CMG COMPUTER MODELLING GROUP LTD.

CMG 2019新功能
What's New in General Release
2019.10

Future of Simulation

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Outline

- General Simulation
- Performance Enhancements
- Chemical EOR and Unconventional Reservoirs
- Builder
- Results
- CMG Cloud
- CoFlow-X

Why CMG ?

CMG delivers a paradox: fast answers from complex reservoirs with easy-to-use products and workflows.

CMG exceeds customer's expectations every year:

- By remaining focused on reservoir simulation
- By investing in Research & Development initiatives
- By providing unparalleled customer service

Product Suite

History Matching, Optimization & Analysis

Black Oil & Conventional

Compositional & Unconventional

Thermal & Advanced Processes

Integrated Asset Modelling

Visualization: Pre-Processing

Visualization: Post-Processing

Fluid Property Modelling

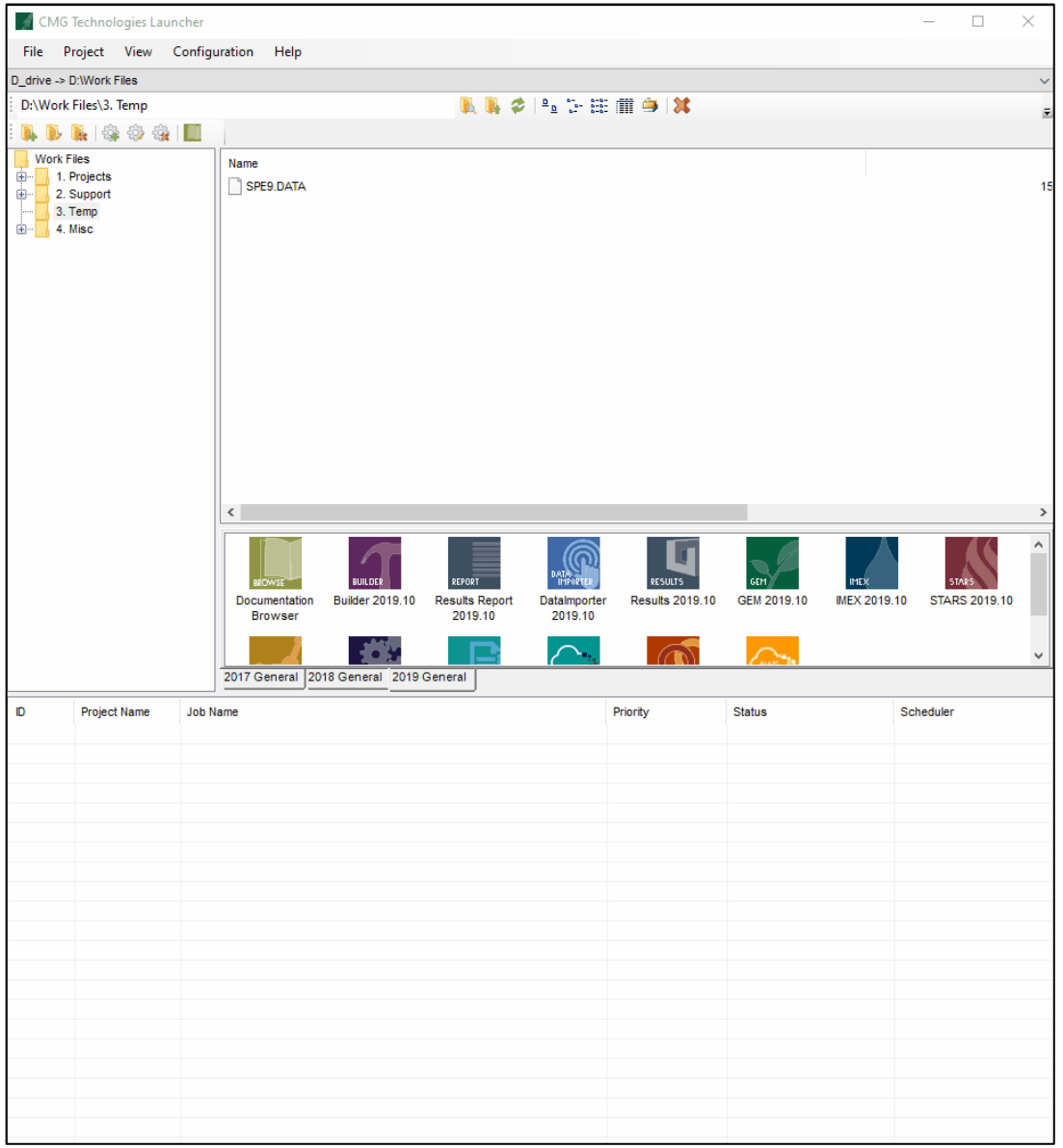
Reservoir & Production Modelling

General Simulation

Direct Run of ECL100 Datasets

Run Eclipse E100 datasets directly in IMEX.

IMEX now automatically recognizes ECL100 datasets, converts the datasets and runs them seamlessly.



Future of Simulation

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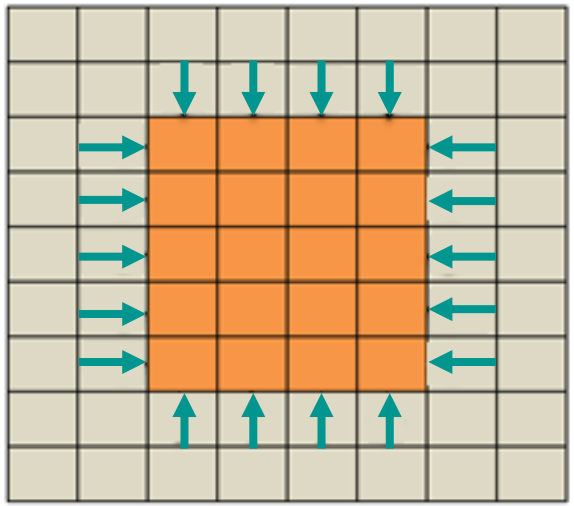
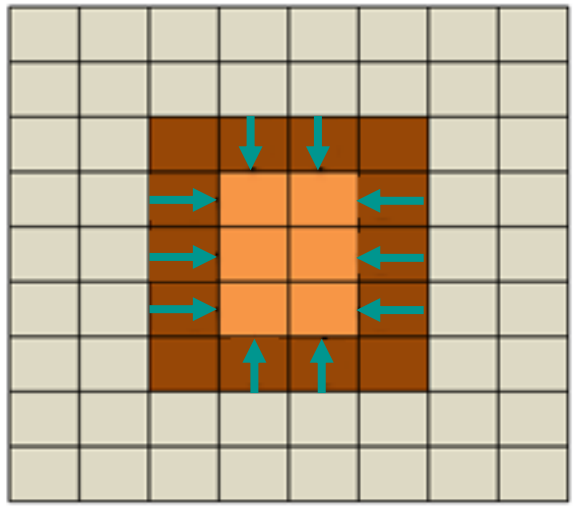
Flux Boundary

- Flux boundaries allow runs to be performed on a small section of a field using boundary conditions established from a full field run
- Flux boundary information can be recorded dynamically during a full-field run and retrieved as boundary conditions to enable the reduced run
- Two options are available for boundary types – flux & pressure



*FLXB-TYPE *FLUX



*FLXB-TYPE *PRESSURE

Cells not included in flux boundary, treated as null blocks in reduced run

Cells included in flux boundary

Border cells in which the primary variables are considered to be known during a time step

Trigger Enhancements

Add flexibility to simulations with complex, sophisticated logic using Triggers

Triggers allow users to specify a series of actions to be performed if specific conditions are met.

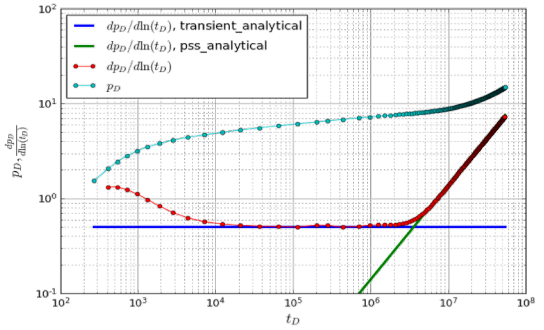
Several enhancements have been added to Triggers:

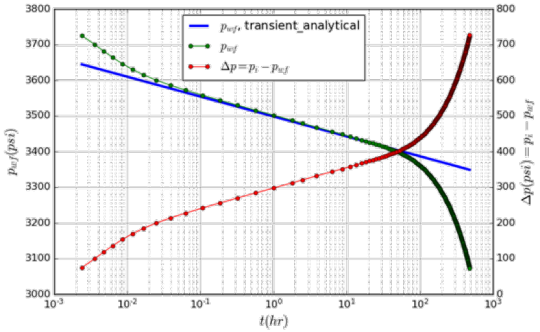
- Static Trigger Variables
  - KEYWORDS: TRGVARS
  - TEMPLATE: mxwwm083.dat, gmtrg030.dat
- Time delay between Actions
  - KEYWORDS: TIME_DELAY
  - TEMPLATE: gmtrg027-028.dat
- Output Trigger Variables

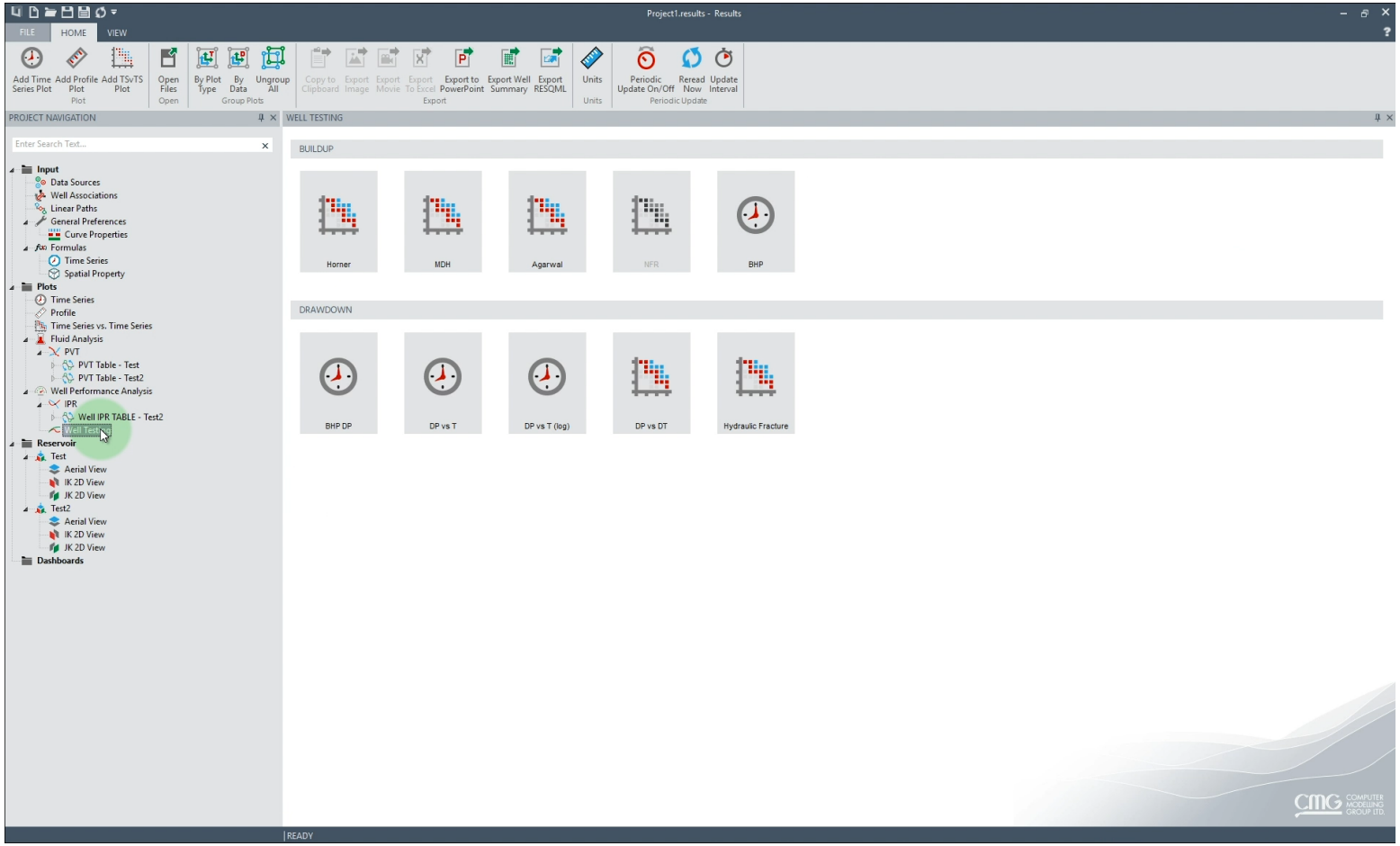
Well Testing Output

Users can now plot the following pressure-transient derivative curves with the click of a button:

- Horner
- MDH
- Agarwal
- NFR
- BHP
- BHP DP
- DP vs T
- DP vs T (log)
- DP vs DT
- Hydraulic Fracture







Future of Simulation

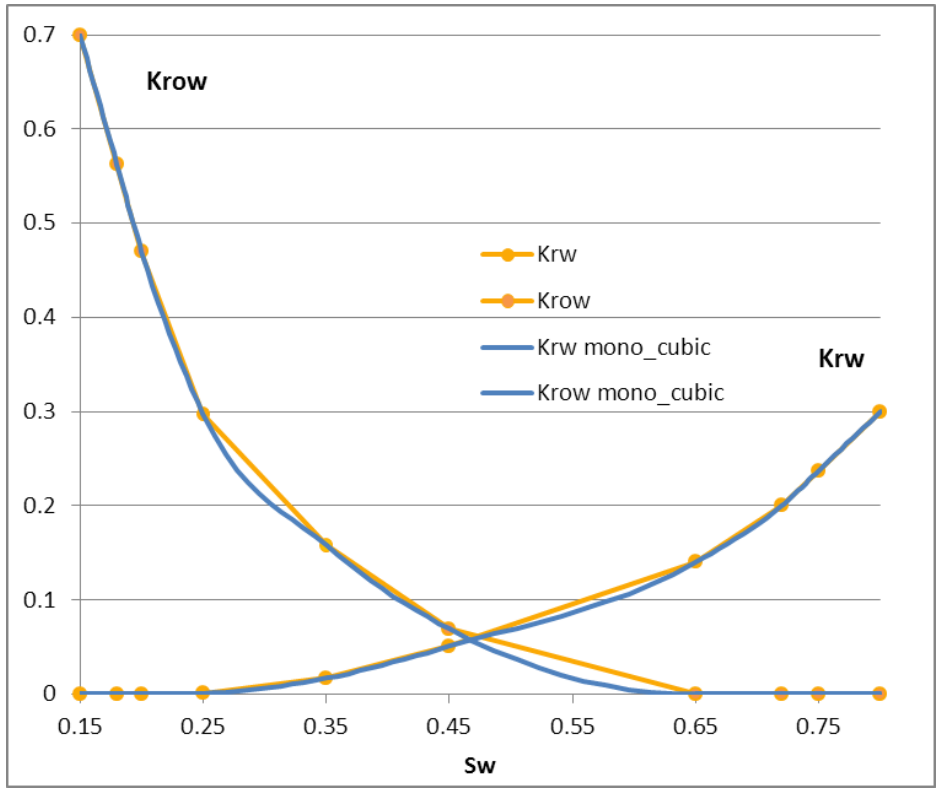
Miscellaneous

Aquifer – boundary flux & pressure

- Users can now define boundary flux or boundary pressure aquifers that can change over time.
  - KEYWORDS: AQMETHOD FLUX|PRESS

Monotone Cubic Interpolation for Relative Permeability

- Use the monotone cubic interpolation for more accurate and smoother interpolation of rock-fluid tables. The monotone cubic interpolation ensures the smoothest interpolation while maintaining monotonicity.
  - KEYWORDS: INTPL MONO-CUBIC
  - Template: mxsmo001.dat & mxfrr027.dat

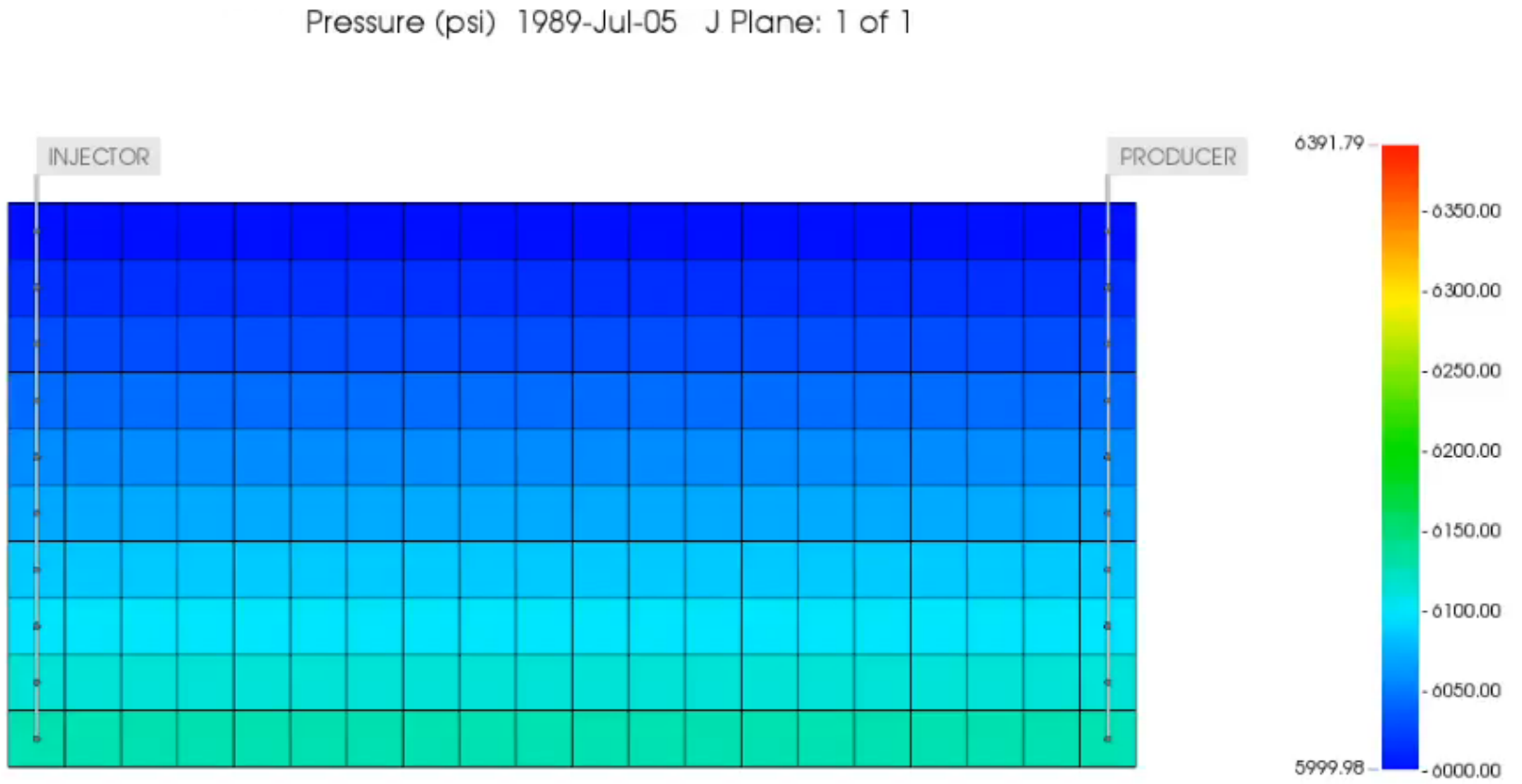


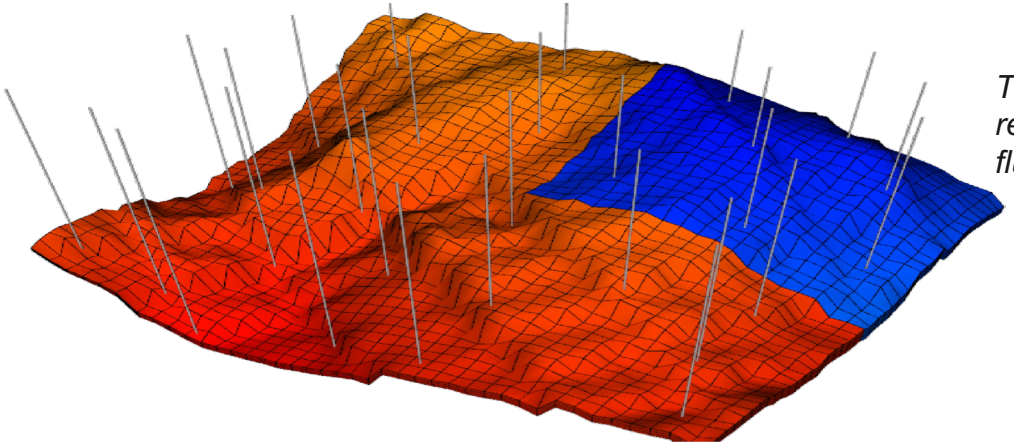
Monotone Cubic Interpolation for Relative Permeability

Threshold Pressure

The threshold pressure option prevents flow from immediately occurring across adjacent initialization regions and/or fault planes, until the potential difference exceeds a desired threshold value.

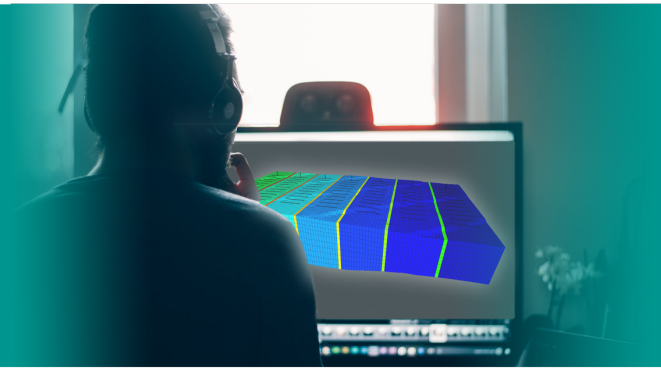
- KEYWORDS:
  PTHRESH-IREGN
  PTHRESH-FAULT
- Template:
  gmgro024.dat





Threshold pressure provides a more accurate representation of the reservoir's geology and fluid flow.

Performance Enhancements

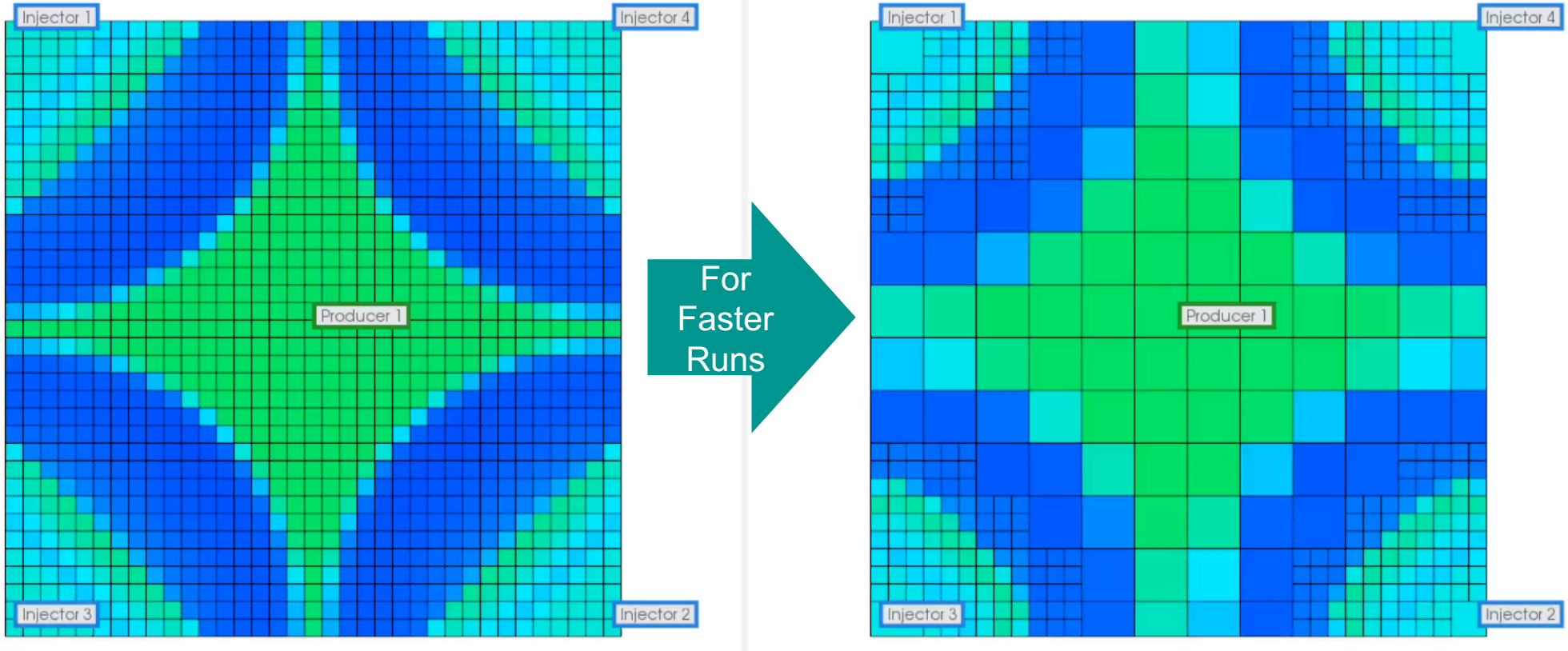


New in 2019.10: Performance

- DynaGrid – now available in IMEX
- Autotune-AI – now available in IMEX
- Conjugate Gradient Solvent for faster geomechanical simulation
- Combinative ILU Preconditioner

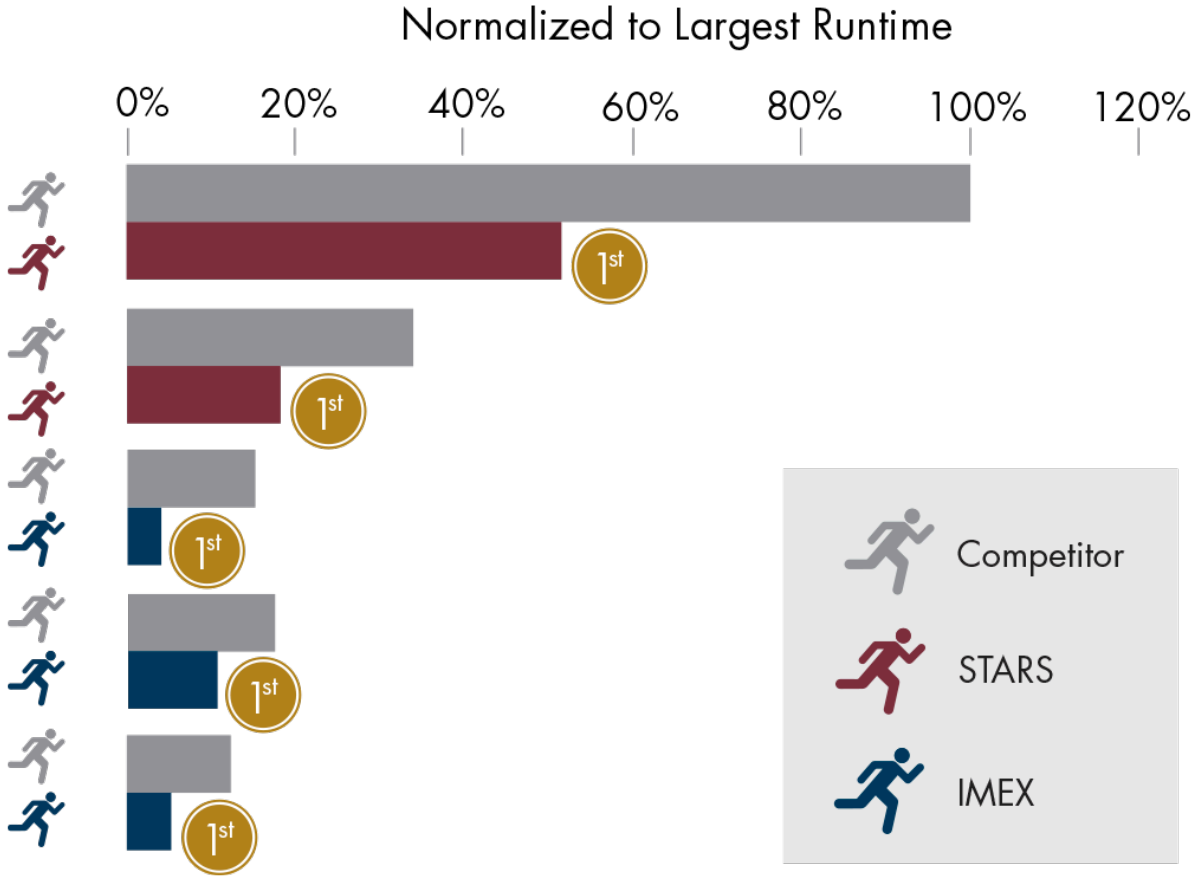
DynaGrid

Use DynaGrid (dynamic gridding) to achieve faster IMEX runs. Amalgamate grid-blocks based on pressure or phase saturation gradients.



Autotune-AI

- Artificial intelligence-based adaptive time stepping control
- Apply the optimal numerical settings beneficial to your specific models and processes
- Now available in IMEX
  - Keyword: AUTOTUNE



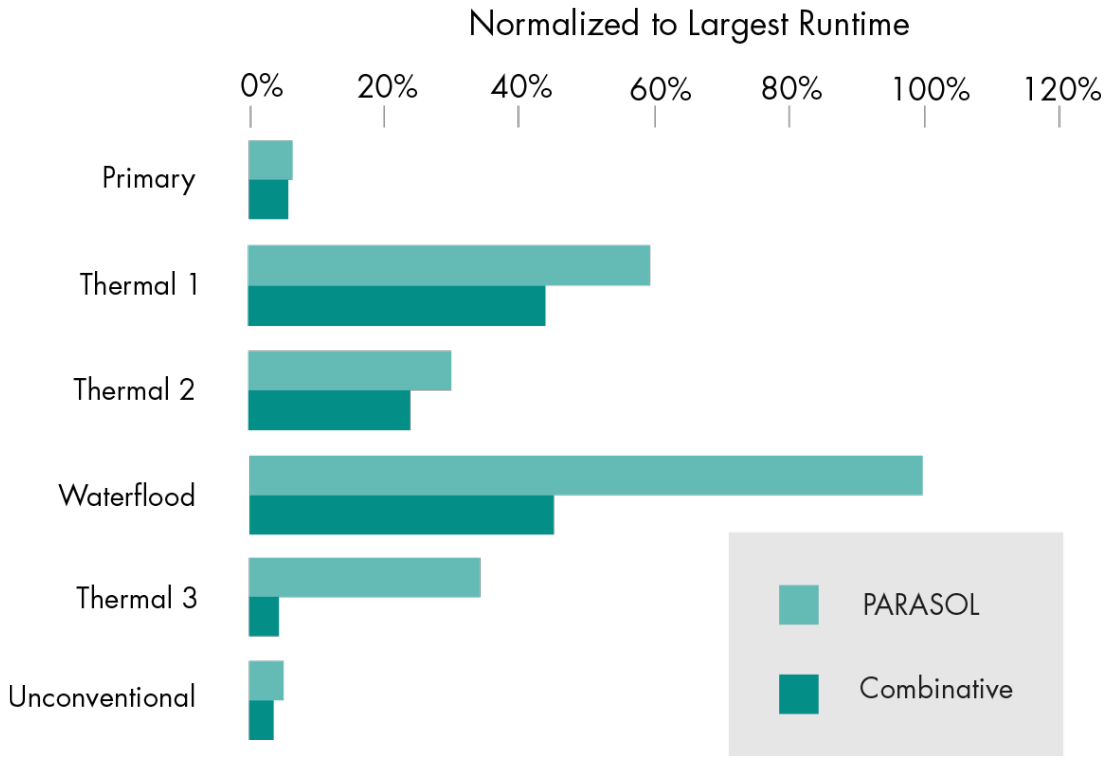
Geomechanics Solver

Achieve 10% to 40% speed-up with CMG's new Preconditioned Gradient Linear Solver (PCG). Large geomechanical models will achieve faster run times and be more memory efficient.

Keyword: SOLVERG PCG

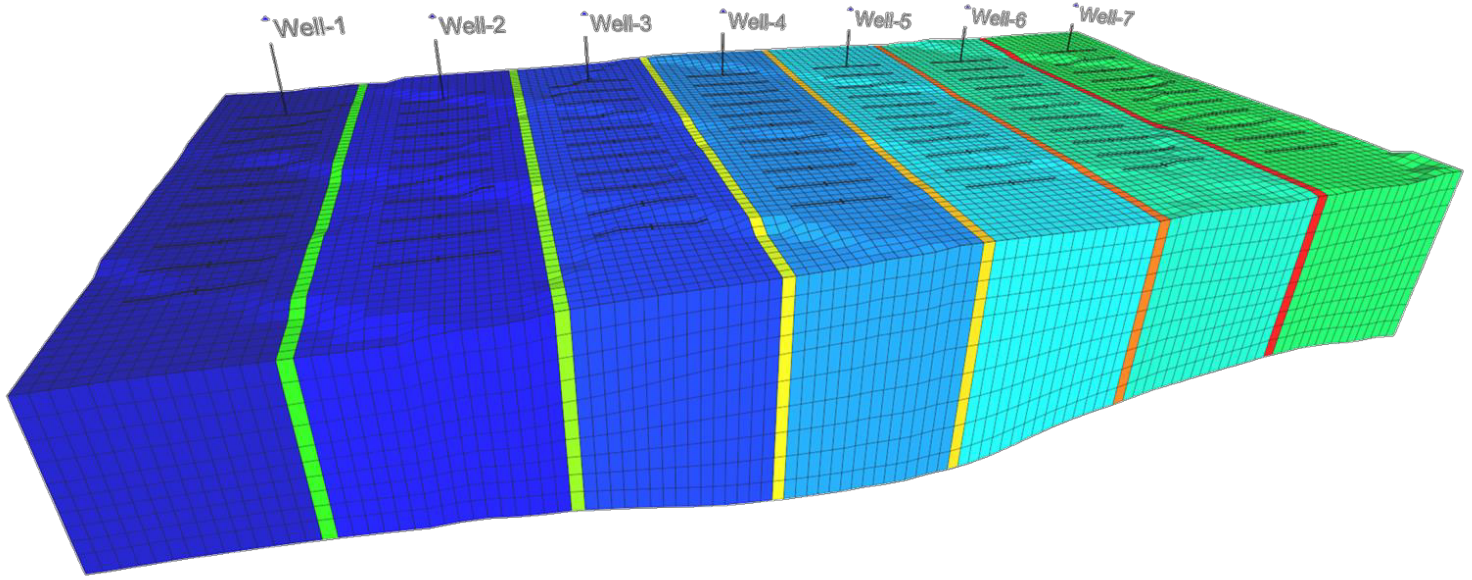
Combinative ILU Preconditioning

- Achieve even faster simulator runtimes for large models, with the improvements in preconditioning for the combinative solver
- An optional ILU solver can be used to approximately solve for the pressure equation before updating the whole flow system using the parallel solver *PARASOL
- This combinative two-stage preconditioner is recommended for large models (over 25,000 grid cells) that requires between 20-40 solver iterations per Newton cycle
    - Keyword: COMBINATIVE ILU



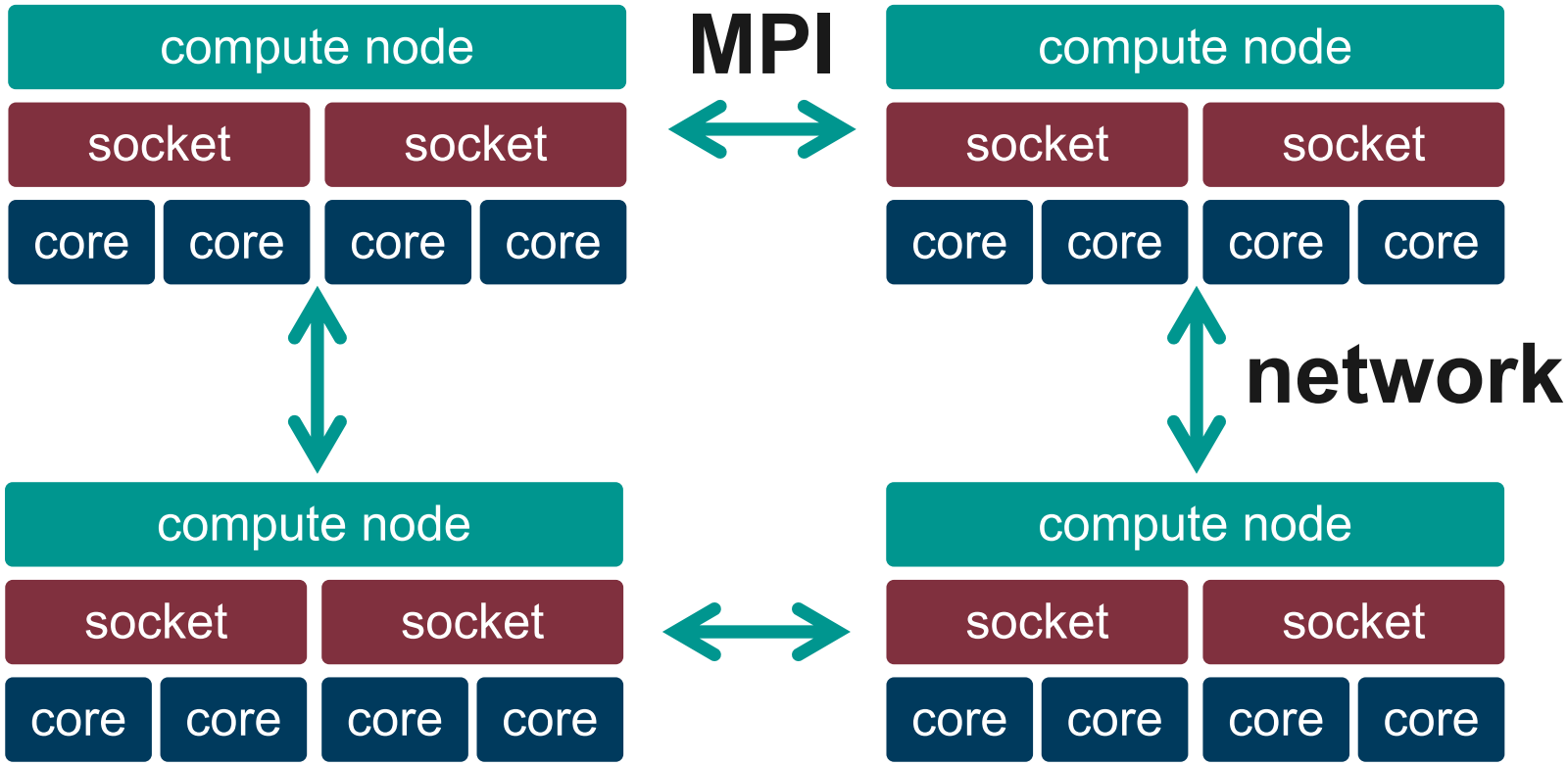
MPI Parallel Processing

Use the cloud to run field-scale reservoir models faster by using CMG's Hybrid MPI technology (also known as distributed computing)



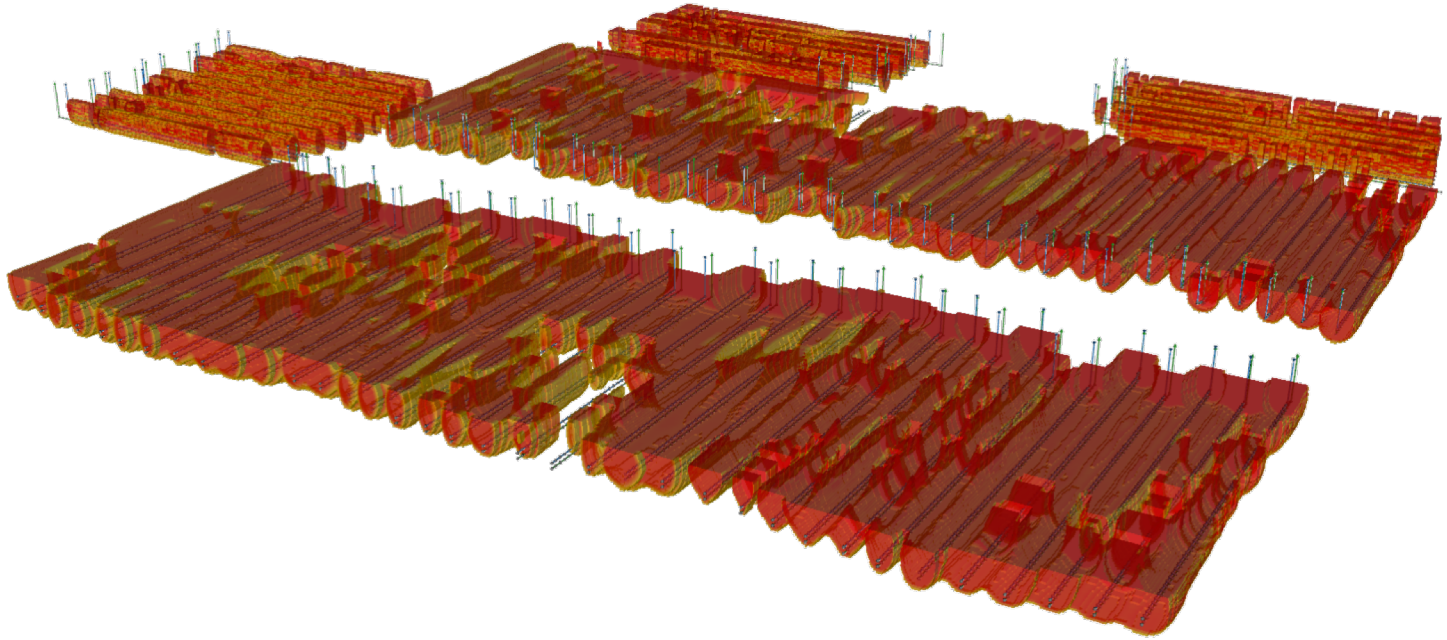
MPI Parallel Processing

Distributing a single simulation over multiple machines in a cluster



MPI Parallel Processing

- More cores
  - Faster run times
  - Cheaper runs on CMG Cloud
  - Faster time to decision
- More total memory
  - Larger reservoirs



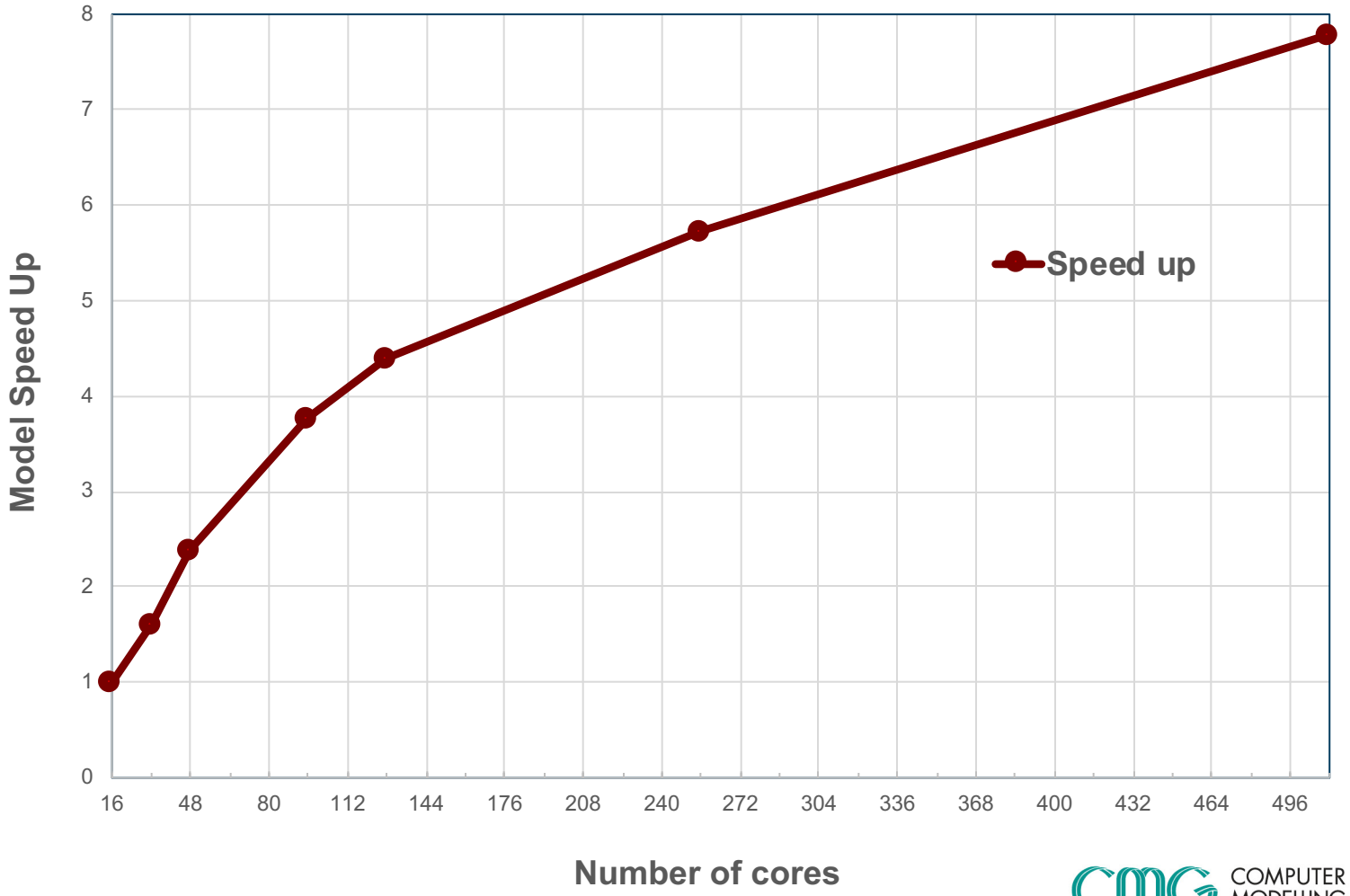
MPI Parallel Processing

Model information:

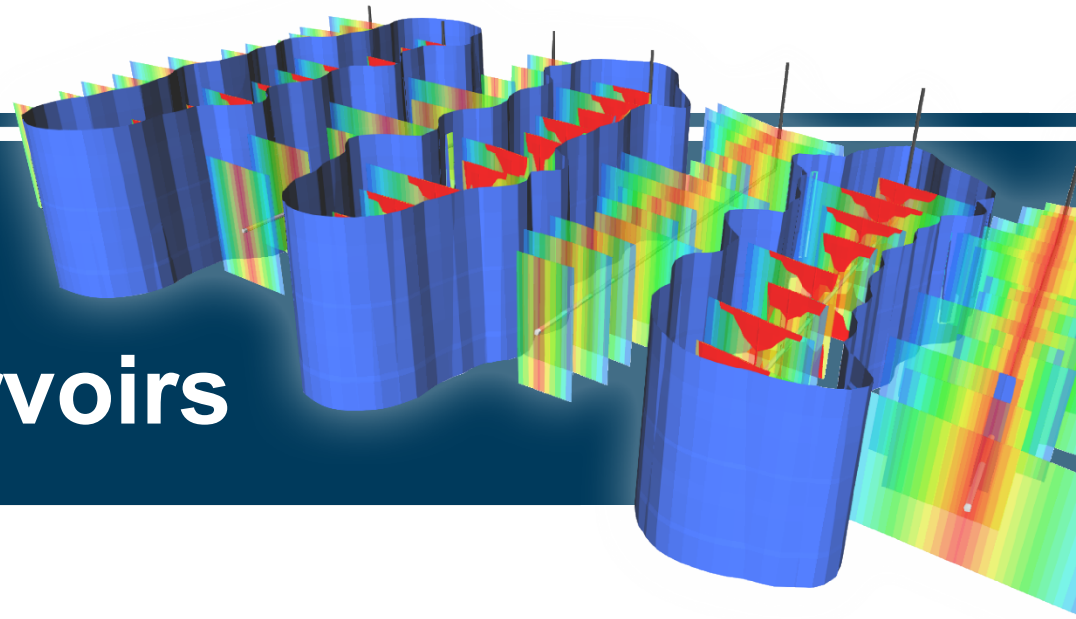
- SAGD pad model with 8 well pairs
- 1 million active grid blocks
- 7 years of simulation time

Simulation information:

- Model ran as received from client, no additional changes were made
- Autotune is on



Chemical EOR & Unconventional Reservoirs



Review of Chemical EOR Modelling

Polymer Modelling	IMEX	GEM	STARS
Composition Effect on Viscosity	✓	✓	✓
Salinity Effect on Viscosity	✓	✓	✓
Shear/Velocity Effect on Viscosity	✓	✓	✓
Temperature Effect on Viscosity	-	✓	✓
Degradation	-	✓	✓
Resistance due to adsorption	✓	✓	✓
Wettability Alteration	✓	✓	✓
Alkaline & Surfactant Modelling			
Adsorption	-	✓	✓
IFT Reduction	-	✓	✓
Wettability Alteration	-	✓	✓
Surfactant Partitioning	-	✓	✓
Surfactant in-situ (soap)	-	✓	✓
Microemulsion Viscosity	-	Oleic Phase Only	✓
Salinity Gradient	-	SP Only	✓
Geochemistry Modelling			
Ion Exchange	-	✓	✓
Precipitation/Dissolution of Minerals	-	✓	✓
pH dependent adsorption	-	✓	✓
Gel Modelling	-	✓	✓
Foam Modelling			
Empirical model	-	✓	✓
Mechanistic Model	-	✓	-

New in 2019.10: Chemical EOR

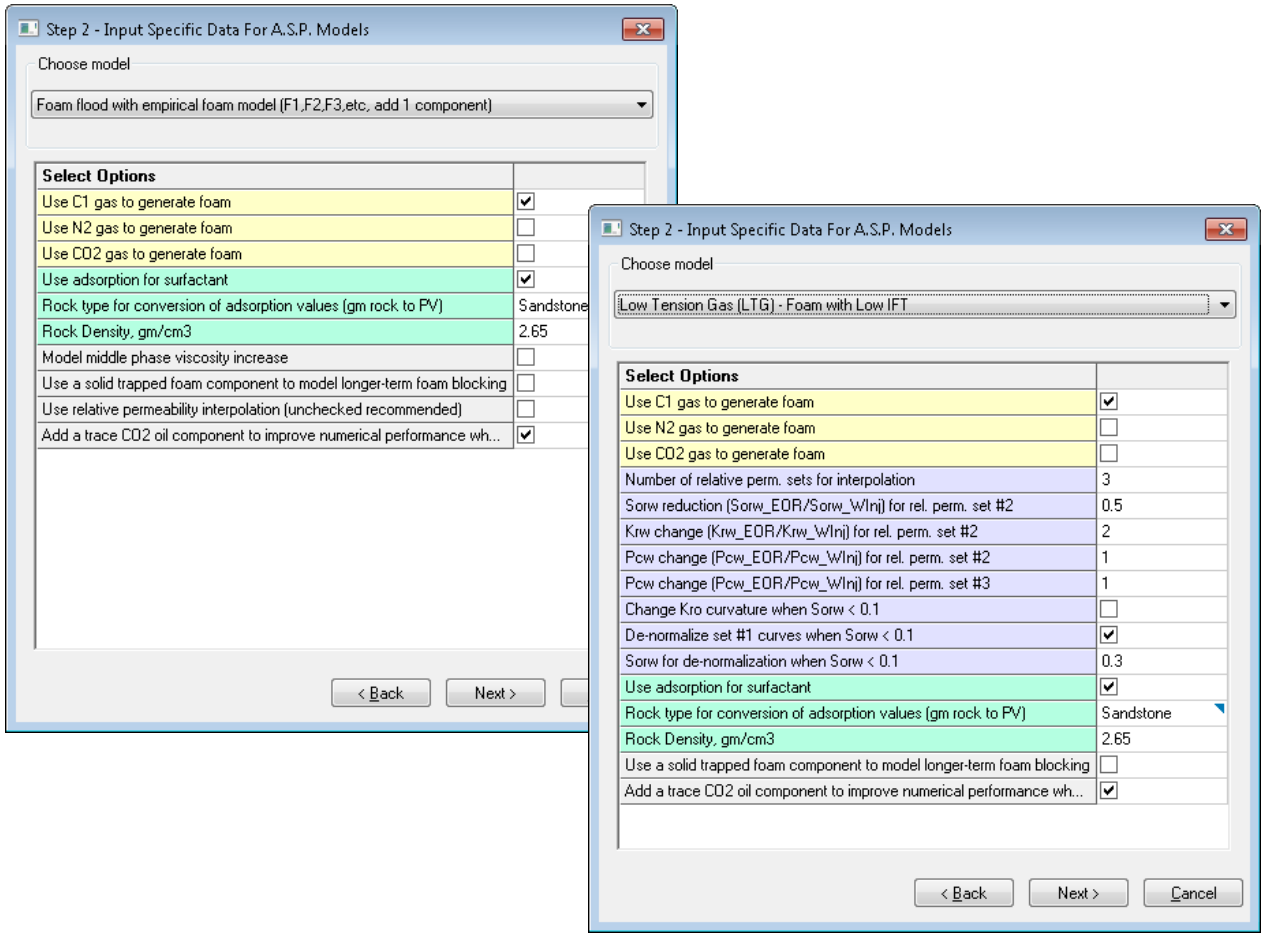
- Process Wizard Improvements
- Polymer/Salt Solution Viscosity Table
- New RPT Interpolation Variables
- ASP Modelling in GEM
- Passive Tracer
- Anisotropic Rocks

Chemical EOR: Process Wizard Improvements

GEM process wizards for:

- Low Tension Gas (LTG)
- Foam flooding

Improved polymer wizard in STARS and GEM



Polymer/Salt Solution Viscosity Table

Model the effect of salinity on polymer solution viscosity as a function of polymer concentration.

Alternative to the correlation of VSSALTCMP

- Keyword: PMIX SALTABLE

```
*PMIX *SALTABLE
SLN 0  **SALINITY
0.0     1.000000    ** POLYMER CONC. & MIXTURE VISCOSITY
0.1     1.687096
0.2     2.374193
0.3     3.061290
0.4     3.748387
0.5     4.435483
0.6     5.122580
0.7     5.809677
SLN 9.0
0.0     1.100000
0.1     1.787096
0.2     2.474193
0.3     3.161290
0.4     3.848387
0.5     4.535483
0.6     5.222580
0.7     5.909677
```

New RPT Interpolation Variables

Interpolate between relative permeability tables based on Pressure or Polymer Adsorption.

Model the effect of pore pressure and polymer adsorption on relative permeability using IMEX's new Relative Permeability Interpolation option.

Keyword: INTCOMP PRES|POLYADS

Geochemistry Enhancements

Damping of Chemical Reactions

By default, chemical reactions are assumed to be instantaneous. A new rate-based treatment is implemented to mimic non-instantaneous chemical reactions.

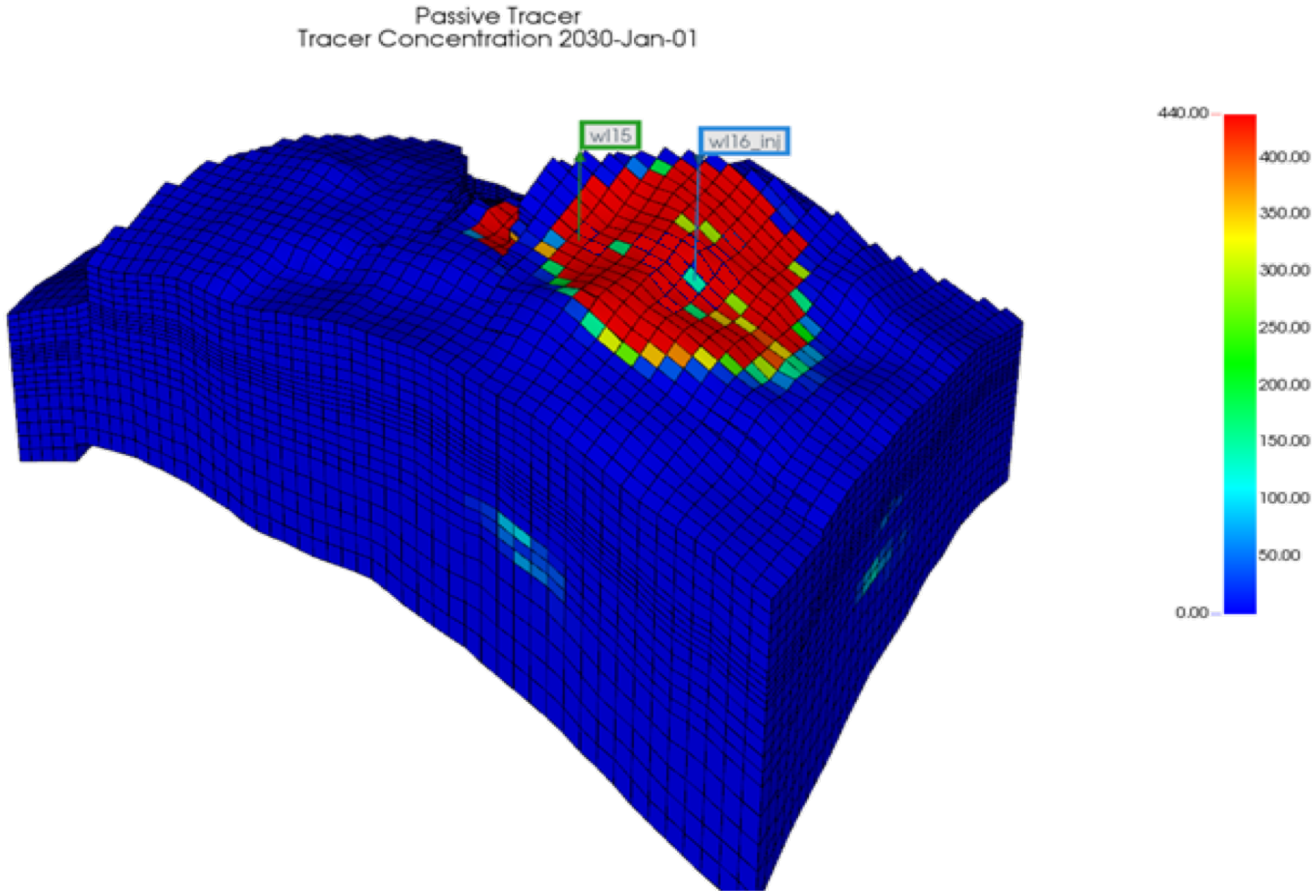
These rate-based formulations can be applied to any geochemical reactions and have been found to help with numerical stability, resulting in much faster run times on your datasets.

Keyword: CRDAMP-ALL; CRDAMP
Template: gmghg033.dat

Passive Tracer

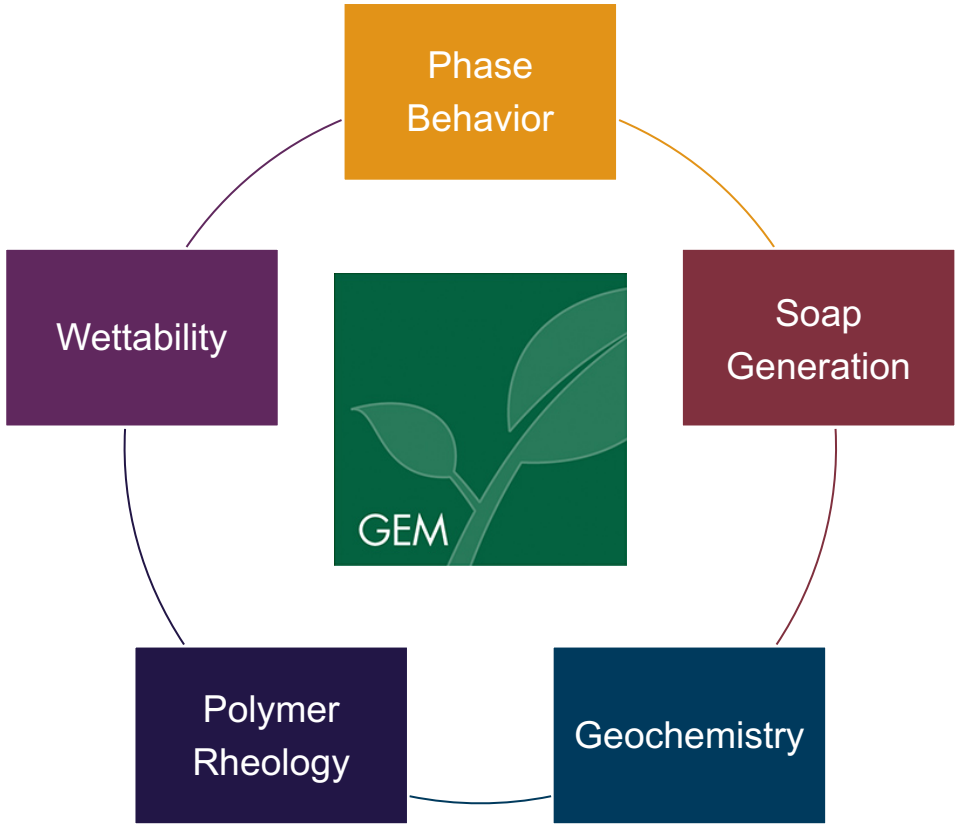
- Use IMEX's new Passive Tracer option to track fluid movement from desired reservoir regions, injection wells, and aquifers.
- Tracer can be defined as partitioning tracer between liquid-gas and liquid-liquid phases.
- Other functionalities include reversible and irreversible adsorption of tracer to reservoir rock, molecular diffusion mechanism, and physical dispersion due to mechanical mixing.

Keyword: TRACER
Template: mxtrc001-020.dat



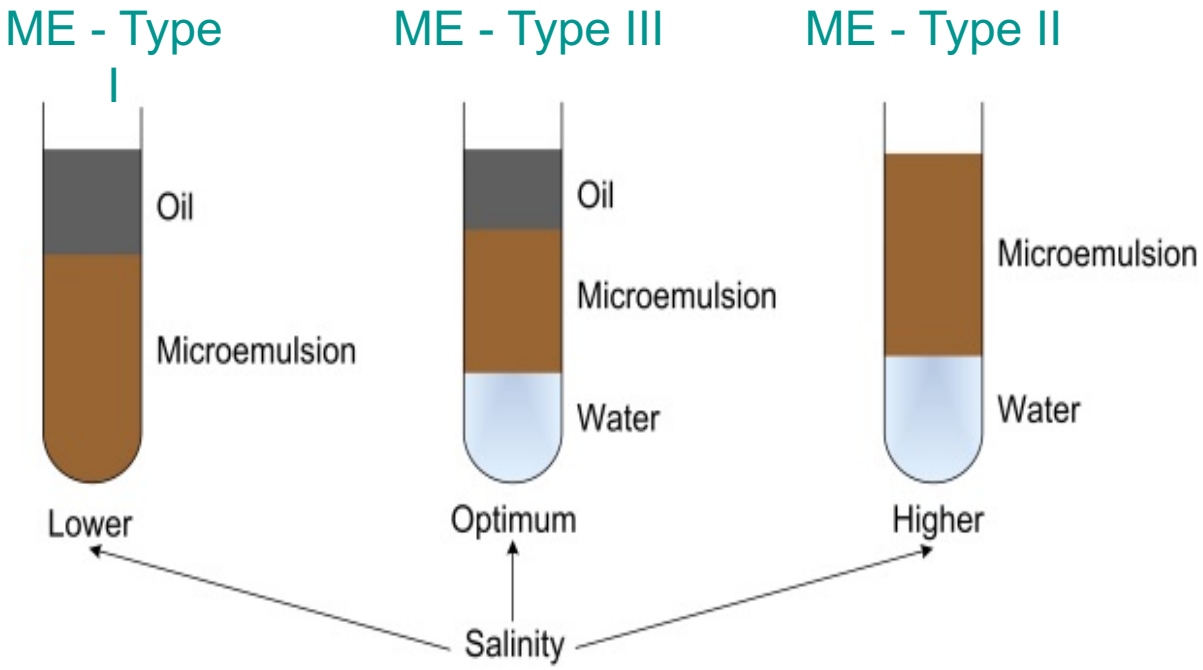
ASP Modelling in GEM

Model Alkali-Surfactant-Polymer injection in GEM



ASP Modelling in GEM

Microemulsion Phase Behavior

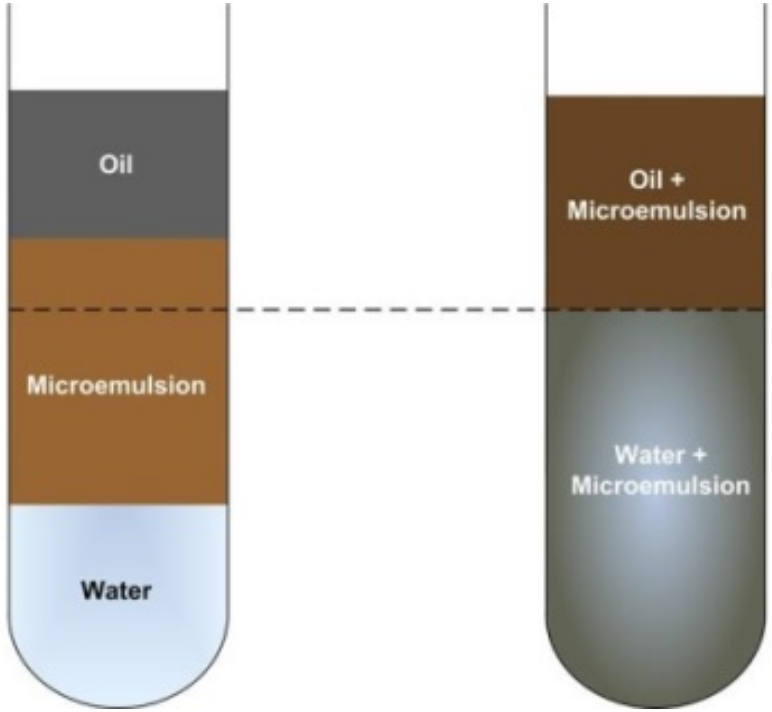


ASP modeling with 3 phases is computationally intensive and imposes a limitation for field-scale simulations.

Future of Simulation

Conventional Approach

New Approach SPE 179559



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ASP Modelling in GEM

Mechanistic modeling approach built in a robust EOS simulator allows to:

- Model emerging EOR processes: e.g. Low Salinity Waterflooding
  - SPE 166447; SPE 173194; SPE 174294; SPE 180089; SPE 188219
- Model sequential recovery injection: e.g. HSW + LSW + Chemical/Gas Flooding
  - SPE 187132
- Model hybrid EORs: e.g. Low Tension Gas, Low Salinity Chemical Flooding, Low Salinity WAG
  - SPE 169071, SPE 179550; SPE 165903

Anisotropic Rocks

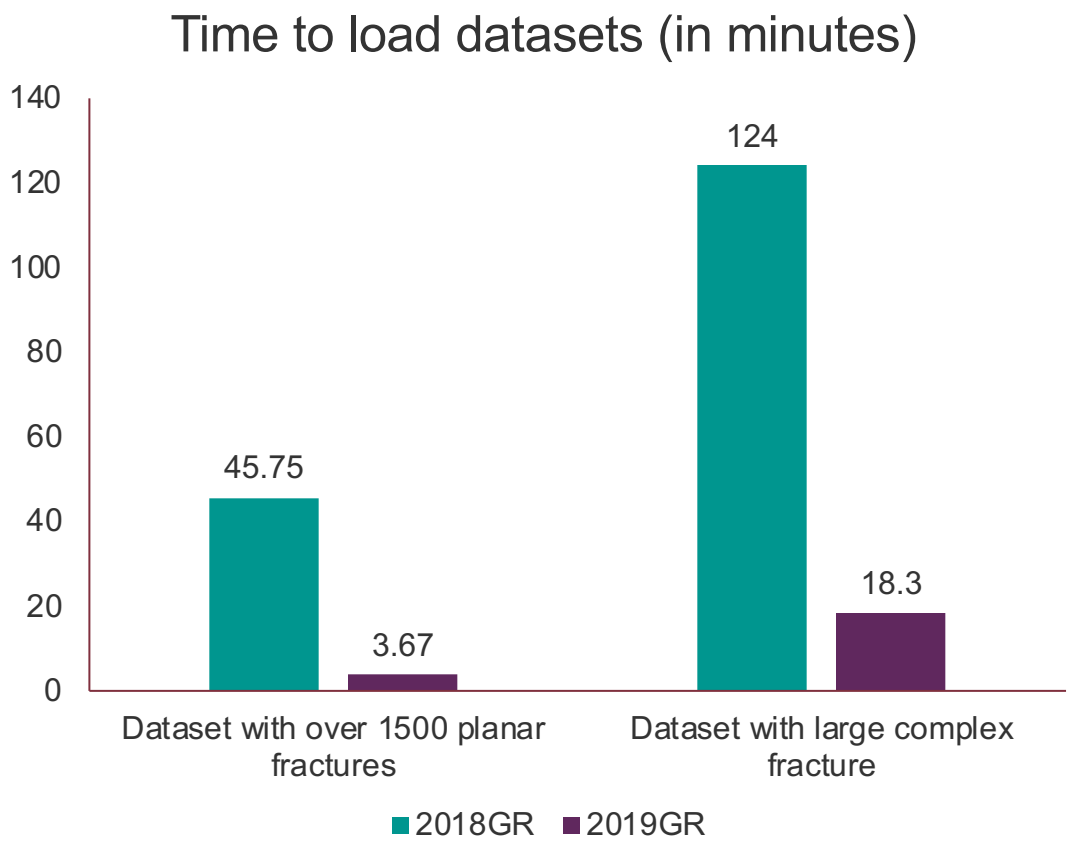
- Define anisotropic geomechanical properties to grid-blocks to accurately capture geomechanical effects.
- Properties such as Young's Modulus; Poisson's Ratio and Biot's coefficients can now be modelled as direction dependent properties.
  - Keywords: ELASTMODI, ELASTMODJ, ELASTMODK, POISSRATIOIJ, POISSRATIOIK, POISSRATIOJK, BIOTSCOEFI, BIOTSCOEFJ, BIOTSCOEFK
  - Templates: mxgmc096-097.dat, gmgmc082-083.dat, stgeo096-097.dat

BUILDER

New in 2019.10: Builder

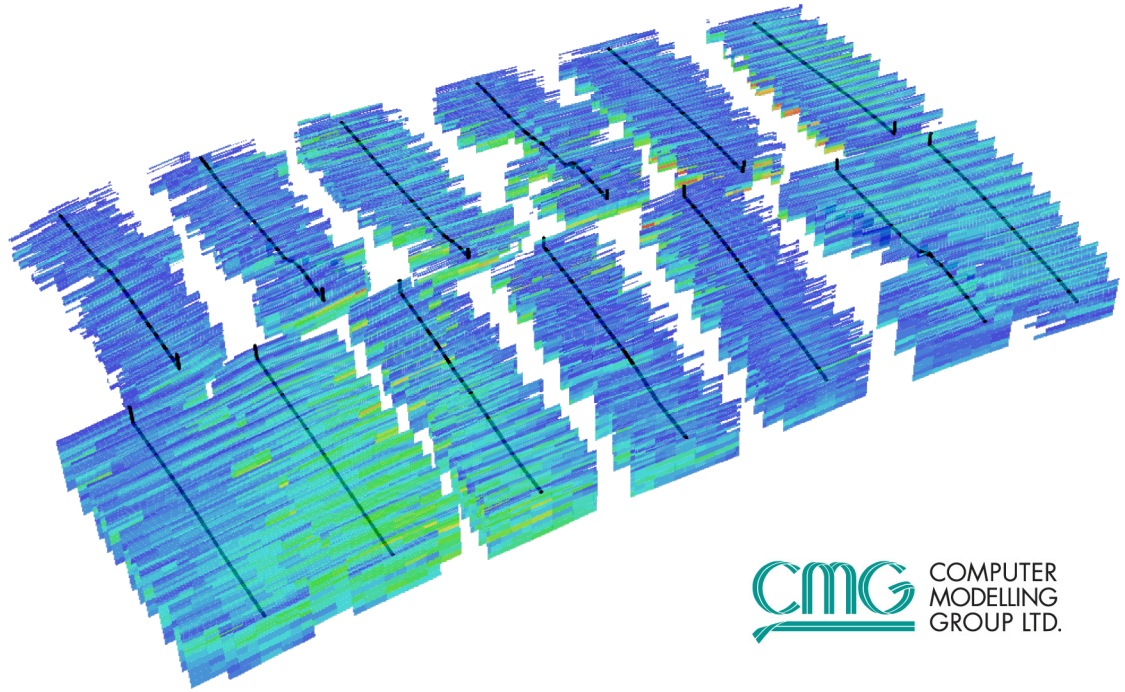
- Performance Improvements
- New options - Geomechanics Features
- New options - Hydraulic Fractures

Performance Improvements



Dataset Loading

Models with higher levels of refinement will likely see greatly improved performance when loading datasets. Hydraulic fracture operations such as modifying minimum fracture spacing and importing *.csv's will also be noticeably faster



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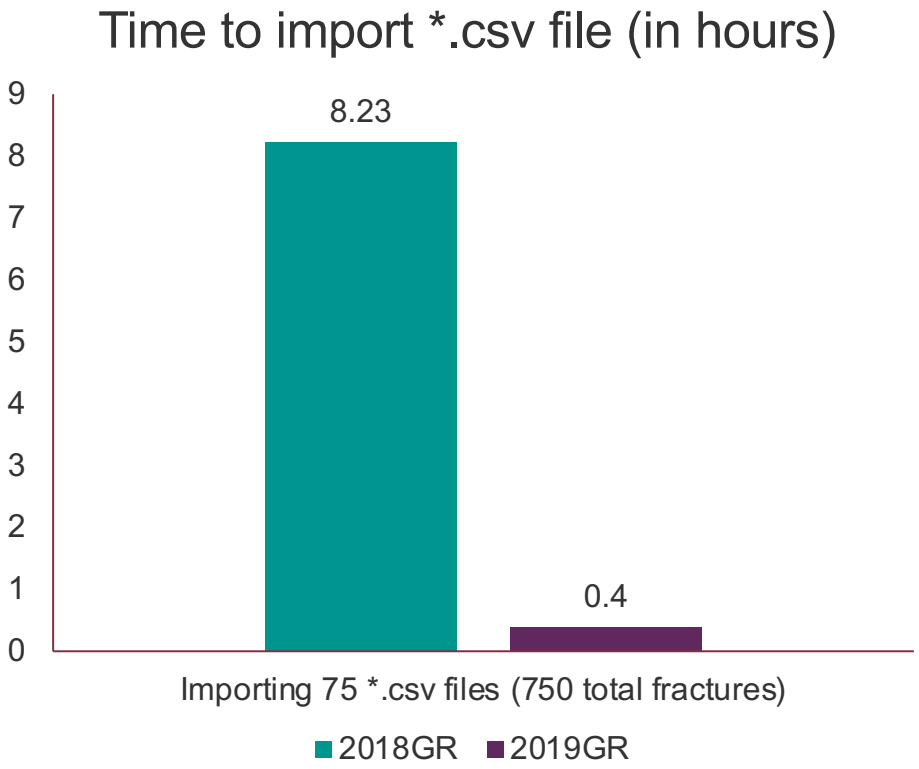
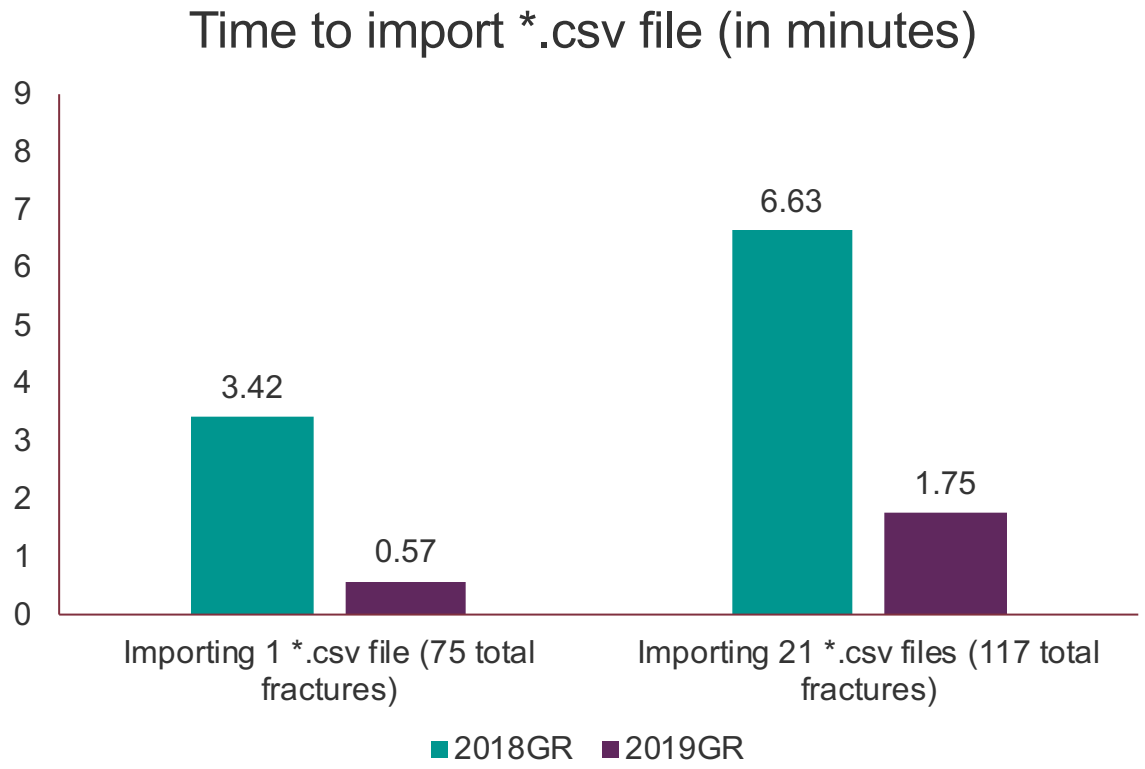
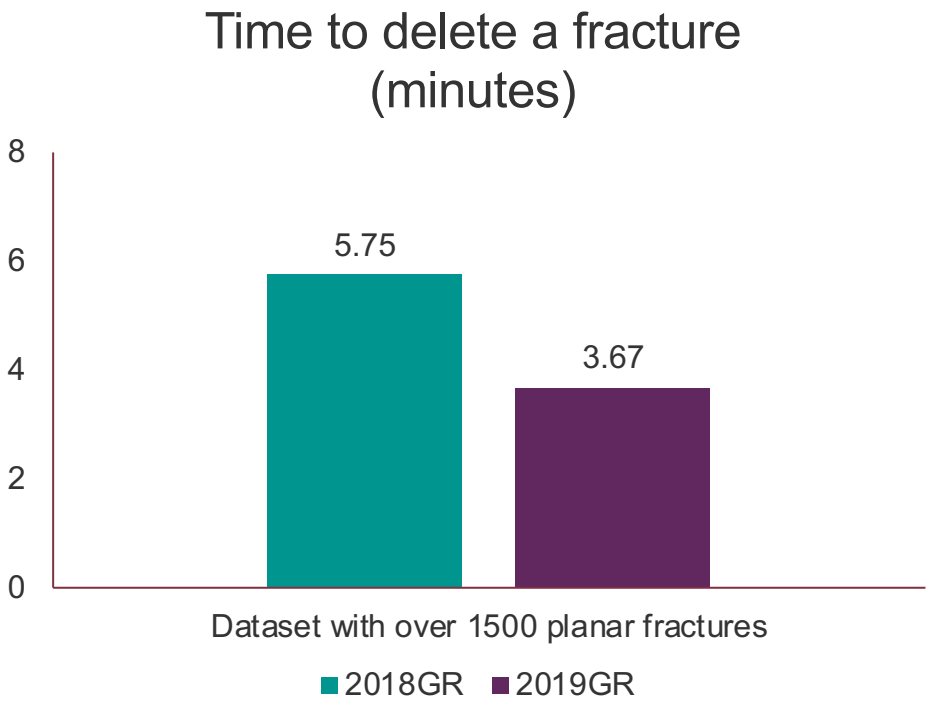
Performance Improvements

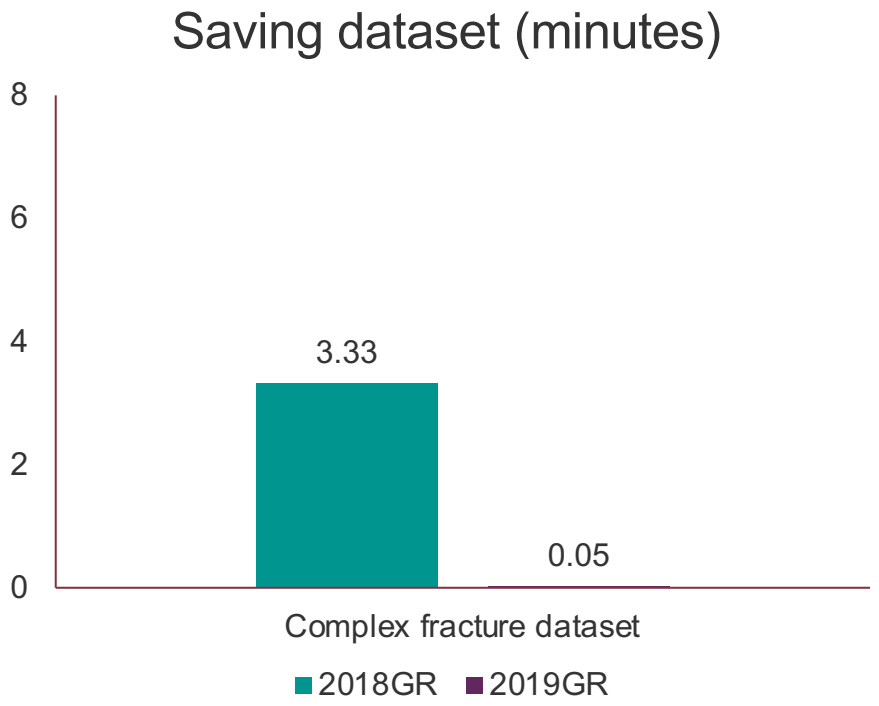
GOHFER-Format Frac File Import Speedup





Performance Improvements





Geomechanics Features

- Workflow to create Geomechanics grid has improved
  - Bounding box display has been added for GEOGRID placement
    - Property settings have been added for bounding box customization
  - RESCUE import option added for creating GEOGRID

- Property specification interface has been added for GEOGRID related properties
  - RESCUE import can also be used for importing/mapping properties

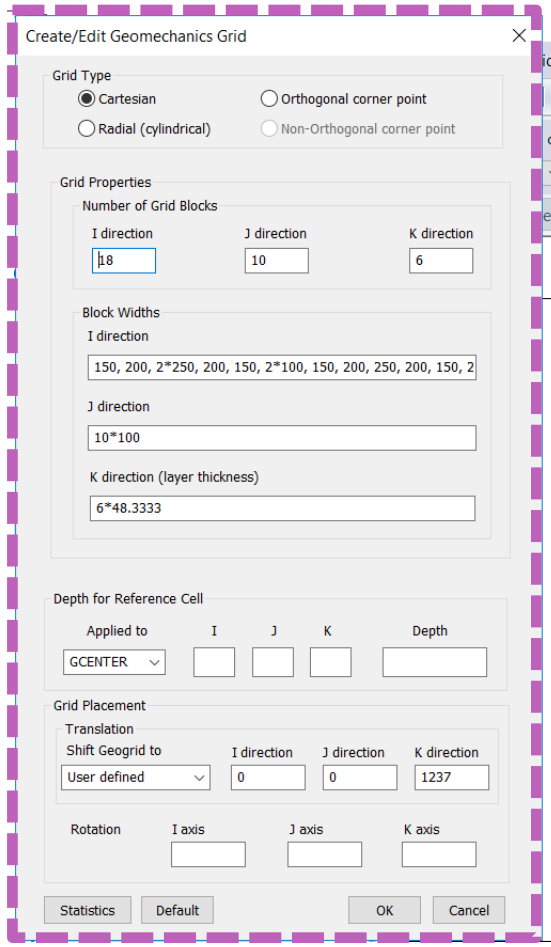
Creating a New Geomechanics Grid

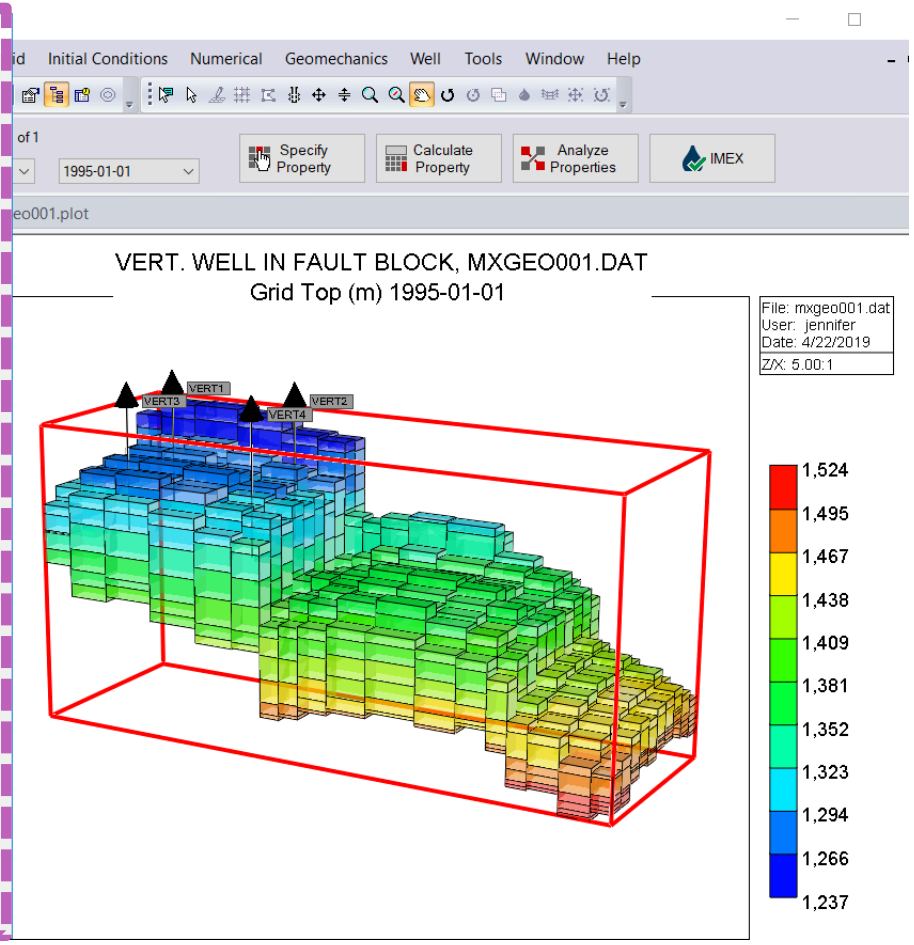
Open a dataset without any Geomechanics information

Go to the Geomechanics menu and select the “Create/Edit Grid” menu option

Bounding box is automatically displayed in the 3D view

Grid dimensions are automatically pre-populated to match dimensions of host grid to make GEOGRID creation easy





Hydraulic Fractures – New options

Visualize checkbox

- If disabled fractures will not be rendered
- Disabling visualization provides significant performance improvements when working with large hydraulic fracture models

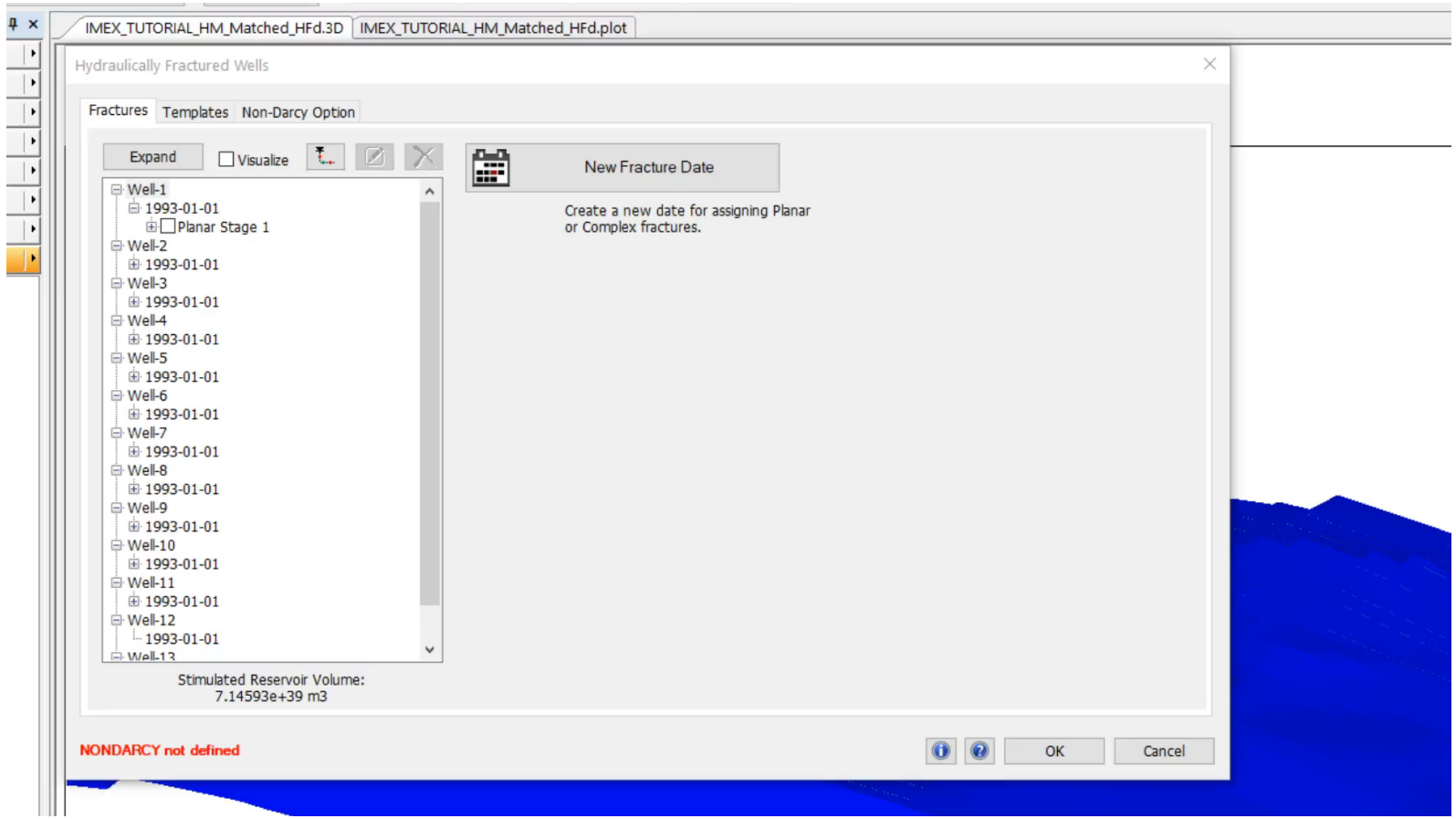
Multiple fracture selection

- Multiple stages/fractures can be checked before performing an operation
- Once all desired stages/fractures have been checked, a single operation (deletion/update template) can be executed
- Significant reduction in time spent selecting and deleting individual items

Hydraulic fractures – New options

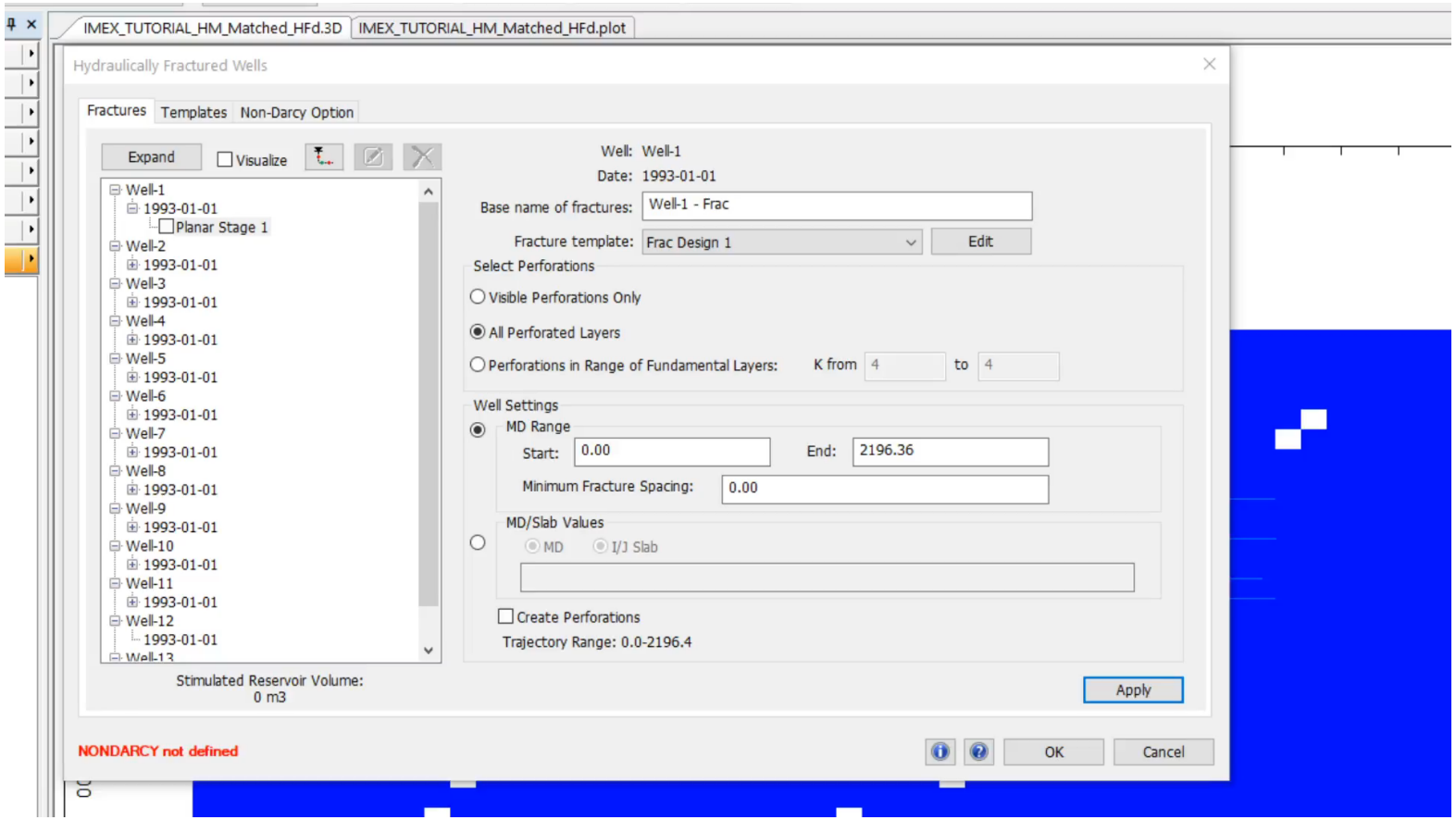
Change templates in bulk:

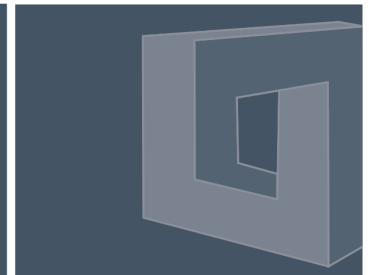
- Improved workflow for setting fracture templates for stages/fractures
- Change fracture design
- Delete fractures



Hydraulic fractures – Generate fractures using MD's

- Allow users to quickly generate fractures based on MD
- User can specify start/end MD range with a fracture spacing
- User can enter a comma separated list or a range of MD values
- Option to create perforations for fractures automatically if they don't already exist





RESULTS

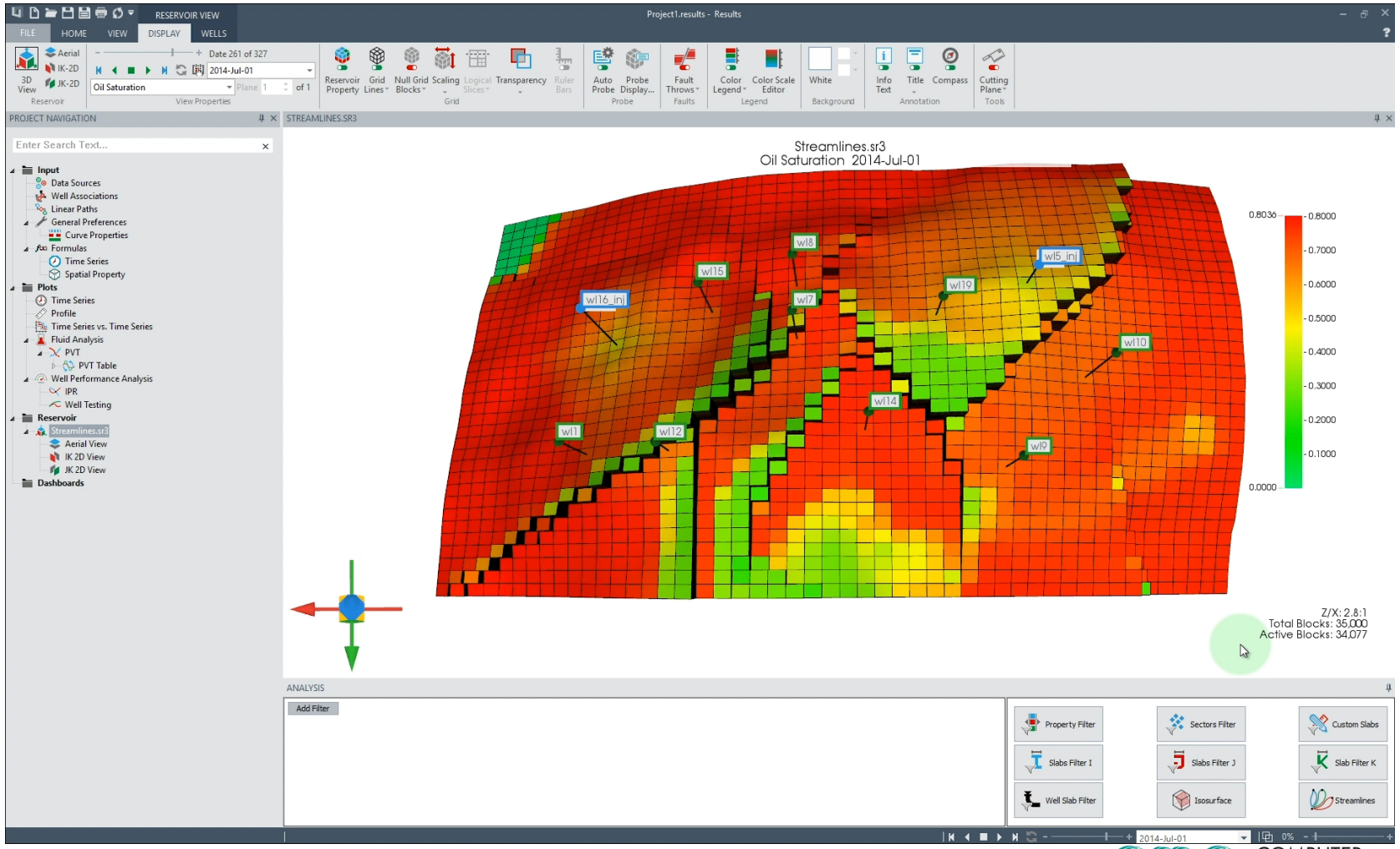
RESULTS

New in 2019.10: Results

- Streamlines
- PVT Plots
- Export to PowerPoint
- Improved 3D view

Streamlines

Use streamlines to visualize fluid movement within the reservoir for more insightful analysis



Future of Simulation

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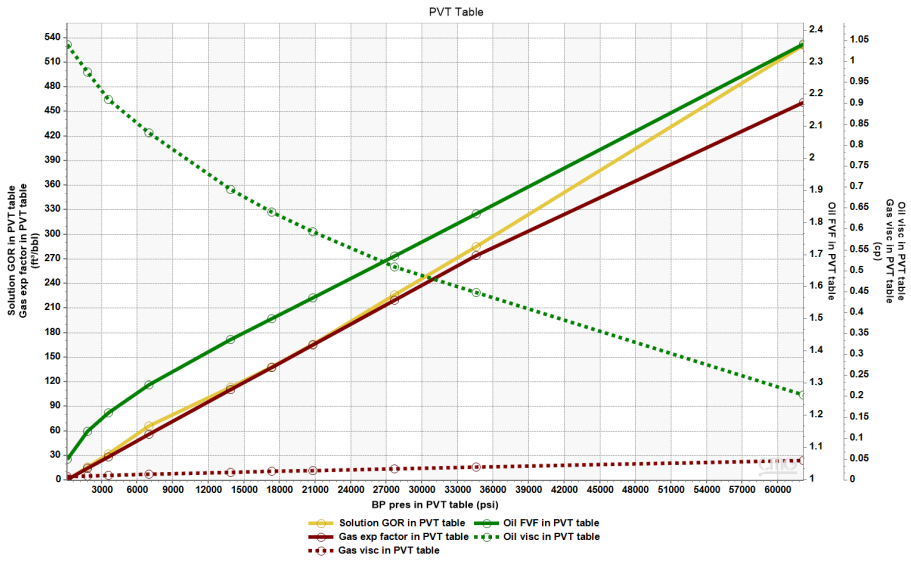
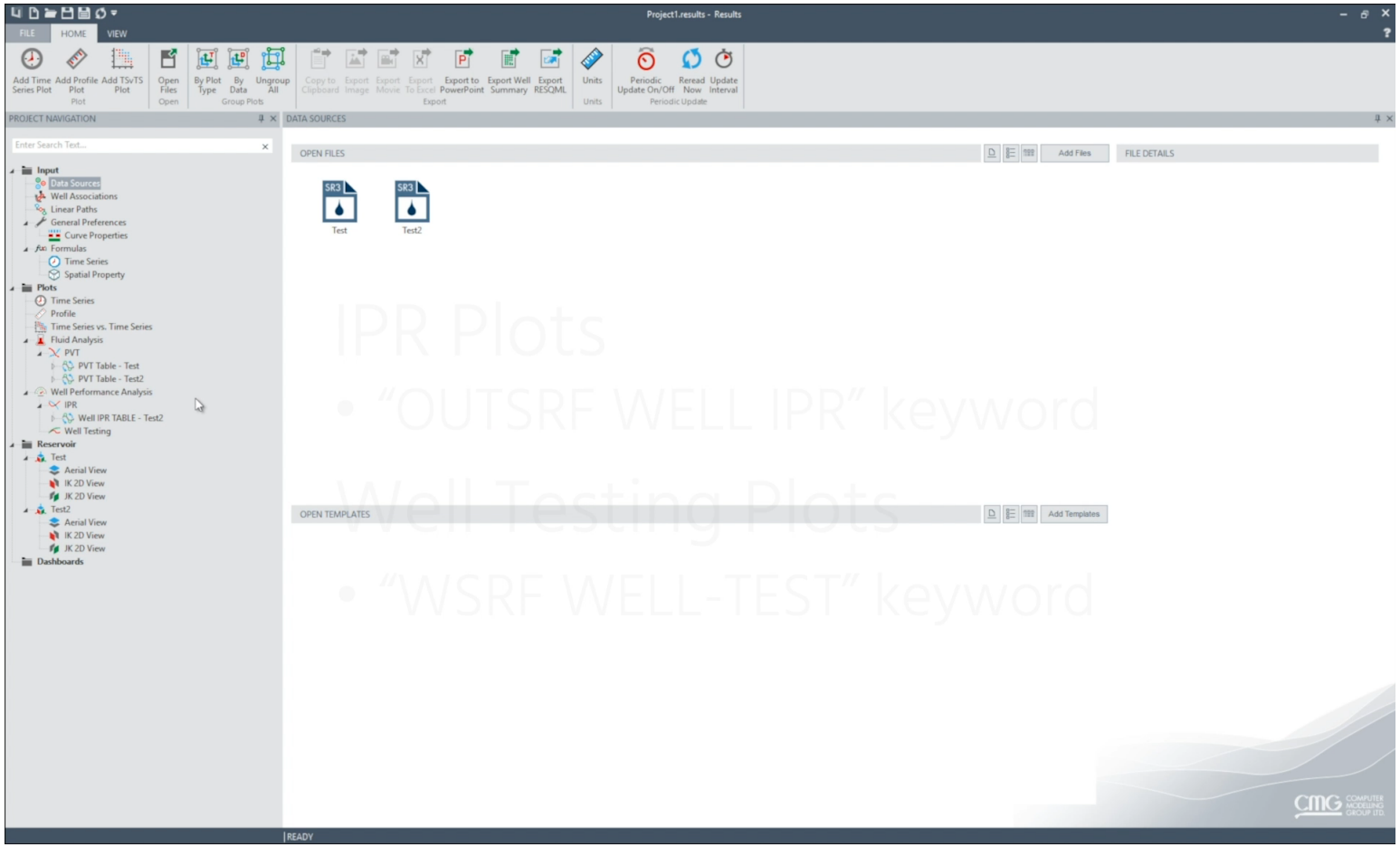
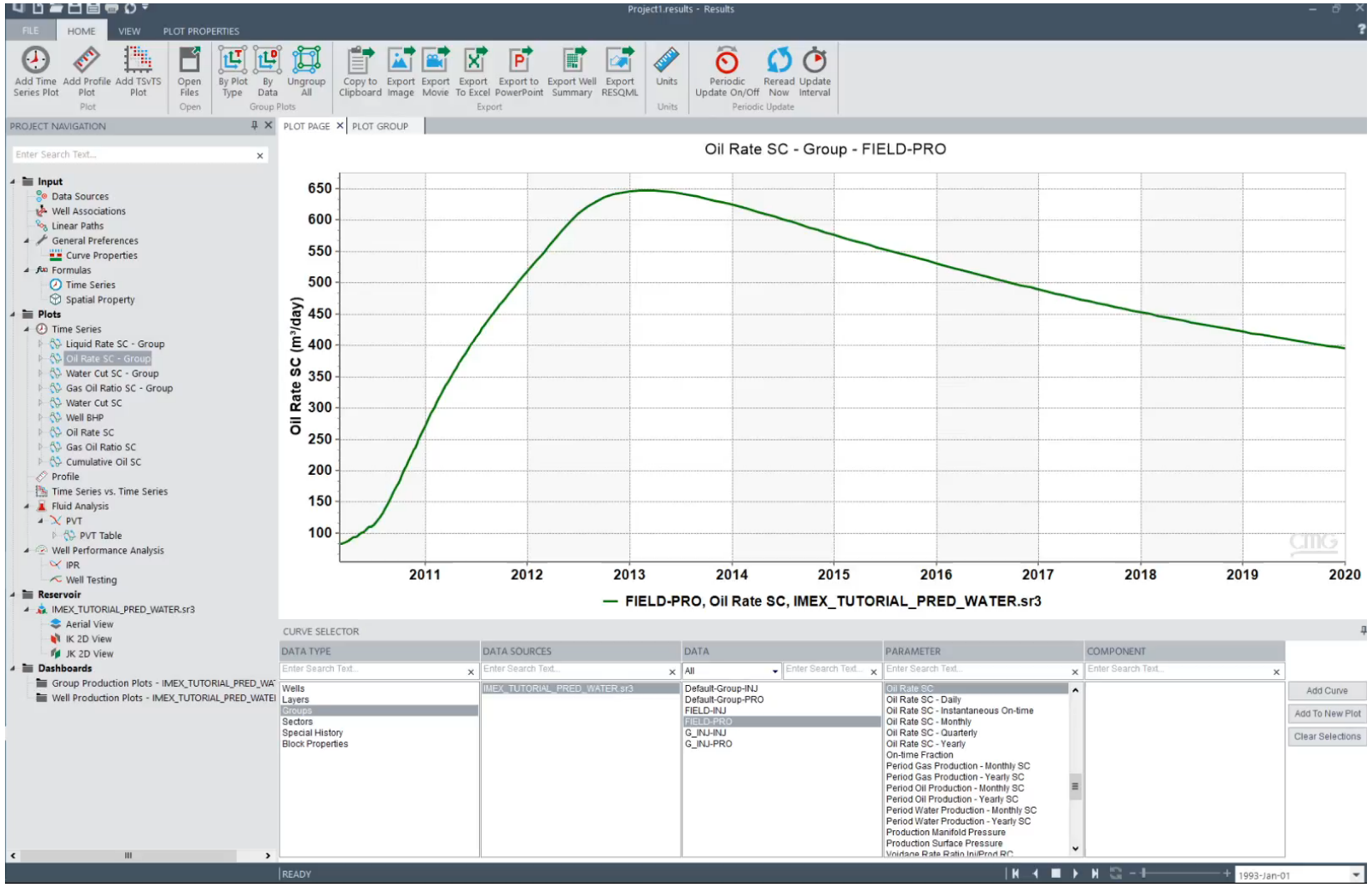
PVT Plots

Results now displays fluid PVT property plots for specific grid cells.





Export Directly to PowerPoint



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CMG Cloud

Choose the Cloud

Current Challenges

- Variable Workloads
- Different Model Fidelities
- Growing Simulation Needs
- Limited On-Premise Resources
- Aging On-Premise Resources
- Capital Efficiency

CMG Cloud Solutions

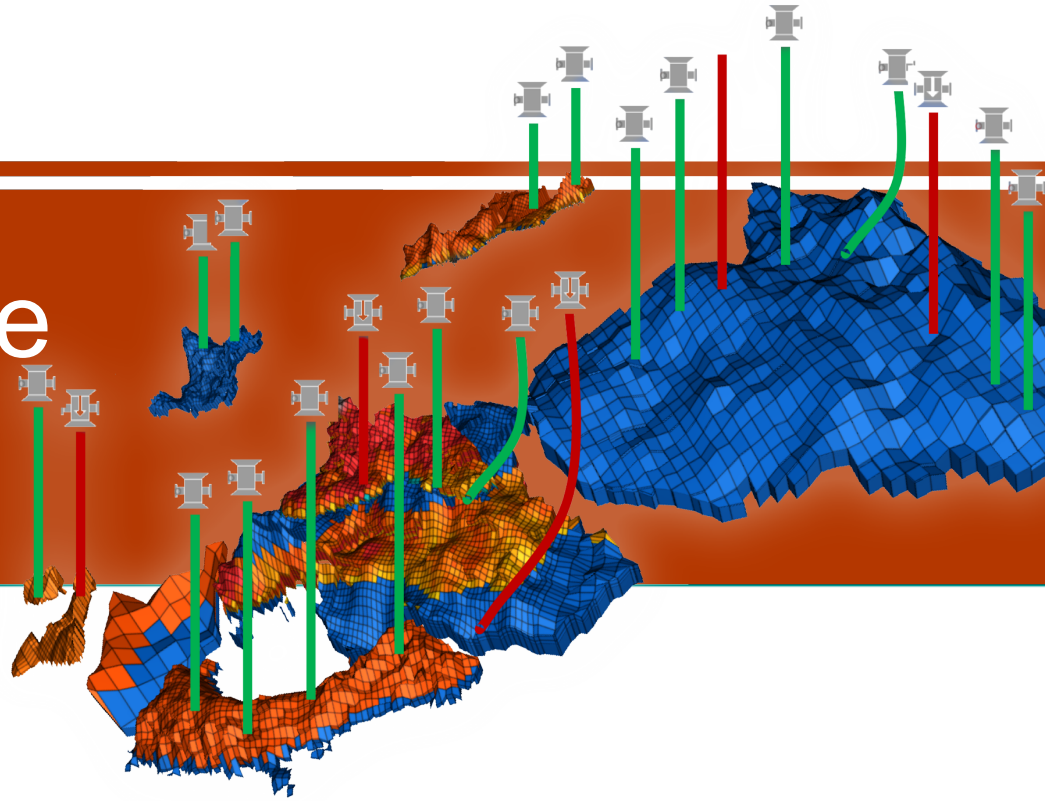
Improve project delivery with instantly scalable and flexible options based on project needs

Access latest CMG software releases, and industry's best hardware

Securely access anywhere in the world, 24/7

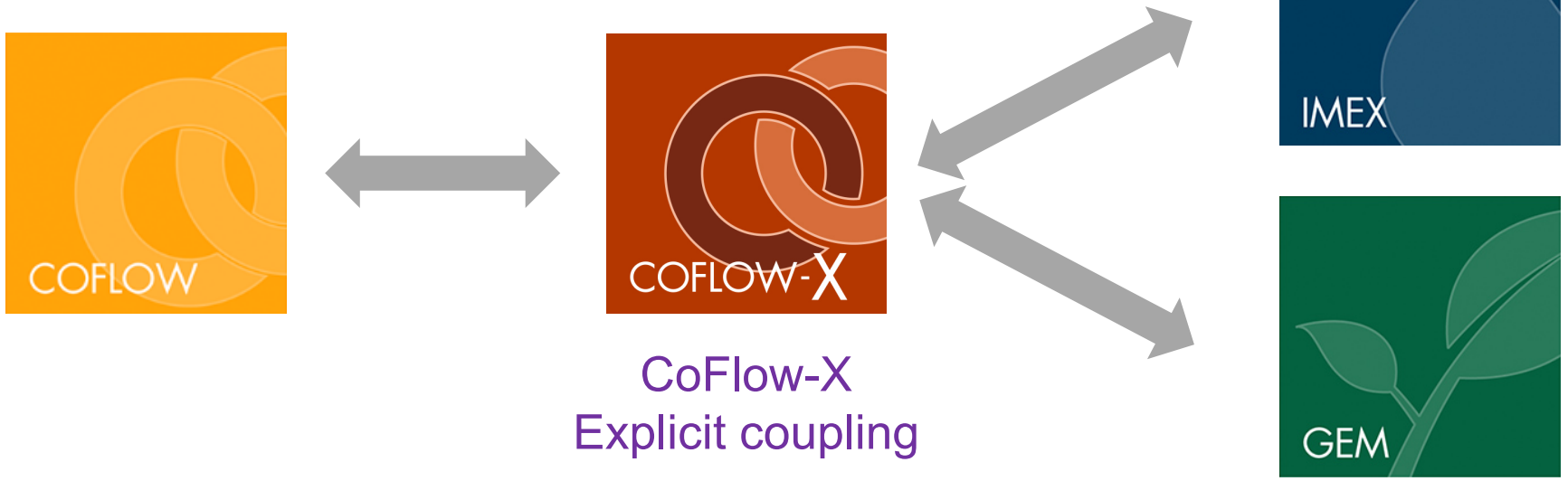
Improve usage efficiency with pay-per-use hardware and software

CoFlow-X: The Bridge to IPSM



CoFlow-X

Integrated production modelling with wells and facilities in CoFlow and reservoirs in IMEX or/and GEM



CoFlow-X
Explicit coupling

Unlimited no. of IMEX and GEM models

The production engineer can enjoy all the tools of CoFlow while allowing the reservoir engineer to keep using CMG tools that they love.

Benefits of CoFlow-X

Benefits of Coupling CoFlow with IMEX and GEM

Recovery process modelled on industry leading simulators

Any simple/complex recovery process can be modelled

Couple CoFlow & other CMG software to the workflow

Connect the CoFlow surface network (with blended fluid) to any number of IMEX and/or GEM dynamic models

NFRs, HFs, cEOR…etc

Explicitly coupled to improve performance

Production engineer can enjoy all the tools of CoFlow

Integrate existing CMG reservoir models with CoFlow production models instantly

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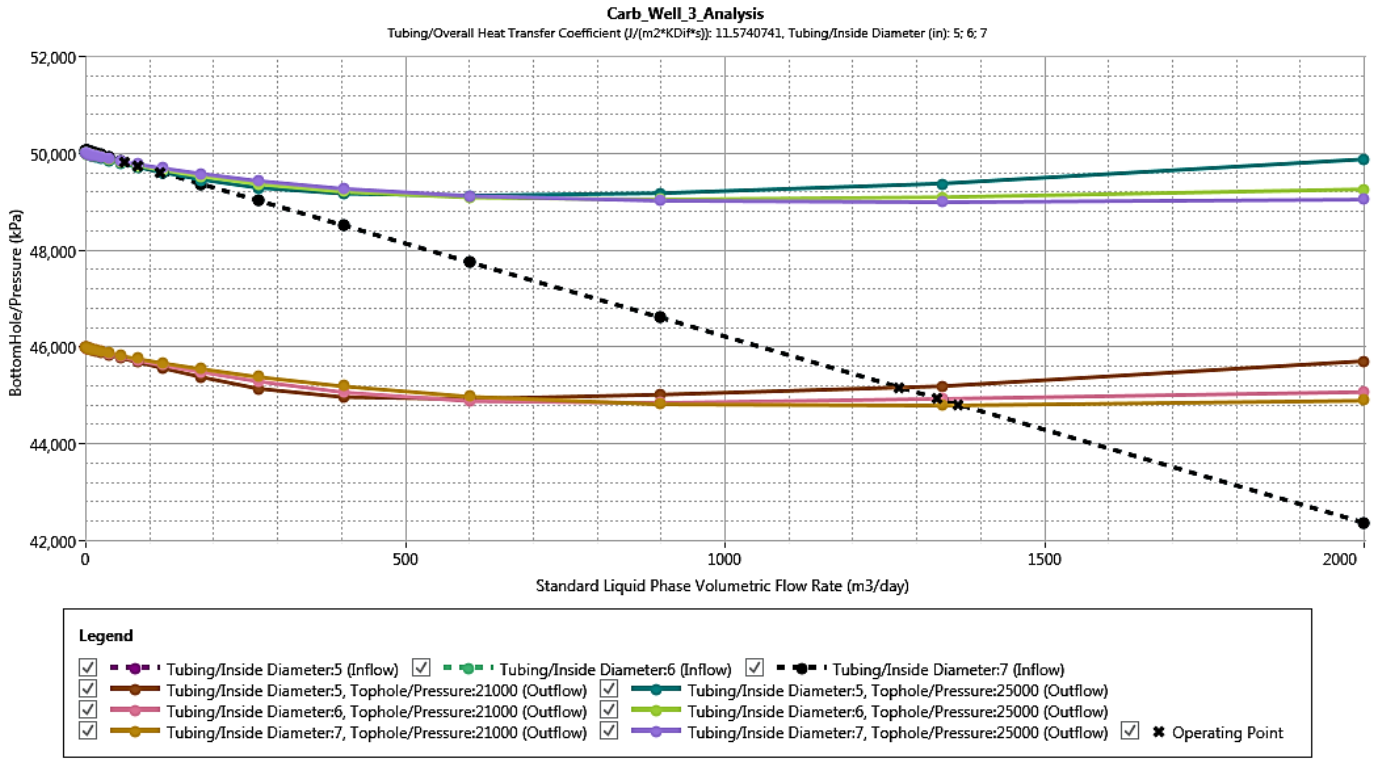
Well Engineering

- Evaluate well performance
- Design optimal well completions
- Perform Sensitivity Analysis
- Identify problems that limit well production
- Enhance production from existing wells
- Model downhole equipment such as choke, separators and flow control devices
- Multi-fidelity options in pressure-drop and heat-loss calculations



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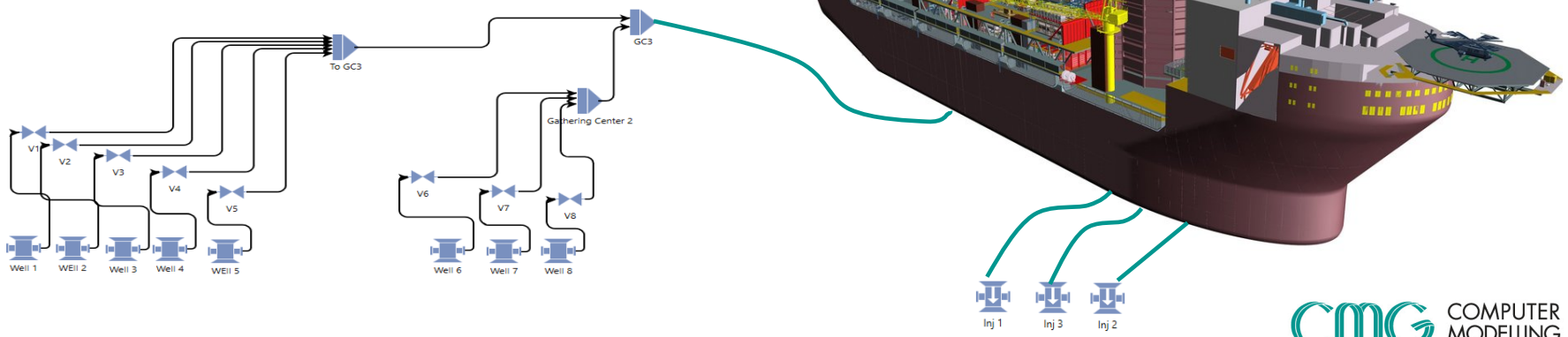
Artificial Lift Assessment

- Pumps
  - Model different type of pumps & compressors
  - In-built library of standard pumps
  - Model multi-stage pumps
  - Import pump performance data from external sources
- Gas lift
  - Model different types of gas lift valves
  - Different gas lift valve transport models
- User selection of fidelity

Facilities Design & Engineering

- Design and size pipelines and equipment such as pumps and compressors
- Optimize production from complex surface networks
- Design and optimize water or gas injection networks
- Calculate full-field deliverability
- Multi-fidelity modelling options



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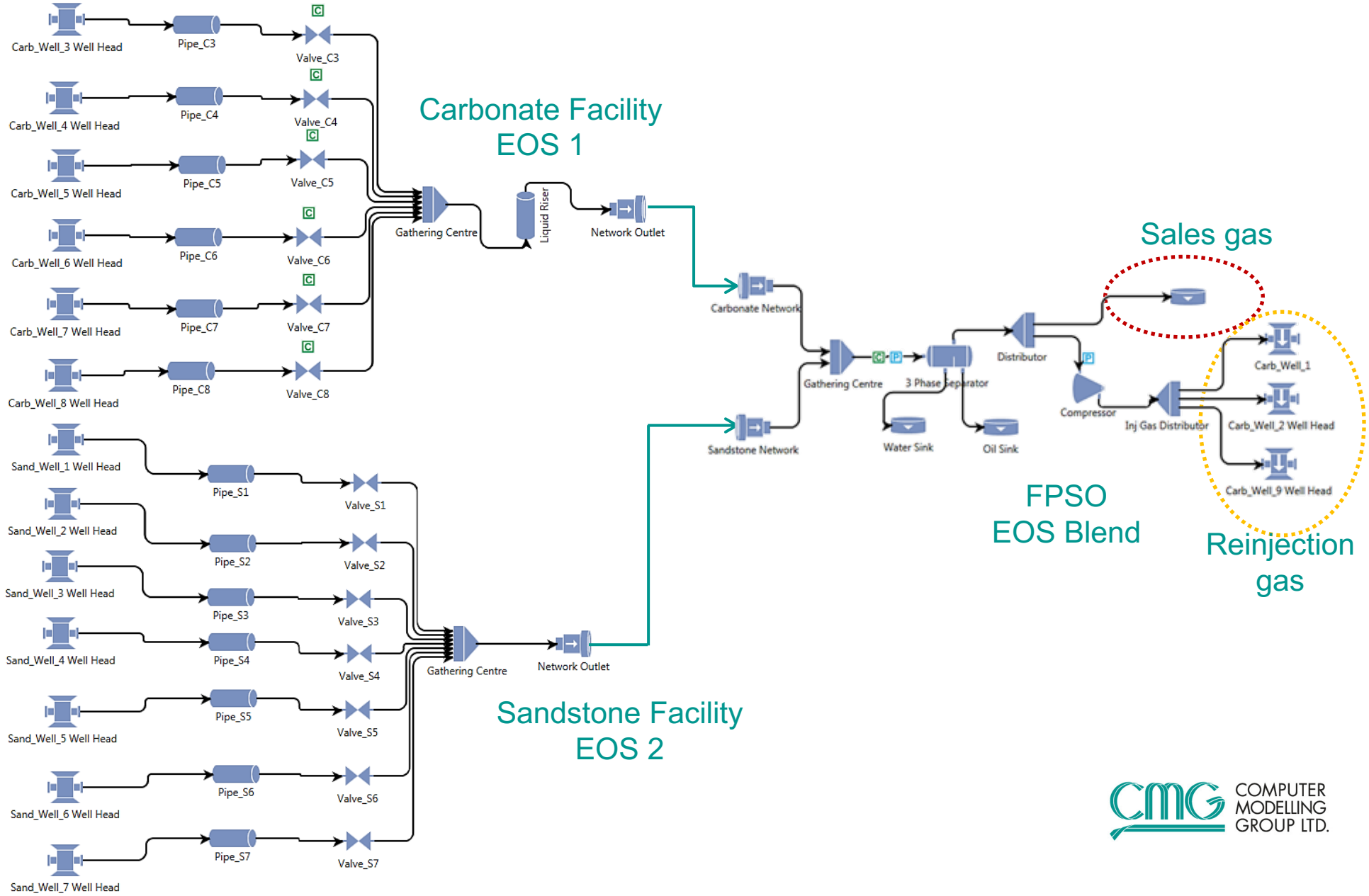
Case Study – IPSM in CoFlow-X



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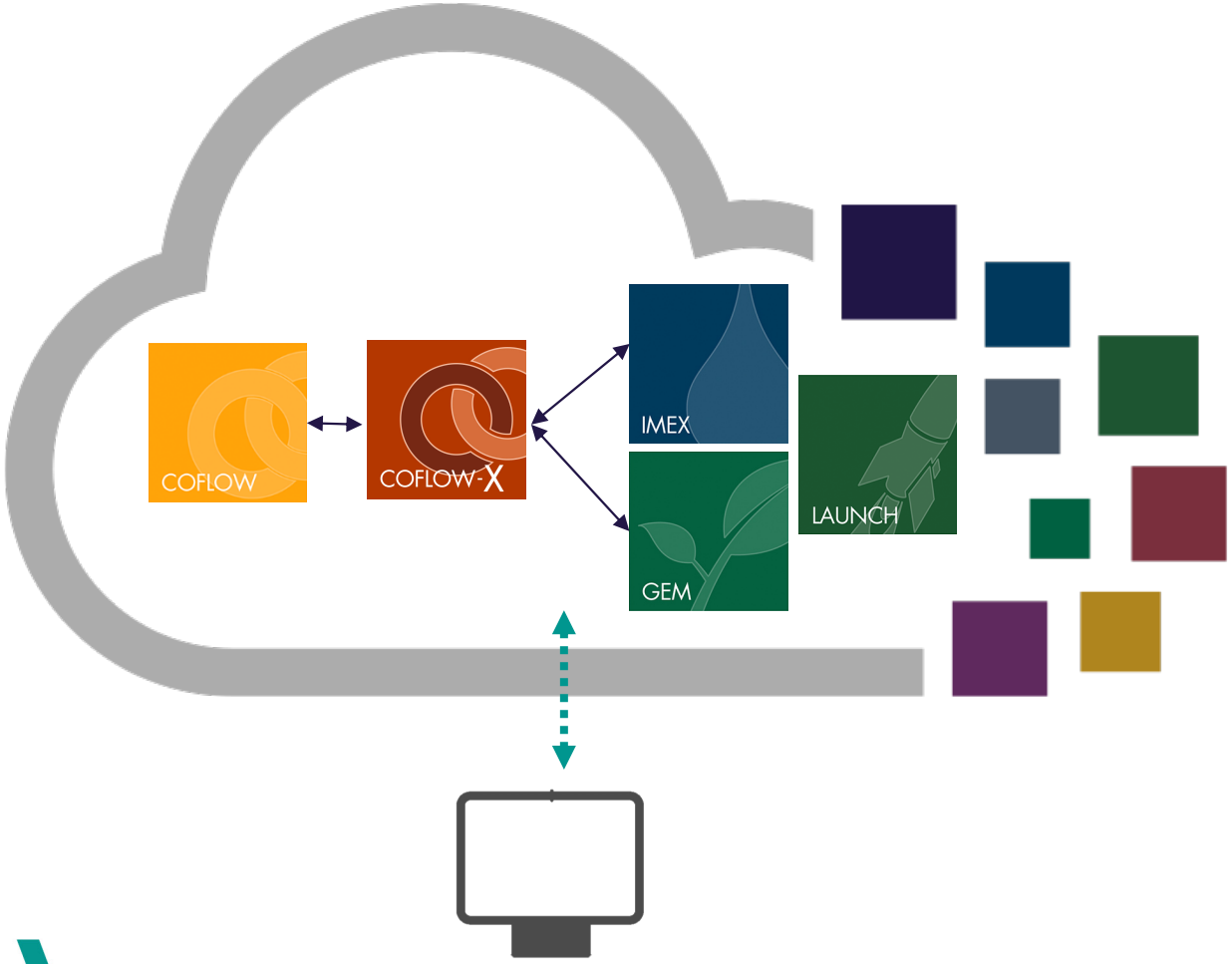
CoFlow-X Summary

- Modern user interface to couple reservoir and production models
  - No need for tedious scripts
- Very easy to use
  - Absolutely no changes needed in your datasets!
- Smart software
  - Automatic well coupling, intelligent coupling time selection
- No limit on the number of reservoirs
  - Any number of IMEX, any number of GEM, or a mix of the two

CoFlow & CoFlow-X on the Cloud



Benefits

- Instantly scalable and flexible hardware and software options
- No need to buy additional hardware
- Availability of the latest version of all our simulators
- Immediate availability, no queuing is required for large numbers of runs
- Instant access, 24/7 to fulfill your projects on time

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Thank You