Analysis of temporal variability and spatial characteristics of heat waves in Central Europe using extremity index

O. Lhotka (1,2) and J. Kyselý (1)

(1) Institute of Atmospheric Physics AS CR, Prague, Czech Republic
(2) Faculty of Science, Charles University, Prague, Czech Republic

E-mail: ondrej.lhotka@ufa.cas.cz | kysely@ufa.cas.cz

Introduction

- Heat waves (periods of extremely high air temperature in summer) have been intensively studied due to dramatic events in the last two decades
- Temporal variability of these events in Europe and Czech Republic was analysed by many authors (e.g. Della-Marta, Haylock, Luterbacher & Wanner (2007), Kyselý (2010))
- In these studies, heat waves were mostly defined from station (point) data only
- There is a need to examine these events not only from the aspect of air temperature and duration, but also from the view of their spatial extent
- In this study, extremity index of heat waves is proposed that takes into account their spatial extent, duration, and temperature, and temporal variability of heat waves over Central Europe is analysed

Data and methods

- Surface air temperature data over land areas of Europe were obtained from E-OBS gridded dataset (Haylock et al., 2008)
- In this study, the definition of heat wave was based on the persistence of hot days (HD)
- Any day was considered a hot day when the mean of Tmax deviations from the 95% quantile of summer Tmax distribution in the area of Central Europe was greater than zero (Figure 1)

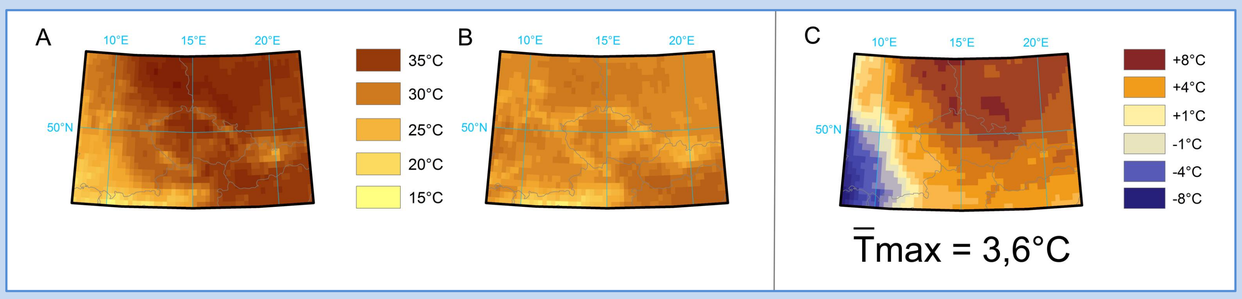

Figure 1: Calculation of hot days (example for August 1, 1994) - the grid map of the 95% quantile of summer Tmax distribution (B) was subtracted from the grid map of Tmax values for the given day (A); the resulting grid map (C) has the mean of Tmax deviations from the 95% quantile of summer Tmax distribution > 0°C so this day was classified as a hot day.

- Heat wave over Central Europe was defined as a period of at least three consecutive hot days; for this period, the grid maps of Tmax deviations were summed up
- The area where the sum of Tmax deviations was positive represents the spatial extent of a heat wave (A_{hw}); the greatest value of the sum of Tmax deviations over grid points represents temperature magnitude of a heat wave (TS_{max}); these variables were analysed over Central Europe, which covers an area of 669,584 km2 (A)
- The extremity index of heat waves (I_{hw}) was proposed to combine the spatial extent and temperature magnitude of heat waves and to describe their intensity:

$$I_{hw} = TS_{\max}\left(\frac{A_{hw}}{A}\right)$$

Results

- Over 1950-2011, the total number of hot days in Central Europe was 220
- These days formed 21 heat waves, defined as periods of at least three consecutive hot days
- The most severe heat wave in Central Europe according to I_{hw} occurred from July 23 to August 6, 1994; this event persisted for 15 consecutive days, the maximum value of the sum of Tmax deviations from the 95% quantile was 62.9°C, and it affected almost whole Central Europe
- Other significant heat waves (I_{hw}>20°C) in Central Europe occurred in 1957, 1959, 1992, 2006, and 2010 (Figure 2)

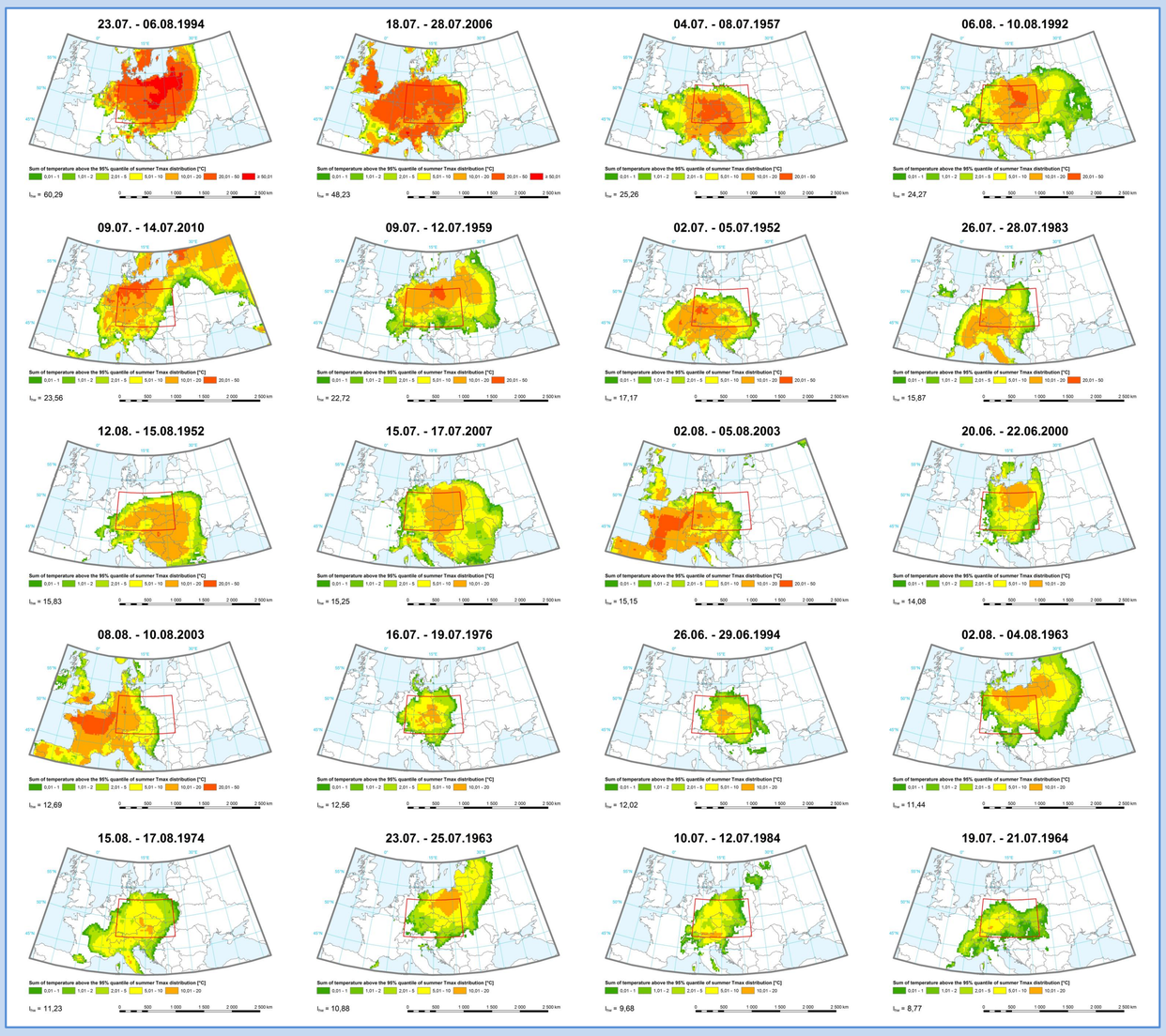

Figure 2: Twenty most severe heat waves in Central Europe during 1950-2011. The heat waves are ranked according to I_{hw} in descending order.

- We analysed the temporal variability of hot days and heat waves during the 1950-2011 period. In Figure 3, the number of hot days for each year was marked by red dots and the sum of I_{hw} was marked by grey columns

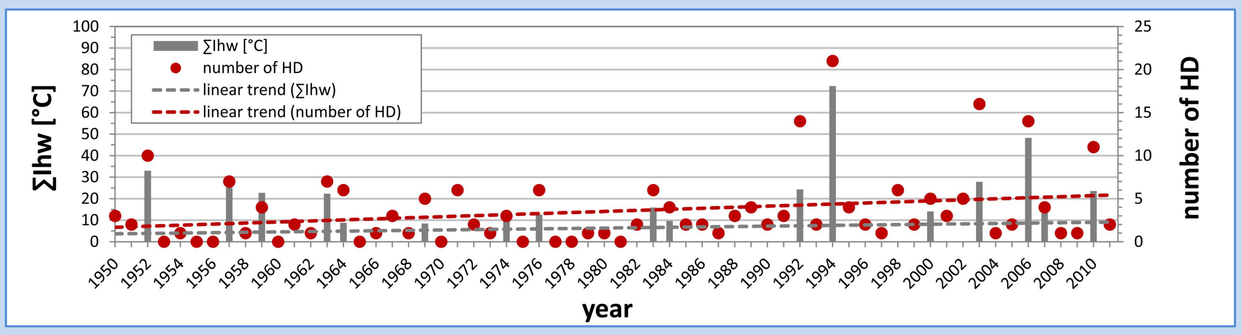

Figure 3: Temporal variability of hot days and heat waves during the 1950-2011 period.

Discussion and conclusion

- High values of I_{hw} and the number of hot days occurred predominantly in the last two decades
- On the other hand, low values were typical for the period between 1964 and 1991
- Further work is needed to analyse the relationship between the extremity index and circulation indices for the Central European region
- In addition, the spatial characteristics of heat waves may be utilized to validate outputs of regional climate models because simulated heat waves have up-to-now been evaluated mainly from the aspect of their temperature and duration, not their spatial extent and patterns

Acknowledgments

- The study was supported by the Czech Science Foundation, project P209/10/2265, and the Ministry of Education, project 7AMB12AR005

References:

DELLA-MARTA, P M - HAYLOCK, M R - LUTERBACHER, J - WANNER, H (2007). Doubled length of western European summer heat waves since 1880. In: Journal of Geophysical Research, 112(D15), D15103.

HAYLOCK, M R - HOFSTRA, N - KLEIN TANK, A M G - KLOK, E J - JONES, P D - NEW, M (2008). A European daily high-resolution gridded data set of surface temperature and precipitation for 1950–2006. In: Journal of Geophysical Research, 113(D20).

KYSELÝ, J (2010). Recent severe heat waves in central Europe: how to view them in a long-term prospect? In: International Journal of Climatology, 30, 89–109.