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EXTENDED ABSTRACT

Determination of human thermo-physiological comfort based on meteorological data as a decision support for physical activity recommendations.

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Abstract: Accurate assessment of human thermo-physiological comfort represents a central challenge in biometeorology. This requires a parameter capable of objectively quantifying thermal stress on the human body in a manner that is applicable across varying climates, seasons, and spatial scales. Such an index must extend beyond the consideration of air temperature alone, yet remain interpretable for non-expert users by conveying the extent to which current meteorological conditions impose physiological strain.
In this context, the Universal Thermal Climate Index (UTCI) was employed. The UTCI quantifies thermal stress based on a combination of meteorological variables, including air temperature; mean radiant temperature, wind speed, and humidity. Additionally, it is coupled with a dynamic clothing model, allowing for contextual adaptation to different thermal environments.
As part of the KliMate project, the overarching objective is to strengthen the resilience of older adults to extreme weather events—particularly heatwaves—which are increasing in both frequency and intensity due to anthropogenic climate change. To this end, meteorological, air quality, and pollen data were integrated to generate easily accessible and understandable information for the target population.

Keywords*: Universal Thermal Climate Index (UTCI), thermal stress, biometeorology, aging population, climate adaptation, heat resilience, numerical weather prediction, public health, KliMate project*

Introduction

Assessing human thermo-physiological comfort with precision remains a central challenge in biometeorology. This task requires a parameter that can objectively quantify thermal stress on the human body, independent of regional climate, seasonality, or spatial scale. Beyond simple air temperature, a comprehensive index should integrate various meteorological influences while remaining interpretable for non-specialist users.
The Universal Thermal Climate Index (UTCI) is well suited for this purpose. It synthesizes multiple environmental inputs, including air temperature, mean radiant temperature, wind speed, humidity, and incorporates a dynamic clothing model, and metabolic rates, offering context-sensitive estimations of the thermal stress.

This study was conducted by GeoSphere Austria (former Zentral Anstalt für Meteorologie und Geodynamik, ZAMG) with project leader AIT Austrian Institute of Technology GmbH and in cooperation with Akademie für Altersforschung am Haus der Barmherzigkeit (AAF), Karl-Landsteiner Institut für Gesundheitsförderungsforschung (KLI-GFF), NOUS Wissensmanagement GmbH (NOU), Studio Dankl (SDA) and Universität für Bodenkultur Wien (BOKU). The project was funded by the FFG (Austrian Research Promotion Agency).

2. Methodology

The work conducted within the framework of the KliMate project, aims to enhance the climate resilience of older adults—a group particularly vulnerable to heat-related morbidity and mortality. Using outputs from numerical weather prediction models, forecasts of the UTCI for the subsequent 48 hours can be produced. Under certain simplifications, the UTCI can be applied to both observational and forecast datasets. The Universal Thermal Climate Index (UTCI) is designed to provide an assessment of thermal stress based mainly on meteorological factors for the user's specific geolocation. However, since local parameters individually and locally specific factors such as clothing insulation and solar radiation at the individual level are typically unknown, certain assumptions must be made.
Important notice for the target group is that Important for the target group is the following: Heat stress is not the same as temperature. Therefore, despite the simplifications above, the UTCI retains its benefit by enabling a more accurate estimation of the efficiency of evaporative cooling, particularly through the incorporation of wind speed and atmospheric humidity. Higher humidity reduces evaporative cooling during the process of sweating. In addition, the presence of wind or drafts can promote evaporative cooling. Direct solar radiation warms the body directly, which further increases the heat stress. As a result, the UTCI allows the derivation of more precise behavioural recommendations. An interdisciplinary team of experts will develop these recommendations in advance. During the first year of the project, a structured literature review and online research were conducted using relevant keywords as a basis for the development of these recommendations.

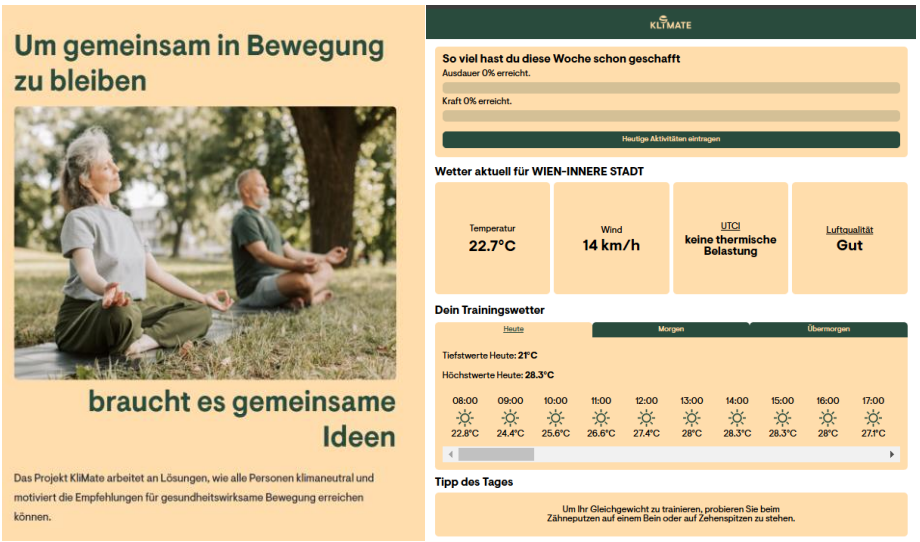

Figure 1: The homepage of the project: https://kli-mate.at/ (left) and the application (right).

3. Results

To support this goal, meteorological data werewas combined with air quality and pollen forecasts to produce, easily interpretable information for the target groups. An interdisciplinary team of medical, environmental, and behavioral science experts developed evidence-based behavioural recommendations, which are linked to specific UTCI values. Using outputs from numerical weather prediction (NWP) models, 48-hour UTCI forecasts can be generated for specified locations (Figure 2). These forecasts enable anticipatory behavioural planning, such as identifying optimal times for night-time ventilation to cool indoor environments without increasing thermal exposure.

The UTCI values are translated into text-based and color-coded formats to ensure accessibility for the target audience. This information is designed to be integrated into a web-based application that is currently under development. The application will provide personalized, location-specific recommendations to promote health-preserving behaviours, encourage active mobility where appropriate, and foster social participation during periods of thermal stress. The forthcoming implementation of this approach in a user-friendly digital application represents a promising step toward translational biometeorology: bridging scientific models with public health communication. Future developments will include real-time updates, adaptive personalization features, and evaluation studies to measure behavioural outcomes and health impacts. An example of the application is shown on Figure 3.

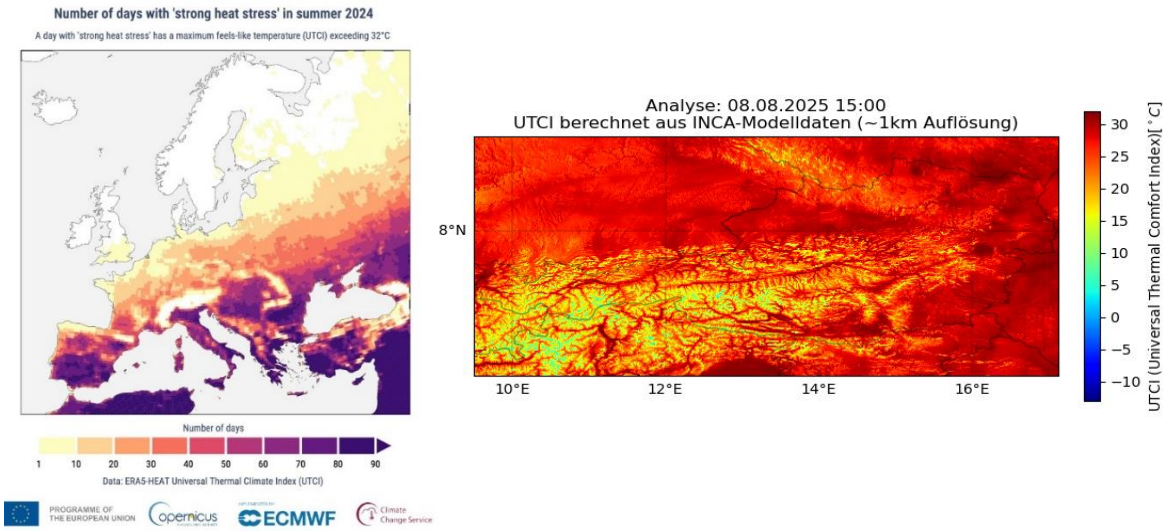

Figure 2: Example of a forecast of the number of the days with "strong heat stress" in summer 2024. Local effects, e. g. elevation of the Alps, could have a significant cooling effect. However, coarse resolution does not reflect the situation in the valleys (left). Regions south and east of the Alps are among the most affected. The urban heat island effect in cities intensifies heat stress (right).

					UTCI
Shadow	30 °C	1 km/h	40%	30 °C	**30 °C**
Light windy	30 °C	20km/h	40%	30°C	**27 °C**
Mugginess	30°C	1km/h	55%	30°C	**31°C**
Long-wave down radiation	30°C	1km/h	40%	50°C	**41°C**
Mugginess,with sunshine	30°C	1km/h	55%	50°C	**42°C**
Mugginess,windy,shadow	30°C	20km/h	55%	30°C	**28°C**

UTCI (°C)	Stress category
UTCI > 46	extreme heat stress
38 < UTCI < 46	very strong heat stress
32 < UTCI < 38	strong heat stress
26 < UTCI < 32	moderate heat stress
9 < UTCI < 26	no thermal stress
0 < UTCI < 9	slight cold stress
-13 < UTCI < 0	moderate cold stress
-27 < UTCI < -13	strong cold stress
-40 < UTCI < -27	very strong cold stress
UTCI < -40	extreme cold stress

Source: Blazejczyk et. al 2014

Figure 3: Example of the UTCI (Taking into account loose clothing at rest)

Development of Recommendations

In the frame of the project, recommendations were developed in two key areas:

(1) Physical activity and active mobility under adverse weather or air pollution conditions, and

(2) General lifestyle-based adaptations to unfavourable weather and air quality situations.

The following environmental conditions were identified as relevant for behaviour recommendations created for the target population: heat, air pollution (fine particulate matter and ozone), pollen exposure,

and extreme weather events. The UTCI framework is particularly effective in accounting for the impact of humidity (perceived as mugginess) as well as the cooling effect of wind, thereby enabling more context-sensitive and appropriate decision-making. The primary target group comprises individuals aged 65 and older. In addition, specific recommendations were also developed for people with chronic cardiovascular or chronic respiratory diseases. During the first year of the project, a structured literature review and online research were conducted using relevant keywords to inform the development of these recommendations.

Within the project consortium, it was agreed that the recommendations developed in the KliMate project should contribute to achieving the Austrian national physical activity guidelines issued by the Fonds Gesundes Österreich (FGOE).

Conclusions:

As part of the KliMate project, the overarching objective is to strengthen the resilience of older adults to extreme weather events—particularly heatwaves—which are increasing in both frequency and intensity due to anthropogenic climate change. To this end, meteorological, air quality, and pollen data were integrated to generate easily accessible and understandable information for the target population.

- *Urban Planning*: Planning of cooling measures, green spaces, and construction projects
- *Healthcare:* Civil protection, heat warning systems, medical research
- *Occupational Safety (heat-exposed professions):* Worker protection in construction, agriculture, heavy industry, etc.
- *Sports*: Optimization of clothing and equipment, training under extreme conditions, assessment of stress

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