COMPUTER MODELLING GROUP LTD.

What's New in GEM

GEM

Compositional & Unconventional Simulator

Version 2021.10

cmgl.ca

#FutureOfSimulation

Simulator Changes

Surface Complexation Modeling

Sorption of ions on the rock surface depends on chemical and electrostatic effects. Modeling of electrostatic effects through surface complexation reactions is implemented in this release. The surface complexation reactions along with the chemical reactions help model surface charge balance following the Gouy-Chapman double layer theory and the Stern-Grahame assumptions. This allows dynamic calculation of Surface or Zeta-potentials in the reservoir which are then related to laboratory generated wettability alteration and relative permeability characteristics for prediction of the incremental oil recovery. The feature is expected to be especially useful for carbonate reservoirs undergoing waterflooding with changing salinity and pH conditions.

See template data sets gsmsmo155-159.

K-Value Formulation for Aqueous Phase Solubility

An alternate method of calculating aqueous phase solubility using gas-water and oil-water K values is implemented. The K values could be generated by any thermodynamic program (viz., WinProp) and input to GEM in the form of tables for the applicable range of pressure, temperature, and compositions. These K values are then used to calculate aqueous phase solubility of a component during the flow simulation.

See template data sets gmghg044-46.

Consolidation of Solubility Models

Different solubility models in GEM are now consolidated so it is possible to choose a model for one component and choose another model for the other component using new keyword *SOLUBILITY-MODEL in the same data file. The available options are, *KVALUE, *ENI, *HARVEY, and *HENRYCST.

See template data set gmghg045.

Mineral Equilibrium Reactions

GEM now provides the ability to model mineral reactions as pseudo-equilibrium reactions wherein equilibrium is reached very fast compared to regular TST based mineral reactions. Mineral equilibrium reactions require much simpler input data (only equilibrium constants) compared to TST reactions where, in many situations, reliable input data like reactive surface area, activation energy, and frequency factor may be challenging to obtain. The feature is expected to be useful to researchers, as well as practicing reservoir engineers.

See template data sets gmghg047-048.

Improvements in Models with Water Vaporization

Disallow rate and equilibrium reaction cut-offs when water saturation in grid-block reaches user specified threshold via *SWR-H2OVAP.

See template data set gmghg043.

Addition of Hydrogen and Helium to GEM's Component Library

Hydrogen and Helium are added to the internal component library to facilitate use of GEM in energy transition simulations like H_2 or He storage. A new keyword *LIB-SHIF *JYCORR | *ZRACORR is provided to optionally calculate volume shift of library components using Jhaveri-Youngren or Zra correlations that are consistent with WinProp calculation.

See template data set gmflu003.

Enhancements in 3-Phase WAG Hysteresis Modeling

Three phase WAG hysteresis calculations now strictly adhere the Larsen and Skauge (1998) procedure for modeling of drainage and imbibition loops by default. Use *HYSKRW *3PWAGW *LS-PREV, if behavior prior to GEM 2021.10 is desired.

See template data set gmsmo154.

Tracer Modeling Speedup and Enhancements

An explicit method involving sub time-stepping for tracer flow is implemented to reduce the computation time. The method is especially useful in models with many tracers and with relatively moderate heterogeneity where CFL criterion is readily satisfied. Two methods based after Sagen (1996) and Palagi (1992) are available for the determination of sub time-step size.

The default method of tracer flow solution has been changed to *EXPLICIT. Keyword *TRCR-SOLVE *EXPLICIT | *IMPLICIT is introduced to select either of the methods. Additional tracer simulation controls are provided through new keywords *TRCR-CFL, *TRCR-DTMIN and *TRCR-DTMAX, the latter two optionally controlling the minimum and maximum sub time-step size.

Time saving in calculations is also achieved through skipping of calculations for tracers that exist in the model but at the time of calculation are dormant.

Now sector information as well as tracer produced amounts from oil, gas, and water well streams are written out to simulation results file, by default.

See template data sets gmtrc018.

Added ability to retain tracer injection concentration, if specified for a shut-in injector, to be applied when the well starts injecting.

See template data set gmtrc019.

Dynamic Well-Index Calculations

Allow update of well indices on change of permeability/transmissibility multipliers in general including such changes caused by coupled geomechanics calculations. So far, this feature was available only for compaction/dilation models. The existing data sets that use permeability coupling in geomechanics may see a change in flowing bottom-hole pressure due to this. If the updated well index is excessive, the keyword *WIRANGE may be used to control it. If required, well-index, could be output via *OUTSRF *SPECIAL *WINDEX and plotted in RESULTS.

See modified template data set gmgmc009.

Improvements in Adaptive Time Stepping (ADTSC)

The algorithm for the penalty for time-step cut has been improved for models that allow use of *NEWTONCYC in presence of *ADTSC. The time-step growth factor is adjusted to allow faster increase in the time-step size for models allowing use of *DTWELL with *ADTSC.

USER_INPUT Initialization

Allow input of maximum water saturation through existing keyword *SWOC, which was not permitted for USER_INPUT initialization so far. This is particularly useful for models with aqueous phase solubility and water vaporization.

See template data set gmghg043.

Implicit Switching

Now hysteresis calculations are taken into consideration during implicit switching to improve convergence in models with relative permeability/capillary pressure hysteresis.

Output Enhancements

Special History Output for DFN Grid-Blocks

Special history for DFN grid-blocks can now be output via keyword *OUTSRF <property> UBA *DF | *DU | *DS *ifr* for a particular discrete fracture unit or segment's intersection with the grid-block.

See template data set gmgro034.

Linear Solver Enhancements

Optional Cut Direction Specification for Parallel Linear Solver

The syntax of *PPATTERN *AUTOPSLAB is modified to include optional cut direction via sub-keywords (*I | *J | *K).

The selected direction may also be specified by command-line option '-parasol (i|j|k)*n* or existing '-pslabdir (i|j|k), where i, j, or k indicate the desired direction of portioning.

See template data set gmpar014.

Geomechanics Changes

Water Weakening

The water saturation can now be used in the geomechanics to change rock properties such as Young's modulus, Poisson's ratio, Biot's coefficient, cohesion, friction angle, and thermal expansion coefficient. A user-specified lookup table is used for each rock type to obtain new values of properties at every time step.

Besides the water saturation, oil saturation and gas saturation can also be used to alter the rock properties. The increase in water saturation can make the rock weaker; therefore, rock mechanical properties could be changed with time with changing water saturation. The change of mechanical properties will affect the stresses and deformation.

See template data set gmgmc089.

Enhanced Non-linear Elastic 2

The nonlinear elastic constitutive model was modified to handle discontinuous loads. In the old code, an explicit method is used. That means, the rock properties related to the constitutive model were updated at the end of time step. This approach will not cause much deficiency if the load is continuous. However, when the load is discontinuous (such as external loads), the explicit approach may lead to a wrong result. To remedy this situation, an implicit method is used to instantly update the rock properties when a load is applied.

Modified Cam Clay Model

The Cam Clay (MCC) model has been revised to solve the Mandel-Cryer phenomenon for an undrained problem. Keyword *MICSIM has been introduced to use a simplified form of the Cam Clay model. New keyword *MCHARDF allows the user to choose between two pre-consolidated functions described in the manual.

See template data set gmgmc048.

Grid Section Changes

Bi-Directional Permeability Distribution for Hydraulic Fractures

A permeability distribution within a fracture can now be defined in horizontal and vertical directions, such that the horizontal or vertical permeability away from the fracture origin could dissipate linearly or exponentially with distance.

New keywords *KH_TYPE, *KV_TYPE, *K_CENT, *KH_TIP, *KV_TIP, *KH_DECLINE, *KV_DECLINE and *ELLIPTICAL_DISTRIBUTION (*ON |*OFF) are introduced within Planar Fracture Template to control the distribution.

The *ELLIPTICAL_DISTRIBUTION *ON keyword transforms the fracture permeability distribution from a usual rectangular shape to an ellipse-like shape following the user's specified fracture geometry inputs.

See template data set gmfrr020.

Property Distribution Data Template

A new keyword *PDD allows the user to define a template of property distribution data with respect to coordinate offsets. The template may then be used via *PDD_DATA in both the Reservoir Description and Well and Recurrent Data sections by a fracture grid created with *PLNR_REFINE or *PLNR_FRAC.

See template data set gmfrr021.

Allow Hydraulic Fractures to Pass Through Inactive Grid-Blocks

The hydraulic fractures can now pass-through inactive grid-blocks, such as blocks with zero-porosity, zero-net-gross or explicitly defined null grid-blocks. The option, invoked by new keyword *HF_IN_NULL, creates active fracture zone within the blocks. The properties of fracture zone can be defined through newly introduced keywords *POR_NULL, *NETGROSS_NULL, *PERMI_NULL, *PERMJ_NULL and *PERMK_NULL. Certain restrictions related to restarts apply.

See template data set gmfrr022.

Ease of Using Block Group Names

*BLOCKGROUP or *SBLOCKGROUP names can now be referenced with the wildcards '*' and '?'. Wildcard '*' replaces any number of characters at the end of a block group name or it can be used on its own to represent all block groups. Wildcard '?' replaces any single character anywhere in the block group names. These names must appear in quotes.

Triangular or Polygon DFN

In addition to default quadrilateral shaped discrete factures GEM now allows modeling of discrete fractures with triangular and polygon shapes.

See template data set gmgro036.

HFs in LGR Blocks

The origin of a planar hydraulic fracture (*PLNRFRAC, *PLNR_REFINE) can now be assigned to a one-level LGR grid. For this scenario, hydraulic fracture is restricted to be created within a referenced region where the fundamental blocks should be statically refined in the Reservoir Description section. The referenced region must be pre-defined with the refined blocks using a structured block group (*SBLOCKGROUP) and be associated to the fracture using the new sub-keyword *USE_SBG.

See template data set gmfrr023.

Separate Matrix and Fracture Pinch Out

The pinch out array *PINCHOUTARRAY now supports the vertical pinch out of matrix and fracture blocks, separately. For *DUALPOR and *DUALPERM natural fracture models, if none of the *MATRIX or *FRACTURE qualifier is specified, the *PINCHOUTARRAY will be applied to both matrix and fracture blocks as before.

Pore Volume Cut-off for Refined Grids

New keywords *PVCUTRG and *PVCUTRG-FR control the threshold level at which a refined matrix or fracture cell's pore volume is small enough to be considered zero. Such a block will be systematically removed from the fluid flow simulation either through nulling or pinching out.

Grid Offset, Orientation and Direction

*XOFFSET, *YOFFSET, *ROTATION, *AXES-DIRECTIONS can now be specified in grid building procedure. This is particularly useful when DFN or Independent well data are read in with a particular offset, orientation, and axes direction. The combination of the keywords can be used together to match reservoir grid to DFN or well trajectories

Well Management Changes

Grid-Independent Wells

A new Well Management keyword, *WBRANCH, has been introduced to define the multi - lateral well trajectories using spatial coordinates and measured depths. The well main branch and subordinate branches can be conveniently relocated using keyword *WBSHIFT and *WBROTATE. Well perforations and associated index parameters can be specified in terms of the measured depth intervals (*PERF-MD) rather than the traditional block address. There is no need to redefine the perforations in case of a recurrent grid change since the well layers (i.e., intersections with grid blocks) will be automatically reconstructed based on the given well branches and measured depth intervals.

Any existing layer control option (e.g., *LAYER-CTRL and *KRPERF) takes the new syntax with the branch names and measured depth intervals.

See template datasets gmwwm127 and gmwwm128.

New Hydraulic Table Lookup Methods

Two new table lookup methods (*PTUBE-FIXFRAC *NEWTON | *TIMESTEP) have been implemented to provide more flexible controls on handling the implicit WHP well constraint, especially when it is close to a lift failure. These options sometime avoid the frequent lift failures by effectively lowering the enforced WHP from the specified values.

Template Dataset Changes

The following Table lists new or modified template data files.

GMFLU003	Use of H_2 and He properties from GEM's Component Library.
GMGHG043	Water Vaporization and Halite Precipitation during CO_2 Injection.
GMGHG044	K-Value formulation for aqueous phase solubility.
GMGHG045	Use of different solubility models for CO_2 and H_2S via *SOLUBILITY-MODEL keyword.
GMGHG046	CO_2 Sequestration and Water Vaporization using pre-generated K-value tables.
GMGHG047	Modeling of Calcite dissolution with the Mineral Equilibrium reaction feature.
GMGHG048	Modeling of Halite precipitation with the Mineral Equilibrium Reaction feature.
GMGHG049	Methanation reaction modeling during H_2 and CO_2 storage in the aquifer.
GMGMC009	Special history output of Well-Index
GMGMC048	Enhancements in the Modified Cam Clay Model
GMGMC088	Skempton and Mandel-Cryer Effects
GMGMC089	Effect of water saturation on geomechanical properties (Water-Weakening)
GMGRO034	Special history output for discrete fracture network segment
GMGRO036	Triangular Shape DFU in a Discrete Fracture Network.
GMFRR020	Bi-directional Distribution of Permeability in HF
GMFRR021	Assignment of grid-block property through PDD data.
GMFRR022	Hydraulic Fractures Across Inactive Blocks
GMFRR023	PLANAR Fractures in pre-existing Local Grid Refinement
GMPAR014	Partition direction specification through *PPATTERN *AUTOPSLAB (*I | *J | *K) *inum*

GMSMO154	3-Phase WAG Hysteresis - Larsen and Skauge (1998) drainage and imbibition loops
GMSMO155	Surface Complexation Modeling. Relative permeability interpolation based on EQVSCX (1)
GMSMO156	Surface Complexation Modeling. Relative permeability interpolation based on EQVSCX (2)
GMSMO157	Surface Complexation Modeling. Relative permeability interpolation based on Zeta Potential.
GMSMO158	Surface Complexation Modeling. No Relative permeability interpolation for comparison with gmsmo157.
GMSMO159	Surface Complexation Modeling of a Slim Tube experiment
GMTRC018	Tracking movement of components through regional tracers
GMTRC019	Tracer injection specification for a shut-in injector
GMWWM127	Use of Grid-independent Well Option.
GMWWM128	Use of Grid-Independent Well with recurrent grid refinement.

Miscellaneous Changes / Bug Fixes

Bug-Fixes/Improvements

- Fixed pressure calculations with respect to reference depth in models where reference depth is defined above the gas-oil contact in DEPTH_AVE initialization.
- An error in reading of binary interaction coefficients for the surface equation-of-state set has been fixed.
- For GEM-GAP coupled models fixed IPR generation for injectors in presence of Triggers.
- Allow internal trace-component in GEM-Surface network coupled models with aqueous phase solubility.
- Fixed SETPI for coupled outboard runs.
- Fixed output of well index statistics (*WISTAT).
- Fixed turbulent D-factor calculations, especially for models with single phase gas.
- Ensure consistency between *COVTAB and *COVB-STRESS in overburden stress tables.
- Fixed inheritance of *RRFT from fundamental to the refined grid
- Provide a new sub-keyword *COMPH2O of *AQLEAK to allow leakage of H_2O to aquifer in models with aqueous components and salinity.

Data Incompatibilities with Previous Versions of GEM

- Restarts generated from previous versions are not compatible with this version of GEM due to additional reading/writing of data.