

# Multi-Scale Geostatistical History Matching using Block-DSS and Uncertainty Quantification

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Ph.D. Candidate

# Outline

## Introduction

- Proposed Work. Theoretical Concepts

## Multiscale Geostatistical History Matching

- MSGHM. MSGHMEA. Case Study

## Uncertainty Quantification – Work In Progress

- Particle Swarm Optimisation. Case Study

## Conclusions

- Conclusions

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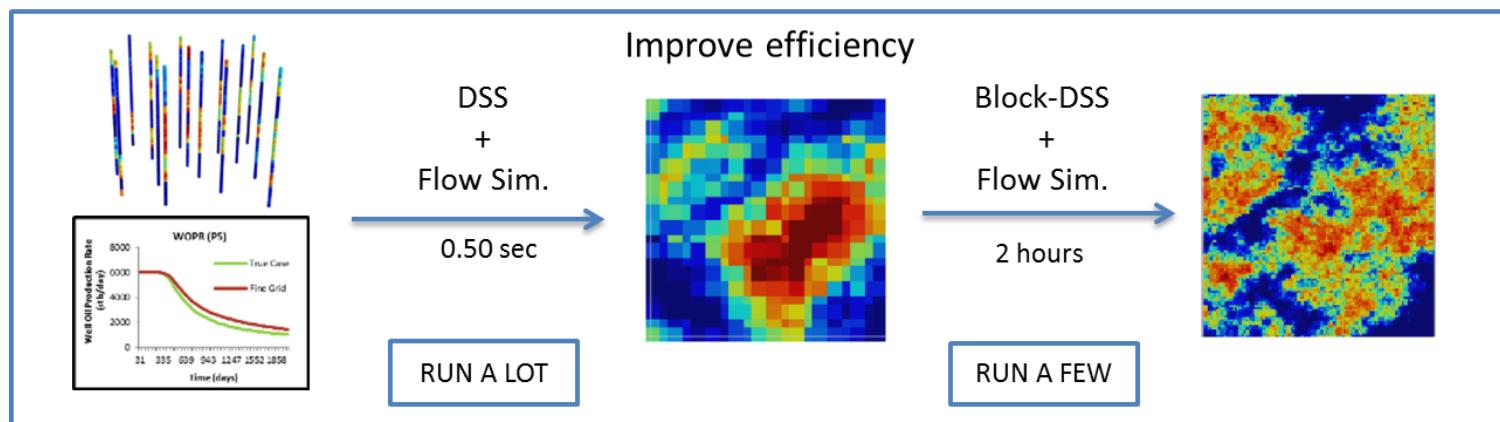
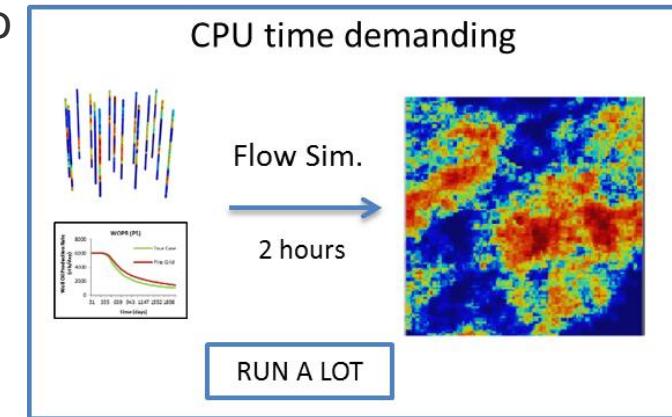
## Conclusions

- Conclusions

# Challenge

Reservoir modelling conditioning to dynamic data and well log data:

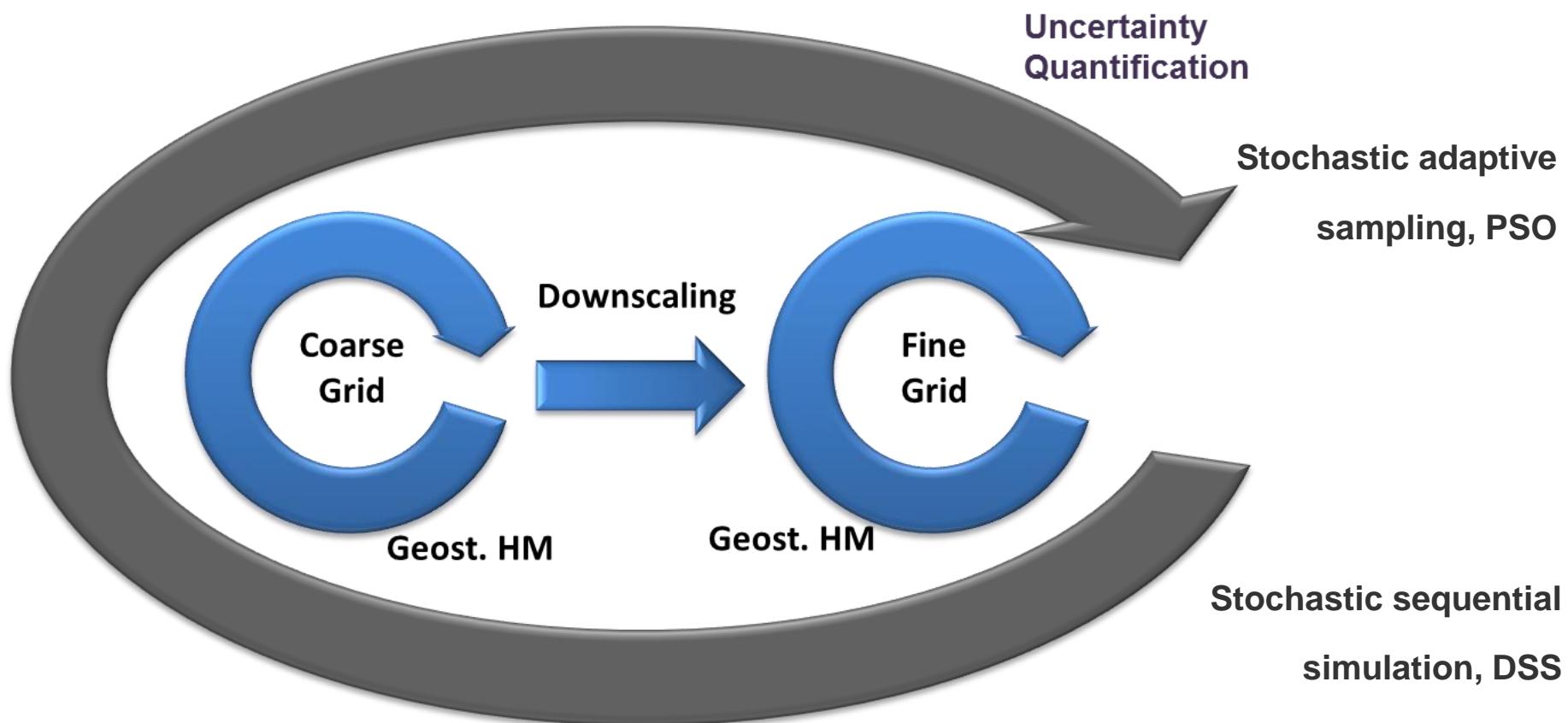
- Modelling the geological properties conditioned to production data
- Very time-consuming
- Provides a better reservoir knowledge
- Essential to investment decisions



# Project Contribution

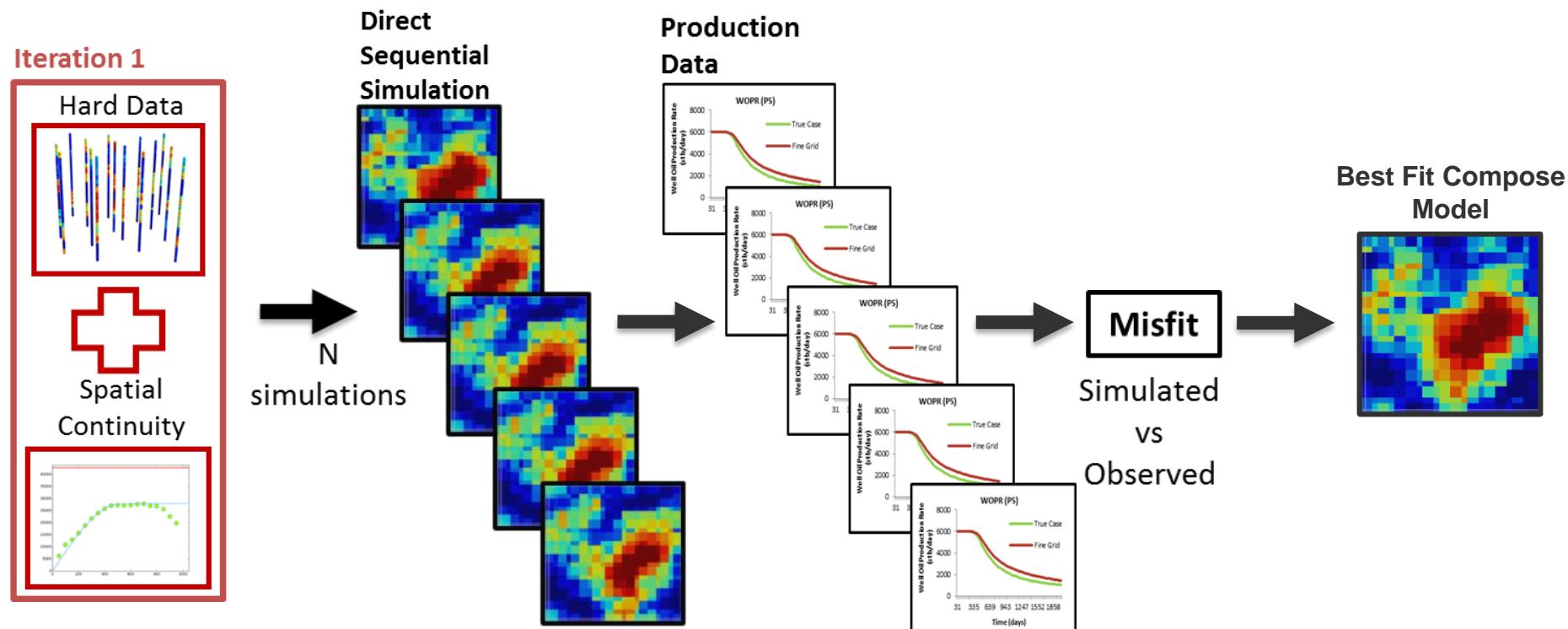
- Build a 3D high resolution model:
  - conditioned to the known data, dynamic data and well log data
  - faster and with accuracy
  - uncertainty assessment
- Provide a new workflow and a software tool that is able to optimize the 3D model construction in two different scales

# Workflow



# Geostatistical History Matching

Mata Lima (2008)



# Geostatistical History Matching

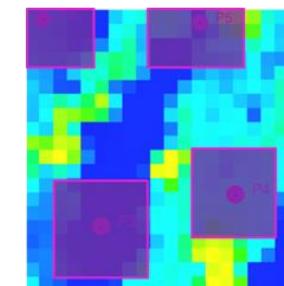
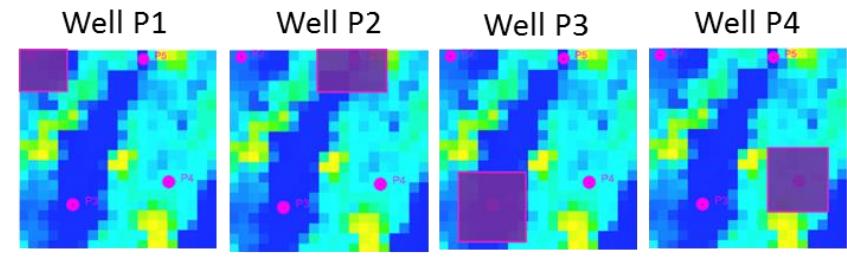
## Multi-Criteria Objective Function

$$Misfit = \sum_{i=1}^{N_{wells}} \sum_{j=1}^{N_{variables}} \sum_{k=1}^{N_{time}} \frac{(q_{ijk}^{obs} - q_{ijk}^{sim})^2}{2\sigma_{ij}^2}$$

Well P2

$\left. \begin{array}{l} WOPR_{sim} | WOPR_{obs} \\ WBHP_{sim} | WBHP_{obs} \end{array} \right\}$

## Local Perturbation

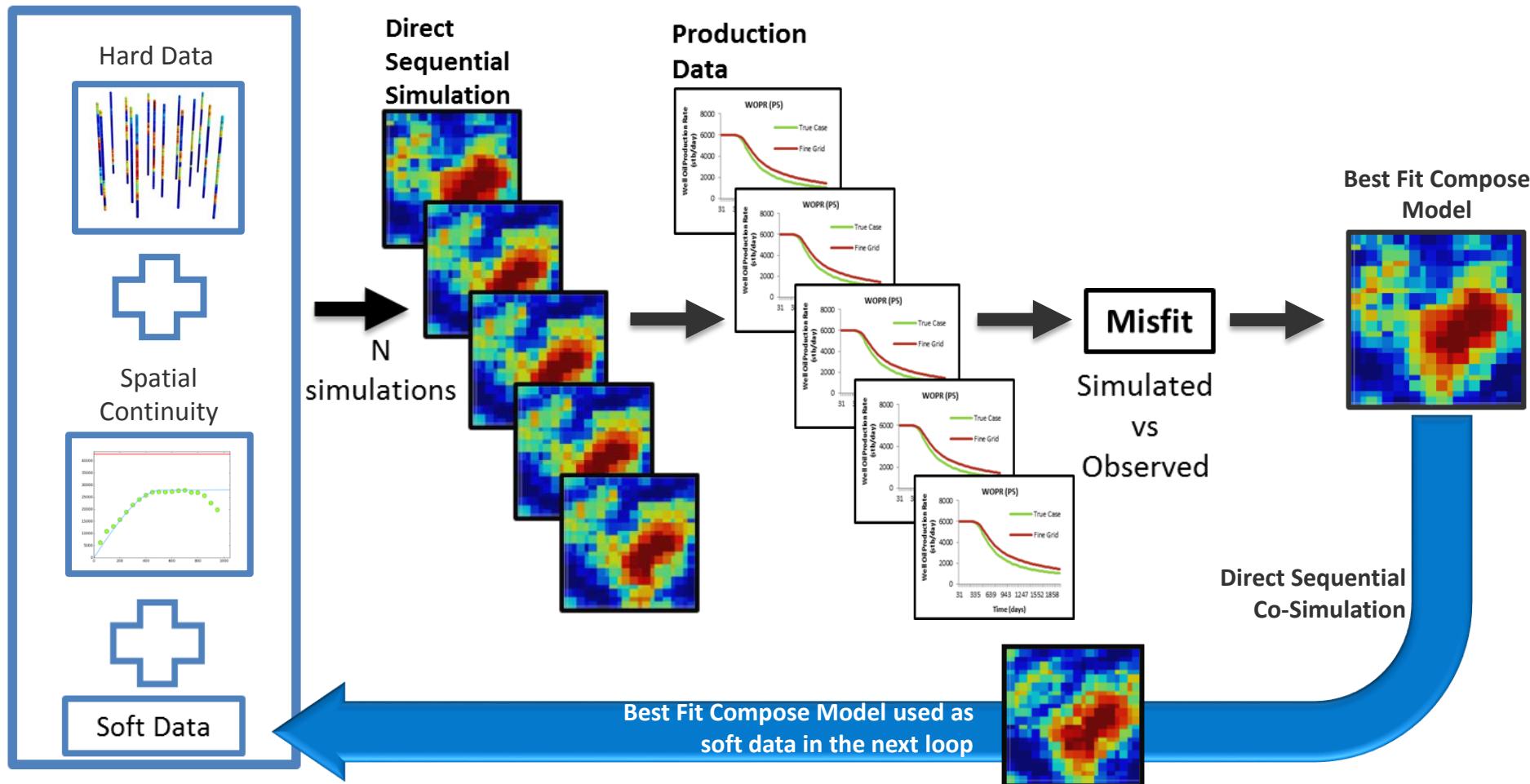


Best Fit  
Composed  
Model

# Geostatistical History Matching

Mata Lima (2007)

Iteration 2, 3,...,n



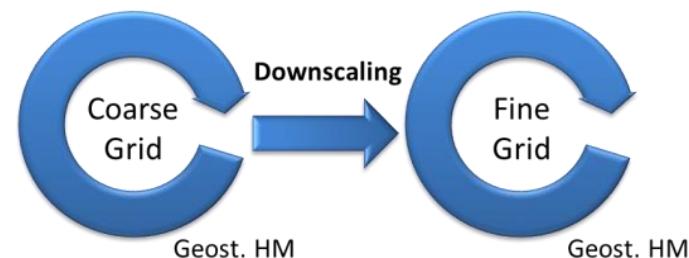
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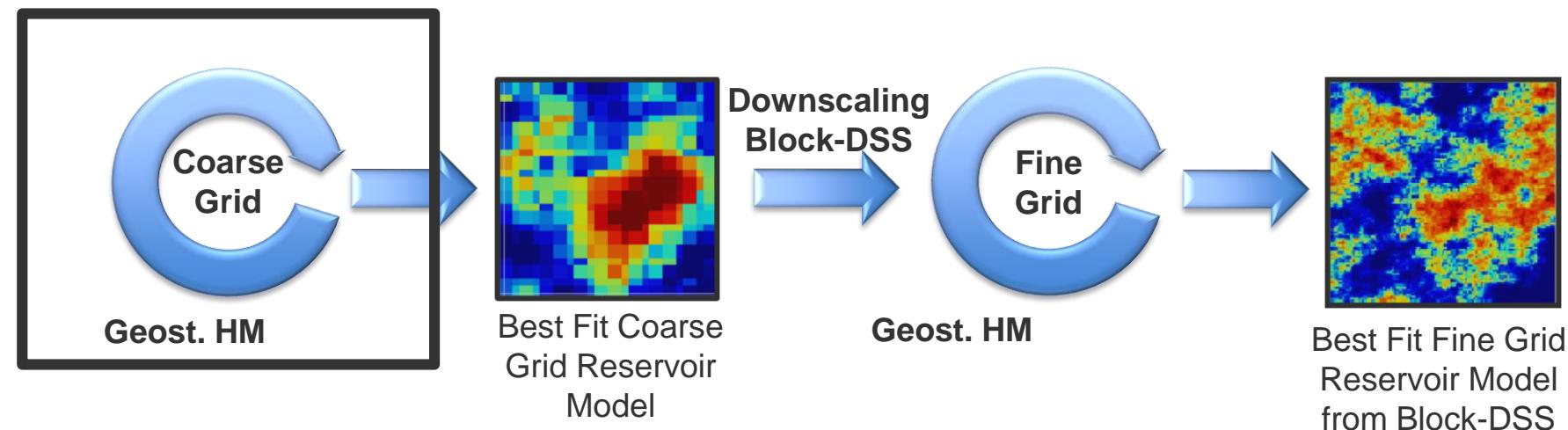
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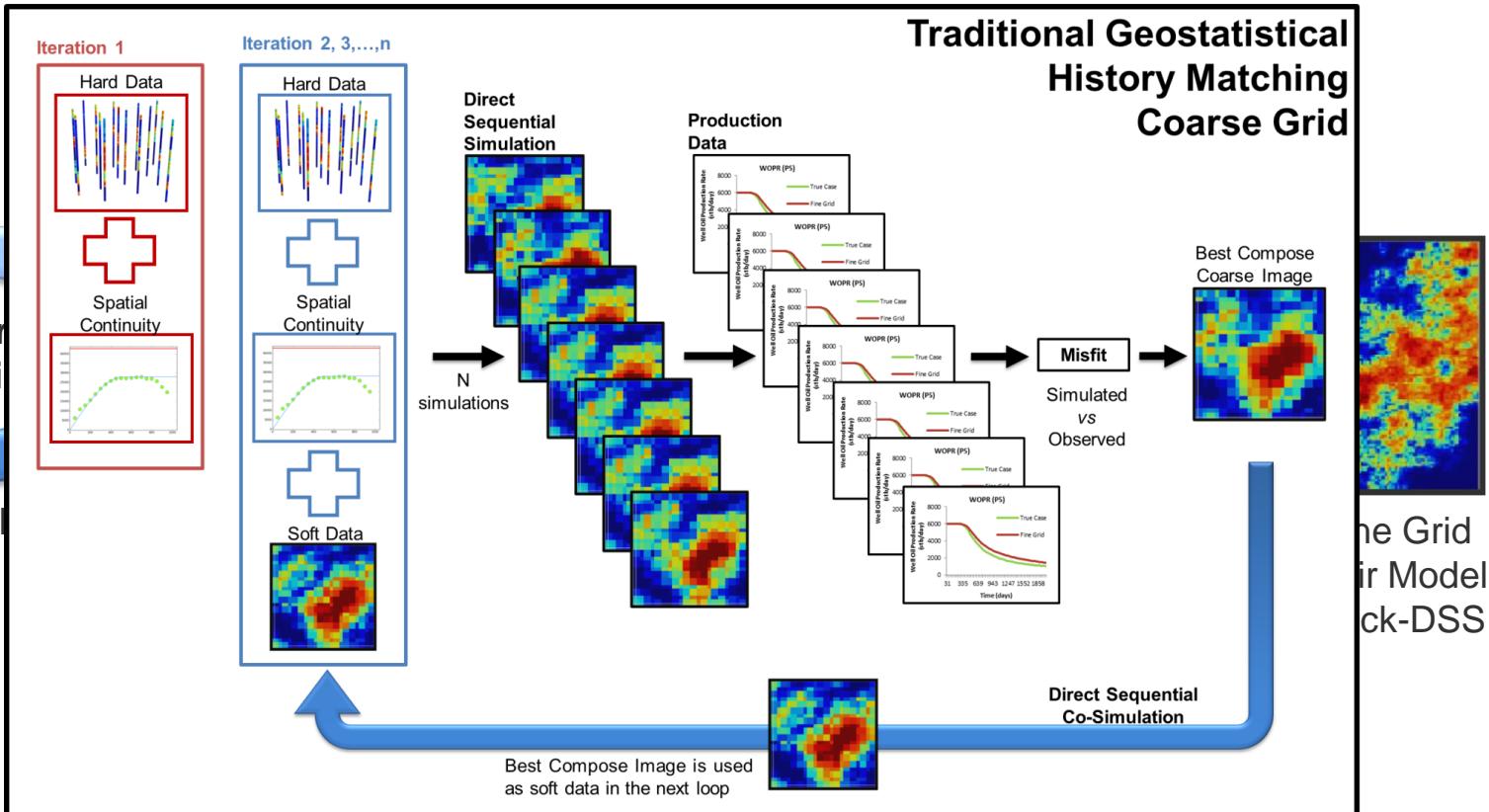
# Multi-Scale Geostatistical History Matching



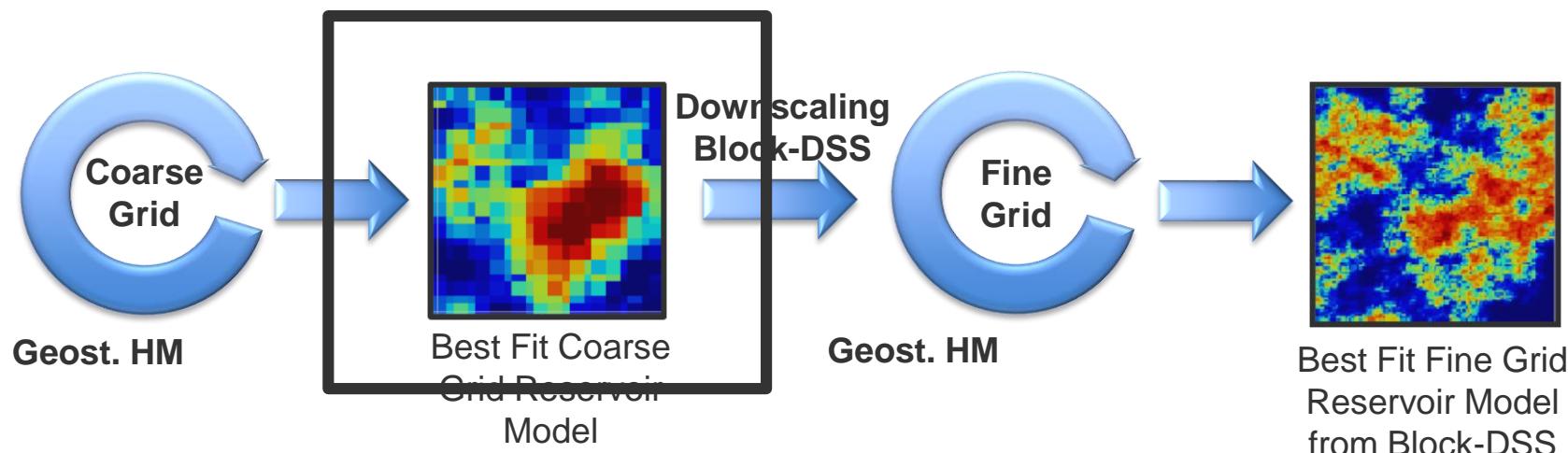
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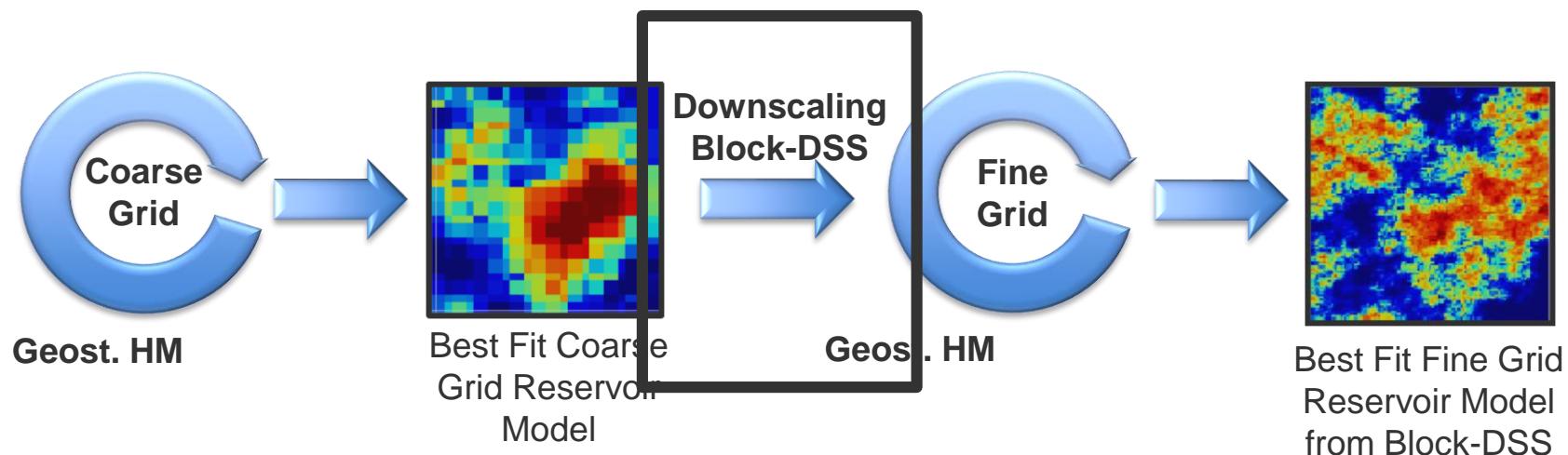
Geost. H



# Multi-Scale Geostatistical History Matching



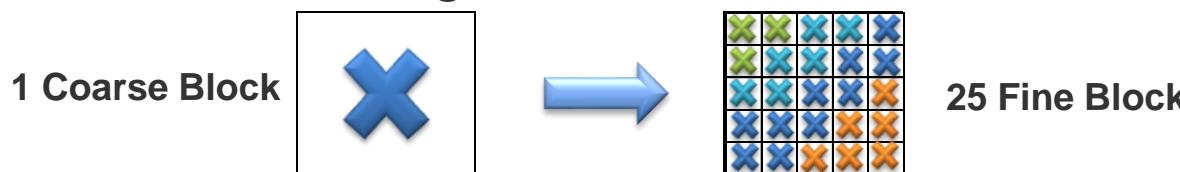
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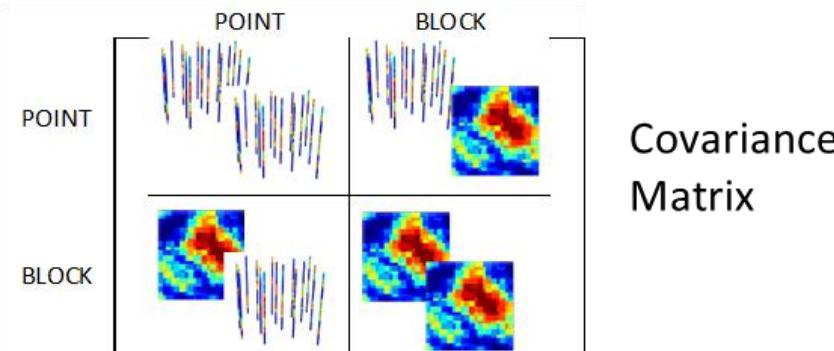
# Block-DSS

Liu &amp; Journel (2009)

- Stochastic Downscaling

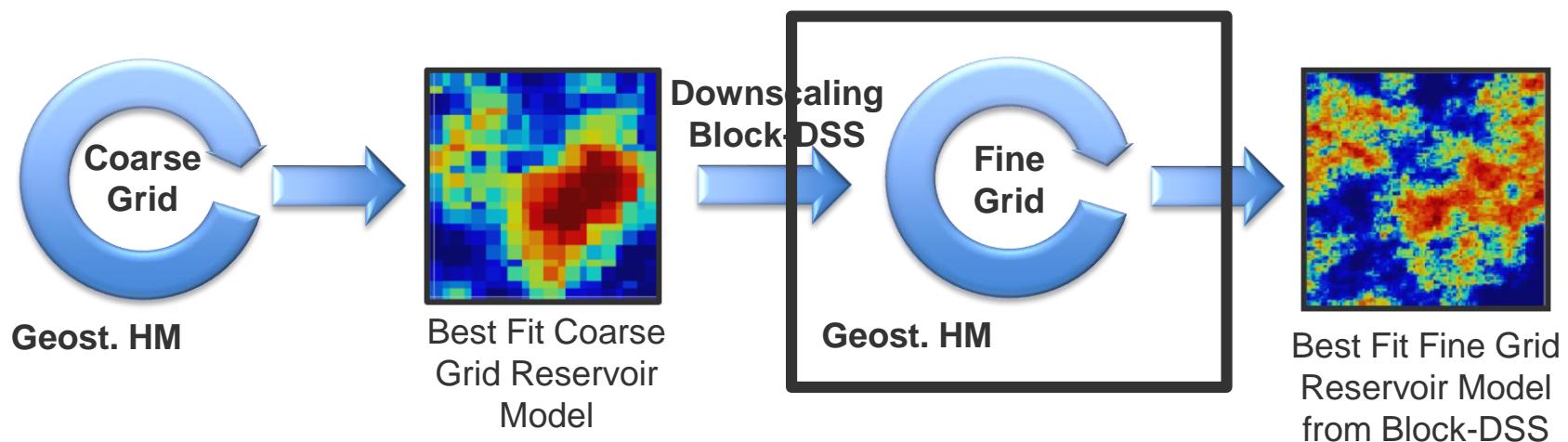


- Simulate models with a high resolution conditioned to low resolution models
- Incorporate information from different scales : Block data and Point data



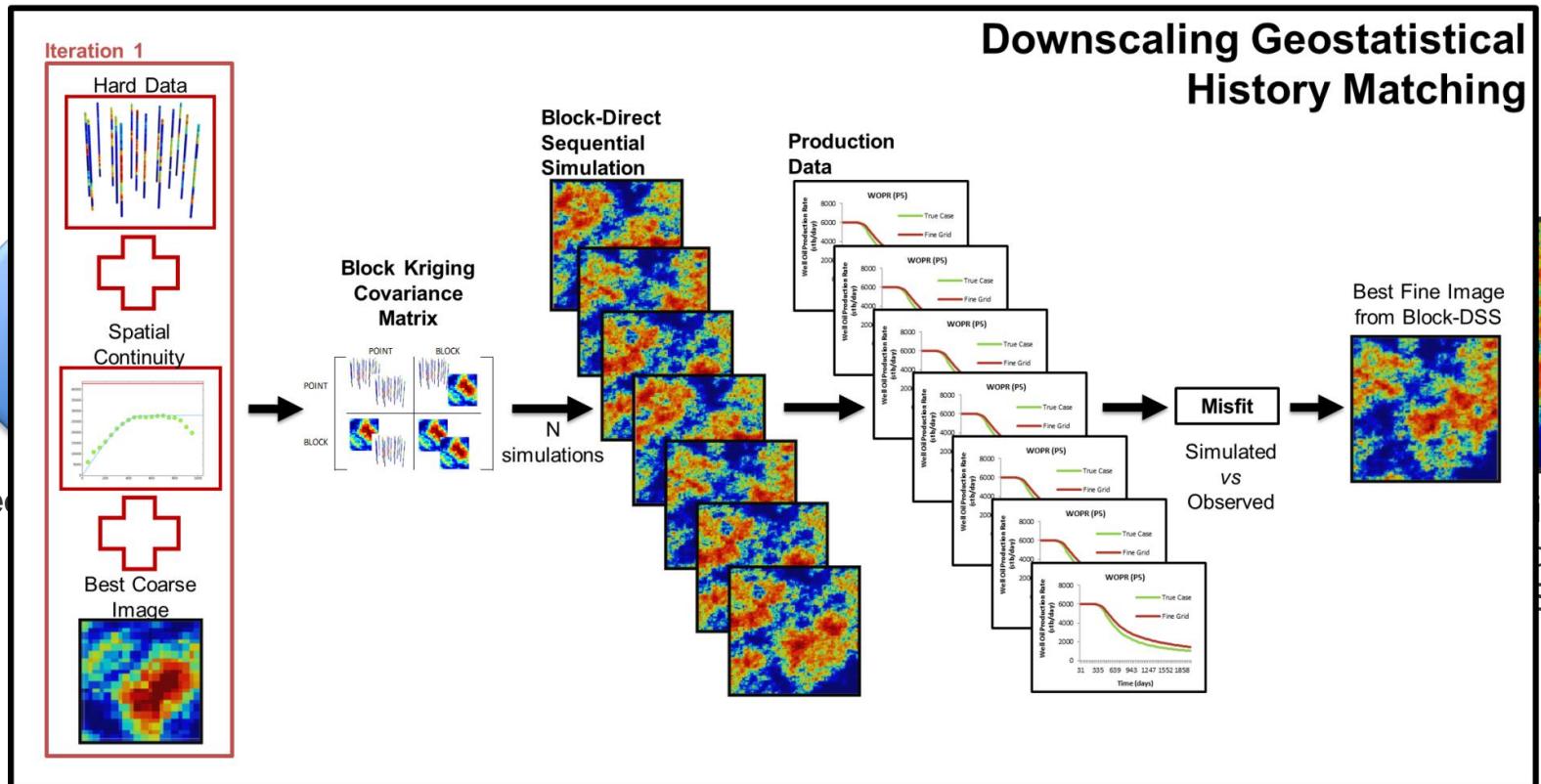
# Block-DSS

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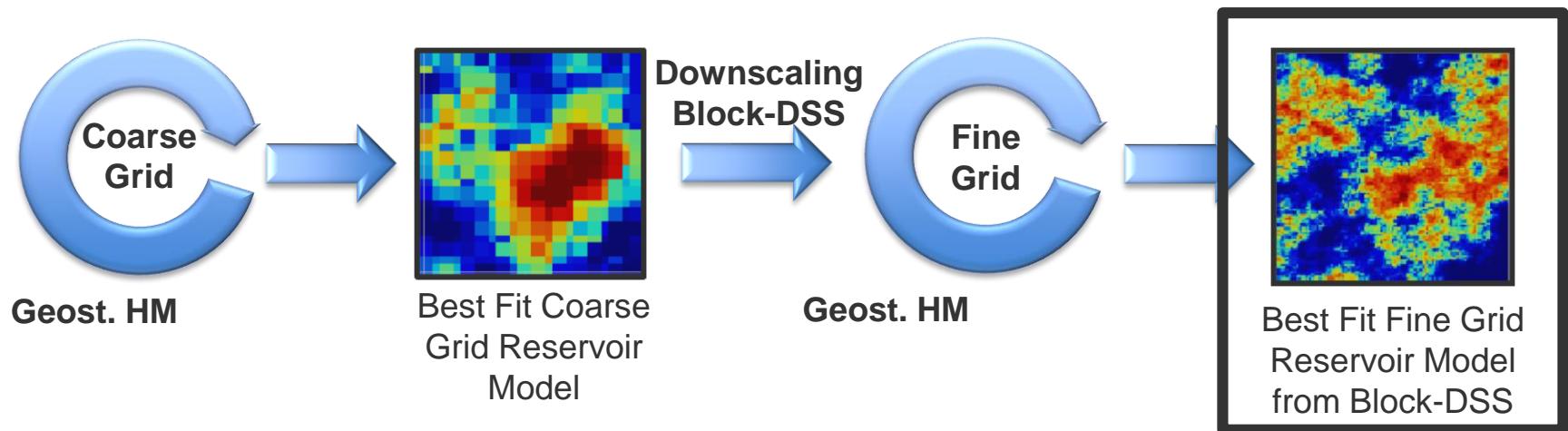
# Block-DSS

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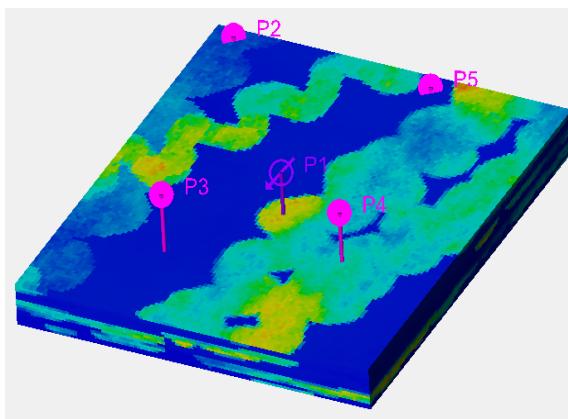
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Liu &amp; Journel (2009)



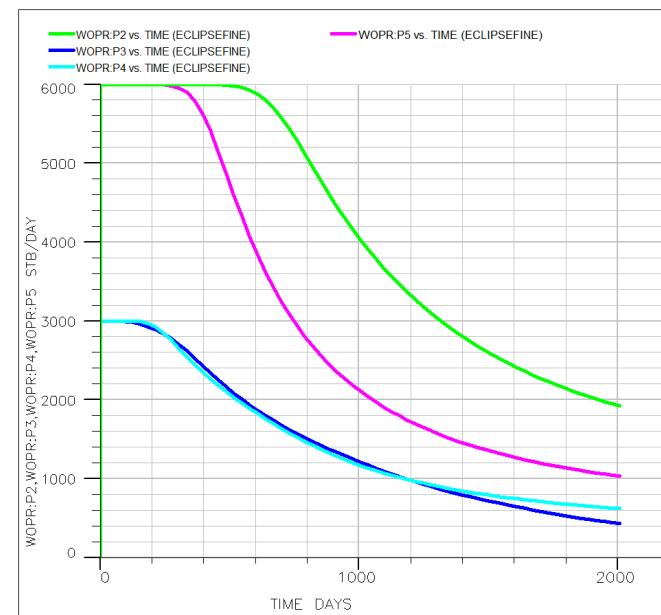
# Case Study : Synthetic 3D Model

## Synthetic reservoir

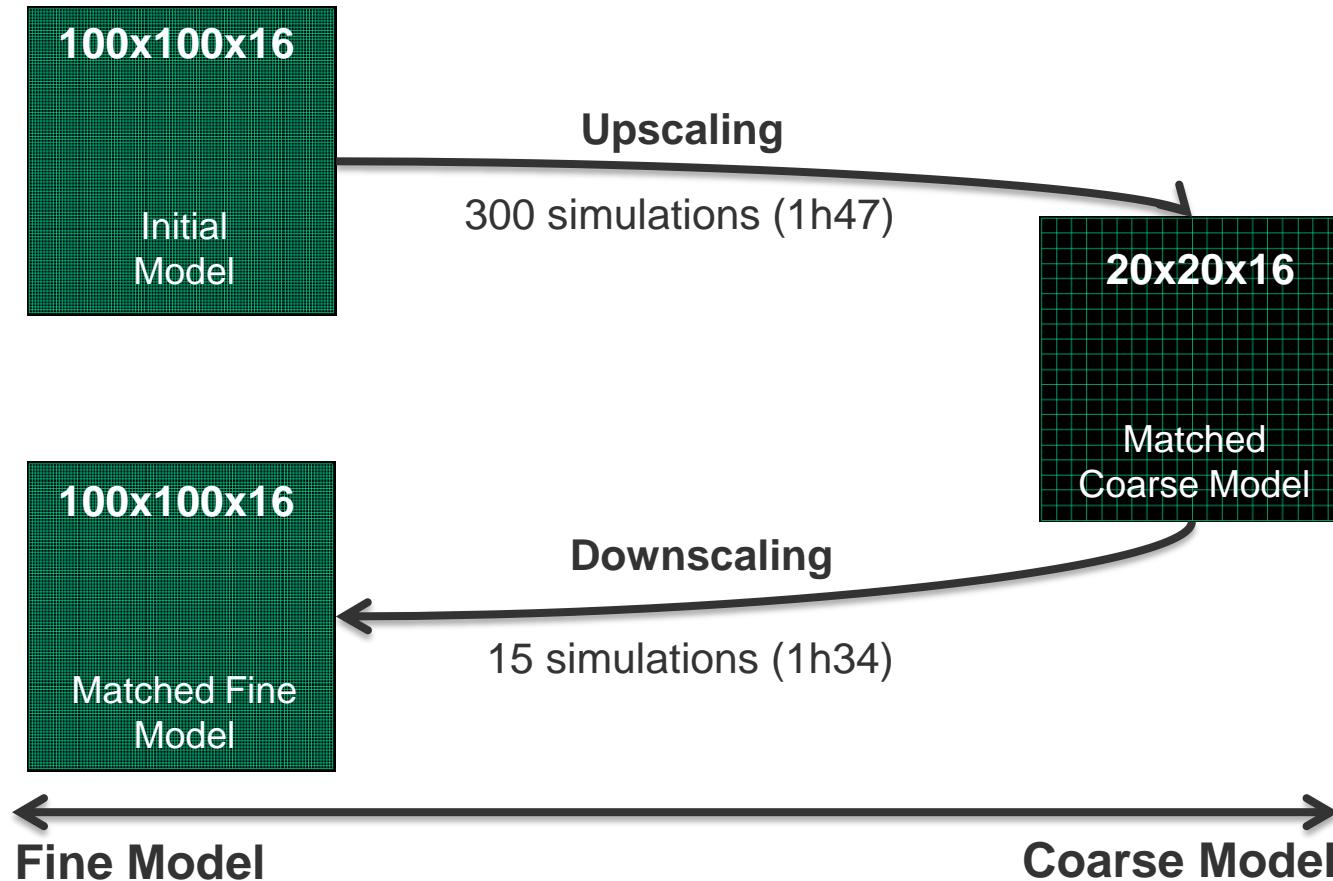


- Five spot
- Sand + Shale
- Aquifer
- 5½ years
- Liquid Rate

## Well Oil Production Rate

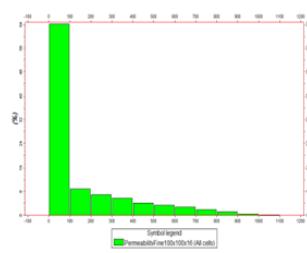
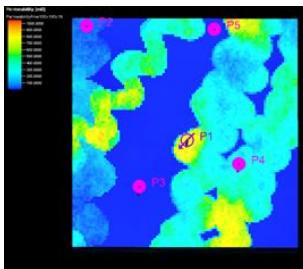


# Case Study : Synthetic 3D Model

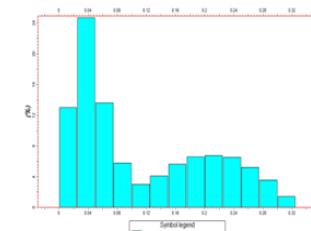
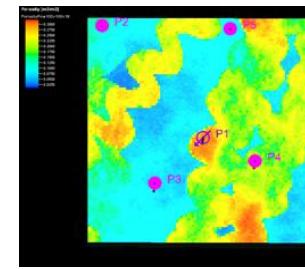


# MSGHM - Case Study : Coarse Model

- True Model (Permeability)

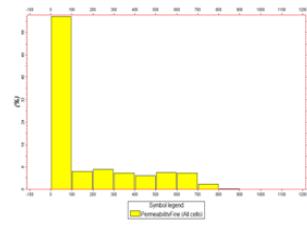
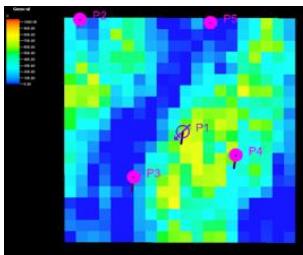


- True Model (Porosity)

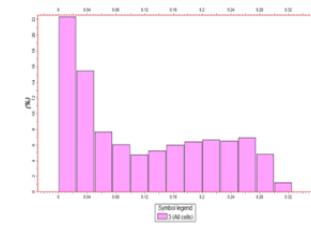
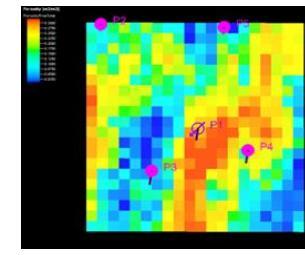


## Best Coarse Iteration

- Iteration 30 (Permeability)

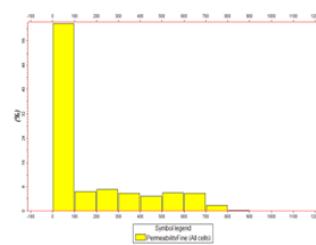
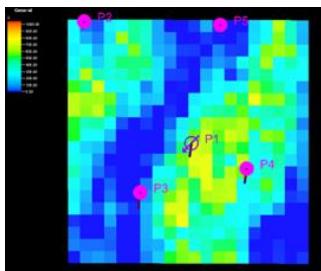


- Iteration 30 (Porosity)

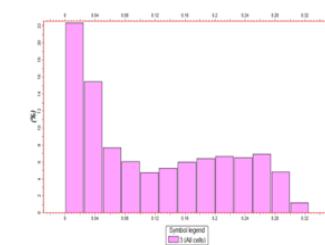
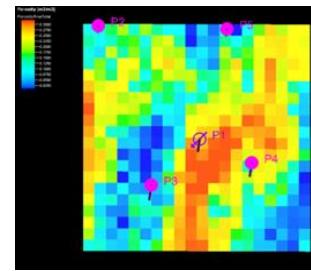


# MSGHM - Case Study : Fine Model from Block-DSS

- Coarse Model (Permeability)

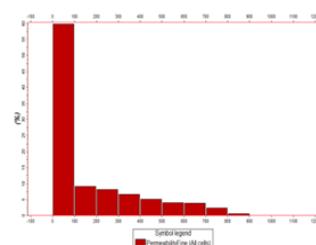
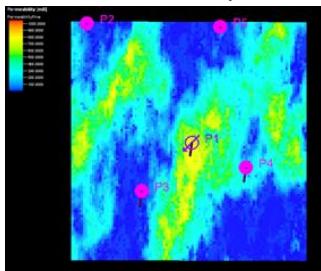


- Coarse Model (Porosity)

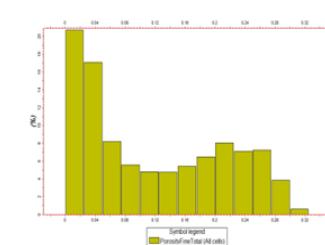
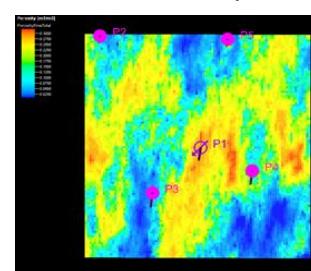


## Best Fine Iteration

- Iteration 07 (Permeability)

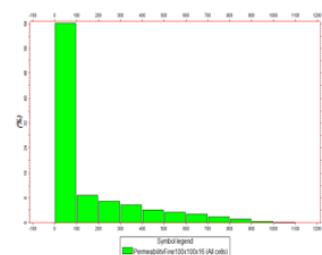
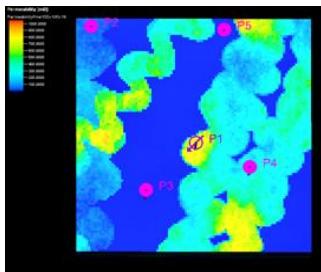


- Iteration 07 (Porosity)

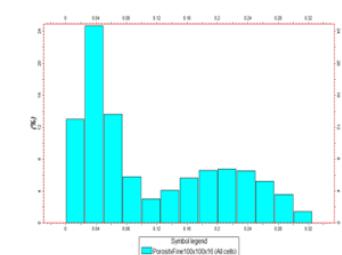
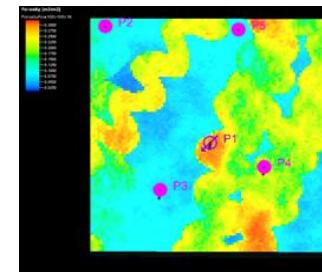


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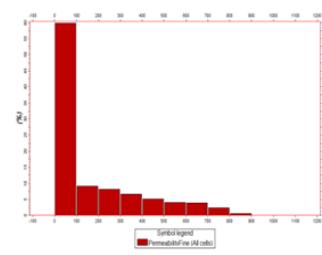
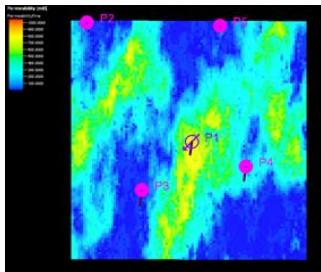


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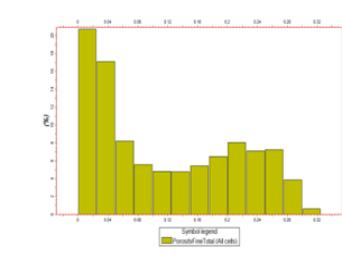
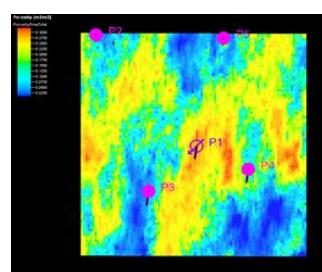


## Best Fine Iteration

- Iteration 07 (Permeability)

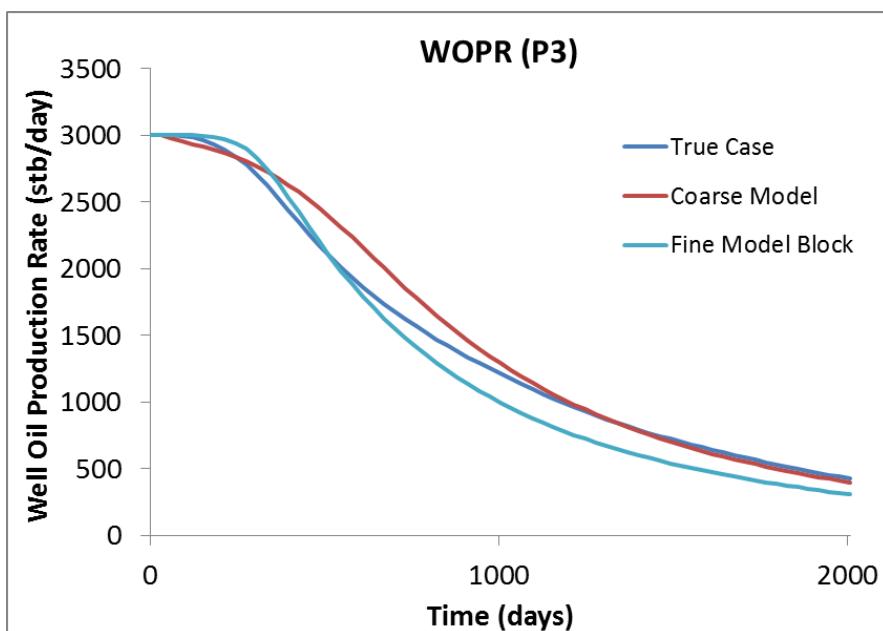


- Iteration 07 (Porosity)

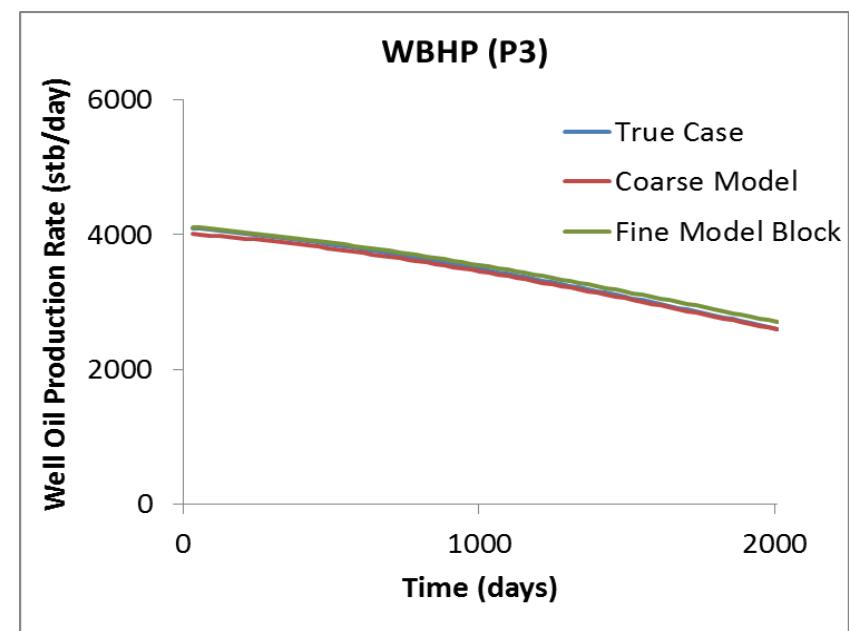


# MSGHM - Case Study : Production Data

Oil Production Rate – Well P3



Bottom Hole Pressure – Well P3



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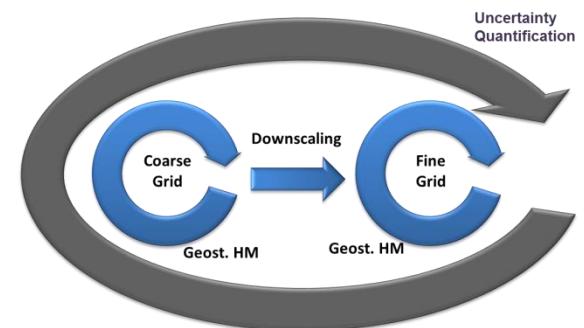
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## Conclusions

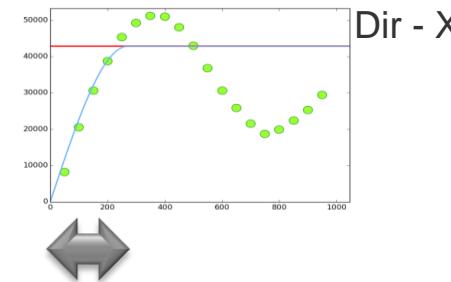
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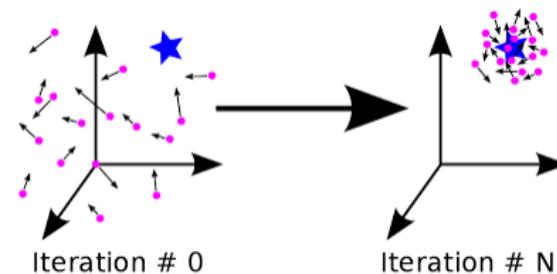
# Uncertainty Quantification

- Assume stationarity and no uncertainty in the geological parameters → huge lack of parameters information

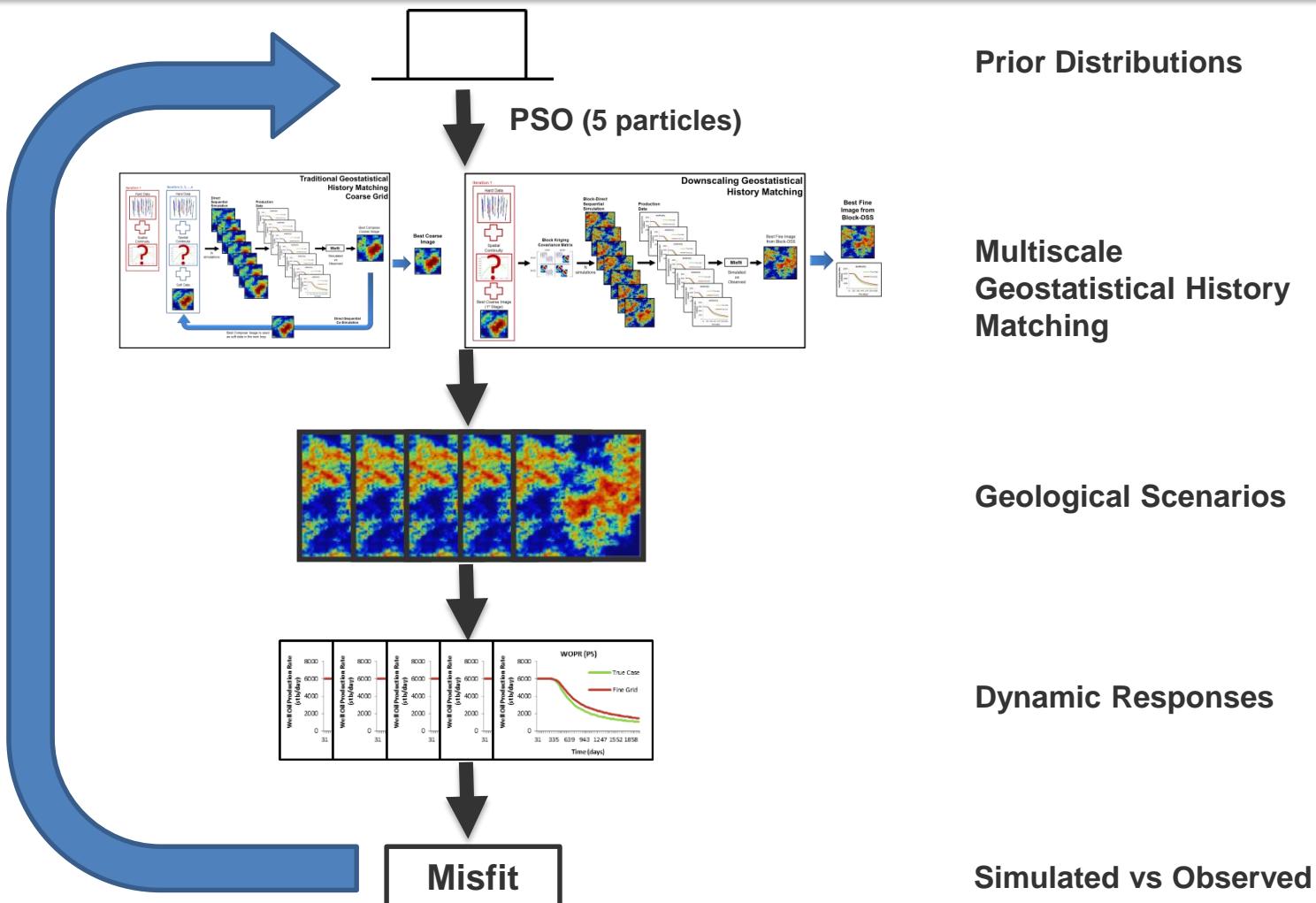
- Spatial continuity of geological properties: porosity and permeability



- Particle Swarm Optimization



# Uncertainty Quantification - Workflow

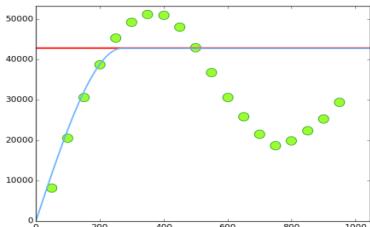


# UQ – Case Study : Prior Distribution

## Coarse Grid

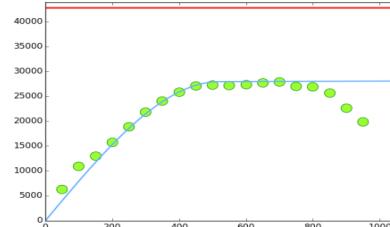
- Variogram angle: [75,90]
- Variogram range:

Dir - X



[200,600]

Dir - Y

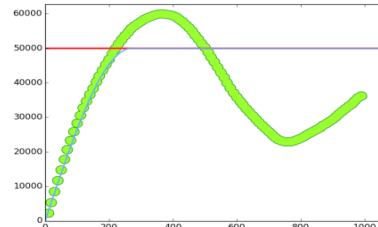


[400,1000]

## Fine Grid

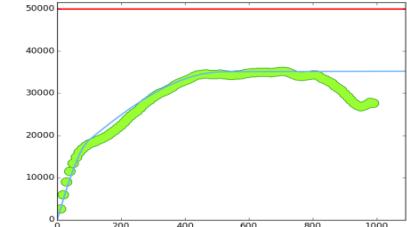
- Variogram angle: [75,90]
- Variogram range:

Dir - X



[200,600]

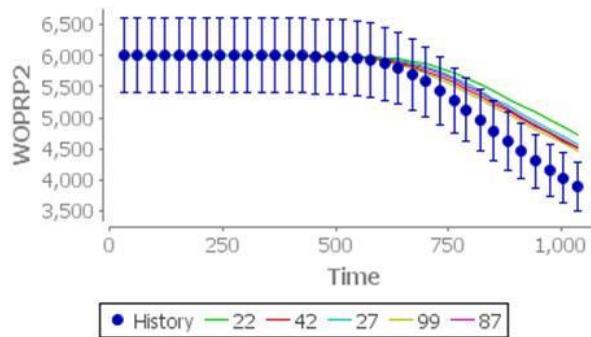
Dir - Y



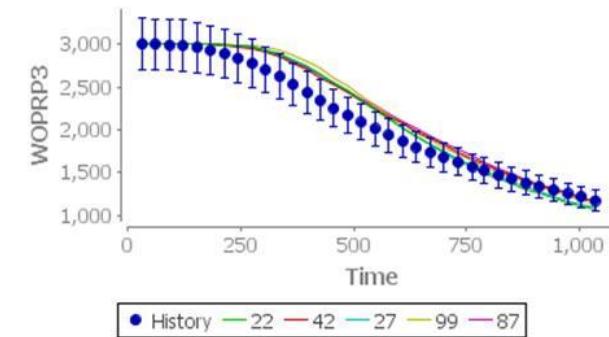
[50,150] [400,1000]

# UQ – Case Study : Best HM per Well

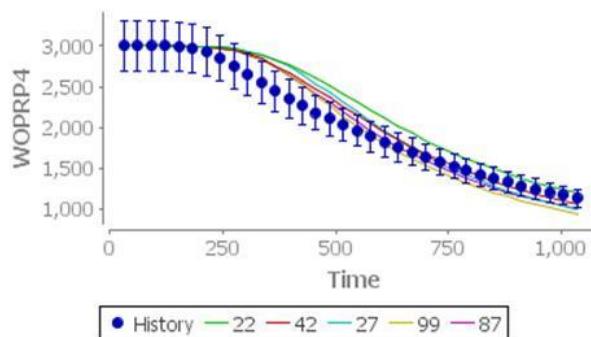
Oil Production Rate – Well P2



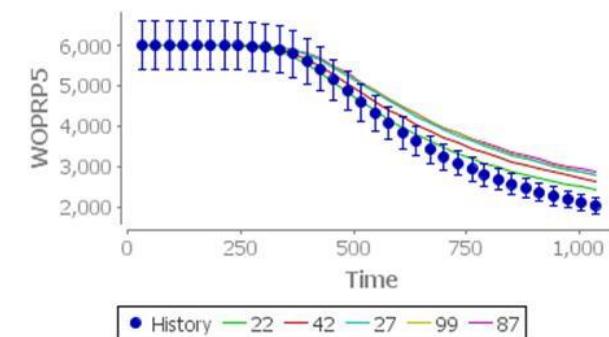
Oil Production Rate – Well P3



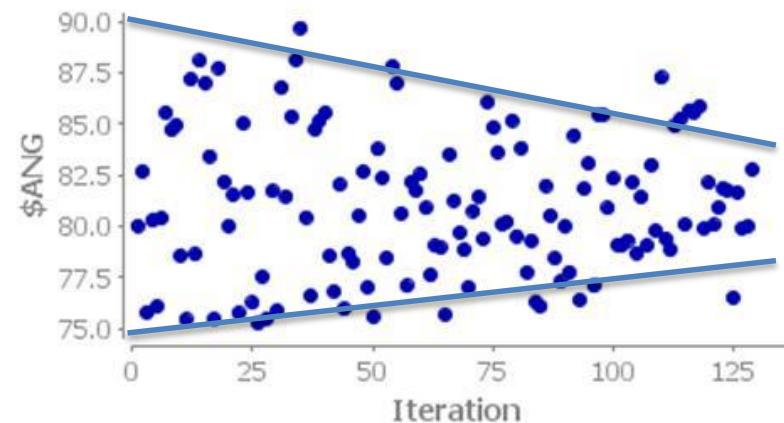
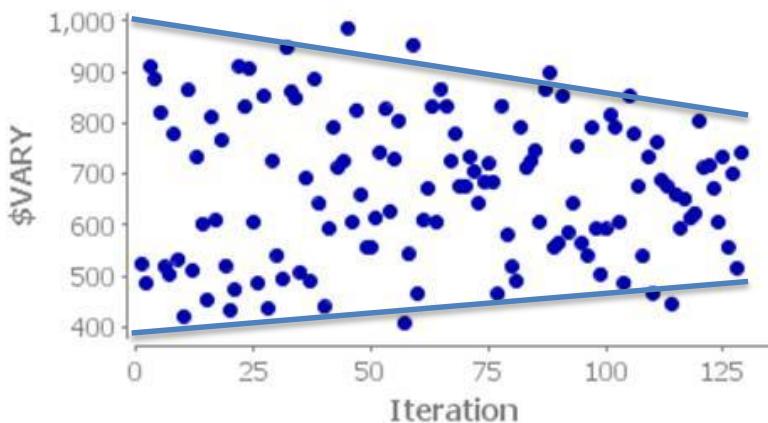
Oil Production Rate – Well P4



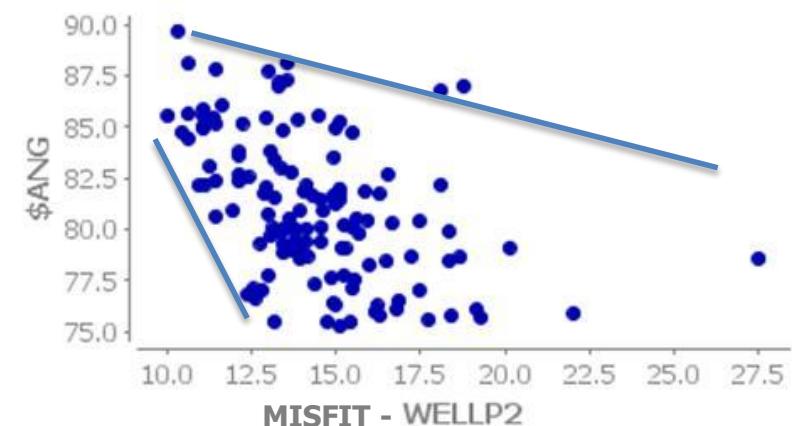
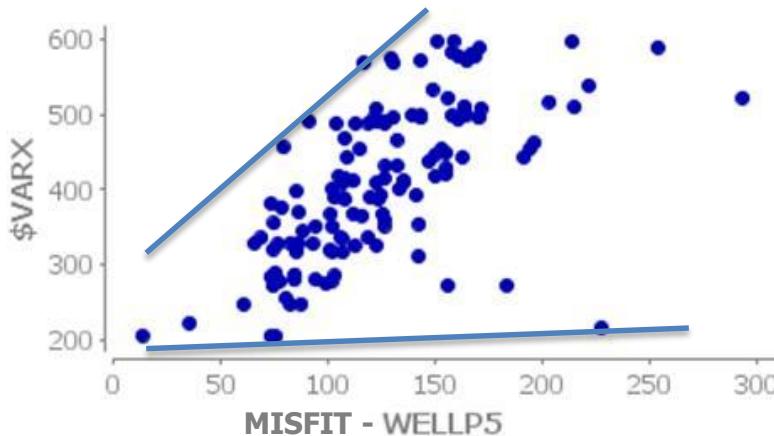
Oil Production Rate – Well P5



# UQ – Case Study : Parameter Evolution through HM



# UQ – Case Study : Parameter vs Misfit



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# Conclusions

- Reduces the over parameterization problem in the fluid flow equations;
- Faster assimilation of large scale corrections into history matching;
- The coarse geological model is retained through the downscaling step, providing a better initial model for the final adjustment on the fine scale;
- The downscaling allows us to characterize the small scale heterogeneity in the fine grid reservoir model and history match it;

# Conclusions

- Both **results** from the fine grid and the coarse grid **are consistent with the true model geology**;
- The **best-fit model** is able to **reproduce the spatial distribution** of the main channels;
- The **space of uncertainty** is **reduced** and can be assessed, generating multiple history matched models;

# References

- Aanonsen, S. I. and Eydinov, D. (2006). "A Multiscale Method for distributed Parameter Estimator with Application to Reservoir History Matching", *Computational Geosciences* 10 (1) (March):97-117
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- Mata-Lima, H. (2008). "Reservoir Characterization with Iterative Direct Sequential Co-simulation: Integrating Fluid Dynamic Data into Stochastic Model", *Journal of Petroleum Science and Engineering* 62 (3-4) (September): 59-72
- Soares, A. (2001). "Direct Sequential Simulation and Co-simulation", *Mathematical Geology* 33 (8): 911-926.