Forward modeling gravity gradients of the mid-ocean ridge near Iceland

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Gravity gradients from the GOCE satellite mission area carry information from the solid Earth that was not available before. However, the fit of geophysical models to satellite gravity data shows notably large residuals due to deficiencies in the models, making it difficult to further constrain current solid Earth models by GOCE data. Our objective is to explain the gravity gradient signal at satellite altitude with available information on crustal layering and density variations, and to explore the sensitivity of the gradients to density changes in the crust. In a next step the model can be tuned to the gradients from combined GOCE and GRACE data to improve knowledge of the lithosphere structure. For this purpose we select the area of the Reykjanes Ridge, the mid-ocean ridge south-west of Iceland, because the structure of the ridge is clearly visible in gravity data.

We use a forward modeling approach based on spherical harmonic analysis and synthesis. The approach can accommodate variations in thickness of layers and lateral variations in density within a layer. An advantage of the method is that it produces spherical harmonic coefficients of the gravitational potential that can easily be filtered to compare with gravity data that is low-pass or high-pass filtered.
The CRUST2.0 model is used to represent crustal densities, while density variations in the top part of the upper mantle are derived from S-wave velocities using published values for the seismic velocity to temperature derivative and thermal expansion. A dynamic topography model with maximum spherical harmonic degree 30 is used for the remainder of the mantle.

The focus is on sensitivity to the density changes in the crustal layers. It was found that an increase in density of 300 kg/m3 in the upper crust produces a decrease in Tzz of 0.1 E and a 0.06 E change in Txx at satellite level with maximum spherical harmonic degree 90. The change in the spatial pattern with depth of the density increase is small, suggesting that separating different layers is difficult in the thin crust of the mid-ocean ridge. Because of the shallow crust in the ridge area there is a large contribution from the upper mantle. Our model shows a contribution of -3.7 to 2.2 E and a dynamic topography contribution of -0.3 to 0.5 E. This demonstrates the importance of having a good model for the mantle before the structure of the upper crust can be improved using GOCE gradients.