Modeling of Condensation Risk in COMSOL Multiphysics®

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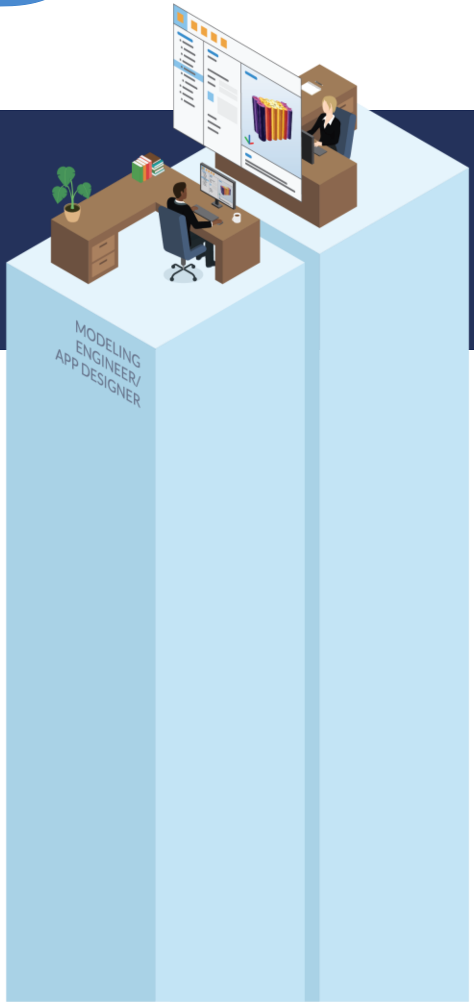
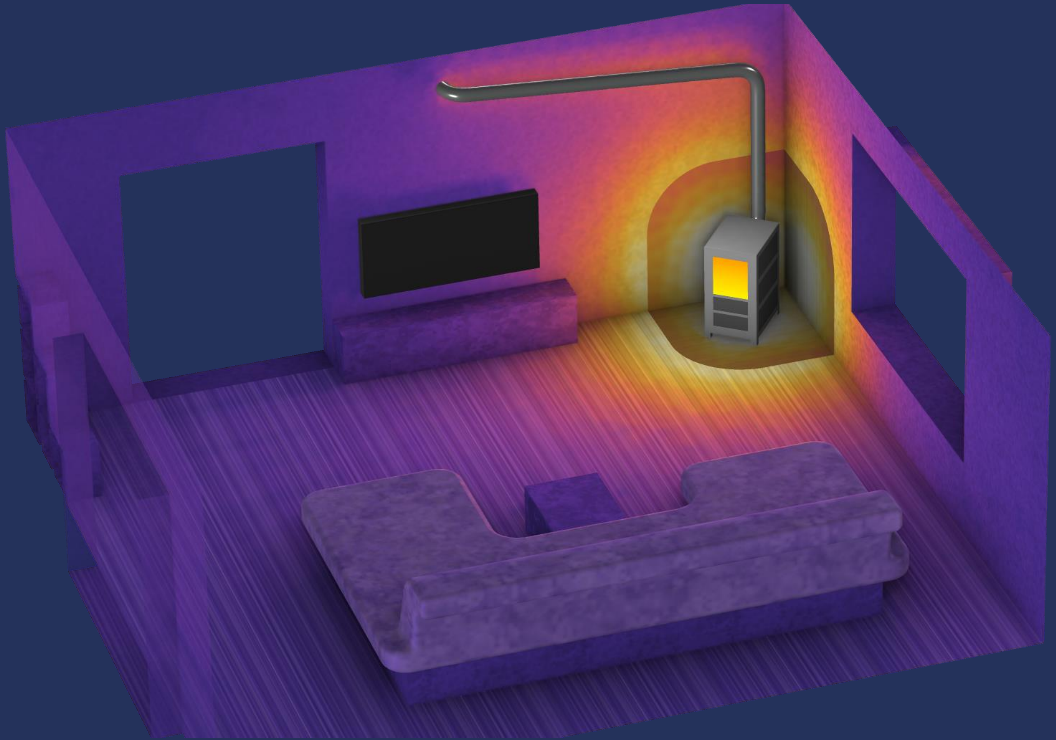


Agenda

- Heat Transfer Module
- Heat and Moisture Transport physics interfaces
- Example 1: Condensation Risk in a Wood-Frame Wall
- Example 2 (Live demo): Condensation Detection in an Electronic Device



Heat Transfer Module

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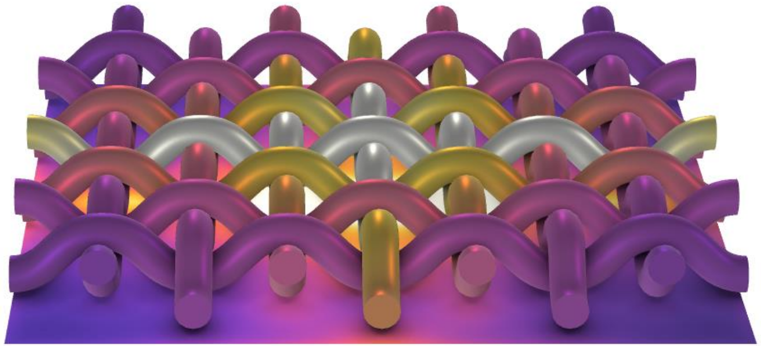
Heat Transfer Mechanisms

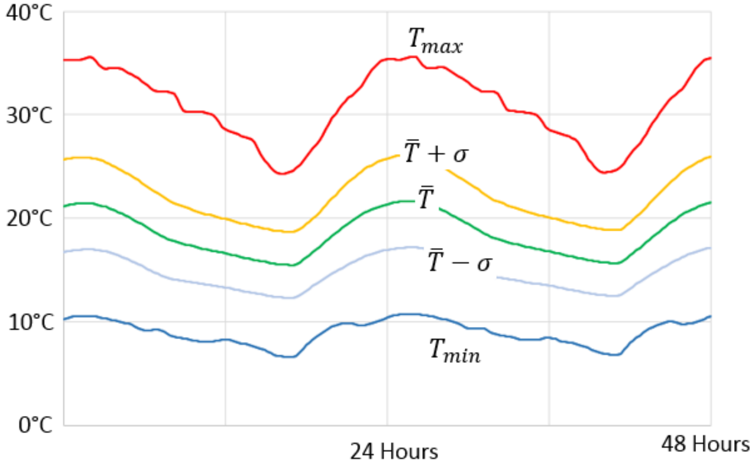
- Conduction:
  - Fourier's law
  - Isotropic, anisotropic, linear, and nonlinear thermal conductivity
- Convection:
  - Natural and forced convection
  - Laminar and turbulent flow
- Radiation:
  - Surface-to-surface
  - Surface-to-ambient



Conduction in a fiber structure.

Meteorological Data

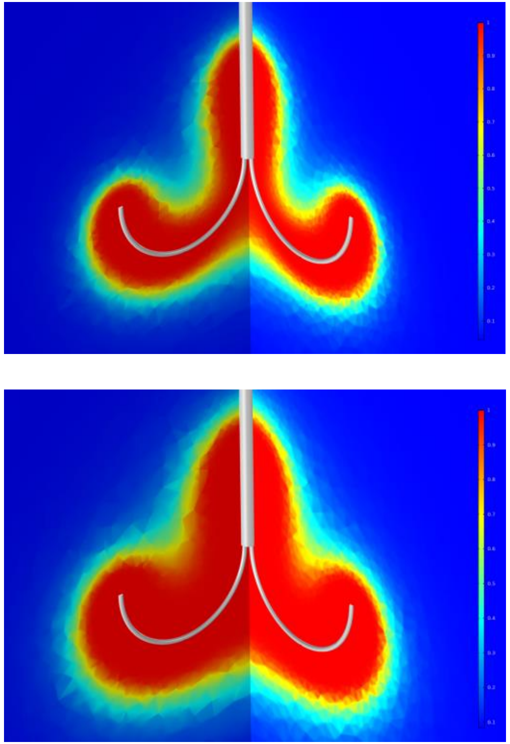
- Historical data for about 8000 weather stations all other the world (Weather Data Viewer 5.0, ASHRAE 2013 and 6.0, ASHRAE 2017)
- Temperature, dew point, air pressure, wind speed, and direct and diffuse solar irradiation as a function of calendar day and time
- Integrated in heat transfer interfaces



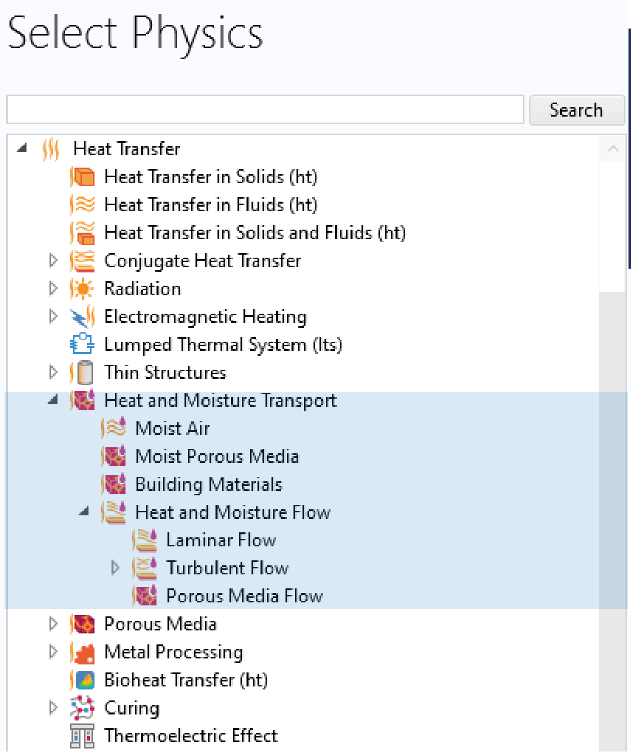
Temperature variation during two days.

Unusual possibilities

- Heat Transfer in Thin Structures
  - Thin layers, films, fractures, layered materials
- Heat Transfer in Porous Media
- Heat Transfer in Biological Tissues
  - Living tissue (blood perfusion, metabolic heat…)
- Phase Change and Material Transition
  - Heat capacity formulation
  - Deformed geometry
  - Irreversible transformations in solids
- Multiphysics
  - Electromagnetic heating or e.g. **Heat and Moisture Transport**



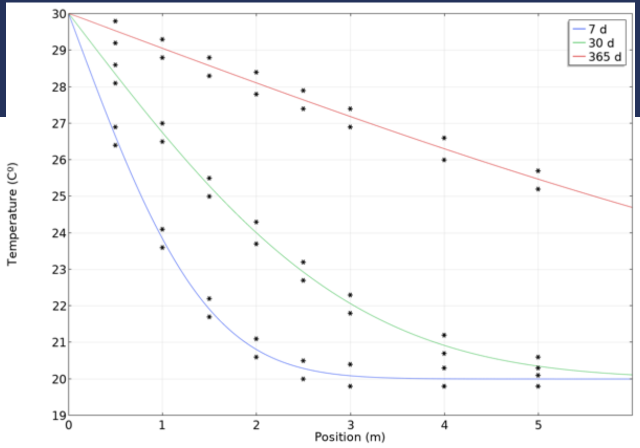
Tissue necrosis area during tumor ablation process at 2.5 min (top) and 5 min (bottom).



Heat and Moisture Transport physics interfaces

- Dependent variables:
  - Relative Humudity ϕ
  - Temperature T
  - Eventually velocity and pressure u, v, w, p
- Predefined multiphysics couplings for moisture transport, flow, and heat transfer

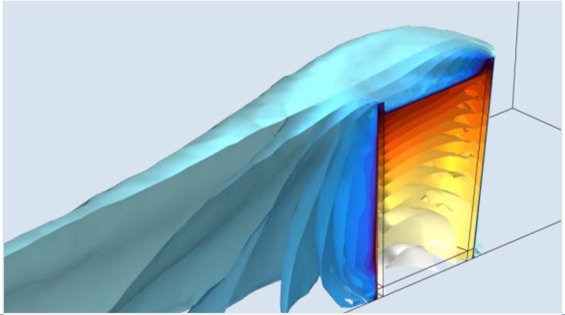
Heat and Moisture Transport physics interfaces



Comparison of COMSOL Multiphysics temperature profile (solid lines) with ISO 15026 reference range (*). Model available in database: https://www.comsol.com/model/heat-and-moisture-transport-in-a-semi-infinite-wall-39001

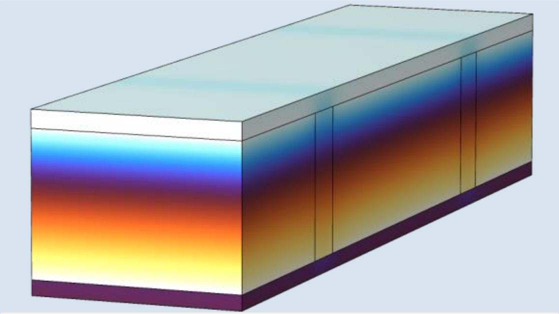
- Building material model follows ISO 15026
- Transport in air and in hygroscopic media
- Thermal properties are dependent of the moisture content and account for latent heat of evaporation
- Wet and moist surface conditions to account for evaporation and condensation

Inspiration from our Application Library



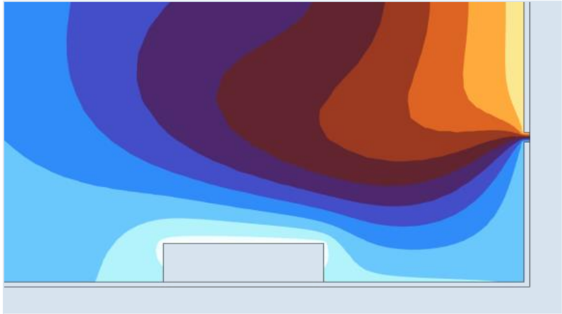
Evaporative Cooling of Water

- Heat Transfer in Moist Air
- Moisture Transport in Air
- Turbulent Flow, Low Re k-ϵ



Wood-Frame Wall

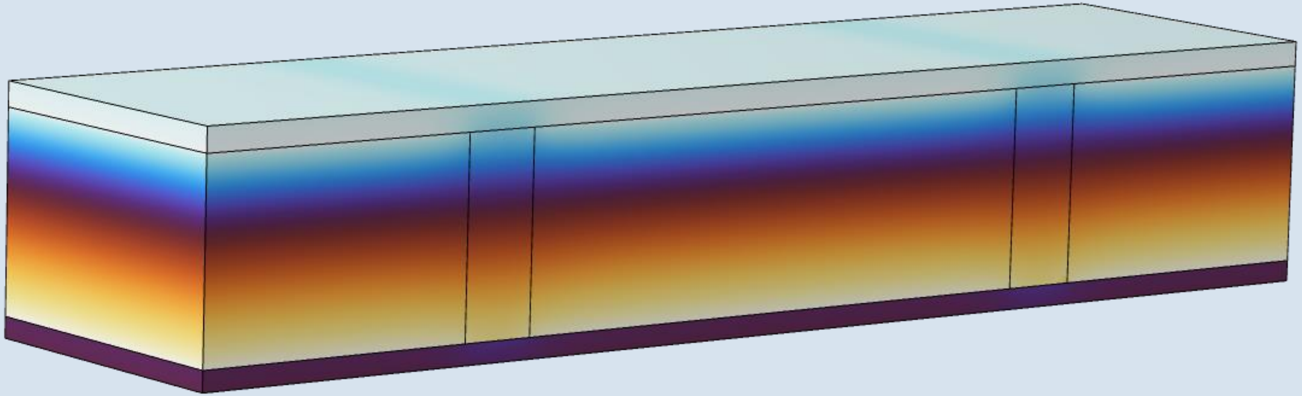
- Heat Transfer in Building Materials
- Moisture Transport in Building Materials



Condensation in electronics

- Heat Transfer in Solids and Fluids
- Laminar Flow
- Moisture Transport in Air

Example 1: Condensation Risk in a Wood-Frame Wall



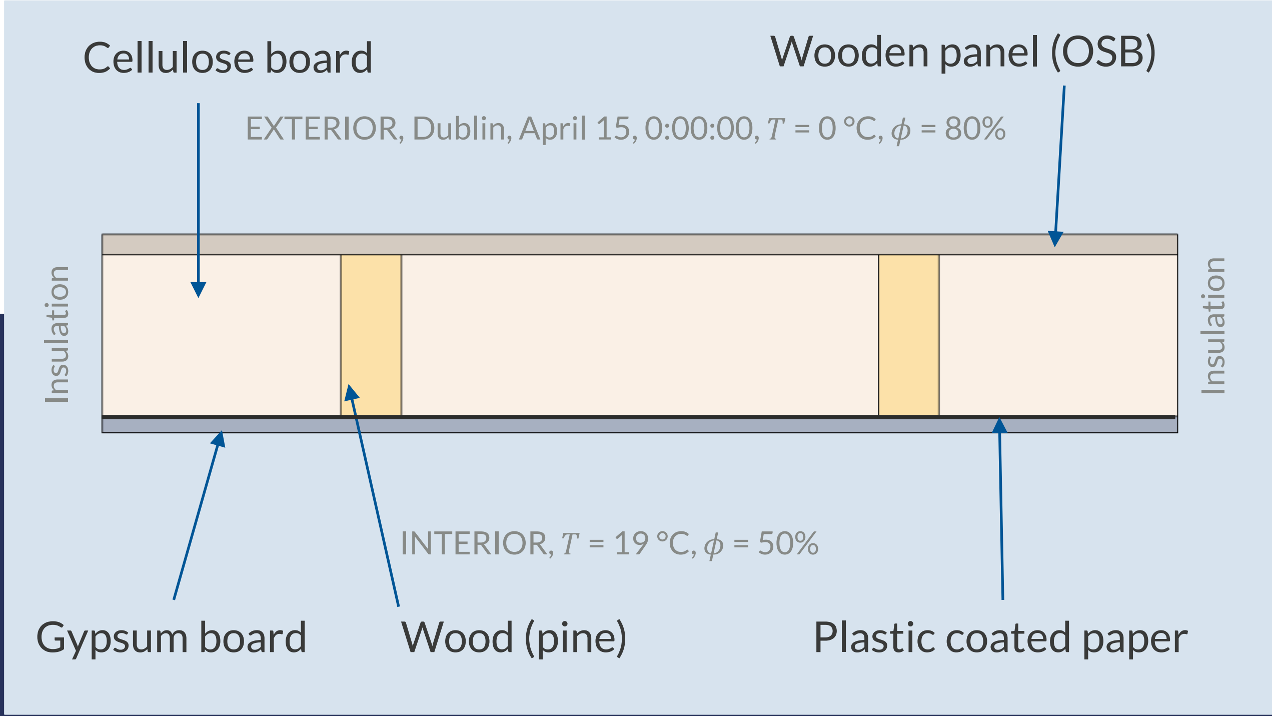
Heat Transfer in Building Materials

- Heat flux to exterior
- Heat flux frinterior

Moisture Transport in Building Materials

- Moisture flux - exterior
- Moisture flux – interior
- Thin Moisture Barrier

Material and Boundary conditions



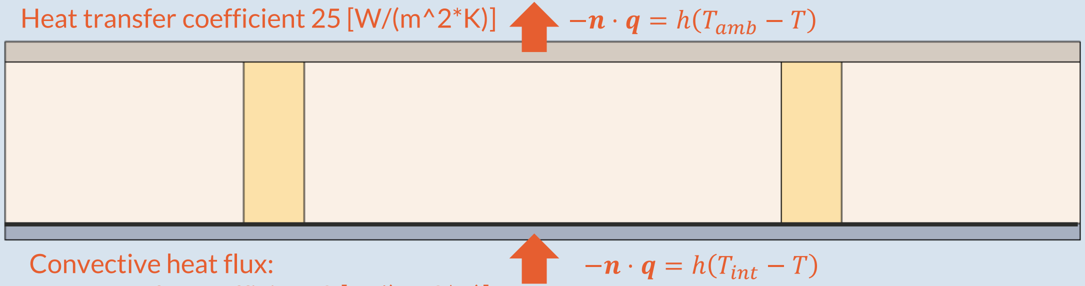
Material and basic boundary conditions setup

Material and Boundary conditions

EXTERIOR, Dublin, April 15, 0:00:00, T = 0 °C, ϕ = 80%

Convective heat flux:
Heat transfer coefficient 25 [W/(m^2*K)]

$$-\boldsymbol{n} \cdot \boldsymbol{q} = h(T_{amb} - T)$$



Convective heat flux:
Heat transfer coefficient 8 [W/(m^2*K)]

$$-\boldsymbol{n} \cdot \boldsymbol{q} = h(T_{int} - T)$$

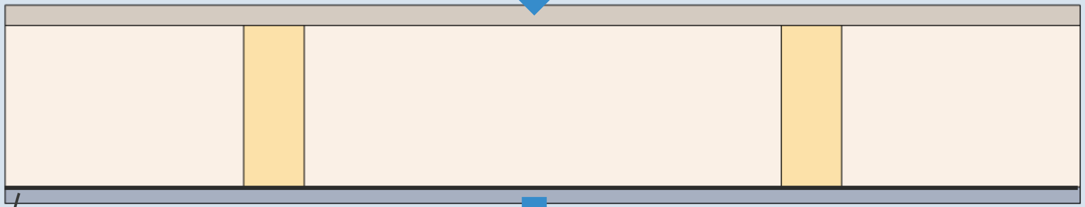
INTERIOR, T = 19 °C, ϕ = 50%

Material and Boundary conditions

EXTERIOR, Dublin, April 15, 0:00:00, T = 0 °C, ϕ = 80%

Convective moisture flux:
Moisture transfer coefficient 25e-8 [s/m]

$$-\boldsymbol{n} \cdot \boldsymbol{q} = \beta\left(\phi_{amb} \cdot p_{sat}(T_{amb}) - \phi \cdot p_{sat}(T)\right)$$



Convective moisture flux:
Moisture transfer coefficient 8e-8 [s/m]

$$-\boldsymbol{n} \cdot \boldsymbol{q} = \beta\left(\phi_{int} \cdot p_{sat}(T_{int}) - \phi \cdot p_{sat}(T)\right)$$

INTERIOR, T = 19 °C, ϕ = 50%

Thin Moisture Barrier:
Vapor resistence factor [1] = function of humidity
Layer thickness 5 [mm]

Required Material Properties

Material type:

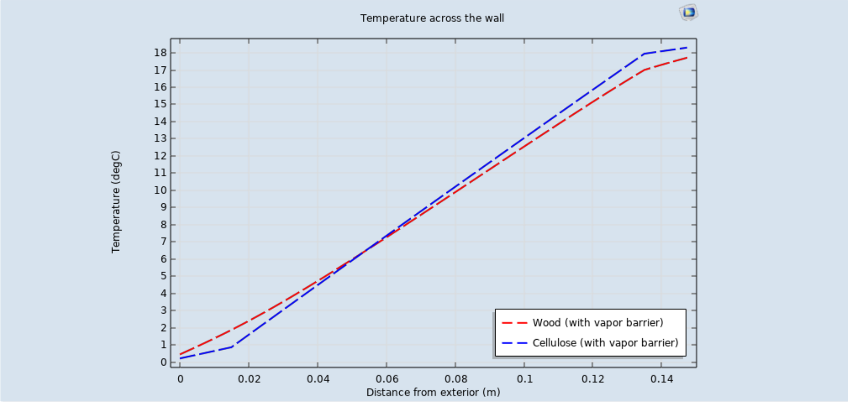
Solid

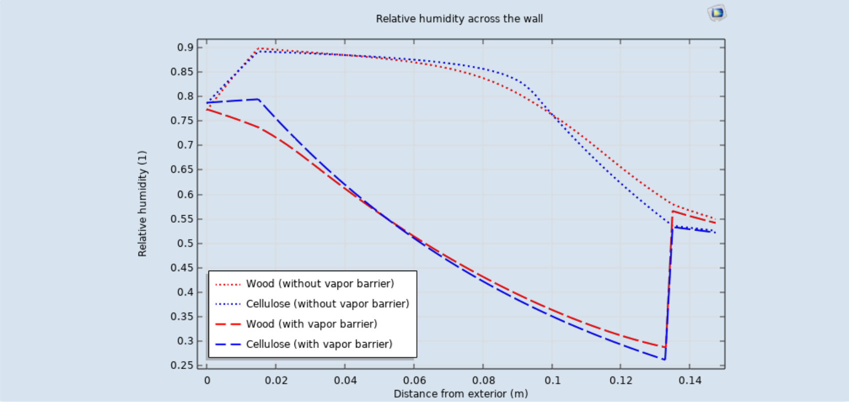
Material Contents

	Property	Variable	Value	Unit
☑	Density	rho	532	kg/m^3
☑	Heat capacity at constant pressure	Cp	2700	J/(kg·K)
☑	Thermal conductivity	k_iso ; kii = k_iso, kij = 0	k(phi)	W/(m·K)
☑	Diffusion coefficient	D_iso ; Dii = D_iso, Dij = 0	Dw(phi)	m^2/s
☑	Water content	w_c	wc(phi)	kg/m^3
☑	Vapor resistance factor	mu_vrf	mu_vrf(T,pA,phi)	1
	Vapor permeability	delta_p_iso ; delta_pii = delta_p_iso, delta_pij = 0	delta_p(phi)	s

Example of required material properties

Results, stationary study





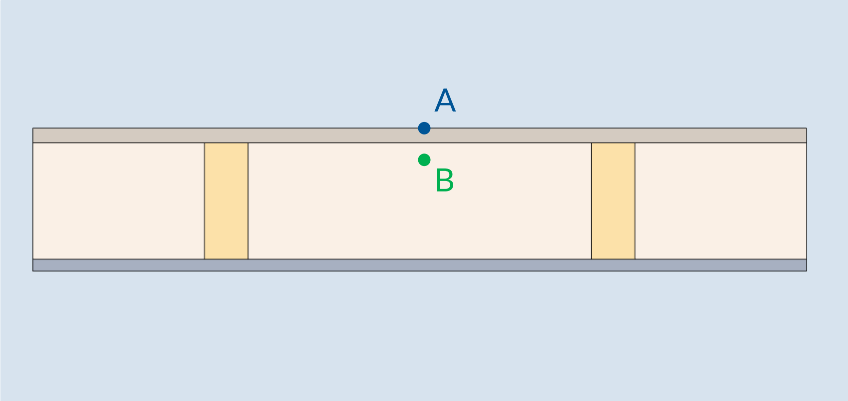
Temperature across the wall

- Cut lines intersect wooden panel (exterior) and gypsum board (interior)
- Vapor barrier has almost no effect

Relative humidity across the wall

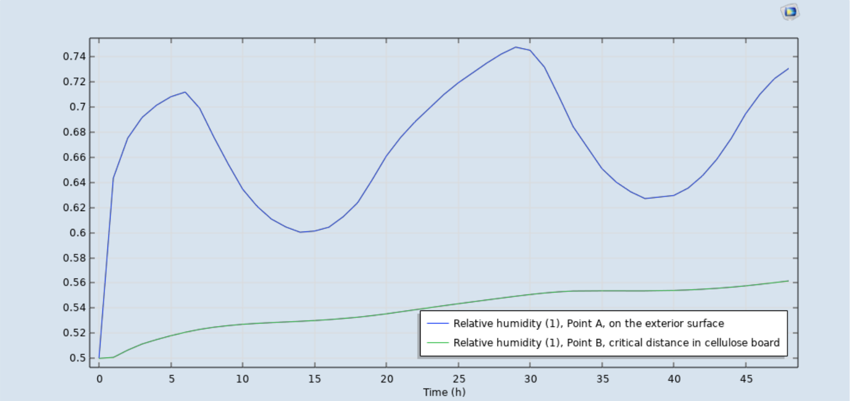
- Comparision between setup with and without vapor barrier
- Condensation risk

Results, time dependent study: 15.4. and 16.4.



Position of two monitoring probes

- A: On the exterior surface
- B: At the critical distance in cellulose board



Relative humidity over two days

- Two days is a short period for reaching the stationary results

Example 2: Condensation Detection in an Electronic Device

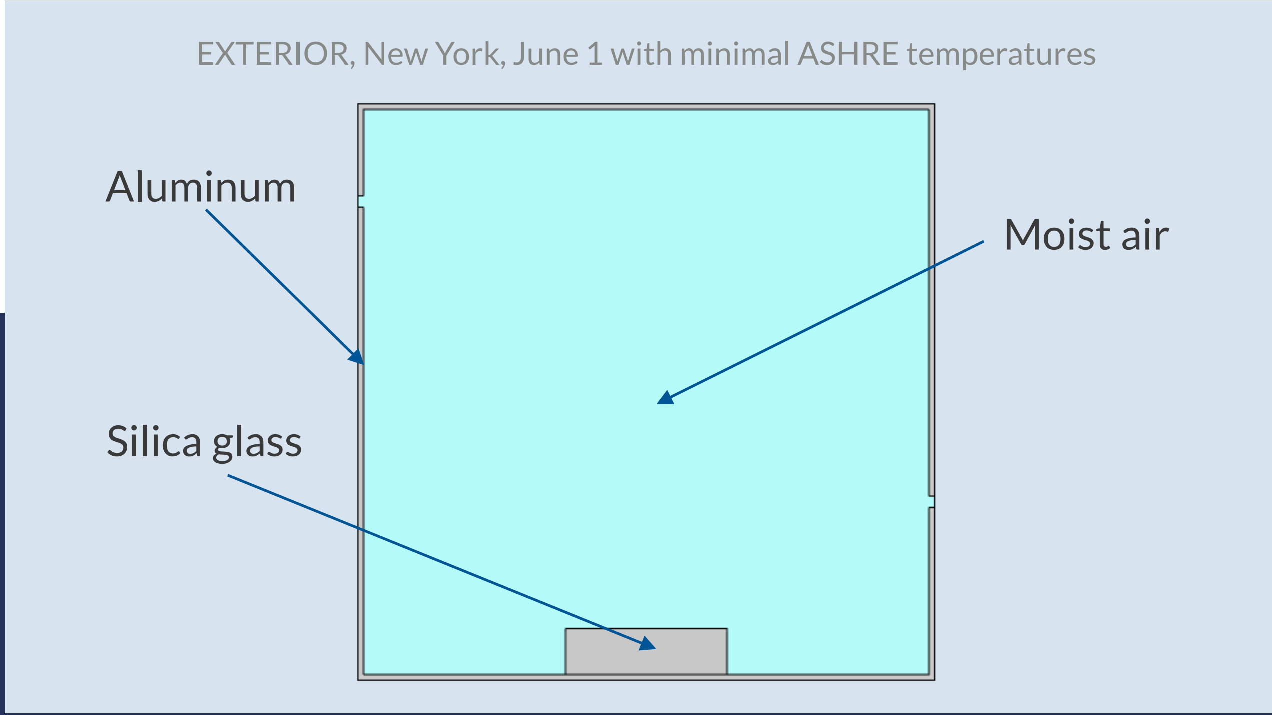
JFK Airport in New York

- Consider minimal 1st June temperature
- Compute condensation risk during the day

Outdoor electronic device

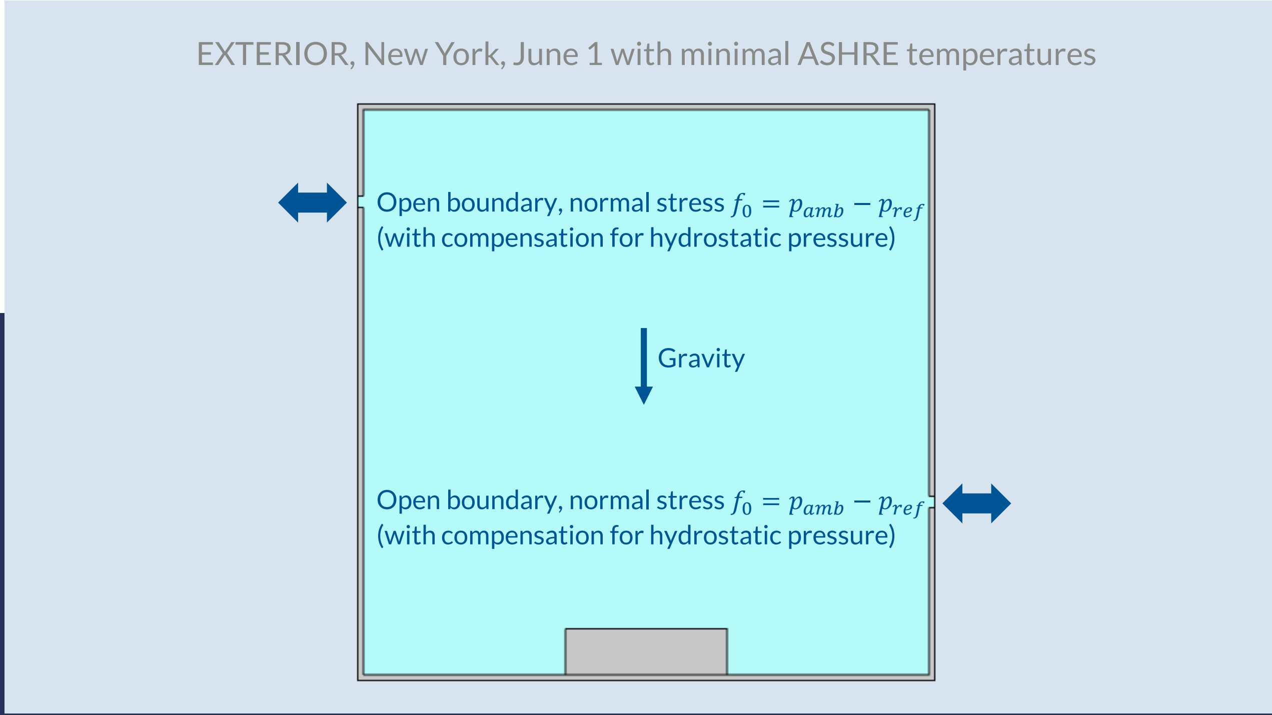
- Heat Source: 1 W
- Convective heat flux around

Material and Boundary conditions



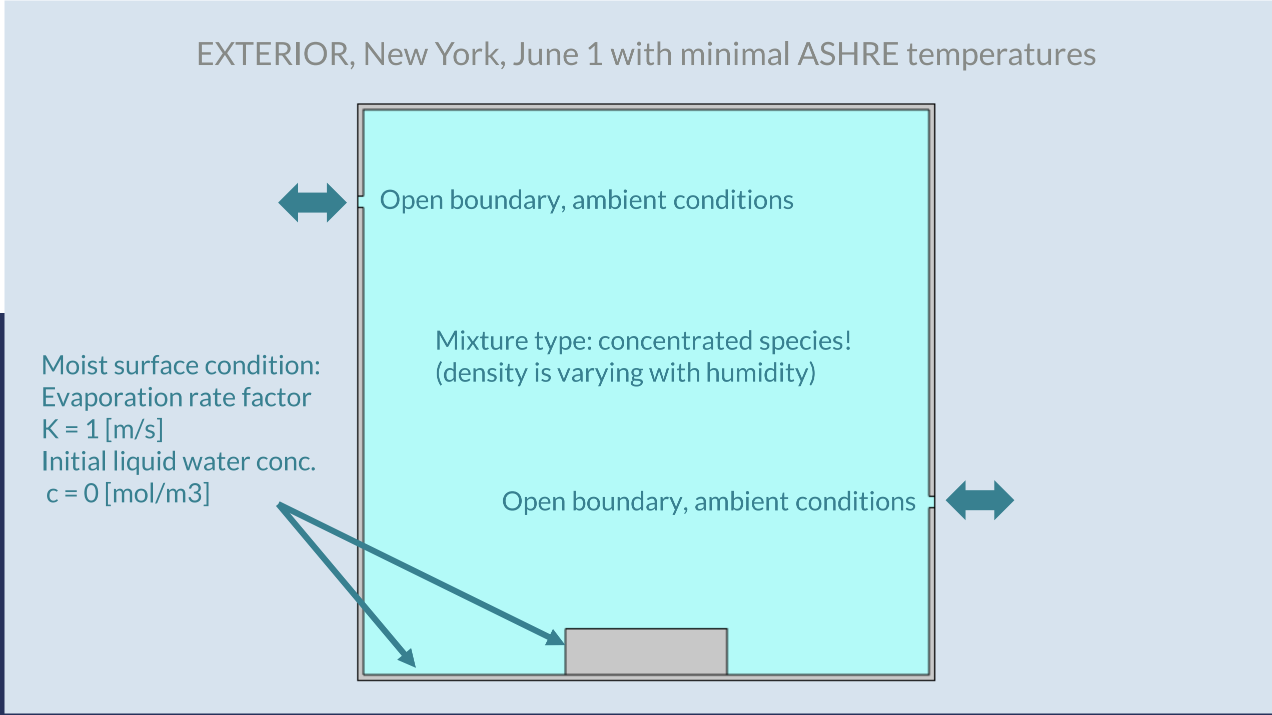
Material and basic boundary conditions setup

Material and Boundary conditions

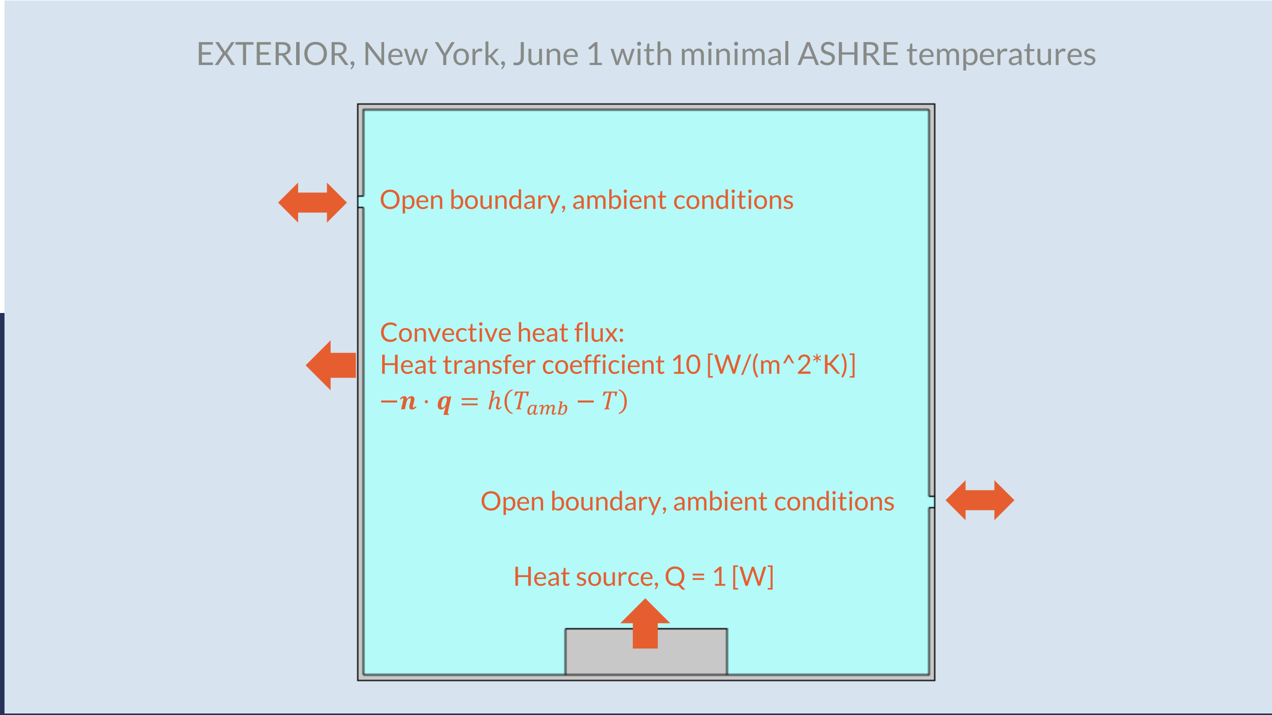


Laminar Flow

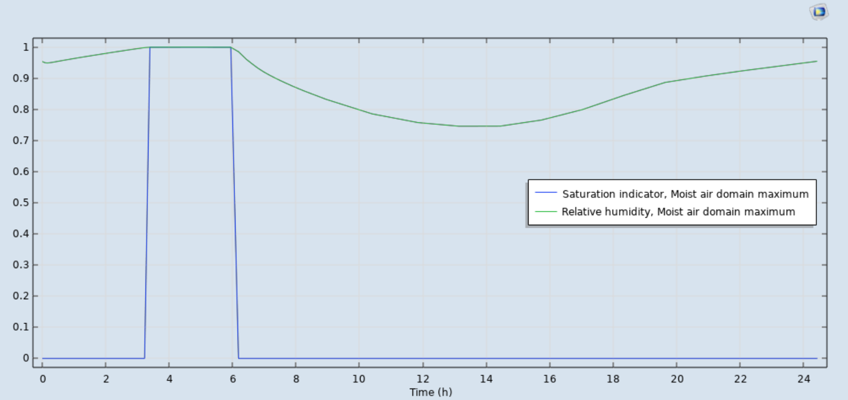
Material and Boundary conditions

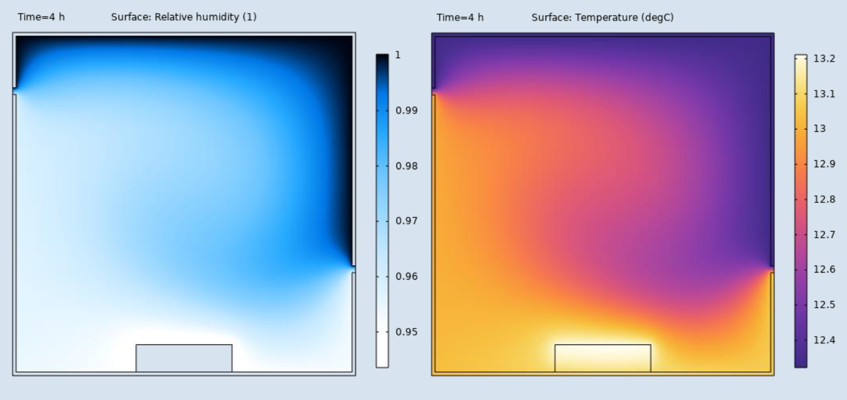


Material and Boundary conditions



Results, time dependent study over 24 hours



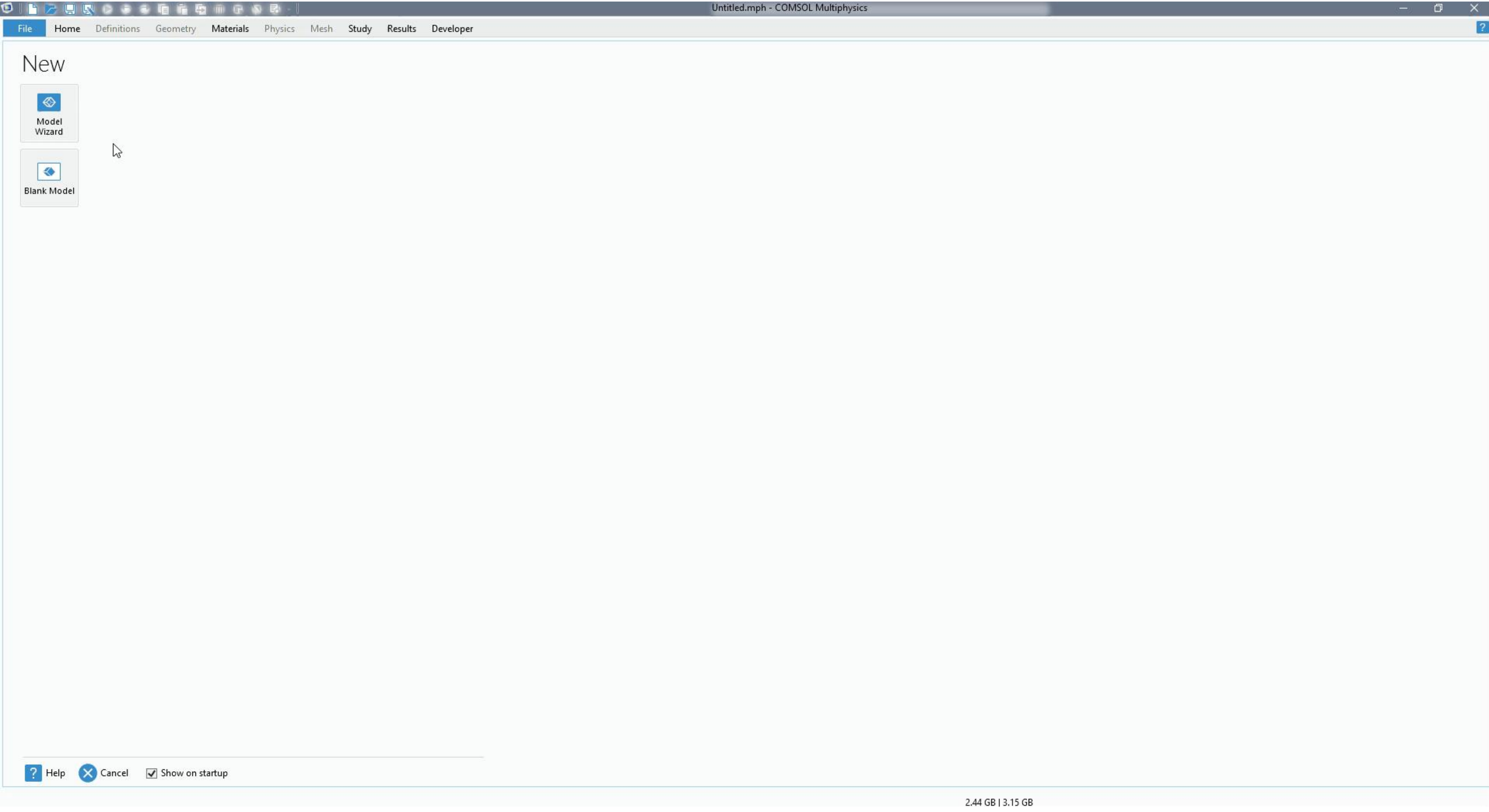


Relative humidity over 24 hours

- Max relative humidity in the moist air domain
- Saturation indicator (from 0 to 1)

Relative humidity and temperature at 4 am

- Regions with relative humidity close to1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Study
Results
Developer
New
Model Wizard
Blank Model
Help
Cancel
Show on startup
2.44 GB | 3.15 GB

Thank you for your attention

You can find a video screen record of my model settings. Visit our **Youtube** channel and find „*Odpolední kurz simulací proudění tekutin (CFD) v COMSOL Multiphysics* “

https://youtu.be/glYNbBHQi9A