Applying Genetic Programming to Reservoir History Matching Problem

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Outline

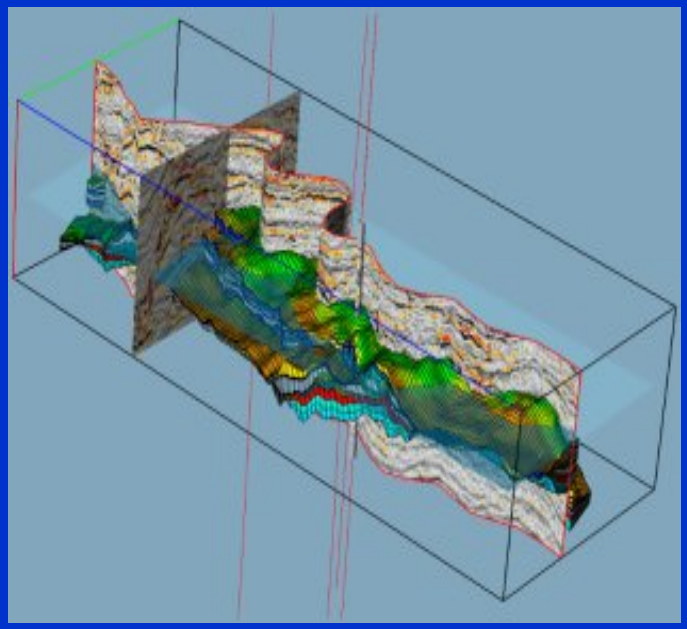
- Oil Exploration and Production
- History Matching Problem
- A GP Solution
- Business Impacts
- Current Status

Oil Exploration and Production

- Currently, less than one third of proven reserve is recovered by oil and gas companies.
- How to reduce the amount of bypassed oil is of great importance to the world's energy supply.
- One key step to increasing oil recovery is using data integration intelligently to provide accurate reservoir characterization and modeling.
- With such information, better reservoir management decisions can be made to optimize oil production.

Integrated Earth Modeling

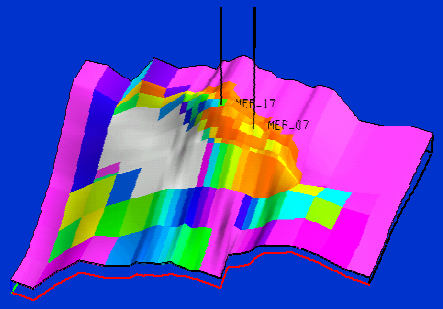
Static Data:
- Seismic
- Well Logs
- Cores
- Geostatistcs
- etc.



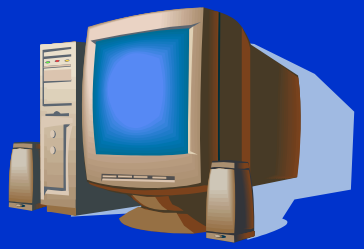
Dynamic Data:
- Well production (oil/gas/water)
- Shut-in/Pressure
- Well testing
- Tracer test
- etc.

- To Drill or Not to Drill ?
- Where to Drill ?
- How to Drill ?

History Matching Problem



Geological model created with static data

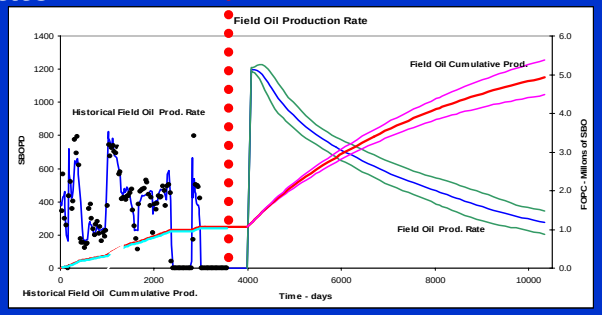


Select a set of geological properties values to run simulation

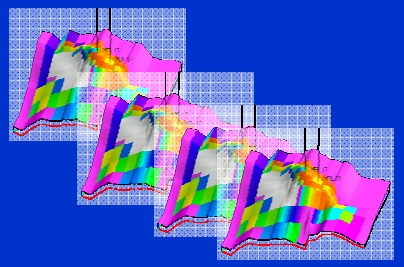
Select models with simulation outputs that best match production data

History Match

Forecast With Uncertainty



Forecasting future production



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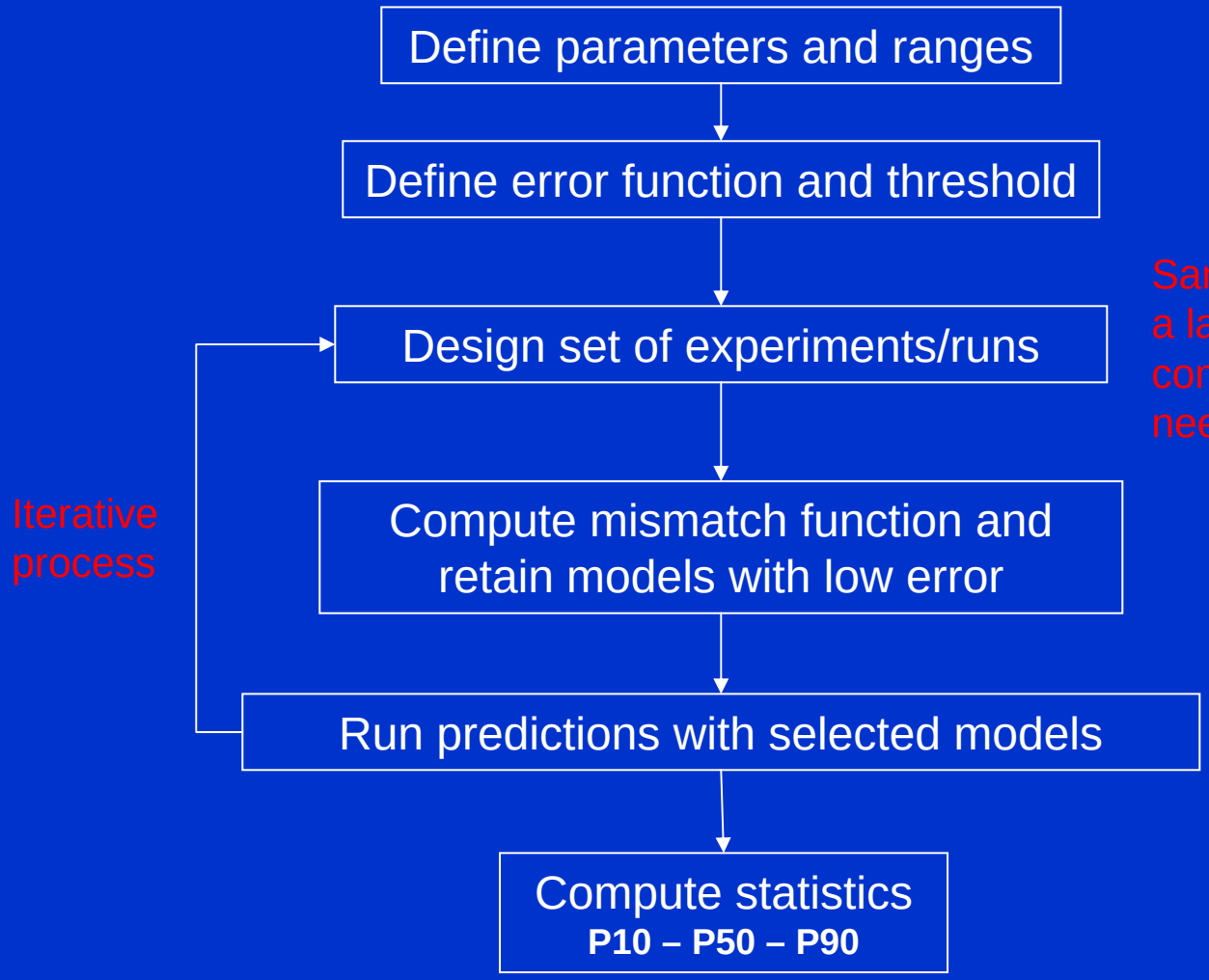
History Matching Process



Sampling strategy: a large number of combinations is needed

Iterative process

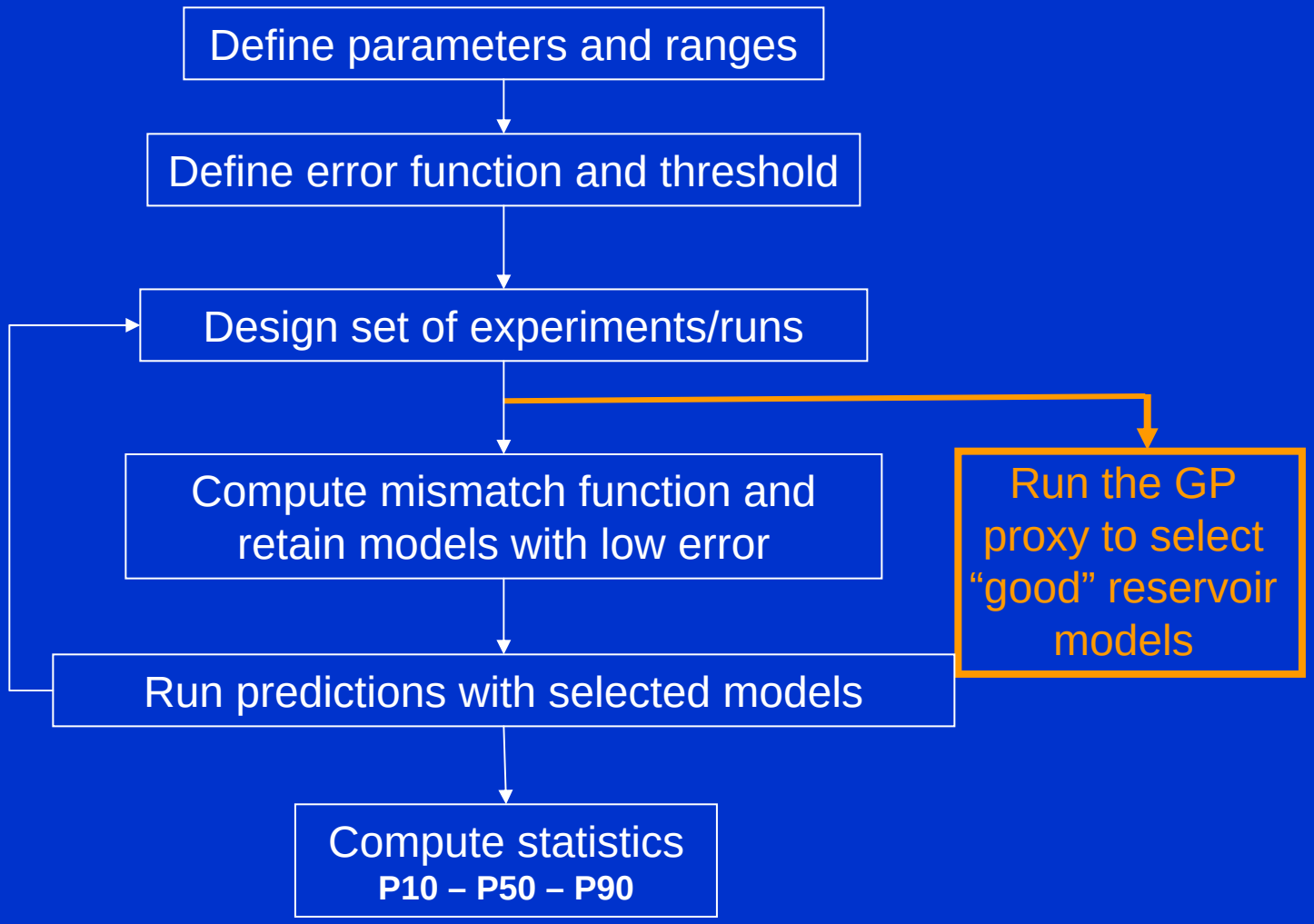
Issues

- Each reservoir simulation takes 2 to 10 hours to run.
- Only a relatively small number (hundreds) of simulations are practically possible and the identified “good” reservoir models (good match to the production data) is limited.
- The quality of these “good” models are constrained to the simulation setup.
- As a result, our confidence of the production forecasts and uncertainty estimation is not always high.

A Genetic Programming Solution

- Use GP symbolic regression to construct a “proxy” for reservoir simulator.
- This “proxy” is a classifier which predicts if a reservoir model is “good” (good match to the production data) or “bad” (poor match to the production data).
- Such a “proxy” can be used in the place of reservoir simulator to identify many (millions) “good” models.
- With a larger number of “good” models, we have a higher degree of confidence of the generated production forecasts and uncertainty estimation.

GP-enhanced History Matching Process



Case Study

- 894 simulation results, conducted using 10 reservoir geological variables, were collected.
- Among them, 541 are “bad” and 353 are “good” according to the error threshold decided by experts.
- The error is defined as the sum squared error between simulation outputs and production data (water/oil/pressure).
- 298 data were used for GP training, 298 for validation and 298 for testing.

Classification Results

Accuracy

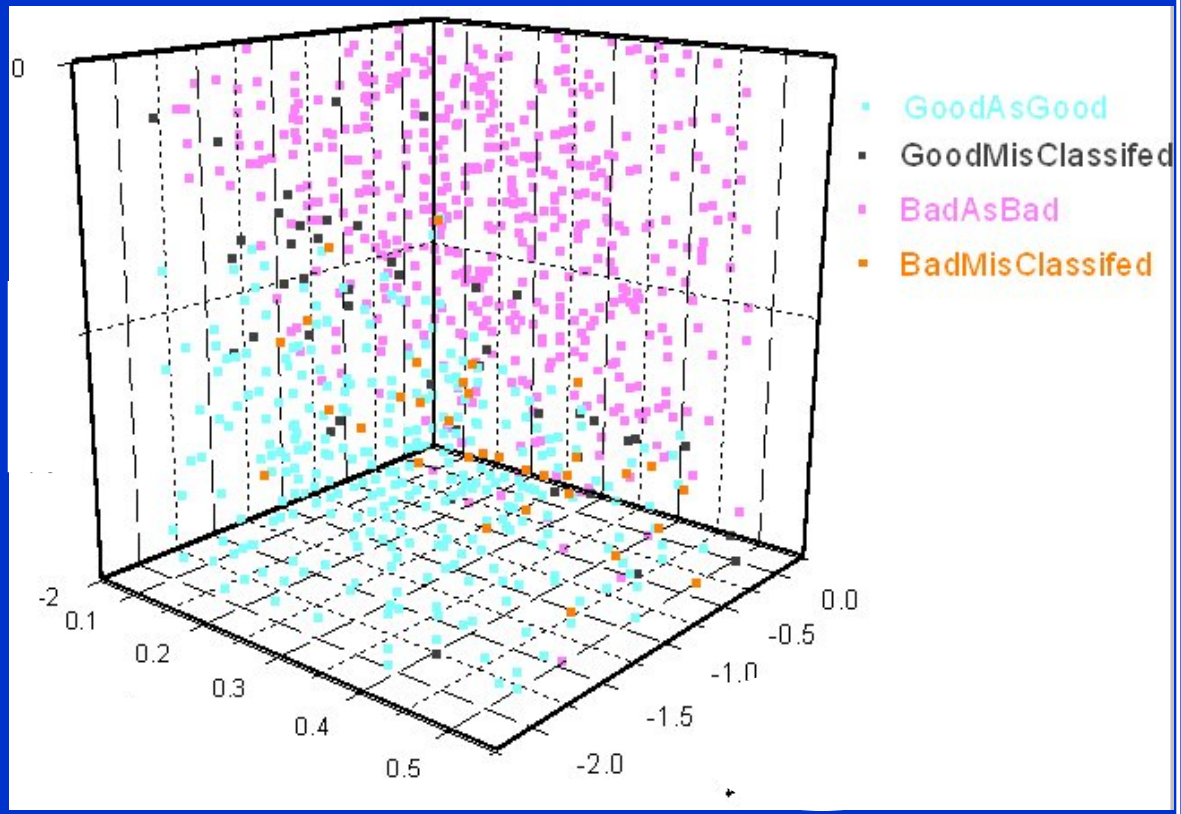
Training:
91.61%

Validation:

91.28%

Testing:

90.94%



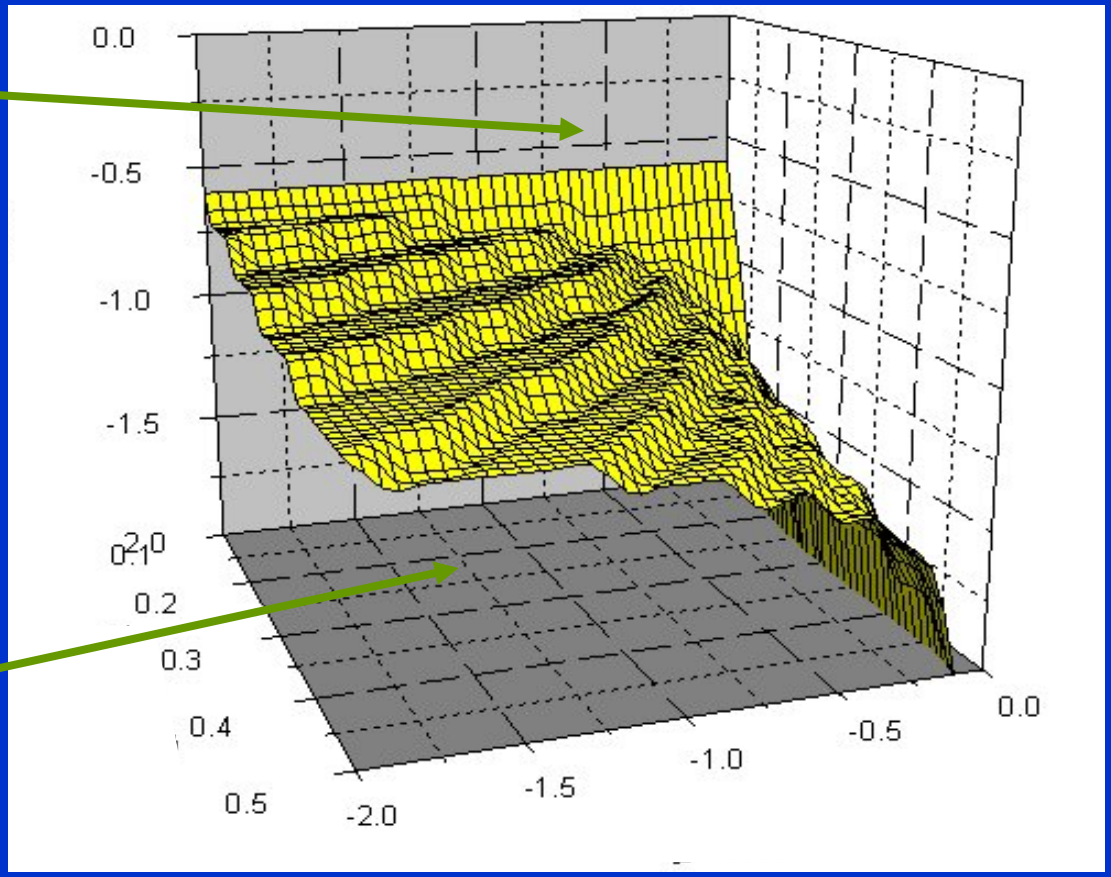
Interpolation & Interpretation

- The GP classifier (with 4 variables) is used to interpolate new sampling points.
- For each variable, 21 sample points are selected, evenly sampled between its high and low values.
- The total number of sampling points is 21^4=194,481.
- Among them, 73,135 are identified as “good” models while 121,346 are classified as “bad” models.

Good Models Upper Bound (MAX)

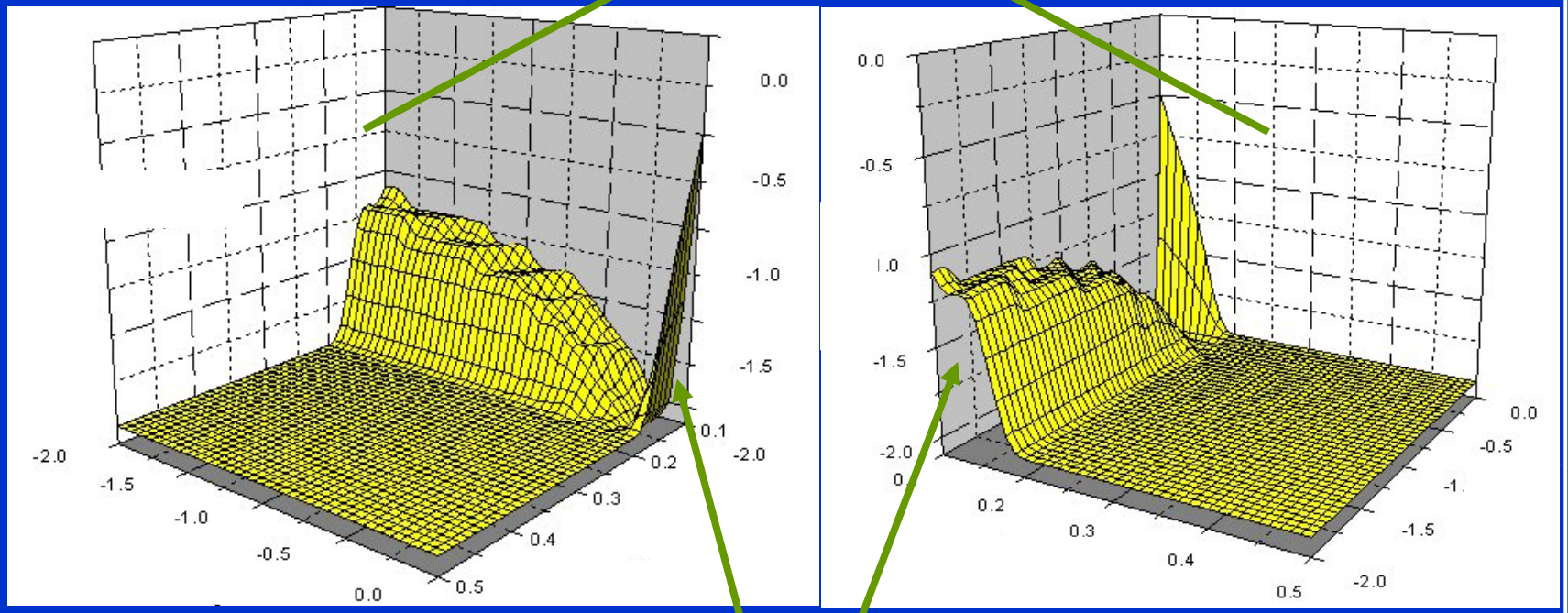
Bad Models Space

Good/Bad Models Space



Bad Models Lower Bound (Min)

Good/Bad Models Space



Good Models Space

Business Impacts

- Reduced cycle time (simulation run time).
- Increase knowledge of the dynamics of the reservoir:
  - impact of parameters on the response;
  - identification of preferred regions in the parameter space;
- Increased confidence of the forecast production and estimate uncertainty.
- Better reservoir management decisions.

Current Status

- The field engineer agrees with the identified reservoir geological characteristics.
- Some new insights of the reservoir are discovered by this work.
- We are applying the same method to another oil field.
- The GP identified “good” models will be used to evaluate production forecasts and uncertainty estimation.