Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Cloud Software Solutions for Integrated Geothermal Studies

Oleksandr Burachok, Giovanni Sosio, Matthias Zeug, Alexandros Savvatis

Schlumberger, Günther-Wagner-Allee 19, 30177 Hannover

gsosio@slb.com

Keywords: Geothermal; Reservoir modelling; Multi-disciplinary; Cloud computing; Simulation

ABSTRACT

The reliability, risk assessment, and mitigation of any project depends on three key pillars: data availability, team expertise, and tools used to perform the study. The geothermal industry has widely adopted different software to support the exploration, assessment, and exploitation of geothermal resources. However, the tools adopted by engineering companies, consultants, and operators have varying levels of complexity, performance, adequateness, and cost. Simplistic but versatile thermohydraulic simulators, dedicated geomodeling tools and data visualization engines and ad-hoc geophysical processing codes, often developed as a research effort from different vendors are combined and used by different stakeholders in a project. This results in miscommunication between project team members, possible data loss, and simplifications enforced by the workflow or software limitations.

On the other hand, the oil and gas industry has pushed the general trend toward the integration of all possible data in one software platform to create comprehensive and highly detailed models without a need for any simplification. To accomplish this, development of integrated software platforms, in which users of different expertise domains work with common datasets and carry out multidisciplinary workflows on a single model, has been realized. These software platforms significantly increase the performance of a project from data analysis through seismic and petrophysical interpretations, geomodeling, well planning, hydrothermal, and geomechanical simulations for project sustainability assessment, performance optimization, risk assessment, and mitigation.

We introduce a next step in the evolution of integrated modeling practices, which is the movement away from the desktop system to a cloud-based infrastructure solution. This arrangement has been developed to facilitate the adoption of modeling tools by removing the need for software licensing, installation and maintenance, and to reduce the cost and need of continuous updates of user IT infrastructure by providing a common highly secured data storage and flexible (theoretically unlimited) access to computing power.

The DELFI cognitive E&P environment makes applications and workflows accessible to all users and enables team members to build common workspaces for data, models, and interpretations while respecting proprietary information boundaries. Each user has a dedicated workspace with access to the latest versions of all applications needed to perform the current tasks. Common data storage and computing power provide flexibility and scalability when they are needed, virtually unlimited computing power with no constraints on local infrastructure.

Examples of how the proposed solution is used for on-demand reservoir simulation will be shown, applied to the performance assessment and the related uncertainty analysis of geothermal projects in the area of Munich (Germany).

1. INTRODUCTION

The success of a modeling study, and in particular the ability to mitigate the potential risks relies on three pillars: data availability, team expertise, and the tools used to perform the study. The most common approach taken in the geothermal industry is to adopt different software to be used by petrotechnical experts representing different domains, from exploration to exploitation of geothermal resources: each domain expert would perform their part of the study using software tools specifically designed for that domain and that part of the workflow, installed on an individual workstation (Figure 1). The modeling tools adopted by different players in the industry—consulting and operating companies alike—respond to different levels of complexity, requirements, performance, and associated costs. Simplistic thermohydraulic simulators, dedicated geomodeling tools, and data visualization engines often developed as a research effort from different vendors, are being used by different stakeholders in a project (Brentini et al., 2017, and Andenmatten Berthoud, 2018). This diversity of tools multiplies the interfaces between users—thus increasing the risk of miscommunication between project team members—of data compatibility and transfer issues (including possible loss of data), and the need to simplify the workflow and eventually the models enforced by software limitations.

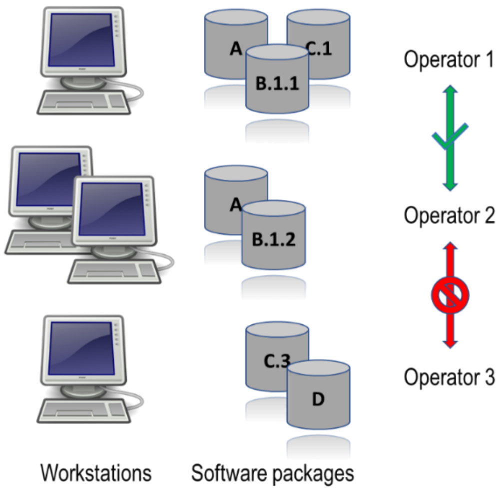

Figure 1: Traditional modeling architecture.

On the other hand, a general trend toward more integration has been pushed forward by the oil and gas industry, with the aim to combine all possible data and workflows in one single environment, and to create comprehensive and highly detailed models without sacrificing data consistency and quality because of the imposed simplifications (Sosio *et al.* 2019a). This was achieved by the development of integrated software platforms, allowing users of different expertise domains to work with common datasets and carry out multidisciplinary workflows on a single shared model. These software platforms facilitate the project design and feasibility phase, from data analysis through seismic and petrophysical interpretations, geomodeling, well planning and coupled hydrothermo-mechanical simulations, as it was shown in a variety of geothermal projects (Burachok et al. 2019; Mandiuc et al. 2018; Matthes et al. 2015; Sosio et al. 2016, 2018, 2019b), and allow a consistent approach to evaluate the financial sustainability and mitigate the technical and geological risks thanks to in-built, multiple-realization concept.

This paper describes an evolution of the integrated modeling practices, consisting in the transition from desktop-based or "on-premise" systems to a cloud-based infrastructure solution. Such an arrangement is designed to allow focusing on the technical modeling tools, facilitating their adoption by reducing nontechnical concerns such as software licensing, installation and maintenance, and to reduce the need of continuous updates of user IT infrastructure by providing a common data storage and flexible access to the computing power.

Cloud-based software solutions, such as a proprietary cognitive E&P environment, give all users the access to shared applications and workflows and enables them to build and share common workspaces for data, models, and interpretations, while respecting proprietary information boundaries. Each user has a dedicated workspace with access to the latest versions of all applications needed to perform their current tasks. Common data storage and computing power deployed on globally accessible cloud platforms provide flexibility and scalability when they are needed, allowing access to virtually unlimited computing power with no constraints on local infrastructure.

2. INTEGRATED GEOTHERMAL MODELLING WORKFLOW

A modeling workflow that encompasses different geoscience domains, as mentioned before, emphasizes the need and advantages of integration and multidisciplinary collaboration within a common modeling environment (Figure 2). The three key parts of the workflow are well data interpretation, geological and geophysical (G&G) modeling, and thermohydro-mechanical simulations. Workflow steps on well data include petrophysical and wellbore image log interpretation, as well as 1D geomechanical modeling based on the well logs and drilling data. In geological modeling, a structural model is built from the results of seismic interpretation and a 3D geocellular grid is built; the results of the well data interpretation are used to distribute reservoir properties across the grid, conditioned to seismic attributes or seismic inversion. In case of dual-porosity systems, a discrete fracture network with explicit fractures can be generated and upscaled to the geological grid. Finally, for dynamic simulations, a thermohydraulic model based on the geological grid is first validated against available production and tracer test results, and a 3D geomechanical model is created and validated based the 1D analyses and used for full-field 3D stress modeling. Finally, these two dynamic models can be coupled to simulate changes in pressure, temperature, and stress over time, which can be used to infer production sustainability and cold-water breakthrough times, together with fault stability and microseismic event prediction for different operating conditions.

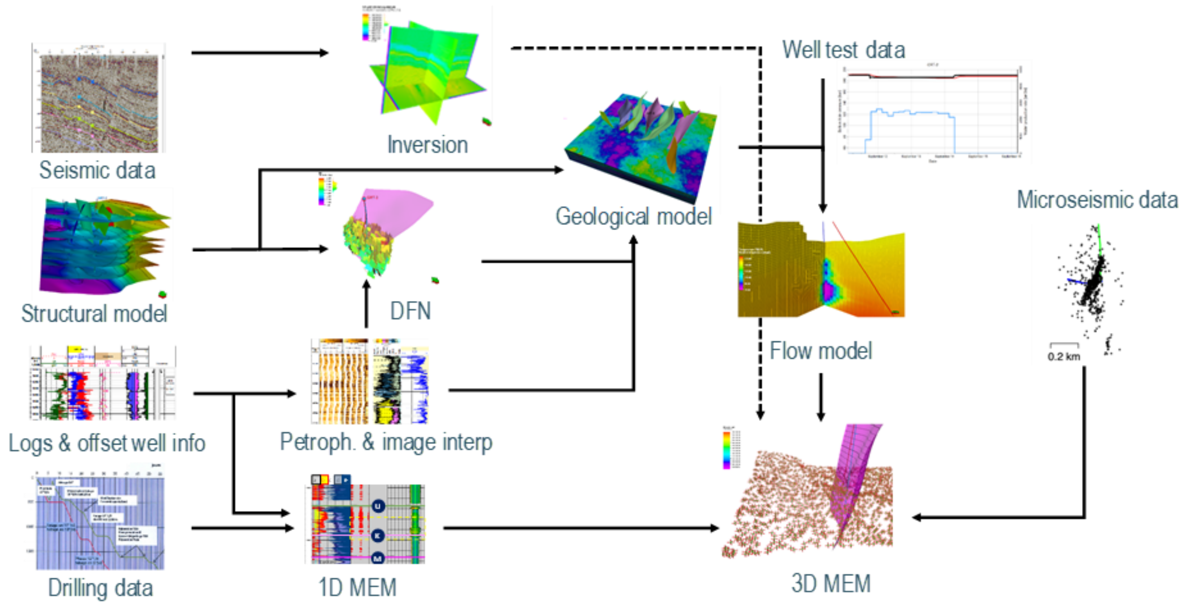

Figure 2: An example of an integrated modeling workflow for a geothermal site (adapted from Sosio et al., 2019).

This workflow was successfully applied for the modeling of the ECOGI project site in Rittershoffen, located in the Upper Rhine Graben (Mandiuc et al. 2018; Sosio et al. 2016, 2018, 2019b).

One common modeling software platform was also used for several other geothermal projects and successfully served a variety of applications: for instance, the application of seismic-based geomechanical data to estimate the reservoir properties (Burachok et al. 2014); the identification of potential drilling targets based on seismic data (Matthes et al. 2015); the modeling of natural fractures using a tectonic-based approach for the Geneva Basin (Lo et al., 2019); the evaluation of pressure and temperature changes on stress relocation in the geothermal doublet system in the Upper Jurassic reservoir of the Southern Bavarian Molasse Basin (Savvatis et al. 2019); the quantification of exploration risks by means of thermal basin modeling in the St. Gallen area of Switzerland (Omodeo-Salé et al. 2020); and the evaluation of potential geothermal energy production from Ukrainian oil and gas fields (Burachok et al. 2019).

These studies used an integrated modeling approach with the common modeling environment and a common software project; however, the presence of multidisciplinary teams, often located in different countries, has sometimes caused delays due to miscommunication, versioning, data transfer issues, and limited computing infrastructure (Figure 3). To eliminate these gaps and further streamline the process, a cloud-based solution was offered for commercial application.

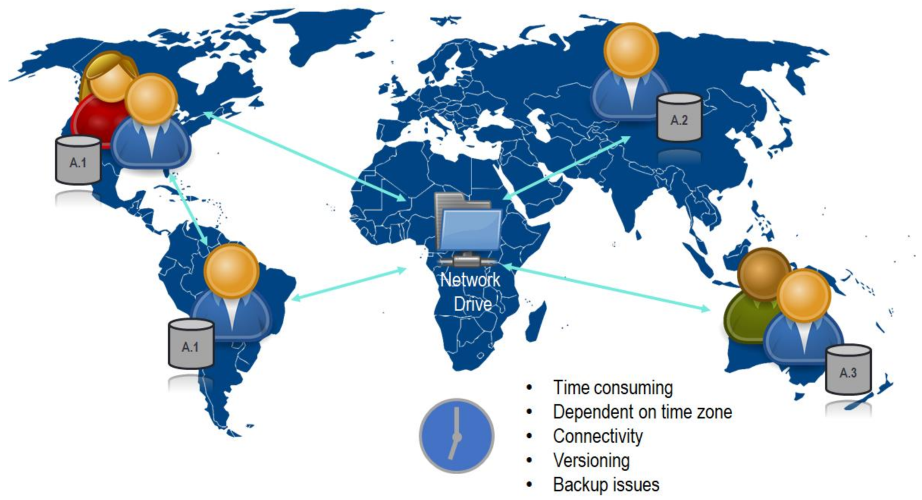

Figure 3: Common collaboration issues.

3. NEXT STEP IN EVOLUTION: FROM AD-HOC TO CLOUD-BASED SOLUTION

After impacting the oil and gas industry, the digital transformation—an integral part of the “industrial revolution 4.0”—has also been embraced by the geothermal industry, including for the reservoir modeling (Elliott et al. 2020). The next step in the evolution of integrated modeling is the transition from a desktop-based system to a cloud-based infrastructure solution. Such a solution, as mentioned before “liberates” the software modeling and simulation tools from the need of software installations, updates and maintenance, and license administration; in turn, the reduction in these administration-intensive requirements enables lower operating costs together with significant savings on the updates of local user IT infrastructure. The performance and the usability of the software platforms are improved by the availability of shared, highly secured data storage, as well as by flexible access to computing power, providing efficient data access, interpretation, modeling, and project execution, with ultimately a faster transformation of data into decisions (Figure 4).

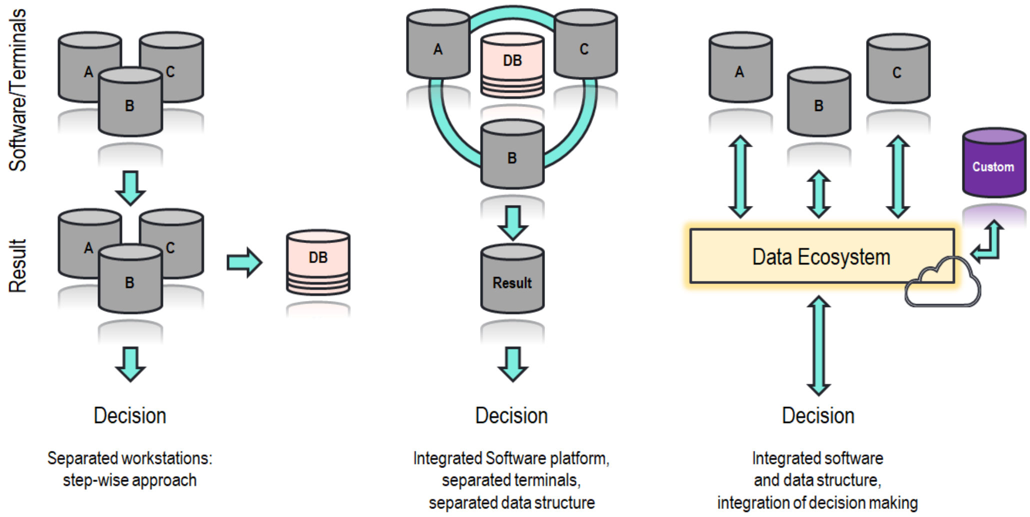

Figure 4: Evolution of integrated modeling.

The steps of the geothermal integrated modeling workflow described above are already fully implemented inside the cloud-based proprietary cognitive E&P environment and is now being tested and adopted by a number of geothermal operators and consulting companies in Europe. Apart from better integration and access to theoretically unlimited computing power, a driver toward cloud-based solutions for geosciences, as mentioned before, is the support to turning data into decisions (Figure 5). For geothermal projects, high-performance computing facilitates the decision process by allowing multiple scenarios and multiple realizations, and therefore a thorough analysis of the uncertainties and of the sensitivity of the input parameters, thus optimizing the value of a project (Van Der Kooij, 2020). Cloud-based solutions allow to perform these analyses and the corresponding simulations from a common software platform and flexible access to the required simulation power. The functionalities of such a cloud environment allow displaying the results of the uncertainty scenarios in dedicated dashboards, highlighting the most sensitive parameters in an intuitive fashion, facilitating their understanding by all stakeholders and indeed the decision-making process to assess and reduce the related uncertainty in terms of data acquisition and operational decisions.

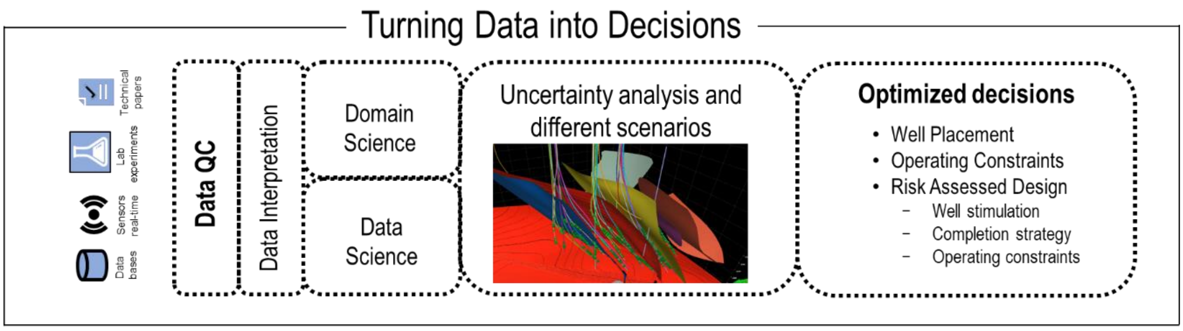

Figure 5: Global vision of cloud-based solutions.

Cloud-based solutions also offer the possibility to apply automated “big-data” interpretation and quality control to large datasets, including multiple global knowledge bases. This can be useful to complement the gaps in available data from a specific field, which is often an issue in the early stages of geothermal site modeling, with “learnings” taken from larger available datasets, some of which are made available to the public by the relevant national authorities. Machine learning algorithms enable additional empowerment of human user expertise, which transforms into better decision making and reduction of potential risks.

Moreover, the access to cloud services from mobile devices gives increased control on operations monitoring, ultimately enabling frequent updates to the model during critical project execution periods, such as well drilling or production testing, facilitating the application of a "living model" approach (Figure 6).

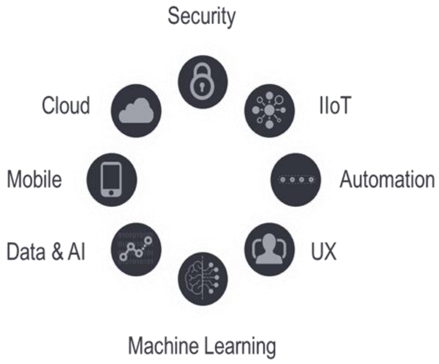

Figure 6: Digital amplification in a cloud-based environment.

Finally, "hybrid" cloud-based and on-premise solutions are designed for the users who elect to benefit from well-established in-house desktop solutions but at the same time are constrained by local computing infrastructure. In the most typical application of such a hybrid solution, a "static" model of a geothermal site can be built on a locally installed version of the software platform, but to reduce the project runtime by optimizing computationally extensive hydraulic or geomechanical simulations, it is possible to submit simulation runs to the cloud-based computational resources directly from the local workstation. Monitoring the progress of the run remotely through a mobile device (Figure 7) enhances the capability of fast decision making and immediate job modification.

Figure 7: Remote simulation job execution and monitoring.

4. APPLICATION OF CLOUD-BASED SOLUTIONS TO GEOTHERMAL SITE MODELLING: CASE STUDIES IN BAVARIA

The cloud-based solution was used for a hydrothermal project in the Molasse basin of the southern Bavaria during the planning phase. This project is to be realized with multiple geothermal doublets. By using thermo-hydraulic simulations, the productivity of the reservoir, the sustainable management of the reservoir, as well as the hydraulic and thermal impact on neighboring projects should be evaluated for different operating scenarios.

The simulations were performed with ECLIPSE E100 Temperature option, using the On-Demand Reservoir Simulation (ODRS) solution, with which the simulations are uploaded to the DELFI cloud from a local Petrel installation, launched, and downloaded back to the local computer.

The first part of the study was to evaluate the productivity of the reservoir and to forecast the maximum possible production of the project for the different operating scenarios. For this purpose, an uncertainty analysis with 216 simulations was performed for each operating scenario with various realisations of the hydraulic parameters of the reservoir. The considered period of the simulations was a maximum of 5 years and the grid results were disabled. The simulation time was accordingly short, with CPU times ranging from 3 minutes (181.99 seconds) to 7.1 minutes and a mean of 4.7 minutes (279.7 seconds). Using a single license of ECLIPSE, which had been the case so far, would have resulted in a total simulation time of 16.8 hours for each operating scenario. The simulation time in the cloud could be reduced to under 2 hours by simulating the cases simultaneously (Figure 8, left). Including uploading and downloading, the process took about 4 hours, depending on the internet connection.

The second part was the evaluation of the sustainable management of the reservoir and as well the hydraulic and thermal impact of neighboring projects for the different operation scenarios. The performed uncertainty analysis included 64 simulations with a considered period of 50 years and both hydraulic and thermal grid results every 5 years. The simulations had CPU times ranging from 1 hour (3591.3 seconds) to 2.93 hours (10541.62 seconds) and a mean of 1.70 hours (6105.1 seconds). Due to the longer simulation time, the number of simulations in the uncertainty analysis was reduced to 64. Nevertheless, the total simulation time would have been approximately 4.5 days if a single license were used. Using ODRS reduced it to an overnight process (Figure 8, right). A challenge in the second part was the size of the simulation results of about 2 GB per case (over 120 GB in total per operational scenario), which had to be downloaded from the cloud. The simulations were started from a laptop and therefore the cases had to be prepared and exported locally during the day. In the evening, the process for the simulation in the cloud was started. This slight adaptation allowed relatively complex simulations to be started from a laptop and further allowed mobility of the user.

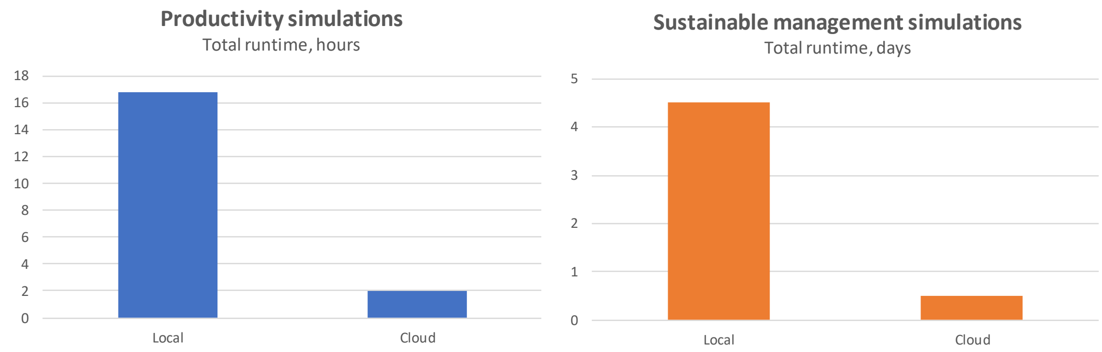

Figure 8: Total simulation runtimes for two sets of uncertainty analysis, comparing a locally installed simulator with on-demand reservoir simulation on the cloud.

The complexity and requirements of simulations in geothermal projects have increased in recent years, while time remains an important factor in the realisation of a project. As the presented project shows, in order to meet the by now high demands of geothermal projects, simulations in the cloud can be the more time and cost-efficient solution.

CONCLUSIONS

Several successful applications of well-established integrated oilfield modeling workflows have been recently shown for geothermal sites in Europe and beyond. Multidisciplinary teams executing studies in a common software environment gain efficiency through improved collaboration, and the quality of the results is improved by the consistency across different geoscience domains. A proposed workflow can be applied to different stages of geothermal projects to reduce exploration uncertainty, predict the subsurface performance and the sustainability of production; and finally to quantify, mitigate, and monitor the potential or existing operational risks, leading to more informed and faster decision making.

The next step in the digital evolution is the transition from standalone workstation-based modeling toward a cloud-based software offering. This allows a simpler, faster and less costly modeling-to-execution cycle for geothermal projects, notably by eliminating the need of software installation, licensing, and updates. A shared and secured data storage, together with flexibility and scalability of a remote environments with virtually unlimited computing power and no constraints on local infrastructure, add to the value of these solutions. Access to knowledge sources and automation at every level makes it possible to turn data into decisions faster.

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