Release Notes
OpenFlow Suite 2023

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BeicipFranlab

Dear User,

We are thrilled to release OpenFlow Suite 2023!

This latest version marks a new milestone in the continuous development of our subsurface software technologies, as our focus has been to address the emerging challenges faced by the energy industry.

Our simulators have undergone major advancements, not only to strengthen our regular oil and gas exploration and production workflows, but also to offer cutting-edge capabilities for deep geothermal exploration and development projects, natural hydrogen exploration, and CO2 storage site exploration, development and monitoring.

Several new numerical schemes for heat transport, fluids injection or geomechanics are available, along with many new options and performance optimizations, ensuring increased productivity when building, running and analyzing models.

Another standout feature of the 2023 version is the introduction of a new method for quantifying model uncertainties through multiple geological scenario testing, empowering geologists to make better informed decisions.

We hope that you will enjoy exploring OpenFlow Suite 2023. If you require any assistance in installing or using this new version, please feel free to contact us at support@beicip.com.

We thank you for your trust,

The Software Team

RELEASE NOTES | OpenFlow Suite 2023

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The OpenFlow Platform

Security & Performance

The OpenFlow platform, core of our software suite, evolves this year with two major upgrades:

- The **Oracle Java Database Connectivity** (JDBC) has been upgraded from version 6 to 11 (21.8.0.0), unlocking the use of Oracle encryption and providing access to many new functionalities for better performance and security;

- **OpenInventor** has been upgraded from version 10.11.1 to version 2023.1.0 to enhance the user experience when visualizing data and models in 2D and 3D with better loading performance and improved rendering.

DionisosFlow®

Advanced, Inspired & Innovative

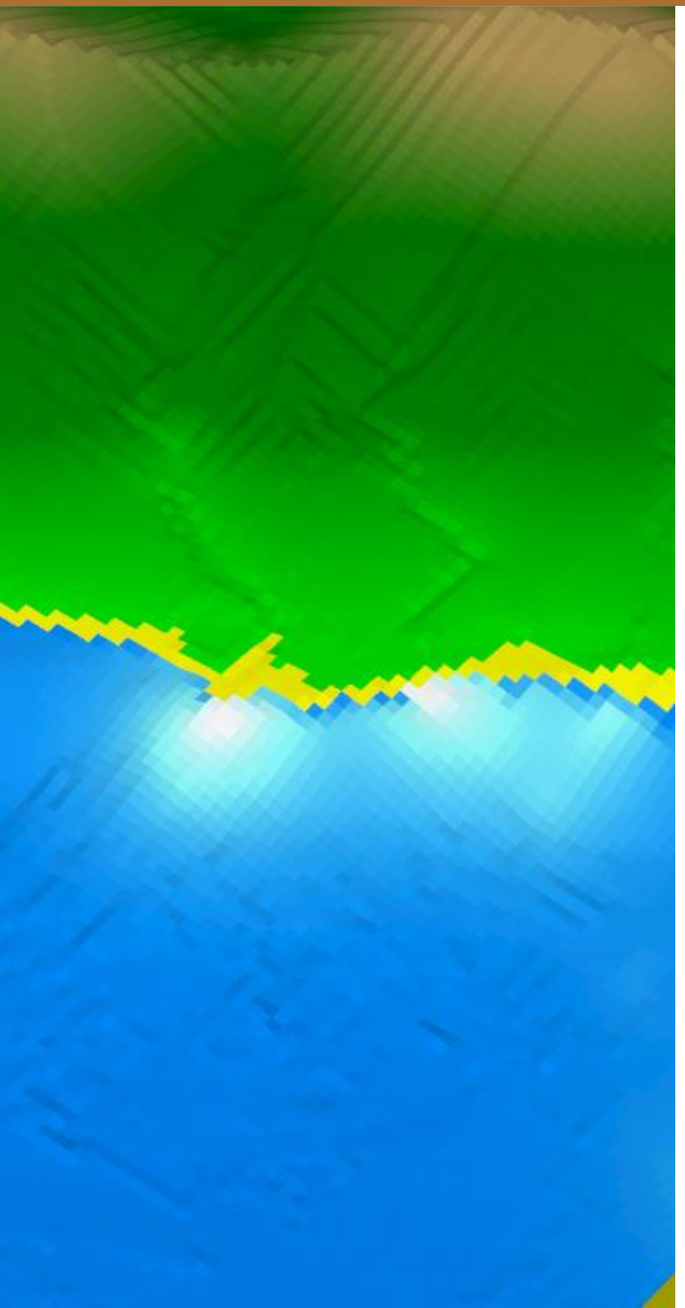
DionisosFlow® **2023** introduces new developments that leverage the improved performance and capabilities that were brought to the software in the last few years, while laying the foundation for future advancements in the software.

The predictivity of process-based modelling is very much dependent on the processes modelled and the ability of the algorithms to reproduce the physics that govern natural phenomena. In this version, DionisosFlow® offers new processes and advanced algorithms, particularly in **nutrients supply** and **water flow**.

DionisosFlow® 2023 thus brings a new **"tracer"** editor to model nutrient leaching and bioavailability in the marine realm for organic matter production and carbonate growth. These tracers are a stepping-stone for further developments in primary diagenetic modelling. This version also brings an **advanced water flow** algorithm that is the result of years of R&D dedicated to enhancing its calculation, as water flow is one of the most influential processes in sedimentary systems. Additionally, it is now possible to use **cyclical climatic curves per sediment type** in order to reproduce climate induced grain size variability.

Through its link to CougarFlow® and its 2023 functionalities, it is also now possible to test and quantify the impact of **different conceptual models** on simulation results, unlocking a unique and powerful workflow for mitigating the risk on reservoir and seal presence, quality or source rock occurrence and richness.

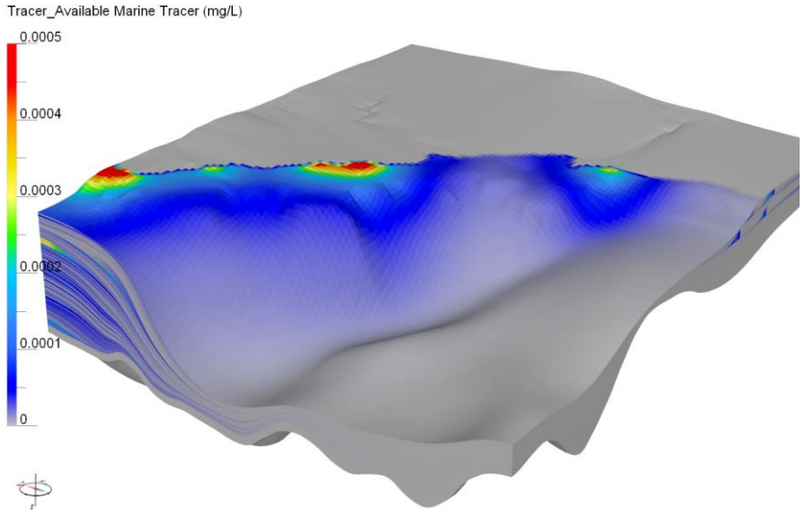
Finally, and as with every new version, DionisosFlow® 2023 also offers a number of adjustments and additions that will enhance the user experience and provide more versatility.

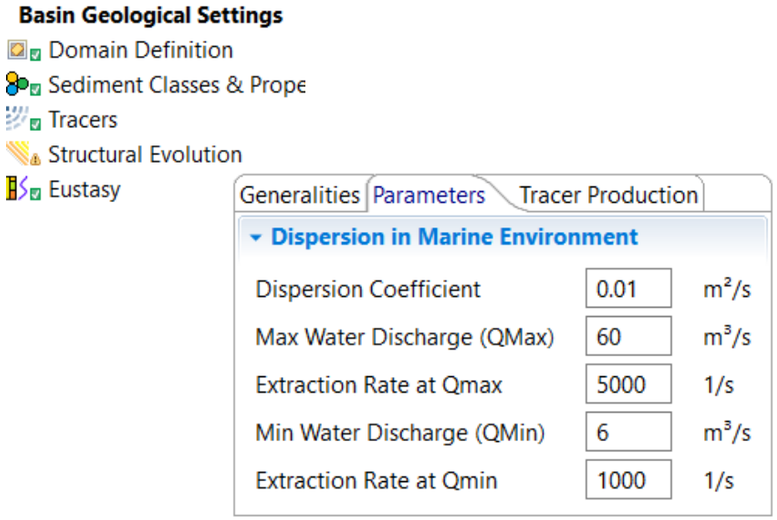


Tracers (1/2)

Sedimentary sources and sinks are not only linked mechanically through the weathering and erosion of sediments in the hinterland and its transport to sedimentary basins, but also chemically through the leaching of nutrients in terrestrial domains and its transport to marine realms. Such **nutrient supply** is responsible for the production of an important proportion of organic and inorganic marine sediments that are eventually preserved in the geological record.

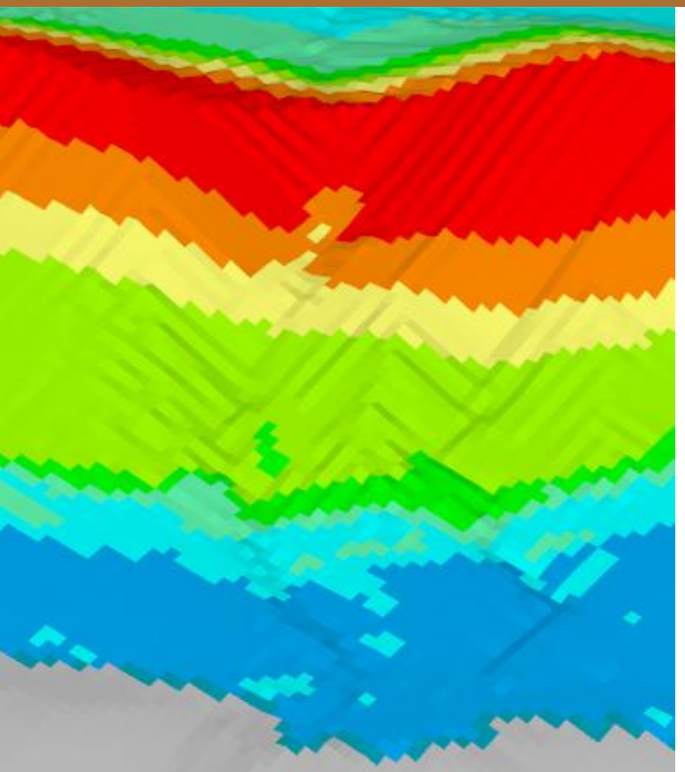
A new "**Tracer**" context and editor has been added to simulate the leaching, transport, diffusion, and biological availability of terrestrially derived nutrients in marine basins.





Once the "Tracer" context is activated, any number of tracers can be added in the tracer editor. Tracers will be produced under the effect of rainfall at a user defined rate that depends on sediment proportions in the exposed domain. Sourcing tracers from outside the modelled domain is also possible as part of boundary sediment sources.

Once produced, tracers will be transported with the water flow to reach the marine realm where an extraction rate will be applied to render some of these nutrients biologically available.



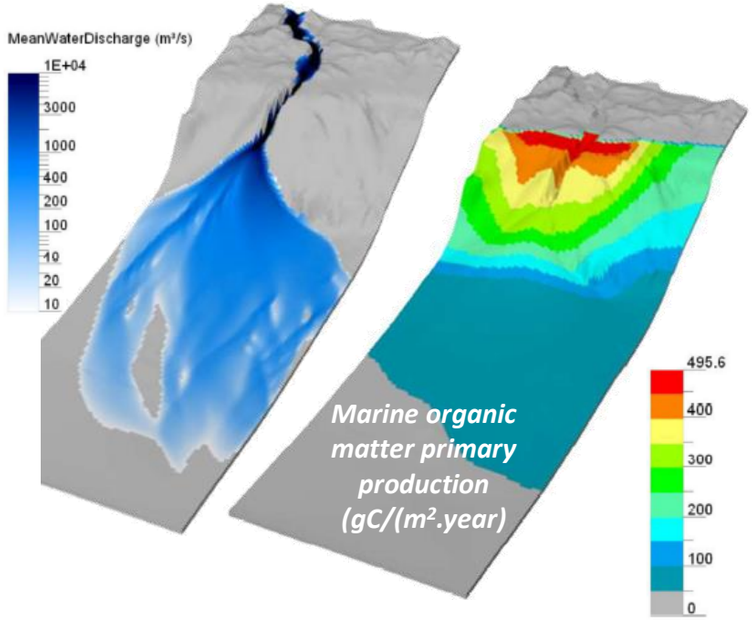
Lithology dependant tracer production in continental domain

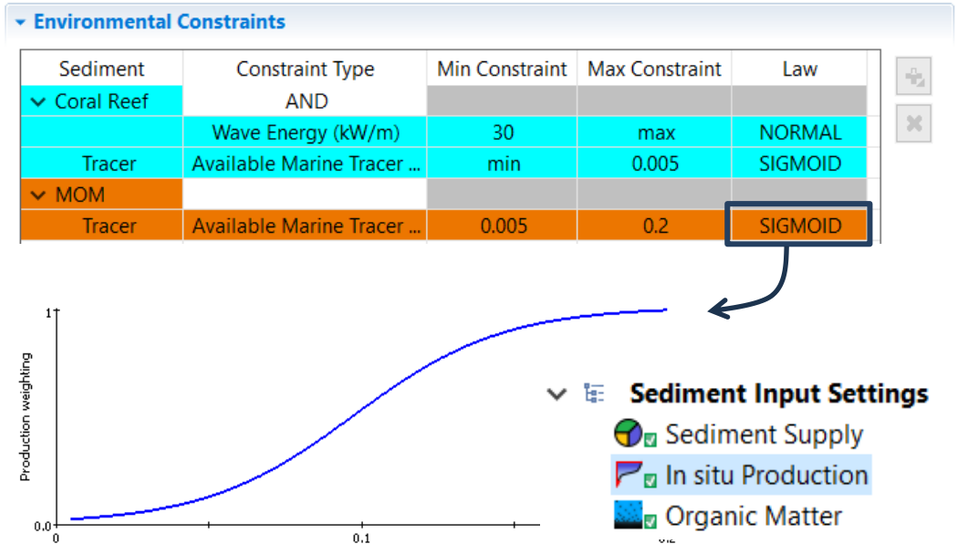
Tracers (2/2)

Once the tracers reach the marine realm and are made biologically available, they can be used as **nutrients** to control the **primary production** of marine organic matter.

Several new outputs are now available as a result of tracers simulation. The main output, however, which can be used to constrain marine organic matter production is the "**Available Marine Tracer**".

Under the "**In-Situ Production**" editor, in the "**Environmental Constraints**" the user is now able to use **marine tracers as nutrients** and constrain the production of marine organic matter using a sigmoid law.

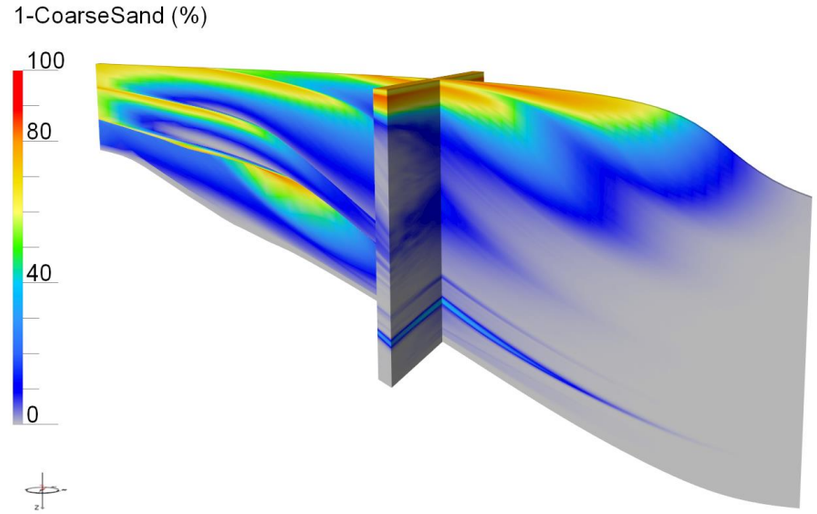


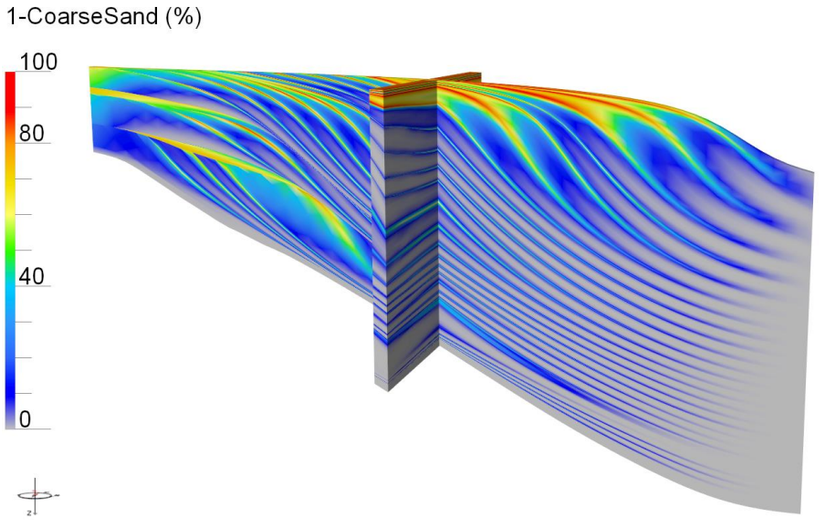


Organic matter is not the only beneficiary of the tracer option. **Carbonates** can also be constrained with tracers positively or negatively as some types of carbonates would benefit from **land derived nutrient supply**, but others prefer clear water away from any land influence.

Sediment Specific Climate Curves

High frequency climate cycles such as **Milankovich cyclicities** exert an important control on clastic sediment supply as well as carbonate and organic matter production. Integrating such cycles in DionisosFlow® has already been an existing option, however, limited to controlling all clastics and all carbonates equally and simultaneously. This hinders the reproduction of natural reactions to high frequency climatic cycles. Thus, we introduced the capability of independently applying **climate cycles for each type of sediments**.



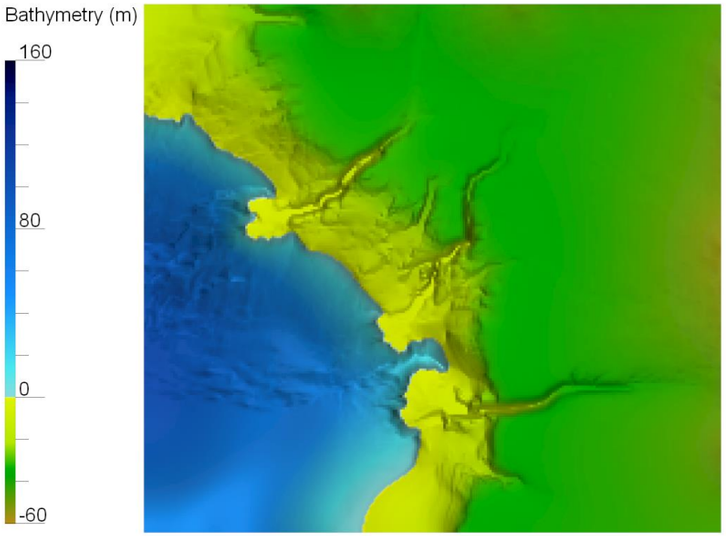


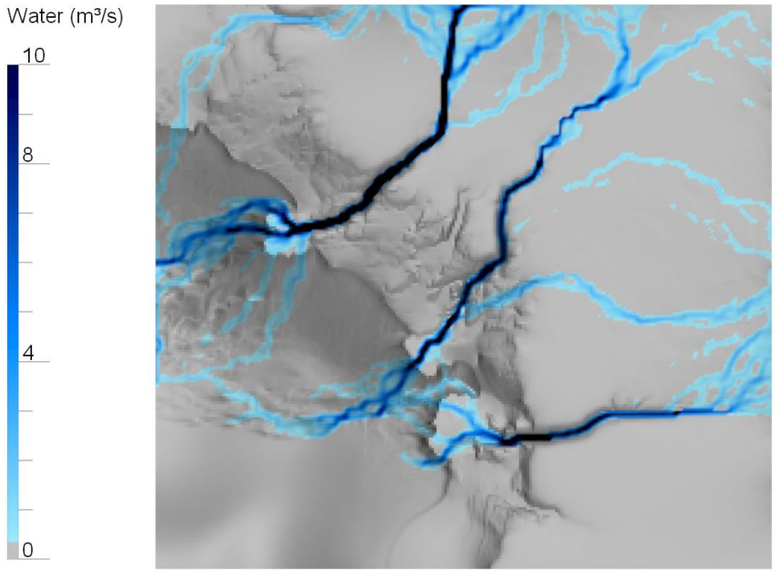
Under the climate editor in the DionisosFlow® guideline, it is now possible to add **multiple curves with various frequencies** in order to influence multiple sediments simultaneously in phase or out of phase. This will allow the user to model scenarios where the effect of climate cycles on coarse and fine sediments is out of phase and rather opposite.

Such versatility allows the user to model sedimentary architecture that was previously problematic.

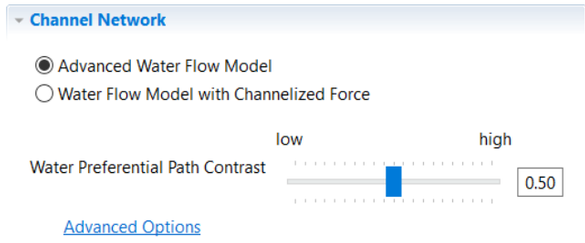
Advanced Water Flow

Water flow is a major process in forward stratigraphic modelling. It is one of the main drivers of geomorphological evolution through sediment erosion, transport, and deposition. This year we introduce a new and **advanced water flow modelling** capability based on the use of **rugosity maps**. This option comes from recent developments allowing for a more realistic representation of natural processes. Additionally, this new algorithm incorporates a discretization of the Gauckler-Manning-Strickler continuous equation which reduces numerical noise.

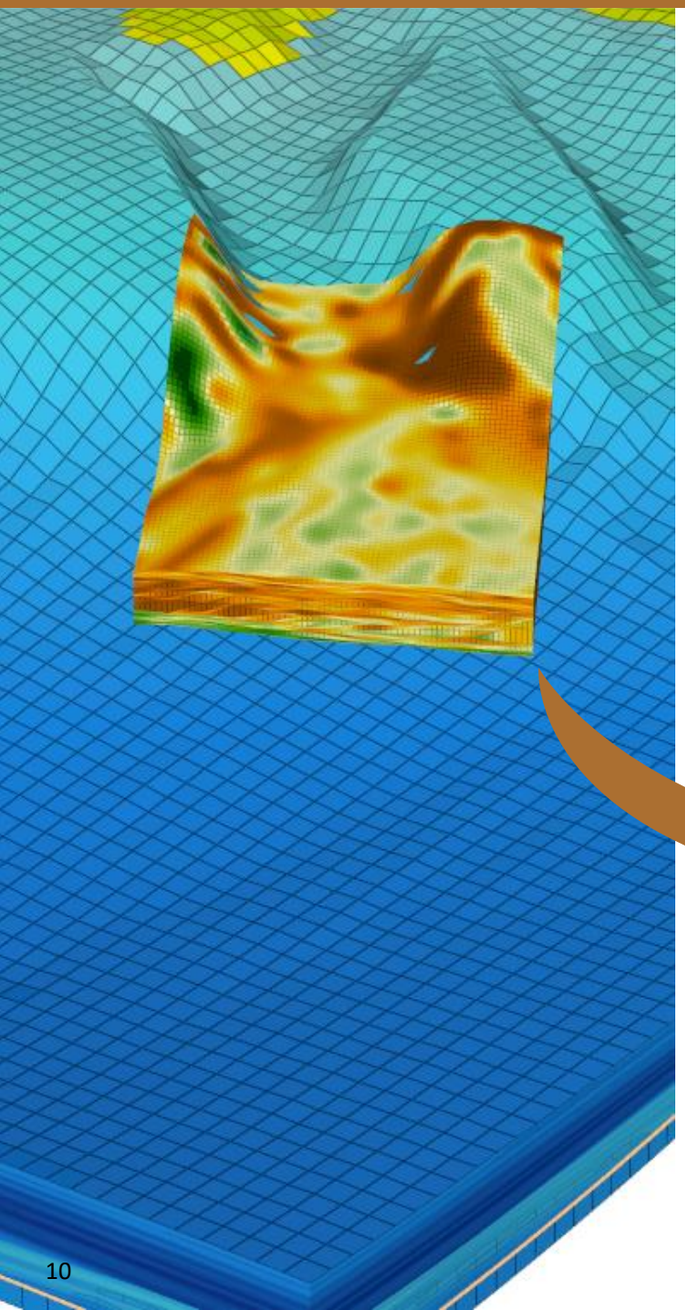




Under "**Transport Processes**" the user now has the choice between two options to model a channel network: the rugosity based "**Advanced Water Flow**" and the classical "Water Flow Model with Channelized Force".



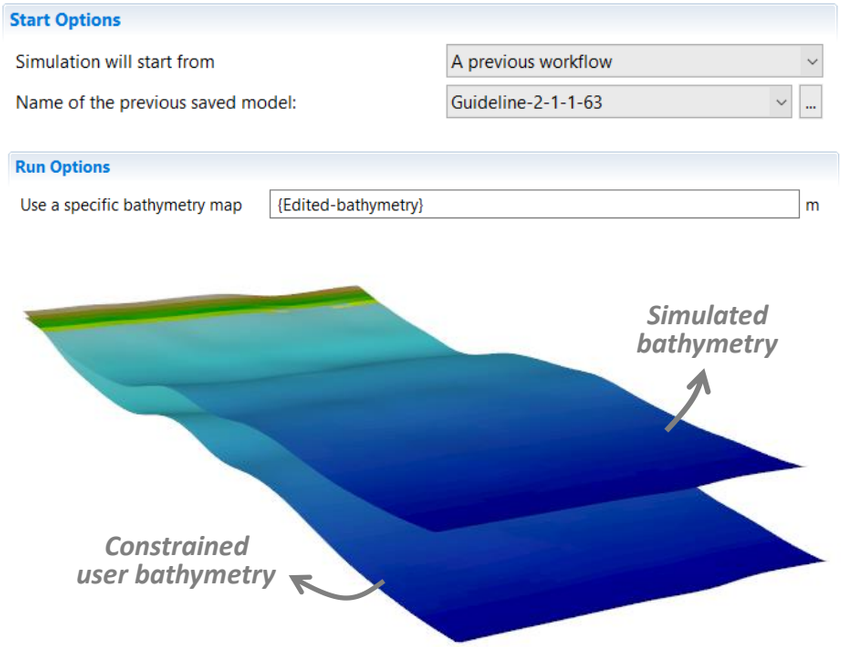
A new water mixing model is now available to control the behaviour of water flow once entering a marine domain.



Additional New Options

From Previous Workflow with User-Defined Bathymetry

Model initiation from a previous workflow is a very useful modelling approach in DionisosFlow that allows the user to model and calibrate a stratigraphic succession one sequence at a time and initiate younger sequences from modelled older sequences. This approach is now more versatile by allowing the user to adjust the starting bathymetry of a "**from a previous workflow**" model. This option is used in specific cases where enough bathymetry constraints are available and a small mismatch between bathymetry data and model bathymetry is still observed.



Synthetic Seismic for Reservoir Grids

Recent developments in DionisosFlow resulted in several types of grids as output (stratigraphic grid, fitted grid, reservoir grid).

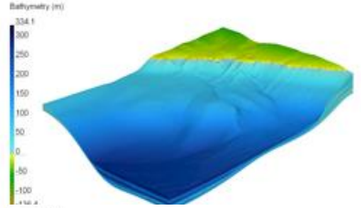
Synthetic seismic is now available on all of these grids, including **reservoir grids**.

Multi Geological Scenario Analysis

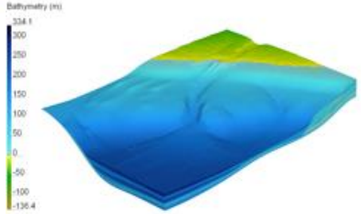
Every DionisosFlow® model should start with a conceptual model that gets tested and subsequently passed to **CougarFlow®** for uncertainty and sensitivity analyses. **Multi-geological scenario analysis** with CougarFlow® is a new map-based tool that allows for the classical CougarFlow® uncertainty analysis to be done while considering **any number of conceptual models.**

The results of multi-response surfaces can now be combined with a user defined weight to produce **risk and probability maps.**

Conceptual model 1:
- Haq et al. 2014 sea level
- Age model based on ICC 2017



Conceptual model 2:
- Miller et al. 2005 sea level
- Age model based on ICC 2008

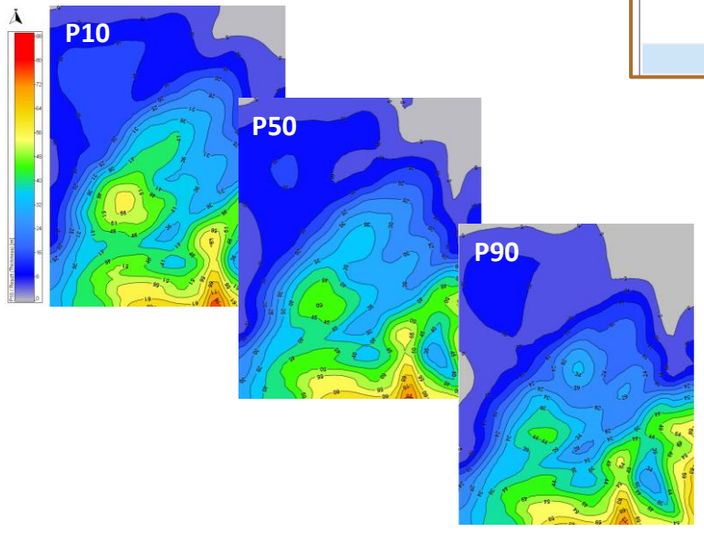


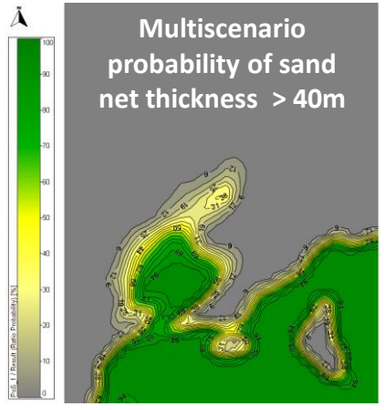
3000 results

7000 results

Configuration

MOI	Weight
Concept_1	0.3 (30.0%)
Concept_2	0.7 (70.0%)





This tool is a unique solution to quantify the geological risk on any DionisosFlow® output even if the **uncertainty** is linked to the **conceptual model** (e.g. age of rifting events, location of sediment entry points, types of carbonate producers, presence or absence of an upwelling system...).

KronosFlow™

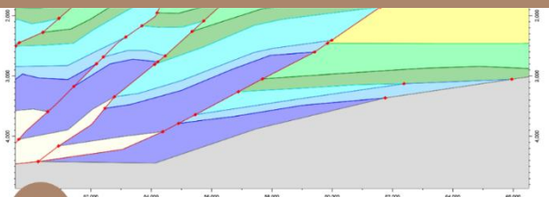
Balancing & Time Efficiency

The 2023 version of **KronosFlow™** aims at strengthening the structural restoration part of the workflow by bringing an innovative **quick-look balancing module**. This dedicated mode will allow you to quickly check the validity of the present-day interpretation by flattening all blocks on a reference horizon, and even correct potential balancing issues in this restored state.

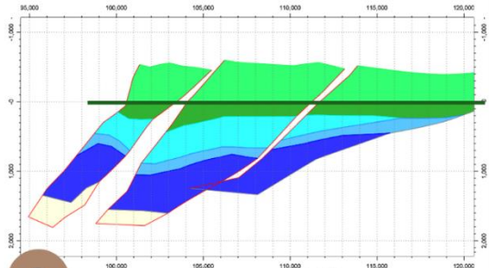
Most of the new options of KronosFlow™ 2023 are focused on bringing **more efficiency** and **saving time** along the workflow. In addition to the balancing tool that will allow validating the present-day digitization faster, run time has been drastically decreased thanks to an optimized simulation result import and the possibility to retrieve the temperature regime from a reference simulation to avoid computing it again.

A new technical calculator option is the possibility to model **heat advection in faults**, i.e. the transfer of heat with water in permeable faults. This option will allow for a better assessment of the geothermal potential of a basin, especially in high enthalpy area, as well as offer a sounder approach for traditional oil and gas system exploration.

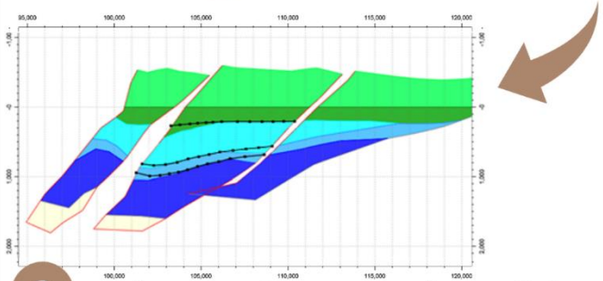
Quick Look Balancing Module



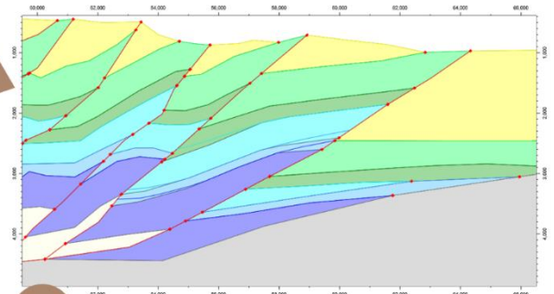
1 Present day section digitization



2 Scattering and flattening



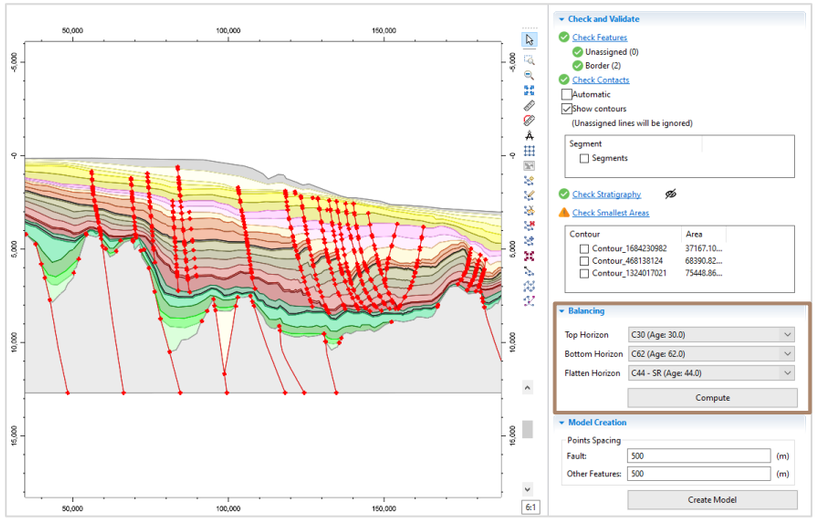
3 Redrawing in restored conditions

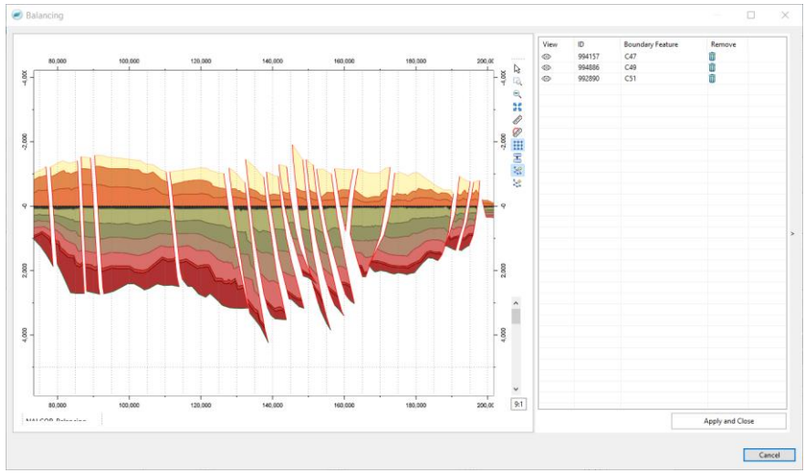


4 Retroimpact on Present day geometries

In order to quickly check the validity of the present-day geometry and correct it if necessary, KronosFlow™ 2023 offers a new **balancing** module. Directly available in the Digitization section, it allows flattening all the fault blocks on a reference horizon at a click.

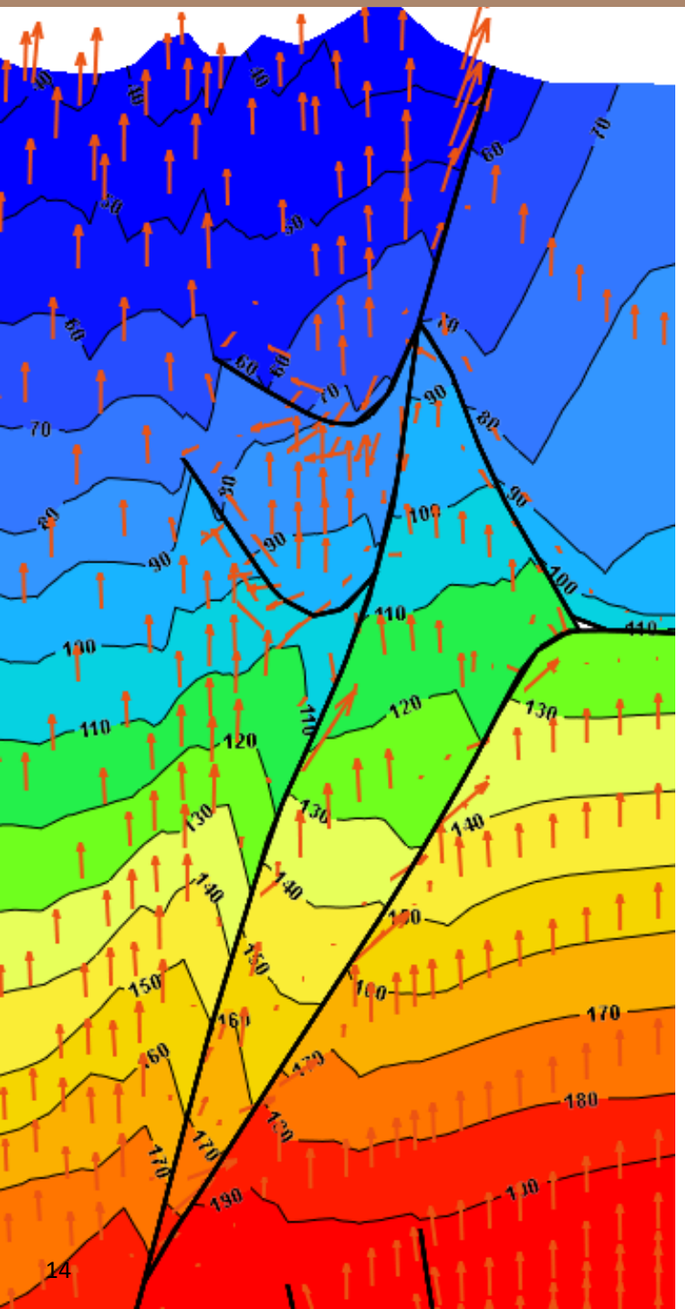
In this restored state, it becomes easy to check the fault throw consistency, quickly identify balancing issues, and even redraw the horizons. After validation of the corrected version of the horizons in restored conditions, the **modifications are automatically transferred on present day geometries**, these horizons being redrawn through a forward restoration process.





This new module is available through a new **Balancing** section in the right-hand side panel of the Digitization section. You will simply need to define the top and bottom horizons of the interval to consider (which allows separating the fault blocks) and the reference horizon used for flattening.

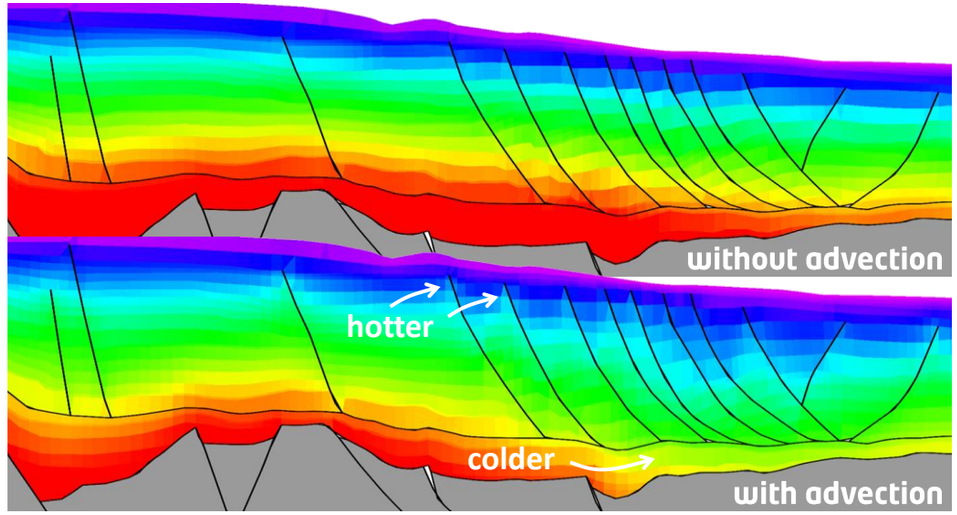
A new dedicated window opens with the scattered and flattened block. The traditional manipulation and edition tools are available to move the blocks, measure distances, and redraw the horizons. All geometry modifications are recorded in a table, which allows updating several lines at once and preserving the necessary editions. When done, a validation button allows retro-impacting automatically the present-day geometry.

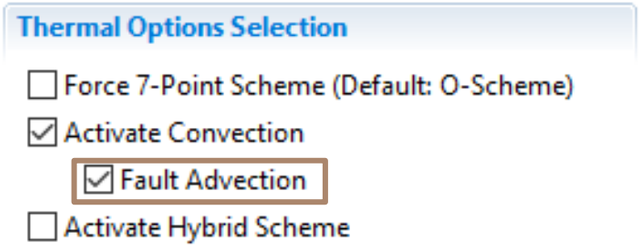


Heat Flow Computation in Faults

In order to better assess the geothermal potential of your basin, it is now possible to consider the heat advection processes in permeable faults. This option allows to model the movement of hot water from the deep part of the basin to the shallowest layers, creating locally hotter areas at the tip of the faults, and cooling down their base.

Necessary for a proper assessment of the heat in place, this option also brings a better temperature computation that will impact the source rock maturity and potential alteration effects around fault systems.





Available in the **Thermal Options Selection** section of the **Tune Numerical Parameters** tab of the ArcTem run editor, the **Fault Advection** option can be simply ticked on to allow the transfer of heat with water in permeable faults. Just make sure the flow along and across faults is activated and that the bottom thermal condition is not a thermal gradient.

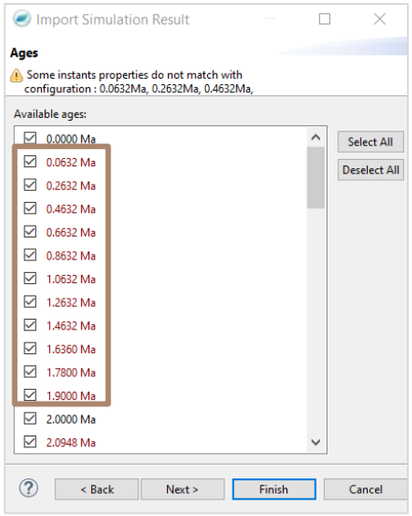
Note that for now, this option is not compatible with the Hybrid Scheme option. It is also not yet possible to tune the fault conductivity in order to adjust the heat transfer in faults through the rock matrix.

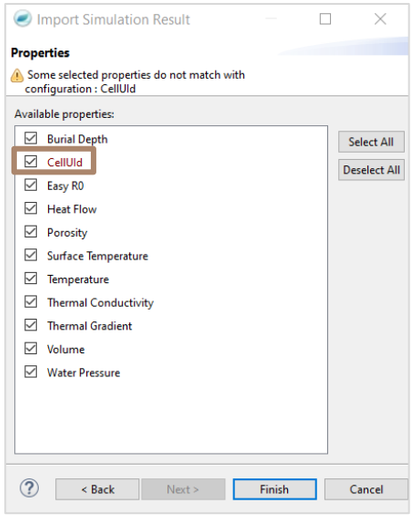
Result Import Optimization

Optimized Simulation Result Import

Simulation results are now imported in parallel with the simulation itself. As soon as an event has been computed, the step is imported in the scenario and can be visualized.

This transparent functionality will allow you to check your results sooner, as the simulation progresses, and stop the run if you catch a problem. It will also drastically improve the total run time (simulation + import) as gains up to **40%** can be expected, depending on the section resolution and steps number.





Customization of the Import ArcTem Result Option

When importing manually a simulation result from the disk into the Scenario Explorer, more options are now available. It indeed becomes possible to select the ages and properties to import, limiting the amount of data to what is necessary.

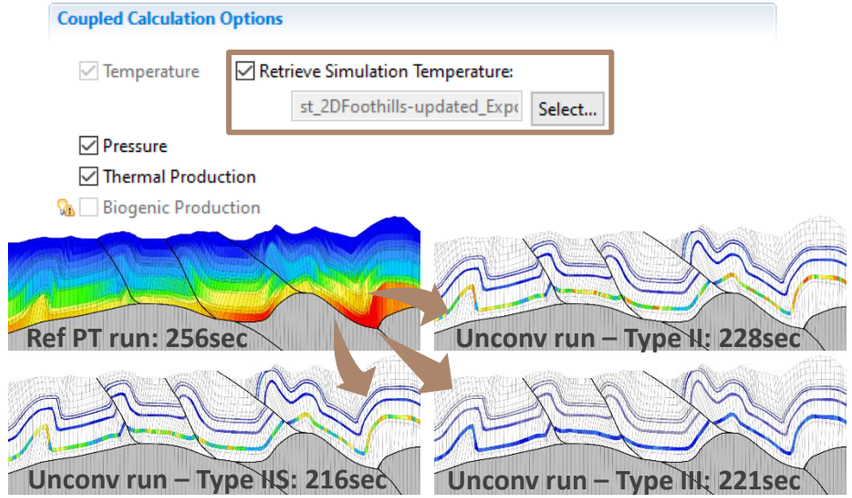
If some specific options were manually activated in the input files to ask for some specific output properties (cell id for example) or additional time steps, it is now possible to import that extra data into the scenario for a simplified visualization and post-processing.

And More...

Temperature Conditions from Previous Simulation

Once the model calibrated in Temperature and Pressure, you can simply reuse the computed temperature field for subsequent expulsion, unconventional or migration simulations. This will drastically reduce the simulation time and allow you to test more easily various scenarios.

You can expect a run time reduction of **30%** depending on the complexity of the simulation. Note that only simulations with the same mesh and ages are compatible and that you will obviously not be able to account for the HC effect on temperature in these decoupled simulations.



Copy/Paste of Models in the Study Explorer

KronosFlow models can now be duplicated with a simple **Ctrl-C + Ctrl-V** in the Study Explorer. The copy used to be only possible through a selection of the model and selection of the copy and paste options with a right-click, the process failing half the time.

This copy preserves all information of the initial model. The possibility to initialize a model from a previous digitization remains available at model creation and should be used if the new model is made to adapt the present-day interpretation or stratigraphy.

TemisFlow™

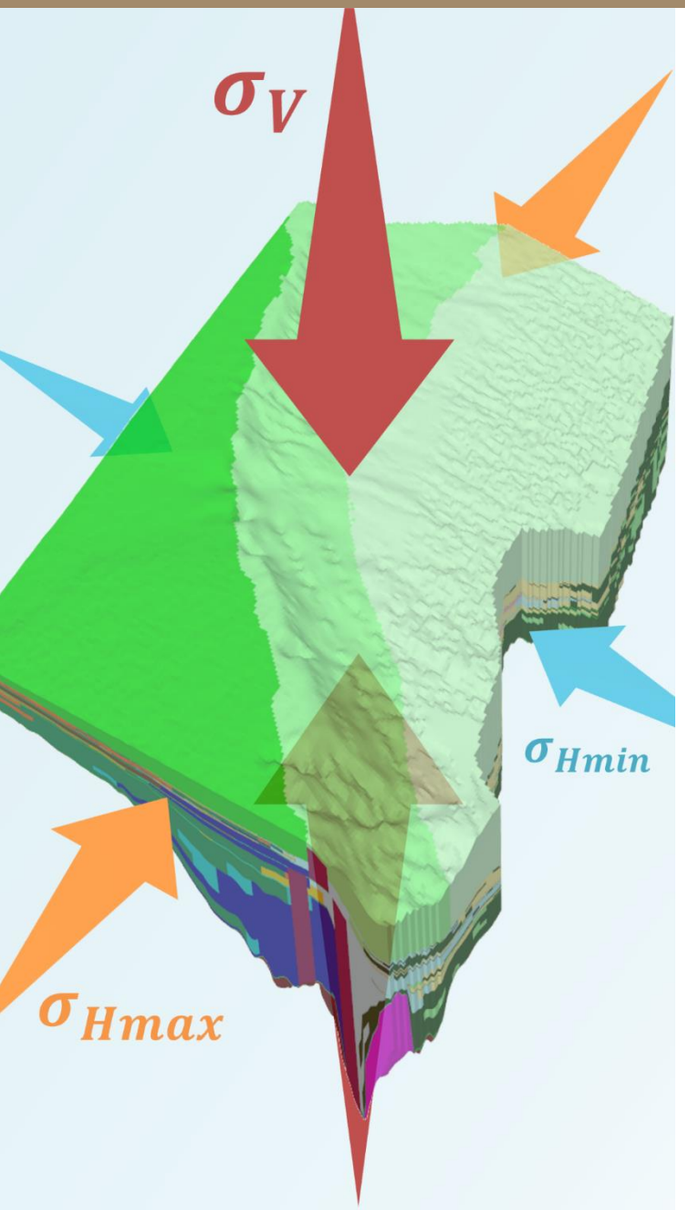
More Physics for More Versatility

If **TemisFlow™ 2023** strengthens its regular workflows for oil and gas exploration, it also lays the cornerstone for a new type of basin modeling usage, oriented towards new energy sources and decarbonation.

Both ArcTem and historical simulator Visco evolve to address advanced processes. **Lateral stress** can now be accounted for in basin simulation for a better assessment of porosity/permeability and resulting pressure distribution. **Deep gas sources** can be input in TemisFlow™ models, unlocking **deep CO2** or **H2S** risk assessment, but also exploration workflows for **natural hydrogen** or **helium**. This same functionality has also been thought to evaluate **CO2 storage potential** in saline aquifers, allowing for a preliminary but sound characterization of storage capacity, seal efficiency and aquifers connectivity. Coupled with **new dissolution laws**, this functionality is a key step towards new generation basin modeling.

Increased performance is also at the heart of TemisFlow™ 2023 with the availability of the **Decoupled Darcy Migration** scheme in ArcTem as well as the possibility to **use an existing temperature run** for further pressure, expulsion and migration simulation. **Parallelization** and **results import** have also been improved to speed-up calculation time and results access. Many other improvements related to visualization options, trap charge assessment or the link to DionisosFlow® have also been brought.

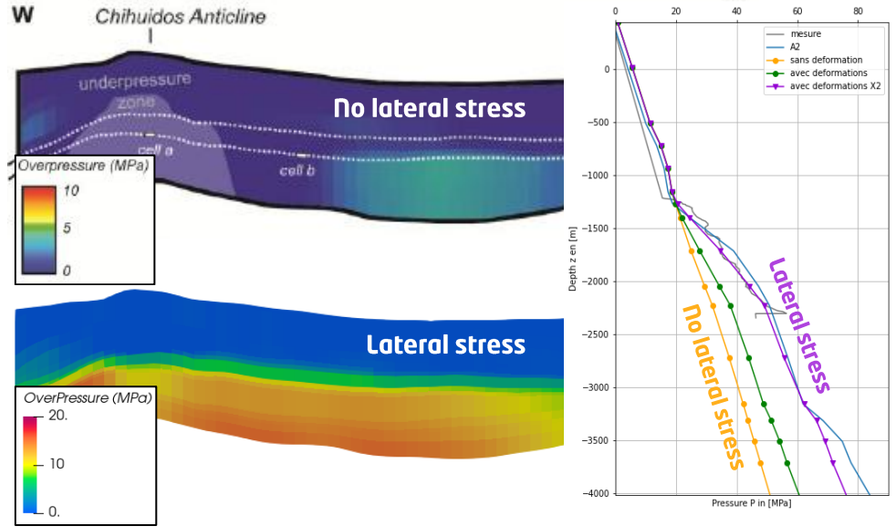
Last but not least, CougarFlow® 2023 brings awaited and yet unique possibilities with **multiple geolgical scenario testing** and the capability to define discrete parameters as uncertain such as **facies** or **source rock** properties. Combined with the existing **Map Analysis** module, these latest developments are a real breakthrough in risk assessment workflows.



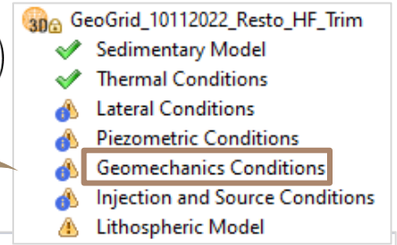
Geomechanics Conditions for Better Pressure Prediction

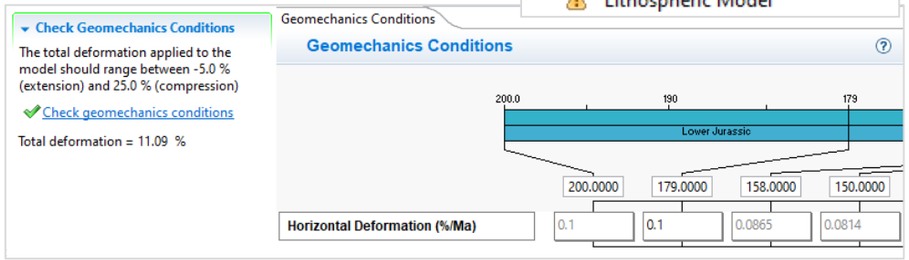
TemisFlow 2023 offers the possibility to take into account the **lateral deformation** of the basin for a better computation of the pressure regime through time. An efficient approach is used to limit the extra simulation time needed: the additional horizontal stress is added to the vertical constrain to consider an effective stress representative of the complete stress regime.

Working for both extensive and compressive systems, this option impacts the porosity computation and allows representing overpressure effects that were not possible to consider before (as shown in the picture to the right).



$$d\sigma_z^* = d\sigma_v' + \frac{E}{\nu(1+\nu)}\left(d\varepsilon_x + d\varepsilon_y - \frac{2(1-\nu)d\varepsilon_x d\varepsilon_y}{d\varepsilon_x + d\varepsilon_y}\right)$$

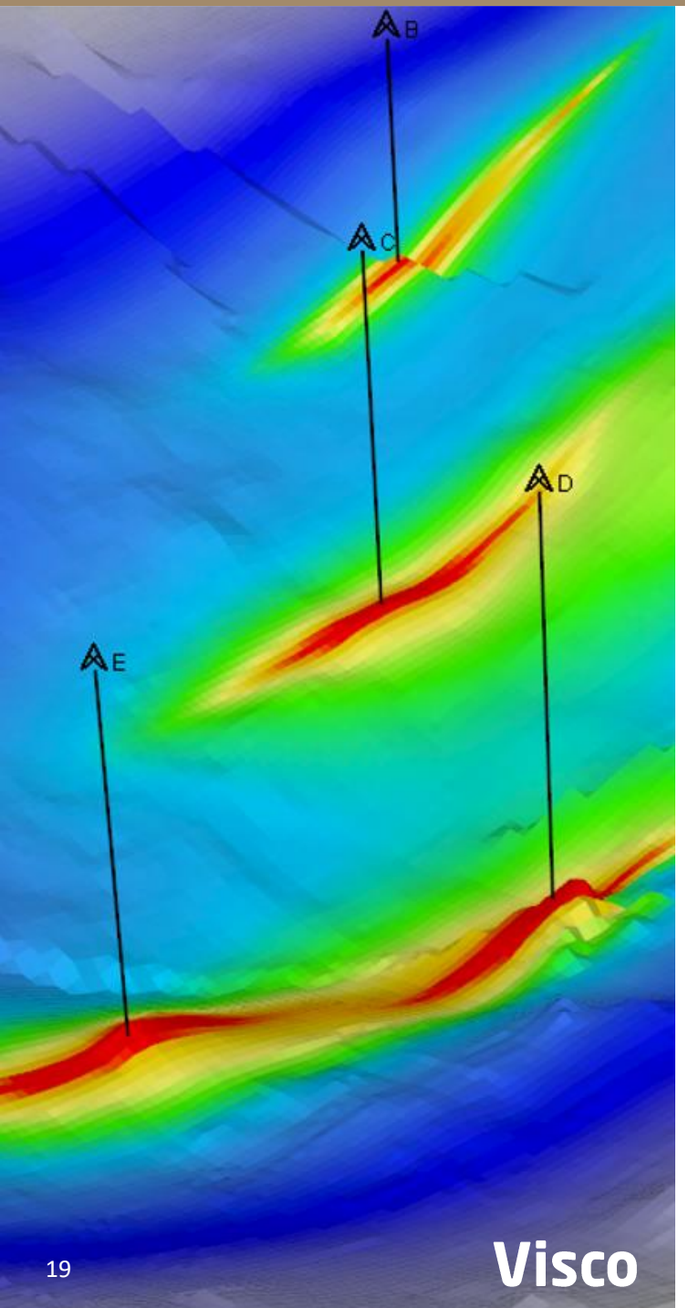




A new dedicated editor called **Geomechanics Conditions** is available under the GeoGrid. Simply define the rate of horizontal deformation at each time step (either negative for extensive settings and positive for compressive ones). The corresponding horizontal stress is automatically estimated. Don't forget to activate the option in the Arctem run options.

This approach is a nice quick look for decision making on more complex geomechanics, like the full integration of a geomechanics calculator (Aster) with the basin modeling calculator (Arctem) offered at IFPEN.

ArcTem

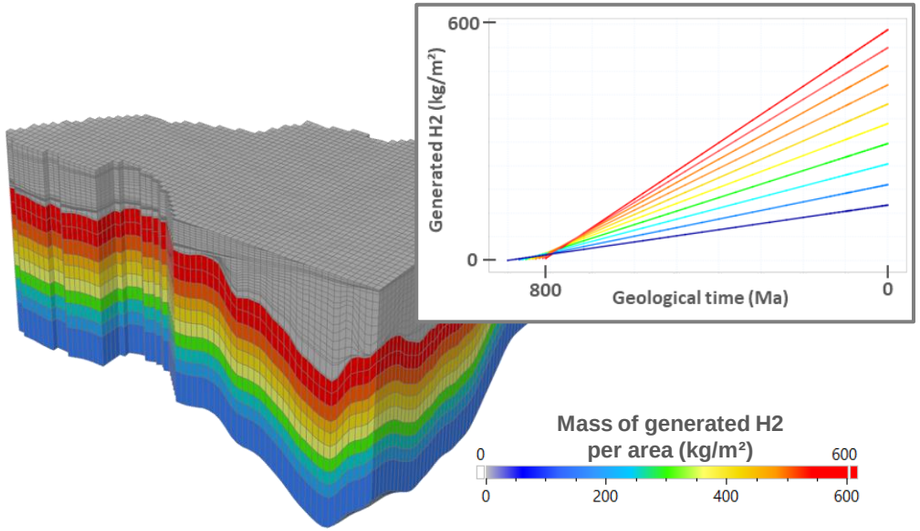


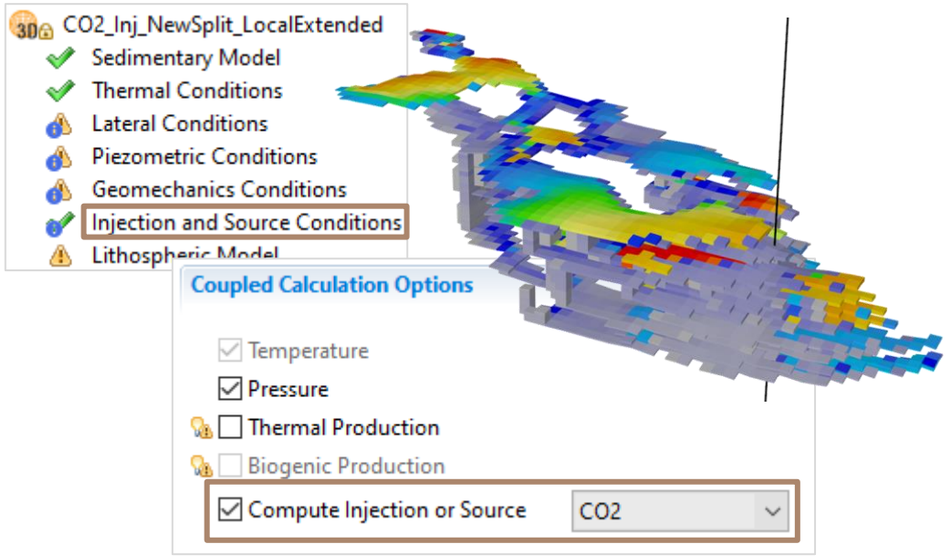
Visco

"Chronogenic Sources": Deep Gas Sources and CO2 Injection

A new type of **gas sources** is available in TemisFlow 2023 with a generation rate only dependent on time. These new "chronogenic" sources will allow to easily model deep gas sources - for **natural hydrogen** or **helium** assessment for instance - or acid gas presence risk like H2S or CO2.

It will also offer an efficient approach to model **CO2 injection** and perform a quick screening of the aquifers at basin scale to identify the best storage locations.





Benefiting from the full Darcy migration, the gas displacement is properly represented as well as the impact of the injection on the pressure field. This allows for a proper assessment of the risks of leakage, seismicity, fault reactivation, and clean water aquifer pollution.

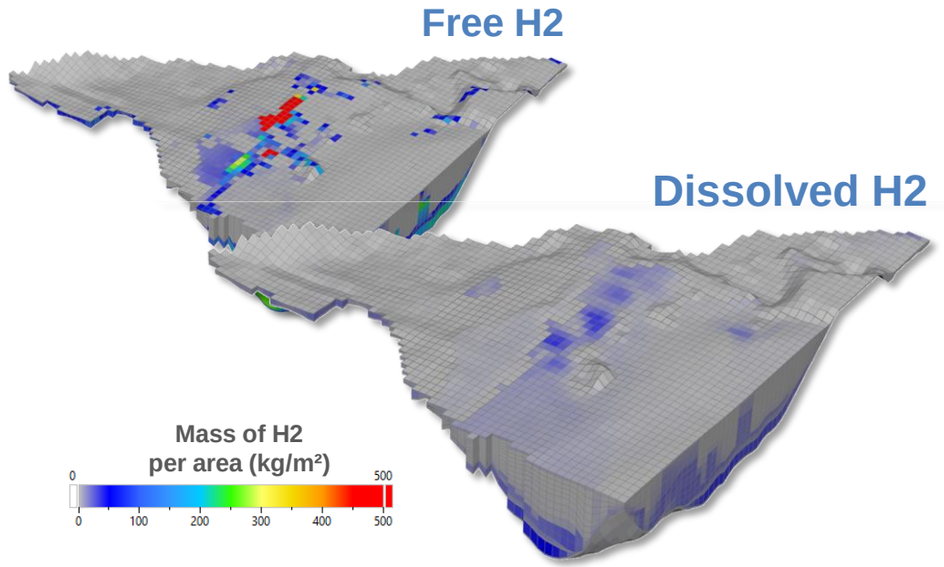
A new dedicated editor is made available to define the generation or injection rate for each layer through time. These sources can then be coupled or not with classic thermogenic or biogenic productions through the Visco run editor.

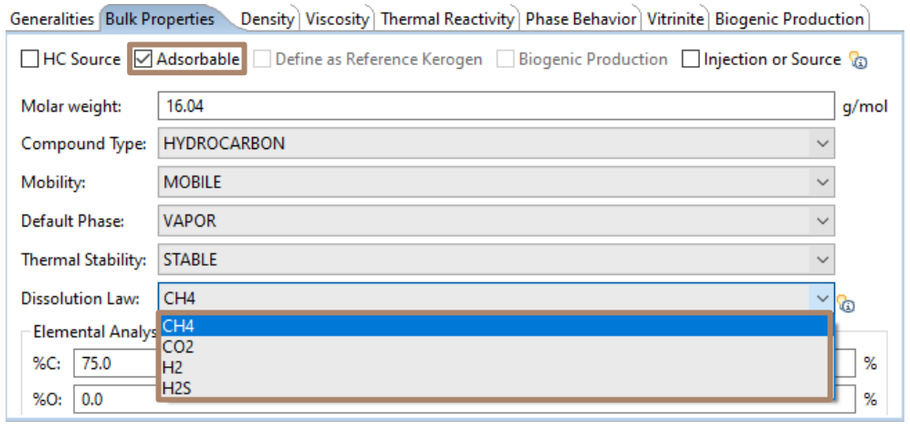
Visco

New Dissolution Laws for Various Gases

More **dissolution laws** are now available for Darcy migrations with the Visco calculator. In addition to the already present methane dissolution law, specific laws have been added for **carbon dioxide**, **dihydrogen**, and **hydrogen sulfide**. These laws will drive the amount of component that is dissolved in water or desorbed back into its free form depending on pressure and temperature conditions. Both dissolved and free forms will migrate independently and both amounts are given as output of the Darcy simulations.

These new dissolution laws are the perfect complement to the new deep gas sources and injection editor for a full representation of the gas presence within the basin.





In order to consider the possibility to adsorb one of the gas fractions, tick on the **Adsorbable** option in the geochemical library and select one of the four dissolution laws in the dedicated section. You can then activate the dissolution option in the Visco run editor in the Migration Scheme options.

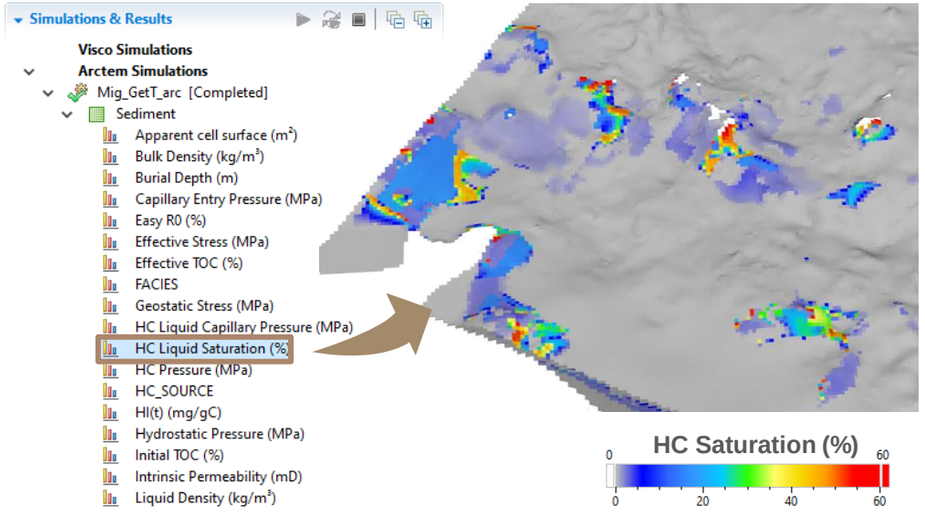
Note that only one gas fraction at a time can be dissolved for the moment. This option is also only available for the Visco simulator for now.

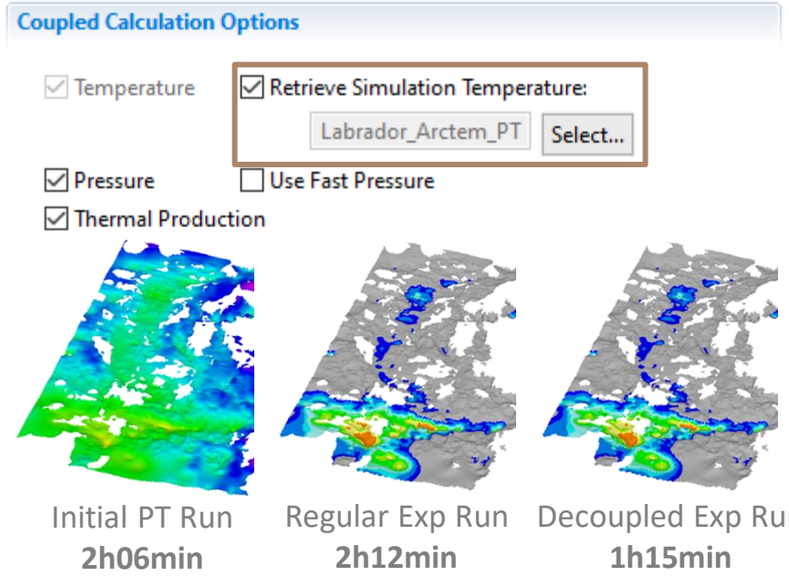
ArcTem Simulator Performance Improvement

Decoupled Darcy Migration

Continuing the implementations of all Visco functionalities into ArcTem, a major addition has been brought in this version: it is now possible to launch a **Decoupled Darcy Migration** run in 3D with **ArcTem** for an efficient play and prospect assessment.

Available for both non-compositional and compositional schemes, this new migration simulation option benefits from the effective specs of the ArcTem simulator listed here-after for an optimal simulation runtime.





Initial PT Run **2h06min**

Regular Exp Run **2h12min**

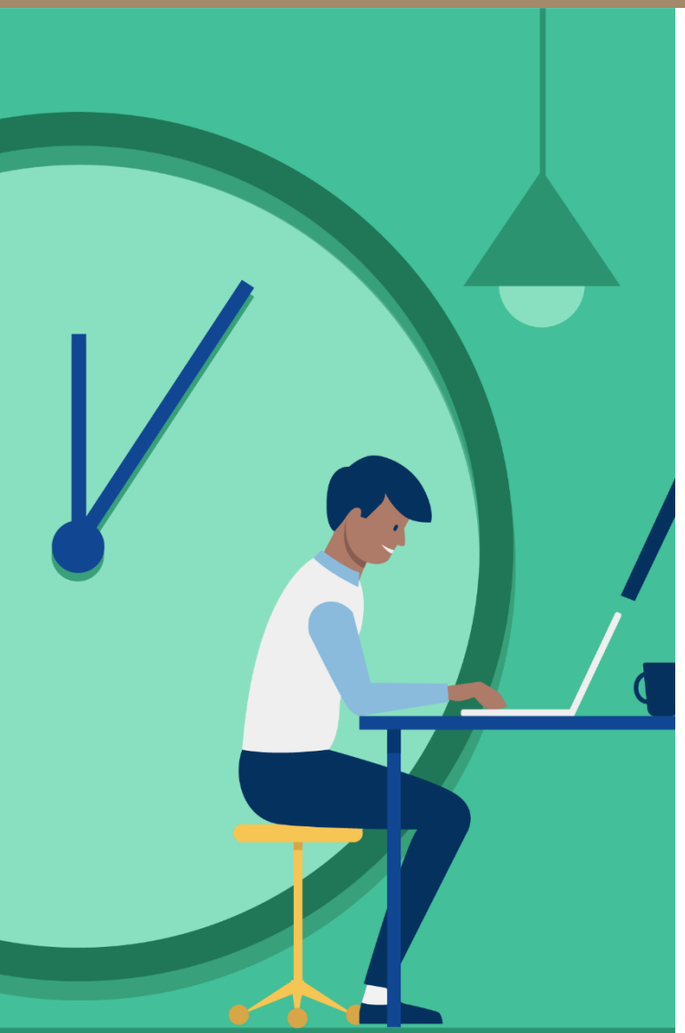
Decoupled Exp Run **1h15min**

Temperature Conditions from Previous Simulation

After calibrating the model's Temperature and Pressure, you can conveniently utilize the calculated temperature distribution for subsequent simulations involving expulsion, HC retention in source-rocks, or migration. This approach will significantly decrease the simulation duration and enable easier testing of different scenarios.

Depending on the simulation's complexity, you can anticipate a reduction in runtime of **more than 40%.** Note that these decoupled simulations are only compatible with simulations with the same mesh and ages, and obviously do not incorporate the impact of hydrocarbons on temperature.

ArcTem

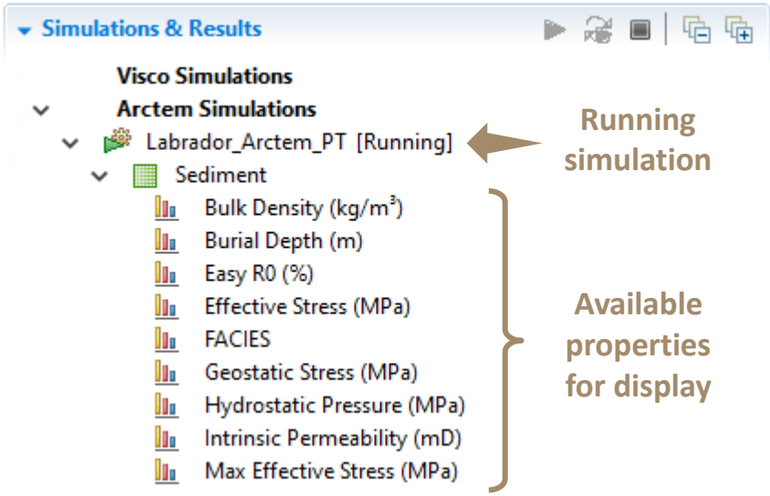


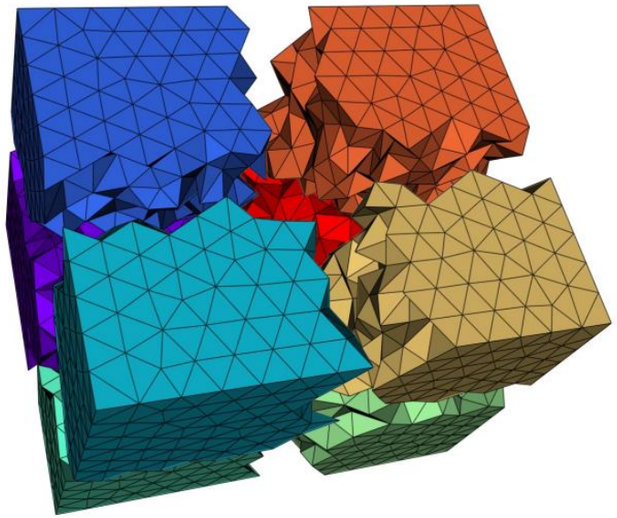
ArcTem Simulator Performance Improvement

Optimized Simulation Result Import

The simulation results are now imported simultaneously with the ongoing simulation process. Each computed event is promptly incorporated into the scenario and made available for visualization.

This transparent functionality enables you to monitor and assess your results at earlier stages of the simulation, allowing you to halt the run if any issues are detected. Additionally, this approach significantly enhances the overall runtime (simulation + import), potentially resulting in gains of up to 40%, depending on the resolution of the grid and the number of steps involved.



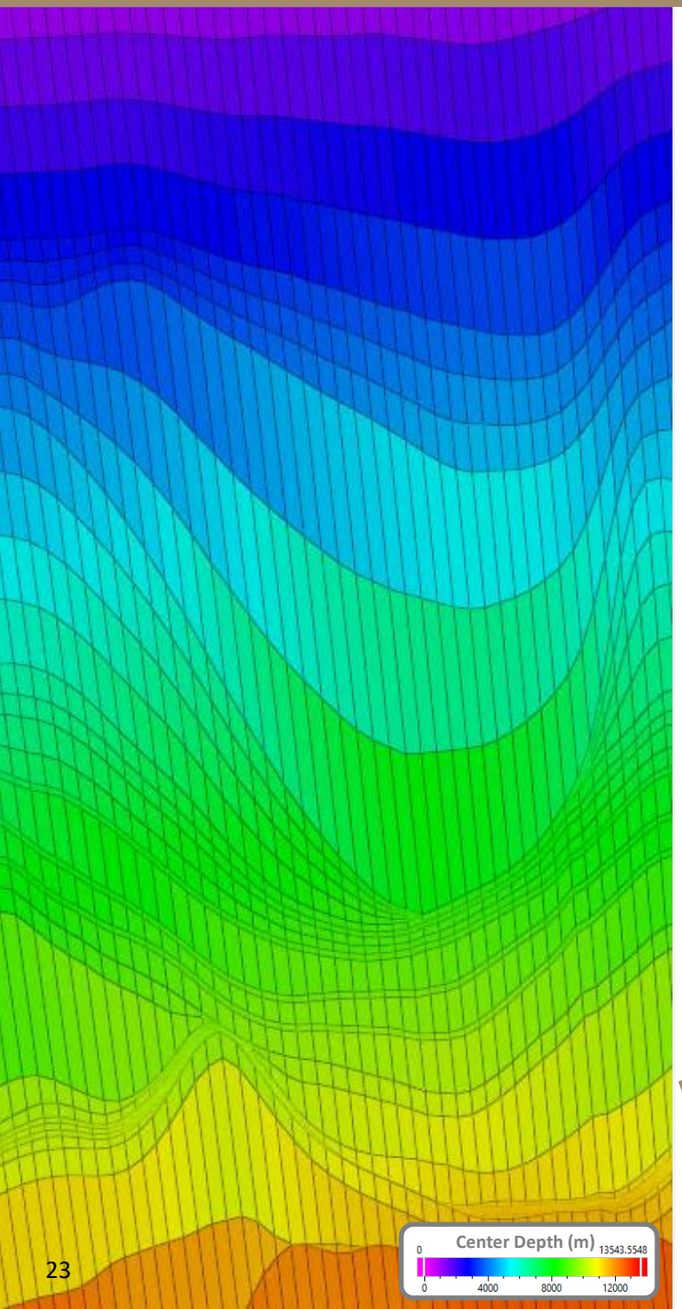


Better Parallelization

A new partitioner (ParMETIS) is now used to optimize the parallelization of ArcTem simulations. This results in a lower runtime (performance varies with resolution and CPU number) and a better parallelization speedup.

Improved Run Importer

When manually importing a simulation result from the disk into the Scenario Explorer, additional options are now accessible. This allows for the selection of specific ages and properties to be imported, effectively reducing the amount of data to only what is required.

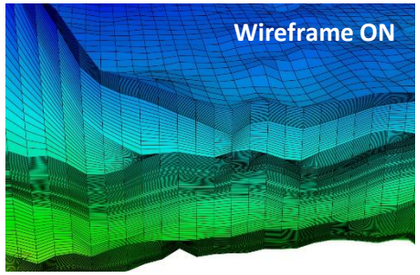


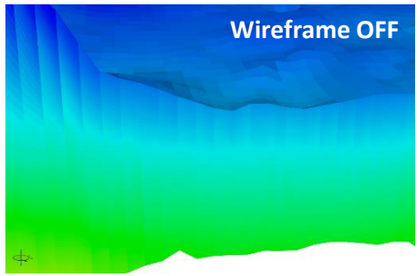
New Visualization Options

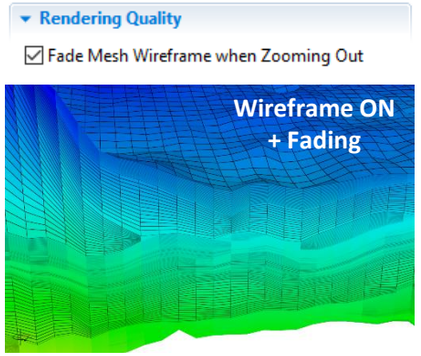
Better Mesh Rendering

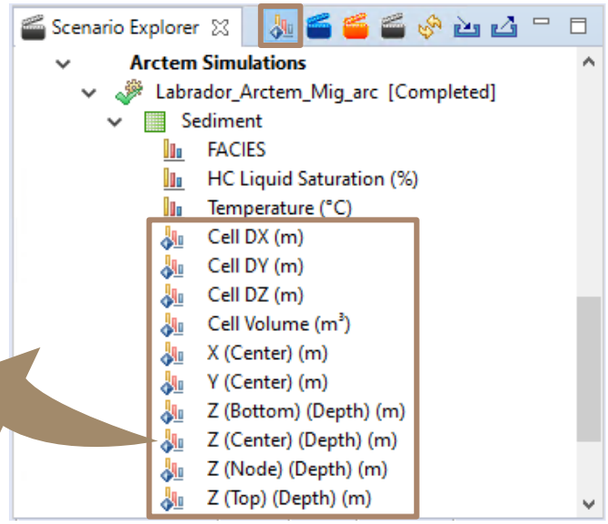
A new OpenInventor library has been setup in the 3D Viewer. It allows for the **Fade Mesh Wireframe when Zooming Out** option to be effective when ticked on.

This option puts some transparency on the mesh when it becomes too dense, making it possible to see the property rendering in these areas. It is a nice compromise between displaying fully the stratigraphy (wireframe on) and seeing the property values (wireframe off).





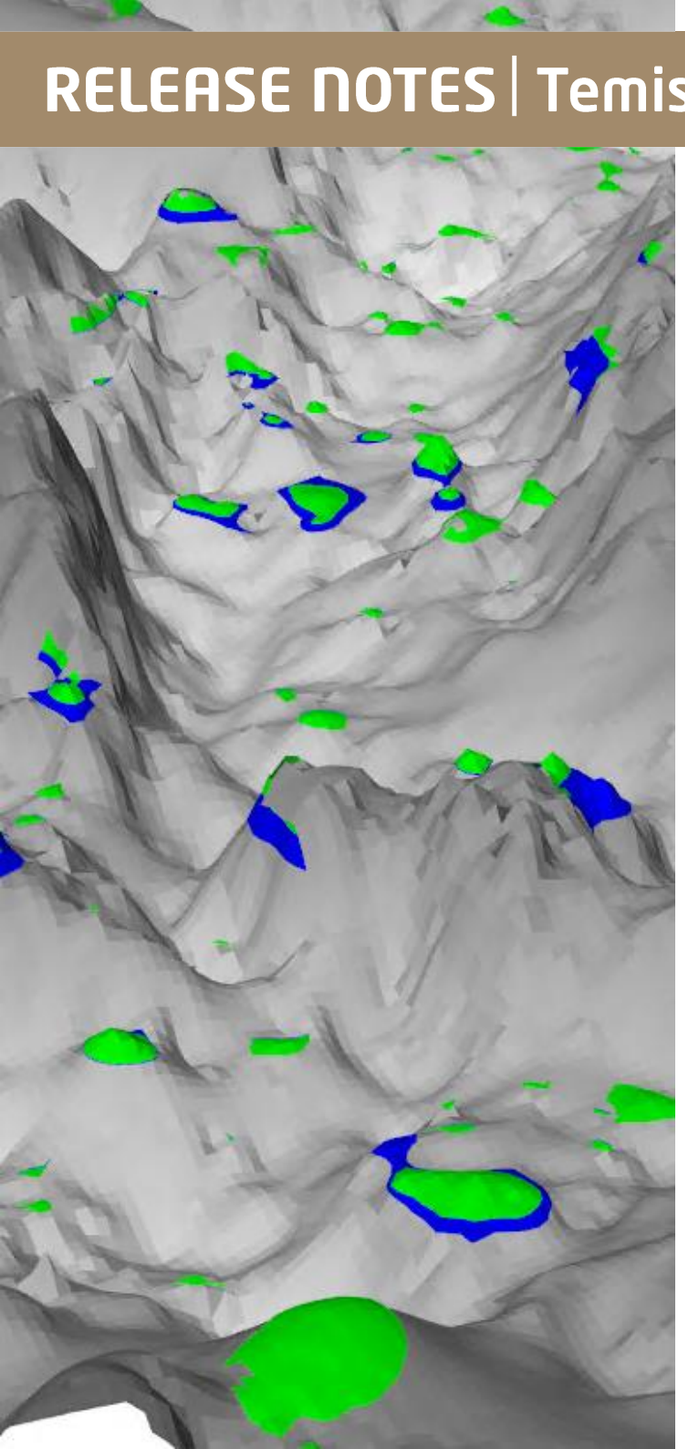




Geometrical Properties for ArcTem 3D Grids

Geometrical properties are now available for display and general post-processing for ArcTem 3D simulation results. These properties cover the cell resolution (DX, DY, DZ), coordinates (X, Y), depth (Bottom Z, Center Z, Top Z), and volume, in addition to the burial depth already available before.

In order to have access to them, simply use the dedicated **Show Geometric Properties** option at the top of the scenario. You can also decide to hide them to reduce the number of properties listed by using the same icon.

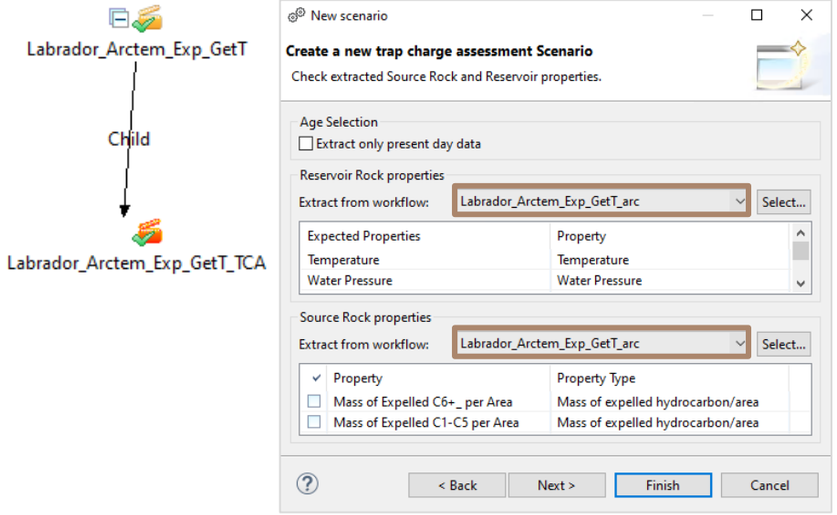


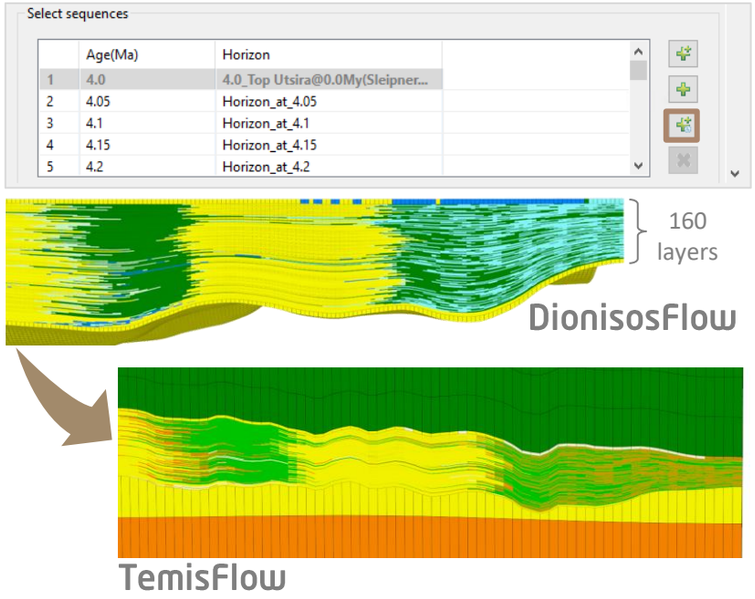
And More

TCA Model Generation from an ArcTem Grid

It is now possible to use the results of an ArcTem simulation to generate a TCA model for a quick migration simulation. As for the traditional option from a Visco run, results from an expulsion or a Darcy migration can be used, and models with different resolutions can be combined.

To do so, simply use the dedicated **Create Trap Charge Assessment Scenario** icon at the top of the Scenario Explorer and select the ArcTem workflow to define the reservoir and/or the source-rock properties.





New Option in the DF2TF Link

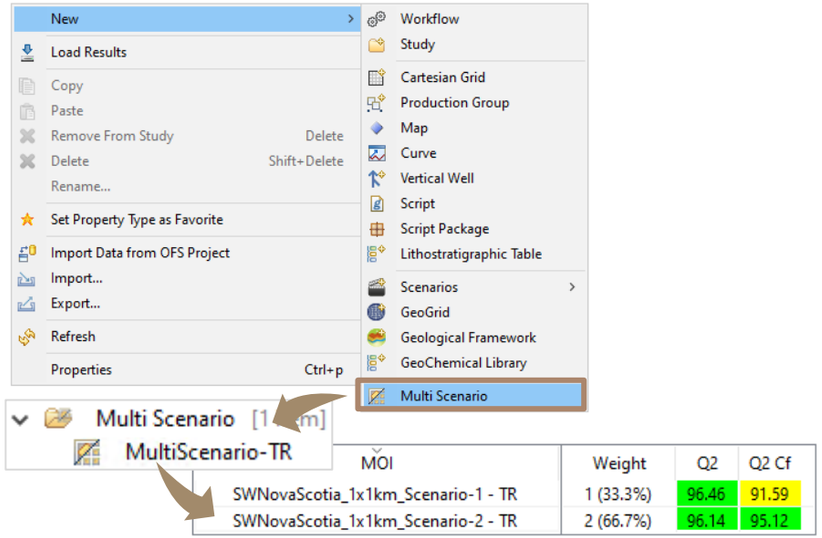
As more resolution is expected in basin models and high-performance computation allows running heavier models, a new option has been implemented in the DionisosFlow to TemisFlow link to efficiently **add every layer** of the forward stratigraphic model into the petroleum system model. This way, no information is lost when moving from DionisosFlow to TemisFlow as no vertical upscaling is necessary.

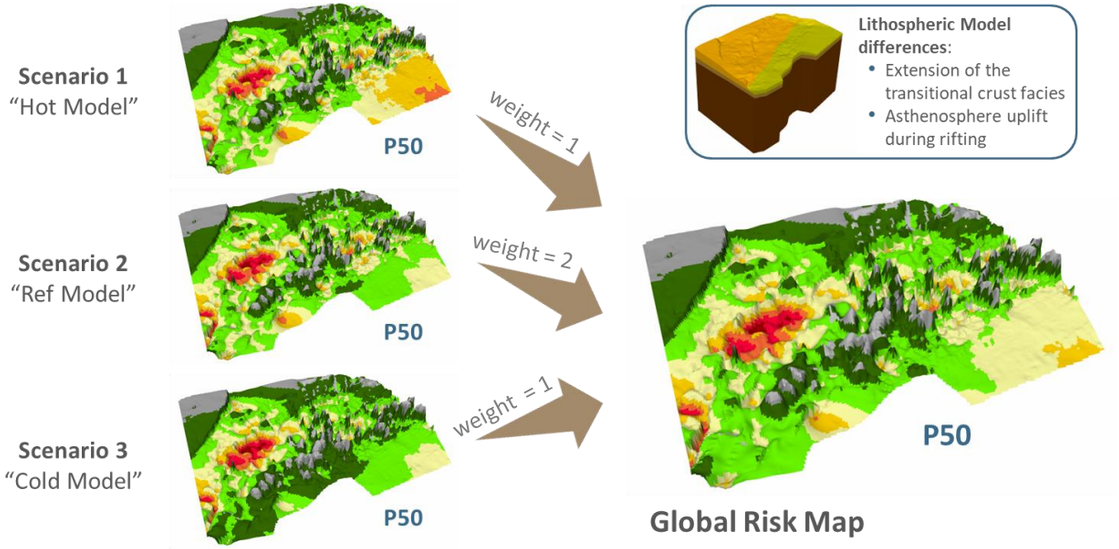
This can be of course done for the whole sedimentary column if modeled in DionisosFlow of for a specific unit. To do so, simply use the dedicated icon to the right of the horizon table in the DF2TF wizard.

Multi Geological Scenario Analysis with CougarFlow®

Developed through a second phase of the ERIS industrial project sponsored by TotalEnergies, this new CougarFlow® functionality gives the possibility to **combine multiple independent geological scenarios** within a single uncertainty analysis. For instance, scenarios with variable rifting phases and crust geometries, scenarios with various salt restoration strategies, scenarios with different seismic interpretations…

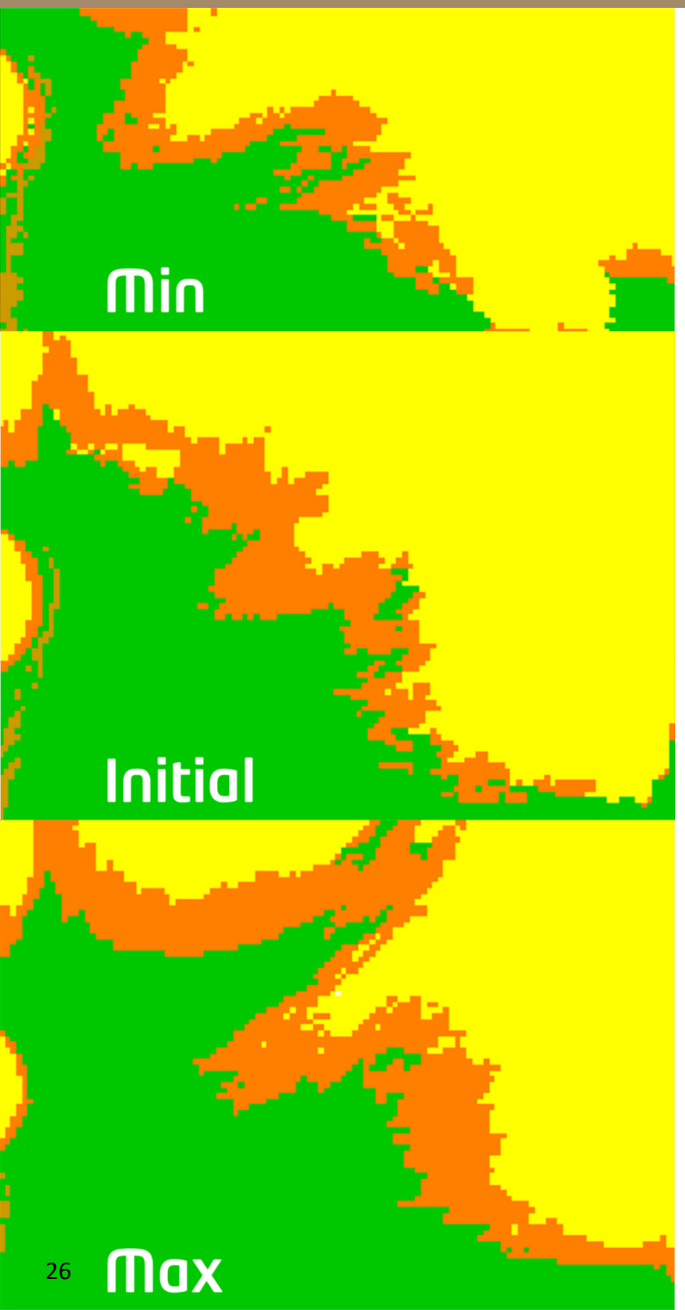
It is possible to give different user-defined weights to each conceptual model depending on the confidence or validity of each of them. The subsequent Monte Carlo sampling considers each response surface accordingly to produce one single analysis representative of all geological possibilities.





This new functionality is based on the Map Analysis methodology. The editor allows to combine several Maps of Interest containing the same property, as long as they have the same resolution and domain. The philosophy of the editor is then the same as the traditional Map Analysis.

As it combines results coming from different scenarios, the new multi-scenario analysis has to be created in the Study Explorer and is then stored in its dedicated folder.

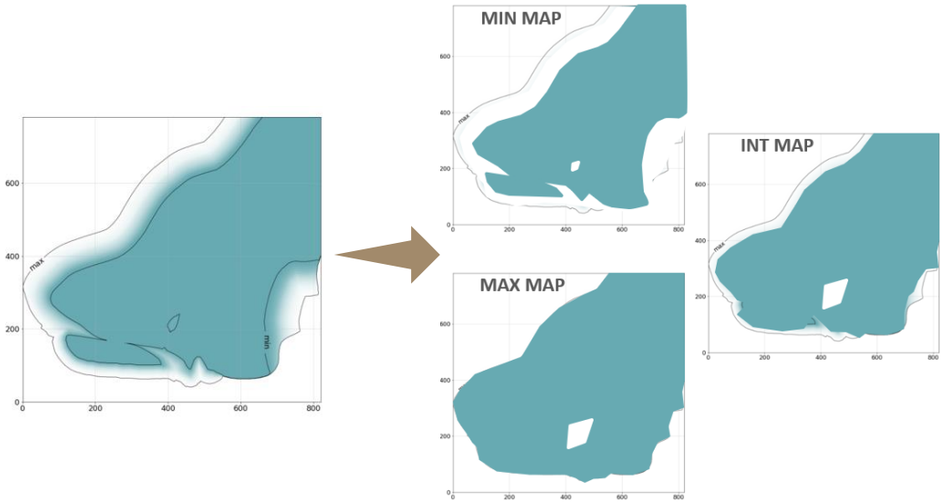


Uncertainty on Discrete Parameters in CougarFlow®

Coming as another piece of the ERIS consortium sponsored by TotalEnergies, CougarFlow® can now handle uncertainties on **discrete parameters** to measure their impact on the simulation results. This involves any facies or kerogen maps present in the GeoGrid.

A dedicated experimental design was created mixing LHS for traditional continuous parameters and **quadratic** for the new discrete parameters, where only the min, initial, and max values can be assigned.

Name	Type	Activity	Initial	Min	Max
Ea			0	-1	1
HF			0	-1	1
Kerogen			0	-1	1
Petroleum System Model.For u	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap
Petroleum System Model.For u	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap
Petroleum System Model.For u	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap
Petroleum System Model.For u	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap
Petroleum System Model.For u	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap
Lithofacies			0	-1	1
Facies for 50.00 Ma.LI@0.0My	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap
Facies for 72.00 Ma.LI@0.0My	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap
Facies for 94.00 Ma.LI@0.0My	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap
Facies for 99.00 Ma.LI@0.0My	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap
Facies for 101.00 Ma.LI@0.0My	Integer Map	Compute Visco	InitialMap	MinMap	MaxMap



The variability of each uncertain discrete parameter is therefore defined through three maps (min, initial, and max) that represent the lateral variability of the sediment bodies or the extension of the source rock kitchen. As for any map-based parameter, these limits can be edited in the Map Editor or defined by drag and dropping maps from the Study Explorer.

Note that no variation will be set by default (as a % default range would not make sense), so do not forget to set it up!

CougarFlow®

DionisosFlow® & TemisFlow™ Multi-Scenario Analysis

CougarFlow ® keeps evolving to address geoscientists' needs in uncertainty modeling and risk mitigation.

After its unmatched Map Analysis and Assisted Calibration modules, **CougarFlow 2023** offers DionisosFlow® and TemisFlow™ users the ability to test **multiple geological scenarios**. It means that uncertainties can now be at the core of the model itself and not only at simulation parameters level. Tested concepts can even be **weighted** according to geoscientists' beliefs and data confidence.

Another major evolution is the possibility to define **discrete parameters** such as **lithofacies** maps or **source rock** distributions as uncertain. This long-awaited feature completes CougarFlow's offer for a thorough understanding and quantification of the risk associated to basin models.

Other **improvements** have been brought to the software, such as the possibility to load uncomplete DionisosFlow® or TemisFlow™ results for analysis, a new objective function for calibration in DionisosFlow®, the ability to run Groovy scripts on all CougarFlow® simulations at once, a better constrained response surface, an optimized results selection with PumaFlow™, and more.

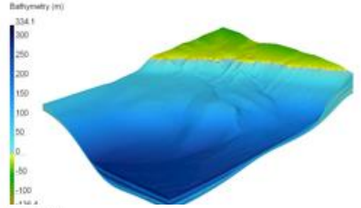
Multi Geological Scenario Analysis

Every DionisosFlow® or TemisFlow™ model should start with a conceptual model that gets tested and subsequently passed to CougarFlow® for uncertainty and sensitivity analyses.

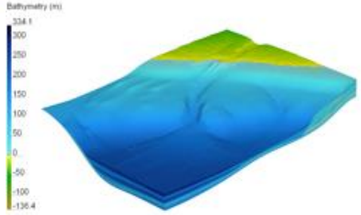
Multi-geological scenario analysis with CougarFlow® is a new map-based tool that allows for the classical CougarFlow® uncertainty analysis to be done while considering any number of conceptual models.

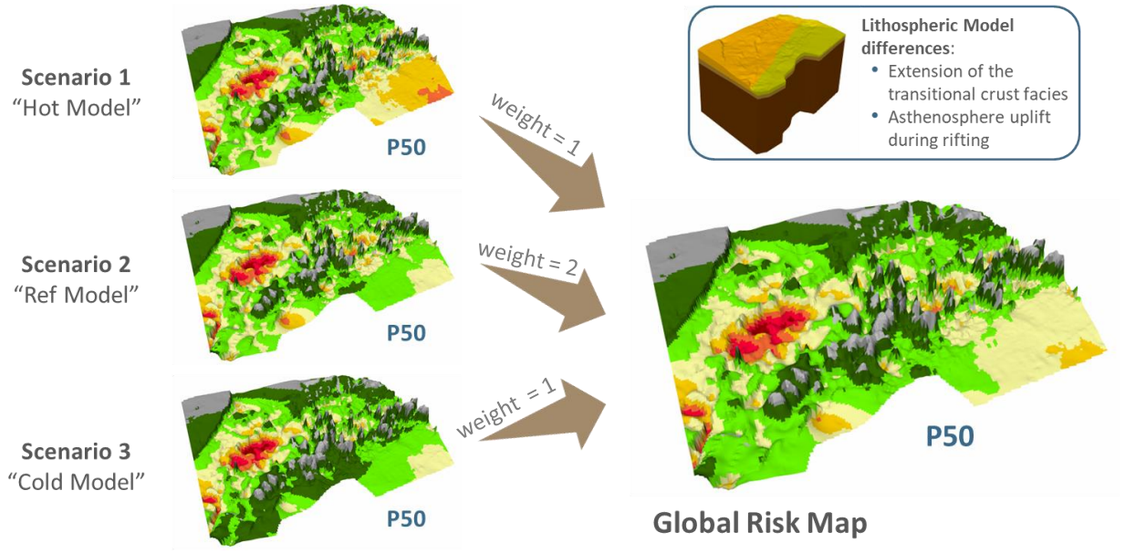
The results of multi-response surfaces can now be combined with a user defined weight to produce **risk and probability maps.**

Conceptual model 1:
- Haq et al. 2014 sea level
- Age model based on ICC 2017



Conceptual model 2:
- Miller et al. 2005 sea level
- Age model based on ICC 2008





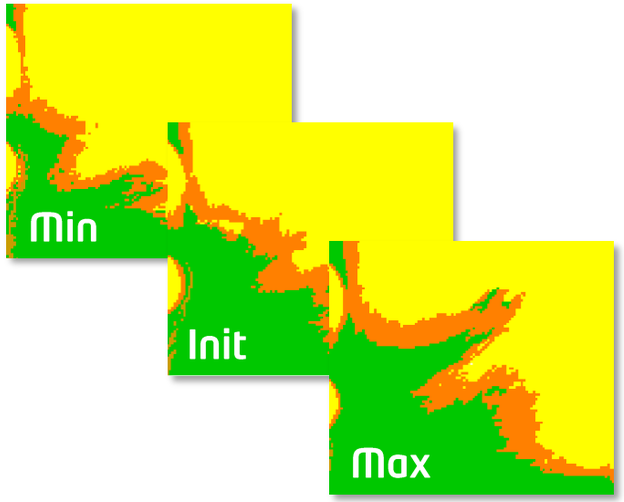
This tool is a unique solution to quantify the geological risk on any DionisosFlow® or TemisFlow™ output even if the **uncertainty** is linked to the **conceptual model.**

More Parameters & Results

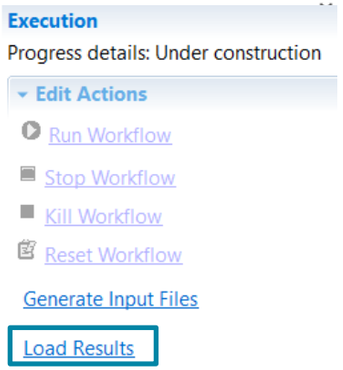
Uncertainty on Discrete Parameters in TemisFlow™

CougarFlow has been enhanced to incorporate the capability of accommodating uncertainties related to discrete parameters, enabling the assessment of their influence on simulation outcomes. This functionality specifically applies to facies or kerogen maps within the GeoGrid.

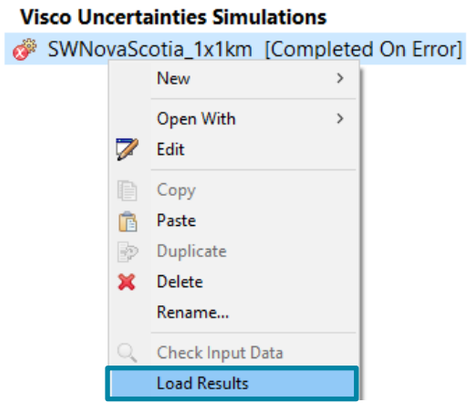
To facilitate this, a specific experimental design was developed, combining Latin Hypercube Sampling (LHS) for conventional continuous parameters and quadratic methods for the newly introduced discrete parameters.

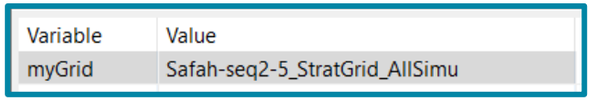


DionisosFlow



TemisFlow





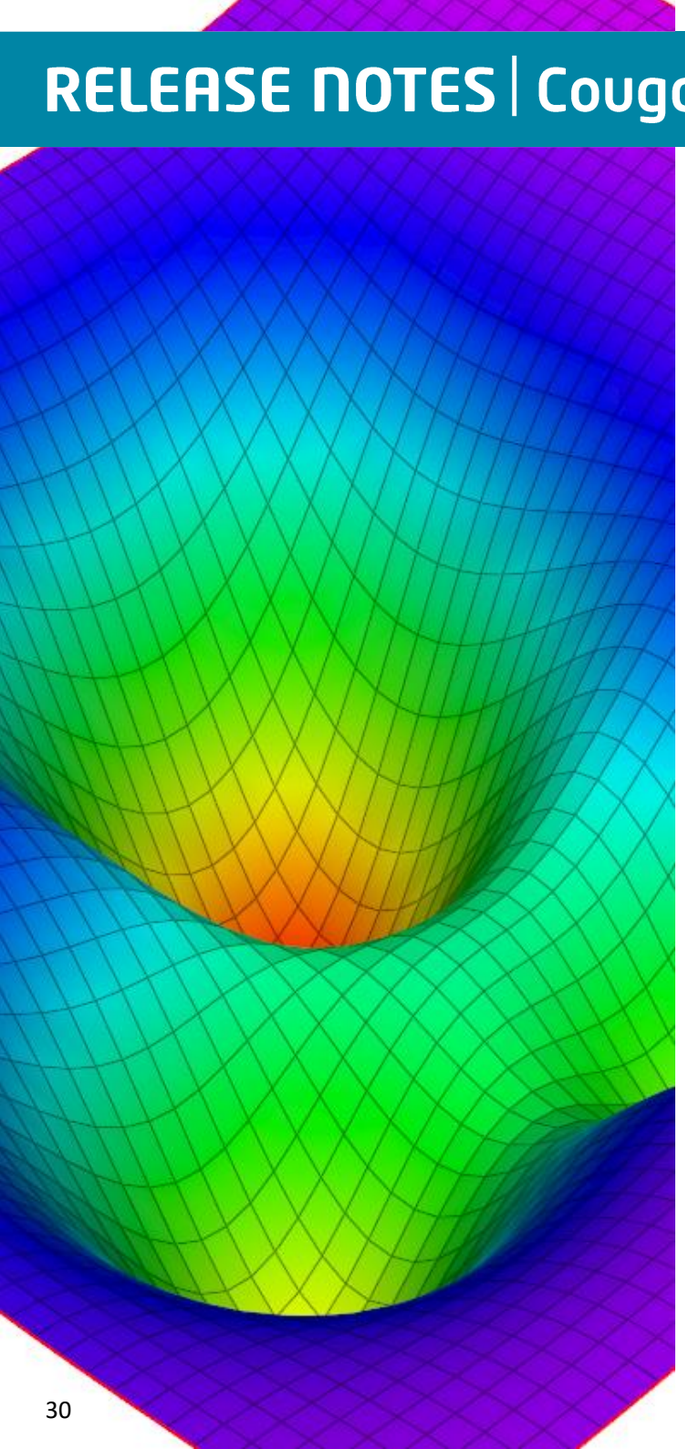
Variable	Value
myGrid	Safah-seq2-5_StratGrid_AllSimu

Load Results Option

This option allows the user to save precious time and load CougarFlow results even if they are on error or not completed. This option is available for both DionisosFlow® and TemisFlow™.

Post-Processing Groovy Scripts Improvements

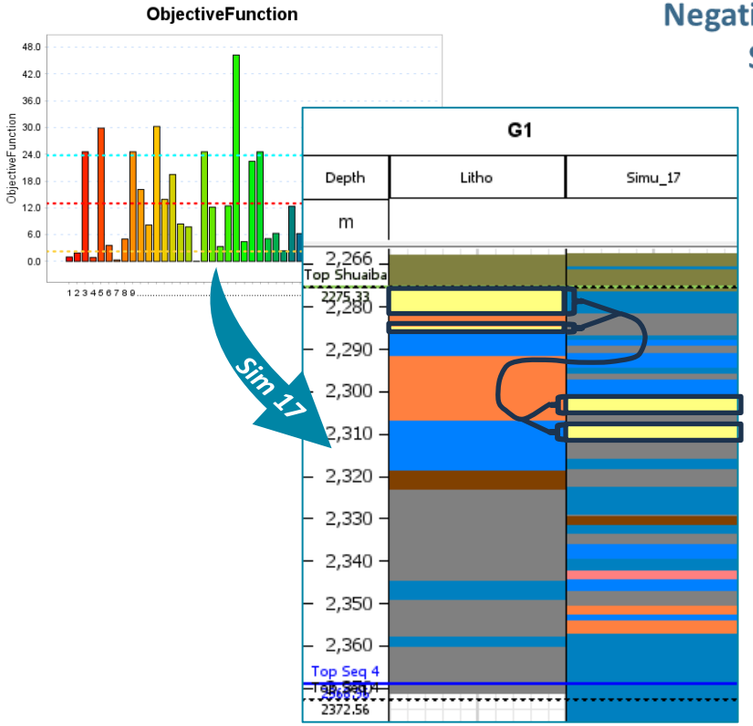
Groovy scripts allow the user to push the software further and produce customized results. To facilitate the application of scripts on CougarFlow® simulations, it is now possible to run Groovy on all CougarFlow® simulation at once by selecting “AllSimu” in the “Apply Groovy Script” wizard.

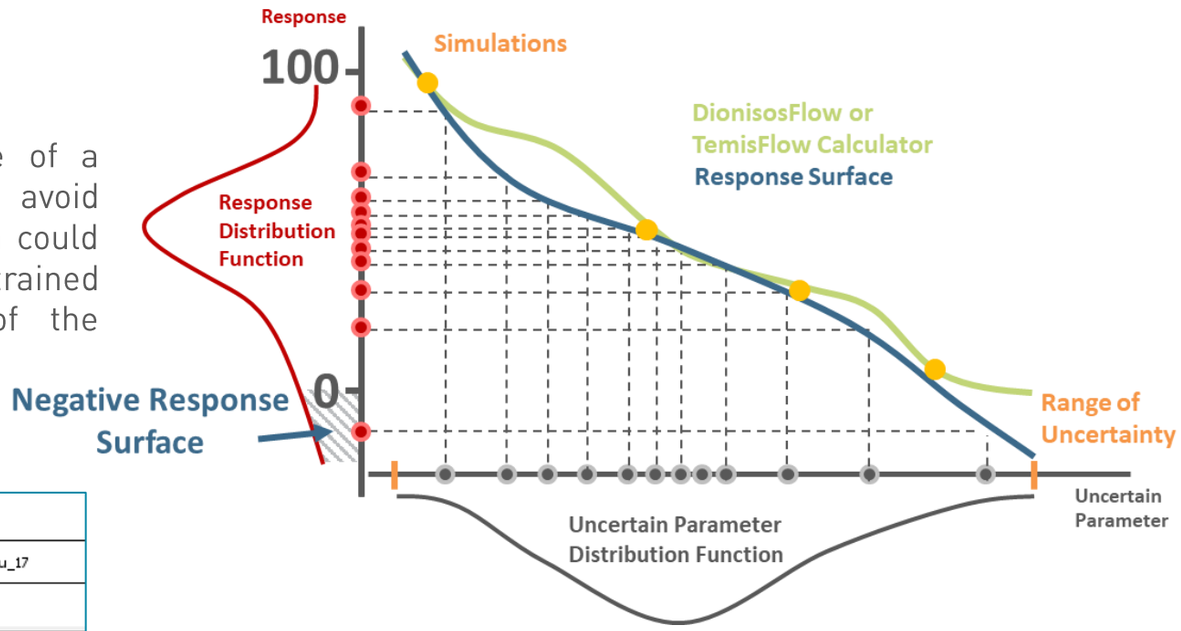


More Parameters & Results

Positive Response Surface

A new way of analyzing the response of a response surface is now employed to avoid negative values at the lower end, which could sometimes result from a poorly constrained response surface at the extremes of the uncertain domain.





New Objective Function in DionisosFlow®

A new objective function calculation is now available to allow the user to calibrate their model for a thickness of a **particular facies**, regardless of where it occurs within the modelled sequence.

Optimized Result Selection in Reservoir Context

Workflows with a huge number of results can hinder the performance of data loading in the Uncertainty Editor. This has been optimized in the 2023 version by allowing you to select only the necessary data for the analysis.

FracaFlow®

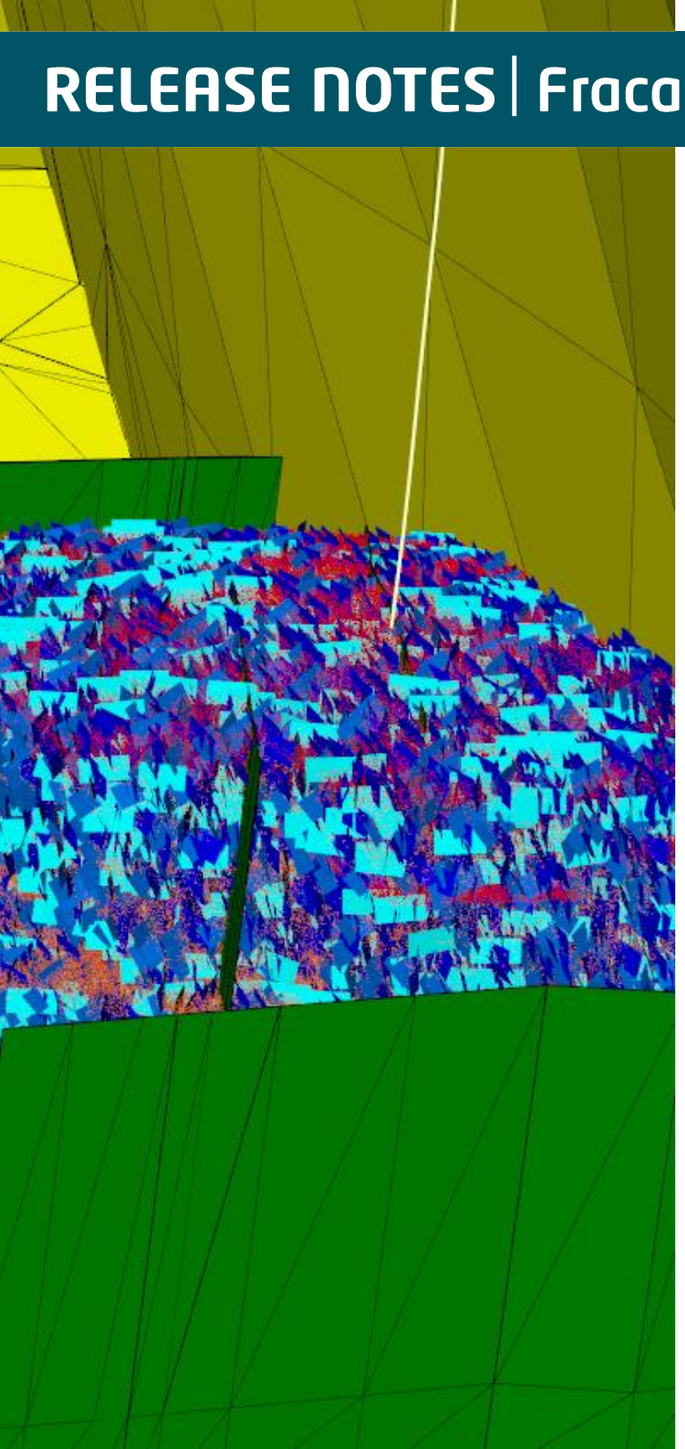
AKC & Flow-Based Upscaling

This new version of FracaFlow® focuses on improving its most used modules, e.g. the automatic KH calibration and the upscaling to reservoir simulation.

These awaited enhancements strengthen FracaFlow®'s main workflow, by making the interfaces more friendly or offering new options and new tools.

The main developments are:

- New display of the results in the calibration module (AKC)
- New light tool to easily compute the distance of a well to the nearest fault
- Unlock of the cell-by-cell computation option of the Flow-based upscaling

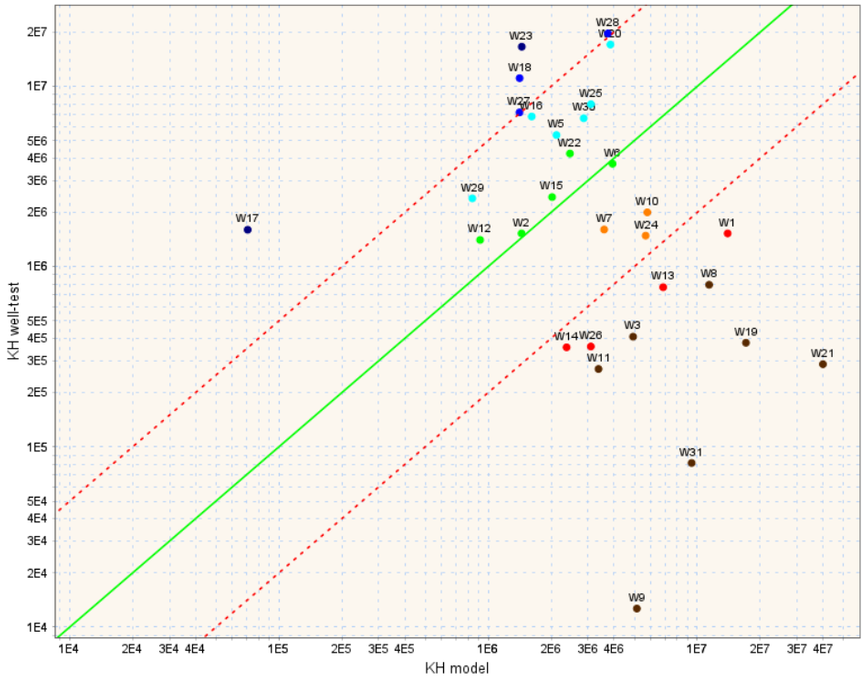


New Display for KH Calibration

The dynamic calibration of the fracture is a key step in the FracaFlow® workflow. After defining the geometrical attributes (density, orientation) of the different fracture and fault sets, it consists in assessing the conductivity of each family based on the comparison of the KH interpreted from the well-tests and the KH computed from the fracture model. This process is an optimization loop: the user has to define a range of conductivities for each set, then the software tries to find the best conductivities to match the interpreted KH and the computed KH.

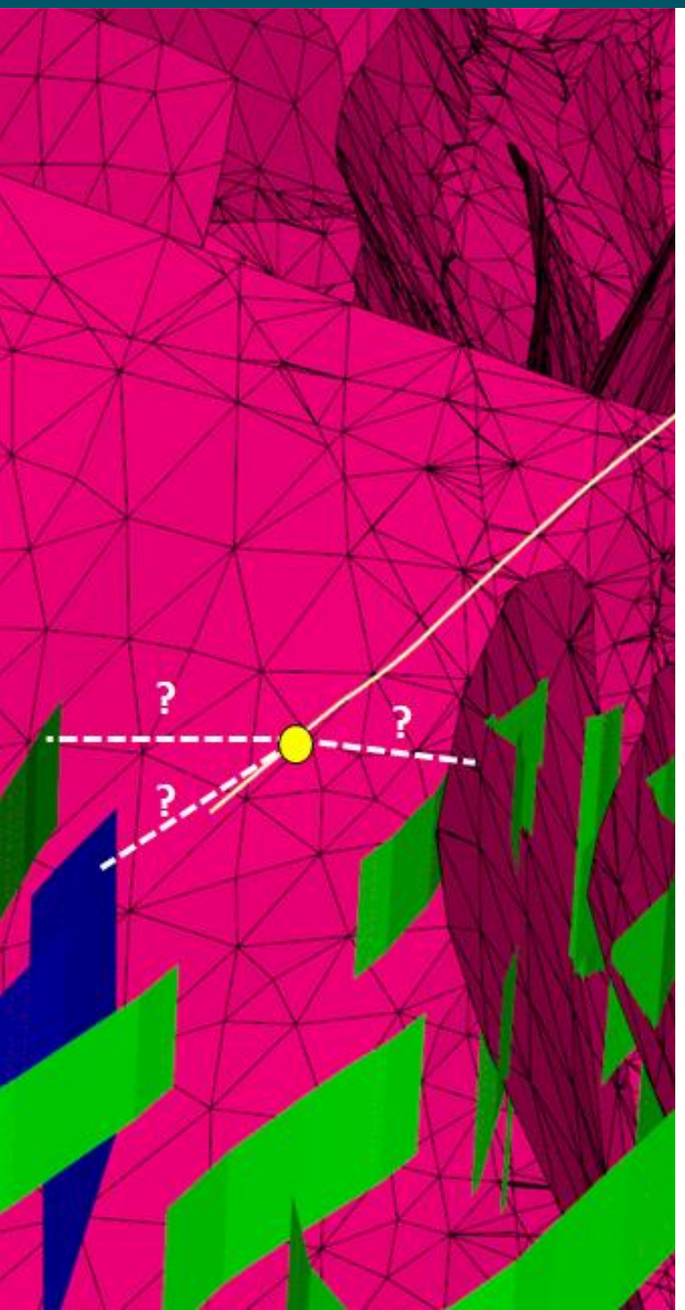
The **Results** panel has been reviewed to display the calibration in a more friendly and comprehensive way.

Well	H	KH well-test	KH model	KH model / KH well-test
W1	318	1.527E6	1.395E7	9.138
W10	147.768	1.999E6	5.766E6	2.884
W11	85.286	2.704E5	3.369E6	12.461
W12	24.628	1.405E6	9.157E5	0.652
W13	135.833	7.681E5	6.862E6	8.934
W14	54.991	3.566E5	2.371E6	6.649
W15	68.976	2.429E6	2.022E6	0.832
W16	52.554	6.797E6	1.616E6	0.238
W17	1.723	1.6E6	7.096E4	0.044
W18	32.909	1.109E7	1.414E6	0.127
W19	345.578	3.78E5	1.706E7	45.148
W2	32.918	1.527E6	1.444E6	0.946
W20	94.767	1.704E7	3.842E6	0.225
W21	575.01	2.874E5	3.982E7	138.537
W22	46.422	4.237E6	2.461E6	0.581
W23	32.713	1.657E7	1.448E6	0.087
W24	147.081	1.484E6	5.66E6	3.813
W25	44.772	7.955E6	3.1E6	0.39
W26	51.711	3.603E5	3.097E6	8.596
W27	22.578	7.163E6	1.412E6	0.197
W28	77.782	1.964E7	3.739E6	0.19
W29	19.168	2.39E6	8.404E5	0.352
W3	84.78	4.084E5	4.929E6	12.069
W30	43.736	6.648E6	2.863E6	0.431
W31	199.798	8.138E4	9.387E6	115.34
W5	44.524	5.364E6	2.122E6	0.396
W6	38.332	3.719E6	3.934E6	1.058
W7	85.551	1.605E6	3.585E6	2.234
W8	181.065	7.925E5	1.138E7	14.36
W9	71.531	1.268E4	5.138E6	405.24



The table now lists all the wells used in the calibration process, their chosen H and shows the interpreted KH (KH well-test) and the computed KH (KH model). A last column shows the ratio of both, with a color code depending on its value.

Finally, a log-log cross-plot displays both KH. Lines corresponding to respectively ratios of 1/5, 1 and 5 are also highlighted for a quick assessment of the calibration quality.

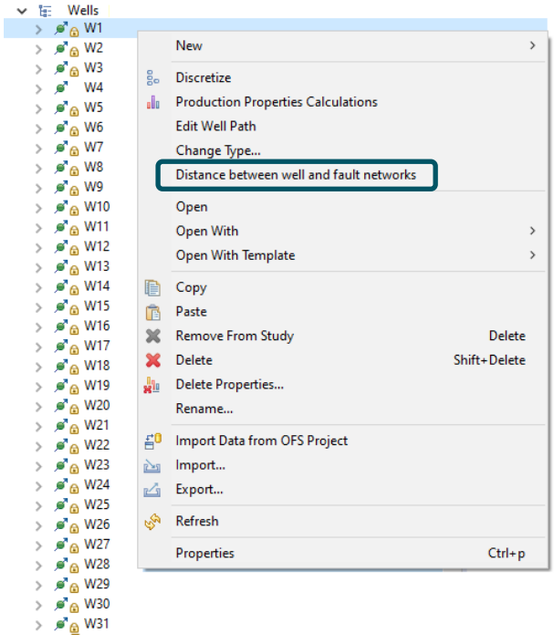


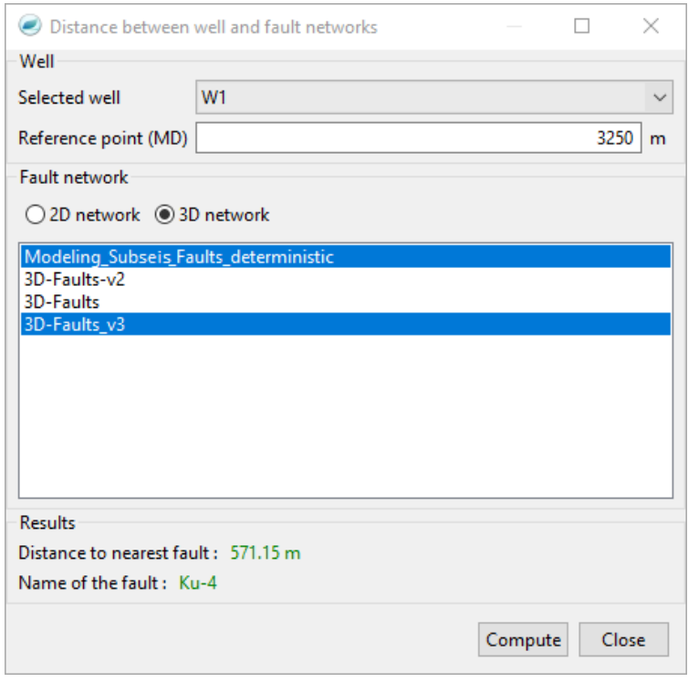
Well Distance to Nearest Fault

Faults play an important role in a fracture network: they are major structural events that may cause fracturing having a potentially high impact on fluid flow.

Therefore, the faults constitute a key data which is often used. A quick estimation of the distance of the wells to the nearest fault is therefore an important and common step in the understanding of the fracture network and the impact of faults.

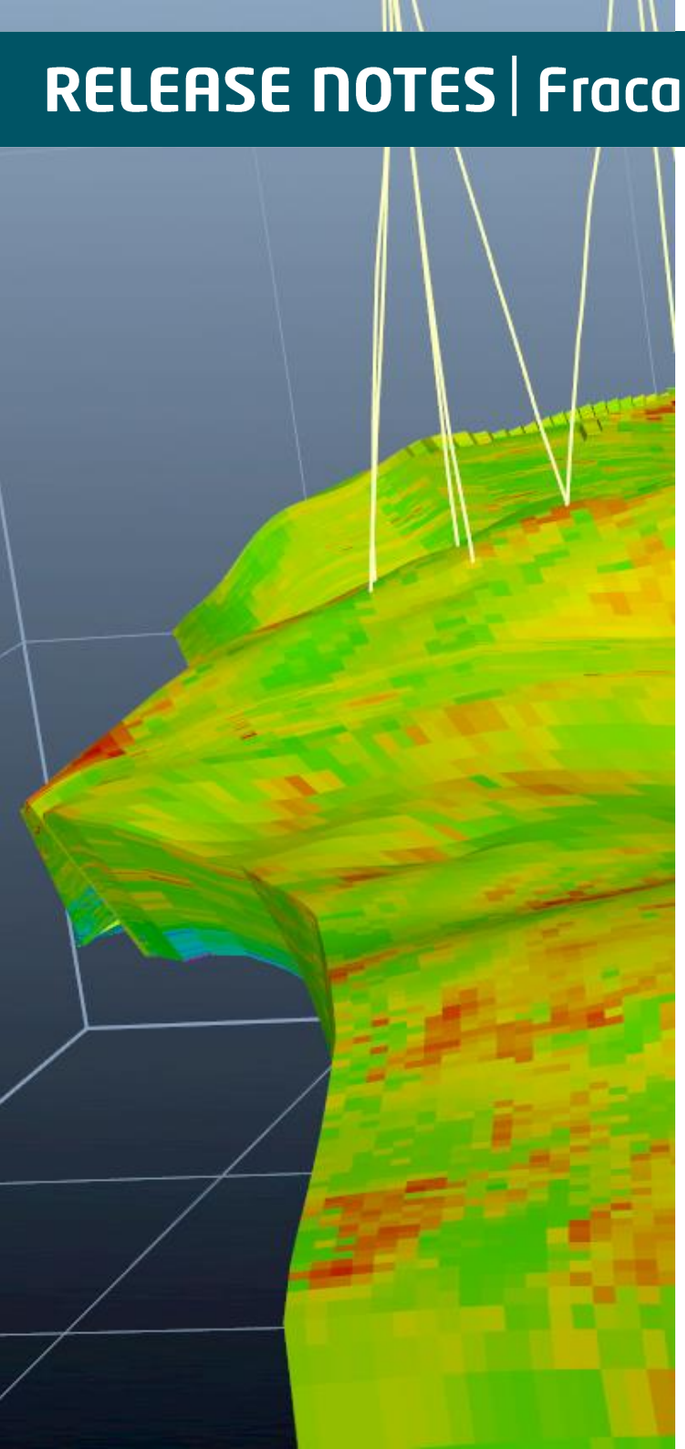
A new and light tool has been added to FracaFlow® for this purpose.





A simple right-click on a well opens an interface to select one or several fault networks (lineaments/polygons or surfaces): the distance will be computed in 2D or 3D between a point of the well trajectory (specified by its MD) and the selected networks.

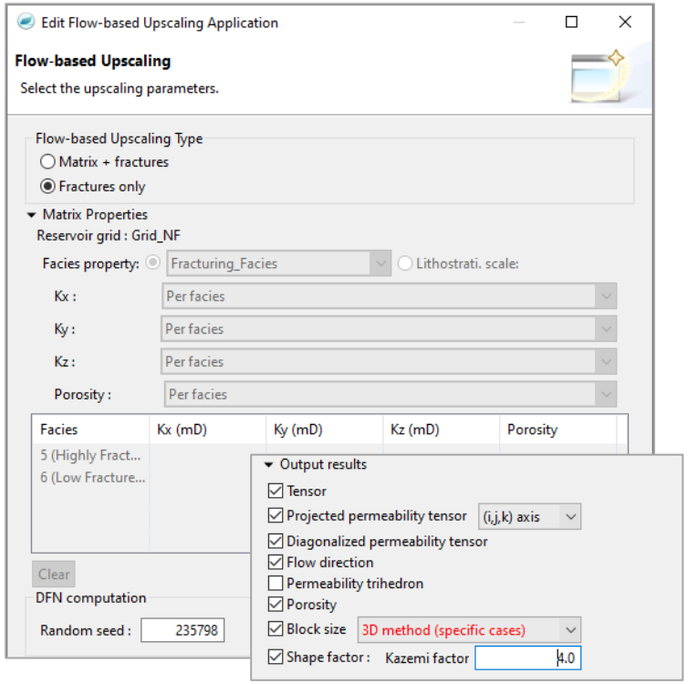
The result shows the distance to the nearest fault and the name of this fault.

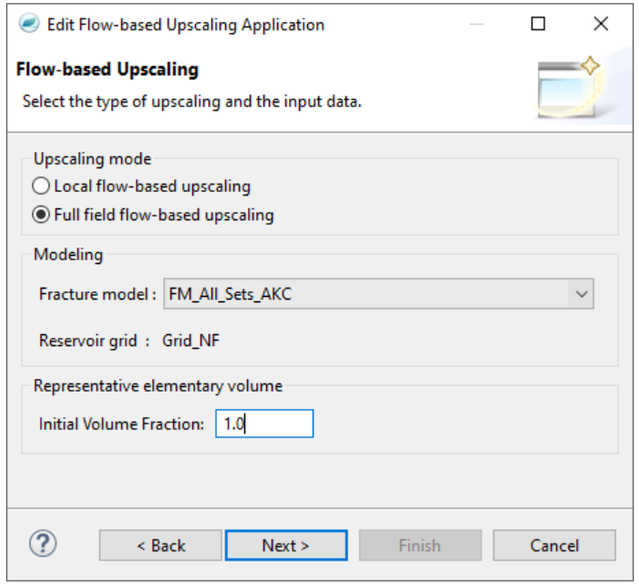


Full-Field Flow-Based Upscaling

The upscaling is the final step of the workflow: it consists in computing the equivalent parameters of the fracture network and populating the reservoir grid.

According to the connectivity of the network, the computation is not the same. The analytical upscaling, based on Oda's formulation (1995) takes as an assumption that the fracture network is fully connected. Otherwise, the user is supposed to run another kind of computation: the flow-based upscaling (also known as numerical upscaling).

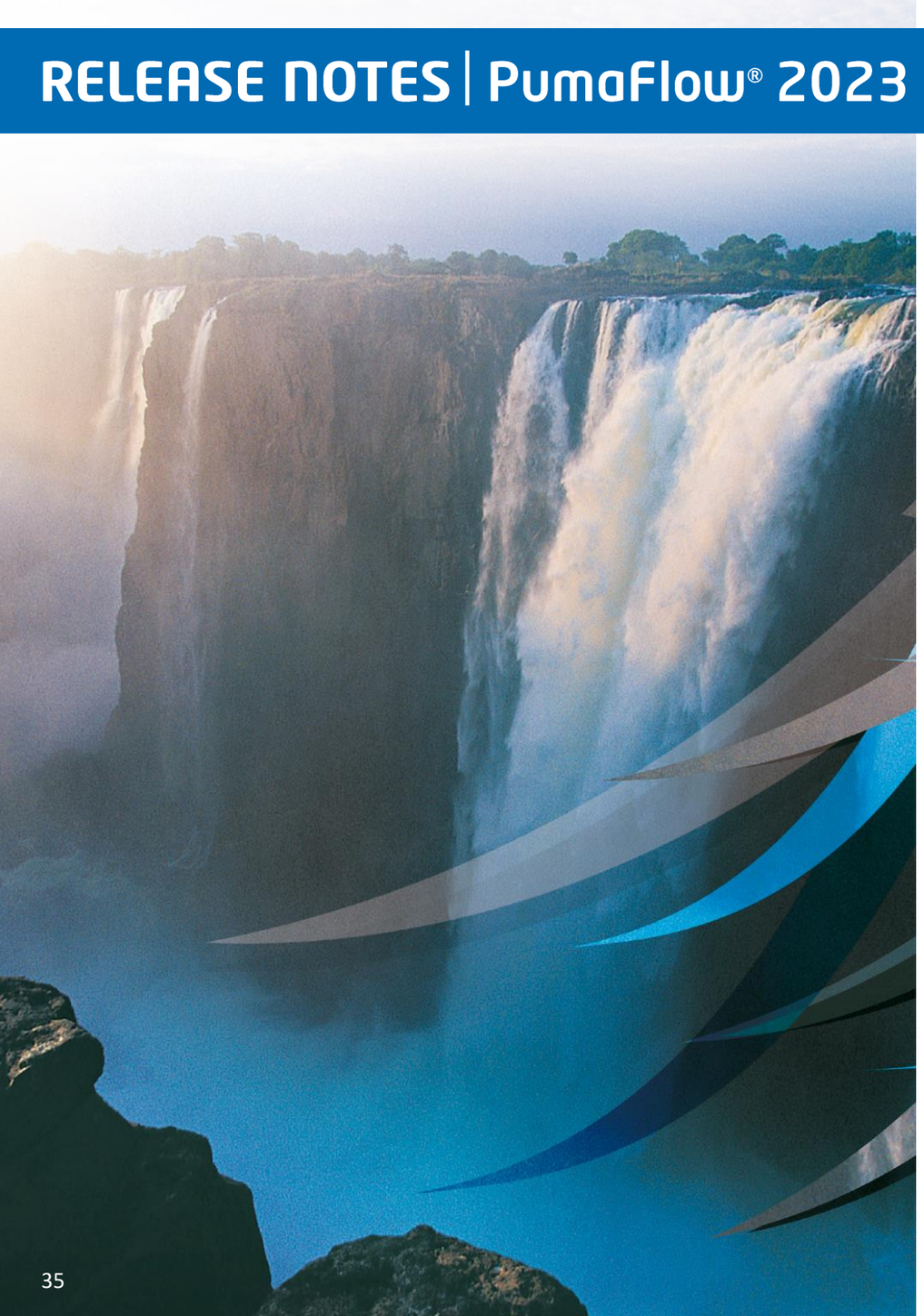




This option was until now only available in its interpolated version, at the cost of results affected by artefacts, because the duration of the process prevented an explicit calculation in every cell.

The performance of computers and the possibility of running this calculation on several processors offered the opportunity to unlock the cell-by-cell version for more precise results.

Consequently, the interpolated method of analytical and flow-based upscaling is no longer available.



PumaFlow®

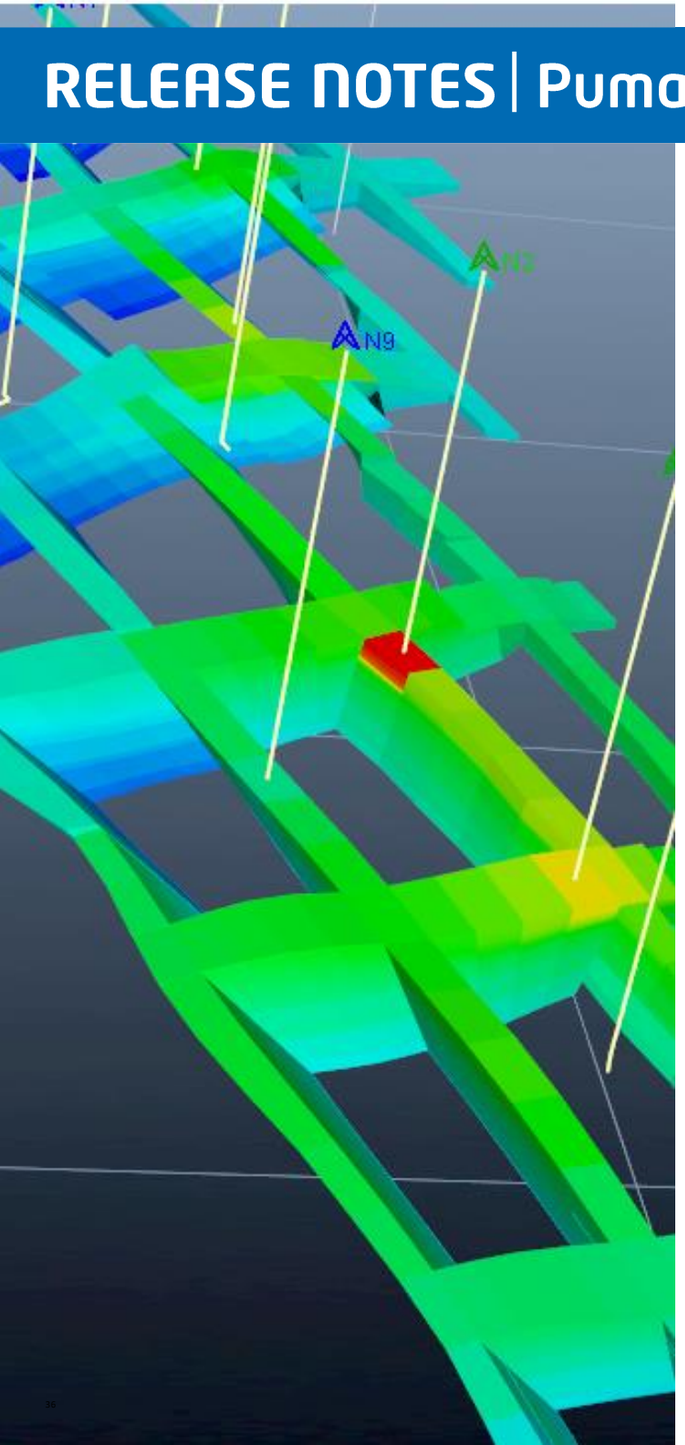
From Oil & Gas to Geothermal & Carbon Storage Simulation

PumaFlow® keeps evolving to help geoscientists address new challenges, in particular in the field of geothermal energy and carbon storage.

One of the main highlights of this 2023 version is PumaFlow®'s capability to accurately predict produced fluids temperature at surface through the implementation of heat losses along producers in addition to injectors.

The second item is related to the fracturation risk associated to fluids injection. All geo-mechanical options are now fully interfaced to easily define the needed parameters for effective stress computation and rock failure alert. This is particularly critical to evaluate the seismicity risk in geothermal development projects or carbon storage.

PumaFlow® 2023 also strengthens its regular oil and gas workflows through the correction of reported bugs and the integration of several improvements, such as the new export options available in the External Activity module for a better uncertainty management.

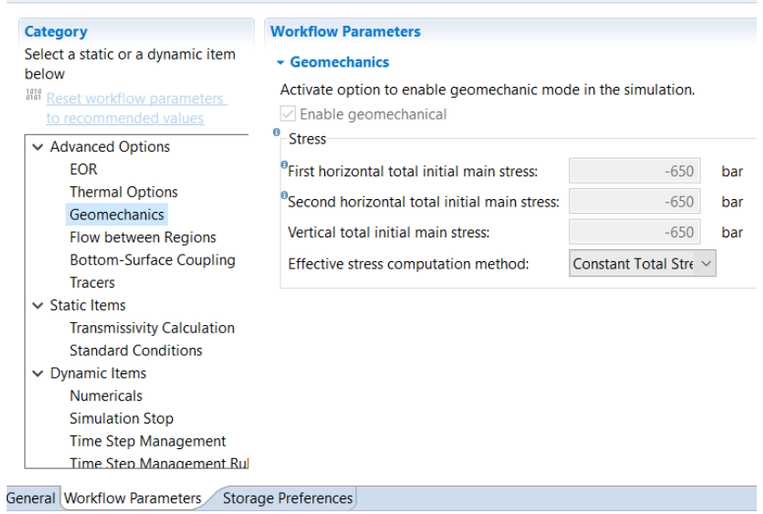


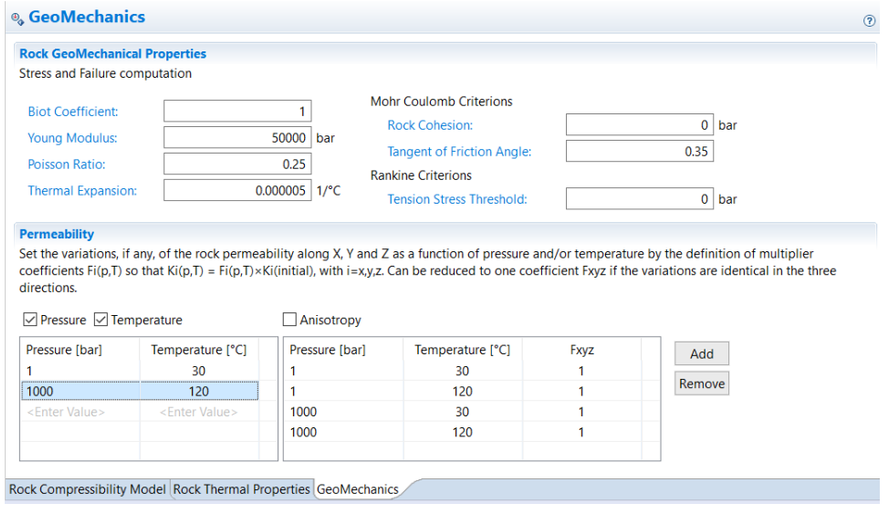
Geomechanical Rock-Type Parameters

All geomechanical parameters describing rock types are available in a dedicated panel allowing to group options related to:

- Effective Stress calculation
- Hydromechanical and thermal fractures failure criteria
- Pressure and temperature tabulated multipliers on porosity and Permeability

These options are crucial to evaluate the seismic risk in carbon storage and geothermal studies.

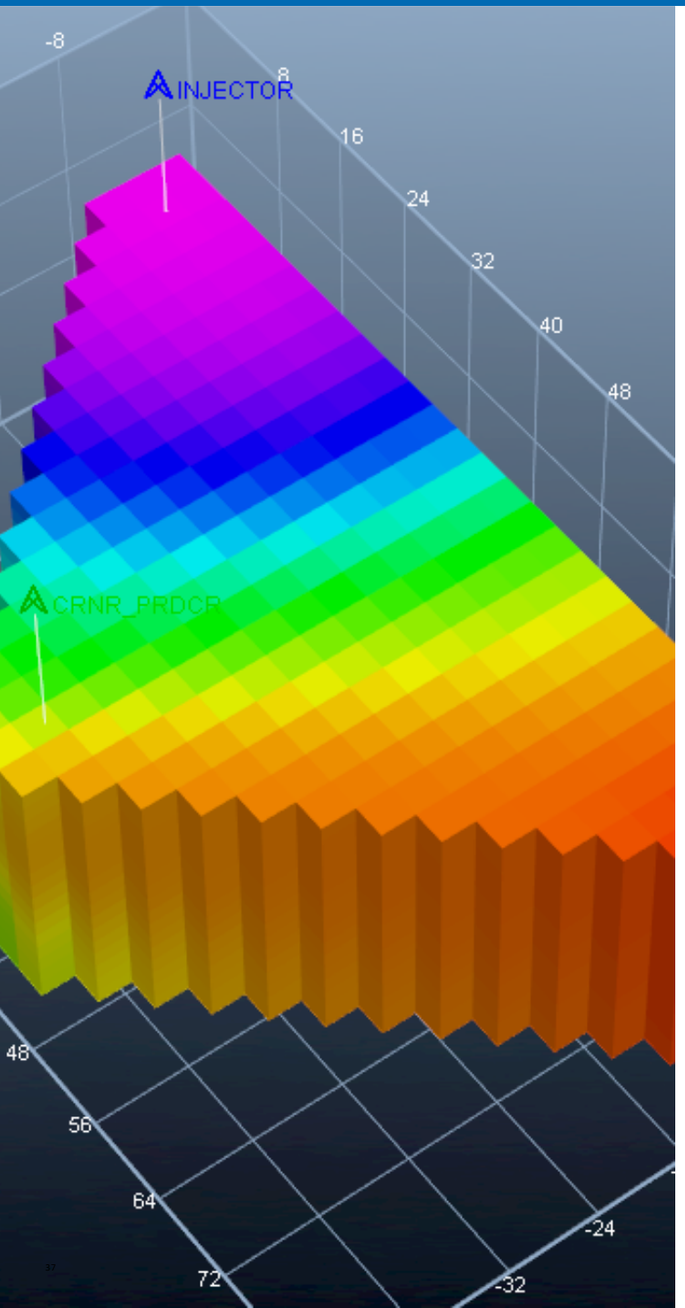




Initial Total Stress is included in the general parameters of geomechanical runs. It triggers computation of effective stress and geomechanical alerts in all cells of the grid.

PumaFlow evaluates two rupture criterions, Morh-Coulomb and Rankine. The loading index and the stress margin are computed to evaluate cells which have exceeded the limit and the minimum stress reached by the criterions.

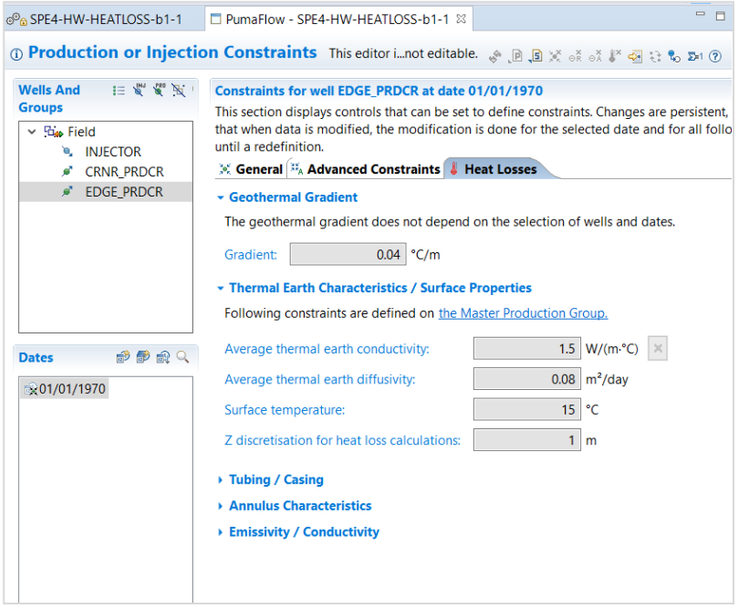
It is possible to define perm multipliers related to pressure and temperature in order to reproduce impact of these properties on permeability.

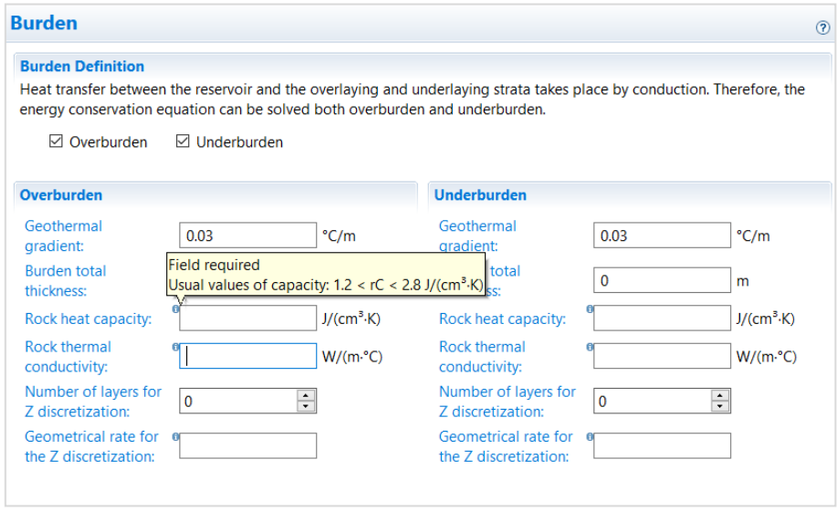


Geothermal Heat Losses & Burdens

Both injectors and producers can have now heat losses computed from analytical laws to estimate well head temperature in geothermal doublet.

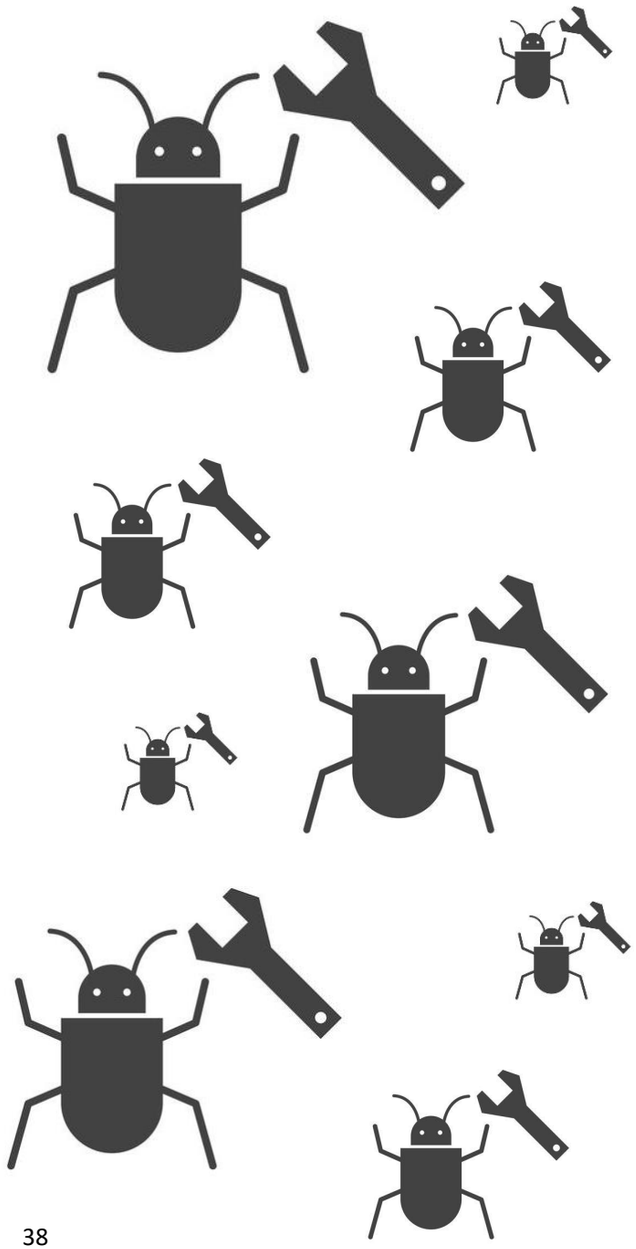
Thanks to this option, well head temperature are more precisely related to bottom home temperature. Well completion can include all casing and tubing elements.





Thermal Burden parameters are set by default to more physical and numerical values avoiding initialization errors.

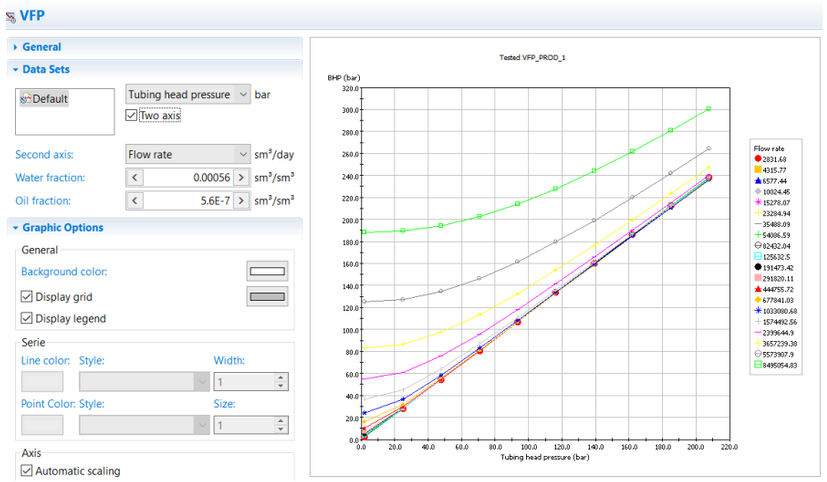
Thermal burdens can reduce the number of cells in a model to compute the heat flow in the area of interest.

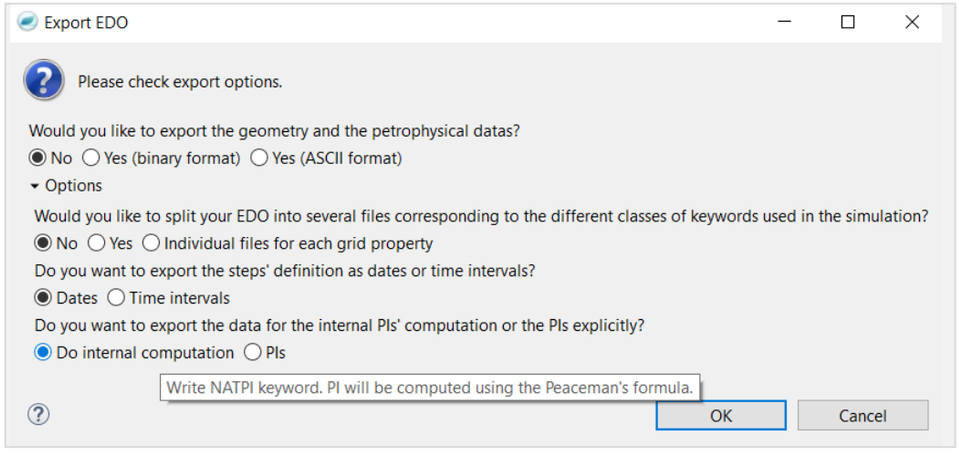


Corrections & Improvements

The Field Units of the Gas Water VFP table are now corrected.

Importing UNRST files is now possible even if no *.INIT file is present.





The Keywords export filter has been made more flexible to allow choosing between fixed PI or on the fly calculated PI.

This is very usefull in workflows with uncertainties where input parameters (like Permeability) have an impact on the calculation.

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