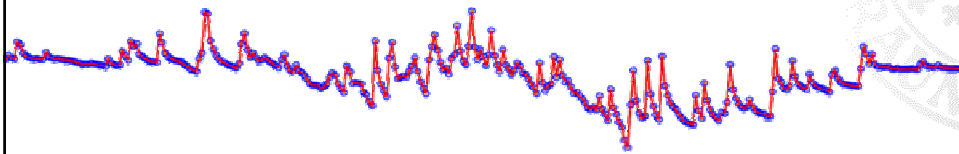
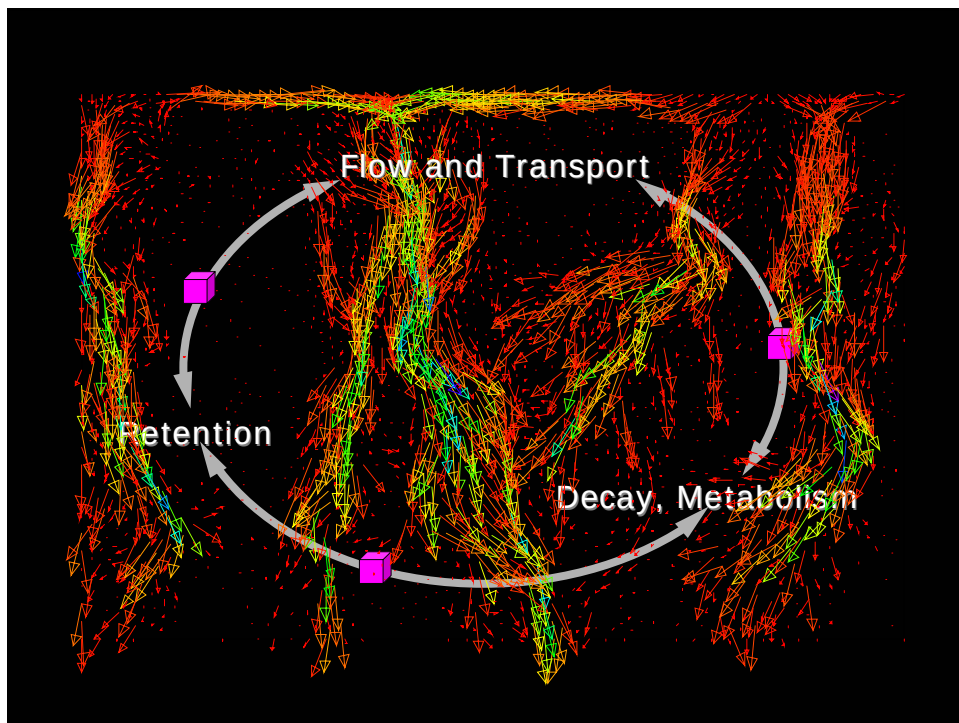


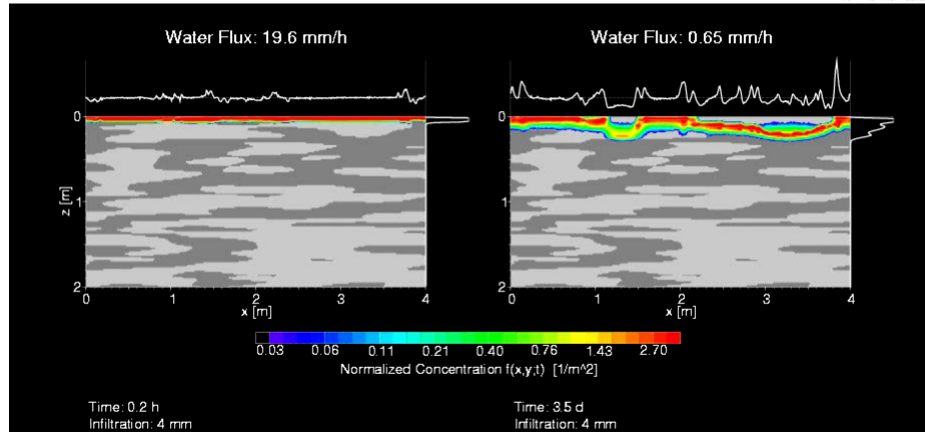
Determination of Effective Parameters for Modeling Water Transport on the Lysimeter Scale



Wolfgang Durner, Ulrike Jansen, Sascha Iden

Technische Universität Braunschweig, Germany



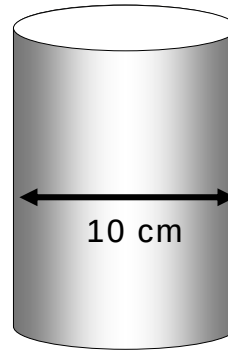


Outline

- **Hydraulic Properties of homogeneous systems**
 - Hydraulic Properties of heterogeneous systems
 - Effective hydraulic properties of heterogeneous systems determined by inverse modeling

The Aim of the Game

Find a description for the soil water dynamics that “perfectly” reproduces all observable macroscopic behaviour



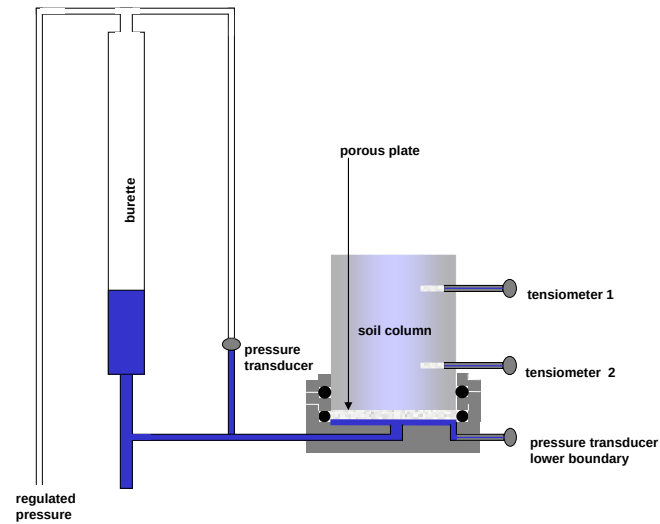
The Richards equation

$$C(h) \frac{\partial h}{\partial t} = \frac{\partial}{\partial z} \left(K(h) \frac{\partial h}{\partial z} - K(h) \right)$$

Inverse Modellierung

- 1 Involves **experiments** where the system state changes, as enforced by changes in boundary conditions (controlled or just observed)
- 2 State **observations** (water contents, water potentials, concentrations; water fluxes at boundaries, mass fluxes at boundaries)
- 3 **Simulation** of the experiment that aim to match the observations (involves non-linear minimization of an error criterion)

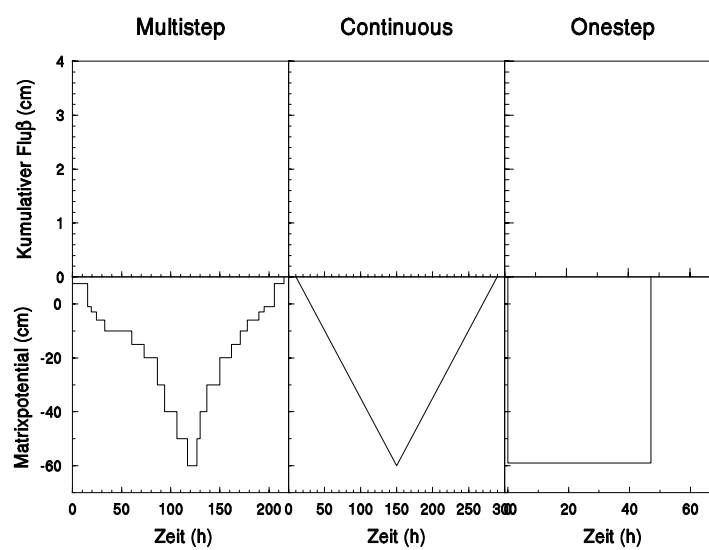
Typical MSTO



(Hopmans, Simunek, Romano and Durner, Methods of Soil Analysis, 2002)

Diffuse Einträge in das Grundwasser: Monitoring – Modellierung – Management | Graz, 29.-31. Januar 2007

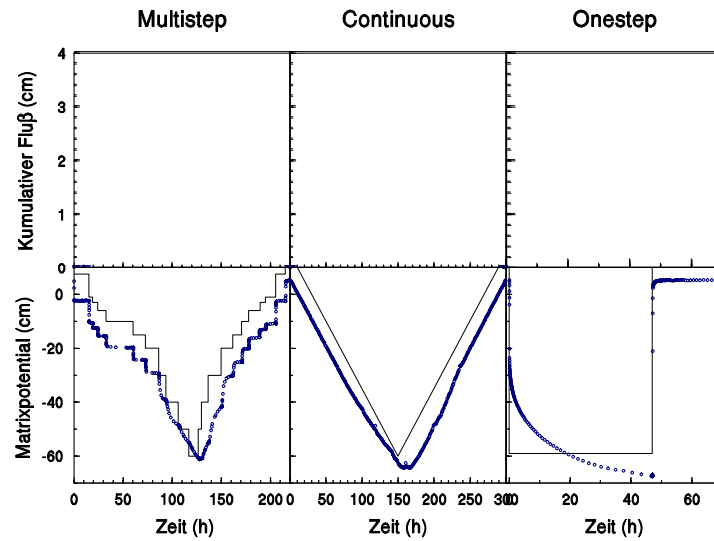
Lab inflow/outflow experiment: boundary conditions



Diffuse Einträge in das Grundwasser: Monitoring – Modellierung – Management | Graz, 29.-31. Januar 2007

Lab inflow/outflow experiment: **tensiometer response**

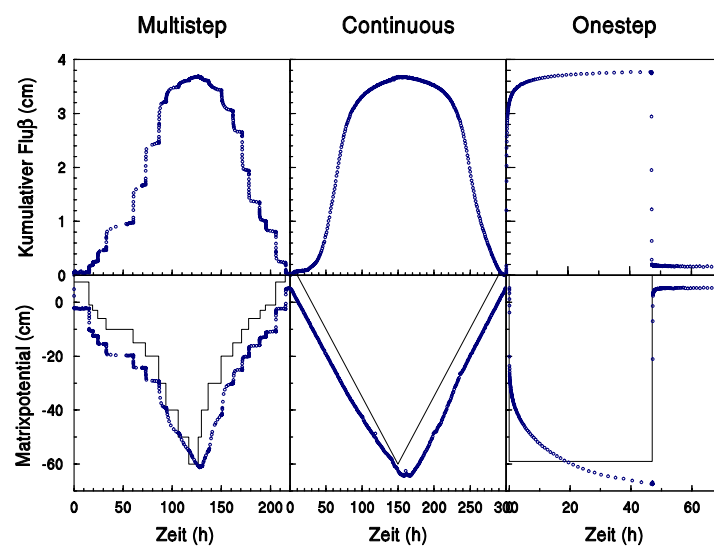
EXAMPLE



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Lab inflow/outflow experiment: **flow response**

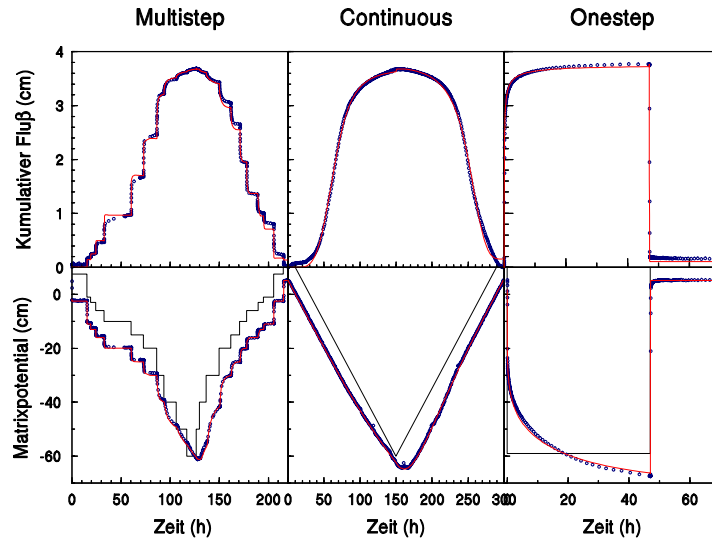
EXAMPLE



Diffuse Einträge in das Grundwasser: Monitoring – Modellierung – Management | Graz, 29.-31. Januar 2007

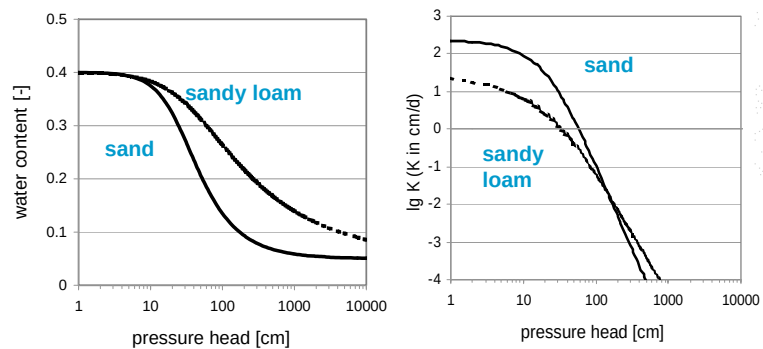
Lab inflow/outflow experiment: modeling results

EXAMPLE



Diffuse Einträge in das Grundwasser: Monitoring – Modellierung – Management | Graz, 29.-31. Januar 2007

material properties



Diffuse Einträge in das Grundwasser: Monitoring – Modellierung – Management | Graz, 29.-31. Januar 2007

13

The usual assumptions ...

$$C(h) \cdot \frac{\partial h}{\partial t} = \frac{\partial}{\partial z} \left(K(h) \frac{\partial h}{\partial z} - K(h) \right)$$

- Rigidity
- One-phase flow
- No vapor transport
- Isothermal conditions
- Independency from chemical properties

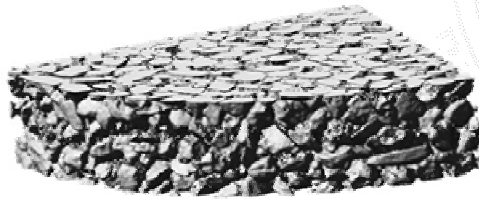


Photo: P. Ioannidis, FIMOTUM, 2005

- **REV**
- **macroscopic "homogeneous"**

Hydraulic properties on the lysimeter scale



$$C(h) \cdot \frac{\partial h}{\partial t} = \frac{\partial}{\partial z} \left(K(h) \frac{\partial h}{\partial z} - K(h) \right)$$

still applicable?

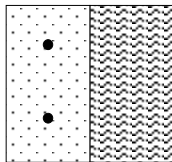




Outline

- Hydraulic Properties of homogeneous systems
- Hydraulic Properties of heterogeneous systems
- Effective hydraulic properties of heterogeneous systems determined by inverse modeling

Basic considerations

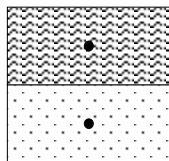


**sand
and
loam**

effective WRC:
arithm. mean
of local WRCs

effective conductivity:
arithm. mean
of local conductivities

Basic considerations

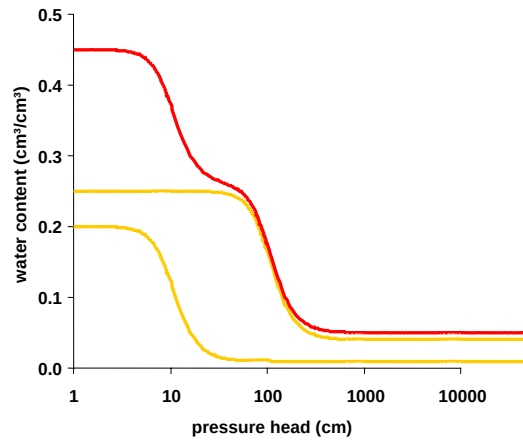


**loam
above
sand**

effective WRC:
it depends ...

effective conductivity:
harmonic mean

Effective retention curve of silt + sand

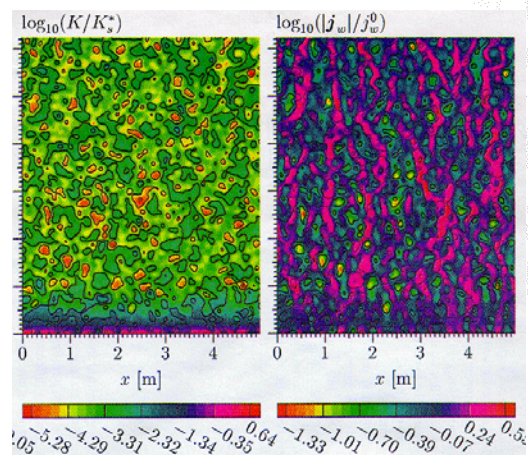


Unsaturated flow in a Miller-Miller-similar porous medium

Flow path formation
depends on local
properties

AND

boundary
conditions



(Roth, WRR, 1996)

Outline

- Hydraulic properties of homogeneous systems
- Hydraulic properties of heterogeneous systems
- **Effective** hydraulic properties of heterogeneous systems determined by **inverse modeling**

Inverse modeling of heterogeneous systems

1. Creation of „virtual realities“ ...

- homogeneous, layered, stochastic heterogeneous, structured, without roots and with roots, ...

2. ... to obtain synthetic measurement data ...

- MSO, evaporation experiments, infiltration experiments, natural boundary conditions

3. ... that are evaluated by inverse simulation.

- Investigate (1):
role of type, density, noise, errors in measurements
- Investigate (2):
effects of erroneous assumptions

Questions

1) Is internal heterogeneity *evident* in the observations ?

2) Exist *apparent* effective properties?

3) Exist *true* effective properties ?

Invariant with respect to

- Spatial scale of the medium
- Temporal scale and type of boundary conditions
- Moisture range

kinds of internal heterogeneity



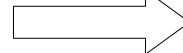
stochastic



stratified



structured



- Virtual heterogeneous soil systems:

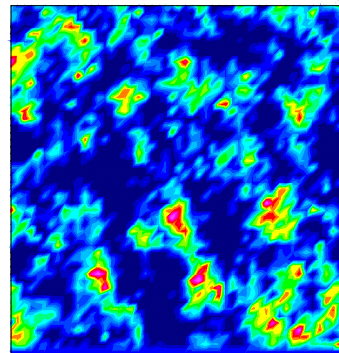
Effects of local random heterogeneity (Wienhöfer)

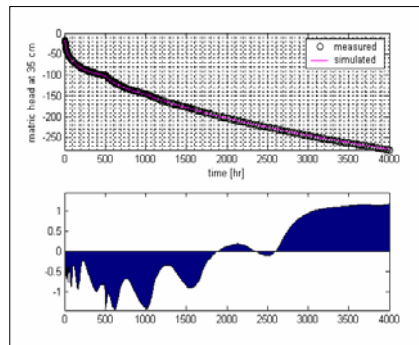
Miller-similar stochastic medium

Log-normal scaling factor $\sigma_{\log \alpha}$

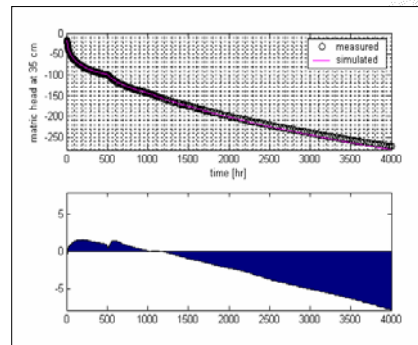
System size 50 x 50 cm

Variation of isotropy and
correlation length



Miller-Miller scenarios: varying the standard deviation of $\log(\alpha)$ 

loamy sand,
 $\sigma = 0,01$

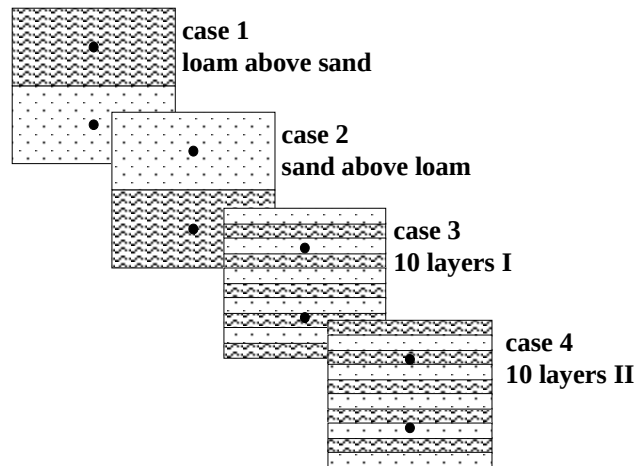


loamy sand,
 $\sigma = 0,5$

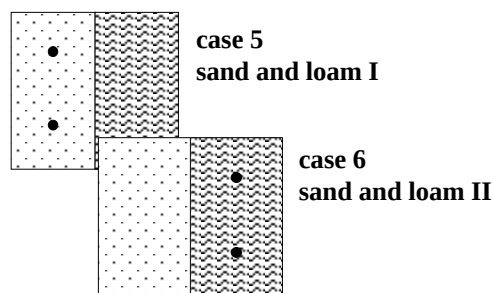
- Virtual heterogeneous soil systems:

Effects of local deterministic heterogeneity (Foit)

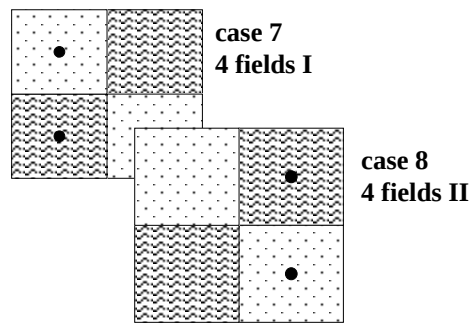
Layered



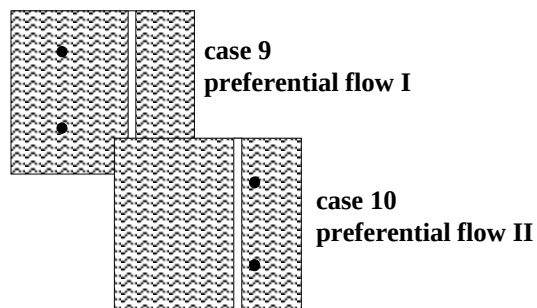
vertical



chess fields

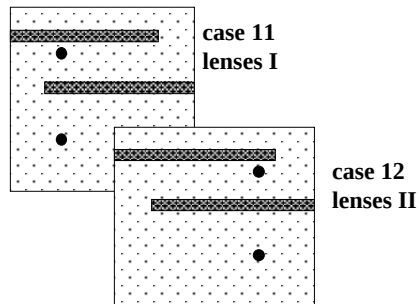


vertical structure - loam with preferential flow path
($K_s = 150 K_{\text{matrix}}$)



horizontal structure

- sand with lenses of low permeability
 $(K_s = 1/150 K_{\text{matrix}})$



Some tentative conclusions ...

- (1) Is internal heterogeneity *evident* in the observations ?
 - yes, by systematic mismatches
 - In practice hidden by measurement noise
- 2) Exist *apparent* effective properties, and are they in accordance with the local parameterization ?
 - for moderate heterogeneity: yes
 - for stronger heterogeneity: unclear
- 3) Exist *true* effective properties ?
 - answer is postponed ...

- Virtual heterogeneous soil systems:

Layered heterogeneity on the lysimeter scale (Jansen)

Hypothesis

- ❖ **Lysimeters** are ideal for bridging the gap between the lab and the field scale

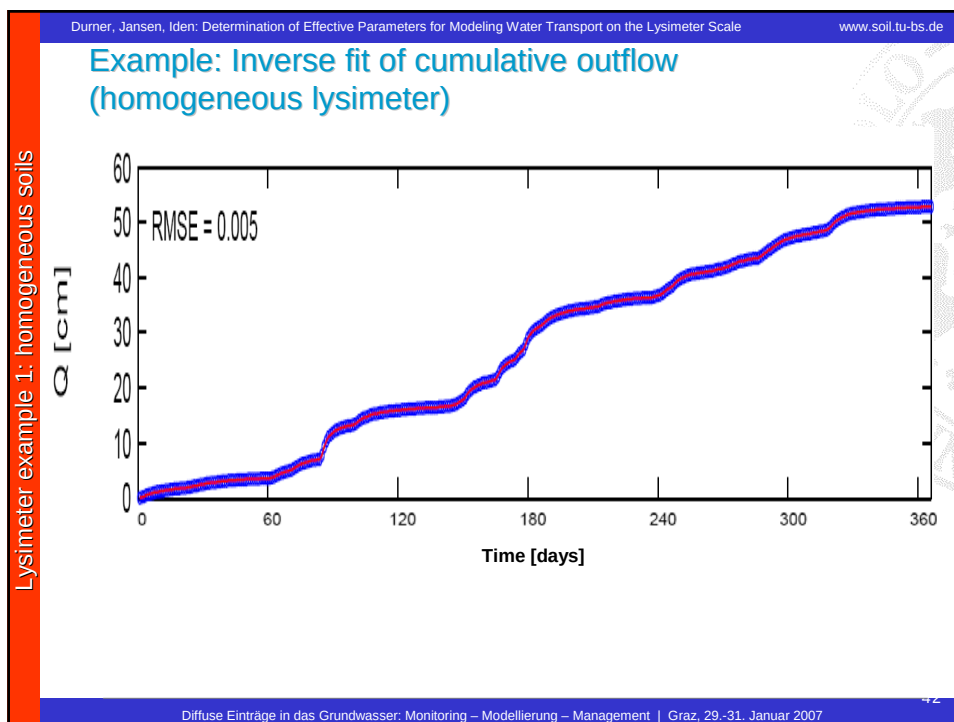
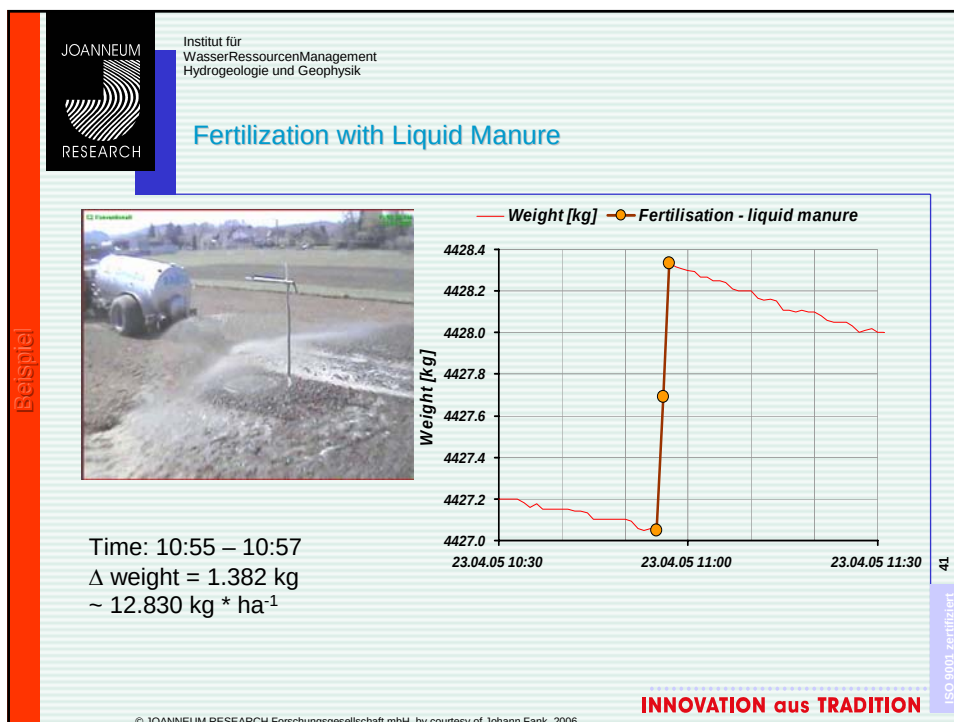

 10^{-4} m^3
 10^{-3} m^3
 10^{-2} m^3
 10^{-1} m^3
 10^0 m^3

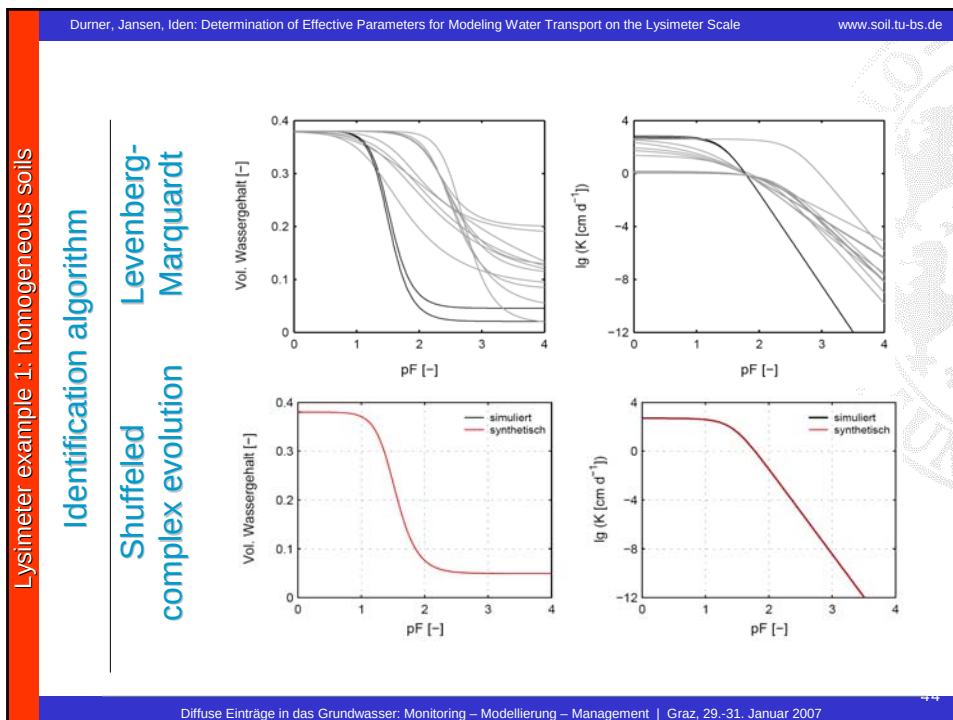
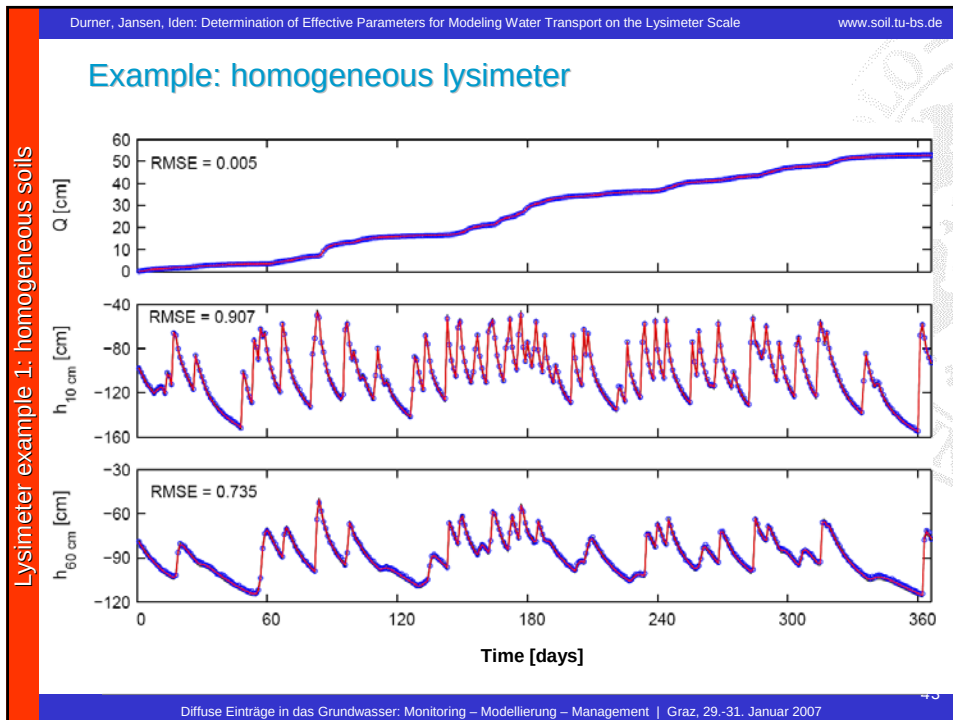
Lysimeters
... are
systems
at the
appropriate
scale



Properties of modern lysimeters

- Undisturbed soil
- Control of pressure at bottom
- *Contrary to the field:*
High precision monitoring of water fluxes at boundaries

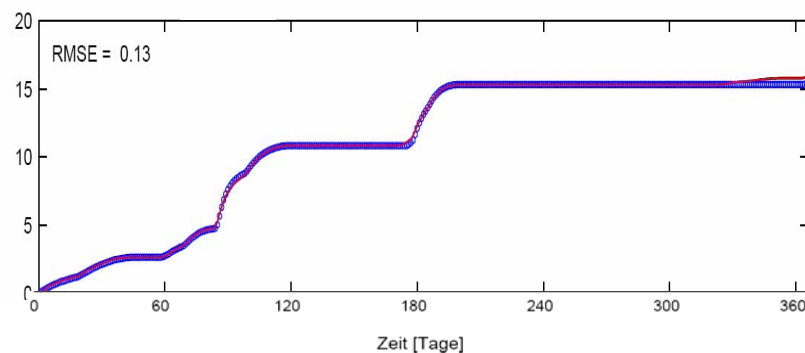




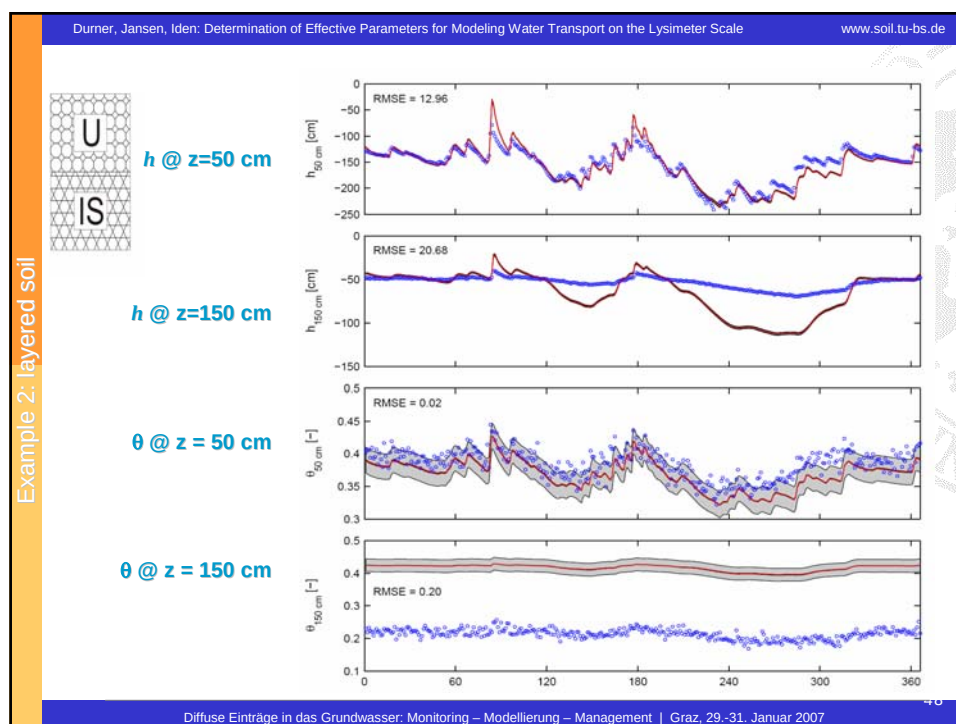
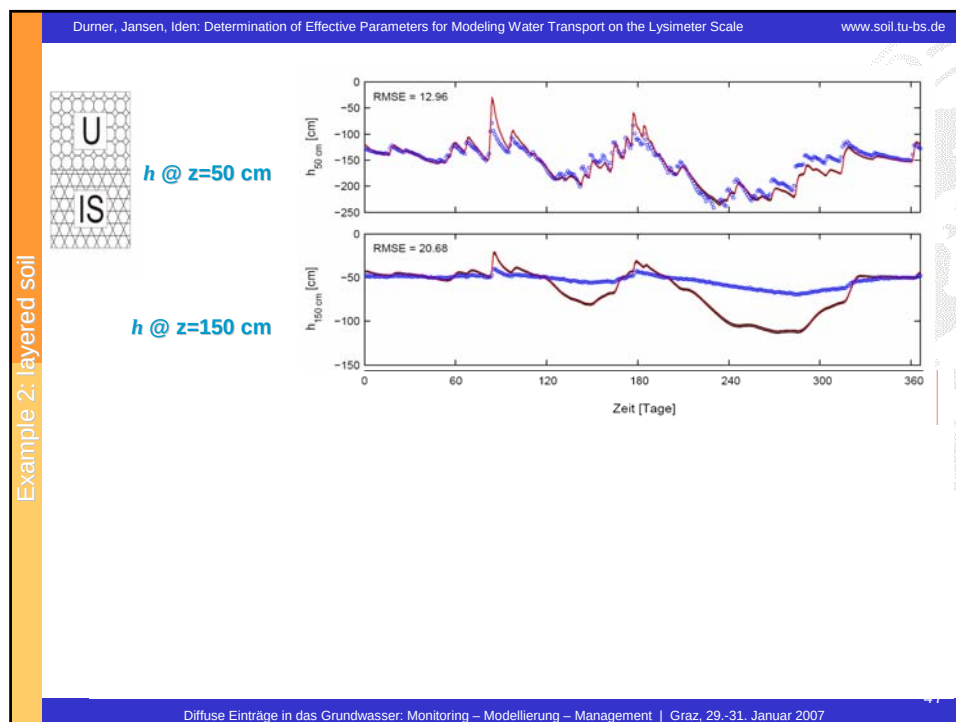
Lesson 1

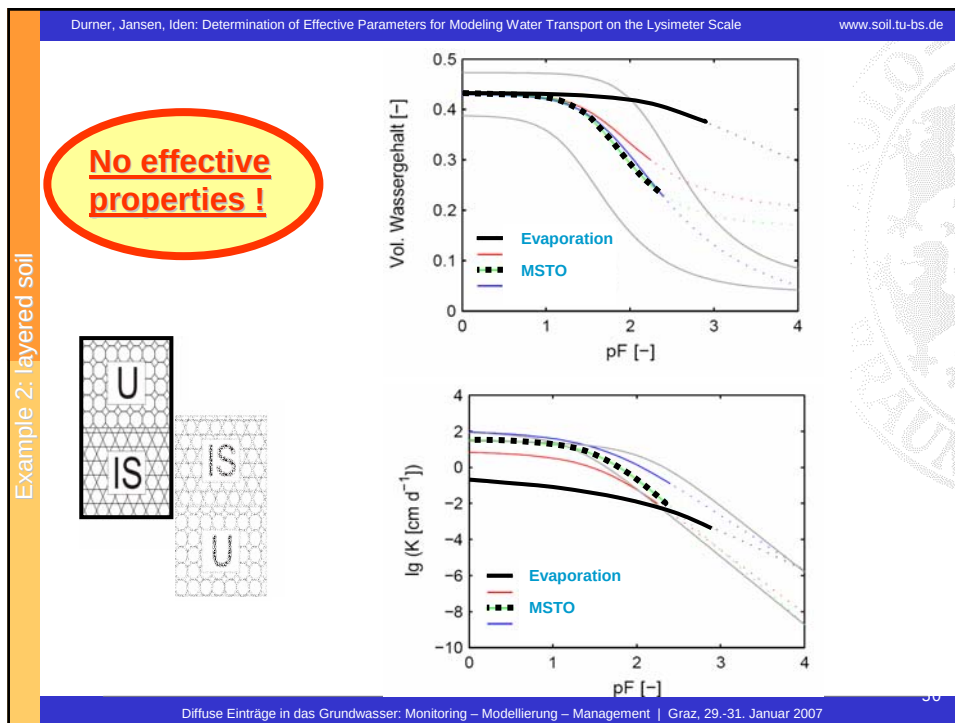
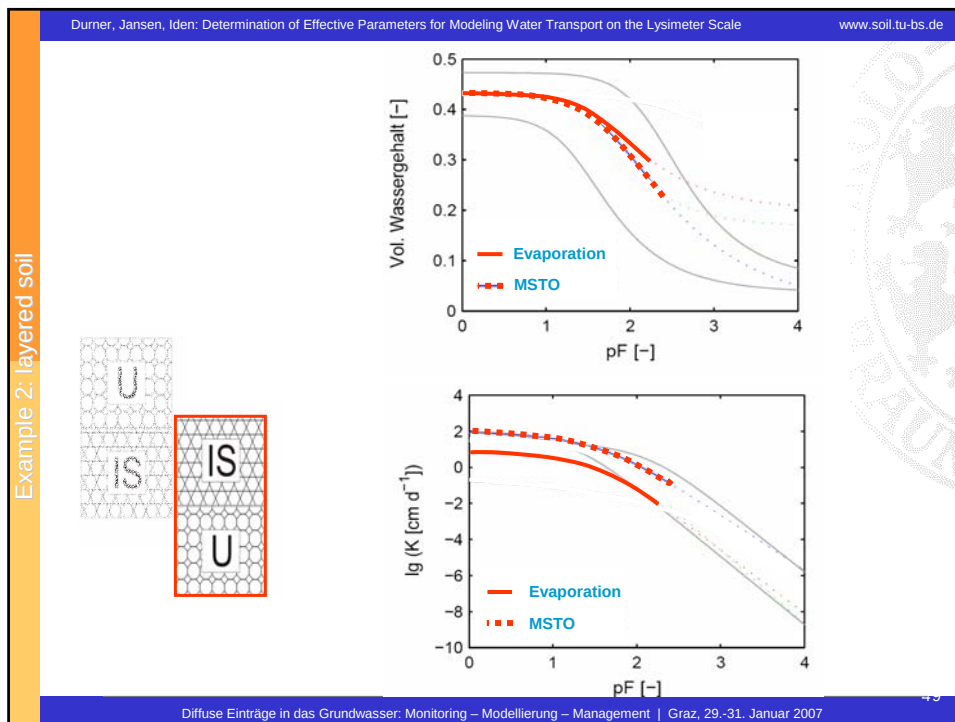
- By principle we can successfully fit observations from lysimeters under natural atmospheric conditions
- A unique parameter identification requires the use of robust global algorithms

layered
soil;



Example 2: layered soil





Lesson 2

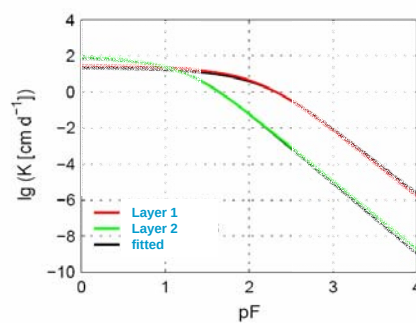
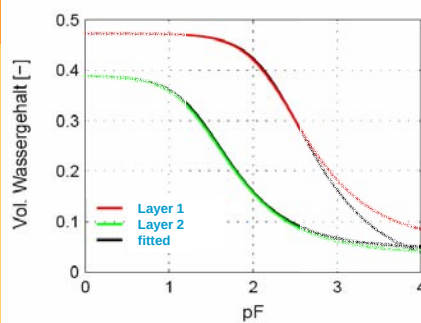
- We can fit outflow observations even for strongly heterogeneous lysimeters assuming they have quasi-homogeneous properties
- But different experiments lead to different identified properties
- And: the internal state variables can no longer be matched

Layered systems – individual fit for layers



The good news:
Simultaneous estimation for structural units possible!

Example 2: layered soil



Summary (1 of 2)

- ❖ »Inverse Modeling« of laboratory systems is a developed tool to interpret experimental observations in an consistent and integrated manner.
- ❖ Typical observations in the field yield not sufficient data (with respect to type, quality, and resolution) to get unambiguous and conclusive results.
- ❖ To bridge the gap between the lab and field scale, inverse modeling of processes in lysimeters is useful and very promising.

Summary (2 of 2)

- ❖ No unique effective hydraulic properties exist for large layered systems with strongly heterogeneous local properties.
- ❖ Water fluxes across boundaries could be well described for each of the investigated scenarios.
- ❖ All these results are obtained for ideal cases, which are never fully met in nature

Thank You!