzarakis 2007).

One of the famous touristic destinations in Greece is Peloponnese, which is a peninsula that covers an area of some 21549.6 square kilometers and constitutes the southernmost part of mainland Greece. The peninsula has a mountainous interior with deep gorges and rivers ending in jagged coastline and vast beaches. Peloponnese attracts thousands of tourists every year, who arrive to admire the large number and the wide variety of attractions offered: endless beaches, as well as mountainous tourist resorts make Peloponnese an ideal destination all year long.

The objective of this study is to quantify the present and future projections (SRES A1B) of human-bioclimatic conditions in terms of PET, in Peloponnese, based on the KNMI regional climate model simulations.

2 Data and Methodology

The human-bioclimatic conditions over Peloponnese were assessed using the thermal index PET. It is equivalent to the air temperature at which - in a typical indoor setting (without wind and solar radiation) - the heat balance of the human body (work metabolic rate 80 W of light activity, that should be added to the basic metabolic rate 86.5 W); heat resistance of clothing 0.9 clo, which is the reference clothing insulation value used for the formulation of PET) is maintained with core and skin temperatures equal to those of the under assessment conditions (Höppe 1999). The PET assessment scale is depicted in Table 1. The datasets required for PET analysis concern air temperature, relative humidity, wind speed and cloudiness, which are gridded values derived by the simulations of the RAMCO-2 (KNMI) regional climate model (for the near future 2031-2050 and the far future 2071-2100 with respect to the reference period 1961-1990, under A1B scenario. The present version of RACMO, version 2.1 (van Meijgaard et al. 2008), consists of the physics package of the global circulation model of the ECMWF (European Centre for Medium-Range Weather Forecasts) embedded in the dynamical kernel of the numerical weather prediction model HIRLAM (HIgh Resolution Limited Area Model). Recently RACMO has been identified as the best European regional climate model participating in the ENSEMBLES project.

For bioclimatic purposes the wind speed was adjusted according to the following formula (Kuttler 2000):

$$WS_{1.1} = WS_h * (1.1/h)^{\alpha} \quad \alpha = 0.12 * z_0 + 0.18$$

where WS_h is the wind speed (m s^{-1}) at the anemometer height (h, usually 10 m a.g.l.), α is an empirical exponent, depending on the surface roughness, and z_0 is the roughness length. Wind velocity was estimated at 1.1 m, which is the center of gravity of the human body and builds

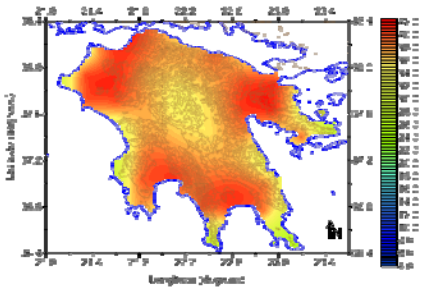
the reference level for human biometeorological studies. PET was calculated using "RayMan" model, appropriate to calculate radiative heat transfer and human biometeorological indices (Matzarakis et al. 2010).

Table 1. Physiological Equivalent Temperature (PET) for different grades of thermal sensation and physiological stress on human beings (Matzarakis et al. 1999)

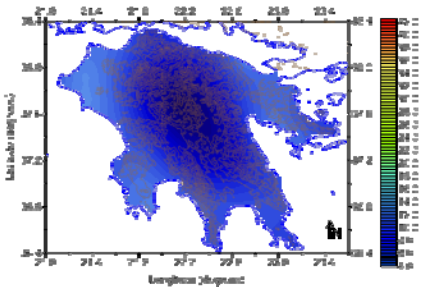
PET (°C)	Thermal sensation	Physiological stress level
<4	very cold	extreme cold stress
4-8	cold	strong cold stress
8-13	cool	moderate cold stress
13-18	slightly cool	slight cold stress
18-23	comfortable	no thermal stress
23-29	slightly warm	slight heat stress
29-35	warm	moderate heat stress
35-41	hot	strong heat stress
>41	very hot	extreme heat stress

3 Results and Discussion

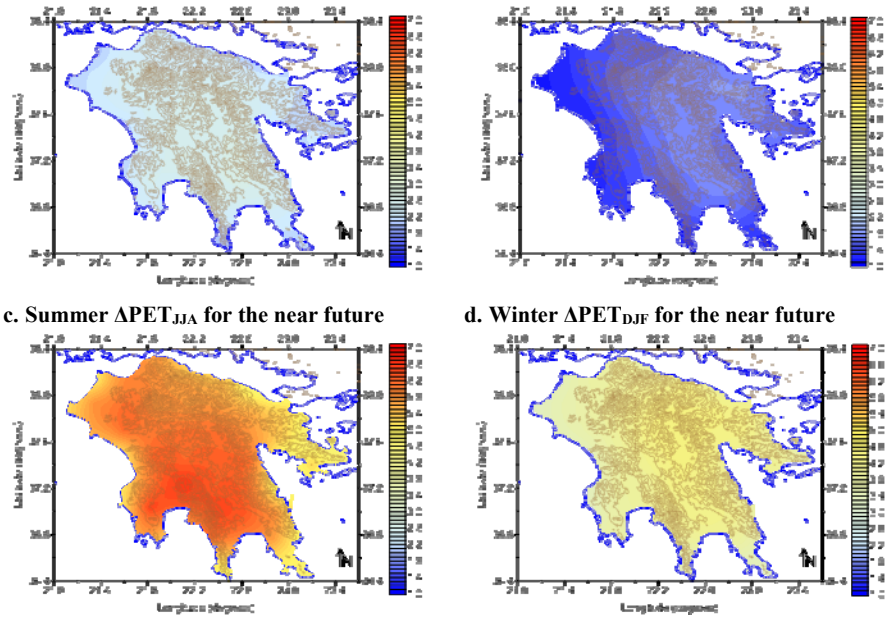
The spatial patterns of the simulated summer PET_{JJA} values over Peloponnese appear in Figure 1a. As far as the reference period is concerned, PET_{JJA} ranges between lower values (<36 ^{o}C) over central mountainous regions against higher values (38 ^{o}C – 42 ^{o}C) over NW plains, south coastal areas (Messinia, Lakonia) and NE regions (Argolida, Korinthia). The increase of PET_{JJA} in the near future is projected to be 2.1 ^{o}C over the coastal zone against 2.6 ^{o}C in the continental interior of Peloponnese (Fig. 1c). Higher increase will take place for the projections in the far future (Fig. 1e); namely 4.8 ^{o}C for the eastern and 5.2 ^{o}C for the western coastal areas and above 6.4 ^{o}C over south mountainous region (Taygetos Mt). Within the reference period, winter PET_{DJF} appear to be less than 6 ^{o}C over central highlands, increasing towards the coast, reaching 14 ^{o}C at the NW and SW coastal zone against 12 ^{o}C over the highlands of Korinthia and Argolida in the east (Fig.1b). The increase of PET_{DJF} in the near future is projected to be lower in the western parts (<1.3 ^{o}C) against 1.7 ^{o}C – 1.8 ^{o}C over central mountainous regions (Fig. 1d). The simulated pattern appears a longitudinal gradient from west to east. Higher increase will take place for the projections in the far future; namely more than 4.3 ^{o}C for central mountainous areas against less than 3.6 ^{o}C over west and south coasts (Figure 1f). The PET_{DJF} isolines follow the respective altitude contours



a. Summer PET_{JJA} for the reference period



b. Winter PET_{DJF} for the reference period



c. Summer ΔPET_{JJA} for the near future **d. Winter ΔPET_{DJF} for the near future**

e. Summer ΔPET_{JJA} for the far future **f. Winter ΔPET_{DJF} for the far future**

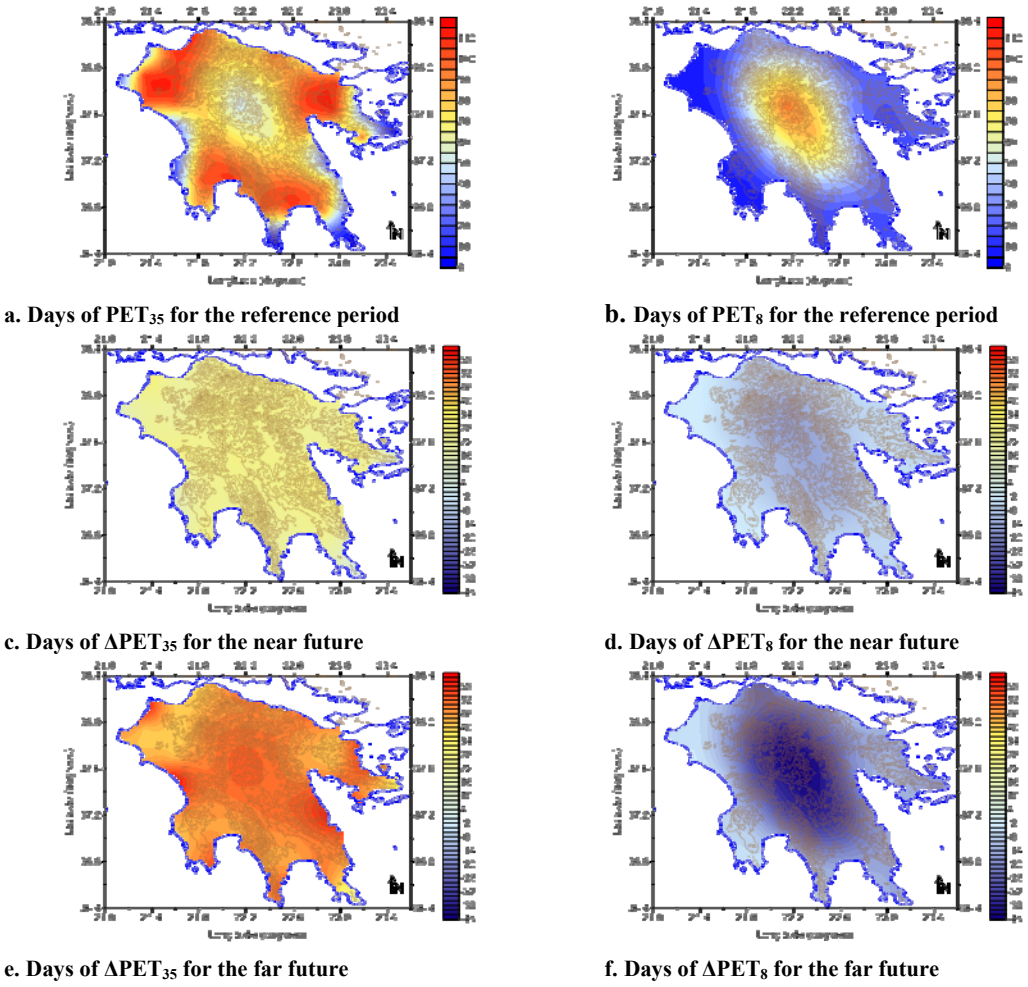
Fig. 1. Spatial distribution of summer (left graphs) and winter (right graphs) PET values for the reference period 1961-1990 along with the projected changes in the near future (2031-2050) and far future (2071-2100), from the reference period.

Strong to extreme heat/cold stress patterns over Peloponnese appear in Figure 2, in terms of number of days with PET>35°C (PET_{35}) and PET<8°C (PET_8), respectively. Within the reference period, high PET_{35} values (>100 days) are simulated over NW, NE and S regions against lower values (<60 days) over central highlands (Fig, 2a). The increase of PET_{35} in the near future is projected to be more than 25 days over the mountainous interior compared to less increase (<16 days) over the coastal regions, due to beneficial impact of sea breeze during summer (Fig. 2c). Higher increase will take place for the projections in the far future; namely more than 50 days appear over central mountainous areas and in some cases at west (Kyparissia Gulf) and east (Leonidio Gulf) coastal regions (>56 days) and at north-west parts of Peloponnese (Argolida; >52 days), as well (Fig. 2e). These findings indicate a complex spatial distribution of increases in PET_{35} for the far future projections.

As far as PET_8 is concerned, strong to extreme cold conditions illustrate an opposite pattern from that of PET_{35}, within the reference period (Fig. 2b). Specifically, PET_8 increases from the west coasts (<10 days) towards central mountainous regions (>90 days). Further, higher PET_8 values (20-25 days) appear at the south and east coastal regions, which are affected more by the northerly cold winds during winter, against western parts, which are protected by the high mountain ranges across Peloponnese. The western coastal regions are influenced more by the warm sectors of depressions coming from the west. The decrease of PET_8 in the near future is projected to be more than 15 days over the continental interior, against less decrease at west (<5 days) and east (<7 days) parts of Peloponnese (Fig. 2d). Higher decrease will take place for the projections in the far future; namely the decrease is simulated to be less than 8 days at the west and 16 days at east regions, towards more than 40 days over central highlands (Fig. 2f).

The number of days with comfortable conditions (18°C<PET<23°C; PET_{18-23}) range from 54 days at coastal areas to less than 40 days over central mountainous regions (not shown). The model simulations for the near future indicate a complex pattern with respect to PET_{18-23}. A decrease of comfortable conditions is projected over the continental mountainous interior of Peloponnese against an increase of almost 2 days at NW parts and 3-4 days at the east (Korinthia, Argolida). The projected decrease of comfortable conditions is more pronounced than the increase (not shown). On the contrary, slight increases in PET_{18-23} are depicted over the majority of Peloponnese, with respect to the far future (not shown). Thus, the comfortable

conditions seem to increase over NW parts (6-9 days), east coastal zones (7-10 days) and south coastal region of Messinia (7-9 days), against lower values (<3 days) over continental highlands in the interior of Peloponnese.



a. Days of PET_{35} for the reference period

b. Days of PET_{8} for the reference period

c. Days of ΔPET_{35} for the near future

d. Days of ΔPET_{8} for the near future

e. Days of ΔPET_{35} for the far future

f. Days of ΔPET_{8} for the far future

Fig. 2. Spatial distribution of days with PET>35 °C (left graphs) and PET<8 °C (right graphs) for the reference period 1961-1990 along with the projected changes in the near future (2031-2050) and far future (2071-2100), from the reference period.

It is known that tourism, especially summer tourism, can be described by the Triple S (Sun, Sea and Sand), configured mainly by weather and climate. An additional factor that could be added to the triple S, or used as single winter S, is snow, the main decision factor for winter tourism (Matzarakis 2006). Peloponnese largely satisfies the criteria of triple S and the additional factor of snow, as well. The findings of this study suggest that, due to the mosaic of microclimates appeared in the diverse terrain of Peloponnese, the impacts of climate change on tourism potential could be easily mitigated by an extension of the touristic period (mainly in summer) towards cold period, when mild conditions are projected in the future. Similarly, Matzarakis and Nastos (2011) studying the tourism potential in Crete Island, Greece, concluded that the natural tourism potential is high and, thus, an extension of the tourism period is possible. The mild periods of the year are suitable for wellness and cultural tourism of specific population groups and, therefore, contribute to the extension of Crete's tourism period.

Further research is needed in order to simulate better the thermal human bioclimatic conditions and the consequential tourism potential in Peloponnese. Thus, the future simulations of thermal indices by an ensemble of regional climate models could further substantiate the view put forward by the authors of this study.

Conclusions

Tourism potential is in close relation with the present and future projected human bioclimatic conditions, in terms of thermal indices. Results showed that Peloponnese, a region of great touristic interest due to the mosaic of microclimates appeared, shows favorable human bioclimatic conditions, which are expected to be influenced by the oncoming climate change. Nevertheless, the impacts of climate change on tourism could be mitigated by an extension of the touristic period towards the cold season, when mild conditions are future projected, in order to achieve the resilience of the society.

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