A COMPARISON OF AN UTCI TO SOME OTHER SELECTED INDICES

Martin Novák[1,2]
[1]Czech Hydrometeorological Institute, Regional branch in Ústí n.L., POBox 2, 400 11 Ústí n.L., Czech Republic;
[2]Charles University in Prague, Faculty of Science, Department of Physical Geography and Geoecology, Albertov 6, 128 43 Praha 2, Czech Republic.

Abstract. The thermal discomfort is very important for meteorosensitive people. There exists a lot of indices for describing thermal comfort/discomfort or thermal load of human body. A new Universal Thermal Climate Index (UTCI) is among preferred indices for use in CHMI's biometeorological forecast, but isn't the only possible. This paper brings a demonstration of indices' basic theoretical properties and a quick comparison of an UTCI to some other selected indices for some selected extreme weather situations.

Key words: biometeorological forecast, thermal comfort, UTCI, biometeorological indices.

Introduction

The studying thermoregulation system of the human body and its load by an environment is one of the key components of the human biometeorology evidently. More than one hundred biometeorological thermal indices were constructed in the last ninety years throughout the world. These indices rate a load of the thermoregulation system. Some of these indices were determined empirically, based on the selected meteorological and health data. New type of the indices based on the physilogical reaction of the organism to the environmental conditions was developed from seventies of the 20th century.

The air temperature isn't a determining factor of the load the human body. We have to look at comprehensive action of the environment. We can describe this action by mean meteorological characteristics: air temperature, humidity, wind velocity and radiation balance of the body surface. Most of the indices used in human biometeorology allows two or three variables only. The calculation doesn't include a radiation factor usually. However, the radiation factor is important to the description of the body surface balance.

A new Universal Thermal Climate Index (UTCI) is one of the indices with a physiological basis. A develop of this index was finished in 2009. Its calculation is based on the default constant values for the "ideal person" (metabolism rate, work, clothing etc.) and input meteorological variables. These parameters are routinely measured or countable directly from commonly measured data. Therefore the UTCI is potentially acceptable for use in a biometeorological forecasting or warning systems (HHWS). It is necessary to test the UTCI properties before its routinely using.

Material and methods

The UTCI's basic properties were tested on typical very warm summer day at this article. Changes of the UTCI values induced by changes of the direct short- and long-wave radiation amount were tested too. A total quantity of the solar radiation is significantly modulated by the cloudiness namely.

A number of thermal indices doesn't involve an element of solar radiation, but the UTCI includes radiation factor desribed by the *mean radiant temperature* (*Tmrt*). A value of T*mrt* is determined by height of the Sun above the horizon (Sun altitude), moisture and pollution of the atmosphere, a radiant characteristics of the surrounding area (albedo, caloric receptivity of the surface, buildings etc.). However, radiant characteristics of near area, as well as the current distribution of water and pollutants in the boundary layer of the atmosphere mainly, are practically unique at every point. Therefore we have to use approximate calculations. The *Tmrt* values were calculated by the *Bioklima 2.6* freeware [Blazejczyk et al., 2010].

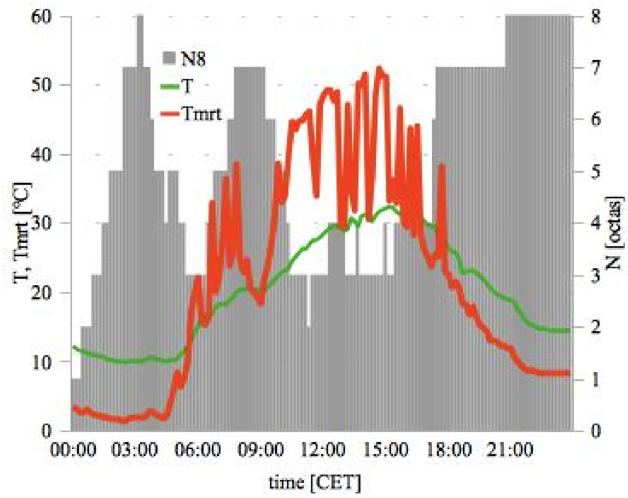

Figure 1. A dependence mean radiant temperature *Tmrt* on cloudiness (*N*) and air temperature (*T*). Default conditions: *sunny* place, *station* = Doksany (50°28' N, 14°10' E, 158 m asl.), *date* = July 17, *time* = 15:00 CET, *h* = 50 %, *v* = 2 mps.

The dependence of the *Tmrt* on air temperature (*T*) and amount of cloud cover (*N*) is evident from *Tab. 1* and *Fig. 1*. The *Tmrt* values are valid for sunny places, i.e. places exposed to direct solar radiation at least most of the time. Table 1 shows calculated Tmrt values for different *T* values and for three variants of the cloudiness. There were used values representing a clear (*N* = 0), half covered (*N* = 4) and overcast (*N* = 8) sky. The values of cloudiness are expressed in octas sky. This expression is common for an observation at the meteorological (synoptic) stations. The Tmrt values also depend on geography location, Sun altitude and time. We have chosen the Doksany station (WMO ID = 11509).

Real *Tmrt* values course on a warm summer day (*Fig. 1*) is demonstrated by data from Doksany meteorological station. Its geografical and meteorological data were used for the calculation. The meteorological data were available with a 10 minutes time step from the automatic measurements. The cloudiness (*N*) was observed with a 1 hour time step only, the observation was realised between 5:00 and 22:00 CET. The cloudiness time serie (with normal 10 minutes time step) was supplied by satellite pictures and direct solar radiation data.

Table 1. A comparison of mean radiant temperatures (*Tmrt*) and *UTCI* values for a different cloudiness (*N* = 0, 4 and 8 octas).*N*Default conditions: *sunny* place, *station* = Doksany (50°28' N, 14°10' E, 158 m asl.), *date* = July 17, *time* = 15:00 CET, *h* = 50 %, *v* = 2 mps.

T [°C]	*Tmrt*) [°C]	*Tmrt*) [°C]	*Tmrt*) [°C]	*UTCI* [°C]	*UTCI* [°C]	*UTCI* [°C]
10	34,2	29,9	11,7	15,7	14,2	7,8
15	39,1	35,0	17,8	20,6	19,3	13,5
20	44,0	40,1	23,8	25,3	24,1	19,2
25	48,8	45,1	29,7	30,1	29,1	24,9
30	53,5	50,0	35,3	35,4	34,6	31,0
35	58,1	54,7	40,7	41,4	40,6	37,3

The comparison the UTCI to selected commonly used biometeorological indices was the main goal of this article. We were these comparatice indices:

- Net Effective Temperature *NET*,
- Humidex (by Atmospheric Environment Service of Environment Canada),
- a CHMI's version of the perceived temperature *PT(CHMI)*,
- Heat Index (by NWS NOAA).

Net Effective Temperature is mainly used in East and Southeast Asia in recent year [Yip et al. 2007], in Europe this is used e.g. in Germany or Poland. The NET index is a function of air temperature, relative humidity and wind velocity. This one was established on the empirical grounds and developed since 1937 (as *Effective Temperature - ET*). First version of this index was only for warm part of the year but current version is usable throughout the year.

Humidex was developed in Canada. It was primarily intended to use in warm part of the year but it is also usable throughout the year. This index is a function air temperature and relative humidity (or dew point).

The *PT(CHMI)* index is used in forecasting service of Czech Hydrometeorological Institute (CHMI). This index was established empirically. Its construction is adapted to the climatic conditions of the Czech Republic [Vavruška, 2011]. The *PT(CHMI)* index is a function of air temperature, relative humidity and wind velocity.

Heat Index was developed by NWS NOAA (USA) [Robinson, 2001]. It is a function of air temperature and relative humidity only. It is the most widely used index to determine the possible rate of summer thermal discomfort probably. The restrictions of Heat Index on the summer season only is logical because of its use at temperatures below 20 ° C is excluded. An using of the Heat Index for air temperature between 20 and 25 ° C is very problematic (Fig. 3).

The UTCI values were calculated with using software Bioklima 2.6. There were calculated values of UTCI and UTCI* [Blazejczyk, 2011]. The UTCI* differs from the original UTCI by simpliffication of the basic equation. Both versions (UTCI and UTCI*) are functions of air temperature, relative humidity, wind velocity and mean radiant temperature. The UTCI and UTCI* values are not identical, but these are relatively close. The range of their changes caused by changes of the input data mutually corresponds, even when mean radiant temperature is changing (*Fig. 2*).

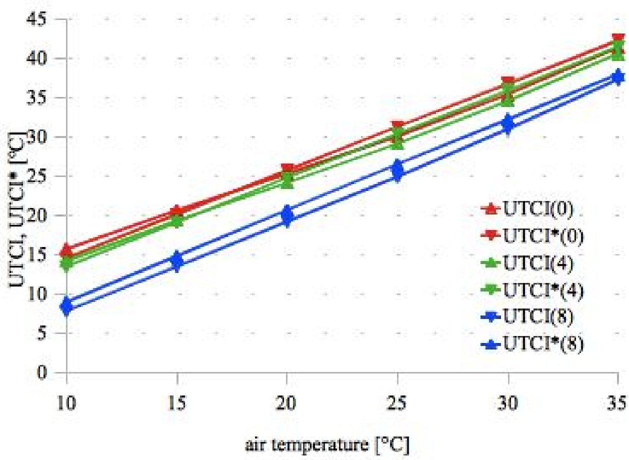

Figure 2. A comparison of *UTCI(N)* and *UTCI*(N)* (Błażejczyk, 2010) for a different cloudiness (*N* = 0, 4 and 8 octas). Default conditions: *sunny* place, *station* = Doksany (50°28' N, 14°10' E, 158 m asl.), *date* = July 17, *time* = 16:00 CEST, *h* = 50 %, *v* = 2 mps.

Results and disscussion

The UTCI values were compared to selected indices (NET, Humidex, PT(CHMI) and Heat Index) in the first phase. The real meteorological data were used for this comparison. We have chosen very warm day, Sunday, July 17 when maximal air temperature reached 32,7 °C at the Doksany station. A variability of the cloudiness led to fluctuations of a mean radiant temperature. This fact was projected to increasing UTCI variability when other indices followed more conservative air temperature. *Fig. 3* shows that Heat Index (gray line) is unacceptable for the all day or all year round evaluation of thermal comfort/discomfort. The Heat Index values are unrealistic if air temperature is below 25 °C. Concretely, we can not use the Heat Index at intervals of 0:00 to 9:00 and 19:00 to 23:50 CET. This index reported a similar patterns as other indices (without radiant factor) in phase between 9:00 and 19:00 CET.

Even during the maximal load the Heat Index didn't reach higher values then 'caution' category on its assessment scale. For comparison to other indices: Humidex reached 'some discomfort' category maximally, NET 'hot' and UTCI 'strong heat stress' category.

Determining of possibility to use the UTCI in routine practice CHMI's forecasting service was the main goal of this work. Therefore we compared the UTCI* to PT(CHMI) directly (*Fig. 4*). There is possible to find several differences between both indices. The rate of variability is the main difference. The PT(CHMI) index doesn't respond to fluctuations of the real *Tmrt* values because the construction of this index includes the reductive hypothesis of a coequality of air temperature and mean radiation temperature (*T* = *Tmrt*). The second difference is stronger decline of UTCI* values in the evening. This decrease is caused by a stronger reaction of the UTCI* to higher wind speed. The rate of chilling is lower in the case of PT(CHMI). The fluctuation of the UTCI* around 21:00 CET demostrates the strength of a relationship between UTCI* and wind velocity. The short-term weakening of wind (of 4 mps) resulted in reduction of the UTCI* (of 9 °C).

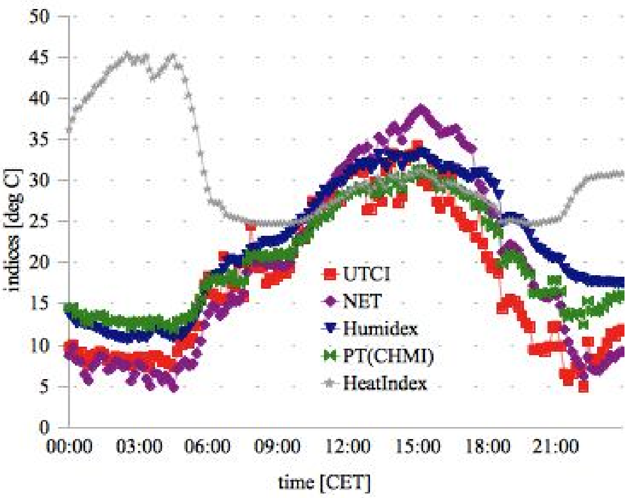

Figure 3. Values of selected indices during a warm summer day (July 17, 2011) with maximum air temperature *Tmax* = 32,7 °C at meteorological station Doksany (50°28' N, 14°10' E, 158 m asl.).

Conclusions

A warm summer day was chosen to compare selected indices because UTCI was tested earlier in extreme winter conditions [Novák, 2011], especially during the episode known as "Kyrill" in January 2007. The UTCI has problems in the extremally windy conditions. If wind speed is higher than 30 mps than UTCI reached uncorrect values. This problem is solved by authors of the UTCI now.

The *Fig. 3* shows a main difference between UTCI and other indices, i.e. higher variability of the UTCI values. This is due to stronger variability of the mean radiant temperature compared to air temperature. Other tested indices do not include radiant factor. Therefore, these indices – unlike UTCI – do not respond tochanges of a cloudiness. The course of the UTCI illustrates the real load of a human body better, including the short-time fluctuations of this load. Differences between the UTCI* values and the PT(CHMI) index are seen best in *Fig. 4*.

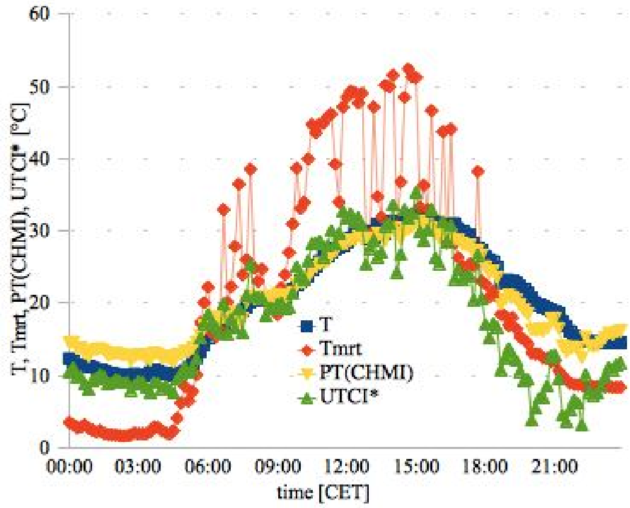

Figure 4. Differences between *UTCI** and *PT(CHMI)* depending on *Tmrt* – July 17, 2011 at meteorological station Doksany (50°28' N, 14°10' E, 158 m asl.).

All the selected indices actually represent an equivalent temperature, what describes the apparent temperature of the surrounding environment for the idealized human body. Therefore, values of these indices are basically comparable. The assessment scales are established for most of selected indices, except the PT(CHMI) index. The values of all tested indices reached categories representing a higher rate of thermal discomfort. The indices expressed discomfort in same time between 10:30 and 18:00 CET. Most of these indices held values with the same level of discomfort but the UTCI values fluctuated between 'moderate heat stress' and 'strong heat stress' categories. The time of maximal load occurred around in the same moment, according most indices at 15:10 CET and in accordance to the UTCI at 15:00 CET. The UTCI shows same or better response compared to other indices in this warm summer day unlike previous tests in windy winter conditions.

Tests on real data of the one of the very hot days in summer 2011 showed that the UTCI values (respectively UTCI* values) promptly react to changes of direct solar radiation described by the mean radiant temperature. This behavior of the UTCI describes the real load much better than other tested indices at sunny places. Compared with PT(CHMI) the UTCI has an additional advantage of international comparability. Therefore, it should be implemented the UTCI to forecasting practice at CHMI, especially into biometeorological forecast model, after further tests.

Acknowledgements This work was supported by the grant SVV-2011-263 202.

References

Blazejczyk K. et al., 2010. Nowy wskaźnik oceny obciążeń cieplnych człowieka. Przegląd geograficzny, 82(1), pp. 49-71.

Blazejczyk K., 2011. Mapping of UTCI in local scale (the case of Warsaw). Prace i studia geograficzne, WGiSR UW, 46.

Novák M., 2011. UTCI – first test in the Czech republic. Prace i studia geograficzne, WGiSR UW, 47, pp. 319-325.

Robinson, P.J., 2001. On the definition of a heat wave. In: Journal of Applied Meteorology and Climatology, 40, pp. 762-775.

Vavruška, F., 2011. Cítěná teplota. Personal message by e-mail, 2011, March 3.

Yip, K.M., Leung Y.K., Yeung, K.H., 2007. Long-term trend in thermal index and its impact on mortality in Hong Kong, Hong Kong Observatory Reprint, No. 710.