RadThermIR simulation and measurement of temperature distribution on CUBI

Stefan Hoch and Lukas Gräser, DLR

7th RadTherm UGM 2011, Munich
The CUBI

- basic idea:
  - physical test object for IR signature modelling under time-varying weather conditions
  - geometry is simple, but includes shadowing effects
  - shape and dimensions are specified, while materials and points of measurement are not
CUBI configuration of DLR

- material: 4 mm steel plates
- insulation: 60 mm layer of rock wool inside
- distribution of 47 temperature sensors (Pt100), under steel layer, connected to data logger
- stands on wooden pallet in order to be decoupled from the ground
Location

CUBI is placed at the area of DLR Satellite Ground Station near Weilheim, Germany
Weather station (Kroneis)

- Pluviometer
- Anemometer with vane
- Barometer
- Hygrometer/Thermometer
- Star pyranometer (solar irradiance, 0.3 – 3 µm)
- Pyrgeometer (downwards LWIR, 4.5 – 44 µm)
- Data logger
RadThermIR model

- RadTherm version 10.0.0
- 14 multi-layer plates (20 x 20 facets each)
- layers: 4 mm steel (mild) + 60 mm rockwool
- natural weather environment, data from weather station
- piece of ground: 10 m x 10 m, resolution 60 x 60 patches
- distance from ground to CUBI base: 10 cm, pallet is not modelled
- convection type
  - outside: ”Wind”
  - inside: ”H and T fluid”, $H = 5 \text{ W/(m}^2\text{K)}$, fluid node for interior air
RadThermIR model
Weather file format (XWA)

- date and time
- wind speed, wind direction
- air temperature
- relative humidity
- barometric pressure
- direct solar beam irradiance
- total solar irradiance
- diffuse solar irradiance
- broadband effective sky temperature
- sensor band effective sky temperature
- cloud cover
- rain rate, rain temperature
- solar zenith and azimuth angle
Weather file format (XWA) – used data

- date and time
- wind speed, wind direction
- air temperature
- relative humidity
- barometric pressure
- direct solar beam irradiance
- total solar irradiance
- diffuse solar irradiance
- broadband effective sky temperature
- sensor band effective sky temperature
- cloud cover
- rain rate, rain temperature
- solar zenith and azimuth angle
Workflow

- CUBI_model.tdf
  - weather
  - RadThermIR simulation
  - check weather data
    - select time range
  - CUBI temperatures
  - cut-out
  - Simulation result plot/visualization
  - CUBI temperature plot/visualization
Weather case 1: sunshine

- Feb 5, 2011, 08:17 – 18:37
- no rain
- rel. humidity 32%-75%
- air temperature 3 – 12 °C
- wind speed 1 – 6 m/s
Weather case 1: sunshine

—heavy shadow on step:

![Graph showing temperature over time with a peak at 15:00.]

![Diagram showing a 3D model with a shadow on a step.]

Simulation vs Measurement

05.02.2011
Weather case 1: sunshine

south face:
Weather case 1: sunshine

- north face:
Weather case 1: sunshine

- close to ground:
Weather case 2: rainfall and wind

- Jan 14, 2011, 08:47 – 17:57
- rain rate ~1 mm/h
- rel. humidity 83 – 87%
- air temperature 8 – 9 °C
- wind speed 5 – 10 m/s
Weather case 2: rainfall and wind

upper face:
Weather case 2: rainfall and wind

side face:
Weather case 2: rainfall and wind

> close to ground:

![Graph and diagram related to weather case 2]
Weather case 3: night

- Jan 15, 2011, 18:12 – Jan 16, 08:42
- no rain
- rel. humidity 85 – 97%
- air temperature -2 – 3 °C
- wind speed 0 – 1 m/s
Weather case 3: night

upper face:

![Graph showing temperature over time for simulation and measurement with a cube diagram on the right side.]
Weather case 3: night

Side face:

- Temperature [Celsius]
  - Simulation
  - Measurement

- Time

Graph showing temperature changes over time with simulation and measurement data.
Weather case 3: night

- close to ground:
Summary and Conclusion

- Comparison workflow of measurement and RadThermIR simulation exists
- Different weather conditions have been checked
- Simulation of RadThermIR model agrees well with measurements:
  - in most cases, the difference is $< 3$ K
  - greater deviations under direct solar irradiation

Outlook:
- Continuous optimization of the model, identification of disturbances
- Installation of IR-Camera planned
- Visualization of data by Visualization Toolkit (vtk)

Thanks to
E. Lindermeir, T. Schwarzmaier, H. Stöhr