ASSISTED HISTORY MATCHING

Fast screening of geological realizations by dynamic flow simulation

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AGENDA

- Project overview
- Seismic-to-simulation workflow overview
- Assisted HM methodology
  - Objective function setup
- **Qualitative screening of geomodels based on Objective function**
- Key learnings

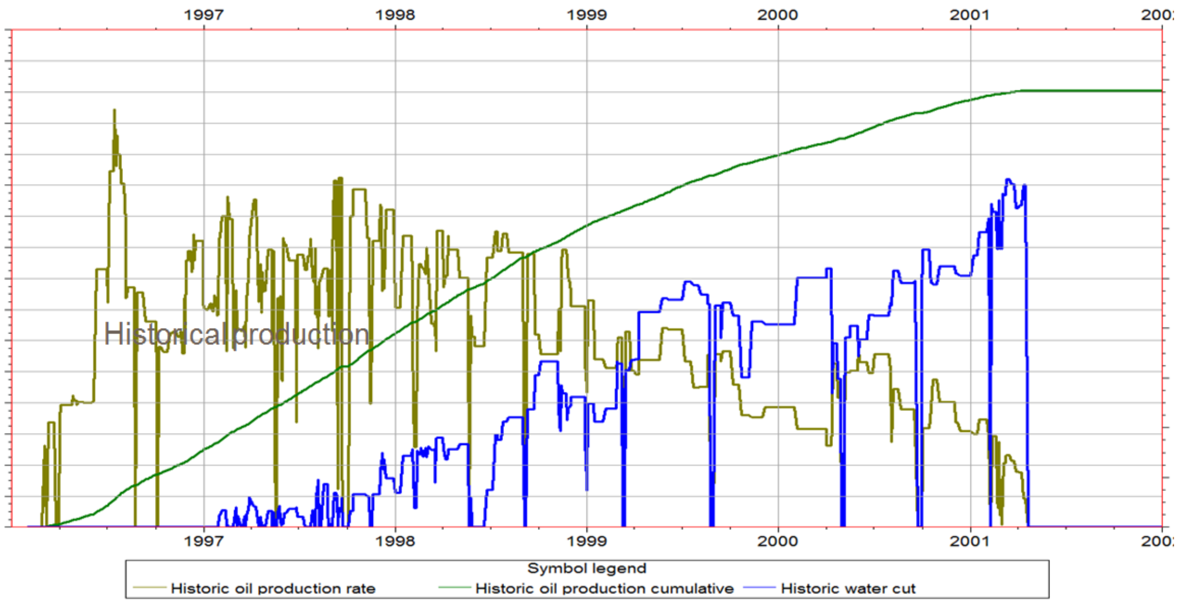
Project overview

Brown field in re-development

Data from 11 wells used for matching

- Historical production
- Reported static pressures
- Flowing bottom hole pressures
- Pressures and SWAT measured during redevelopment drilling campaign
- Grid dimensions (geo): 207x340x70 cells
- Active: 806 663
- No upscaling
- 2 analytical CT aquifers

Historical production



Integrated uncertainty workflow

Integrated workflow that contained 27 uncertain parameters range and distribution (static and dynamic parameters all together, including structure / depth conversion uncertainty, saturation table endpoints, OWC …)

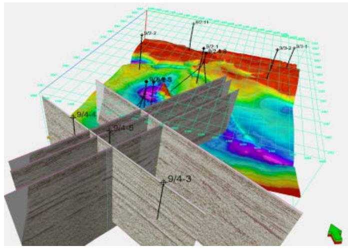
Description of static variables:

Variable	# of variables
Velocity Model	2
Petrophysical modeling, (variogram, poro-perm correlation coeff, stochastic variables*)	11 (*3)
Oil-water contact	3

Description of dynamic variables:

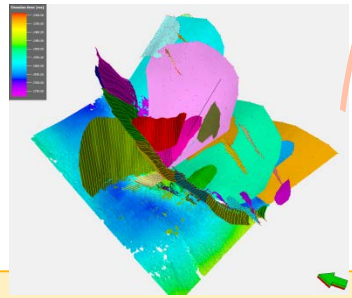
Variable	# of variables
Fault transmissibility multipliers	4
Oil-Water Relative permeability Corey exponent	1
KvKh	1
Aquifer	3
Saturation table End Points (SWL;SWCR;KRWR; SOR)	2

Seismic-to-simulation workflow



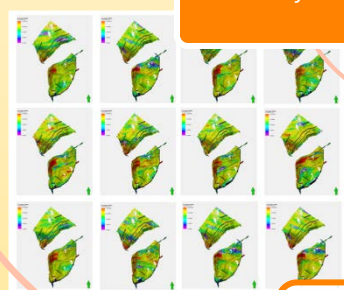
Well and seismic data

Structural and Stratigraphic model



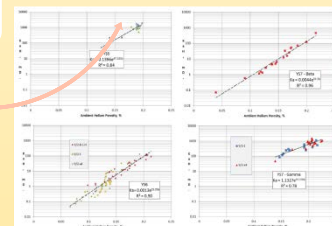
- Stochastically modeled
- SGS; upscaled logs etc.

Porosity modeling



Permeability

- CORE
- SCAL
- PORO-PERM correlation



- SATNUM regions
- Saturation End Points

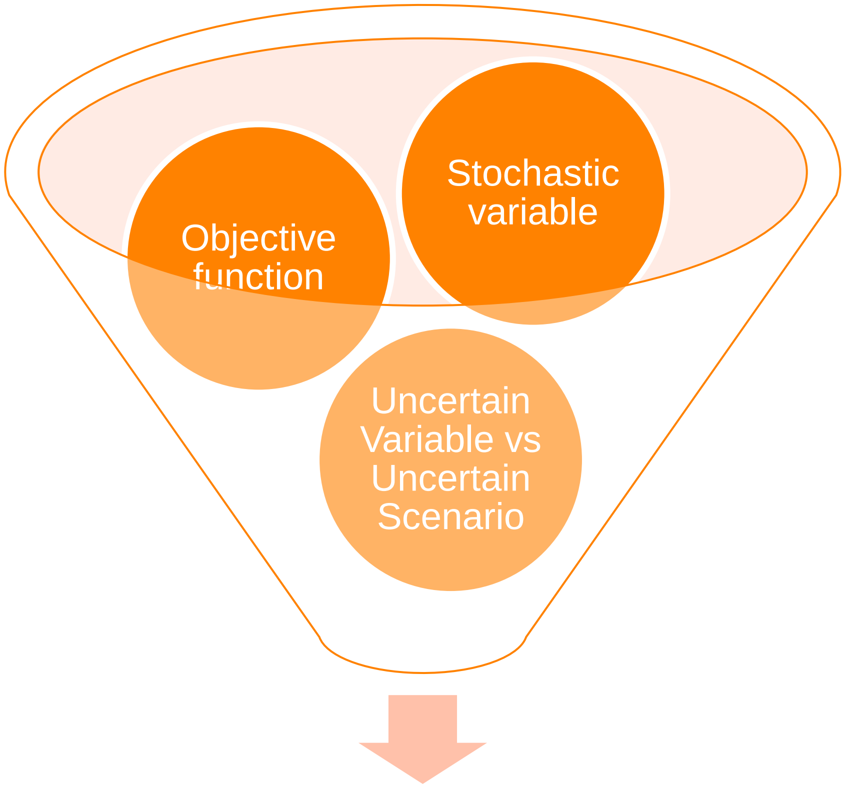
SWL, SWCR, KRWR. SOR
And KVKH

Objective Function
screen realizations according to production history

- OWC
- Aquifer CT
- Relative Permeability tables
- Schedule file

Flow Simulation

Challenges and limitations of Optimization algorithms and 3D modeling software



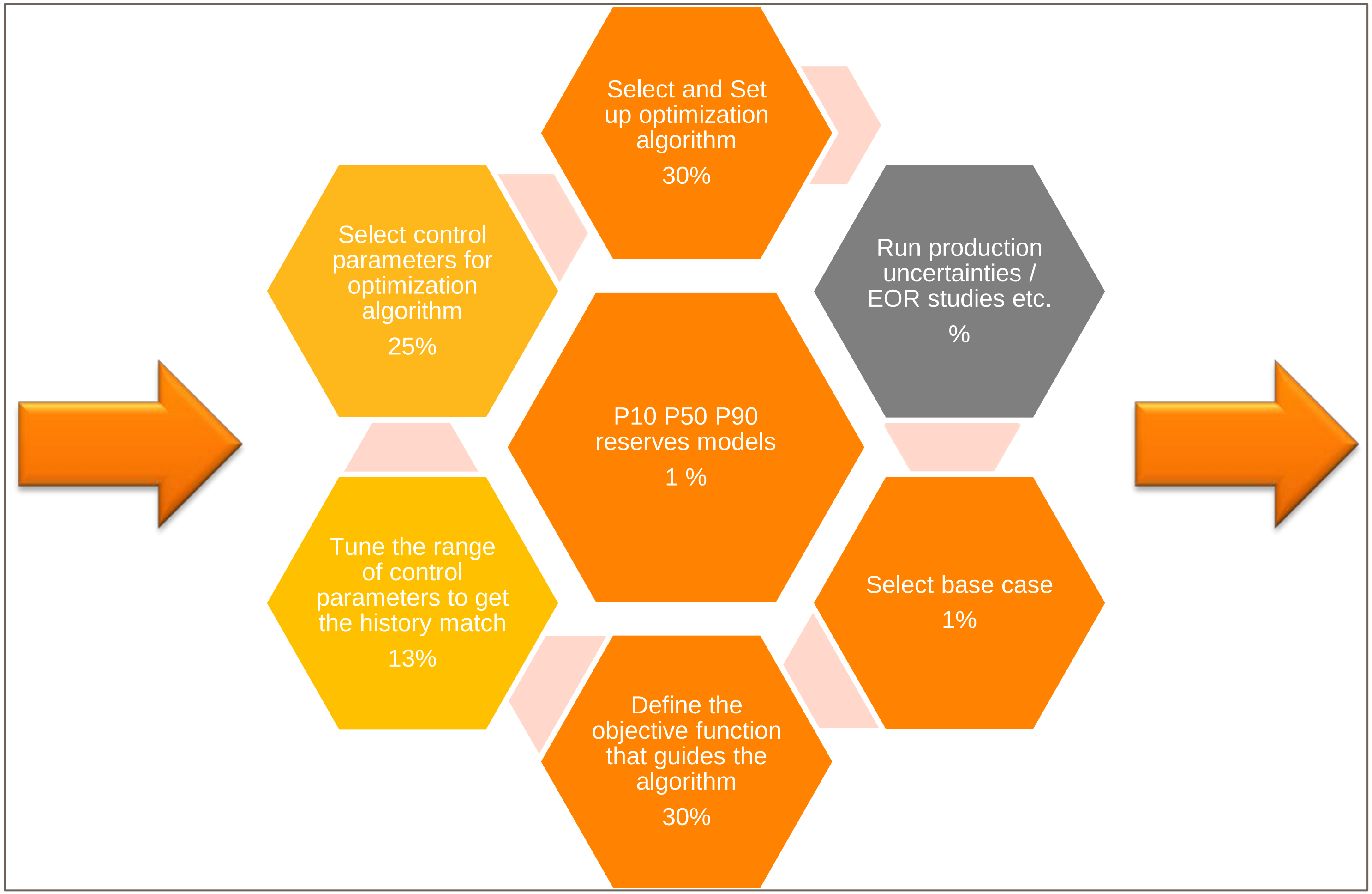
Set of history matched reservoir models

Objective function is main input to optimization algorithms. Optimization algorithm will perform accordingly to objective function setup.

Modeling software is grid centric. No easy way to explore uncertain scenarios (different geological concepts), thus predicted reserves range is usually narrow.

Assisted history matching

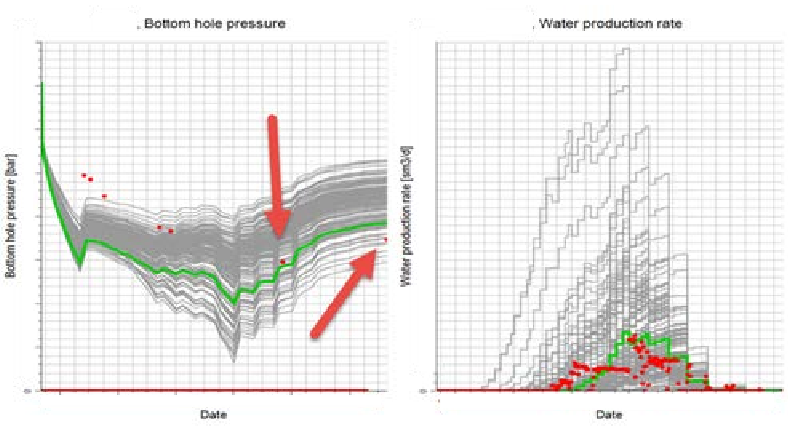
Typical process

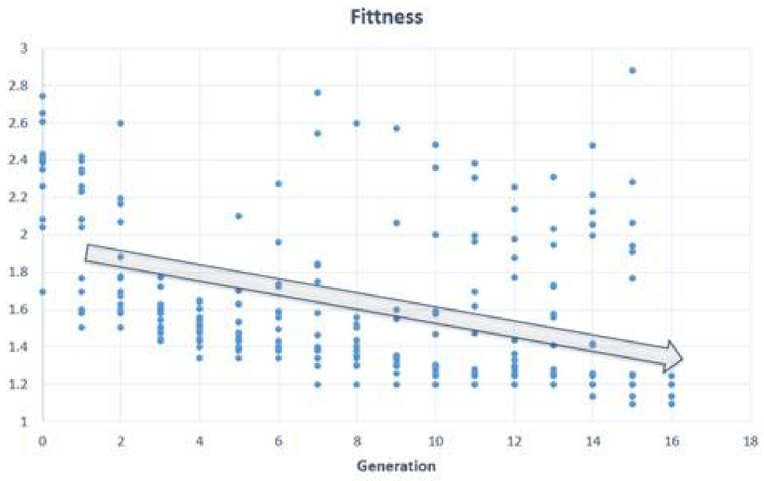


% represents time spent on each task

Assisted history matching

Example





Explore the optimization space.

Assisted history matching (with optimization algorithm at its center) requires large set of initial models to calibrate optimizer with respect to model variables (usually 10x # of active model variables (Uncertainties) typically 200 initial runs).

Perform optimization = algorithm will launch multiple ‘ensembles’ or ‘generations’ until it converges.

Optimization algorithm will perform accordingly to objective function setup.

Optimizer working as expected, OF drives convergence toward lowest mismatch.

Alternative Methodology

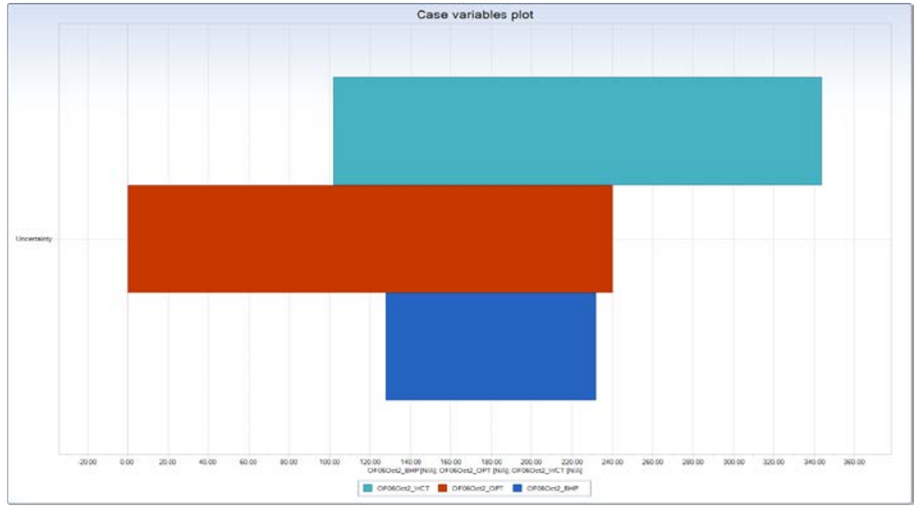
Screening of geological realizations by dynamic flow simulation

% represents time spent on each task

Objective function

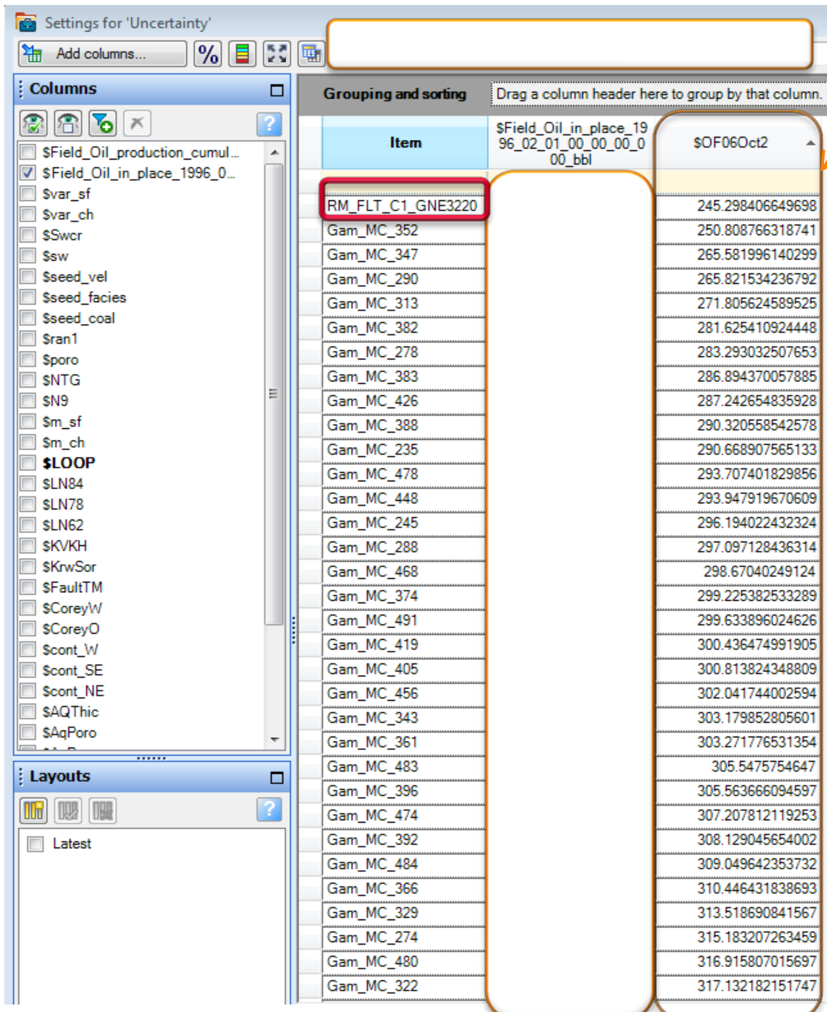
Setup

Identifier name	Quantity name	Measur. error	Identifier weight	Quantity weight	Time weight	Ignore zeros
4_ST2	Bottom hole pressure	1	1	0.2	Default	✓
A1_A	Bottom hole pressure	1	1	0.2	Default	✓
A2	Bottom hole pressure	1	1	0.2	Default	✓
A2_B	Bottom hole pressure	1	1	0.2	Default	✓
A4	Bottom hole pressure	1	1	0.2	Default	✓
A4_A_D9	Bottom hole pressure	1	1	0.2	Default	✓
A4_BT2	Bottom hole pressure	1	1	0.2	Default	✓
A5_GI	Bottom hole pressure	1	1	0.2	Default	✓
A5_WI	Bottom hole pressure	1	1	0.2	Default	✓
A6	Bottom hole pressure	1	1	0.2	Default	✓
A6_A	Bottom hole pressure	1	1	0.2	Default	✓
A8_T2	Bottom hole pressure	1	1	0.2	Default	✓
4_ST2	Oil production cumula	100000	0.9	2	Default	
A1_A	Oil production cumula	100000	0.9	2	Default	
A2	Oil production cumula	100000	0.9	2	Default	
A2_B	Oil production cumula	100000	0.9	2	Default	
A4	Oil production cumula	100000	0.9	2	Default	
A4_A_D9	Oil production cumula	100000	0.9	2	Default	
A4_BT2	Oil production cumula	100000	0.9	2	Default	
A5_GI	Oil production cumula	100000	0	0	Default	
A5_WI	Oil production cumula	100000	0	0	Default	
A6	Oil production cumula	100000	0.9	2	Default	
A6_A	Oil production cumula	100000	0.9	2	Default	
A8_T2	Oil production cumula	100000	2	2	Default	
Field	Oil production cumula	1000000	10	1	Default	
4_ST2	Water cut	0.05	1	0.1	Default	
A1_A	Water cut	0.05	1	0.1	Default	
A2	Water cut	0.05	10	0.2	Default	
A2_B	Water cut	0.05	1	0.1	Default	
A4	Water cut	0.05	1	0.1	Default	
A4_A_D9	Water cut	0.05	1	0.1	Default	
A4_BT2	Water cut	0.05	1	0.1	Default	
A5_GI	Water cut	0.05	1	0.1	Default	
A5_WI	Water cut	0.05	1	0.1	Default	
A6	Water cut	0.05	10	0.2	Default	
A6_A	Water cut	0.05	1	0.2	Default	
A8_T2	Water cut	0.05	1	0.1	Default	
Field	Water cut	0.05	50	1	Default	



The uncertainty in the observation data allows to assume that *Cumulative Oil production* along with *Field Water Cut / Cumulative Water production* should have the highest impact on the quality of the match, since there is highest confidence in these measurements. It is reflected on the tornado chart as these parameters are outstanding as compared to bottom-hole pressure.

Qualitative selection of models with lowest mismatch



Calculated mismatch

Calculated mismatch (the value) is also available for the reference case(highlighted in Red). This provides means to qualify the realizations with respect to reference case. It can be seen that the reference case has the smallest mismatch (245), which makes it best case of the set. There are however many cases (U&O realizations) that are relatively close. For the purpose of this study the screening threshold was set at mismatch value of 300.

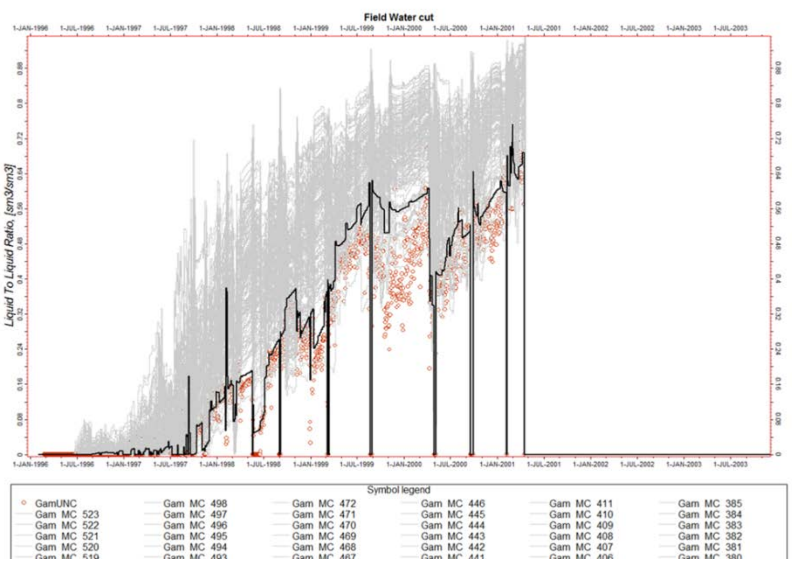
Alternative Methodology, part 1:

Obtaining a representative ensemble of realizations

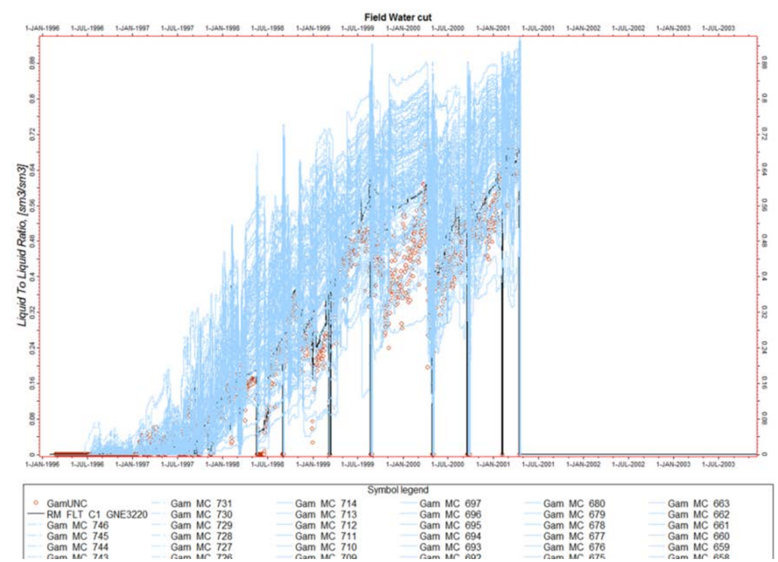
1. Define uncertain parameters range and distribution (including all static and dynamic parameters, including structure / depth conversion uncertainty…)
2. Run XXX models in history mode and check if ranges must be tuned
3. Tune the range so that you have an ensemble of models that are not skewed in one direction only, using sensitivity analysis tools

Example on field watercut:

Initial ensemble, all realizations produce too much water.



After few iterations, some models produce less water.

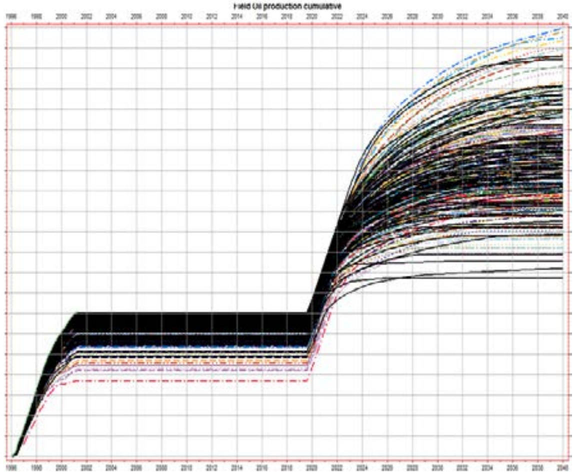


Alternative Methodology, part 2:

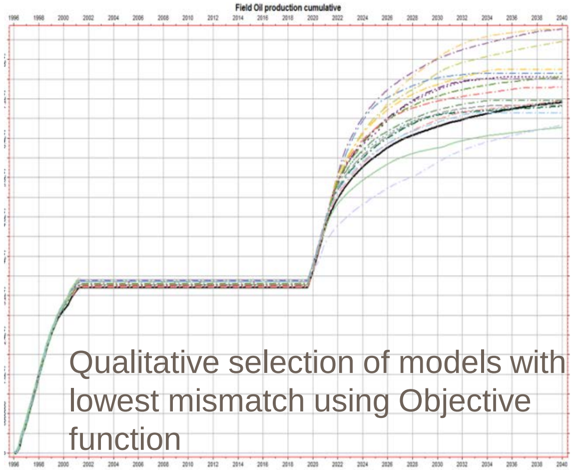
Using a Objective function (mismatch function) to qualify the models / discard the models that are totally off, and analyze the qualified models

1. Mismatch function needs to be carefully defined, based on confidence on data / reliability of observations
2. Run 300 models in history + forecast mode and define a threshold for mismatch function, above which you decide that the HM is not good enough
3. Do probabilistic analysis on the selected realizations

Cumulative Oil Production
before screening

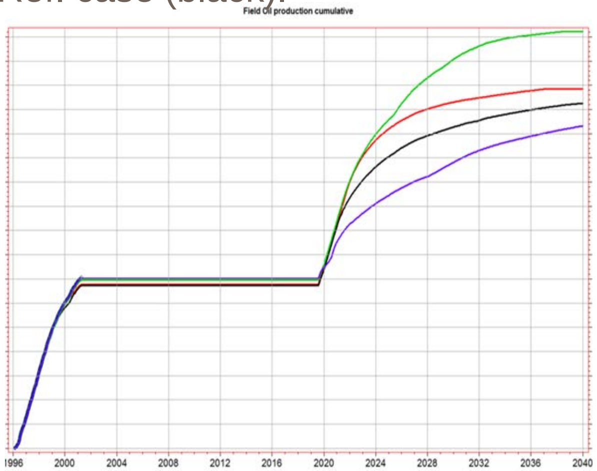


Cumulative Oil Production
Screened set of models



Qualitative selection of models with lowest mismatch using Objective function

Probabilistic reserves profiles
P10 (green), P90 (blue), P50 (red), Ref. case (black).



Summary & Key learnings

REPSOL

Screened realizations can be manually fine tuned to production data

Workflow centric screening that helps select the model(s) that honors production history instead of HM of random geological realization

Simpler method that don’t require full optimization loop

Time spent on multidisciplinary collaboration instead of tuning optimization

More detailed sensitivity analysis; understanding impact of model uncertainties on planed development wells

Thank you