Magnetotelluric Constraints on Upper Mantle Viscosity Structure and Basal Melt Beneath the Greenland Ice Sheet

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The MAGPIE Project
Magnetotelluric Analysis for Greenland & Postglacial Isostatic Evolution
An international research project to constrain glacial isostatic adjustment (GIA) processes in Greenland.
Introduction

Vertical land motion in Greenland is caused by two processes:
A. Earth's elastic response to present-day deglaciation
B. Earth's glacial isostatic (GIA) response to past deglaciation

Both processes are operating in Greenland today. To estimate present melting using the elastic response (A), we need to remove the GIA response (B). GIA in Greenland is poorly constrained due to lack of knowledge of viscosity heterogeneity in the upper mantle.
**Using Magnetotellurics to infer Upper Mantle Viscosity Heterogeneity**

Magnetotellurics (MT) is an electromagnetic method that can constrain electric conductivity variations at depth. The method uses lightning and solar wind as a varying electromagnetic source (right) that produces electric currents in conductive rocks at depth. By measuring the electric and magnetic fields simultaneously (below), MT analysis can place constraints on the conductivity of the crust and upper mantle.

Dependence of electrical conductivity ($\sigma$) on temperature ($T$) and water content ($C_W$)

$$\sigma = AC_W^n \exp \left( \frac{-\Delta H}{RT} \right)$$

Dependence of strain rate on temperature ($T$) and water content ($C_W$)

$$\dot{\varepsilon} = A\sigma^n d^{-p} C_W^r \exp(\alpha \varphi) \exp \left( \frac{-\Delta H}{RT} \right)$$

Similar dependences on temperature and water content mean that variations in viscosity can be inferred from constraints on electrical conductivity (from MT).

[Liu & Hasterok, 2016; Selway et al., 2020]
Some 2018 pilot data were also collected at Summit Station.
Preliminary Results

Greenland is thought to have passed over the Iceland plume 60-90 million years ago [Steinberger et al., 2019], likely leaving a trail of heat and low viscosity behind it. Our survey is designed to look for this trail.

- **Crust - top of mantle**
  - NE-SW current orientation at EastGRIP
  - Summit is getting more conductive with depth

- **Lithospheric Mantle**
  - WNW-ESE current orientation
  - Getting slightly more conductive with depth
  - EastGRIP and Summit are similar

- **Several hundred km**
  - East-West orientation at EastGRIP
  - EastGRIP getting more conductive with depth
  - EastGRIP differs from Summit
Summary

• Our goal is to use MT to constrain lateral viscosity variations within and beneath the Greenland lithosphere.

• The MAGPIE team performed a magnetotelluric (MT) survey in northeast Greenland in Summer 2019.

• Preliminary MT results suggest deep variations that may be associated with the Iceland Plume track.

• Constraints on viscosity variations can improve models for Glacial Isostatic Adjustment (GIA).

References


