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SpannEnD – a 3D geomechanical model of Germany for the prediction of the recent crustal stress state

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Abstract. The recent crustal stress state is a crucial parameter in the search for a high-level nuclear waste repository. It is relevant not only for site selection and short-term stability during operation but also for predicting long-term safety. However, the level of knowledge in this regard is still limited in Germany. It is based on stress orientations and stress regime information from the World Stress Map (WSM) project and pointwise stress magnitude records.

We present the results of a 3D geomechanical numerical model that improves the state of knowledge by providing a continuum-mechanics-based prediction of the recent crustal stress field in Germany. The model extends over an area of $1000 \times 1250\,\mathrm{km}^2$, covering Germany and nearby regions. It contains 22 geological units, each parameterized with individual properties (density, Young's modulus and Poisson's ratio). We assume linear elasticity, and the finite element method is used to solve the equilibrium of forces. The model is calibrated with horizontal stress magnitude records and validated with additional data, for example, vertical stress magnitudes or data of the WSM project. Our model results are in a good agreement with a mean orientation of the maximum horizontal stress (S_{Hmax}) derived from the WSM, as indicated by a mean of the absolute differences of 12°. Furthermore, the model results lie entirely within the standard deviation of the derived orientation of S_{Hmax}. Mean values of the absolute stress differences between calibration data and model results of 4.6 MPa for the minimum horizontal stresses (S_{Hmin}) and 6.4 MPa for the S_{Hmax} also show a good agreement.

The model results can be used, for example, for the calculation of fracture potential, for slip tendency analyses or as boundary conditions for smaller local models. For smaller model volumes, where little or no stress information is available, it provides synthetic stress magnitude data that can be used for calibration. As such, the model provides a valuable starting point for the detailed assessment of stability at yet-to-be-determined siting regions for a high-level nuclear waste repository.

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