Energy and Green House Gas Mitigation Technologies

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Imperial College London, South Kensington Campus, London SW7 2AZ

Modelling Geological CO_2 Storage

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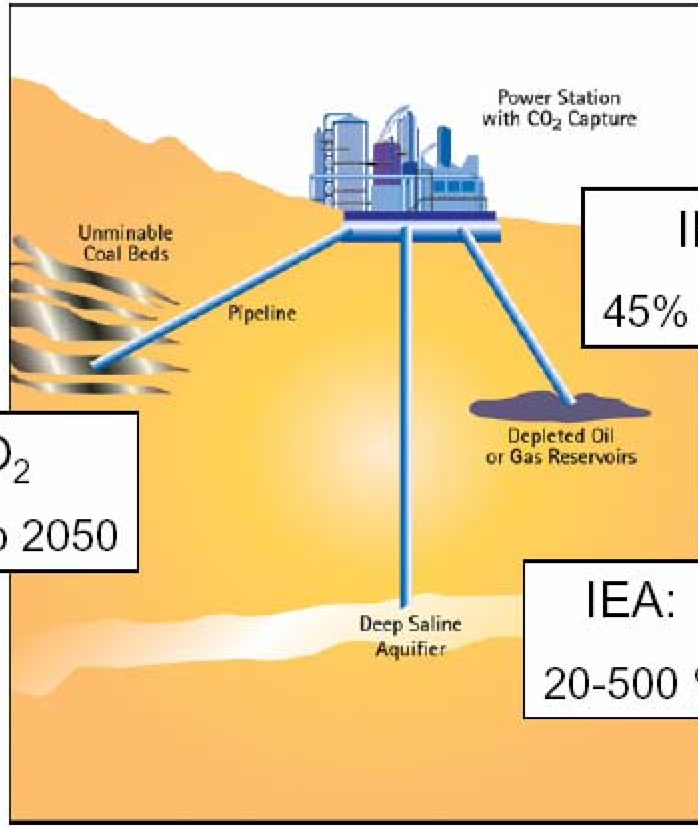
Geological storage of carbon dioxide



IEA: 40 Gt CO_2

<2% of Emissions to 2050

Parson & Keith:
370-1100 Gt CO_2

IEA: 920 Gt CO_2

45% of Emissions to 2050

Parson & Keith:
740-1850 Gt CO_2

IEA: 400-10 000 Gt CO_2

20-500 % of Emissions to 2050

Parson & Keith:
370-3700 Gt CO_2

Source: Freund, IEA - Comparative potentials at storage costs of up to \$20/t CO_2

Source: Parson & Keith, Science 282, 1053-1054, 1998

736 Gt in North Sea alone (DTI)

Why geological storage?

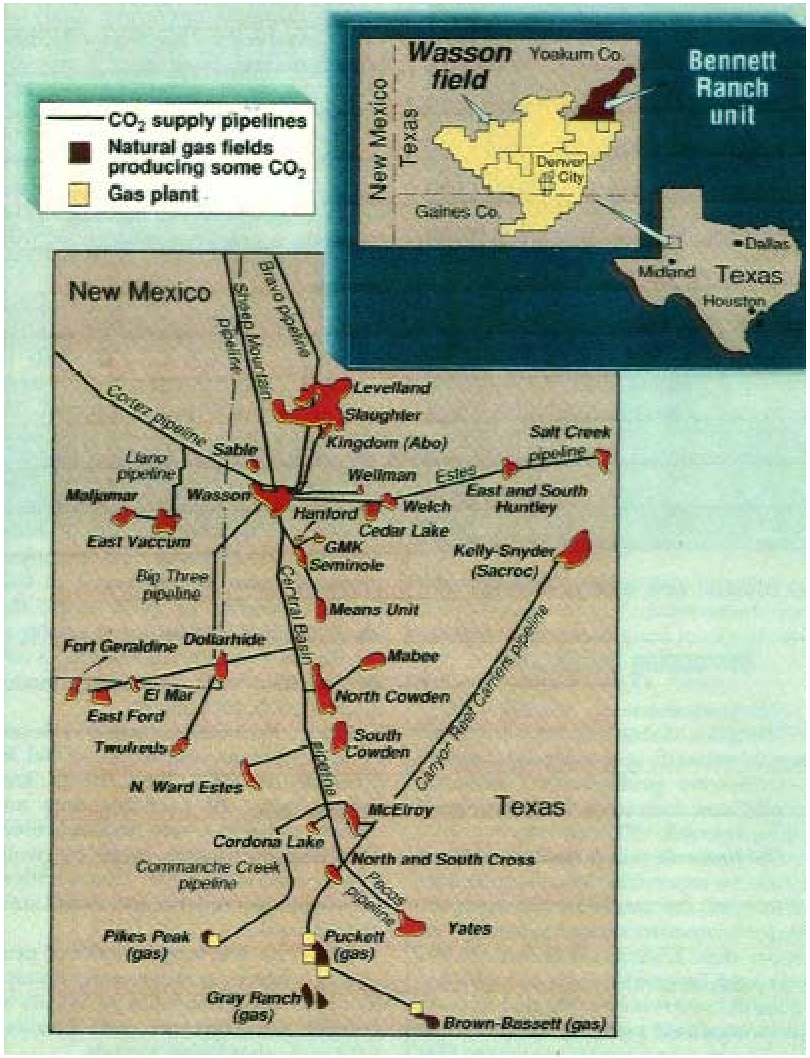
- Technology already established – many carbon dioxide injection projects in the world.
- Allows smooth transition away from a fossil fuel economy.
- Economic benefit of enhanced oil recovery.
- Has potential to have a large impact on carbon dioxide emissions quickly.
- Low emission option for developing countries – e.g. China and India who will invest in coal-burning power stations anyway.

Current projects – planned or underway

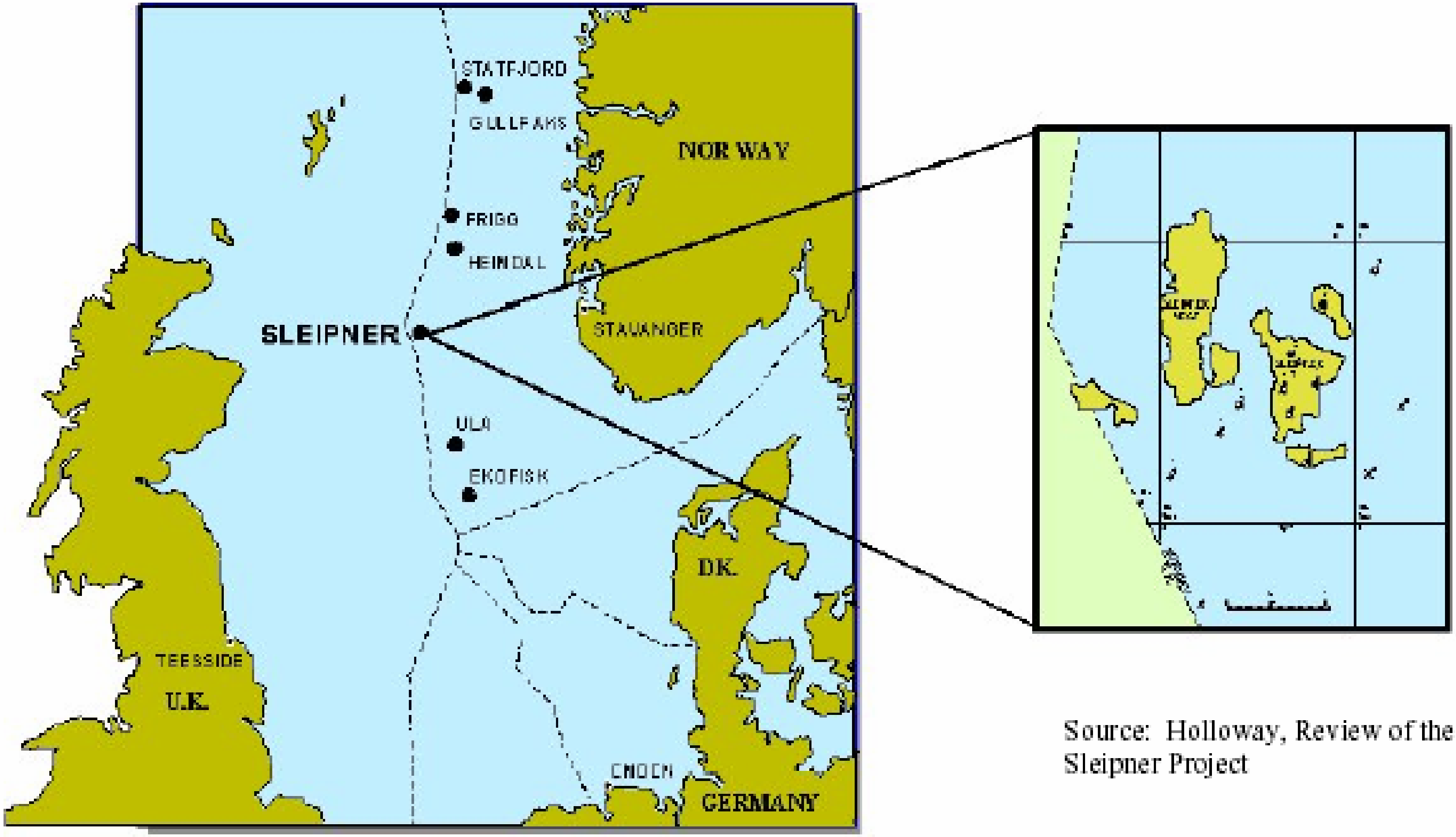
Source: Peter Cook, CO2CRC

Current oil field projects

- 66 CO_2 injection projects worldwide.
- Many in West Texas.
- Uses natural sources of CO_2 from underground reservoirs.
- Extensive pipeline infrastructure.
- North Sea plans in Miller (BP) and Draugen (Shell/Statoil)



Sleipner project

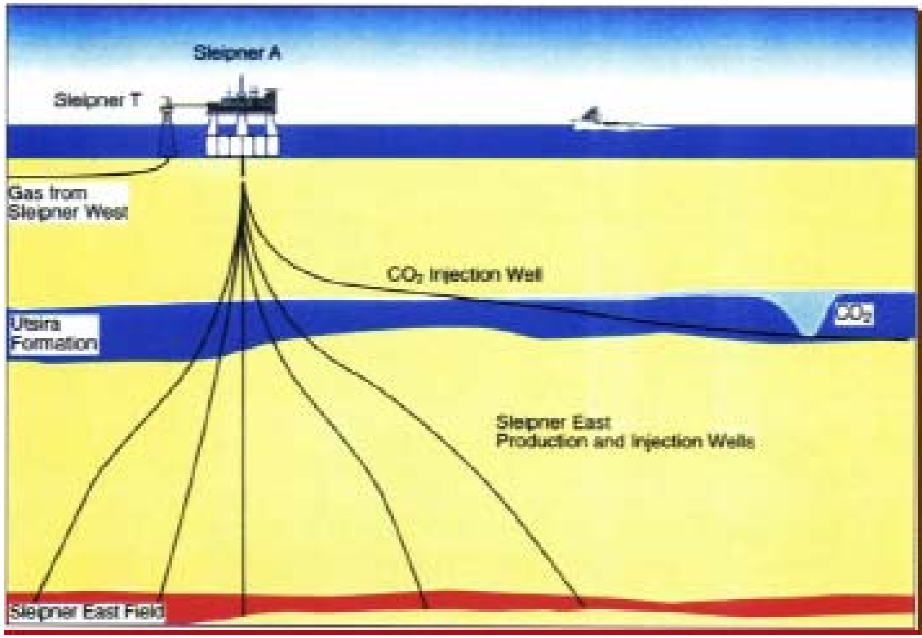


Source: Holloway, Review of the Sleipner Project

250 km offshore – production started in 1996

Sleipner project (continued)

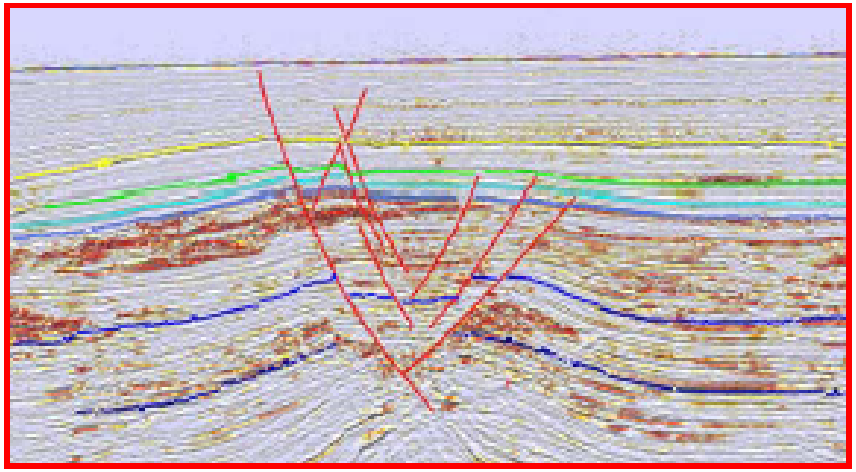
- 1 million tonnes CO_2 injected per year.
- CO_2 separated from produced gas.
- Avoids Norwegian CO_2 tax.
- Gravity segregation and flow under shale layers controls CO_2 movement.



Issues to address

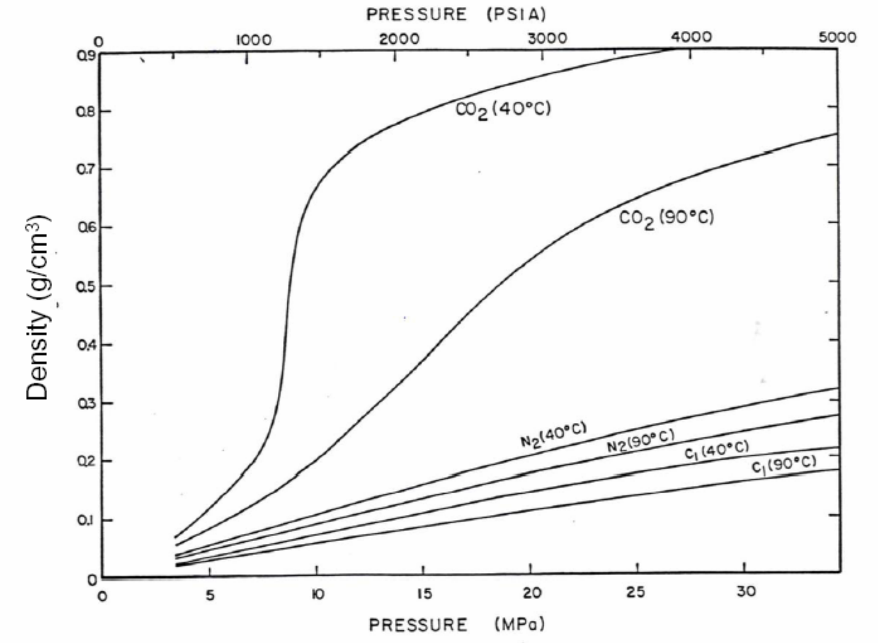
- How to separate carbon dioxide from the exhaust stream of a coal or gas-burning power station efficiently.
- Investment in pipeline infrastructure.
- Will the carbon dioxide remain underground?
  - Where will the carbon dioxide go and how can it be monitored?
  - Integrity of the geological seal
  - Leakage through wells
  - Long-term fate, including geochemical reactions

Saturation of CO_2



Carbon dioxide properties

- Critical point of CO_2 is 31^{o}C and 72 atm (7.2 MPa).
- CO_2 will be injected deep underground at supercitixcal conditions (depths greater than around 800 m).
- CO_2 is relatively compressible and its density, although always less than water is typically less than oil.
- Low viscosity – typically around10% that of water.



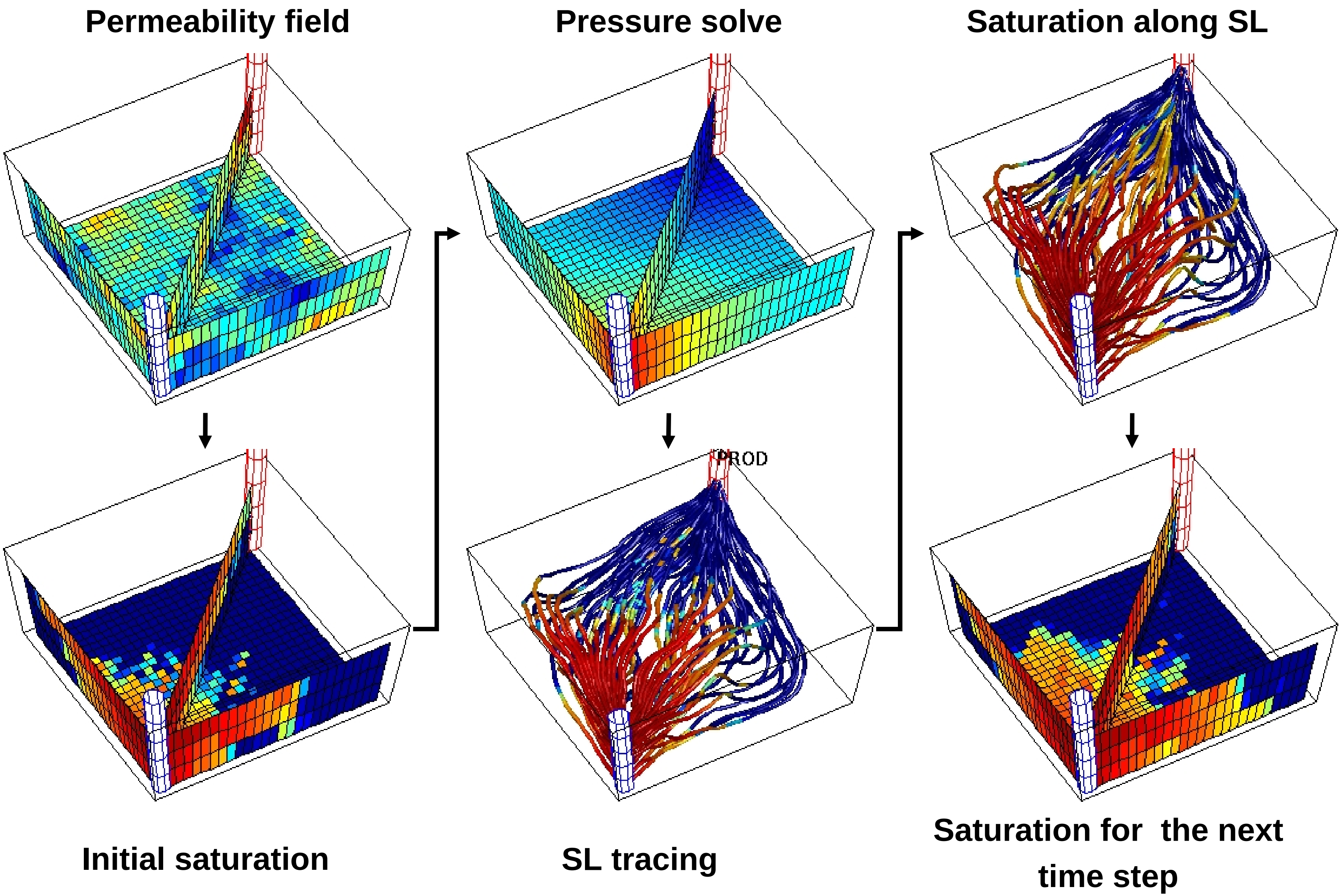
CO_2 injection in the North Sea

- Ideal opportunity: light oil (reservoir pressures typically above the MMP), mature fields, nearby sources of CO_2.
- At least 3 billion barrels of extra oil could be recovered in theory.
- Known well-characterised geological traps.
- Pipeline infrastructure and few, known wells.
- UK Government backing of CO_2 sequestration in recent energy white paper.
- Experience with gas injection in the North Sea (but not CO_2!); CO_2 injection elsewhere.

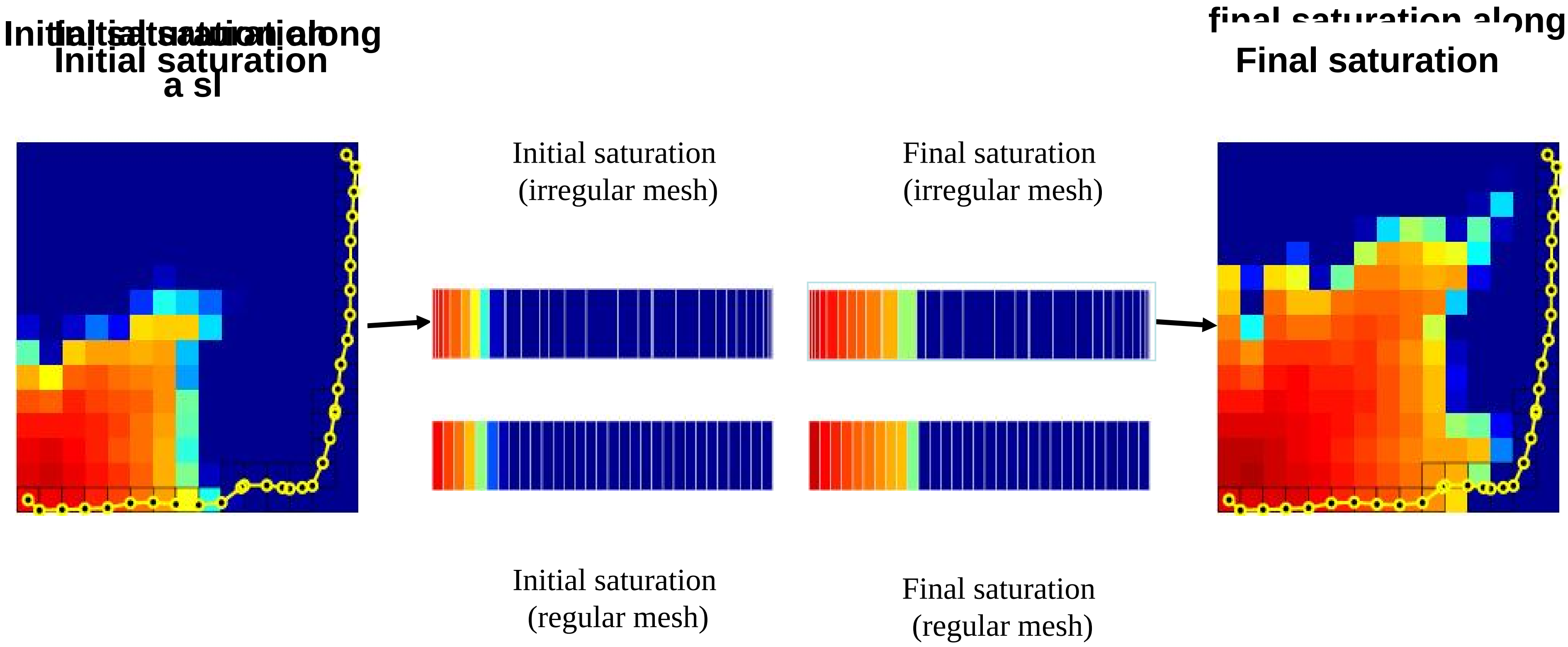
Some numbers

- Current emissions are around 25 Gt CO_2 per year (6 Gt carbon).
- Say inject at 10 MPa and 40^oC – density is 700 kgm^{-3}.
- This is around 10^8 m^3/day or around 650 million barrels per day. Current oil production is around 80 million barrels per day.
- Huge volumes – so not likely to be the whole story.
- Costs: $6 – 200 per tonne CO_2 injected.
- 1-3p/KWh for electricity for capture and storage.
- Could fill the UK emissions gap in 2020 easily.

Overview of the streamline method

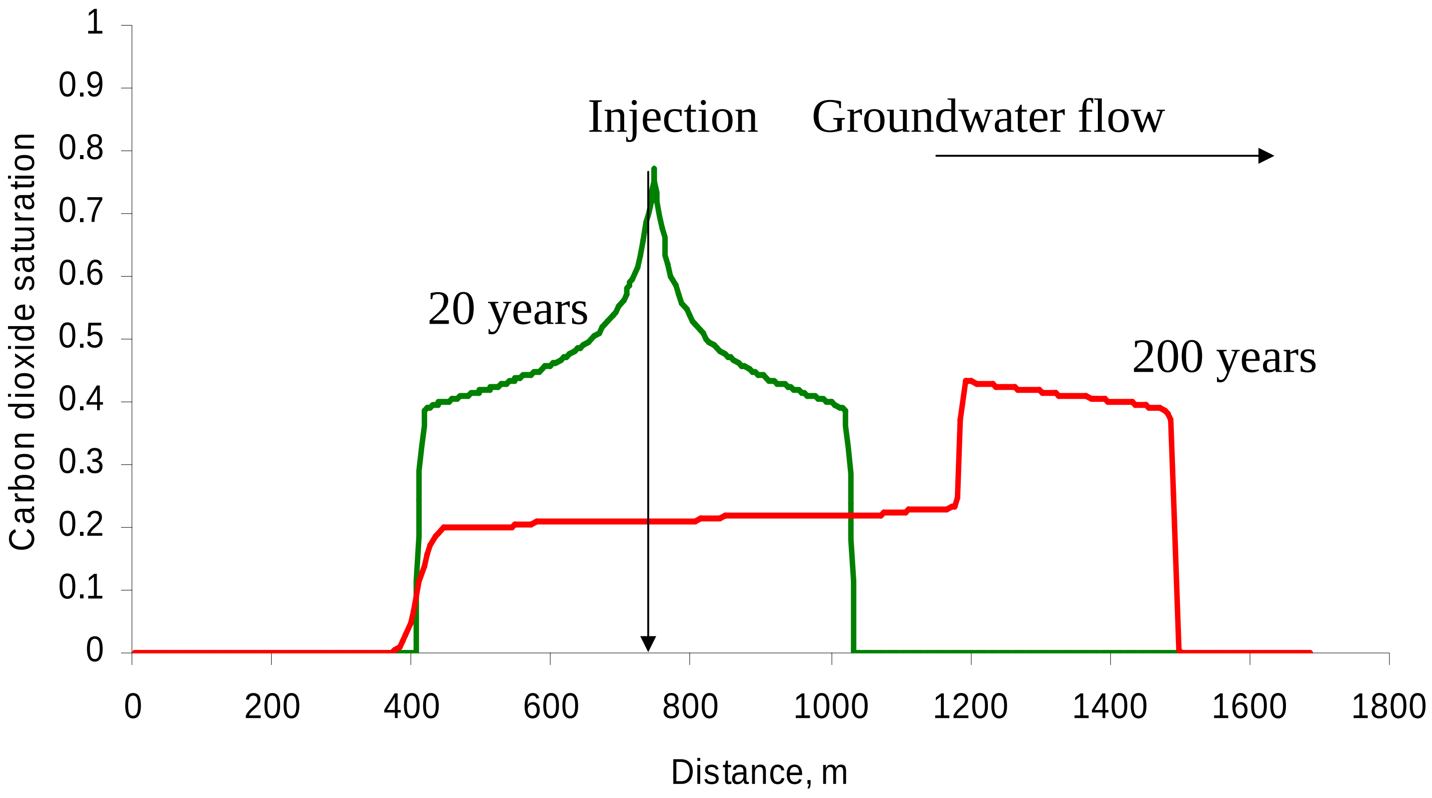


Saturation update



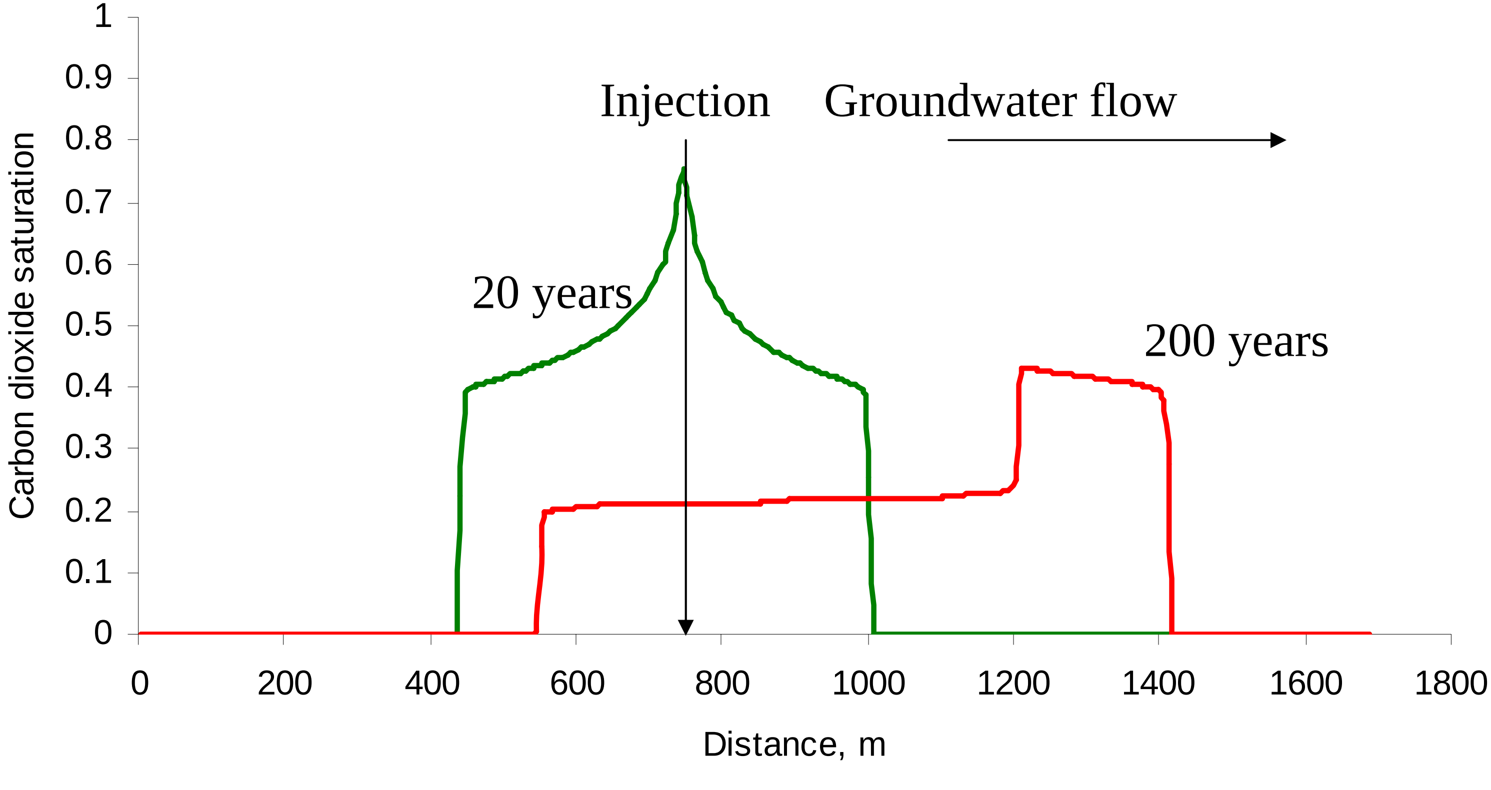
1D simulations

1D simulation. Inject for 20 years then 180 years of groundwater flow. Advection only.



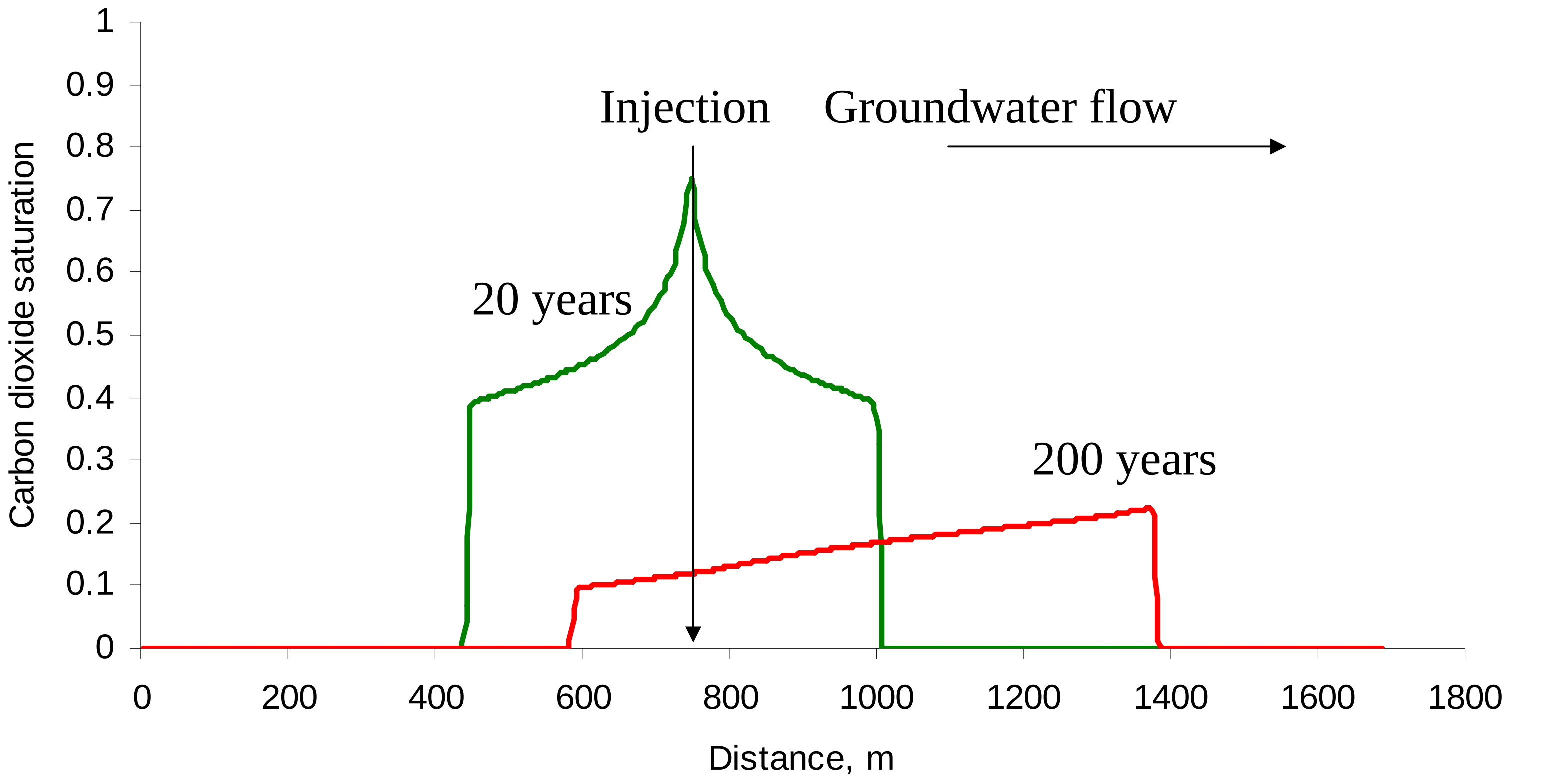
1D simulations (cont.)

1D simulation. Inject for 20 years then 180 years of groundwater flow. Advection and dissolution.



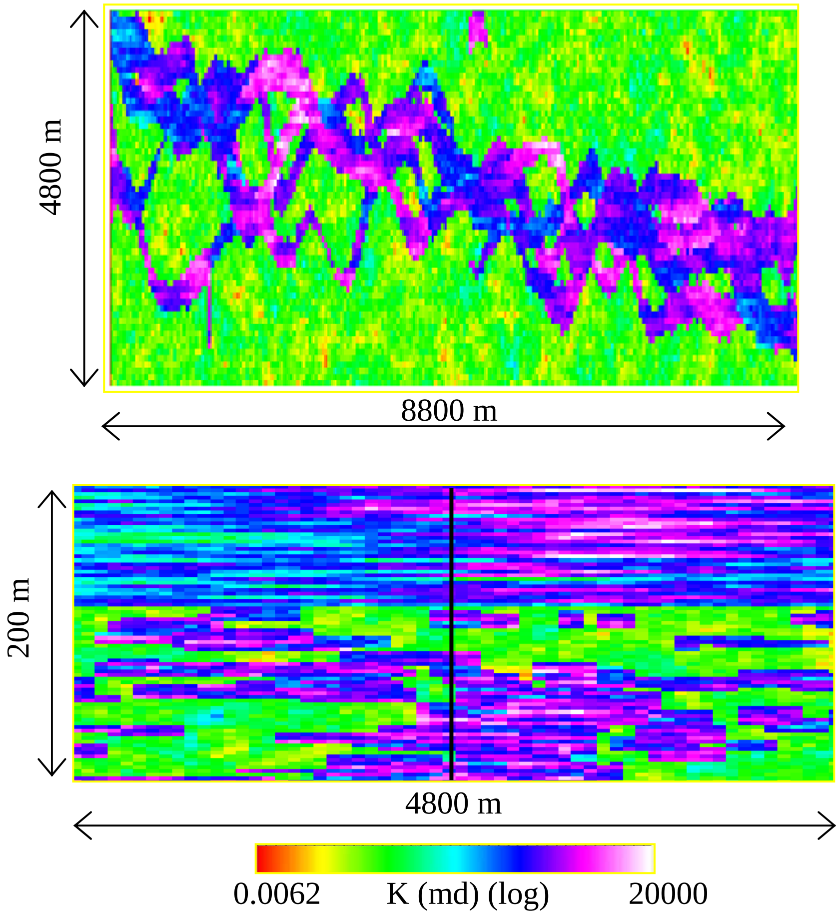
1D simulations (cont.)

1D simulation. Inject for 20 years then 180 years of groundwater flow. Advection and dissolution and reaction.



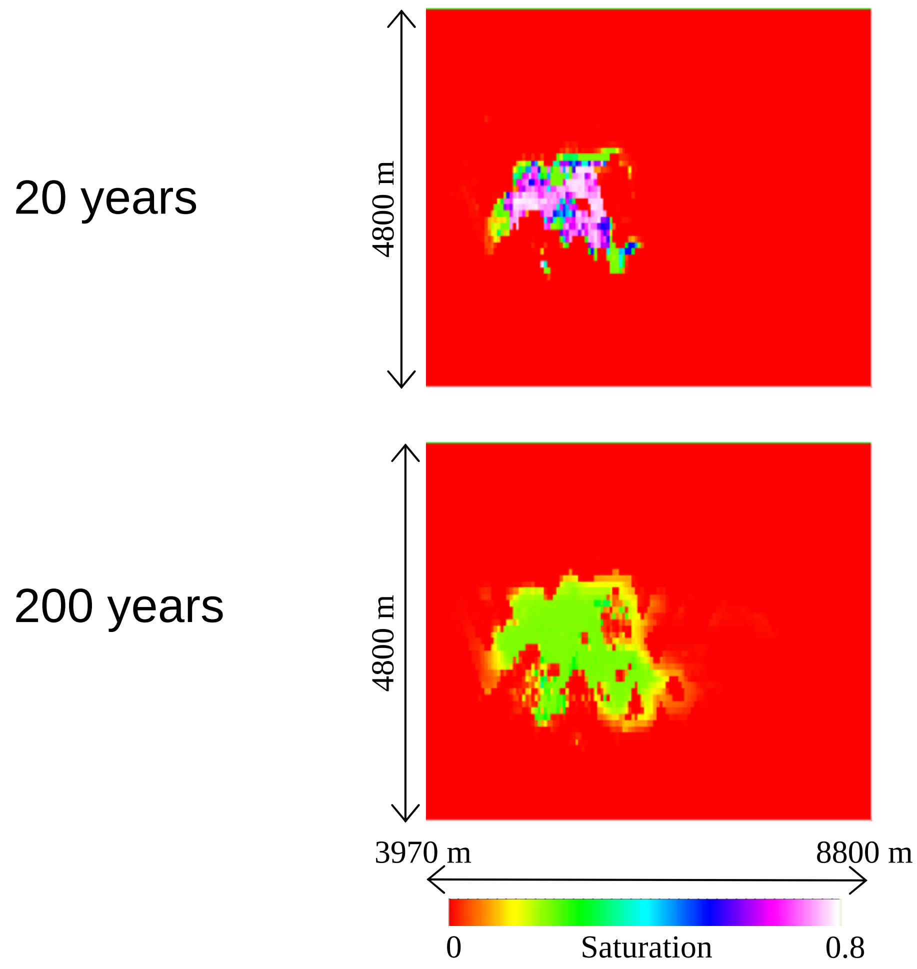
3D simulations

1 million cell representation of North Sea Field (SPE 10 case). Permeability field.



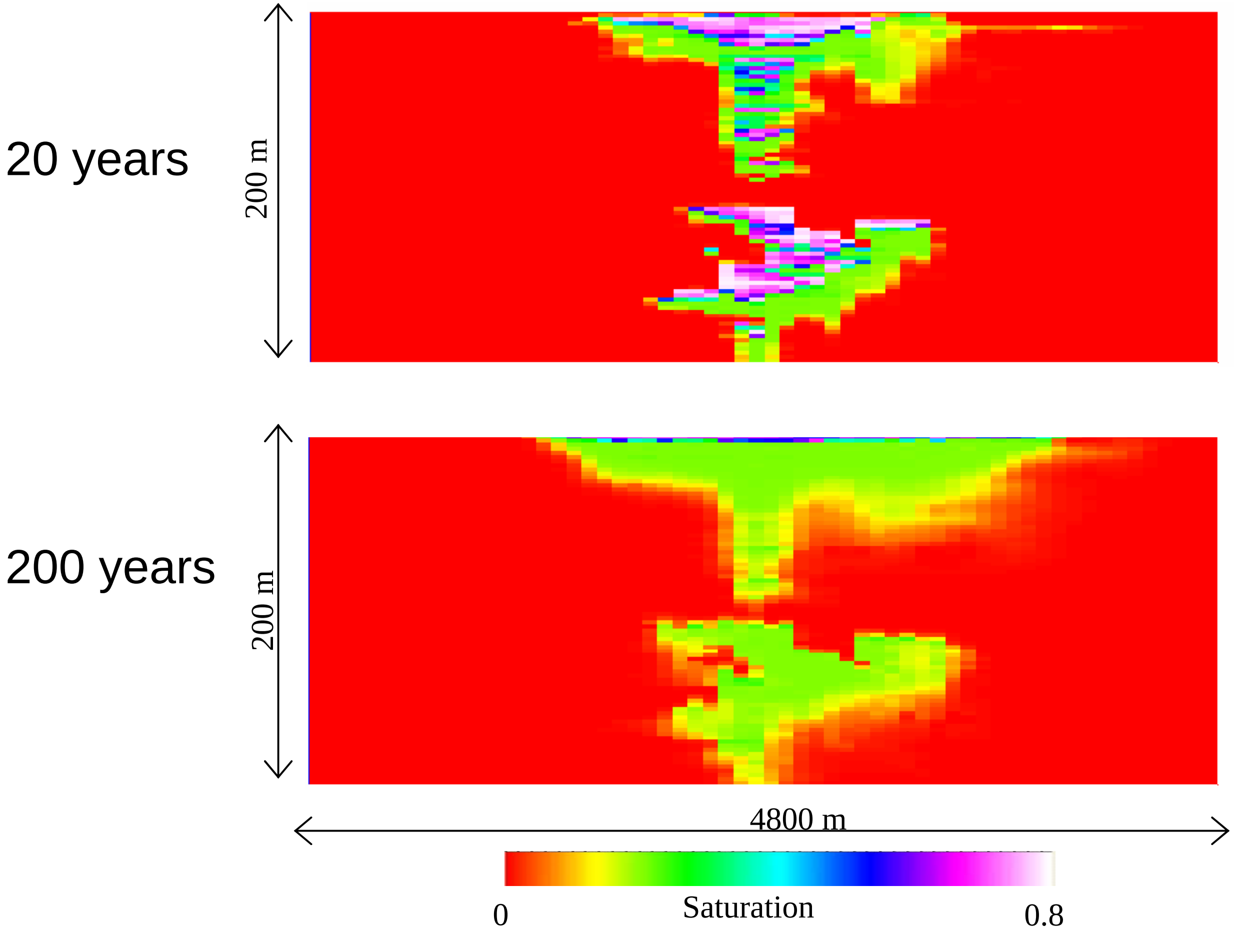
Horizontal slice - advection

Simulation of sequestration. CO_2 saturation shown.



Vertical slice - advection

Simulation of sequestration. CO_2 saturation shown.

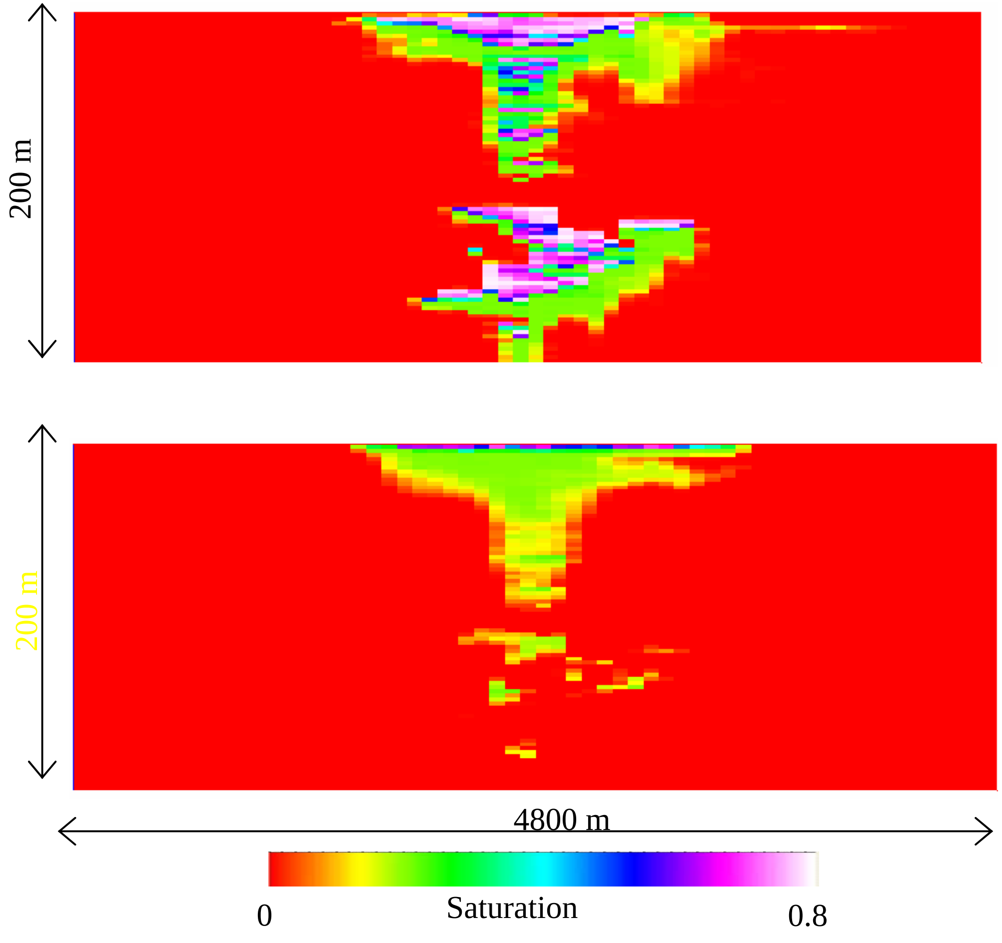


Vertical slice - dissolution

Simulation of sequestration. CO_2 saturation shown.

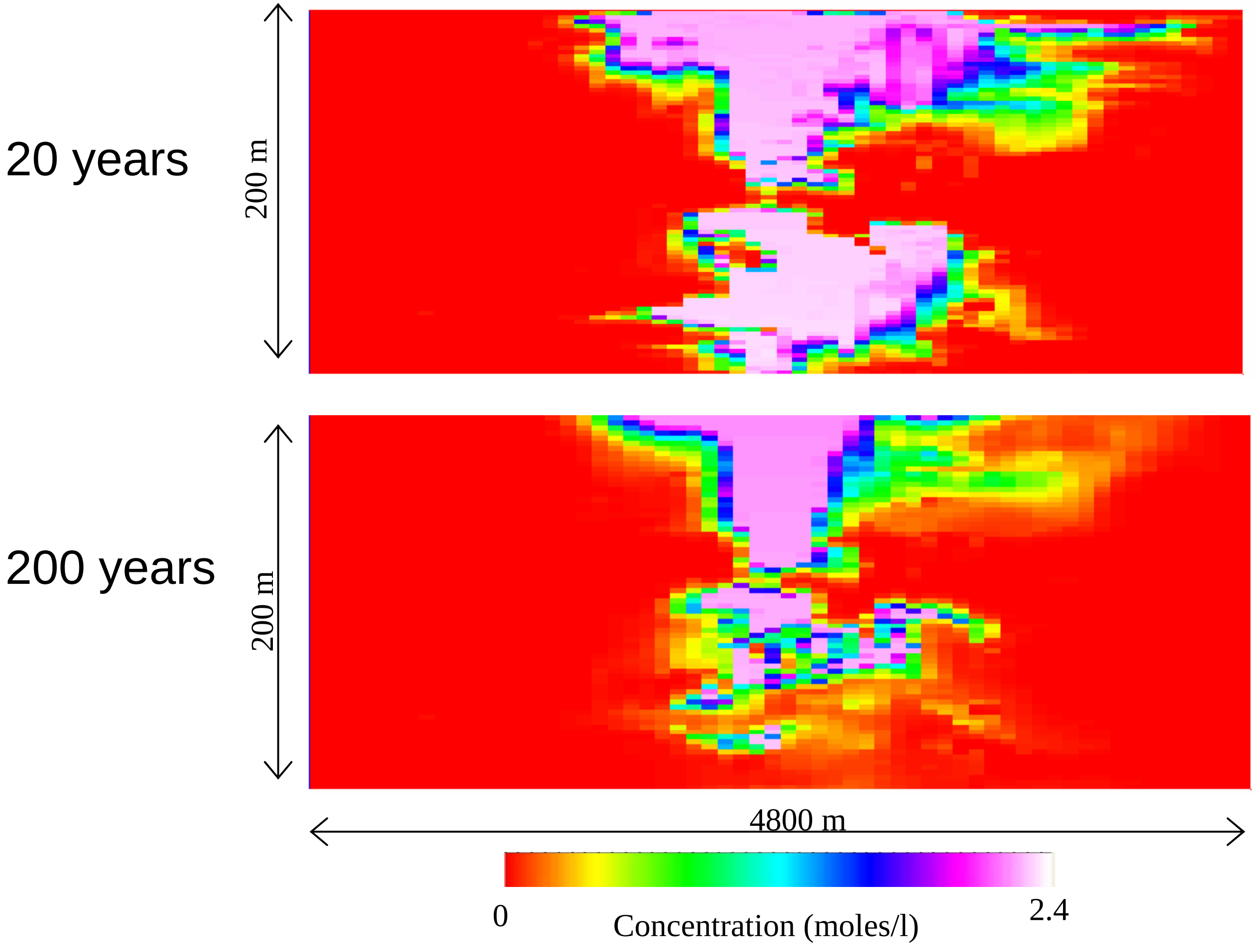
20 years

200 years



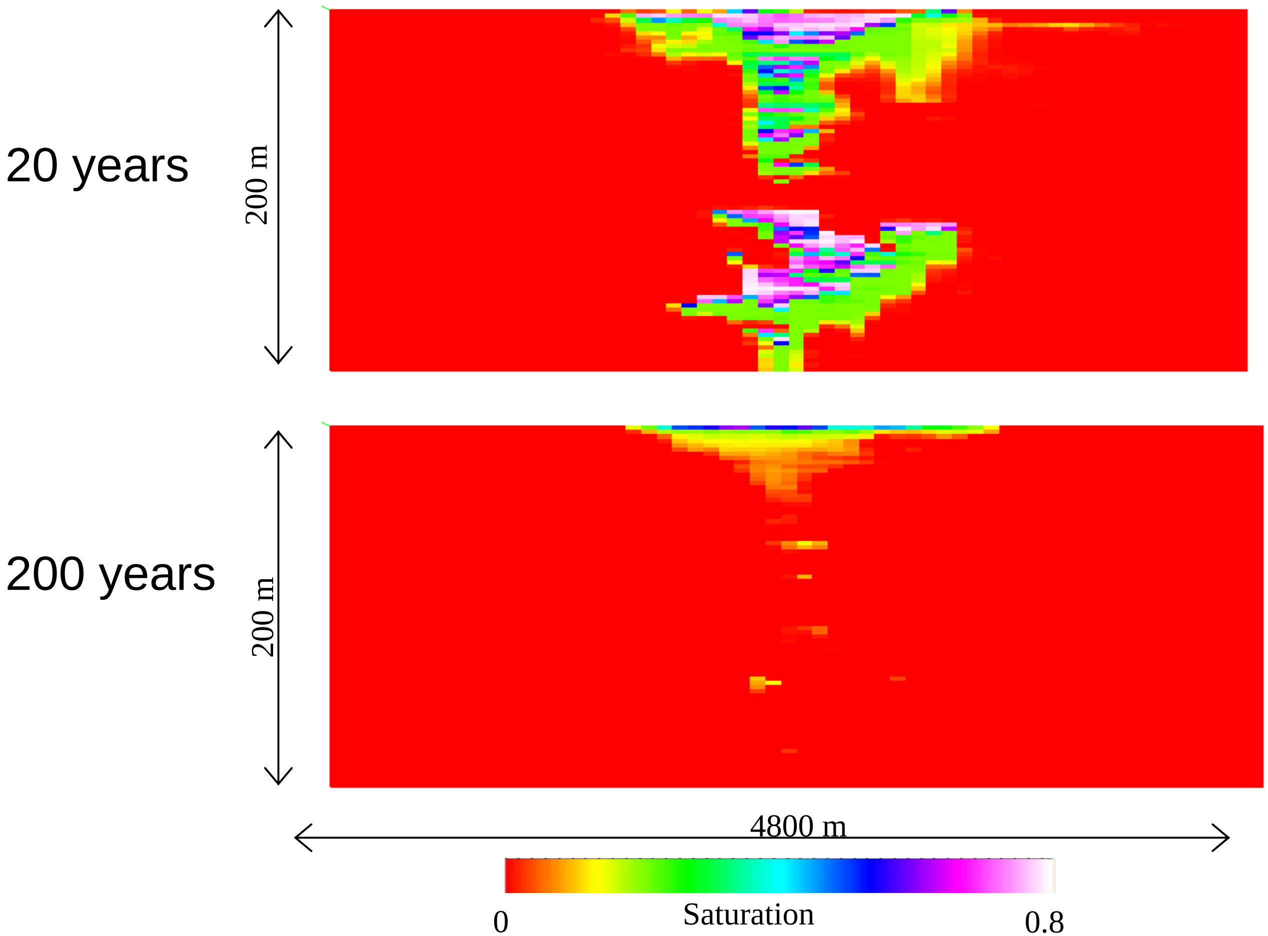
Vertical slice - dissolution

Simulation of sequestration. CO_2 concentration shown.



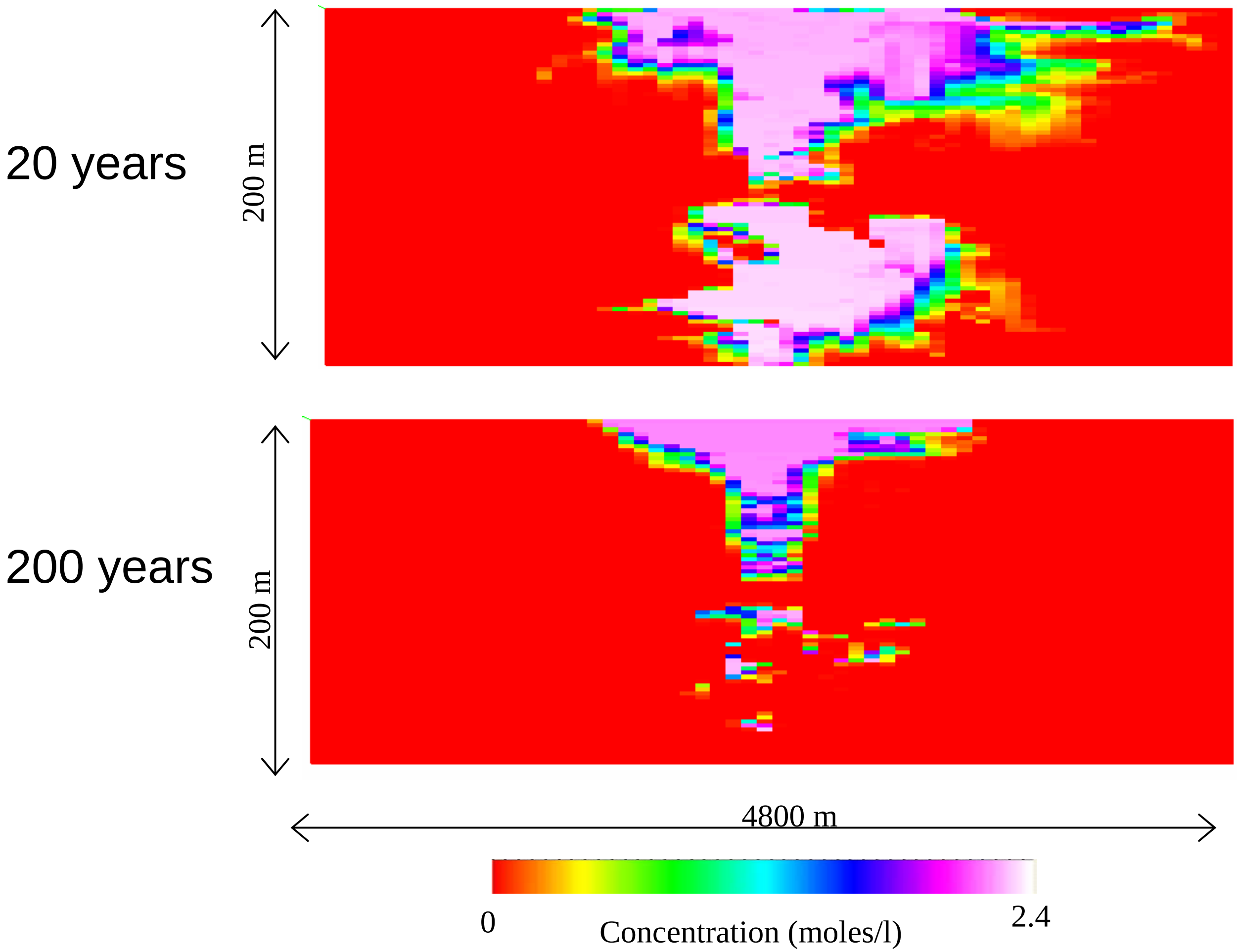
Vertical slice - reaction

Simulation of sequestration. CO_2 saturation shown.



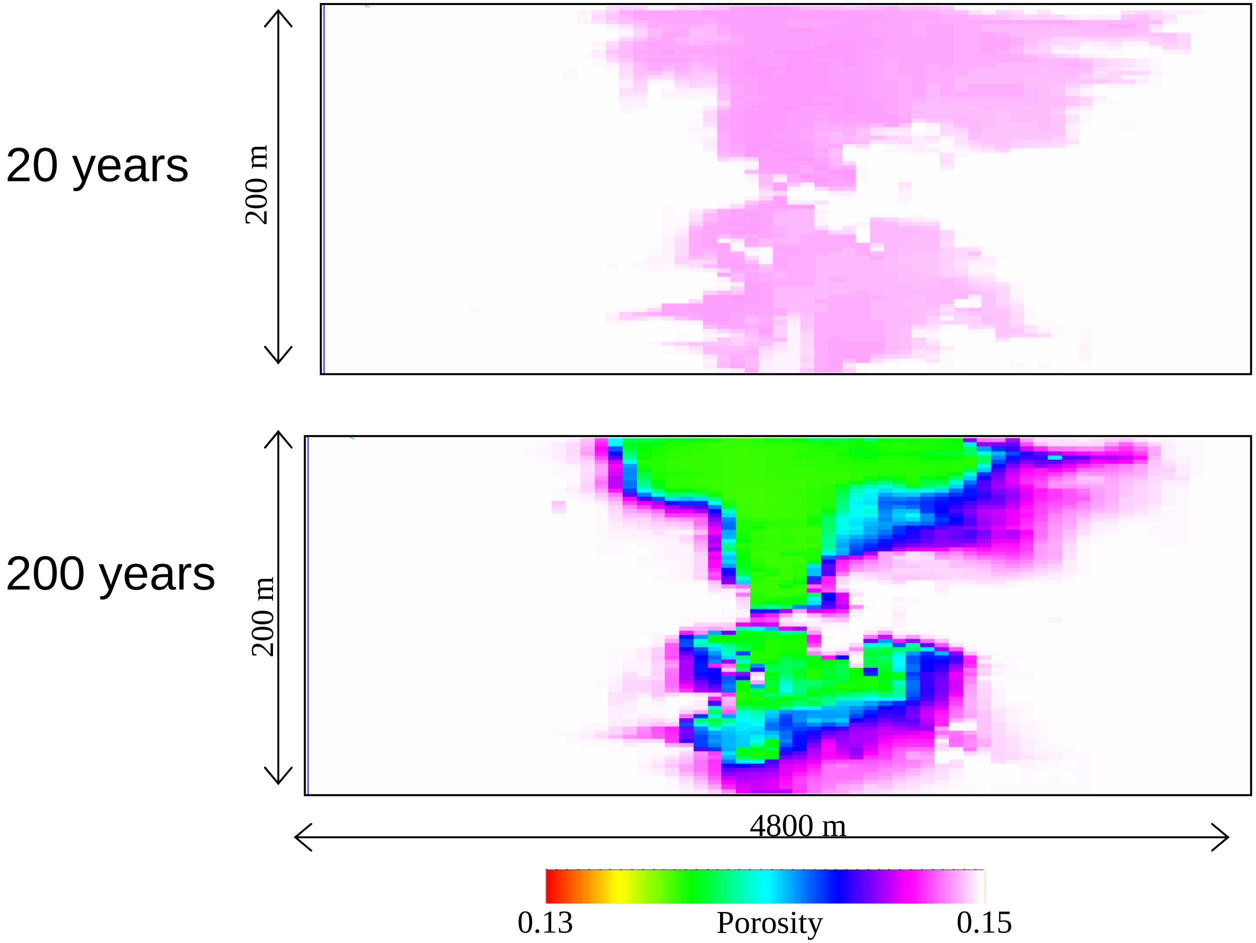
Vertical slice - reaction

Simulation of sequestration. CO_2 concentration shown.



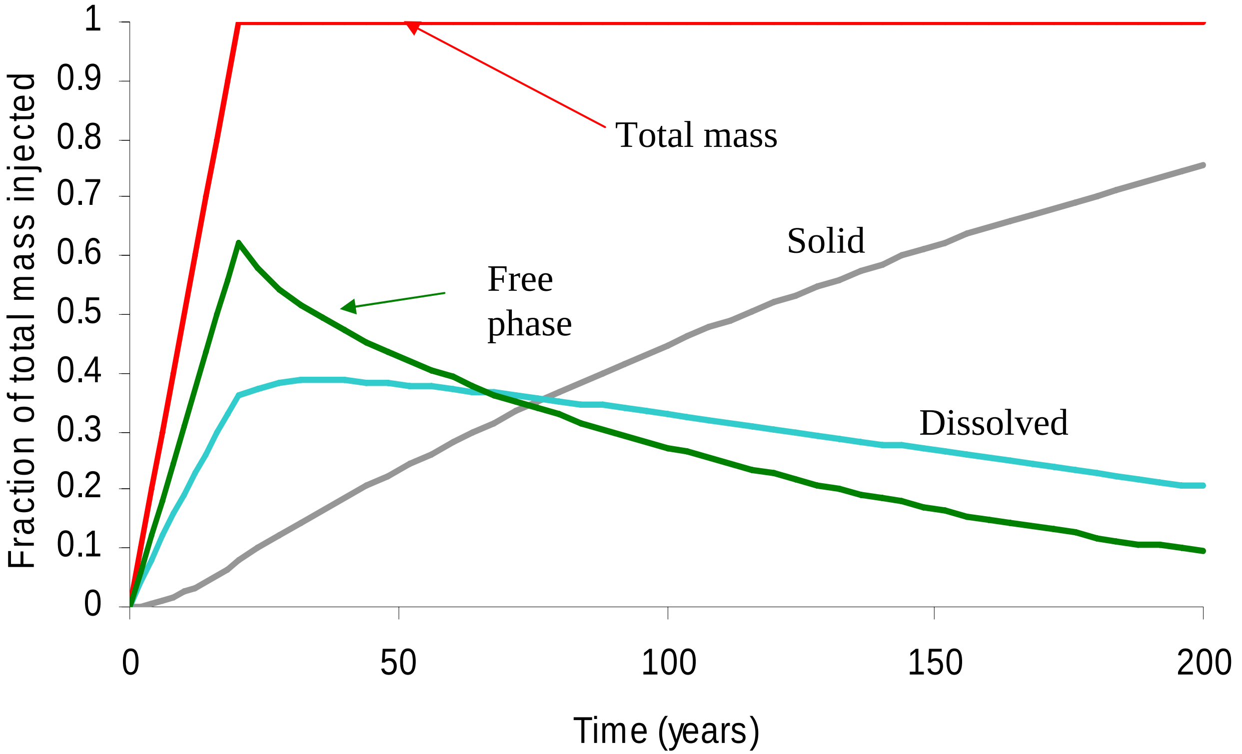
Vertical slice - reaction

Simulation of sequestration. Porosity shown.



Mass in each phase

Study how much mass is in which phase. Sequestration efficiency around 2 – 3 % only.



Streamline recap

- Ideal method for handling initial injection phase – complex thermodynamics and reservoir heterogeneity combined.
- Can handle rate-dependent mass transfer – fractures or reaction chemistry.
- Readily study large, finely gridded models.
- Huge uncertainties in geochemical characterisation.
- Need work on trapping and relative permeability.

Overview

- Carbon capture and storage is a key component to reduce atmospheric CO_2 emissions.
- UK has a strategic opportunity to take a lead in CCS.
- Unique combination of fossil-fuel burning power stations close to oil fields ripe for CO_2 flooding plus pipeline infrastructure.
- Main issues to predict where the fluid moves (charactersiation and simulation), monitor where the fluid moves (4D seismic) and long-term fate (geochemistry, dissolution.

Thanks

- Lynn Orr (GCEP) and Jon Gibbins (Imperial) for slides and useful insights.
- E I Obi (now at Total) the PhD student who did the work.
- Shell and BP for (past) financial support.