wintershall dea

ENSEMBLE MODELLING

LESSON LEARNED FROM OVER 2 YEARS – MARIA FIELD CASE STUDY

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Stavanger – 7th December 2022

AGENDA

- Maria Overview
- Why ensemble based modelling
- 7 Learnings
- Summary & Conclusion

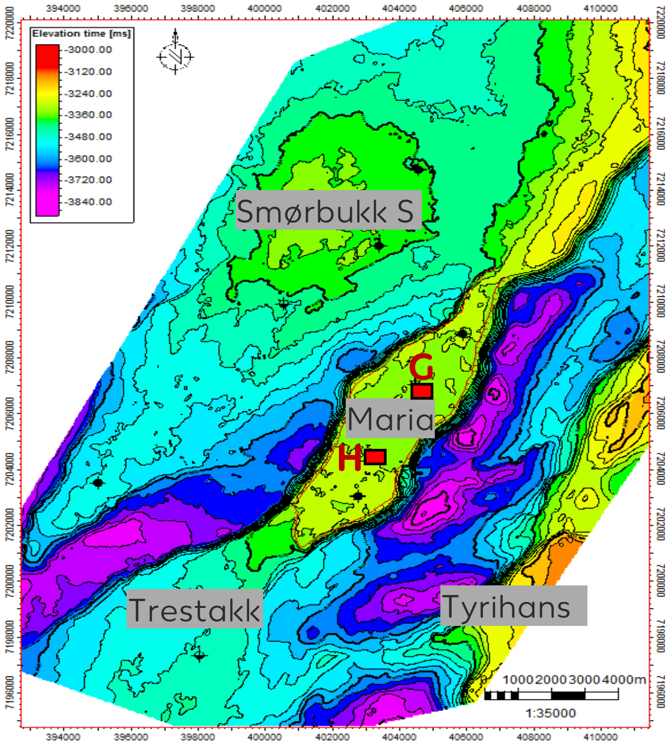
MARIA OVERVIEW

Location
- Norwegian Sea (Mid Norway), Halten Terrasse
- Water depth: 300 m

Description
- Jurassic Garn sandstone reservoir; 35 API oil
- Surrounded by producing fields (same formation)
- Sub-sea development with two templates (H & G)

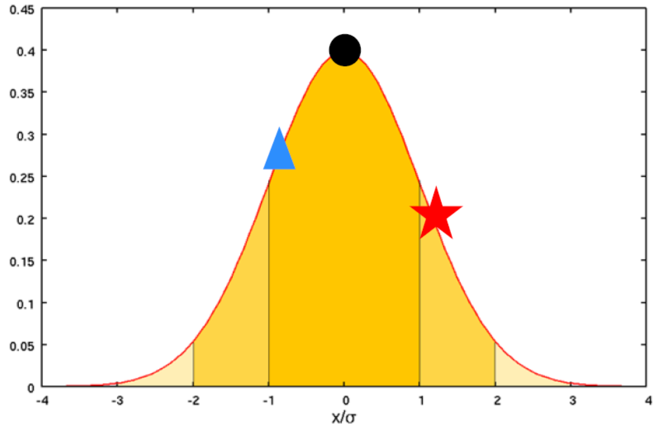
Key dates
- Discovery: 2010
- Appraisal: 2012
- On stream: 2017
- Phase 2 PDO: 2022

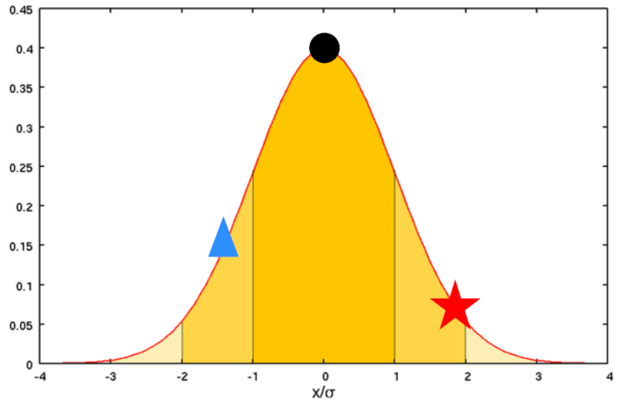
Ownership
- Wintershall Dea (Operator): 50%
- Petoro: 30%
- Sval Energi: 20%



WHY ENSEMBLE BASED MODELLING?

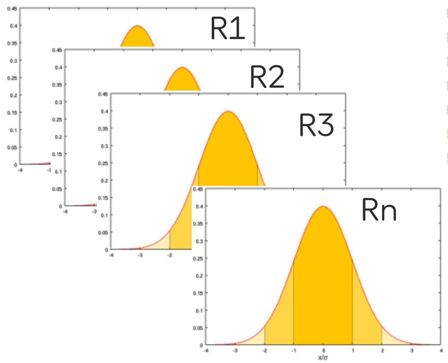
- Sampling from the entire uncertainty span of each input parameter and not only one point
- Covers a combination of input parameters
- History matching
  - Reduces uncertainty consistently and systematically
  - Eventually improves the predictive power of the simulation model
  - Less biased compared to manual history matching
  - Conflicts in the model are naturally easier recognizable
- Highly multi-disciplinary modelling by nature

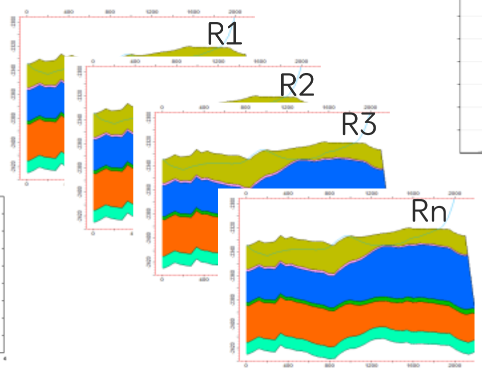


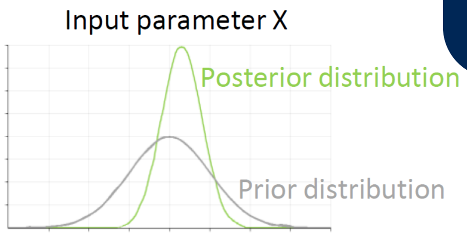


ENSEMBLE BASED MODELLING WORKFLOW

Step 1
Generate multiple equiprobable realizations of the model including all the static and dynamic model uncertainties

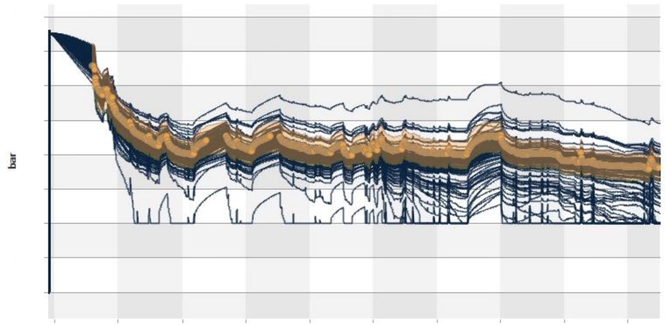


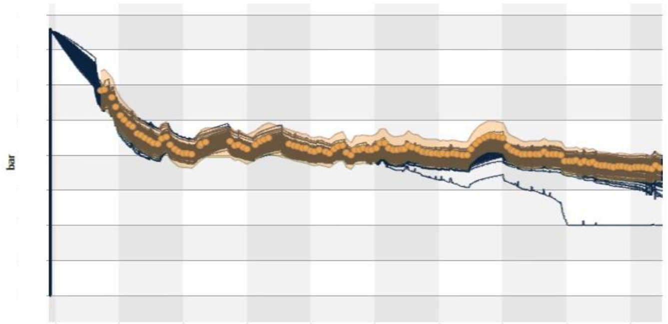




Step 2
History match all the realizations by conditioning the prior ensemble to the dynamic data

- Reduced uncertainty in input parameters
- Posterior ensemble converged towards observed data
- Significant reduction in simulated ranges

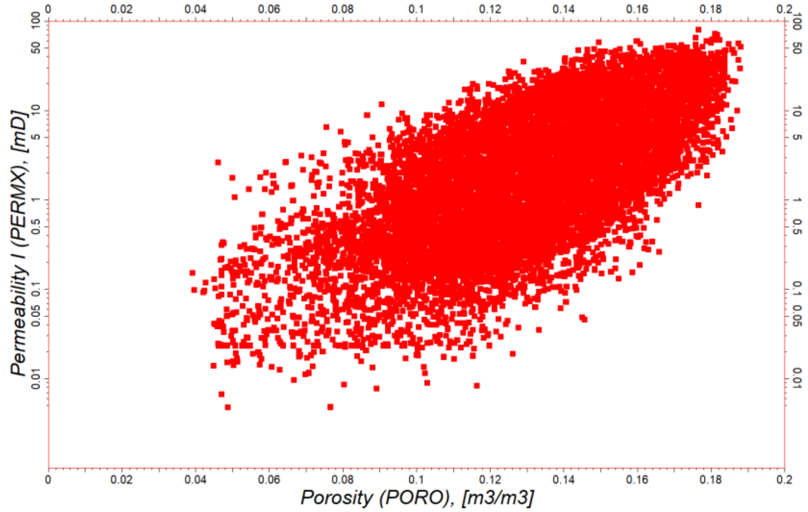




Learning 1	Learning 2	Learning 3	Learning 4
Sense checking	**Ensemble ≠ Scenarios**	**Objective Function**	**No Data**

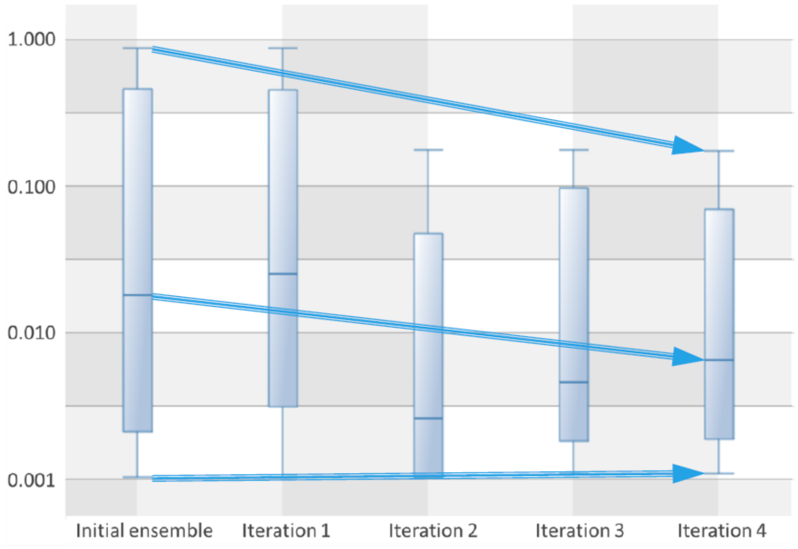
Learning 5	Learning 6	Learning 7
Reality	**Communication**	**In-Place volume distribution**

LEARNING #1
SENSE CHECKING

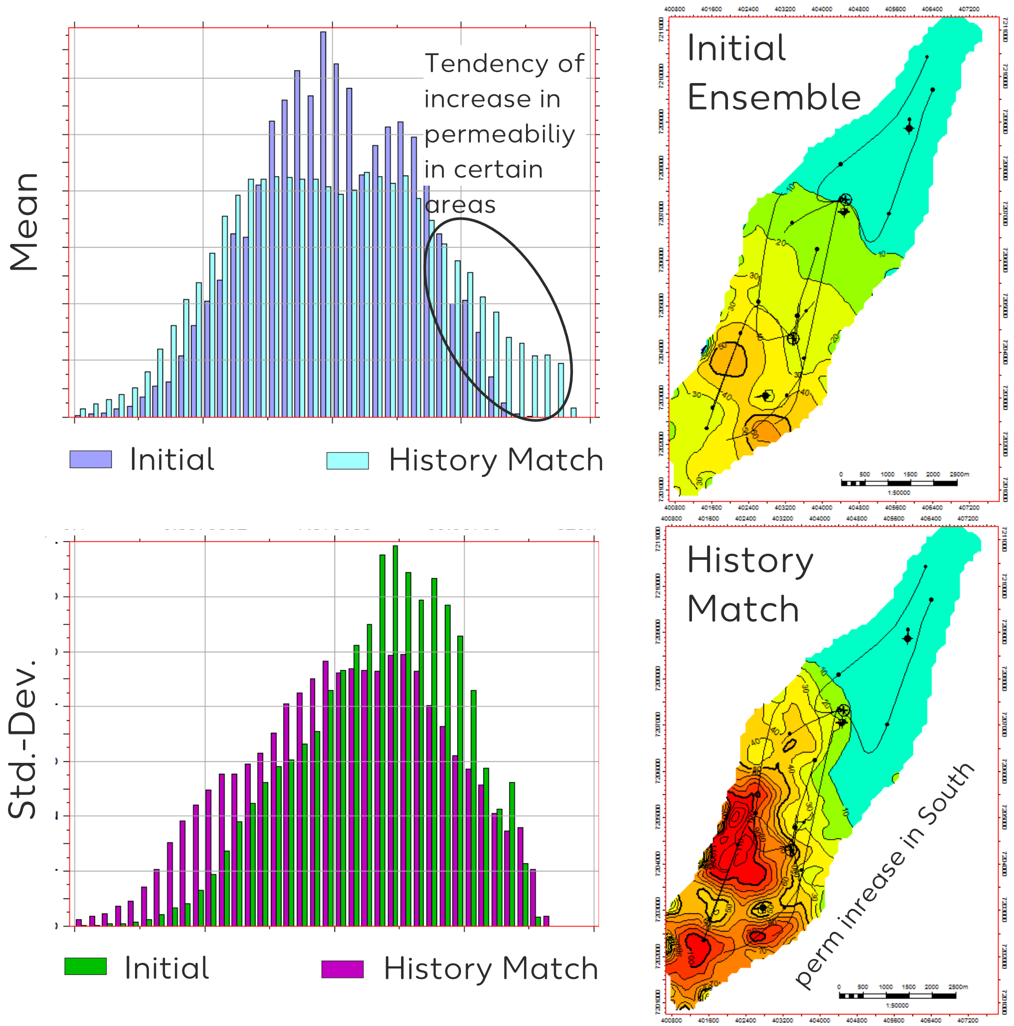


Use results for

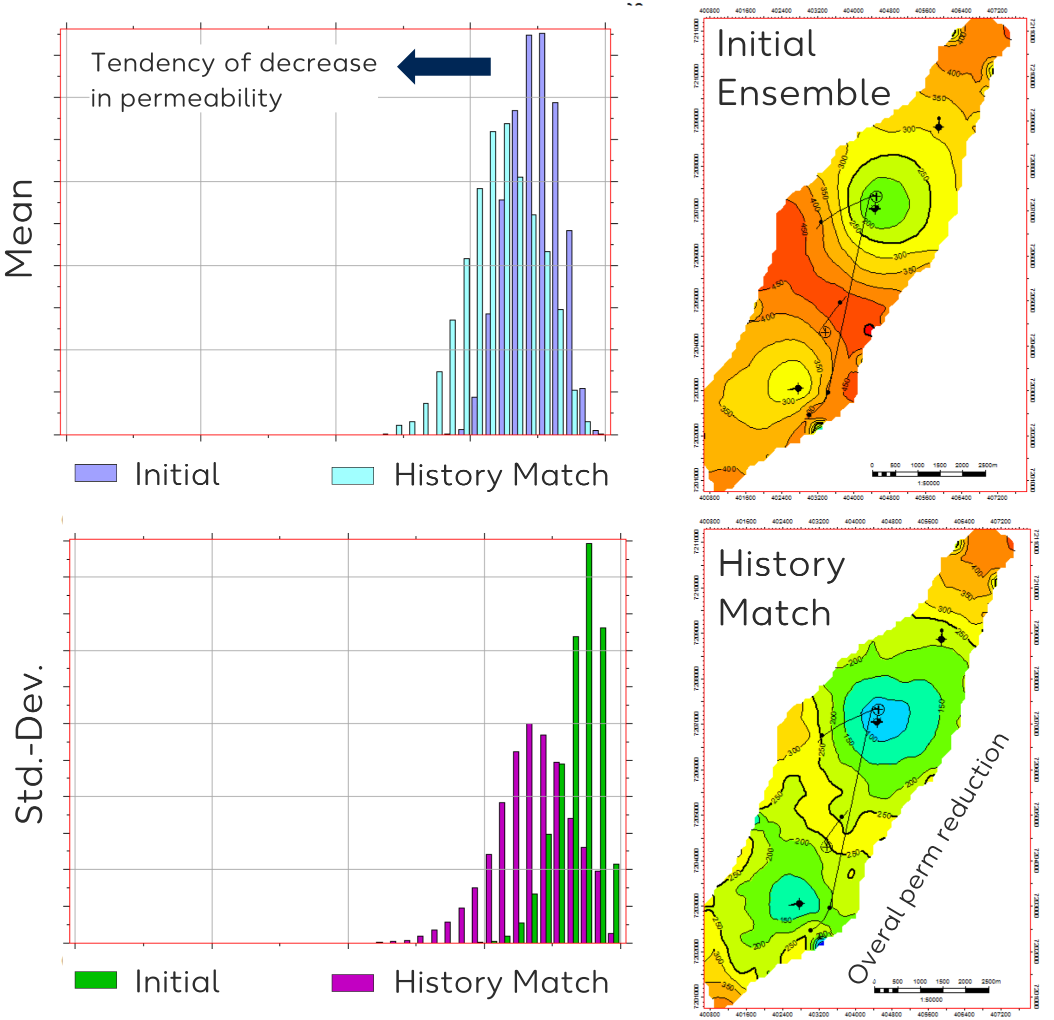
- Sense checking
  - Does it make sense based on experience if a parameter tends to increase?
  - Could it cover just another uncertain parameter, which was possibly left out (structural uplift vs. permeability increase, …)?
  - Is the geological concept preserved throughout the history matching
- Extracting sensitivities (indirectly)
  - What is the impact of the sealing layer on the possible planned scenarios



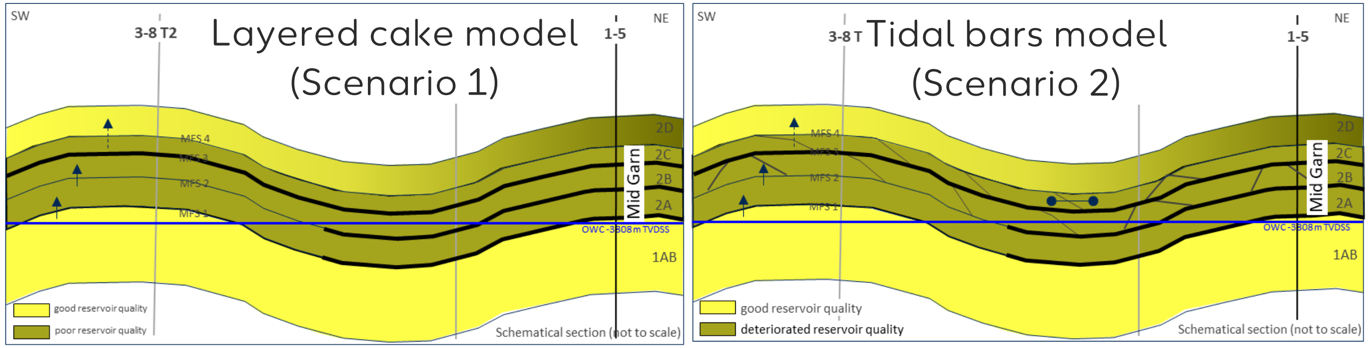
Garn 2D



Garn 1B

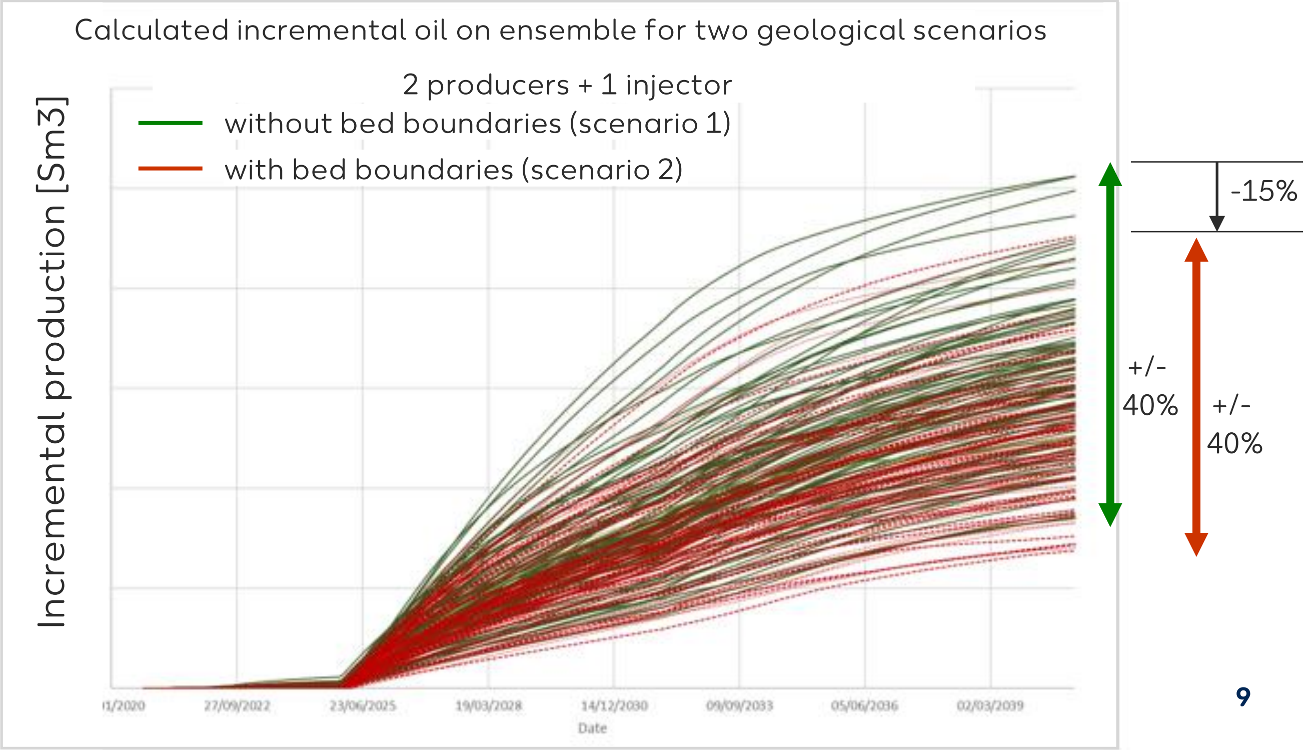


LEARNING #2
ENSEMBLE ≠ SCENARIOS



An ensemble is not equal to the range of its scenarios

- The range of a predicted outcome can create a comfort feeling and it should not be forgotten that the ensemble is build on a certain geological scenario.
- What is the impact of the geological scenario on the planned development concept?



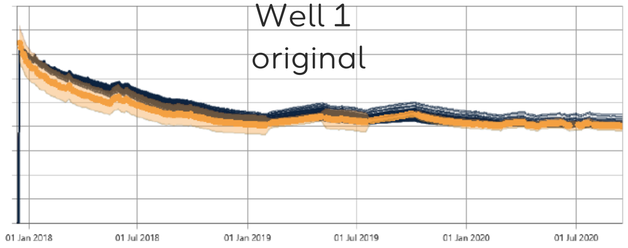
LEARNING #3
OBJECTIVE FUNCTION

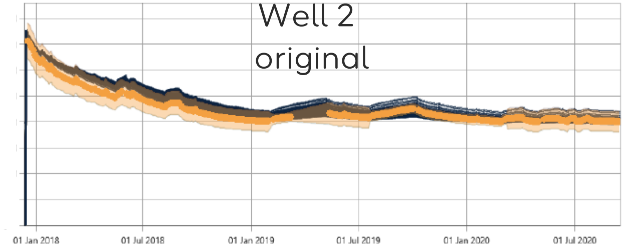
Setting up and cross-check the objective function

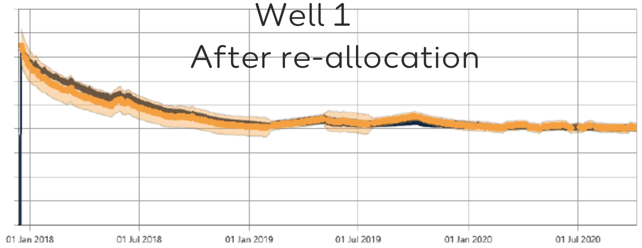
- Exclude wrong data points/ outliers (obvious)
- Set up the correct tolerances
  - Uncertainty in the measurement
  - Can give "weight" for a parameter – is that wanted?

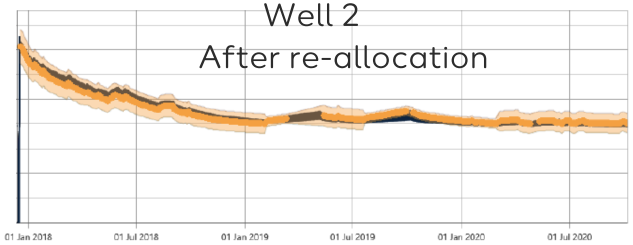
- How many data points to include?
  - As many as possible/ weekly/ monthly?
  - Can greatly affect the match quality

- Which parameters to include in objective function?
  - Measured bottom hole pressure (if available)
    - Water (production rate, cut, cumulative)?
    - The more parameters per well the more weight



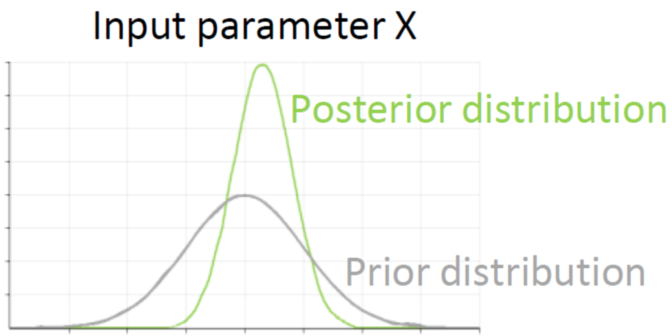


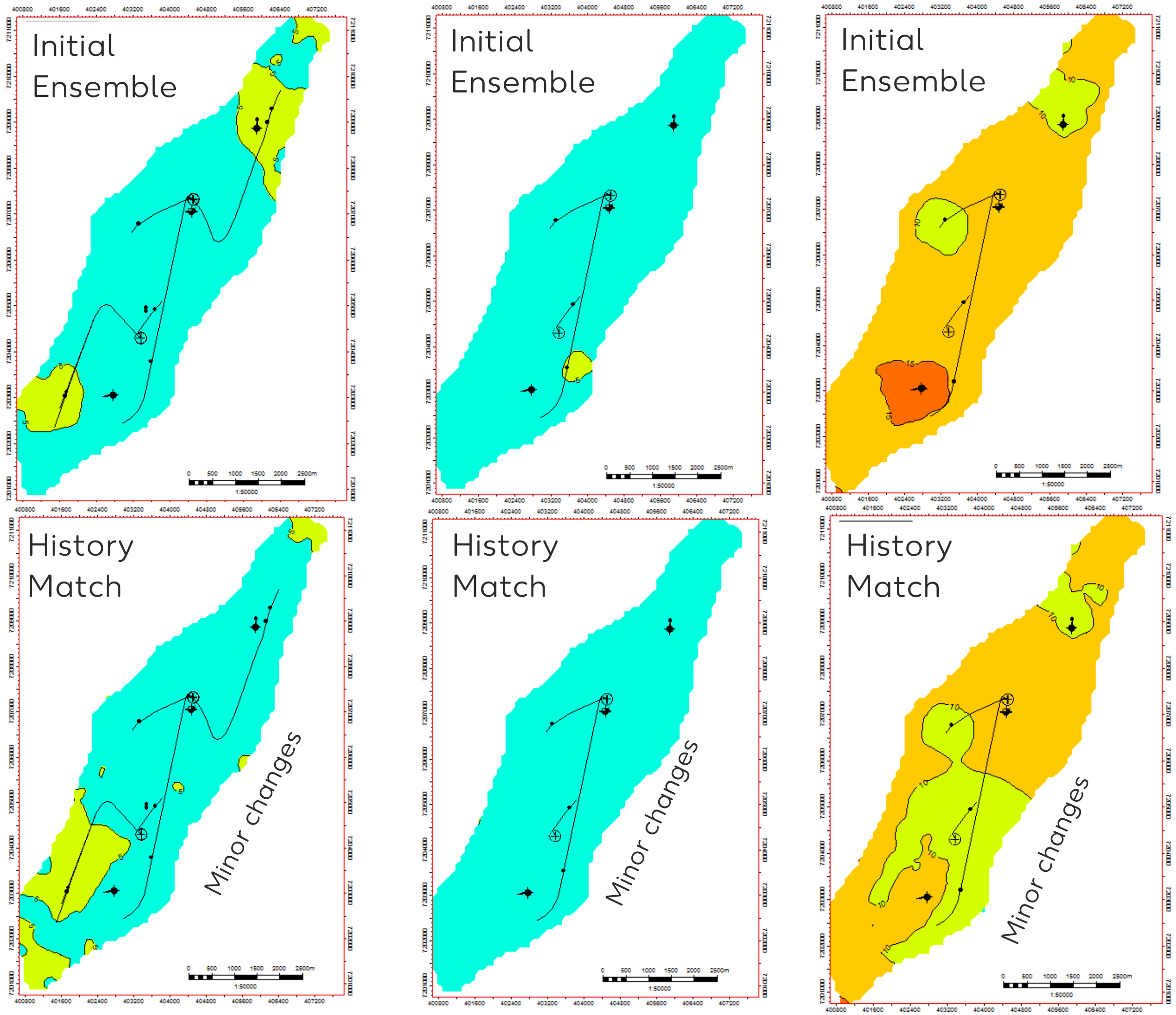




LEARNING #4
NO DATA

- If there is no observed data from a certain zone/compartement, there will be no uncertainty reduction.
- How does this influence your planned development scenario?



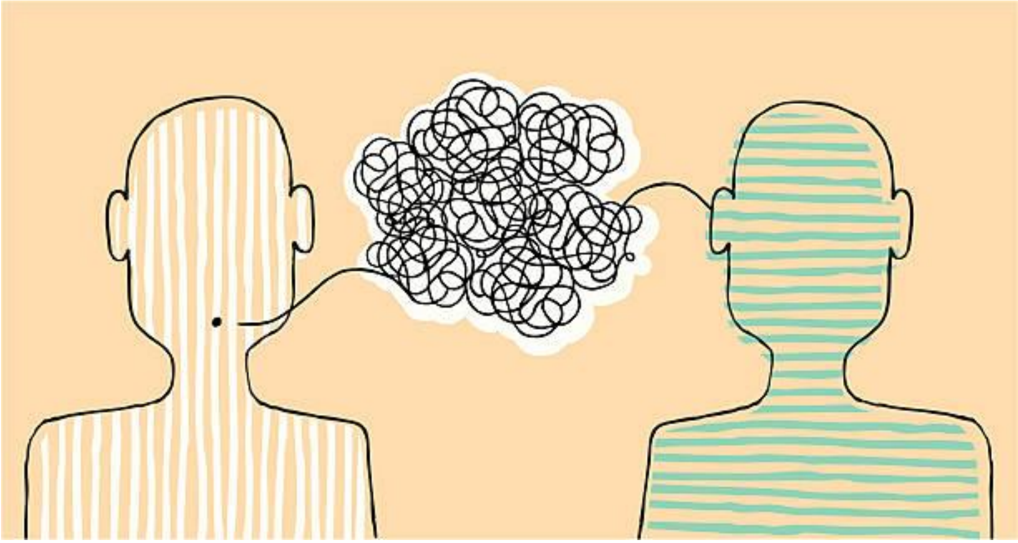


LEARNING #5
REALITY

- Ideally: Run ensemble based modelling on all possible geological scenarios
  - BUT: **Not practical** due to limited time and resources
- Practically/Pragmatically: Investigate several scenarios and run ensemble based modelling on a few scenarios
- Define uncertainty in input parameters as «correctly» as possible
  - Never give the software more freedom than necessary
  - The software might compensate for one «missing uncertainty» by another «over-represented uncertainty»

LEARNING #6
COMMUNICATION

- Low, Mid, High ≠ P90, P50, P10
- Sum of P50s ≠ P50 of the sums
- Make sure you know how your output will be used and communicate the „boundary" of provided data
  - Facility Engineering – Production Engineering - Economics

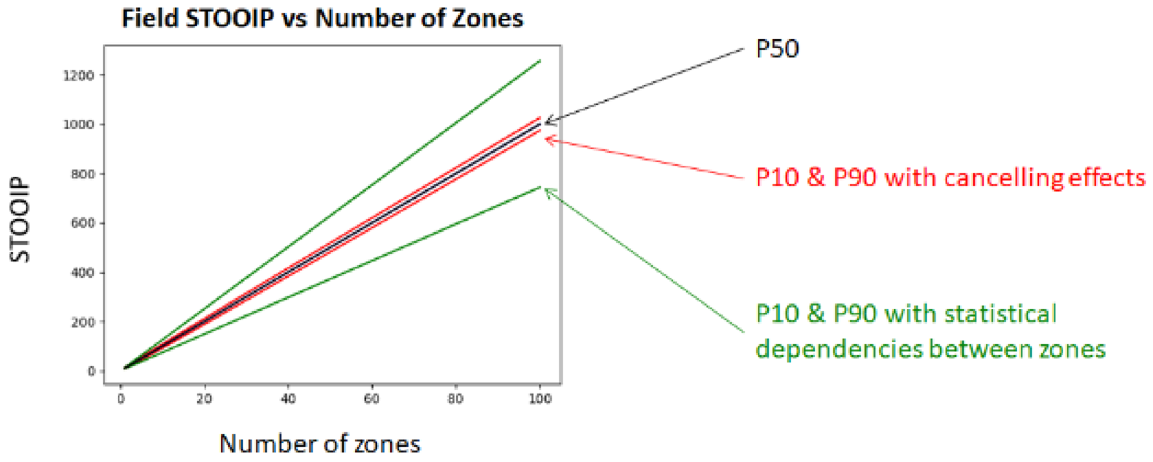


LEARNING #7
IN-PLACE VOLUME DISTRIBUTION

Why is in-place distribution not getting larger?

- Introducing the large uncertainty on petrophysical properties and dynamic data alone will not necessarily lead to a wide in-place volume range even in the undrained zones/compartments.
  - Structural uncertainties, different contacts or geological models are needed to widen the range

- Cancellation effect between multiple zones sampled independently
  - Introduce dependencies between the zones



SUMMARY & CONCLUSION

- More cases to run; Time-consuming
- Crucial to perform proper QC
- Parametrization might be time-consuming; needs several iterations
  - Important to cover all uncertain parameters, otherwise, the result can become misleading
- Based on assumptions (like every model)
- No valid assumptions → no valid conclusions
- Crucial to define uncertainty in the input parameters "correctly"
- Sensitivity analysis: can't assign a certain response to a certain parameter

- You will always understand the model better using the entire posterior distribution, not just some point estimate derived from it
  - There is a lot of information about the uncertainty in the entire posterior distribution. We lose this information when we plug out a single parameter and then perform calculations with it. This loss of information leads to overconfidence.
- Overfitting - two important principles:
  - Adding parameters (making the model more complex) nearly always improves fit of a model.
  - While more complex models fit the data better, they often predict the new data worse.