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Nick Woodman
William Powrie

When does a fracture matter for a borehole heat exchanger ?

Engineering and the Environment
The University of Southampton

GSHPA technical seminar
Leeds, 24 May 2018

Intro



neighbour scheduling underestimate carbon ecosystem
imbalance disadvantages alternative sustainable
anisotropic hydrogeological reliable
hybrid integrated renewable benefits financial
cost capacity advantages challenges
regulation equilibrium assumptions
accuracy heterogeneous management
homogeneous storage longterm
safety policy isotropic transient
understanding regional impacts sensitivity
impacts multiple
gas bacteria
urban ideal green
fossil economical cycle
co2 piles licence plume
expenses real efficiency
interaction growth
steady dispersion targets
surrounding layered
distance design uncertainty
optimization discharge
space improvement
advection interference ecological
environment emissions geology
intermittent overestimate climate guidance
savings undesirable incentive
legislation season solar innovative
sensitivity

460
research
papers

Intro

Methods

Fracture

Groundwater

Uncertainty

Sensitivity

Conclusion

Intro

$$\text{Apparent thermal conductivity} = \text{Effective thermal conductivity} +$$

Darcy velocity
*
dispersivity tensor
*
heat capacity
of fluid

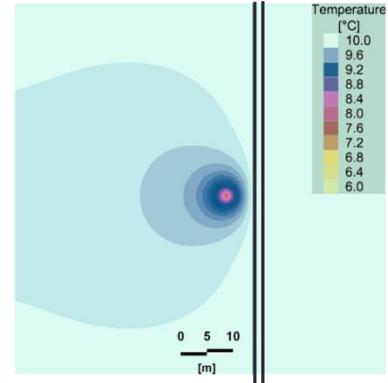
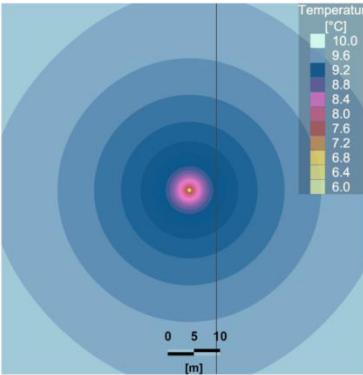
(Sauty *et al.*, 1982)



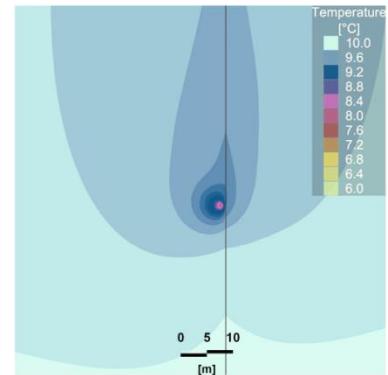
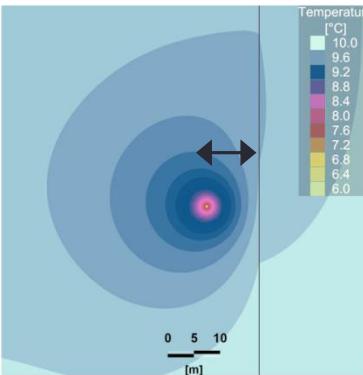
Intro

Dehkordi *et al.*, 2015

Fracture aperture



Fracture distance



Intro

Methods

Fracture

Groundwater

Uncertainty

Sensitivity

Conclusion



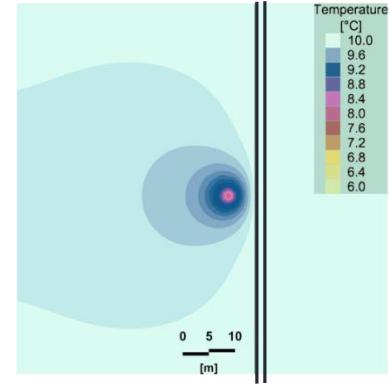
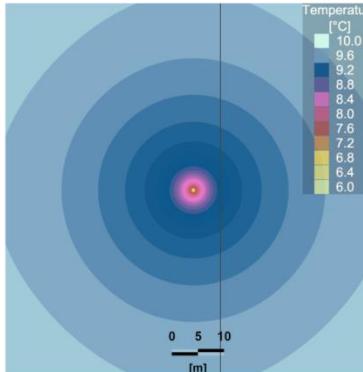
Intro

Fracture in
impermeable
matrix

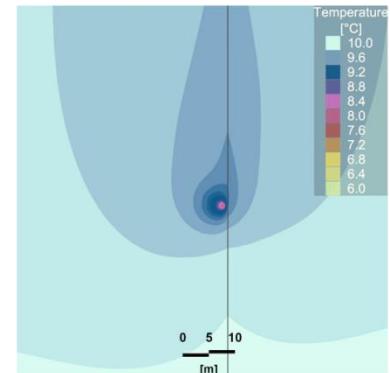
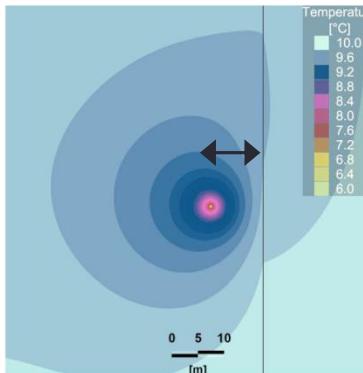
→ ↑ apparent
thermal
conductivity

Dehkordi *et al.*, 2015

Fracture aperture



Fracture distance



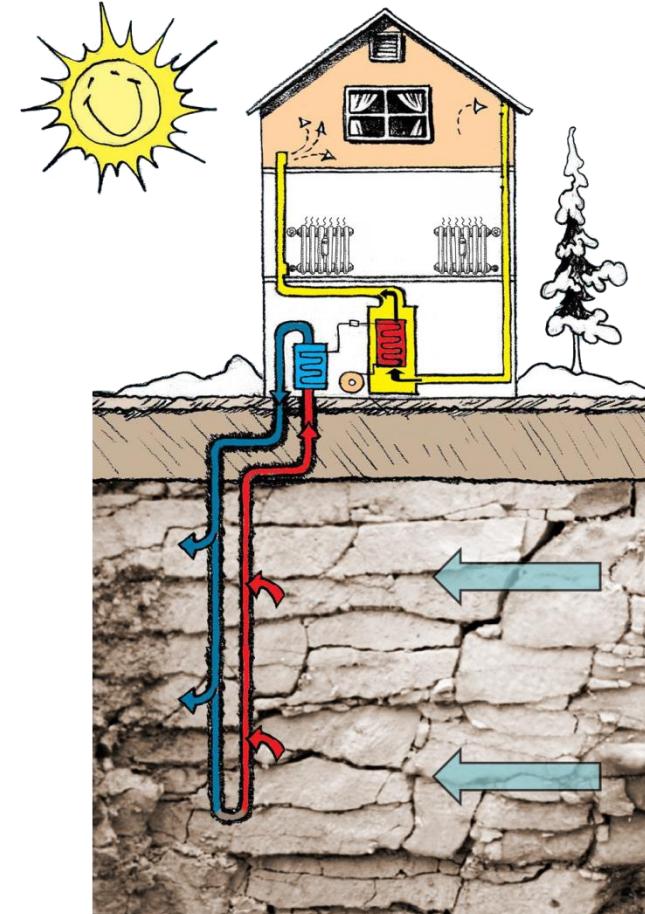
Intro



fracture influence

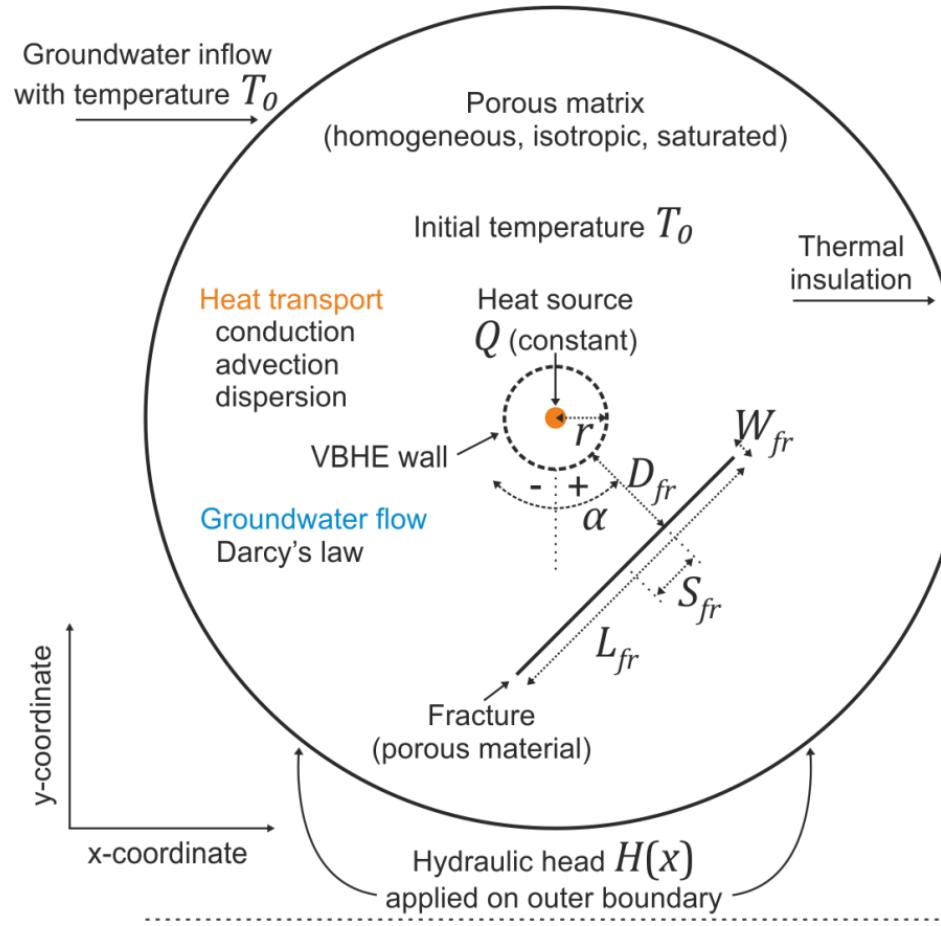
groundwater & uncertainty

effective parameters

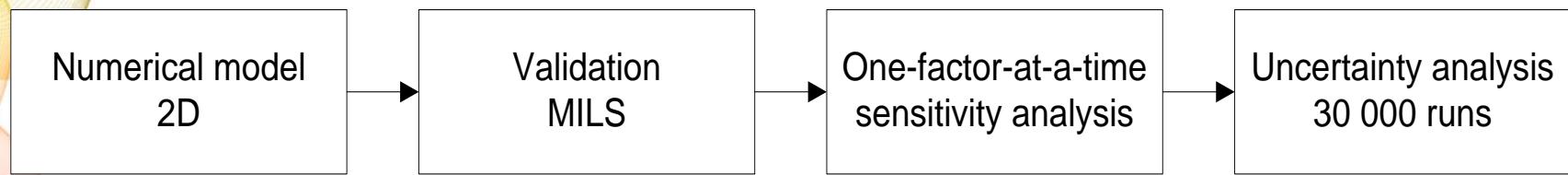




Concept



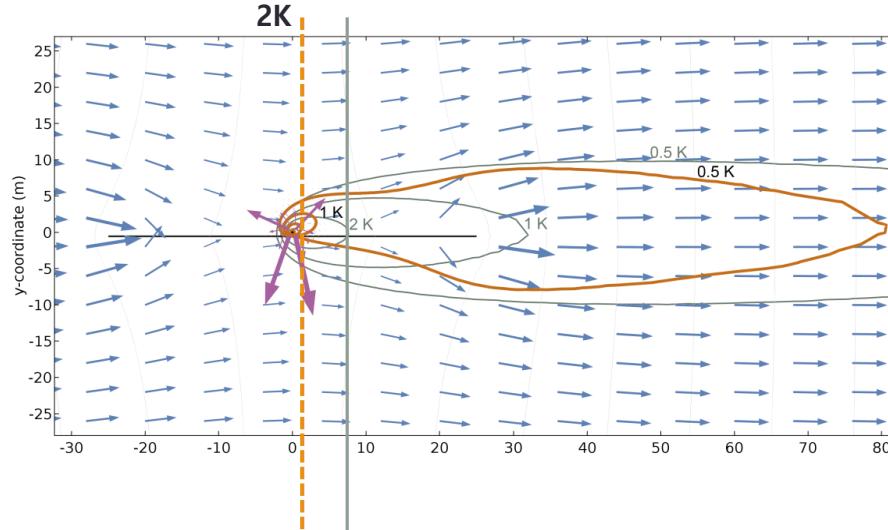
Workflow





Example

Distance 0.5 m

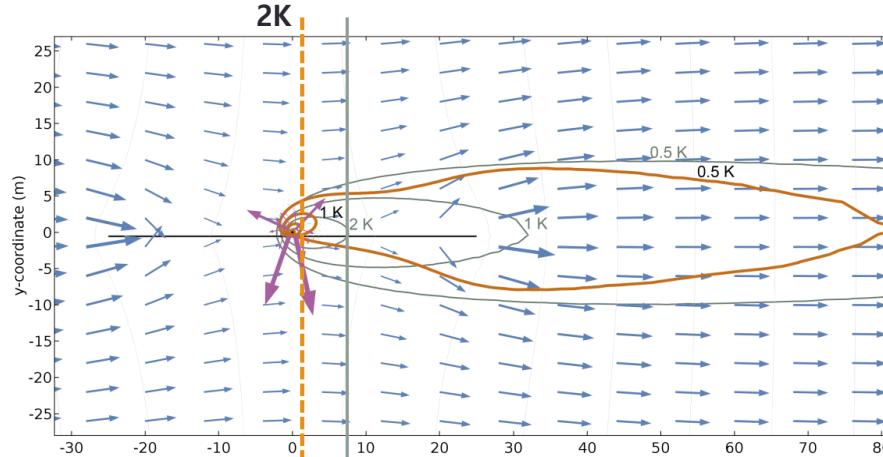


after 30 years



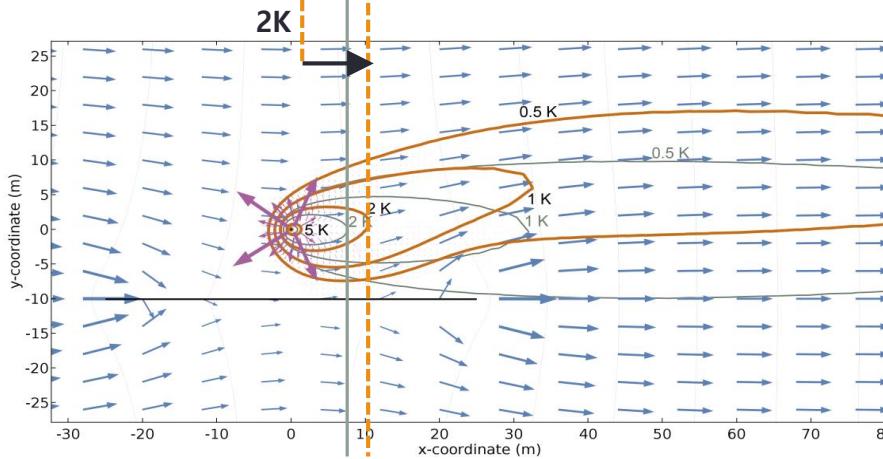
Example

Distance 0.5 m

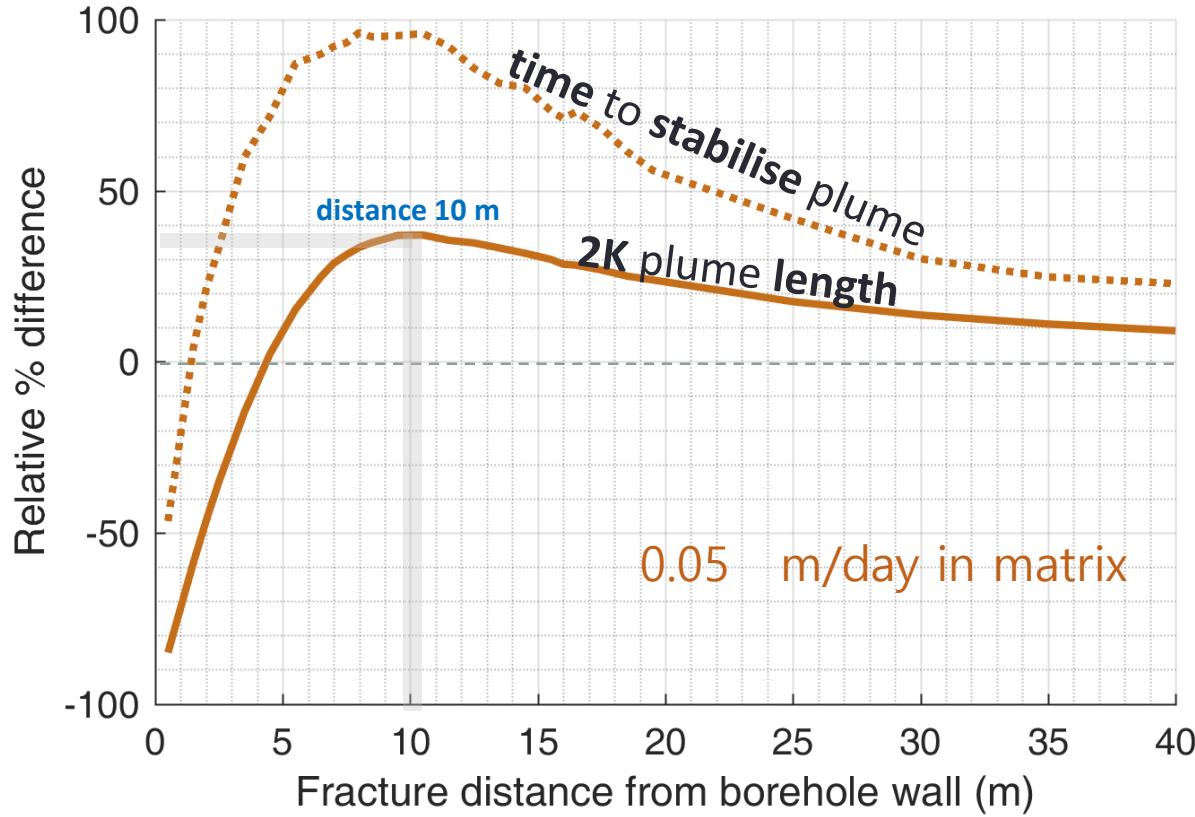


after 30 years

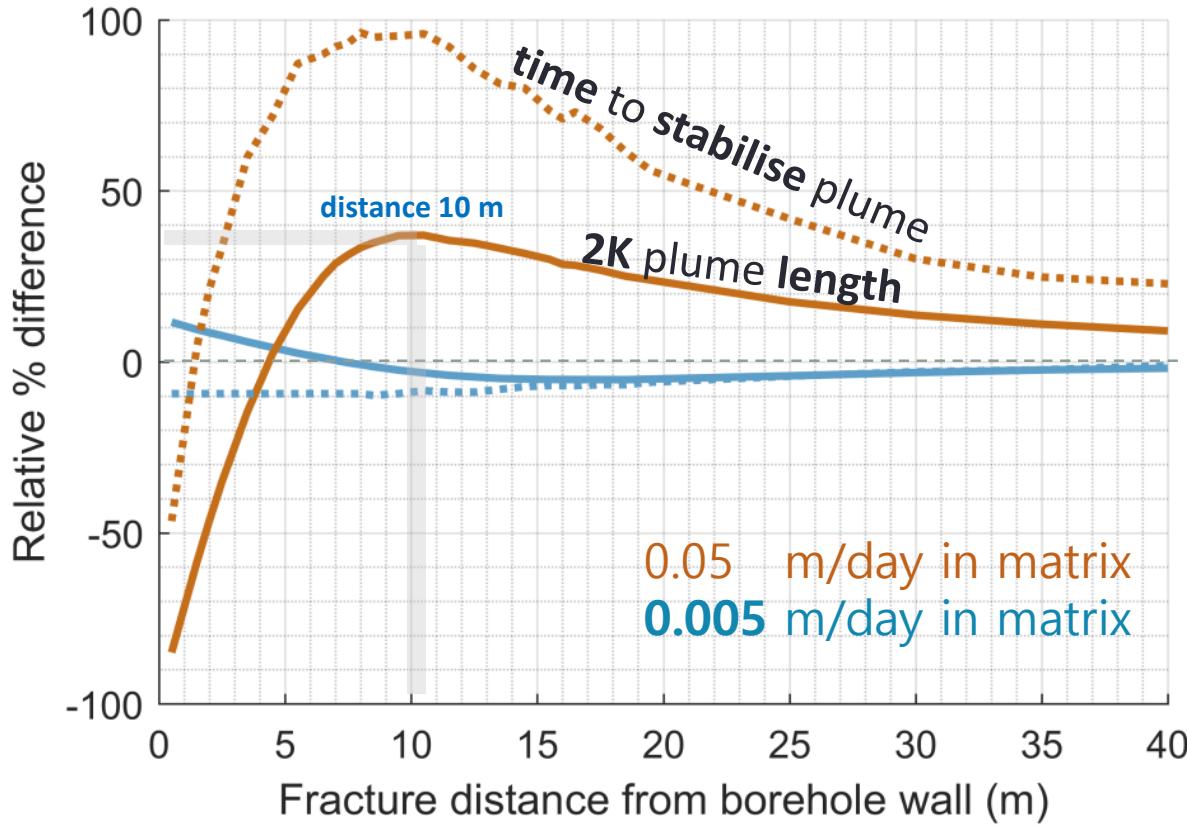
Distance 10 m



Effects

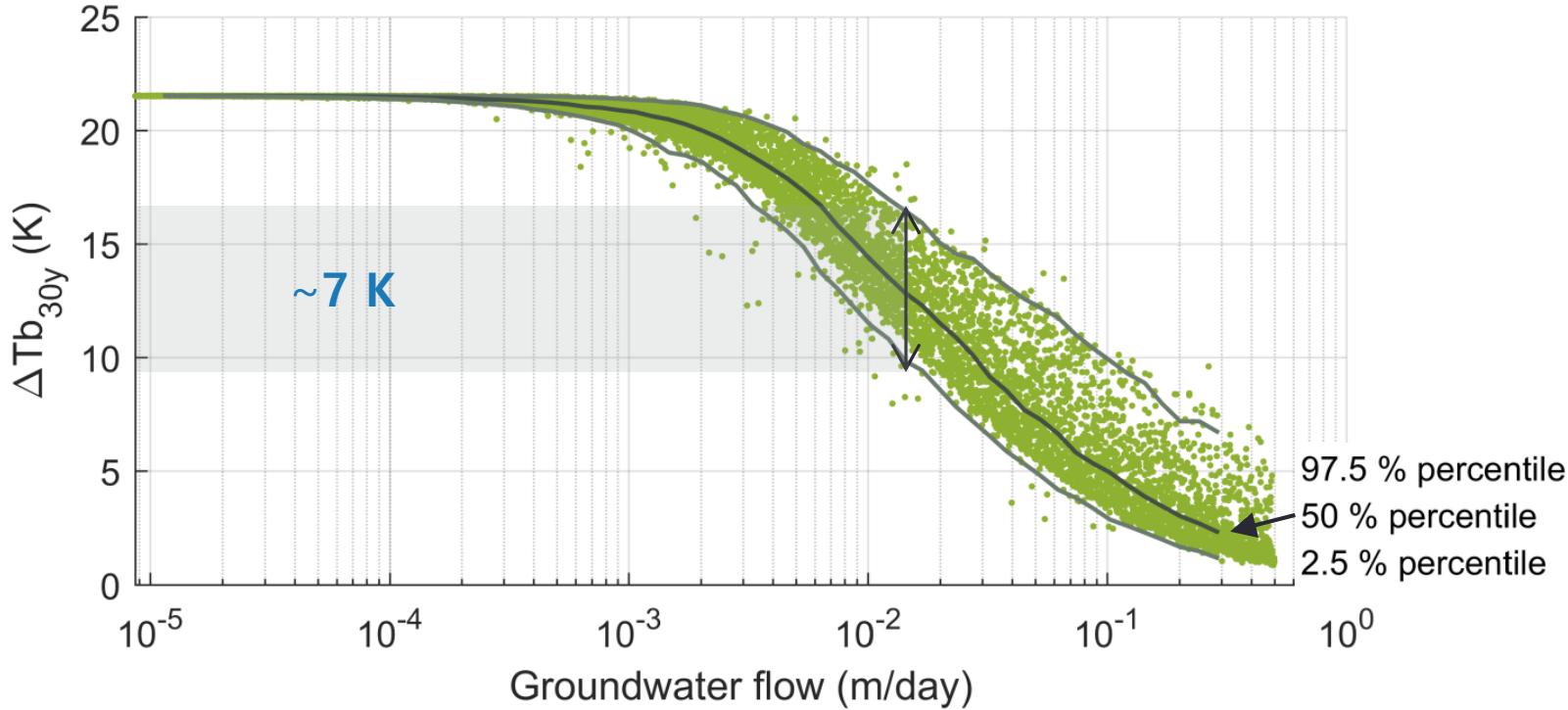


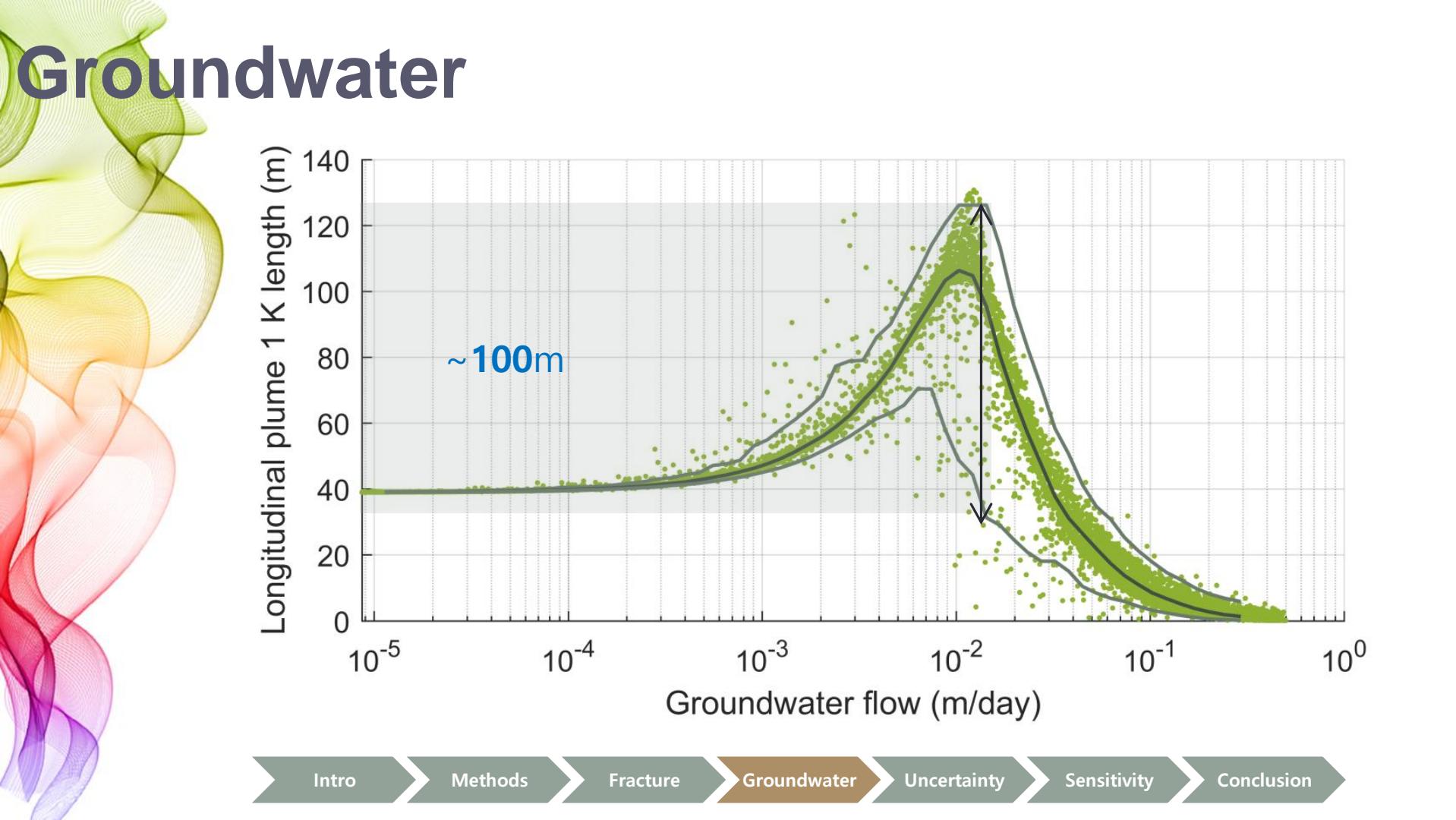
Effects





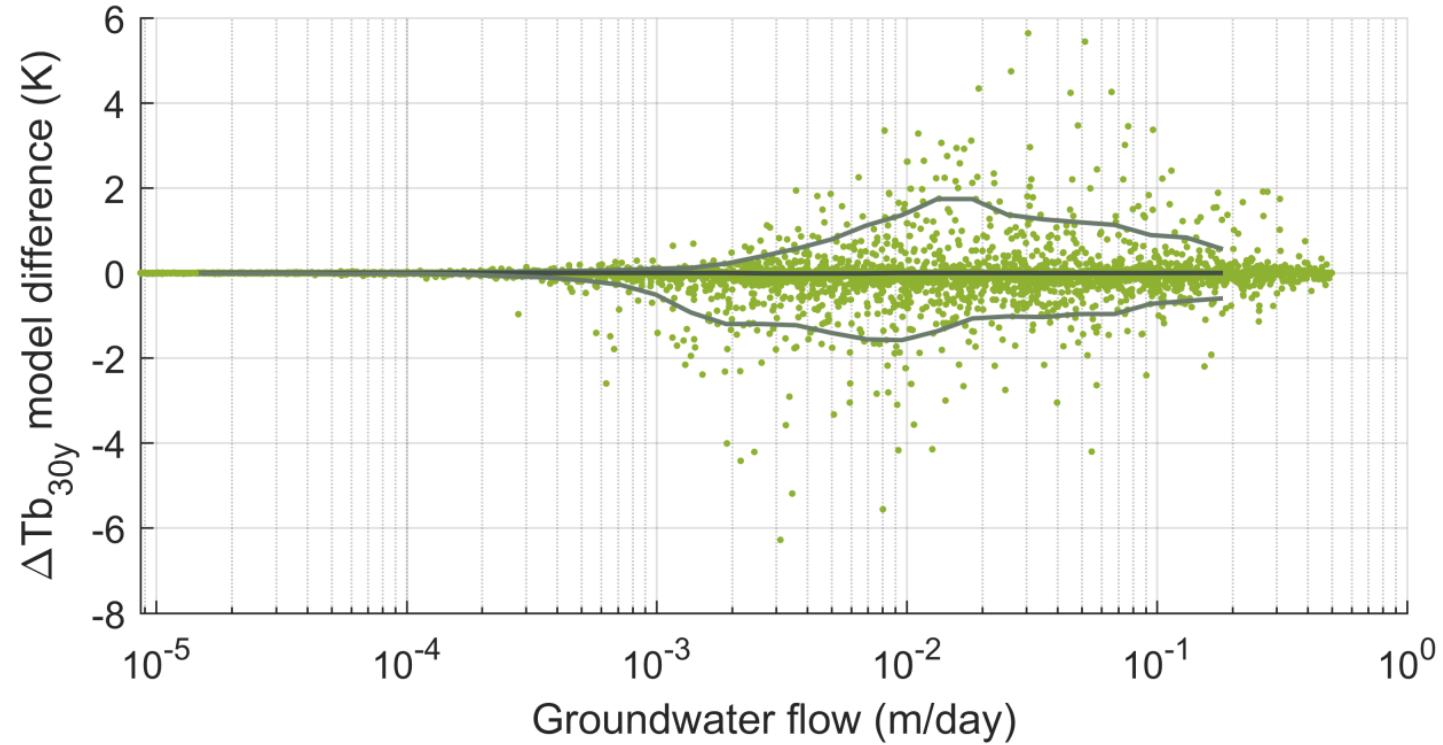
Groundwater

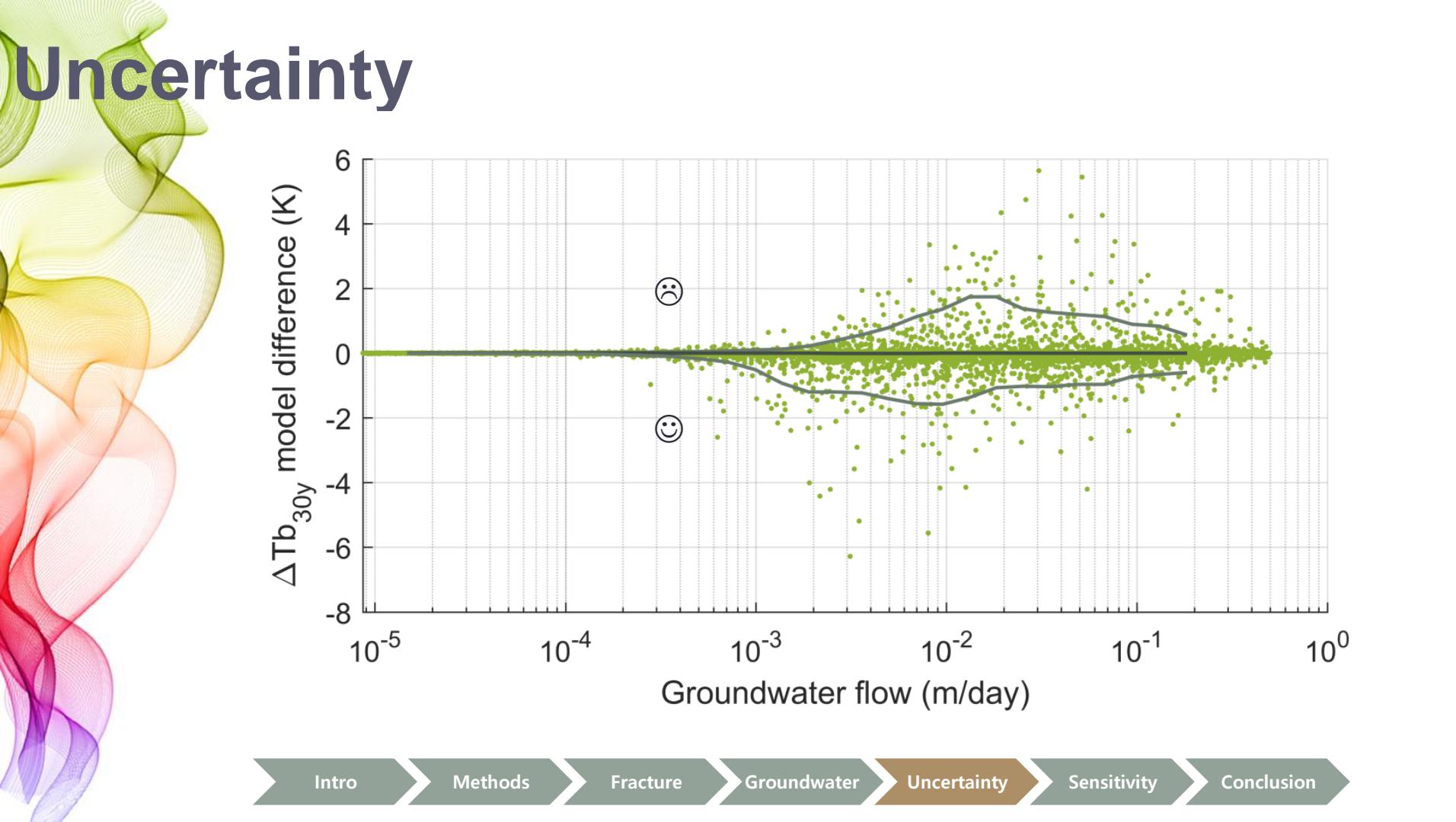


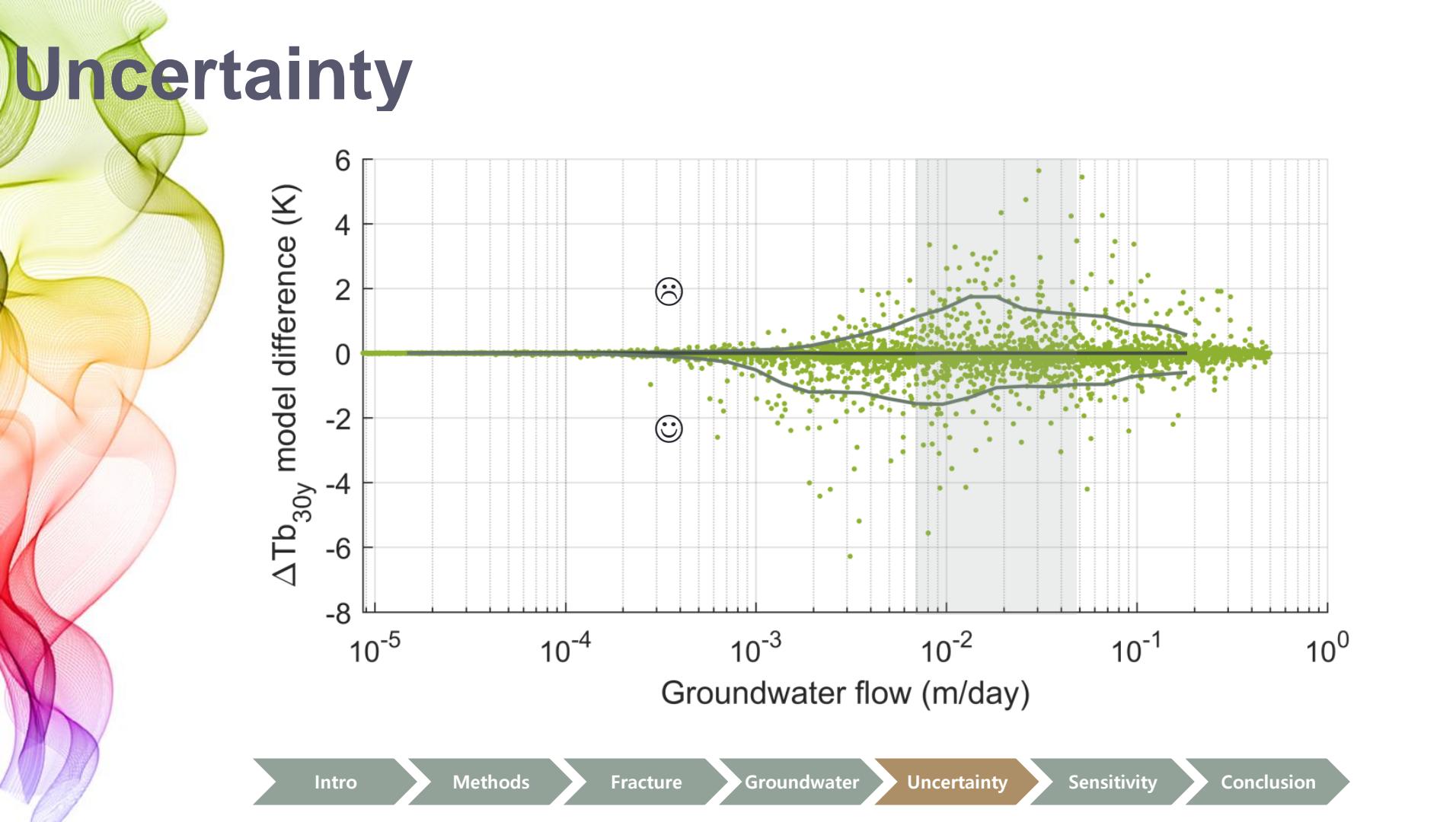




Uncertainty

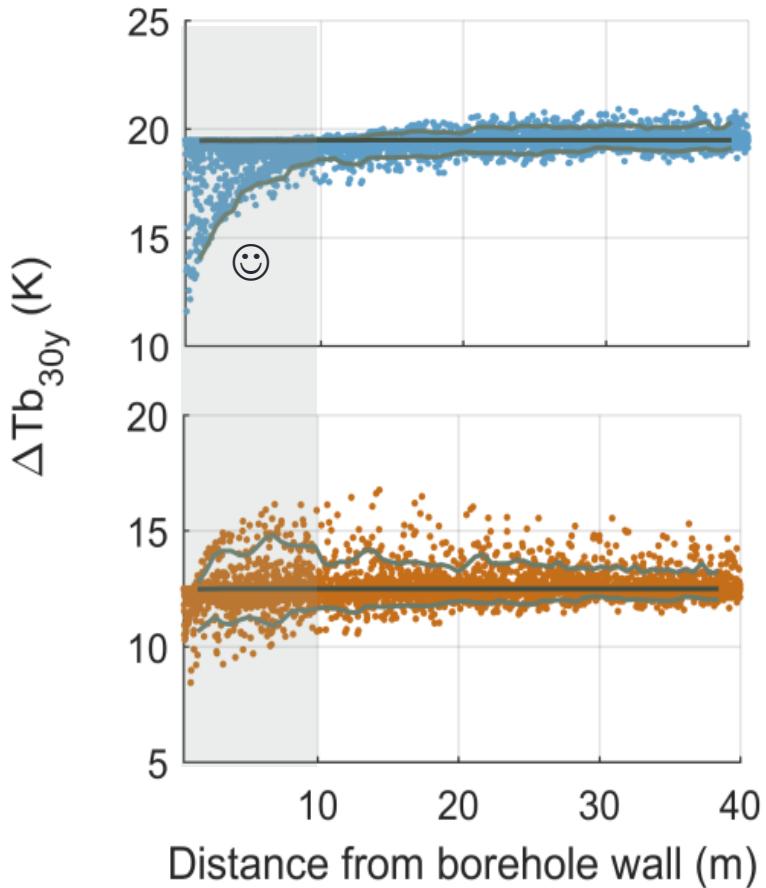








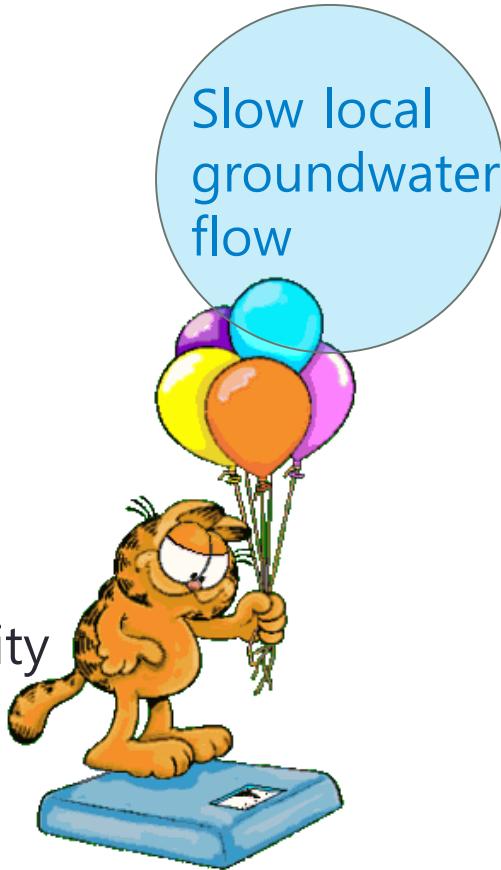
Sensitivity



0.005 m/day in matrix

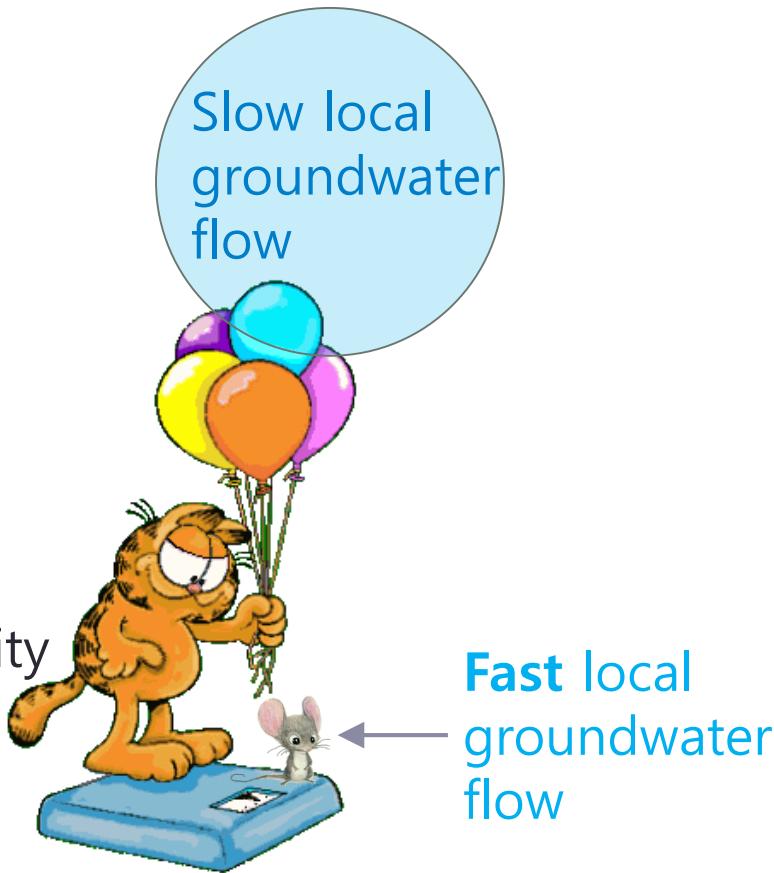
0.05 m/day in matrix

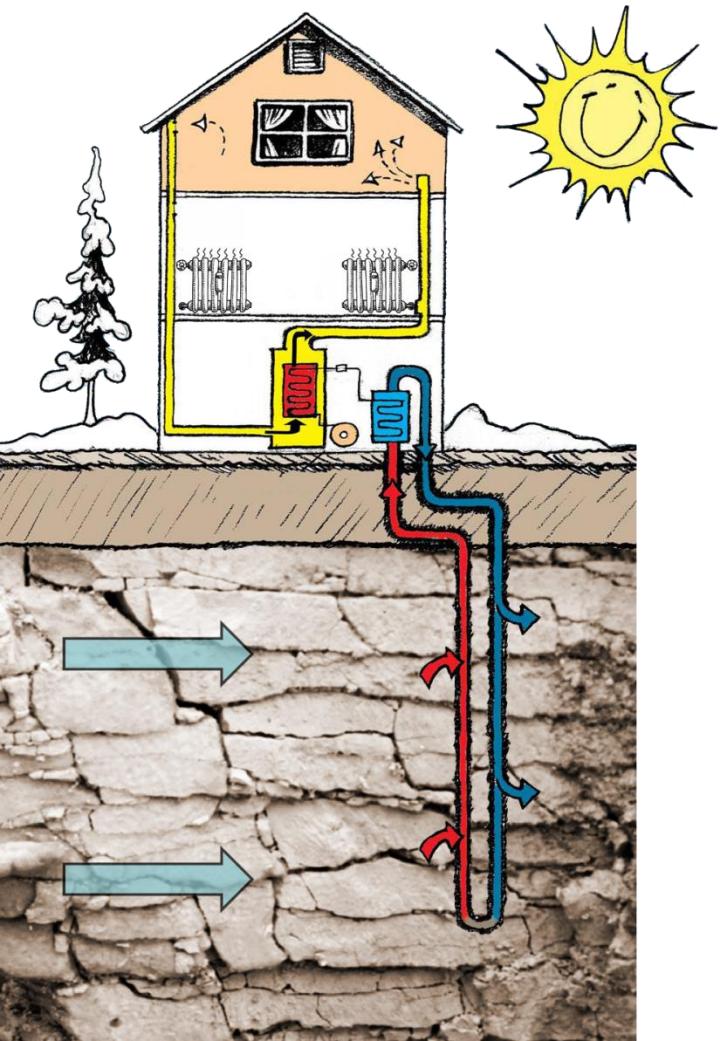
Apparent thermal conductivity





**Apparent
thermal
conductivity**





Thank you

Questions & advice welcome

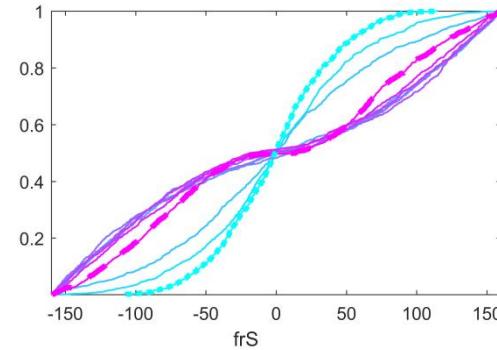
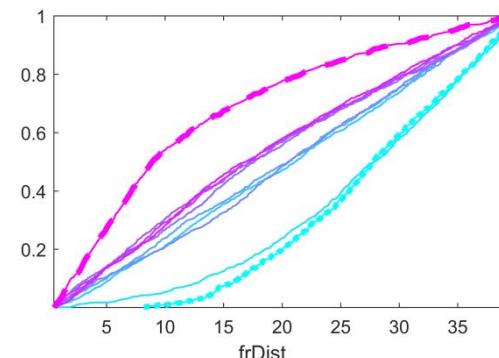
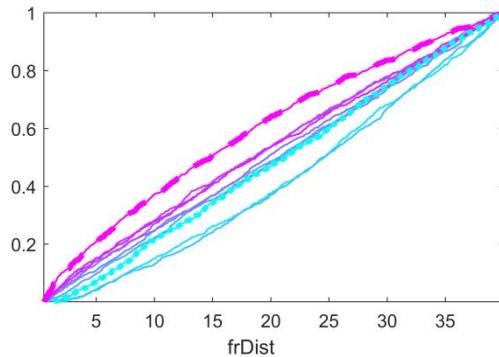
Oleksandra Pedchenko
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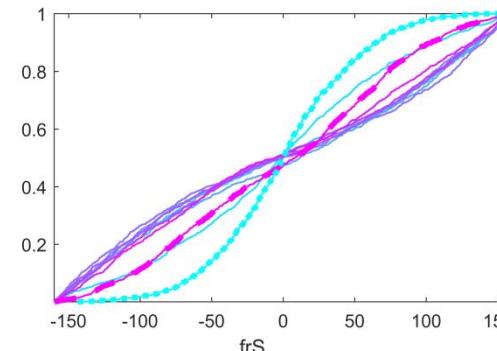
Q&A supplements



Sensitivity

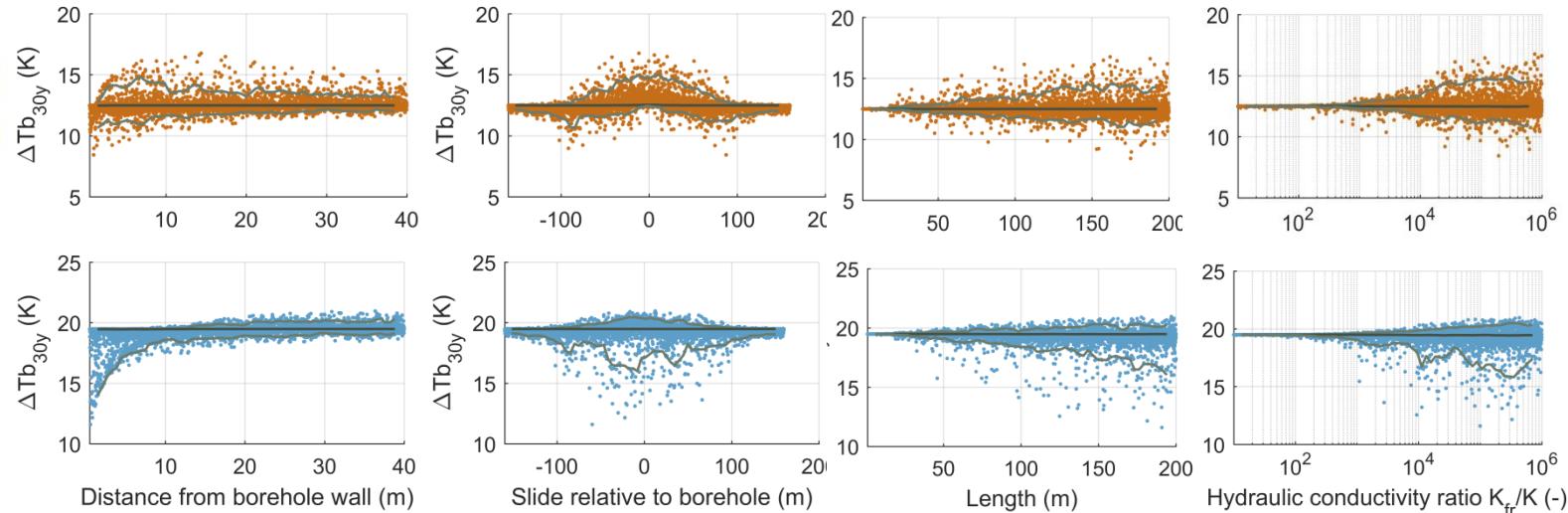


0.05 m/day

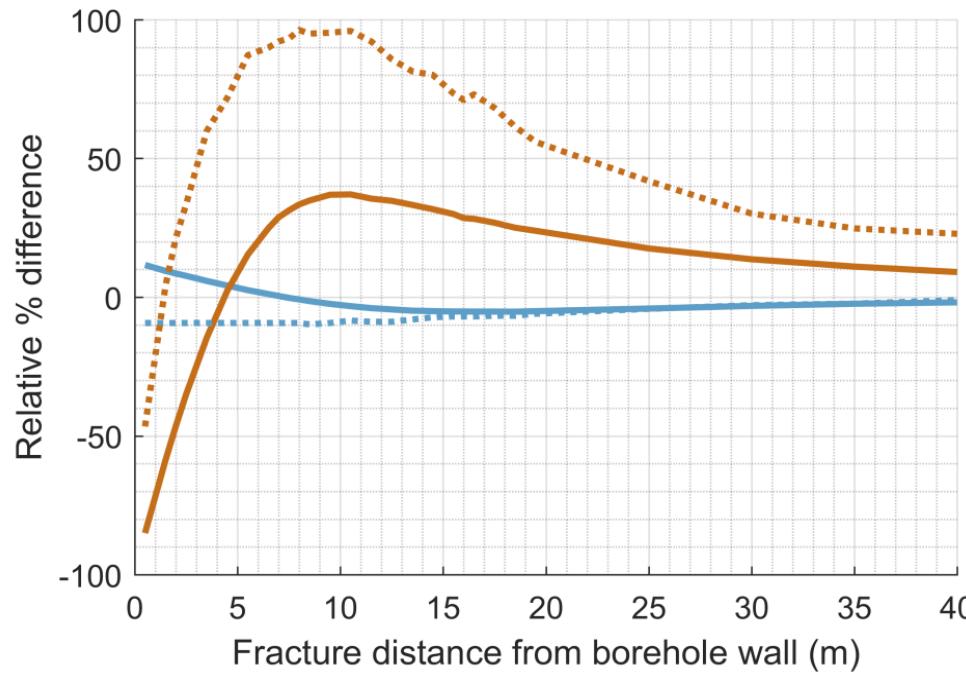


0.005 m/day

Uncertainty



0.005 m/day in matrix



- $X_{\text{plume} 2.0K}$ 30y: 46.0 - 54.2 m (nMILS: 48.6 m), $v_D = 0.005 \text{ m/day}$
- $X_{\text{plume} 2.0K}$ 30y: 1.1 - 10.5 m (nMILS: 7.7 m), $v_D = 0.050 \text{ m/day}$
- TimeSS_{plume}: 75.9 - 83.2 y (nMILS: 84.1 y), $v_D = 0.005 \text{ m/day}$
- TimeSS_{plume}: 0.4 - 1.6 y (nMILS: 0.8 y), $v_D = 0.050 \text{ m/day}$

Intro

Apparent thermal conductivity

$$\lambda_a = \lambda_A + \alpha \gamma_F |v|$$

effective thermal conductivity of porous medium

dispersivity tensor

heat capacity of fluid

Darcy velocity

(Sauty et al 1982)