GEFÖRDERT VOM
Bundesministerium
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Towards validating numerical simulations of drawdown in unconfined fractured rocks with field experiments:

A comparative study at sub-seismic scale

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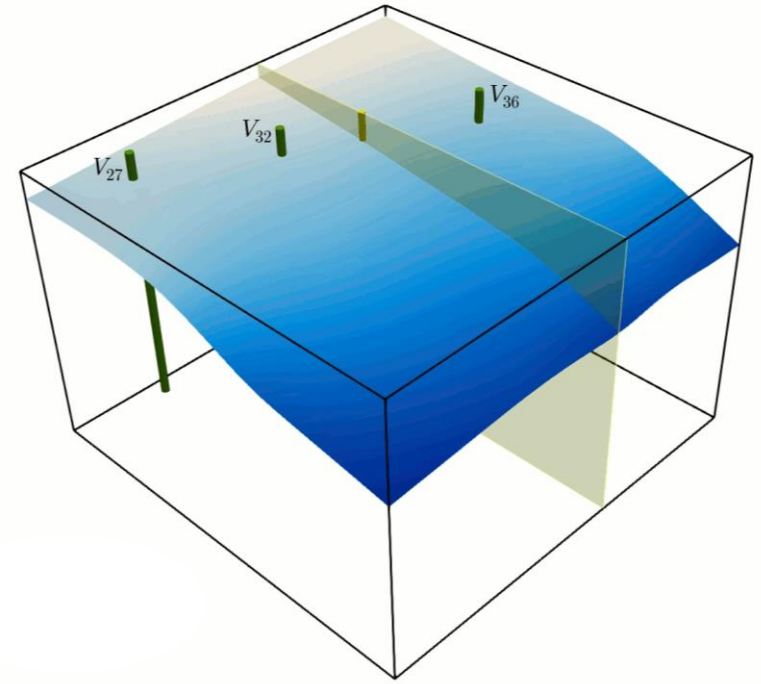

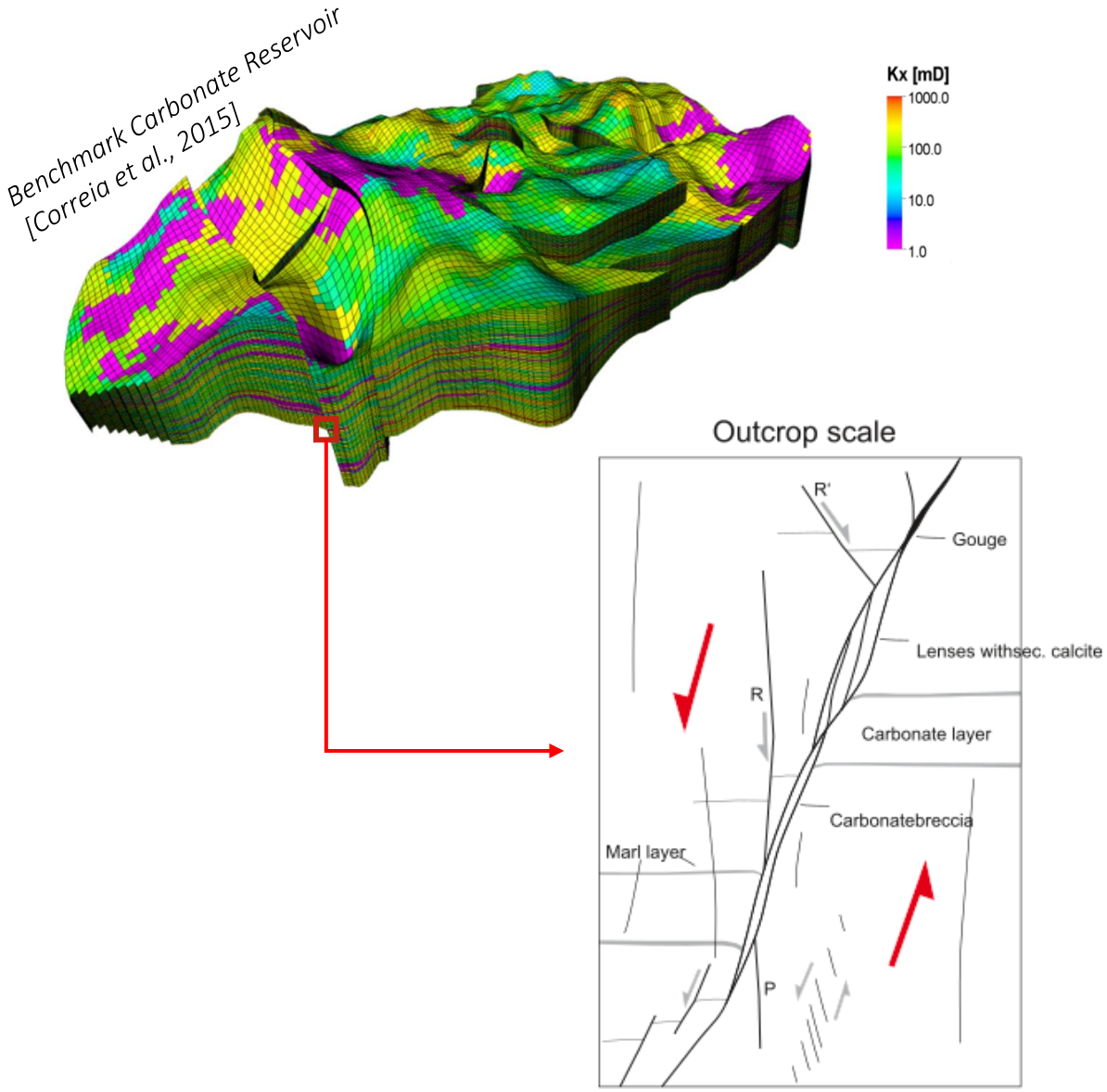

Upscaling hydraulic properties of fault & fracture zones is crucial for reservoir engineering!

Difficulites:

- Multi-scale presence (≠ REV-cocept)
- Fault- & damage-zone geometry
- Single fracture properties
- Etc...

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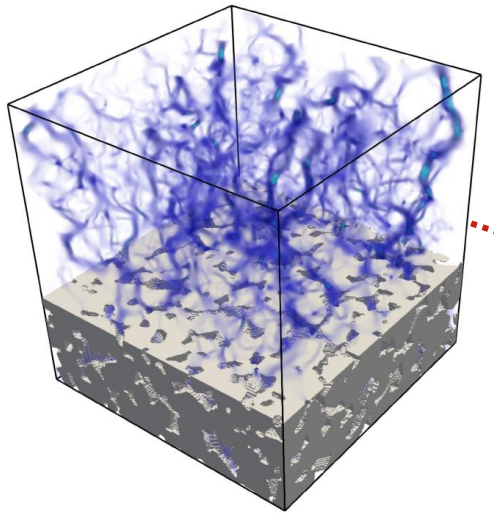
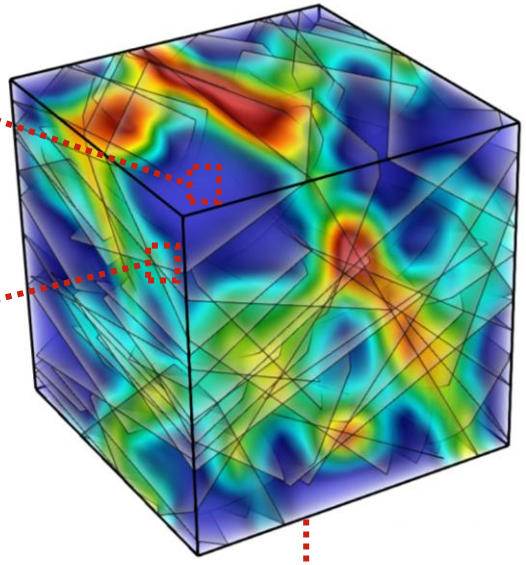
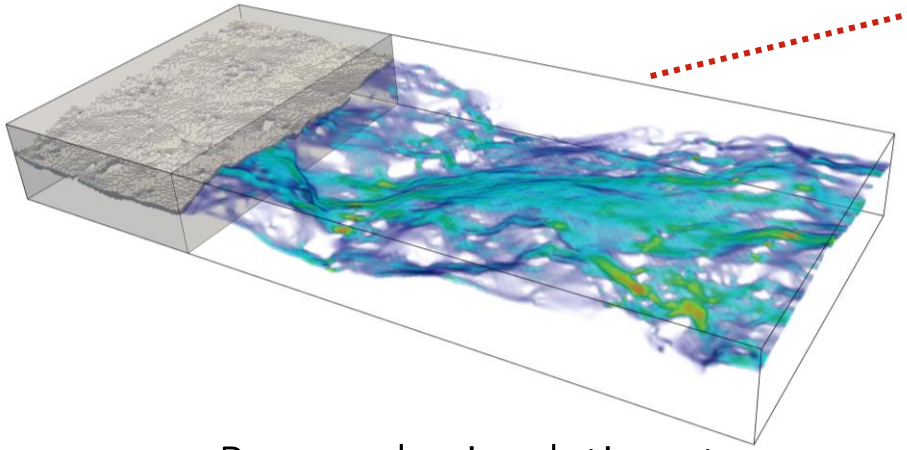


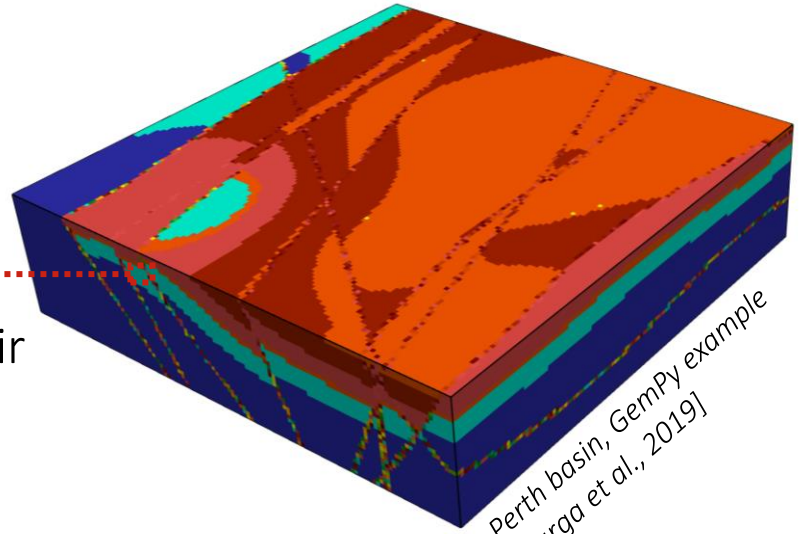




2 Network scale simulations to upscale permeability tensors

1 Pore scale simulations to derive fracture & matrix permeability parametrizations

3 Input for reservoir scale simulations



Perth basin, GemPy example [Varga et al., 2019]

Refs:
Eichheimer et al., 2019: https://doi.org/10.5194/se-10-1717-2019
Kottwitz et al., 2020: https://doi.org/10.5194/se-11-947-2020

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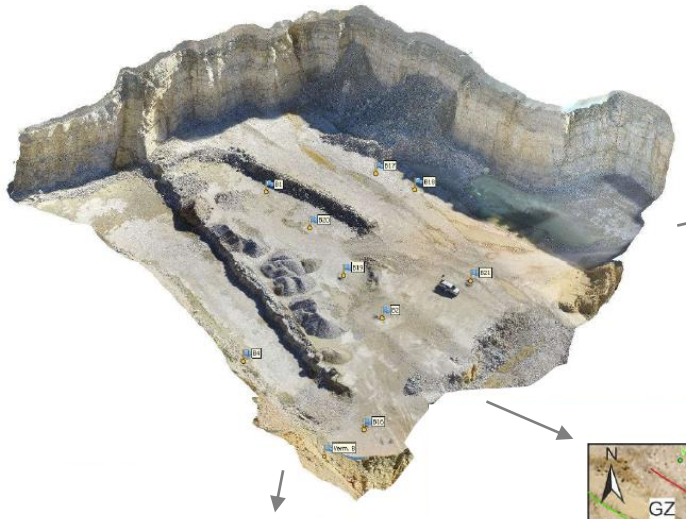
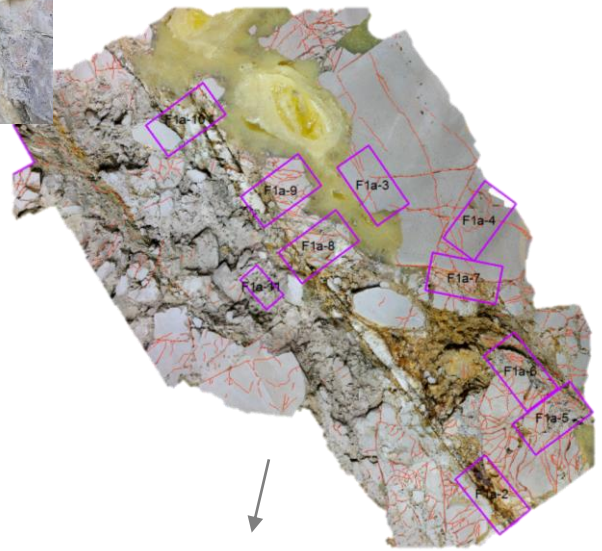
Permea

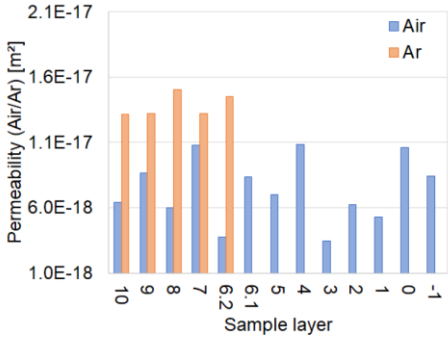
Malm (Upper Jurassic) quarry in Franconian Alb

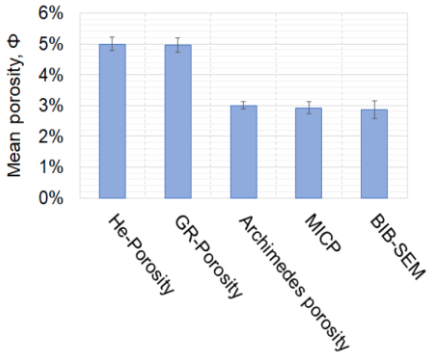


transfer sampling



petrophysics





hydraulic tests

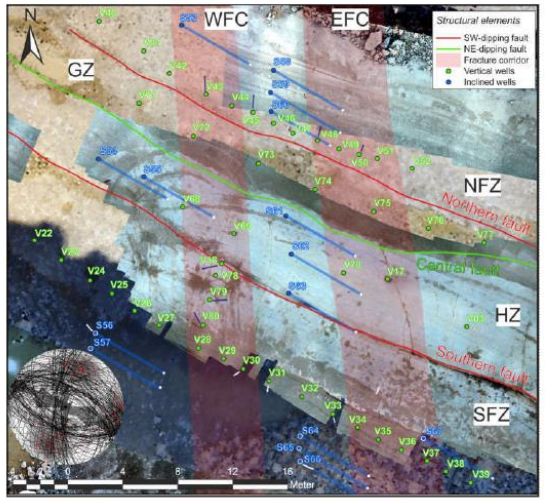
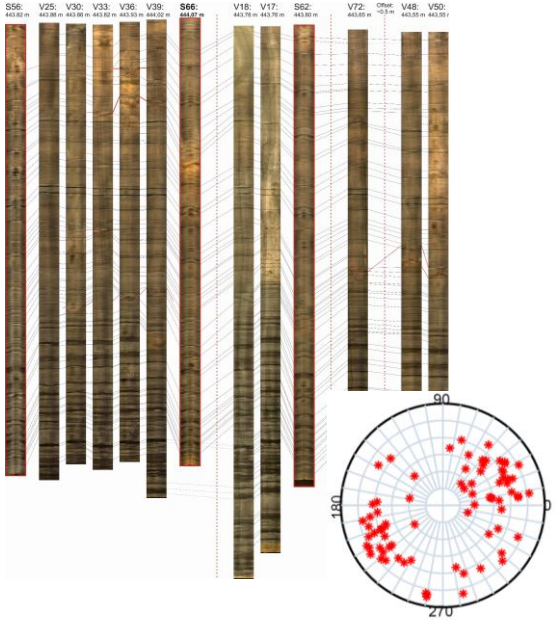
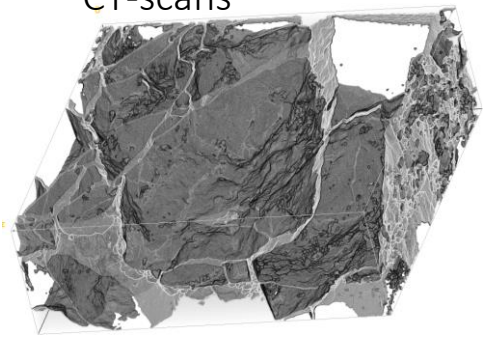


image logs & fracture data



CT-scans



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MAP Microstructure and Pores GmbH

Refs:
Freitag et al., EGU22-8457
Freitag et al., 2022: https://doi.org/10.5194/se-2022-18

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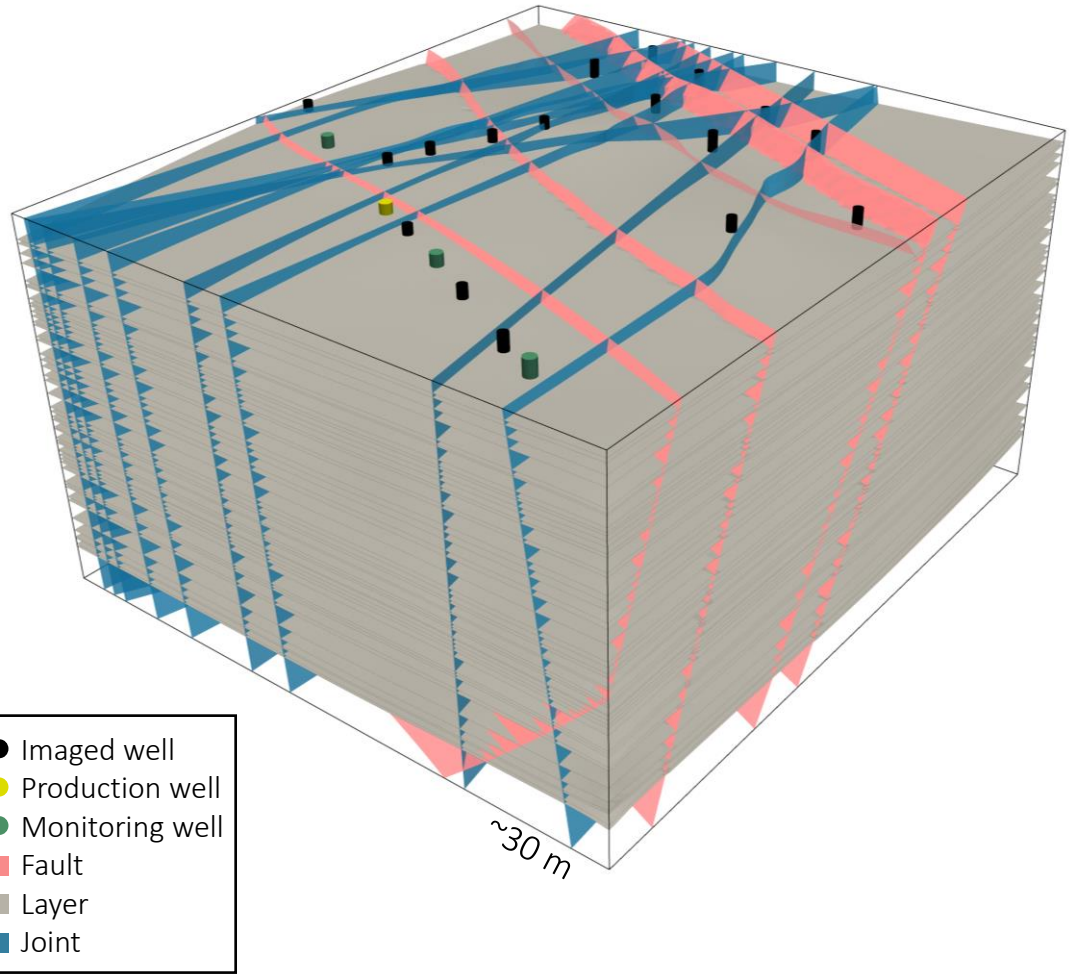
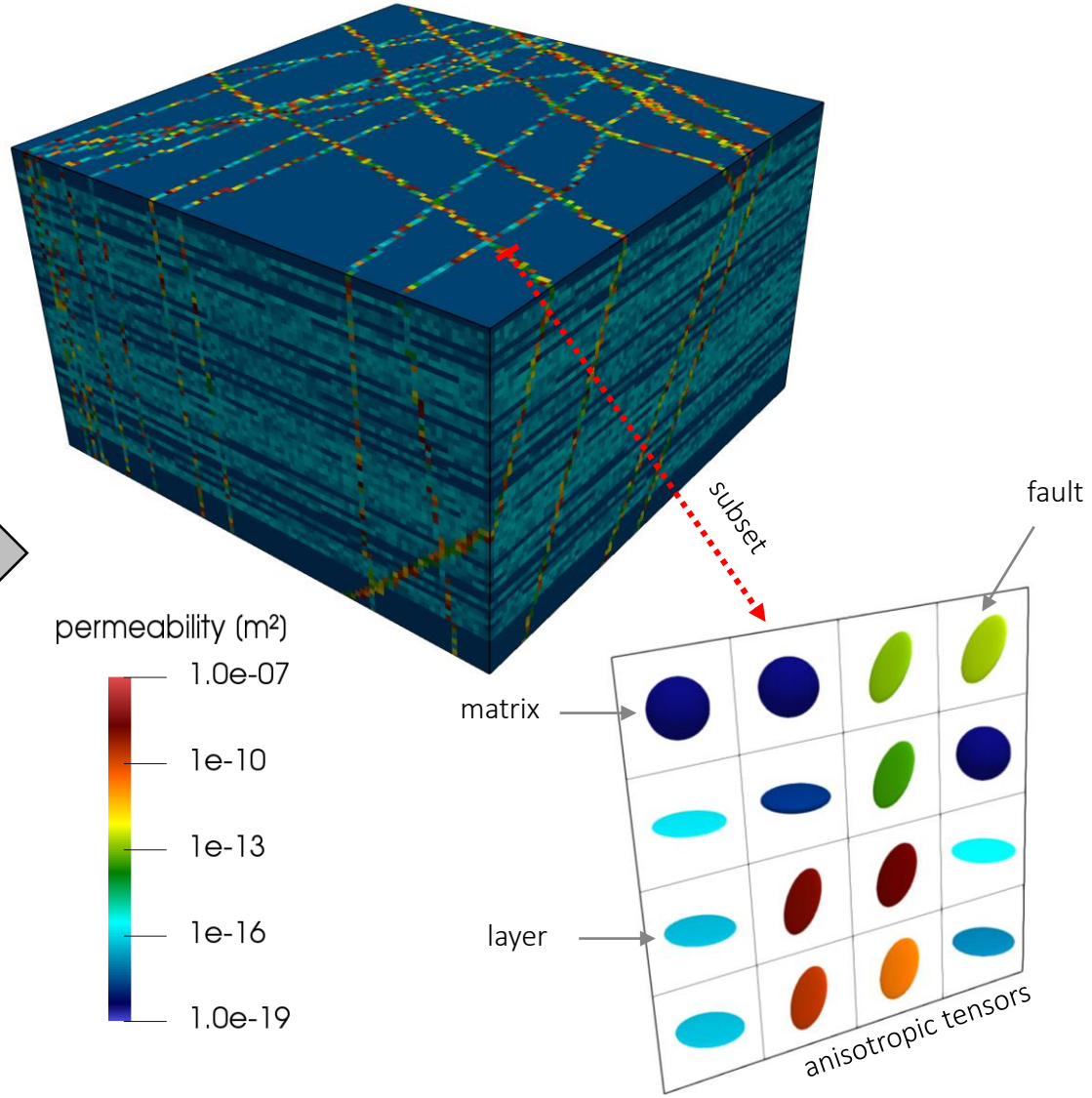
structural modelling with GemPy:

[Varga et al., 2019]



(single) continuum voxel model:



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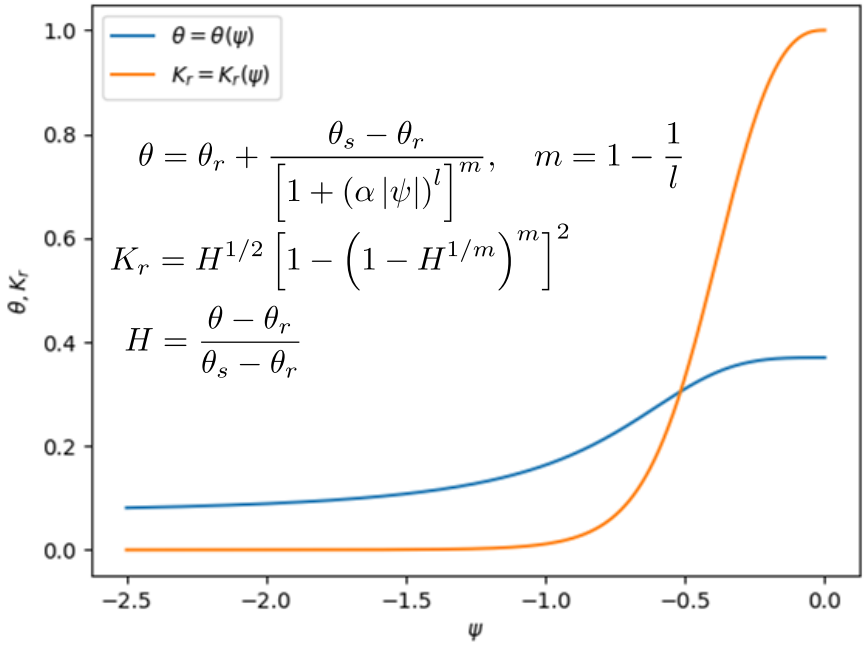
transient, mixed saturated groundwater flow:

$$\frac{\partial \theta}{\partial t} + S_w S_s \frac{\partial h}{\partial t} = \frac{\partial}{\partial x_i}\left(K_r \, \mathbf{K} \, \frac{\partial h}{\partial x_i} \right)$$

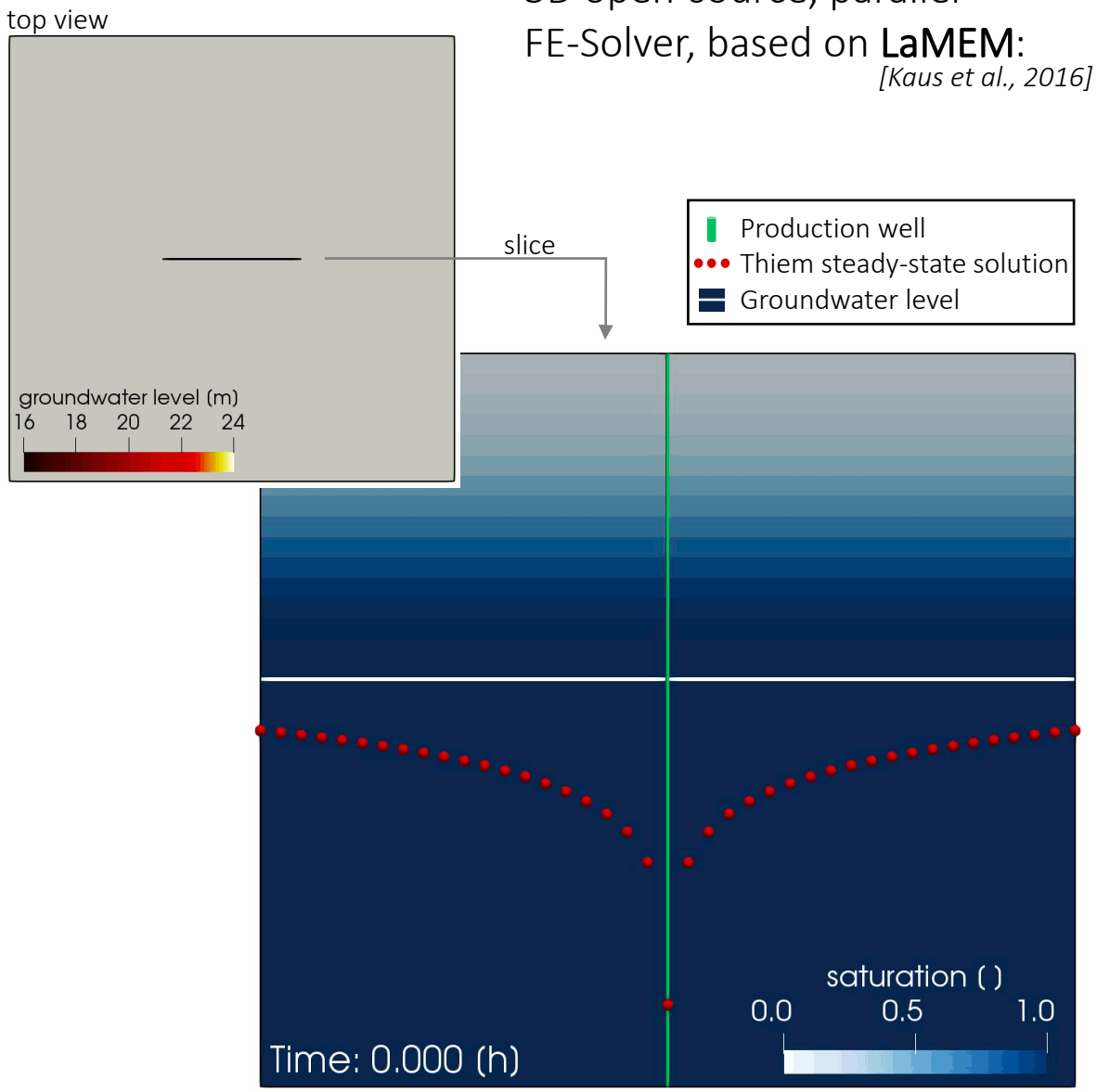
h - hydraulic head
S_w - fluid saturation
S_s - specific storage
$\mathbf{K}$ - conductivity tensor

$\psi = h - z$ - pressure head
$\theta = \theta(\psi)$ - fluid content
$K_r = K_r(\psi)$ - relative permeability

van Genuchten model:



3D open-source, parallel FE-Solver, based on **LaMEM**:
[Kaus et al., 2016]



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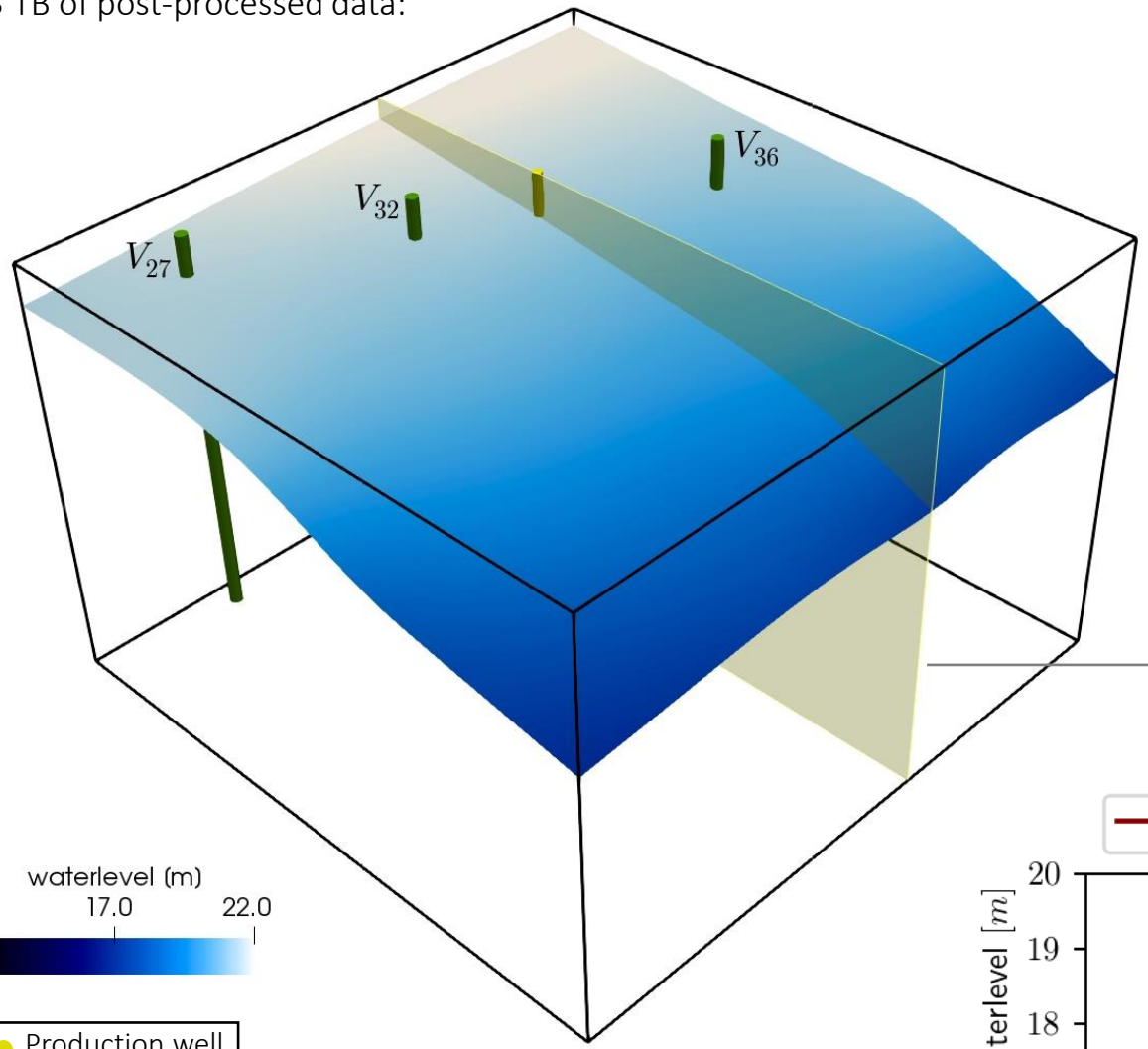
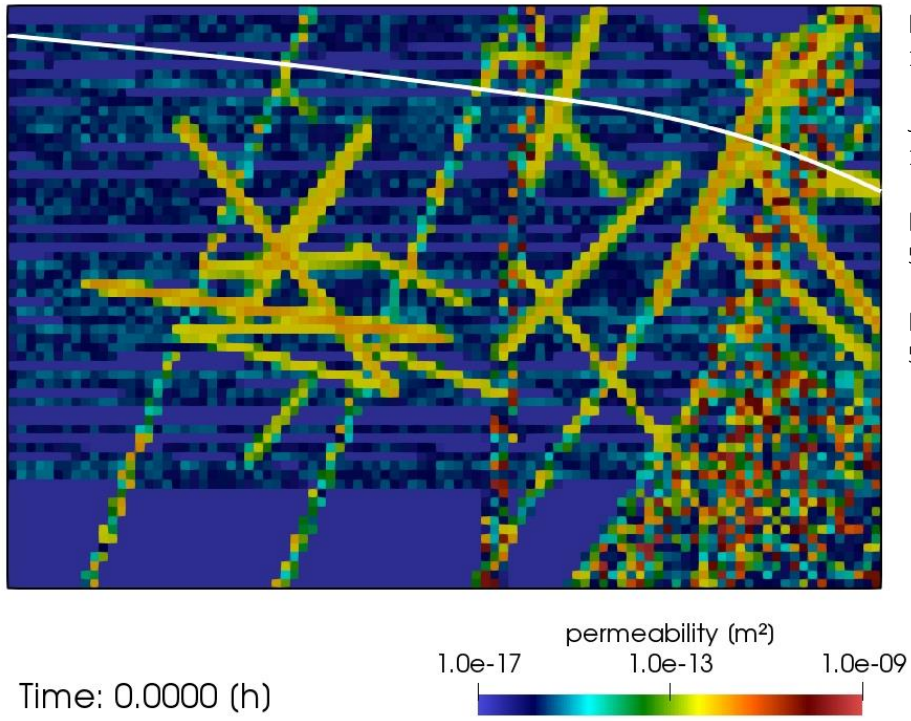
After ~1000 simulations &
~3 TB of post-processed data:



slice

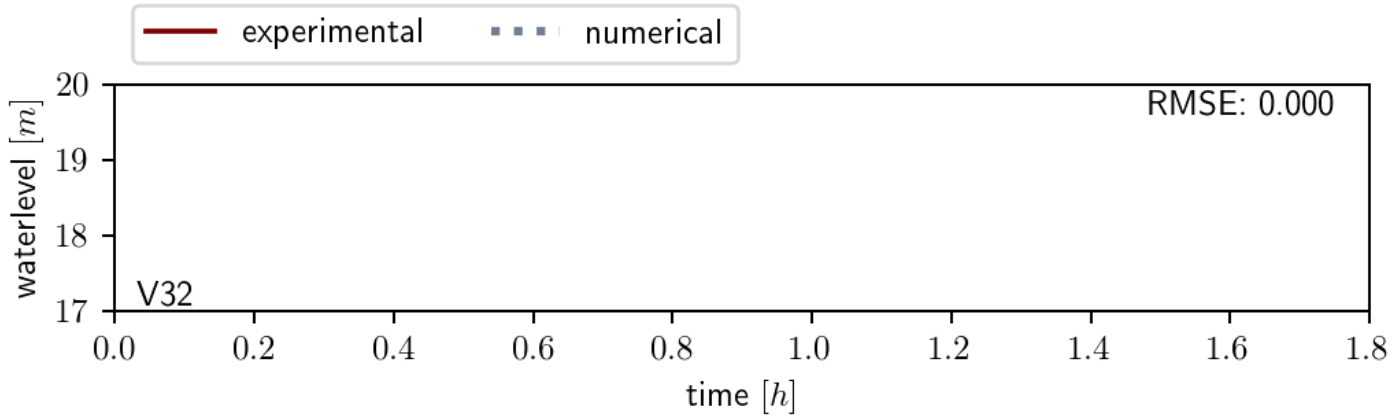


Fault k [m²]:
1e-16 – 1e-12

Joint apt [m]:
1e-07 – 1e-03

Layer apt [m]:
5e-06 – 1e-05

DFN apt [m]:
5e-05*$L^{0.5}$



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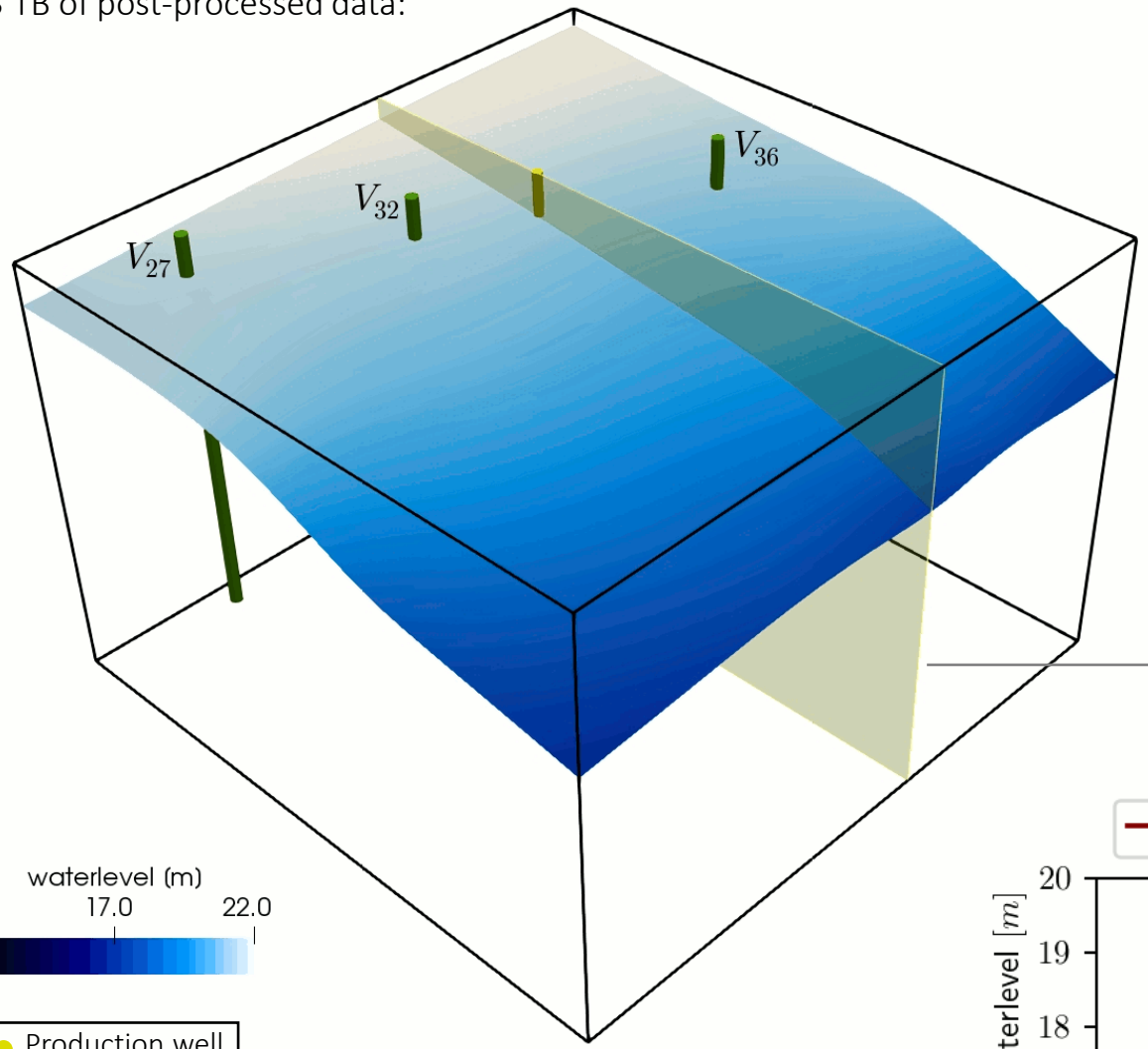

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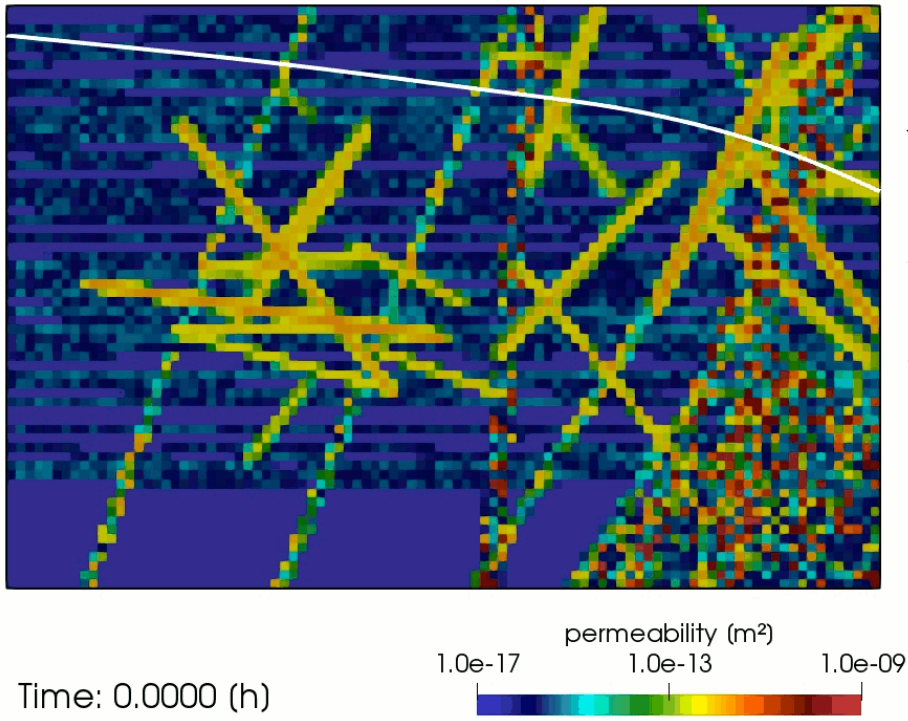

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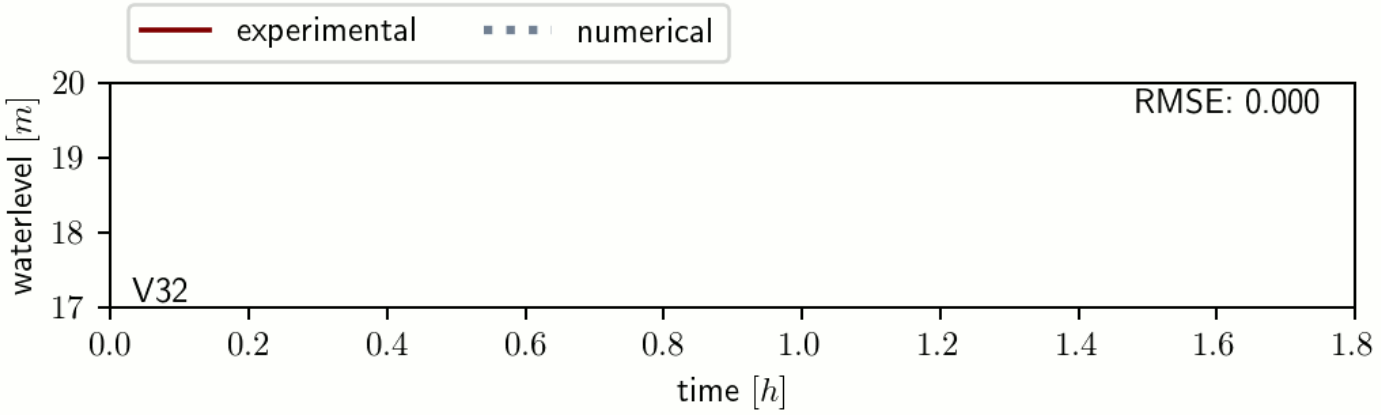

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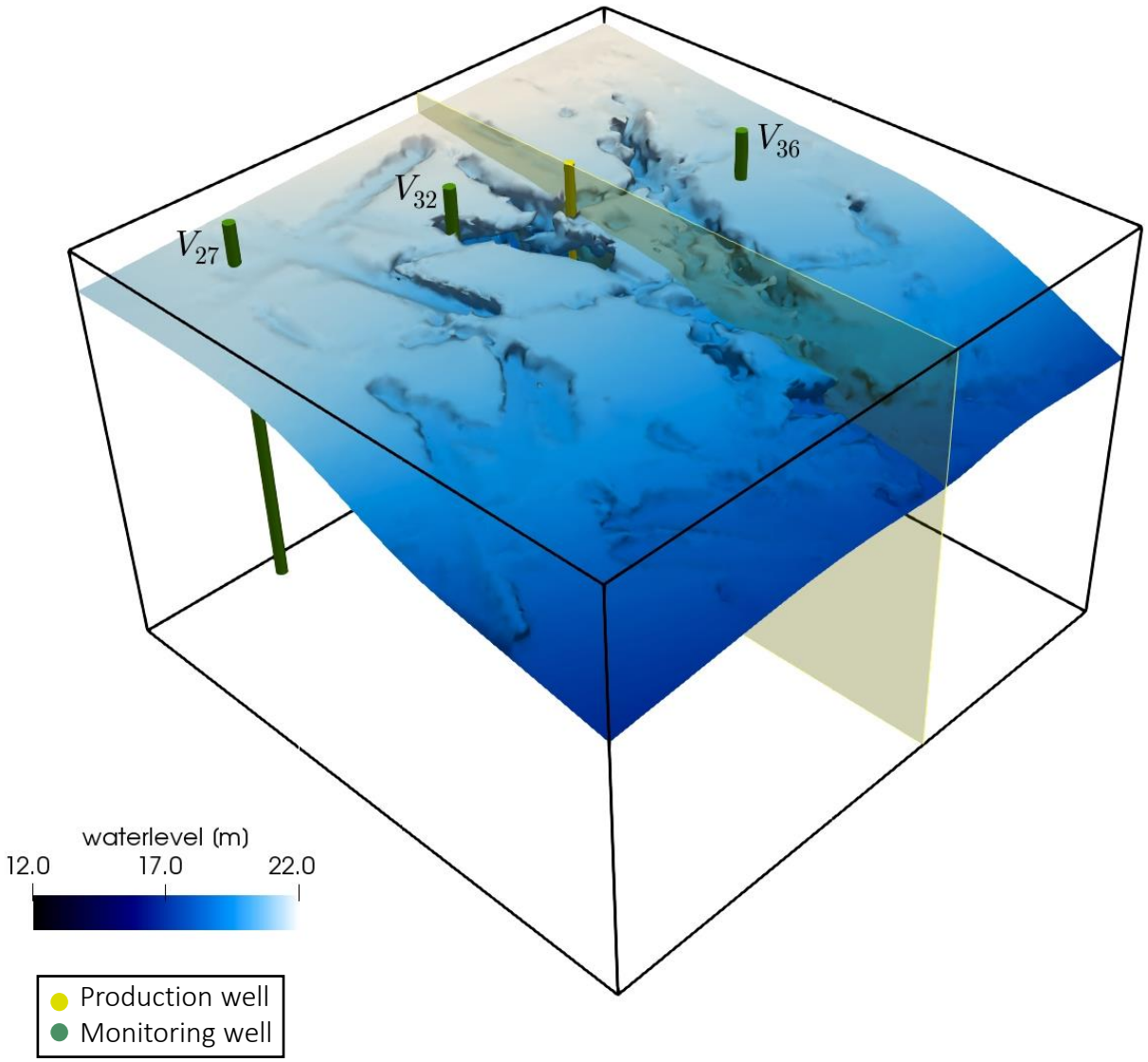

- Reproduce the drawdown in the 2 other observation wells
- Validate the model with more conducted pumping tests
- Future project plans:
  Use proper inversion techniques instead of guided-forward modelling

Thank you for your attention!

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