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

Miruna Dobre *FPS Economy, Metrology, National standards, BE*

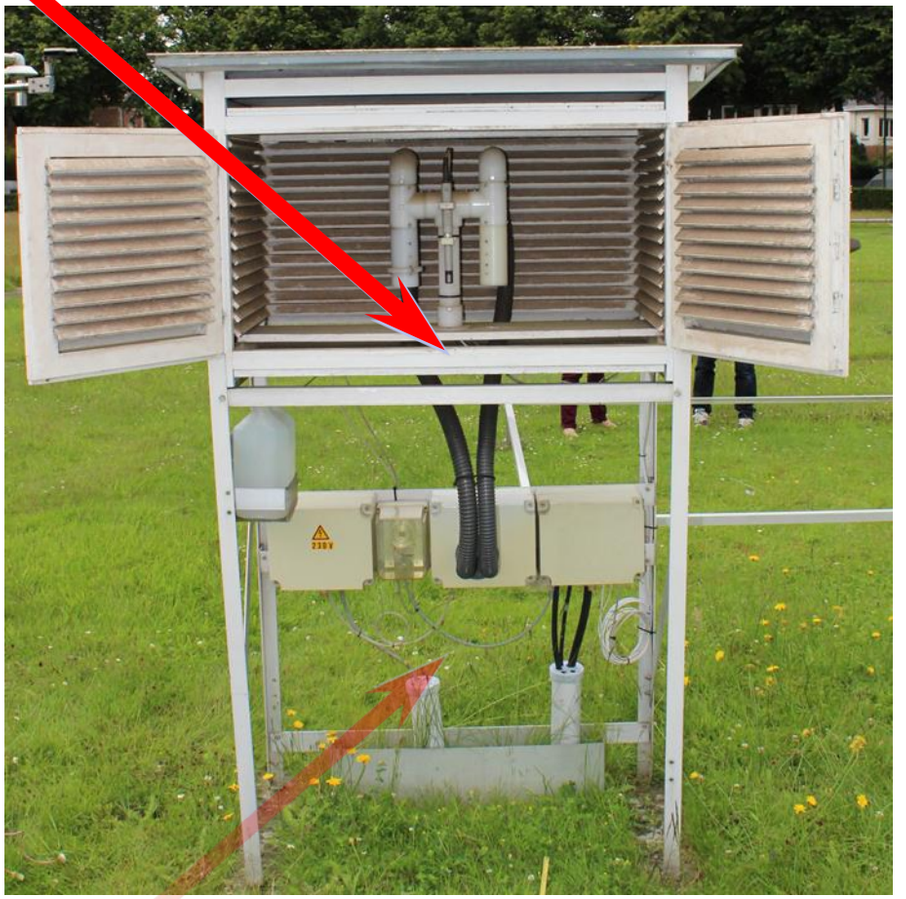
D Sestan *Faculty of Mechanical Engineering and Naval Architecture, HR*

A Merlone *Istituto Nazionale di Ricerca Metrologica, IT*

A thermometer measures only it's own temperature!

Measurement of the air temperature
20 ± **0.5 °C**

Measurement of the triple point of water temperature
0.01 **± 0. 0001 °C**



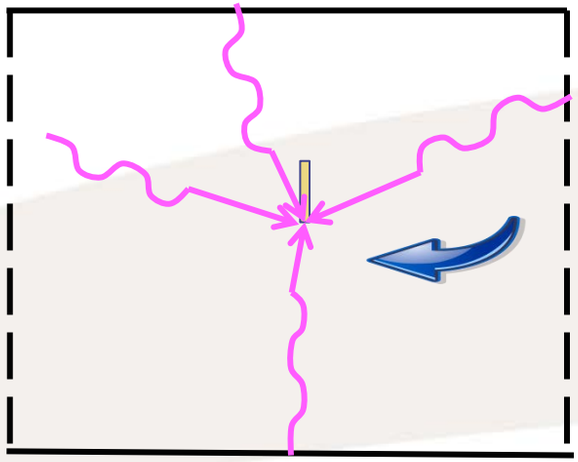
$$T_{air} = T_{sensor} + \Sigma Cor_{\ sensor} + \Sigma Cor_{\ IN\ env} + \Sigma Cor_{\ OUT\ env}$$

Physical model based on energy balance

Radiation from screen walls

Convective flow around sensor

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



The approach: calculate the difference between Tair and Tsensor for different values of an influencing environmental parameter and estimate the meaurement uncertainty related to that factor

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Heat transfer modes involved in temperature measurement inside a meteorological screen

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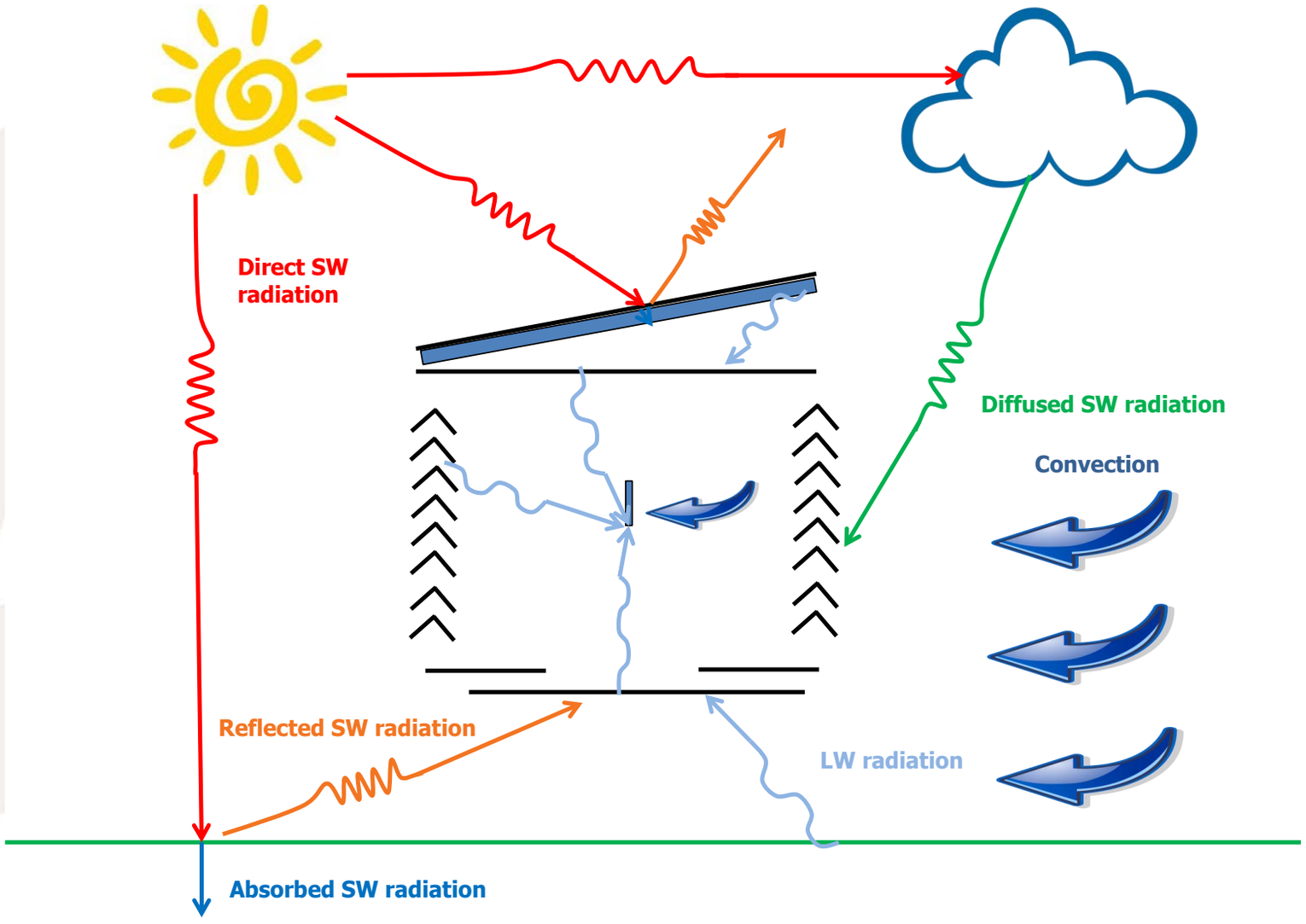
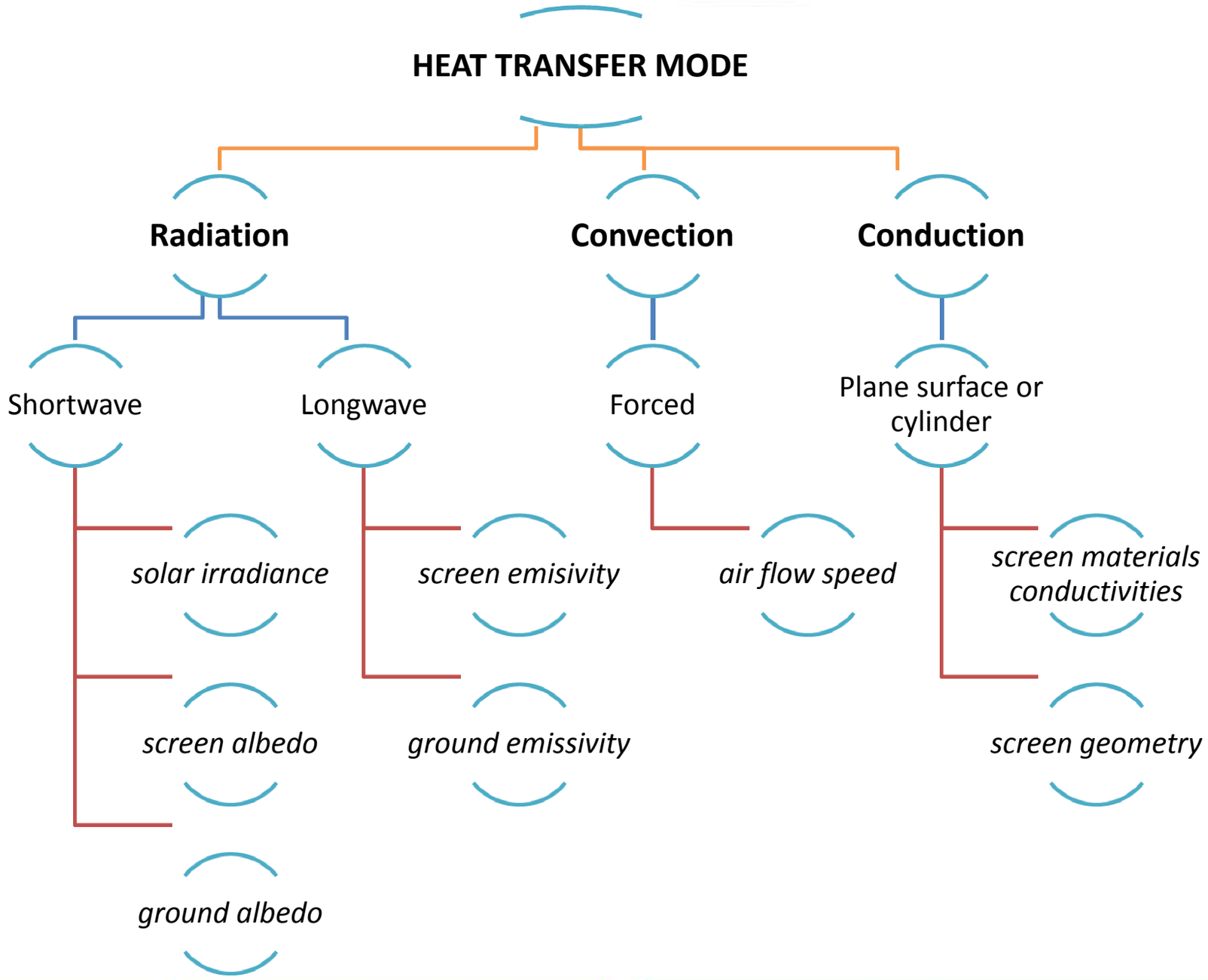
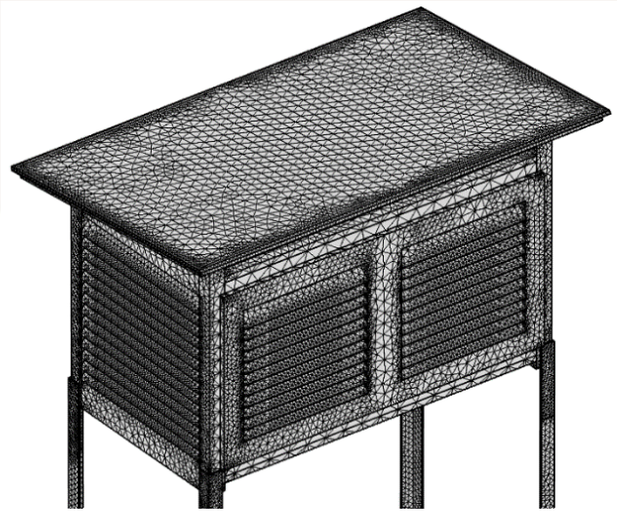


Environmental parameters



Numerical solution

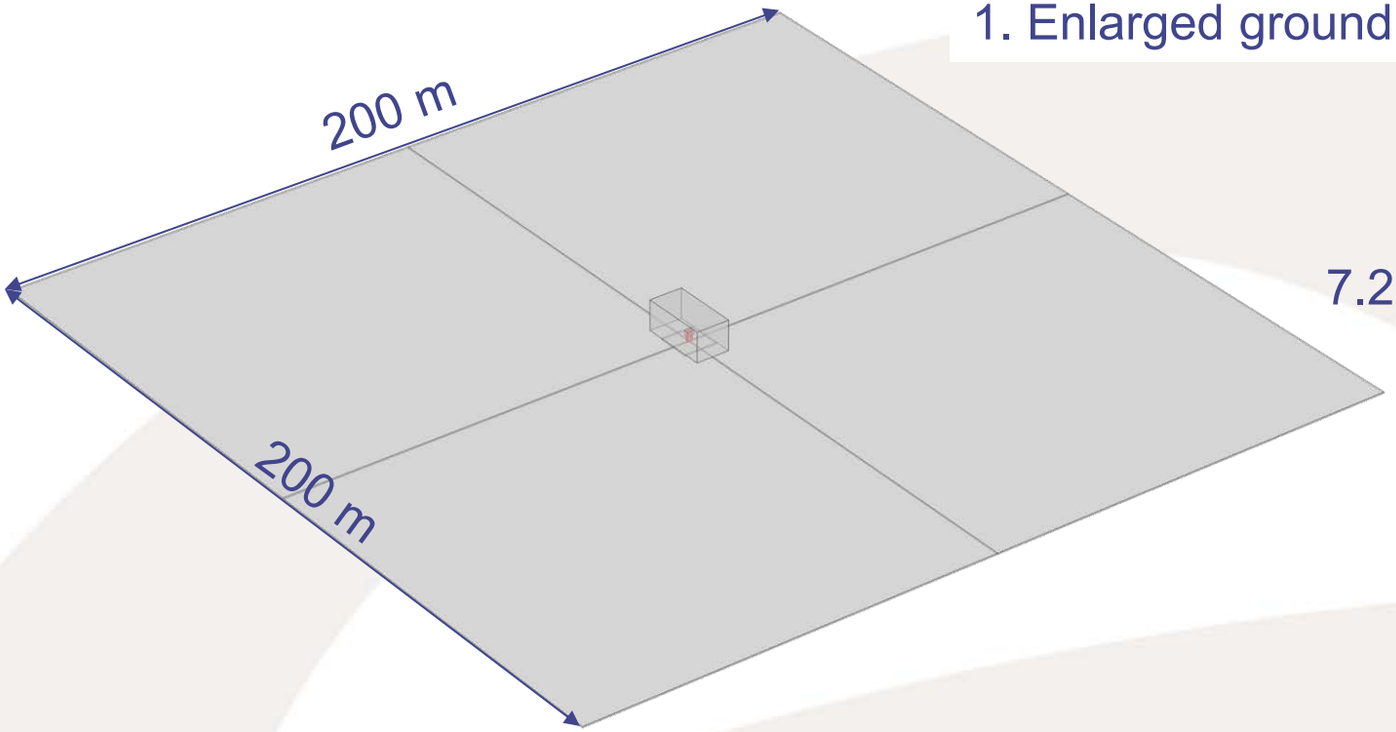


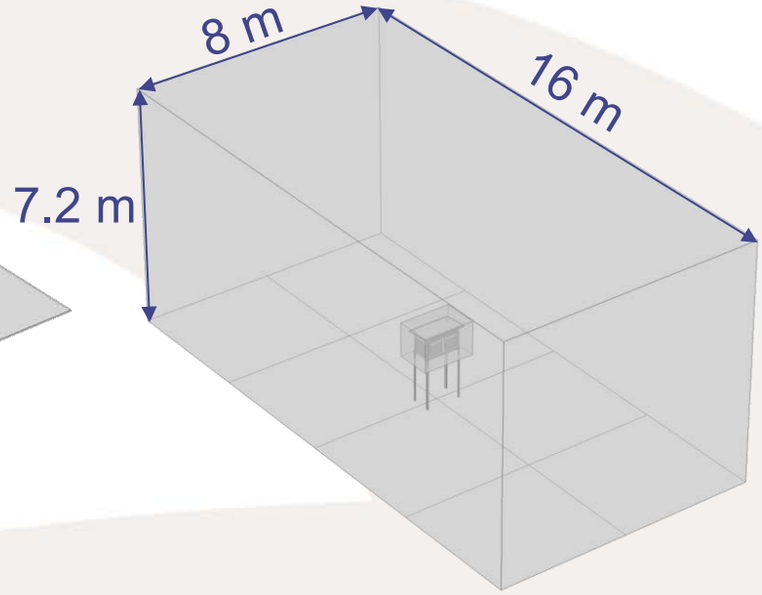
- Collaboration with Belgian Royal Meteorological institute* : model is based on the real wooden screen, installed in Brussels.
- Comsol software + heat transfer module is used
- The numerical simulation includes solving of the fluid flow equations coupled with the heat transfer equations, including 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

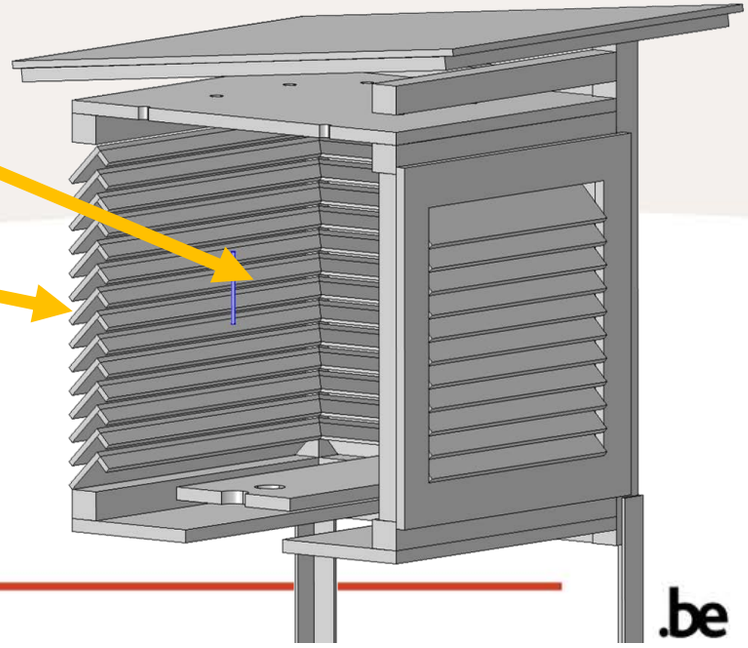
Model geometry

1. Enlarged ground and air domains

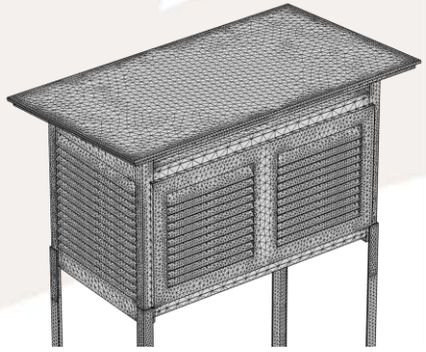




2. Realistic tthermometer geometry: wire wound PRT sensor protected by stainless steel sheath



3. Double louvers

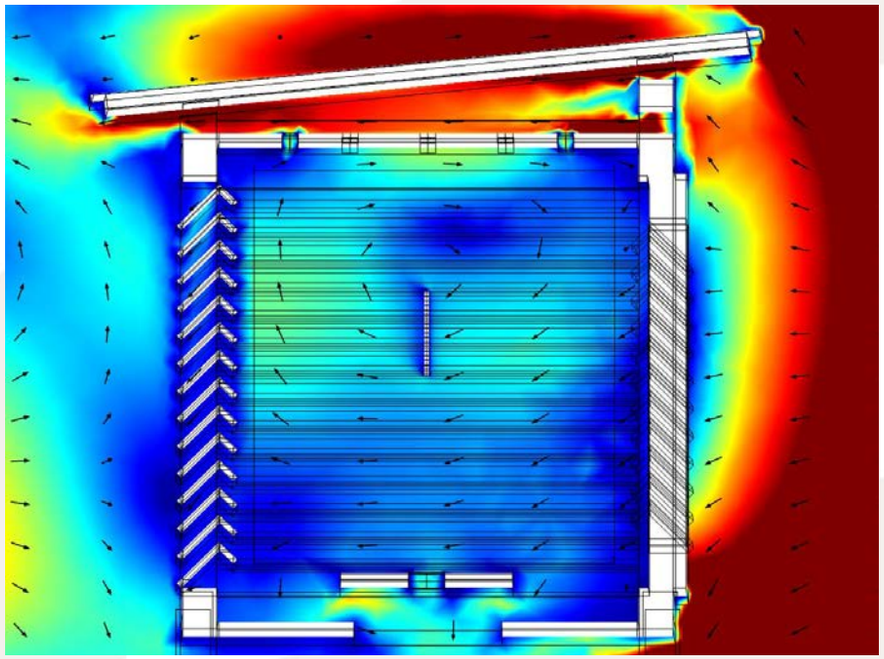


Final mesh: 1.6 million elements (mostly tetrahedral)

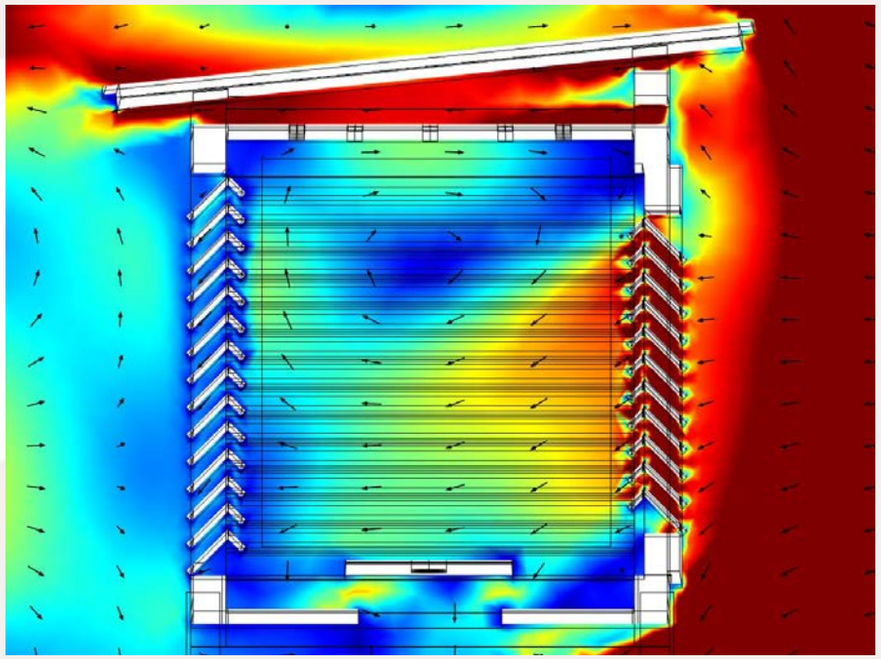
Numerical simulation: results

- 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/m^2
- Ground and ambient temperature 20 °C

Velocity profile



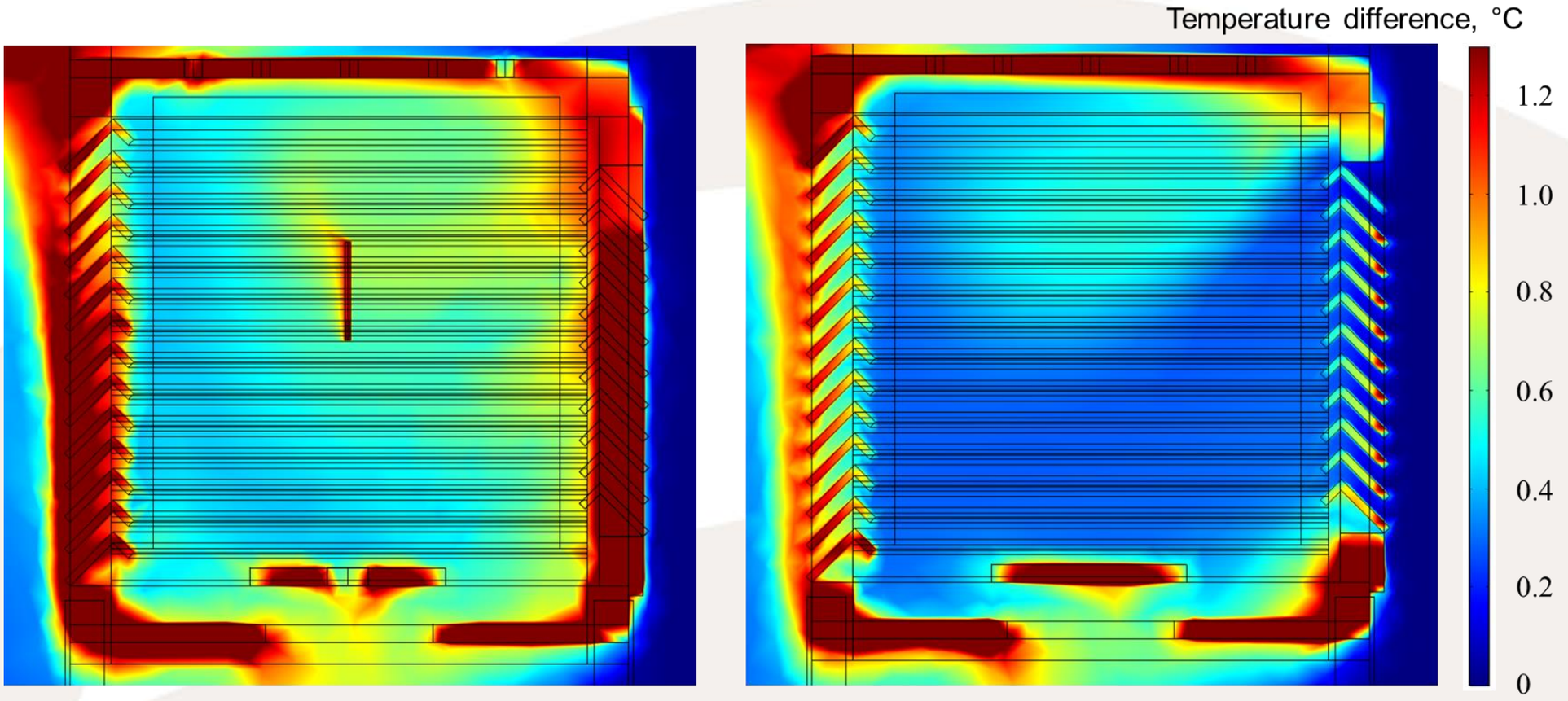
Plane through the screen center (behind the door frame).



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.

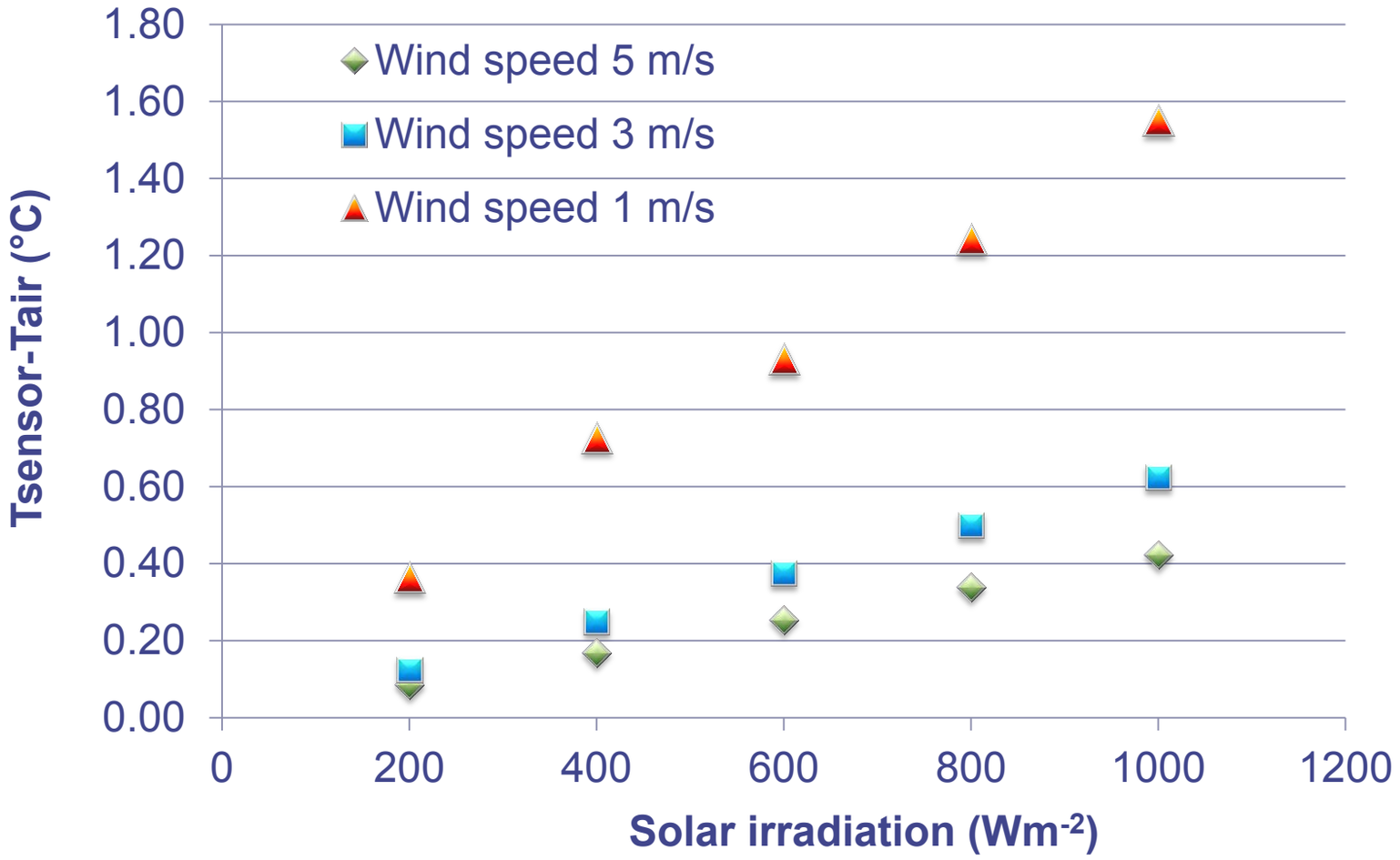
Temperature profile



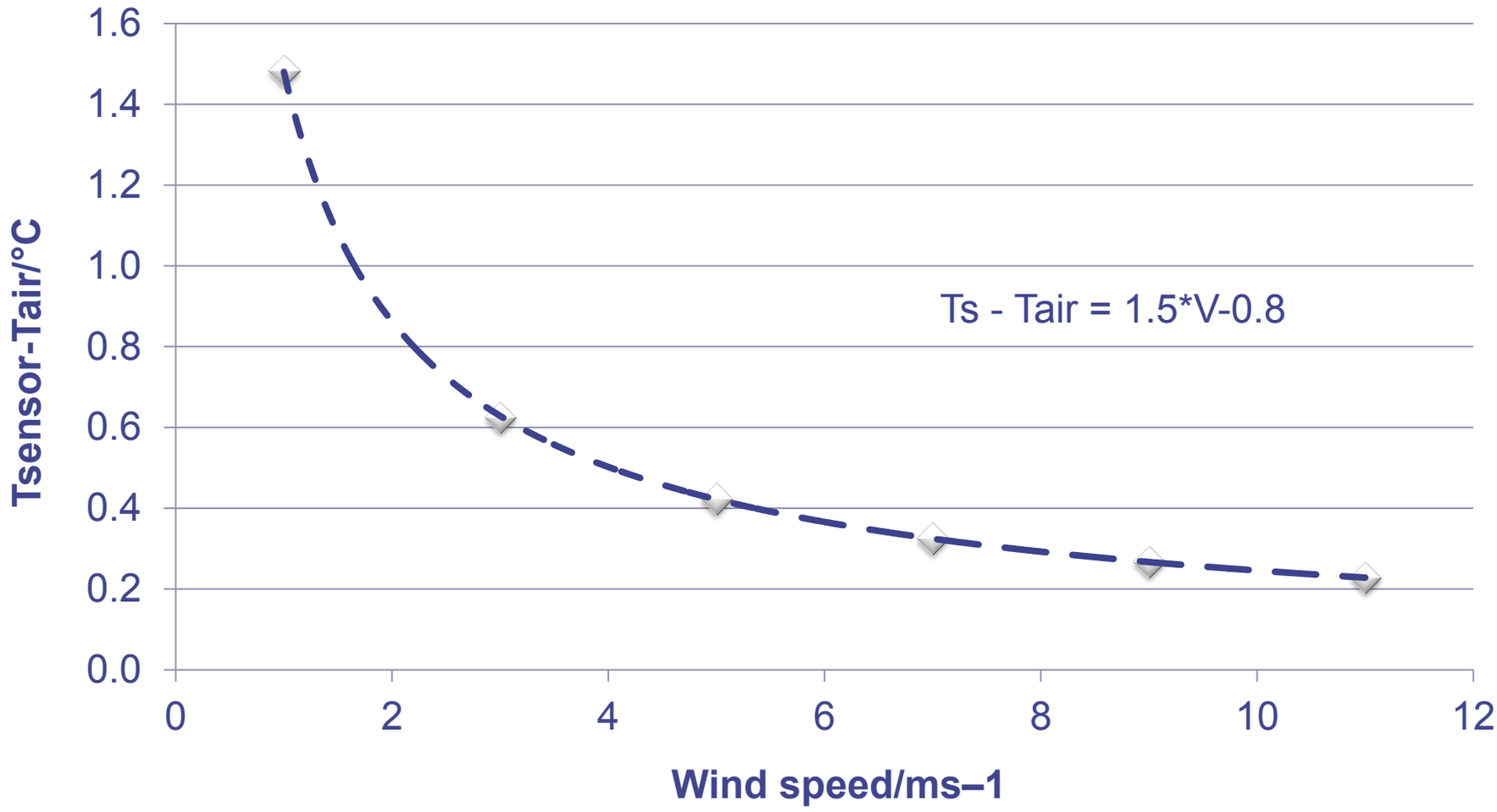
Screen painting white and clean, ground covered by grass

- **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 influence: find correction equations



Solar irradiation 1000 Wm^{-2}

Uncertainty contributions related to environmental parameters

Factor	Parameter	Range of parameter	Range of difference Tsensor-Tair °C	Uncertainty °C
Grass	Absorptivity	0.7 – 0.84	0.62	0.36
Paint	Absorptivity	0.2 – 0.45	0.09	0.05
Ground temperature	Temperature	10 – 20 °C	0.28	0.16
Air temperature	Temperature	10 – 20 °C	0.27	0.16
Sensor material	Copper, steel		0.24	0.14
Sun position	Hour	12:00 – 19:00	0.34	0.20
			Combined uncertainty (k=1)	**0.49**

Worst case: low wind speed (1 m/s) and high solar irradiation 1000 W/m^2)

Acknowledgment

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