# IceBase: A suborbital survey to map geothermal heat flux under an ice sheet

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**Summary:** NASA will solicit suborbital missions as part of its Earth Venture program element in the coming year. These missions are designed as complete PI-led investigations to conduct innovative hypothesis or scientific question-driven approaches to pressing questions in Earth System science. We propose to carry out a suborbital magnetic survey of Greenland using NASA's Global Hawk unmanned aerial vehicle to produce the first-ever map of the geothermal heat flux under an ice sheet. Better constraints on geothermal heat flux will reduce the uncertainty in future sea level rise, in turn allowing a more informed assessment of its impact on society. The geothermal heat flux depends on conditions such as mantle heat flux, and the tectonic history and heat production of the crust, all of which vary spatially. Underneath ice sheets, the geothermal heat flux influences the basal ice. Therefore heat flux is an important boundary condition in ice sheet modeling. Using magnetic data to constrain heat flux is possible because the magnetic properties of rocks are temperature dependent until they reach the Curie temperature. The technique has applications to understanding the response of Greenland ice sheet to climate forcing because the basal heat flux provides one of the boundary conditions. The technique also helps to locate the oldest ice. The oldest ice in Greenland should be found in areas of very low heat flux, and the identification of those areas is provided by this technique. Ice cores from the areas of oldest ice help to decipher past temperatures and $CO_2$ contents. Our latest model of the geothermal heat flux under the Greenland ice sheet (http://websrv.cs.umt.edu/isis/index.php/Greenland_Basal_Heat_Flux) is based on low- resolution satellite observations collected by the CHAMP satellite between 2000 and 2010. Those observations will be enhanced by the upcoming Swarm gradient satellite mission, but the resolution will improve by less than a factor of two, from 400 km resolution to approximately 250 km resolution. A high altitude, suborbital magnetic survey of Greenland would provide a heat flux model with resolution comparable to the crustal thickness, and would provide details of the high heat flux region associated with the Iceland mantle plume in E /SE Greenland, and the low heat flux region in NW Greenland, adjacent to the Canadian Shield. Magnetic field measurements from 20 km altitude are strongly preferred over lower altitude observations because of their ability to sample the longest wavelengths, provide uniform calibration with sufficient sensitivity, and suppress local remanent magnetic field signatures. We validate our heat flux estimates by assessing the possible contributions from remanent magnetism and variable susceptibility, and from other lithospheric processes such as structure, volcanism and impact, from unmodeled external magnetic fields, and from the assumptions utilized in the heat flux model.

## A joint US-Danish effort

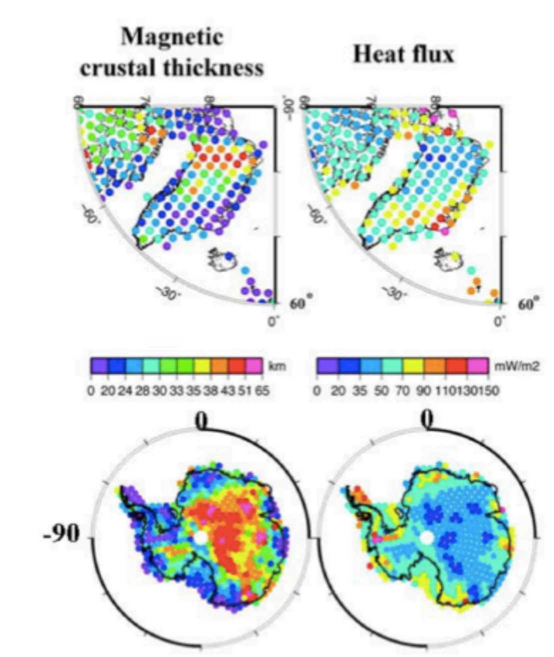
### Front


### Back (peelable)

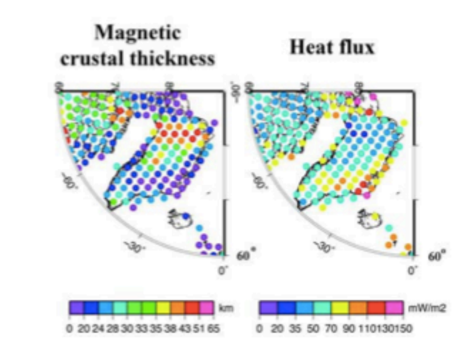
IceBase is a proposed suborbital survey designed to map the geothermal heat flux under the Greenland ice sheet for the first time. The survey would carry NASA magnetometers mounted on high-altitude NASA aircraft, supported by the DTU magnetometer array in Greenland. The results of the survey will reduce the uncertainty in future sea level rise, in turn allowing a more informed assessment of its impact on society. For further information contact michael.e.purucker@nasa.gov

IceBase er et forslag om opmåling fra fly, som for første gang vil kortlægge den geotermiske varmestrøm under den grønlandske indlandsis. Opmålingen vil udføres med NASA magnetometre på højtgående NASA fly og støttes af målinger fra DTU's kæde af magnetometerstationer i Grønland. Resultaterne af opmålingen vil reducere usikkerheden i forudsigelsen af den fremtidige havvandsstigning, og dermed give en forbedret vurdering af dennes påvirkning på samfundet. Nærmere oplysninger kan fås ved kontakt til jrgm@space.dtu.dk.

## Magnetic crustal thickness/heat flux:




## Plan for analysis of science data

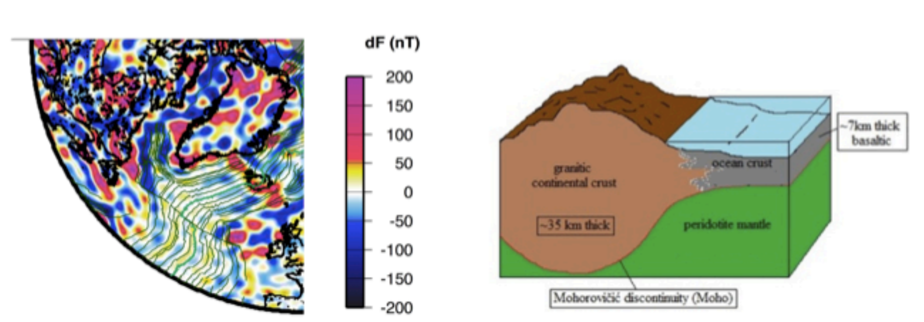



- Remove airplane fields
- remove time-variable core field
- remove time-variable magnetospheric field
- remove tidal oceanic magnetic field
- remove coastal effect
- remove ionospheric currents
- level flight lines
- grid data
- Remove crustal field signatures unrelated to crustal thickness
- Determine depth to Curie isotherm using MCT (magnetic crustal thickness) and DBT (power-spectral) approaches.
- determine heat flux using 1-D heat conduction eq. or utilizing the four layer model (sediment, upper, middle, lower crust) of Fox Maule et al. (2009), with calibration/validation provided by other independent approaches.
- Ice sheet evolution using these boundary conditions.

## Science concept

Fox Maule, Purucker, Olsen, Mosegaard, 2005, Science, Heat Flux Anomalies in Antarctica revealed by satellite magnetic data

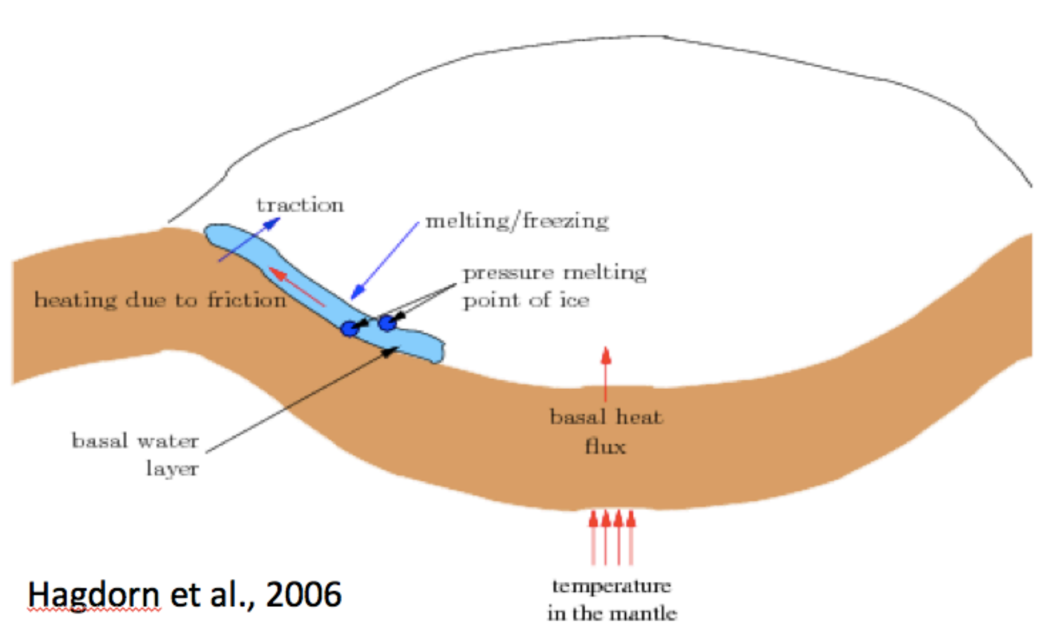
Moho assumed to coincide with Curie isotherm and to be at 580 C




Magnetic field dF ~ Crustal thickness x magnetic susceptibility

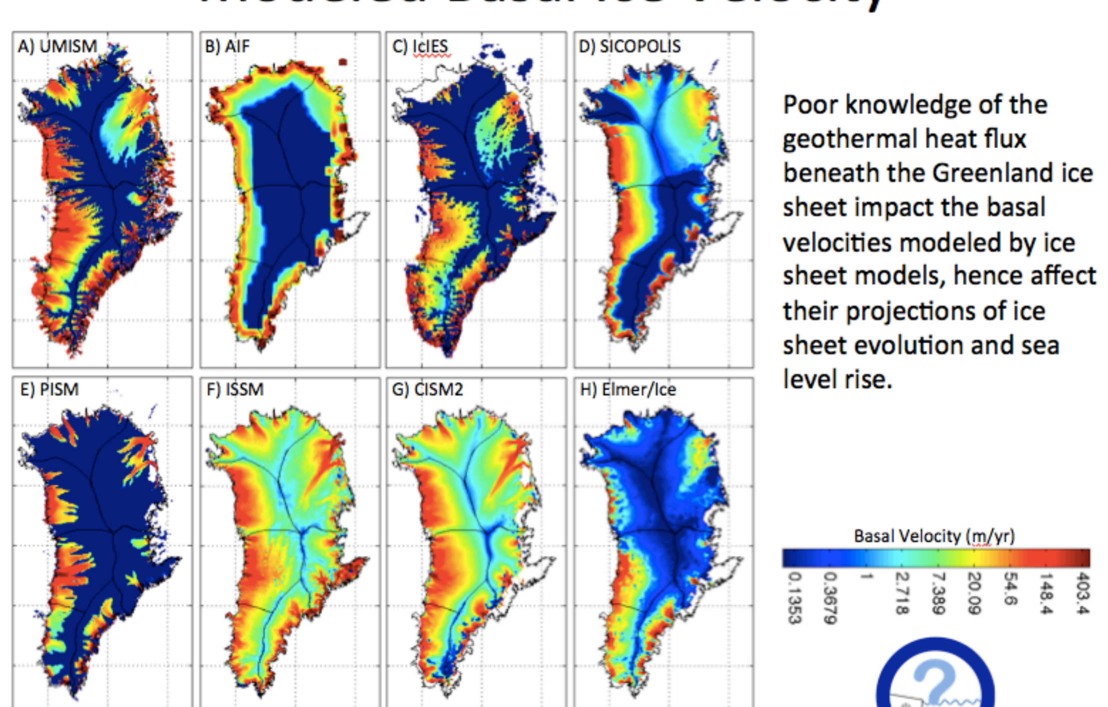
Heat flux q ~ 1/Crustal thickness [Steady state 1-D heat conduction eq. w no lateral variations of material properties or heat production. 30-60% or more of surface heat flux is due to crustal heat production.]

## Basal boundary condition




Hagdorn et al., 2006

## Modeled Basal Ice Velocity




Poor knowledge of the geothermal heat flux beneath the Greenland ice sheet impact the basal velocities modeled by ice sheet models, hence affect their projections of ice sheet evolution and sea level rise.

From Nowicki et al. (2013)

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