Quantification and Reduction of Uncertainties in 3D Stress Models

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The undisturbed stress state of a potential site for nuclear waste disposal is of key importance for the assessment of long-term stability of the geotechnical installations and for seismic hazard assessment. In particular, the stability of pre-existing faults within and near a repository can only be evaluated with the knowledge of the initial stress state. 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 $S_{hmax}$ and $S_{hmin}$ 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. This provides a comprehensive assessment of the stress state and its uncertainties.

Furthermore, we present an approach to reduce the previously quantified uncertainties in the model results: We use additional borehole observables (Formation Integrity Tests) and observed seismicity and - if available - its focal mechanisms. These observables cannot provide any data records on the stress state. Yet, the information that can be extracted is valuable as it contains upper boundaries for the magnitudes of the minimum principal stress (Formation Integrity Tests) and the maximum principal stress/differential stress (seismicity), respectively. 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.