ASSESSMENT METHOD FOR CLIMATE AND TOURISM BASED ON DAILY DATA

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ABSTRACT The described method allows the integration of weather and climate for tourism and recreation issues as it implements several factors and facets, like thermal (a.e. physiologically equivalent temperature), physical (a.e. precipitation and wind) and aesthetical (a.e. sunshine duration and cloud cover). Spliting up the months into three periods, which represent more accurately the vacation times, provides more reliable information for tourism and recreation. Additionally, detailed information about extreme events can be given through the use of frequencies of classes and amounts of threshold values.

KEYWORDS: *Tourism, climatology, Climate-Tourism Index*

INTRODUCTION

Existing methods for the evaluation of climate for tourism purposes are based on mean monthly values, and climate indices consider only basic climate elements, a.e. air temperature, air humidity or precipitation (Mieczkowski, 1985, Abegg, 1996, Matzarakis and de Freitas, 2001, Matzarakis et al., 2004). The climate indices do not have a thermo-physiological relevance nor do they provide information about frequencies of classes or extreme events. Additionally, they do not offer high temporal resolution. The existing indices do not cover all relevant and important parameters and facets (de Freitas, 2003, Matzarakis and de Freitas, 2005). New approaches for the development include the diverse facets of climate for tourism and a subject of research (de Freitas, 2003, Matzarakis et al., 2007, Matzarakis, 2007).

METHODS AND DATA

In the past, tourism climatology information was provided through climate indices such as those found in applied climatology and humanbiometeorology. There are more than 200 climate indices. In general, the tourism climate indices can be classified into three categories (after Abegg, 1996). Elementary indices are synthetic values that do not have any thermo-physiological relevance and are generally unproven. The bioclimatic and combined tourism climate indices involve more than one climatological parameter and consider the combined effects of them.

An example of a combined index is the Tourism Climate Index (TCI). Developed by Mieczkowski (1985) the TCI uses a combination of seven parameters, three of which are independent and two in a bioclimatic combination (Eq. 1).

$$TCI = 8 * Cld + 2 * Cla + 4 * R + 4 * S + 2 * W \qquad (1)$$

Where Cld is a daytime comfort index, consisting of the mean maximum air temperature $T_{a,max}$ (°C) and the mean minimum relative humidity RH (%), Cla is the daily comfort index, consisting of the mean air temperature (°C) and the mean relative humidity (%), R is the precipitation (mm), S is the daily sunshine duration (h), and W is the mean wind speed (m/s). In contrast to other climate indices, every contributing parameter is assessed. Because of a weighting factor (a value for TCI of 100), every factor can reach 5 points. TCI values >= 80 are excellent, while values between 60 and 79 are regarded as good to very good. Lower values (40 – 59) are acceptable, but values < 40 indicate bad or difficult conditions for tourism (Abetz, 1996; Mieczkowski, 1985).

The climatic indices shown have a number of weaknesses. From a climatology point of view, they do not include the effects of short and long wave radiation fluxes, since they are generally not included in climatic records. The required short and long wave radiation fluxes are calculated using synoptic data and theoretical calculations from astronomical data (VDI, 1998; Matzarakis et al., 2007). A full application of thermal indices on the energy balance of the human body gives detailed information about the effect of the thermal environment on humans (VDI, 1998). Common applications are PMV (Predicted Mean Vote), PET (Physiologically Equivalent Temperature), SET* (Standard Effective Temperature) and Perceived Temperature pT (in Matzarakis, 2006). All those thermal indices are well documented and include important meteorological and thermo-physiological parameters (Matzarakis, 2007).

The advantage of these thermal indices is that they all require the same meteorological input parameters: air temperature, air humidity, wind speed, short and long wave radiation fluxes. In table 4, threshold values of the thermal indices Predicted Mean Vote (PMV) and Physiologically Equivalent Temperature (PET) are explained for different levels of thermal sensitivity and physiological stress on humans. Internal heat production: 80 W, heat transfer resistance of clothing: 0.9 clo (according to Matzarakis and Mayer, 1996) giving a possibility to access the thermal environment of humans (Tab. 4). The thermal environment of humans can be altered by parameters such as 'Internal heat production' (e.g. 80 W) and 'Heat transfer resistance of clothing' (e.g. 0.9 clo).

Based on recent findings (de Freitas, 2003; Matzarakis et al., 2004; Matzarakis, 2006) the following scheme was developed. The presented method considers thermal/human-biometeorological, physical and aesthetical facets, which include most factors and parameters for the description of climate in tourism (de Freitas, 2003; Matzarakis, 2006).

The following factors are considered in detail:

a) Basic and available parameters (air temperature, air humidity, wind speed, precipitation) on daily basis,
b) High temporal resoluted information in decades (separation of months in three intervals),
c) Analysis of climatological and human-biometeorological conditions based on frequency classes and threshold values,
d) Consideration of thermal comfort, heat stress, cold stress and "sultriness" based on human-biometeorological thresholds and human energy balance i.e. PET,
e) Consideration of precipitation and its amount and type i.e. snow cover, dry days or wet days,
f) Consideration of fog and sunshine/cloudiness conditions,
g) Consideration of high wind conditions.

In the following section the climate-tourism analysis is outlined and some examples for Heraklion in Crete/Greece are given.

RESULTS AND EXAMPLES

The results presented here are based on an analysis of daily data from the station Heraklion of the Hellenic National Weather Service for the period 1951 to 2011. Classical analysis of monthly means and frequencies was performed but results are not presented here (Matzarakis et al., 2005). In Fig. 1 the temporal development of physiologically equivalent temperature of the annual, seasonal and tourism period (April to October) is shown for the period 1955 – 2001. Fig. 2 contains the temporal development of the annual precipitation sum and the amount of days (precipitation higher than 1 mm). On the one side, detailed information (Fig. 1 and 2) about the temporal development and the annual variability of important climate variables can be extracted. On the other side, these graphs do not allow conclusions about frequencies and extreme events.

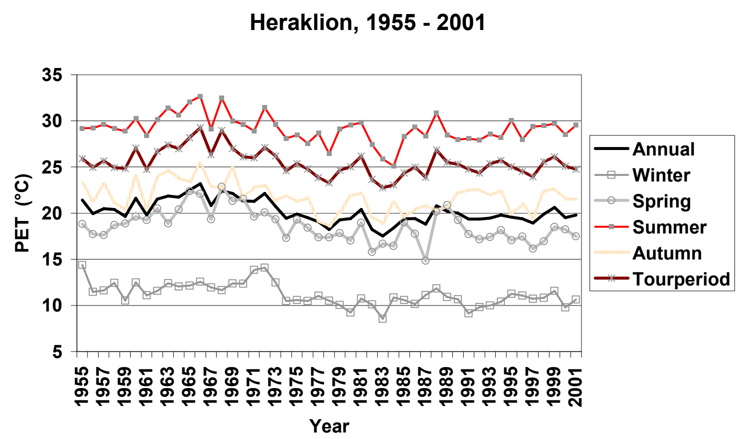

Figure 1: Seasonal, annual and tourism period (April to October) development of PET for Heraklion, Crete for the period 1955 – 2001

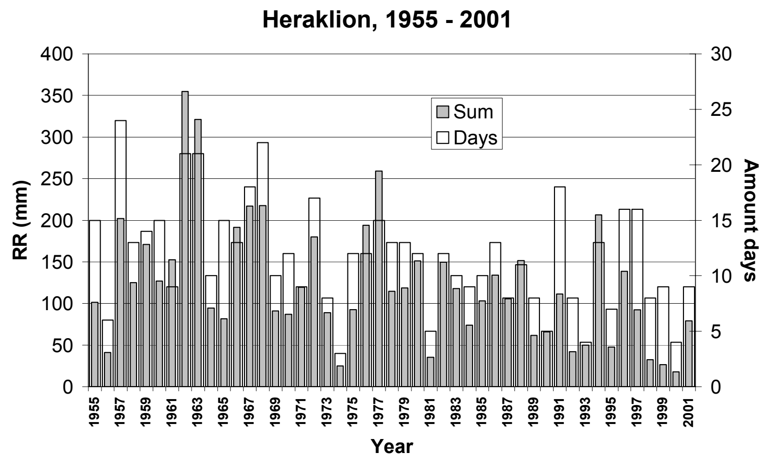

Figure 2: Sum of precipitation in mm and amount of days with precipitation (> 1 mm) for April to October in Heraklion for the period 1955 - 2001

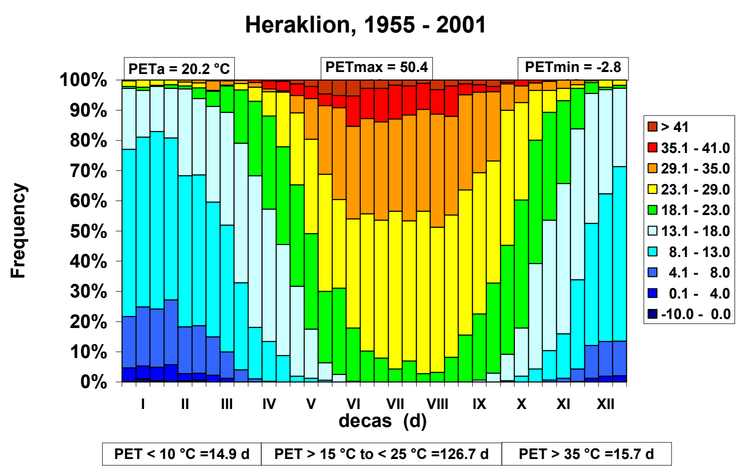

Figure 3: Frequency distribution of PET-classes (Bioclimate diagram) for Heraklion, Crete for the period 1955 – 2001

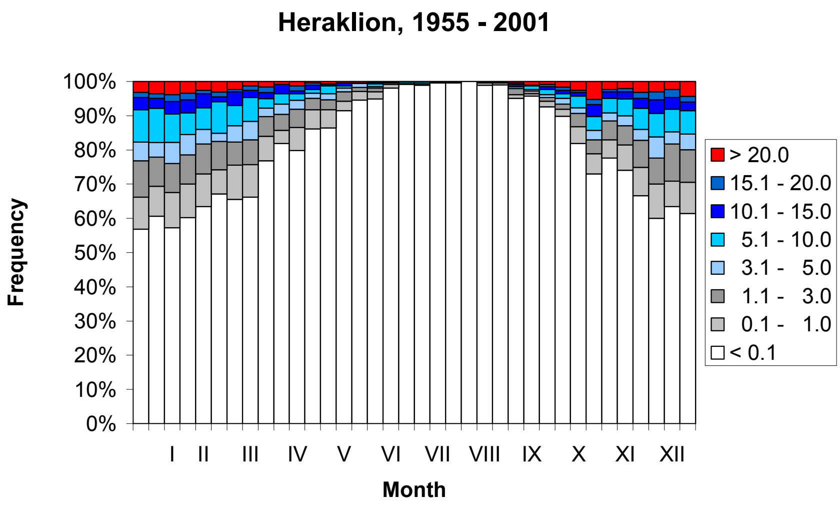

Figure 4: Frequency distribution of precipitation for Heraklion, Crete for the period 1955 – 2001

Fig. 3 and 4 show another relevant way how information based on frequencies of classes can be presented. In Fig. 3 and 4, the months are separated into three intervals in order to get a more detailed picture of the climate conditions of the year. A more detailed description can be presented when the classes of climate paramters a.e. PET (Fig. 3) or precipitation (Fig. 4) are considered according to human-biometorological and climatological threshold values. The diagrams not only show the frequency classes but also the maxima, minima and mean conditions. The indication of threshold classes of thermal comfort classes and heat/cold stress conditions can also be applied. In a similar way the precipitation conditions can be shown using frequency classes that go from no to less to high precipitation or may use other threshold values.

Another possibility, which allows a more detailed description of climate in tourism, are the Climate-Tourism-Information-Schemes (CTIS) (Matzarakis, 2007). The CTIS are based on the frequency distributions of parameters and values (see Fig. 3 and 4). Relevant and important bioclimatological and climatological parameters are integrated in this scheme and shown in percentages of occurrence or not occurrence. Additionally, the frequency of extreme events is or can be implemented. The inclusion of parameters depends on whether or not they are important for a particular region in a seasonal or annual manner.

For Heraklion the following threshold criteria have been choosen:

- Thermal acceptance (PET between18 °C and 29 °C)
- Heat stress (PET > 35 °C),
- Cold stress (PET < 8 °C),
- Cloudy (> 5 octas),
- Fogy (based on relative humidity > 93 %),

- „Sultriness“ (based on vapour pressure > 18 hPa),
- Dray (precipitation < 1 mm),
- Wet (precipitation > 5 mm),
- Windy (wind speed > 8 m/s).

In Fig. 5 the CTIS, which include the several facets of climate in tourism (de Freitas, 2003, Matzarakis, 2006) are shown. Several values and parameters are illustrated, for which data exist or can easily be calculated. All parameters used, except precipitation, also build the input parameters for the calculation of thermal comfort indices in the CTIS (Matzarakis, 2006, Matzarakis and Rutz, 2005, Matzarakis et al., 1999, 2005, 2007, VDI, 1998).

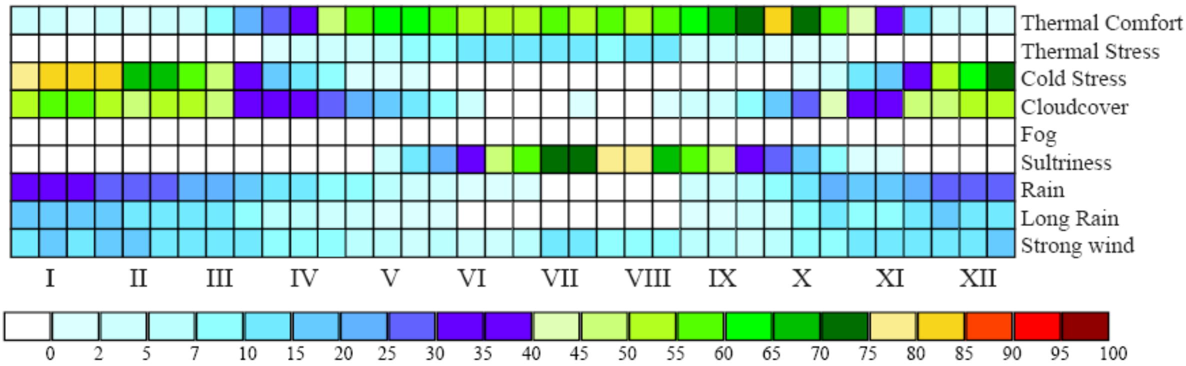

Figure 5: Climate-Tourism-Information-Scheme for Heraklion, Crete for the period 1955 – 2001

CONCLUSIONS

The presented approach for the integration of climate information in tourism has several advantages. The separation of the months into three intervals (weeks are also possible) allows a higher than monthly resolution. The use of frequencies of climate and human-biometeorological values and variables based on several facets of climate in tourism is an easyly understandable and all-embracing possibility. Depending on specific regions or specific tourism uses, it is possible to also include other parameters like days with frost in the analysis; or to reduce the number of parameters as, for example, no information on snow conditions is required for summer regions (i.e. Mediterranean). Another advantage is that the CTIS can be used for tourism all year round, as they use the implementation of several facets of climate and tourism. The separated presentation and implementation of individual factors and facets allows the CTIS to provide a detailed description including information on different uses in tourism climatology.

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