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

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1. Introduction

The Hálslón 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 (Figure 1), 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 Hálslón's load for a Young's modulus ranging from 10 GPa to 100 GPa. For the Poisson's ratio we chose a value of 0.25.

Comparing our estimates to the actual subsidence after filling of the reservoir will e.g. allow a determination of the effective Young's modulus.

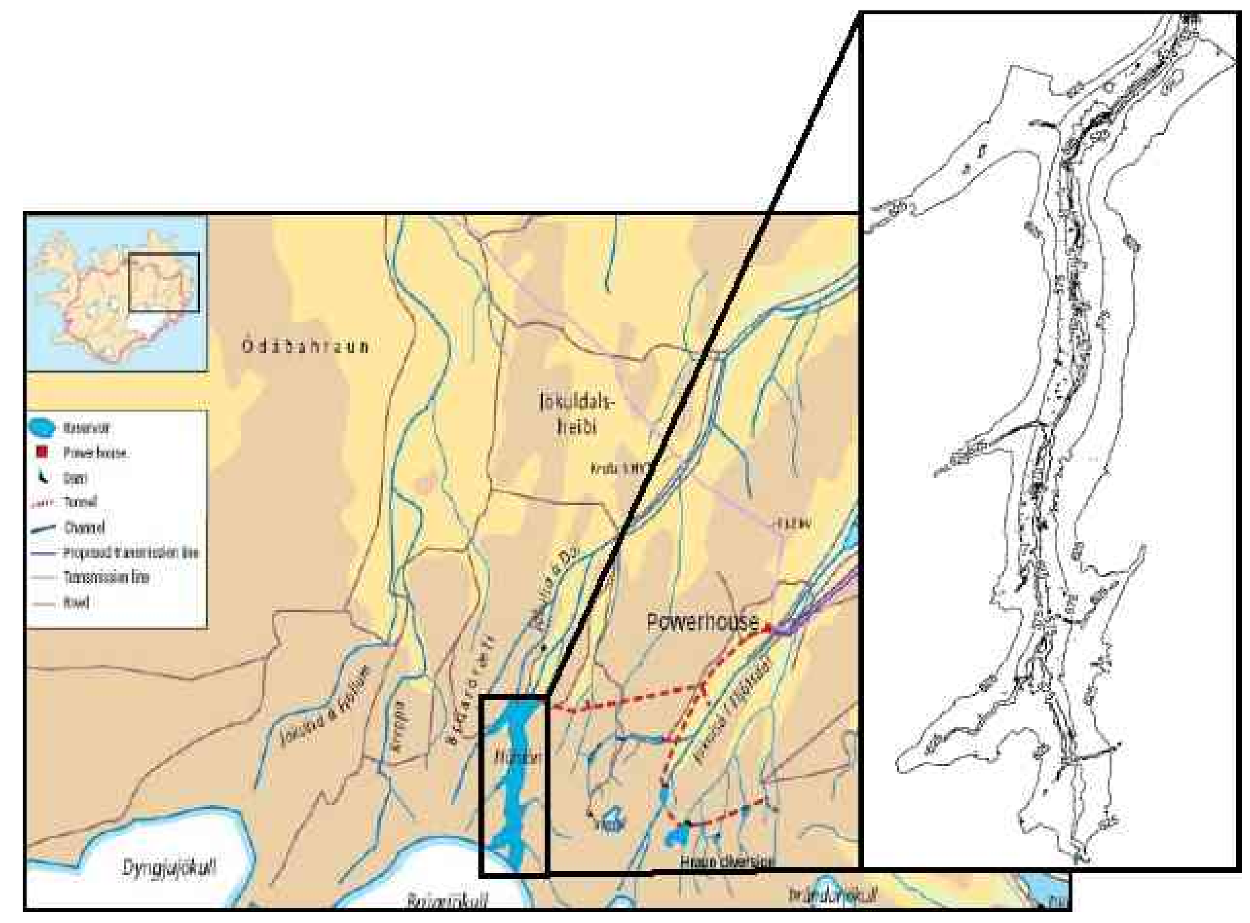


Figure 1: Map showing the future location of the reservoir. Close-up shows topography of the reservoir. Steepest parts are in the North. Each contour line represents 25 m elevation difference. (changed from: Landsvirkjun, EIA)

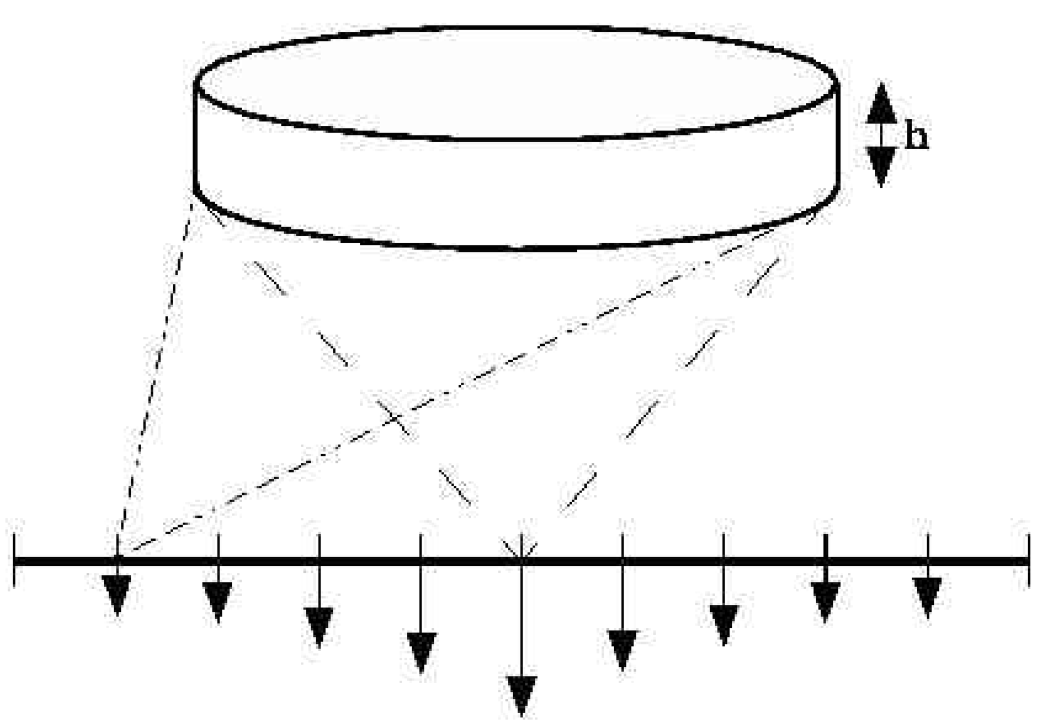


Figure 2: The image shows a one dimensional scheme of the used technique. Assuming a disk load with height *h*, radius *r*, and Volume *V*, the influence of the load on subsidence (vertical arrows) is calculated for each grid point (different line styles refer to separate computatlional steps).

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.

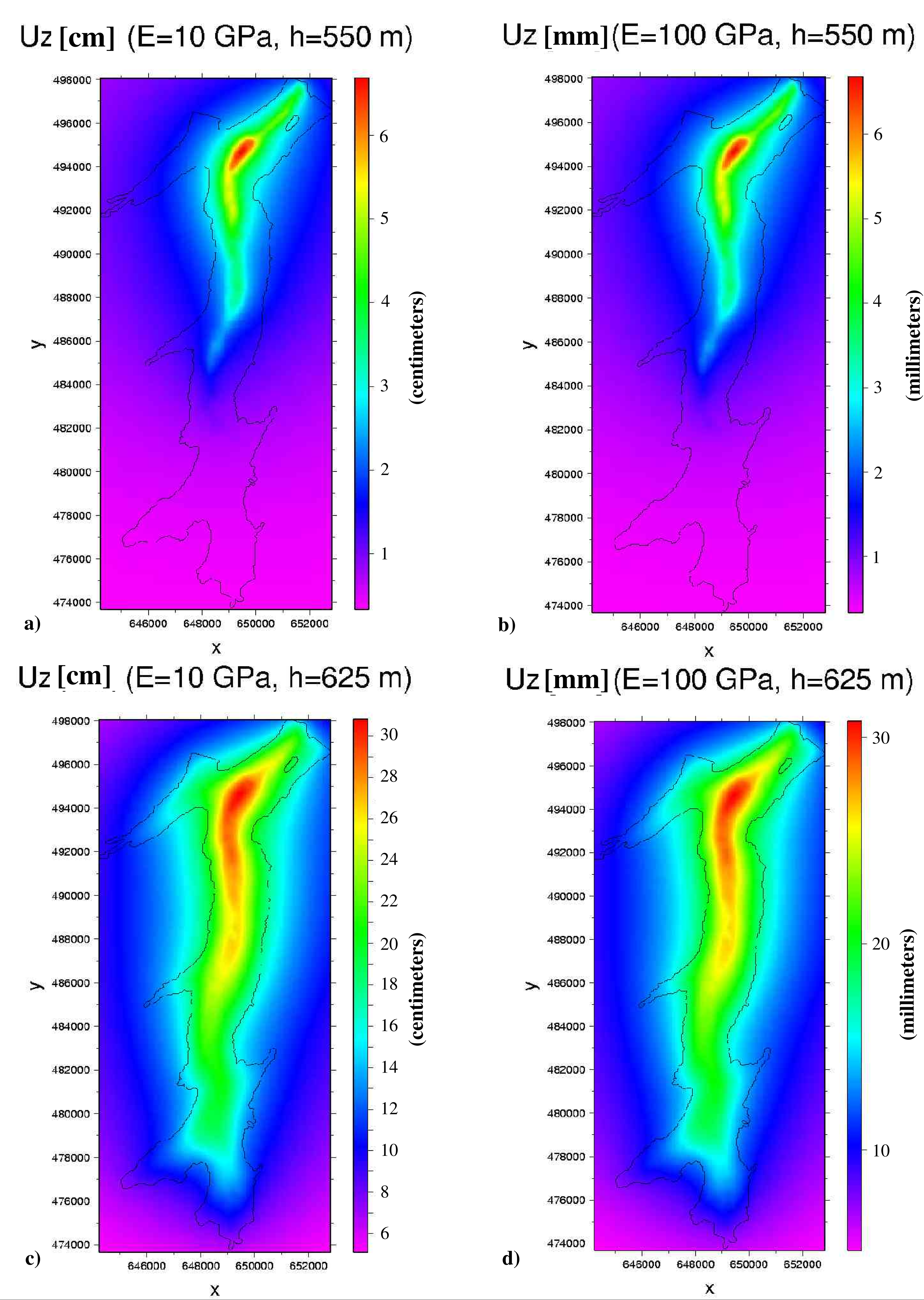
Pinel *et al.* (2006) derived Green's functions that amongst others give the elastic Earth response to a load. Convolution of these Green's functions with a load enables the introduction of complex load shapes (Figure 2). We use the actual geometry of Hálslón in our calculations.

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 displacment 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 Hálslón 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.

Figure 3: a,b) The subsidence at the lowest water level (550 m a.s.l.) modeled with a Young's modulus 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 x 50 m grid,



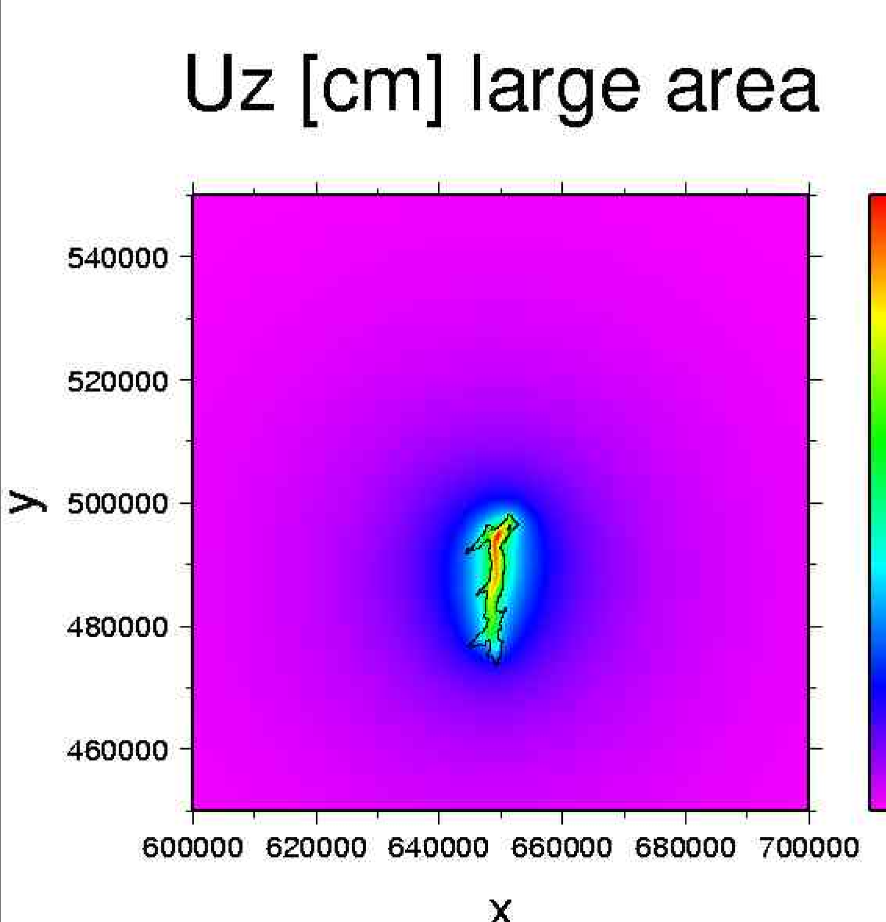


Figure 4: The image shows the large scale impact of the Hálslón reservoir. It was modeled using a Young's modulus of 50 GPa, a 200 m x 200 m grid, and a water surface at 626 m a.s.l. For this Young's modulus the subsidence exceeds 1 mm within a distance of about 10 km from the reservoir (X and Y coordinates in meters, subsidence in centimeters).

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 Hálslón and future deformation monitoring will provide a test on these models.

References:

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