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# The use of COMSOL for Building Constructions Engineering regarding Heat and Moisture Transport

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# Content

- Introduction
- Casus Hunting Lodge St. Hubert
- Moisture damage analysis tower
- Measurements
  - Wind velocity and direction
  - Driving rain
  - In- and outdoor temperature and relative humidity
- Modelling and simulation
  - CFD
  - COMSOL
- Conclusions

# Introduction:
# Hunting Lodge St. Hubert

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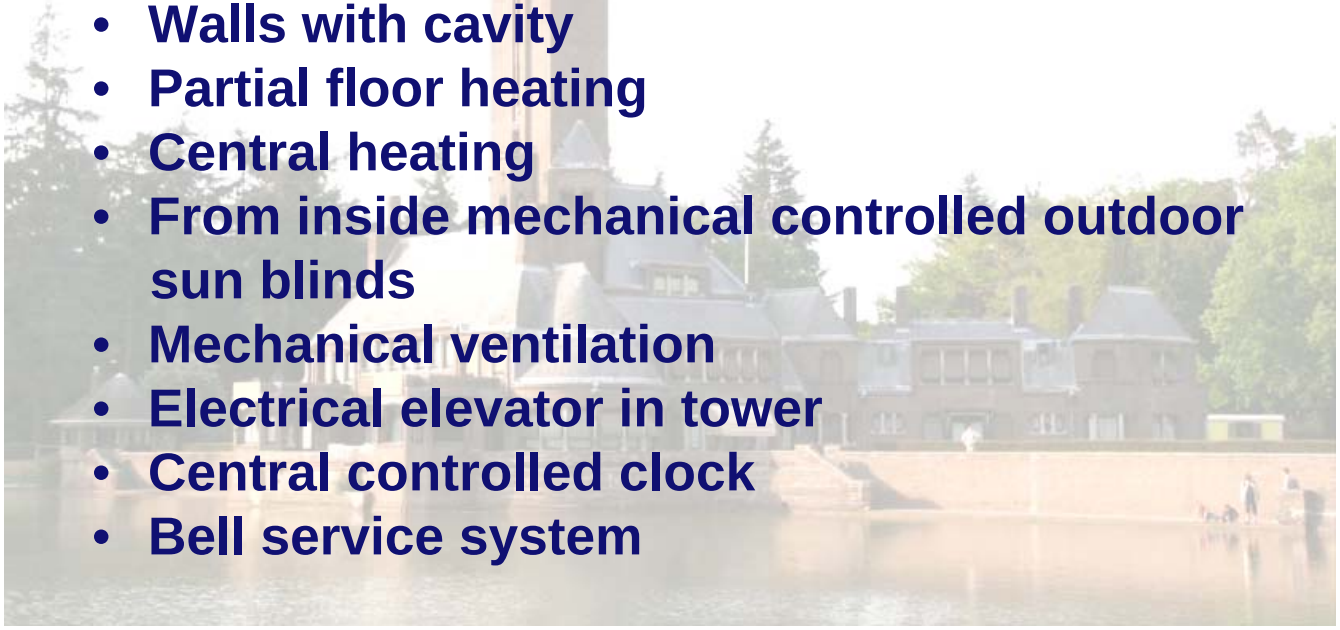
# Hunting Lodge St. Hubert

- Top 100 monument in The Netherlands
- Architect Berlage
- Built between 1916 and 1922 for rich industrial
- High Tech building for its time
  - Walls with cavity
  - Partial floor heating
  - Central heating
  - From inside mechanical controlled outdoor sun blinds
  - Mechanical ventilation
  - Electrical elevator in tower
  - Central controlled clock
  - Bell service system



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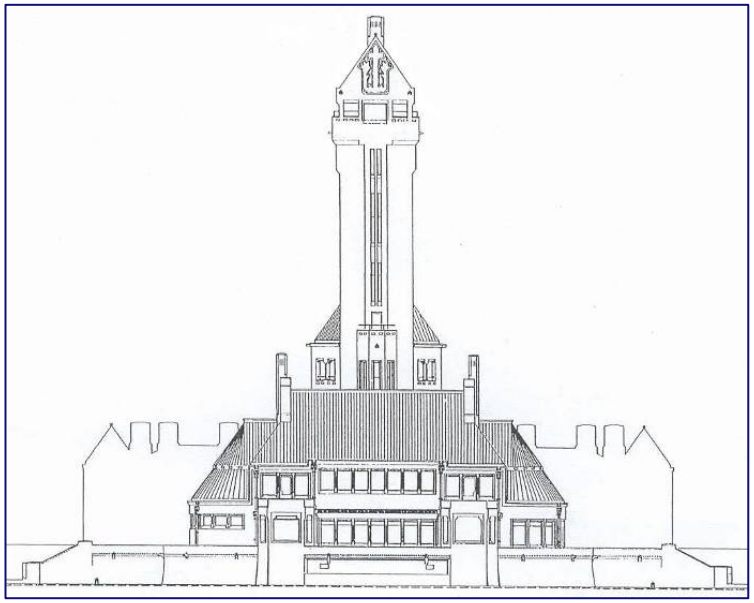
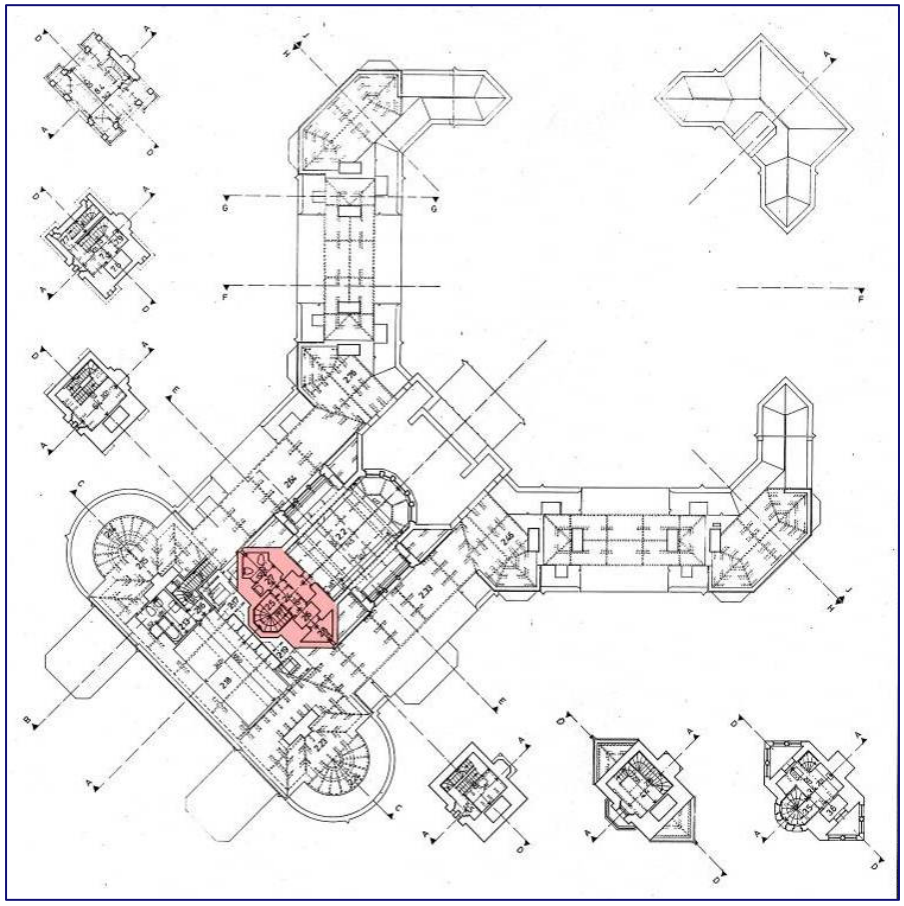
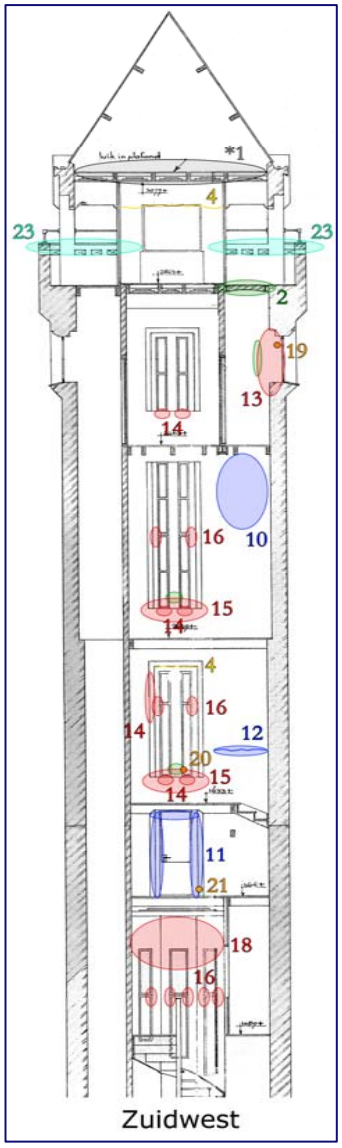
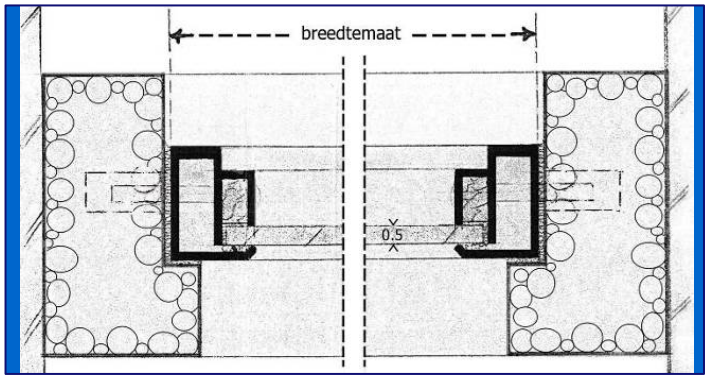


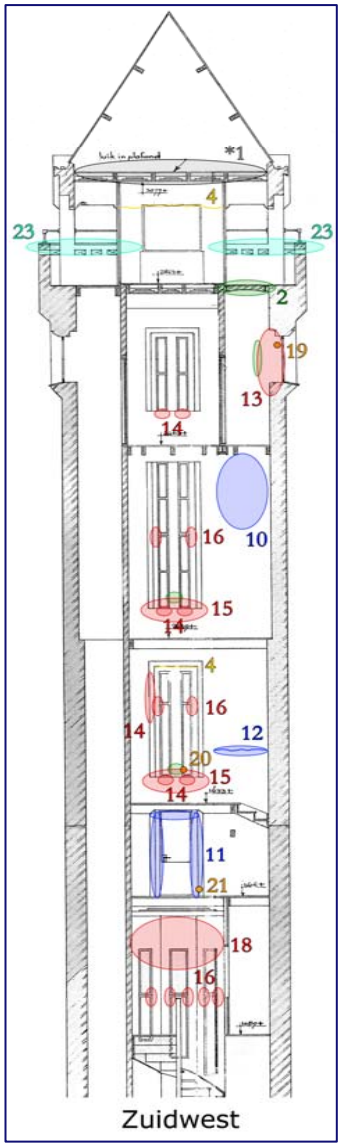


# Moisture damage analysis

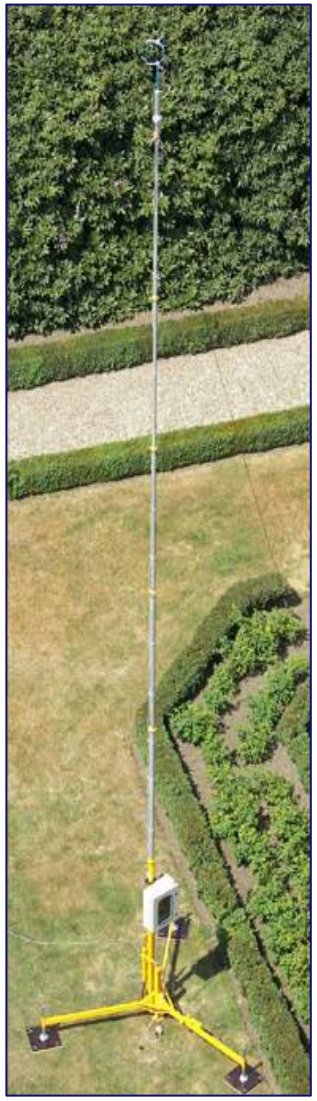



# Moisture damage analysis




# Measurements

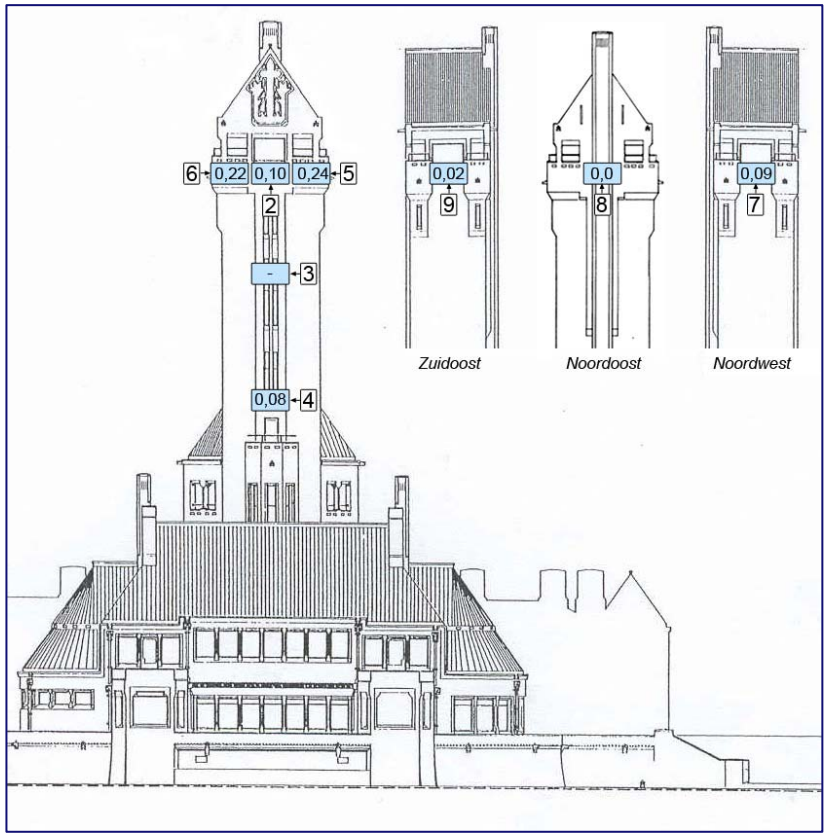


Wind velocity and direction

Horizontal rain fall

Vertical wind driving rain

# Measurement results



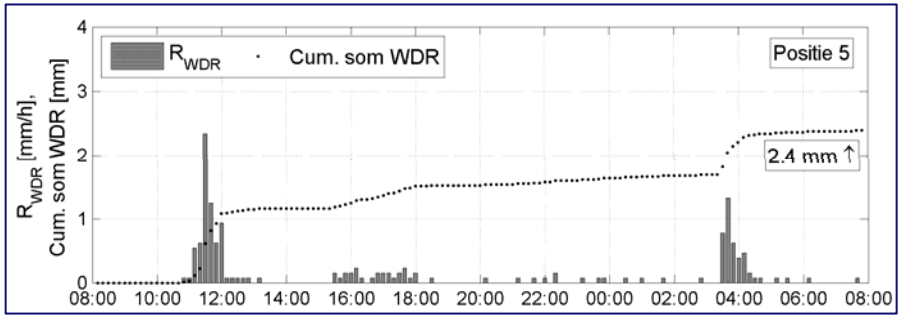

Catch ratio:

$$\eta = \frac{R_{wdr}}{R_h}$$

R : rain intensity [mm/h]

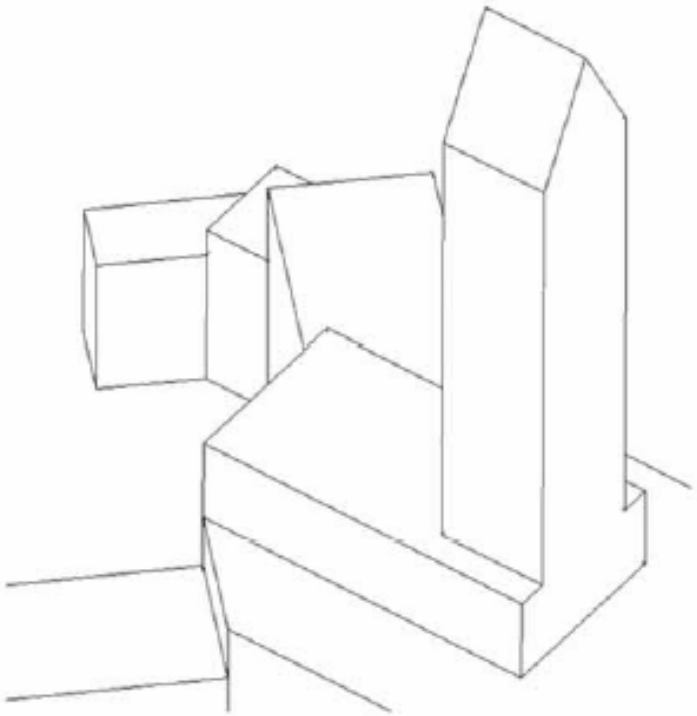
wdr : wind driving rain

h : horizontal

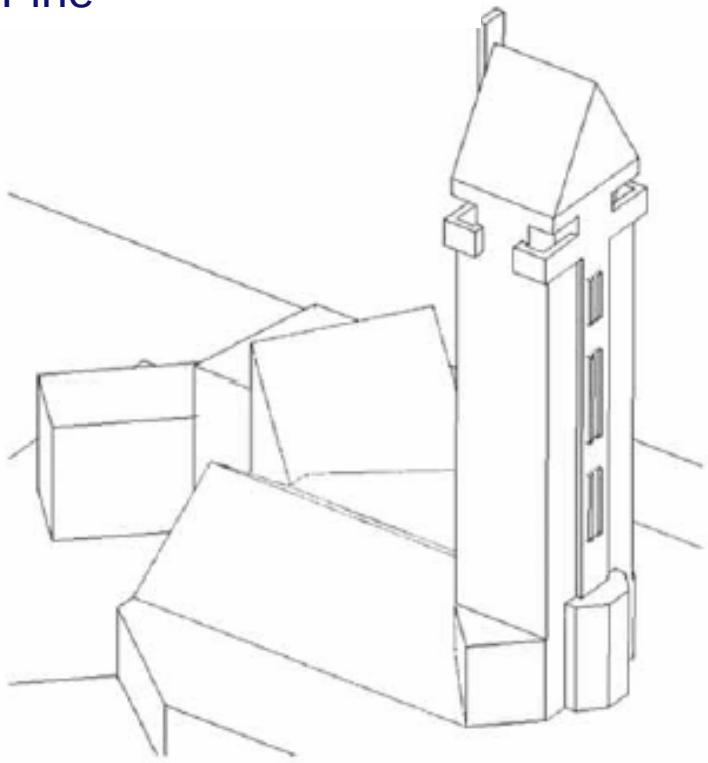


# CFD geometries

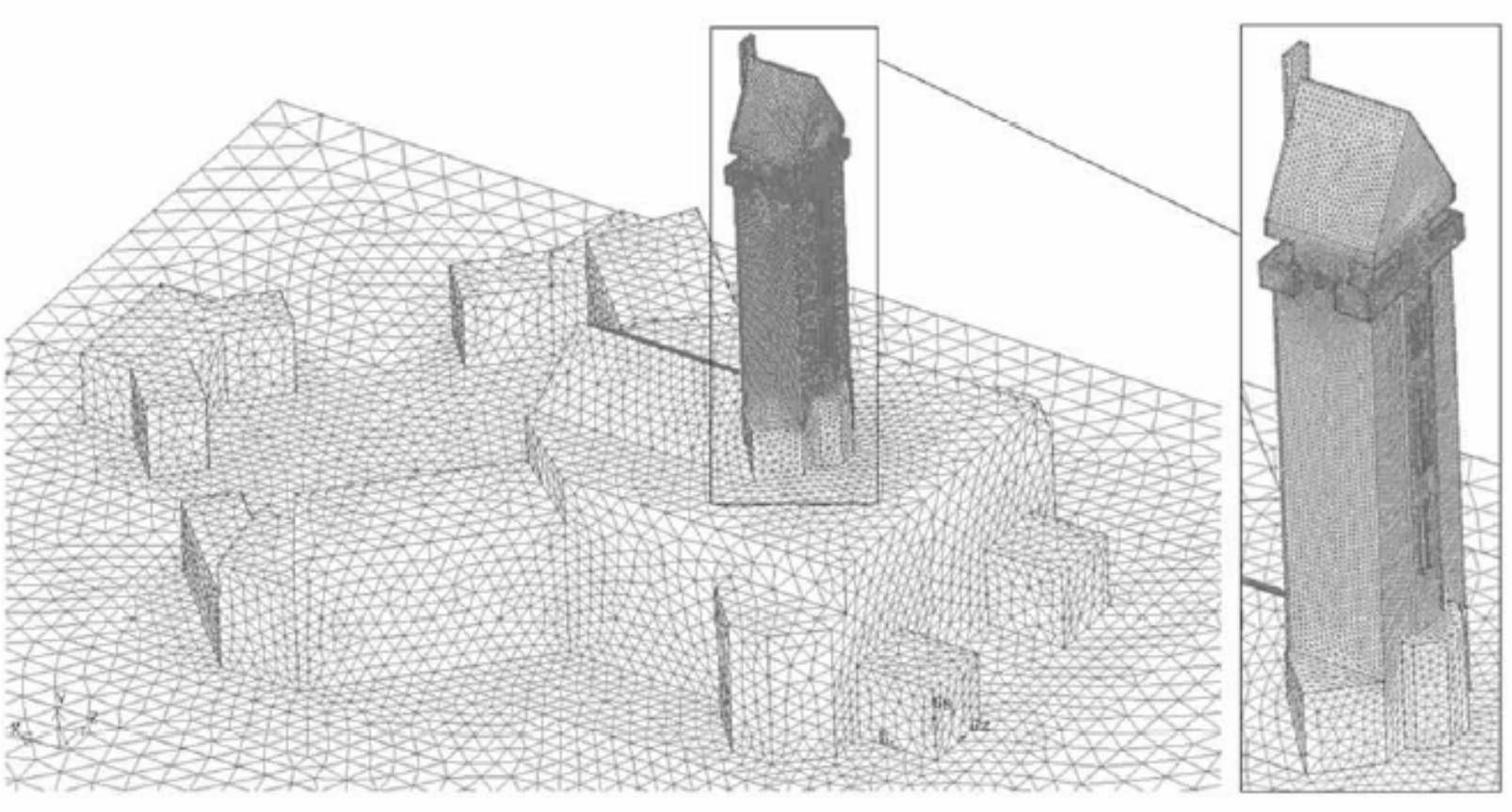
Course



Fine

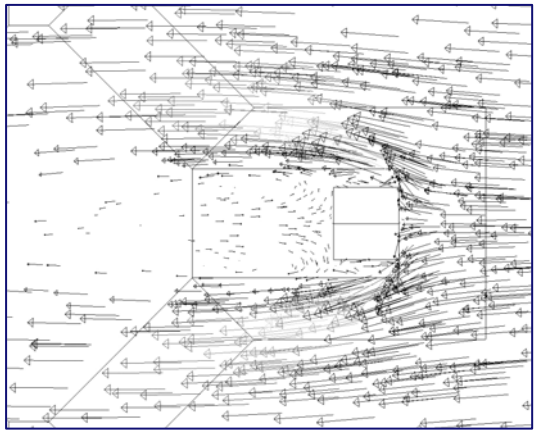


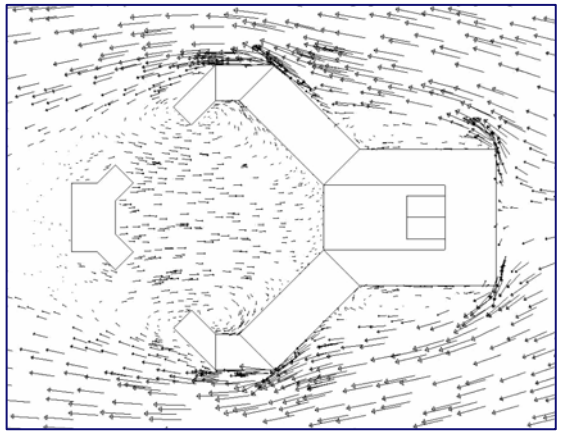
# CFD grid

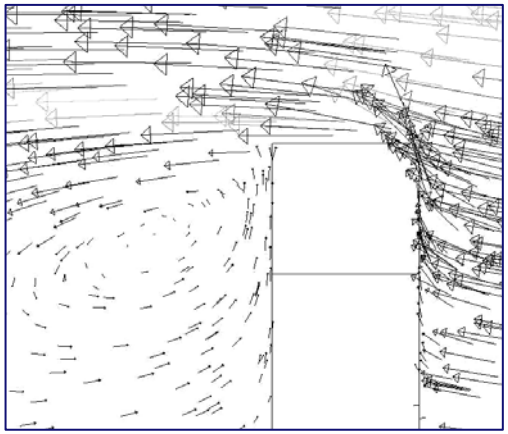


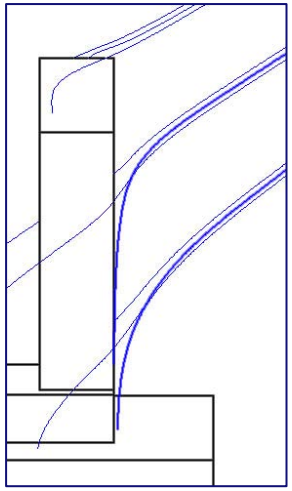
# CFD results

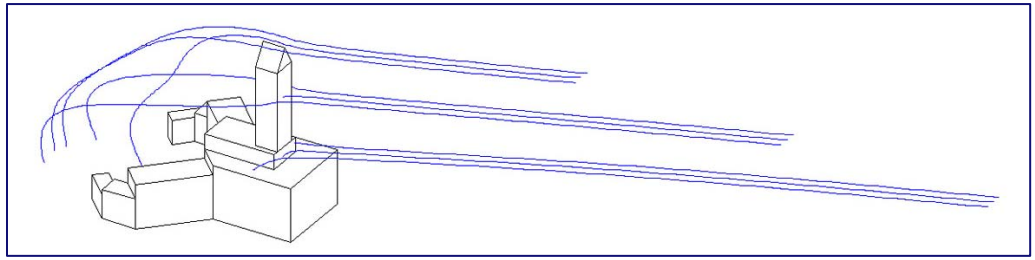
## Wind velocities and directions





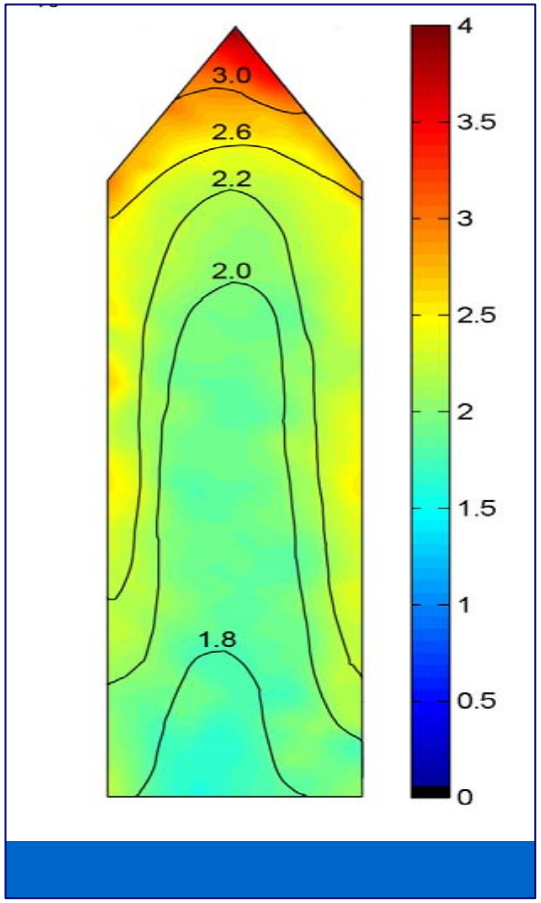




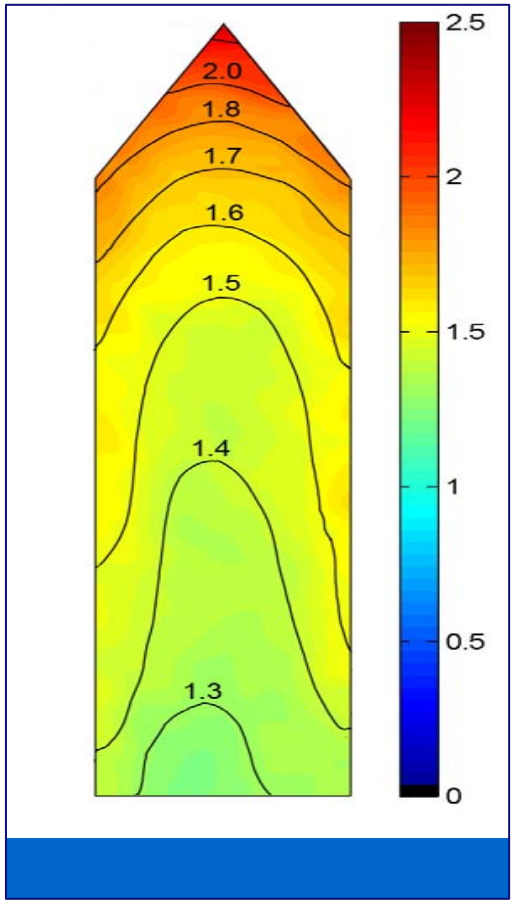


Raindrop trajectories

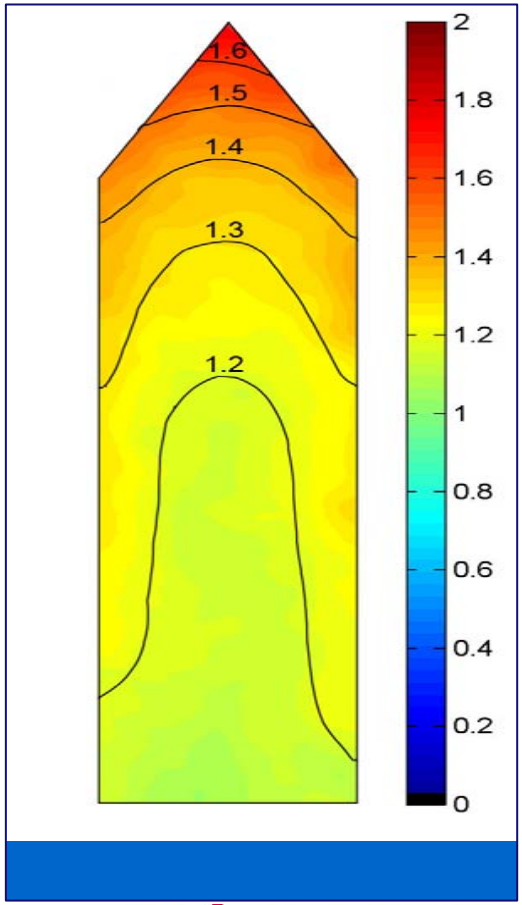
# CFD Droplet driving rain results




d=0.8 mm

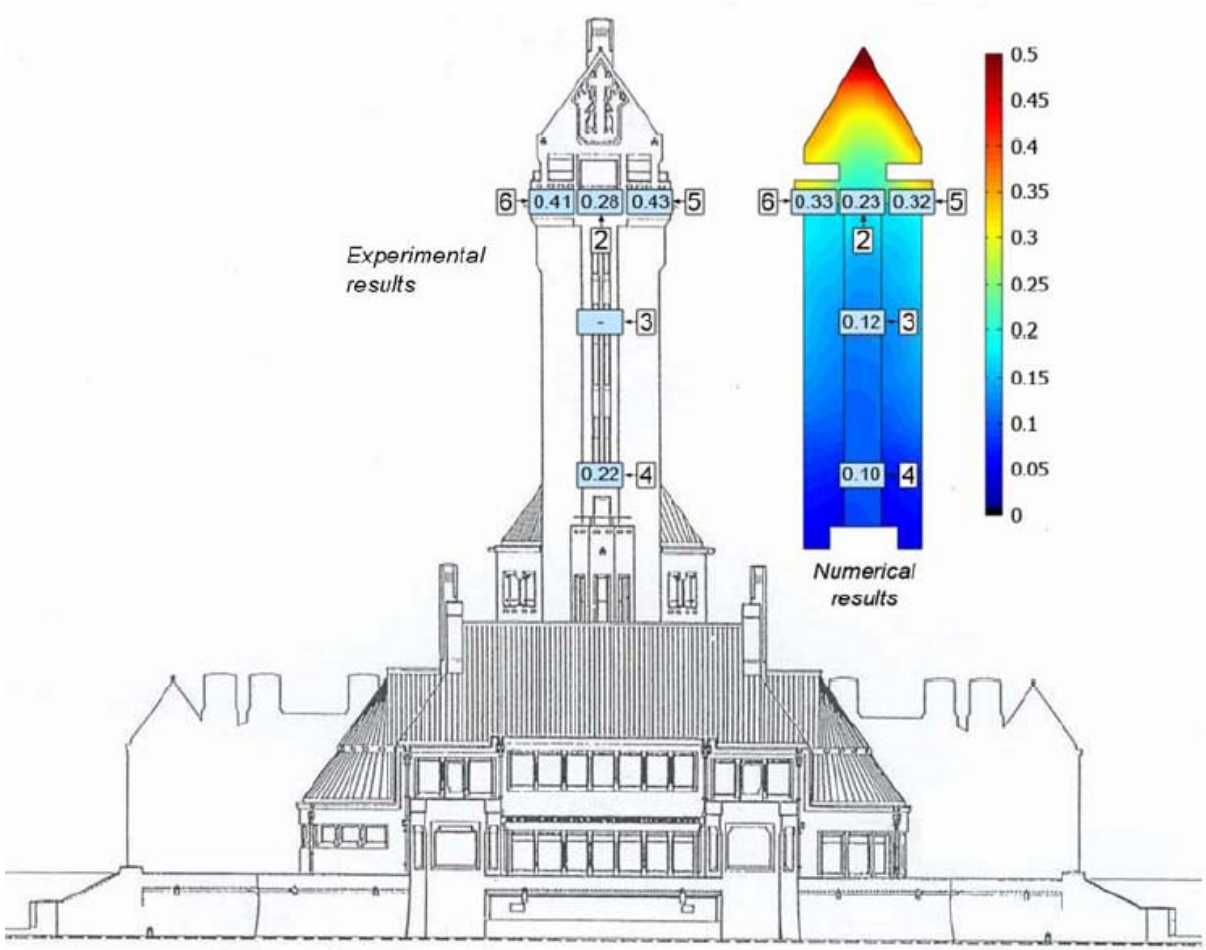



d=2



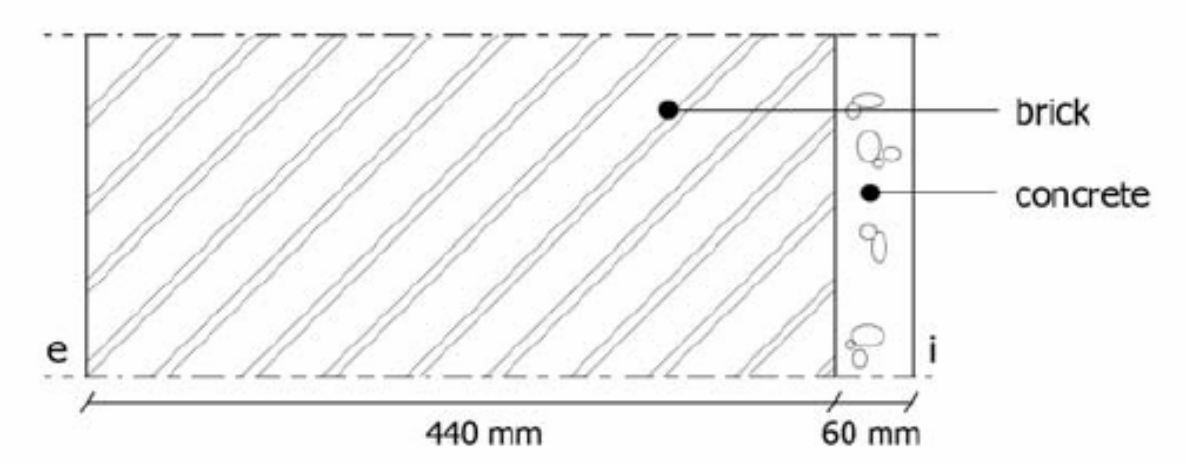

d=5

# Comparison: Measurement and CFD Results

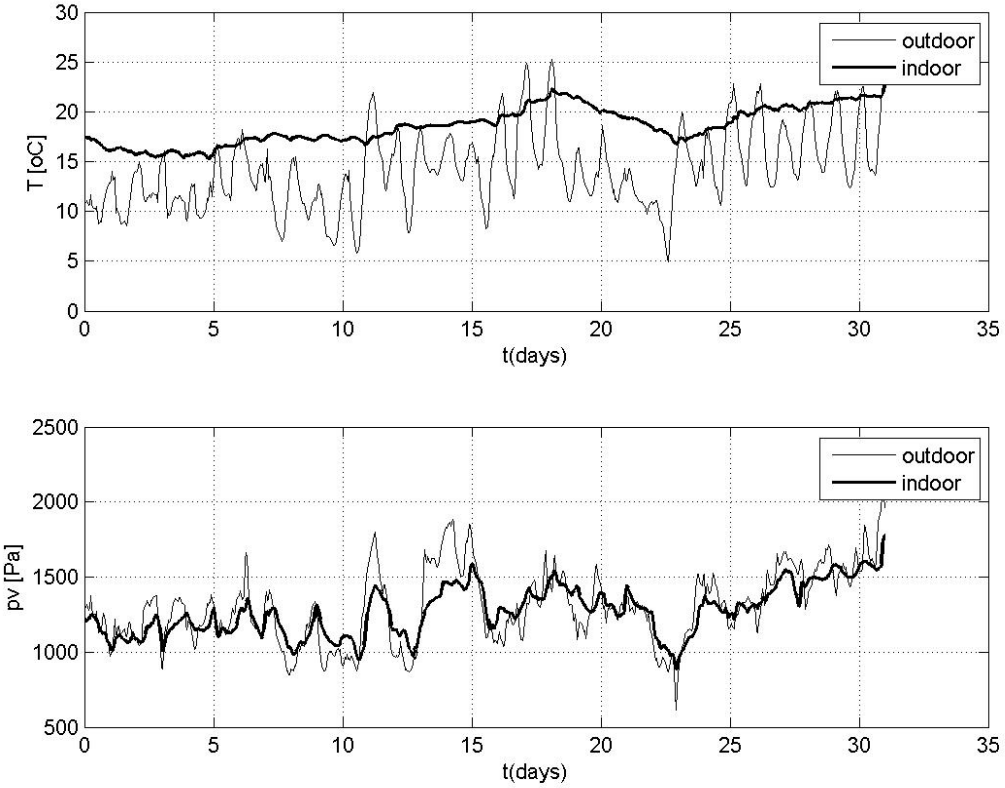


# Measurements:
# Indoor temperature and relative humidity

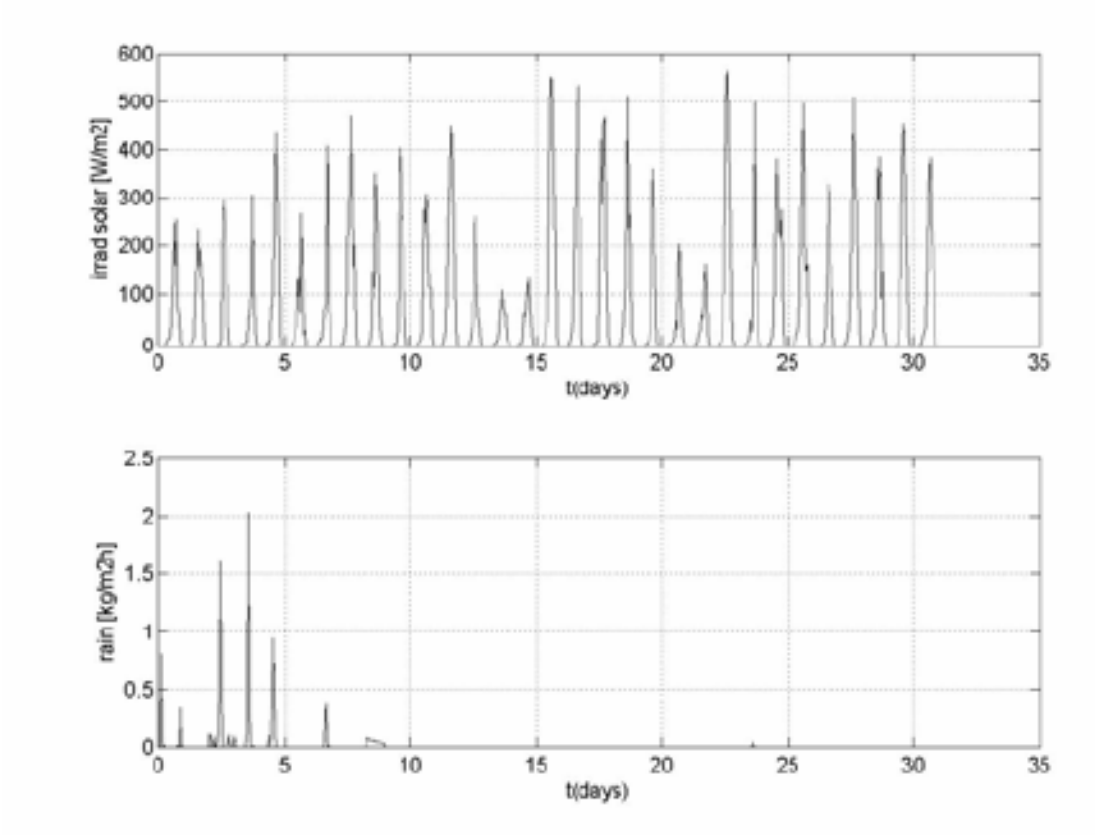

# Modelling and simulation COMSOL: Geometry



# Modelling and simulation COMSOL: Input data temperature and vapour pressure



# Modelling and simulation COMSOL: Input data sun irradiance and driving rain



# Modelling and simulation COMSOL: PDEs

$$C_T \frac{\partial T}{\partial t} = \nabla \cdot (K_{11} \nabla T + K_{12} \nabla LPc)$$ Heat PDE

$$C_{LPc} \frac{\partial LPc}{\partial t} = \nabla \cdot (K_{21} \nabla T + K_{22} \nabla LPc)$$ Moisture PDE

$$LPc = {}^{10}\log(Pc)$$

# Modelling and simulation COMSOL: Coefficients

$$C_T = \rho \cdot c$$ Thermal capacity

$$K_{11} = \lambda$$ Thermal conductivity

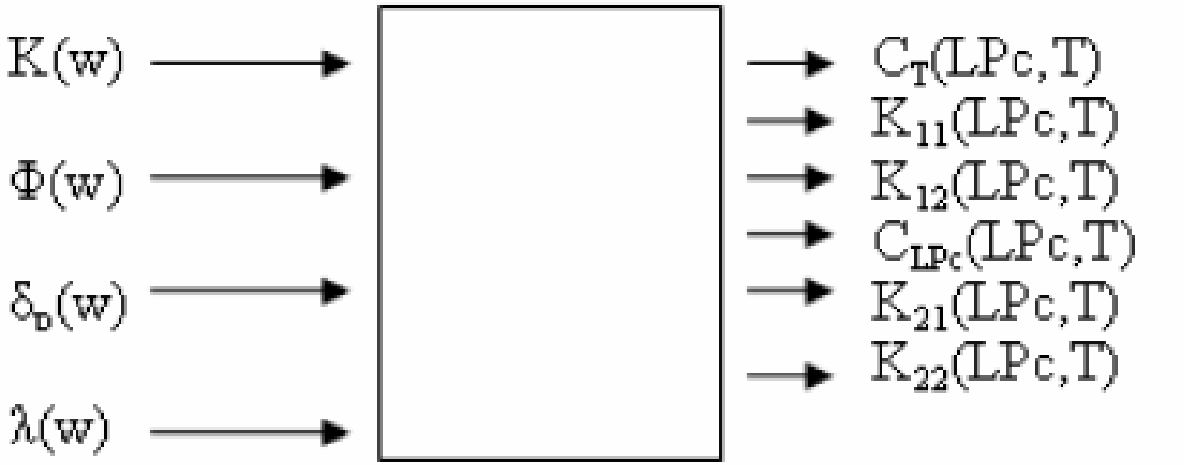
$$K_{12} = -l_{lv} \cdot \delta_p \cdot \phi \cdot \frac{\partial Pc}{\partial LPc} \cdot Psat \cdot \frac{M_w}{\rho_a RT},$$ Latent heat evaporation

$$C_{LPc} = \frac{\partial w}{\partial Pc} \cdot \frac{\partial Pc}{\partial LPc}$$ Moisture capacity

$$K_{21} = \delta_p \cdot \phi \cdot \frac{\partial Psat}{\partial T}$$ Vapour permeability

$$K_{22} = -K \cdot \frac{\partial Pc}{\partial LPc} - \delta_p \cdot \phi \cdot \frac{\partial Pc}{\partial LPc} \cdot Psat \cdot \frac{M_w}{\rho_a RT},$$ Liquid permeability

# Conversion estimated material properties into PDE coefficients



# Modelling and simulation COMSOL: Boundary conditions

The (i)nternal boundary conditions are:

$$q_i = \alpha_i \cdot (T_i(t) - T) \qquad [W/m^2],$$

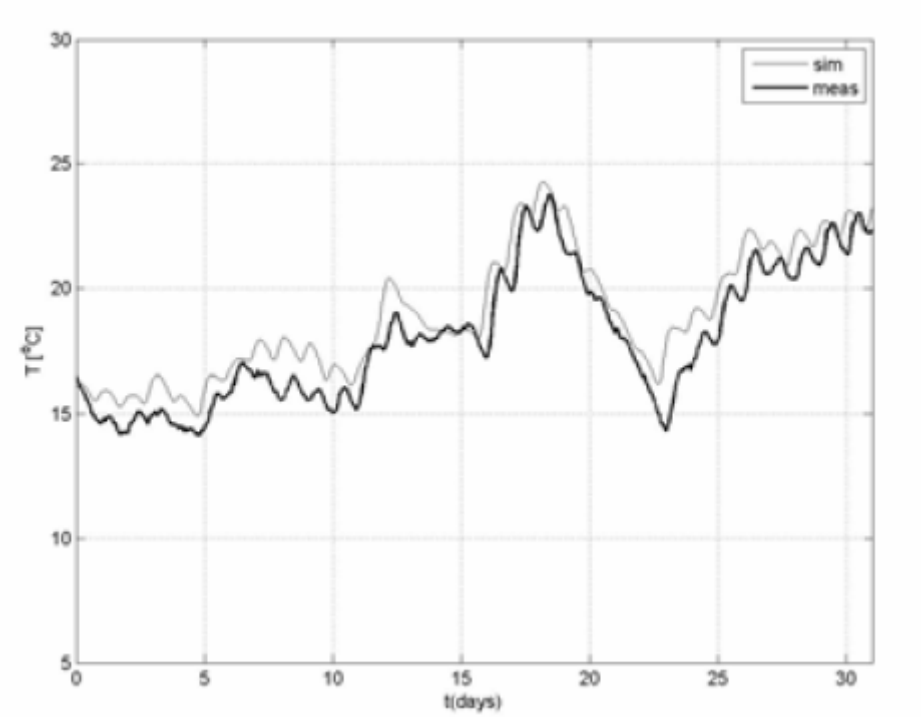
$$g_i = \beta_i \cdot (p_i(t) - p) \qquad [kg/sm^2]$$

The (e)xternal boundary conditions are:

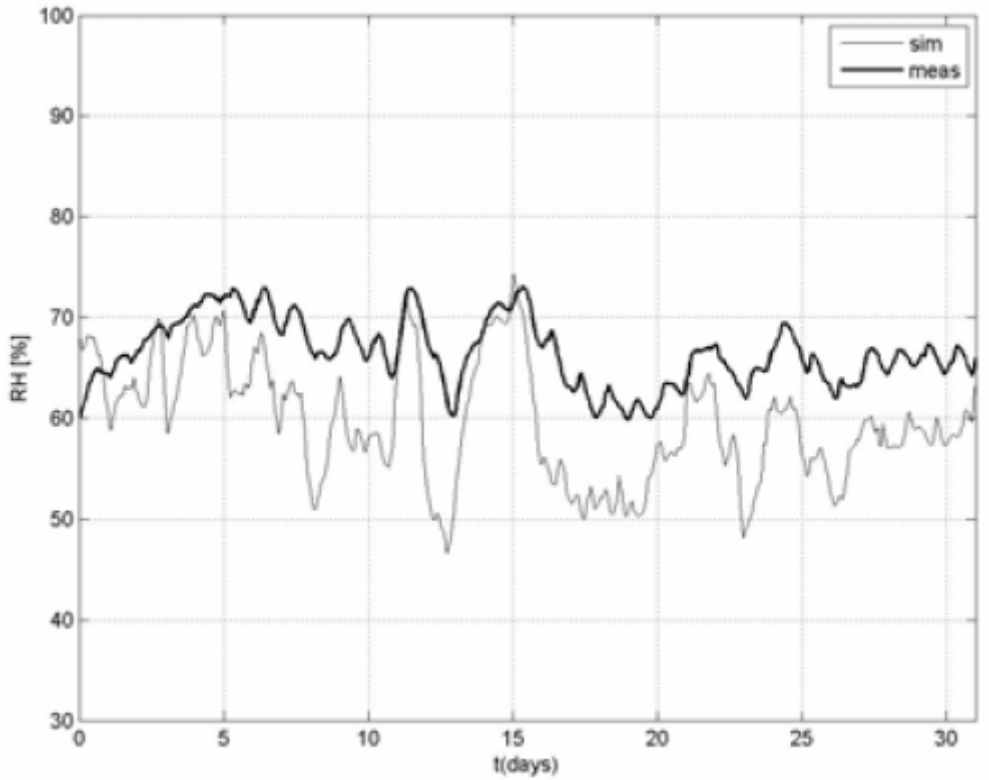
$$q_e = \alpha_e \cdot (T_e(t) - T) + q_{solar}(t) \qquad [W/m^2],$$

$$g_e = \beta_e \cdot (p_e(t) - p) + g_{rain}(t) \qquad [kg/sm^2]$$

# Modelling and simulation COMSOL: Results surface temperatures



# Modelling and simulation COMSOL: Results relative humidity at surface



# Conclusions

- 1st attempt to use COMSOL for rain penetration
  - Only 1 D
  - Estimated material properties

- Future work:
  - 2 and 3D
  - Measured material properties
  - Simulation of variants to solve problem