SpannEnD

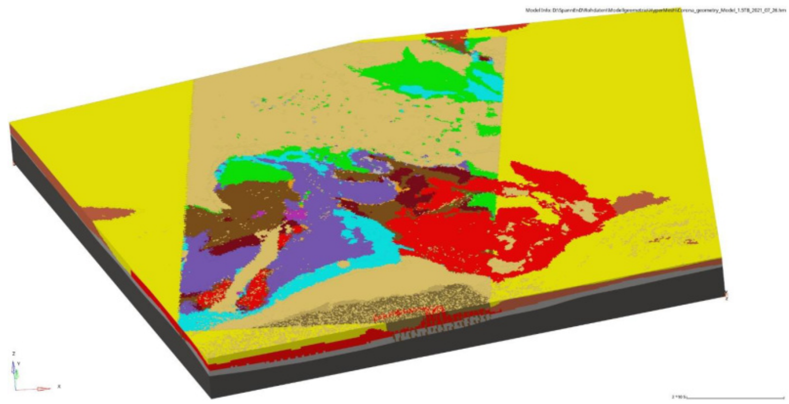

Figure 1: Screenshot of the geomechanical-numerical model used. The Dimensions are ~1000 x 1250 x 100 km^3. The central more colorful part corresponds approximately to the area of Germany.

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Project Term
2020 - 2021

Clusters
Lichtenberg Cluster Darmstadt

Software
Abaqus

Institute
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Introduction

The crustal stress state is an important information for many geological applications, e.g. directional drilling, stimulation and save usage of geothermal reservoirs or the search for and long-term safety of a high-level radioactive waste deposit. However, the state of knowledge for Germany is mainly based on pointwise, sparse and frequently incomplete data sets. Therefore, we developed a geomechanical-numerical model of Germany to provide a continuum mechanics based prediction of the crustal stress state in 3D which is calibrated with available data sets. Our recent model contains about 11.1 million available elements and therefore a main memory of up to 1.5 TB was needed. Since, the main memory of the server of our working group was too small we decided to use the Lichtenberg HPC for our calculations.

Methods

The 3D geomechanical-numerical is based on available geological geometry models which describe the distribution of geological units in the subsurface of our model region. If necessary, additional geological data have been used to close gaps between or within these models. The final model covers an area of 1000 x 1250 km^2 and reaches a depth of 100 km. The geometry model was extended by discretization and parameterization to a geomechnical-numerical model. Since, we assume linear elasticity an individual Poisson's ratio and Young's modulus was assigned to each geological unit (overall 22 units). Additionally, densities were assigned. Displacement boundary conditions are defined at the edges of the final model which are used for calibration with magnitudes of the minimum and maximum horizontal stress (S_{hmin} and S_{Hmax}). For the validation additional magnitude data sets and orientations of S_{Hmax} are used. As FEM solver we used Abaqus™ v2019.

Results

An improved prediction of the crustal stress state of Germany could be achieved by our geomechanical-numerical model, which provides the complete 3D stress tensor. Our model predicts an almost homogeneous N-S orientated pattern of the S_{Hmax} orientation. A median deviation of 0.3° in comparison to the mean orientation of S_{Hmax} derived from the World Stress Map (WSM, www.world-stress-map.org) project indicates an overall good fit. Furthermore, almost all results are within the standard deviation of the mean WSM data. However, some model regions show significant deviations. The results also show a good fit to all three principal stress magnitudes of the vertical stress (S_V), S_{hmin} and S_{Hmax} indicated by absolute differences of 0.0 MPa for S_V, 4.6 MPa for S_{hmin} and 6.4 MPa for S_{Hmax}. The differences to the calibration (S_{hmin} and S_{Hmax}) data are mainly within in a range of +/- 10 MPa for the S_{hmin} magnitudes and within a range of +/- 20 MPa for the S_{Hmax} magnitudes. Despite the overall good fit, some data indicate too low S_{hmin} values in the upper part of our model. The Results are described and discussed in detail in Ahlers et al., 2022a. The model geometry and the results of our model have been published (Ahlers et al., 2022b).

Discussion

Our model predictions are in good agreement with the mean orientations of the S_{Hmax} derived from the WSM and with magnitude data used for calibration and additional stress magnitude data of different geological regions, e.g. Molasse Basin, Upper Rhine Graben or North German Basin. However, some local differences occur and also a minor but possibly systematic deviation of the S_{hmin} occur in the uppermost 1.5 km of our model. Some of these differences occur likely due to geological units which are not well represented in our model, e.g. salt units or weak sedimentary layers since we assume linear elasticity or thin units which can not be represented by our coarse vertical resolution of ~250 m.

Publications

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Last Update: 2022-07-15 10:55