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USE OF THE UTCI IN THE CZECH REPUBLIC

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Abstract

The new Universal Thermal Climate Index (*UTCI*) was designed for use in the human bioclimatology and biometeorology field. This article describes a set of basic tests used to test the *UTCI*. These tests were made using real data from selected meteorological stations in the Czech Republic. Days with extreme temperatures and days with extremely windy conditions (extratropical cyclone known as 'hurricane Kyrill', January 18-19, 2007) were selected for the *UTCI* testing. The Universal Thermal Climate Index is different from other, more commonly used indices. A complete set of meteorological and radiation factors: air temperature, humidity, wind speed and mean radiation temperature were used using when testing the *UTCI*. Other indices were calculated using limited numbers of the following factors: air temperature and humidity (*Heat Index*), air temperature and wind speed (*Wind Chill*), and also air temperature, humidity and wind speed (*NET*). Testing of the *UTCI* was necessary before the possible application of this index in the national weather service of the Czech Republic (CHMI).

Key words

UTCI • thermal comfort/discomfort • biometeorological indices • bioweather forecast

Introduction

In the Czech Republic, work on a bioweather forecast (BWF) started in the 1980s. The city of Pilsen city in western Bohemia, was the first (in 1988) city in which a BWF was experimentally issued, the next was for the Northern Bohemia Region (in 1992). By 1993, the whole territory of the Czech Republic was using BWF. The Czech territory was divided into 7 basic areas (Fig. 1) for this purpose. These areas were defined by synoptic (the large-scale circulation) and climatological (the ratio of continentality or oceanicity of the climate) points of view. The administrative division of the districts was taken into consideration.

The current BWF model is based on a combination of selected meteorological characteristics and simple synoptic interpretation grounded on the atmospheric front passages (Fig. 2). The values of the meteorological characteristics contribute to the total biotropy index by exceeding, respectively falling below defined limits. The input data include: maximal and minimal air temperature (at 2 m above ground level), temperature changes at the isobaric level of 850 hPa, relative humidity (at 2 m a.g.l.), significant decrease of the atmospheric pressure, and the wind gusts. The next input includes data on long-lasting temperature inversions in the atmospheric boundary layer.

At present, the bioweather forecast forms an integral part of the CHMI's daily information

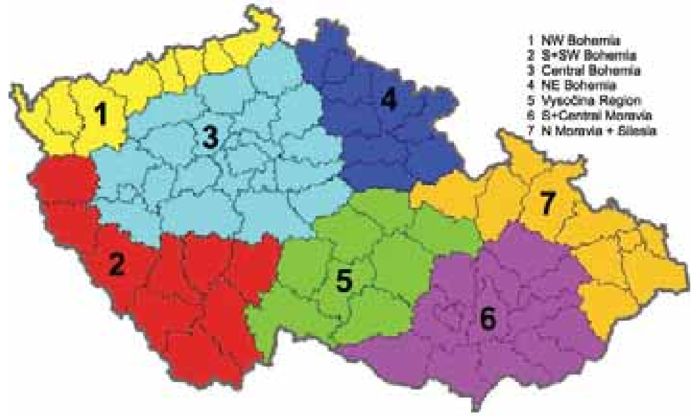

Figure 1. The divisions of the Czech Republic for biometeorological forecast purposes.

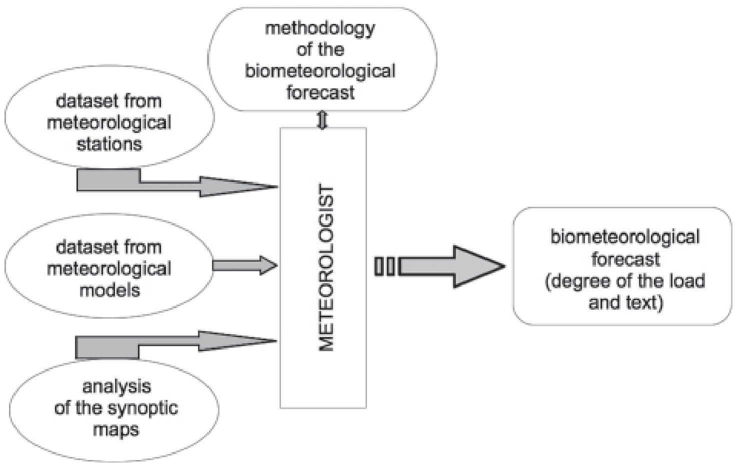

Figure 2. The scheme of the current biometeorological forecast model.

output. The BWF is made available through the media or CHMI's websites. The current BWF model needs to be changed to improve the present weather service. An insufficient description of the immediate influence of the air temperature (*T*), air humidity (*H*), wind (*W*) and radiation budget (*R*) on the human body is the greatest deficiency of the current BWF. There are several biometeorological indices used to solve this deficiency problem. The majority of indices do not include all of the above listed four factors. The well-known Wind Chill Temperature Index is calculated with the use of the air temperature and wind speed only (*TW index*). The Net Effective Temperature (*NET*) is a combination of the air temperature, wind speed, and air humidity (*THW index*) in the current version. The Heat Index is computed with the use of the air temperature and air humidity (*TH index*) and the CHMI's perceived temperature. Radiation is very significant in the human body energy budget. Therefore a new biometeorological index, that was developed in Commission 6 of the International Society of Biometeorology (ISB), was selected for possible application into a new BWF model. This new index is called the Universal Thermal Climate Index (*UTCI*). It is calculated with the use of the meteorological variables: air temperature at 2 m a.g.l., relative humidity (or vapour pressure) at 2 m a.g.l., wind speed (at 10 m a.g.l.) and mean radiant temperature (Błażejczyk 2011). All of these factors are available from basic meteorological measurements done at the meteorological stations.

Materials and methods

It was necessary to do the basic *UTCI* testing before deciding to actually apply the *UTCI* to the future BWF model. Theoretical and measured meteorological data were used for the tests. The *UTCI* values for summer days were also compared with the other selected indices.

The tests of the *UTCI* response to the changes of the individual components were the first step in this study. The Universal Thermal Climate Index values were computed for chosen air temperature values. The computation was done at intervals from -10°C to +30°C (the common range of air temperature in Central Europe). A five degree step was used (Novák 2011a). Two meteorological characteristics were constant and the third one was variable. A dependence of the *UTCI* on the radiant part of the human body energy budget is described by the difference between air temperature and mean radiant temperature (Fig. 3). The constant values of the relative humidity (*H*=50%) and the wind speed (*W*=1 m·s^{-1}) were used in this graph. The next two dependencies on the wind speed (Fig. 4) and the relative humidity (Fig. 5) were constructed in a similar way. The constant values of the relative humidity (*H*=50%) and the difference between air temperature and mean radiant temperature (*Tmrt*=*T*) were chosen for the study of the *UTCI* reaction to the wind speed. The reference constants were *W*=m·s^{-1} and *Tmrt*=*T* for calculating the dependence of the *UTCI* on the relative humidity.

Tests with real meteorological data formed the second part of this work. The aim of these tests was to recognize the behaviour of the *UTCI*, particularly in extreme weather conditions in Prague. The first step was to choose the coldest (December 20) and the warmest (July 23) days of 2009 at the Praha-Libuš meteorological station (WMO ID 11,520, 50°00'30''N, 14°26'53''E, 303 m a.s.l). The most recent example of extreme conditions was the extratropical cyclone 'Kyrill' (January 18-19, 2007) which was an episode with the highest wind speed (very high average wind speed, extreme wind gusts). Meteorological data from the 'Kyrill' episode were measured at the Praha-Karlov station (WMO ID 11519, 50°04'03''N, 14°25'07''E, 232 m a.s.l). Both Prague stations were selected because the BWF is primarily for people, and Prague being the largest city in Czech is ideal for this purpose.

The next step in the *UTCI* tests was to compare the *UTCI* with other selected biometeorological indices. The very warm summer day of July 17, 2011 was used for the comparison with data from the Doksany meteorological station (WMO ID 11509, 50°27'31''N, 14°10'14''E, 158 m a.s.l.). This station was selected because it is situated in one of warmest areas of Czech. The Universal Thermal Climate Index was compared to the following indices: *Heat Index*, Net Effective Temperature (*NET*), perceived temperature *PT*(CHMI) (*THW* index used at the CHMI).

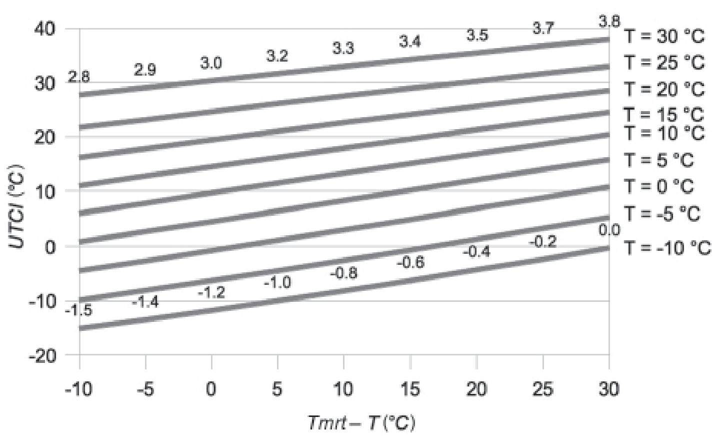

Figure 3. The dependency of the *UTCI* on the difference between mean radiant temperature and air temperature *Tmrt*-*T* (for *W*=1 m·s^{-1}, *H*=50%).

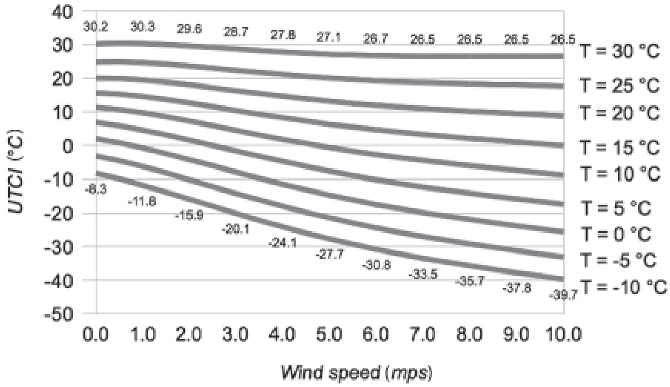

Figure 4. The dependency of the *UTCI* on wind speed (*Tmrt*= *T*, *H*=50%).

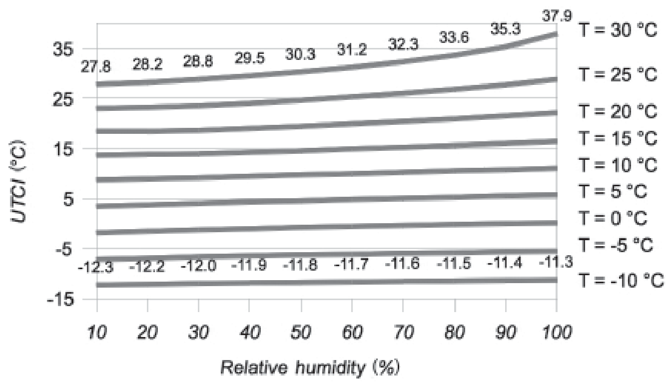

Figure 5. The dependency of the *UTCI* on relative humidity (*Tmrt*=*T*, *W*=1 m·s^{-1}).

Results and conclusions

The relationship of the *UTCI* and relative humidity (Fig. 5) is weaker than the relationship of the *UTCI* and mean radiant temperature (Fig. 3). The relationship between the *UTCI* and wind speed is even weaker (Fig. 4). According to Figure 3, the *UTCI* values increase significantly with great radiation contribution to the balance of the human body surface (i.e. positive difference *Tmrt*–*T*). The difference between air temperature and *UTCI* is very small for a 'light radiant situation' (*Tmrt*~*T*), but the *UTCI* values are about 10°C higher than air temperature for a full radiant situation (typically clear sky in the early afternoon). This fact confirms the need for the use of the radiant factor in a biometeorological index construction, particularly in summer months.

The dependency of the *UTCI* on wind speed seems very strong especially for lower air temperatures (Fig. 4). It was possible to observe this *UTCI* property during the 'Kyrill' episode (Fig. 9). In this graph, however, the *UTCI* behaviour for wind speed above 20 m·s^{-1} was very strange. Therefore, theoretical curves of the *UTCI* dependency on wind speed were constructed for speeds above 10 m·s^{-1} (Fig. 10, Fig. 11). The first problem concerned wind speed intervals between approximately 20 and 30 m·s^{-1}. The *UTCI* values increase with higher wind speed in this interval. The course of the *UTCI* was contrary to the theoretical assumption that a higher wind speed brings a stronger cooling effect. The second problem concerned wind speeds higher than 30 m·s^{-1}. The *UTCI* values fall very rapidly when the wind speed increases. The *UTCI* values even descend below 0 K (-273,15°C). A temporary solution to the problems was suggested: to use wind speed equal to 20 m·s^{-1} for all values above this limit (20 m·s^{-1}). This solution is acceptable because an increase in the cooling effect of the wind above this limit is

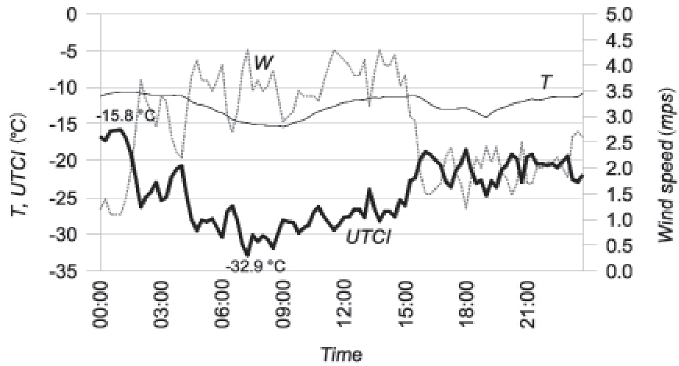

Figure 6. The course of the *UTCI*, air temperature (*T*) and wind speed (*W*) during the coldest day of 2009 at the Praha-Libuš station (December 20).

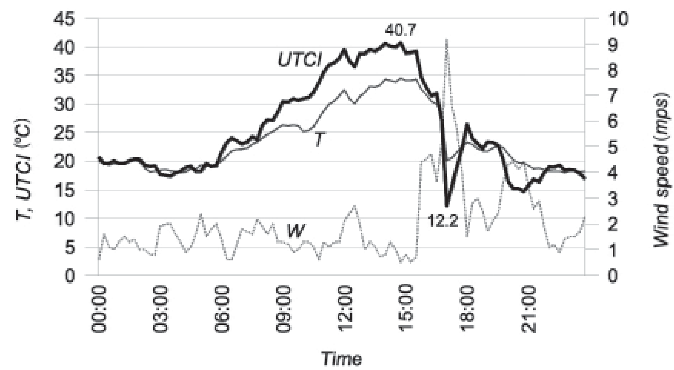

Figure 7. The course of the *UTCI*, air temperature (*T*) and wind speed (*W*) during the hottest day of 2009 at the Praha-Libuš station (July 23).

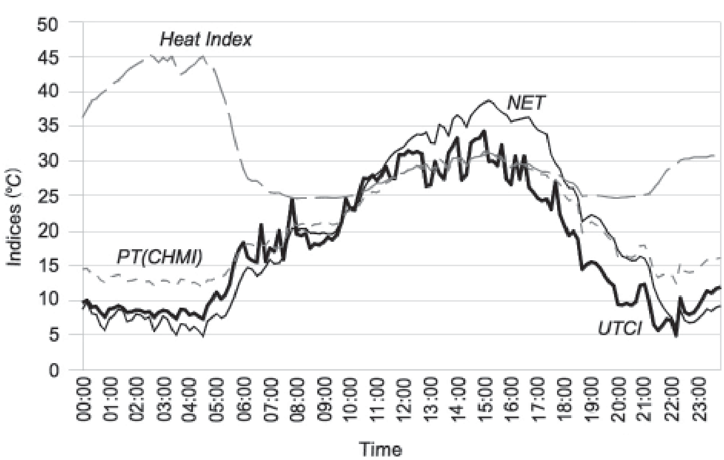

Figure 8. The course of the *UTCI*, *Heat Index*, Net Effective Temperature (*NET*) and CHMI's Sensational Temperature (*PT*(CHMI)) during the warm summer day of July 17, 2011 at the Doksany station.

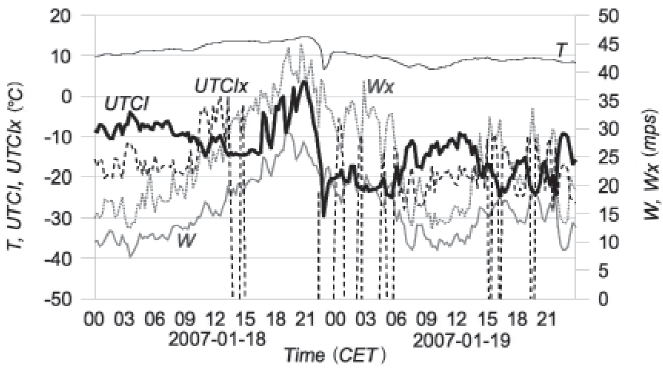

Figure 9. The course of the *UTCI*, air temperature (*T*), wind speed (*W*), maximal wind gusts in 10 minutes intervals (*Wx*) and maximal *UTCI* calculated with the use of the *Wx* (*UTCIx*) during the 'Kyrill' episode at the Praha-Karlov station (January 18-19, 2007).

disputable. When wind speeds are above 20 m·s^{-1}, people usually stay in buildings. An exposure of the human body surface is minimalized because people wear sufficient clothing and do not stay outdoors long.

The *UTCI* and other meteorological characteristics in Figure 6 confirm theoretical assumptions, for example, of the very cold central European day with a maximal air temperature below -10°C; the coldest day of 2009 in the city of Prague (December 20). The daily average of the air temperature was -12.4°C at the Praha-Libuš meteorological station. The *UTCI* values were lower when the wind speed was higher. The *UTCI* values were higher in the late afternoon and in the evening, when the wind speed was lower. The difference between air temperature and the *UTCI* was maximally almost 20°C (about 7:00 CET), when wind speed was greater than 4 m·s^{-1}.

The second real example is represented in Figure 7. In this case, the course of the *UTCI* confirms a dependency on the mean radiant temperature. July 23 was the hottest day in 2009 in the city of Prague (daily maximum air temperature was above 34°C, minimum about 18°C, and the daily average was 23.4°C at the Praha-Libuš station). The *UTCI* values were very similar to the air temperature in the second half of the night, and in the morning (approximately between midnight and 5:30 CET). The difference between mean radiant temperature and air temperature was increased before noon and the *UTCI* increased faster than the air temperature. The faster growth of the mean radiant temperature associated with a rising insolation was the reason. The fall of the *UTCI* and air temperature in the late afternoon (between 16:00 and 17:00 CET) was caused by a thunderstorm with clouds (slow decrease of the *UTCI* and air temperature after 16:00 CET), precipitation, and higher wind speed with gusts (there was a fast fall of wind speed with gusts after 16:30 CET).

A comparison of the *UTCI* with other selected indices was the last component of these tests (Novák 2011b). A difference between air temperature and an equivalent temperature (for example *Heat Index*, *PT* (CHMI), *NET*, *UTCI*) is very interesting during the warm period of the year. For this paper, the summer date of July 17, 2011 was chosen as an example of a warm summer day. The meteorological data were from the Doksany station (40 km north from Prague). The minimal air temperature was relatively low on this day (9.9°C at 2:30 CET), but maximal air temperature was high (32.5°C at 15:10 CET). The daily average of the air temperature was 21.8°C on this day. The daily course of the relative humidity was typical for a summer day – minimal value was in the afternoon (24% at 15:00 CET) and maximal value in the early morning (96% at 3:40 CET). The early hours of this day were calm (wind speed about 0,5 m·s^{-1}). The maximal wind speed was in the evening (7.9 m·s^{-1} at 20:00 CET). The sky was overcast in the morning (about 3:00 CET) and in the evening (from approximately 18:00 CET). There was about 4 octas during the day with minimal variability (cloudiness between 3 and 5 octas from 9:00 to 17:30 CET). The graph (Fig. 8) shows a very different course of the *Heat Index* in the night hours. Such a difference is a typical attribute of this index for air temperature below approximately 25°C.

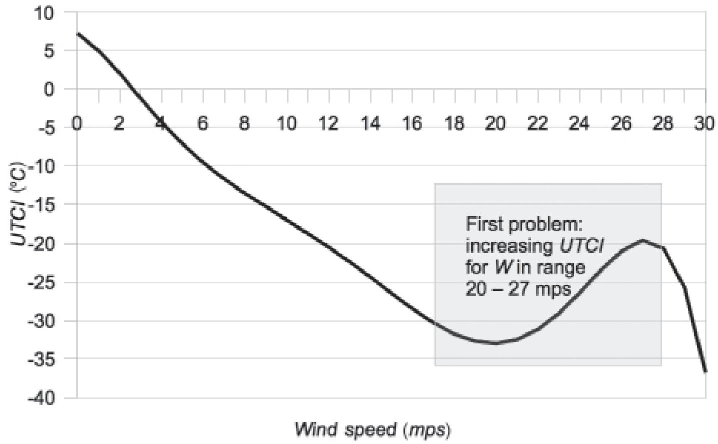

Figure 10. The problem with the *UTCI* for wind speed above 20 m·s^{-1}.

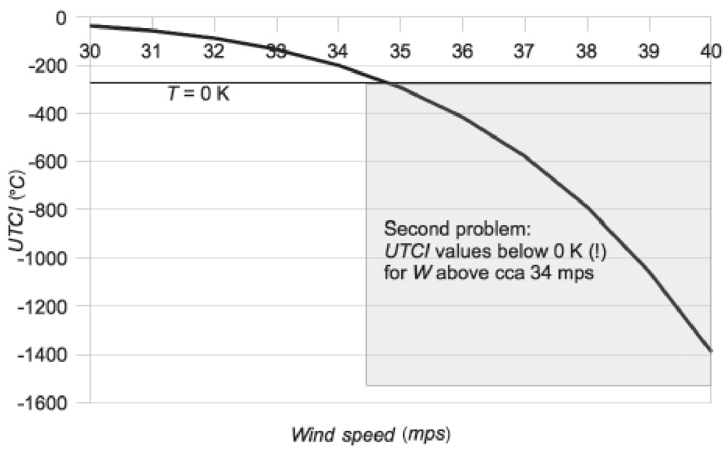

Figure 11. The problem with the *UTCI* for wind speed above 30 m·s^{-1}.

This difference is an argument for the elimination of this index from bioweather forecasting in the central European region. The courses of the *NET* and the *PT*(CHMI) are similar but the *UTCI* is more variable than the others during the day. This stronger variability is caused by the influence of the radiant factor on this index.

The results of the *UTCI* tests prove that this index is very suitable for description of biometeorological conditions during the warm period of the year and especially during sunny days. A course of the *UTCI* is also useful during cold days, but there is a problem during windy conditions. The values of the *UTCI* fall very fast when wind speed increases. This fall does not pose a problem for the use of the *UTCI* in the BWF model because this forecast is focused on average conditions at a time interval (at least 1 hour). The real average wind speed at this interval is not above the critical limit for populated places in Central Europe. The positives points of the *UTCI* are: the use of the radiant factor, direct input operational meteorological data for calculations, and integration into meteorological models (Jendritzky 2012).

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Editors' note:
Unless otherwise stated, the sources of tables and figures are the author(s), on the basis of their own research.

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