COSEISMIQ Project: Control Seismicity and Manage Induced Earthquakes

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Abstract

Controlling induced seismicity is particularly important for the future development of geothermal energy in Europe, as deep geothermal energy exploitation projects such as Basel (2006) and St Gallen (2013) have been aborted due to the felt induced earthquakes they created and an increasing risk aversion of the general population. Analysis of induced micro-seismicity allows to obtain the spatial distribution of fractures within the reservoir, which can help, not only to identify active faults that may trigger large induced seismic events, but also to optimize hydraulic stimulation operations and to locate the regions with higher permeability, enhancing energy production. The project COSEISMIQ integrates seismic monitoring and imaging techniques, geo-mechanical models and risk analysis methods with the ultimate goal of implementing innovative tools for the management of the risks posed by induced seismicity and demonstrate their usefulness in a commercial scale application in Iceland.

Seismic Network

As a demonstration site, we selected the Hengill region in Iceland. The Hengill volcanic complex is located in SW Iceland on the plate boundary between the North American and Eurasian plates. In this region, the two largest geothermal power plants of Iceland are currently in operation, the Nesjavellir (120MW electricity) and the Hellisheidi (303MW electricity) power stations. In October 2018, we densified the permanent seismic network run by ISOR and IMO in this area (14 stations) with 23 additional broadband stations.

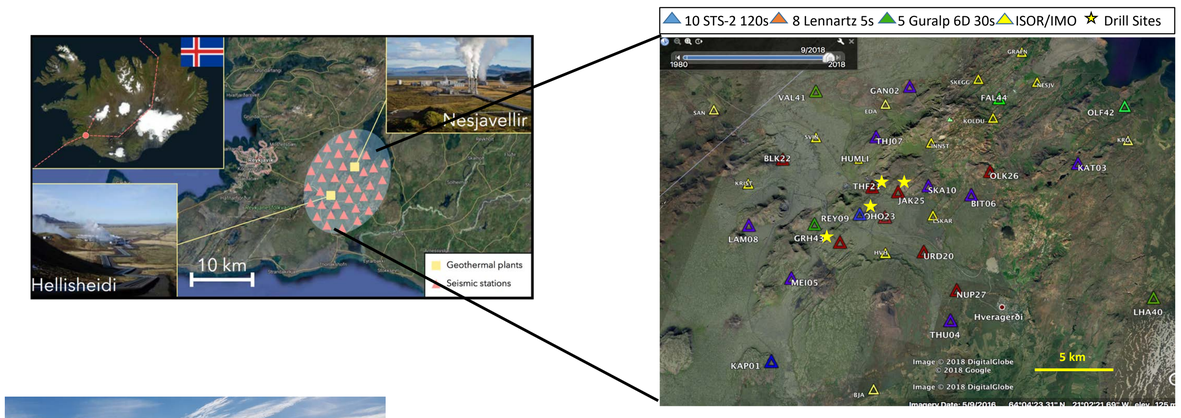

Fig 1. Dense seismic network in the Hengill area installed in October 2018. The yellow stars mark drill sites that are planned to be stimulated later this year.

Advanced Traffic Light System (ATLS)

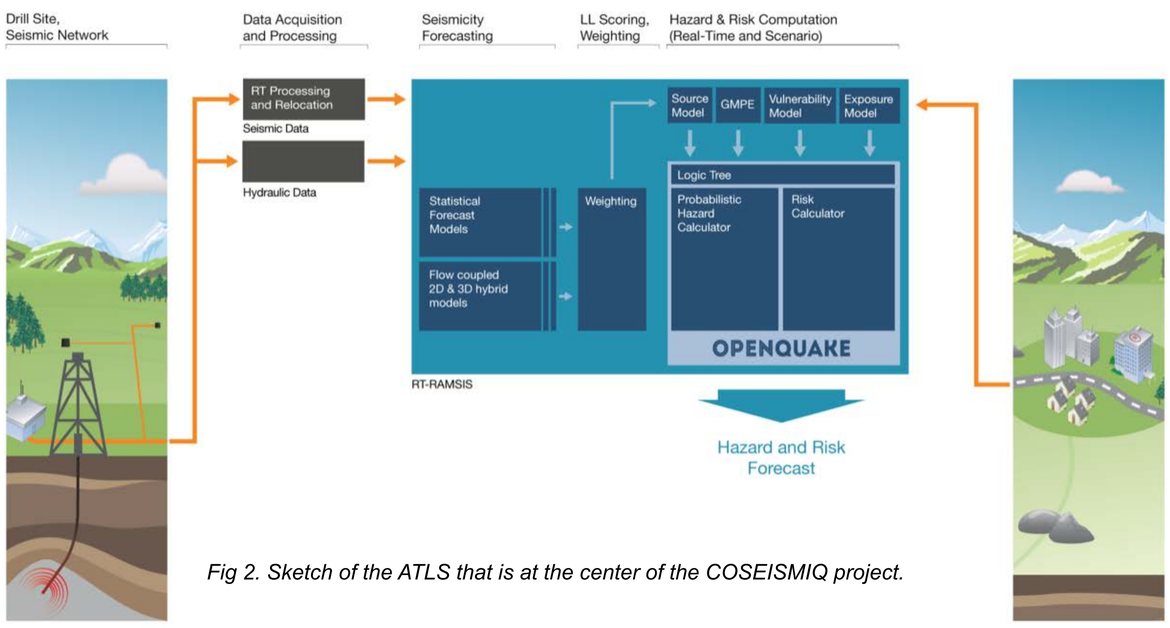

Fig 2. Sketch of the ATLS that is at the center of the COSEISMIQ project.

Modelling

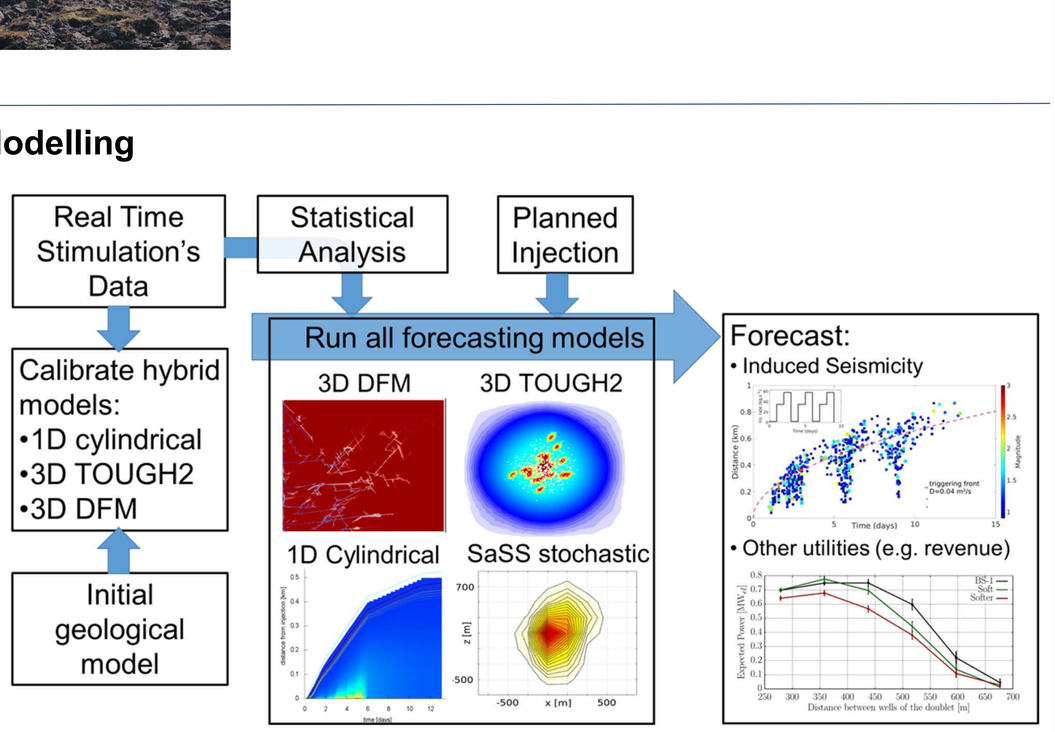

Fig 3. ATLS integrates forecasts both of induced seismicity and of the efficacy of a given injection plan from its suite of models. These models are of varying complexity and take into consideration several observations besides observed seismicity.

Real-time processing of induced seismicity

As induced seismicity sequences are often characterized by very short inter-event times, the application of standard network monitoring tools at regional levels is often not sufficient. An additional challenge is to accurately locate and quantify seismicity at magnitudes well below the traditional resolution of regional networks. Induced seismicity hazard assessment requires seismic catalogues in real-time with:
- low, reliable magnitudes of completeness (near M0).
- locations accurate to 50-100 meters.

We are currently developing new modules for SeisComp3 (regional real-time monitoring system), such as Scanloc, Scxcorr (ccloc) and ScDD to overcome these issues.

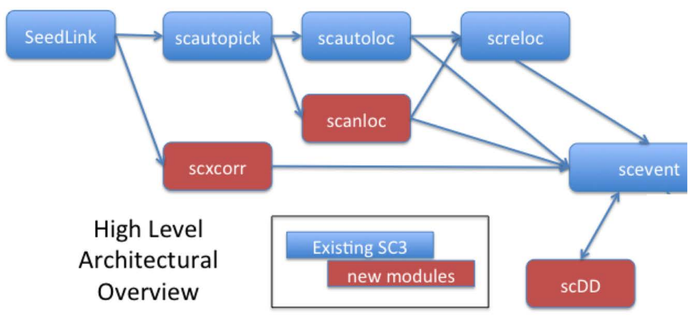

Fig 4. SeisComp3 consists of different modules solving different tasks. Blue reactangles denote standard/existing SC3 modules. Red rectangels denote new (or in development) SC3 modules for real-time induced seismicity monitoring

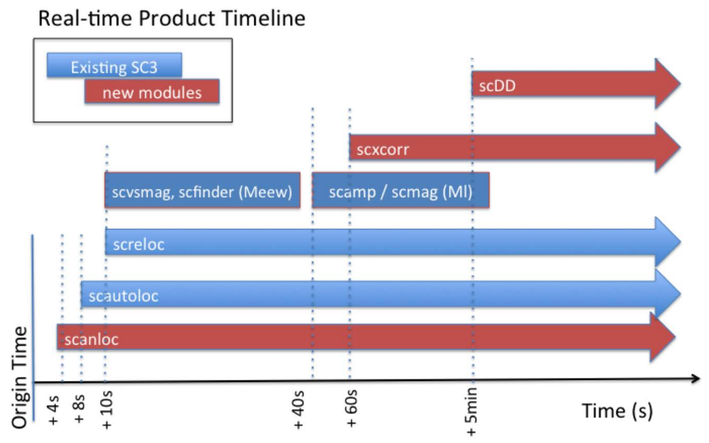

Fig 5. Each new module interacts with existing SC3 modules/ information flow. In real-time, scanloc can be expected to work within the ATLS, and results from other modules will be available within minutes of an event and can be revised after manual review, if needed.

Seismic events

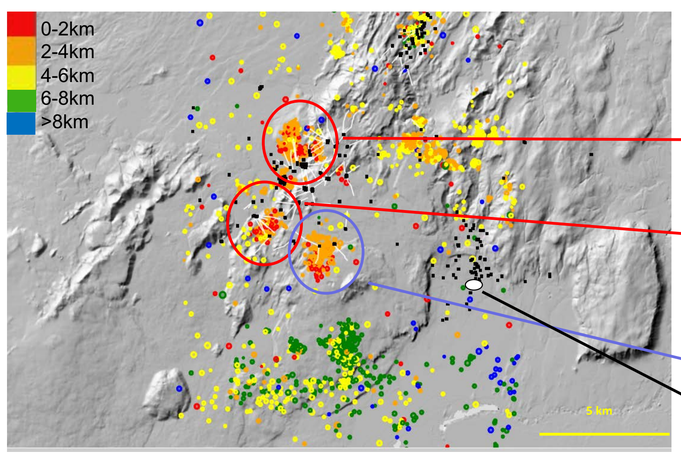

Fig 5. Automatically located seismic events in the Hengill area from October 2018 to March 2019. The clusters coincide with zones of water injection/production.

Húsmúli reinjection field

Gráuhnjúkar reinjection field: subsurface too hot, better to be used for production

Hverahlíð Production field: why so much seismicity?

Town of **Hveragerði** with 3000 inhabitants

Outlook

-Improve location accuracy
-Catalogue completeness with different approaches
-Develop accurate fluid flow model
-Model induced seismicity in this complex setting
-Risk assessment (operator/civil protection)

<u>Improved system understanding:</u>
-Vp/Vs tomography to estimate depth of magma
-Model 2-phase geothermal system (steam, heat source)
-Understand absence/presence of induced seismicity associated with different well operations