Preserving Geological Realism for Channelized Facies Estimation on Brugge Field

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uni CIPR

Yuqing Chang, Andreas S. Stordal, Randi Valestrand

What is History Matching?

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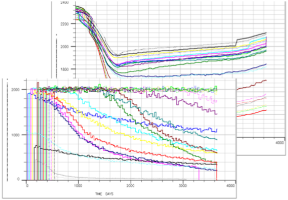
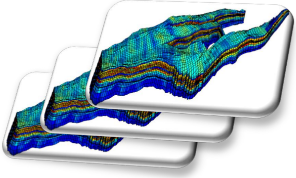
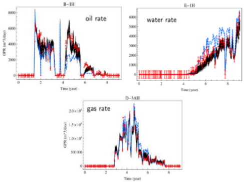
Oil field production



Production data



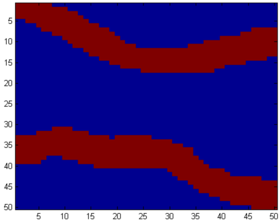
Estimate model parameters



HM and forecasting

Motivation

- Challenges:
  - Facies types are represented by discrete integer variables, while facies estimation using ensemble methods requires continuous fields
- Proposed solutions:
  - Parameterization of facies field



(Sebacher et al. 2014)

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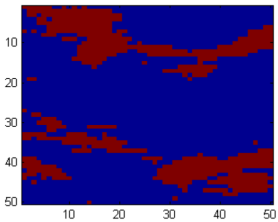
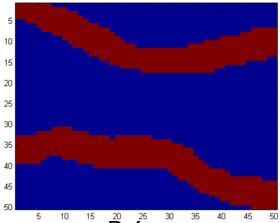


Updated



Reference

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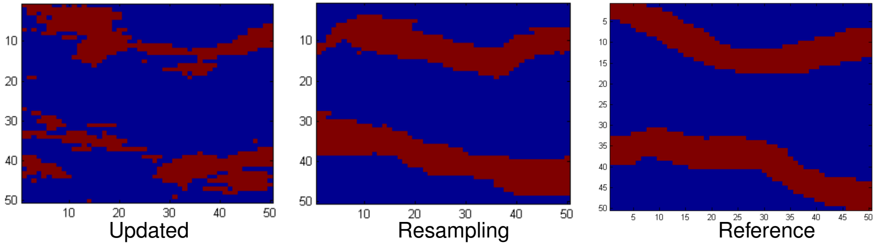
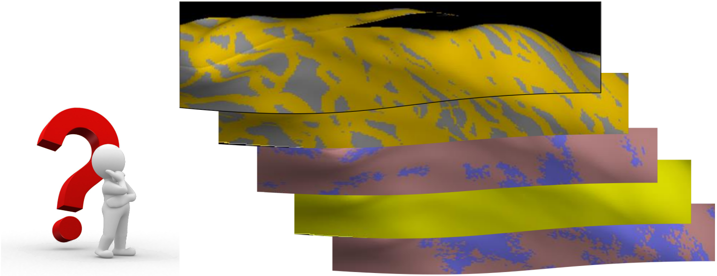
  - Resampling with geostatistical tools



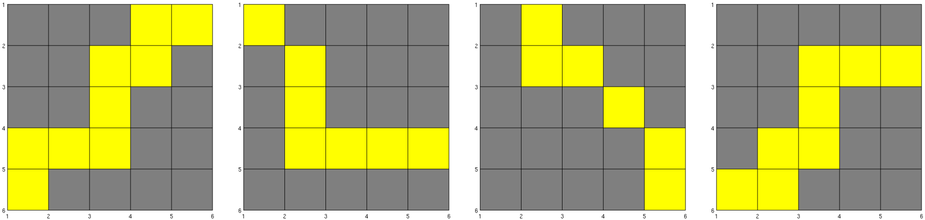
(Sebacher et al. 2014)

Problem Statement



- How to act on a complex reservoir with channelized layers and non channelized layers?
- How to get realistic geological model for the real field?

Facies Parameterization



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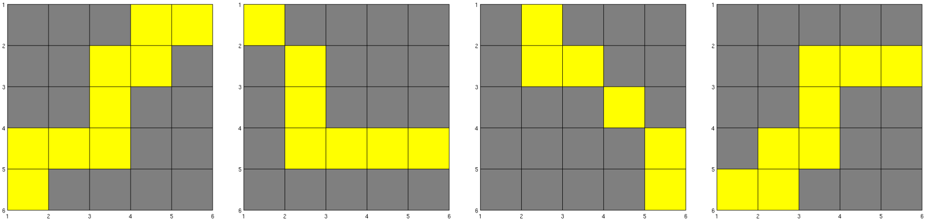
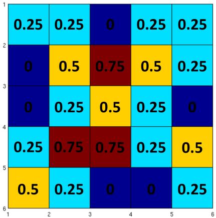
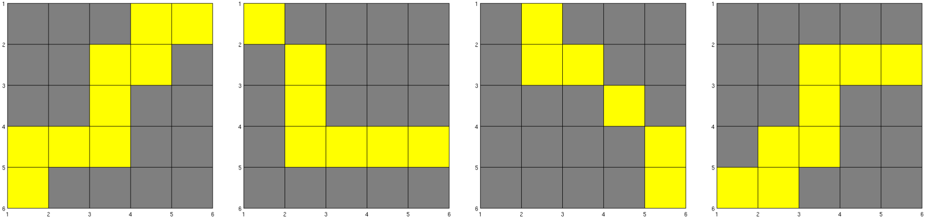
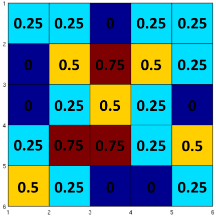


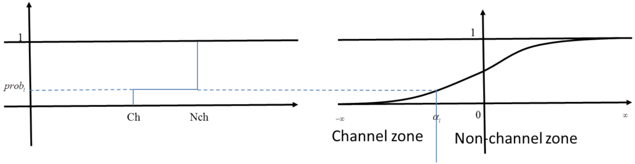


Initial facies probability

Facies Parameterization



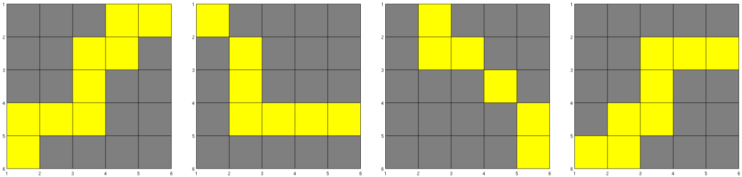




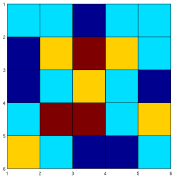
Initial facies probability

Normal score transformation

Preserving Channel Continuity

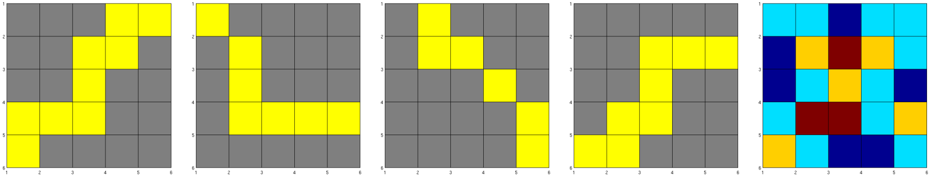


Initial ensemble



Initial prob

Preserving Channel Continuity



Initial ensemble

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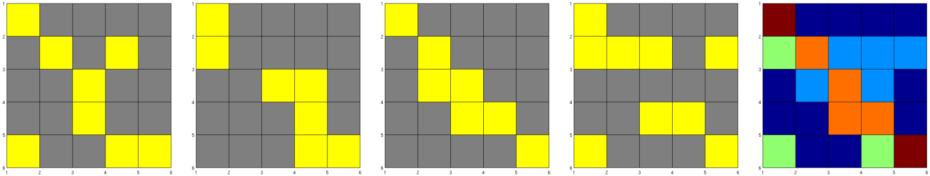

Updated ensemble

Updated prob

What is dummy well?

- A user-defined well to specify the vertical depth of log data.
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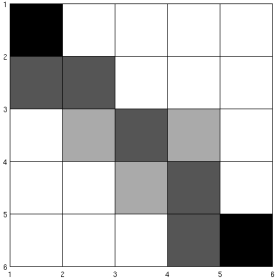
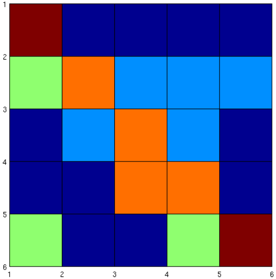


Revert shale to channel



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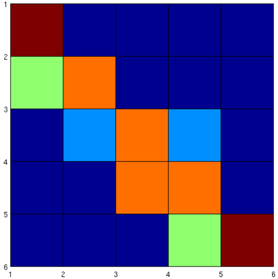

Potential dummy well locations

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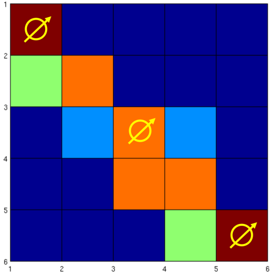
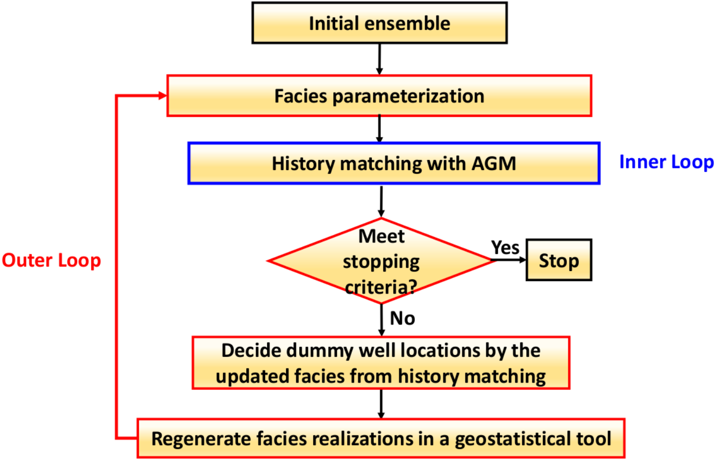
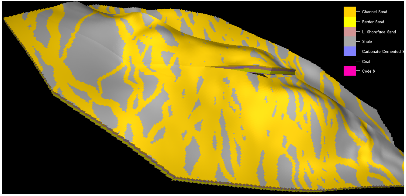


Potential dummy well locations

Facies Updating Workflow



Stratigraphy in Brugge Field



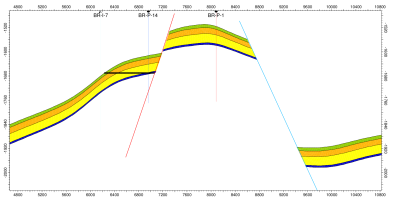


Table: Stratigraphy and the existing wells in the Brugge field

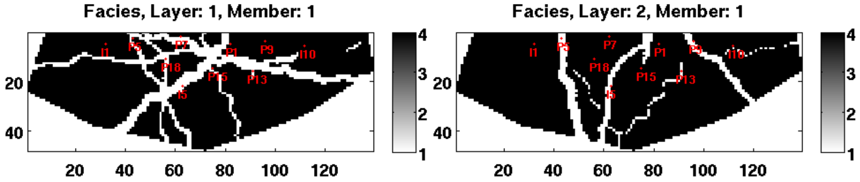
Formation	Layer	Facies Type	Deposition
Schelde Fm	1-2	F1, F4	Fluvial
Waal Fm	3-5	F3	Lower Shoreface
Maas Fm	6-8	F2	Upper Shoreface
Schie Fm	9	F3, F5	Sandy Shelf

History Matching Settings

- Geological model:
  - Grids: $139 \times 48 \times 9$
  - 7 producers, 3 injectors
- Reservoir simulation:
  - Static variables: Facies (θ), permx (lnK), poro (ϕ)
  - Measurements: BHP, WOPR, WWPR
  - Number of variables: 74250
  - Number of geological realizations: 102
  - Production time: 10 years
- Data assimilation:
  - Inner loop (AGM): 43 assimilation steps
  - Outer loop (facies modeling): 3 iterations
  - State vector: For the j^{th} ensemble at the k^{th} assimilation step:

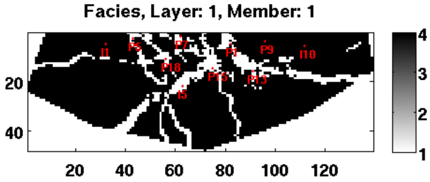
$$\mathbf{x}_j^k = [\theta^T, lnK^T, \phi^T, \mathbf{d}_{sim}^T]_j^T$$

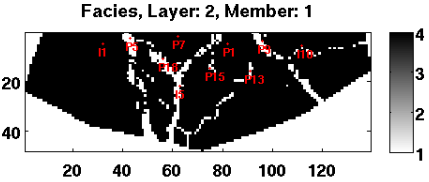
Facies Updates



Initial ensemble

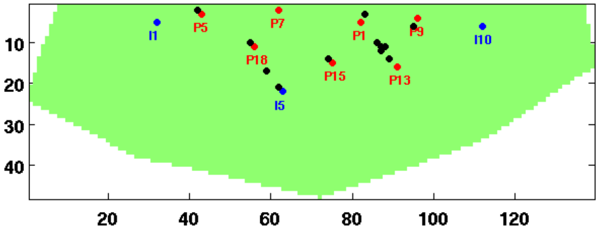
Facies Updates





Updated ensemble, inner loop 1

Facies Updates



Dummy well locations, outer loop 1

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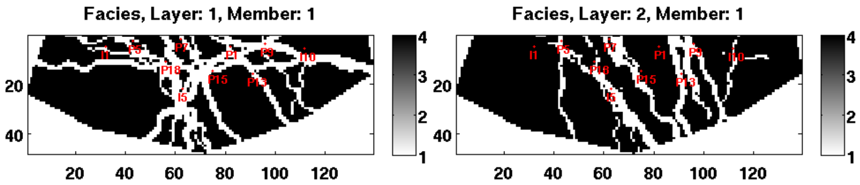
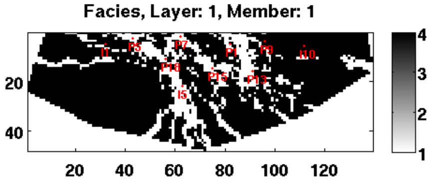
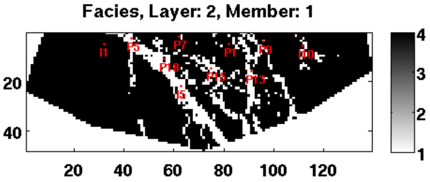


Facies regeneration, outer loop 1

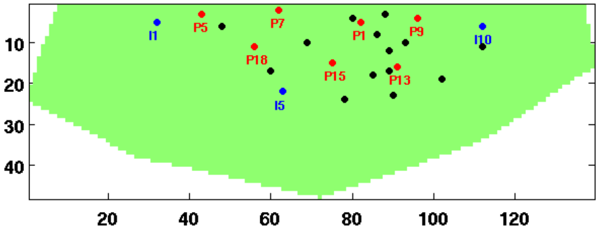
Facies Updates





Updated ensemble, inner loop 2

Facies Updates



Dummy well locations, outer loop 2

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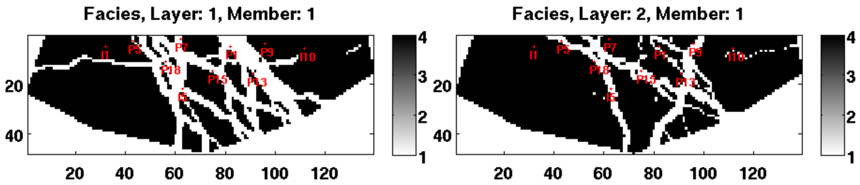

Facies regeneration, outer loop 2

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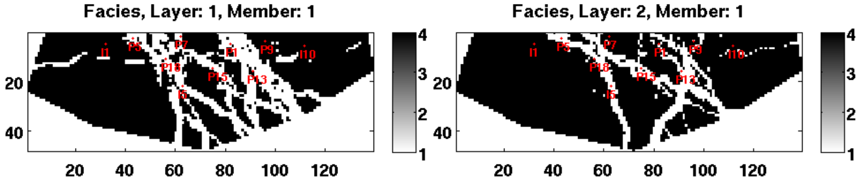
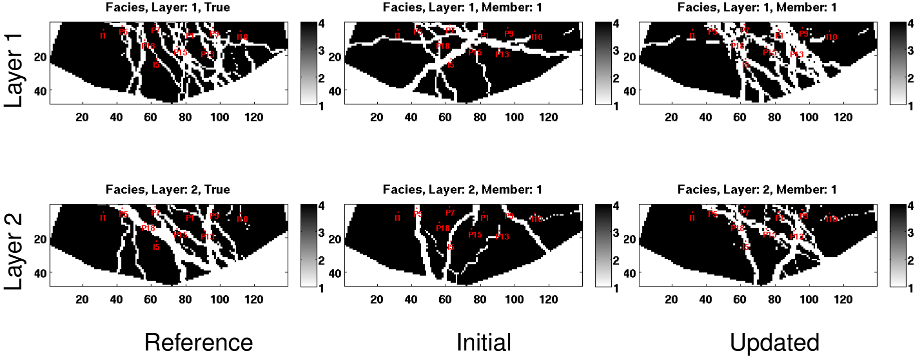
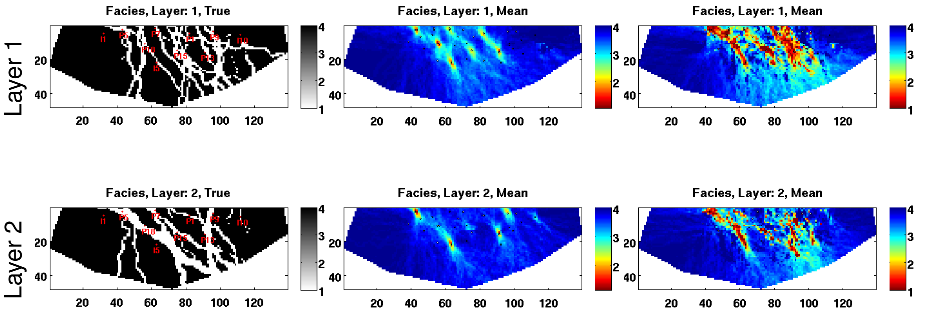


Updated ensemble, inner loop 3

Facies Updates



Facies Mean

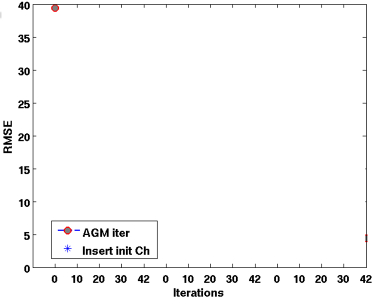


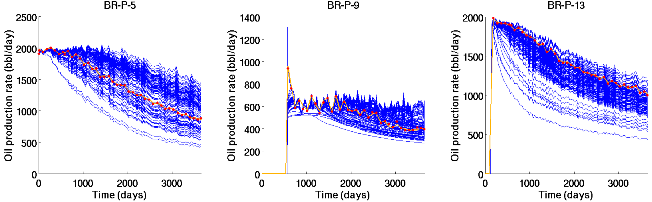
Reference

Initial Mean

Updated Mean

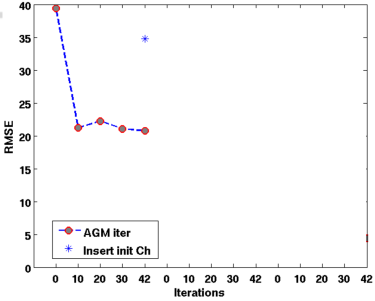
Data Mismatch

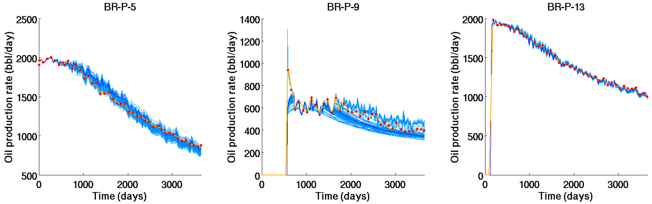




Initial ensemble

Data Mismatch





Updated ensemble, inner loop 1

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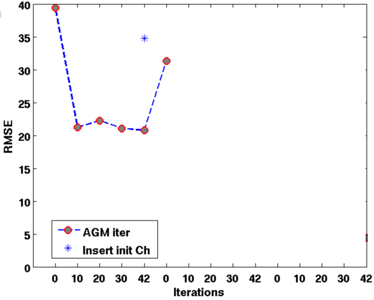
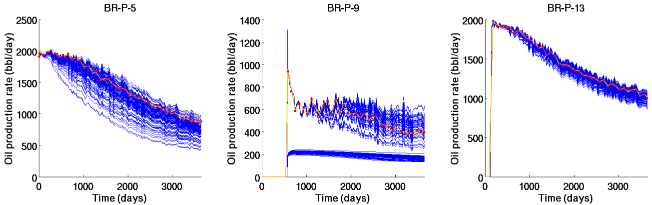
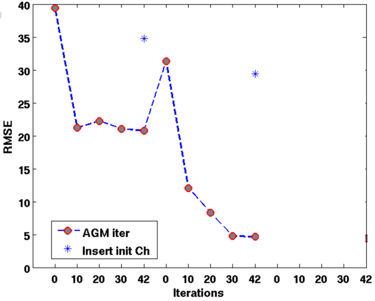
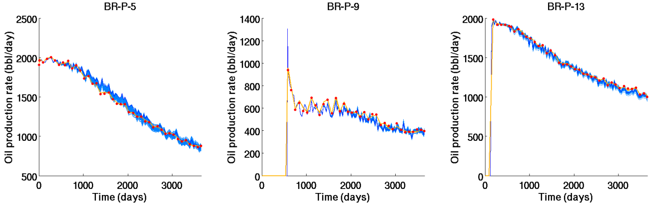




Facies regeneration, outer loop 1

Data Mismatch





Updated ensemble, inner loop 2

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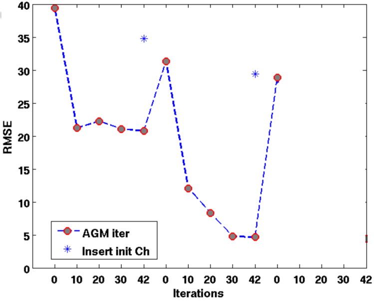

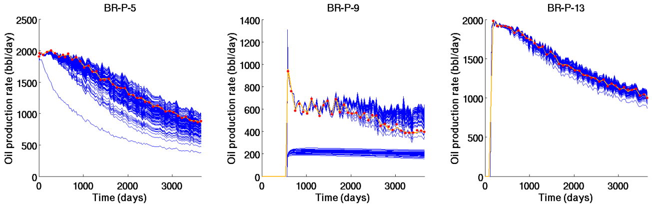

Facies regeneration, outer loop 2

Data Mismatch

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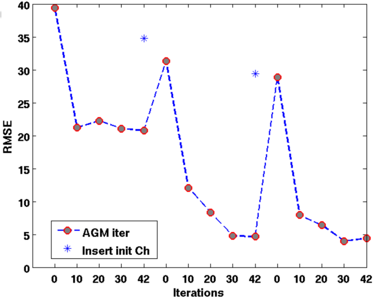
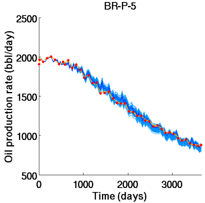
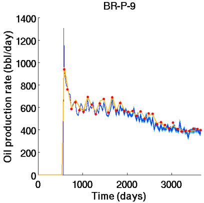
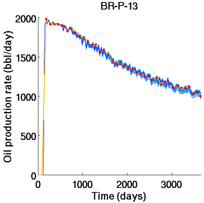


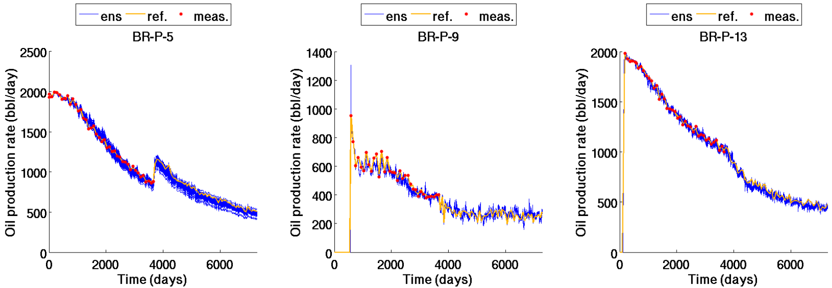






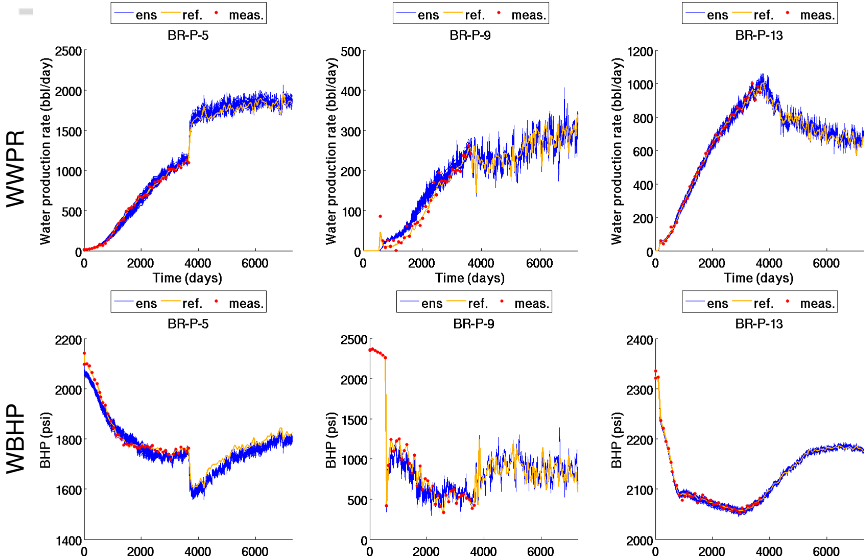
Updated ensemble, inner loop 3

Forecast of the second 10 years



Oil production rate in twenty years

Forecast of the second 10 years



Summary

- We applied a normal score transformation on the Brugge field for facies parameterization.
- Iterative Adaptive Gaussian Mixture (IAGM) filter was applied to estimate reservoir parameters including facies, permeability and porosity.
- Dummy wells were placed to condition the channel regeneration in the facies modeling.
- We observed a satisfactory data match and successful forecast results from the updated ensemble.

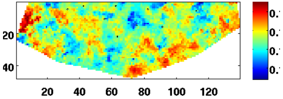
Acknowledgement

- The authors would like to thank the IRIS/Uni Research CIPR cooperative research project ”Integrated Workflow and Realistic Geology” which is funded by the industry partners, Total, Eni, ConocoPhillips, Petrobras and Statoil, and the Research Council of Norway (PETROMAKS2).
- We thank Alexey Khrulenko from IRIS for his generous help on the facies modeling and upscaling workflow.
- The authors also thank Schlumberger for providing academic licenses for Eclipse and Petrel software.

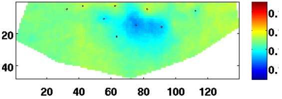
Thank you!

Backups

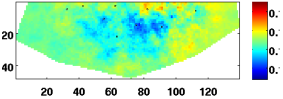
Poro: layer 3



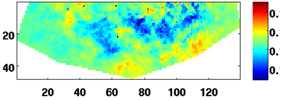
(a) Reference



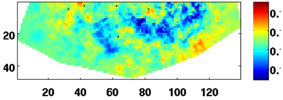
(b) Initial



(c) Inner loop 1

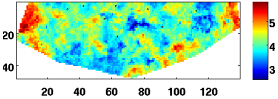


(d) Inner loop 2



(e) Inner loop 3

Perm: layer 3



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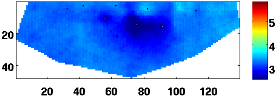

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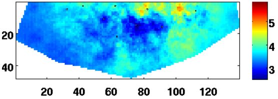

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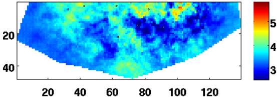
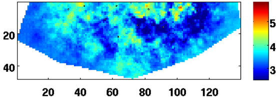


(d) Inner loop 2



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