Stochastic approaches to seismic reservoir characterization for improved modeling and prediction

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IRIS

IOR conference, 24 April 2018

Introduction

- *Improved oil recovery*: Several recovery methods to improve hydrocarbon flow and increase production after depletion and injection/flooding.

- More accurate physical/mathematical models can also improve the model prediction and allow optimizing the reservoir production.

Introduction

- *Static (seismic) reservoir characterization*: An initial static model (elastic and petrophysical properties) is built from geophysical data (prior to production).

- *Reservoir monitoring*: 4-D seismic data include repeated seismic surveys. Changes in saturation and pressure can be estimated from changes in elastic properties and seismic response.

- *Dynamic modeling and seismic history matching*: The static reservoir model is updated by assimilating production data and 4-D seismic data.

Seismic reservoir characterization

- Seismic data **S** depend on reservoir properties **R** through elastic properties **m**

- We can split the inverse problem into two sub-problems:
  - $\mathbf{m} = g(\mathbf{S})$ g seismic linearized modeling
  - $\mathbf{R} = f(\mathbf{m})$ f rock physics model

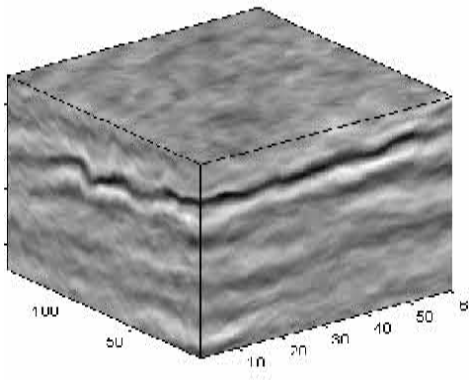
$$\mathbf{R} = f(g(\mathbf{S}))$$

Seismic reservoir characterization

Seismic inversion: Estimation of elastic properties from seismic amplitudes and travel-time

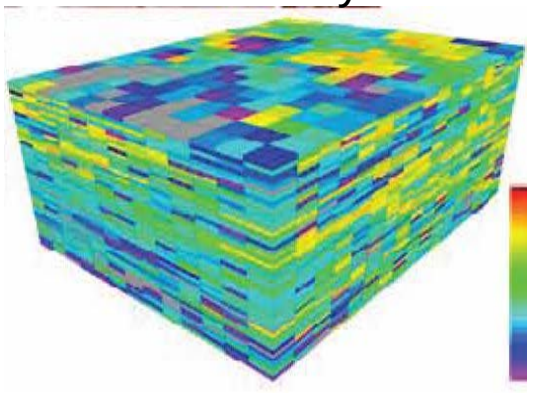
Petrophysical inversion: Estimation of petrophysical properties from seismic data or seismic velocities

Seismic data

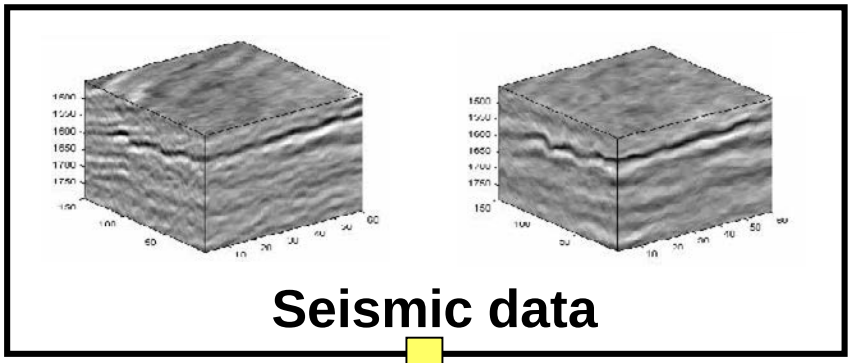


Inverse problem

Porosity



Seismic reservoir characterization

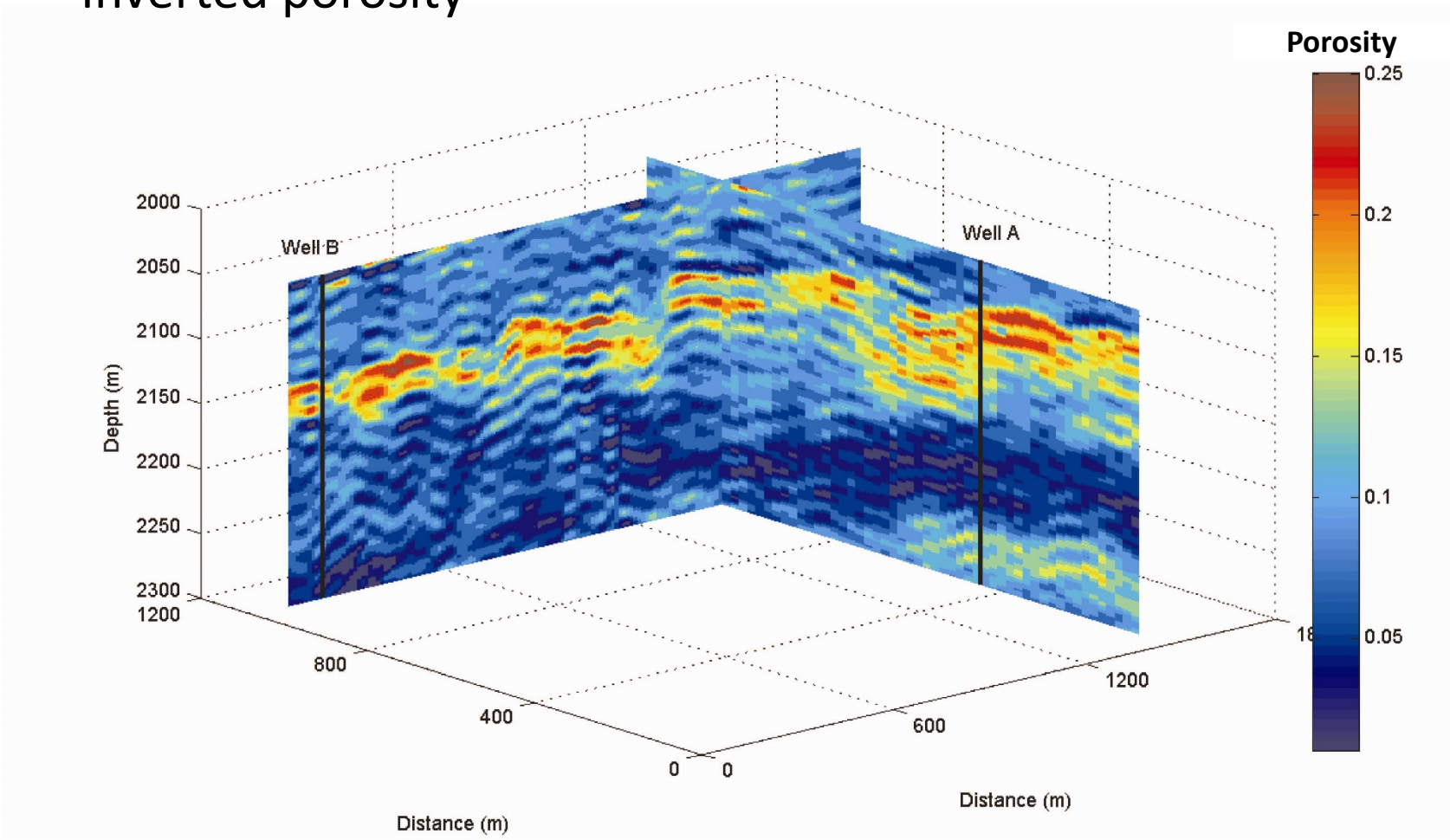


Seismic reservoir characterization

- There are various approaches for ***quantitative estimation of reservoir properties*** from seismic data:
  - Linear or non linear regression
  - Bayesian methods
  - Stochastic optimization methods
- The ***probabilistic framework*** is ideally suited to model the uncertainty.
- *Spatial variations* in reservoir properties and *inter-dependence* between different properties are complex to model.

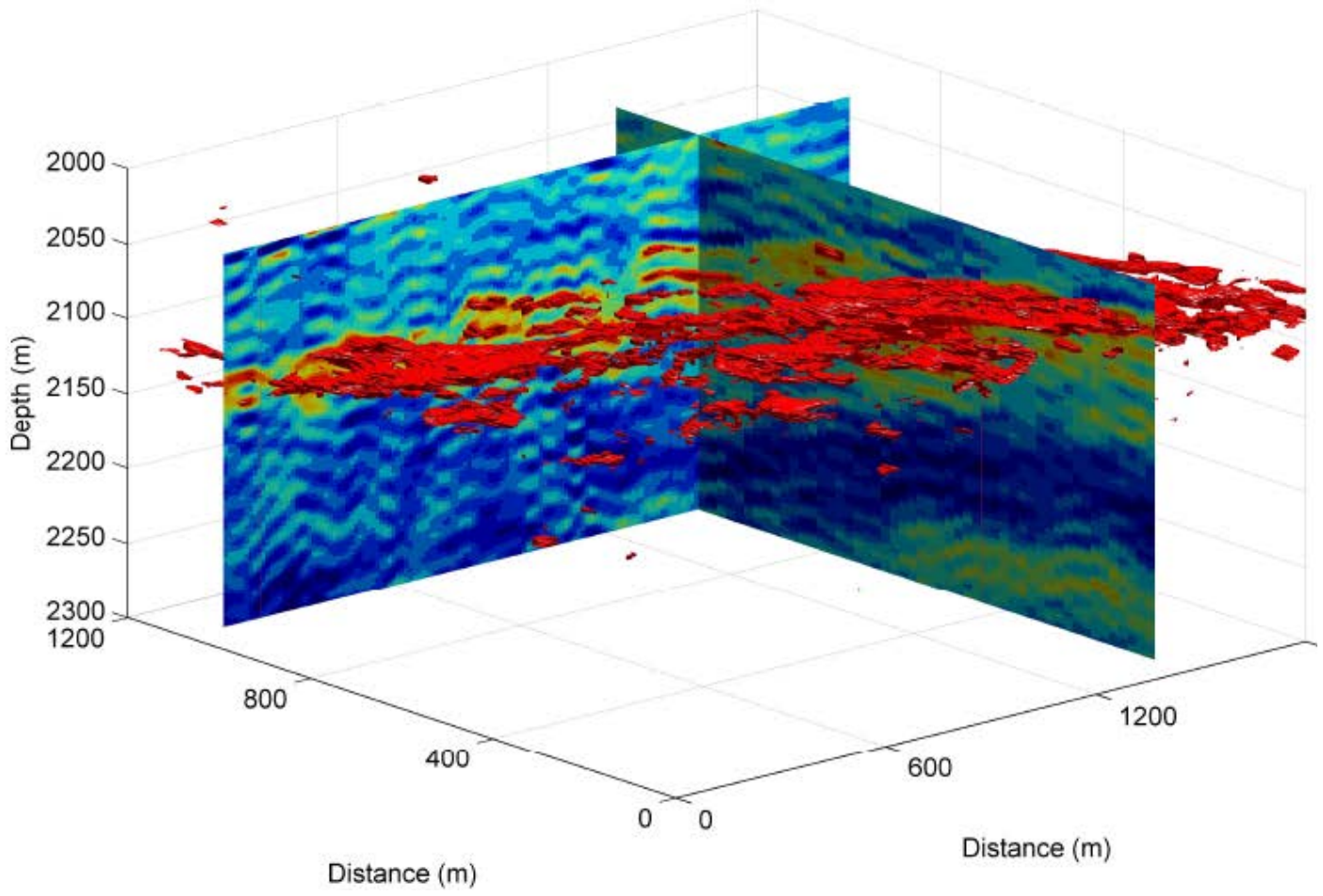
Seismic reservoir characterization

Inverted porosity



Bayesian petrophysical inversion

Isoprobability surface of 70% probability of hydrocarbon sand

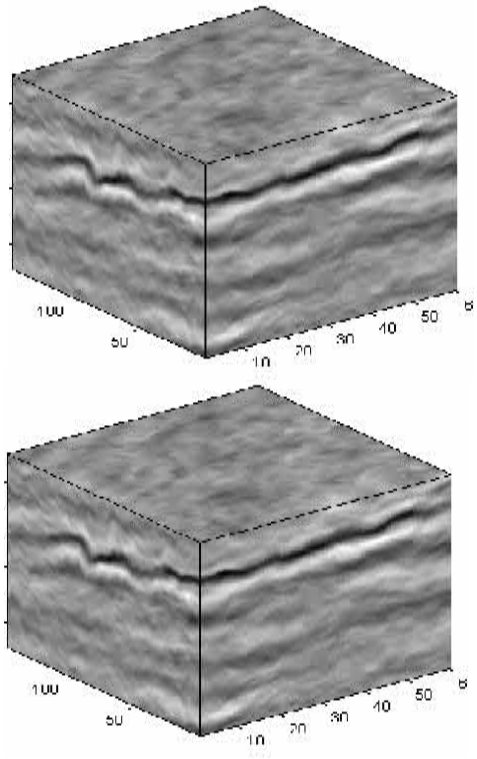


Grana and Della Rossa, 2010

Reservoir monitoring

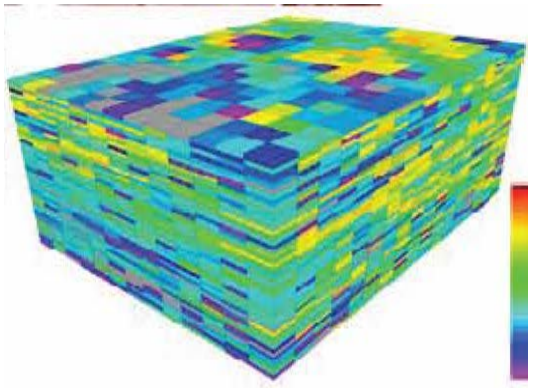
- In time-lapse reservoir modeling we aim to model reservoir property changes from repeated seismic surveys.

Time-lapse seismic data



Inverse problem

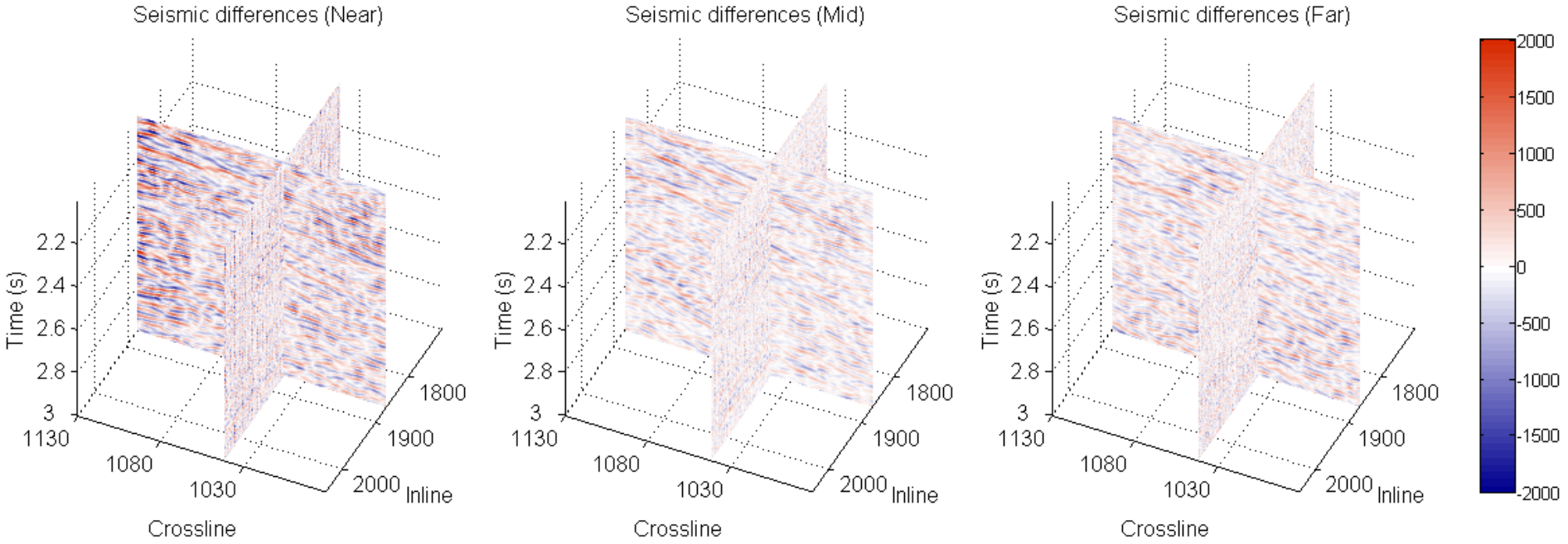
Reservoir property changes
(saturation and pressure)



Grana and Mukerji, 2014

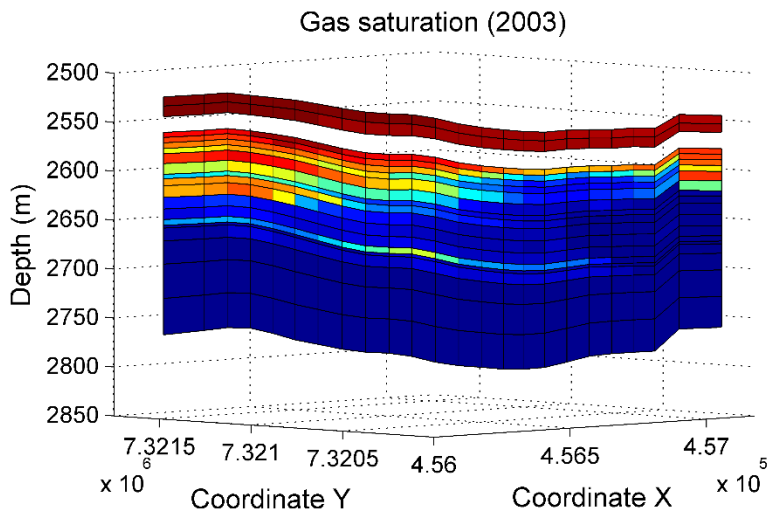
Reservoir monitoring

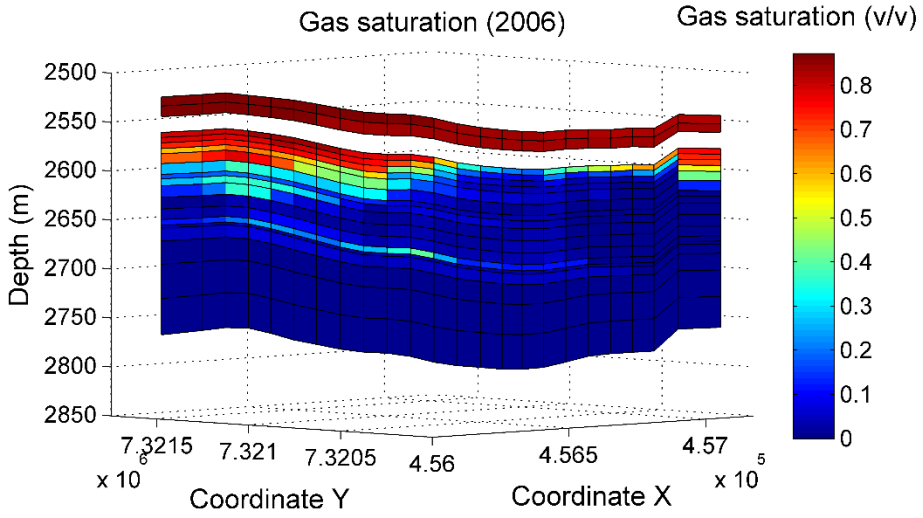
Seismic amplitude differences between 2003 and 2006 (3 angle stacks) after time-shift correction

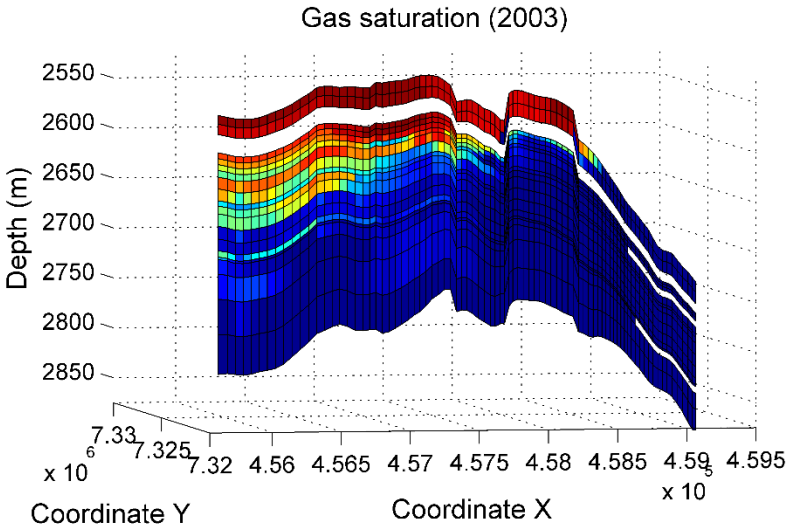


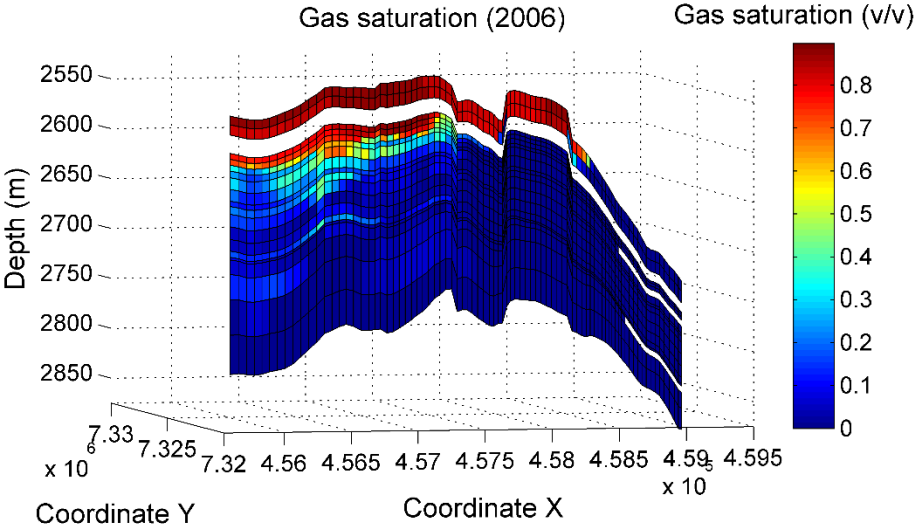
Norne dataset, processed by Gboyega Ayeni, PhD thesis, Stanford University

Reservoir monitoring

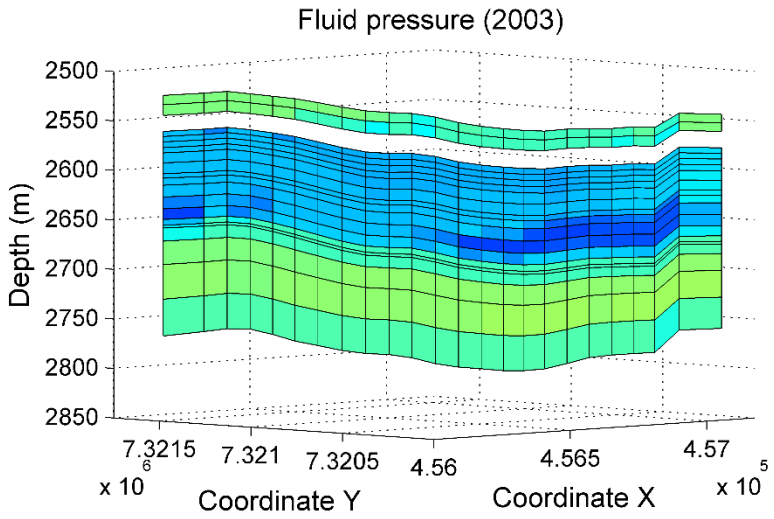


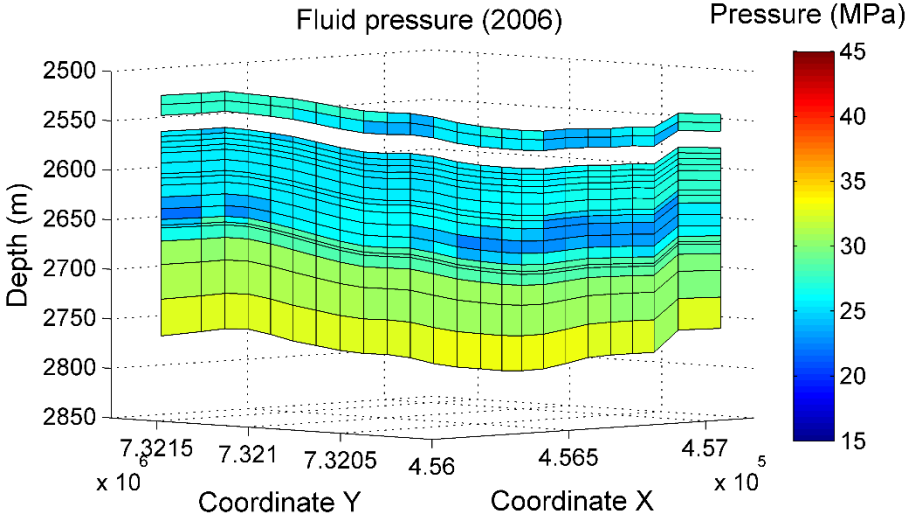


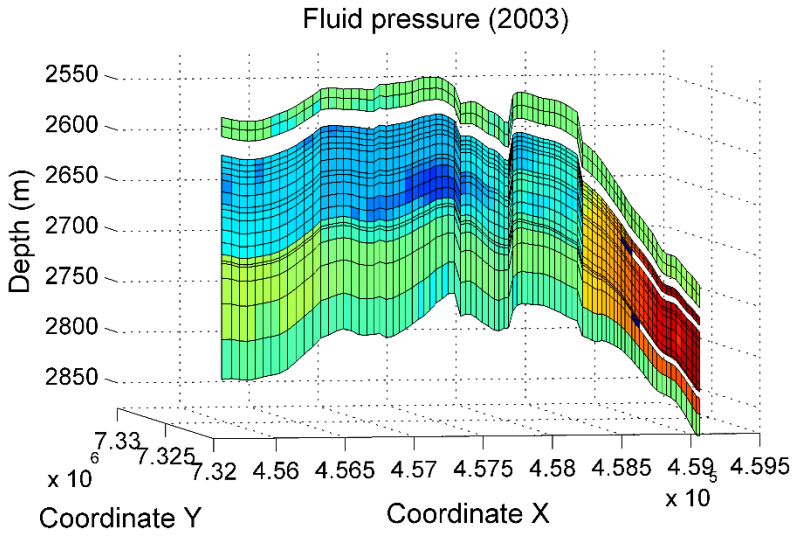


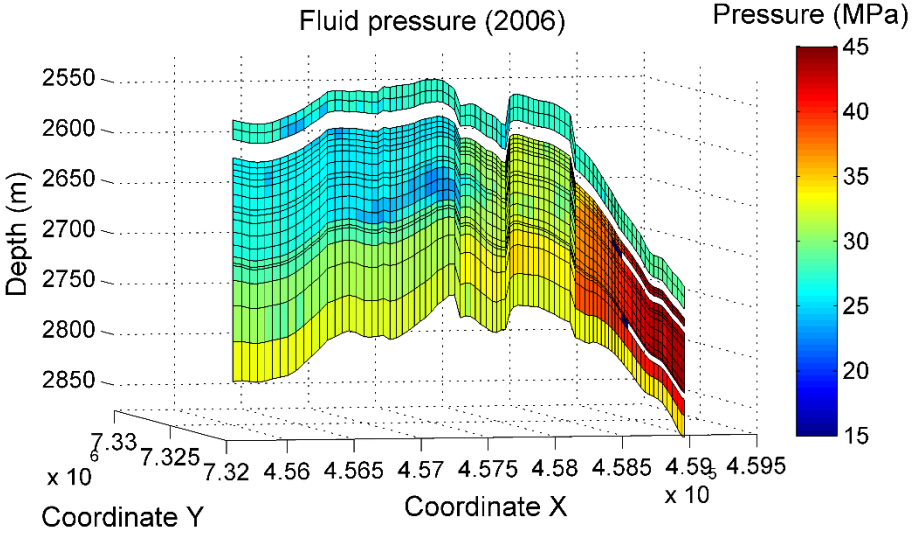


Reservoir monitoring

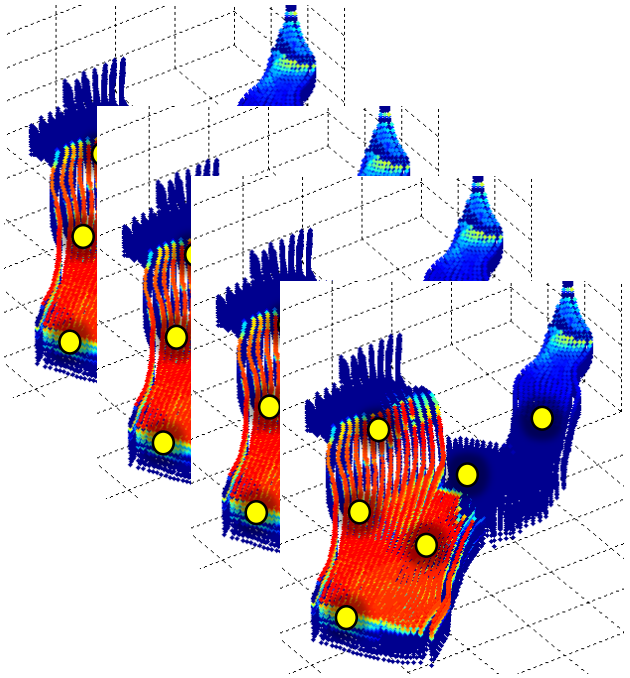


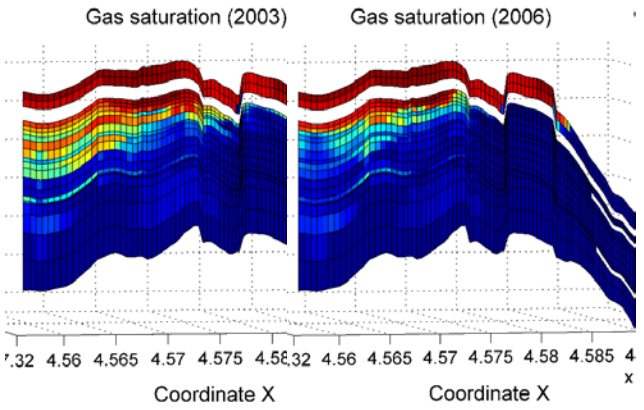






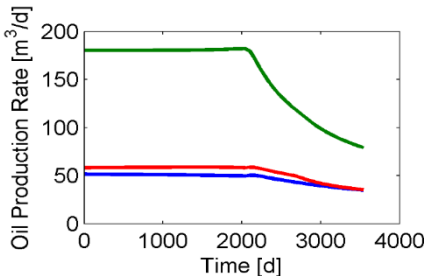
History matching

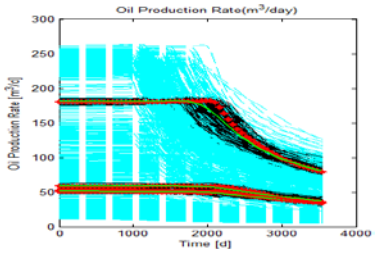


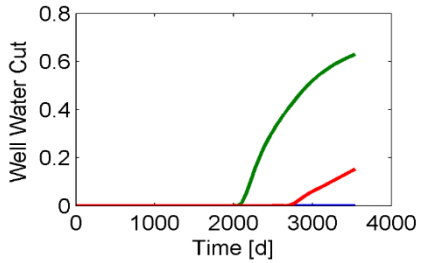


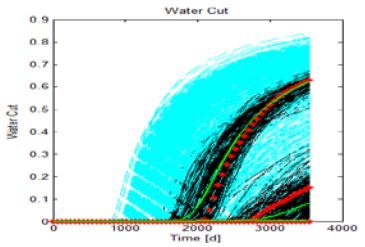
Fluid flow simulation

Production predictions



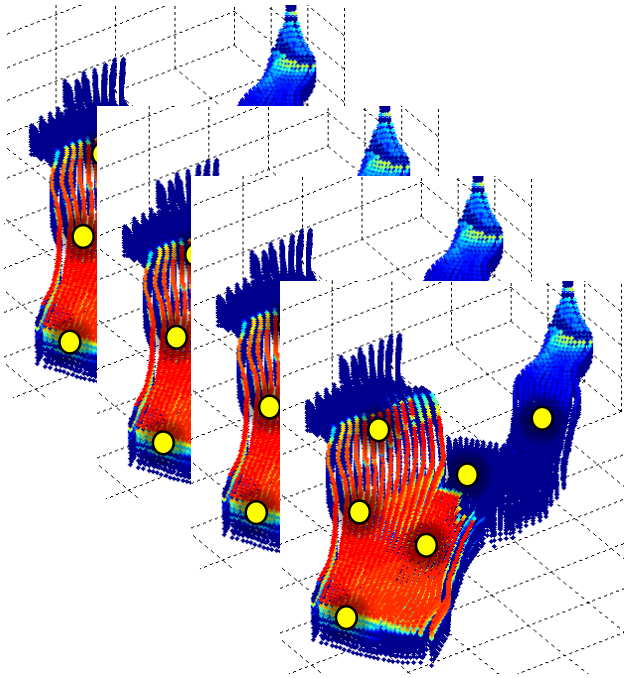


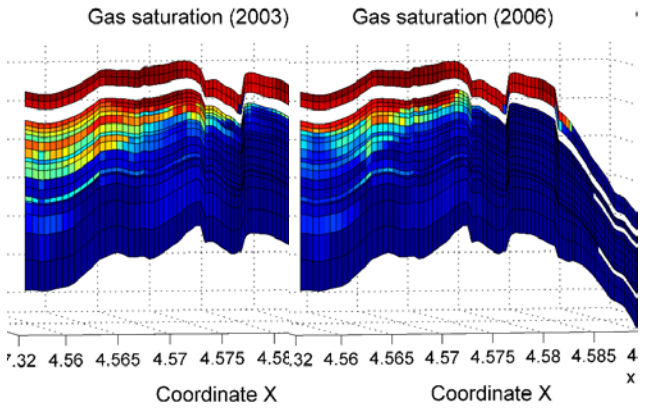




History matching

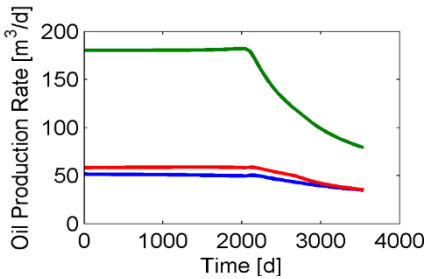
Seismic history matching

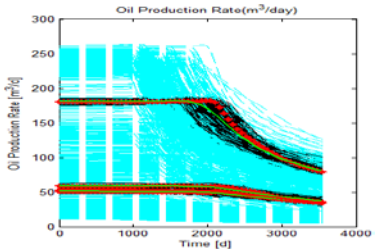


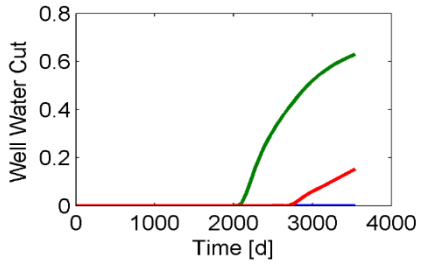


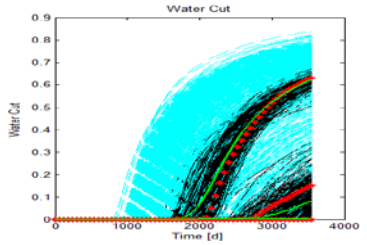
Fluid flow simulation

Production predictions

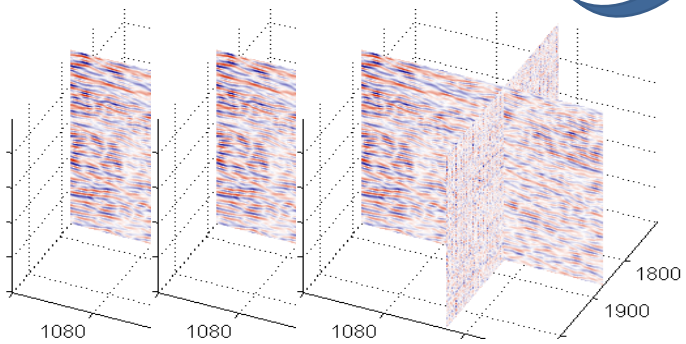








Seismic History matching

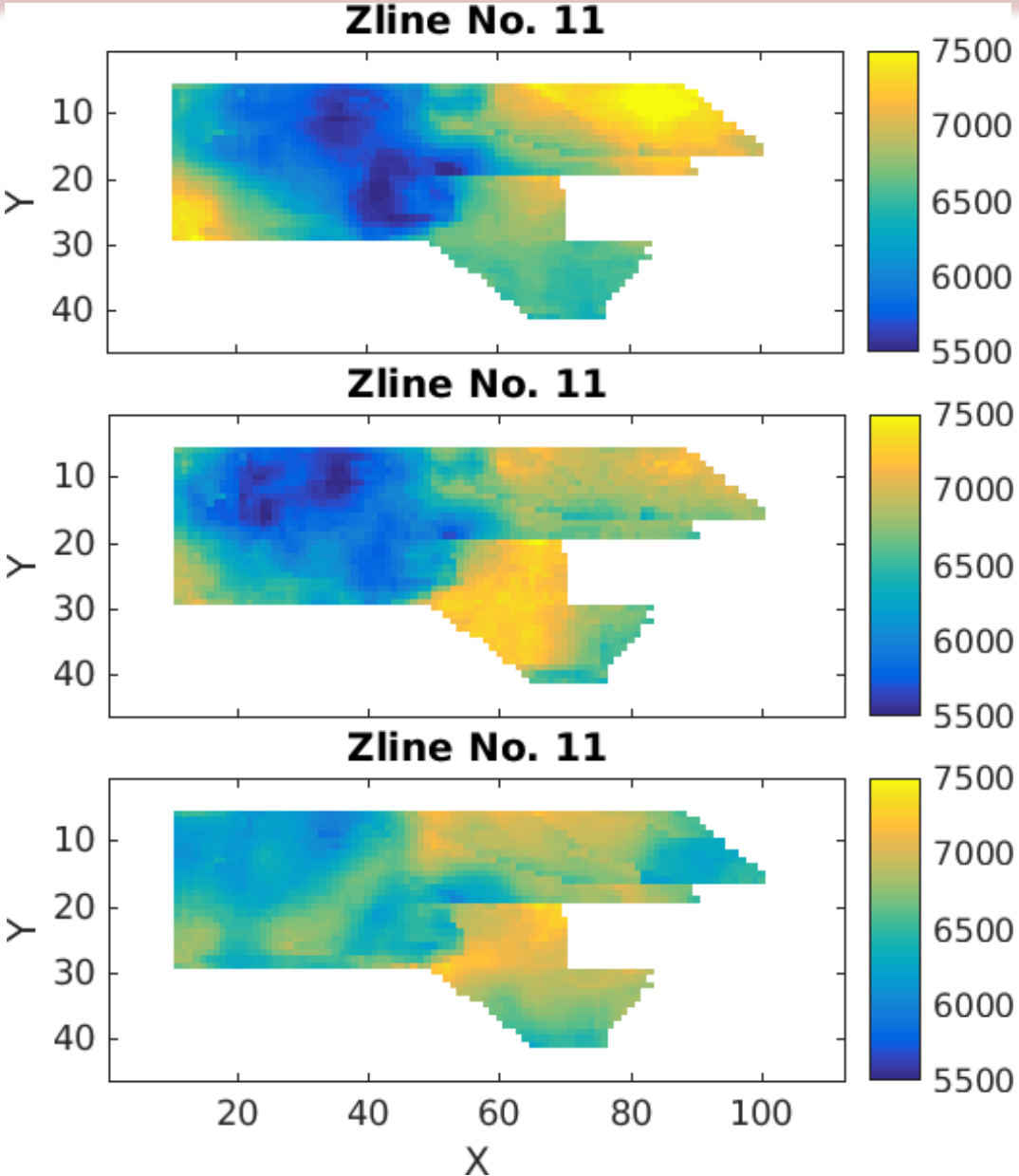


Application: Norne field

Inverted seismic impedance

Updated impedance model after history matching (ensemble mean)

Initial impedance model (ensemble mean)



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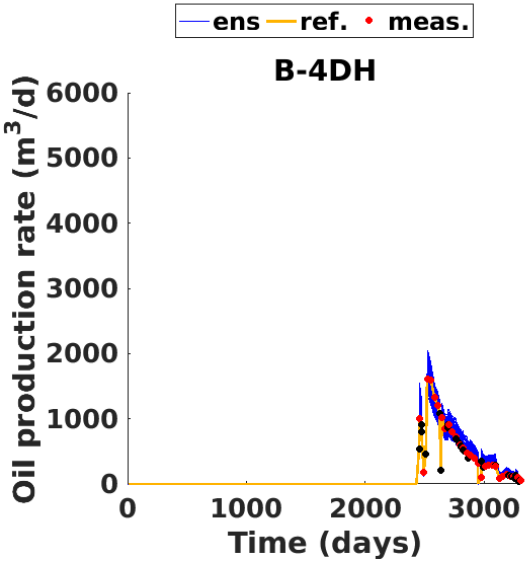
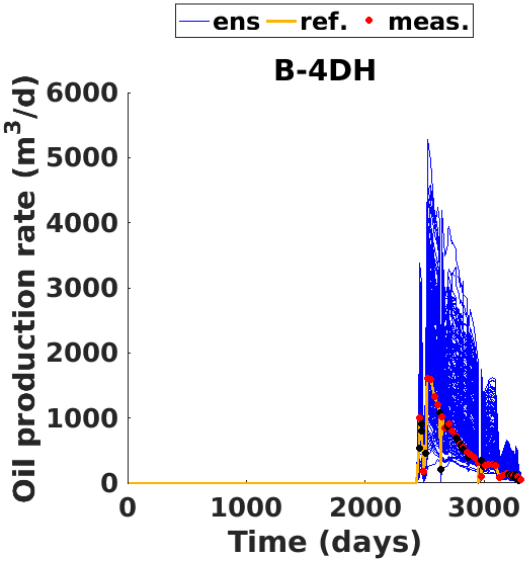
Application: Norne field

Updated oil production after history matching



Initial oil production before history matching



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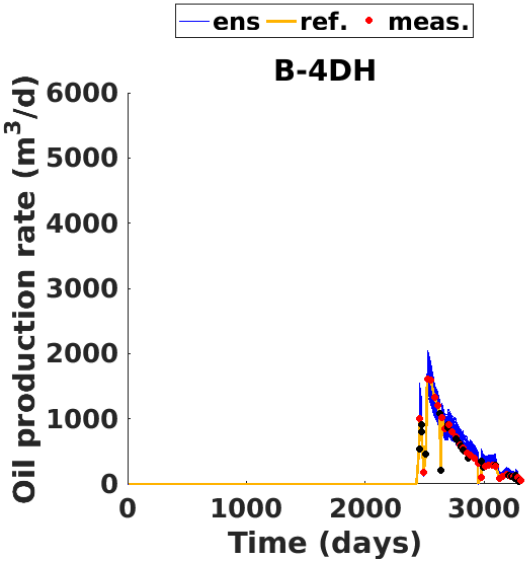
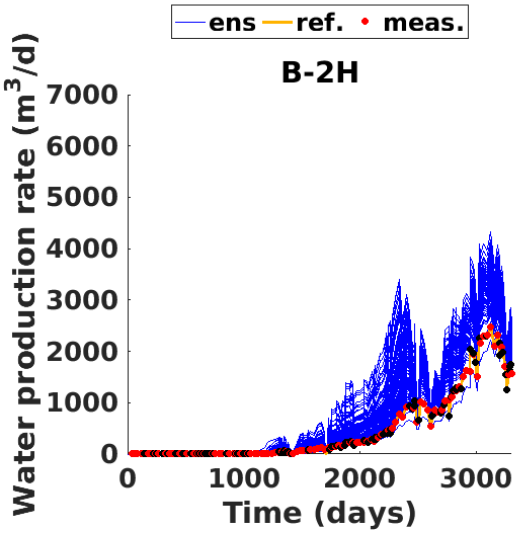
Application: Norne field

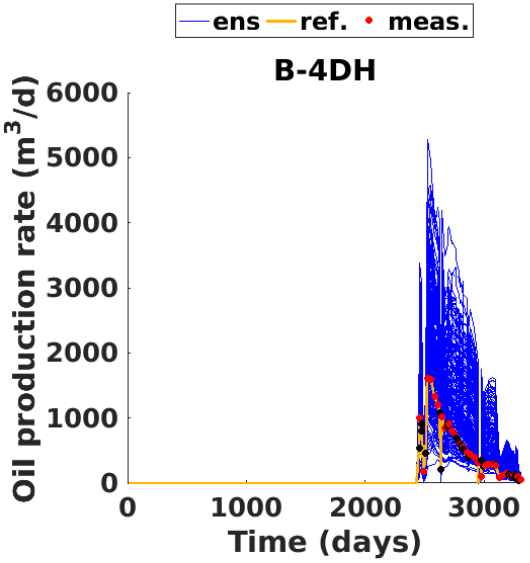
Updated oil production after history matching

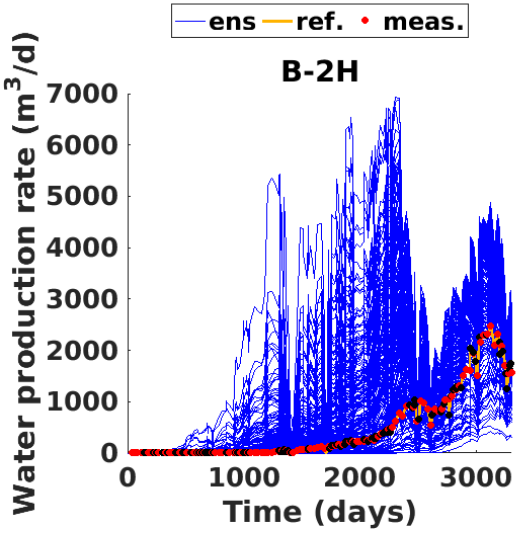




Updated water production after history matching

Initial oil production before history matching





Initial water production before history matching

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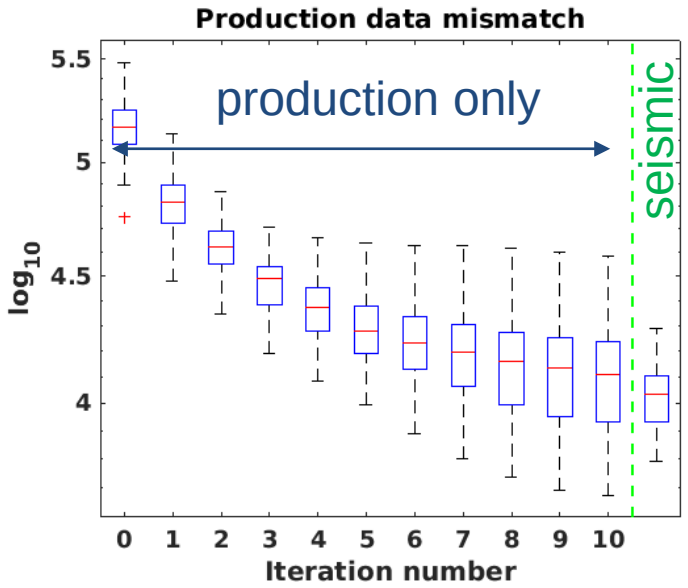
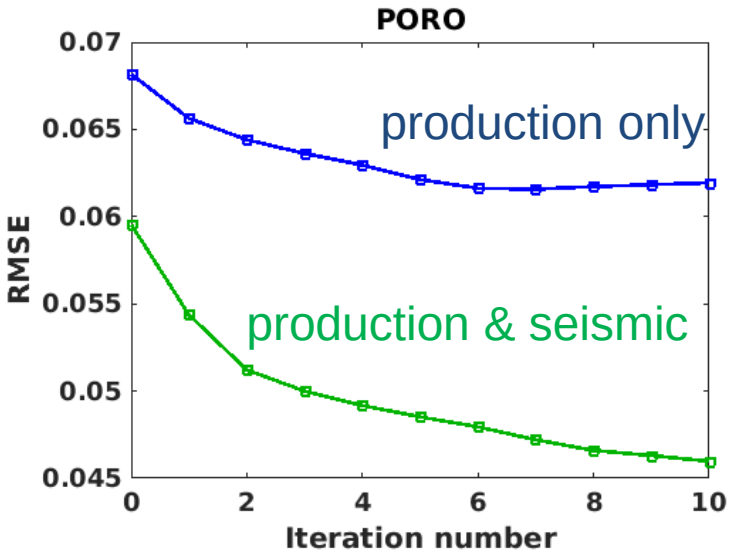
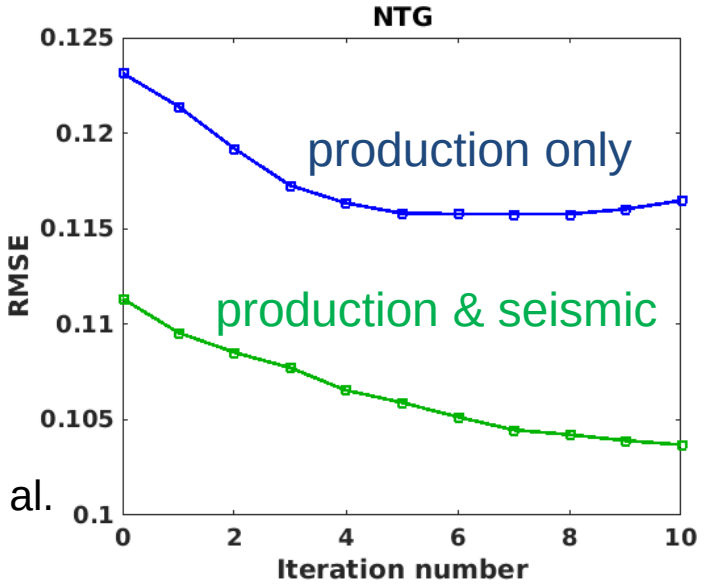
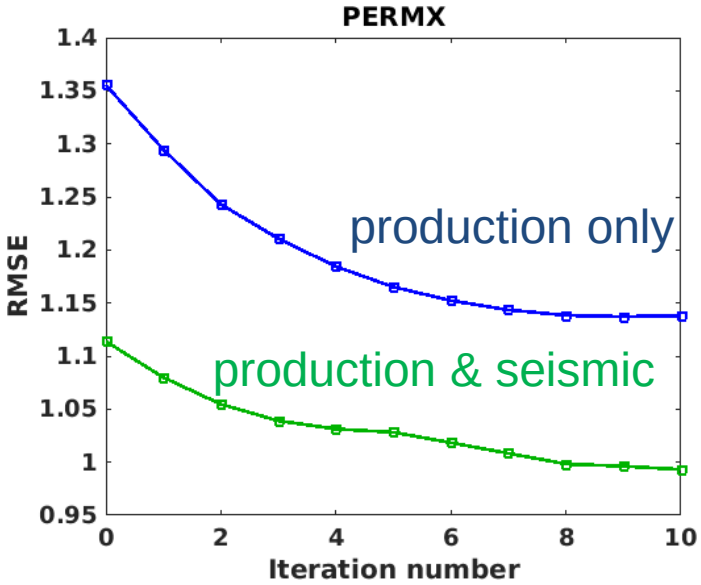
Application: Norne field









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Future work

- To investigate data re-parameterization model to reduce the number of ensemble members.
- To investigate advantages and disadvantages of different model parameterizations to obtain more accurate results.
- To develop methods that can provide geologically consistent reservoir models.
- To study the value of information of seismic data.

Acknowledgements

Dario Grana acknowledges the IOR technical committee for the invitation and IRIS for the collaboration and support

The 2018 user partners and observers:

The National IOR Centre of Norway

Acknowledgement:

The authors acknowledge the Research Council of Norway and the industry partners, ConocoPhillips Skandinavia AS, Aker BP ASA, Eni Norge AS, Maersk Oil; a company by Total, Statoil Petroleum AS, Neptune Energy Norge AS, Lundin Norway AS, Halliburton AS, Schlumberger Norge AS, Wintershall Norge AS, and DEA Norge AS, of The National IOR Centre of Norway for support.