Crustal subsidence due to the Hálslon reservoir: predicting the elastic Earth response

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1. Introduction

The Hálslon reservoir in NE-Iceland will be part of the the Kárahnjúkar hydropower project and become the largest man-made load on the Icelandic crust. The reservoir will be situated on the northern edge of the Vatnajökull ice cap, and it will contain about 2.4 km³ of water when full. The crust will give an instantaneous elastic response when the reservoir is filled. Later, a visco-elastic response due to stress relaxation will result in further subsidence.

We present forecasts of the elastic vertical displacement induced by this Hálslon’s load for a Young’s modulus of 50 GPa the elastic response will range from 3 cm to 15 cm throughout an annual cycle. Furthermore the results show that subsidence will be highest in the northern part of Hálslon where topography is steepest (see Figure 1) and the dams are located (not yet included in the model).

Figure 4 shows the elastic response due to the reservoir on a larger scale. It was modeled using a Young’s modulus of 50 GPa and a water surface at 625 m a.s.l. The impact of the reservoir exceeds a 50 km radius.

2. Using Green’s Functions

Green’s functions are a mathematical tool to solve differential equations. These functions have to be derived for each specific problem. When they are applied they will give the system’s response to that problem.

Pinel et al. (2006) derived Green’s functions that amongst others give the elastic Earth response to a load. Convolution of these Green’s functions with a load enables the introduction of complex load shapes (Figure 2). We use the actual geometry of Hálslon in our calculations.

3. Results & Conclusions

We modeled the elastic response of the crust for the lowest and highest water expected levels during an annual cycle (550 m and 625 m a.s.l. respectively). Figure 3 shows the resulting subsidence, and the outline of the completely filled reservoir. The relation between Young’s modulus and vertical displacement is linear, which is shown by the scales in Figure 3. Thus, assuming a Young’s modulus of 50 GPa the elastic response will range from 3 cm to 15 cm throughout an annual cycle. Furthermore the results show that subsidence will be highest in the northern part of Hálslon where topography is steepest (see Figure 1) and the dams are located (not yet included in the model).

The N-S distribution of subsidence due to the canyon topography is in all pictures clearly visible. All results are gained using a 50 m × 50 m grid.

Figure 3: a,b) The subsidence at the lowest water level (550 m a.s.l.) modeled with Young’s modules of 10 and 100 GPa, respectively. c,d) The vertical displacement when reservoir is completely filled (625 m a.s.l.) modeled with a Young’s modulus of 10 and 100 GPa, respectively (see scale). The N-S distribution of subsidence due to the canyon topography is in all pictures clearly visible. All results are gained using a 50 m × 50 m grid.

4. Outlook

Future modeling will include the dams and estimate the horizontal displacements, which are not expected to be more than a third of the subsidence (Pinel et al., 2006). The final relaxed state of the Earth after loading will be modeled by applying Green’s functions for a thick elastic plate overlying a fully relaxed fluid (Pinel et al., 2006). To model the temporal evolution of subsidence a comparison to a visco-elastic model using the Finite Element Method (FEM) for an axisymmetric load (Pagli et al., 2006) will be attempted as well. The filling of Hálslon and future deformation monitoring will provide a test on these models.

References:


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