

Application of a Bioclimatic Index for Evaluating the Attractiveness of Two Highly Touristic Beaches in Santorini and Kos

CHATZIPAVLIS A.*¹, MONIOUDI I.N.¹, VELEGRAKIS A.F.¹, CHALAZAS T.¹, CHATZISTRATIS D.¹

¹ Department of Marine Sciences, University of the Aegean, University Hill, 81100 Mytilene, Greece

*corresponding author:

e-mail: a.chatzipavlis@aegean.gr

Abstract Beaches have a high hedonic value and economic potential; they are pillars of tourism which has been increasingly associated with vacationing wholly, or partially, at coastal locations and beach recreational activities according to the 3S (Sun, Sea and Sand) touristic model. The visitor's satisfaction and the attractiveness of a beach depends on several climatic factors such as temperature (i.e. thermal sensation index - PET), wind, cloudiness and rain. Future changes in the climatic conditions under Climate Change, such as temperature increases (and corresponding thermal discomfort) can affect the attractiveness of the beaches. A specialized bioclimatic index (the Climate Index for Tourism – CIT) was used in order to: (a) assess the ideal climate conditions for a tourist to visit the beach; and ii) evaluate the present and future attractiveness of the island 3S destinations of Kos and Santorini, as a touristic product..

Keywords: CIT, PET, Tourist Satisfaction, Tourism and Climate Change

1. Introduction

Beaches are the focus of the 3S (Sun-Sea-Sand) touristic model, a most significant sector of the touristic industry, currently the 3rd largest economic activity and one of the fastest growing sectors of global economy (WTTC, 2022). In Greece tourism is the main pillar of the national economy, accounting directly for 18% of the country's GDP and employing more than 900,000 people, which is equivalent to 20% of the total workforce (SETE, 2023). Furthermore, the number of international tourist arrivals almost doubled in less than a decade (from 15,000,000 in 2012 to about 30,000,000 in 2020), with 89.5% of total arrivals occurring during the period April - October and 70.0% between June - September (ALPHA BANK, 2021).

However, coastal 3S tourism is threatened by changes in the environmental conditions and climate disruptions. Future projections suggest that climate change will significantly impact coastal ecosystems and infrastructure/assets by experiencing severe flooding and erosion (IPCC, 2023), which will eventually lead to the

reduction of the beach carrying capacity (i.e. the number of beach visitors that can be hosted simultaneously at a beach). At the same time, changes in the meteorological conditions (i.e. temperature, wind, cloudiness and precipitation) are expected to alter the preferences of beach visitors and modify their choices for a holiday destination (Matzarakis et al., 2007). It is suggested, that the effective and sustainable design of development plans in 3S destinations should incorporate projections of the future environmental and climate conditions.

In this work, the attractiveness of two highly touristic island destinations (Kos and Santorini) in terms of the ideal climate conditions/human sensation is assessed with the use of the thermal sensation PET index and the Climate Index for Tourism (CIT – De Freitas, 2008), on the basis of current and future projections of the climate conditions.

2. Methodology

An Hourly meteorological records of temperature, cloudiness, precipitation and wind velocity were provided from the Hellenic National Meteorological Service (HNMS) for the last available annual period of 2019 - 2022. The meteorological data were used to assess the current bio-climatic state/conditions of Kos and Santorini. Monthly means have been estimated for the last available year (2022) and for the period of the touristic season (April - October), which have been compared with monthly projections of the reference years 2050 and 2100, extracted the Copernicus ERA5 e-database (<https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview>) and the Royal Netherlands Meteorological Institute (KNMI) (http://climexp.knmi.nl/selectfield_cmip5.cgi?id=someone@somewhere#surface). Due to the great uncertainties in the projection of future wind, the records of the last available year (2022) were also included as input data in the projected dataset for the years 2050 and 2100.

More specifically, the hourly data recorded from the HNMS meteorological stations were converted to daily means by taking into account the average values during the

hours of high touristic demand (11.00 - 16.00) for visiting a beach. Temperature, cloudiness, humidity and wind velocity records were used to estimate the thermal sensation index, PET (Physiologically Equivalent Temperature) with the use of the RayMan model (Matzarakis et al., 2007) that takes into account an internal

heat production of 80 Watt, (due to human activity of a person with height of 1.75 m, weighting 75 kg and with metabolism rate of $45\text{W}/\text{m}^2 \approx 0.8$ Met and mean body area of 1.8m^2) and thermal clothing resistance of $0.9 \text{clo} \approx 0.14 \text{m}^2 \cdot \text{K}/\text{Watt}$ (ASHRAE, 2004).

PET (°C) [T]	ASHRAE scale [TSN] [T]	Cloud Cover ($\leq 40\%$) [A]	Cloud Cover ($\geq 50\%$) [A]	Rain (>3mm or >1hr duration) [P]	Wind (>6m/s at ground) [P]
38+	Very hot (+4)	4	3	2	3
32-38	Hot (+3)	6	5	2	4
27-32	Warm (+2)	7	5	2	4
23-27	Slightly warm (+1)	8	4	1	4
17-23	Indifferent (0)	5	3	1	2
13-17	Slightly cool (-1)	4	3	1	2
10-13	Cool (-2)				
6-10	Cold (-3)				
6-	Very cold (-4)				

Figure 1. Score and scale of the PET and CIT index (modified from De Freitas, 2008).

The climate satisfaction/comfort of the beach visitor was evaluated with the use of Climate Index for Tourism (CIT) who consists of 3 main variables: i) Thermal (T), Aesthetic (A) and Physical (P) that combine into a range of worse-ideal human conditions as $\text{CIT} = f[(T,A)*P]$ (Figure 1). The Thermal (T) variable, depicts the human energy equilibrium and was identified with the use of the PET thermal sensation index that takes into account the thermal stress levels of the ASHRAE scale (ASHRAE, 2004): Temperature ranges between -4 (Very Cold) to +4 (Very Hot). The Aesthetic (A) variable is estimated from the cloudiness level (ranging from 0% clear sky to 100% - full cloud coverage), whereas Physical (A) variable is estimated from the precipitation and wind velocity records (ranging from a scale between 1-4). As “Ideal” climate

conditions are considered those that reflect slight thermal stress (equivalent to 23-27 °C, PET) and slight cloudiness (sky coverage $\leq 40\%$).

3. Results

When examining the distribution of PET sensation index during the touristic season, it is evident that the prevailing values are those of the ideal conditions of a 3S destination (27-32 °C) for both Kos and Santorini (Figure 2a and 2b). During this period, PET values smaller than 13 °C were found to be minor while the amount of very warm (32-38°C) and hot days (> 38 °C) were found to be more in Kos than Santorini.

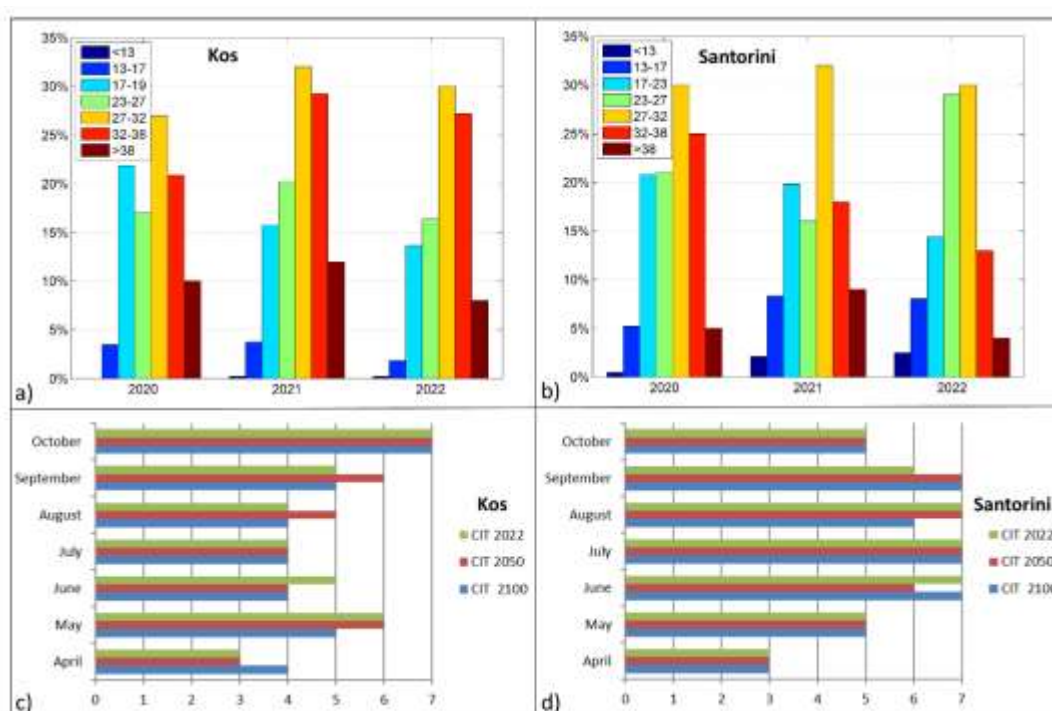


Figure 2. a) and b) Annual distributions of the PET thermal sensation index temperature range, during the touristic season (April–October) for the period 2020–2022 in Kos and Mykonos; c) and d) Monthly distribution of the CIT index for 2022, 2050 and 2100 in Kos and Mykonos.

CIT values were found to be greater than 4 during the period between June – September, which is also the period of high demand (70% of international tourist arrivals). Despite the uncertainties in model projections concerning the future climate, it seems that the CIT index will not show

substantial differentiations in the reference future years of 2050 and 2100 compared to 2022. A slight increase by 1 point is evident for the period June–September for Santorini, and for the months May and September for Kos (Figure 2c and 2d)

4. Conclusions

Results are very encouraging for the touristic product of the two islands, on the basis of the future climate projections. According to the analysis, it is evident that both the thermal sensation PET index and the climate index for tourism (CIT) will not be affected significantly in the future. A slight increase of the CIT index is projected for

specific months during the touristic season for both islands, which is expected to enhance the attractiveness of Kos and Santorini as 3S destinations. However, and despite the uncertainties that characterize model projections for future climate, it has to be noted that the attractiveness of a 3S destination is dependent from other important environmental factors such as beach erosion, which is expected to reduce the beach carrying capacity.

Acknowledgements

This research was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the “2nd Call for H.F.R.I. Research Projects to support Post-Doctoral Researchers” (Project Number: 211).

References

- ASHRAE, (2004). Thermal Environmental Conditions for Human Occupancy. American Society of Heating and Air-Conditioning Engineers (ASHRAE) Report No. 54, 42 pp., ASHRAE Inc., Atlanta, GA, USA
- ALPHA BANK, (2021). Greece: Economic and Financial Outlook. Alpha Bank, Economic Research Division, 9 pp. (available at https://www.alpha.gr/-/media/alphagr/files/group/agores/greece-economic-and-financial-outlook/greece_efo_september2021.pdf)
- De Freitas, C.R., Scott, D. and McBoyle, G., 2008. A second generation climate index for tourism (CIT): specification and verification, *International Journal of Biometeorology*, 52, pp. 399–407, doi: 10.1007/s00484-007-0134-3
- IPCC, (2023), Sixth Assessment Report (AR6) “Climate Change 2023”, Intergovernmental Panel for Climate Change (IPCC), 86 pp.
- Matzarakis A., De Freitas C.R. and Scott D. (2007). Assessment Method for Climate and Tourism Based on Daily Data, *Developments in Tourism Climatology*, 52–58.
- SETE, (2023). Employment in Accommodation, Restaurants and Rest Sectors of Greek Economy, 2013–2022, Greek Tourism Confederation (SETE), 34 pp. (available at https://insete.gr/wp-content/uploads/2023/05/23_05_Employment_2013-2022-1.pdf).
- WTTC, (2022), Travel & Tourism Economic Impact Global Trends 2022, World Travel & Tourism Council (WTCC), United Kingdom.