PANACEA

SEVENTH FRAMEWORK PROGRAMME

Predicting **a**nd mo**n**itoring the long-term beh**a**vior of **C**O_2 inj**e**cted in deep geologi**c**al form**a**tions

History matching CO_2 plume in the upper Utsira Formation

EWRE

Statoil

Brainstorming Day
Paris, December 19, 2014

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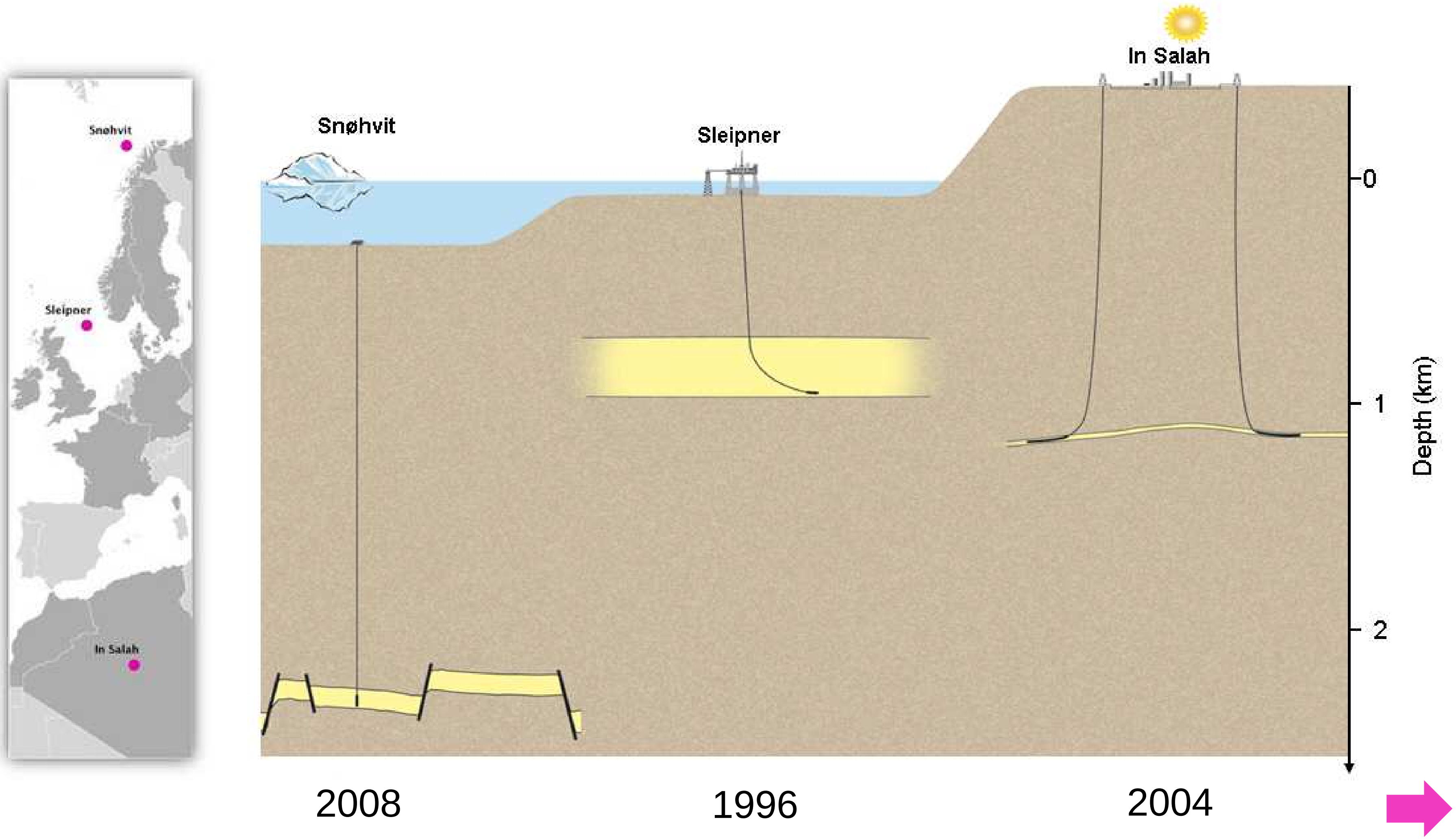
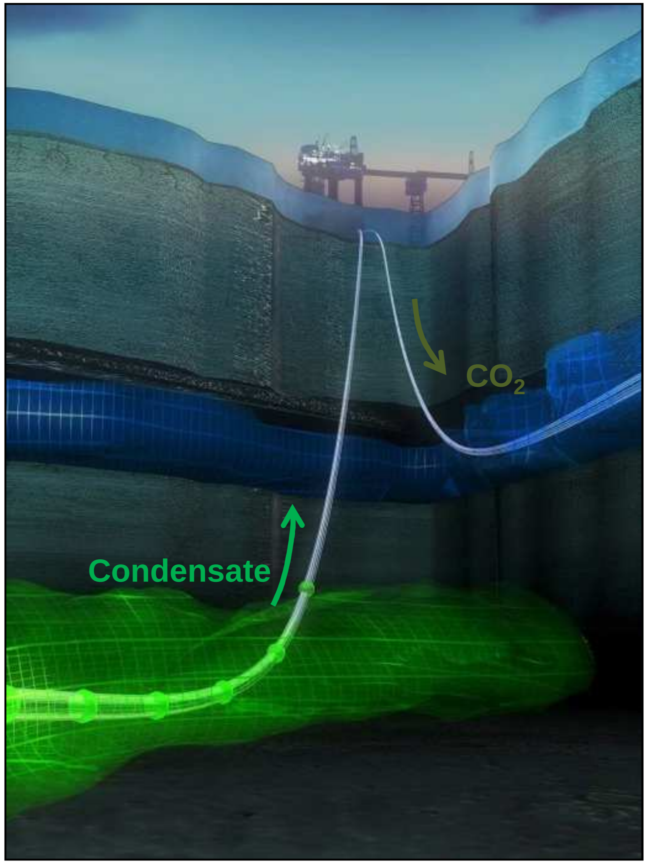
Commercial storage projects



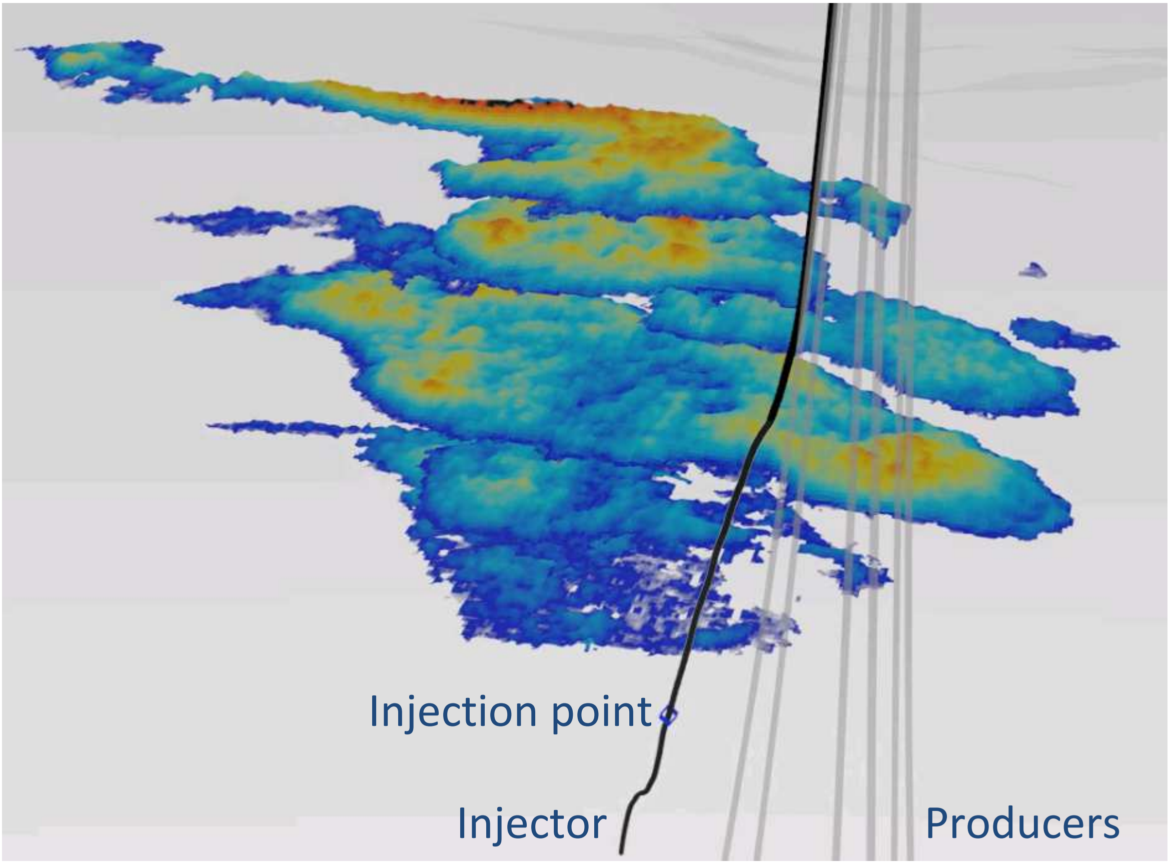
From: O. Eiken et al., 2011

The pioneering project, Sleipner

- *Main learning: CO_2 storage is technically feasible*



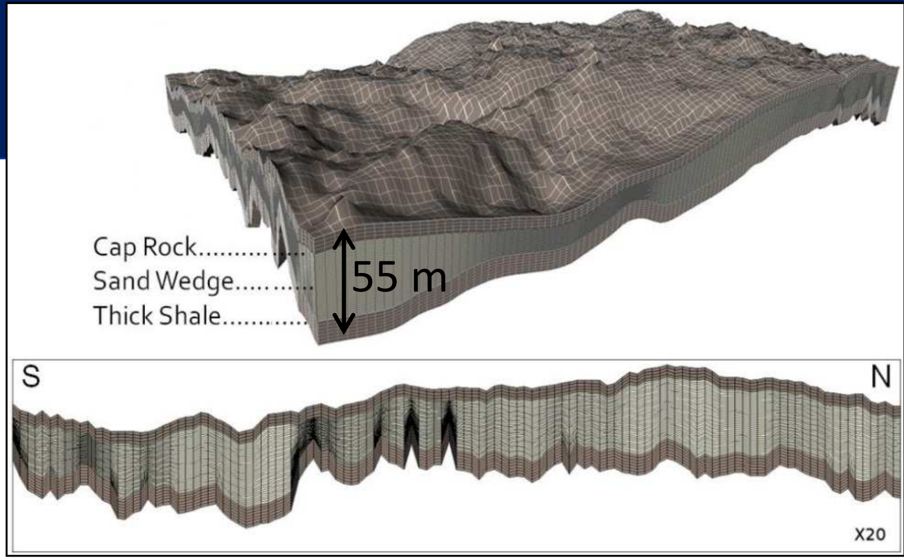
Time-lapse seismic image



From: A. Kiær, 2014

The Layer 9 model

➢ *Benchmark for dynamic simulation*



- Longest history of CO_2 injection
- Repeated seismic surveys
- Challenging history match due to uncertainties on state and properties of injected CO_2
- A relevant case for assessing the long-term behavior of injected CO_2 in saline aquifer

- 525,900 elements, 3x6 km^2 mesh with a cell resolution of 50x50 m^2
- Injection rate is inferred from seismic
- Injection point is at the location of first CO_2 arrival in Layer 9
- Bases of history match is visual comparison between simulated plume and seismic boundary

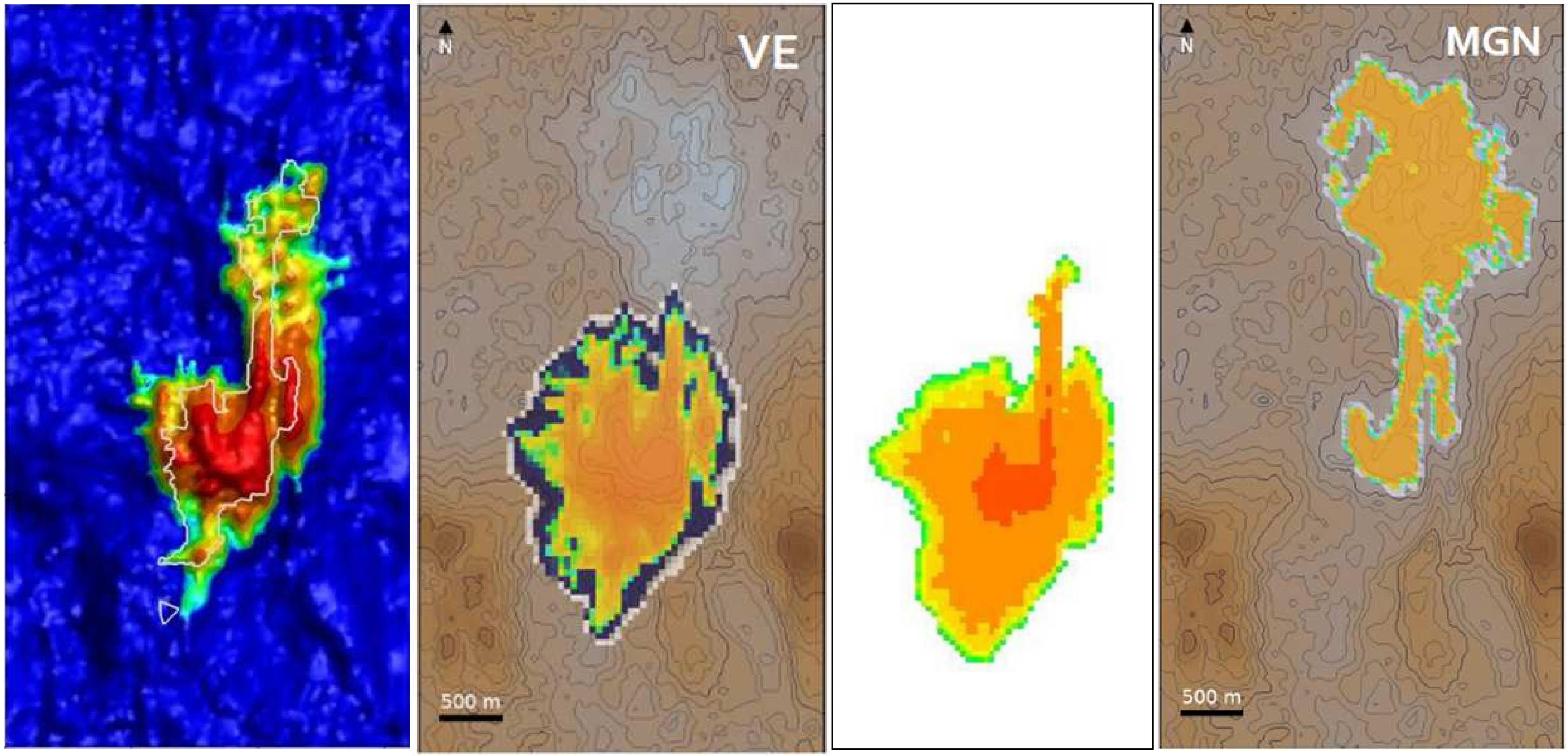
PFLOTRAN simulator

- PFLOTRAN is an open source, massively parallel subsurface flow and reactive transport code
- Solves a system of equations describing multi-phase, multi-component and multi-scale flow in porous media
- Ability to simulate large models with reasonable simulation time and dedicated models for CO_2 sequestration
- Solution technique is MPHASE, solving a non-isothermal, two-phase flow (liquid and gas), with 2 components (H_2O and CO_2) miscible in all proportions in both phases

Sensitivities and resulting effects

Case	Classification	Modification	Effect	Result
1	Heterogeneity	Permeability and porosity variation with elevation to account for rock consolidation	General improvement of HM	No noticeable CO_2 northern propagation compared to homogeneous permeability
2	Uncertainty in input data	Reduced injection rate, 20% of base case	Could reduce the transverse spread of plume	No noticeable positive plume propagation pattern change
3	HM parameter	Use of linear relative permeability	Enhances phase segregation	Negligible improvement (maybe due to pseudo linear relative permeability implementation in PFLOTRAN)
4+5	Uncertainty in input data	Lower hydrostatic pressure + mass correction	CO_2 in gas phase	North-propagated plume is achieved
6	Physical properties	CO_2-Methane mixture (1.2% Methane) injection	Lower gas mixture density	Reasonable match to seismic observation
9	Uncertainty in initial condition	CO_2-Methane mixture (4% Methane) injection	Higher CH_4 concentrations to account for in-situ Methane	Best match

Match to 2008 plume



This work | CO2BOS | GEM | IP Migration

Conclusions

- Performed study is a relevant contribution to Panacea project through code comparison and HM to widely used benchmark
- Exhaustive study on important parameters that can influence CO_2 plume movement
- Heterogeneity in Utsira has negligible effect on plume movement
- Pressure and temperature variations inside the storage reservoir have first order effect on CO_2 dynamic behavior especially near the CO_2 critical point
- Residual components play important role in enhancing the physical properties of the injected phase influencing consequently the CO_2 plume dynamic behavior

Thank you for your attention

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