3D modelling of the Excavation Damaged Zone around HLW/ILW tunnels and shafts using a Marked Point Process technique

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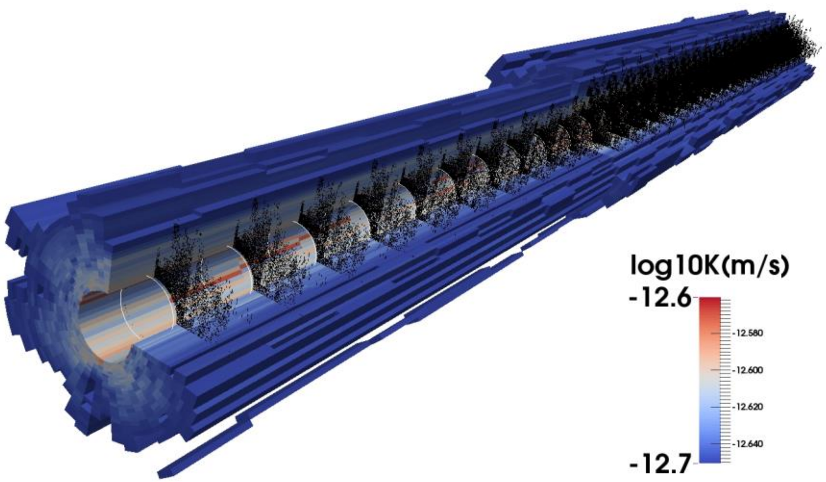

Outline

- Context
  - *The 2D approach. Summary*
  - *Geostatistical framework*
- Methodology. Marked Point Process
- Application
- Concluding remarks

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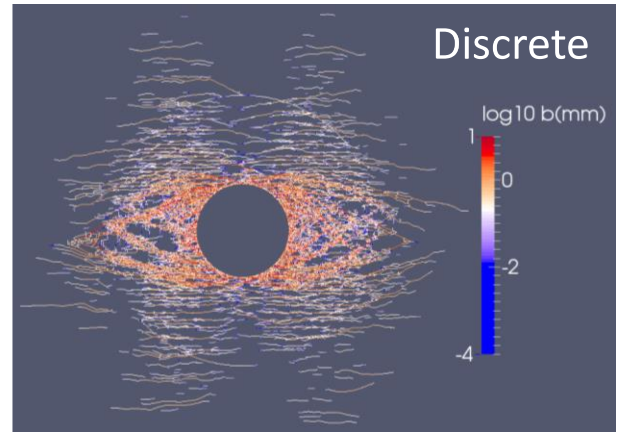
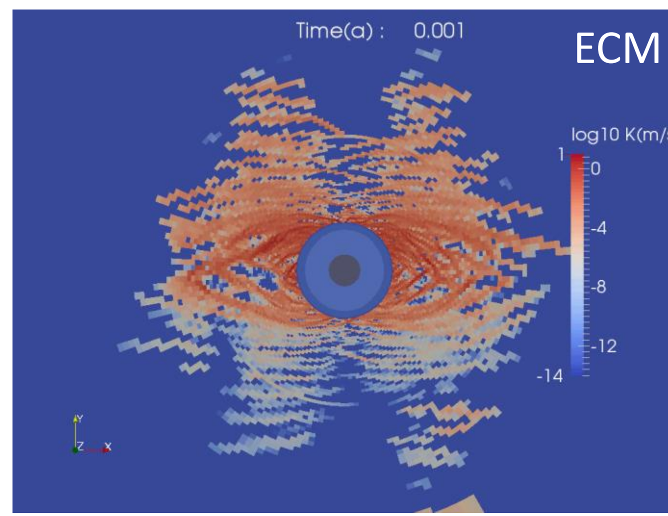
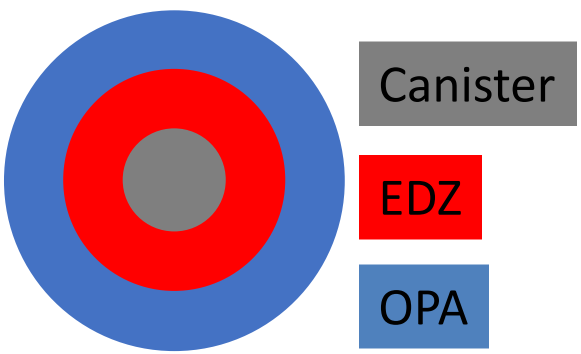
1. Context. Previous work

- Traditional THM models not well-suited to Safety Analysis on long term repository induced effects due to complexity (long model runs)
- SA demands models that are:
  - Simple and fast
  - Plausible
  - Heuristic, based on physical processes
  - Validated
- Previous work: 2D-EDZ abstraction methodology
- This presentation: enriched methodology, 3D



Alcolea et al. 2016

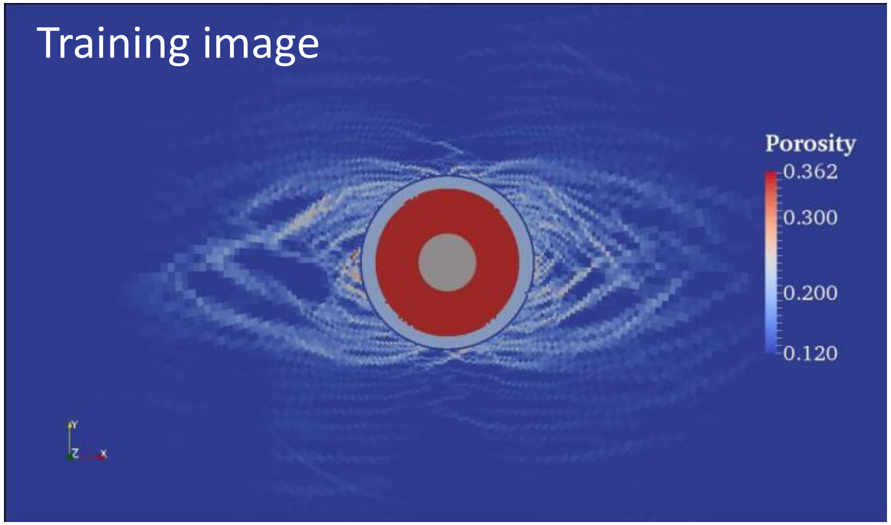


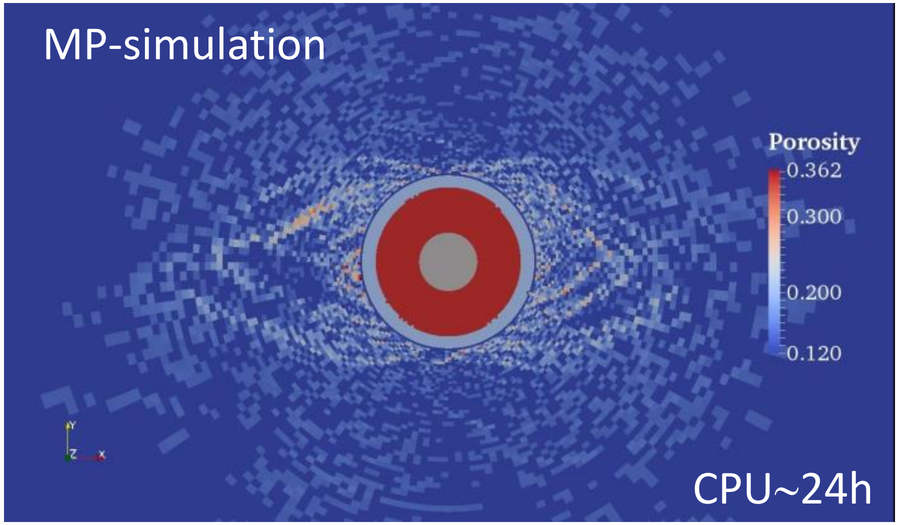


Abstracted, hydraulically equivalent model

1. Context. Geostatistical framework

- DFN simulations mimic in some way the excavation process. Yet, SA cannot rely on a single simulation of the near field given a certain stress state and rock parameters.
- Need for stochastic 3D simulations.
- Traditionally, two-point geostatistical techniques (variograms). Information loss on connectivity caused by smoothing.
- Recently, multi-point statistical techniques. Promising but computational effort prohibitive.





- Novel alternative: the Marked Point Process (MPP).

2. Methodology. Marked Point Process (MPP)

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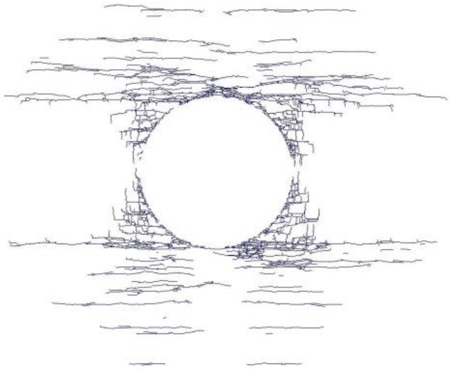
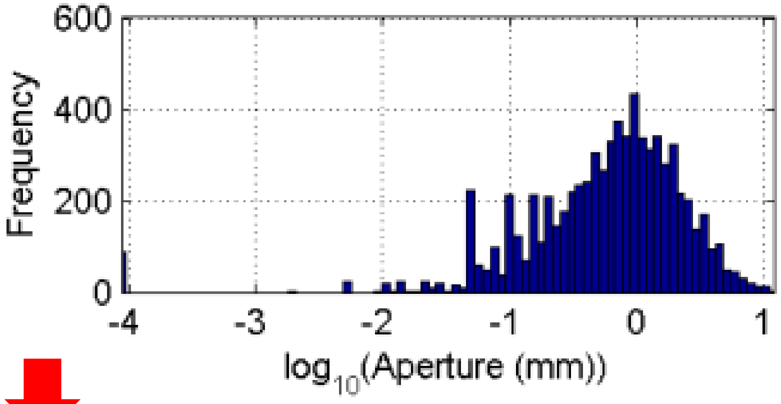
- Point process: random process for which any one realization consists of a set of isolated points in space and/or time. Example: center of gravity of the EDZ fractures.
- Marked point process: point process with random attributes. Example: each point (fracture) has an associated length, aperture, inclination, roughness, etc.

Both fracture location and attributes are random, but inherited from what?

Use DFNs mimicking the excavation process as “training images”. Extract attribute pdfs





Sample attributes to generate 2D slices and stack them in 3D

2. Methodology. Marked Point Process (MPP)

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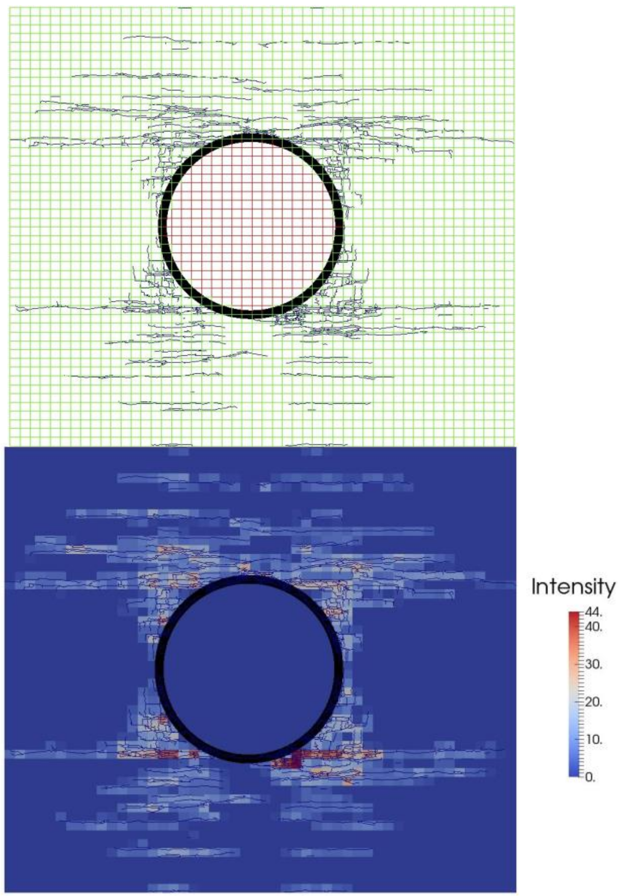
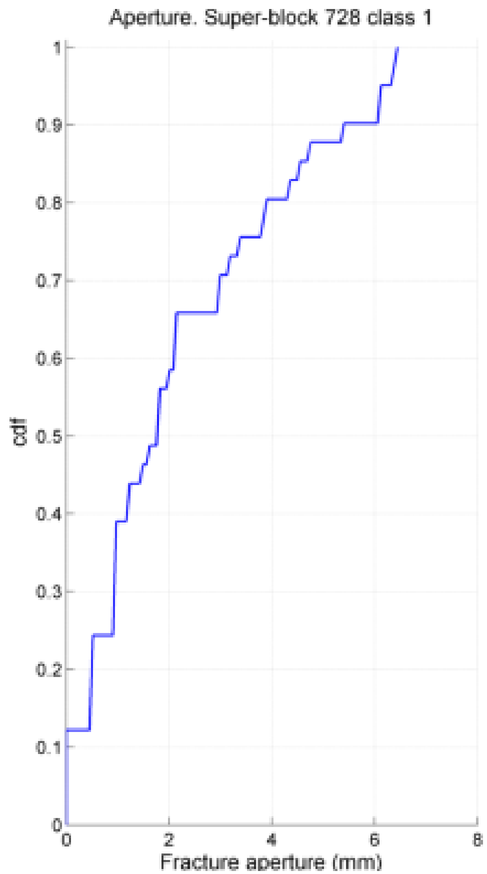
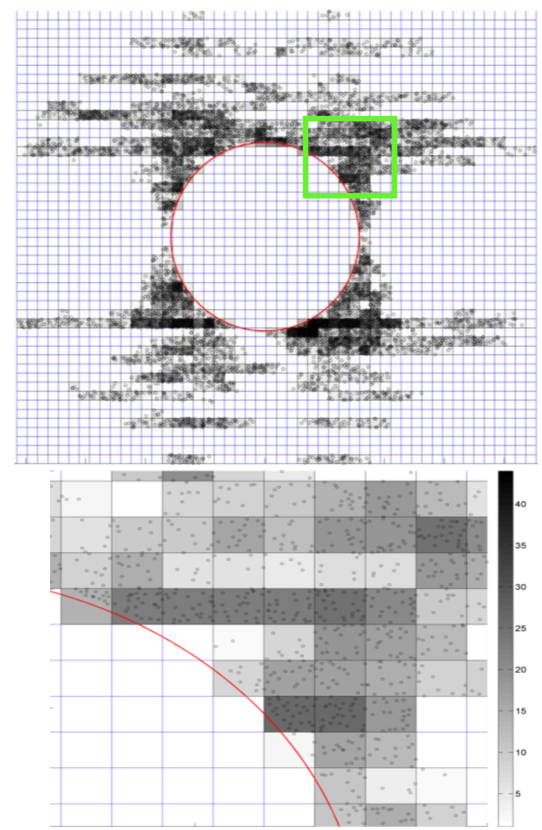
- Step 1. Generate a super-block grid (mesh free) and intensity map (i.e., fracture density) of the training image



- Step 2. Scan training image within each superblock and get attributes (L, b, θ).



- Step 3. Generate fracture locations randomly (Poisson distribution) according to the intensity map.



2. Methodology. Marked Point Process (MPP)

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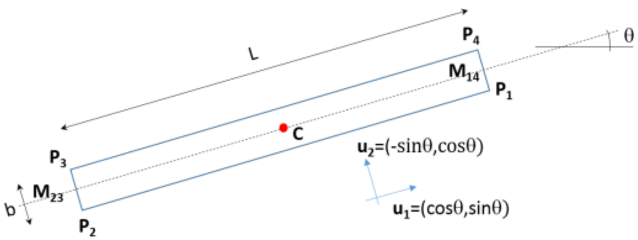
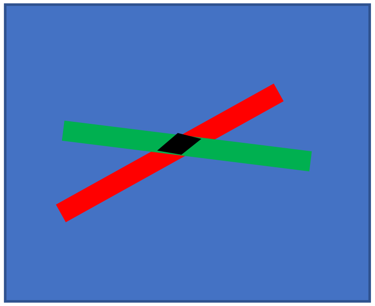
- Step 4. Sample cdfs and get attributes for each point. Generate fracture "patch". Very simple geometric problem.

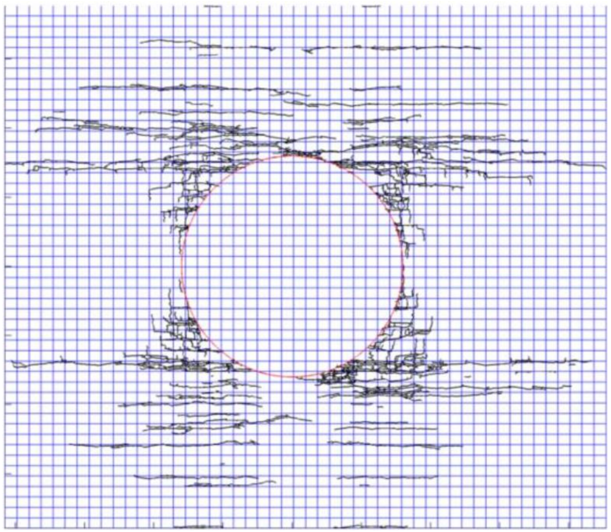


- Step 5. Check fracture overlaps. Very important to avoid "super-conductive" features. Upscale 2D slices.

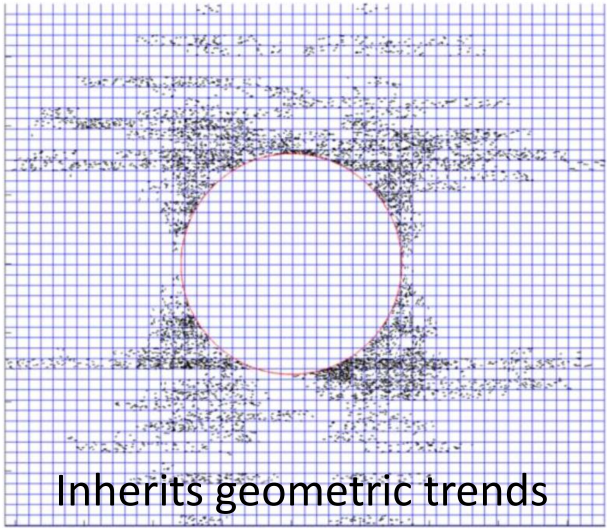


Split one or resample

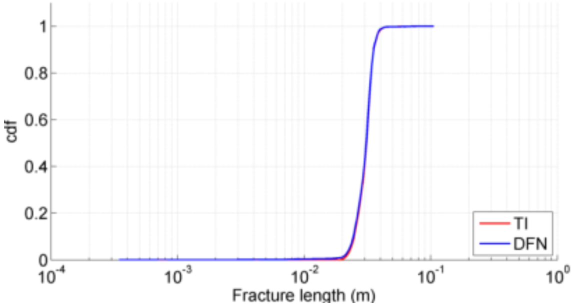
Training image

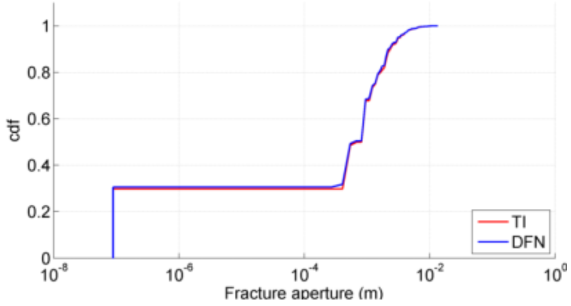


Random simulation



Pattern reproduction





Apparent loss of connectivity?

By-product of the TI definition

2. Methodology. Marked Point Process (MPP)

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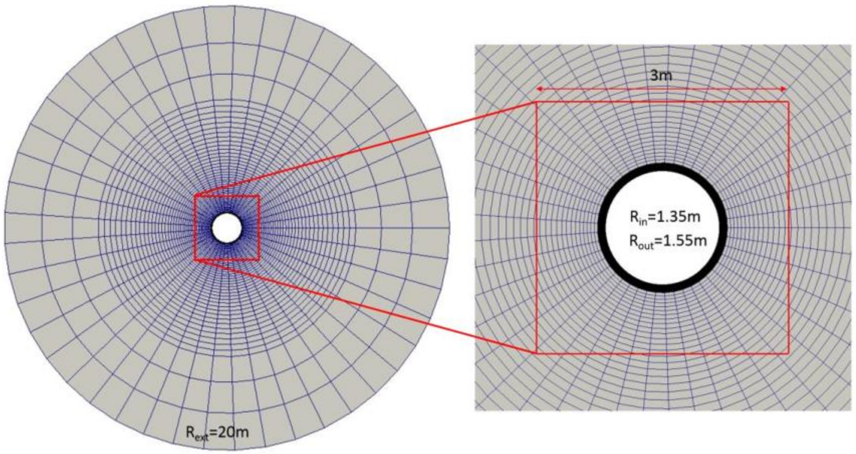
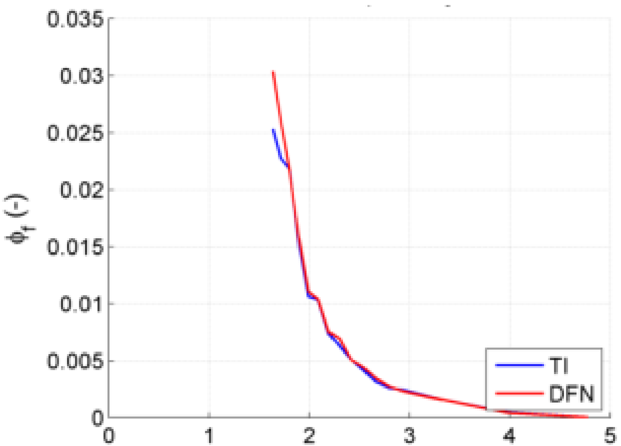
- Step 6. Upscale & abstract 2D slices

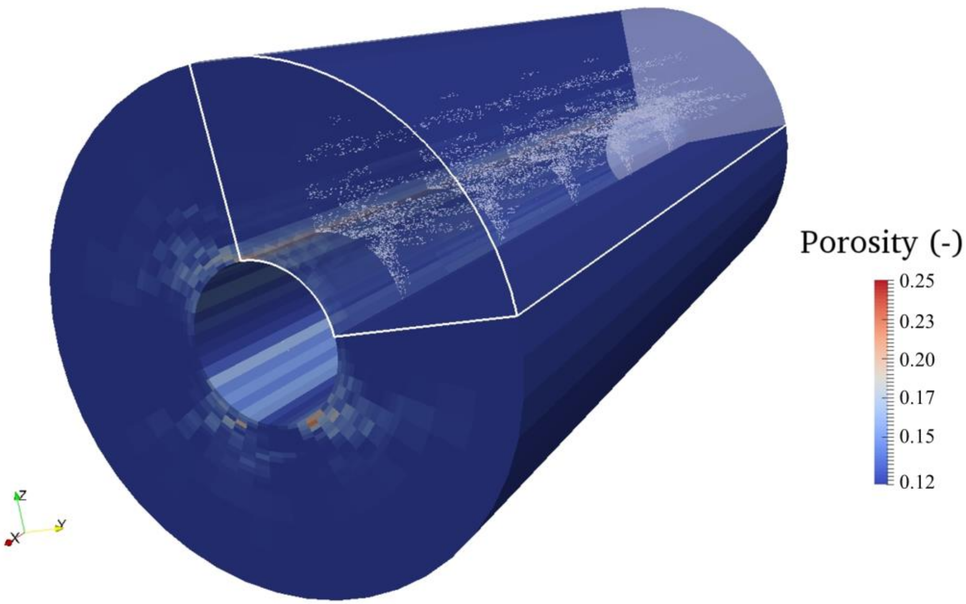


Inherits hydraulic behaviour



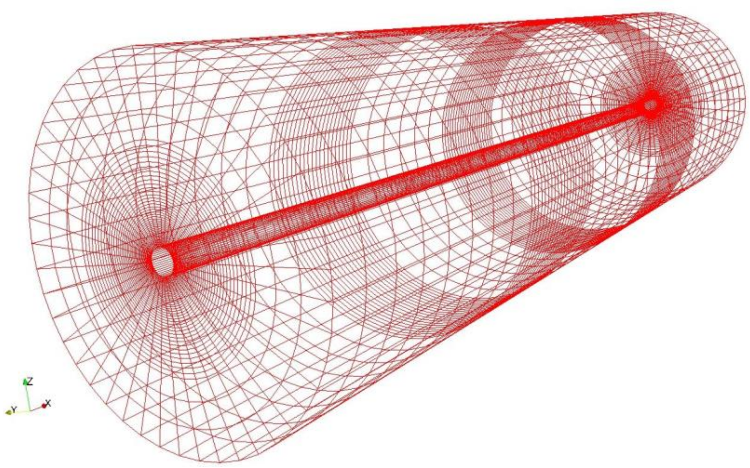
Radial distance (m)

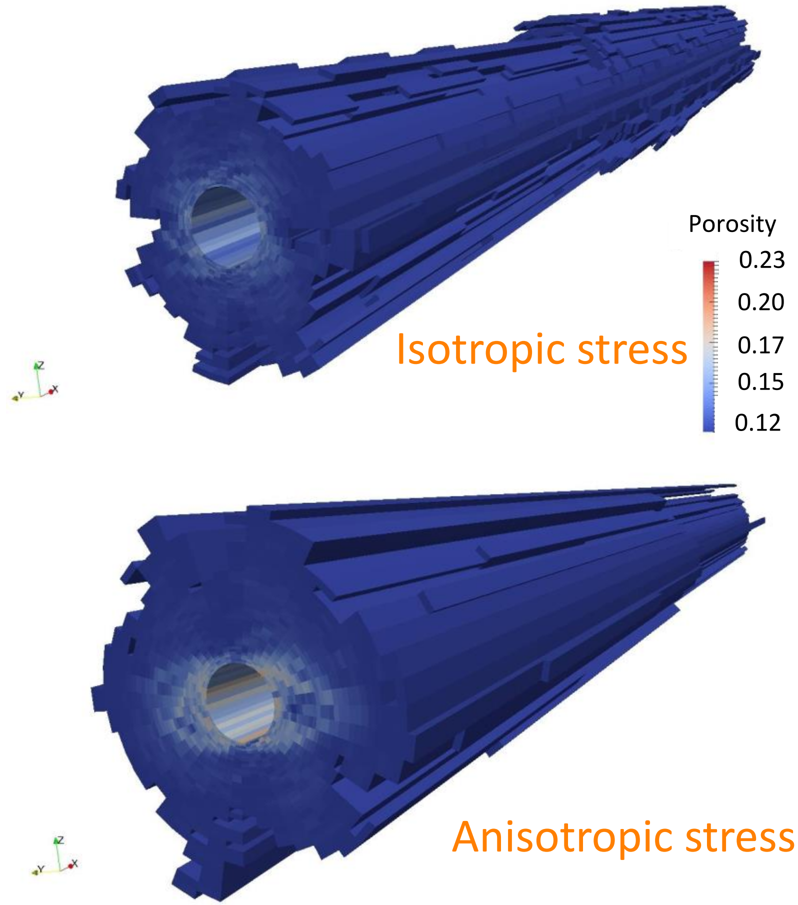
- Step 7. Stack 2D upscaled slices randomly
  - Ignore 3D propagation and simply stack independent slices. Fractures do not propagate more than one slice.
  - Sample a cdf representing length along the third dimension (orthogonal to 2D slices) and elongate fracture accordingly.



3. Application 1. HLW/ILW tunnels

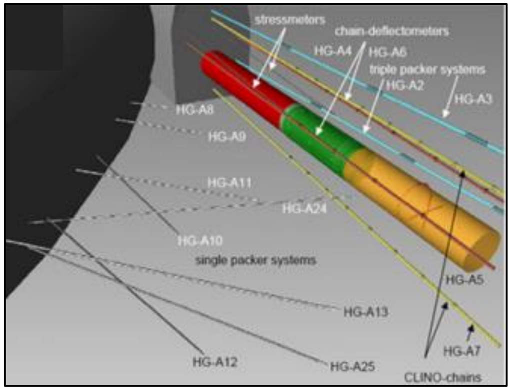
- Prior sensitivity analysis to stress state and rock strength parameters. DFNs as training images
- Simulation of a 150m length gallery (1/5 of true length).
- Combination of training images for different areas of the tunnel. Refinement around transition zones. Several combinations tested.
- 30 slices. Overall, ~65000 elements. Virtually no limit.



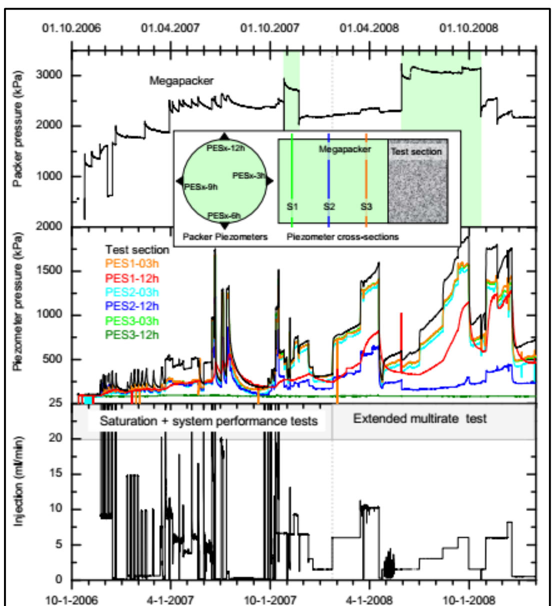


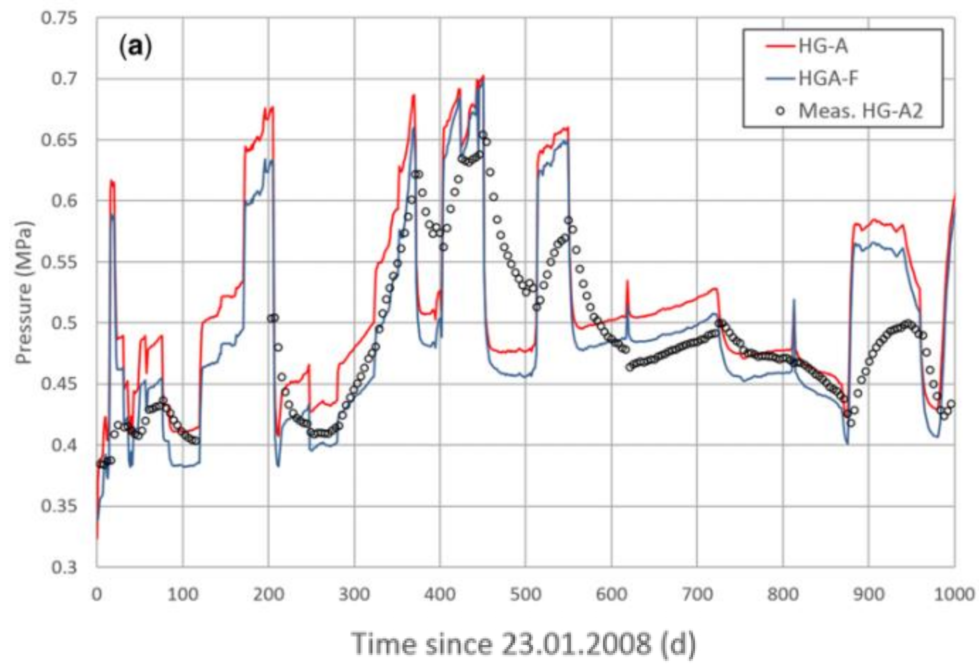
3. Application 2. HG-A in Mont Terri URL

- Inverse calibration of the multi-rate hydraulic test



Basic layout & boundary conditions





Previous fits using the 2D approach not satisfactory:

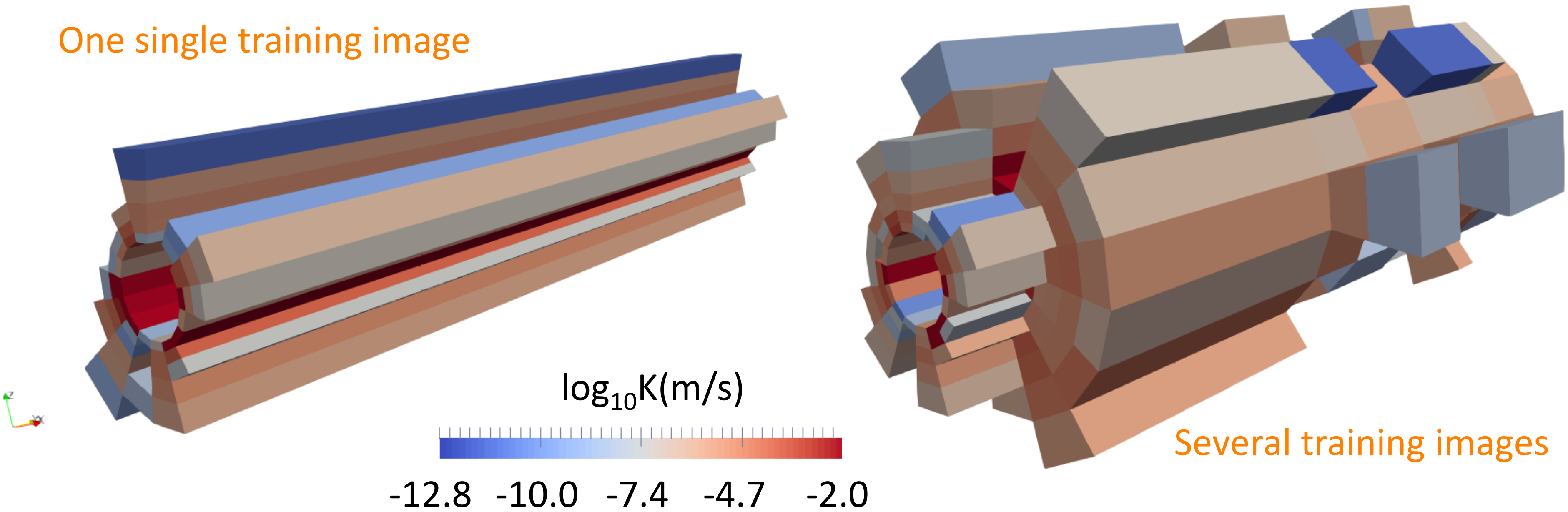
(1) calibration was not done, and

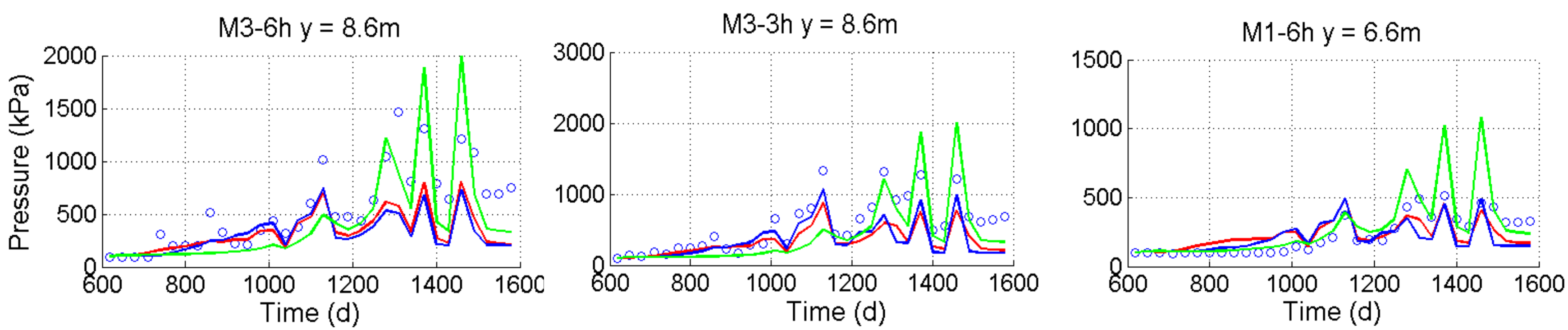
(2) the saturation of the system is clearly a 3D phenomenon.

3. Application 2. HG-A in Mont Terri URL

- Different combinations of training images for test, seal and open sections have been calibrated

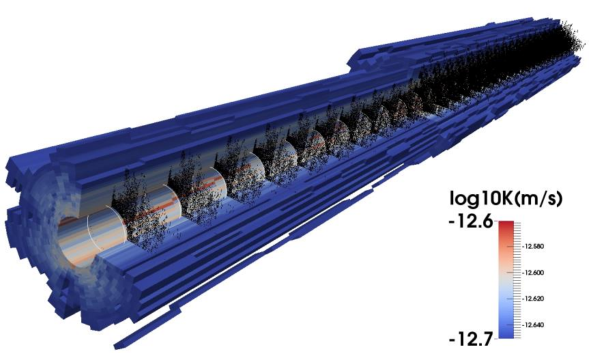
One single training image

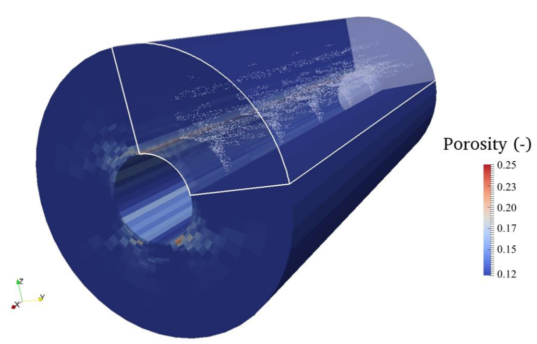


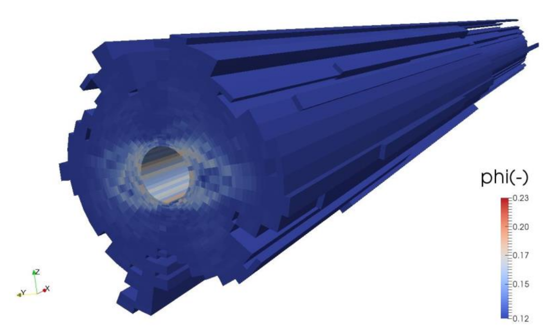


4. Concluding remarks & future work

- Versatile methodology for the development of 2D/3D abstracted models of the EDZ
  - Simple and fast models. Suitable for Safety Analysis
  - Plausible models. Based on existing databases
  - Heuristic models. Based of physical processes
- Method based on a Marked Point Process technique. The quality and accuracy of the simulations depend to a great extent on the quality and accuracy of the training images
- Future work:
  - Inclusion of more data sets and modelling of other experiments, e.g., gas injection
  - Test the impact of the training images by calibrating more simulations
  - Change the concept of training image. Use directly a 3D mechanical simulation of the EDZ







Thanks to Uli Kuhlmann and Paul Marschall for their cooperation

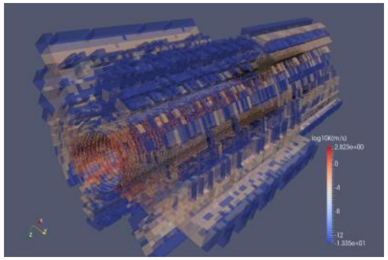
Thanks to Nagra for funding this project

Thank you for your attention

Ground water

Geothermal

Rock mechanics



Surface water

Software devel.