COMBINING MONITORING DATA AND FLOW SIMULATIONS FOR IMPROVED CO_2 STORAGE SECURITY

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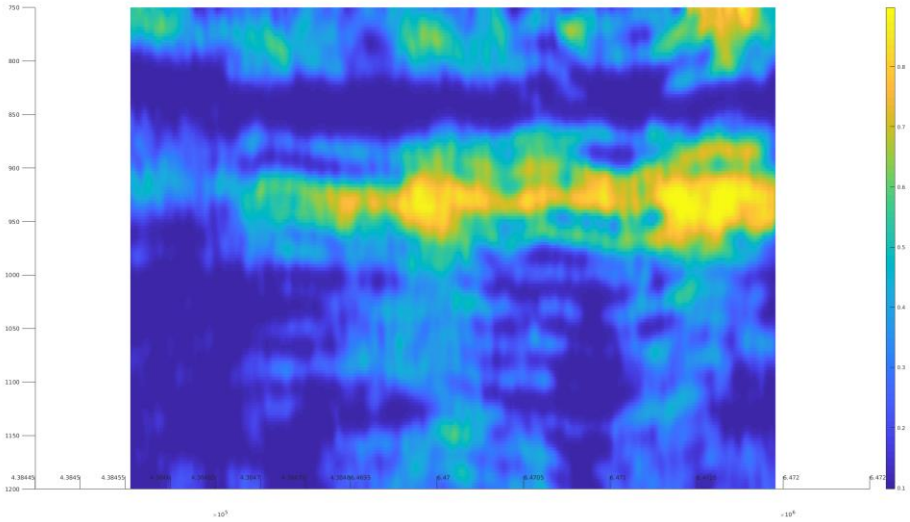
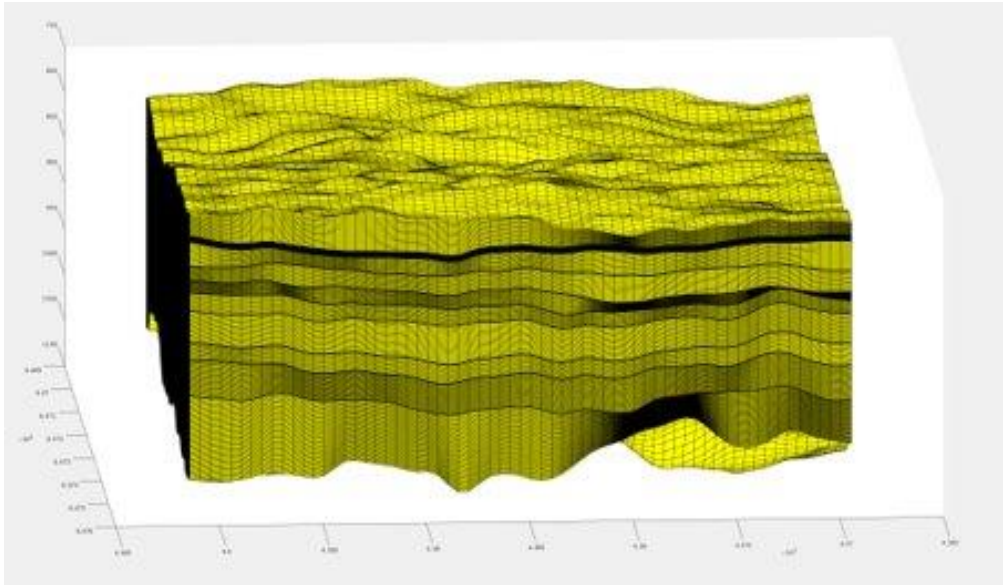
Overview

- Combining simulations and monitoring
  - Why?
  - How? – VE and adjoint-based optimisation
- The new, multi-layered Sleipner model
- How to model leakage through the layers?
- Optimisation

Combining flow simulations and monitoring data – Why?



Monitoring data



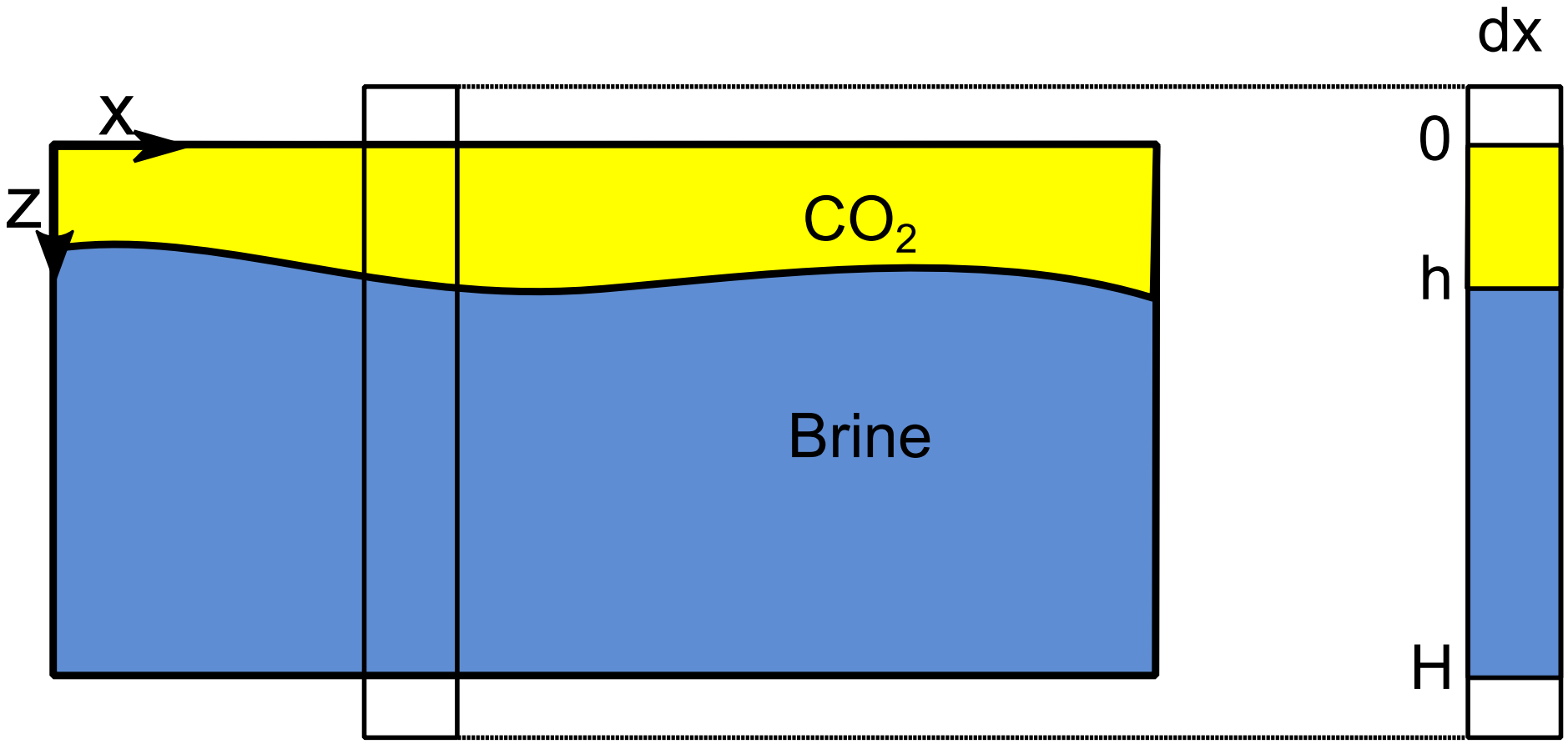
Numerical model

How? - Optimisation

- **Simulate**
- Evaluate objective function (minimise difference in CO_2 saturations)
- Find a new, better set of parameters (k, phi, rho)
- **Simulate** with new parameters
- Keep going until objective function is small enough.

- Speed up simulations – Vertical Equilibrium simulations

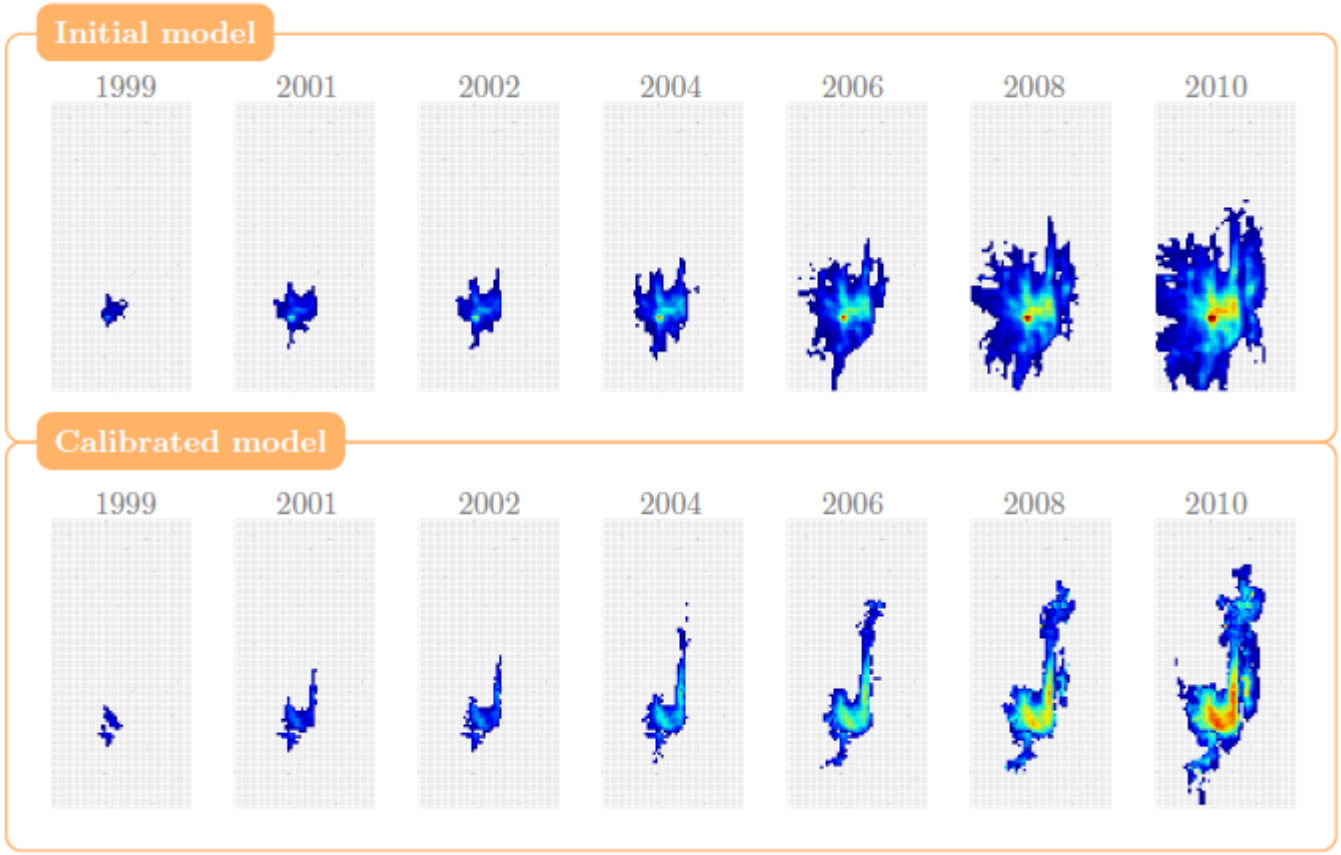
Vertical Equilibrium Simulations



Optimising Sleipner layer 9 model

Matlab Reservoir Simulation Toolbox (MRST)

Porosity
Permeabilty
CO_2 density
Top surface



Nilsen et al. 2017
Energy Procedia

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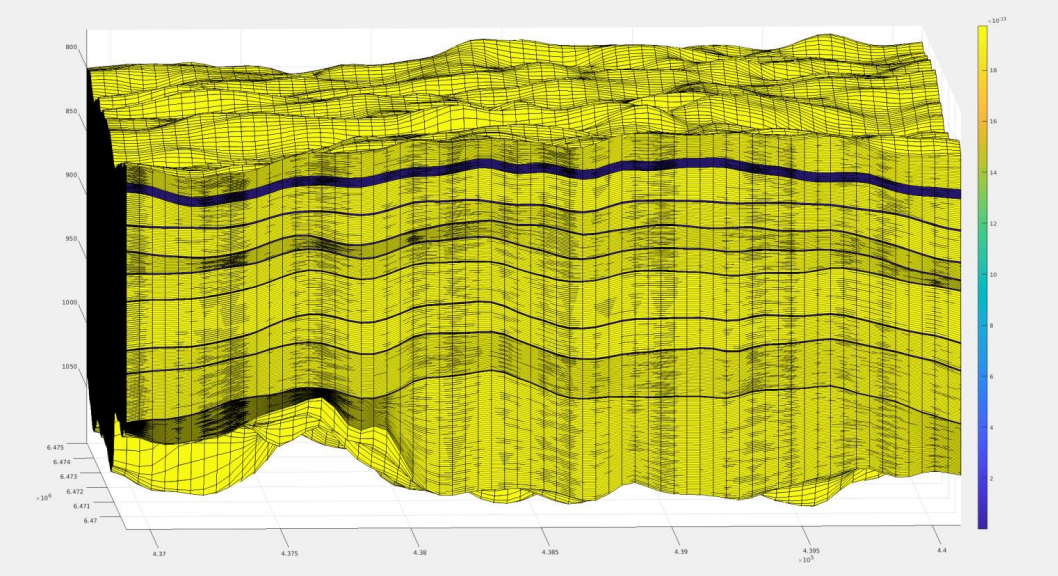
New multi-layered Sleipner model

- Recently released by Equinor.

- Will soon be released to a limited number of test users through the CO2DataShare online portal
- https://portal.co2.sigma2.no/

- Before being released to the public after the test period is over.



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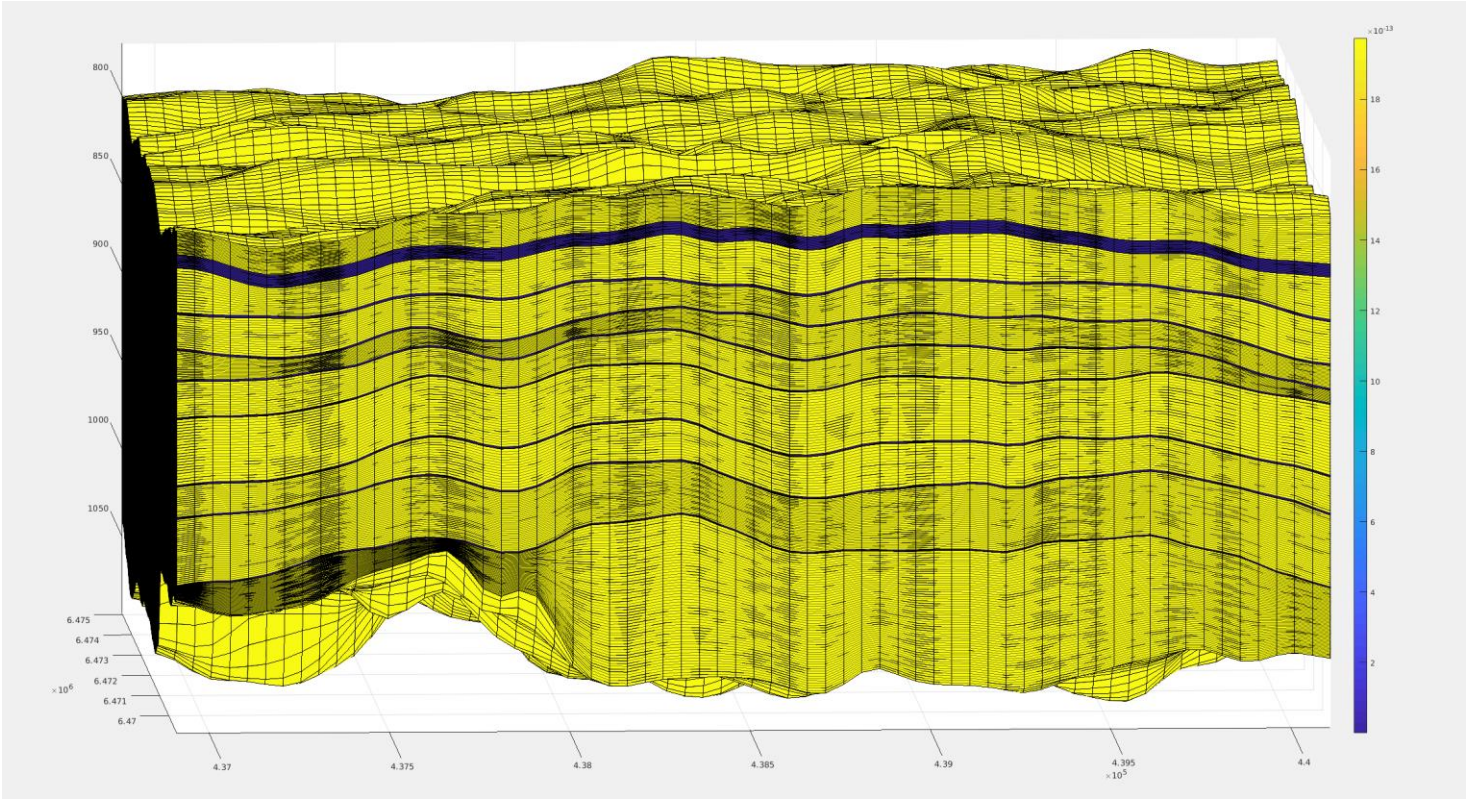
New multi-layered Sleipner model

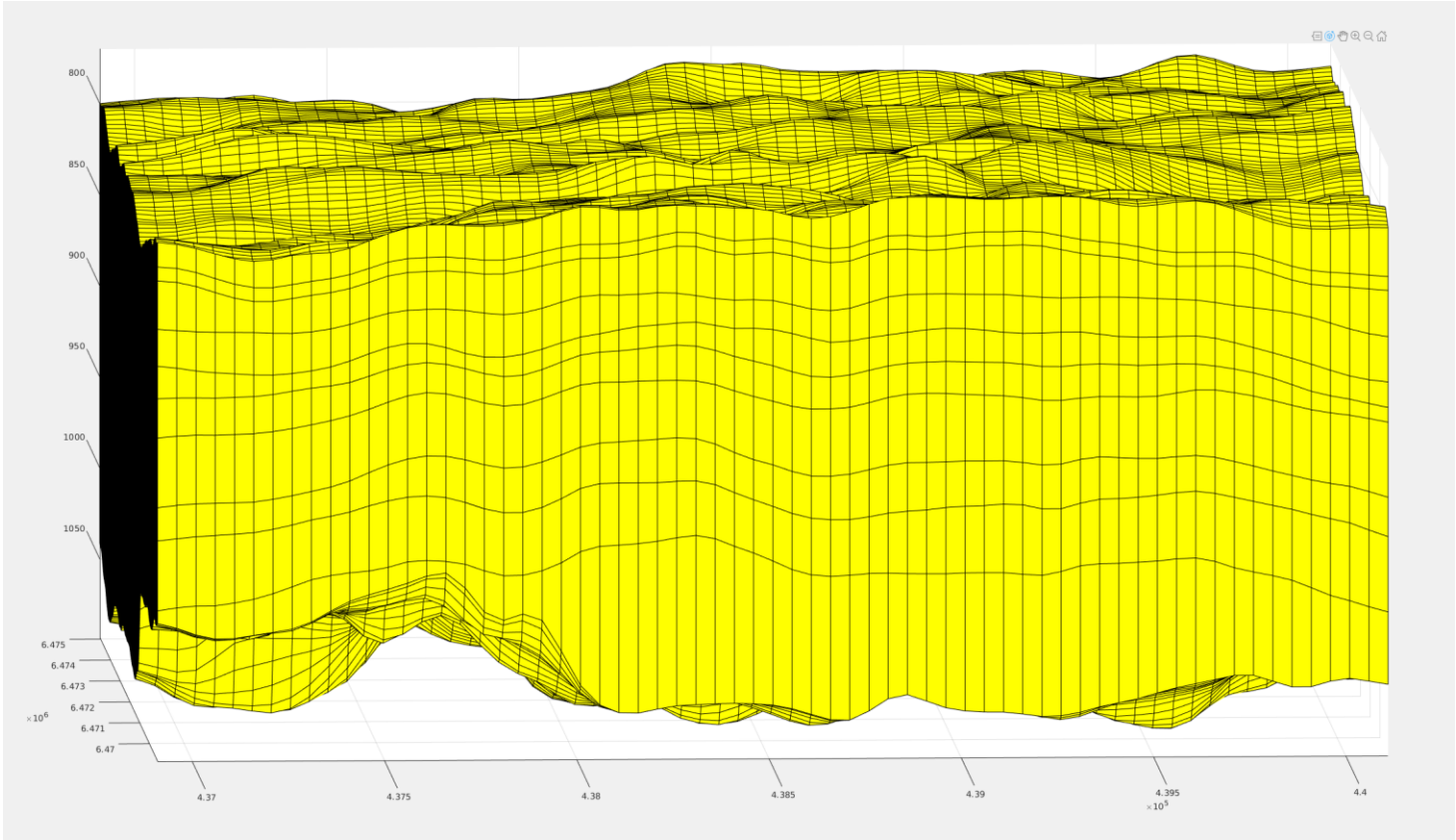
- ~1.9 million cell model
- Thin shale layers between thicker sand layers
- Two perm values:
  - k_{sand} = 2 D, k_{shale} = 0.001 mD
- Two porosity values:
  - ϕ_{sand} = 0.36, ϕ_{shale} = 0.34



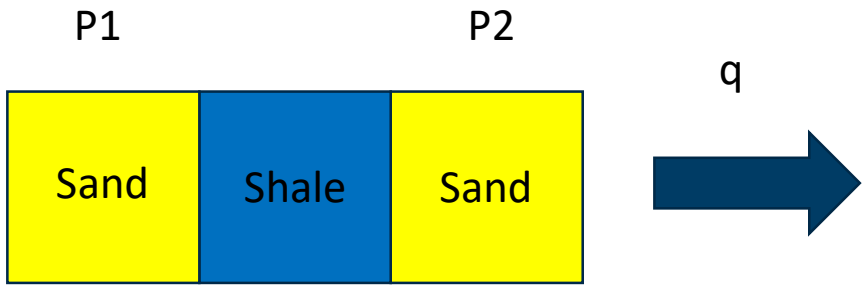
Stacked VE models

MRST co2lab

Multiple stacked VE models



Shale layers represented by modified transmissibilities



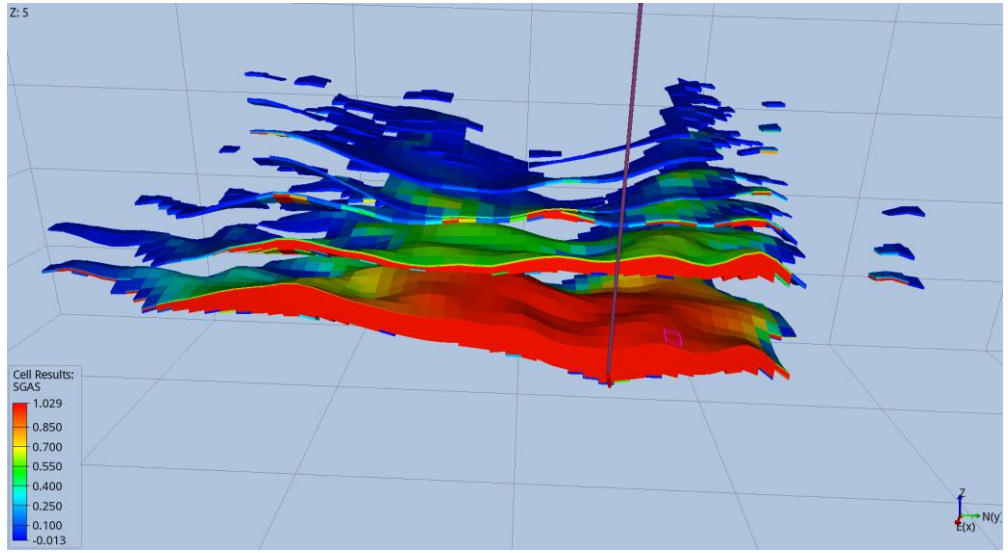
- Single phase
- Incompressible
- 1D

- $T = q/(P2 - P1)$

Comparison with finescale simulations

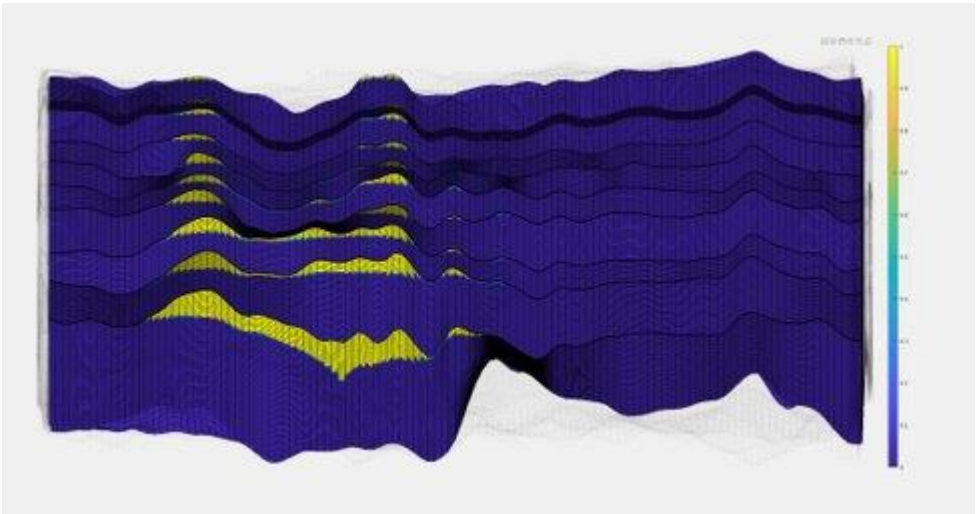
Full simulation (OPM)

- ~1.9 million cells
- 17 hours – 8 processors

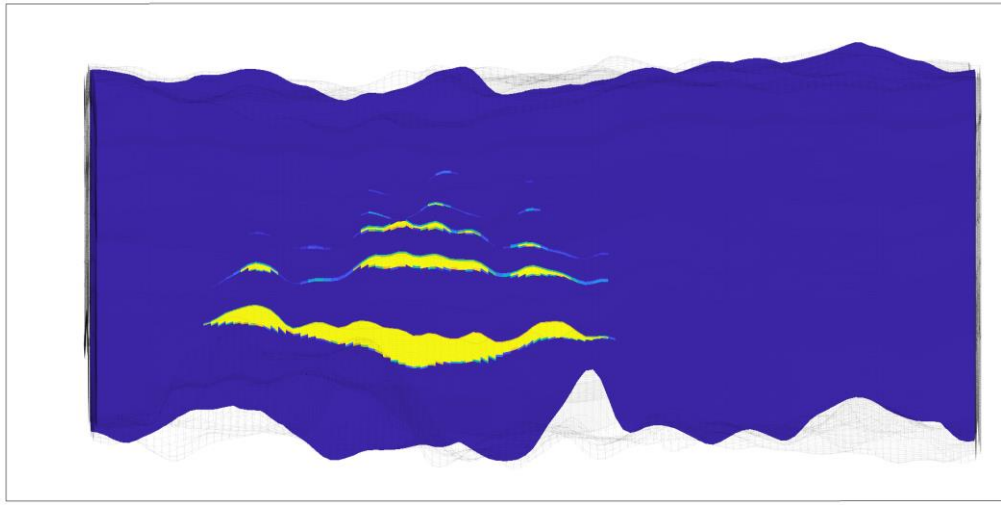


VE

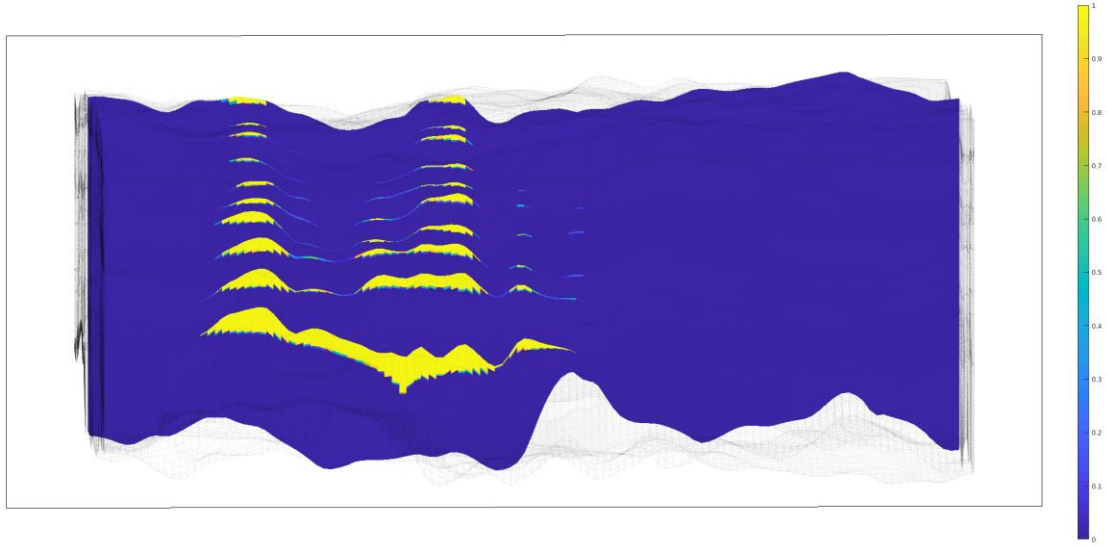
- ~75 000 cells
- 3 minutes



Hybrid VE



Hybrid VE



Stacked VE

How does CO2 leak through shale layers?

- How do we model leakage through layers?
  - Stacked VE models with altered transmissibility – timescales still not correct
  - Hybrid VE – difficult to optimise
- ‘Pressure dependent’ upscaled relative permeability
  - Only allow CO_2 to move upwards if pressure difference is high enough.
- Do we even have diffuse leakage or is it point leakage?

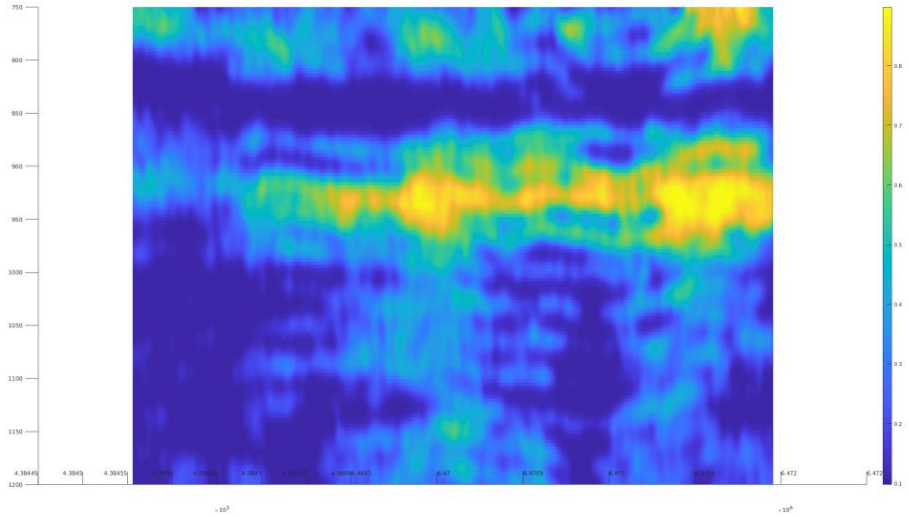
Simulating the new Sleipner model

- Work in progress!
- BUT Although model is large, the important information can probably be represented much more efficiently in a VE setting.
- Then we can optimise it to monitoring data.

Preliminary optimisation

- CO_2 saturations derived from rock physics inversion of a vertical seismic slice taken in 2008.
  - Yan et al. (2018) Geophysical Prospecting.

- Average CO_2 saturation within parts of the slice which coincide with grid cells in the reservoir model.



Preliminary optimisation

- Data to optimise to:
  - CO_2 saturations from inverted seismic data
  - Plume outlines from seismic data
  - Gravity data

- Factors to optimise
  - Layer transmissibility
  - Permeability / porosity / CO_2 density
  - Layer thickness
  - Time dependent diffuse leakage through layers
  - Diffuse leakage vs point leakage.

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Summary

- Monitoring data can provide more insight into reservoir models.
- Some challenges with modelling the new, multilayered Sleipner model.
- Model can probably be simplified to pick out the pertinent features.
- Optimisation can be used to find out a lot more about the layered system.

- Lots more exciting research to be done!

Acknowledgements

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