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3D stress field simulation for Greater Munich, Germany

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Geotechnical applications such as tunneling, storage of waste, wellbore planning, or reservoir engineering requires detailed 3D information on the rock properties and behavior of the continuum. One of the key parameters is the contemporary crustal in-situ stress state. However, generally the availability of stress data on reservoir scale is scarce or no data exists at all. Furthermore, stress data is often limited to the orientation of the maximum horizontal stress. Hence, geomechanical-numerical modelling provides an approximation of a continuous description of the 3D in-situ stress state. We present a model workflow that shows (1) how to calibrate a regional scale model of Greater Munich with stress orientations and magnitudes mainly from borehole data and (2) how to derive from the regional model boundary conditions for a local high-resolution model of a geothermal reservoir site. This approach using two models is an alternative to the required trade-off between resolution, computational cost and a sufficient number of calibration data which is otherwise inevitable for a single model.

The incorporated 3D geological models contain the topography from a digital elevation model and 6 stratigraphic units with different elasto-plastic rock properties. The local model mimics the area of a planned reservoir and its resolution is significantly higher than in the regional model and down to 10 m near the planned borehole trajectories using 21×10^6 tetrahedron finite elements with linear approximation functions. The uncertainties of the calibrated regional model are large since no information on the magnitude of the maximum horizontal stress is available. Even in the entire Greater Munich area only two reliable leak-off tests that deliver the magnitude of the minimum horizontal stress could be used. These uncertainties are transferred also to the local model. Hence we also show how to quantify for the workflow in general the systematic uncertainties and discuss methodological uncertainties in order to assess the reliability of the model result and to recommend which additional stress data are needed to lower the uncertainties of the models.