22.5 Heat-related discomfort: Universal Thermal Climate Index (UTCI)

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Universal Thermal Climate Index (UTCI)	**Climate Resilience** **Natural and Climate Hazards** **Health and Wellbeing**
Description and justification	UTCI index represents air temperature of the reference condition with the same physiological response as the actual condition. The UTCI provides a one-dimensional value that reflects the human physiological reaction to the multi-dimensional outdoor thermal environment (Bröde et al., 2012). It can predict both whole body thermal effects (hypothermia and hyperthermia; heat and cold discomfort), and local effects (facial, hands and feet cooling and frostbite). Applications of the UTCI include weather forecasts, bioclimatological assessments, bioclimatic mapping, urban design, engineering of outdoor spaces, outdoor recreation, epidemiology and climate impact research.
Definition	The UTCI is the air temperature that would produce under reference conditions the same thermal strain as the actual thermal environment. In other words, the UTCI is the reference environmental temperature causing strain.
Strengths and weaknesses	+ Mathematical expression of a person's thermal comfort in the outdoors + The output is expressed in easily understandable temperature units, e.g., °C.
Measurement procedure and tool	The human body core temperature must be maintained within a narrow range around 37°C to ensure proper function of the body's inner organs and the brain, thus optimising human comfort, performance and health. In contrast, the temperature of the skin and extremities can vary widely, depending upon environmental conditions. This variation in the temperature of extremities is one of the mechanisms to equilibrate heat production and heat loss. The heat exchange between the human body and environment can be described in the form of the energy balance equation:

M + W + C + K + E + Q + Res ± S = 0

where

M=heat produced by metabolism;
W=heat generated by muscular activity;
C=sensible heat flux (heat transferred by convection);
K=heat transferred through conduction contact with solid bodies);
E=latent heat flux (evaporative heat flux);
Q=radiative heat transfer;
Res=heat transfer through respiration; and,
S=heat content of the body.

The UTCI is derived from this mathematical model of thermoregulation with an integrated adaptive clothing model that also accounts for predicted votes of the dynamic thermal sensation based on core and skin temperature (Fiala et al., 1999, 2001, 2003; Havenith et al., 2011). The deviation of UTCI temperature from measured air temperature depends on measured values of air temperature (T_a) and mean radiant temperature (T_{mrt}), wind speed at a height of 10 m (v_a) and humidity expressed as water vapour pressure (p_a) or relative humidity (rH):

$$\mathbf{UTCI}(T_a, T_{mrt}, v_a, p_a) = Ta + Offset(T_a, T_{mrt}, v_a, p_a)$$

The model reference condition is walking at 4 km/h (135 W/m^2) with T_{mrt}=T_a, v_a=0.5 m/s, rH=50% (T_a >29°C) and p_a=20 hPa (T_a >29°C) (Bröde et al., 2012). The UTCI dynamic model response can be determined using the online calculator available from http://utci.org. The relationship between UTCI temperature (expressed in °C) and physiological stress is shown in the table below (adapted from Błażejczyk et al., 2010).

UTCI (°C) range	Stress category
Above +46	Extreme heat stress
+38 to +46	Very strong heat stress
+32 to +38	Strong heat stress
+26 to +32	Moderate heat stress
+9 to +26	No thermal stress
0 to +9	Slight cold stress
-13 to 0	Moderate cold stress
-27 to -13	Strong cold stress
-40 to -27	Very strong cold stress
Below -40	Extreme cold stress

Scale of measurement	Plot – street – neighbourhood – district
Data source	
Required data	Air temperature, T_a (°C) Mean radiant temperature, T_{mrt} (degrees Kelvin) Water vapour pressure (hPa) Relative humidity (%) Wind speed at a height of 10 m (m/s)
Data input type	Quantitative
Data collection frequency	Frequency as desired. UTCI can be calculated frequently with measurement intervals determined by (automated) weather data acquisition.
Level of expertise required	Low to Moderate
Synergies with other indicators	Direct relation to *Heatwave incidence* and *Number of combined tropical nights and hot days* indicators. Similar to *Physiological equivalent temperature (PET)*
Connection with SDGs	SDG 3 Good health and well-being, SDG 11 Sustainable cities and communities, SDG 13 Climate action
Opportunities for participatory data collection	Participatory data collection is feasible through direct participation in weather data collection
Additional information	
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22.6 Hospital admissions due to high temperature during extreme heat events

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Hospital admissions due to high temperature during extreme heat events	**Health and Wellbeing**
Description and justification	Heat waves are the most significant weather-related cause of human mortality worldwide (Agarwal, Dwivedi & Ghanshyam, 2018).
Definition	The number of hospital admissions per 100 000 inhabitants due to high temperature during extreme heat events from baseline values
Strengths and weaknesses	+ Easy to measure - Difficulties in ruling out other causes for hospital admissions
Measurement procedure and tool	This metric can easily be evaluated using public health data regarding daily emergency room admissions. These data can be used either to evaluate total emergency room admissions, or to assess hospital admissions for specific disease categories such as heat stroke, dehydration and cardiac arrest (e.g., Davis & Novicoff, 2018). Further disaggregation of data may include separation by population demographic (e.g., Gronlund, Zanobetti, Schwartz, Wellenius & O'Neill, 2014).
Scale of measurement	District to metropolitan scale
Data source	