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TOUGH2/3 History Matching Workflow Of A Tracer Test On a High Enthalpy Geothermal Doublet Using The Pre- And Post-Processing Tool RE-Studio©

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ABSTRACT

When building a simulation model, the practical workflows are key to calibrate input data efficiently and to analyze results precisely. In that perspective, Storengy supported the adaptation of a proved pre- and post-processing oil & gas commercial solution, RE-Studio©, to TOUGH2©. This interface comprises several modules aiming at accompanying a TOUGH user all along the phases of building a proper dataset and displaying the TOUGH2© obtained results in 2D or 3D viewers.

An advanced text editor allows users for improving and fastening the dataset building and writing with keywords while easing the possible dataset errors recognition. In order to cope with Storengy needs to model geothermal reservoirs, specific functionalities have been developed to convert geological models built with Petrel© into TOUGH formatted files. The grids thus formatted can then be displayed in the integrated 3D viewer, and static as well as dynamic properties resulting from a simulation can be visualized without requiring any additional software. The 3D Viewer has also been recently improved to handle dual-medium grids.

A 2D viewer is also included, allowing for instance displaying time dependent simulation results along with properties versus depths plots. A close interaction exists between 2D and 3D viewers: cells or groups of cells can be selected in the 3D window and their properties displayed in 2D plots, making the simulation results analysis very flexible for the user.

In order to facilitate the writing of well controls, especially for wells split between several grid cells, a tool has been developed to convert production data into a formatted GENER keyword. This was inspired from tools from the oil and gas industry and is aiming at producing input data for history matching in a more efficient way while making the models more realistic.

The quality of history match is assessed by defining error functions through a very flexible language in the Project Manager. Errors between observed and simulated values can be evaluated at specific dates or computed over all the simulation timeline following least square mean formula. Simulated values can be extracted from time dependent series as well as from grid simulation results. Once computed, function results can be plotted in various formats like histograms or cross plots to see the progress of history match during a project, and advanced data mining techniques like clustering may be applied in order to analyze the hypothesis.

This tool is currently still under development. It is expected to be able to handle local grid refinements (LGR) in 2019. It has been adapted for a use with TOUGH2© / TOUGHREACT© in a first place and has been successfully tested on TOUGH3© as well. The model used for the benchmarking is an EOS1 case, but specific keywords required by other EOS can be implemented on demand. A case study involving tracer tracking on a geothermal doublet in a high enthalpy reservoir was used for reference, and successfully matched.

1. INTRODUCTION

Reservoir evaluation plays an important role for optimal decision-making and affects the entire reservoir management and ultimately the cost of field development projects. In this condition, optimal simulation model is critical since it might impact directly reservoir management strategy.

When building a simulation model, targeting optimal workflow adapted to the simulator is key to calibrate input data efficiently and to analyze simulation results precisely. In that perspective, Storengy supported the adaptation of a proved pre- and post-processor for reservoir simulation, RE-Studio©, to TOUGH2©. Amarile's RE-Studio interface is based on modules, aiming at offering a TOUGH2© user a complete workflow all along a study case, from building and quality checking a dataset, to displaying and analyzing results obtained from TOUGH2© simulations in 2D and 3D viewers.

Each development provided by Amarile is tested by Storengy using a test case: a tracer test performed on a high pressure / high temperature geothermal doublet.

2. RE-STUDIO© FOR TOUGH2©: FUNCTIONALITIES OVERVIEW

The main structure of the software has been developed to cope with TOUGH2© requirements. The interface has been built using a series of modules, each of them handing a phase of the usual workflow of a TOUGH2© study.

2.1 Project Manager

"Project Manager" module is where a TOUGH2© user can manage an entire project. The user can visually organize its project dataset as a tree showing the progression of a project and the hierarchy between the cases as shown on Figure 1. This module also offers the ability to sort, filter, archive models and trace their evolution throughout the reservoir study. Color flags and comments can be added

to the models in order to help the user having a clear overview of his or someone else's work. In addition, the user can assign high level criteria to build automatic Tornado charts.

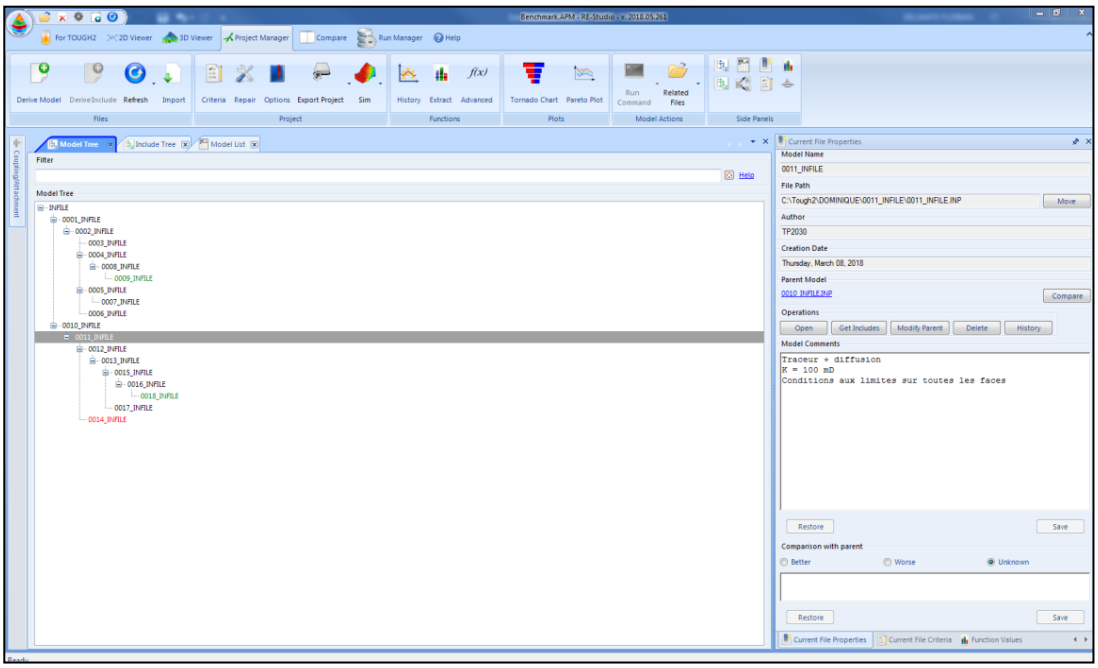

Figure 1: RE-Studio "Project Manager" module

Objective functions can also be defined and customized by the user to allow a powerful analysis of his results obtained from TOUGH2© simulation. This allows to rank and order models from a project, and makes Project Manager a global tool to follow up the evolution of the reservoir model, from the very first run to the final one

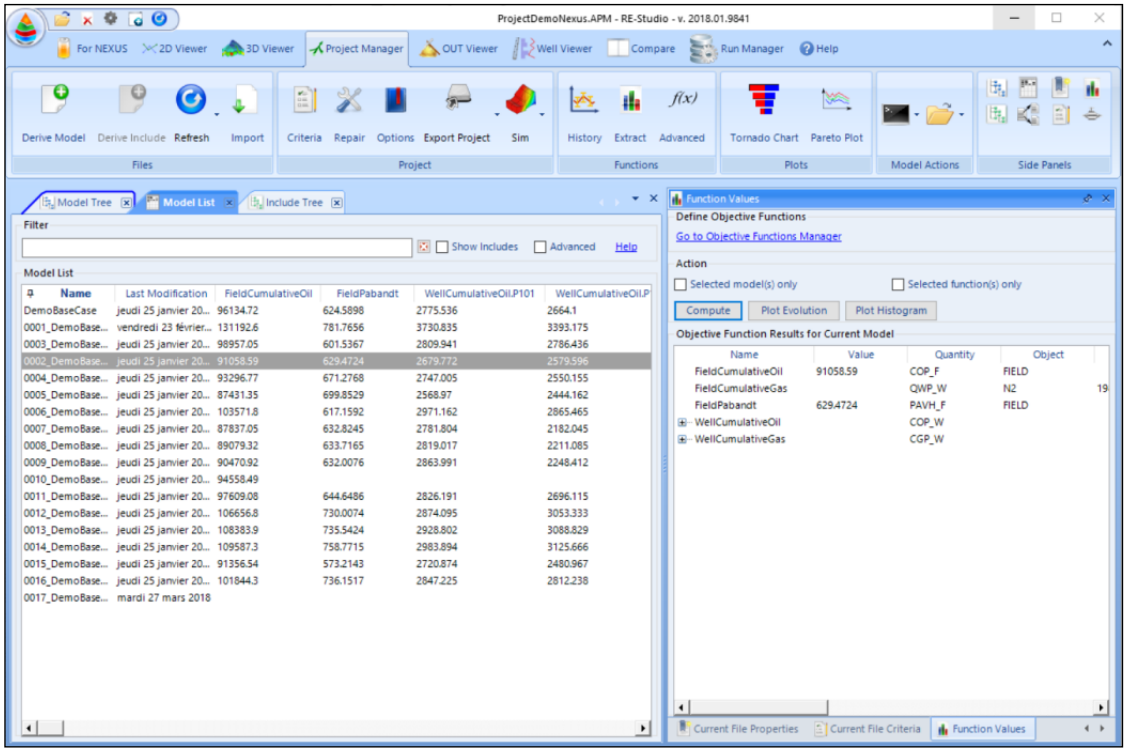

Figure 2: Display of model lists, criteria and objective functions

2.2 For Tough2

"For Tough2" module offers advanced text editing functionalities, allowing a TOUGH2© user to improve and fasten the dataset building. TOUGH2© user guide is dynamically linked to the user data deck, displaying the syntax of the keywords and facilitating their writing. An autocompletion tool (Keyword browser) also makes easier the writing of TOUGH2© keywords.

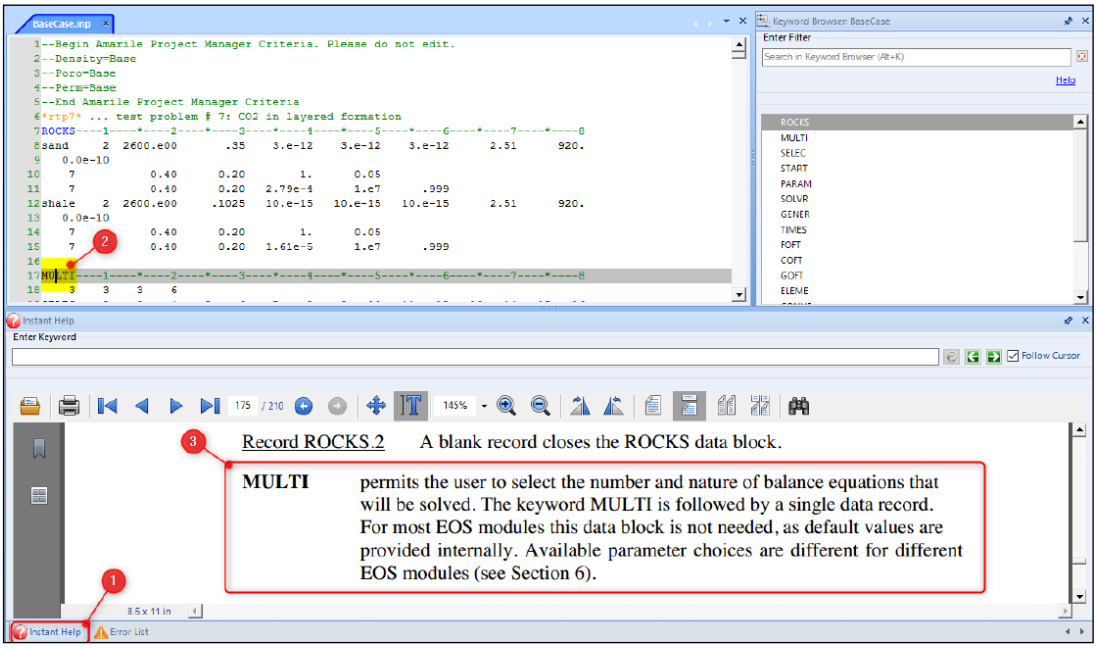

Figure 3: "Keyword Browser" and "Instant Help" panels

Finally, a complete quality checking of syntax and semantic errors is ensured by a check function allowing the user to run a model without errors. Figure 2. shows how an error is tracked in red on line 20 (an unexpected space between columns 21 and 28).

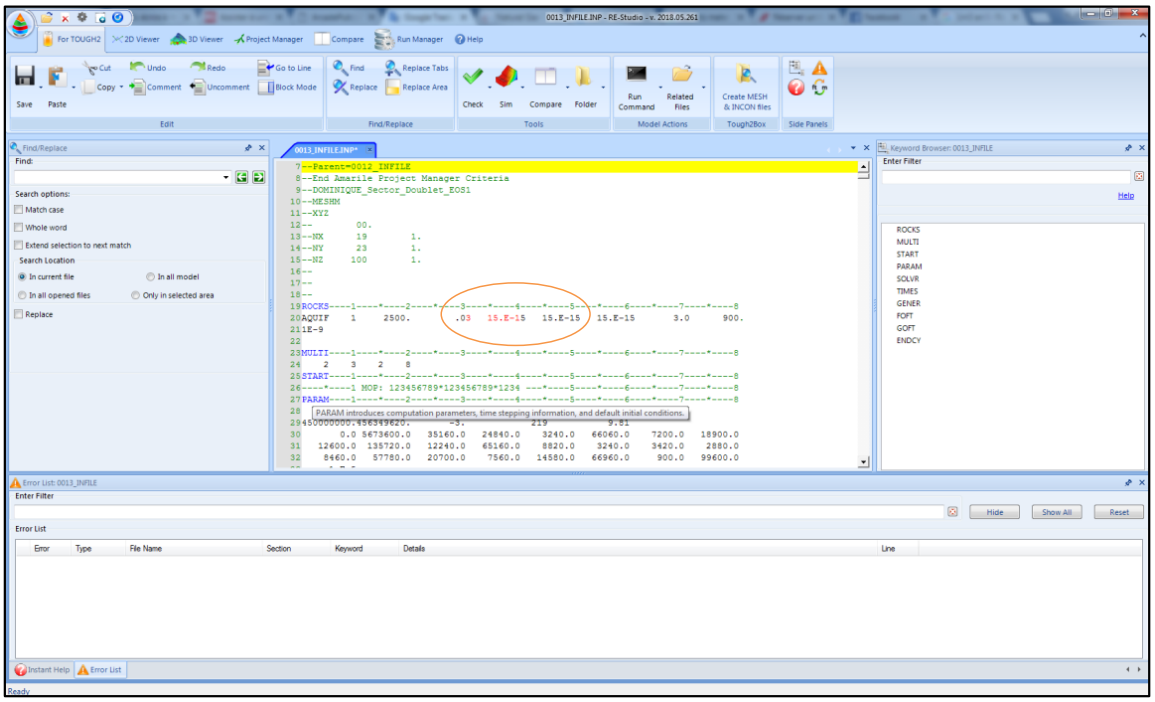

Figure 4: Syntax error detection in RE-Studio's "For TOUGH2" module

2.3 Compare

The data deck comparator is a useful tool to verify the changes made between two files. Syntax differences are highlighted making them straight forward to identify.

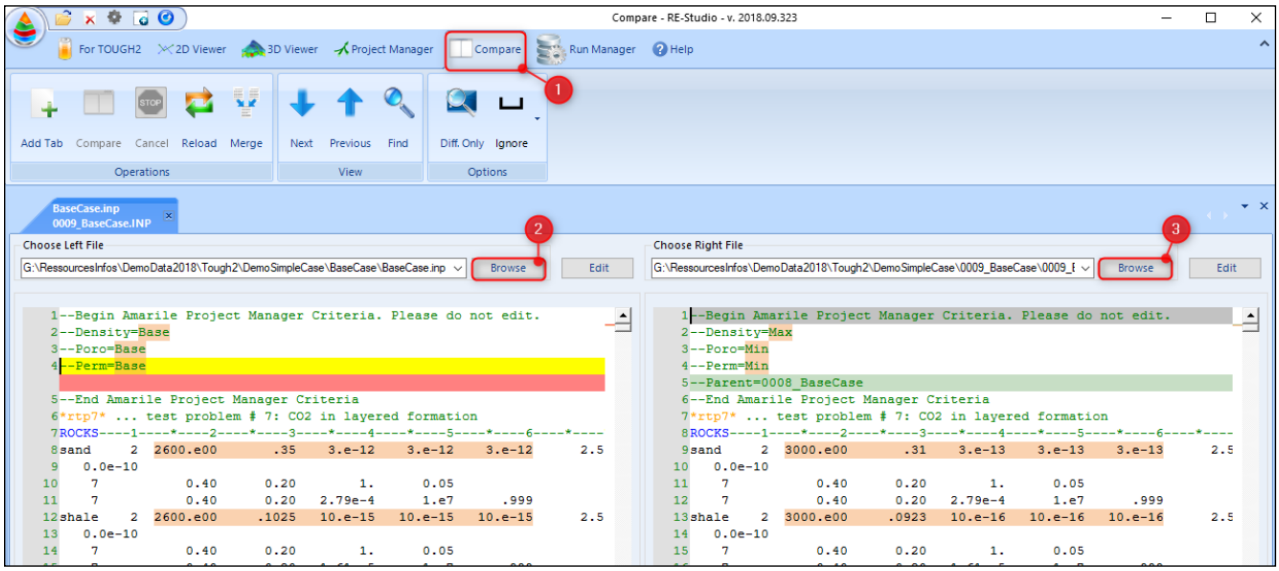

Figure 5: Compare feature in RE-Studio©

2.4 Create MESH & INCON Files

In order to cope with Storengy's need to model geothermal reservoirs, specific functionalities have been developed within RE-Studio to convert geological models built with Petrel© into TOUGH2© formatted files. "Create MESH & INCON Files" button included in RE-Studio allows such a conversion as shown on Figure 3. After clicking this button, the user may provide a *.GRDECL file. Then, he is asked to provide temperature and pressure gradients information.

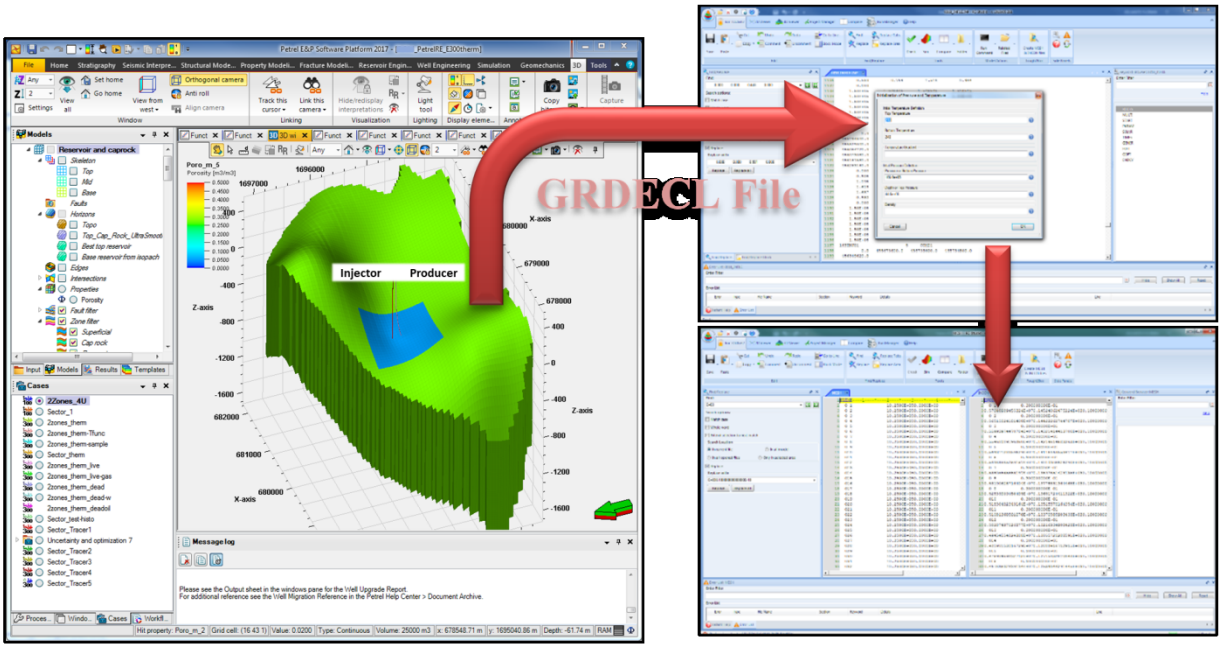

Figure 6: Grid file format conversion using "Create MESH & INCON files" functionality

This feature considerably simplifies the building of a data set, especially if complex geometry grids are to be used.

2.5 3D Viewer

Once formatted into *.GRDECL, grids can be displayed in “3D Viewer” module of RE-Studio (Figure 4), where static as well as dynamic properties can be visualized without requiring any additional software. This viewer has been tuned with a bunch of handy features such as filters, computation of new properties, screenshots and advanced analyzing plots.

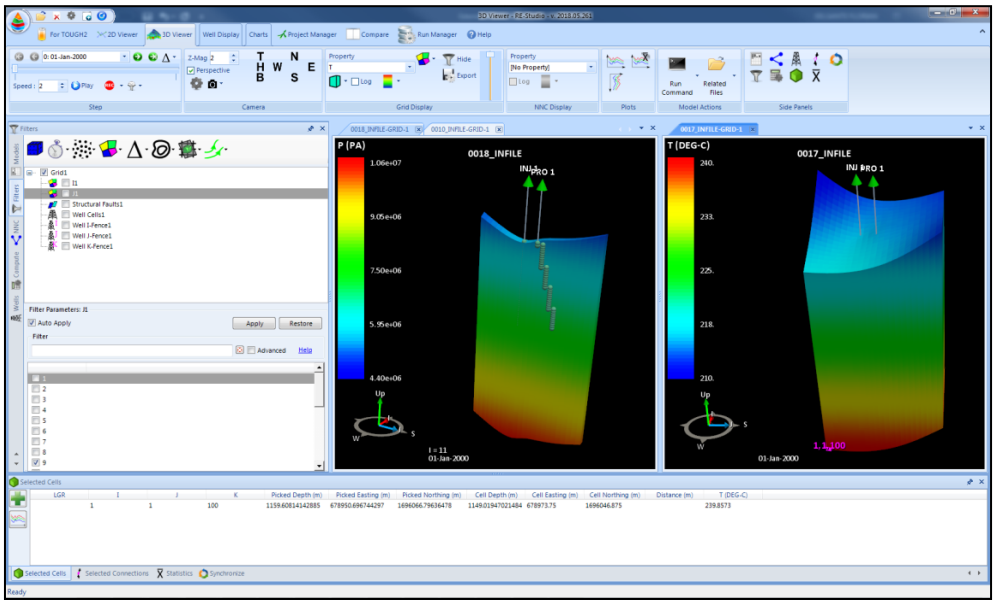

Figure 7: RE-Studio "3D Viewer" module

Among the functionalities offered by the 3D viewer, one can mention: Grid cells filtering, cross sections, maps, iso-surfaces, histograms, cross-plots, vertical sums, time-steps differences, models differences …

It is also from the 3D Viewer that 3D Statistics can be defined for extraction in Project Manager.

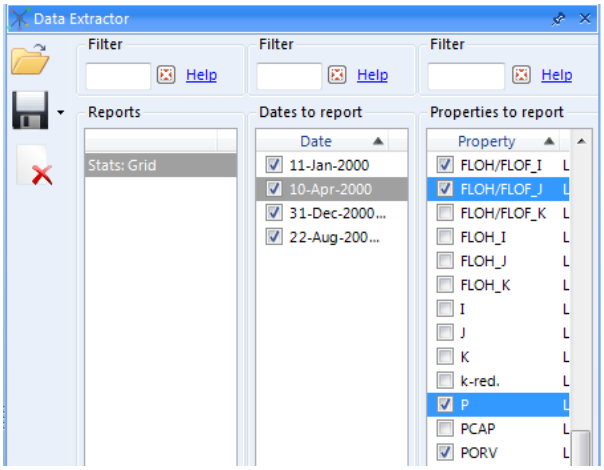

Figure 8: RE-Studio "3D Viewer Data Extractor"

2.6 2D Viewer

A “2D Viewer” module (Figure 5) is also included in RE-Studio, allowing plotting time dependent simulation results along with properties versus depths series. Data used for 2D display can be either retrieved from GOFT / FOFT files, or from the grid cells through the 3D Viewer. Cells or groups of cells can be selected, and the corresponding properties transferred to the 2D Viewer, in function of time or depth.

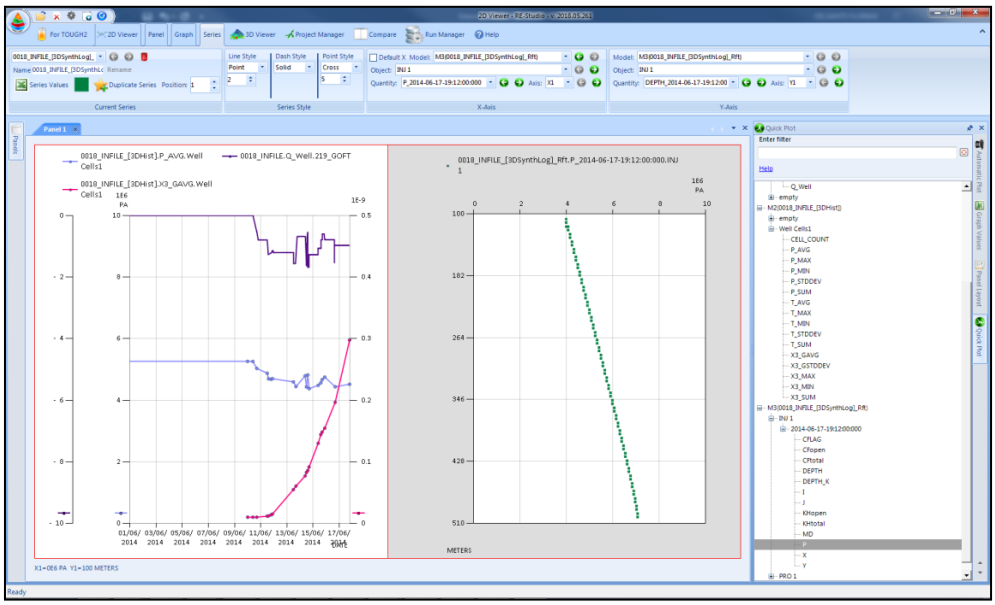

Figure 9: RE-Studio "2D Viewer" module

Functions can be computed within 2D Viewer module in order to customize exiting series from results files, allowing a deeper analysis of the results.

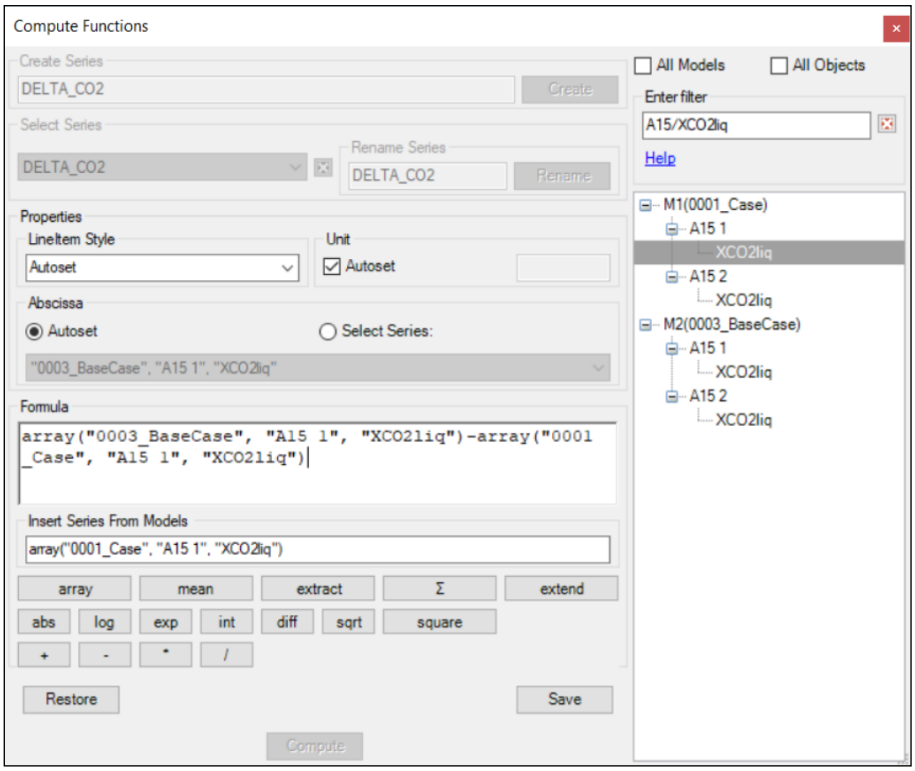

Figure 10: User function computing

Shortcuts buttons make easy links between the viewer and office tools to copy/paste plots as images, or graph values in a spreadsheet for instance.

2.7 Run Manager

Lastly, the "Run Manager" module of RE-Studio can be configured in an adaptive way to fit the user's environment. Ultimately, it allows to directly launch a simulation run from the "Sim" button available in "For Tough2" when an INFILE is open, or from the "Project Manager". The job progression will then be displayed in this window. Progression can be followed and eventually run killed while in progress.

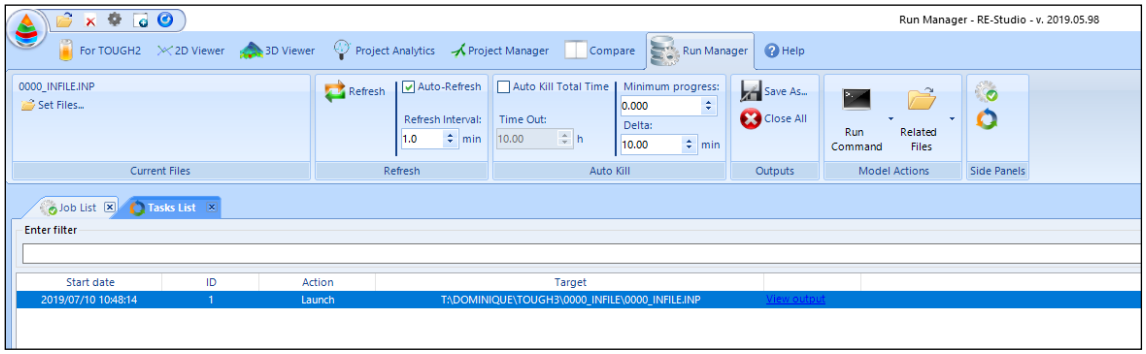

Figure 11: Run Manager module

2.8 Handling of the recently released TOUGH3©

Although the development was done with a strong focus on TOUGH2©, the interface has afterwards been successfully tested on a TOUGH3© case. The test case initially designed for TOUGH2© has been converted for TOUGH3©, the operation being straightforward as the overall structure of the dataset remains almost unchanged. For this reason, the converted dataset is very well handled by the "For Tough" module.

Also, the structure of the output files is similar enough to allow a smooth handling of TOUGH3© results in the 2D & 3D viewers. No particular problem has been encountered in terms of user experience while switching from TOUGH2© to TOUGH3©.

3. APPLICATION EXAMPLE: TRACER TEST MATCHING ON A GEOTHERMAL DOUBLET

RE-Studio© for TOUGH2© has been developed in collaboration with Storengy, and the various functionalities experimented on a test case consisting of a high pressure / high temperature geothermal doublet on which a tracer test has been performed.

The model uses TOUGH2© EOS1 code. To limit computation time, a 23*19*100 sector has been converted in MESH and INCON files. In order to fill the cells with the primary variables, pressure and temperature values for the top and bottom of the grid cells are provided (see Figure 3). The resulting grid is shown on Figure 6.

The tracer is represented by a 2nd type of water (3rd primary variable available in EOS1), and initialized with an extremely low concentration in the grid cells

The two wells composing the doublet are represented in the grid using the sink and sources keyword GENER and controlled by their mass flow rates. The tracer (water 2) is injected during a short period of time (20 minutes) and its concentration is tracked on the outflow from the producing well.

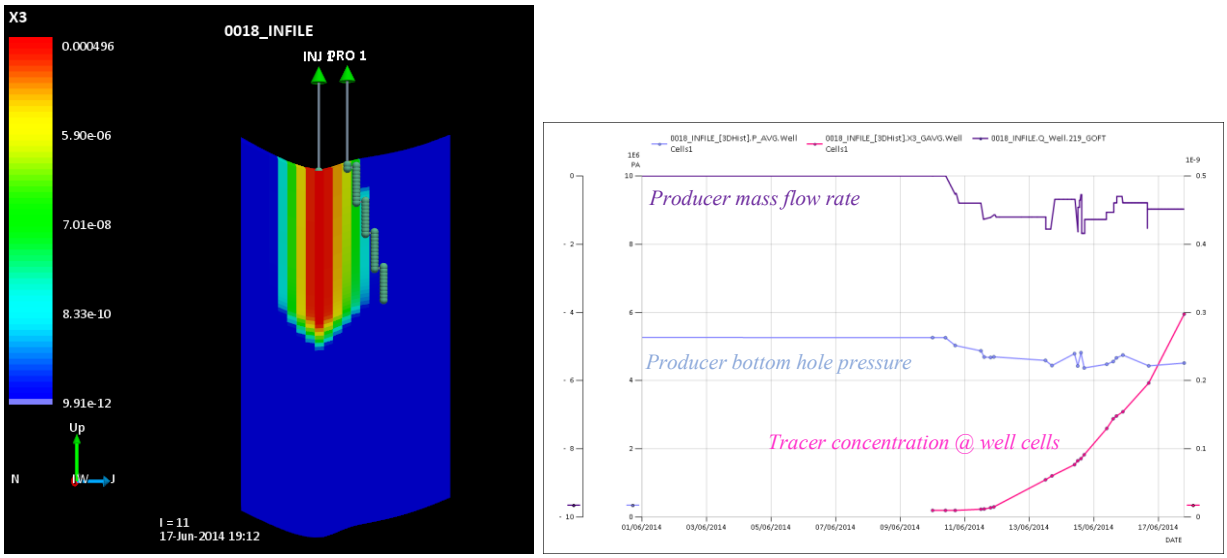

Figure 12: Simulation results displayed in "3D Viewer" (picture on the left) and "2D Viewer" (picture on the right) modules of RE-Studio©

The simulation results can be compared to available historical data by mean of:

- Importing historical data into Re-Studio. Once the appropriate format has been applied to an existing set of data, they can easily be imported and displayed in the 2D viewer together with case results.

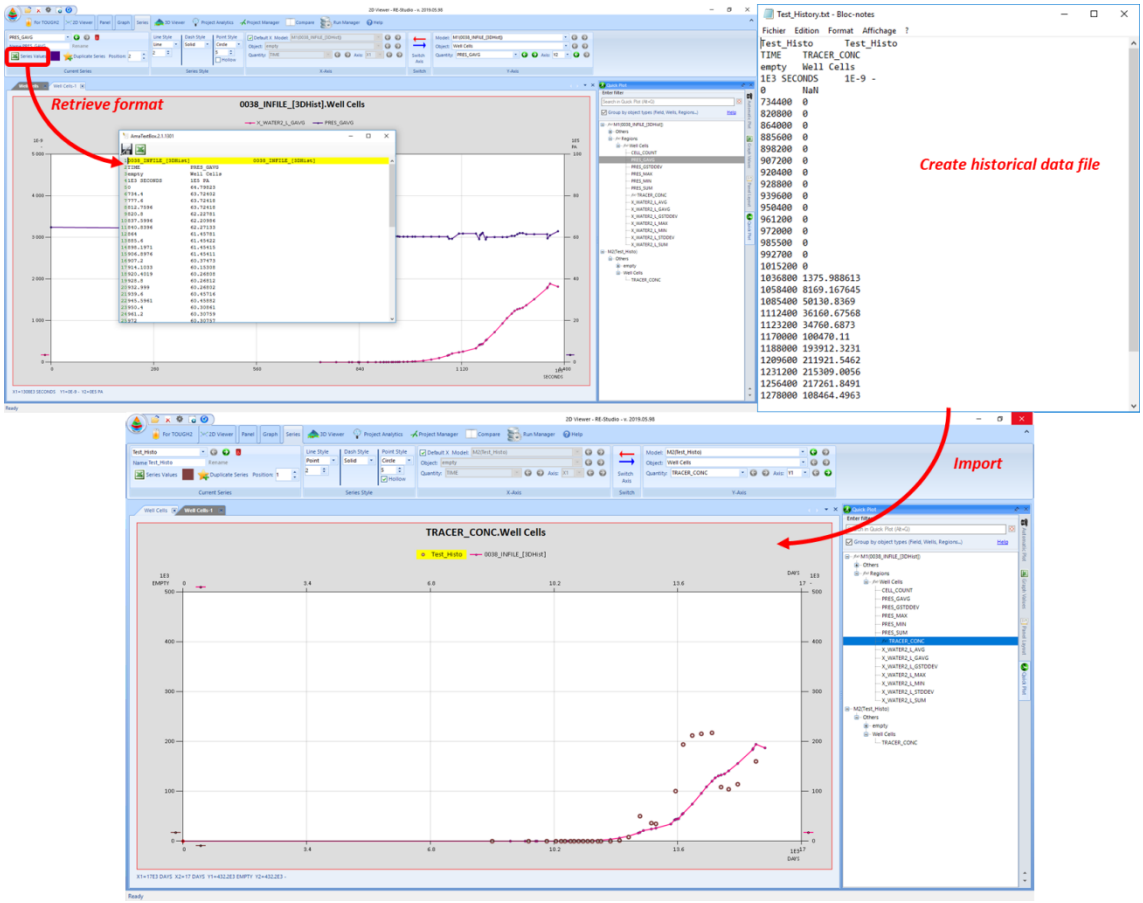

Figure 13: Importing and displaying external data files into the 2D Viewer

- Using the links between Re-Studio and Excel to export graphs value, edit and display them into a spreadsheet.

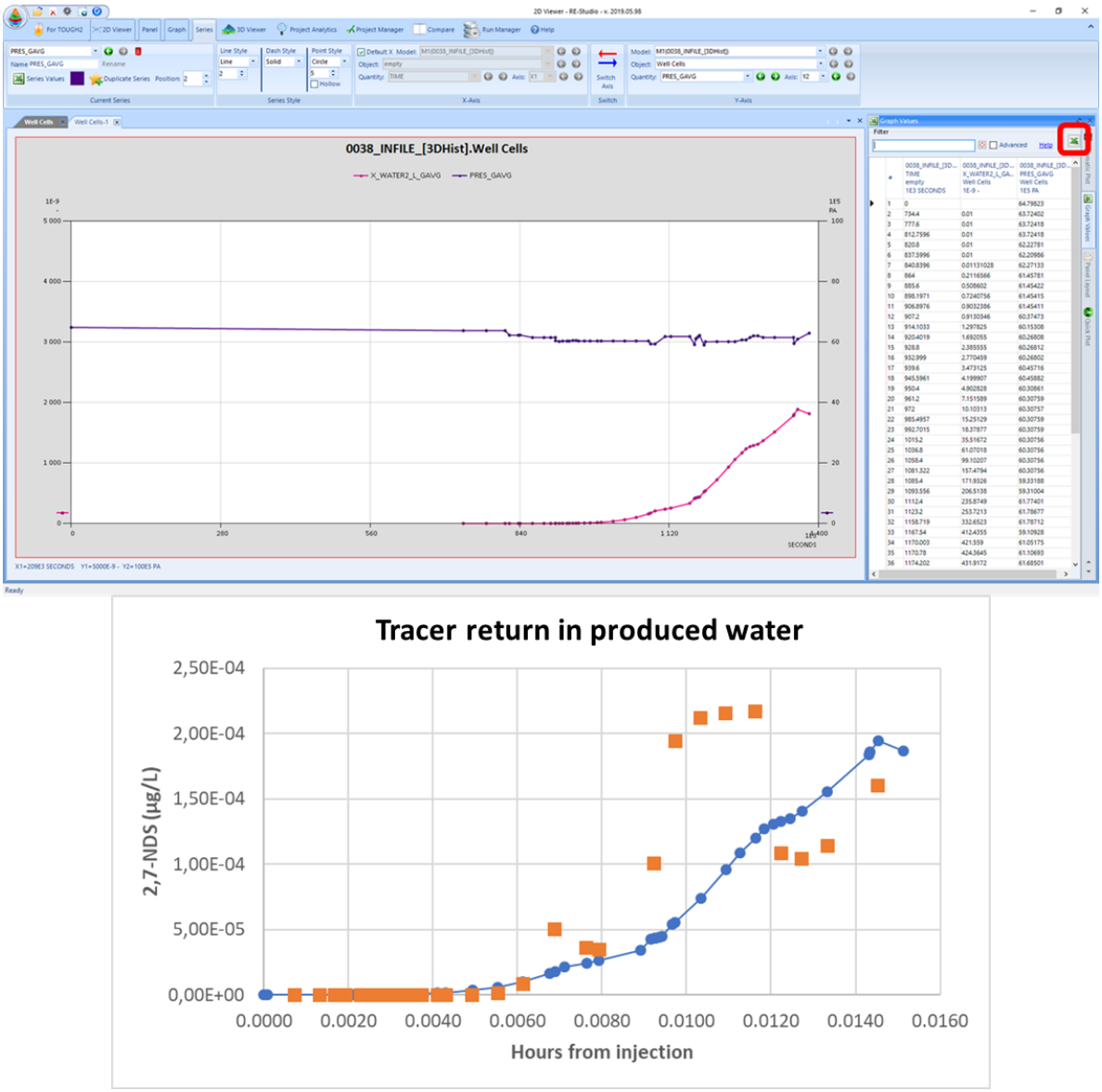

Figure 14: Exporting graph values into a spreadsheet

The study conducted to support the interface developments has allowed to draw some conclusions from the results of the tracer test about the geothermal reservoir interested by the doublet:

- The average porosity and permeability in the vicinity of the wells could be approximated,
- And it appeared that only the upper half of the reservoir seems to be effective for production / injection.

4. ONGOING DEVELOPMENTS

More functionalities are currently being developed by Amarile to enhance the user experience.

4.1 GENER keyword generator

Industrials are often interested in building refined geological grids for their assets, in which wells are spread over a large number of grid cells. Most commercial simulators handle well models, so that a rate measured in the well head can be allocated properly along the various intersected cells. Such a functionality is not available in TOUGH2©, and most users settle for large cell grids in which a well can be represented by a single cell.

The idea of this feature would be to convert a rate history into a formatted GENER keyword with time steps and a cell by cell repartition of the well rate based on the petrophysical properties. The method is inspired by well-known commercial E&P business simulators.

4.2 Dual medium grid converter

The “Create MESH & INCON Files” feature is planned to be enhanced in order to handle dual porosity and dual permeability grids. Petrel© grids containing matrix and fracture properties as long as the SIGMA transmissivity factor between matrix and fracture media will be converted into MESH and INCON files using the MINC option, the SIGMA factor being converted into a matrix cell / fracture cell transmissivity.

4.3 LGR implementation tool

A need has been expressed for the use of local grid refinements, in order to be able to work with a refined model in the vicinity of the wells, and coarser cells in more remote regions. This would prevent the use of large scale refined grids with large number of cells and keep the simulation times reasonable.

This option is currently into processing, with some restrictions in a first place to facilitate their implementation:

- No nested LGRs,
- LGR cannot be in contact with inactive cells,
- LGR do not intersect faults.

Those 3 new functionalities should be delivered and tested in the following months.

CONCLUSION

RE-Studio© for TOUGH2© is currently still under development in order to improve its existing functionalities and offer TOUGH2© users an evolutive pre and post processor to better fit their need and daily task workflow. It has been adapted for TOUGH2© / TOUGHREACT© simulators in a first place and has been successfully benchmarked on TOUGH3©. The model used for the benchmarking is an EOS1 case, but specific keywords required by other EOS can be implemented on demand by Amarile’s RE-Studio development team.

This case study is still in history matching process. Ultimately, an improved comprehension of the reservoir behavior in the surroundings of the doublet is expected, thanks to the history match of the tracer test. In parallel, the development of RE-Studio© for TOUGH2© has been enhanced, with some corrections, addition of new functionalities, and is intended to be pursued in the following months.

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