Quantification and Reduction of Uncertainties in 3D stress models

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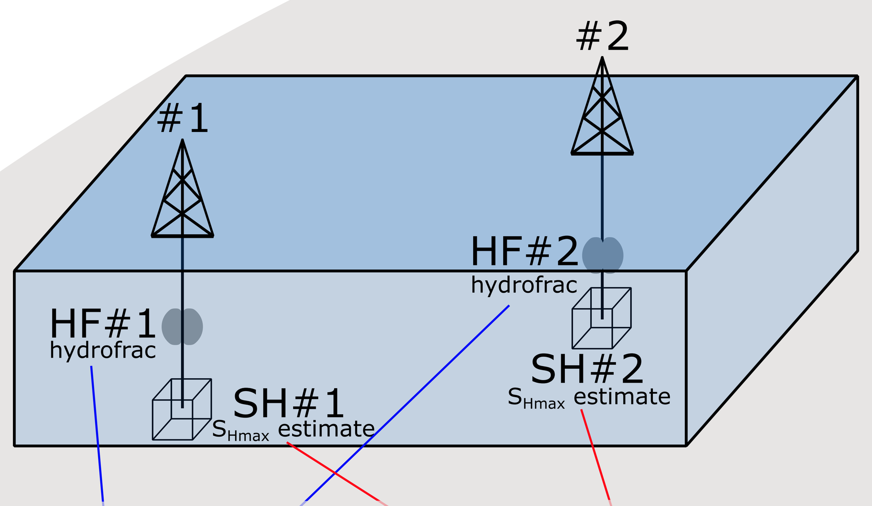
The undisturbed stress state is of key importance for all kinds of subsurface applications as well as for seismic hazard assessment but information on stress magnitudes is rare and unevenly distributed. Thus, 3D geomechanical-numerical modelling is used to estimate the stress state in an area of interest. However, due to the limitation of available data, the modelled stress state has a large uncertainty which has not been rigorously quantified yet. We present an approach to quantify the uncertainties in a 3D geomechanical-numerical modelled stress field. We combine the available SHmax and Shmin data records to pairs. For each pair we compute an individual model scenario. At each location in the model each scenario contains the full stress tensor. Then, from all model scenarios we compute an average value and a standard deviation for each component of the full stress tensor at each location within the model.

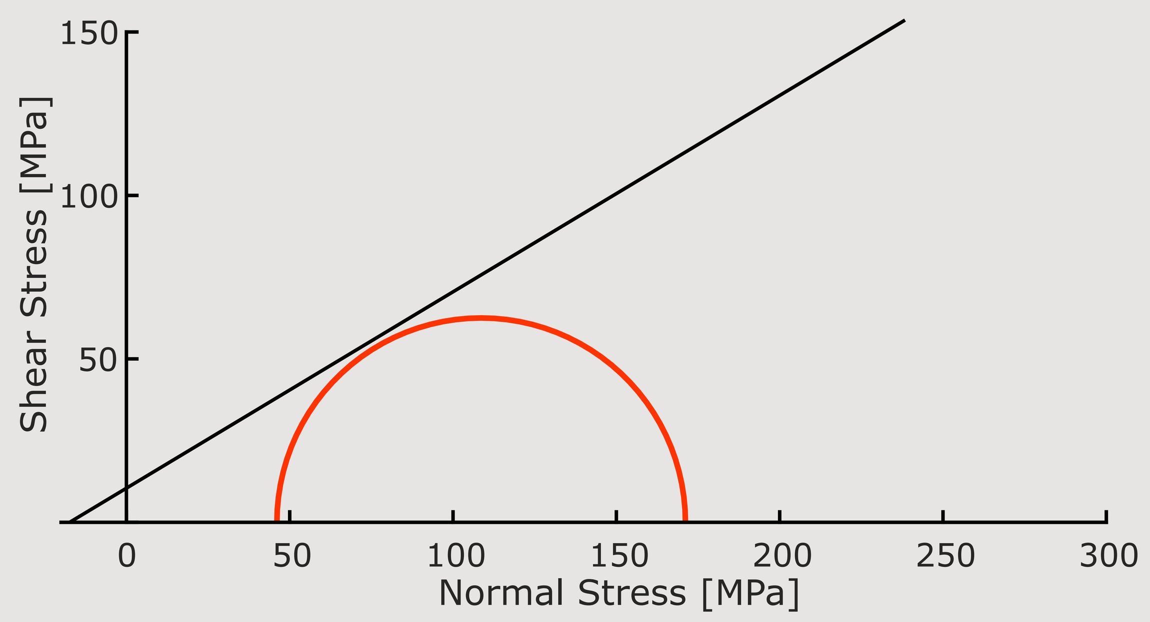
Furthermore, we reduce the previously quantified uncertainties in the model results. We use additional borehole observables (Formation Integrity Tests) and observed seismicity. These observables cannot provide any data records on the stress state. Yet, the information that can be extracted is valuable as it contains boundaries for realistic stress states. These boundaries are compared to the stress states in the individual model scenarios. Then, each scenario is assigned a weight based on its agreement with the additional data. This allows computing a weighted average and a standard deviation. The resulting standard deviation is clearly smaller compared to the unweighted approach and small changes in the average stress state are observed. Thus, even with only limited data record availability, a quantification and even a significant reduction of uncertainties in the modelling results is possible which increases the significance and value of the model.

"Best-Fit" approach

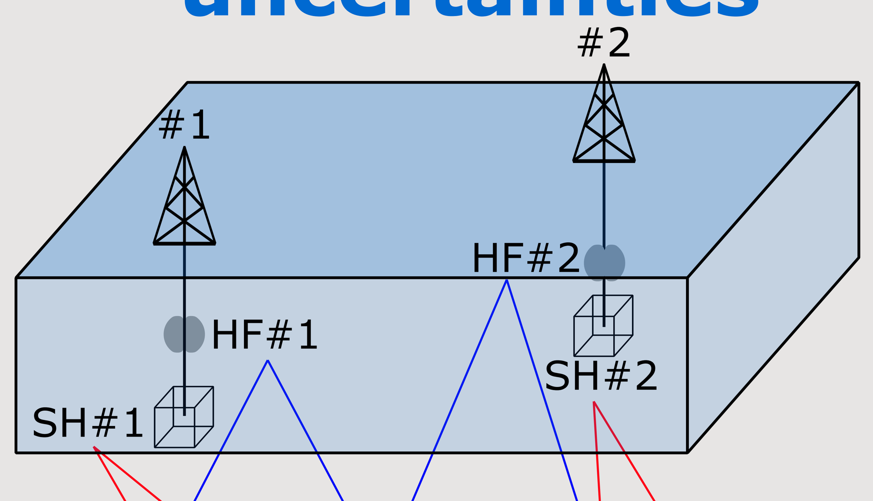


Mean difference between modelled and observed stress states are minimized. The resulting stress state fits all stress data records best - the "best-fit".

$$\begin{pmatrix}\sigma_{11} & \sigma_{12} & \sigma_{13}\\ \sigma_{21} & \sigma_{22} & \sigma_{23}\\ \sigma_{31} & \sigma_{32} & \sigma_{33}\end{pmatrix}$$

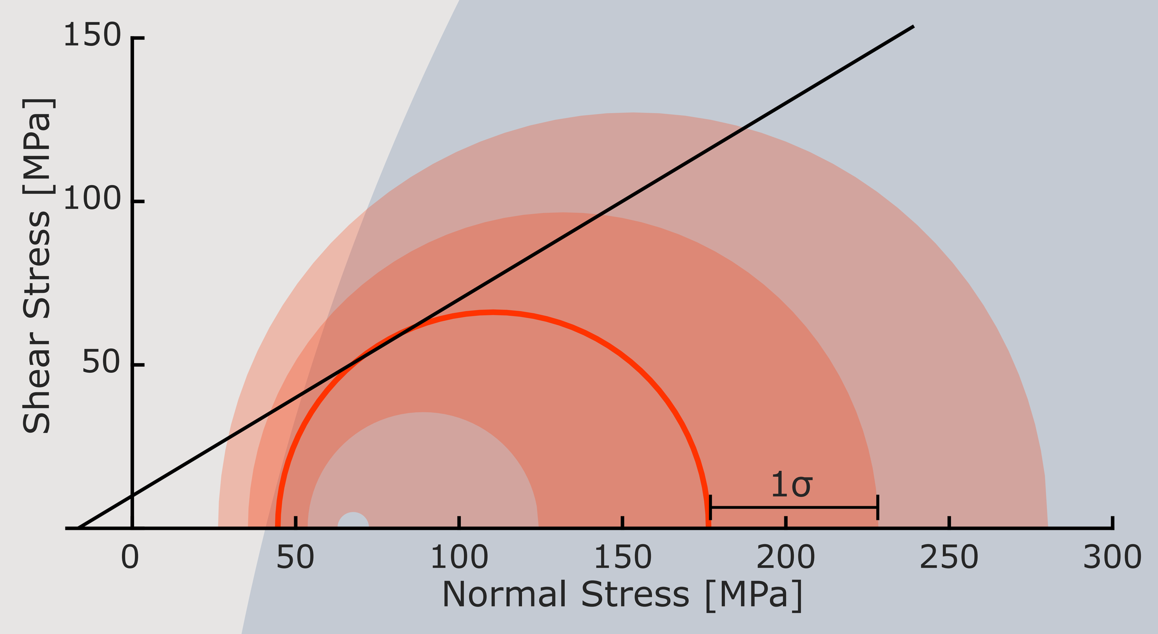


Quantification of uncertainties

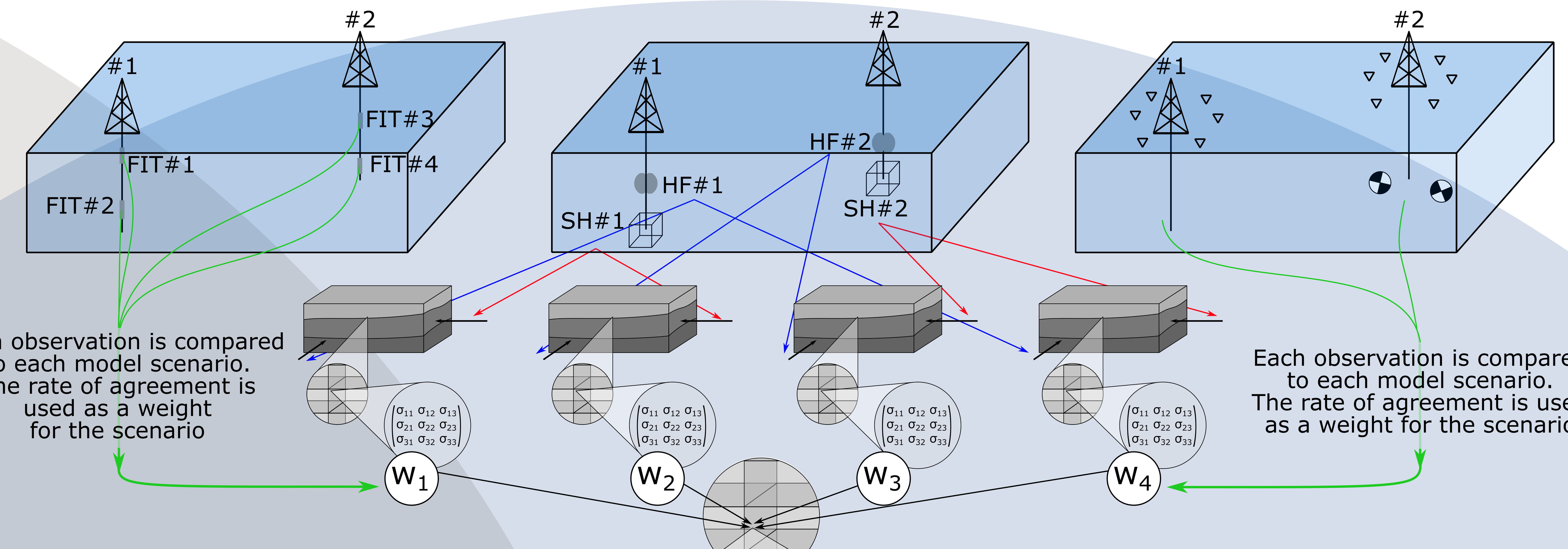


Model scenarios from pairs of data records result in perfect fit for each pair. From all resulting modelled stress states the average and standard deviation are computed.

$$\begin{pmatrix}\bar\sigma_{11} & \bar\sigma_{12} & \bar\sigma_{13}\\ \bar\sigma_{21} & \bar\sigma_{22} & \bar\sigma_{23}\\ \bar\sigma_{31} & \bar\sigma_{32} & \bar\sigma_{33}\end{pmatrix} \pm \begin{pmatrix}\bar\sigma_{11} & \bar\sigma_{12} & \bar\sigma_{13}\\ \bar\sigma_{21} & \bar\sigma_{22} & \bar\sigma_{23}\\ \bar\sigma_{31} & \bar\sigma_{32} & \bar\sigma_{33}\end{pmatrix}$$



Reduction of uncertainties



Each observation is compared to each model scenario. The rate of agreement is used as a weight for the scenario

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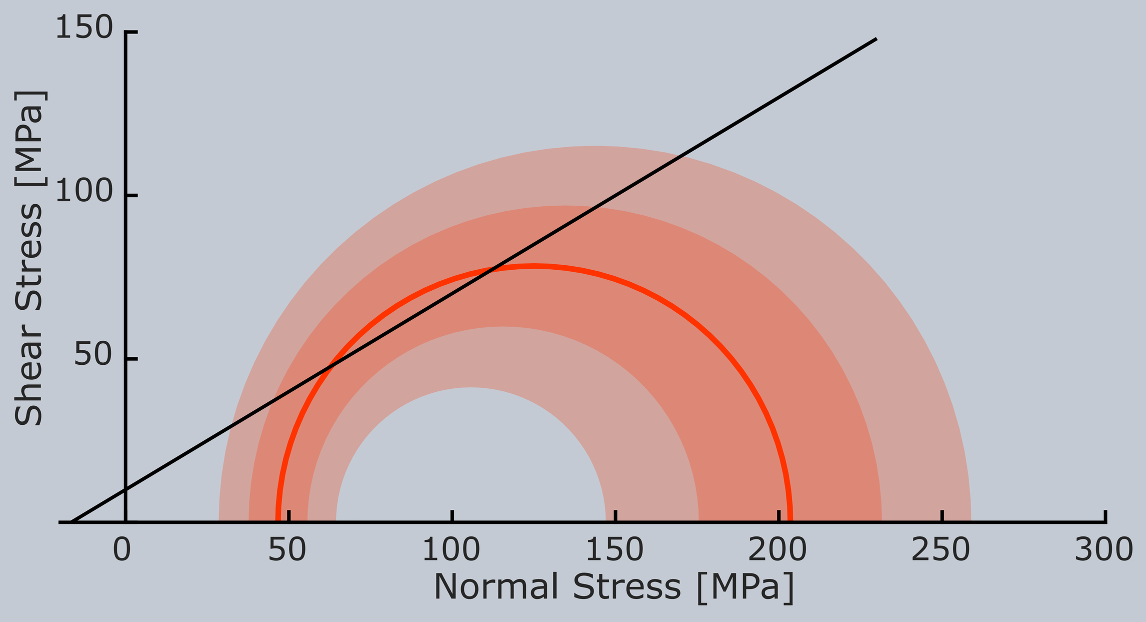
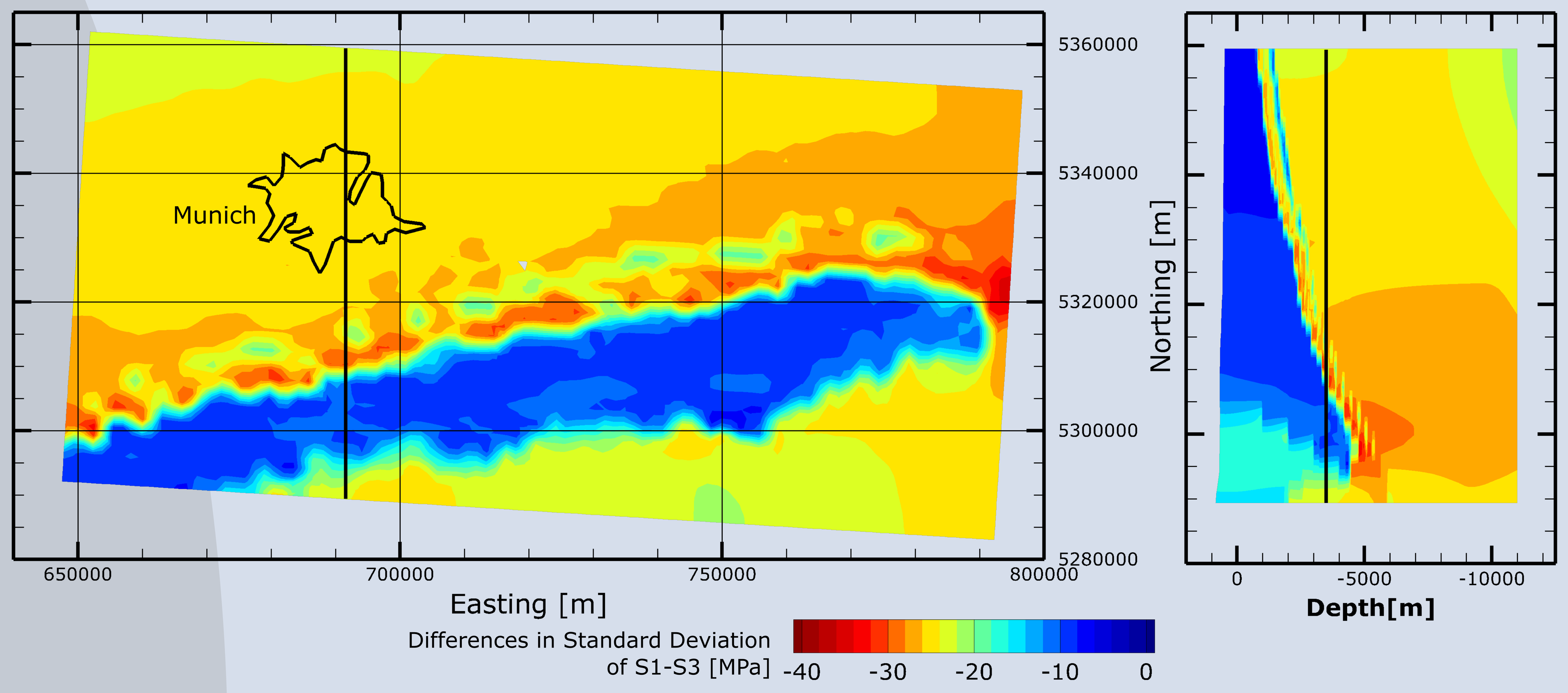


Example: Bavarian Molasse Basin



Download a full paper discussing parts of the poster:

Watch a video of the entire model:

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