Examination of human comfort predictability using ECMWF deterministic model

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INTRODUCTION

Research of the relationship between atmospheric environment and human body goes back to centuries. It is a well-known fact today that our body is exposed to greater bioclimatic load due to the climate change, especially in urban environments. Therefore, people exposed to greater heat risk (e.g. infants and older people, heavy manual workers, or soldiers) have to be aware of the intensifying environmental heat stress influencing them in order to maintain their health. This topic has received a little attention in Hungary until now despite the opportunity of human comfort forecast. Therefore, our goal is to understand this research field thoroughly. The first results of this research are presented in this study.

USED VERIFICATION METHODS

The forecasts was verified in two ways:

1) The reliabbility of forecast of the bioclimatic index values,
2) The goodness of forecast of the thermal sensation and/or risk categories based on different bioclimatic indices.

For the verification of bioclimatic index values three commonly used error statistics was allied, include the Bias (or Mean Error, ME), the Mean Absolute Error (MAE) and the Root Mean Squared Error (RMSE). For representation of relationship between the forecasts and observations the distribution diagrams was prepared in any case.

To verifying multi-category forecasts (e.g. thermal sensation category or risk category) the contingency table was used which is showing the frequency of forecasts and observations in the different range. Contingency tables will normally have as many rows as there are categories in the forecast. For verification purposes, the definition of the forecast and observation variable must be consistent, so a contingency table will have an equal number of rows and columns. In this work – in consideration of the size of contingency table *(e.g. for WBGT: 4X4; for Heat Index: 5X5; for Wind Chill Temperature: 6X6; for THI and UTCI: 8X8; for PET: 11X11)* – we preferred the verification indicators which represents the goodness of forecasts as a single number. Such indicator are the Proportion Correct (PC) and the Heidke Skill Score (HSS):

$$PC = \sum p(f_i, o_i) \qquad HSS = \frac{\sum p(f_i, o_i) - \sum p(f_i)p(o_i)}{1 - \sum p(f_i)p(o_i)}$$

where $p(f_i,o_i)$ shows the joint distribution of forecasts and observations,
$p(f_i)$ and $p(o_i)$ denotes the marginal distribution of forecasts and observations.

RESULTS: Comparing forecasted and measured value of bioclimate indices

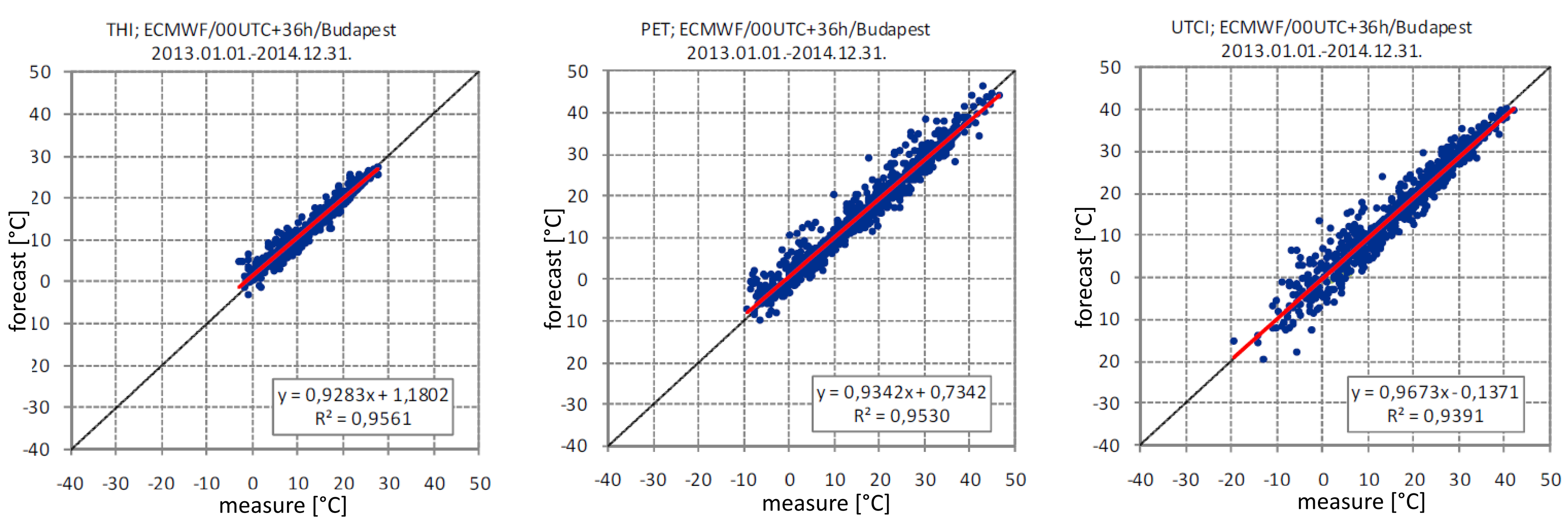

Fig.1.: Scatter plots comparing the forecasted and measured value of the selected bioclimate indices in Budapest. *THI: Temperature Humidity Index; PET: Physiologically Equivalent Temperature; UTCI: Universal Thermal Climate Index*

RESULTS: Error statistics and verification measures

Station	THI forecast						THI category forecast			
	00 UTC			12 UTC			00 UTC		12 UTC	
	Bias	MAE	RMSE	Bias	MAE	RMSE	PC	HSS	PC	HSS
Budapest	0,143	1,075	1,547	**0,042**	**0,990**	**1,401**	0,866	0,809	**0,874**	**0,820**
Győr	0,744	1,205	1,737	**0,673**	**1,134**	**1,637**	0,867	0,812	**0,896**	**0,852**
Szombathely	0,394	1,157	1,717	**0,286**	**1,085**	**1,571**	0,863	0,804	**0,881**	**0,829**
Pécs	0,419	1,121	1,640	**0,251**	**1,012**	**1,464**	0,881	0,830	**0,899**	**0,855**
Szeged	0,572	1,130	1,646	**0,497**	**1,050**	**1,526**	0,864	0,810	**0,871**	**0,819**
Debrecen	0,424	1,072	1,616	**0,333**	**1,005**	**1,475**	0,853	0,793	**0,881**	**0,832**

Station	PET forecast						PET category forecast			
	00 UTC			12 UTC			00 UTC		12 UTC	
	Bias	MAE	RMSE	Bias	MAE	RMSE	PC	HSS	PC	HSS
Budapest	**-0,305**	2,119	2,822	-0,501	**2,055**	**2,653**	**0,677**	**0,635**	0,660	0,616
Győr	0,794	2,230	2,969	**0,709**	**2,065**	**2,788**	0,647	0,601	**0,655**	**0,610**
Szombathely	0,349	1,992	2,820	**0,233**	**1,889**	**2,680**	0,659	0,612	**0,692**	**0,649**
Pécs	0,990	2,186	3,087	**0,770**	**1,983**	**2,817**	0,644	0,597	**0,662**	**0,617**
Szeged	1,646	2,360	3,354	**1,441**	**2,108**	**3,025**	0,612	0,564	**0,645**	**0,601**
Debrecen	1,420	2,162	3,083	**1,259**	**2,008**	**2,817**	0,640	0,593	**0,678**	**0,637**

Station	UTCI forecast						UTCI category forecast			
	00 UTC			12 UTC			00 UTC		12 UTC	
	Bias	MAE	RMSE	Bias	MAE	RMSE	PC	HSS	PC	HSS
Budapest	**-0,694**	2,303	3,103	-0,855	**2,188**	**2,858**	0,793	0,711	**0,811**	**0,736**
Győr	1,062	2,888	4,000	**0,990**	**2,734**	**3,824**	0,742	0,643	**0,748**	**0,652**
Szombathely	**0,014**	2,335	3,339	-0,136	**2,243**	**3,233**	**0,805**	**0,721**	0,804	0,718
Pécs	1,340	2,623	3,884	**1,152**	**2,403**	**3,586**	0,747	0,638	**0,782**	**0,690**
Szeged	2,388	2,940	4,191	**2,204**	**2,712**	**3,885**	0,733	0,634	**0,741**	**0,644**
Debrecen	1,943	2,548	3,620	**1,778**	**2,365**	**3,333**	0,766	0,678	**0,782**	**0,701**

Fig.2.: Error statistics and verification measures of selected bioclimate index forecasts.

USED DATA

The measured data what we used for the verification come from the climate database of the Hungarian Meteorological Service. Different bioclimatic indices was calculated for six meteorological stations: Budapest, Győr, Szombathely, Pécs, Szeged and Debrecen.

In the selection of stations we took into account to be representative in large geographical landscapes.

The weather forecasts taken from the ECMWF deterministic model which can download from the MARS (Meteorological Archival and Retrieval System) database. Because the verification of the deterministic models is an easier task than verification of the ensemble models, so we chose that. At the ECMWF a 10-day deterministic model based on 00 and 12 UTC analysis is operationally launched twice a day. The deterministic model contains 136 layers between surface and 0.1 hPa pressure level in the vertical, the resolution of model is about 16 km in space.

The analyses was carried out every day in the period between 1 January 2013 and 31 December 2014.

RESULTS: Monthly category errors

Fig.3.: Monthly category errors for selected bioclimatic indices.

RESULTS: 10-day average of Mean Absolute Error (MAE)

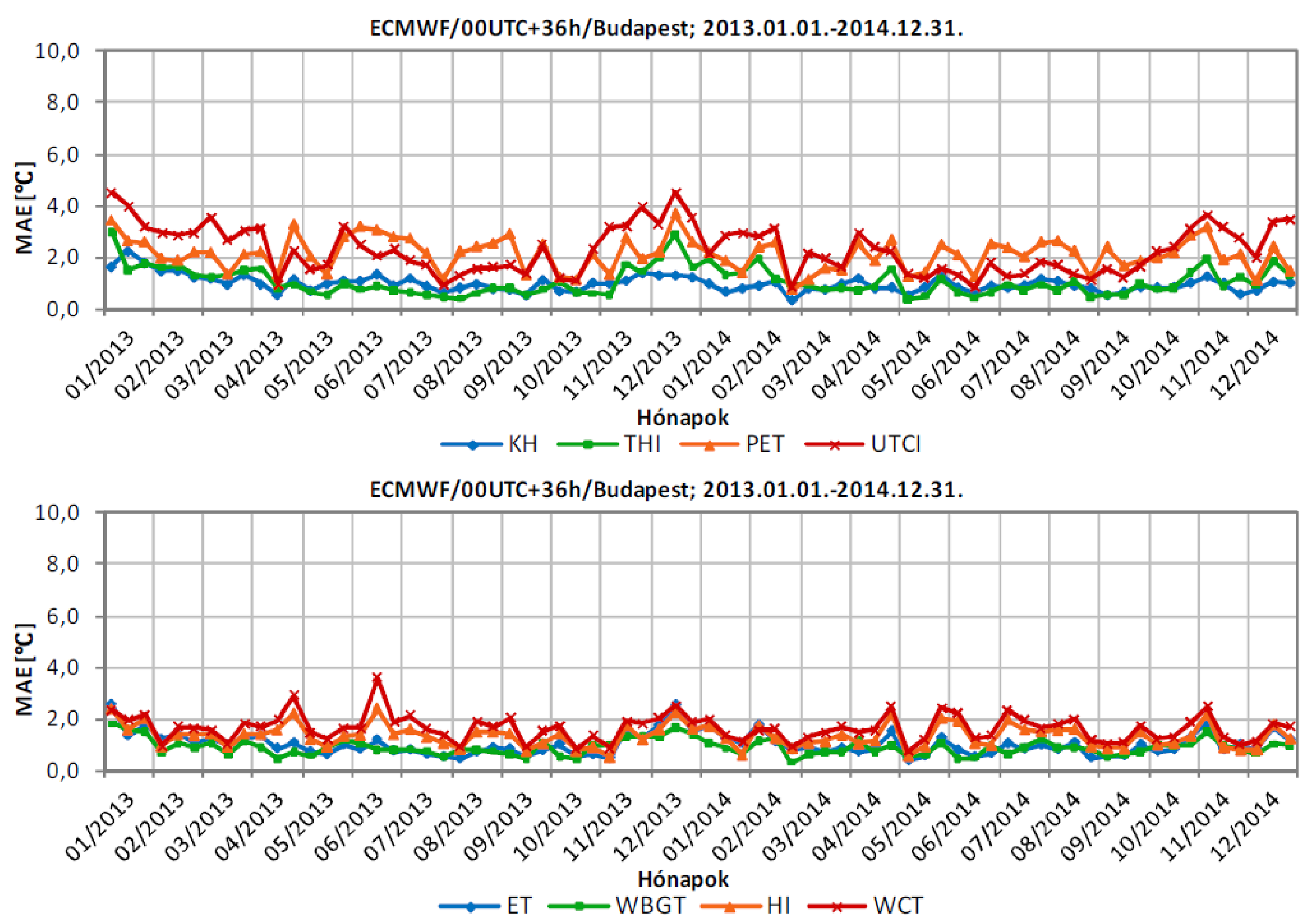

Fig.4.: The 10-day average of MAE of forecasted bioclimatic indices.
KH: Comfort Temperature; THI: Temperature Humidity Index; PET: Physiologically Equivalent Temperature; UTCI: Universal Thermal Climate Index; ET: Effective Temperature; WBGT: Wet Bulb Globe Temperature; HI: Heat Index; WCT: Wind Chill Temperature.

CONCLUSIONS

In connection with the quantification of human comfort predictability the following findings are made:

- The THI predictability, compared to other bioclimatic indices, is exceptionally good. The worst results were found in the UTCI forecast usually.
- Usually, the most predictable season is the summer, while the worst results were clearly in winter.

In the category forecast can be observed the following:

- The thermal sensation range forecast of the THI is excellent in all aspects, while the PET categories forecasts are the least reliable.
- The most reliable and most inaccurate predictions occur in different seasons with higher frequency for each bioclimatic index.

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