Progress towards the final UTCI model

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INTRODUCTION

COST action 730 brings together leading physiologists and meteorologists from Europe and the rest of the world to develop a new weather index which accounts for the physiological and behavioural response of humans coupled with influences of the weather in a more universal and comprehensive manner. This paper presents the role of the physiologists to devise this index.

The purpose of the Universal Thermal Climate Index (UTCI) is to inform the public of how the weather feels, taking into account factors previously considered when developing the wind chill and UV indices, (asymmetric) radiation and humidity.

Present meteorological weather forecast's focus primarily on the predicted air temperature to inform people of how hot or cold the weather shall be. However wind increases body heat loss and causes the temperature felt to be lower than the ambient air temperature. Contrarily long and short wave radiation incident on the body reduces heat loss and causes the perceived temperature to be higher than the air temperature. Furthermore the ambient humidity and precipitation can change the heat loss and also affects the perceived temperature (e.g. feelings of dampness). Additional factors such as cold injury or skin burns may also need to be considered for more extreme climatic condition. Exposed and clothed areas of the body are affected in different ways by the above factors. Thus results from precious work, such as the recent EU projects 'Subzero' and 'Thermprotect' which focused of the effects of climate (cold, wind, moisture and radiation) on the effective insulation of clothing, need to be considered.

METHODS

Development of the UTCI requires the following tasks:

1. Determining which models are available for use in the index. These include both multi-node models and simpler models such as wind chill and UV index.
2. Validating the models available
3. Deciding on the most suitable models to use
4. Devising a scheme to translate the model outputs to a single index
5. Deciding on how the index should be scaled for different conditions
6. Defining a reference person
7. Defining the properties of the clothing worn

8. Providing a method to determine the UTCI from meteorological inputs. This method must be performed quickly as millions of such calculations shall need to be performed daily for weather forecasts of each country.

RESULTS AND DISCUSSIONS

Following the first 1½ years of this COST action, significant progress has already been made with results for the following tasks:

1. Before the start of COST 730, the need for use of an advanced multi-node thermo-physiological model as basis for the UTCI was recognised. Although several such models have been developed to date , not all models were available for evaluation. The two models evaluated in detail were those from Fiala and Tanabe.
2. These two models gave comparable results for climates at or near to comfortable conditions and for 50% relative humidity. However outside such conditions, the Fiala model gave better predictions of the human response.
3. The UTCI model requires accurate prediction of the average human thermo-physiological response for all possible weather conditions. Extensive validation of the now 340-node Fiala model (one of the most advanced multi-node thermo-physiological models available) has demonstrated its ability to predict core and local skin temperatures and sweat rates for people of average fitness over a large range of conditions. After extensive discussion of the Working Group 1 experts in COST 730, a decision has been reached that the group is now satisfied with this model's performance in the main application range of the UTCI. For special climates with local risks (frostbite) additional work may be required.
4. How the model output shall be transformed into an index is a crucial part of the future UTCI model. This transformation could be a single index equation or various equations depending on the domain.
5. In order to help the general public to relate directly to the UCTI, it is proposed that this index should be on the temperature scale (e.g. in degrees Celsius). In this way the influence of factors such as wind and sunshine should be easy to understand, causing the temperature felt to be x °C cooler or warmer than without these factors.
6. As the UTCI should represent the average conditions of a human within a given climate, a reference person shall need to be defined. The reference person proposed has a metabolic rate of 135 W/m2 while walking at 4 km/h . The wind speed should account for this walking speed in accordance with ISO 9920. Wind direction is assumed to be undefined in relation to walking direction.

7. *Clothing worn*

7.1. *Human choice/adaptation of clothing worn*

People tend to adapt their clothing depending on the weather conditions, although this is partly influenced by culture and race which varies from country to country. Thus the UTCI should take these regional differences and adaptations into account. For instance, on a hot summer day, typically less clothing with a low thermal insulation is worn, with possibly more areas of the body being exposed directly or indirectly to sunlight.

However, in winter people tend to wear much more clothing with a higher thermal insulation. Particularly under very cold conditions, more exposed areas of the body such as the head and face should be protected from any wind as this can cause the effective air temperature to drop dramatically, thus increasing the heat loss of the skin to the environment and can even lead to sudden cold injury. Therefore wind protection becomes very important under such conditions. Under wet conditions people tend to wear rain protection which increases the overall water vapour resistance of the clothing. For the UTCI, which clothing is worn could be based on an expert assessment and on a continuous scale, in terms of amount of insulation and amount of body coverage.

The Klima-Michel model, which is presently used by the German Weather Service to predict a perceived temperature, PT (in °C) as a function of weather conditions, assumes the continuous variation of clothing insulation ranging from 1.75 clo (winter) to 0.5 clo (summer) according to the ambient temperature to achieve comfort (i.e. Predicted Mean Vote, PMV = 0) under reference conditions. If the given range of insulation does not allow for comfort there will be a cold stress or heat load respectively. It is proposed that the UTCI model should use a larger range of insulations (2.6 to 0.5 clo) and should also consider the types of clothing that people tend to wear in particular cultures and sessions, with special attention for cold exposure based on ENV342 and results from the EU Subzero project.

7.2. Environmental effects on the properties of the clothing worn

A further consideration which needs to be taken is the influence that the climate on the clothing properties. Factors which can affect/alter the effective insulation and water vapour resistance of the clothing include:

a) wind
b) motion and posture
c) sunlight intensity and direction
d) moisture within the clothing, caused by rain, humidity and body perspiration.

The present clothing model integrated with the Fiala model, is a simple one based on the work of McCullough et al. . A more advanced clothing model shall be required to take into account the factors above, based on ISO 9920 and results from the EU Thermprotect project.

8. The actual method used to determine the UTCI from meteorological inputs shall depend on the computational time and the accuracy required. Possible methods range from a full implementation of the emerging UTCI model (including the Fiala model and the advanced clothing model) to interpolation between points of a multi-dimensional lookup table generated from pre-calculated model results.

CONCLUSIONS

The ultimate aim of developing the UTCI is to inform the general public of the temperature felt, incorporating the climatic factors which alter this from the air temperature. This felt temperature should take into account environmental effects such as wind, air humidity and sunlight. Thus in future a weather report/forecast could state that due to the current wind/sunshine etc. the weather feels x °C cooler or warmer than the air temperature.
The thermo-physiological model now chosen as a basis for the UTCI is the 340-node Fiala model which has been validated for a wide range of climates.
An advanced clothing model shall need to be developed taking into account human behaviour and changes in clothing properties caused by the weather.

REFERENCES