Using MT to constrain Greenland’s glacial isostatic adjustment and ice loss

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SUMMARY

Melting of the Greenland Ice Sheet has been accelerating in the past decade as the climate warms, becoming a major contributor to present and future sea level change. The rate of this ice loss is tracked through satellite and surface measurements of changing altimetry and density structure. However, these measurements are also influenced by the glacial isostatic adjustment (GIA), or post-glacial rebound, of the Greenland mantle in response to past changes in the ice sheet behaviour. The mantle may take several thousands of years to equilibrate after a change in ice loading and the patterns of surface deformation will depend strongly on mantle viscosity. Greenland’s GIA is currently very poorly constrained and is considered to be the biggest uncertainty in ice loss calculations. We report on recently collected MT data from the Greenland ice sheet. By combining these new MT data with seismic data, we are improving constraints on mantle temperature and composition. From this, we will develop constrained estimates of mantle viscosity that including lateral viscosity variations. Our long-term goal is to feed these viscosity data into newly developed GIA and sea-level dynamic models, producing improved estimates of Greenland’s GIA and, ultimately, of the current rate of ice loss from Greenland.

Keywords: Greenland, mantle, viscosity, GIA

INTRODUCTION

In order to track and mitigate the effects of climate change, the volume of ice lost from the great continental ice sheets in Antarctica and Greenland must be monitored. The methods employed to do this – satellite and surface gravity and altimetry measurements – rely on the fact that, as ice melts, mass is lost from the ice sheet. However, these measurements are complicated by the fact that the Earth responds both elastically and viscously to changes in ice sheet mass. This viscous response, glacial isostatic adjustment (GIA), may last for many thousands of years and is strongly dependent on the viscosity structure of the mantle.

Currently, the 3D mantle viscosity structure beneath Greenland is poorly known, seriously impacting the quality of ice loss calculations. For instance, Velicogna (2009) called the GIA correction ‘the largest source of uncertainty in (the) ice mass estimate’ in Greenland.

Mantle viscosity is dominantly controlled by temperature, hydrogen content and the presence of partial melt. It is best constrained with combined MT and seismic data. Previous MT experiments (e.g., Lauritsen, 2016) have highlighted the difficulty in collecting MT data in the complex fjord geometries of coastal Greenland. In this project, we will collect the first MT data on the Greenland ice cap. An additional benefit of this survey design will be the ability to image basal ice sheet melt layers and to investigate proposed links with mantle geotherms.

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Fig.1 Measured uplift rates (circles, Khan et al., 2016) are poorly fit by current GIA and elastic estimates (contours)
The mantle viscosity and heat flow structure of Greenland is likely to be complex. Much of the exposed Greenland basement is Archean to Proterozoic in age and mantle xenoliths have highly depleted compositions (e.g., Bernstein et al., 2006), which would be likely to be associated with high viscosities. However, the Iceland Plume passed beneath central Greenland during the Cretaceous and early Cenozoic (e.g., Tegner et al., 2008), heating and possibly hydrating the mantle and reducing viscosities. High surface heat flow associated with the Iceland Plume track has also been linked to increased basal melting of the Greenland Ice Sheet (Rogozhina et al., 2016).

Data collection for this project will start with a pilot survey at Summit Station in the central Greenland Ice Sheet in July 2018. This station lies on the Iceland Plume track, so these results will provide an initial measurement of the conductivity of the plume-affected mantle, as well as dimensionality and strike data. In addition, we will test various instrument and electrode configurations for the resolution of melt layers within and at the base of the ice sheet. These data will be used to optimise survey parameters for planned future surveys that will extend away from the plume track.

REFERENCES


Lauritsen, N. L. B. (2016). Magnetotelluric investigation in West Greenland-considering the polar electrojet, ocean and fjords (Doctoral dissertation, Technical University of Denmark (DTU)).


