Reservoir Engineering from Seismic to Surface

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Content

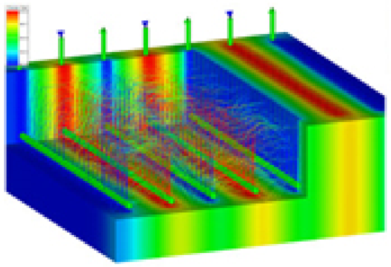
- Introduction into reservoir uncertainty
- Evolution of computer hardware
- Evolution of scalable subsurface software
- Case studies

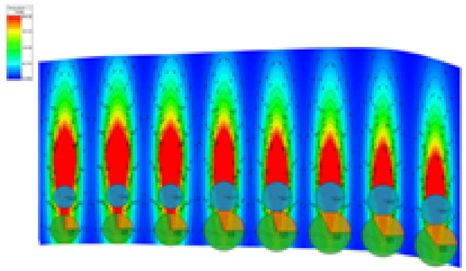
Introduction – Reservoir Uncertainty

- Identifying the potential reservoir using seismic surveying
- Horizon picking by seismic interpretation
- Inferring large areas using limited data
  - Geological heterogeneity
  - Porosity and permeability distribution
  - Compartmentalisation
  - Fluid properties
- Trade off between time and uncertainty

Introduction – Simulation Demands

- Reliant on static & dynamic modelling of reservoirs
- Economic outlay of producing & recovering
  - Standard cost of North Sea Well - ~ $5 - $40million
  - HPHT can be $ six figures!
- Reservoirs are demanding and complex
  - Rock properties, fluids and reservoir description, wells, surface network, compositional and thermal effects, EORs, etc.





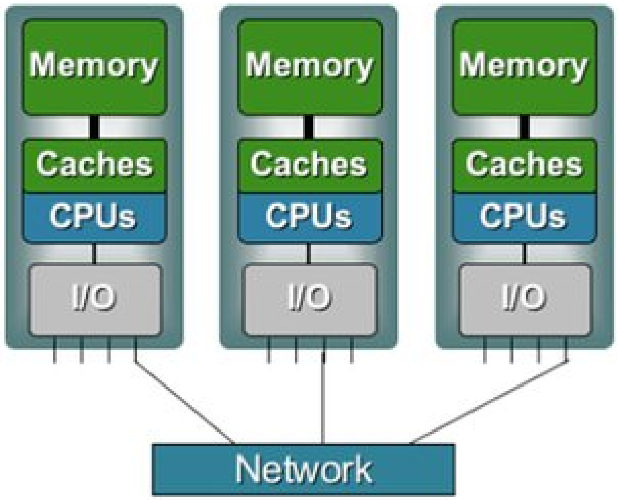
Introduction – Simulation Demands

- Uncertainty analysis often skipped due to available resources and project timeframes
- Hardware and software bottlenecks
  - Compromising expensive data and model resolution

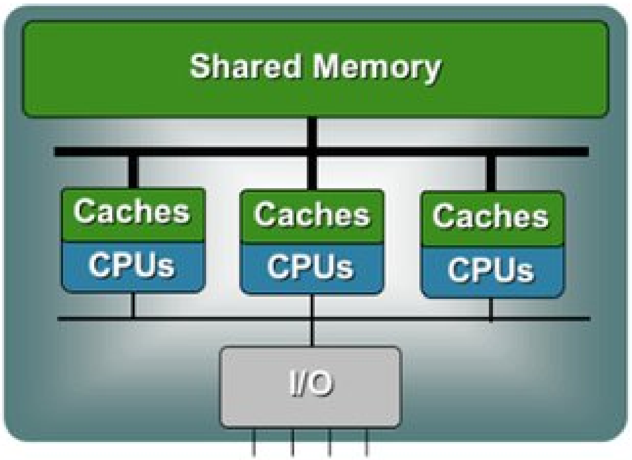
Evolution of Computer Hardware

Hardware – Workstations

- Multi-Core Processors
  - Cores no longer isolated by distributed memory
  - Shared memory system cores communicate directly
  - Fast interactions between cores
  - Equations can be solved directly at matrix level

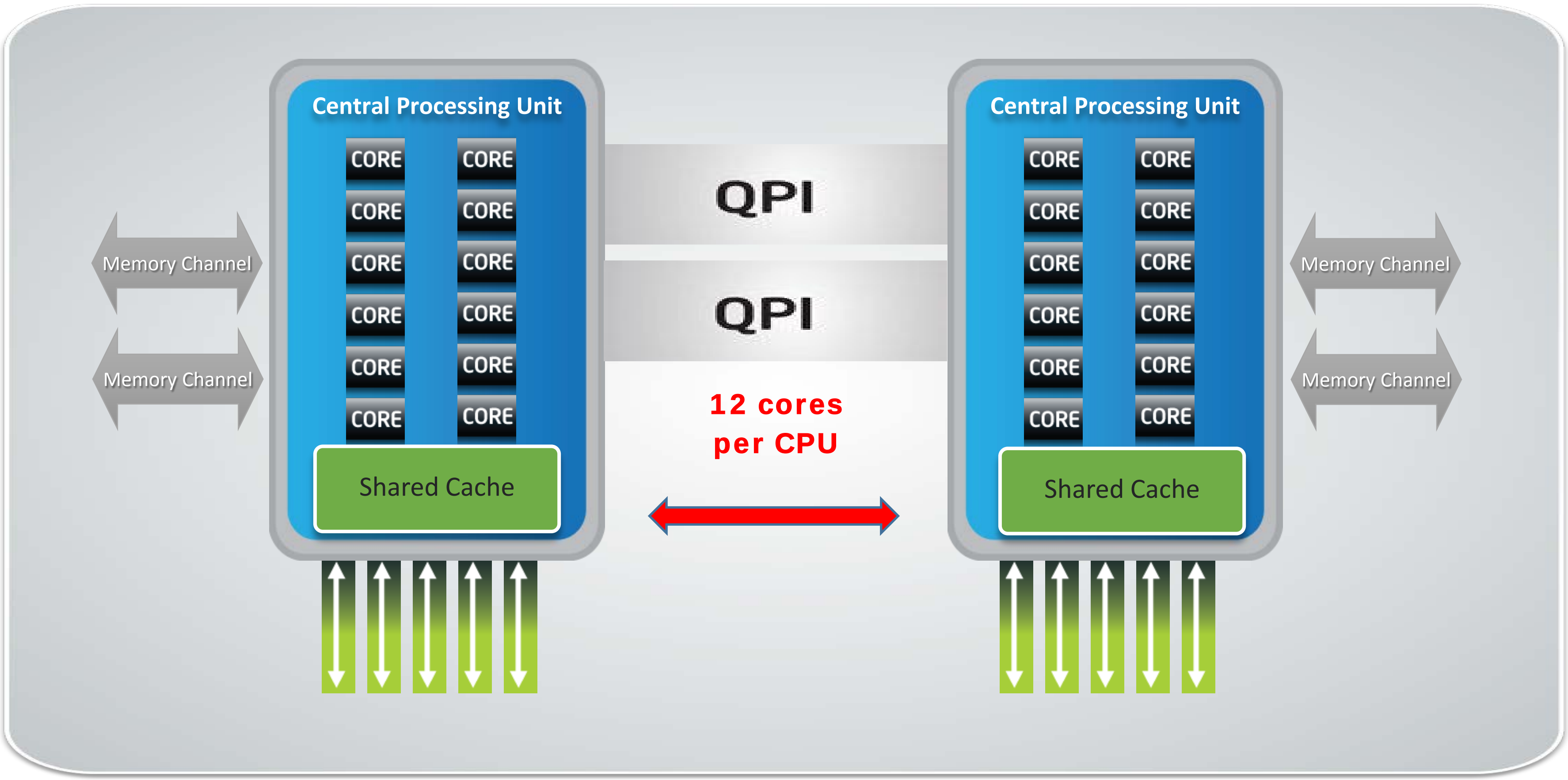


Distributed Memory



Shared Memory

Hardware – Workstations



Hardware – Clusters

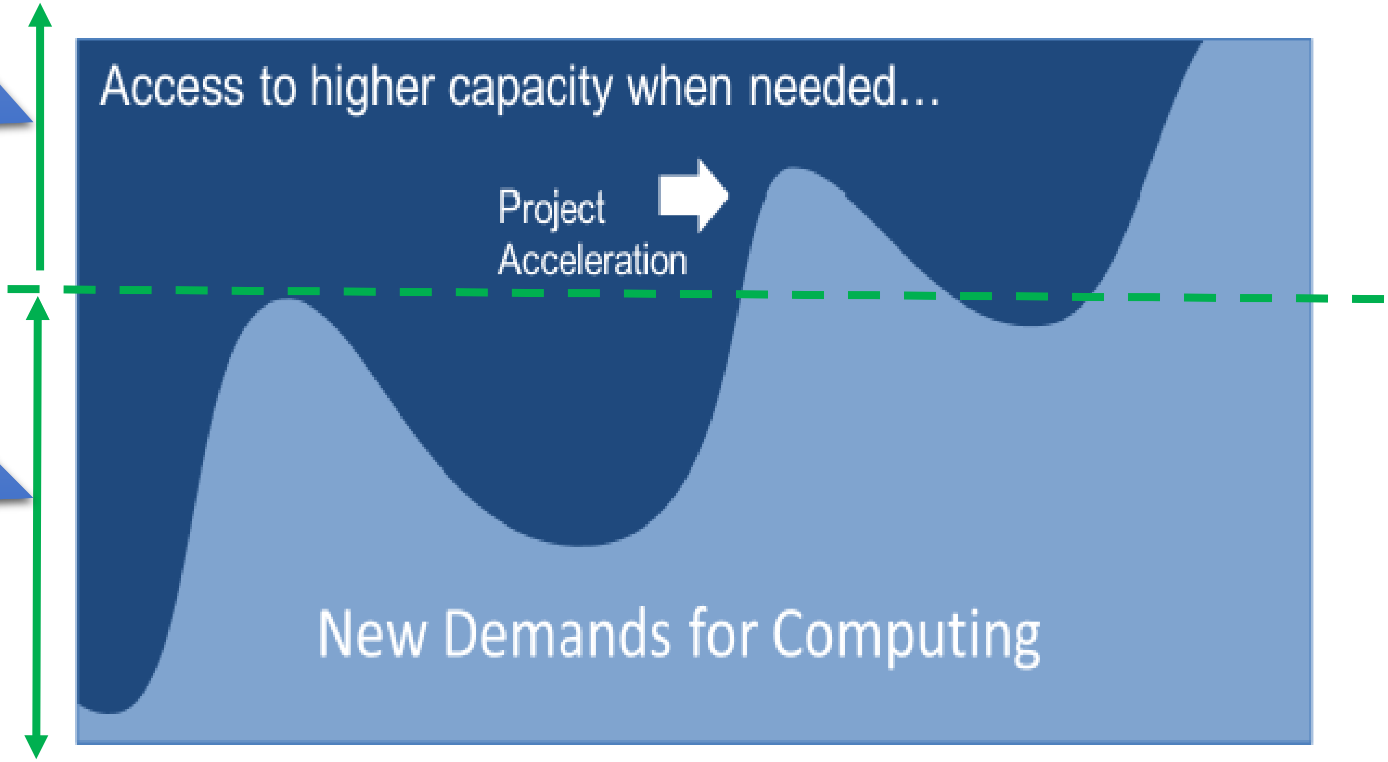
- Used across industries!
- Installed in regular office space
- Air conditioning & LAN connection

- 320 cores, 16 nodes
- Infiniband 56 Gb/s,
- RAM 2.048TB, 120TB disk
- Parallel speed-up ~ 80-100 times

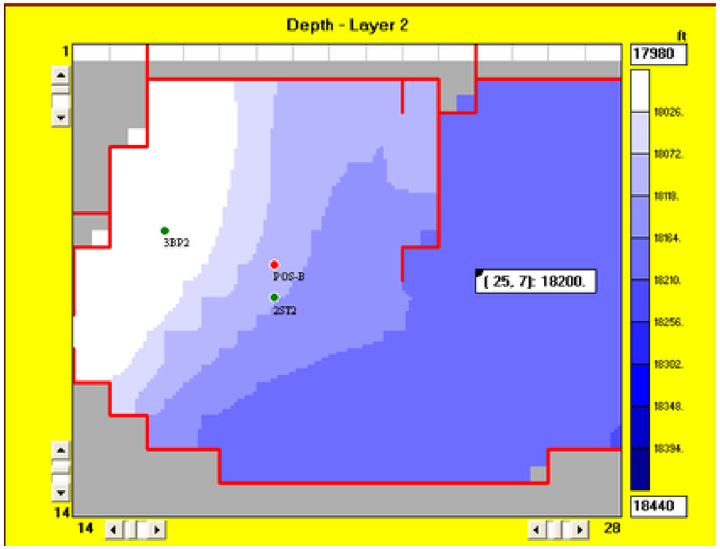
Hardware – Clusters in the Cloud

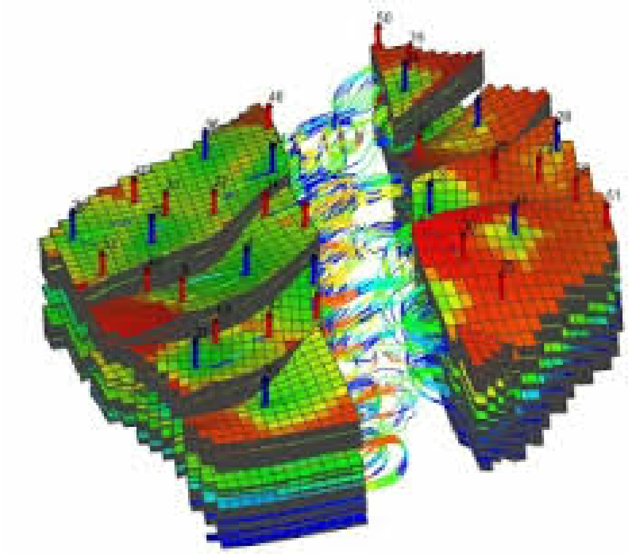
Cloud for seasonal peaks:
AHM
Uncertainty studies
Prediction

Day to day use:
Day to day use
Workstations and
in-house cluster



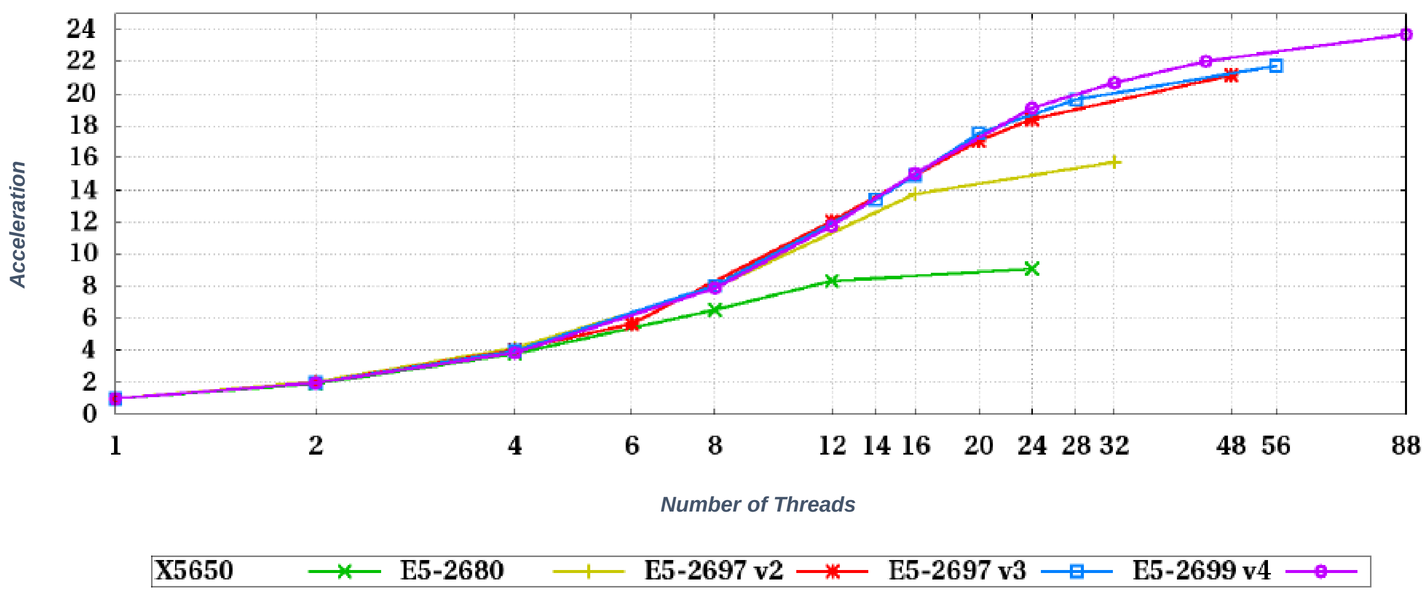
Evolution of Scalable Subsurface Software





Software – Workstations

- Supercomputer with shared memory
- Parallel computing
- No Message Passing Interface required
- OS threads are ~10 times faster

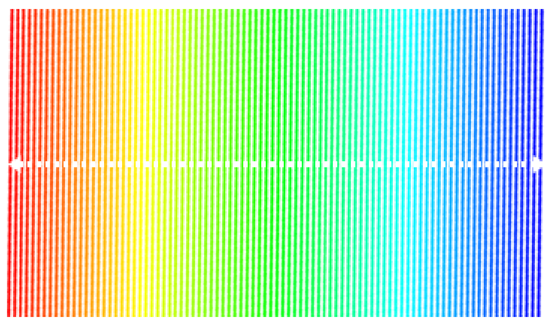


Software - Architecture

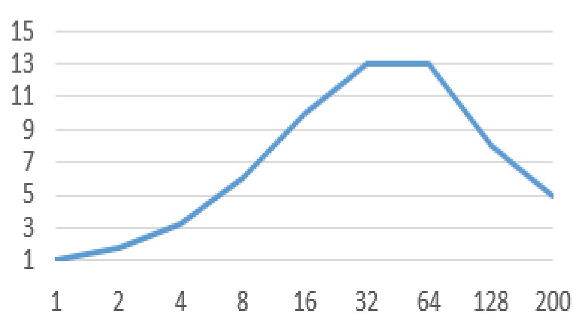
Model: 3 phase model with 2.5 million active cells

Cluster: 10 nodes x 20 cores = 200 cores

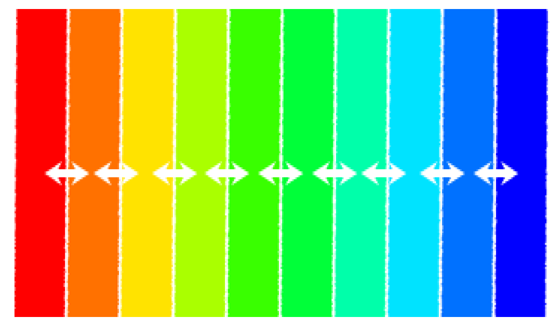
Conventional MPI



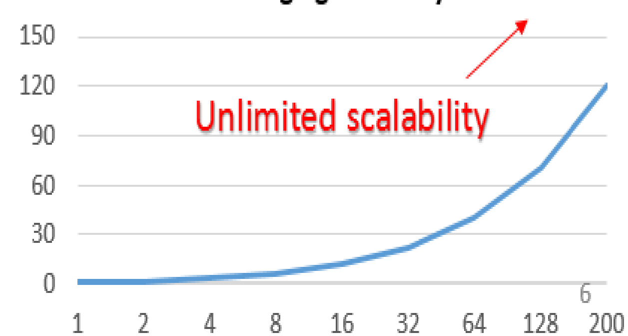
200 domains interchanging boundary conditions



Hybrid approach



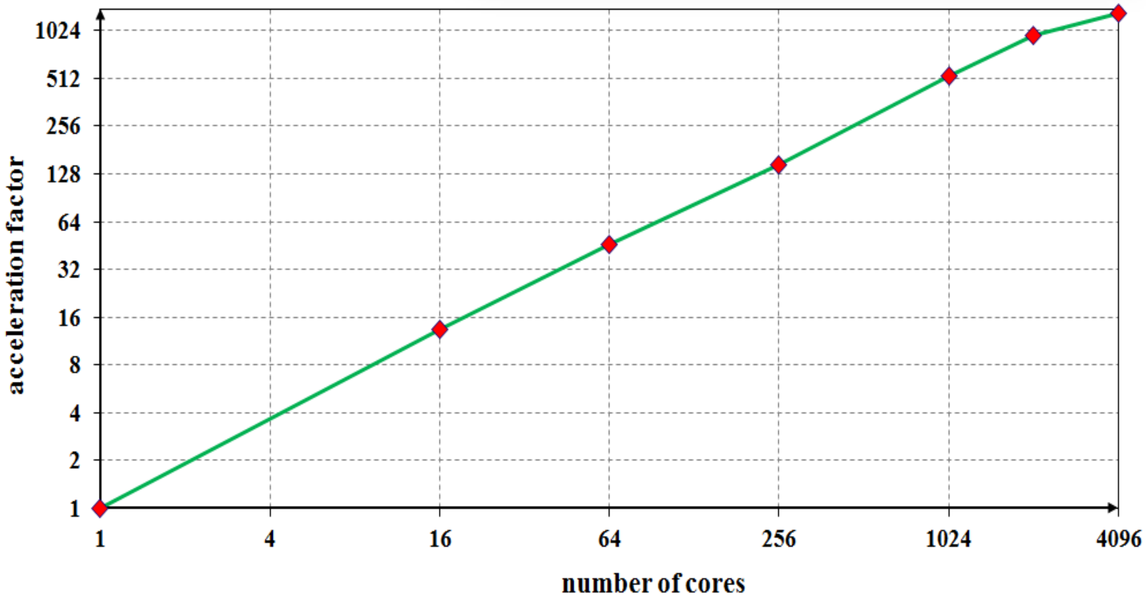
10 domains interchanging boundary conditions



Software – Unlimited Scalability

- 21.8 million active grid blocks
- 39 wells
- 512 nodes used
- 4096 cores

Simulation time reduced from 2.5 weeks to 19 minutes

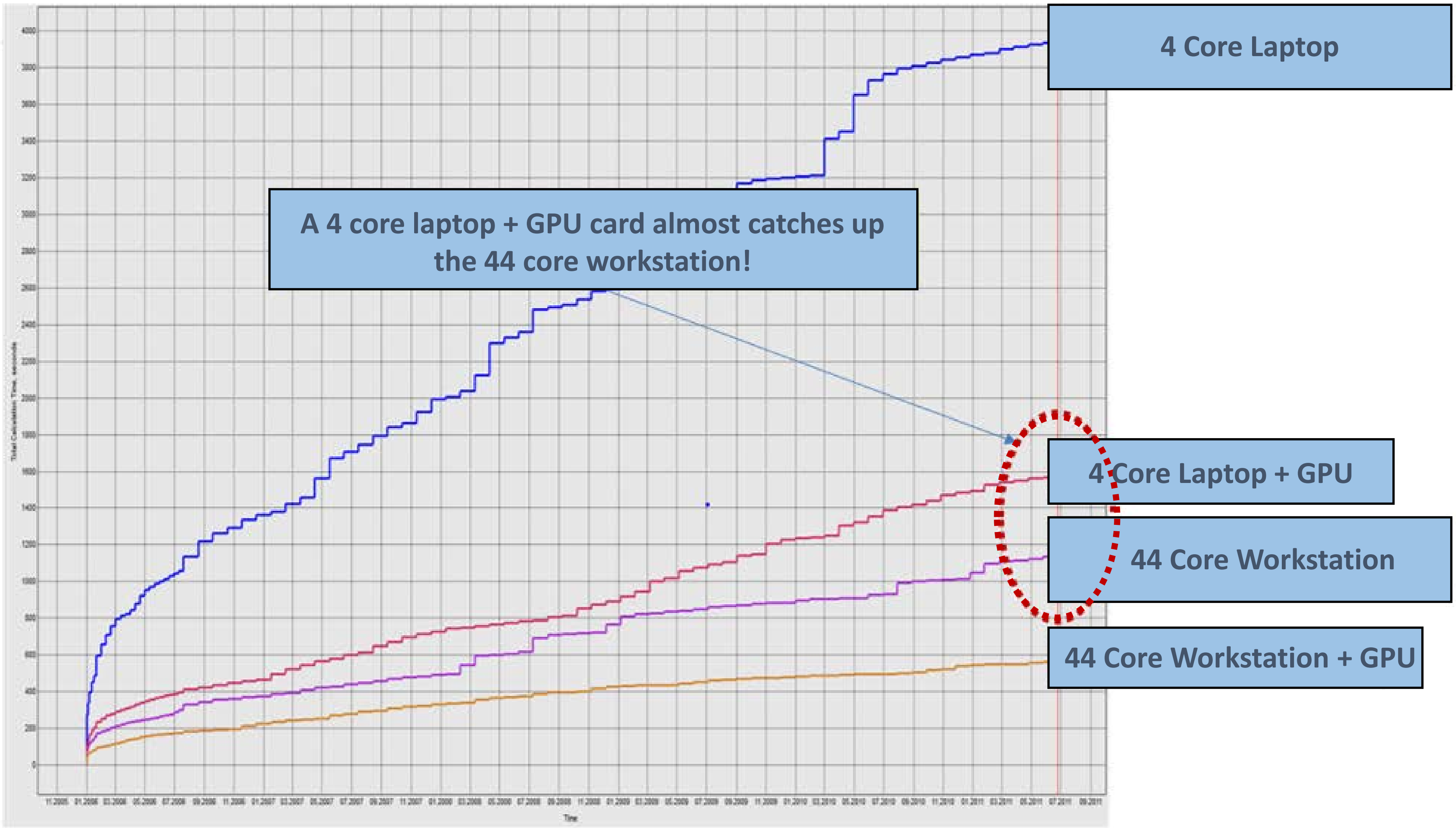


Software – GPU/CPU Development

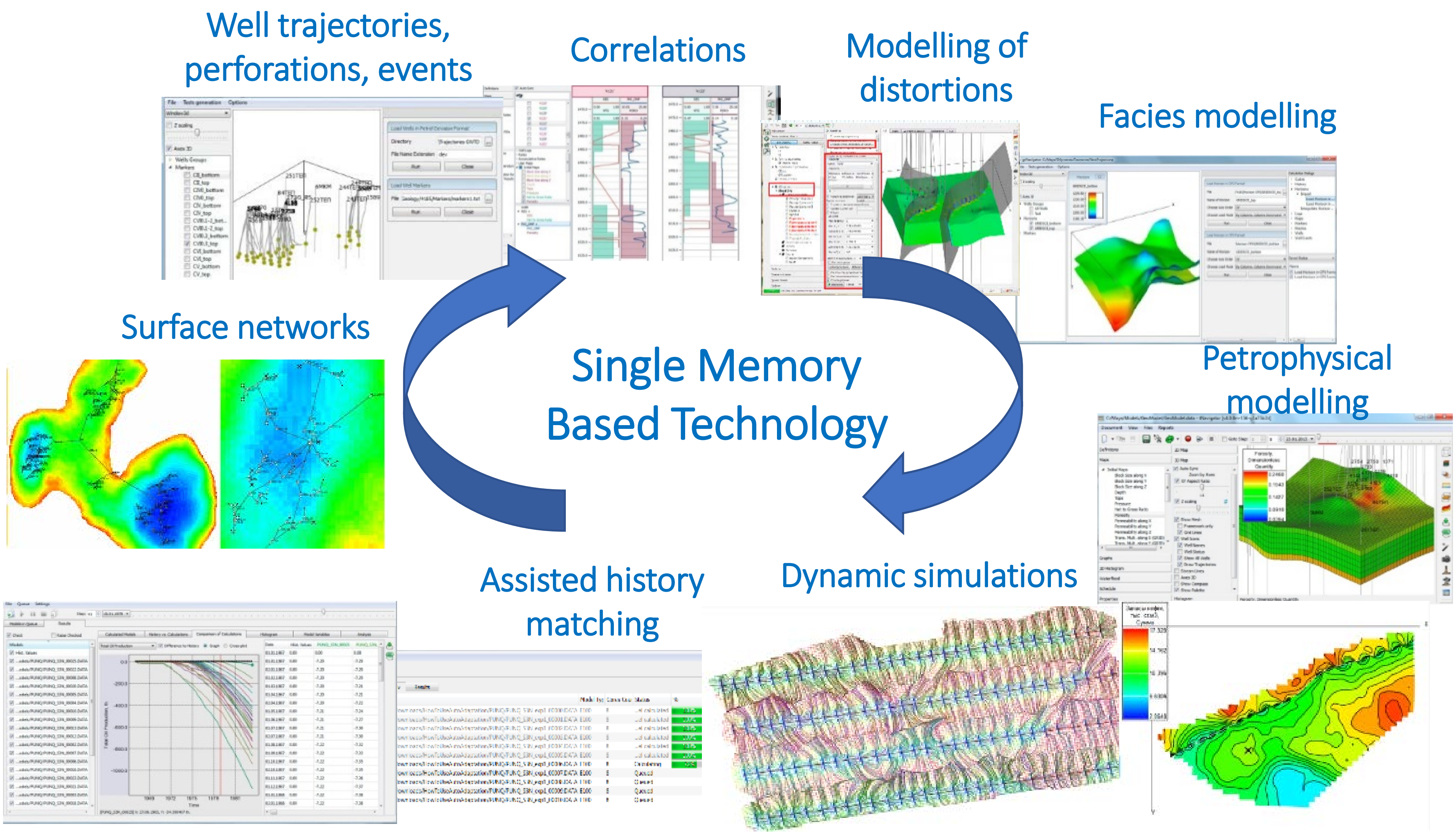
- Reservoir simulation – historically all CPU based
- To switch fully to GPU is high cost of software programming and change of hardware for marginal gains (SPE 163090)
- GPU/CPU hybrid approach shows 2–6 times speed up against fully parallel CPU software
- Expected to see 10 x speed up in future

Same performance seen
as 2-4 cluster nodes!

Software – CPU/GPU Testing



Integrated Workflow – Seismic to Surface



Case Studies

Case Study 1

Computer optimization of development plans in the presence of uncertainty

Key Objectives

- Carry out an independent production forecast targeting the P70 value of the NPV to avoid potential financial downside problems and maximize the asset value to the business
- Capture Uncertainty

Case Study 1

Computer optimization of development plans in the presence of uncertainty

Challenges

- Thousands of simulations required to capture various development scenarios with account for uncertainty

Case Study 1

Computer optimization of development plans in the presence of uncertainty

Solution

- 31 models were created in order to account for uncertainty
- 66,000 simulations ran over a six week period
- Different model realizations & development scenarios
- 31 nodes (each with 16 cores) cloud cluster solution utilised

Case Study 1

Computer optimization of development plans in the presence of uncertainty

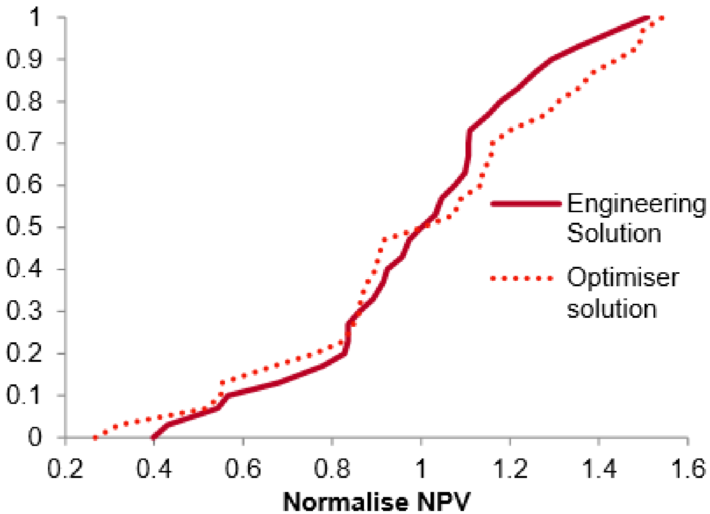
Project Outcome

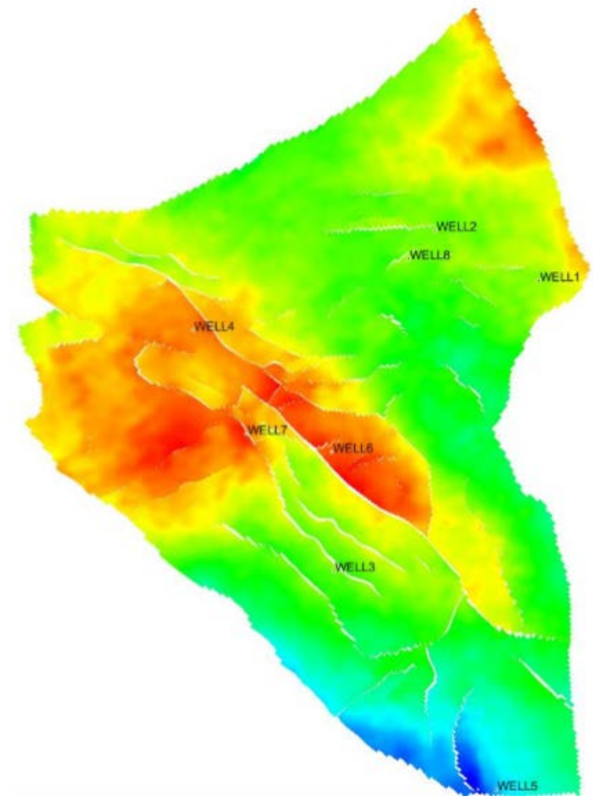
- Development scheme significantly optimized with less RE effort
- A much bigger export capacity (x3) was recommended
- NPV improved by 5% - workflow added value estimated as £1bn
- Final well placements had interesting features that challenged the normal design process

Case Study 1

Computer optimization of development plans in the presence of uncertainty

Optimiser's Solution



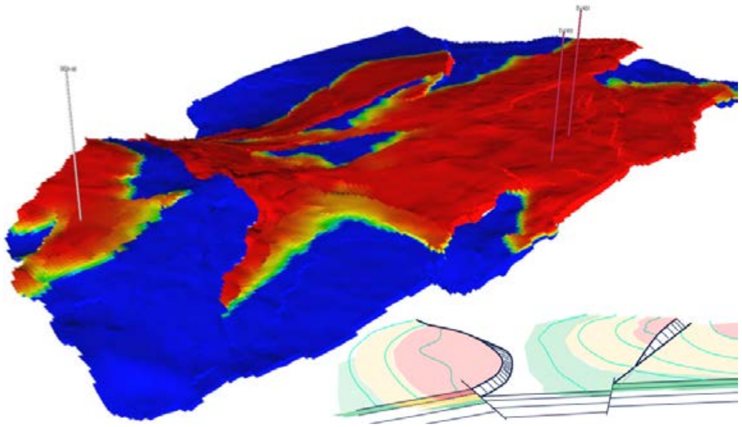


Case Study 2

History Matching of a waterflood in a heterogeneous Brent reservoir

Key Objective

- Locate remaining oil pockets of a poor quality brent reservoir, and quantify if any are large enough to warrant further development



Case Study 2

History Matching of a waterflood in a heterogeneous Brent reservoir

Challenges

- Only 26% recovery despite 38 years of water-flood development
- Significant vertical heterogeneity and flow barriers
- Widespread belief that modelling of the field was so complex the results would always be of limited use
- 660k active cells, 70Gb per run

Case Study 2

History Matching of a waterflood in a heterogeneous Brent reservoir

Solution

- History matched the multi-layered model with realistic heterogeneity
- 550 sensitivity runs in 4 months
- 20 core parallel processing on workstation

Case Study 2

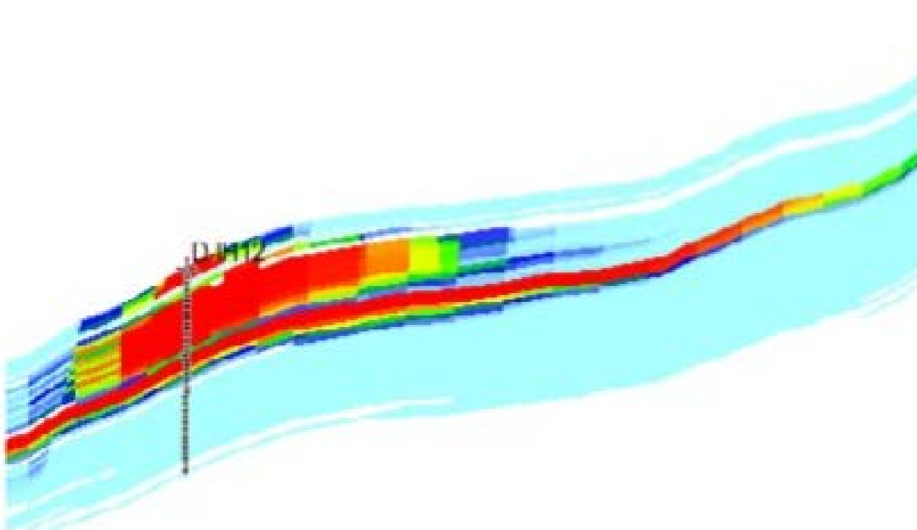
History Matching of a waterflood in a heterogeneous Brent reservoir

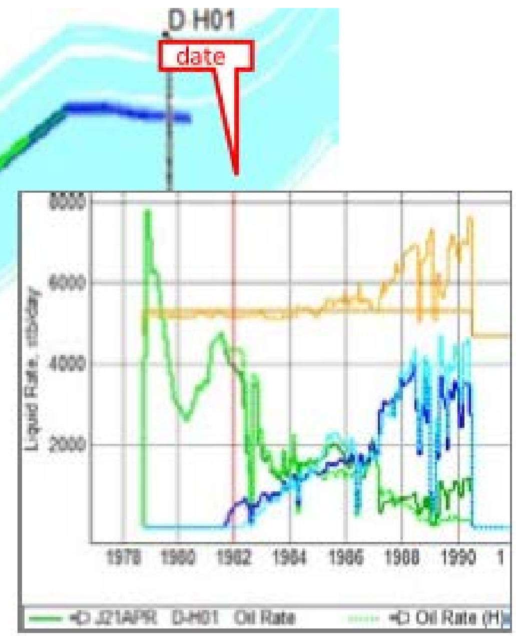
Project Outcome

- Determined the required heterogeneity to match local water breakthrough timing and water cut development
- Fully history matched model identified local thief zones with water breakthrough versus layers with remaining oil
- Main field locations with sufficient oil could be targeted

Case Study 2

History Matching of a waterflood in a heterogeneous Brent reservoir





Accurate water breakthrough and water-rate due to HM'd 'thiefzone' heterogeneity description

Case Study 3

Society of Petroleum Engineers

Integrated Uncertainty Quantification with multiple history matching predication cases

Key Objectives

- To find multiple realistic history matches for 3 conceptually different reservoir models representing P10, P50 & P90
- To create a probabilistic production forecast for a 25 year period, while capturing uncertainty

Case Study 3

Integrated Uncertainty Quantification with multiple history matching predication cases

Challenges

- Geological model and dynamic uncertainties
- Complex simulations
- Lack of tools for integrated uncertainty workflows
- Limited data and time

Case Study 3

Integrated Uncertainty Quantification with multiple history matching predication cases

Solution

- Project team built a unique integrated assisted history matching workflow involving static, dynamic and technological uncertainties
- More than 8000 realizations of the model ran in 2 days
- HPC cluster used with 2000 cores, 100 nodes

Case Study 3

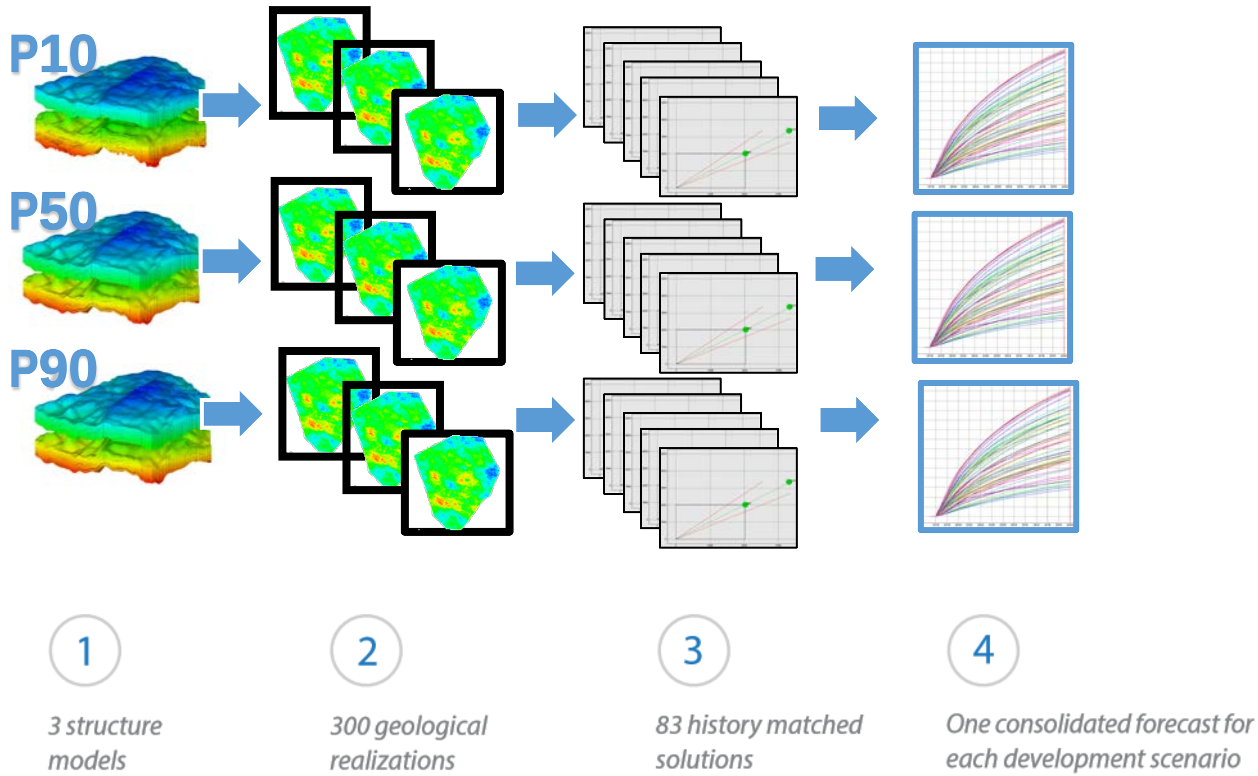
Integrated Uncertainty Quantification with multiple history matching predication cases

Project Outcome

- 83 different realizations of the model with equally good quality were found
- Results made it possible to make comprehensive probabilistic forecast of the reservoir performance
- Drilling plan was reviewed with risk management

Case Study 3

Integrated Uncertainty Quantification with multiple history matching predication cases



Thank you

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