Air temperature measurement uncertainty associated to a mounting configuration temperature sensor-radiation shield

Miruna Dobre  FPS Economy, Metrology, National standards, BE
D Sestan  Faculty of Mechanical Engineering and Naval Architecture, HR
A Merlone  Istituto Nazionale di Ricerca Metrologica, IT
A thermometer measures only its own temperature!

Measurement of the air temperature
20 ± 0.5 ºC

Measurement of the triple point of water temperature
0.01 ± 0.0001 ºC

\[ T_{\text{air}} = T_{\text{sensor}} + \Sigma \text{Cor}_{\text{sensor}} + \Sigma \text{Cor}_{\text{IN env}} + \Sigma \text{Cor}_{\text{OUT env}} \]
Physical model based on energy balance

\[ \propto \sigma (T_w^4 - T_{sensor}^4) + h_c (T_a - T_{sensor}) = 0 \]

**The approach:** calculate the difference between Tair and Tsensor for different values of an influencing environmental parameter and estimate the measurement uncertainty related to that factor.
Heat transfer modes involved in temperature measurement inside a meteorological screen

- Direct SW radiation
- Reflected SW radiation
- Absorbed SW radiation
- Diffused SW radiation
- Convection
- LW radiation
Environmental parameters

HEAT TRANSFER MODE

- Radiation
  - Shortwave
    - Solar irradiance
    - Screen albedo
    - Ground albedo
  - Longwave

- Convection
  - Forced
    - Air flow speed

- Conduction
  - Plane surface or cylinder
    - Screen materials conductivities
    - Screen geometry
Numerical solution

- Collaboration with Belgian Royal Meteorological institute*: model is based on the real wooden screen, installed in Brussels.
- Comsol software + heat transfer module is used
- The numerical simulation includes solving of the fluid flow equations coupled with the heat transfer equations, including direct and indirect shortwave solar radiation (wavelengths shorter than 2.5 μm) together with longwave radiation (wavelengths above 2.5 μm).

*Acknowledgement to Dr. Luis Gonzalez Sotelino & Nicolas De Coster from KMI-IRM, Belgian Meteorological Institute
1. Enlarged ground and air domains

2. Realistic thermometer geometry: wire wound PRT sensor protected by stainless steel sheath

3. Double louvers

Final mesh: 1.6 million elements (mostly tetrahedral)
Numerical simulation: results

- Inlet air speed of 1 m/s
- Surrounding air temperature 20 °C
- Grass ground
- White screen painting
- Screen made of stainless steel
- Solar irradiance 800 W/m²
- Ground and ambient temperature 20 °C
Plane through the screen center (behind the door frame).

Plane located 250 mm on the left of the screen center (behind the door louvers).

Maximum air velocity inside the screen is 0.35 m/s.
Environmental air temperature: 20.00 °C,
Calculated thermometer sensor temperature: 21.13 °C,
Temperatures of the air inside the screen: from 20.23 °C to 21.44 °C.
Wind speed influence under different solar irradiations

- Wind speed 5 m/s
- Wind speed 3 m/s
- Wind speed 1 m/s

![Graph showing the influence of wind speed on solar irradiation](http://economie.fgov.be)
Wind speed influence: find correction equations

\[ T_{s} - T_{air} = 1.5*V - 0.8 \]

Solar irradiation 1000 Wm\(^{-2}\)
## Uncertainty contributions related to environmental parameters

<table>
<thead>
<tr>
<th>Factor</th>
<th>Parameter</th>
<th>Range of parameter</th>
<th>Range of difference $T_{\text{sensor}} - T_{\text{air}}$ °C</th>
<th>Uncertainty °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>Absorptivity</td>
<td>0.7 – 0.84</td>
<td>0.62</td>
<td>0.36</td>
</tr>
<tr>
<td>Paint</td>
<td>Absorptivity</td>
<td>0.2 – 0.45</td>
<td>0.09</td>
<td>0.05</td>
</tr>
<tr>
<td>Ground temperature</td>
<td>Temperature</td>
<td>10 – 20 °C</td>
<td>0.28</td>
<td>0.16</td>
</tr>
<tr>
<td>Air temperature</td>
<td>Temperature</td>
<td>10 – 20 °C</td>
<td>0.27</td>
<td>0.16</td>
</tr>
<tr>
<td>Sensor material</td>
<td>Copper, steel</td>
<td></td>
<td>0.24</td>
<td>0.14</td>
</tr>
<tr>
<td>Sun position</td>
<td>Hour</td>
<td>12:00 – 19:00</td>
<td>0.34</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Combined uncertainty (k=1)</strong></td>
<td><strong>0.49</strong></td>
</tr>
</tbody>
</table>

**Worst case: low wind speed (1 m/s ) and high solar irradiation 1000 W/m²)**
Acknowledgment

This work was done in the frame of the Researcher Mobility Grant, in the scope of the project ‘Metrology for essential climate variables' (ENV58 MeteoMet2).

WWW.METEOMET.ORG