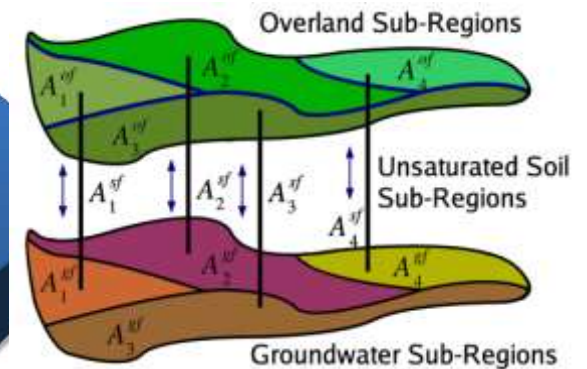
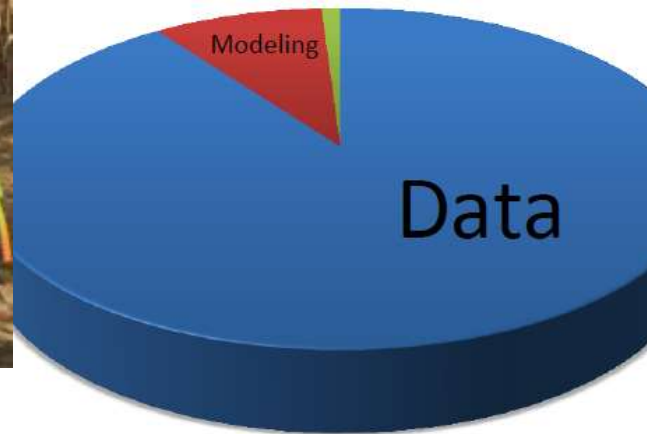
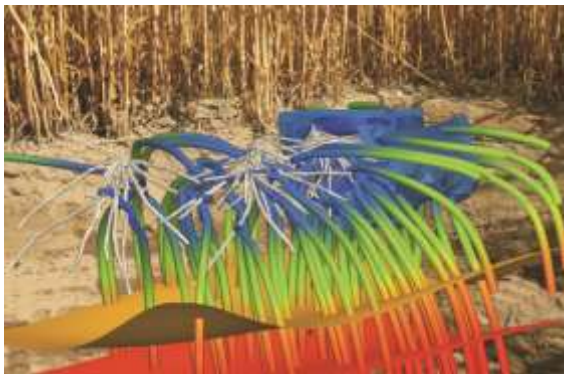




# TERENO Workshop: Data and Modeling Platform Benchmarking Initiatives Update of UFZ Activities



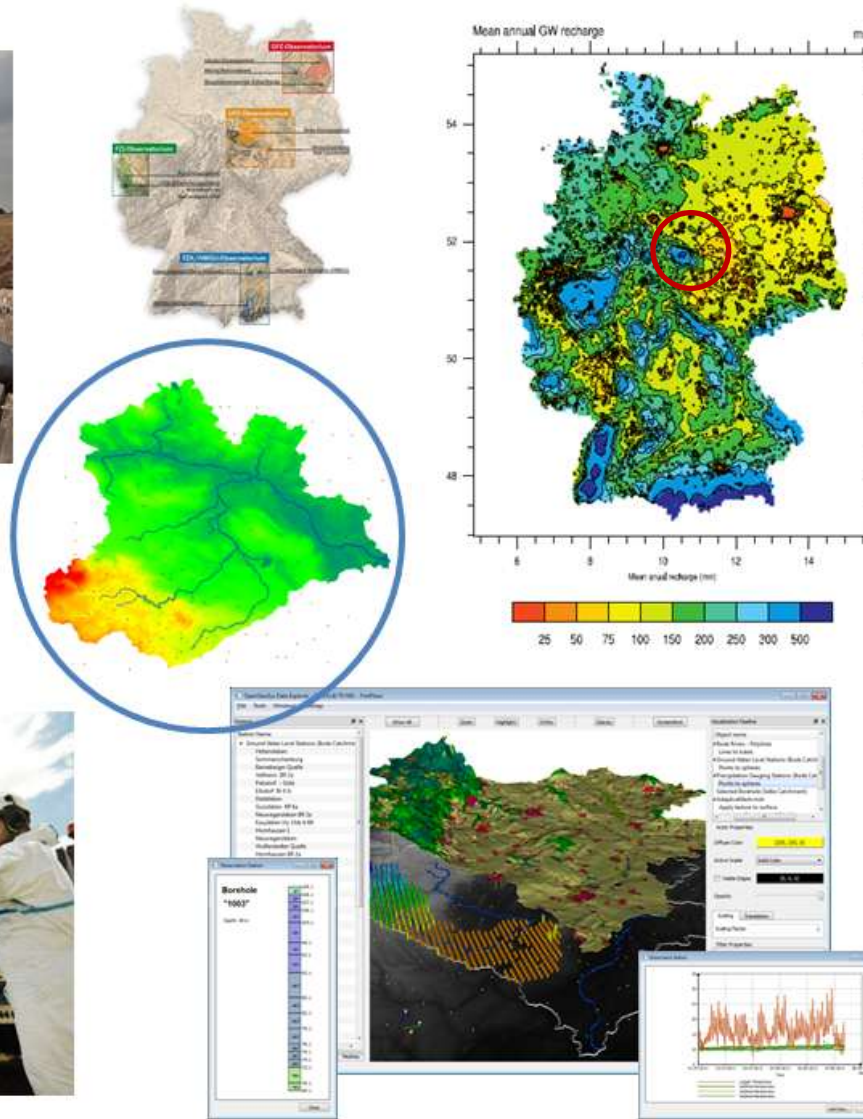
# Cross-Sectional-Competence B: Data and Modeling Platform

## Topic 6 Concept



Cluster 2: TERENO-Bode, e.g. Lysimeter network SoilCan

Cluster 1: Measurement and exploration methods

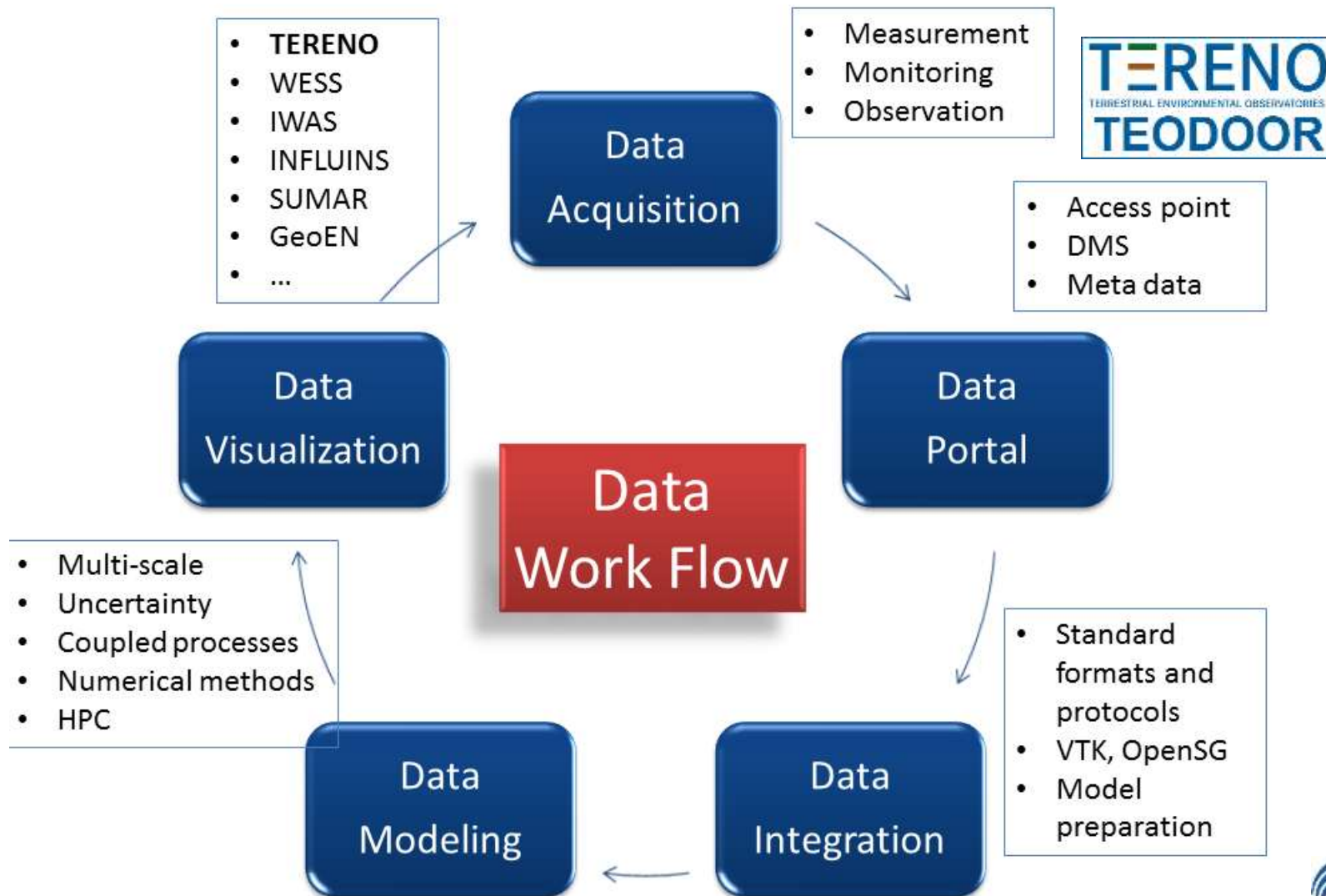


Cluster 3: Exploratory modeling

Cluster 4: Data integration and visualization

# Cross-Sectional-Competence B: Data and Modeling Platform

## Developing Continuous Work Flows



# Benchmarking

# Cross-Sectional-Competence B: Data and Modeling Platform Benchmarking Initiatives – Status-quo



## Process-(PDE)-based

### Complexity

- HYDROCOIN
- DECOVALEX V
- **GEOBENCH**
- CO2BENCH
- HM-INTERCOMP
- ...



## Conceptual models

- DMIP
- MOPEX
- PILPS 1&2
- DMIP I&II (NOAA)
- BALTEX I&II
- GSWP 1&2
- LDAS (NASA)
- ...
- **Scale**



hydrobench - Mozilla Firefox

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ufz.de https://svn.ufz.de/hydrobench

hydrobench

Do you want Firefox to remember the password for "okolditz" on ufz.de?

# Discussion Forum

logged in as Olaf Kolditz

Wiki Timeline Roadmap Browse Source

## Welcome to the HYDRO BENCH PLATFORM

### A community initiative for hydrological benchmarking and model

Hydrological models that incorporate surface-subsurface water interactions use different approaches. Accurate and productive code comparison as well as joint model development of benchmark tests. This benchmark set can be broadly divided into academic and real-world cases. Academic cases are often based on laboratory and field experiments. Furthermore, a number of synthetic cases evaluate individual processes and model coupling phenomena under idealized conditions. Real-world cases evaluate large-scale catchments which are linked to their climate zone. We believe that the platform will support the ongoing model development community effort.

A Trac System allows tracking and handling of software issues, enhancements and code development. Trac|Wiki-System as a platform for a web-based management of hydrologic benchmark development, code comparison, data exchange, documentation and discussion. This page is a link at the bottom of the page. [WikiFormatting](#) will give you a detailed description.

[Academic test cases](#)

[Real-world test cases](#)

## Software codes

This initiative currently comprises the following hydrological software codes:

- [HydroGeoSphere \(HGS\)](#)
- [OpenGeoSys \(OGS\), OGS/SWMM, OGS/mHM](#)
- [ParFlow](#)

## Workshops

In context of this initiative the following international workshops were held:

- [Boulder, Colorado](#)
- [Leipzig, Germany](#)

TestsAcademic - hydrobench · Mozilla Firefox

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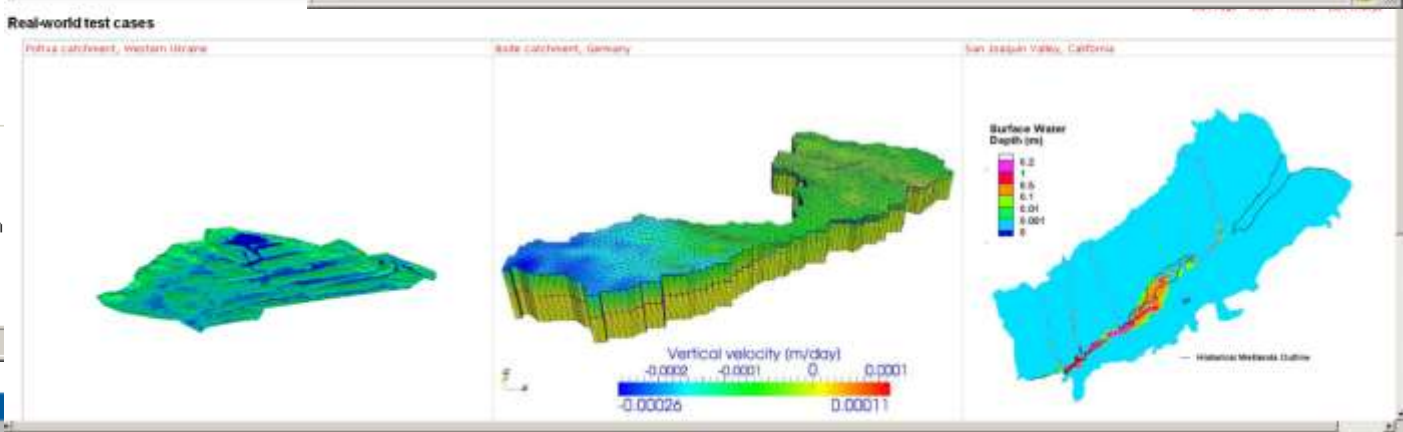
Start Page Index History Last Change

## Academic test cases for hydrological coupling

Soil / aquifer coupling: [Vauclin et al. \(1979\)](#)

Horton overland flow: [Smith & Woolhiser \(1971\)](#)

Borden site: [Abdul & Gilham \(1985\)](#)



# Cross-Sectional-Competence B: Data and Modeling Platform Towards Real-World Benchmarks ...



- TEODOOR: Entry point to observatories, data and models
- Development of real-world benchmarks based on the TERENO observatories

- Technical issues: data explorer

## Scientific Questions (Bode):

- How can we quantify fluxes through the hyporeic zone? (e.g. thermal signatures)
- How can river discharge described with spatially distributed hydrological models?
- How important is hydraulic non-equilibrium to induce preferential flow in different soils ?
- How we can quantify instream turnover and structure-functions in aquatic ecosystems?

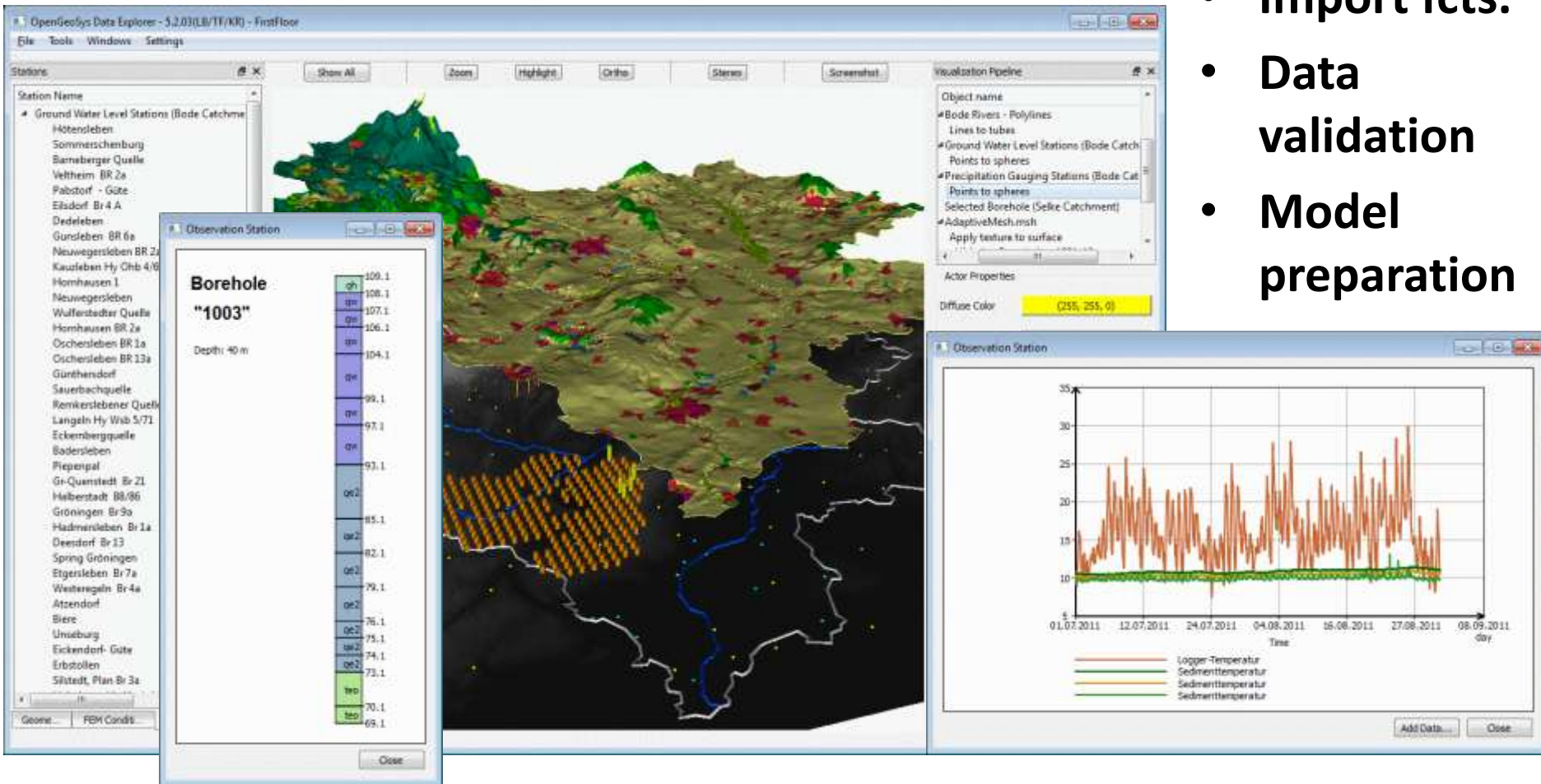


# Cross-Sectional-Competence B: Data and Modeling Platform

## Data Integration for Benchmark Set-Up



- Import fcts.
- Data validation
- Model preparation



Rink et al. (2011): Visual data integration. *EES*, 65(5)



# UFZ News

# Cross-Sectional-Competence B: Data and Modeling Platform Modeling Platform



WRR Editors' Choice Award 2011

Luis Samaniego, Rohini Kumar, and Sabine Attinger,  
“Multiscale parameter regionalization of a grid-based  
hydrologic model at the mesoscale”  
([doi:10.1029/2008WR007327](https://doi.org/10.1029/2008WR007327)).



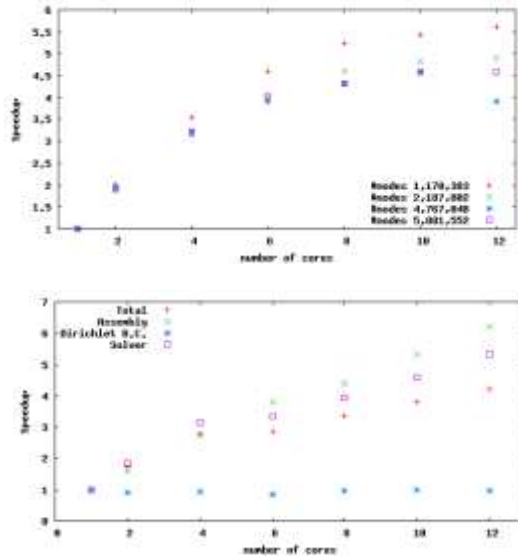
Integrated Water  
Resources Management  
under different  
hydrological, climatic  
and socio-economic  
conditions (22)



# Cross-Sectional-Competence B: Data and Modeling Platform

## High Performance Computing: *HSL „Terrestrial Systems“*

**OpenMP**  
(shared)

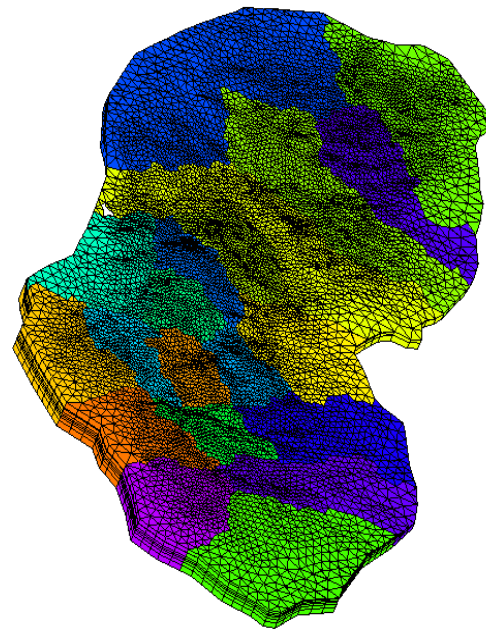


Small machines  
12 CPUs

Kalbacher et al. (2011) *VZI*

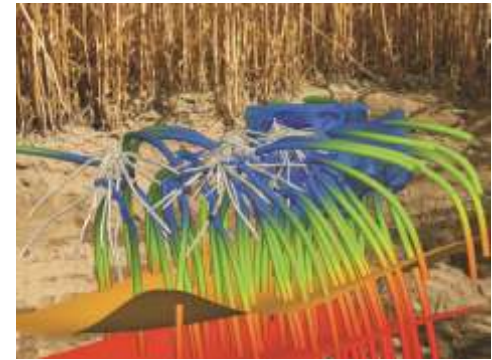
Fischer, Watanabe et al. (2012) *HIC*

**MPI**  
(distributed)



Domain  
Decomposition  
10<sup>3</sup> CPUs

**OpenMP#MPI**  
(hybrid)



- Roots: OpenMP
- Soil: MPI



# Cross-Sectional-Competence B: Data and Modeling Platform

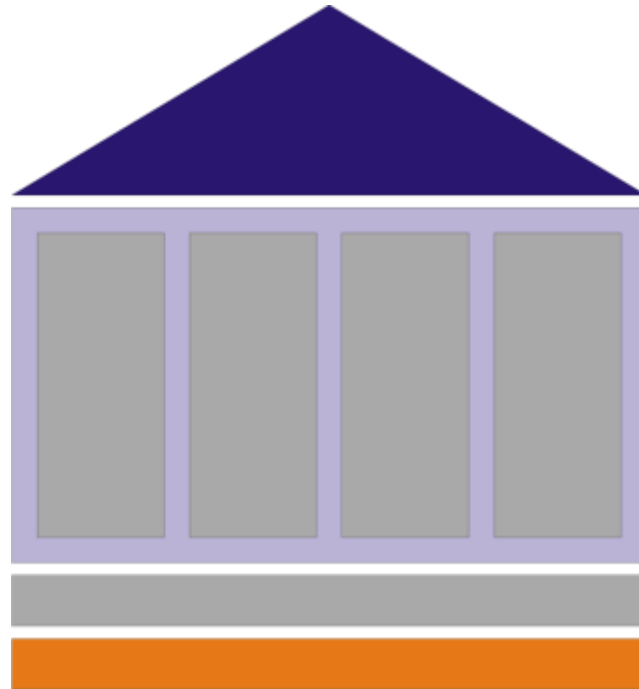
## Data Visualization: *TESSIN VISLab*



**Geological model of Schleswig-Holstein, mobile *VISLab* facility available**

# Cross-Sectional-Competence B: Data and Modeling Platform

## Fine

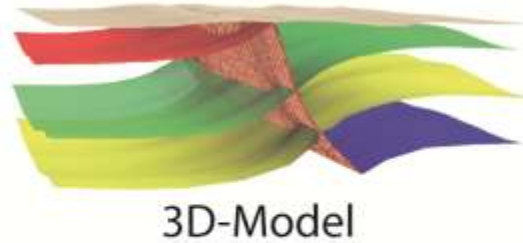


# Cross-Sectional-Competence B: Data and Modeling Platform

## Work Flow Example

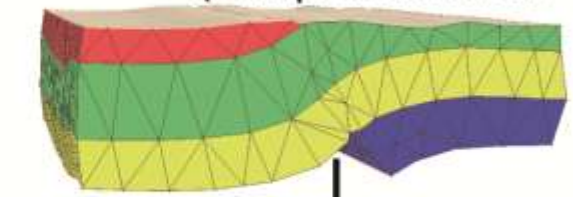


Geological Interpretation

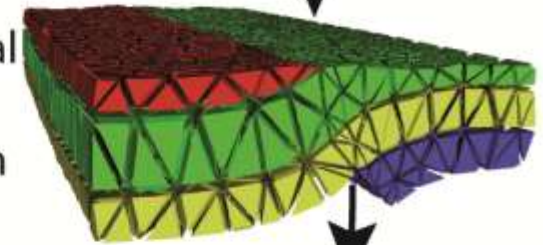


3D-Model

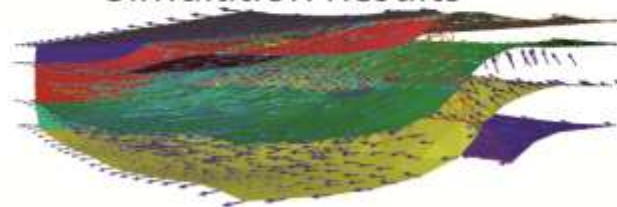
3D Boundary Representation



Tetrahedral Grid for Simulation



Visualization of the Simulation Results



Numerical Simulation

Figure: Zehner, B., 2011



Visualization in a Virtual Environment

## Physics-based

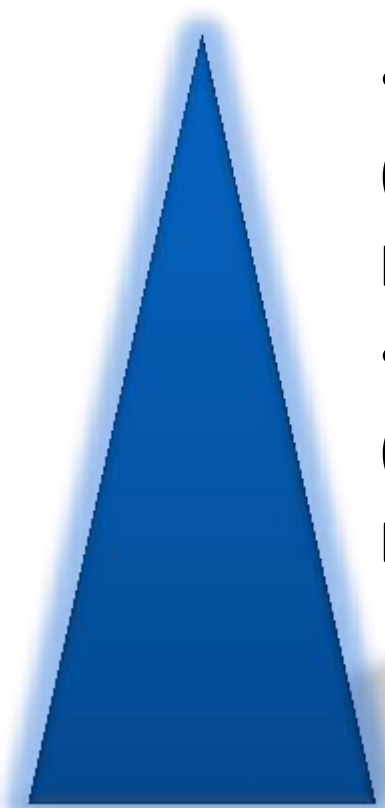
Complexity

- HYDROCOIN
- DECOVALEX
- HM-INTERCOMP
- GEOBENCH
- CO2BENCH



## Conceptual models

- DMIP  
(Distributed Model Intercomparison Proj)
- MOPEX  
(Model Parameter Estimation Experiment)



Scale

# Cross-Sectional-Competences & Clusters Poster Session (more details)



**Cross-Sectional-Competences „Observatories and Modeling“**

## Concepts and Work Flows

**Concepts**

One of the main tasks that is focused on the design, development and implementation of Environmental Observatories with the aim to observe and model the impact of anthropogenic and climate-induced changes in terrestrial ecosystems. A key problem in environmental monitoring is to design the pre-formation measurement infrastructure (sensors, data and systems). Special attention must be given to data availability, accuracy, modeling concepts and simulation tools used to be developed on the other hand which is an important contribution of the cross-sectional competences to Topic 3. Modern computer science concepts have been used to set up the TERENO modeling platform including management and integration of data for conceptual and process based modeling using high-performance computing and scientific visualization.

**Work Flows**

Basically the „Working Cycle“ consists of steps starting with data acquisition. Modern monitoring and observation provide data in increasing quality and quantity. Adequately data processing concepts in order to guarantee full, without lossy access throughout the TERENO will provide open data access scientific community for research. The heterogeneity of environmental data requires data integration tools based about formats (e.g. NetCDF, SHARABLE) integration concept allows the direct numerical models in order to generate whole picture in environmental. Description of coupled processes and scales include a large number of environmental observations because in the address central aspects of the “Working Cycle” during analysis.

**HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH**

**TOPIC 6: Cross-Sectional-Competences „Modeling Concepts and Tools for Topic 3“**

## TERENO Modeling Platform

**Introduction**

• Evaluation of water fluxes for all hydrological compartments in major river basins in Germany.

• Soil erosion, runoff and groundwater recharge.

• New concepts for monitoring hydrological processes and biological changes in the near basin scale.

**Actual tasks include the following ones:**

- Analysis of available data
- Reduction of uncertainty in a framework of model-based forecasts that quantify a range of risk and spatial scale-based processes.
- Coupling of these

**TERENO Data Integration**

• Surface and Groundwater flow of Shweinfurt

• Groundwater recharge patterns and the associated groundwater transport

• Study Site: Sals

• Hydrology and biogeochemical dynamics in high mountain catchment

• Snow-Covered mountain under various climate and morphology

• Snow-avalanche systems and their contribution to alteration of lateral subsidence

• Lake Basin (Pond)

**HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH**

**TOPIC 6: Cross-Sectional Competences „Modeling Concepts and Tools for Topic 3“**

## TERENO Data Integration

**The OpenGeoGIS Data Explorer**

We developed a framework for the visualization and validation of heterogeneous geoscientific data sets in 3D. It allows to detect inconsistencies between data sets, prepare models for the simulation of hydrologic processes and visualise these models as well as simulation results.

**Data Validation**    **Model Preparation**    **Presentation**

**Application to Other Projects:**

The workflows and functionality offered by OGS are not limited to a specific model region and have already been employed in a number of research projects, e.g.

- INFILINS (Germany)
- IWAS (Brazil & Middle East)
- SUMAR (Iran/Palestine)
- WCSS (Germany)

**HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH - UFZ**

- CSCs
- Clusters
- Linking CSC#Cluster



# Cross-Sectional-Competence B: Data and Modeling Platform

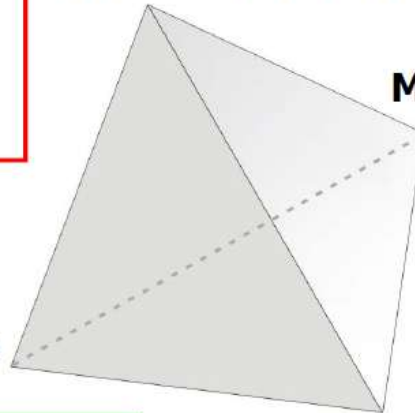
## Coupling Concepts



### Heat transport

$$c\rho \frac{\partial T}{\partial t} = -\nabla(-K\nabla T + \sum_{\beta} h_{\beta} \vec{F}_{\beta}) + q$$

### Thermodynamics



### Mechanics

### Deformation

$$\nabla \vec{\sigma} - \rho \vec{g} = 0$$

$$\nabla \cdot (\sigma - (S^l p^l + S^g p^g) \mathbf{I} - \beta_T \Delta T \mathbf{I}) + \rho \mathbf{g} = 0$$

### Hydraulics

### Fluid flow

$$\frac{\partial}{\partial t} \int_{V_n} M^{\kappa} dV_n = \int_{\Gamma_n} \vec{F}^{\kappa} \vec{n} d\Gamma_n + \int_{V_n} q^{\kappa} dV_n$$

$$M^{\kappa} = \Phi \sum_{\beta} \rho_{\beta} S_{\beta} X_{\beta}^{\kappa}$$

$$\vec{F}_{\beta}^{\kappa} = -\rho_{\beta} \frac{\vec{k} k_{r\beta}}{\mu_{\beta}} (\nabla P_{\beta} - \rho_{\beta} \vec{g})$$

$$\sum_{\beta} S_{\beta} = 1$$

### Chemistry

### Reactive transport

$$\vec{F}^{\kappa} = \sum_{\beta} \left( X_{\beta}^{\kappa} \vec{F}_{\beta} + \rho_{\beta} \vec{D}_{\beta}^{\kappa} \nabla X_{\beta}^{\kappa} \right)$$

$$\ln(K_{P,T}) = \frac{\Delta G_{P,T}^0}{RT}$$

$$K_j = \frac{a_w^{\nu_{wj}} \prod_i (\gamma_i C_i)^{\nu_{i,j}} \prod_m (a_m)^{\nu_{mj}} \prod_g (f_g)^{\nu_{gj}}}{\gamma_j C_j}$$

# Cross-Sectional-Competence B: Data and Modeling Platform

## Coupling Concepts



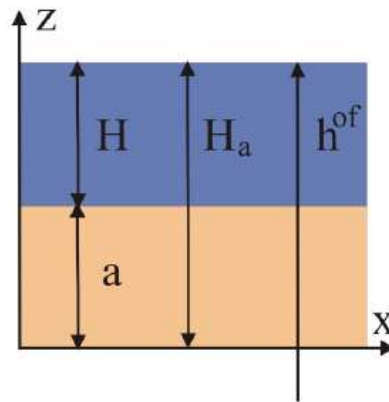
### Compartment Approach

#### H<sup>3</sup> Problem

Diffusive wave surface flow

$$\phi_a \frac{\partial H_a}{\partial t} + \bar{\nabla} \cdot \mathbf{q}^{\text{of}} = q_s^{\text{of}} \quad 0 \leq \phi_a \leq 1$$

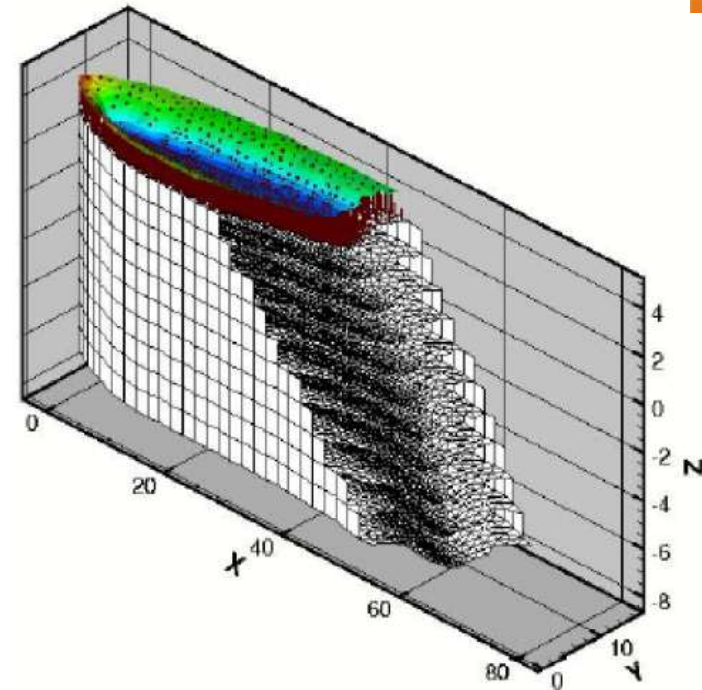
$$\mathbf{q}^{\text{of}} = -\frac{CH^{l+1}}{S_s^{1-j}} \bar{\nabla} h^{\text{of}}$$



Richards flow in soil

$$\phi \frac{\partial S}{\partial t} + \nabla \cdot \mathbf{q}^{\text{sf}} = q_s^{\text{sf}}$$

$$\mathbf{q}^{\text{sf}} = -k_r \mathbf{K} \nabla (\Psi + z)$$



Groundwater flow in aquifer

$$\phi \frac{\partial h^{\text{gf}}}{\partial t} + \nabla \cdot \mathbf{q}^{\text{gf}} = q_s^{\text{gf}}$$

$$\mathbf{q}^{\text{gf}} = -\mathbf{K} \nabla h^{\text{gf}}$$



Übersicht



► AIDA\_V

► Weather

► AIDAG

► find ser

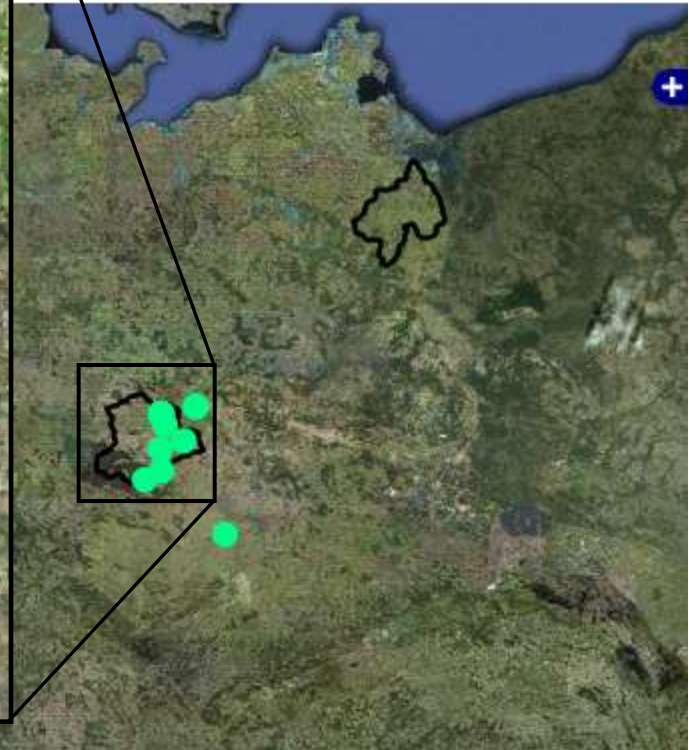
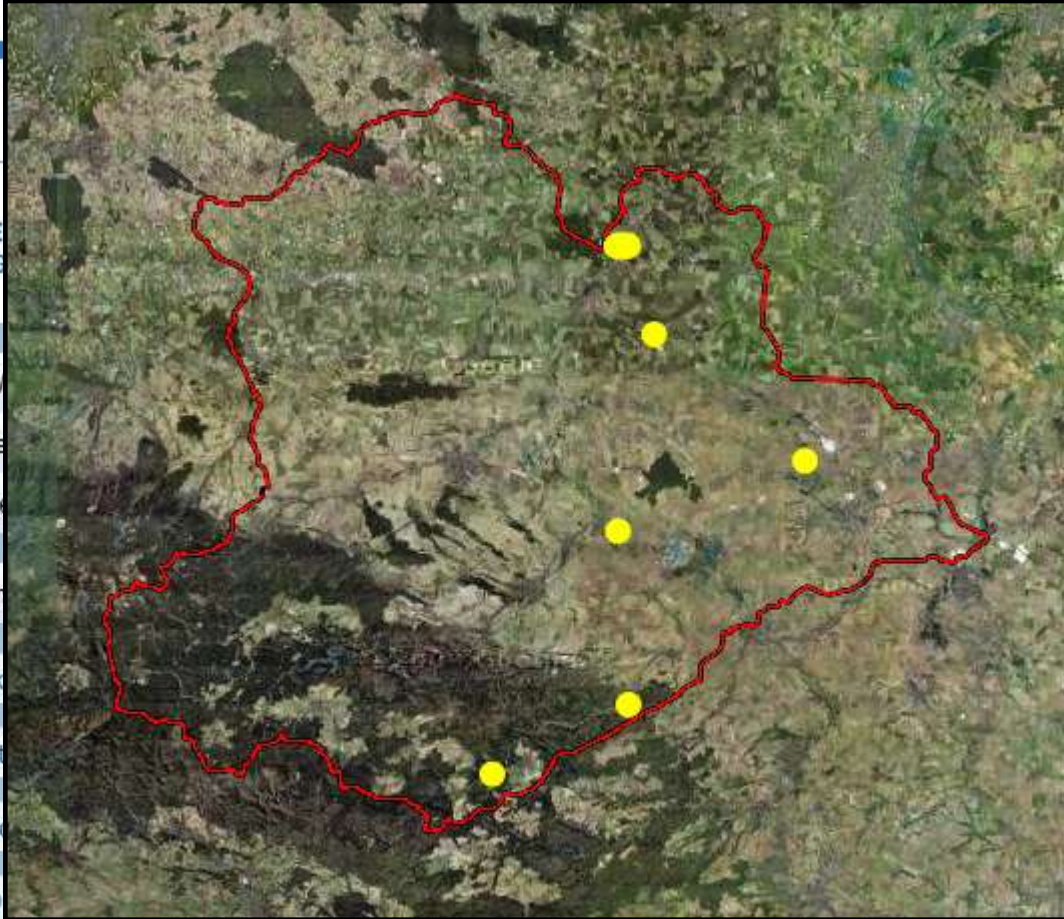
Überblick

Koordinat

Observat

TERENO

## DATA PORTAL



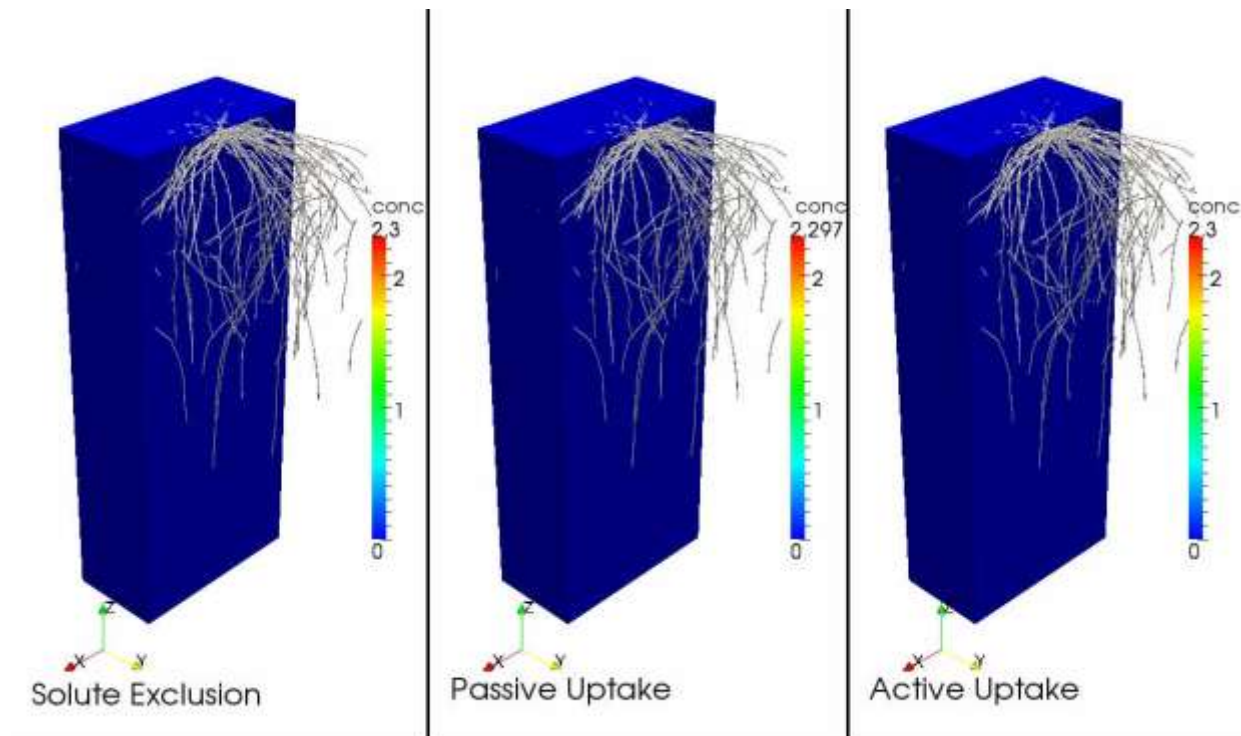
### Data Portal for access to data from all centres



TEODOOR

## CT Modelling: development of coupled process models

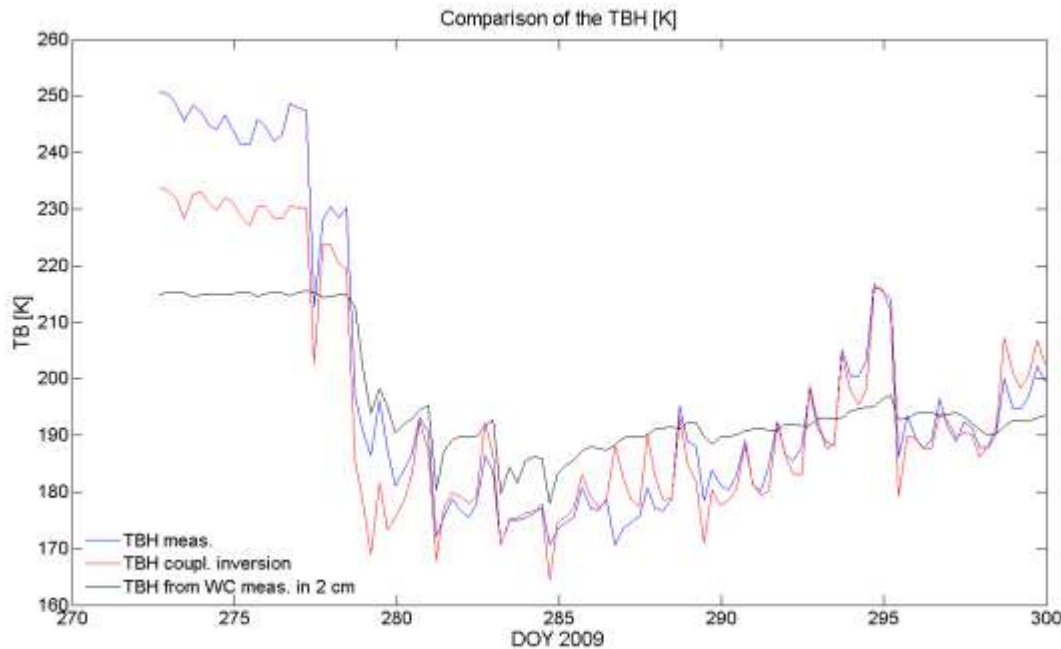
Soil-plant models that couple water flow and transport processes in soils and plants.



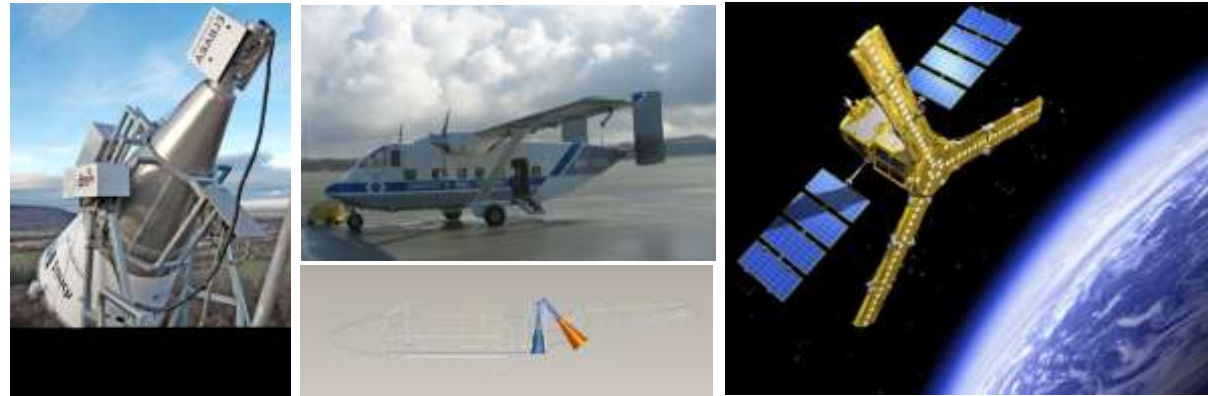
Current work: Include feedbacks between root development and soil environmental conditions.

## CT Modelling: development of coupled process models

Models that couple heat, vapor and liquid water fluxes in soils with models that simulate remote sensing data (e.g. radiative transfer models for passive and active radar)



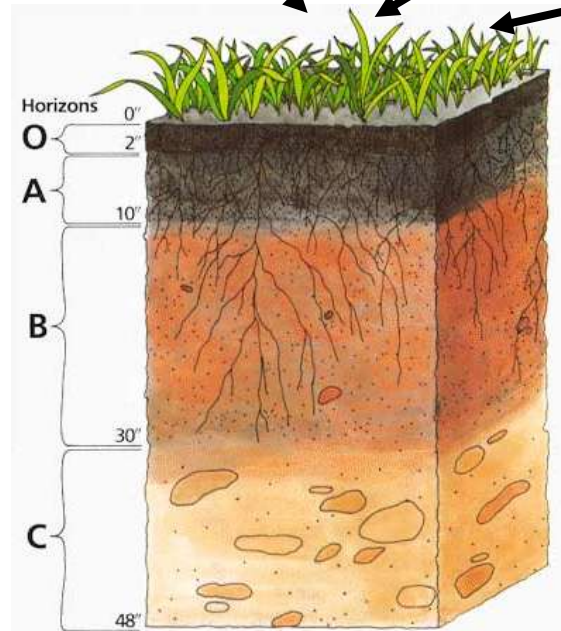
# Particle Filter to estimate soil hydraulic parameters from SMOS



Measuring a soil volume:

Surface to 5 cm depth

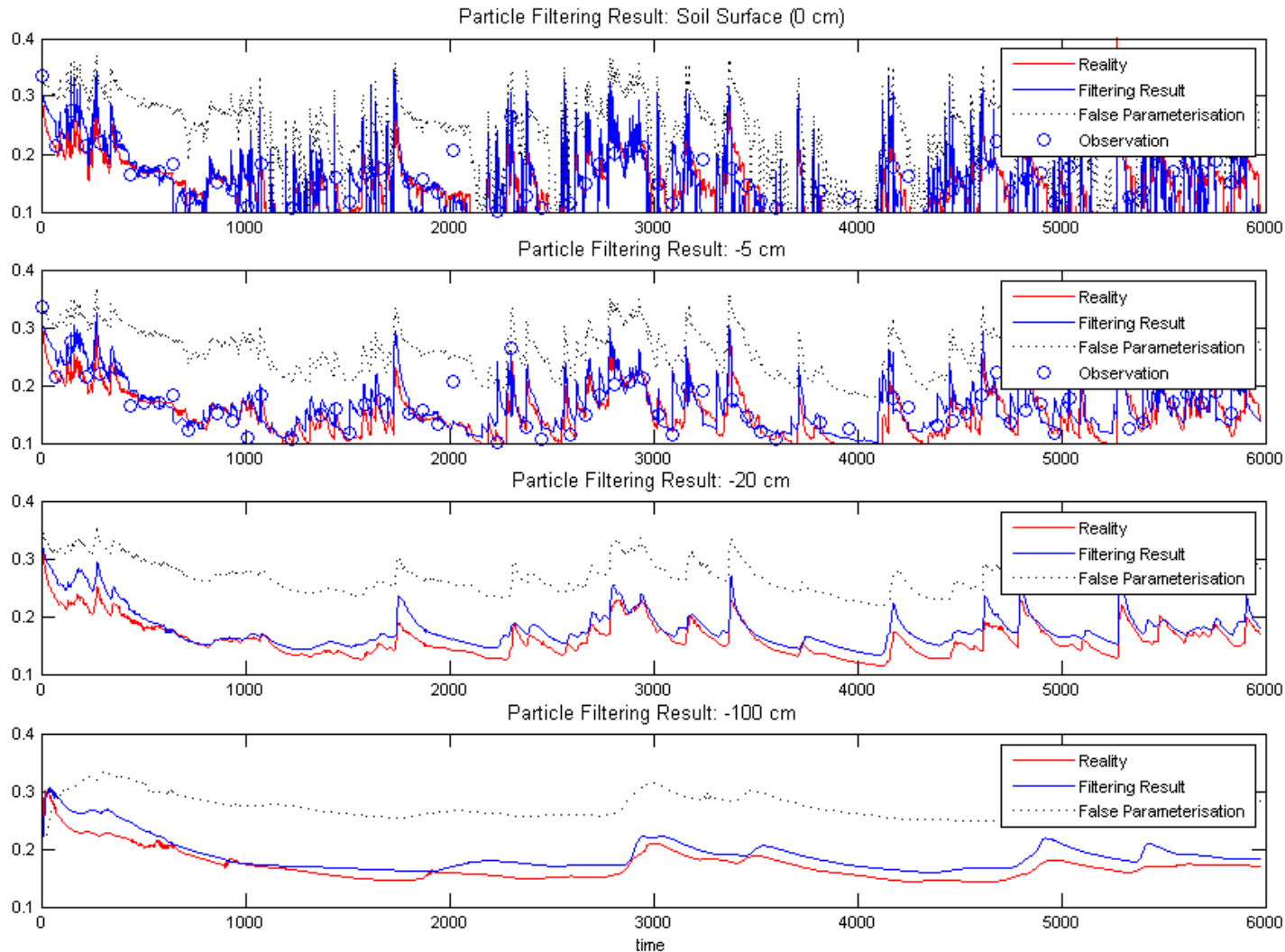
⇒ Assimilation



Top soil moisture measurements with microwave radiometry in L-Band (1 - 2,6 GHz)

- groundbased (ELBARA)
- airborne (PLMR, EMIRAD)
- spaceborne (SMOS, ALOS)

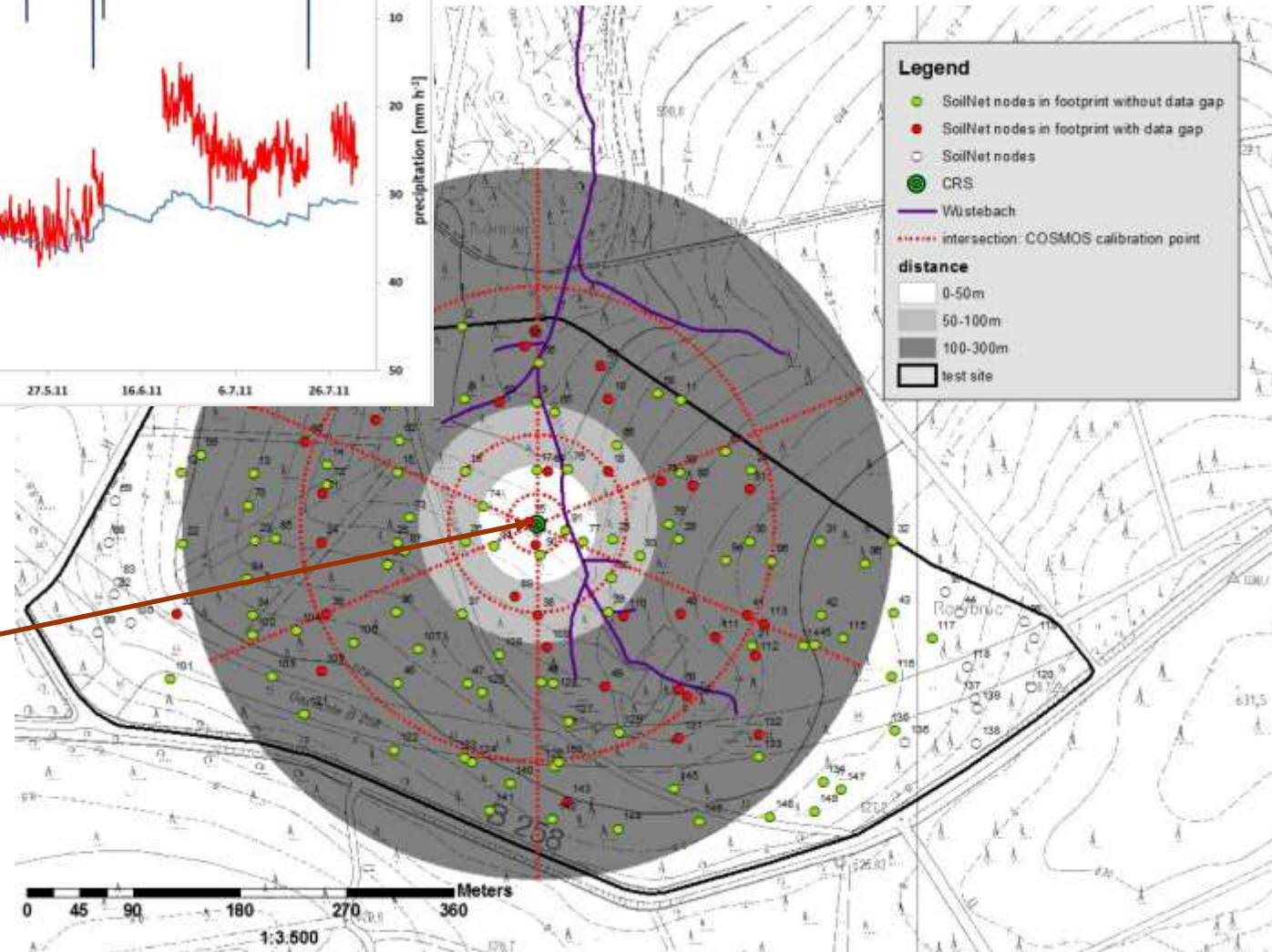
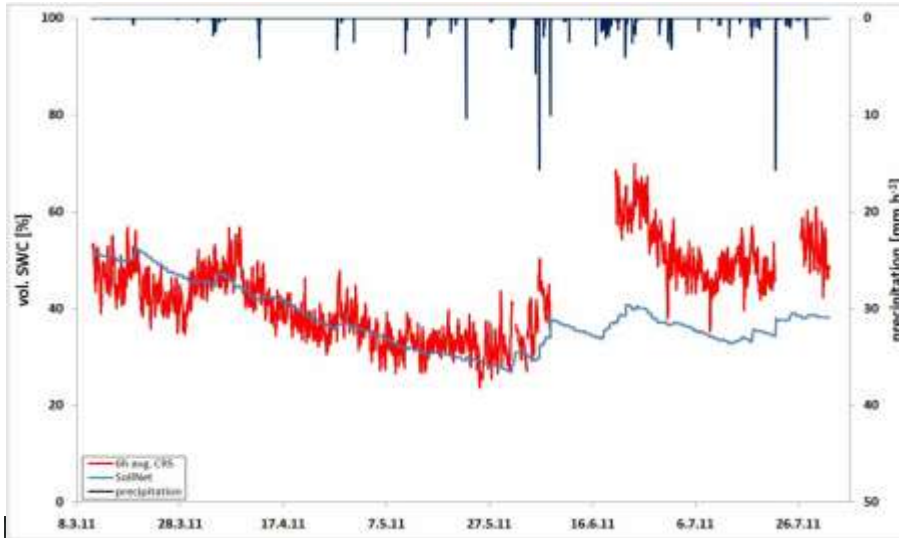
# Particle Filter to estimate soil hydraulic parameters from SMOS



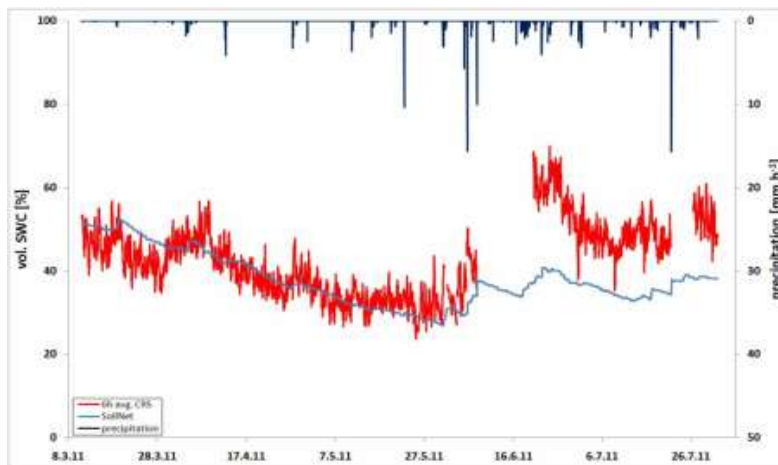
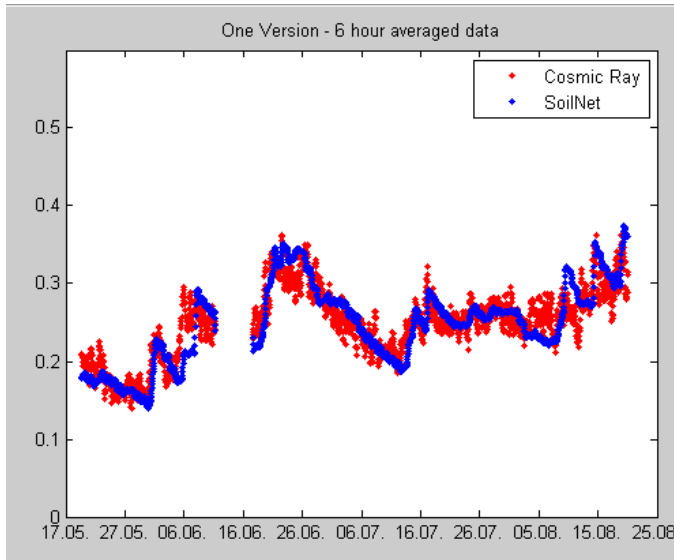


# Development of measurement operator for cosmic ray data

Example: TERENO test site Wüstebach



# Development of measurement operator for cosmic ray data



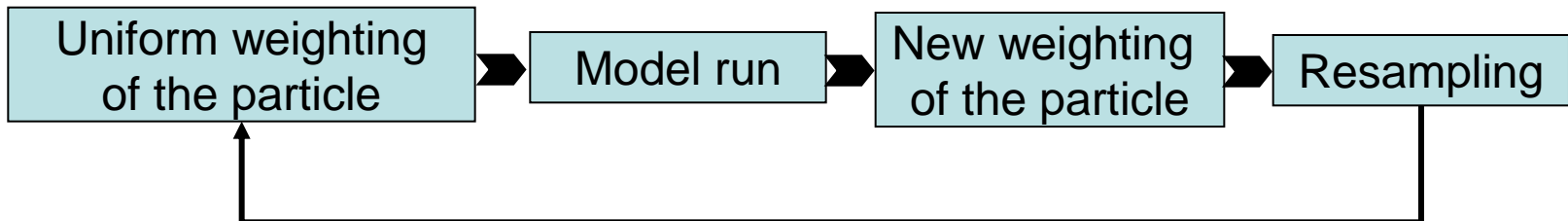
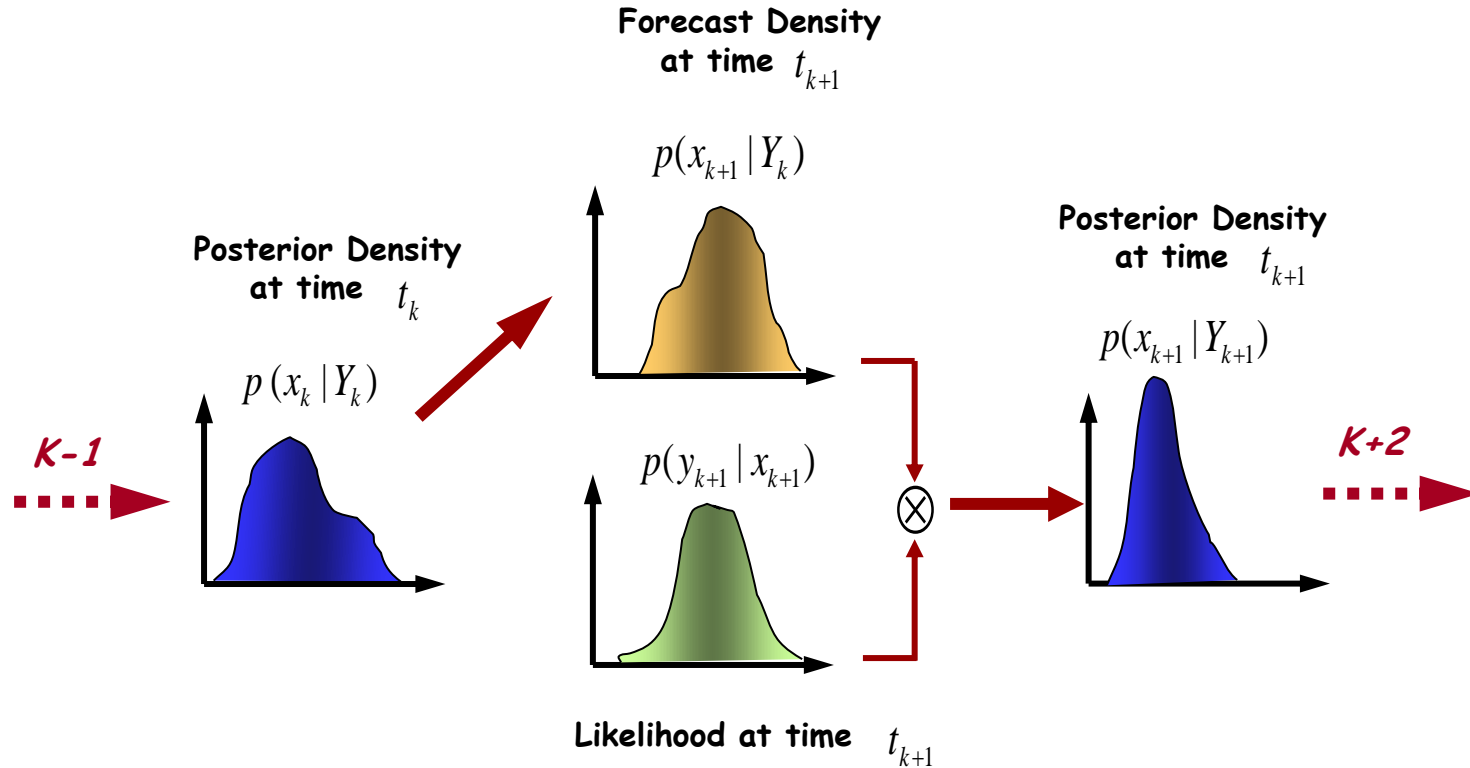
31. Januar 2012



Institut Agrosphäre (IBG-3)

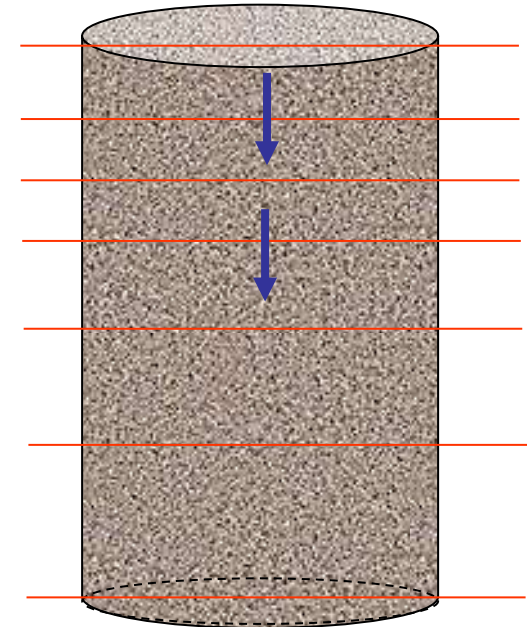
Folie 6

# Particle Filter to estimate soil hydraulic parameters from SMOS



## Particle Filter to estimate soil hydraulic parameters from SMOS

- 1-D physical finite elements model
- Solves Richards equation numerically
- Soil hydraulic properties are parameterised using the Mualem-van Genuchten model
- 1 hour temporal resolution
- Homogeneous soils (clay, loam, silt, loamy sand)



$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left[ k(h) \left( \frac{\partial h}{\partial z} - 1 \right) \right] - Q$$

## Development of measurement operator for cosmic ray data

- Non-linear measurement operator to be used in sequential DA
- This measurement operator determines link between neutron counts (NC) and soil moisture contents taking into account:
  - NC-contribution as function of distance to sensor
  - NC-contribution as function of depth (influence SM-content)
  - Air pressure and solar activity variations
  - Soil moisture heterogeneity within footprint
  - Measurement uncertainties
- Daily assimilation (together with other data) in CLM for updating SM