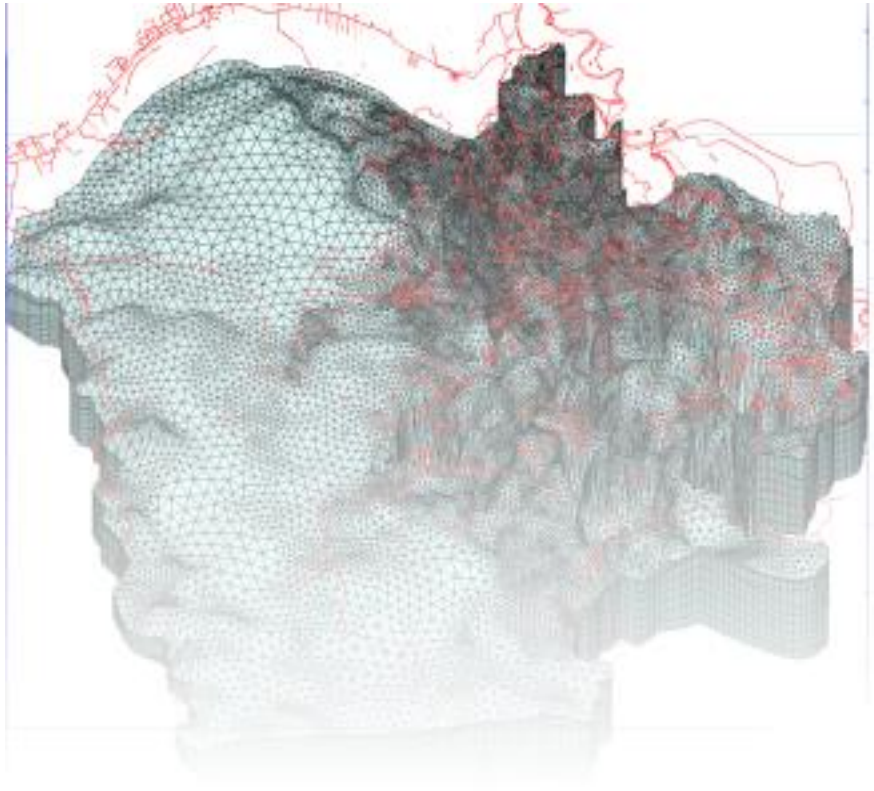
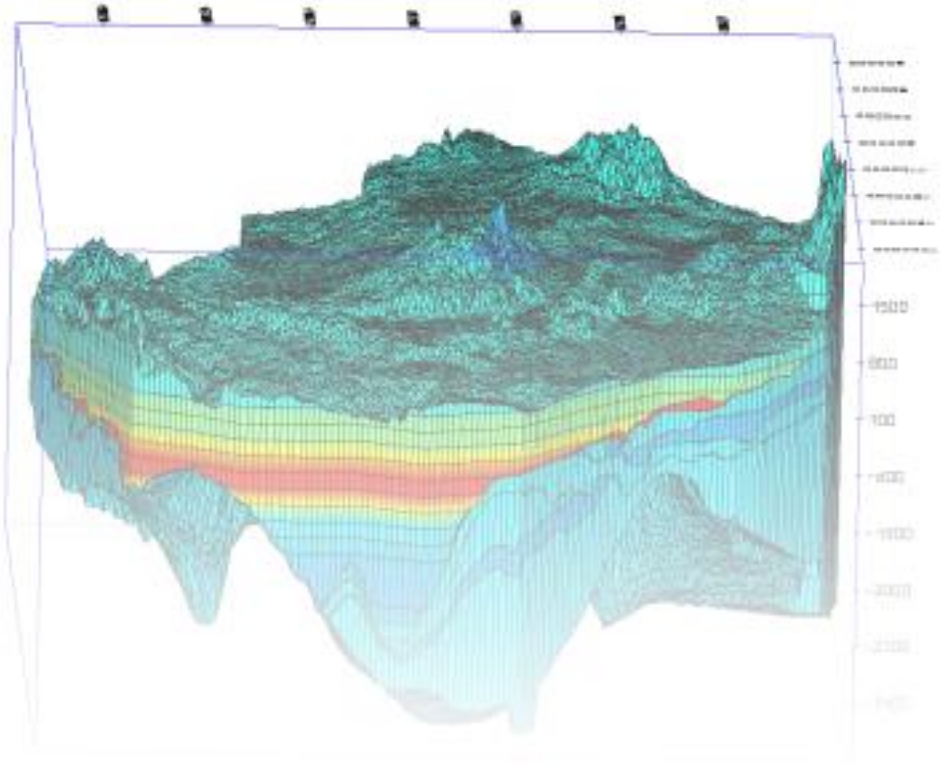




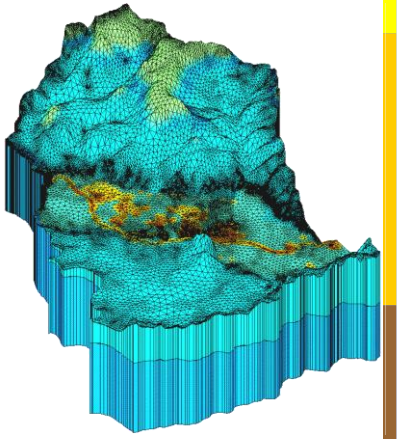
Wolfgang Gossel, Peter Wycisk:

Importance and effects of model couplings in hydrogeology

HydroPredict' 2010

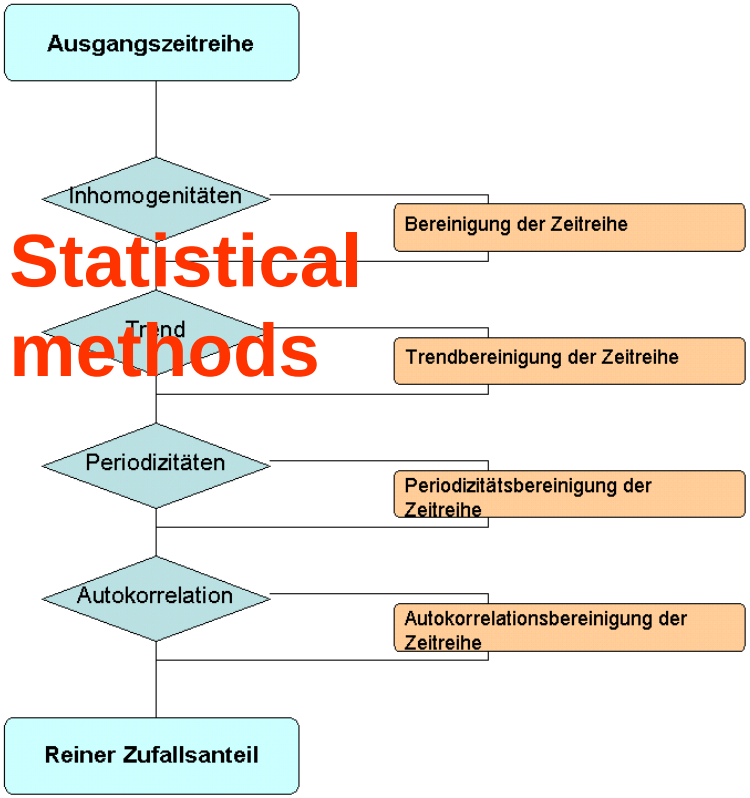
Two examples for solution of hydrogeological problems

- How were the groundwater flow and transport conditions influenced by open pit lignite mining in the region Untere Mulde/Fuhne?
- What was the impact of climate change during the last 140 000 years on the groundwater balances in the Nubian Aquifer System?

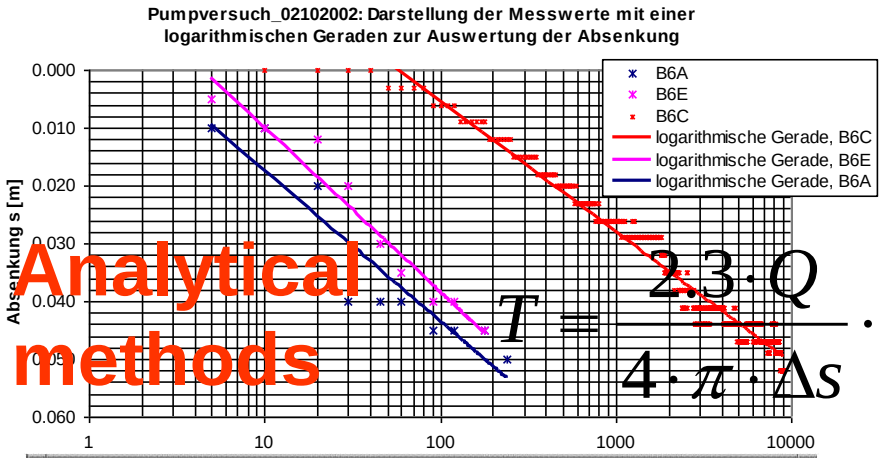


Problem and model

Problem solution with diverse methods:

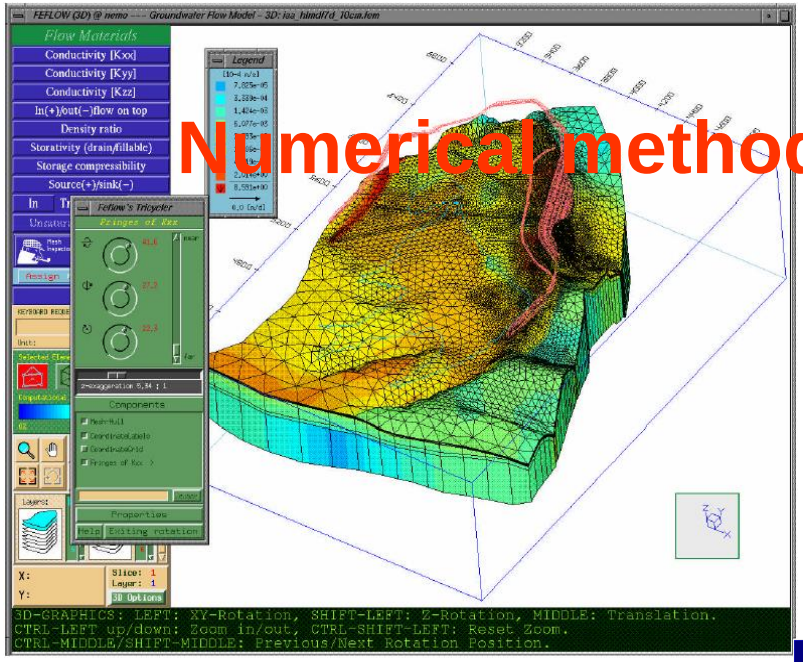


Statistical methods



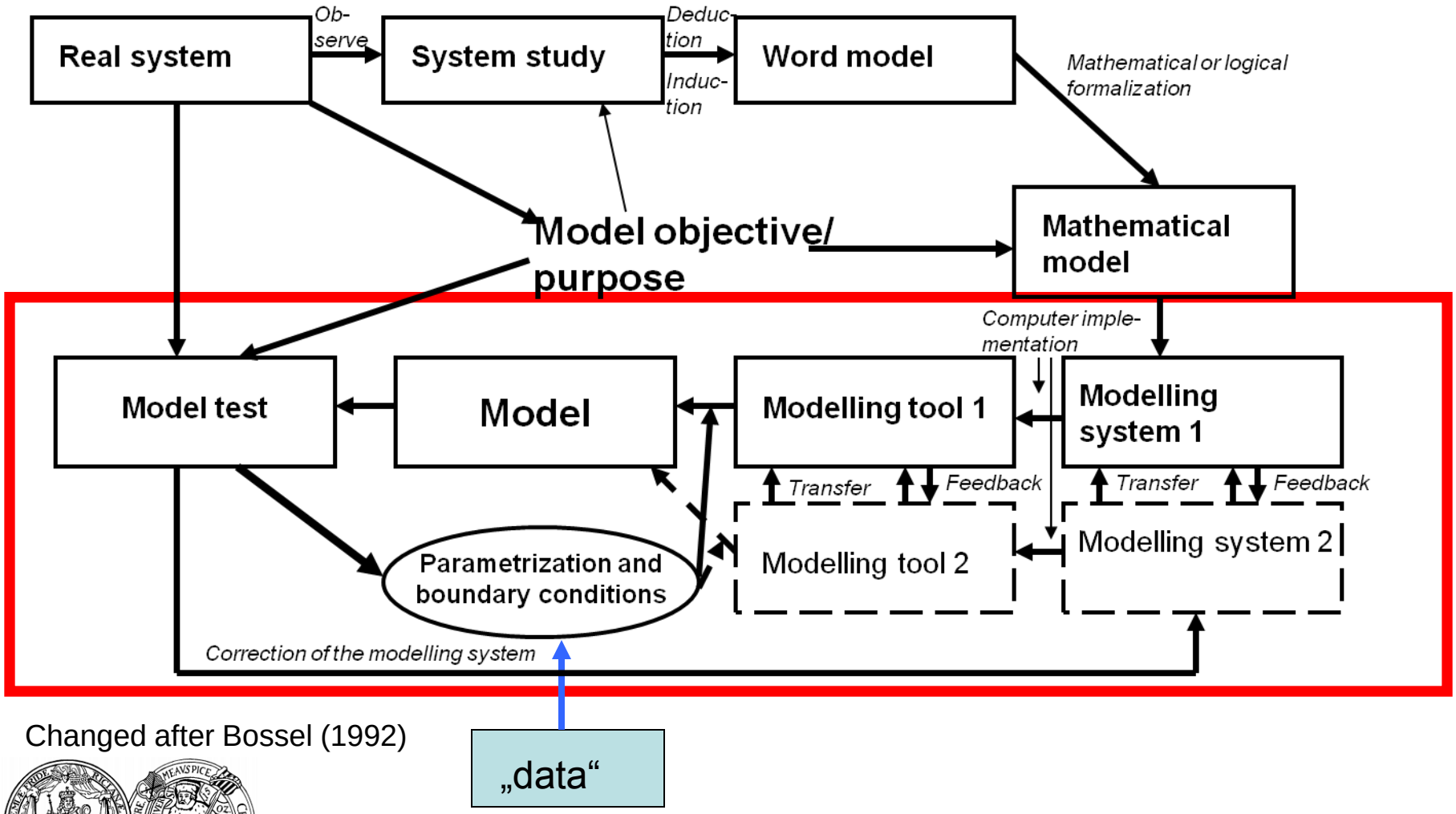
Analytical methods

$$T = \frac{2.3 \cdot Q}{4 \cdot \pi \cdot \Delta s} \cdot \lg \frac{t_2}{t_1}$$



Numerical methods

Modelling systems, -tools and models



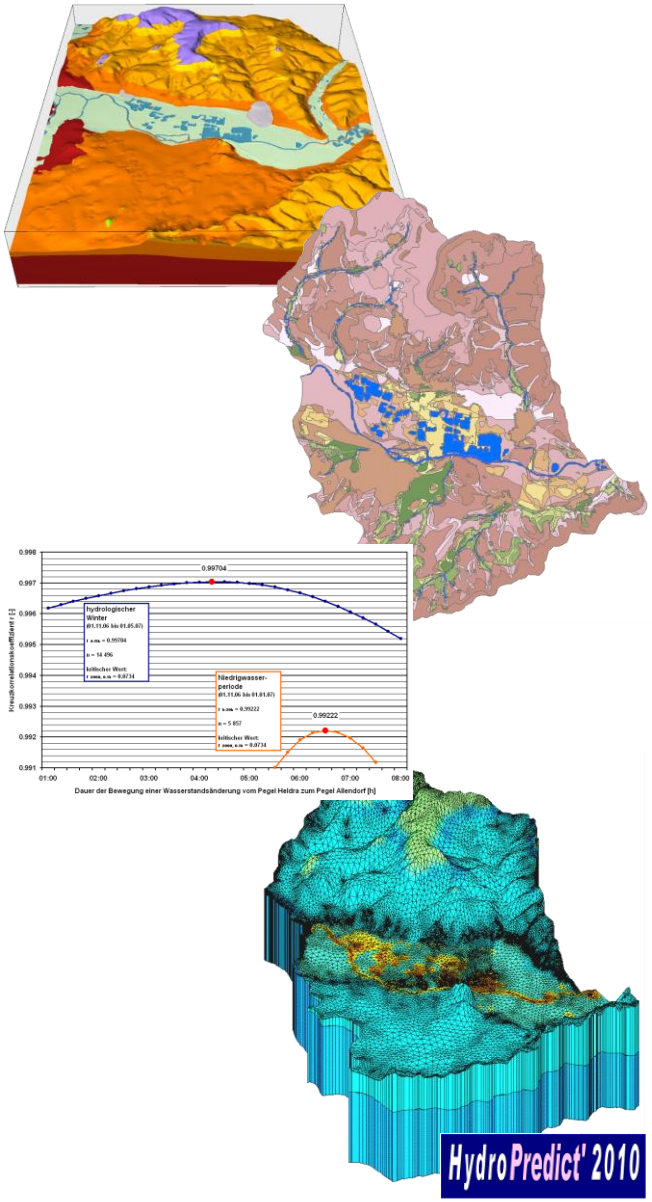
Changed after Bossel (1992)

Modelling systems, -tools and models

Modelling systems → Modelling tools

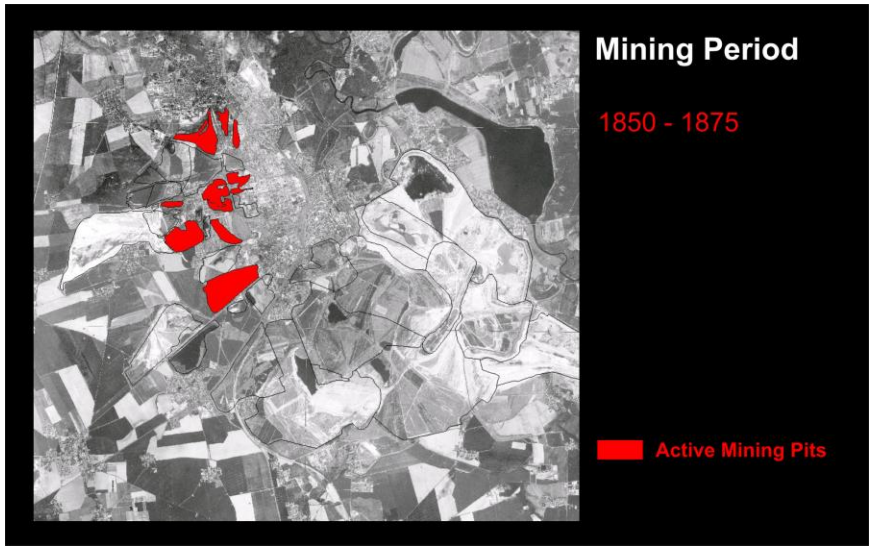
Computer-implementation

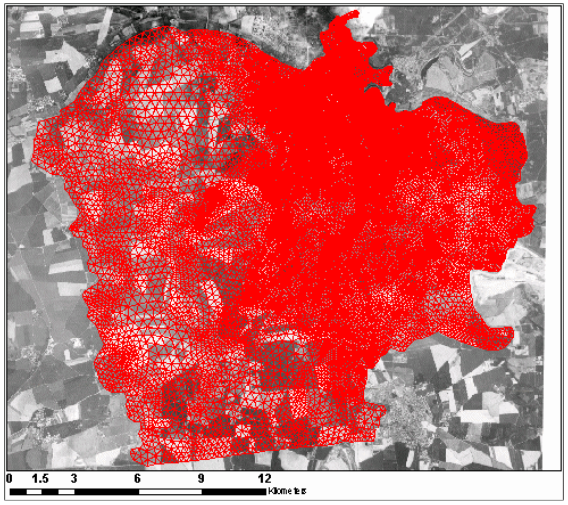
Modelling systems	Modelling tools
Geology (hardrocks, unconsolidated rocks): static, constructive	GSI3D
Groundwater recharge: dynamic, GIS-based	GIS, Excel
Surface water: statistic, time series	Excel, own programming
Groundwater: transient, numeric	Feflow



Suitability of modelling tools

Objective → **modelling tool**





- Dynamic, variability in time domain, long time frames

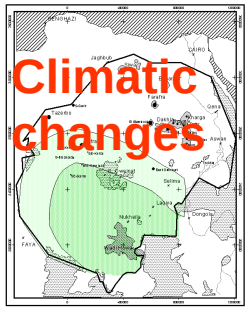
- 3D spatially variable resolution according to data availabilty and objectives

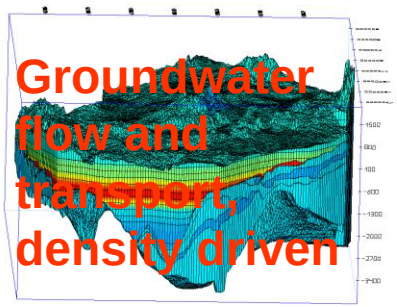
Complexity of models and necessity of couplings

Dependent on:

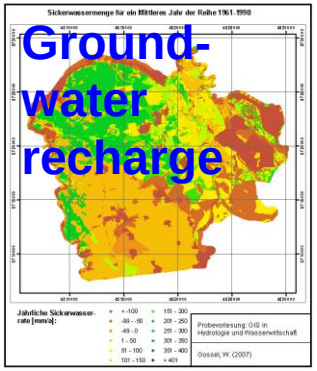
- Number of compartments
- Number of used modelling systems
- Nonlinearity of the functions in modelling systems and the connections of the modelling systems
- Number of parameters
- Heterogeinity of parameters and boundary conditions in time and space

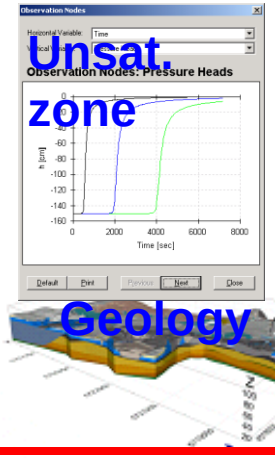
Nubian Aquifer System

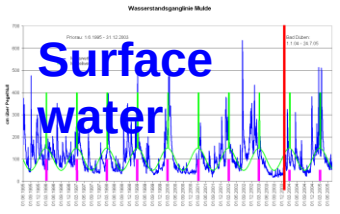


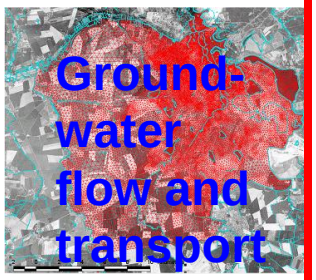


Untere Mulde/Fuhne









Pros and Cons of complex models

Pros:

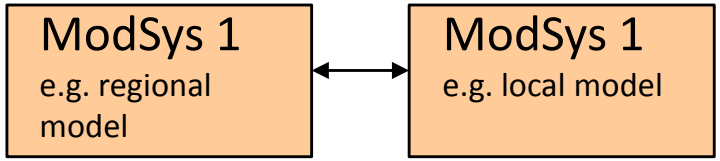
- Substitution of weakly defined parameters (or b.c.) by better systematical approach
- Range of objectives increases

Cons:

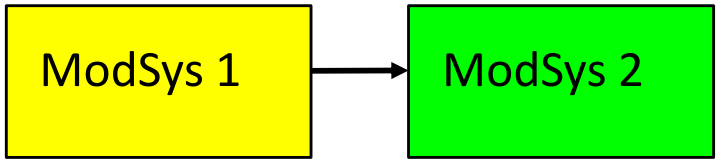
- High affinity to instabilities of the coupled modelling systems
- Sensitivity difficult to measure
- Scale dependency of parameters in different modelling systems
- Technical implementation of interfaces -> solvable

Kinds of coupling

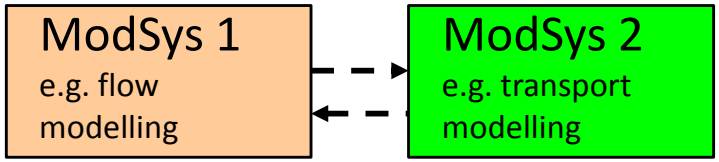
Horizontal coupling



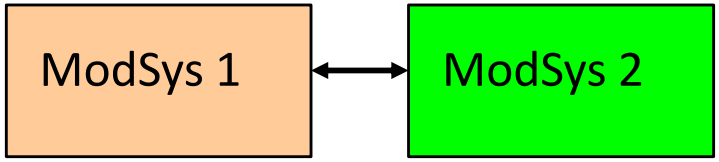
Serial coupling (non iterative)



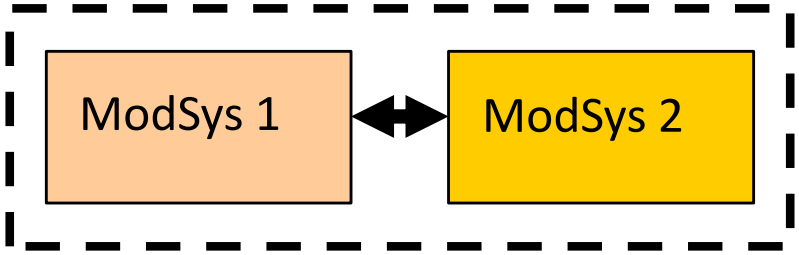
Periodically synchronized coupling



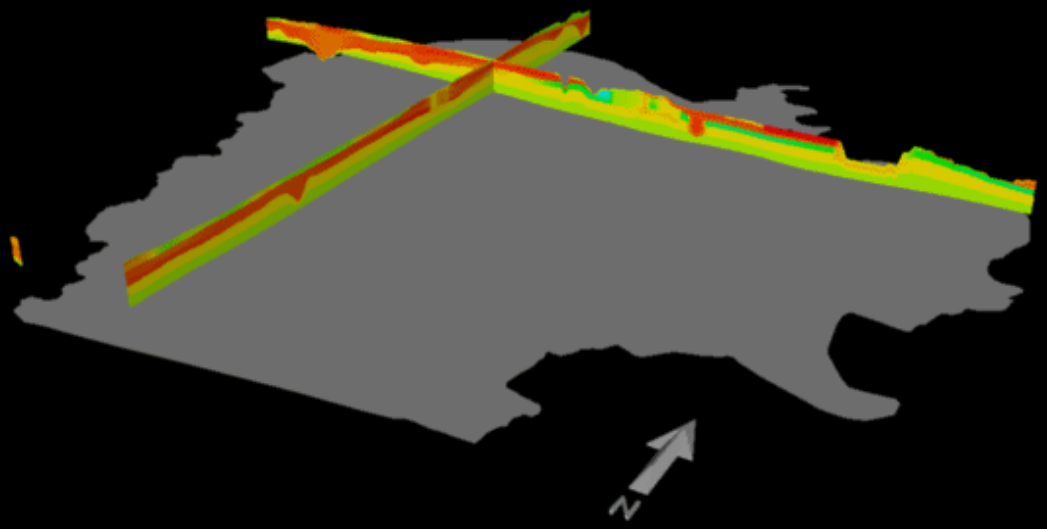
Parallel coupling (iterative)



Integrated coupling

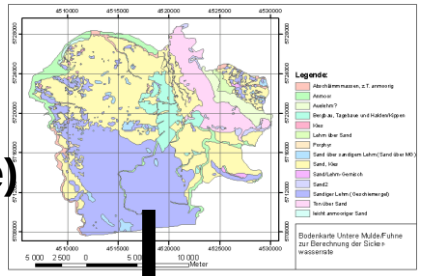


Coupling construktive geolog. mod. with hydrogeol. mod.

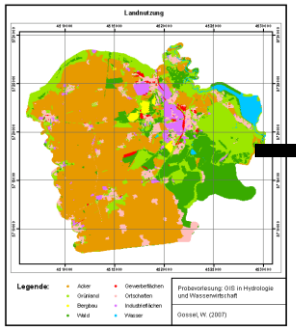


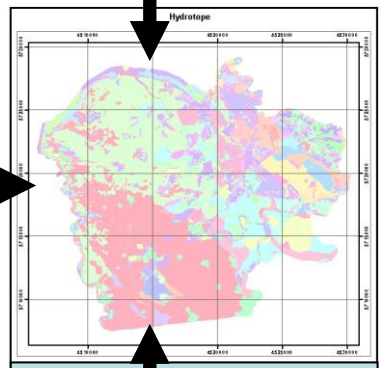
Sequential and serial coupling, periodically synchronized

Soil (substrate)

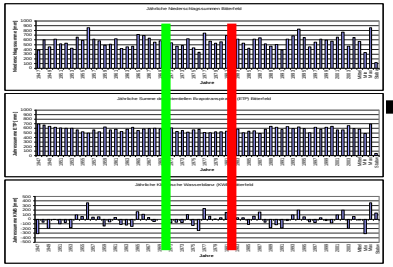


Land use

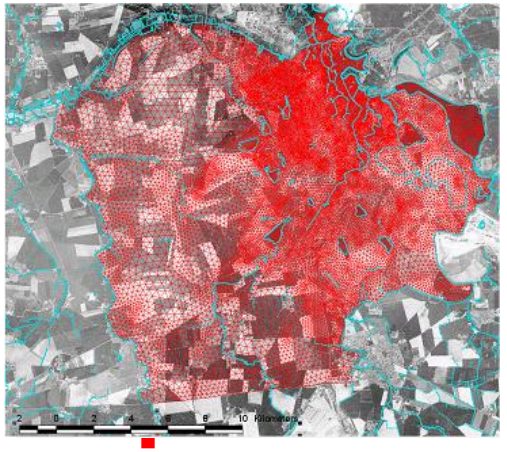


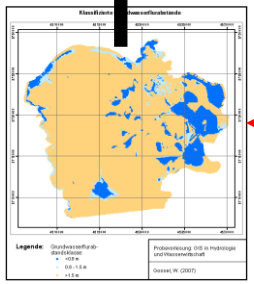


145 hydrotopes



Climatic data

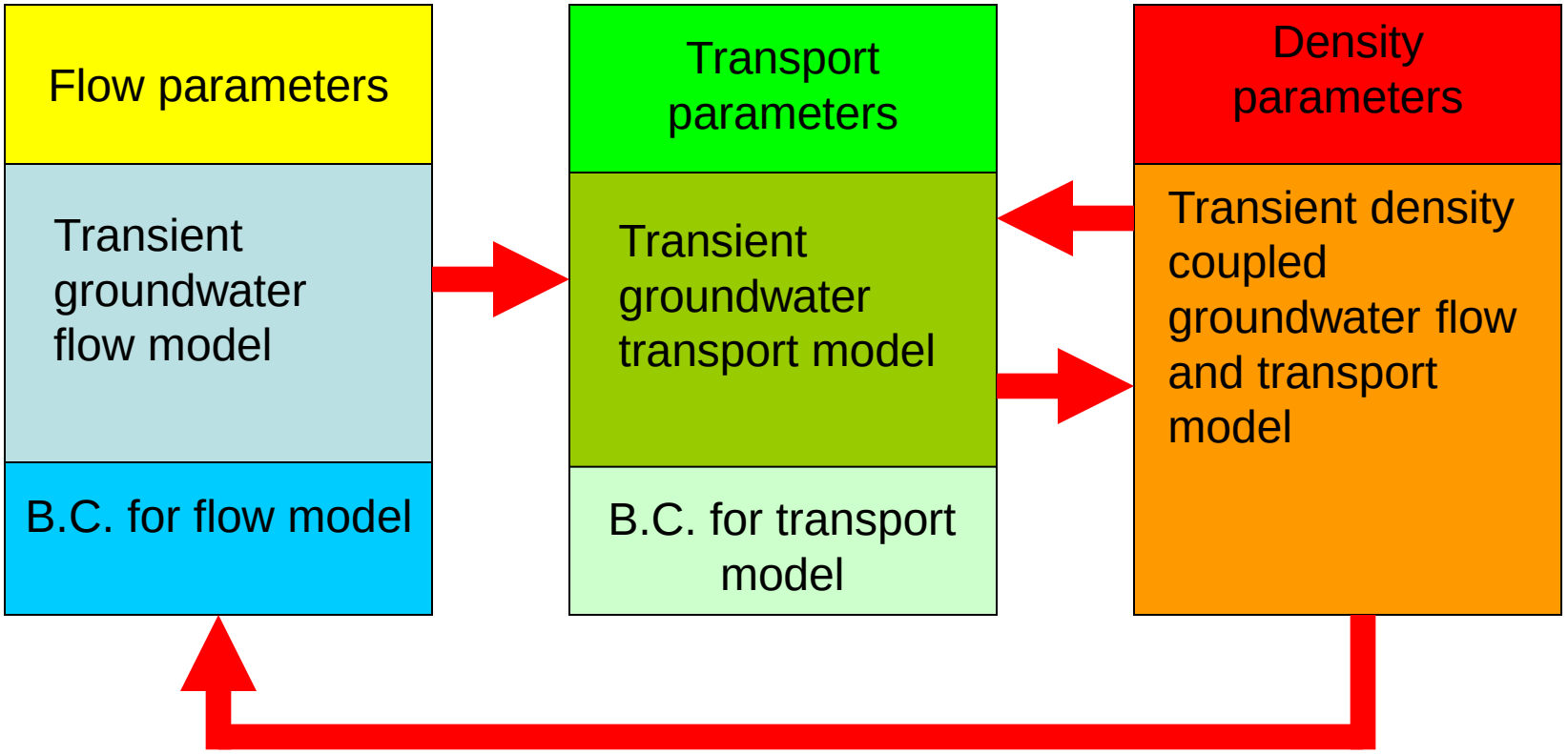




Depth to groundwater

Iterative, integrated coupling

Nubian Aquifer System: Completely density driven groundwater modelling



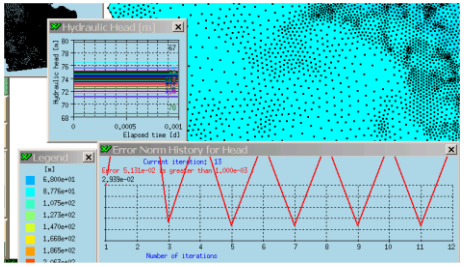
Interfaces of modelling systems

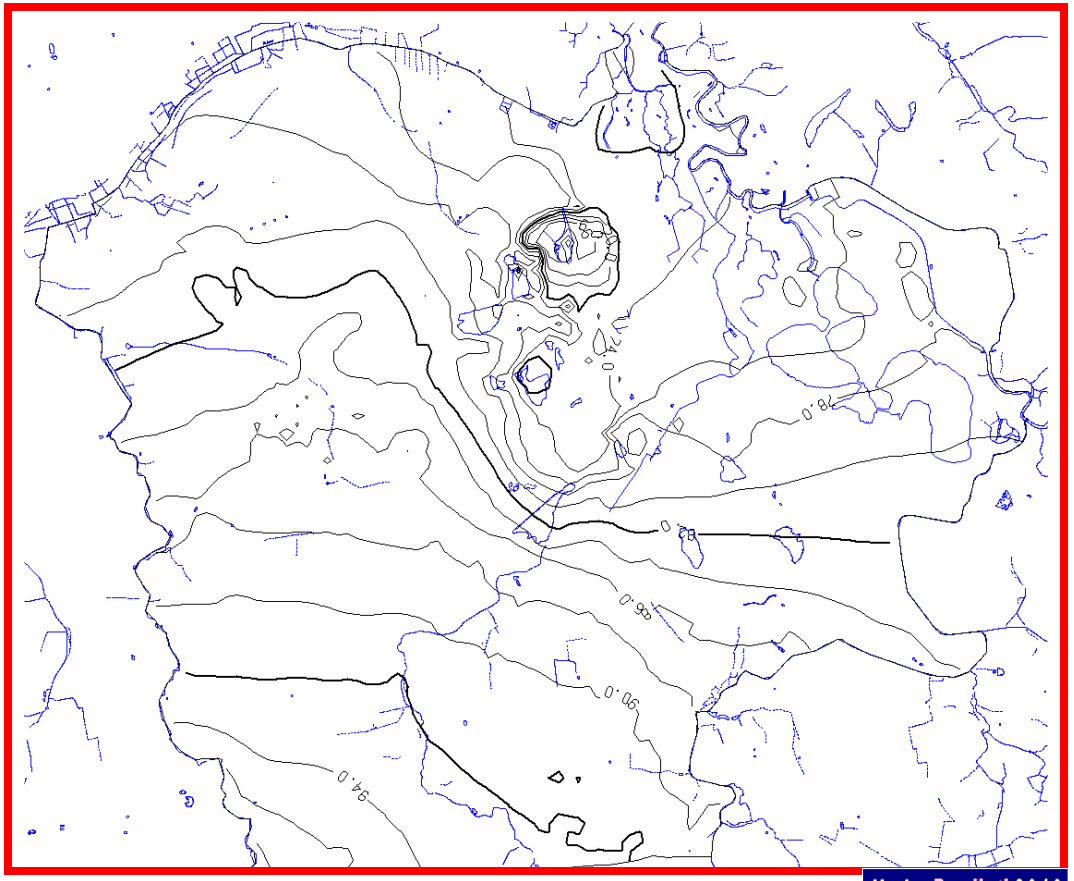
Technical problem: Coupling of modelling systems for surface water (SW) and groundwater (GW)

- Systematical approach: Total discharge of SW doesn‘t influence GW level but SW level
- Level and discharge of SW are dominated by catchment abroad of investigation area
- Realisation of the Transfer-/Leakage-coefficient in groundwater modelling system
- Level-discharge-dependency is implemented in SW modelling system

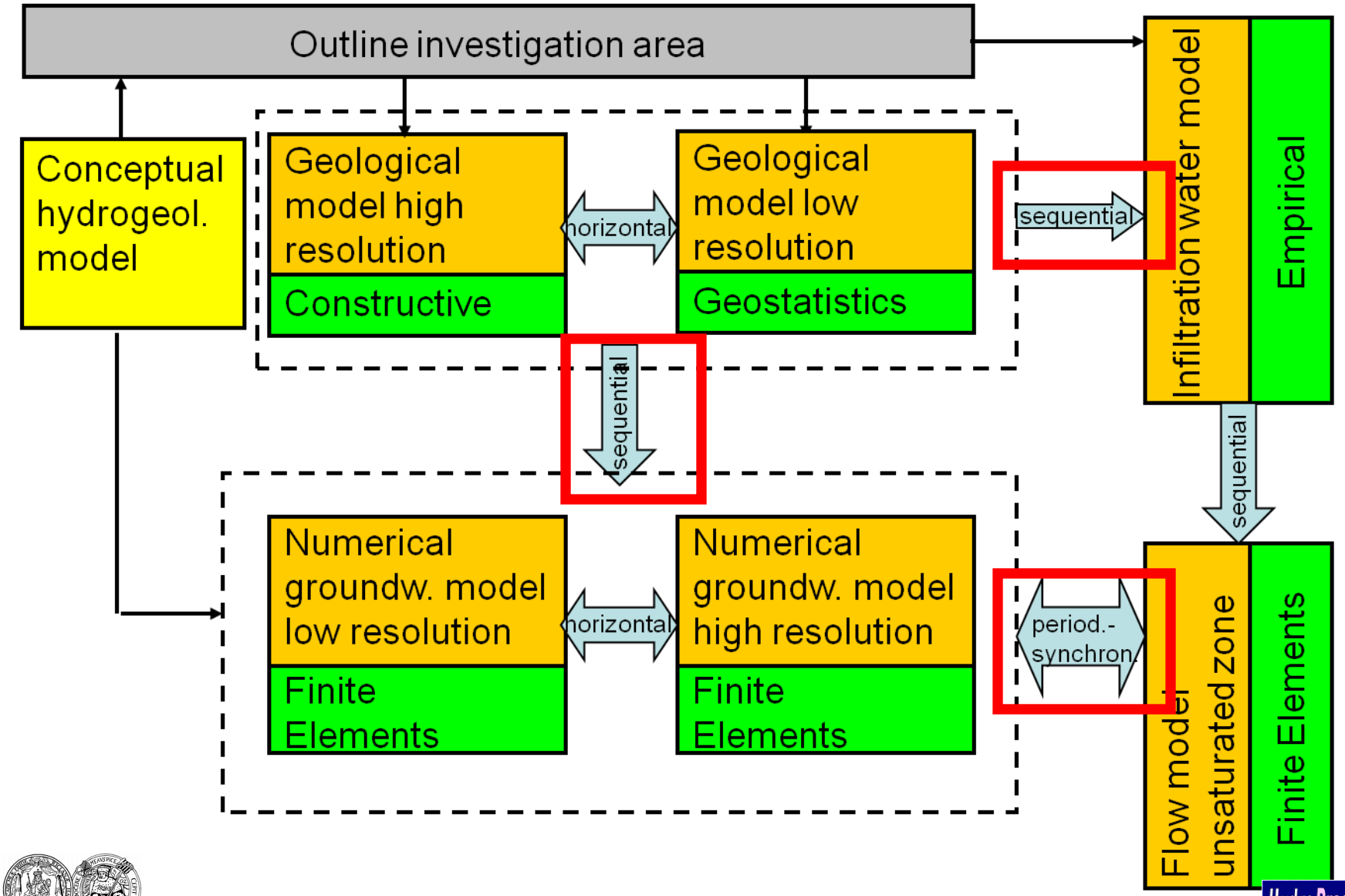
Stability

- **Convergence problems for numerical solutions**
- **Over-/Undershooting at interpolations or in dynamical models between time steps**
- **Oscillations in feedback between modelling systems**
- **Sometimes step back to „effective“ parameters necessary**





Complex example



Calibration of coupled models

Impact of kind of coupling on calibration of models:

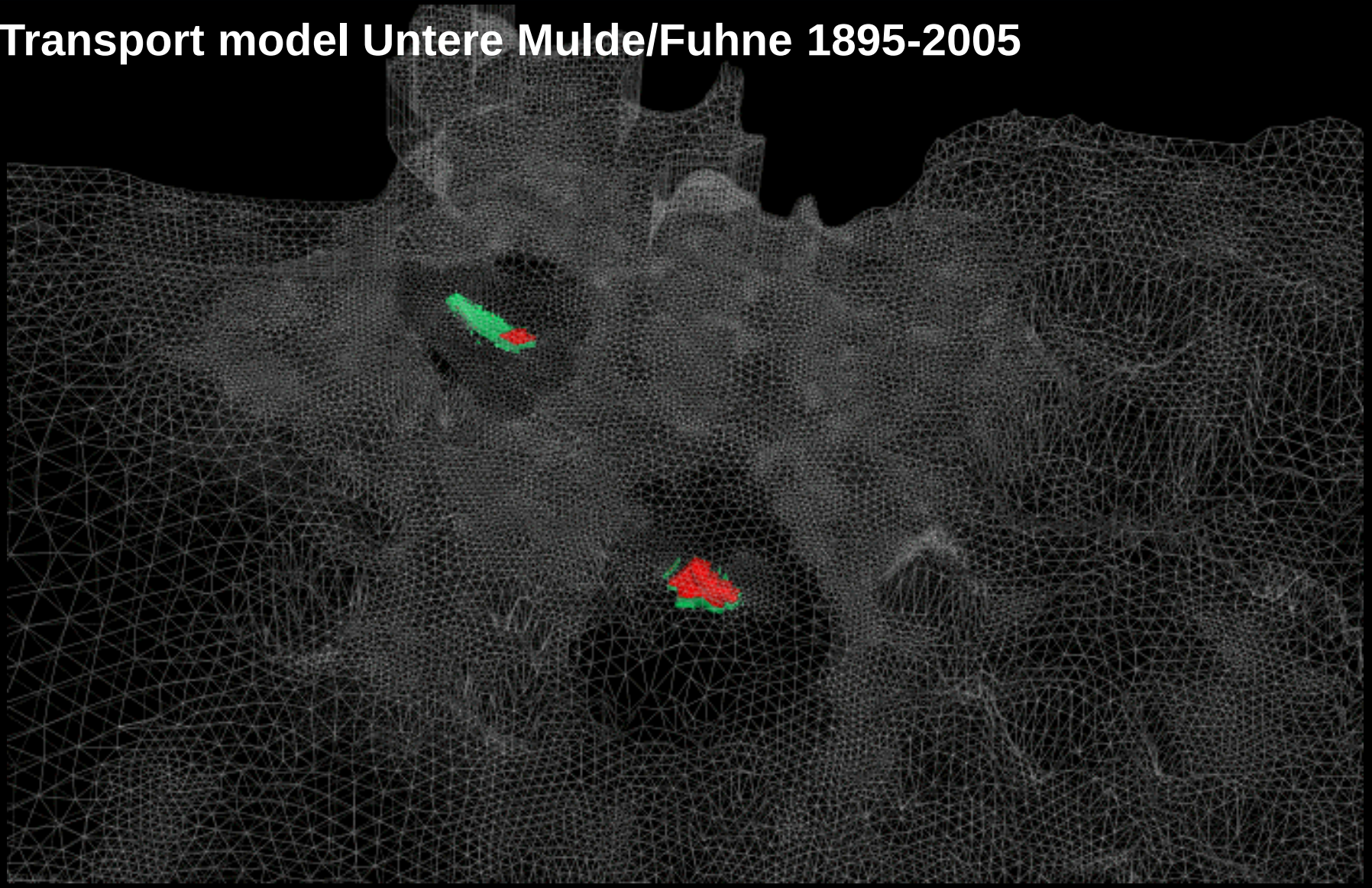
Kind of coupling	Work load	Stability	Transparency
Sequential	middle	high	high
Periodically synchronized	high	high	high
Iterative	low	low	low
Integrated	middle	low	low

Dilemma of the geological model:

- Can not be calibrated on itself but only proven (geometrical criteria).
- Importance: „Database“ for unsaturated and saturated zone modelling
- Solution: Indecies for the derived model and calibration of ranges of values

Results of coupled models

Transport model Untere Mulde/Fuhne 1895-2005



The future ....

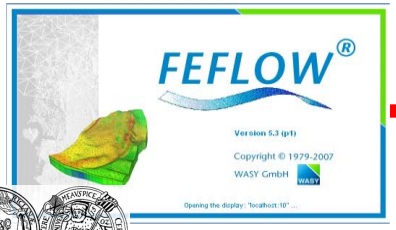
Trends of development of model couplings

- Horizontal coupling needless or integrated
- Vertical couplings applicable via integrated solutions, unstable
- Defined programming interfaces of the tools are good solution, up to now not user friendly
- Data base will dominate the applicability of model couplings

- OpenSource
- Open standards
- Documented interfaces

Additional tools, e.g.

Modpath, MT3D, RT3D, HUF, UZF, Pre- and Postprocessors



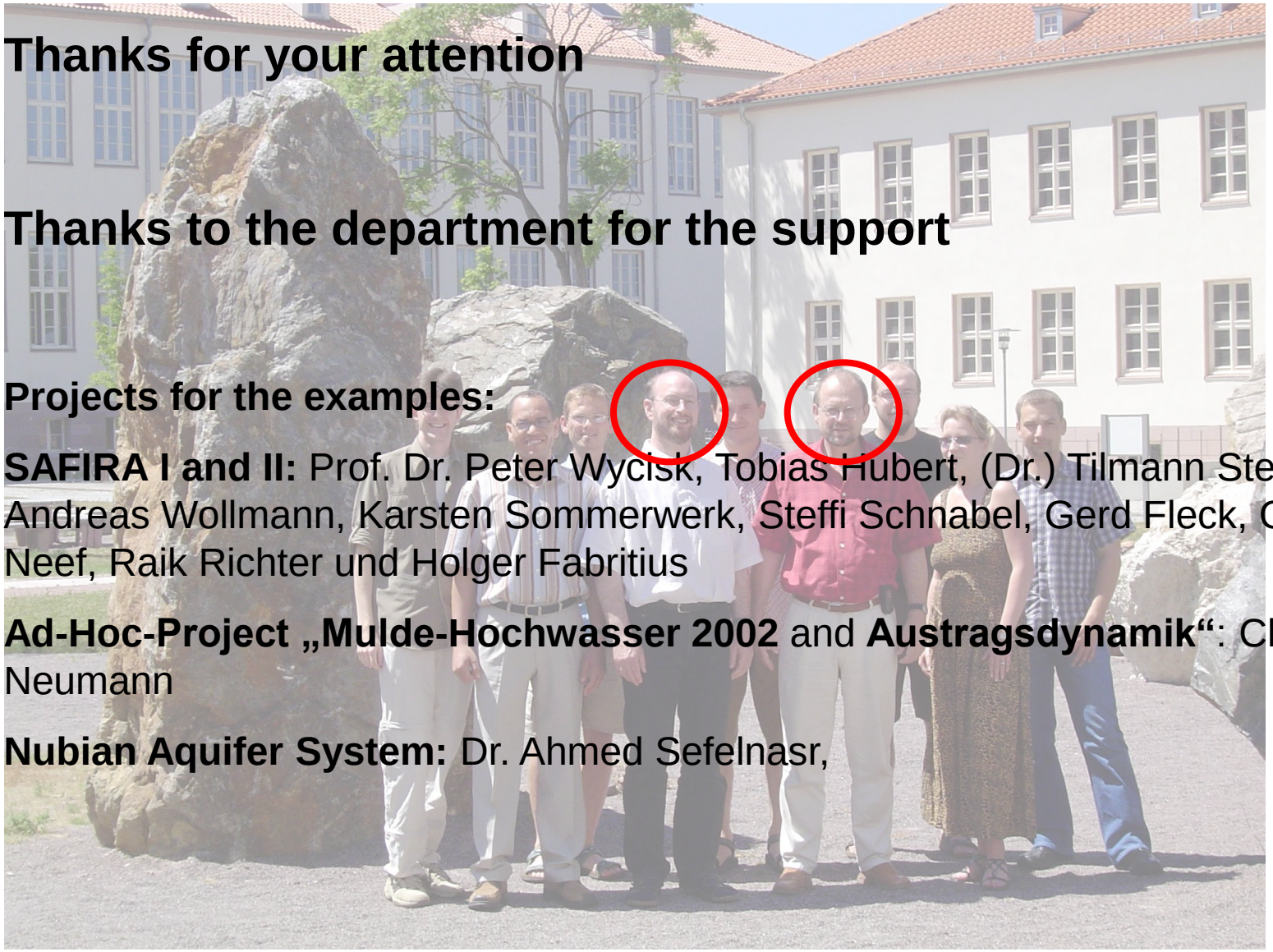
- Closed Source
- Open and proprietary stand.
- Documented interfaces

Integration of transport, density, heat, unsat. zone, discrete features, development of self-made modules

Summary

- Application of complex models increases
- Complex models depend often on couplings of modelling systems
- Different kinds of coupling have consequences for behaviour, calibration, results and prognoses of models
- Systematical application after detailed analyses necessary
- Trend in hydrogeology towards opening of central parts of modelling tools via defined interfaces and standards

Thanks



- **Thanks for your attention**
- **Thanks to the department for the support**
- **Projects for the examples:**

  SAFIRA I and II: Prof. Dr. Peter Wycisk, Tobias Hubert, (Dr.) Tilmann Steinmetz, Andreas Wollmann, Karsten Sommerwerk, Steffi Schnabel, Gerd Fleck, Oliver Neef, Raik Richter und Holger Fabritius

  Ad-Hoc-Project „Mulde-Hochwasser 2002 and **Austragsdynamik“**: Christian Neumann

  Nubian Aquifer System: Dr. Ahmed Sefelnasr,