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Bayesian inference of radiogenic helium-4 and hydraulic head observations: Towards the implementation of a neural network surrogate.

An application the Neogene aquifer, Belgium.

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Outline

Background and objectives

Methods

Results

Conclusions

Q&A

Background Information

Information content in Groundwater levels is limited.

Complexity unsuccessfully captured.

Traditional methods only use one type of data (state-variable).

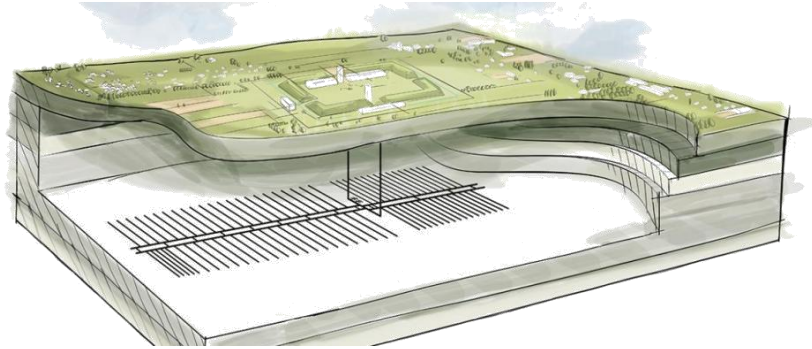
Implementation of other variables ('unconventional') suggested by several studies.

Challenging application: underrepresented in the general practice.

Additional state-variable observations would improve understanding on groundwater systems.

Objectives

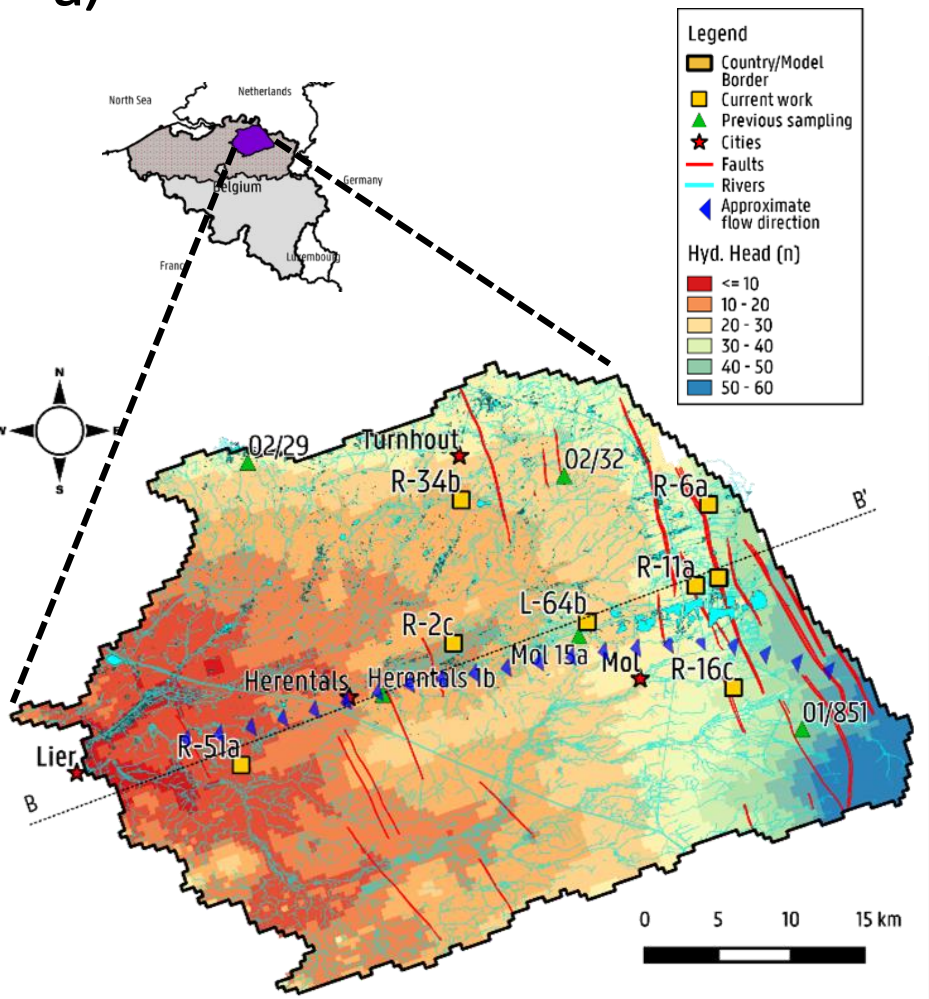
"Assess unconventional state variables to constrain groundwater model parameters to reduce the uncertainty on model outcomes by joint inversion"



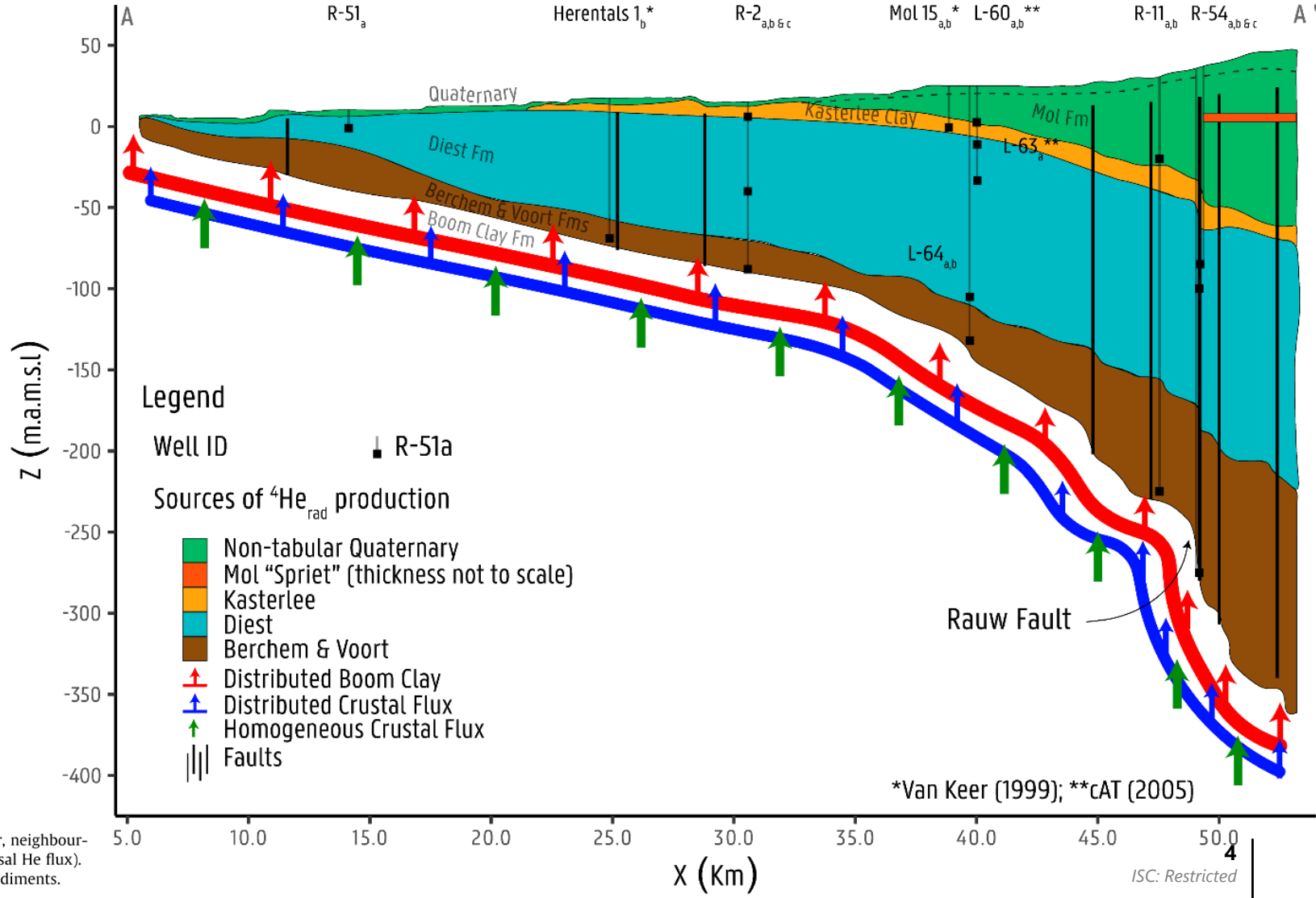
Studies are being performed on **potential disposal systems for radioactive waste.**

Study area – The Neogene aquifer, Flanders (BE).

a)



b) $$J'_{^4He} = \Lambda * \frac{\rho_R}{\rho_w} * \frac{1-\varphi}{\varphi} * (1.19x10^{-13}[U] + 2.88\ x\ 10^{-14}[Th])$$



(a) In situ production within the aquifer matrix.
(b) Helium inflow from deeper parts of the aquifer, neighbouring layers or of the whole underlying crust (basal He flux).
(c) Release of entrapped He from newly formed sediments.

Methods.

Groundwater data compilation (historical) and collection

Joint interpretation of age tracer data (^{14}C, ^{4}He, $^{3}H/^{3}He$) and advective particle ages (MODPATH, 2016) [in review]

$^{4}He_{rad}$ production

Development of $^{4}He_{rad}$ transport model with MT3D-USGS

Coupled groundwater flow and $^{4}He_{rad}$ transport models inversion ($DREAM_{zs}$) [in prep.]

Surrogate NN coupled model inversion (DREAM[1] or other MCMC)

Coupled flow/transport model

Joint Inversion SPSO2011*

Parameters

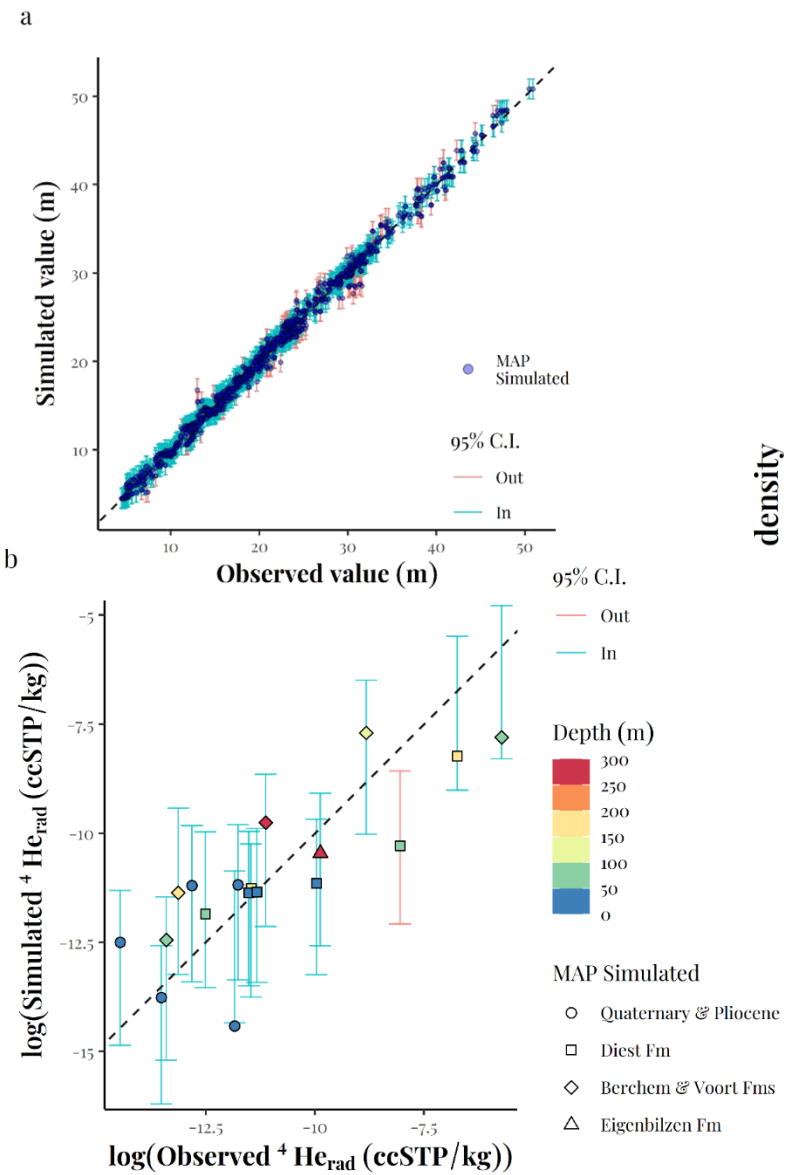
Flow: conductivity.
Transport: diffusion, source release factor.

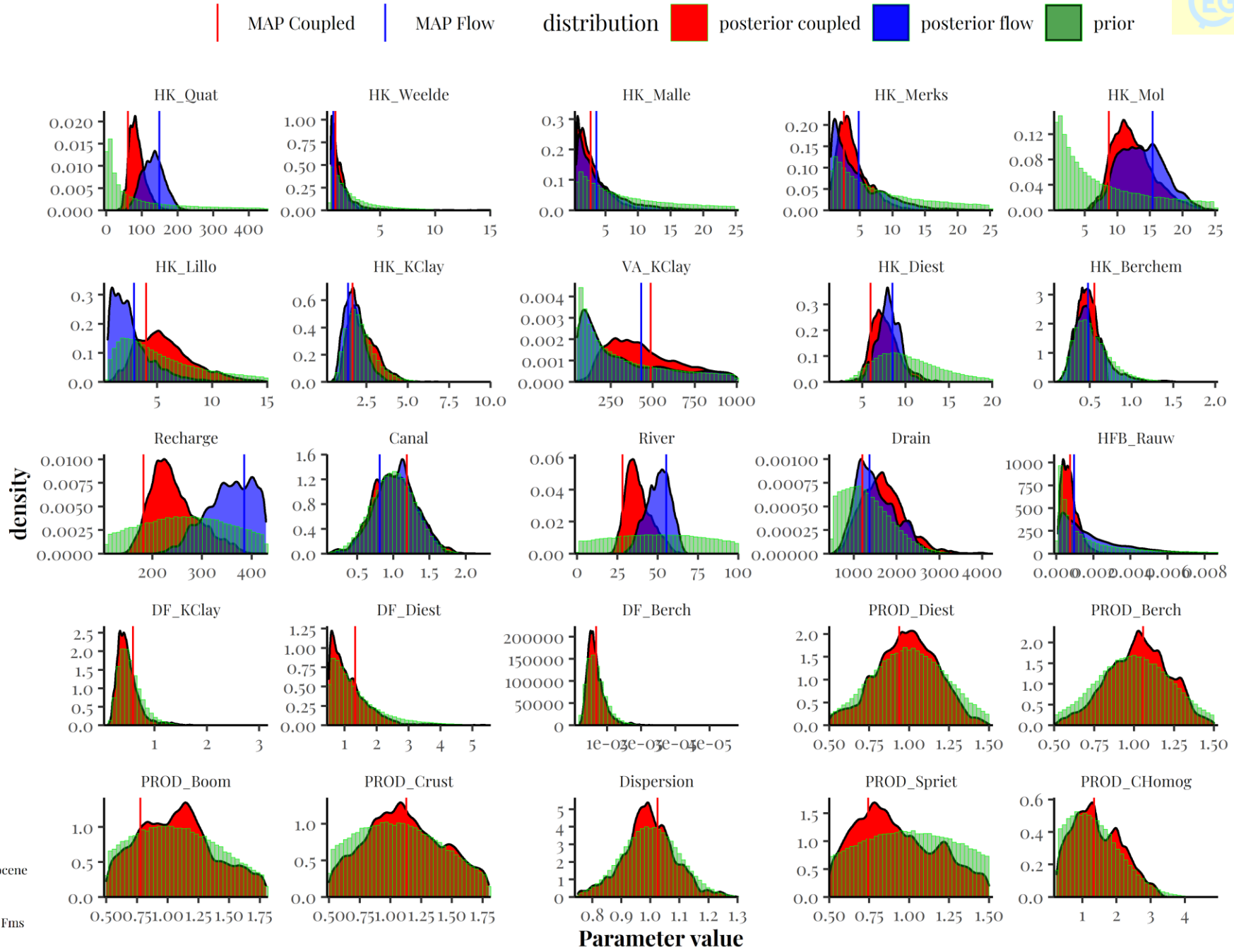
Groundwater flow model (MODFLOW-2005) [Casillas-Trasvina et al., 2021]

Reference *standard particle swarm optimization 2011.

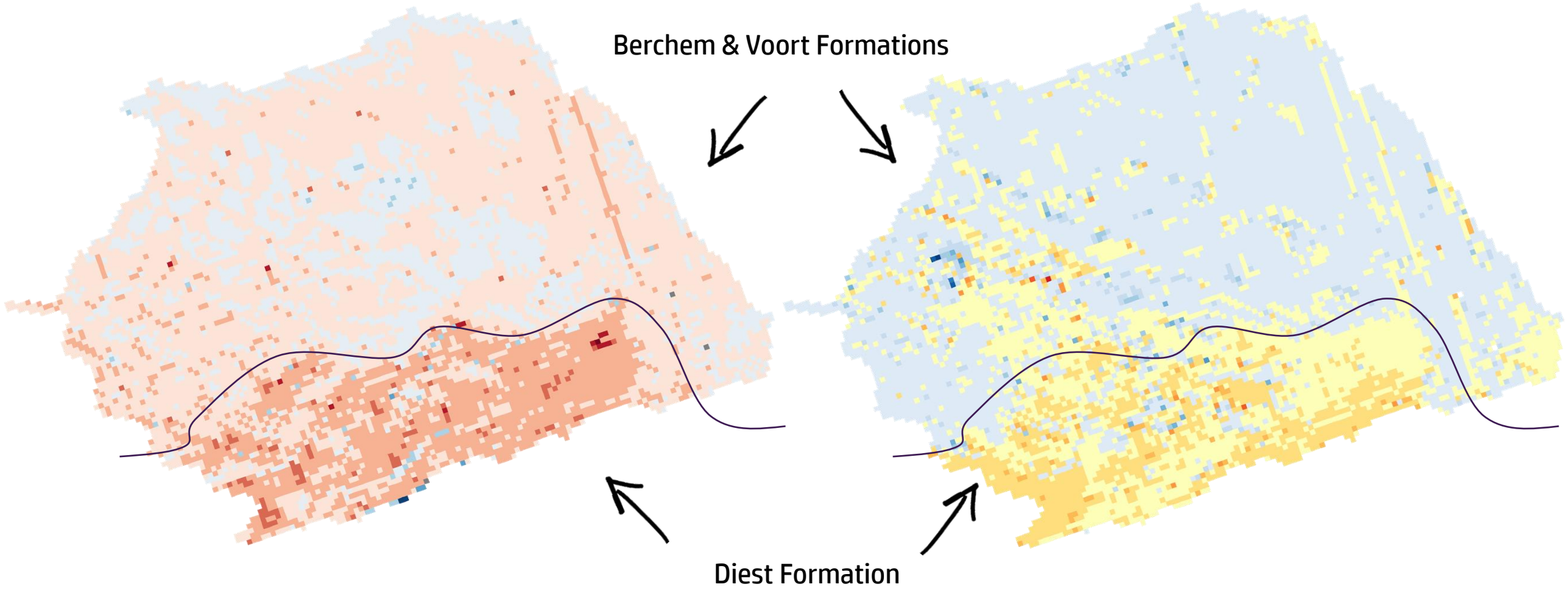
1 DiffeRential Evolution Adaptive Metropolis (DREAM(zs), efficient global MCMC even in high-dimensional spaces) (Laloy, 2012)

Results – DREAM$_{ZS}$





Results – DREAM$_{zs}$ MAP.



log(q Flux (m^3/1 kyr))

1e-09 1e-08 1e-07 1e-06 1e-05 1e-04 1e-03 1e-02 1e-01

log(q Coupled) – log(q Flow)

-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

Conclusions

1) Parameter uncertainty reduced by the inclusion of $^4He_{rad}$ to condition the model inversion.

2) Small changes in the hydraulic conductivity of the Berchem & Voort Formation may result in large *q* variations in the long-term.

3) $^4He_{rad}$ partially addresses the problem of parameter non-uniqueness.

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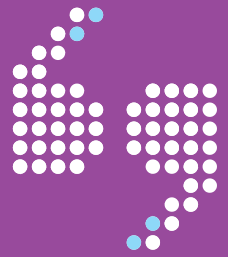

Q&A

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Thanks for your attention!

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