TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Environmental Sciences Institute for Groundwater Management

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INSIGHTS INTO KARSTIC SYSTEMS THROUGH INVERSE APPLICATION OF DISCRETE CONDUIT-CONTINUUM MODELS

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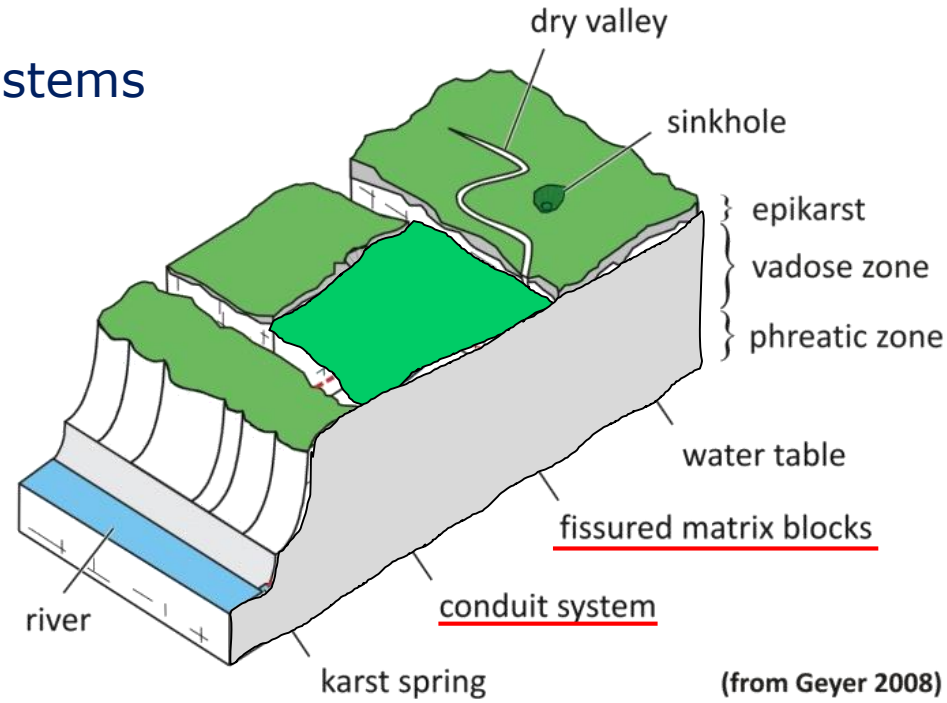
Motivation

Characterization of karst systems

- strong heterogeneity
- anisotropy
- highly variable, non-linear flow



(from Geyer 2008)

Question:

→ gaining insight through inverse modelling (dependent on available data)?

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Motivation

Characterization of karst systems

Example: Sheshpeer Catchment, Iran

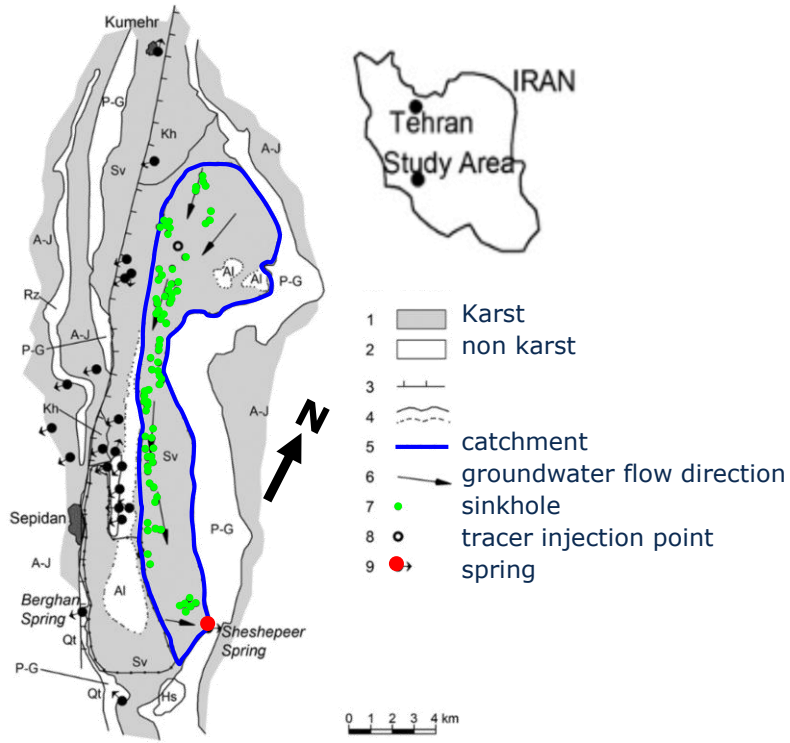
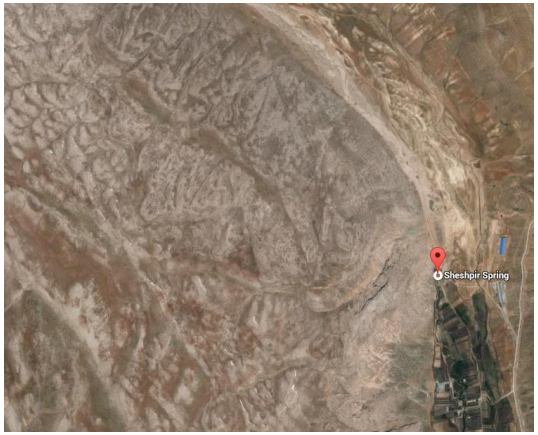


Figure from Raeisi 2010



from Google maps

N°abstract **2405**

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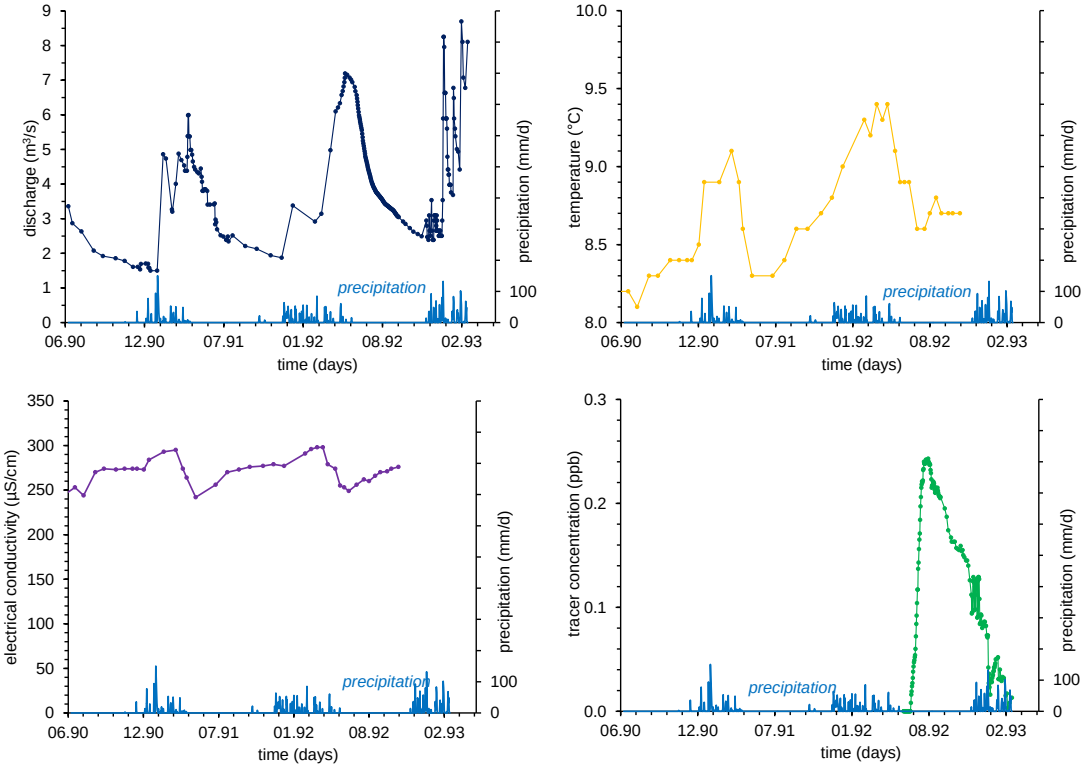
Motivation

Characterization of karst systems

Example: Sheshpeer Catchment, Iran

Measured data (spring)

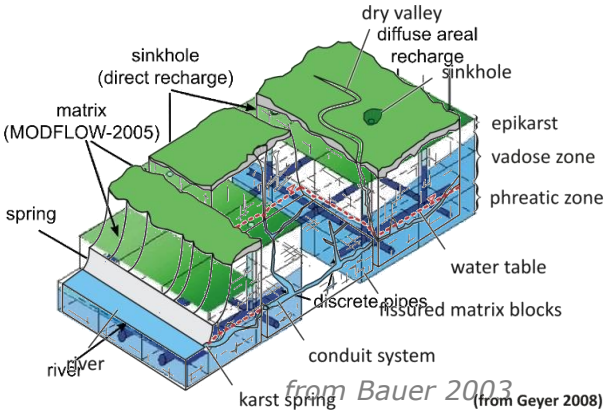
- discharge
- temperature
- electrical conductivity
- tracer concentration



Modelling Approach

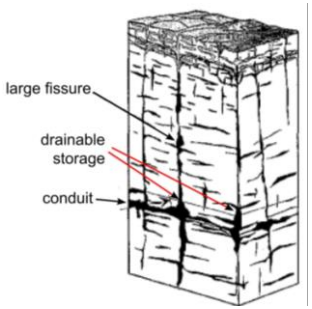
Discrete Conduit-Continuum model – flow process

Based on MODFLOW-2005 Conduit Flow Process (CFP)

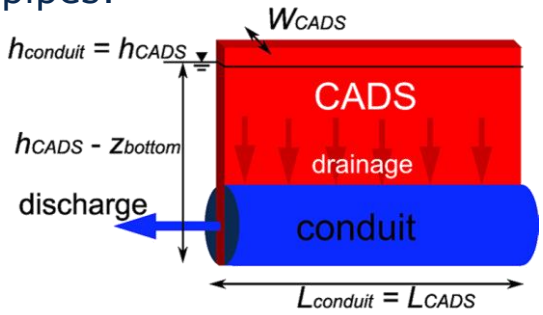


from Bauer 2003

Additional storage for pipes:



from Renner 1996



from Reimann et al. 2014

quantifying groundwater flow

matrix: 3D groundwater flow (Darcy)

conduits: 1D laminar / turbulent pipe flow (Darcy-Weisbach)

head-dependent water transfer between matrix and conduits $Q_{ex} = \alpha_{ex}(h_c - h_m)$

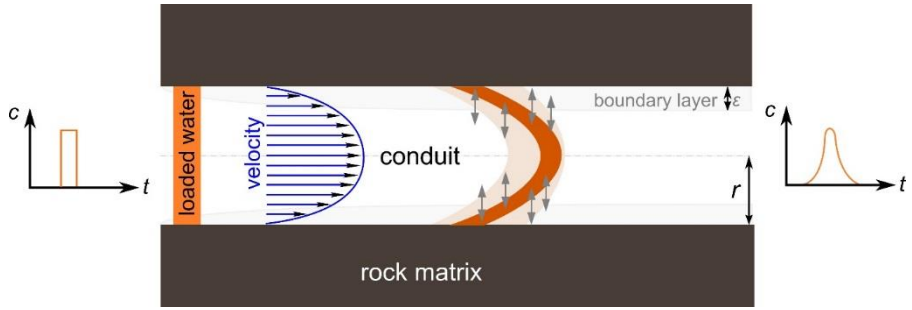
Conduit Associated Drainable Storage CADS (directly linked to conduits)

Modelling Approach

Discrete Conduit-Continuum model – transport process

Based on Conduit Aquifer Void Evolution (CAVE)

- heat and solute transport
- 1D advection with physically based Taylor dispersion, diffusive boundary layer
- 1D radial diffusion / heat conduction around conduit



transport considers flow state (laminar / turbulent), for example Taylor dispersion:

laminar $D = \frac{r^2 v^2}{48 D_{Diff}}$

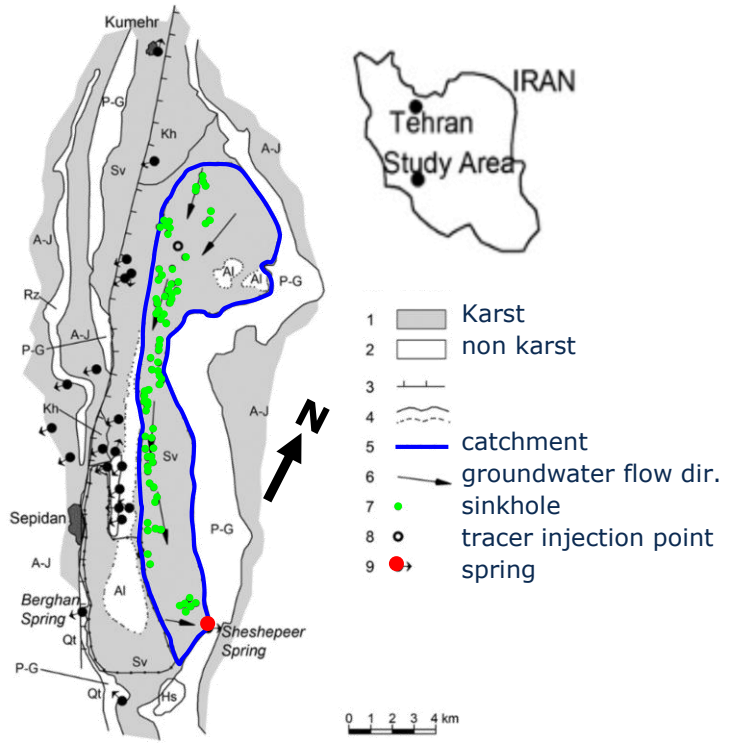
turbulent $D = 10.1 r v_*$

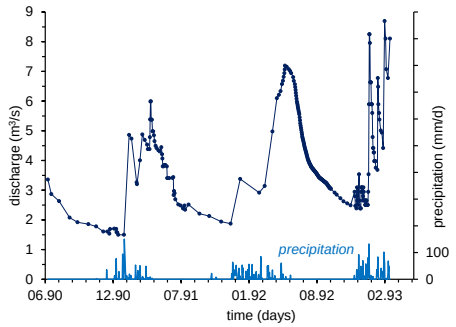
D = Taylor dispersion coefficient
r = conduit radius
D_{Diff} = diffusion coefficient in water
v = velocity
v_* = friction velocity

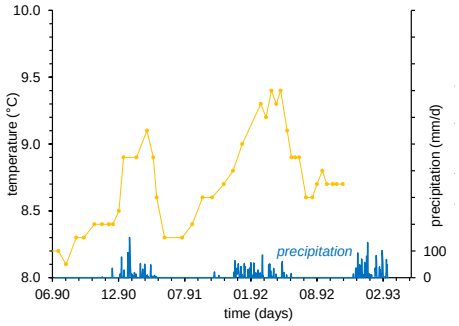
Application

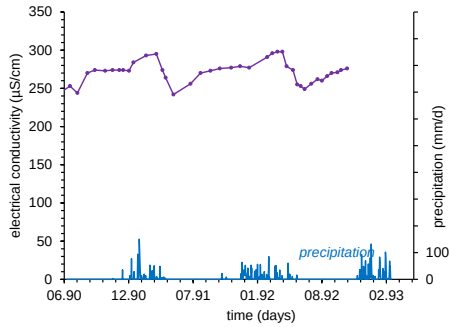
Inverse parameterization with multiple signals

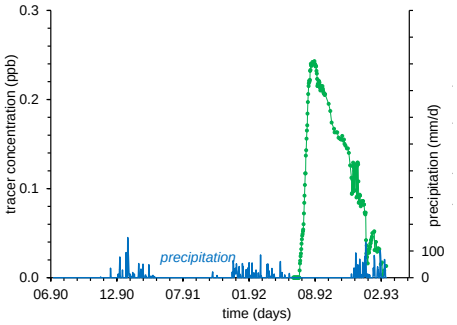
Large scale: Sheshpeer system (Iran)











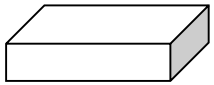
Application

Inverse parameterization with multiple signals

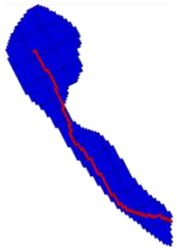
Large scale: Sheshpeer system (Iran)

Approach:

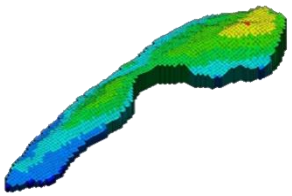
(1) highly idealized models



(2) simplified realistic models



(3) detailed realistic models



seconds to few minutes

model run time

some hours

many, wide range

parameters

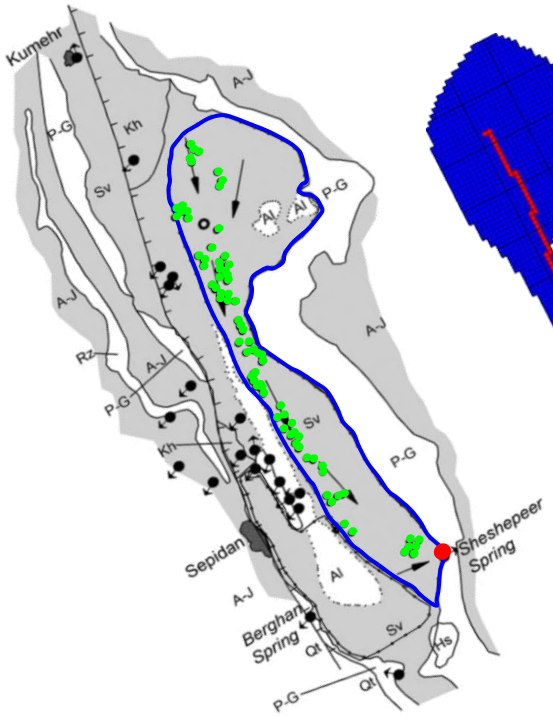
few sensitive, narrow range

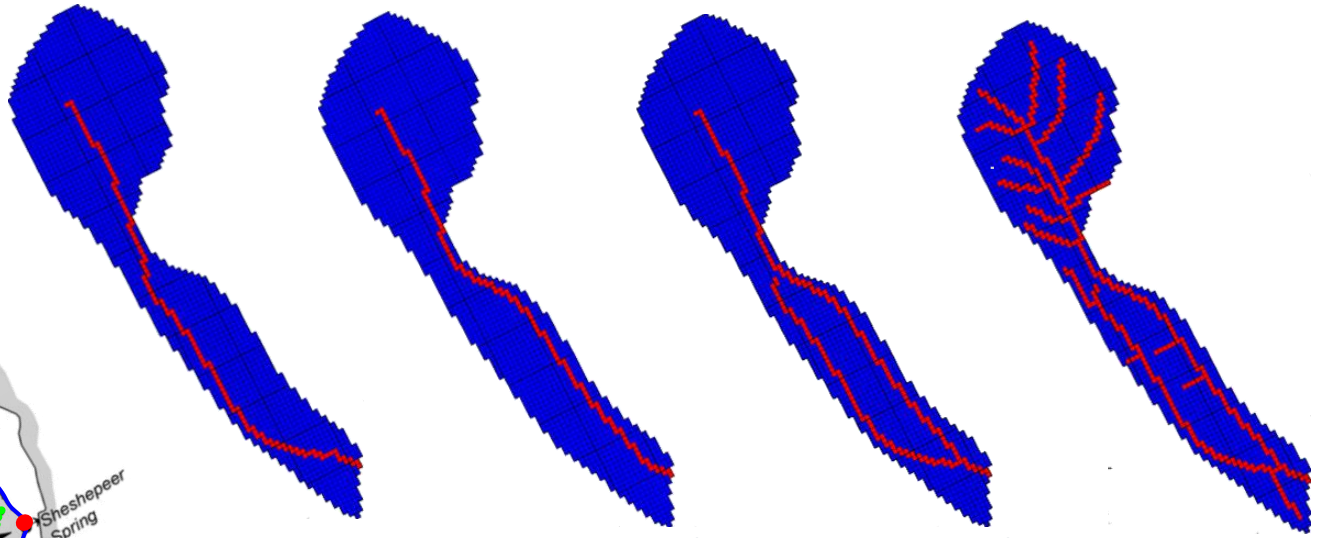
Application

Inverse parameterization with multiple signals

Large scale: Sheshpeer system (Iran)

Simplified realistic models - example: effects of conduit structure (red cells)





variation 1 *variation 2* *variation 3* *variation 4*

model complexity

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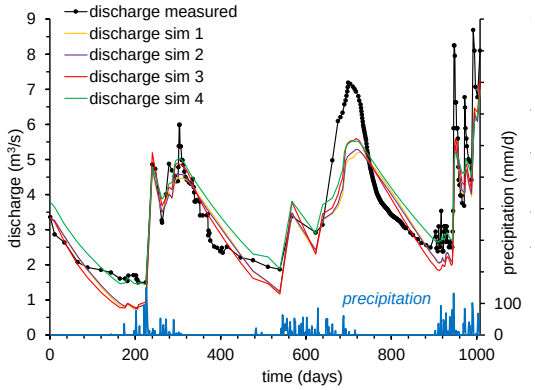
Application

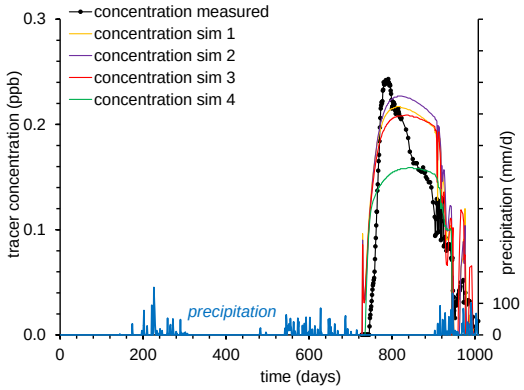
Inverse parameterization with multiple signals

Large scale: Sheshpeer system (Iran)

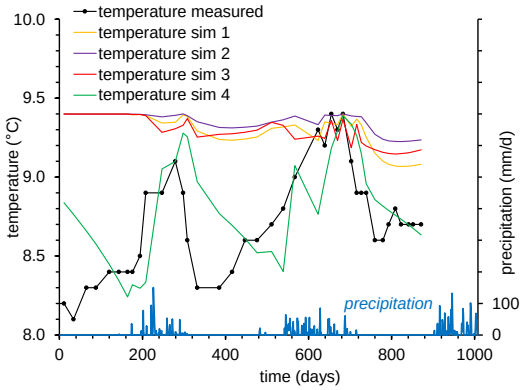
Simplified realistic models - example: effects of conduit structure – calibration with PEST



discharge



solutes (tracer)

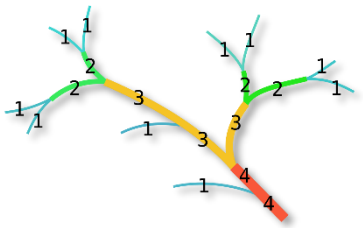


temperature

conduit structure 4 supported

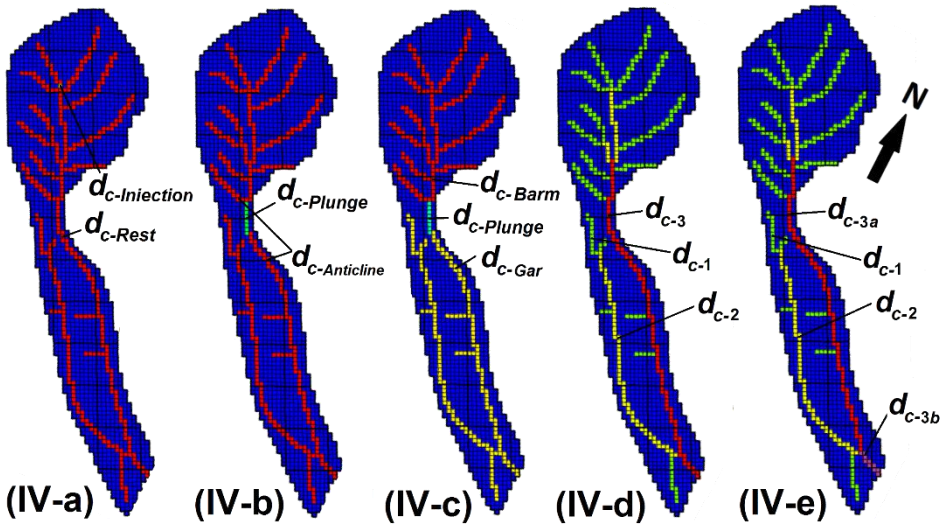
Application

Inverse parameterization with multiple signals



Large scale: Sheshpeer system (Iran)

Simplified realistic models – next stage: parameters refined



1. Vertical saturated conductivity (*VKS*)
2. Saturated water content (*THTS*)
3. Direct recharge component (*CADS-RCH*)
4. Water temperature ($T_{Dir.rech.}$)
5. Hydraulic conductivity (K)
6. Specific yield (S_y)
7. Exchange coefficient (α_{ex})
8. Conduit diameter (d_c)
9. Conduit tortuosity (τ_c)
10. Wall roughness (k_c)
11. Width of CADS (W_{CADS})

variations 4a-e

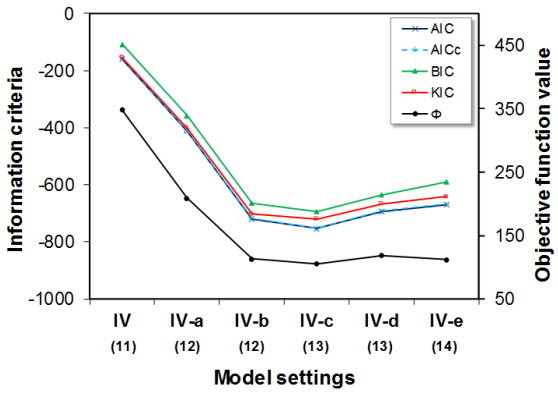
model complexity

Application

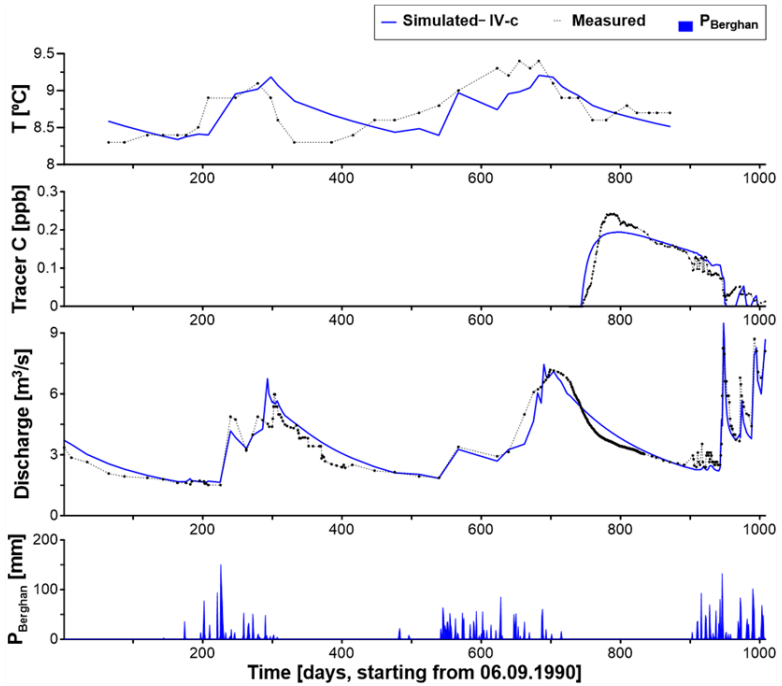
Inverse parameterization with multiple signals

Large scale: Sheshpeer system (Iran)

Simplified realistic models – next stage: Results



variation 4c is statistically supported



Conclusions and Outlook

Conclusions

MODFLOW based discrete conduit-continuum flow and transport model

- approach works at 1st and 2nd level for Sheshpeer catchment
- best model (4c) cannot be proved to represent "the truth" but is only found to be superior to other models tested
- proposed approach needs considerable amount of reliable data

Outlook

- develop "detailed realistic models" (3rd level of approach) for Sheshpeer catchment (maybe after additional field work)
- improve code performance: optimized discretization (trade-off between Taylor dispersion and numerical dispersion)
- try applications with diffuse pollution (e.g. nitrates)
- coupling with integrated hydrologic flow models

Merci pour votre attention!