New features and optimizations in the hygrothermal transport model DELPHIN 6

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Dresden, 09/21 2017

Overview

- Physical model in DELPHIN 6
  - Coupled heat and moisture transport model with detailed moisture transport and storage model
  - Optional ice formation model
  - Optional air flow model (forced flow/bouancy driven), fully coupled to heat and moisture transport model
  - Optional salt transport model including transient phase transitions
  - Many boundary condition models, contact resistances, source/sink models, special models (e.g. interior longwave radiation exchange)

  - Mostly the same as in DELPHIN 5, but thoroughly reviewed and more efficient/stable (*routinely tested with automated benchmarks*)
  - Support for 3D geometries (in *solver*, not in user interface)

- Optimization of the solver engine
  - Iterative preconditioned Newton-Krylov-Methods significantly accelerate simulation of 2D details, enable 3D simulations
  - Parallel solver
  - Optimized memory layout for faster physics evaluation algorithms

The DELPHIN 6 Software

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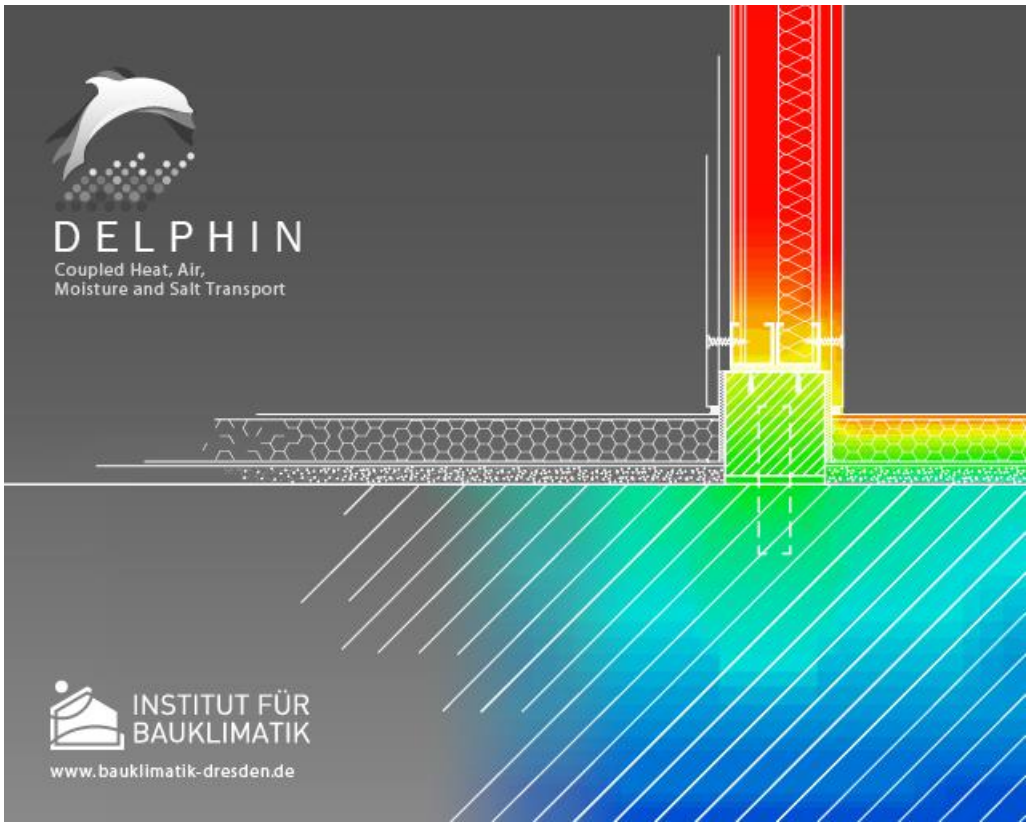
- Executables (Windows executables, on MacOSX and Linux similar naming)
  - DELPHIN 6 User Interface (modelling environment)
    `Delphin6.exe`
  - Console solver (command line argument controlled)
    `DelphinSolver.exe`
  - Graphical (modern) solver, just as fast as the command line solver (except for parallel solver variants), yet with live preview of simulation results
    `DelphinSolverUI.exe`
  - Command line discretizer (can be used to automatically perform grid sensitivity studies)
    `CmdDiscretise.exe`
  - DSixOutputConverter utility (extracts data from output files, converts data into other formats, creates TECPLOT files)
    `DSixOutputConverter.exe`

- Databases (Climatic Data and Materials)
- Post-Processing
  - Either *DELPHIN 5 Post-Processing* (can be installed alongside with DELPHIN 6)
  - Or new *POSTPROC 2* software (recommended for simulation analysis)

New User Interface

- New Icon and Splashscreen

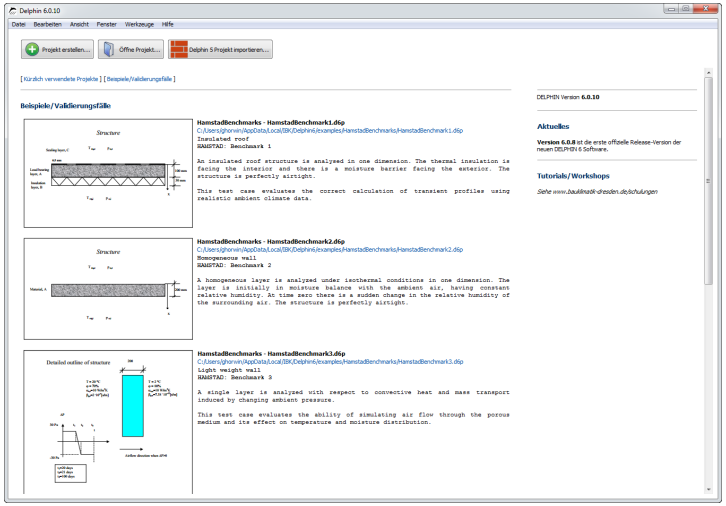


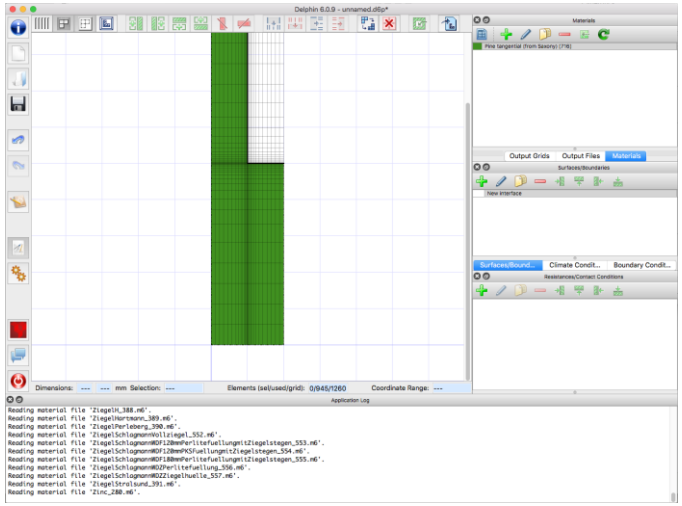
Picture taken from IBK-GWT project about improving construction detail for intersection of interior separation wall with inside-insulated historic brick wall

New User Interface

- Multiple languages
  - Switch with menu option `Edit` → `Languages…`
  - Currently: English, German, French
  - Translation is simple → Translators are welcome!

- Software runs natively on *Windows*, *MacOS* and *Linux*

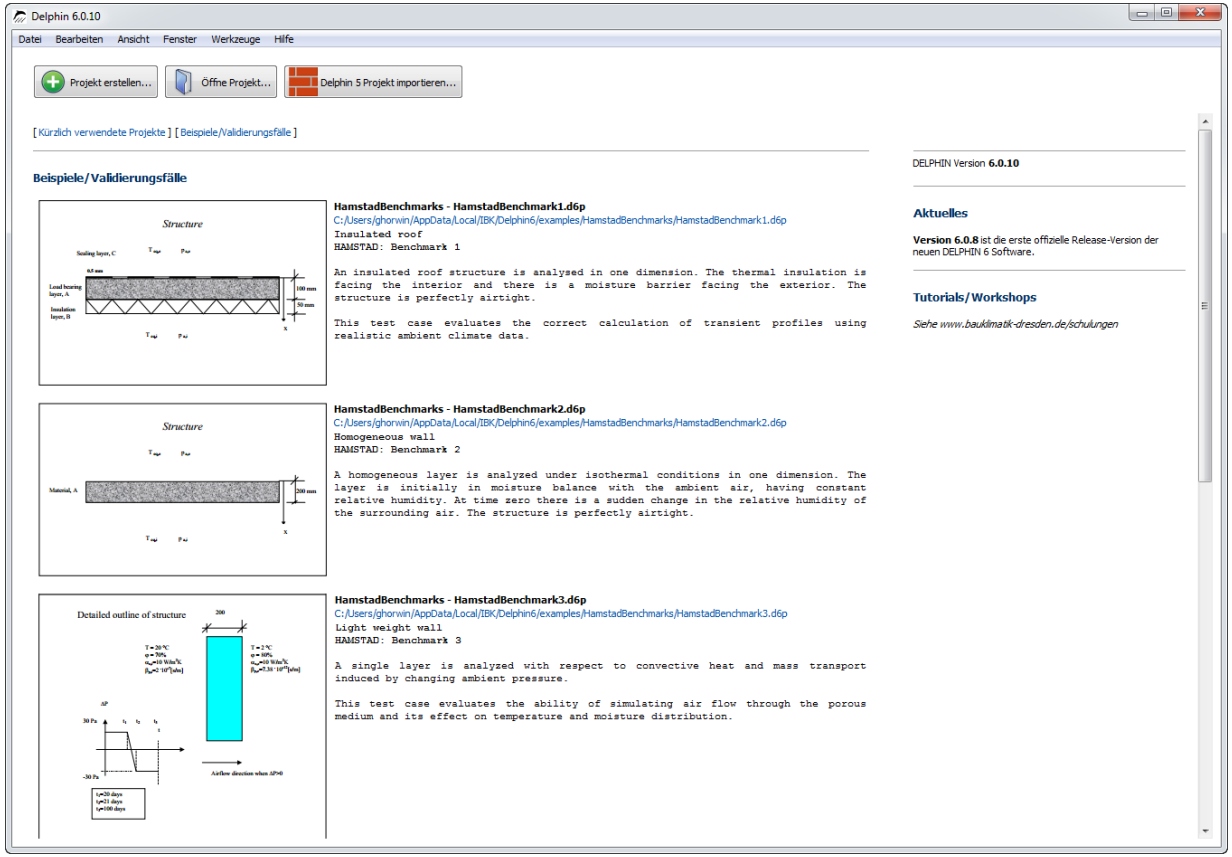




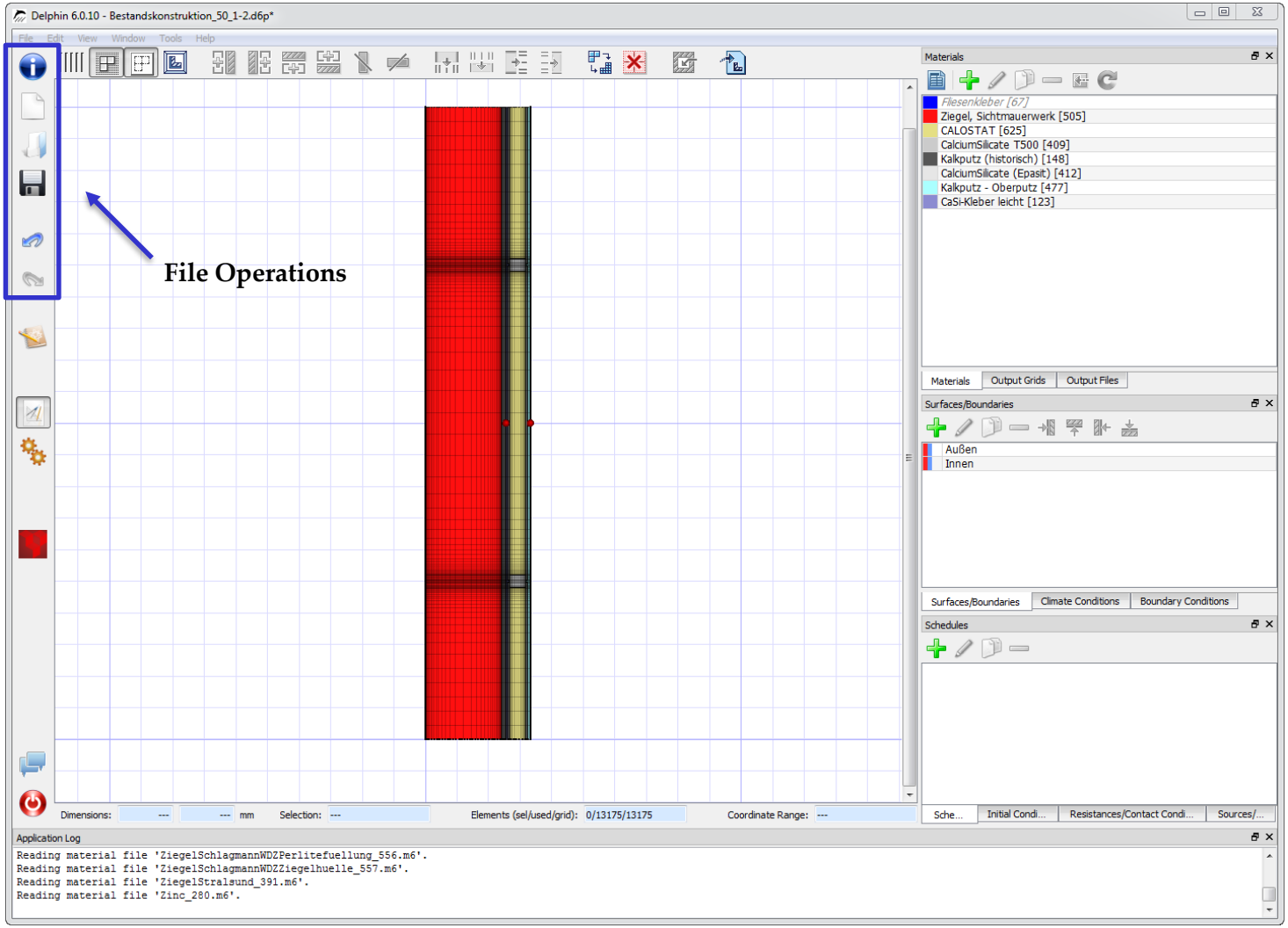
- On Mac OS X: Security → allow software from any sources

New User Interface

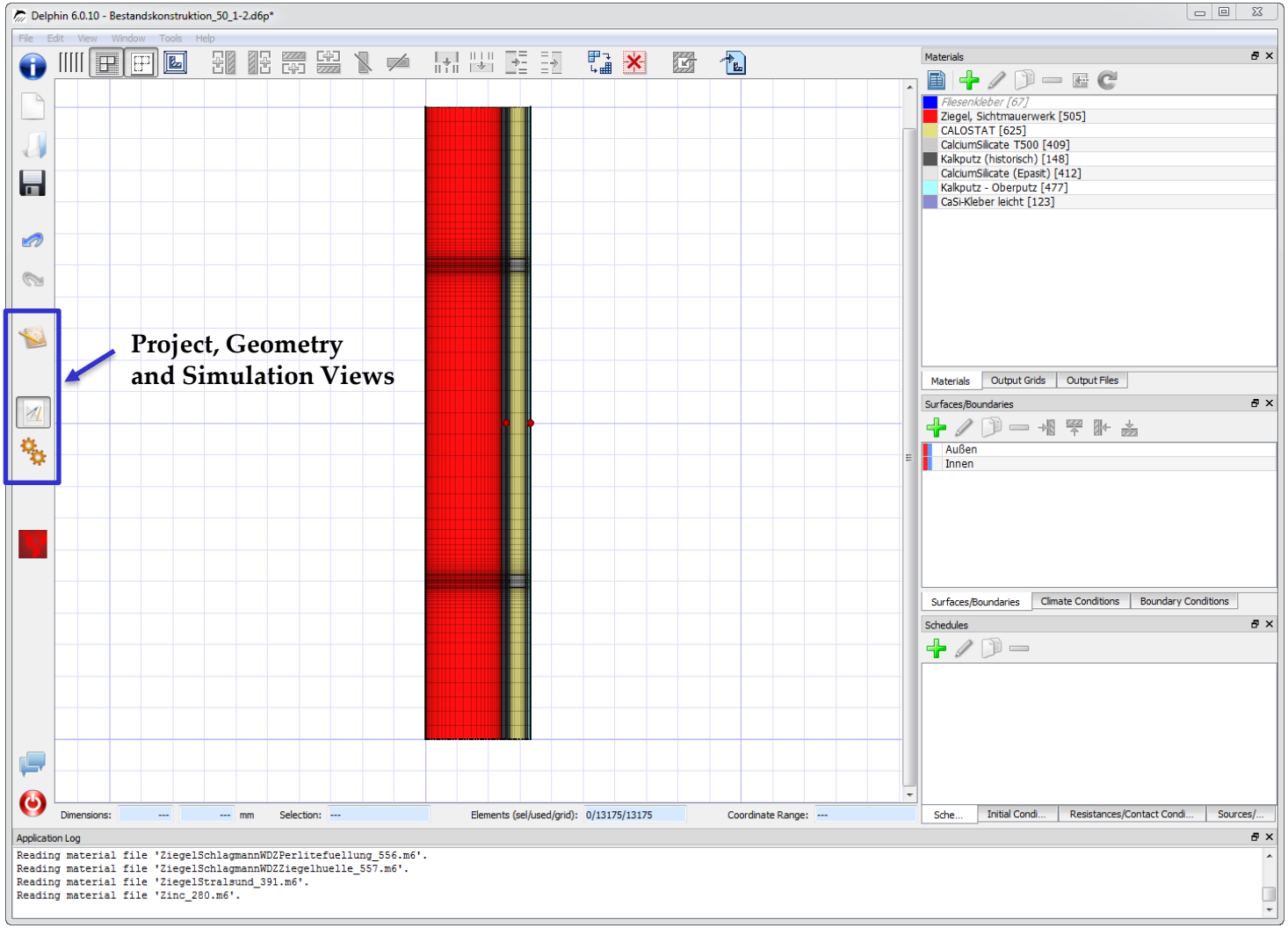
- Welcome page
  - Recently used projects (with preview)
  - Examples/Validation cases (with descriptions)
  - Current version, Update information, Web-content from Bauklimatik-Dresden.de



New User Interface

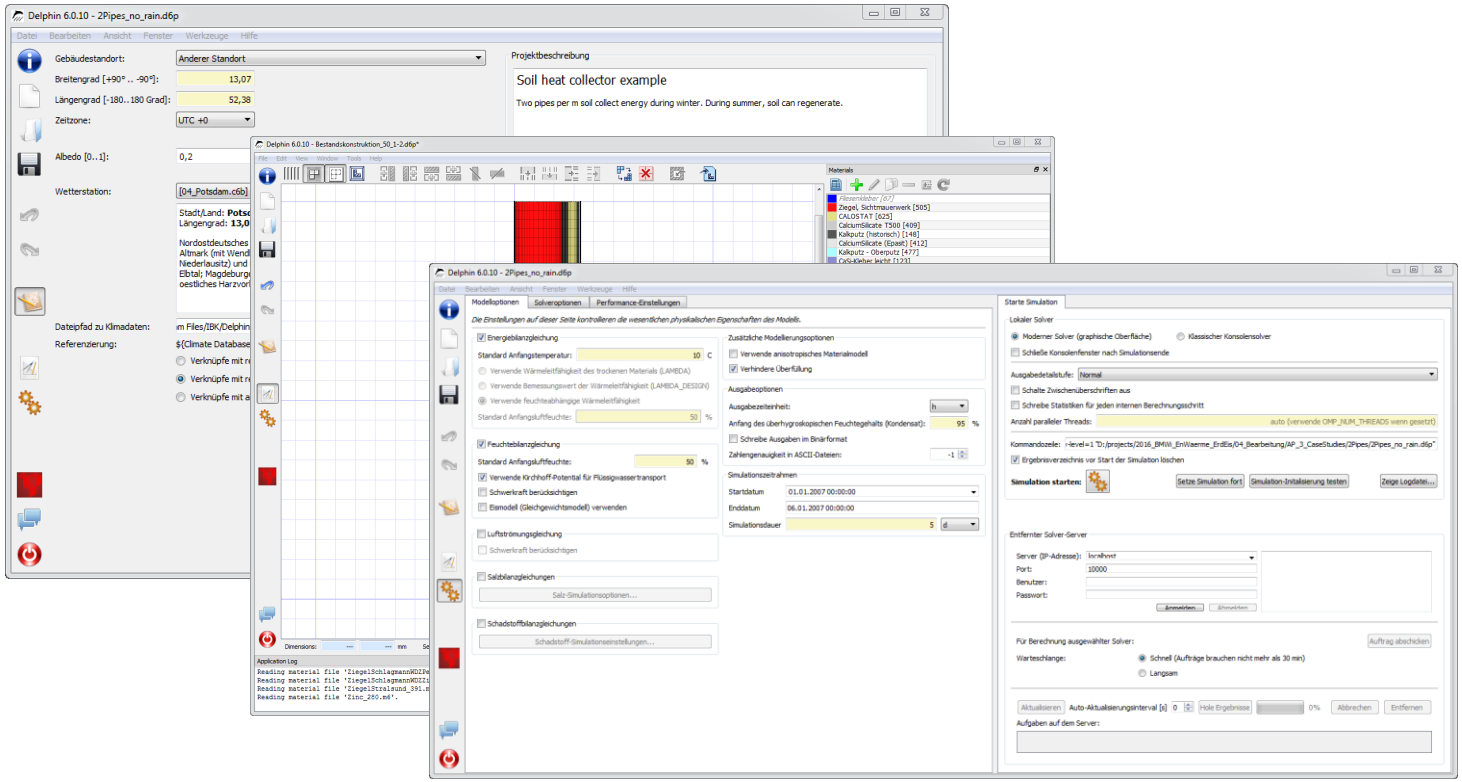


New User Interface

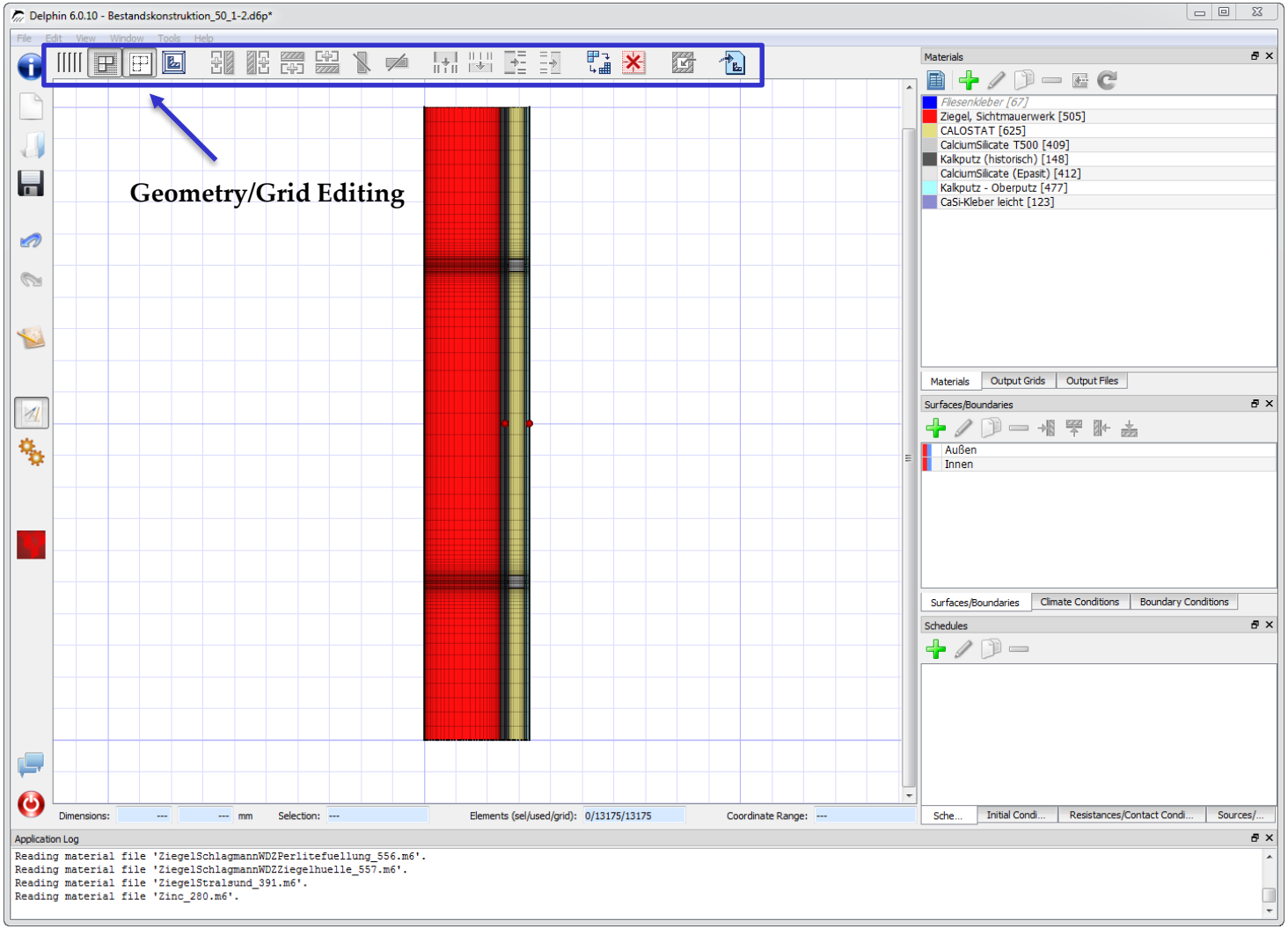


New User Interface

- 3 Views with project data
  - Project properties, location and climate
  - Construction/Geometry view (main modelling view)
  - Simulation view (physical model settings, solver options, simulation start)



New User Interface



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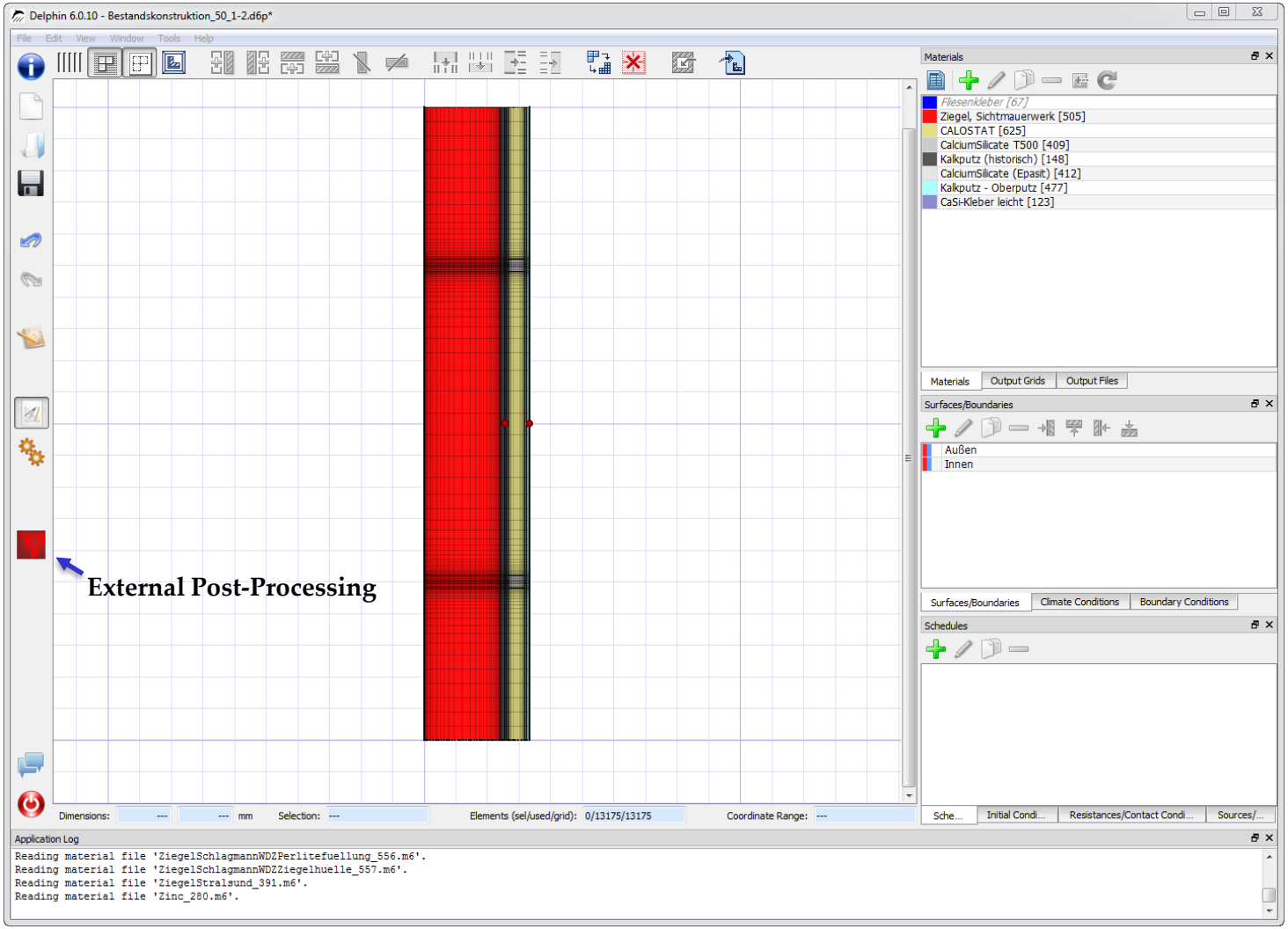

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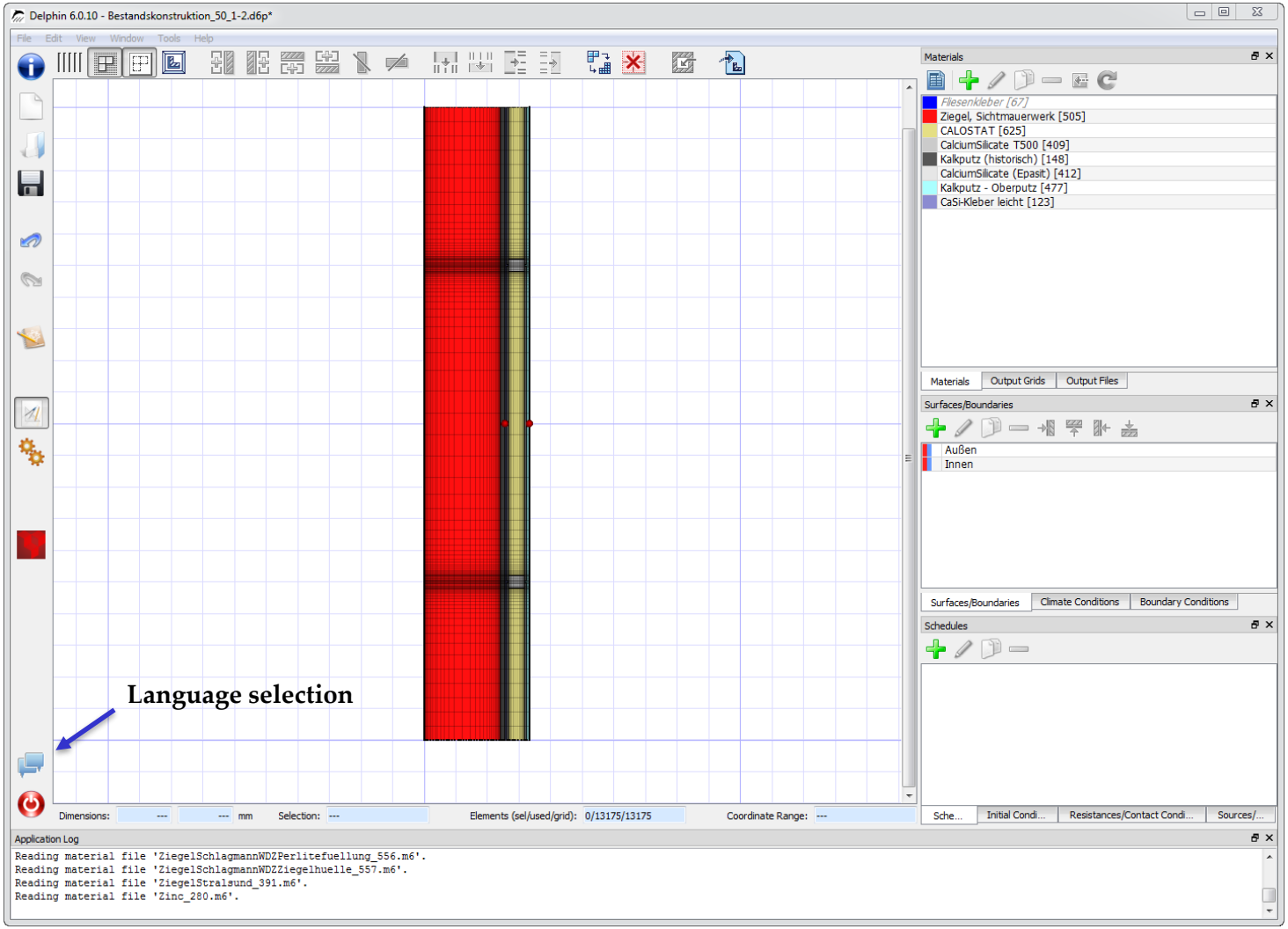
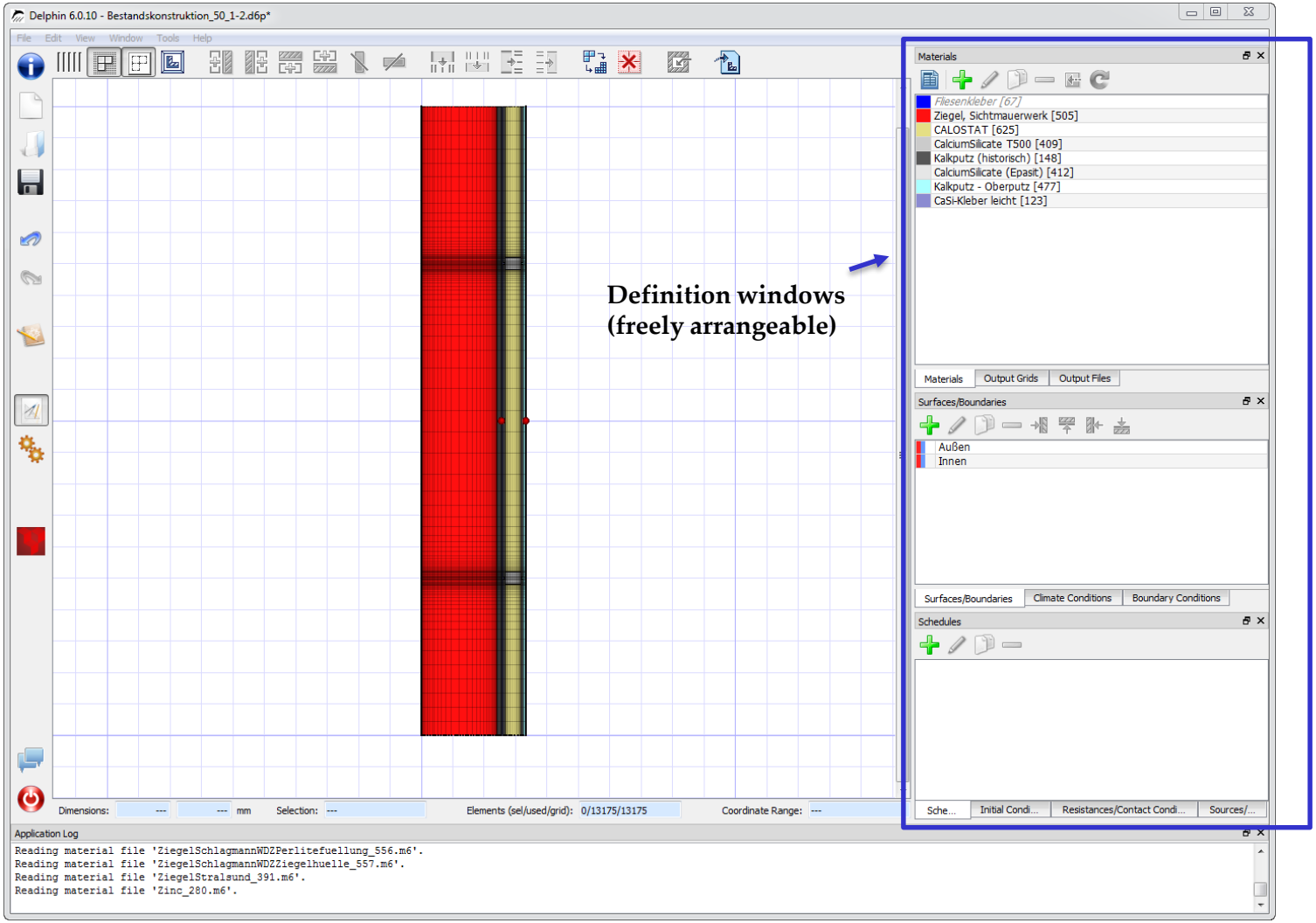
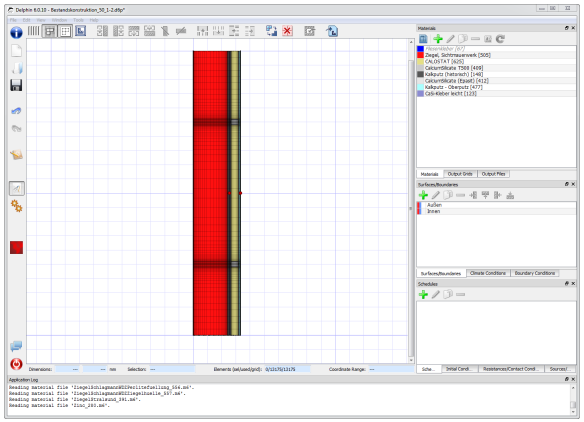


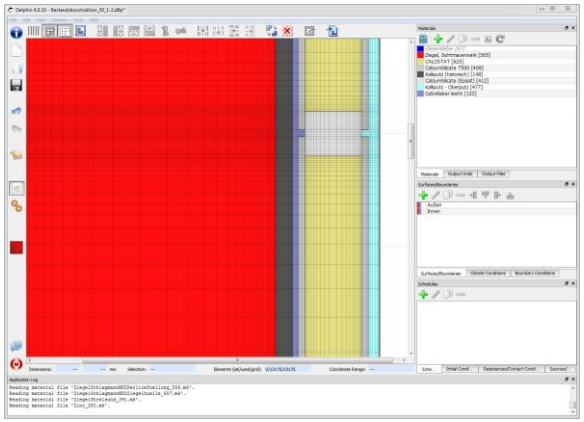
New Modeling View



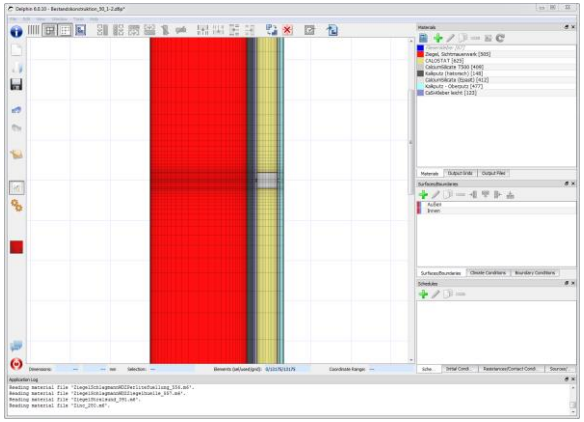
New Modeling View

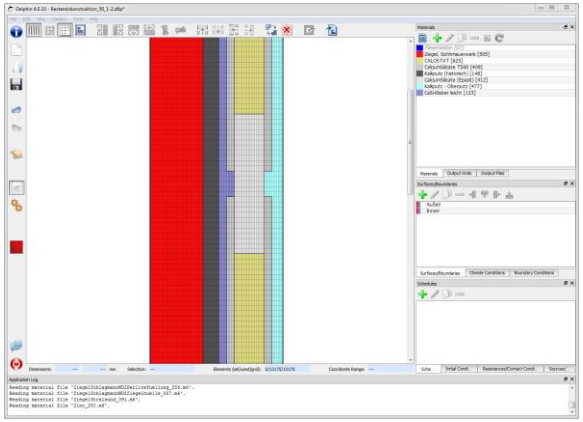
- Zooming via mouse scroll wheel





- Equidistant view toggle mode





Consistent Coordinate System Definition

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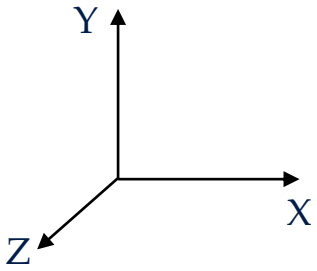
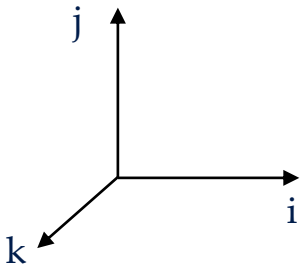
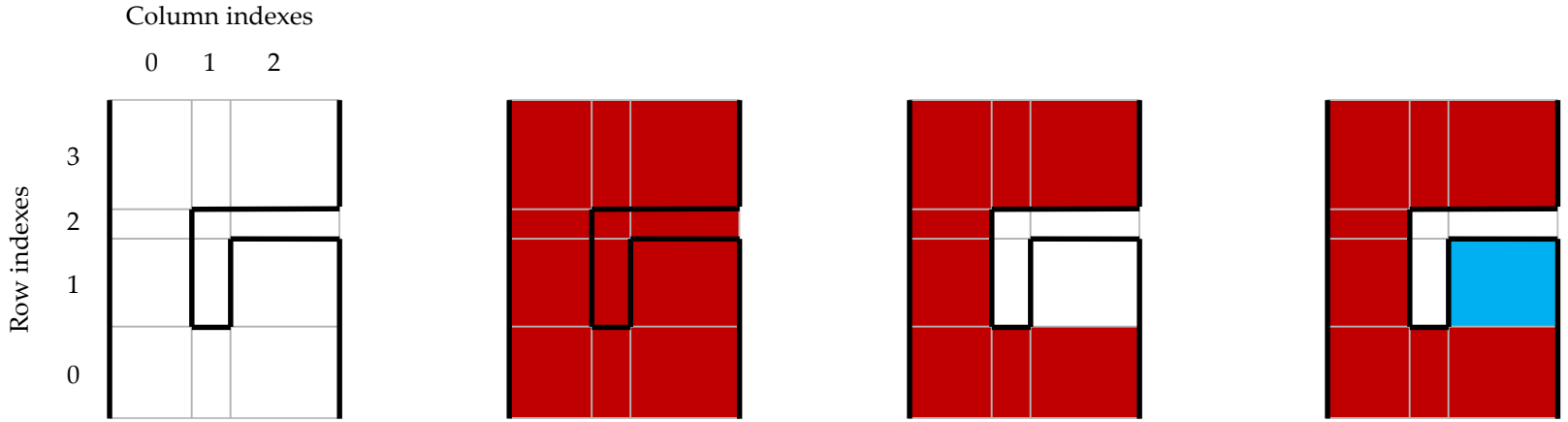
- Coordinates



- Assignment/range indexes



- Assignment order
  - Later assignments override earlier assignments (applies to all assignments)



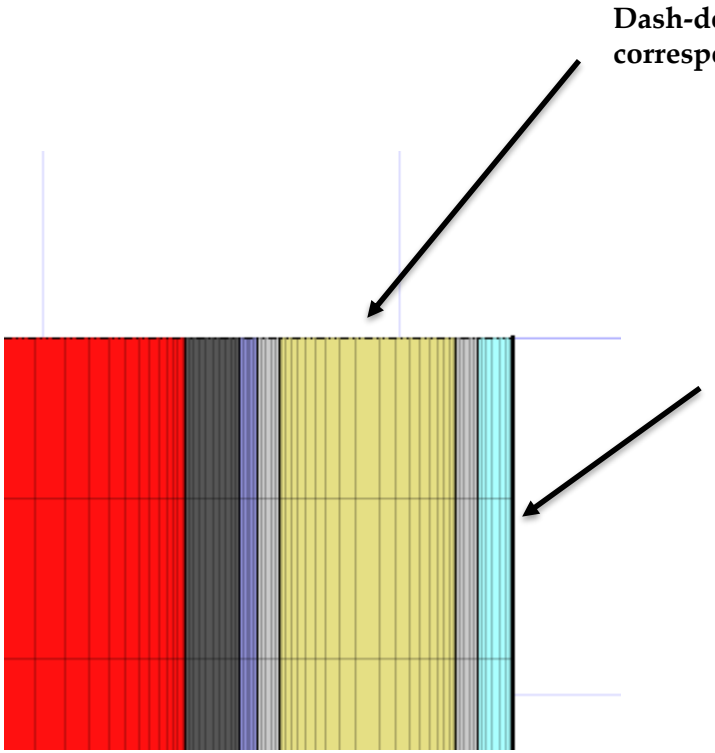
grid without materials assignments

after assigning material to range 0 0 2 3

after assigning VOID material to range 1 1 2 2

after assigning another material to range 2 1 2 1

- Highlighting of edges/boundaries with assignments

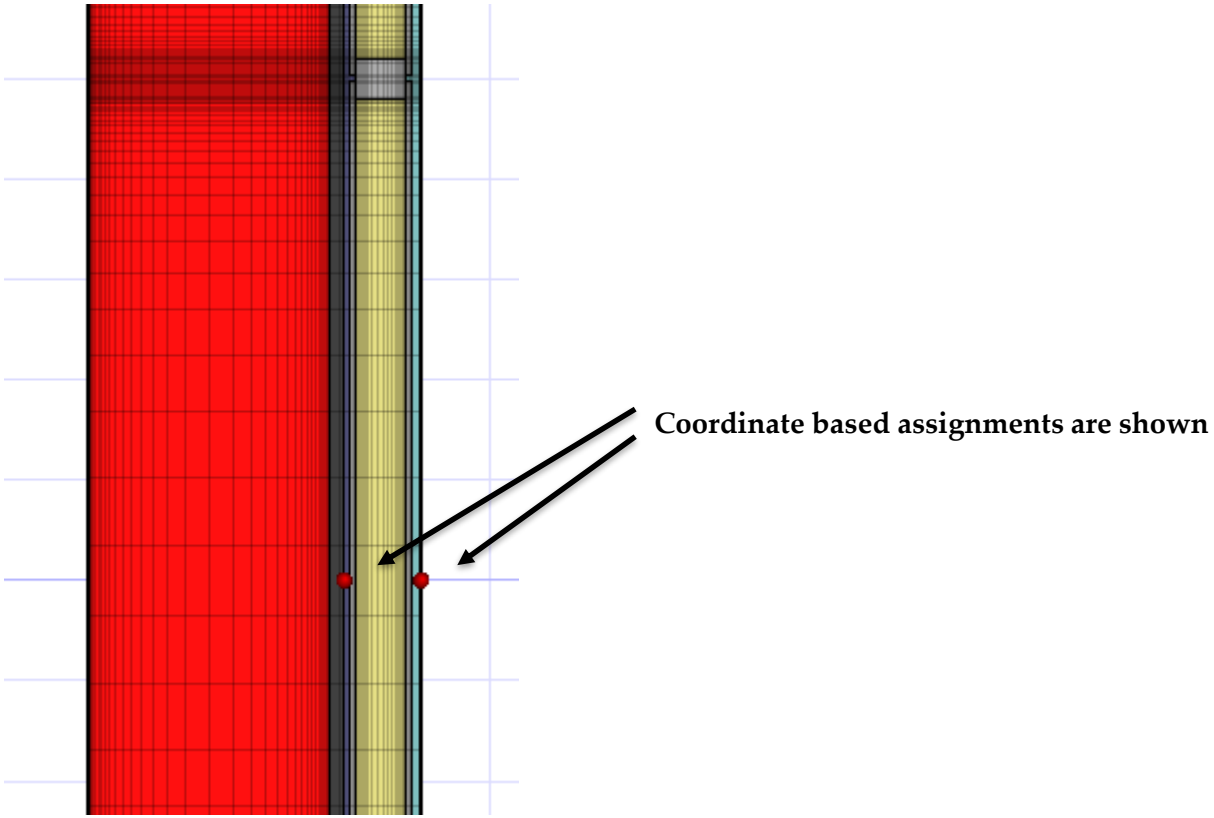


Dash-dot line pattern for boundaries without interfaces, corresponds to symmetry conditions (adiabatic and moisture tight)

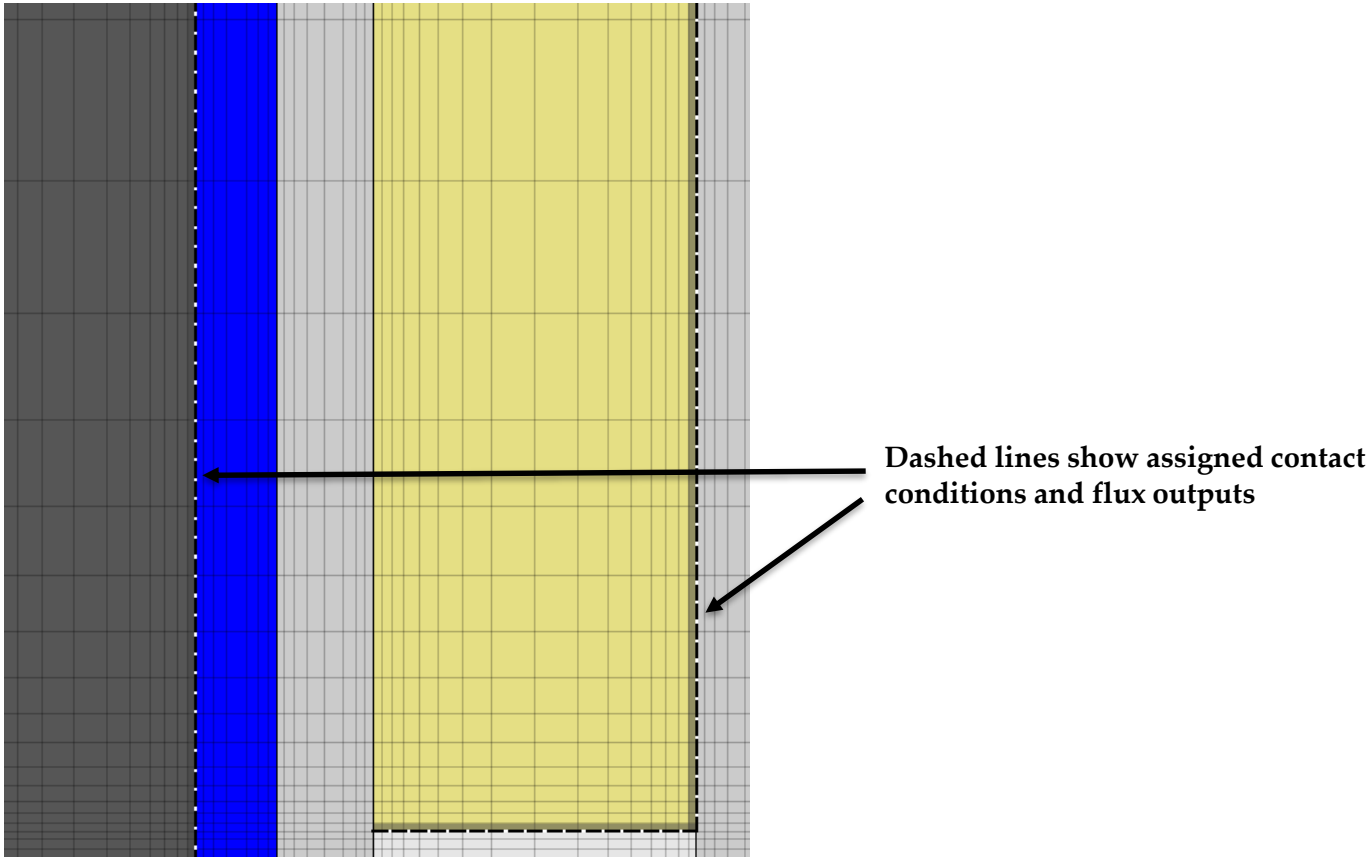
Thick solid lines indicate assigned interface

Modeling Improvements

- Highlighting of coordinate outputs (sensors)

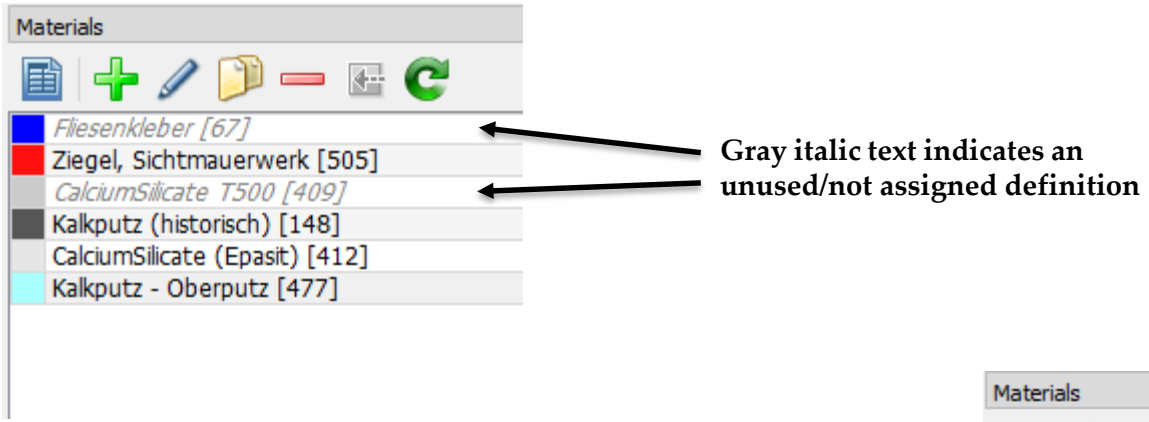


- Highlighting of side assignments



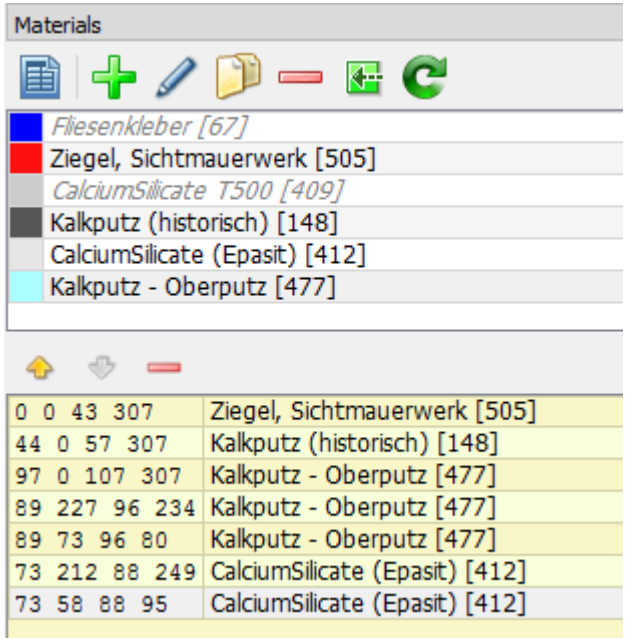
Modeling Improvements

- Indication of used and unused definitions



- Assignment lists are located alongside definition window

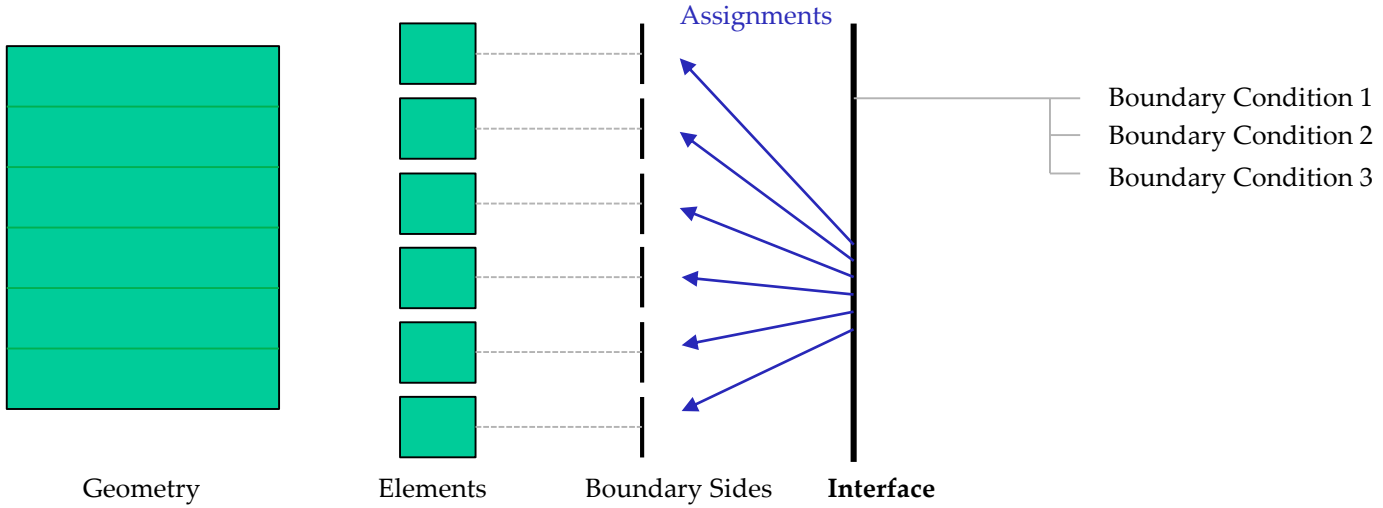
  (re-introduced from DELPHIN 4)



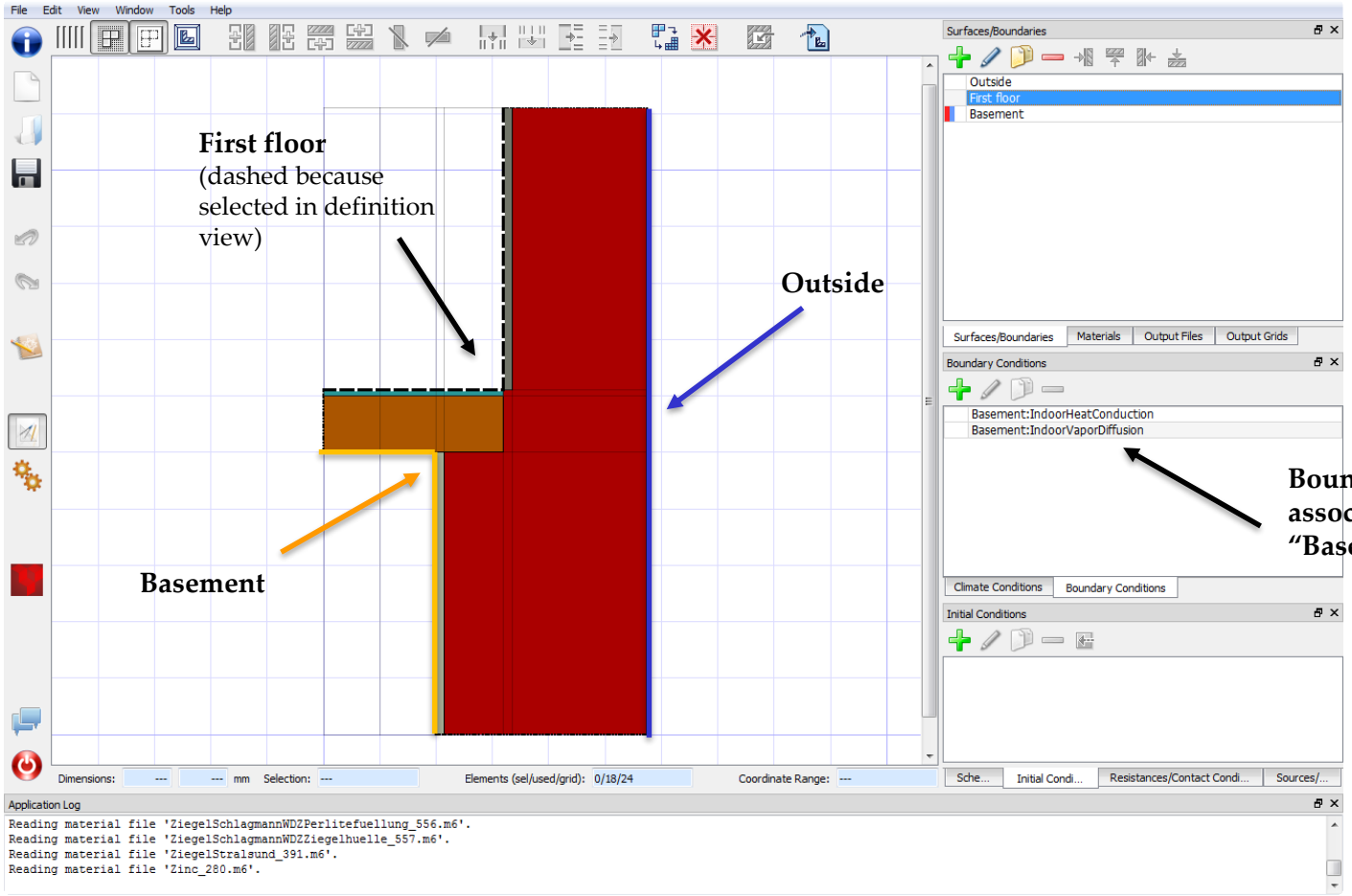
New Modeling Concepts

- No embedded material data
  - Material files (*.m6) are always referenced
  - Material list/definition window lists *Material References*

- *Interfaces* group several boundary conditions
  - Instead of assigning individual boundary conditions to several sides, interfaces are defined (e.g. outside, inside, basement, …) and these are associated with boundary conditions
  - Support for *Engineering Interface Models* (predefined sets of boundary conditions and related climatic conditions)



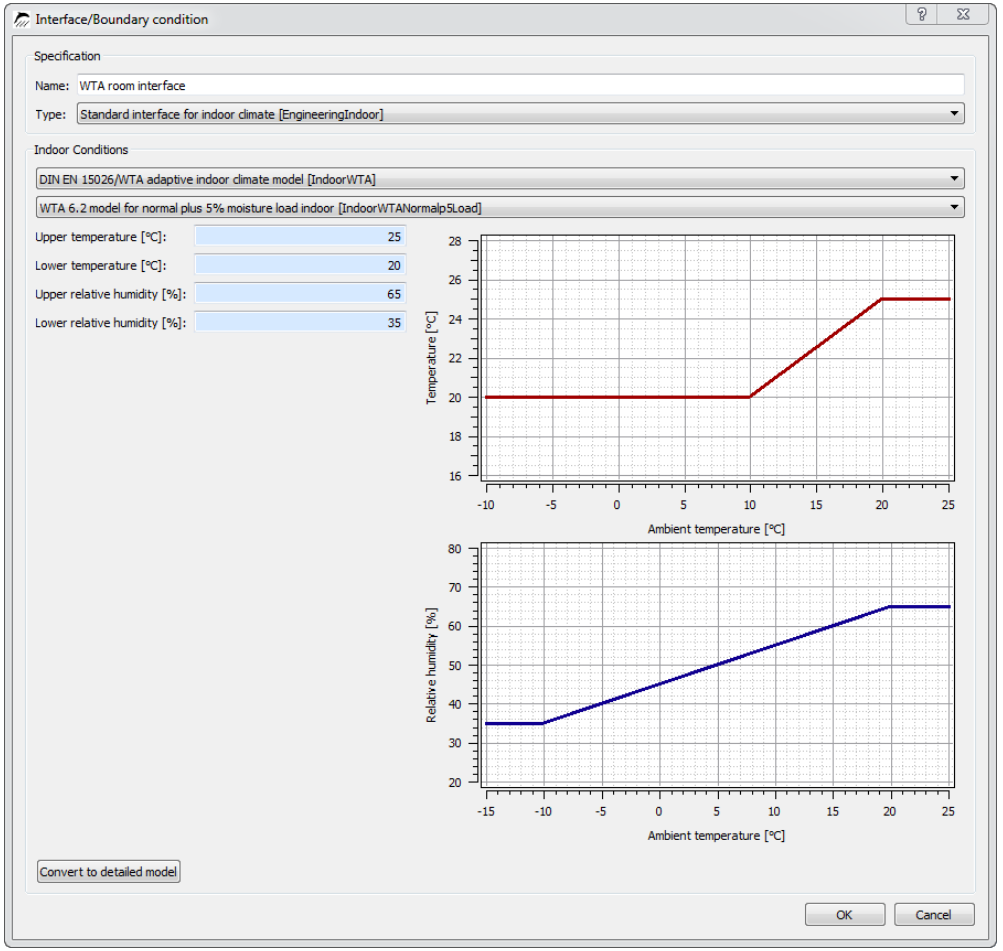
- Interfaces – Example



- Interfaces – Engineering Level
  - DIN indoor and outdoor climate
  - WTA model
  - Standard model

  - Boundary Conditions and Climate Conditions are created automatically during simulation setup

  - Engineering interface definitions can be converted to detailed model

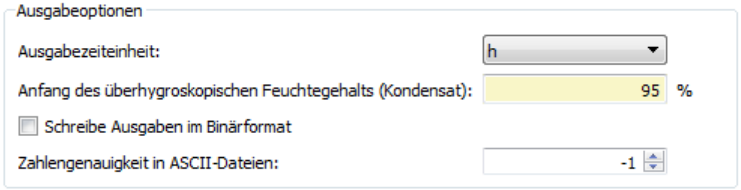


Output handling

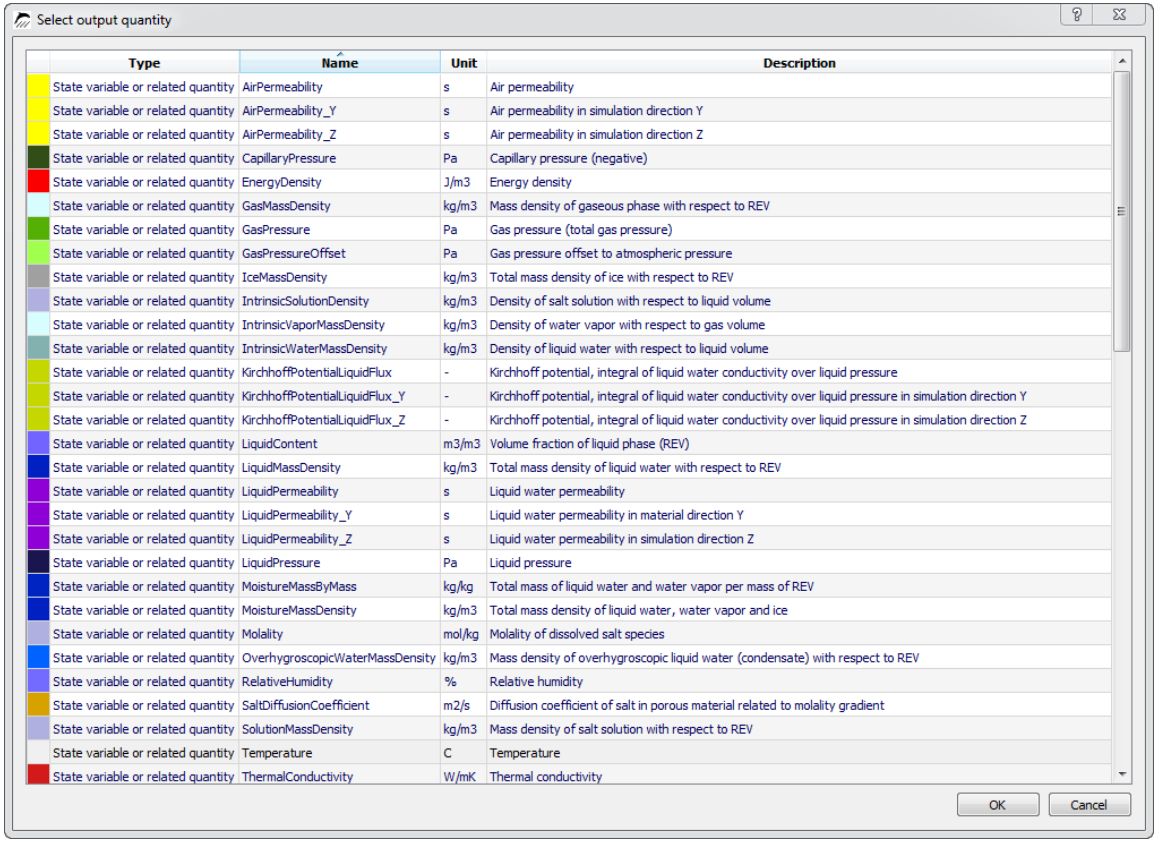
- Output file definitions
  - Filename
  - ***Physical Quantity***
  - Grid reference
  - Time and spatial handling (averaging/integration)
  - Value unit

- Grids
  - Define intervals and output steps

- Global options (for *all* files)
  - Binary/ASCII Format
  - ASCII-Format precision (rarely needed, for example for energy density integrals to compute overall gains/losses)
  - Output time unit (same for all output files)
  - Over-hygroscopic moisture content limit (as relative humidity)



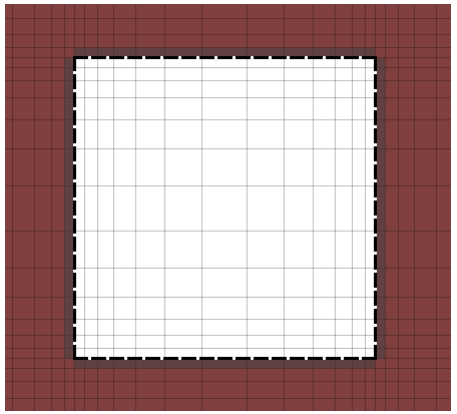
- Physical Quantities
  - Quantity defines also default unit and type (flux or field quantity)
  - Anything calculated in DELPHIN is available as a quantity
  - Includes transport coefficients (which can be monitored in output files)



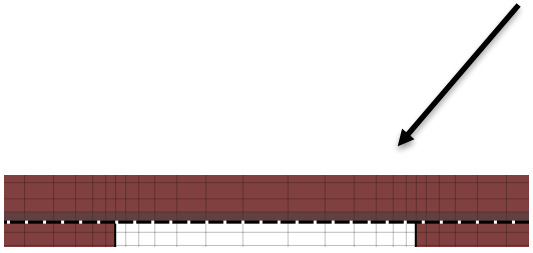
Output handling

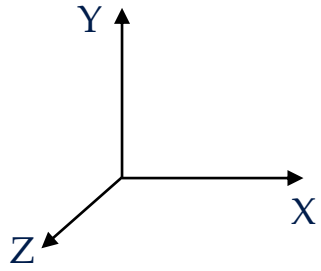
- Flux output sign conventions
  - Distinguish between boundary/surface fluxes and flux fields – **different sign conventions**
  - Fluxes are assigned to sides
  - One flux output (definition) can be assigned to several locations

- Rules
  - When flux outputs are assigned only to boundary sides
    Flux is ***positive*** when it flows ***into*** the construction
    i.e. a positive moisture flux increases the moisture content in the construction, a positive heat flux increases energy density (and temperature)

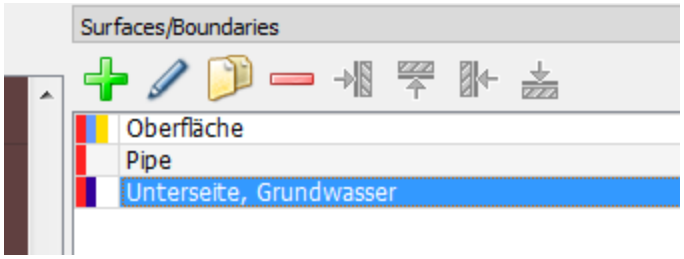


  - When flux is assigned to at least one internal side,
    flux is ***positive*** when it flows into ***positive coordinate*** direction

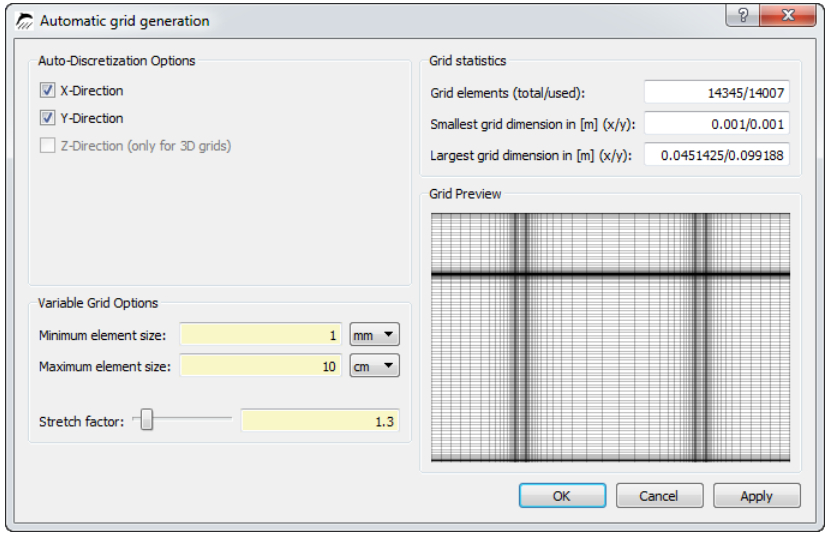




- Schedules
  - Replace time limits for boundary and field conditions, can be specified like output intervals
- Interface – BC indication
  - Color bars indicate types of BC associated with an interface



- Intelligent Auto-Discretization
  - Clusters grid *only at boundaries where interfaces* are assigned
  - Recognizes and keeps field assignments (outputs/sources)



Databases

- Material Data Base
  - set of **m6** Material files (as in DELPHIN 5)
  - data files are read in separate thread – no longer delay when importing materials

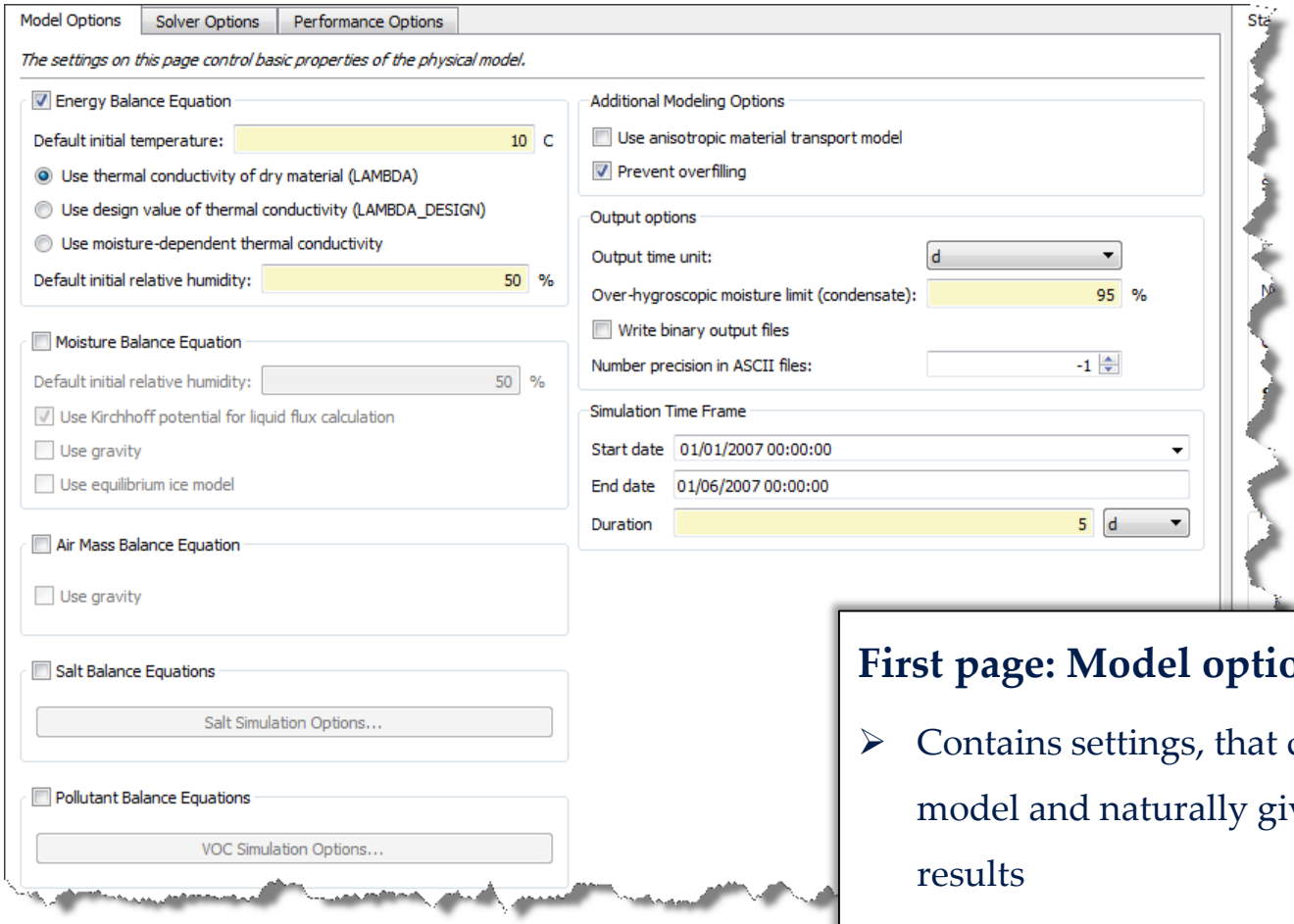
- Climate Data
  - New format: **c6b** climate data container files for use in CCM (Climate Calculation Module)
  - Basically same content as EPW, but binary format (data protection), **epw** natively supported
  - Free Climate Data Editor (CCMEditor) tool available for editing/converting data

- Additional time series (climate data)
  - Still using **ccd** files as in DELPHIN 5
  - Now supporting **csv** files (tabulator separated data files):
    first column time points, second column values, description and units in first row

Example file:

```
Time [d]    Temperature [C]
0.0         10.0
0.02083      9.0
0.041667     8.7
0.0625       7.4
```

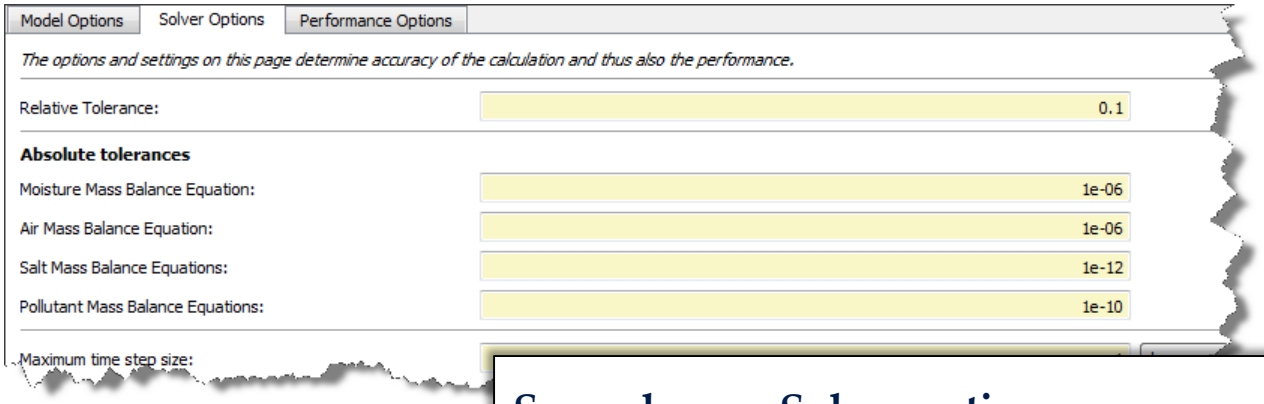
Model and Simulation Settings



First page: Model options

- Contains settings, that define physical model and naturally give different results

Model and Simulation Settings

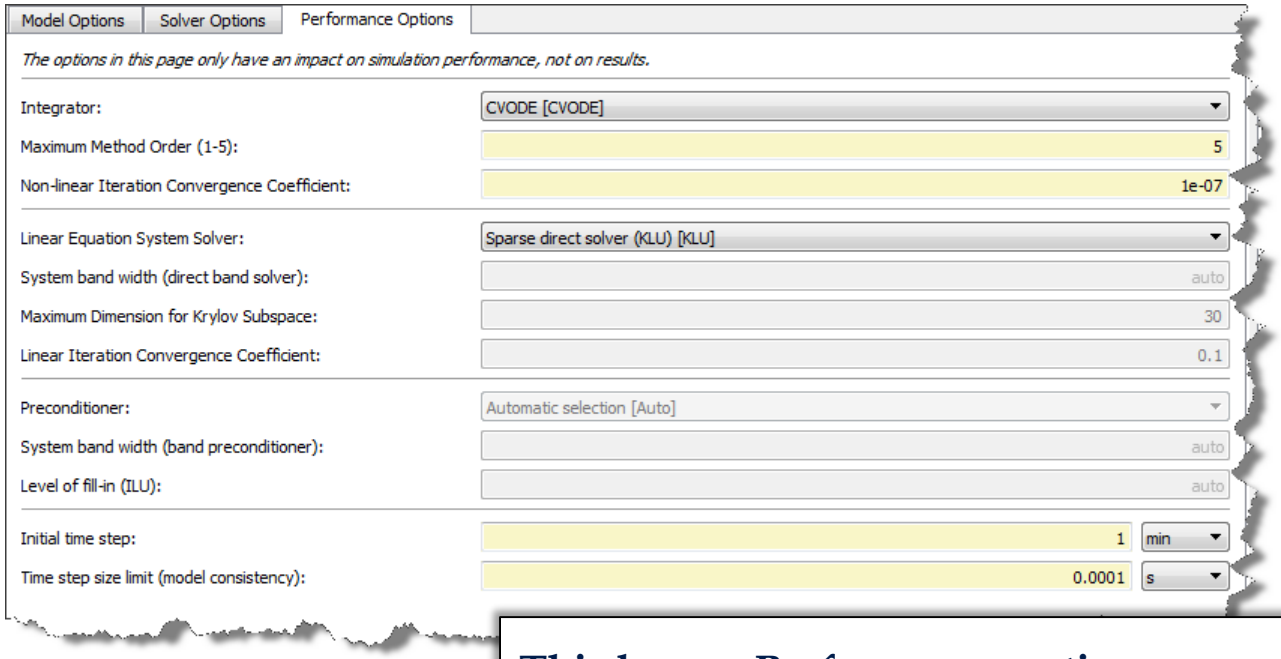


Second page: Solver options

- Tolerances control error test – to how many digits shall my *conserved quantities* be accurate

  Mind: there is a non-linear relationship between conserved quantities and analysed properties (e.g. relative humidity)
- Settings have an influence on model results
- Smaller tolerances **slow down** simulation but can help increase robustness!

Model and Simulation Settings



Third page: Performance options

- Numerical settings only influence simulation speed (differences in order of rounding errors possible)

New Solvers / Performance Optimization

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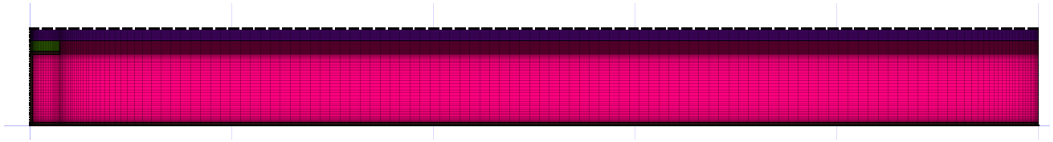
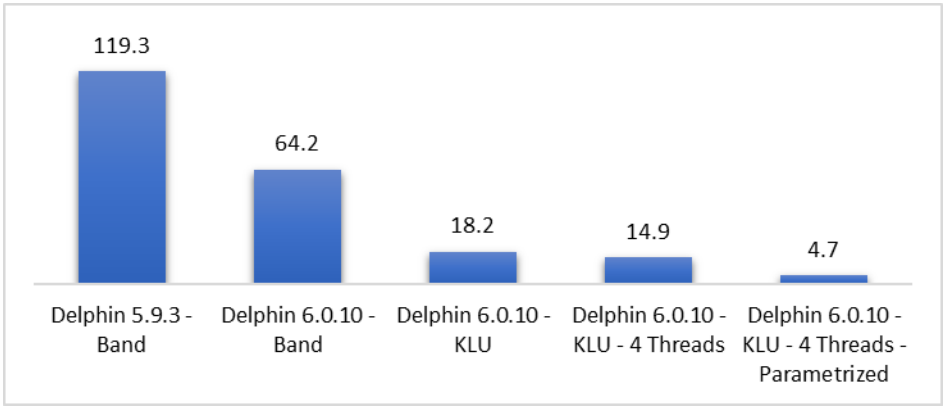
- Time integrators available
  - Explict Euler (for debugging purposes)
  - Runge Kutta 47 (Dormand-Prince), explicit solver
  - Implicit Euler (for testing numerically tricky problems)
  - **CVODE** (default, as in DELPHIN 5)
  - Alternating-Direct-Implicit (ADI), good for certain 2D/3D problems, research code
- Linear equation system solvers (for use within implicit solvers)
  - Banded (general 1D simulations, small 2D simulations)
  - Block-Tridiagonal (VOC/Salt simulations in 1D)
  - **Sparse direct** (KLU solver, for thermal problems in 2D/3D)
  - **GMRES** and **BiCGStab** (for general 2D/3D cases) – Krylov-Subspace methods!
- Preconditioners (for Krylow-Subspace solvers)
  - Banded
  - **ILU** (incomplete LU factorization)
  - … others are research/test implementations
- Physical model evaluation done in parallel (**OpenMP parallelization**)

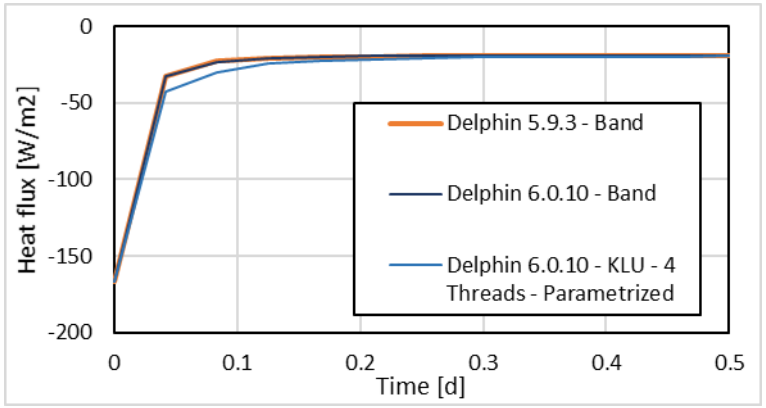
See presentation and workshop from BauSIM 2016 for details

- Example 1 – EN ISO 10211 – Case 2
  - Energy balance only (thermal bridge problem)
  - 36666 Elements, 189 half-bandwidth (rectangular 194 x 189 grid)





Simulation time [s]

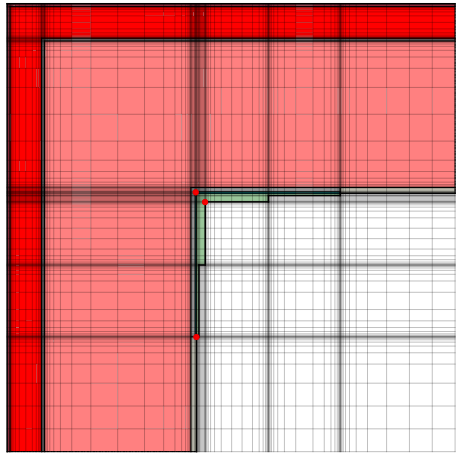


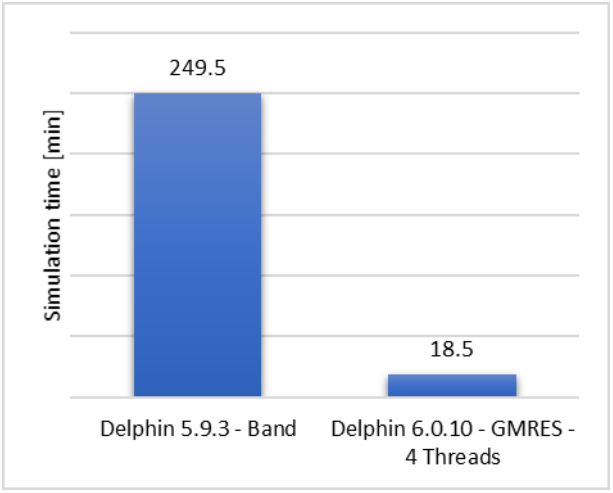
Bottom heat flux density [W/m2]

- Variants
  - Band solver vs. KLU (in DELPHIN 6)
  - Serial/parallel code (1 vs. 4 threads)
  - Parameters for steady-state result (transient accuracy does not matter)

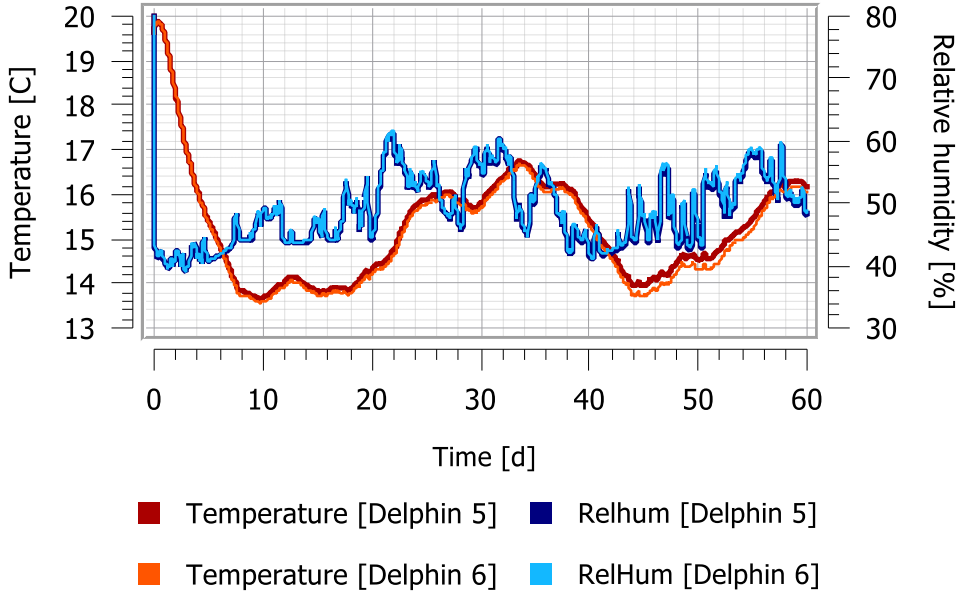
New Solvers / Performance Optimization

- Example 2 – Corner
  - Hygrothermal simulation
  - 10931 Elemente (21862 Unknowns)
- Variants
  - Serial banded solver in DELPHIN 5 (half-bandwidth 223)
  - Parallel GMRES solver in DELPHIN 6 (4 threads), ILU preconditioner, colored Jacobian (14 colors)



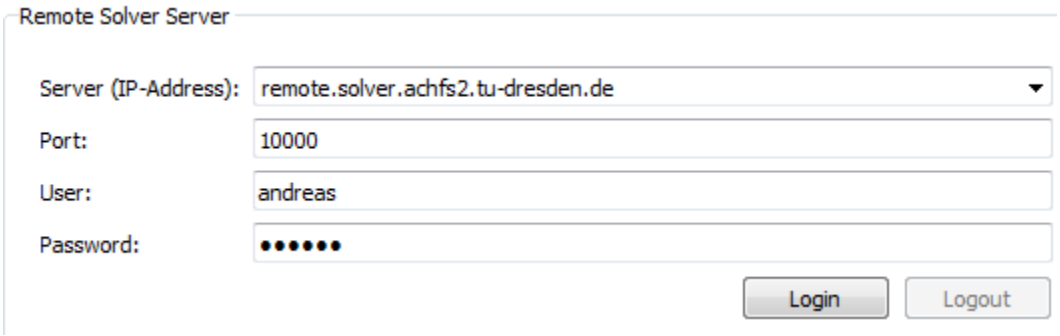


*Simulation time [min], first **60 days** of simulation*



Remote Solver Server

- Send projects to remote (powerful) server and collect results



  - Project input files are collected and exported into project package (*.d6pp)
  - Project package is sent to server, scheduled in either *fast* or *slow* queue (*fast* jobs are automatically aborted after 30 minutes if not yet finished)
  - Once completed, results are archived as 7zip file and retrieved from server
  - Results are extracted in projects directory just as if simulated locally → ready for PostProcessing

New License Model

- Only limited lifetime licenses
  - Much reduced license costs
  - Annual license duration with support and free updates/upgrades
  - Activation provided for work and private computer (linked to person/company)
  - Activation needs to be updated every year (license renewal)
- License/support renewal/extension:
  - Always for 1 year after last license expired, includes free updates/upgrades and support
  - Cannot skip renewal intervals, after approximately 4 years same price as new license
- Pricing:

Commercial license:	800 € initial + 600 €/a
Academic license:	600 €/a
Student/teaching license:	--- €/a

all prices excluding VAT

New features and optimizations in the hygrothermal transport model DELPHIN 6

Dr. Andreas Nicolai

Thank You! Questions?