UNFCCC
WORKSHOP ON MODALITIES AND PROCEDURES FOR CCS UNDER THE CDM

Abu Dhabi, United Arab Emirates –
September 7th-8th, 2011

Use of models in site selection and exploitation

Jean-Pierre DEFLANDRE

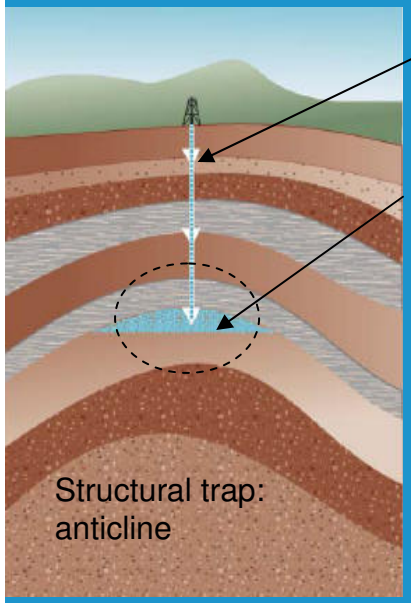
Professor at IFP School - Research project manager in CCS

Outlines

- Introduction on key parameters (V. I. P.)
- The role of modelling in CO_2 geological storage
- An iterative process while considering site monitoring results
- Illustrations
  - Reservoir pressure modelling and monitoring verification with the In Salah case (Algeria)
  - CO_2 plume mapping by using 4D seismic monitoring results at Sleipner (Offshore Norway)
- Conclusions

CO_2 geological storage: key parameters

modifying in situ pressure (P), temperature (T) and fluid composition



- Characteristics of the CO_2 stream (considering impurities)
- Storage site characteristics
  - Storage capacity (V, P, T, k...)
  - Reservoir injectivity (k, P, Q...)
  - Fluid migration within the storage complex (P...)

Storage integrity

Maximum acceptable pressure for efficiency without inducing any unsuitable geomechanical effect

Reservoir pressure prediction and CO_2 plume mapping the two major objectives in modelling of CO_2 geological storage

The role of modelling in CO_2 geological storage

- Part of the site selection decision process (including the site development step)
  - Feasibility step: short term site performance assessment and risk assessment using a 3D preliminary static (geo)model (Go/NoGo?)
  - Prediction of long term performance assessment and risk assessment for site development (considers feasibility feedback)
  - Identification of the storage boundaries (the "storage complex") while assessing uncertainties due to modelling parameters (Go/NoGo ?)
- To help at understanding short and long term site behaviour and designing monitoring plan while running sensitivity studies
- In case of discrepancies (deviation from prediction), to help at evaluating mitigation or remediation scenarios efficiency (for example additional well positioning for reservoir pressure management)

→ **CO_2 geological storage: safe and efficient at both short and long terms considering Human safety and Environment under a sustainable development way.**

CO2 REMOVE research monitoring verification

Modelling in practice: an iterative and complex process

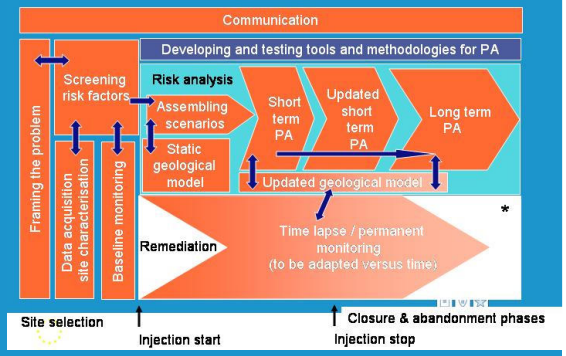
- Iterative between
  - prediction and simulation (mimicking)
  - modelling and monitoring (permanent process)

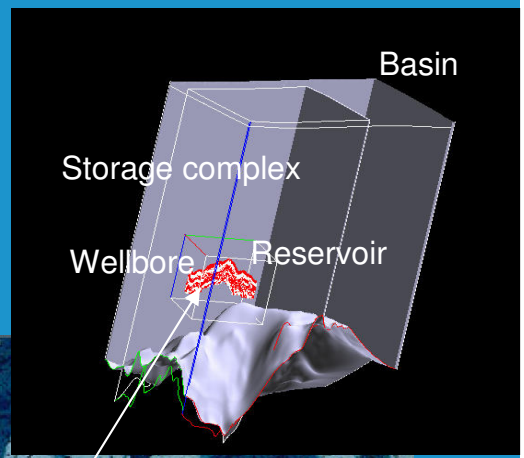
  (...design/constrain/update/design/constrain...)

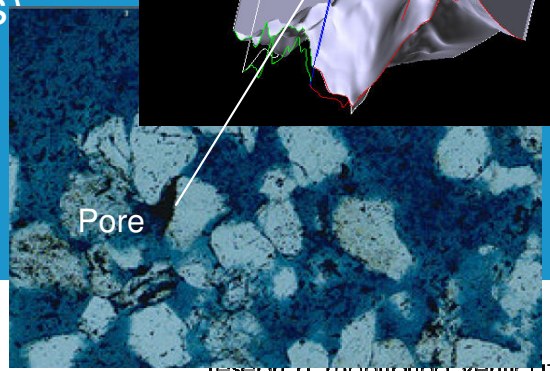
- Multi-scales
  - from pore volume to the basin
  - from a few minutes to thousands of years

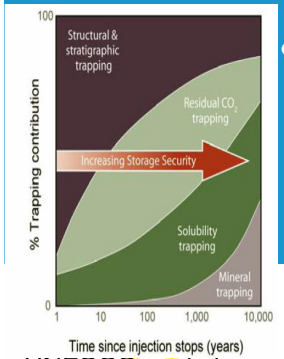
- Multi-physics
  - coupled processes (fluid flow / geomechanics)
  - reactive processes (reactive transport of CO_2 with in situ rock and fluid materials)

Site performance assessment workflow in the frame of CO_2 geological storage









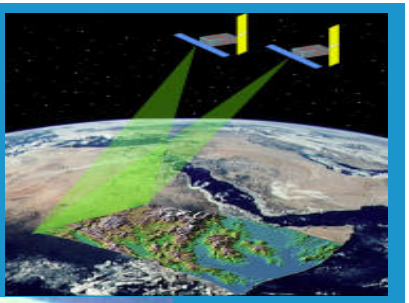
IPCC, 2005

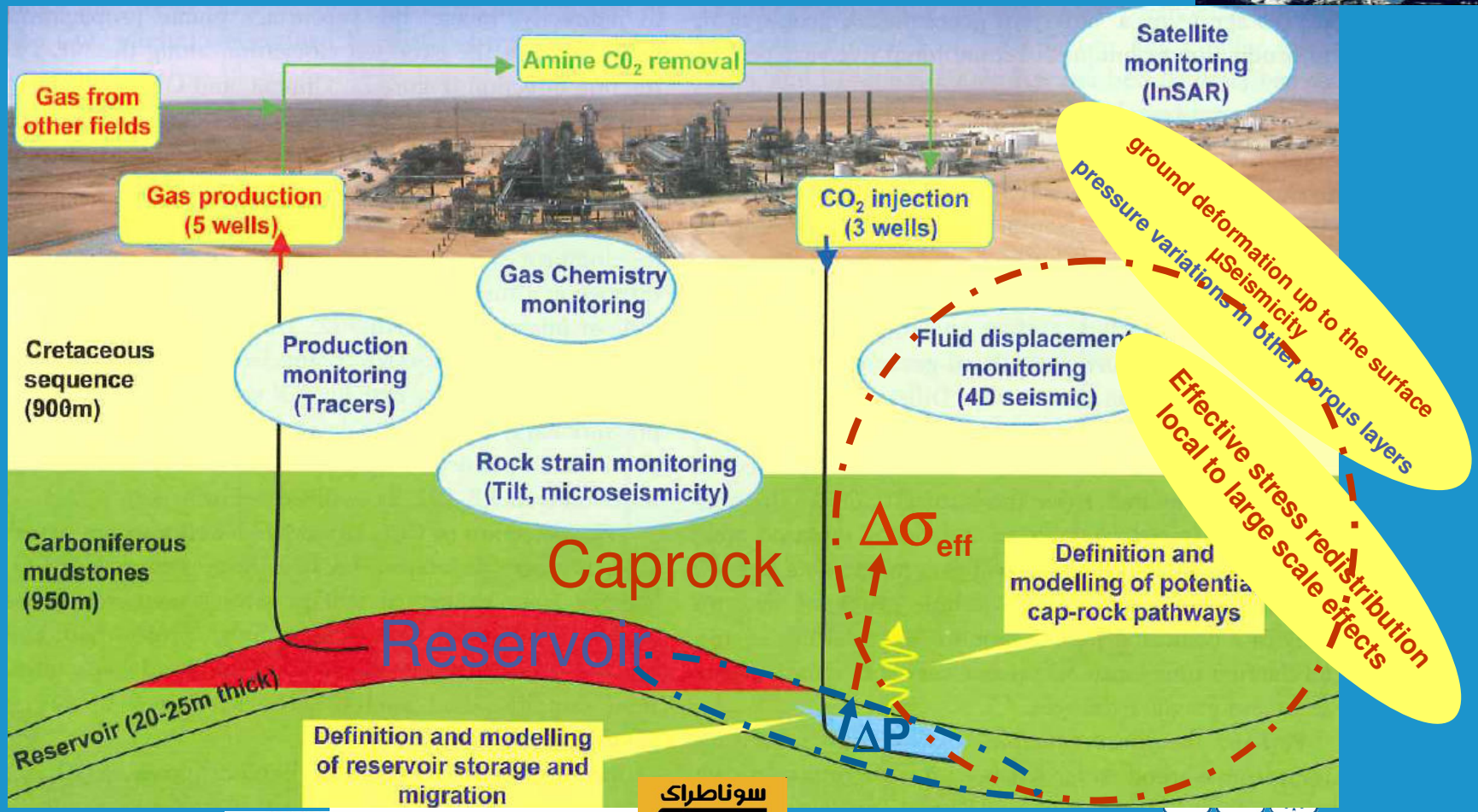
Outlines

- Introduction on key parameters
- The role of modelling in CO_2 geological storage
- An interactive process while considering site monitoring results
- Illustrations
  - Reservoir pressure modelling and monitoring verification with the In Salah case (Algeria)
  - CO_2 plume mapping by using 4D seismic monitoring results at Sleipner (Offshore Norway)
- Conclusions

The In Salah CO_2 industrial pilot site (Algeria)

In Salah JV: BP, STATOIL and SONATRACH

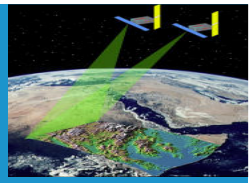




Ringrose et al. 2009

CO2 REMOVE research monitoring verification

3D-reservoir pressure and geomechanical modelling



Measurements/simulations

History matching
→Reservoir model

P_{inj}

t

Computed Measured

Dec. 18th 2004
Max 6 mm

2 months later

Feb. 26th 2005
Max 7 mm

7 months later

Sep. 24th 2005
Max 10 mm

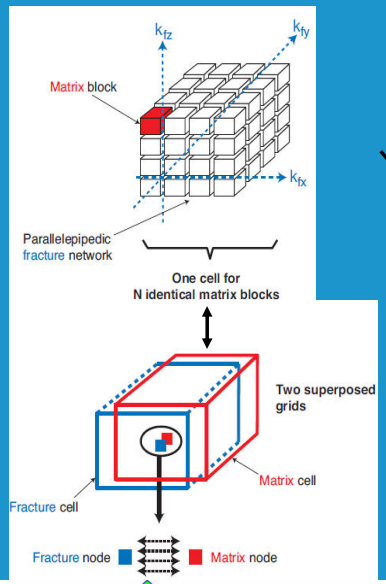
6 months later

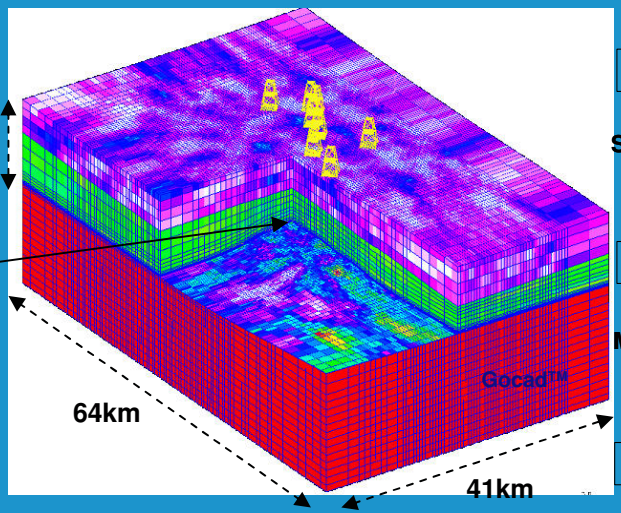
Mar. 18th 2006
Max 12 mm

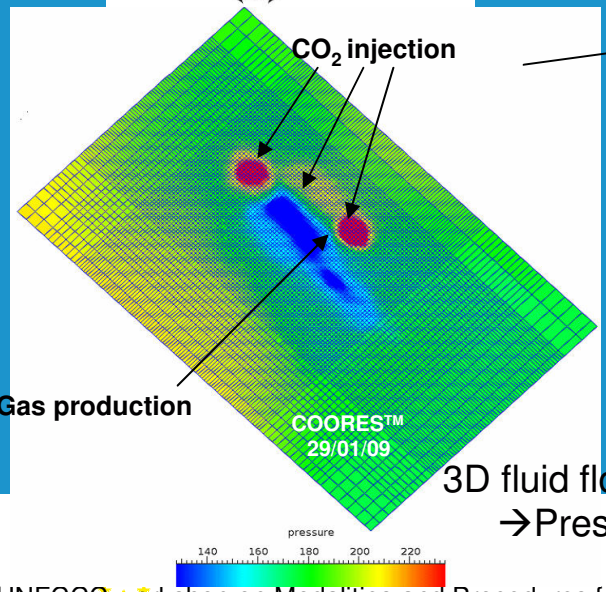
9 months later

Dec. 23th 2006
Max 17 mm

Dual reservoir model







3D fluid flow modelling
→Pressure field

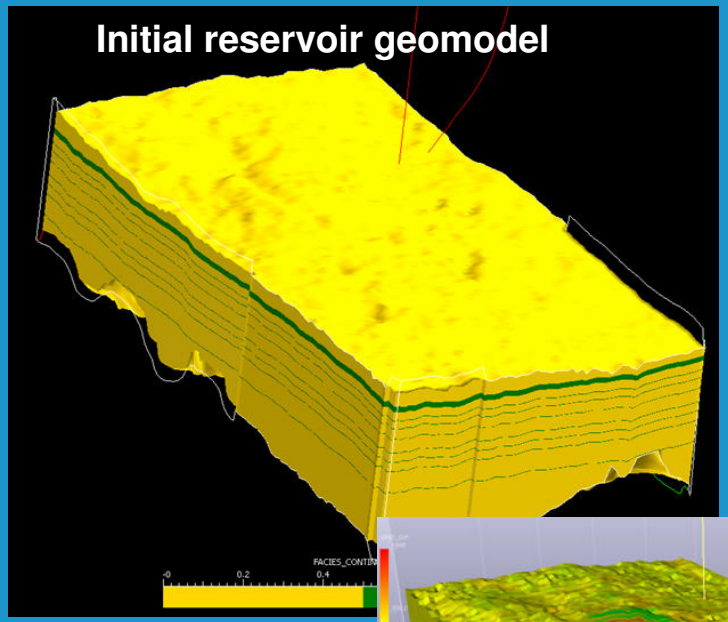
Pressure field simulation coherent with observed induce ground surface vertical deformation

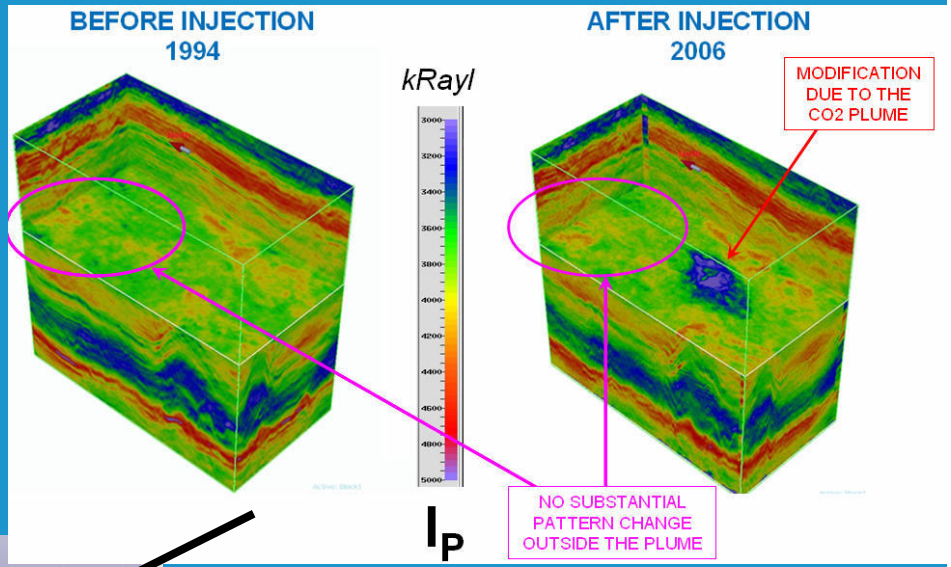
Baroni et al. 2011
and Courtesy of In Salah JIP and MDA/ Pinnacle Technologies for InSAR satellite imaging of surface ground displacements

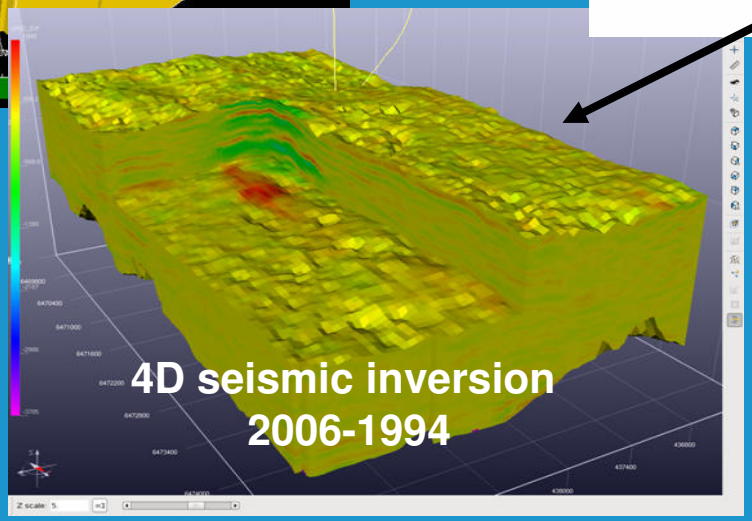
Outlines

- Introduction on key parameters
- The role of modelling in CO_2 geological storage
- An interactive process while considering site monitoring results
- Illustrations
  - Reservoir pressure modelling and monitoring verification with the In Salah case (Algeria)
  - CO_2 plume mapping by using 4D seismic monitoring results at Sleipner (Offshore Norway)
- Conclusions

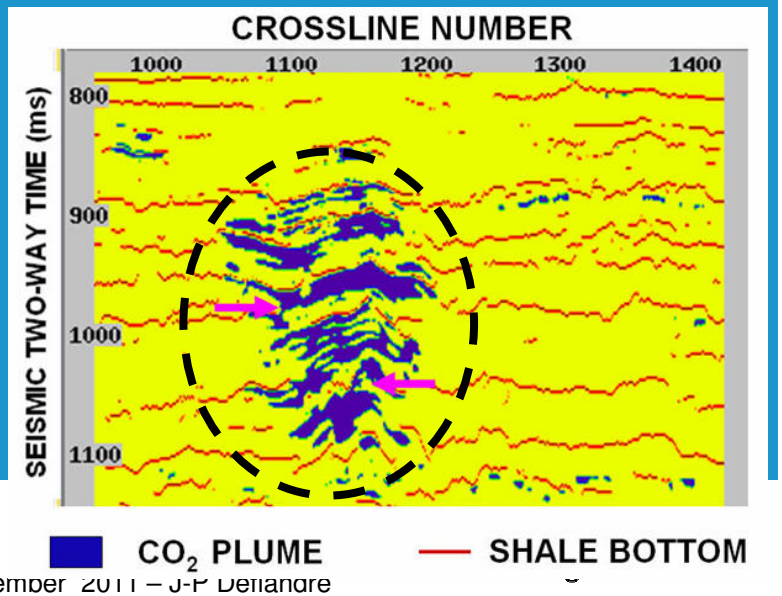
4D-seismic inversion data to thin shale layers positioning and fluid flow modelling







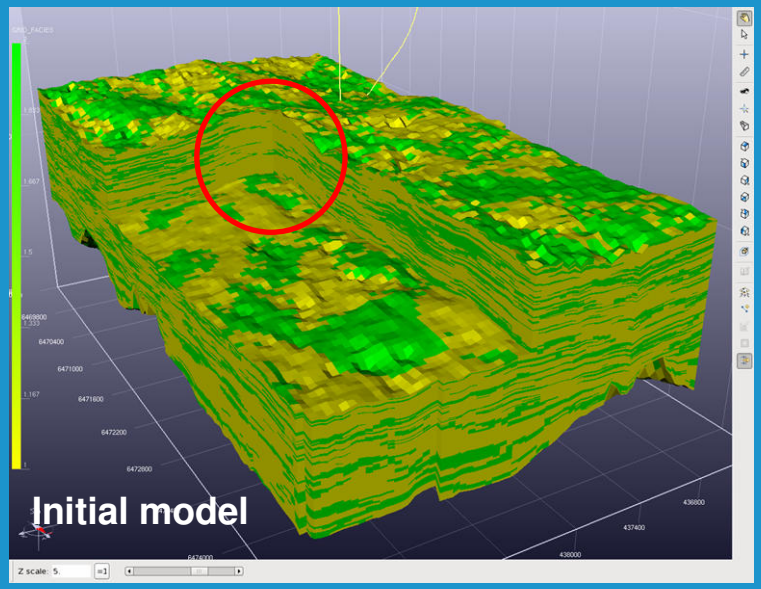
Clochard et al. 2011

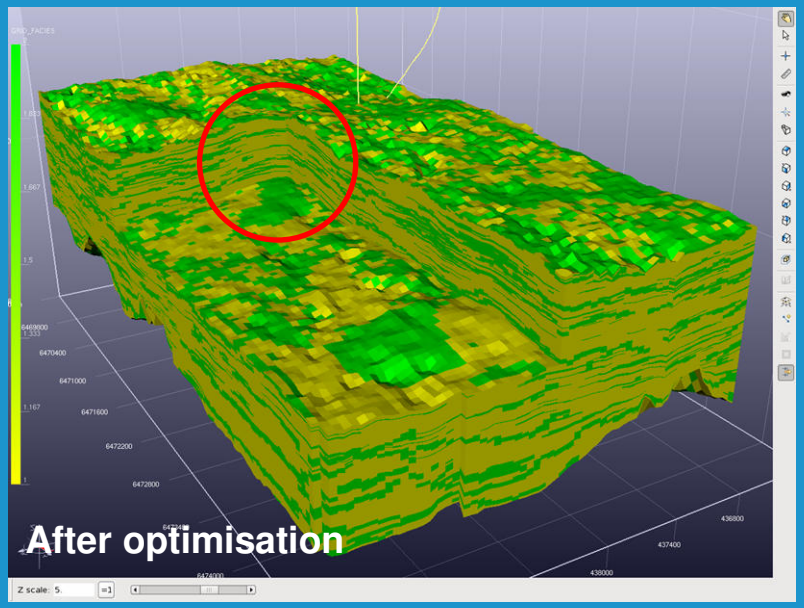


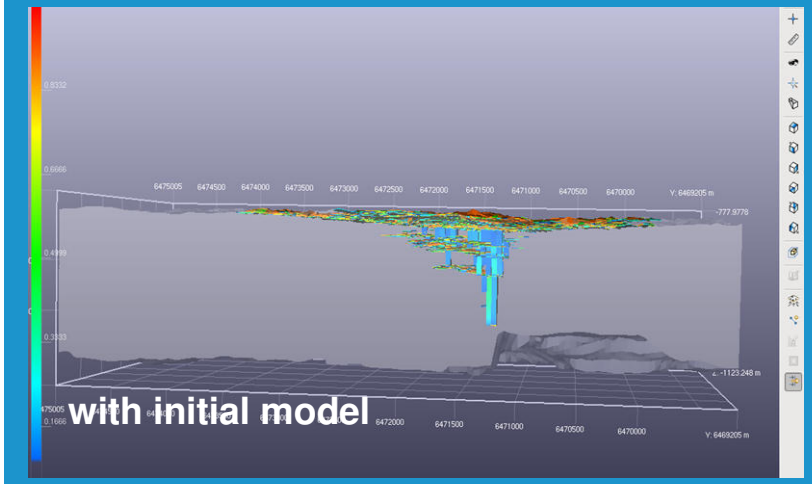
Sleipner

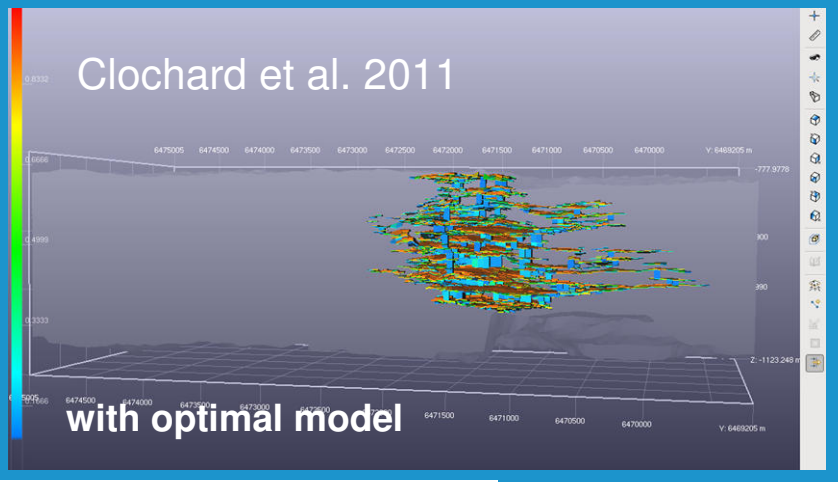
(Deep Saline Aquifer)

Shale – sand distribution & fluid flow modelling results



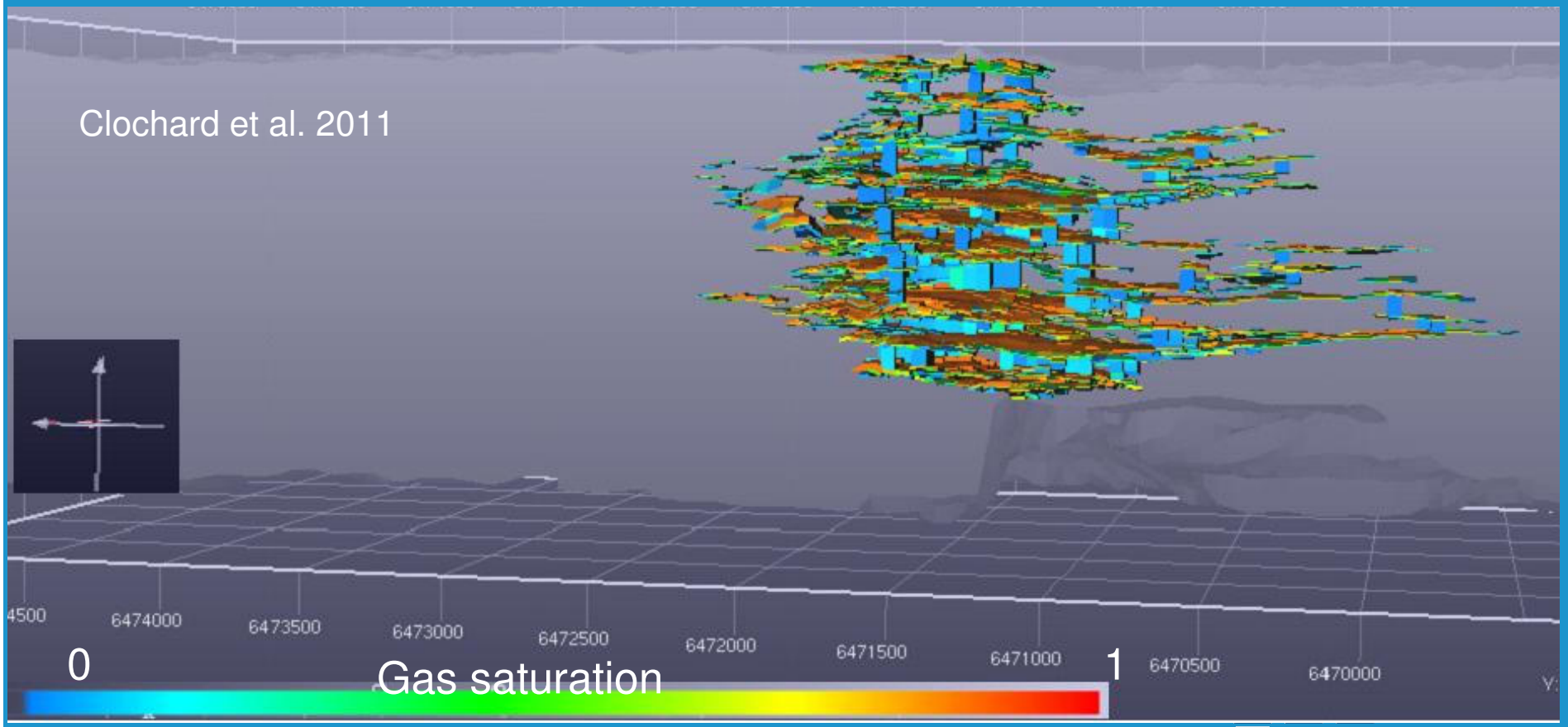






(Iterative) History matching of CO_2 plume based on time lapse seismic inversion (Ip)

CO_2 short term migration in the Utsira sand formation simulation results after optimisation (IFPEN)



Conclusions --- Modelling: to keep in mind

- Requires a wide range of data (baseline data and time lapse observations) using a portfolio of techniques and methodologies (to be site adapted: no prescription but based on a performance achievement)
- Reservoir heterogeneities is one of the main challenge with reactive transport
- Major modelling targets
  - reservoir pressure modelling (safety and efficiency): the driving force!
  - CO_2 plume migration (safety)
  - CO_2 trapping mechanisms (efficiency)
- Modelling is predictive, monitoring not
- Modelling is uncertain, sensitivity studies and monitoring campaigns are necessary: the more you learn the more your reduce discrepancies and uncertainties
- Advanced modelling requires capabilities that may be locally unavailable

Acknowledgements

The results presented here are part of the CO_2ReMoVe project, which is directed to the development of technology and procedures for monitoring and verifying underground CO_2 storage locations. The financial support of the European Commission and the industrial consortium consisting of BP, Statoil, Wintershall, TOTAL, Schlumberger, DNV, ExxonMobil, ConocoPhillips, Vattenfall and Vector, is greatly appreciated. The success of the CO_2ReMoVe project depends to a large degree on the accessibility of the storage sites and the availability of site data, e.g. for In Salah, Sleipner, Snøhvit, Ketzin and K12-B.

more on www.co2remove.eu

Thank you for your attention

Contact:
jean-pierre.deflandre@ifpen.fr