**Introduction**

Human thermal perception is influenced by a lot of meteorological parameters like air temperature ($T_a$), wind speed ($v$) and the different radiation fluxes summarized as the mean radiant temperature ($T_{mrt}$).

**Thermal Indices**

The impact of the individual meteorological parameters on thermal bioclimate can be best estimated by applying thermal indices, e.g. the Perceived Temperature (PT), the Universal Thermal Climate Index (UTCI) or the Physiologically Equivalent Temperature (PET).

To assess thermal stress for humans, the results can be evaluated using thermal stress classifications, which are available for different indices and regions. For Freiburg, the thermal perception classification introduced by [1] was selected (tab. 1).

**Data and Method**

This study is based on meteorological data recorded by the German Weather Service at the station Freiburg (southwest Germany) covering the years 1981 - 2013 in 1h resolution.

To approximate the future conditions REMO regional modelling outputs for the same location have been used covering the years 1950 - 2100 in 1h resolution. The model RayMan [2, 3] was applied for calculating the three thermal indices.

**Conclusions**

For the assessment of thermal stress, PET still appears to be the best choice, as it can be calculated for situations with low $v$ and high $T_{mrt}$ and shows a plausible distribution (fig. 1). PET for REMO data shows a general increase in heat stress (PET $> 35^\circ$C) by 0.5%. Increased heat stress is found to be the largest in summer at daytime (2.8%) but also some increase at night time is evident.

**Sensitivity of the Thermal Indices**

Six modified datasets have been created to show the impact of the different input parameters on the thermal indices. The indices were calculated and evaluated for additional four datasets with modified $T_a$ of +/-2 K and modified $v$ of +/-3 m/s for UTCI, as $v$ in 10 m required. Additionally, two input datasets with reduced $T_{mrt}$ were calculated: one with $T_{mrt} = T_a$ ("shaded") and $T_{mrt} = 0.5 T_a + 0.5 T_{mrt}$ ("half-shaded"). The results for the modified datasets have been compared to those for the default dataset (modified by 0 K, 0 m/s and $T_{mrt} = T_a$ ("sun")).

For the modifications in $T_a$ (fig. 1, left) all three indices agree in the general trend to respond little about the same amount as the modifications in input $T_a$. It can also be seen, that the distribution of PT (left three beans) is very uneven both for the original, as well as for the modified datasets. Comparison of the results for the modified $v$ (center) shows that the indices agree in the trend, but disagree in the amount of their response. UTCI (central part) is based on less data as it requires 0.5 m/s $< v < 17$ m/s, which is not valid for many readings. The modification in input $T_{mrt}$ shows most comfortable conditions for the datasets with $T_{mrt} = T_a$ ("shaded") for all indices.

**Approach the Future Conditions**

The thermal conditions in the future have been assessed using REMO data. The data was separated into three groups: 1971-2000 ("now"), 2020-2050 ("2035") and 2070-2100 ("2085"). For the results of the sensitivity analysis, PET was selected for the assessment. Results were classified using the thermal perception classification after [1] (tab. 1).

Table 1: Thermal sensation classes for human beings in Central Europe, modified after [1].

<table>
<thead>
<tr>
<th>$T_a$</th>
<th>Thermal Perception</th>
<th>Grade of Physiological Stress</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 4</td>
<td>Very cold</td>
<td>Extreme cold stress</td>
<td></td>
</tr>
<tr>
<td>4 - 8</td>
<td>Cold</td>
<td>Strong cold stress</td>
<td></td>
</tr>
<tr>
<td>8 - 13</td>
<td>Warm</td>
<td>Comfortable</td>
<td></td>
</tr>
<tr>
<td>13 - 18</td>
<td>Slightly cool</td>
<td>Slight cold stress</td>
<td></td>
</tr>
<tr>
<td>18 - 23</td>
<td>Slightly cool</td>
<td>No thermal stress</td>
<td></td>
</tr>
<tr>
<td>23 - 29</td>
<td>Warm</td>
<td>Slight heat stress</td>
<td></td>
</tr>
<tr>
<td>29 - 35</td>
<td>Very hot</td>
<td>Moderate heat stress</td>
<td></td>
</tr>
<tr>
<td>&gt;= 35</td>
<td>Very hot</td>
<td>Extreme heat stress</td>
<td></td>
</tr>
</tbody>
</table>

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**References**


