Fast Modelling of Gas Reservoirs using Non-Intrusive Reduced Order Modelling

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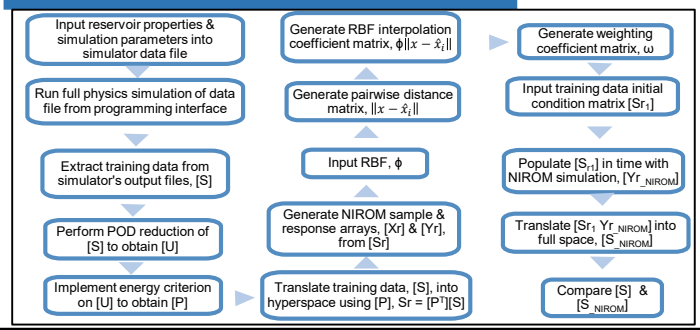
1 Objective

To optimize computational cost and time of modelling gas reservoirs, leading to record time evidence-based decision making

- Other methods for computational speedup: Grid coarsening, GPUs, manipulating iterative solver methods, artificial neural network
- Reduced order modelling (ROM): Applicable to different systems/processes
  - One hidden layer, fast training time, flexible and inexpensive computation
- Intrusive (IROM) and Non-Intrusive (NIROM)
- IROM: dependent on the simulator source codes or governing equations
- Examples: POD & Galerkin projections - including EIM, DEIM, Petrov-Galerkin projections, TPWL and Gauss-Newton approximations
  - Instability and nonlinear efficiency
- NIROMs: independent of source codes and governing equations; require minimal training data and initial state matrix
- Examples: Black Box stencil interpolation, Radial Basis Function (RBF), Proper Orthogonal Decomposition (POD) - RBF, POD-RBF- Empirical Interpolation Method (EIM) / Discrete EIM, POD - in situ adaptive tabulation (ISAT), …
- **POD-RBF**: POD for reducing sample matrix size/dimension, by translating sample matrix into hyper space, and RBF for interpolation

2 Model Implementation and Workflow

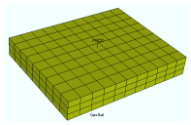


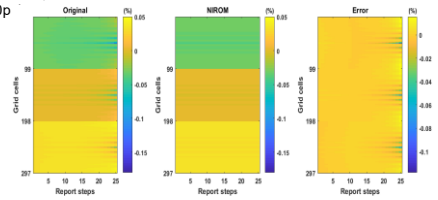
3 Example 1 – Homogeneous Gas Reservoir

Simulation Properties
Grid distribution: 9 × 11 × 3
GIIP: 653.7 MMscf
Simulation Lifecycle: 7500 days
300 days × 25 report steps
Well Controls
a) Rate Control case: 75 Mscf/day
b) BHP Control case: 1000p

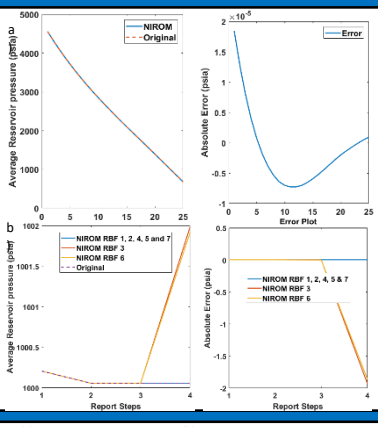
Reservoir Properties

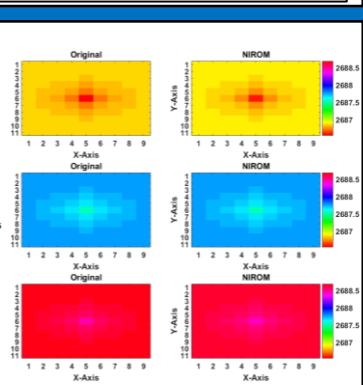
Property	Value
Porosity, φ	0.2
Permeability , k	50 mD
Initial pressure	4800 psia
Reservoir Volume	309.4 Acre-ft





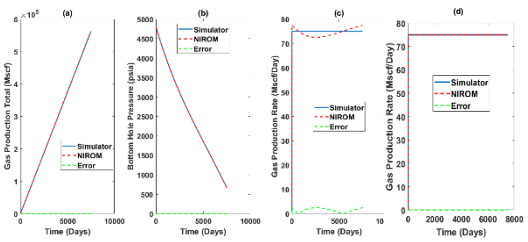
Normalised pressure distribution using 1 POD basis function





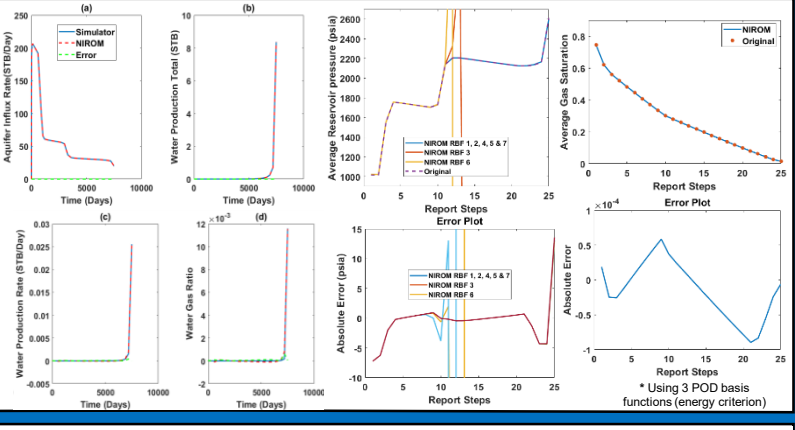
Pressure distribution in psi across each reservoir layer at report step 11

4 Example 1 – Production Profiles and Aquifer model



Gas rate control production profile using 2 (a-c) and 3 (d) POD basis functions respectively

Aquifer model production profile using 6 POD basis functions (energy criterion: 3)

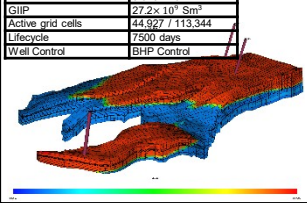


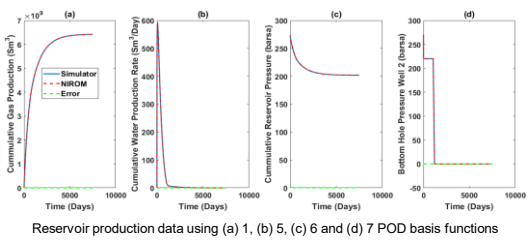
* Using 3 POD basis functions (energy criterion)

5 Example 2 – Modified Norne Field Model

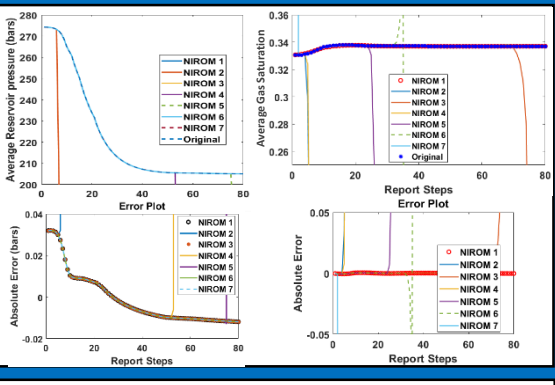
- Real heterogeneous field case
- Aquifer/water influx
- Prod 02 shut-in after 1050 days – low pressure

Reservoir Property	Value
Initial pressure	306.1 bar
Reservoir Volume	3.645× 10^9 m^3
GIIP	27.2× 10^9 Sm^3
Active grid cells	44,927 / 113,344
Lifecycle	7500 days
Well Control	BHP Control





Reservoir production data using (a) 1, (b) 5, (c) 6 and (d) 7 POD basis functions



6 Summary of Results and Conclusions

- POD-RBF NIROM is capable of satisfactory approximation of gas reservoirs' full physics simulator solution - training cases
  - Most suitable basis functions: Linear and Modified Thin Plate functions
  - Requires about 5 POD Basis functions
- CPU time can be reduced by as much as 2 orders of magnitude
  - Further speed ups possible if implemented in compiled language
- Reservoir models with significant amount of water require more POD basis functions to achieve accurate results

7 Further Work

- Develop NIROM for unseen cases and possibly for a real field case
- Explore best choice of training data and more simulation outputs that NIROM can be used to support
- Identify possible constraints of NIROM in gas reservoir modelling

8 Acknowledgements

- Woodside Energy for sponsoring this research
- Larry Kostorz Wawrzyniec for support in facilitating the set-up of the POD-RBF NIROM model