CMG数值模拟技术最新进展
What’s New

Computer Modelling Group Ltd.

Builder

It’s all about speed – with a bit of a refresh

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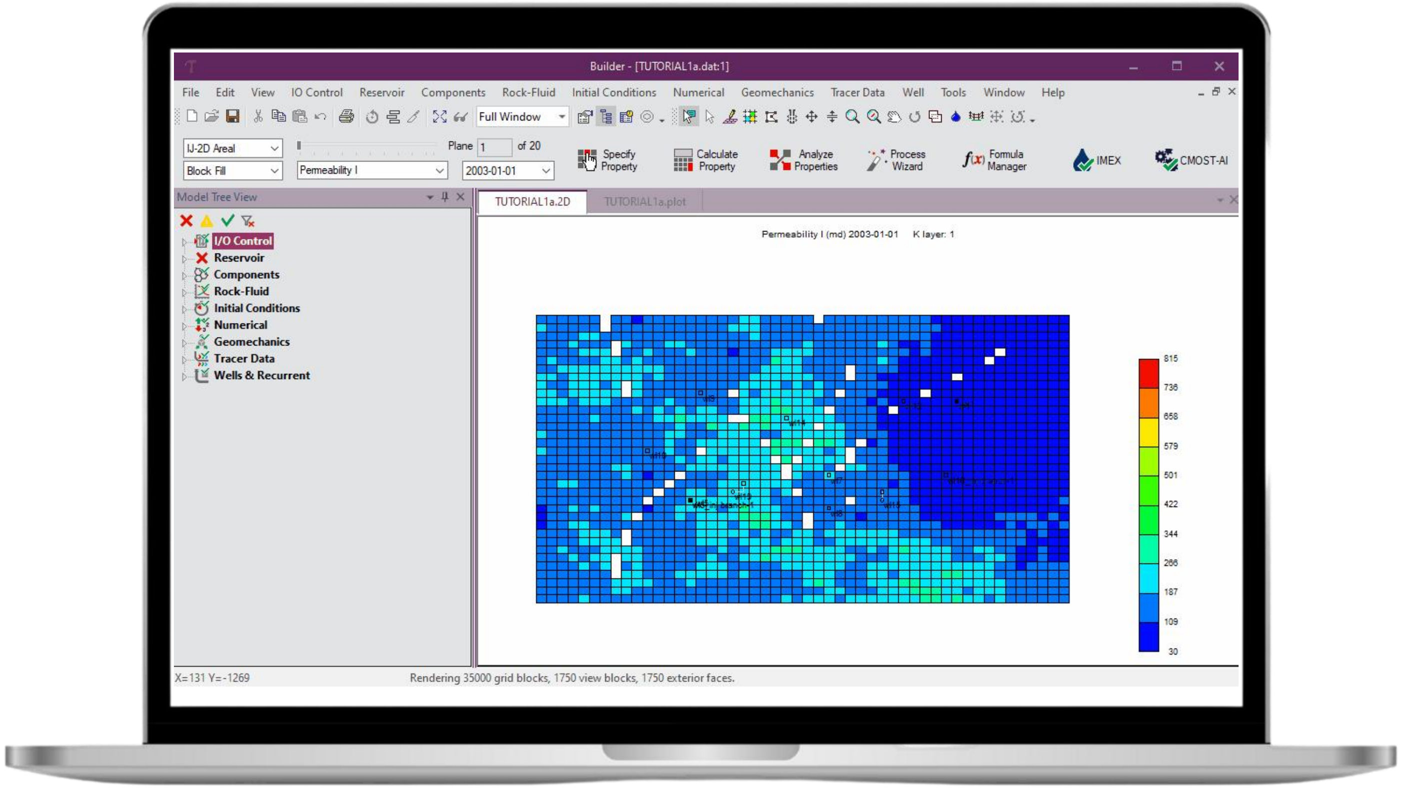
Visual Refresh

Challenge

Interface refresh. User confusion exists with multiple ways to get to options and unclear if they are identical.



Solution

- ☑ New "filter" buttons for quick navigation
- ☑ Modern look – flattened ribbon buttons
- ☑ Revamped model tree
- ☑ Quick access to Process Wizard and Formula Manager

Optimize File Saving Time and Storage

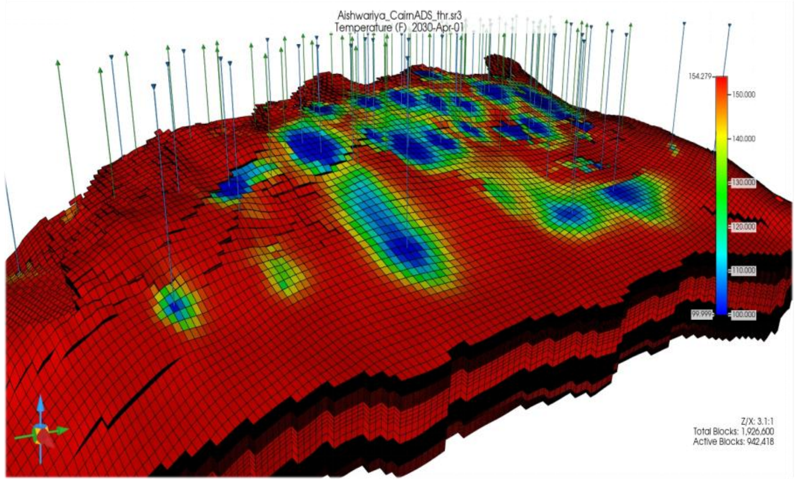
BUILDER

Challenge

Received feedback, especially related to large files sizes, regarding long save times

Solution

- ☑ Simulation Input (**SIP**) format
- ☑ Large file size reduction (avg **85%**)
- ☑ Decreased save time
- ☑ Items stored in SIP
  - Grid
  - Static property arrays
  - PDD Data



```
*FILENAMES *SIPDATA-IN 'TEST.sip'
```

← *Optional*

```
GRID CORNER 50 35 20

CORNERS   SIP_DATA
NULL SIP_DATA
POR SIP_DATA
PERMI SIP_DATA
PERMJ SIP_DATA
PERMK  EQUALSI * 0.1
PINCHOUTARRAY SIP_DATA
```

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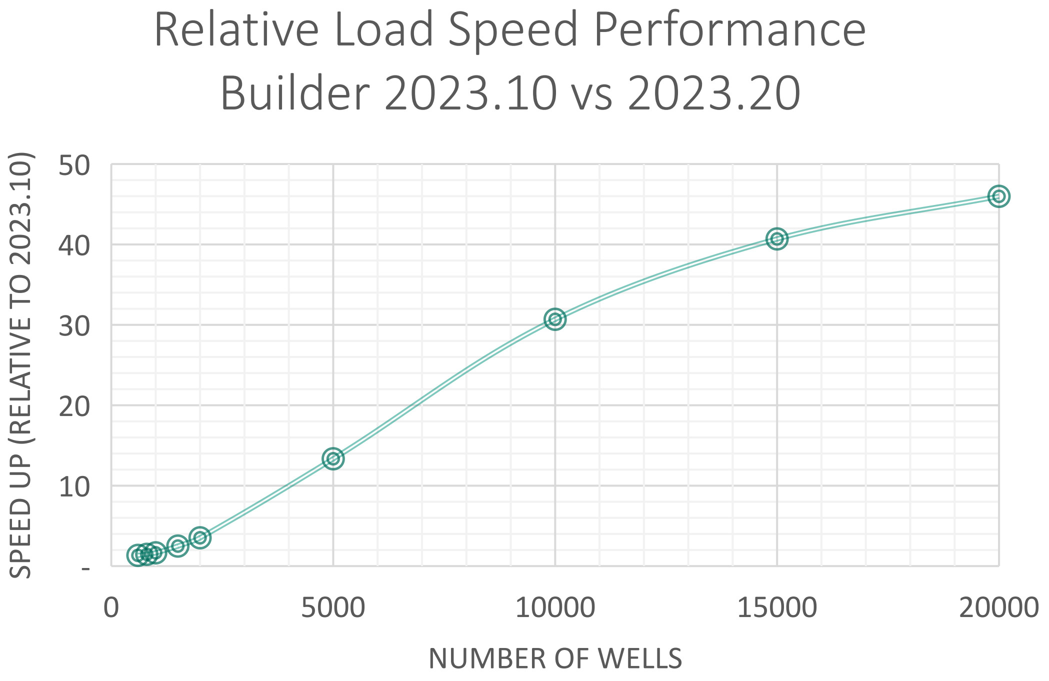
Large Model Load Improvements

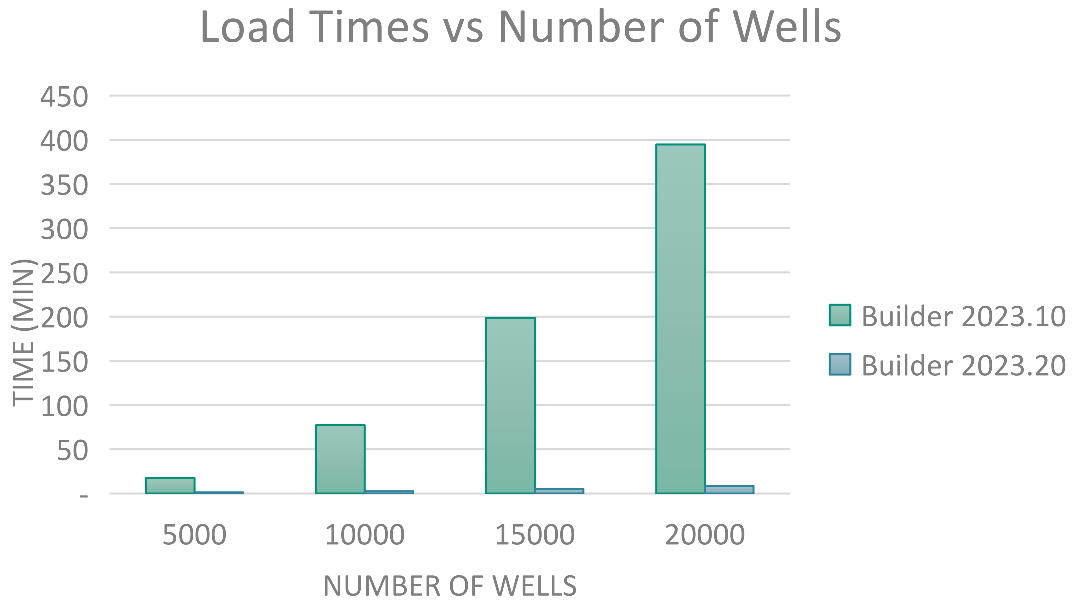
Challenge

Loading large models can be a challenging experience to begin working with the model. Delays impacts model building and analysis which are essential steps for any simulation study

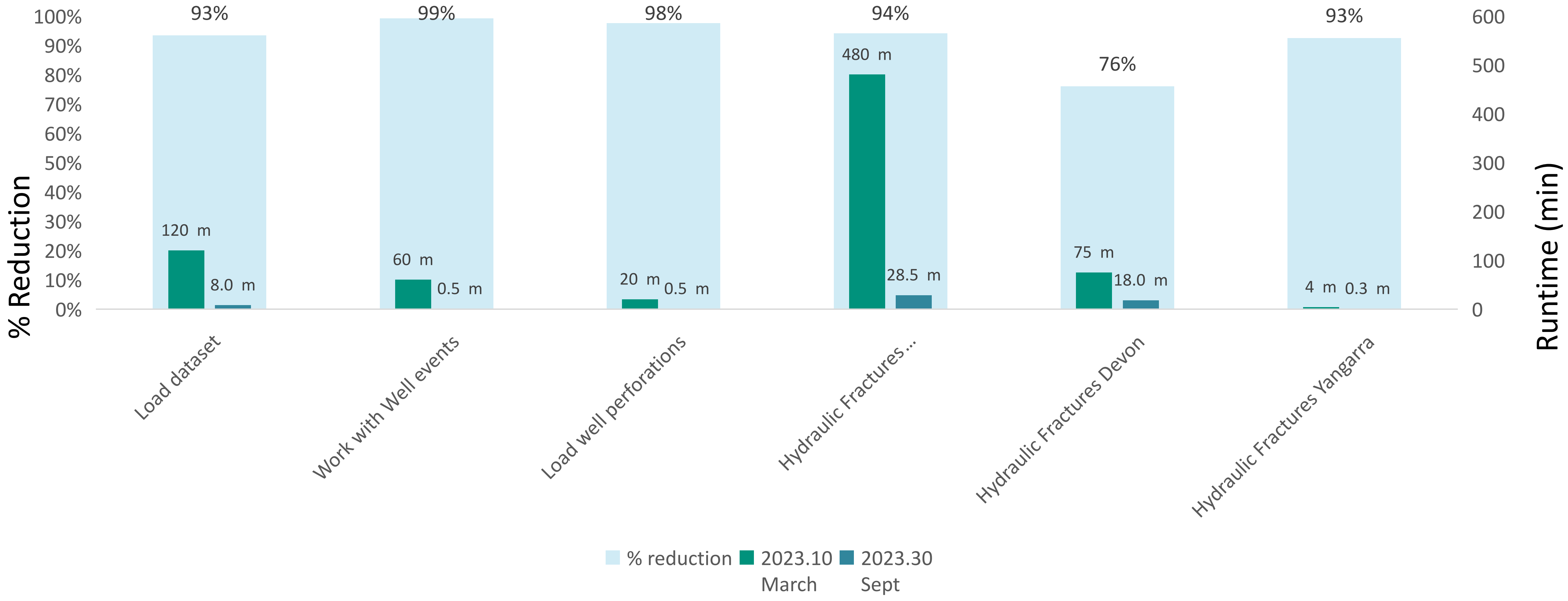
Solution

- Significant improvements have been made in loading large models
- Improvements cover load times of all models, but are particularity noticeable in datasets containing large number of wells
- Exponential improvements can be observed in models with 1500 or more wells





Builder Performance Update – 2023.30



Results

It’s all about speed – and data analysis

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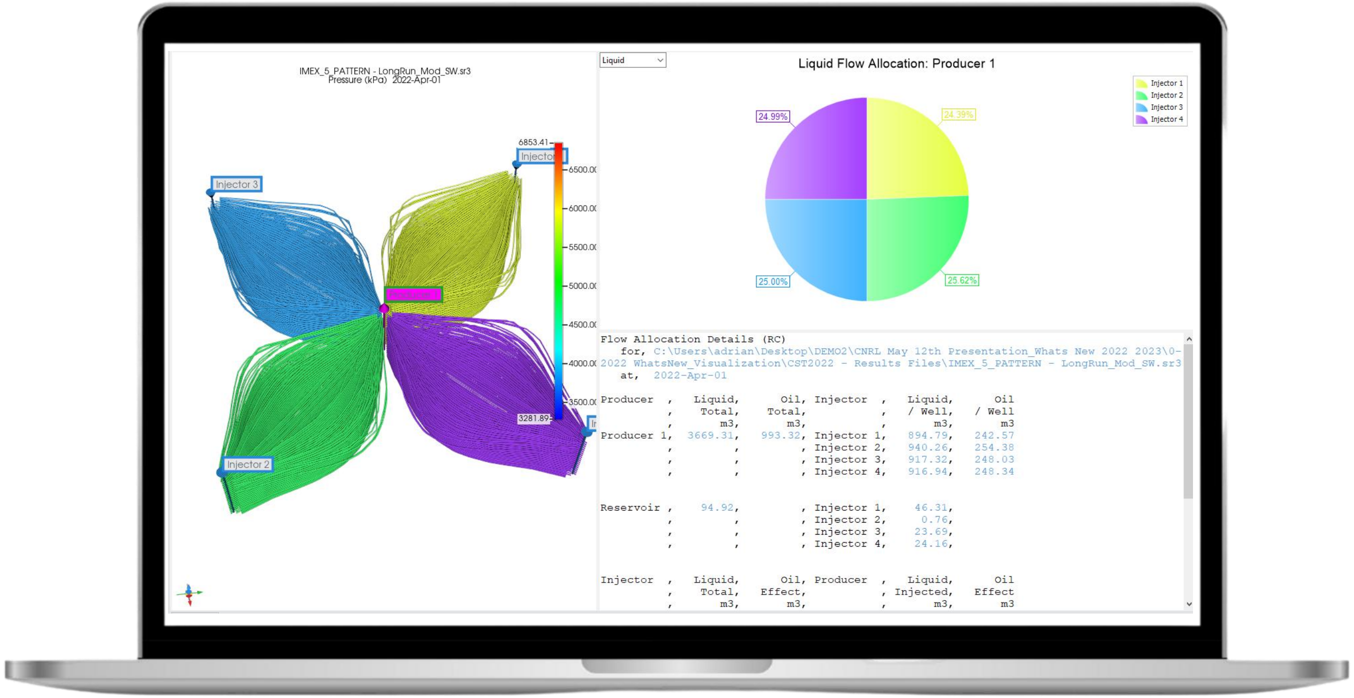
Flow Allocation Dashboard

Challenge

Understanding flow pattens in the reservoir is crucial for field development. Gaining insights require multiple steps and cross referencing to fully understand.



Solution

- Quick way to view streamlines and flow allocations
- Capture flow behavior and producer/injector flow contributions in the subsurface
- Analyze quickly and dynamically in a pre-set dashboard
- Export data directly to Excel for further processing

Contour Map Visualization

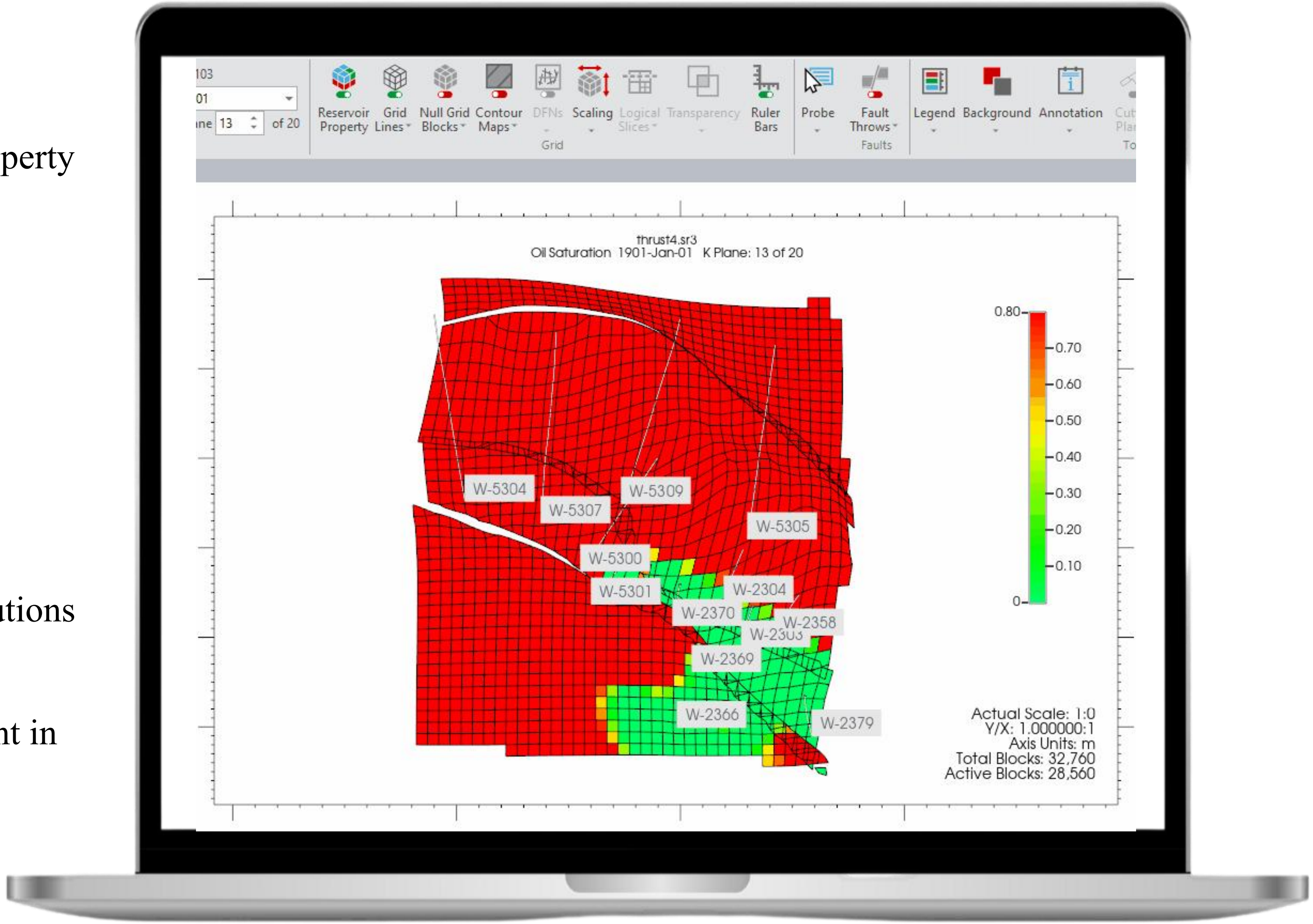
RESULTS

Challenge

Users would like a way to quickly view dynamic property changes over time

Solution

- Users can now see 2D view contour maps
- Quick visual representation of property distributions
- Identify patterns/trends that may not be apparent in other visualizations types



Boundary Polygons and Export of Shapefiles

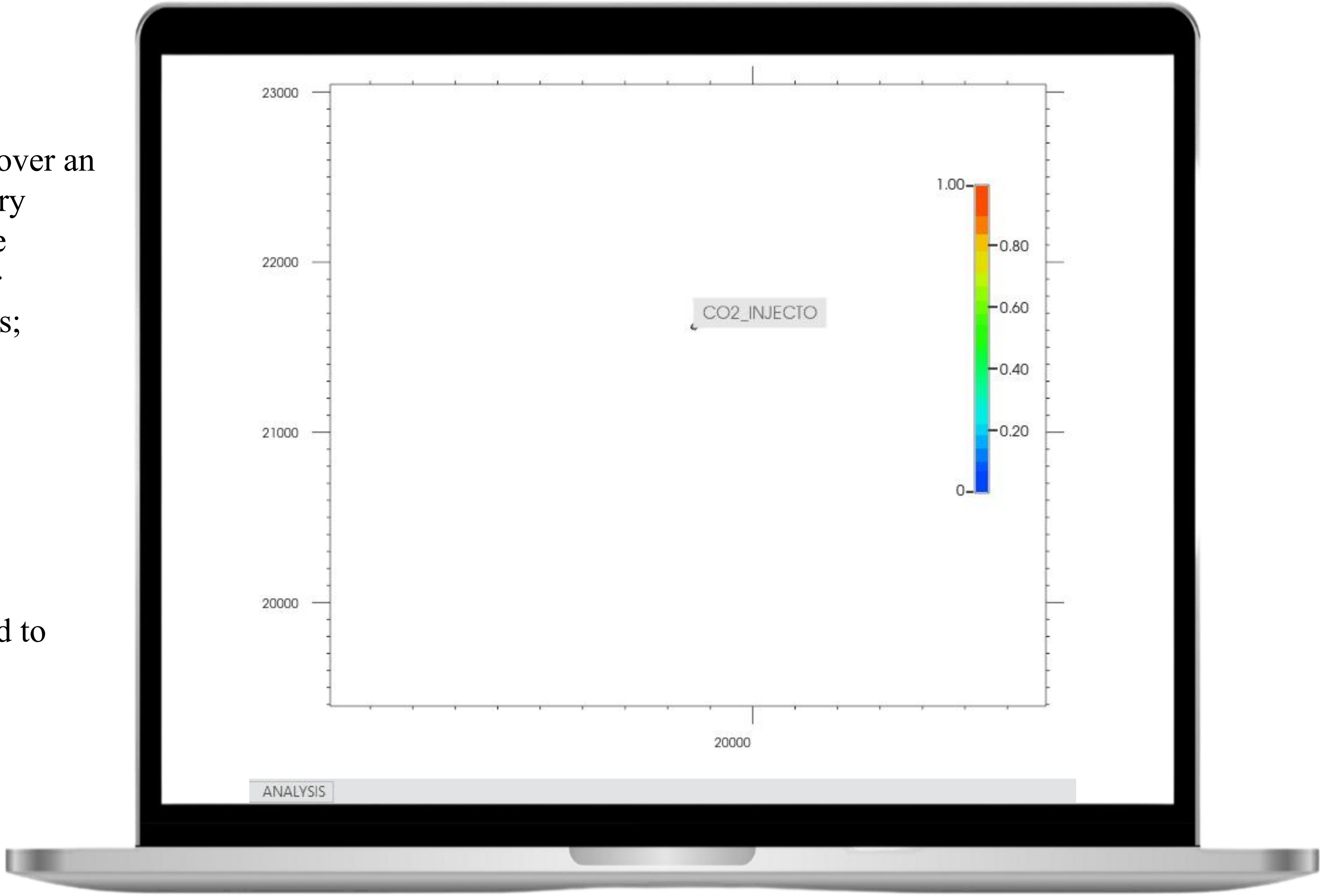
RESULTS

Challenge

Understanding horizontal extent of fluid or pressure distributions over an operating area is crucial in analyzing the effectiveness of a recovery process. It also ensures that the impact does not extend beyond the operator's area of interest. 3rd party software is often employed for capturing and providing views of the aggregated horizontal extents; however, challenges exist in providing such information.

Solution

- Can highlight aerial areas of interest based on active filters
- Highlighted areas at specified time intervals can be exported to shapefiles for further analysis in a GIS application
- Examples:
  - Horizontal plume extent of CO_2 injection
  - Aerial extent of a SAGD steam chamber
  - Polymer injection flood pattern at a specified interval
  - Subsurface fluid migration across lease planes



Vertical Column Property Aggregation

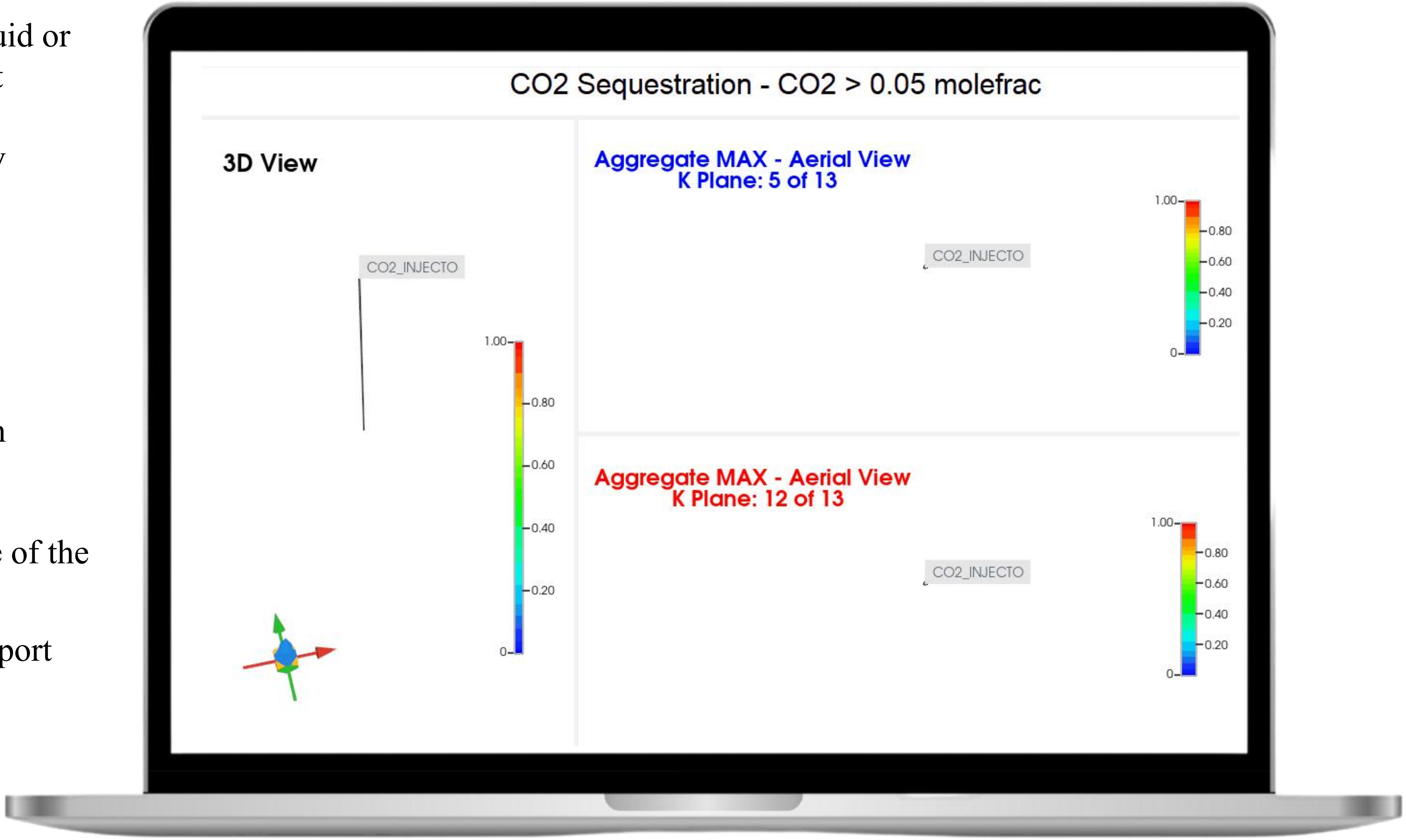
RESULTS

Challenge

Quickly capturing and understand the horizontal extent of fluid or pressure migration over an operating area can give important insights into the recovery process and assessing uncertainty. However, this can be especially tedious in models with many vertical layers.

Solution

- Aggregate property values in the same vertical column
- Aggregate based on Max, Min, or Average values
- Quickly identify fluid horizonal migration irrespective of the current vertical layer displayed
- Combine with Boundary Polygons to highlight and export areas of interest



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Periodic Update Performance Improvements

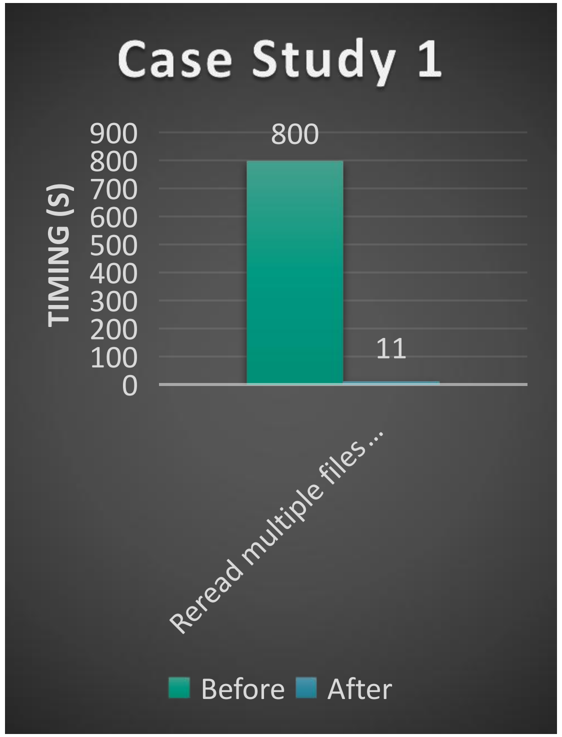
RESULTS

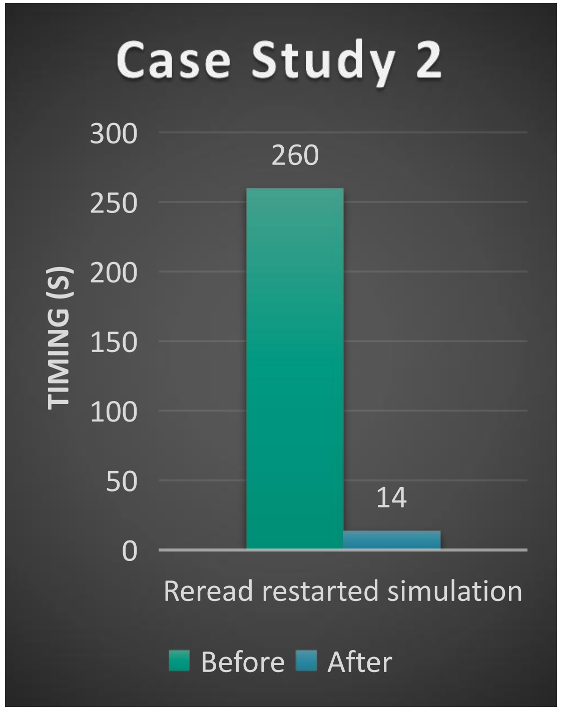
Challenge

Observed delayed performance when using the periodic update option while a simulation is progressing

Solution

- Significant speed improvements in loading and viewing data after a periodic update
- Results becomes responsive faster
- More time spent on analysis
- Improvements are most notable in models with a high number of wells





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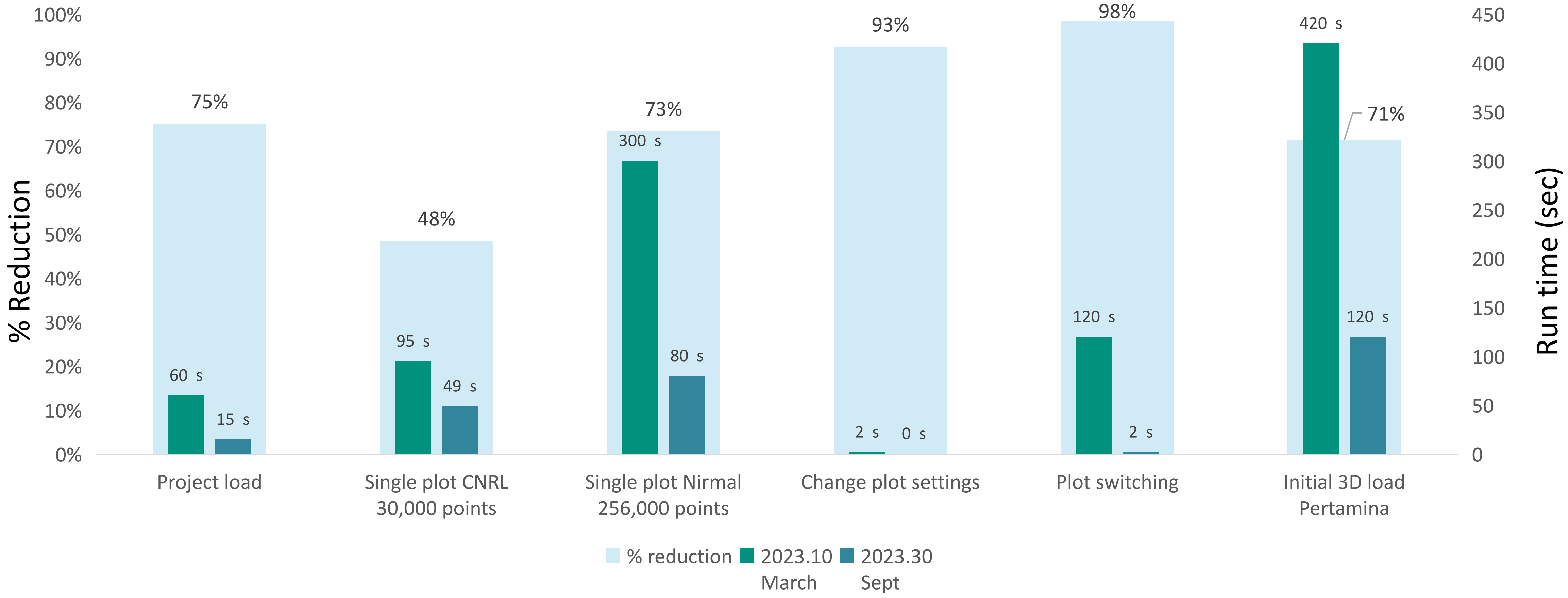
Results Performance Update – 2023.30



CMG Petrel Plugin

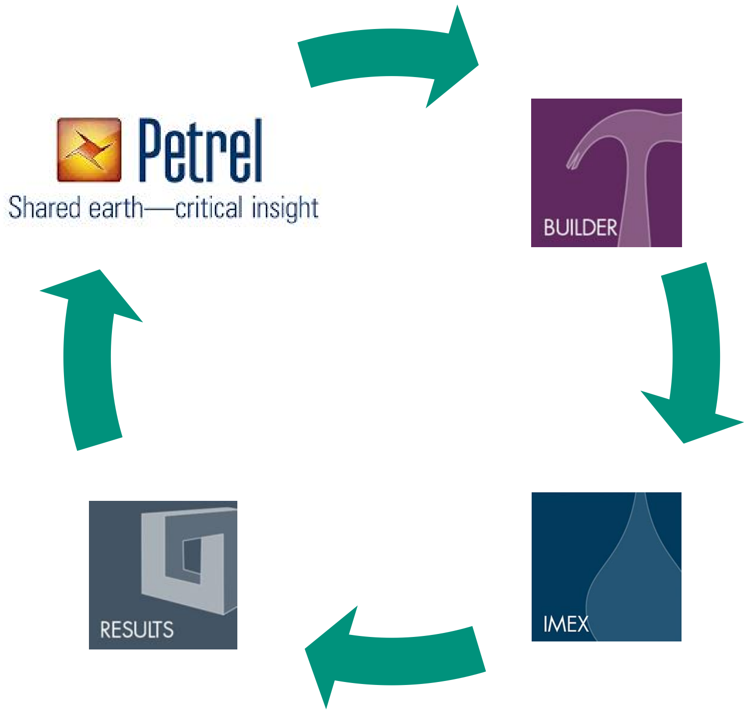
It's all about integration

CMG

CMG Petrel Plugin

Challenge

The current method of transferring data between products (RESCUE) can be improved.



Solution

- [x] Plug directly into Petrel using the Ocean framework

CMG's Petrel-Plugin

Direct connection between Petrel and CMG:

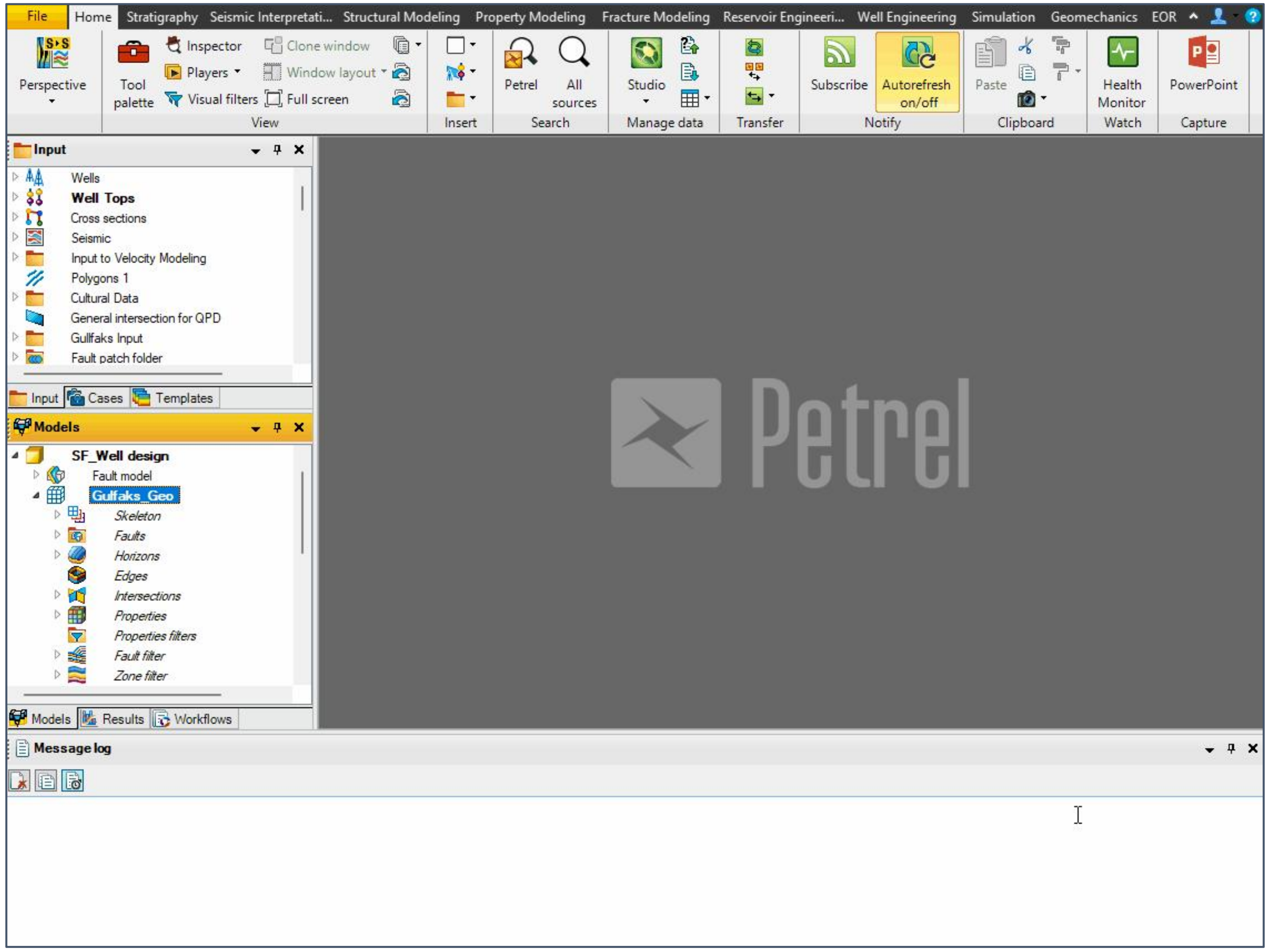
Export - static reservoir data for model creation

- ☑ Model Grid
- ☑ Static reservoir properties
- ☑ Well and completion data

```
*GRID *CORNER 31 39 568

*NNODES 390982
*NODEX SIP_DATA
*NODEY SIP_DATA
*NODEZ SIP_DATA
```

- ➢ Two Files output
  - ➢ *.dat
  - ➢ *.SIP
- ➢ Grid exported in node-based format
- ➢ All wells exported as grid independent



CMG's Petrel-Plugin

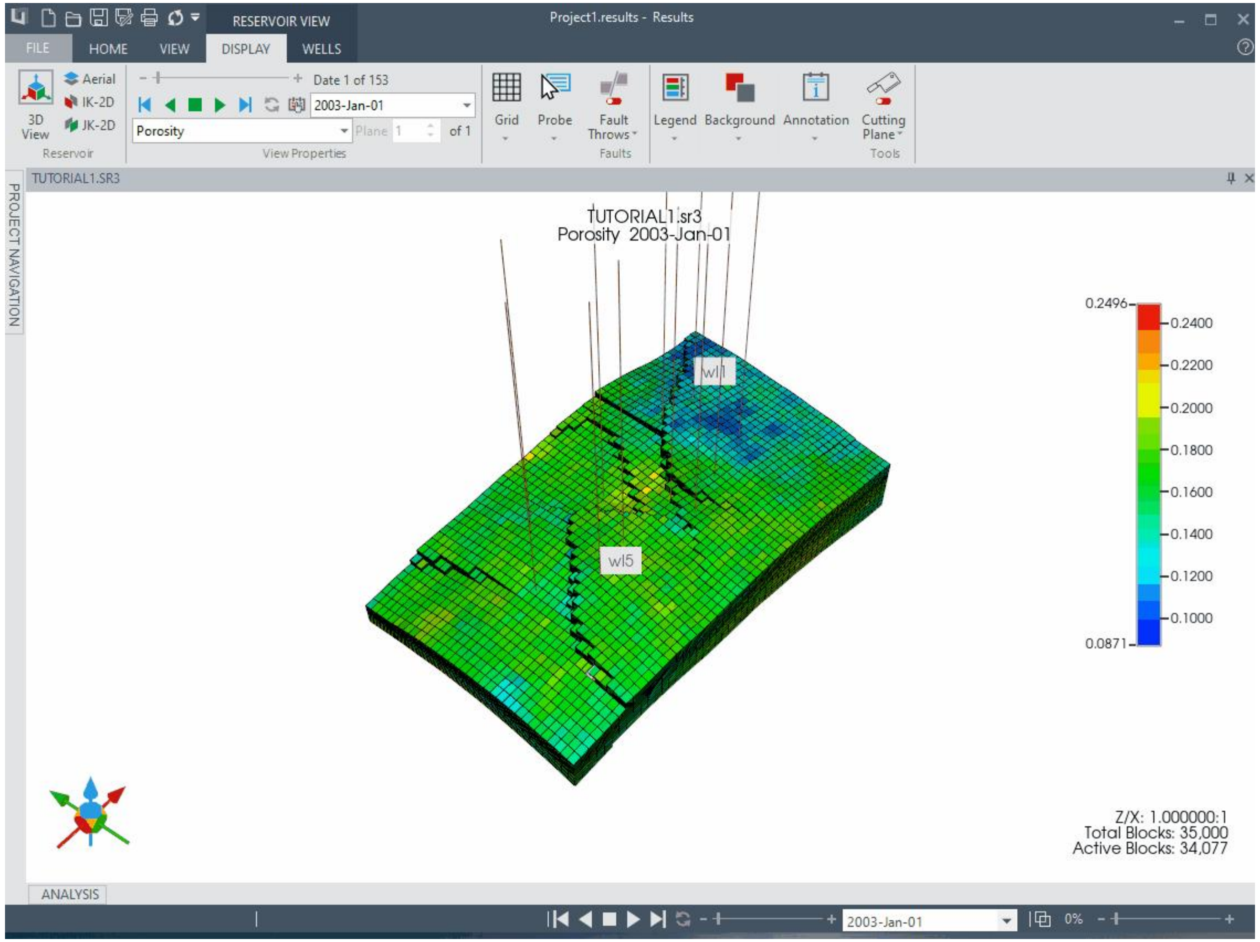
RESULTS

Direct connection between Petrel and CMG:

Export

Import - results of CMG simulations for comparison

- ☑ Grid and model properties
- ☑ Timesteps from simulation (dynamic changes)
- ☑ Well trajectories



CMG's Petrel-Plugin

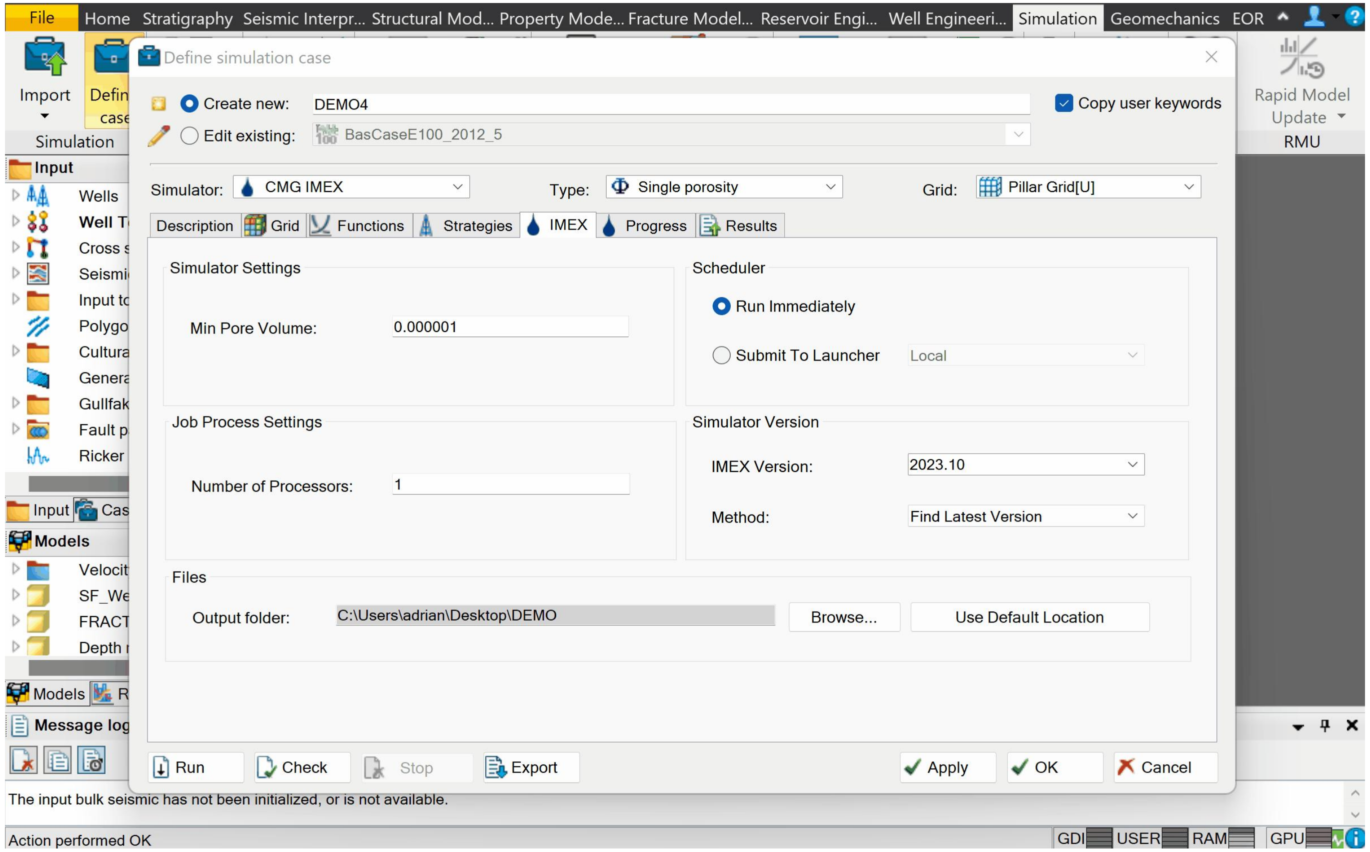
Direct connection between Petrel and CMG:

Export

Import

Simulate – IMEX cases

- ☑ Directly from Petrel RE interface
- ☑ Automatic conversion to CMG format
- ☑ Schedules and runs models in IMEX



Eclipse Integration – CMG's Data Importer

v2023.10

Drag and drop Eclipse models directly into Builder (and IMEX)

Importer utilized >**11,300** times since 2019 for converting Eclipse models to CMG

Option to run Eclipse100 models in IMEX by:

- Conversion via the Data Importer
- Export from Petrel via CMG's new Petrel-Plugin
- **Run ECL100 models directly in IMEX** (converts and runs on-the-fly)

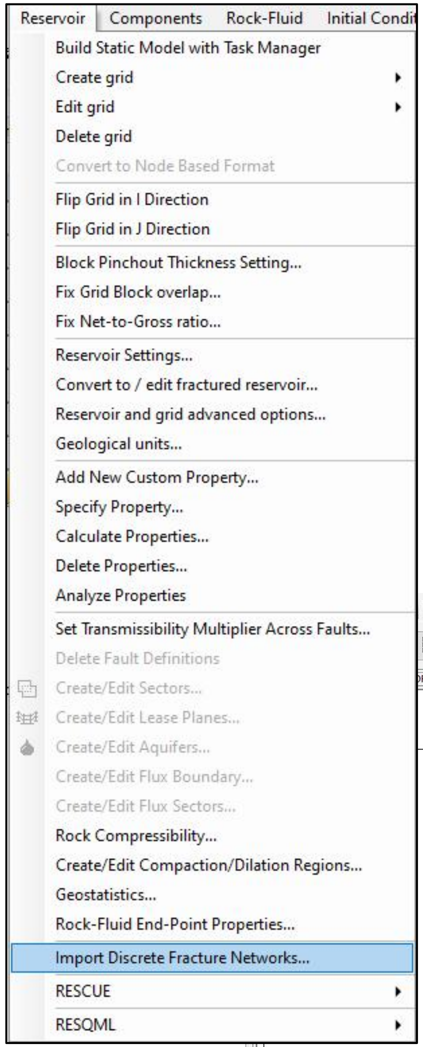
100% of CMG's testbed models (over 200 field cases) can now be run directly without any manual editing!

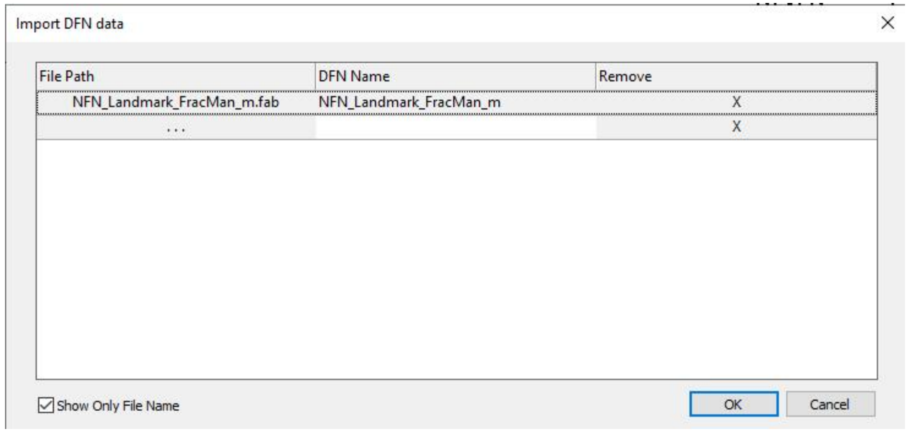
Larger Updates

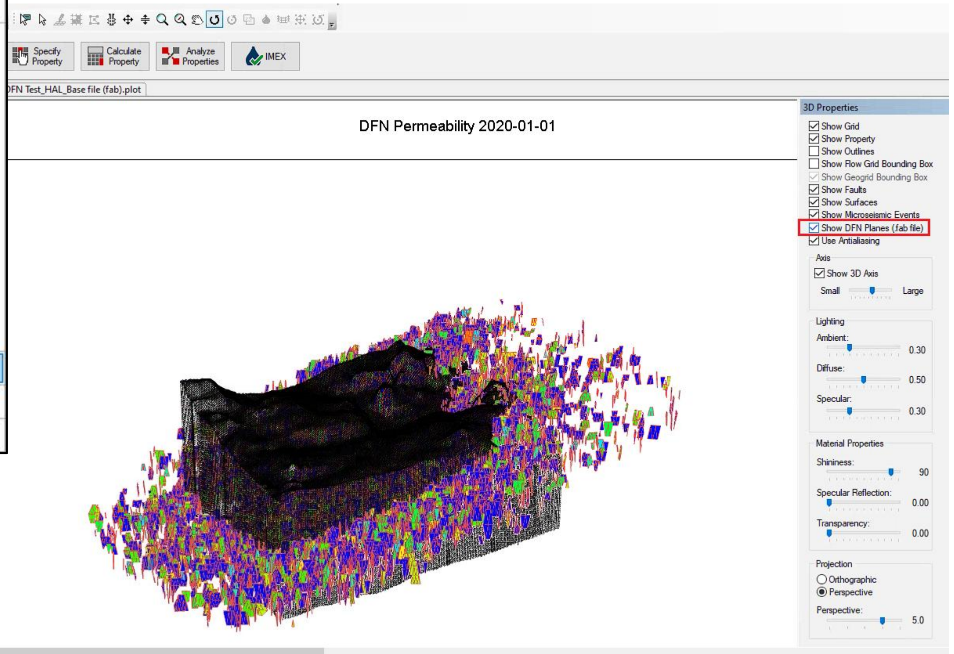
DFN

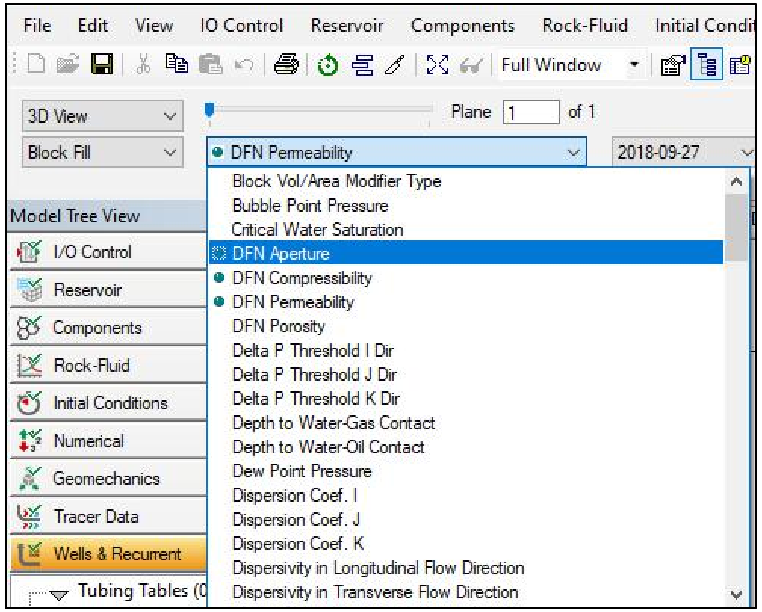
DFN (Discrete Fracture Network)

- Can import multiple FAB files
- Separate DFN properties for permeability, porosity, aperture and compressibility
- Toggle on/off
- Wireframe grid when DFN shown

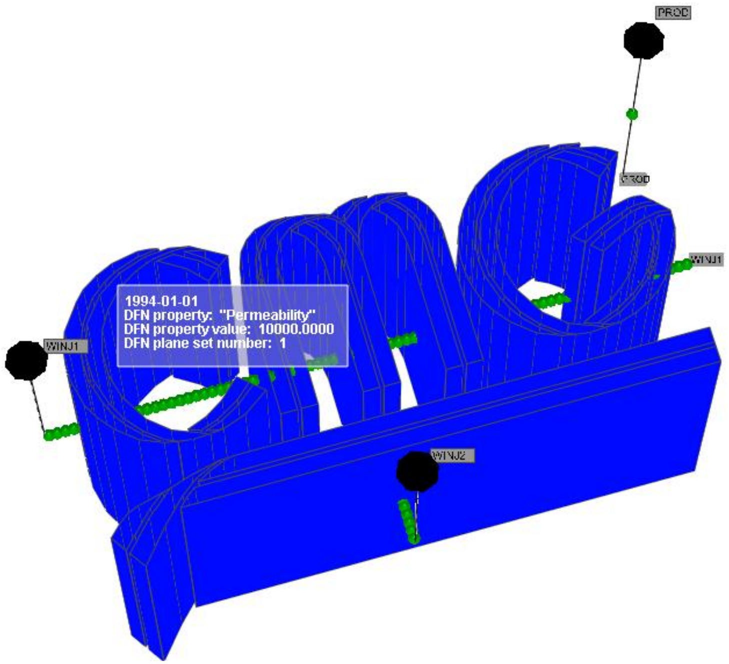








Automatic Nested LGRs



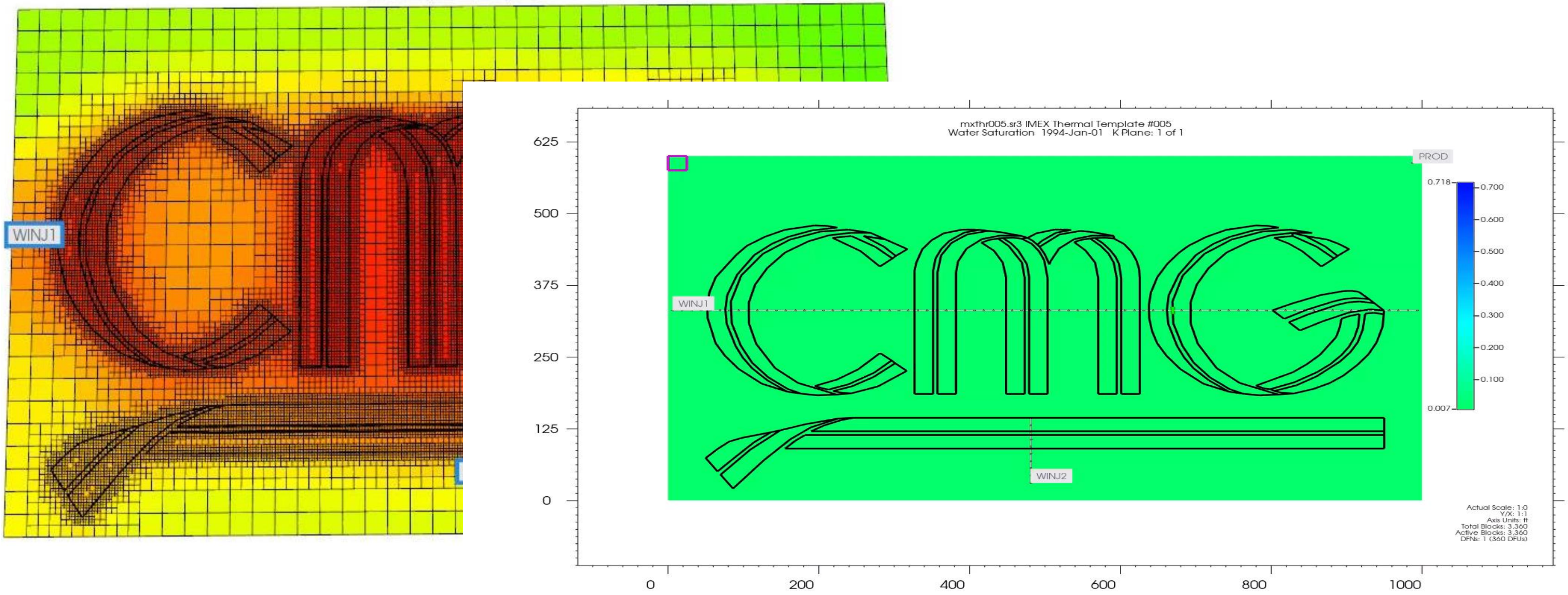
Challenge

- May require finer grid resolution around the DFNs but complex to do manually

Solution

- Local Grid Refinements (LGRs) can now be auto-created around DFNs, providing greater accuracy
- LGRs can be a function of distance and various parameters and works with the new grid independent wells functionality
- Added ability to Shift and Rotate DFNs to easily run sensitivities

Automatic Nested LGRs



CMG Logo defined by DFNs and Automatic Nested Refinements were applied around the DFNs based on a defined distance

Grid-Independent Wells

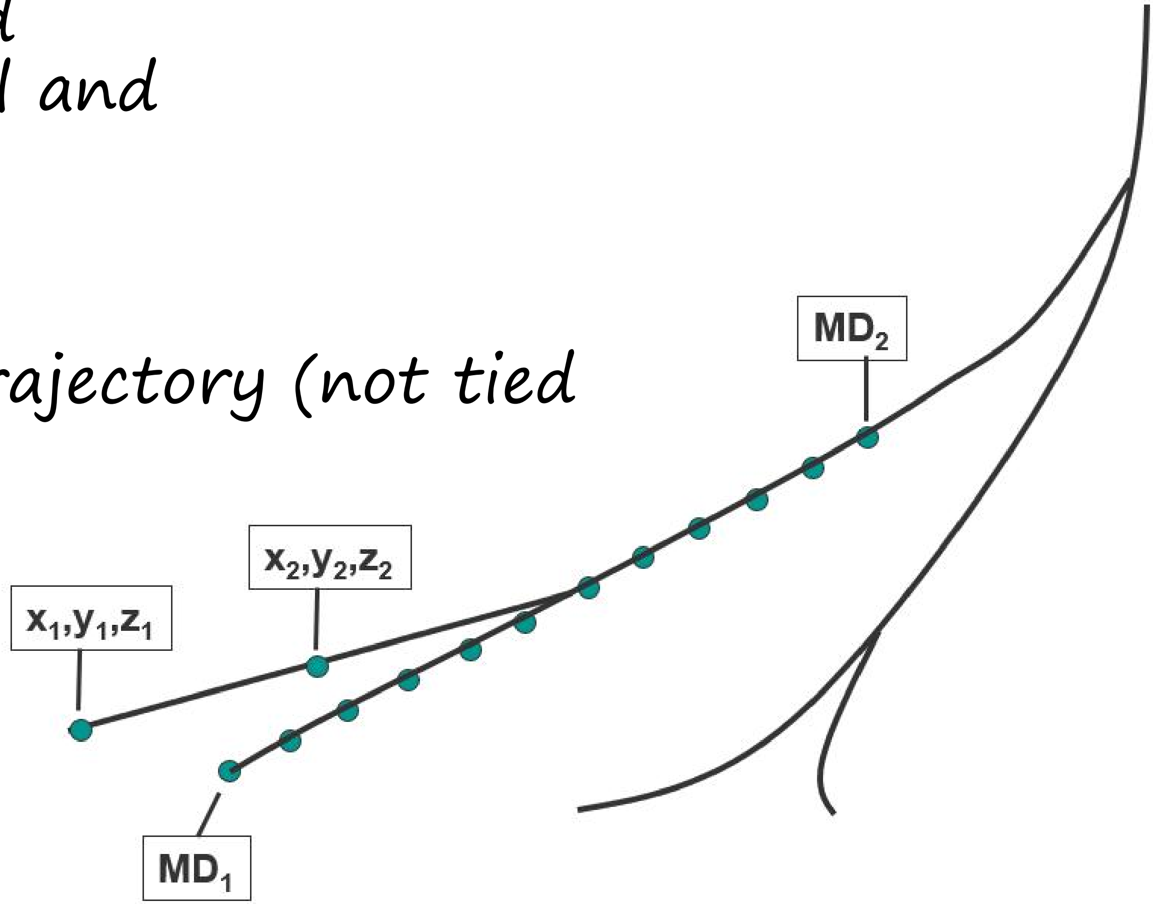
Challenge

Wells historically defined by their grid coordinates making updating the well and running sensitivities difficult.

Solution

Well position based on coordinates/trajectory (not tied to gridblocks)

- Rotate and shift options
- Single and multilateral wells
- Perforations defined based on:
  - Measured Depth Interval
  - Start/End Coordinates



Tracer Module – IMEX/GEM

Complete new module

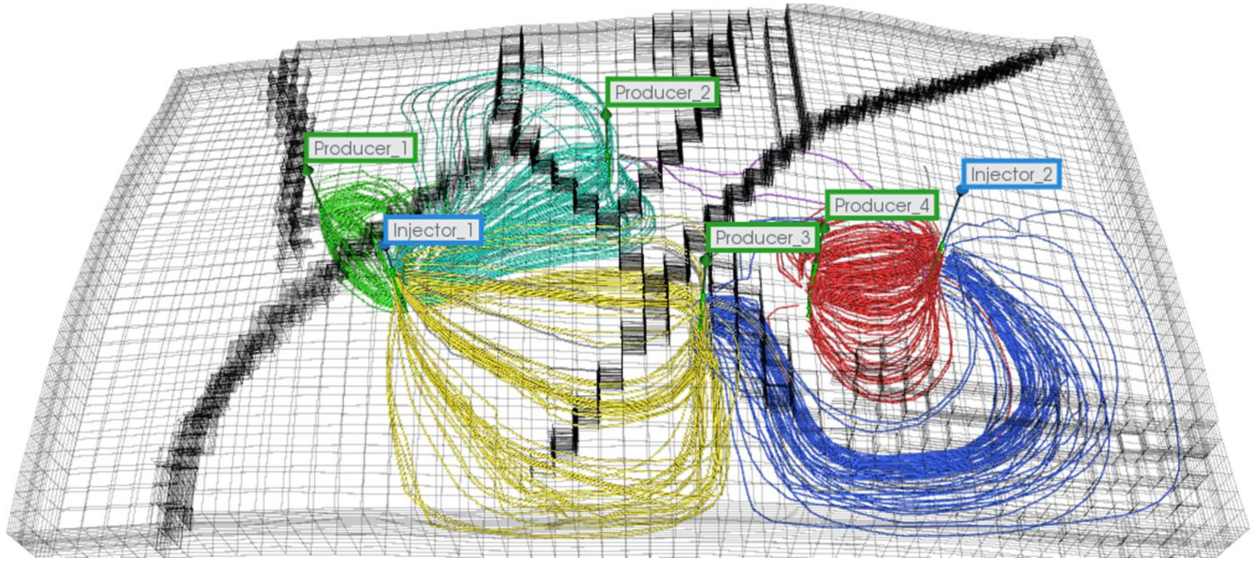
- Tracers are passive ie do not alter flow and so are low computational cost

Tracking:

- Reservoir regions
- Injection wells
- Analytical aquifers

Effects:

- L-L and L-G phase partitioning
- Reversible/irreversible adsorption
- Molecular diffusion
- Physical dispersion



Miscellaneous

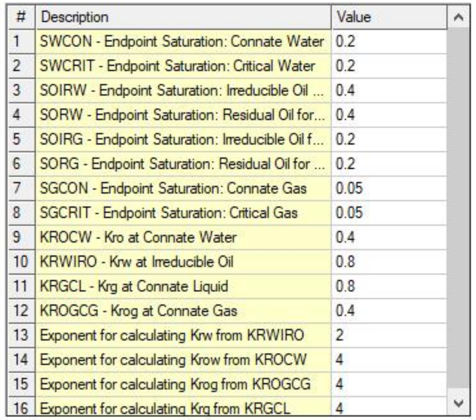
1. Define Rel Perm Correlations directly in the simulation dataset
   - Makes CMOST Sensitivities much simpler
2. Separate transmissibility across a fault can be defined for Matrix and Fracture using *TRANSF
3. Numerical Aquifer added using *AQUNUM and *AQUCON
   - Numerical Aquifer allows more flexibility as well as a pressure drop profile through the aquifer
4. Block selection by well drainage radius
   - Makes History Matching in CMOST much easier
5. LGR and Fracture PV cutoff control
   - For fundamental blocks: *PVCUTOFF and *PVCUTFR, respectively.
   - For LGRs: *PVCUTRG, *PVCUTRG-FR
6. Set thresholds to prevent out of range data entry

   MAXVAL *val1 val2*

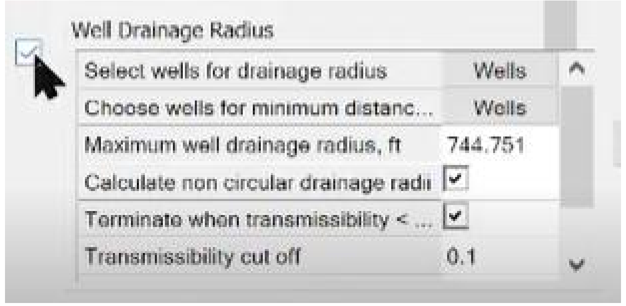
   PERMI MAXVAL 10000 10000 MINVAL 1 0 ALL …

- If the permeability is greater than MAXVAL val1, use MAXVAL val2.
- If the permeability is less than MINVAL val1, use MINVAL val2

AND MUCH MORE…….



#	Description	Value
1	SWCON - Endpoint Saturation: Connate Water	0.2
2	SWCRIT - Endpoint Saturation: Critical Water	0.2
3	SOIRW - Endpoint Saturation: Irreducible Oil ...	0.4
4	SORW - Endpoint Saturation: Residual Oil for...	0.4
5	SOIRG - Endpoint Saturation: Irreducible Oil f...	0.2
6	SORG - Endpoint Saturation: Residual Oil for ...	0.2
7	SGCON - Endpoint Saturation: Connate Gas	0.05
8	SGCRIT - Endpoint Saturation: Critical Gas	0.05
9	KROCW - Kro at Connate Water	0.4
10	KRWIRO - Krw at Irreducible Oil	0.8
11	KRGCL - Krg at Connate Liquid	0.8
12	KROGCG - Krog at Connate Gas	0.4
13	Exponent for calculating Krw from KRWIRO	2
14	Exponent for calculating Krow from KROCW	4
15	Exponent for calculating Krog from KROGCG	4
16	Exponent for calculating Krg from KRGCL	4



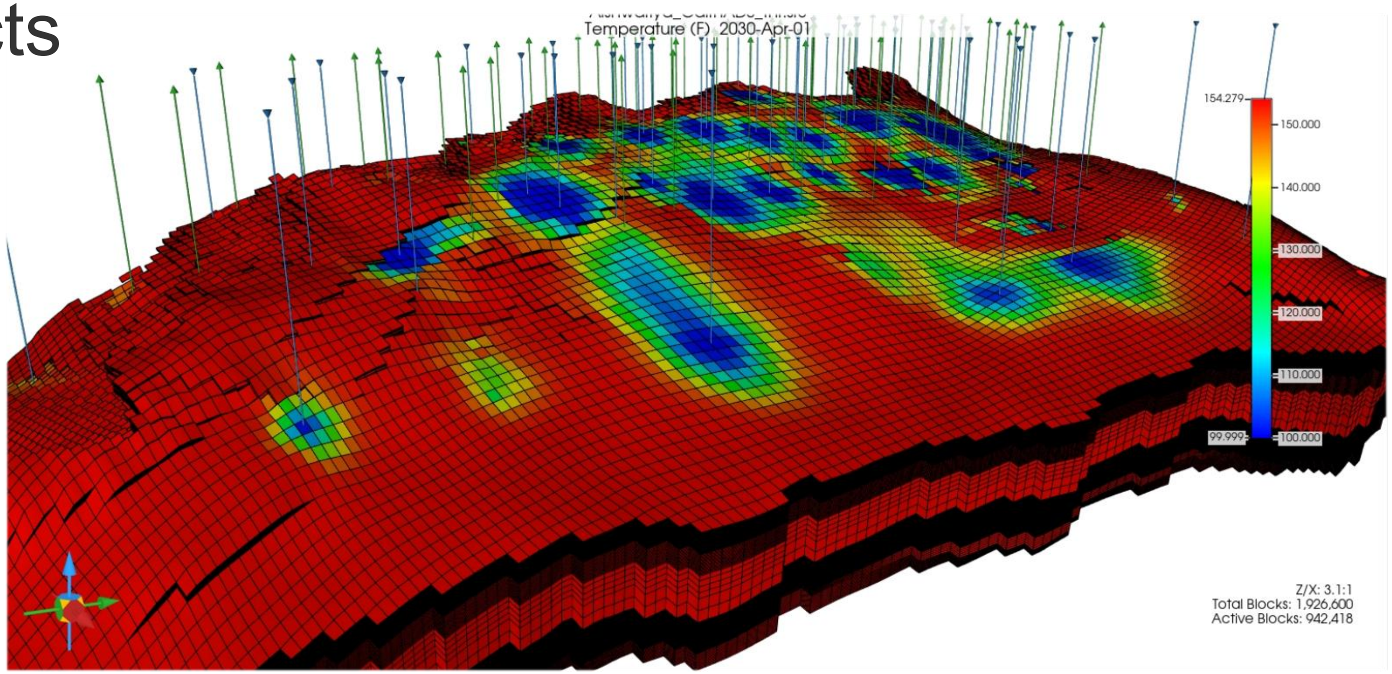
IMEX

All 3 simulators are Thermal

Thermal Black-Oil Modelling

IMEX is now able to model temperature changes and effects on fluid viscosities and other thermal-induced reservoir physics

Applicable in polymer injection projects by considering the thermal effect on mixture viscosity and degradation



IMEX Thermal

IMEX is now able to efficiently solve the thermal energy conservation and model the temperature effects on fluid viscosities and other thermal induced reservoir physics.

`*CP-ROCK`: *Formation rock heat capacity*

`*CP-FLUID`: *Fluid phase heat capacities*

`*INJ-TEMP`: *Injector Bottom Hole Temperature*

`*TEMPER / *TEMPVD / *TRES`:

Reservoir Temperature initialization using Block array, depth table, or constant value

Other Thermal Related Applications:

*TRPOR, *CTPOR:	*Rock thermal expansion (+ compressibility)*
*CROCKTABT:	*Rock compaction/dilation on T*
*GRTEMTAB:	*Geomechanics properties on T*
*INTCOMP TEMPER:	*Rel. perm. table set interpolation on T*
*TRCR-PARCCOR:	*Tracer K-value correlation partitioning on T*
*TRCR-PARCTBLE:	*Tracer tabular K-value partitioning on T*

New Utilities

Geothermal Process Wizard

BUILDER STARS

Guided wizard for building STARS geothermal models

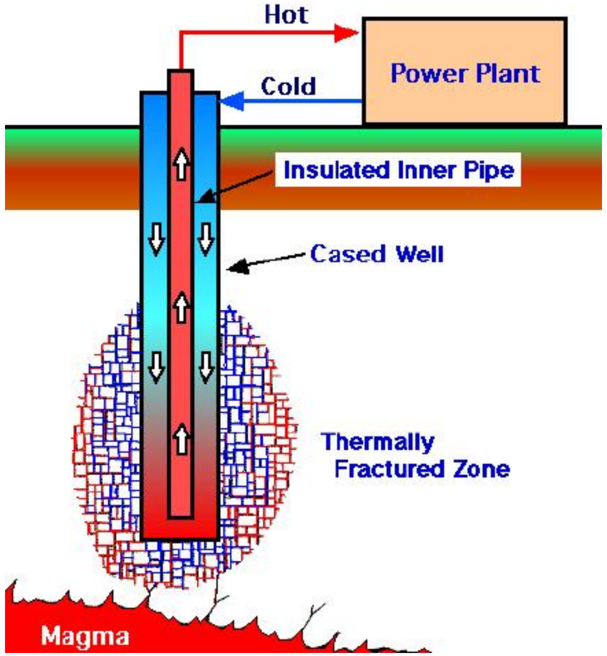
Work with existing models or start from scratch

Guided Process:

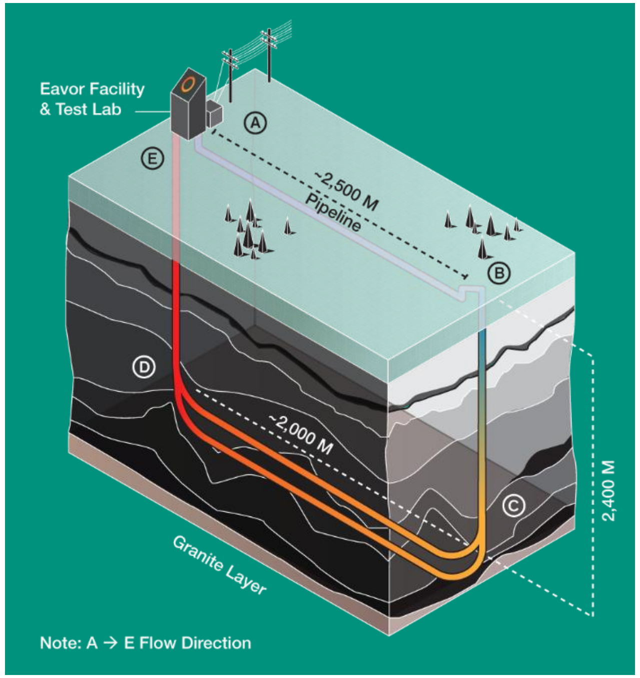
- Grid (to surface)
- PVT fluid model
- Rel Perm
- Thermal properties
- Well configuration (using Flexwell)
  - Open and Closed loop systems

STARS Enhanced to allow better properties, phase identification and stability for super critical water situations

Closed loop systems:



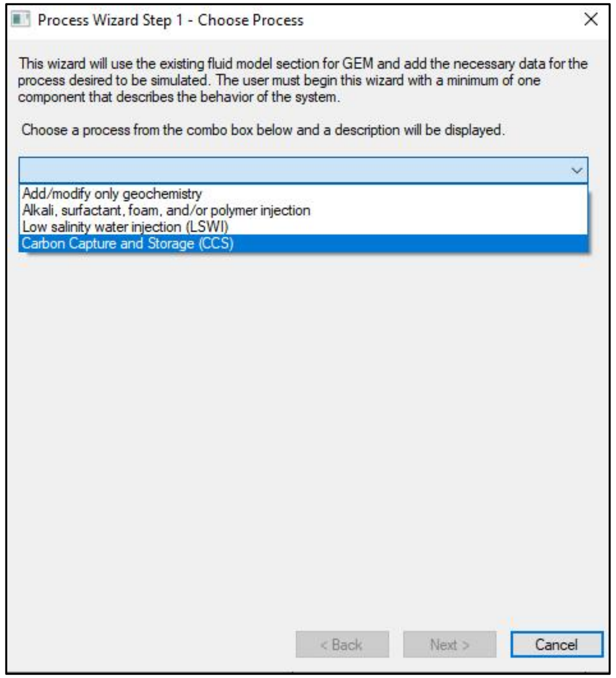
Source: Morita et. al., 2005

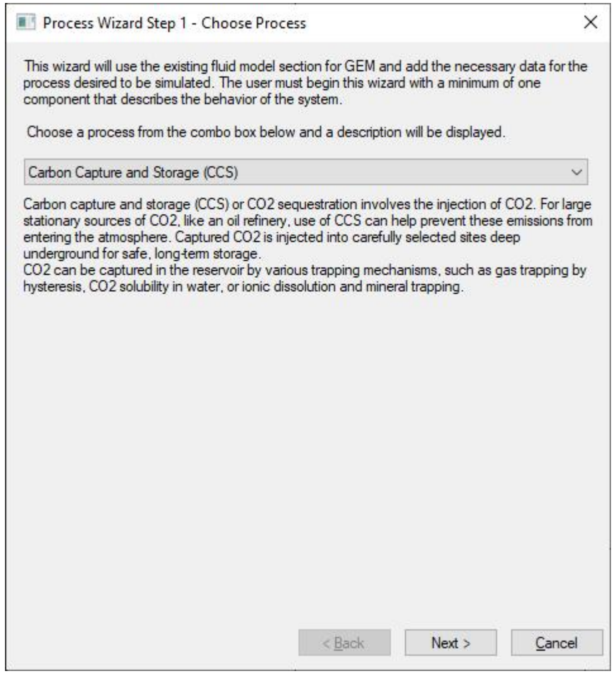


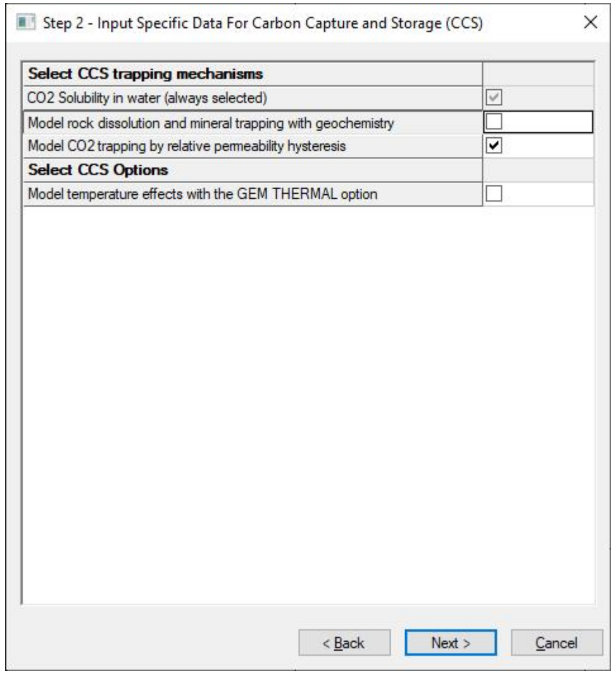
Source: Eavor.com

CCS Wizard

- New Carbon Capture and Storage (CCS) wizard in GEM.
- CO_2 can be captured in the reservoir by various trapping mechanisms, such as gas trapping by hysteresis, CO_2 solubility in water, or ionic dissolution and mineral trapping.





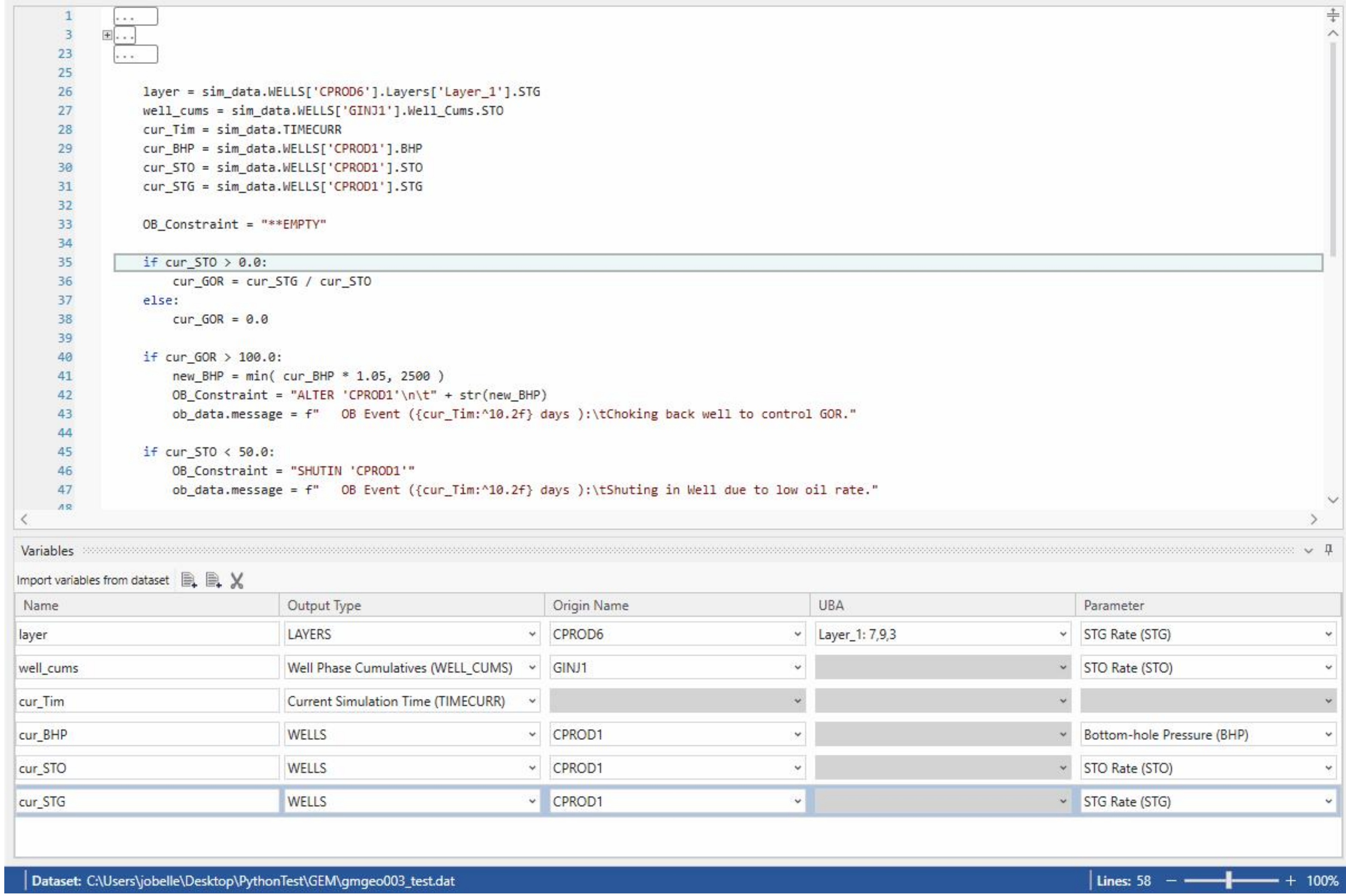


PyControl

Facilitates external control scripts in all 3 of our reservoir simulators

- Create your own well and group control strategies

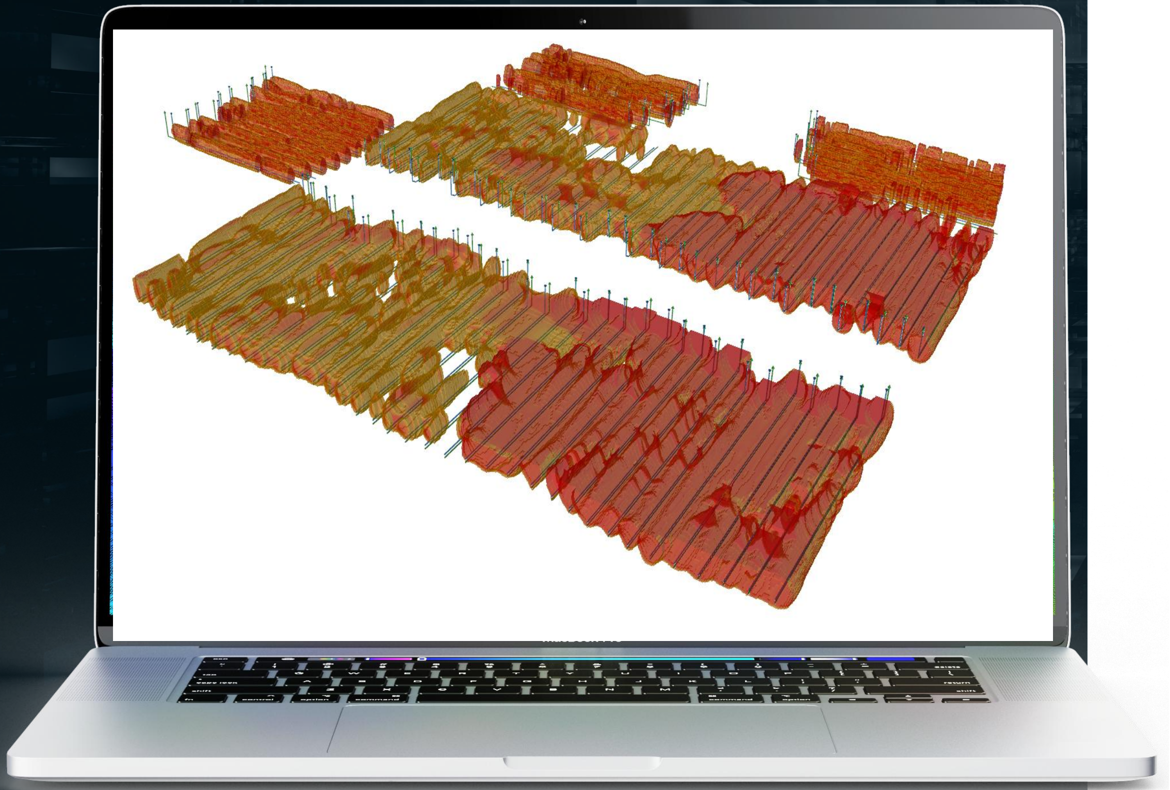
Editor environment that allows users to easily access the data from the simulator.



It’s all about Speed

Thermal heavy oil enhancements

4.5x **Speed enhancements with the latest CMG product release**



Become **EFFECTIVE** and **EFFICIENT**

CMG Unique Differentiators

- ✓ **NCG Injection**
- ✓ **Solvent-Steam Co-injection**
- ✓ **RF Heating**
- ✓ **DME Modelling**
- ✓ **Sensitivity Analysis and History Matching**

Dataset Type	Latest Release	Speedup vs 2021
SAGD (1.6MM Cells, full-pad)	4.5 hours	**2.8x**
SAGD (600K Cells, half-pad)	6.5 hours	**4.5x**
ES-SAGD	<3 hours	**1.6x**
CSS	4 minutes	**4.6x**

Automatic Combinative for speed

Automatic combinative now in STARS (with improved material balance)

- Useful in cases with numerical instabilities

Ex. Dual Permeability Steam Flood

Numerical Setup	Elapsed Time
Autotune Without Combinative	**~9 Hrs**
Autotune With Automatic Combinative	**~1.5 Hrs (6x speedup)**

Automatic combinative enhanced in IMEX by integrating with fluid type

- Noticeable benefit to performance for various situations (such as with near-incompressible fluids)

*COMBINATIVE AUTO

Updates to Promote Faster Simulations

v2023.20

Automatic solver partitioning

Enhancement to Automatic Tuning to allow simulators to switch between 1-D and 2-D partitioning during the run

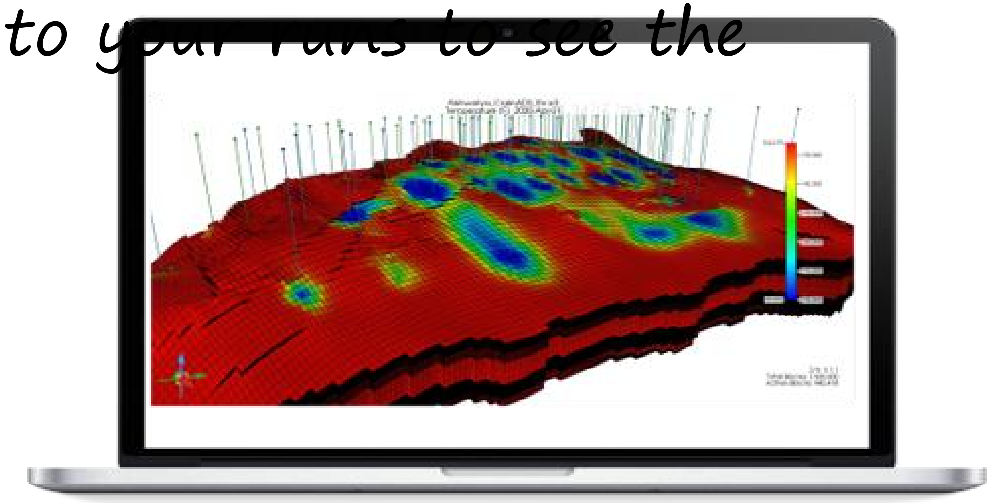
- Provides faster runs for a variety of simulation cases

New parallel solver option

- New option (*PDEGAB 0) can lead to faster parallel runs for many models
- We recommend adding the option to your runs to see the impact

Memory optimization for MPI

- Results in lower memory requirements for MPI (distributed computing) runs



MPI available for all simulators

Run large or field-scale models **efficiently** and **quickly**

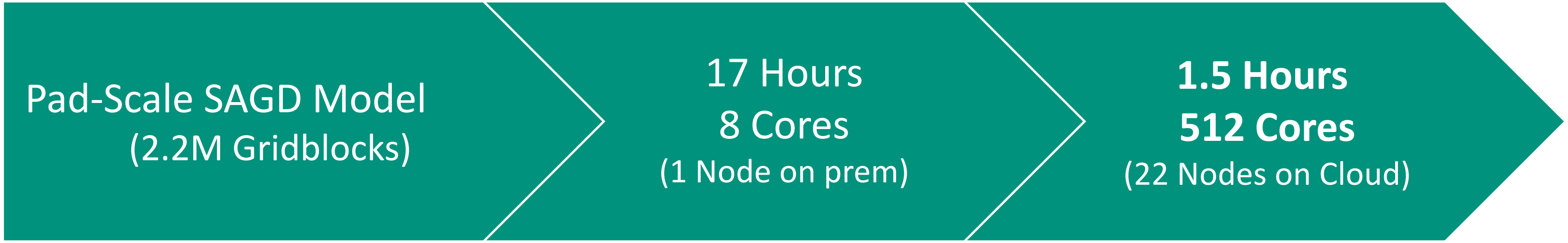
- Hybrid MPI deployed for: STARS, GEM, and IMEX
- Enables running models across 100's of cores, spread across multiple computers/nodes
- Also employs CMG's leading parallel technology within each node, ensuring optimal solution speed

Current Deployments:

- IMEX–v2023.19
- STARS–v2023.19
- GEM–v2020.32

Development focus

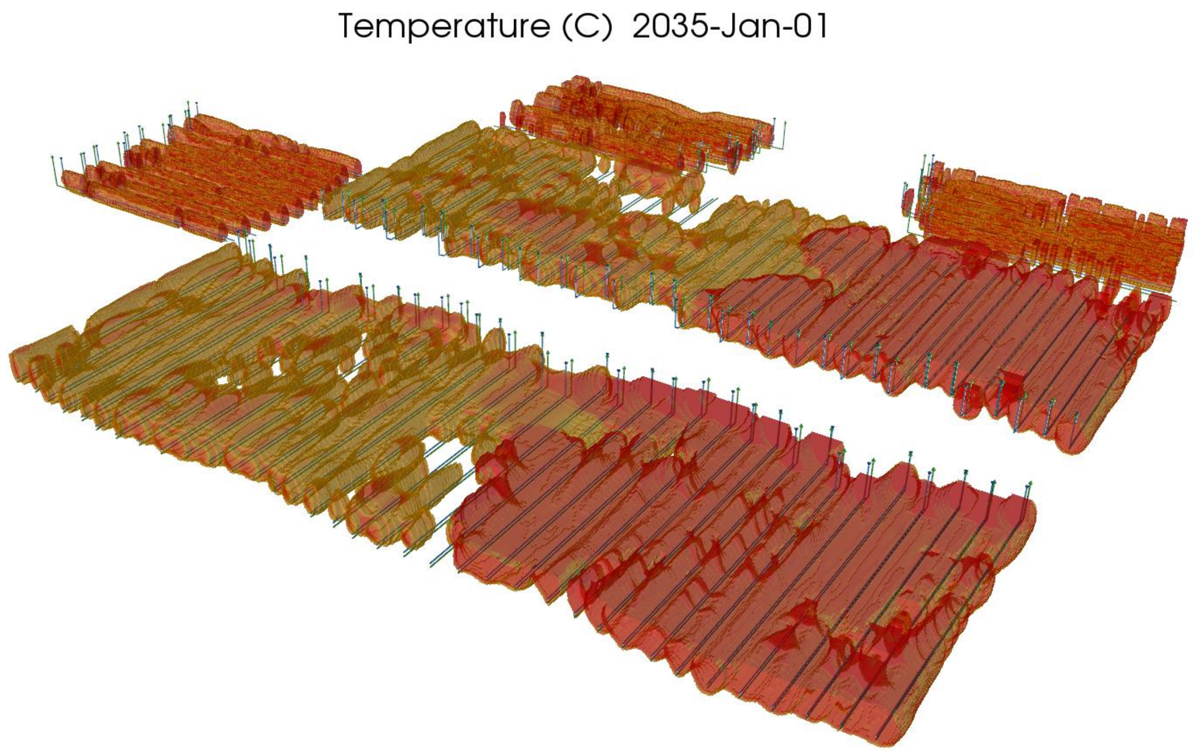
Greater analysis & understanding, in less time–
No matter the model size



STARS Parallel Partitioning Logic

Updated the logic behind model partitioning for running on multiple cores/CPUs

- Provides benefit at all ranges of cores



Overall Speedups (year-over-year comparison)

STARS Field-Model Benchmarks
(**Out-the-Box** comparisons)

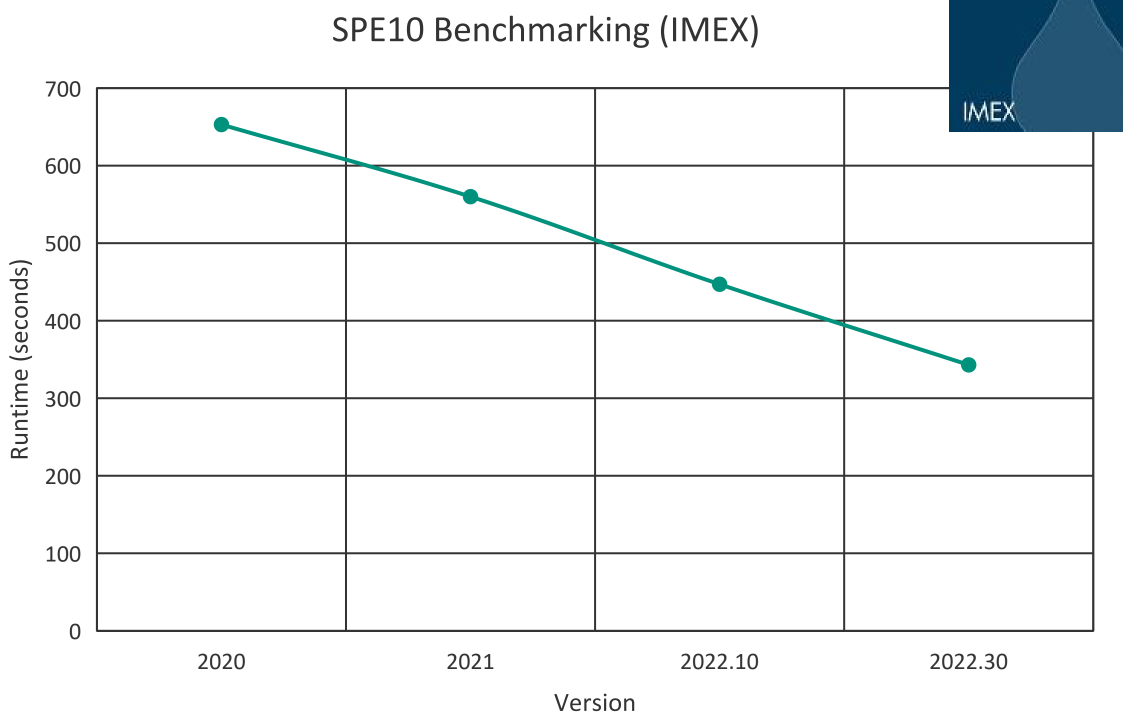
STARS

Dataset Type	2021.10 Release	2022.30 Release	Speedup
SAGD (1.6MM Cells, full-pad)	12.5 Hrs	4.5 hrs	**2.8X**
SAGD (600K Cells, half-pad)	10 hrs	6.5 hrs	**1.5X**
ES-SAGD	4 hrs	<3 hrs	**1.3X**
CSS	12 min	4 min	**3X**

Material Balance Error Improvement:

24-Wellpair SAGD Model
Mat Bal Error dropped- from 4.2% to 0.29% with faster runtime

IMEX



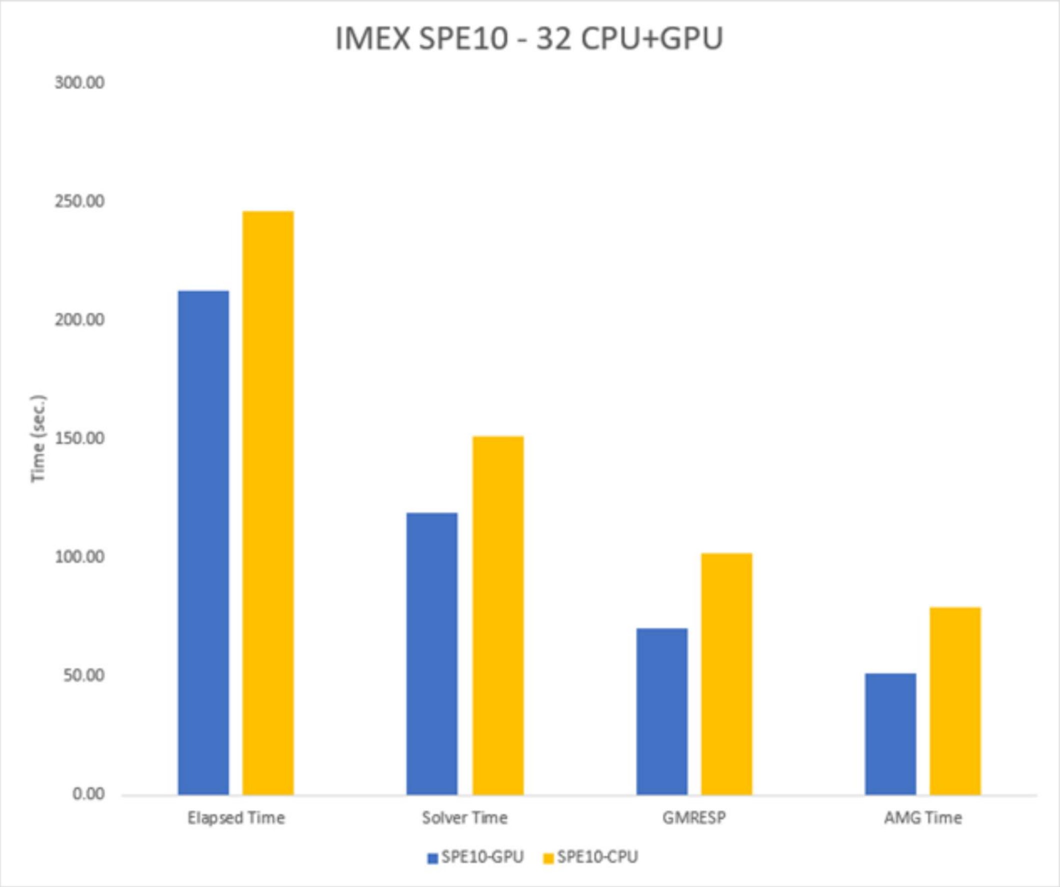
*Ran on 8-cores only

Future GPU Roadmap

CMG

Proof of GPU

In the past year we conducted two preliminary studies and developed proof-of-concept IMEX simulator where we were able to offload part of the linear solver workload to GPU.



Plot shows results of preliminary study

SPE10 benchmark model for IMEX CPU vs GPU-enabled pressure solver only on a gaming video card RTX3090

Demonstrated that acceleration was obtained even through GPU-deployment to a small part of the code

GPU Development Plan

Preliminary investigations conducted (FY24 Q1/Q2) demonstrated the feasibility of GPU solver technology for use with CMG simulators

Established partnership with NVIDIA

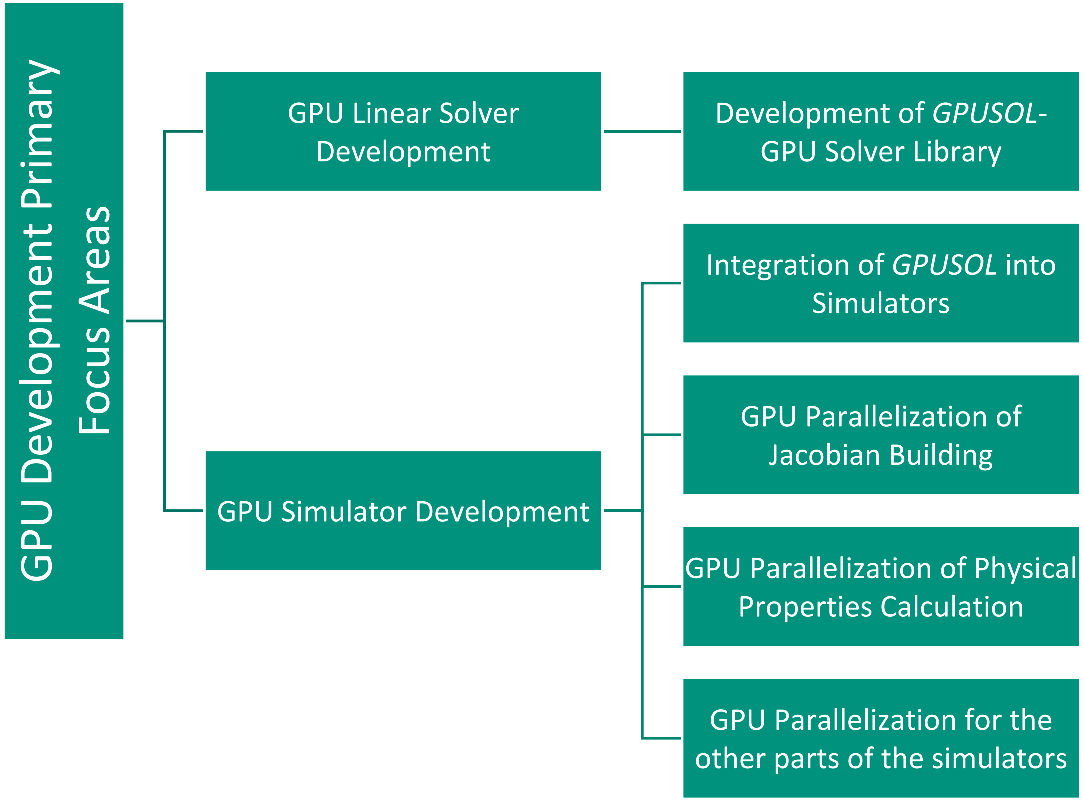
- NVIDIA working with CMG to implement GPU technology

Development split into 2 primary areas:

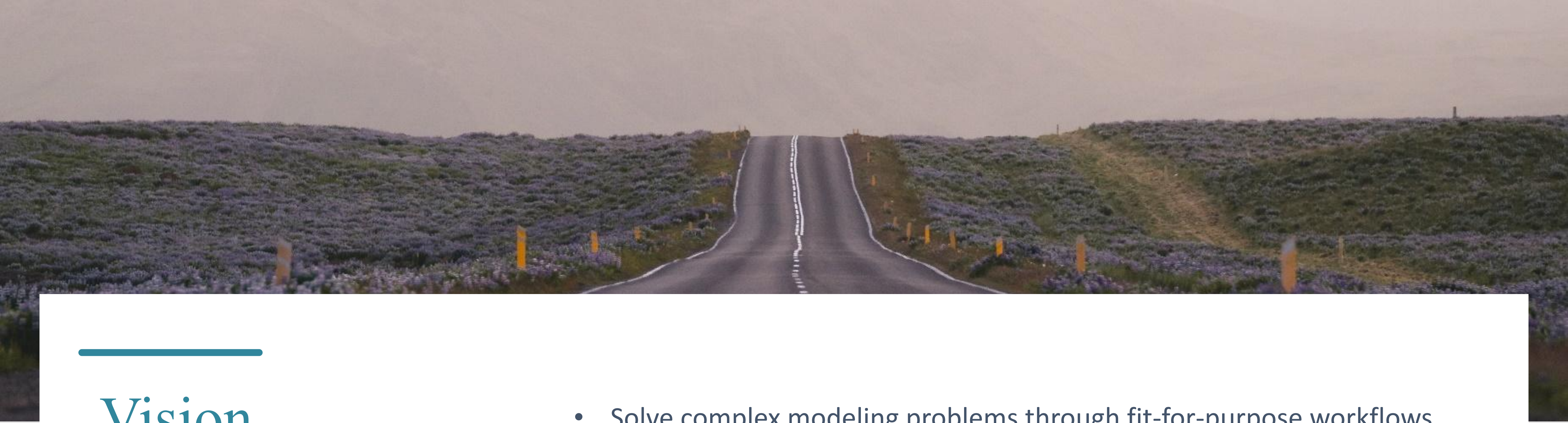
- Linear Solver Development
- General Simulator GPU Development

Current Plan

- IMEX Beta on GPU for March/April 2024
- GEM follow as the next deployment May/June 2024

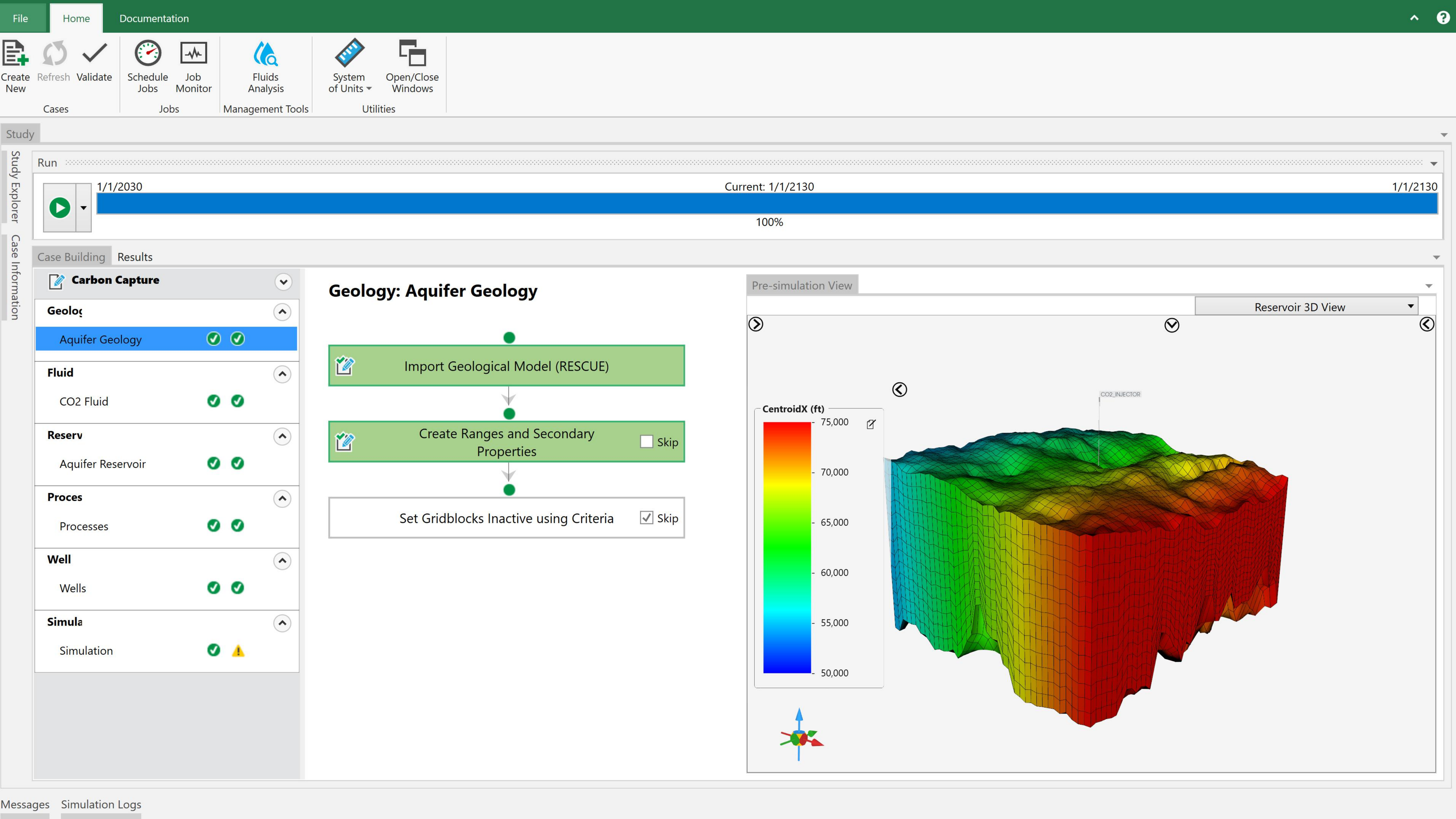


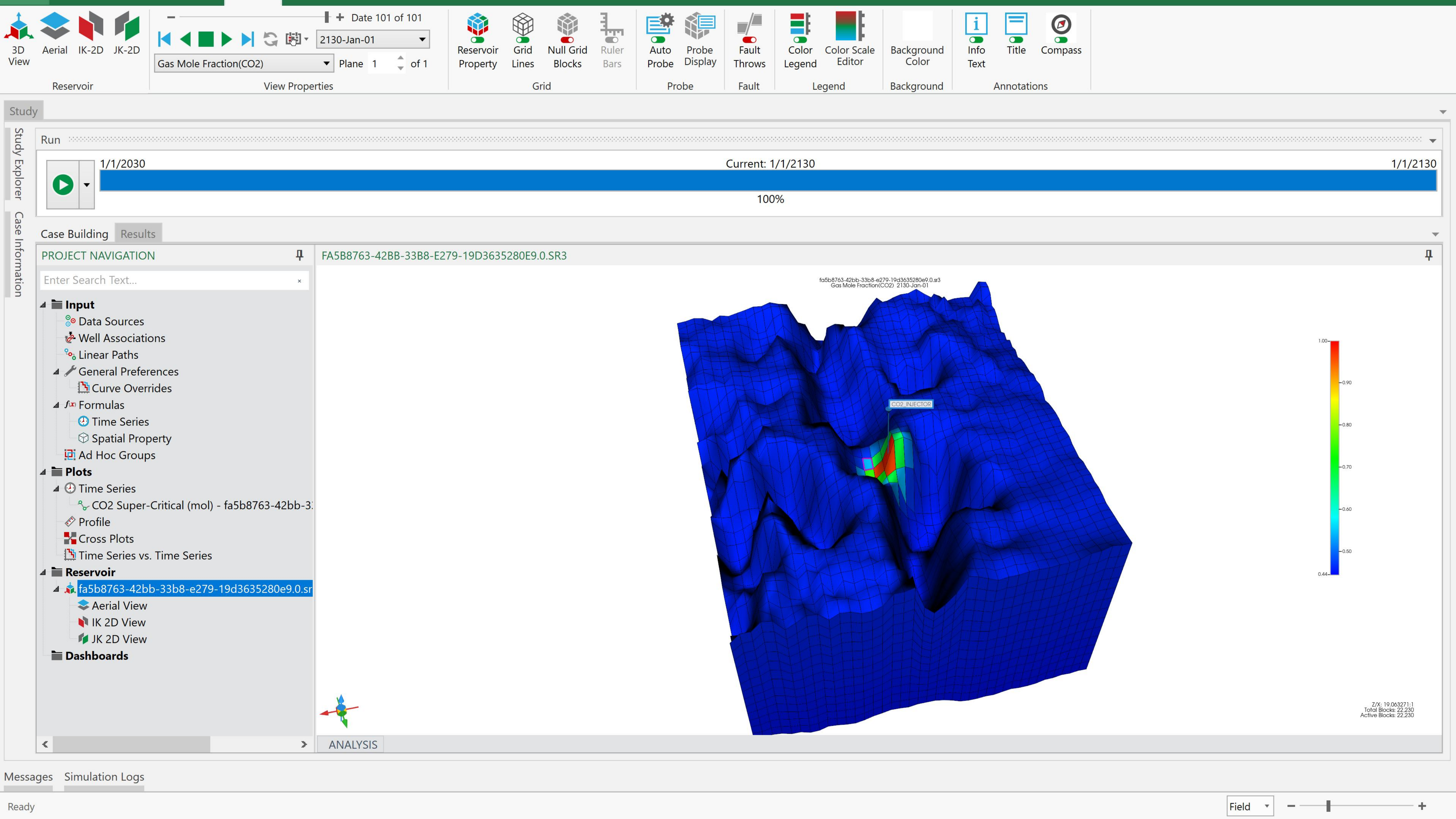
FOCUS CCS



Vision

- Solve complex modeling problems through fit-for-purpose workflows.
- FOCUS CCS – Saline Aquifer
- FOCUS CCS – DHR (Depleted Hydrocarbon Reservoir)
- FOCUS H2 – Hydrogen
- FOCUS GT – Geothermal


File
Home
Documentation
Create New
Refresh
Validate
Cases
Schedule Jobs
Job Monitor
Jobs
Fluids Analysis
Management Tools
System of Units
Open/Close Windows
Utilities
Study
Study Explorer
Case Information
Run
1/1/2030
Current: 1/1/2130
1/1/2130
100%
Case Building
Results
Carbon Capture
Geolog
Aquifer Geology
Fluid
CO2 Fluid
Reserv
Aquifer Reservoir
Proces
Processes
Well
Wells
Simula
Simulation
Geology: Aquifer Geology
Import Geological Model (RESCUE)
Create Ranges and Secondary Properties
Skip
Set Gridblocks Inactive using Criteria
Skip
Pre-simulation View
Reservoir 3D View
CentroidX (ft)
75,000
70,000
65,000
60,000
55,000
50,000
CO2_INJECTOR
Messages
Simulation Logs


3D View
Aerial
IK-2D
JK-2D
Reservoir
Date 101 of 101
2130-Jan-01
Gas Mole Fraction(CO2)
Plane 1 of 1
View Properties
Reservoir Property
Grid Lines
Null Grid Blocks
Ruler Bars
Grid
Auto Probe
Probe Display
Probe
Fault Throws
Fault
Color Legend
Color Scale Editor
Legend
Background Color
Background
Info Text
Title
Compass
Annotations
Study
Study Explorer
Case Information
Run
1/1/2030
Current: 1/1/2130
1/1/2130
100%
Case Building
Results
PROJECT NAVIGATION
Enter Search Text...
Input
Data Sources
Well Associations
Linear Paths
General Preferences
Curve Overrides
Formulas
Time Series
Spatial Property
Ad Hoc Groups
Plots
Time Series
CO2 Super-Critical (mol) - fa5b8763-42bb-3
Profile
Cross Plots
Time Series vs. Time Series
Reservoir
fa5b8763-42bb-33b8-e279-19d3635280e9.0.sr
Aerial View
IK 2D View
JK 2D View
Dashboards
FA5B8763-42BB-33B8-E279-19D3635280E9.0.SR3
fa5b8763-42bb-33b8-e279-19d3635280e9.0.sr3
Gas Mole Fraction(CO2) 2130-Jan-01
CO2_INJECTOR
1.00
0.90
0.80
0.70
0.60
0.50
0.44
Z/X: 19.063271:1
Total Blocks: 22,230
Active Blocks: 22,230
ANALYSIS
Messages
Simulation Logs
Ready
Field

General Development Direction

Speed

- Continue to improve AUTOTUNE; and Builder/Results performance – aim is for any interaction to take only a few seconds
- MPI availability in latest versions of all 3 simulators
- Partnership with nVidia to provide GPU implementation in 2024

Integrated Reservoir and Pipe Network

- CoFlow – separate talk on this product

Simplified workflows

- Builder Wizards
- Focus CCS