THERMAL HUMAN BIOCLIMATIC CONDITIONS FOR AUSTRIA AND THE ALPS

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Abstract: Daily measurements and observations at numerous times of air temperature, relative humidity, wind velocity and mean cloud cover are the required data for the calculation of the Physiological Equivalent Temperature PET. PET represents a thermal index, which is based on the human energy balance of the human body, for the description of the effect of the thermal environment on humans. We analysed the thermal human bioclimate in Austria using the data from the dense climate network with daily measurements and observations at 7, 14 and 19 LST of 201 stations covering the period 1991 to 2000 as input to compute PET. The results were compared with the outcome of the computation using the synoptic data not only from Austria but also from the surrounding countries and the Alps region. The obtained results give fundamental information often demanded by the tourism and recreation authorities.

Keywords *– Physiological Equivalent Temperature, Bioclimate, Austria, Alps*

1. INTRODUCTION

The thermal bioclimate is of high interest for decision makers in the public health and recreation sector as well as for the population in general. Existing descriptions of the thermal human bioclimate was "simple thermal indices", with the major disadvantage that they do not take into account the extensive interactions of all meteorological parameters affecting the thermophysiology of humans. Originally simple climatic indices were used for assessments of climate change issues and thermal comfort studies, e.g. heat stress index, Discomfort Index (Thom, 1959) or Wind-chill index (Steadman, 1971). In terms of the climate change discussion the bioclimate can be also seen from other view of points. As example which areas are suffering more during extreme events a.e. heat waves. How can negative effects on humans be avoided without extensive measures. Are the mountainous areas of the Alps a possible solution or offer they an escape from heat stress ?

2. METHODS

In generally concerning thermal comfort, the human organism is influenced by radiant fluxes, air temperature, water vapour pressure, and wind velocity, which are part of the human energy balance equation as physiological parameters (weight, size, activity, sex, age) and clothing too. Modern thermal indices such as the Predicted Mean Vote (PMV) of Fanger (1972), or one of the latest thermal indices, the Physiologically Equivalent Temperature (PET) (VDI, 1998; Höppe, 1999) are applicable to outdoor situations.
Using the Celsius scale instead of PMV or similar indices makes the results much more easily understandable and applicable for the public.

Using the data from the Austrian climatic network (Figure 1) and the synoptic observations for a larger area bioclimatic maps have been created. The number of climate stations (201) is much lower than the synoptic one (278) and, therefore, has an excellent spatial coverage. Climatic observations are undertaken at 7, 14 and 19 LST, synoptic ones at 6, 12 and 18 UTC. The meteorological elements air temperature T_a, relative air humidity RH, wind velocity v and mean cloud cover c are the necessary input for the calculation of PET. The mean radiant temperature can be calculated by combining the theoretical maximum global radiation and the mean cloud cover within the radiation and bioclimate model 'RayMan' (Matzarakis et al., 2000).

A statistical model was used for the generation of spatially detailed bioclimatic data. The applied multiple regression equation has demonstrated its suitability in former studies (see Jendritzky et al., 1990; Matzarakis (1995) and Matzarakis et al. (1999)). PET is the dependent variable and independent predictors are latitude, longitude, elevation above mean sea level, exposition and land use, respectively.

3. RESULTS

The applied linear regression model calculates the corresponding PET value for each grid cell (raster layer with cells or vector layer with points) based on the digital terrain model. The application of an interpolation method allows the creation of maps for monthly mean PET-values at 7, 14, and 19 CET and of maps with the number of days with PET above or below a certain threshold. The coefficient of determination r^2 varies for the different months between 0.75 (January and February) and a maximum 0.9 in May. An additional analysis using synoptic data for 6, 12 and 18 UTC from a larger area (not shown here) has also been carried out. The comparison of the synoptic and climate-based station data (Fig. 1) and corresponding maps shows that the differences are small and explainable (Zygmuntowski, 2004).

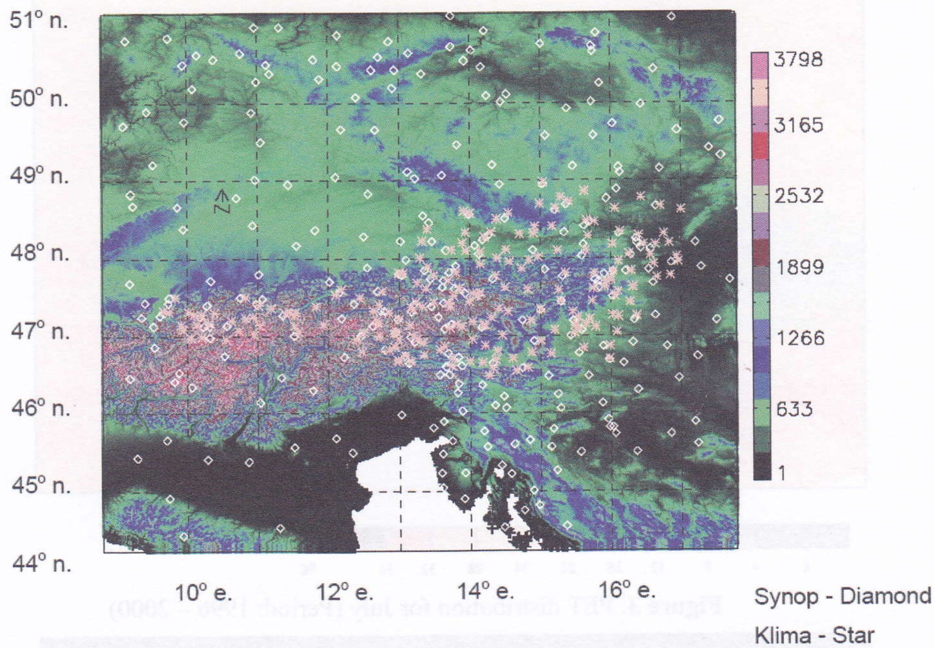

Figure 1. Digital terrain model and distribution of synoptic and climate stations used for the PET calculations

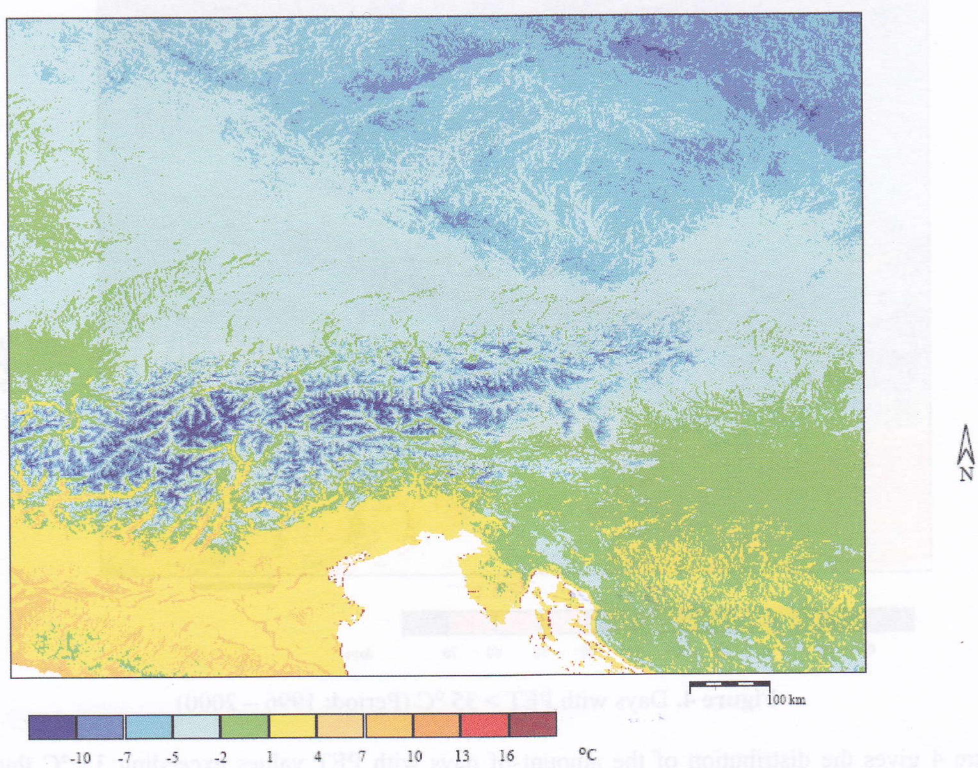

Figure 2. PET distribution for January (Period: 1996 – 2000)

In figure 2, the geographical distribution of the PET values for January at 14 CET are shown. The values ranges from lower than –10 °C on the high areas of the Alps and less than 1 °C in the north of the Alps and south of the Alps with PET up to 10 °C. During the Summer (Figure 3 for July) a high differentiation is existing from north to south and with the increasing elevation. Areas with high heat stress can be identified in the outer alpine regions and in the large valley systems of the Alps during summer conditions.

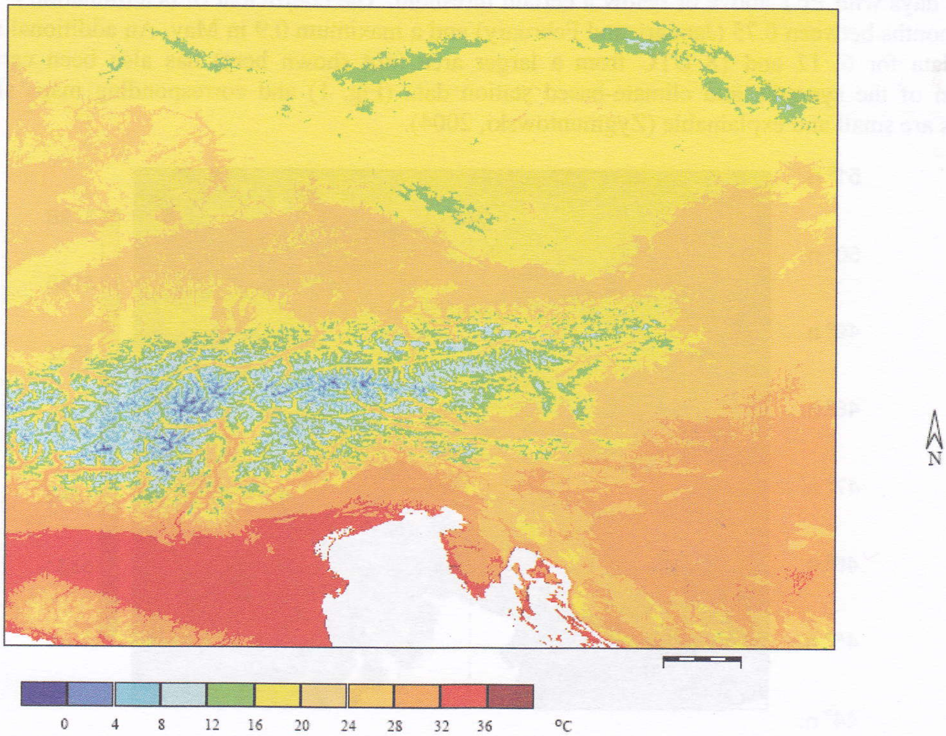

Figure 3. PET distribution for July (Period: 1996 – 2000)

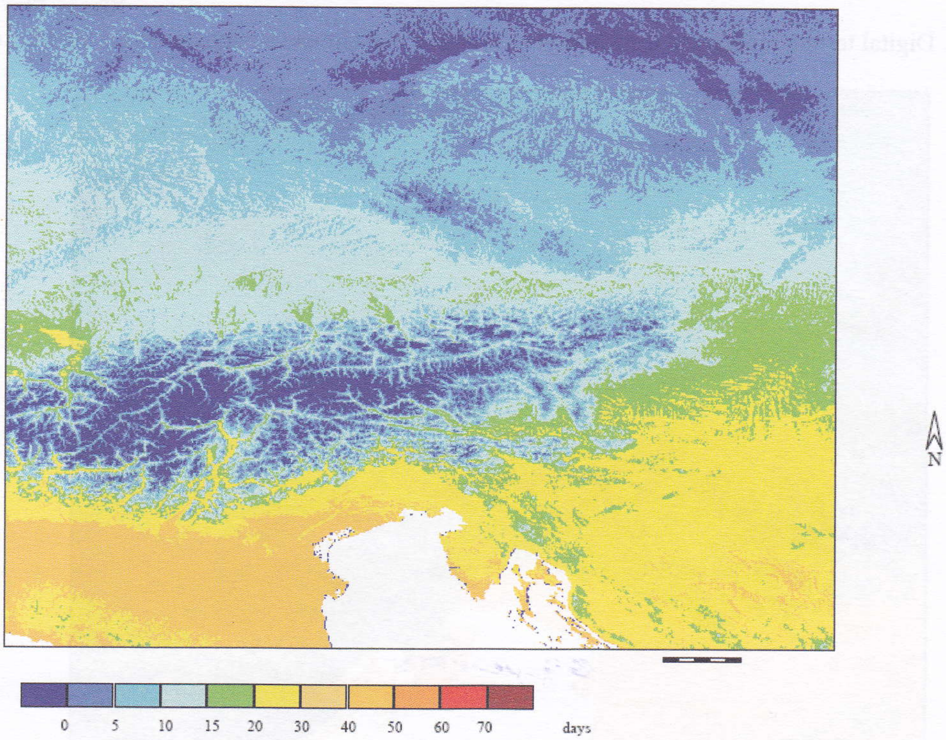

Figure 4. Days with PET > 35 °C (Period: 1996 – 2000)

Figure 4 gives the distribution of the amount of days with PET values exceeding 35 °C thus providing information on frequencies of heat load conditions and heat stress areas. About more than 20 days of the year can be obtained south of the Alps. North of the Alps the amount decreases down. Higher lying areas of the Alps don't show any heat stress conditions during the summer.

4. CONCLUSION

The used methods of analyzing the thermal bioclimatic conditions such as mean values, extremes and frequencies of PET-thresholds values, presents an excellent way of transferring complex scientific information in a form that can be understood easily by decision makers, the general public, and especially tourists. The developed bioclimatic information, which are based on standard climatic parameters (like air temperature, air humidity, wind speed and cloud cover) can be used as an assessment tool for wellness resorts and other kinds of tourism attractions involving both managers and tourist. The presented Physiological Equivalent Temperature (PET) can be easily applied and interpreted by everyone who is acquainted with this temperature scale, since it is using the Celsius scale.

The method for the regionalization of PET-values involving statistical regression coefficients allows the calculation of bioclimatic maps through the application of GIS-techniques. The mapping of modern bioclimatic indices, based on the human energy balance, presents an adequate method for the quantification of the human thermal bioclimate and can be applied to different uses and requirements.

The demand of bioclimatic information for wellness tourism and for tourism and recreation in general is very high. The climate and its effects on recreation and tourism are economic factors, which have to be taken into account when planning and forecasting the tourism development of a region. Extreme events like heat waves and other negative effects of climate on tourists have to be quantified in a human-biometeorological manner for a better protection of human health and an improved quality of domestic and international tourism.

Mountainous areas worldwide and for Europe the alps offer several solutions and possibilities concerning thermal bioclimate. One possibility is the escape during extreme events during summer a.e. heat waves. Another possibility is in the development of new tourism and health or tourism and recreation activities for the replacement of areas which will be not anymore comfortable under the expected climate change conditions.

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REFERENCES

Fanger, P. O., 1972: Thermal Comfort. New York, McGraw Hill.

Höppe, P., 1999: The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environment. *Int. J. Biometeorol.*, **43**, 71-75.

Jendritzky, G., Menz, G., Schirmer, H., Schmidt-Kessen, W., 1990: Methodik zur raumbezogenen Bewertung der thermischen Komponente im Bioklima des Menschen (Fortgeschriebenes Klima-Michel-Modell). *Beitr. Akad. Raumforsch. Landesplan.*, Nr. 114.

Matzarakis, A., Mayer, H., 1997: Heat stress in Greece. *Int. J. Biometeorol.*, **41**, 34-39.

Matzarakis, A., Mayer, H., Iziomon, M., 1999: Applications of a universal thermal index: physiological equivalent temperature. *Int. J. Biometeorol.*, **43**, 76-84.

Matzarakis, A., Rutz, F., Mayer, H., 2000: Estimation and calculation of the mean radiant temperature within urban structures. In: *Biometeorology and Urban Climatology at the Turn of the Millenium (ed. by R.J. de Dear, J.D. Kalma, T.R. Oke and A. Auliciems): Selected Papers from the Conference ICB-ICUC'99, Sydney.* WCASP-50, WMO/TD No. 1026, 273-278.

Steadman, R. G., 1971: Indices of windchill of clothed persons, *J. Appl. Meteorology*, **10**, 674-683.

Thom, E. C., 1959: The Discomfort Index. *Weatherwise* **12**, 57-60.

VDI, 1998: Methods for the human-biometerological assessment of climate and air hygiene for urban and regional planning. Part I: Climate, *VDI guideline 3787*. Part 2. Beuth, Berlin.

Zygmuntowski, M., 2004: Assessment of the climate of Austria based on humanbiometeorological indices and geo-statistical methods for tourism purposes. Diploma Thesis in Meteorology. University of Kiel (in german).