Using probabilistic well vulnerability criteria for a risk-based preventive drinking water safety concept

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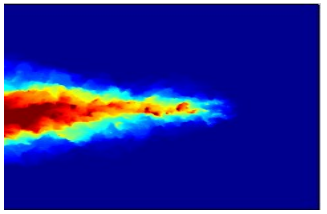
Road map

Need for risk-based decision making

Probabilistic Well Vulnerability Framework



Results & Discussion

From catchment to risk management

- Clean Groundwater
- Protection Zones
  - Advective-based
- Water Safety Plans
  - Hazard identificatio
  - Risk control

Modified after: http://civil.sharif.edu/~ataie/gwsite/gw%20image/ground2large.jpg

Need for more information

Time, Hazard, ...

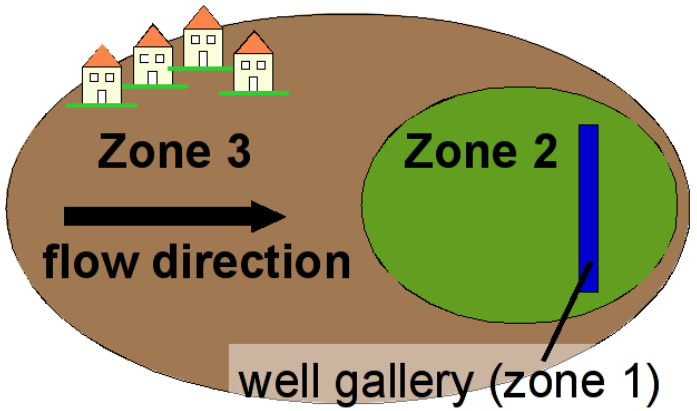
Well Vulnerability Criteria (Frind et. al 2006)

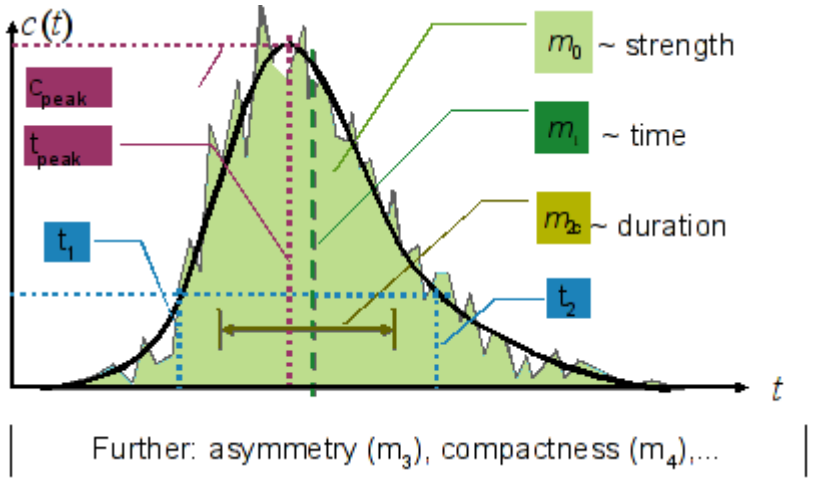
(a) The time between a spill event and arrival of peak concentration at the well,

(b) The level of peak concentration relative to the spill concentration,

(c) The time to breach a given threshold concentration (e.g. a drinking-water standard) and

(d) The time of exposure (exceeding the threshold concentration)





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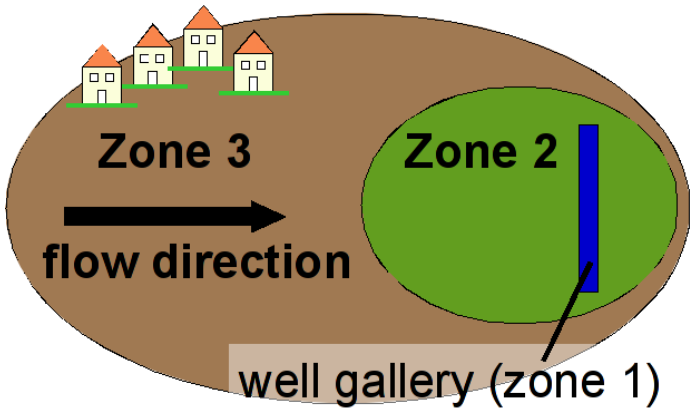
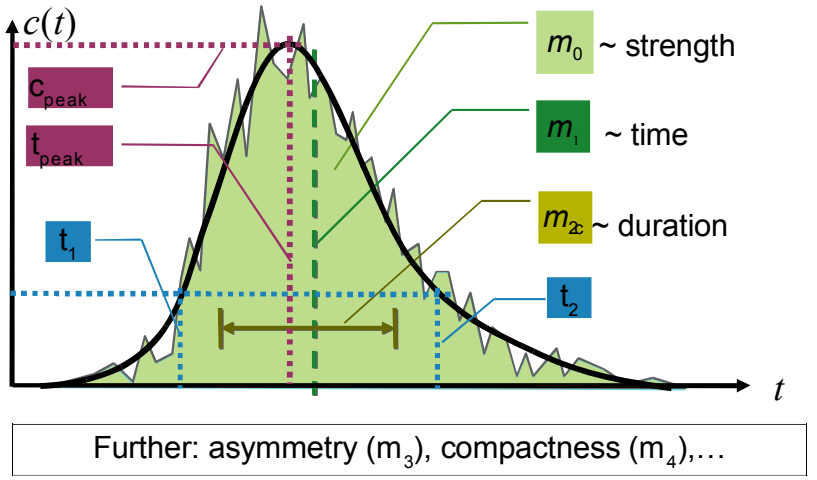




Further: asymmetry (m_3), compactness (m_4),…

A non-perfect world & Study Goal

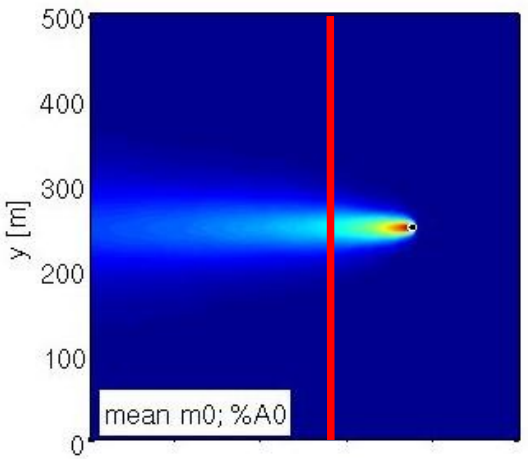
Borden site, Canada

- How homogeneous is nature?
  - Are deterministic approaches valid?
  - Uncertain factors:
    - Data
    - Parameter
    - Model

- Risk and Uncertainty are like brother and sister
  - Probabilistic vulnerability maps
    - Catchment scale
    - Mass flux quantification
  - Well Vulnerability Isopercentiles (VIP)

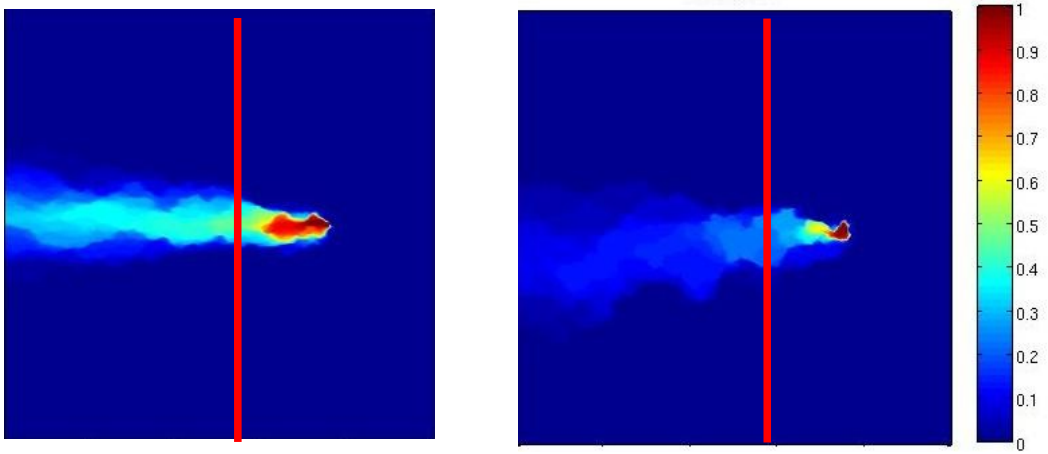
Probabilistic Exposure Risk Assessment
R = entry prop. x damage

Distinguish between dilution and uncertainty



Macrodispersion

Mean K = 5.e-4 m/s
η = 0.35

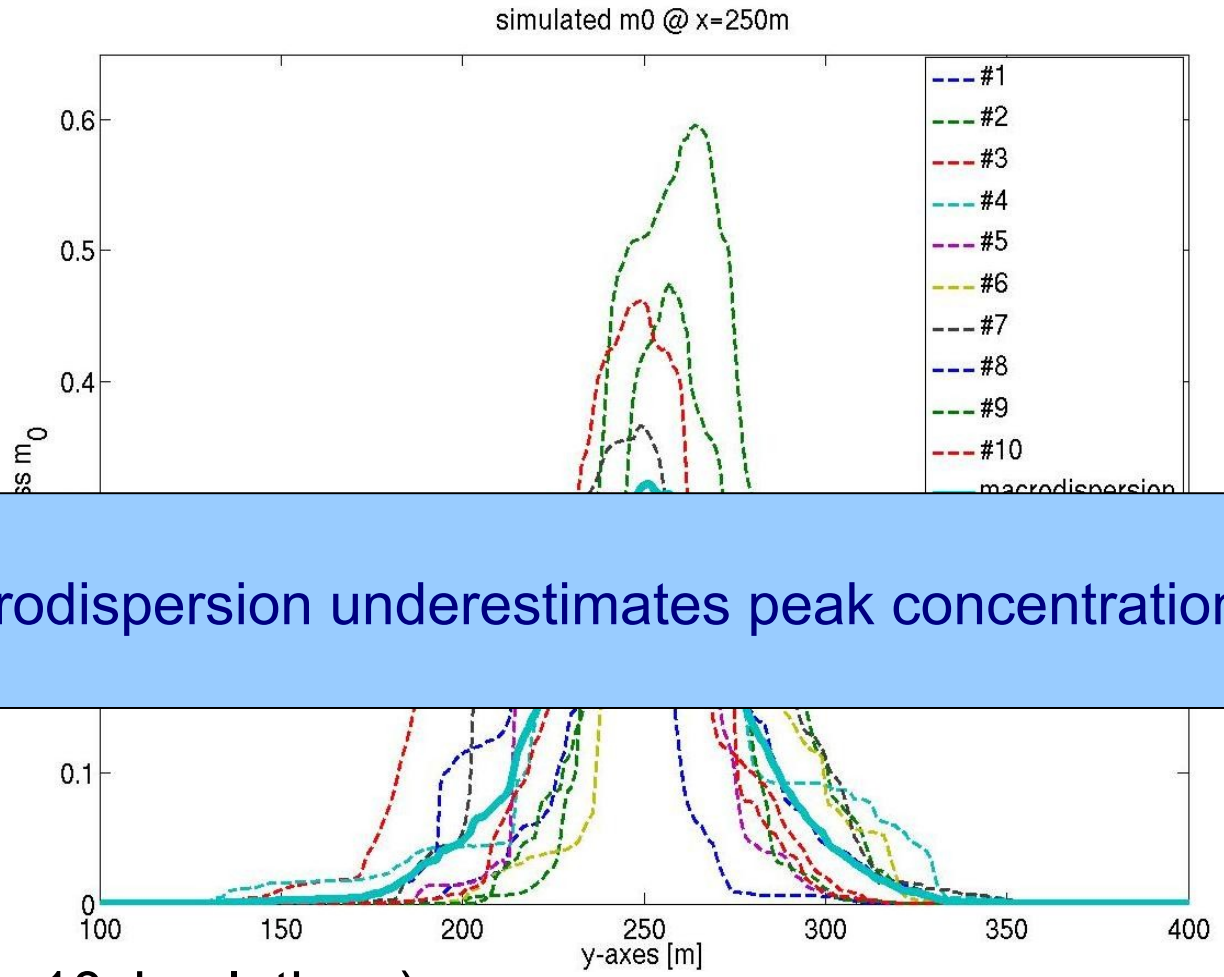


Local scale dispersion

α_L = 2.5 α_T = 0.25

Macrodispersion shows dilution of mass where there is none!

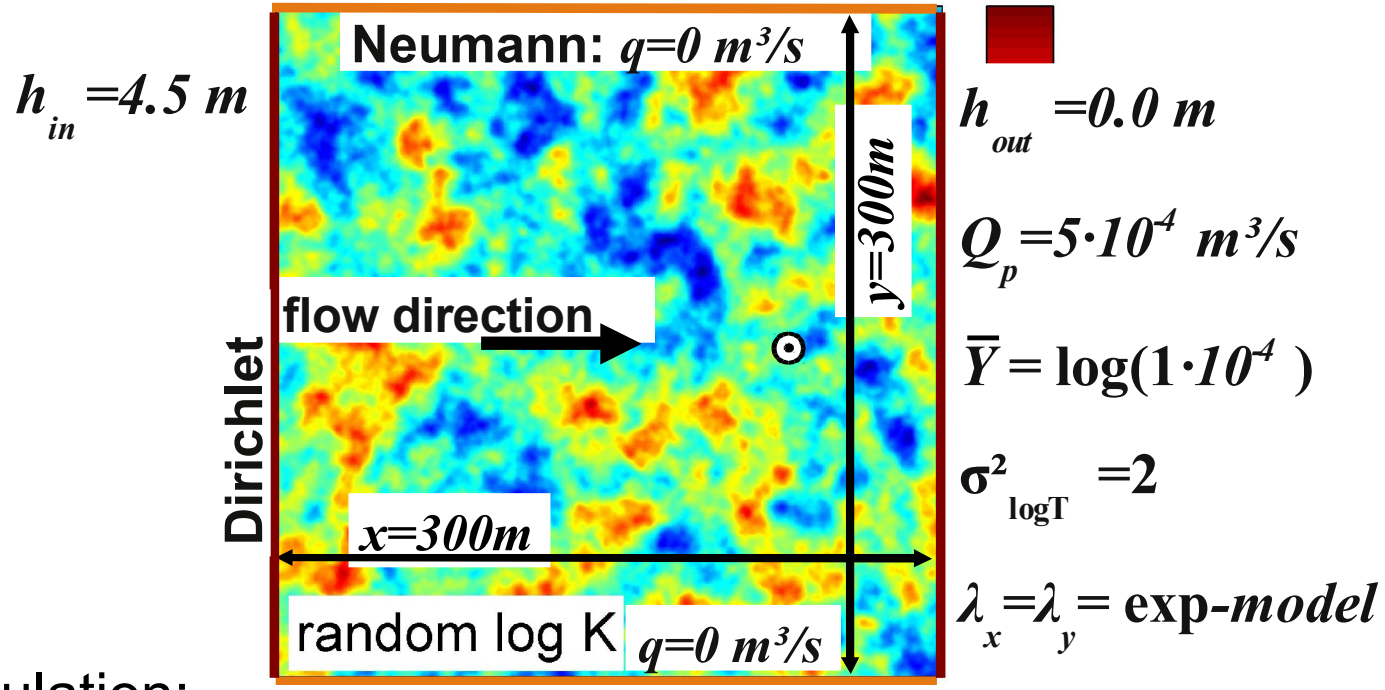
Good reason to use Monte Carlo!



Macrodispersion underestimates peak concentration!

1-D-Sketch (n=10simulations)

Illustrative example



Expensive simulation:

- Monte Carlo
- Fine discretization
- Time-dependant concentration profile

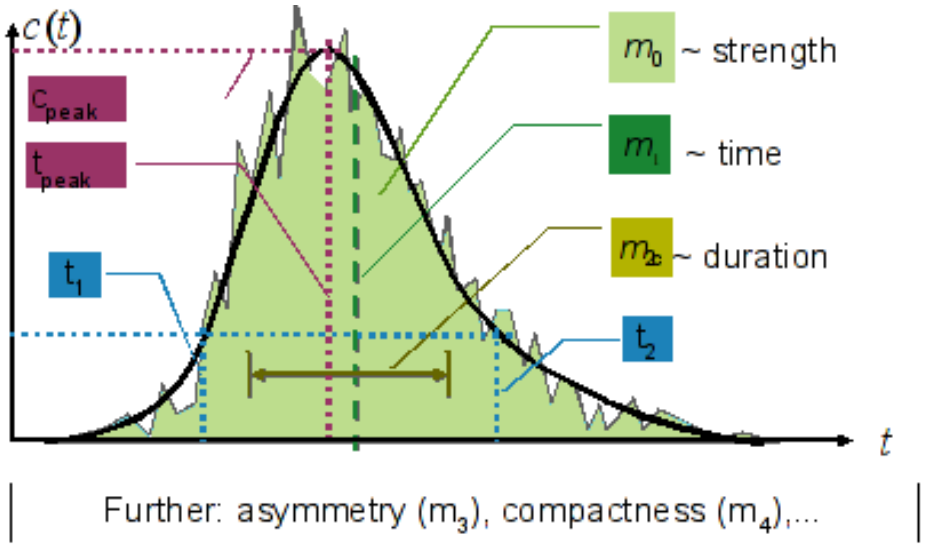
Concentration profile (Temporal moments)

- Model reduction
- BTC characteristics
  - mean
  - dispersion
  - ...
- Reverse formulation
- ADE-based equ.:

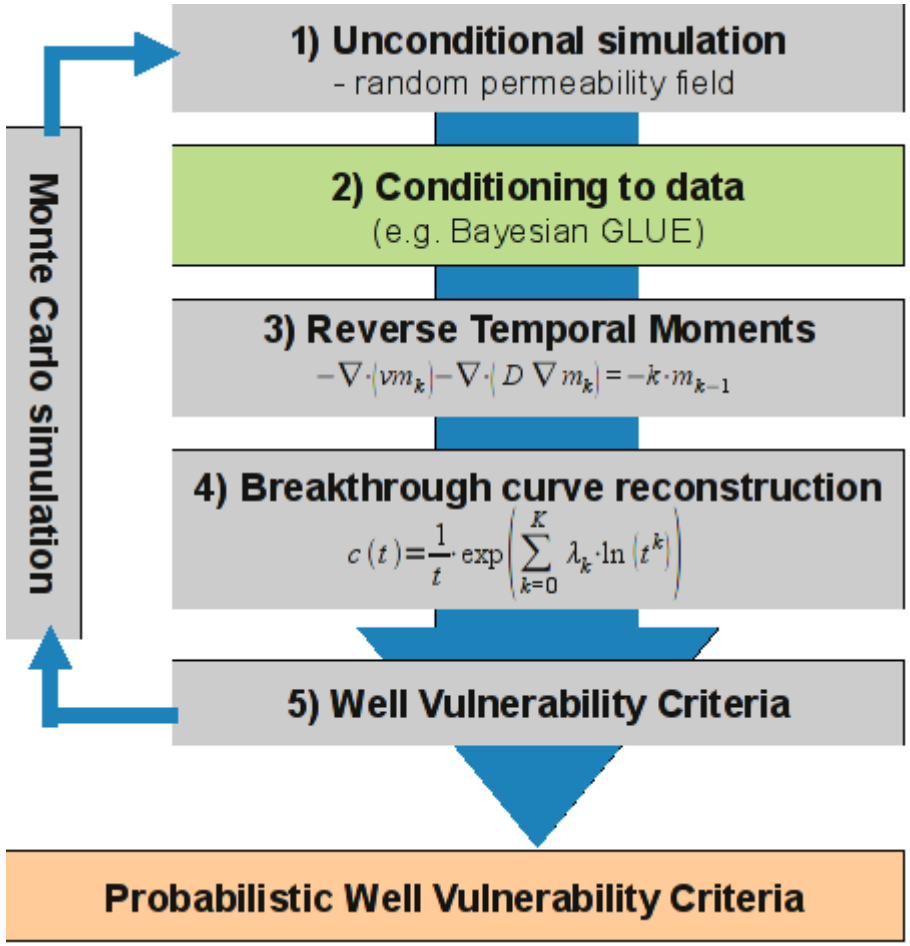
$$-\nabla\cdot\left(vm_k\right)-\nabla\cdot\left(D\,\nabla m_k\right)=-k\cdot m_{k-1}$$

- Full concentration history w/ Maximum Entropy in log-time

$$c(t)=\frac{1}{t}\cdot\exp\left(\sum_{k=0}^{K}\lambda_k\cdot\ln\left(t^k\right)\right)$$

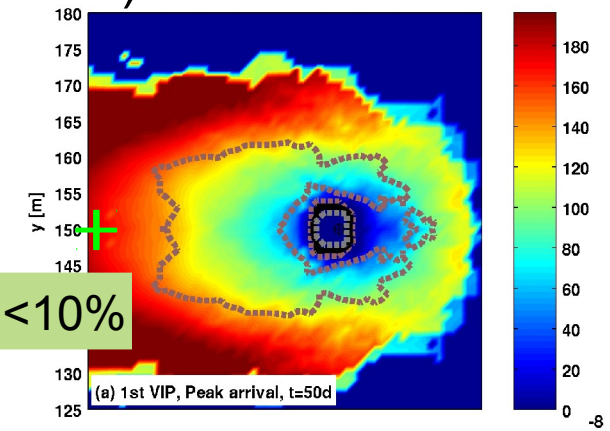


Probabilistic framework



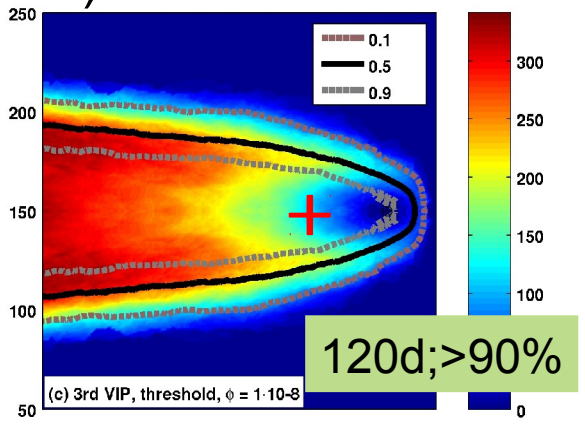
Results

a) Peak arrival

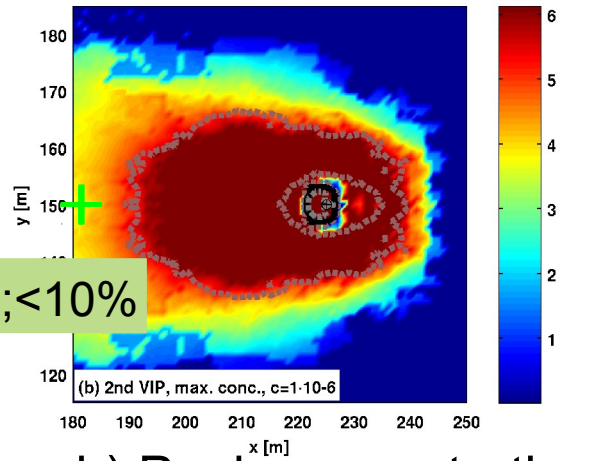


160d;<10%

c) Threshold time

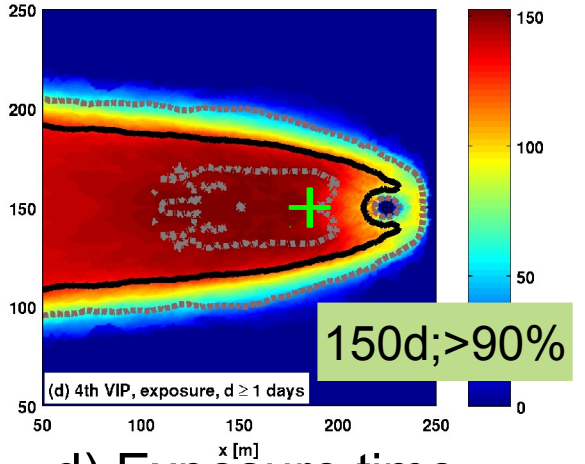


120d;>90%



3.5e-8;<10%

b) Peak concentration



150d;>90%

d) Exposure time

Isopercentiles:
0.1, 0.5, 0.9

# of simulations:
n=100

Discussion

Valuable **Management** Tool:

- Vulnerability isopercentile (VIP) maps are easy to understand
- VIPs support catchment managers with indispensible information
- Allows prioritization of contamination sites
- Justification to regulatory authorities (planning permission)

Technical features:

- Conditioning method can be arbitrarily chosen (e.g. GLUE, EnKF)
- Approach is independent of dimensionality and boundary cond.
- Computational savings and information gain justify model reduction

Future Work

- Data assimilation by Bayesian GLUE
- Collaboration with DTU extension to longterm sources

- Adopting the approach to a fracture-matrix system
- Real case application to a fractured system

Thanks to ...

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