FIELD SCALE ENSEMBLE OPTIMIZATION OF SIMULATOR PERFORMANCE

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SETTING THE SCENE

- Reservoir simulator performance impacted by choice of
  - Time stepping parameters
  - Solver parameters
  - Preconditioners
  - MPI variants

- Current status:
  - Use default parameters
  - Reservoir engineer sets parameters by manual trial and error
  - No framework for tuning an ensemble of models

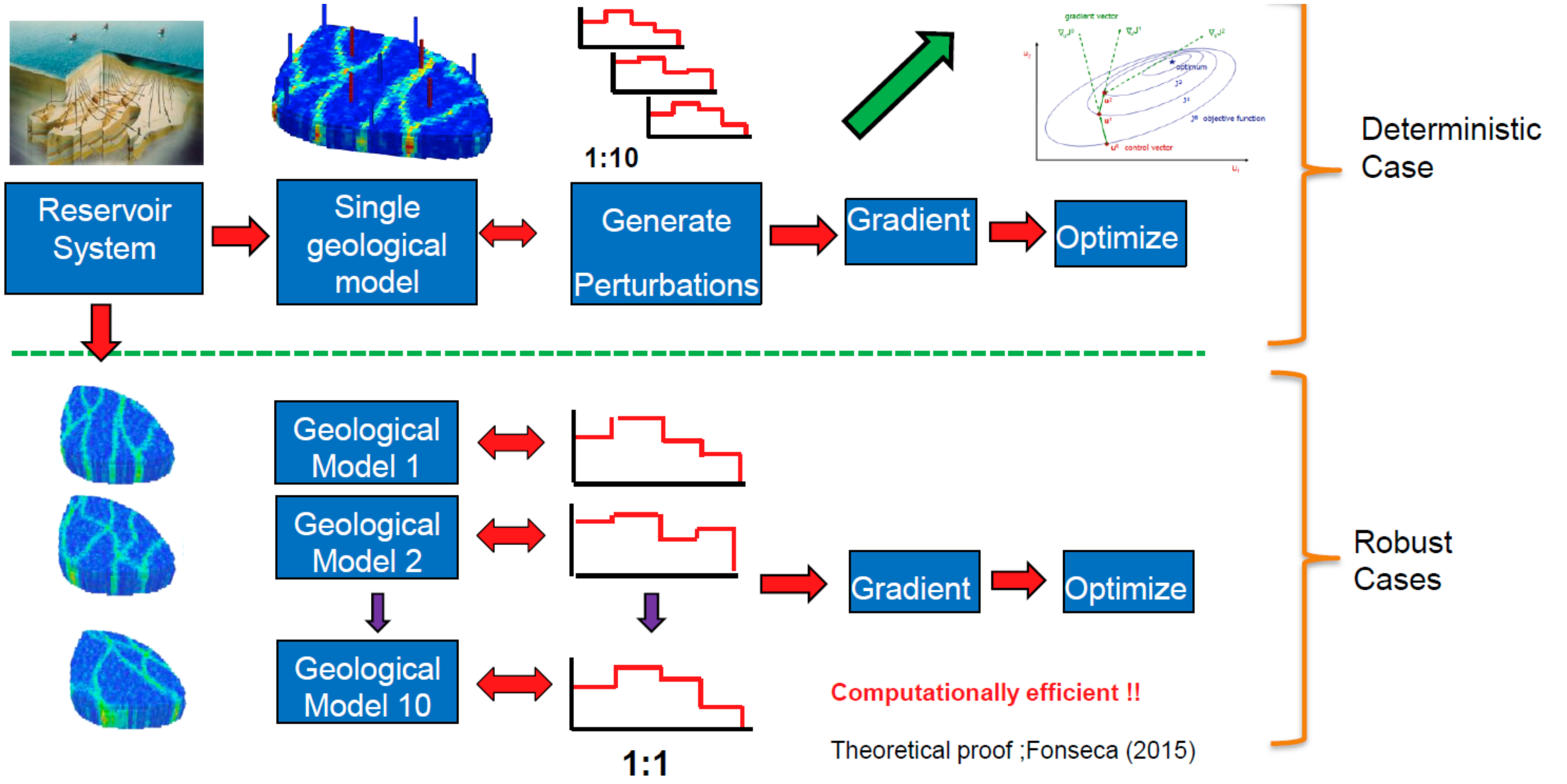
MOTIVATION

- Automate model tuning
- Improve performance of the entire ensemble of models
- Minimize trade-off between speed and accuracy

MODEL TUNING AS AN OPTIMIZATION PROBLEM

- Consider the FLOW simulator as a black box
- Conduct Robust(ensemble of models) optimization with:
  - Controls = FLOW tuning parameters
  - Objective = Minimize number of linear iterations

ROBUST OPTIMIZATION



OPTIMIZATION FORMULATION

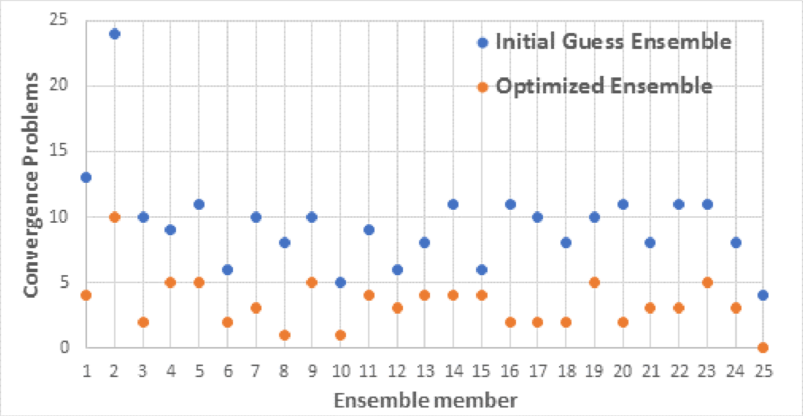
- **Controls**
  - Timestepping parameters
  - linear-solver-max-iter
  - max-strict-iter
  - flow-newton-max-iterations
  - max-welleq-iter
  - newton-max-relax
  - Ilu-relaxation
  - use-gmres
- **Objective**
  - Minimize number of linear iterations

```
TUNING
1  365  0.1  1*  3  0.3  2*  0.75 /
```

```
ecl-deck-file-name=ECL-0.DATA
linear-solver-max-iter=153
max-strict-iter=4
flow-newton-max-iterations=12
max-welleq-iter=15
newton-max-relax=0.499965
ilu-relaxation=0.88721
use-gmres=false
enable-tuning=true
```

OPTIMIZATION RESULTS: MODEL2

- 25 worst performing ensemble members(models) used
  - Linear iterations – 29% mean reduction
  - Convergence problems – 65% mean reduction
  - Newton iteration – ~20% mean reduction
- 20% less runtime with optimized tuning parameters

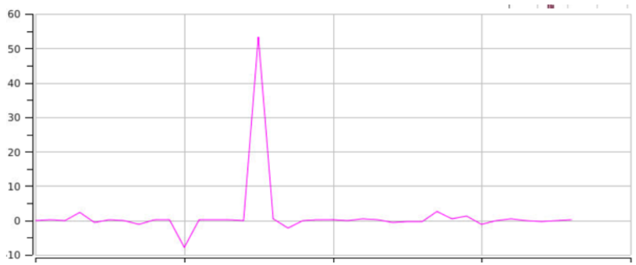


RESULTS CONTINUED: ACCURACY

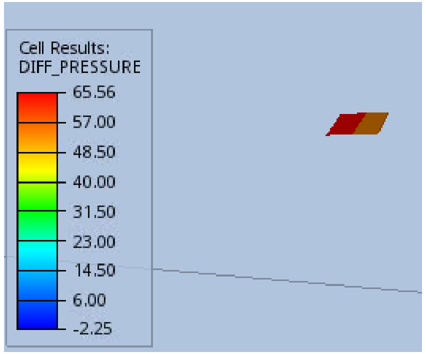
- Summary curves before and after optimization identical
- Upto 65 bar pressure discrepancy – limited to 2 cells in entire model and just for single timestep

- **Required: compareECL scheme to quantify pressure deviations based on number of deviating cells and number of timesteps**

CELL 1 DIFF_PRESSURE



Simulation time



LEARNINGS FROM OPTIMIZATION ON MODEL2

- **max-strict-iter**
  - Reduction from 7 to 4 results in improved performance
  - Pressure deviation as high as 65 bar but only for 2 cells and in single timestep
- **linear-solver-max-iter**
  - Increase from 150 to 220 improves performance
- **flow-newton-max-iterations**
  - Increase from 12 to 20 improves performance
- **Max time step after well modification**
  - Increase from 1 to 10 days improves performance

MPI VARIANTS

- Full ensemble (155 models) run on Model2 with 1, 2, 4, 8, 16 processes
  - 3x increase in convergence issues (on average) when using 8 cpu’s w.r.t serial run
  - Minimum average runtime achieved with 4 processes (86% decrease on average w.r.t serial run)
  - Different ensemble members scale differently

TAKEAWAYS

- Robust optimization workflow is able to automate reservoir model adaptation and tuning
- 30% reduction in linear iterations and 65% reduction in convergence problems – field case (model 2)
- Increase in linear iteration, newton iterations, well iterations – reduced convergence problems – Increased performance
- Quantification of accuracy change important for model tuning and testing
- Each ensemble member performs differently – requirement for robust testing framework

WORK IN PROGRESS

- SIAM Geosciences 2019 (March 11 – 14, 2019, Houston)
  - Robust optimization including preconditioner variants and accuracy quantification