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LONG TERM ANALYSIS OF THERMAL BIOCLIMATE AT THE ADRIATIC COAST

Ksenija Zaninovic[1], Andreas Matzarakis[2]
[1] Meteorological and Hydrological Service, Zagreb, Croatia
[2]Meteorological institute, University of Freiburg, Freiburg, Germany

1 INTRODUCTION

Up to now changes of thermal comfort in Croatia have been investigated for two meteorological stations on the basis of the mean annual and seasonal values of bioclimatic indices. The analysis of climate change through thermal indices in Hvar from the middle 19th century showed a positive trend in all seasons as a result of positive temperature trends and decreasing trends in wind speed (Zaninovic, 1998, Zaninovic and Matzarakis, 2004). On the other hand, the analysis of thermal comfort changes in Hvar from the beginning of 20th century showed the opposite trend as the result of increasing wind speed trend in the century (Zaninovic and Matzarakis, 2005). The thermal comfort at the highest meteorological observatories in Croatia and Slovenia showed the positive trend from the middle 20th century (Zaninovic, 1996, Zaninovic et al., 2005).

In this article are analysed the climate changes of thermal comfort in Hvar, a famous tourist destination in the middle Adriatic, by means of the physiological equivalent temperature during the period 1867-2004. Besides, the bioclimatic condition in Hvar in the period 1961-1990 are presented, as well as the differences between the annual courses of PET in the coldest and warmest year in the period.

2 METHODS

The thermal effective complex deals with the influences of the thermal environment on the well-being and health of human beings. The basis for this is the close relationship between the human thermoregulatory mechanism and the human circulatory system. For the physiologically significant assessment of the thermal environment, and here the physiological equivalent temperature derived from the human energy balance is used (Höppe, 1999). Results from case studies (Matzarakis et al, 1999) enable a process analysis, e.g. in the form of regressions between PET and meteorological input parameters such as single radiative fluxes, mean radiant temperature, air temperature, vapour pressure and wind speed. For calculating the mean radiant temperature, the human-biometeorological radiation model RayMan (Matzarakis et al, 2000) was used, which is well suited for application in applied climatological and meteorological studies.

The changes in human bioclimate in Hvar are investigated by means of the changes in number of days with extremely low and high values of physiological equivalent temperatures in the observing time at 7 a.m., 2 p.m. and 9 p.m. As the extremely low values of PET are assumed to be those below the threshold of the percentile 2, while the extremely high values are those higher than the 98 percentile of PET in the climatic period 1961-1990.

In order to remove short-term fluctuations in data series, they have been smoothed by means of the 11-year binomial moving average filter. The linear trends have been tested for significance by means of nonparametric Mann-Kendall rank statistics (Mitchell, 1966), while the progressive analysis of the time series by means of the statistic *u(t)* was performed in order to determine the beginning of observed trend by means of a sequential analysis (Sneyers, 1990).

3 RESULTS

3.1 BIOCLIMATE OF HVAR

According to the annual course of mean physiological equivalent temperature the thermal sensation varies from very cold mornings and evenings in January, February and December, while the afternoons are cool (Fig. 1). After cool early spring it becomes comfortable in May. June is slightly warm. July and August are warm, but even then the evenings are comfortable, and hot are only the afternoons at the end of July and the beginning of August. Because of the maritime influence the autumn is warmer then spring, and the afternoons stay comfortable almost until the end of October.

The probability of occurrence of different values of PET shows that in Hvar even during the coldest part of winter (first and second ten-day period in January) only 50% of afternoons are cold or very cold, while even then, although very seldom, can be comfortable or even slightly warm in the warmest part of the day. In the summer the afternoons are most often warm or hot, and about 10% of them from the mid July till mid August are very hot.

The comparison between the annual courses during the coldest (1870) and warmest (1949) year in Hvar according to the mean annual values of PET shows significant differences between them. In 1870 cold prevailed in the whole days in January, February and December. In the middle of January it was even very cold all days long, while mornings and evenings stayed very cold until the end of March. On the contrary, in 1949 afternoons in winter were cool. The warm period was longer in 1949 than in 1870, and in 1870 there were no hot afternoons on the average.

3.2 CLIMATE CHANGE OF HVAR BIOCLIMATE

Trend analysis for the number of days with extremely low and high values of physiological equivalent temperature for 2 p.m., for 7 a.m. and 9 p.m. (Table 1) gave the significant changes only for those at 2 p.m., while for morning and evening neither the number of days with low nor with high values of PET showed practically no trend. The trends for the mean PET values in terms, as well as with the trends in minimum and maximum air temperatures were also calculated and have shown identical results. There is a significant positive trend in PET at 2 p.m. with the trend of 1.4°C/100 years, and in maximum air temperature with the trend of 0.65°C/100 years.

Table 1. The PET values (°C) of the percentiles 2 and 98 at 7 a.m., 2 p.m. and 9 p.m. in the period 1961-1990. in Hvar.

Percentiles	7 a.m.	2 p.m.	9 p.m.
2%	-5.1	2.5	-4.2
98%	36.9	41.4	21.8

The variations of the analyzed parameters (Figure 3) show the opposite course of the number of cold and hot days. The greatest number of hot days occurs late 30's and late 40's, with the greatest number of cold days between them in early 40's. Unfortunately, there are missing data from 1943-1945.

The trend of the days with the PET>41.4°C (percentile 98) at 2 p.m. is about 3.2 days per 100 years and is highly significant (α=0.02), and the trend of days with PET<2.5°C (percentile 2) is -4.7 days per 100 years and significant at the level of 0.001. As there is in average about 7 hot/cold days per year, it turns out that there is an increase of 44% of hot days and the decrease of even 65% of cold days in 10 years.

From the graphical representation of the onward (u) and backward (u') progressive test series of the number of hot and cold days it can be seen that during the analysed period the two series (u and u') have one intersection point clearly showing the beginning of trend. In the case of the days in which PET at 2 p.m. exceeds the 98 percentile threshold (41.4°C) the positive trend began in 1939, while u exceeded the 1.96 limit value in 1967, suggesting the beginning of a significant positive trend. The series for the days in which the PET at 2 p.m. falls bellow the limit value of percentile 2 (2.5°C) the negative trend began still in 1886 and began significant in 1912.

The trend analysis for some other threshold values for PET (for the percentiles 25, and 9 at one side and 75 and 91 at another, also calculated but not presented here, gave the similar results concerning trends as well as the beginning of trends.

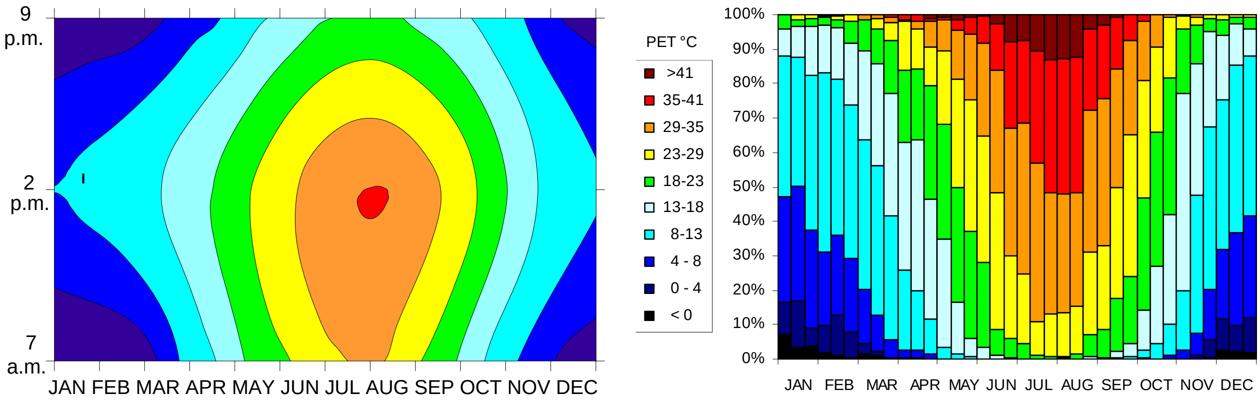

Figure 1. The annual course of PET in the observing times (left) and the probability of occurrence of different PET values at 2 p.m. Hvar, period 1961-1990.

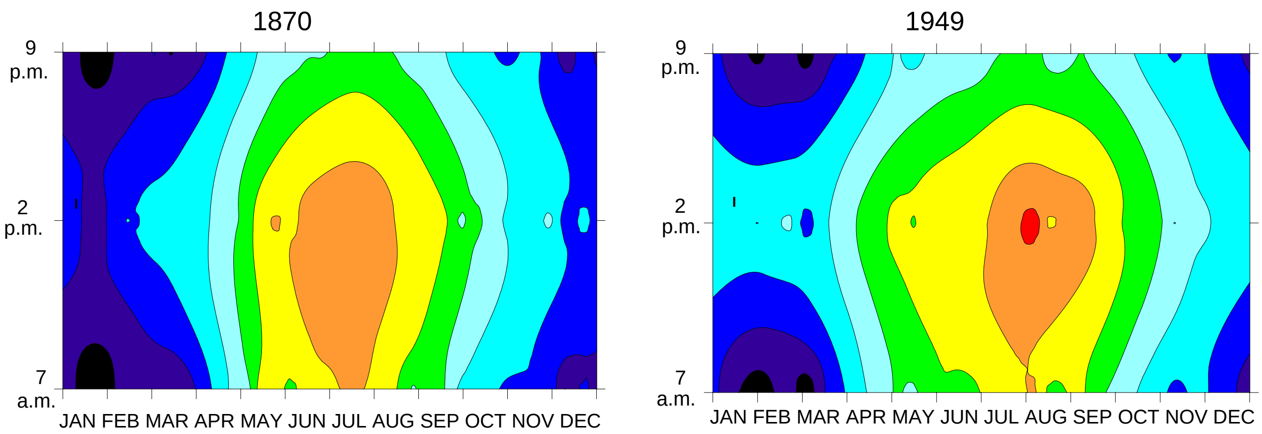

Figure 2. The annual course of PET in the observing times during the coldest (left) and warmest (right) year in Hvar in the period 1867-2004.

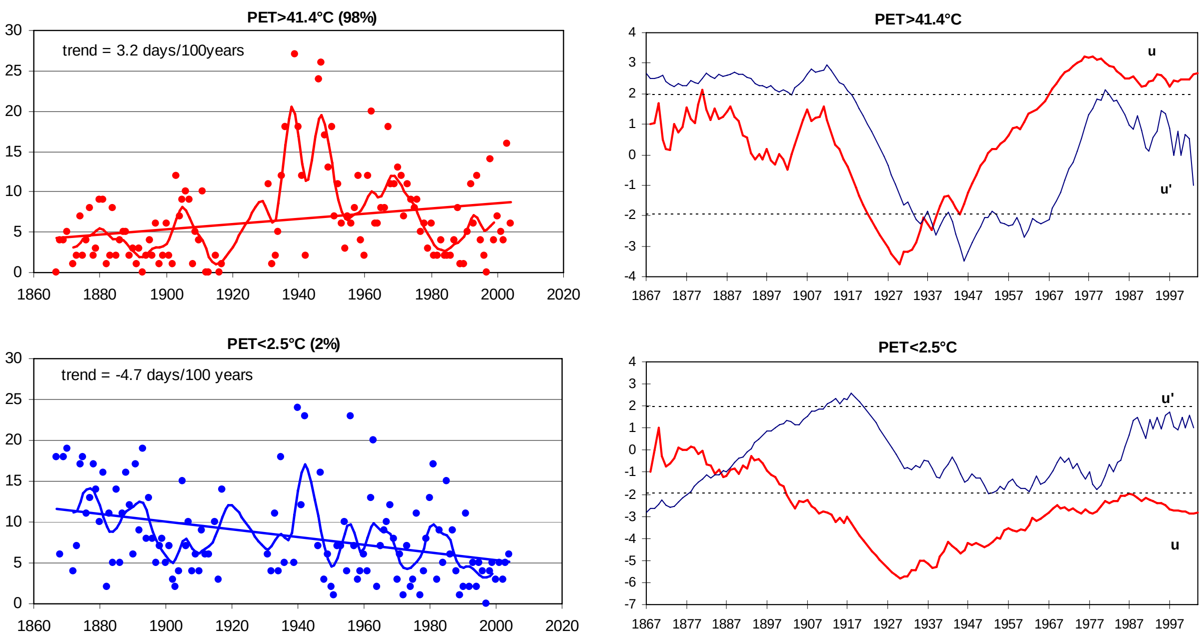

Figure 3. Number of days with PET>41.4°C and PET<2.5°C, weighted 11-year binomial moving average series, and linear trends (left) and progressive trend test (right) during the period 1867-2004 in Hvar.

4 DISCUSSION AND CONCLUSION

The results clearly show the presence of warming in thermal sensation. Trends of the bioclimatic conditions of tourism areas provide information for the tourism industry and governmental authorities, allowing adequate planning for the expected changes in the nature and length of the tourism season .The increase of unpleasant summer heat could have the negative influence on the tourism and lead the constructors to prevent heat stress even indoor. At the other hand, the decrease of winter cold spells at least during the day can provide more pleasant conditions for winter tourism.

This result coincides with earlier investigations into the trends in thermal comfort at Hvar (Zaninovic, 1996, Zaninovic and Matzarakis, 2004). It also clarify that the obtained changes in mean values of PET are the consequence of the changes in the thermal comfort at 2 p.m. implying the changes in maximum values. However, the investigations of climate change in minimum and maximum temperatures in Croatia on some inland lowland and North Adriatic coastal station indicated the decreasing maximum temperatures and increasing minimum temperatures, leading to a significant decrease in daily temperature range (Zaninovic and Gajic-Capka, 1995).

REFERENCES

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

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

Matzarakis, A., Rutz, F. and Mayer, H., 2000: Estimation and calculation of the mean radiant temperature within urban structures. WCASP-50, WMO/TD, No. 1026: 273-278.

Mitchell, J. M.Jr. et al., 1966: Climatic Change. WMO Tech. Note No. 79, pp. 79.

Sneyers, R., 1990: On the Statistical Analysis of Series of Observations, WMO, Technical Note No 143.

Zaninovic, K. and Gajic-Capka, M., 1995: Extreme Temperature Changes in this Century in Croatia. Hrv. Meteor. Cas. 30: 21-26.

Zaninovic, K., 1996: Trends of Thermal Comfort on Dinaric Alps. Proceedings of the 24th International Conference on Alpine Meteorology ICAM 96. 1996 September 9-13, Bled, Slovenia, 425-430.

Zaninovic, K., 1998: Secular Variations and Trends of Thermal Comfort at the Adriatic Coast. Book of abstracts IGU, Climate and Environmental Change. 1998,24-30 August, Evora, Portugal. 181-182.

Zaninovic, K., Matzarakis, A., 2004: Variations and trends of thermal comfort at the Adriatic coast. In: Matzarakis, A., de Freitas, C., Scott, D. (eds.) Advances in tourism climatology. Ber. Meteorol. Inst. Univ. Freiburg Nr. 12: 74-81.

Zaninovic, K., Cegnar, T., Matzarakis, A., 2005: Thermal comfort trends and variability in the Croatian and Slovenian mountains. Croatian Meteorological Journal 40: 198-201.

Zaninovic, K. and Matzarakis A., 2005: Climatic changes in thermal comfort at the Adriatic coast.. In: Amelung, B., Blazejczyk, K., Matzarakis, A., Viner, D. (eds.) Climate Change and Tourism: Assessment and Coping Strategies. Kluwer Academic Publishers, Dordrecht. (in print).