Geothermal heat flux distribution for the Greenland ice sheet, derived by combining a global representation and information from deep ice cores

Ralf Greve[1]

[1]*Institute of Low Temperature Science, Hokkaido University*

The geothermal heat flux (GHF) under the Greenland ice sheet is an important parameter that controls the ice flow via the thermal conditions at the ice base. Due to the kilometre-thick ice cover, direct measurements in the bedrock are very difficult, and even precise information about the thermal regime of the ice base is limited to a few sites where deep ice cores have been drilled. Instead, several approaches exist to infer the GHF distribution under the ice sheet indirectly. These models differ greatly in the predicted distribution of the GHF. Rogozhina et al. (2012) demonstrated that applying either of the distributions by Pollack et al. (1993), Shapiro and Ritzwoller (2004) or Fox Maule et al. (2009) for simulations of the Greenland ice sheet with the SICOPOLIS model (SImulation COde for POLythermal Ice Sheets; www.sicopolis.net) does not reproduce the observed basal temperatures at the deep ice core locations. Therefore, there is an evident need for improvement.

Here, we present an update of the approach pursued by Greve (2005) and Greve and Herzfeld (2013). The underlying idea is first to scale the spherical-harmonic representation by Pollack et al. (1993) for Greenland, and then to modify the GHF values at the deep ice core locations such that a paleoclimatic simulation of the Greenland ice sheet with SICOPOLIS produces an optimum agreement between simulated and observed basal temperatures. A suitable interpolation algorithm combines the background representation of the GHF with the point data at the ice core sites. Compared to the two previous versions, we conduct an improved paleoclimatic simulation with 5 km horizontal resolution, add the NEEM ice core to the previously used cores (GRIP, Dye 3, Camp Century, NGRIP) and include GHF measurements from three rock boreholes.

The resulting GHF distribution is shown in Fig. 1. The underlying global representation by Pollack et al. (1993) leads to, by trend, increasing GHF values from west to east. However, for the actual ice sheet, this trend is strongly superposed by the structure that results from the ice-core and rock-borehole data. GHF values are generally low in South Greenland and the north-western sector around and downstream of Camp Century. By contrast, the area around NGRIP and towards the north-east features elevated GHF values. The general structure of the GHF distribution is quite similar to that inferred by Rezvanbehbahani et al. (2017), but differs greatly from the earlier reconstructions by Shapiro and Ritzwoller (2004) and Fox Maule et al. (2009).

References

Fox Maule, C., M. E. Purucker and N. Olsen. Inferring magnetic crustal thickness and geothermal heat flux from crustal magnetic field models. Danish Climate Centre Report 08-01, Danish Meteorological Institute, Copenhagen, Denmark, 2009.

Greve, R. Relation of measured basal temperatures and the spatial distribution of the geothermal heat flux for the Greenland ice sheet. Ann. Glaciol., 42, 424-432, 2005. doi: 10.3189/172756405781812510.

Greve, R. and U. C. Herzfeld. Resolution of ice streams and outlet glaciers in large-scale simulations of the Greenland ice sheet. Ann. Glaciol., 54(63), 209-220, 2013. doi: 10.3189/2013AoG63A085.

Pollack, H. N., S. J. Hurter and J. R. Johnson. Heat-flow from the Earth's interior: Analysis of the global data set. Rev. Geophys., 31(3), 267-280, 1993.

Rezvanbehbahani, S., L. A. Stearns, A. Kadivar, J. D. Walker and C. J. van der Veen. Predicting the geothermal heat flux in Greenland: A machine learning approach. Geophys. Res. Lett., 44(24), 12271-12279, 2017. doi: 10.1002/2017GL075661.

Rogozhina, I., A. G. Petrunin, A. P. M. Vaughan, B. Steinberger, J. V. Johnson, M. K. Kaban, R. Calov, F. Rickers, M. Thomas and I. Koulakov. Melting at the base of the Greenland ice sheet explained by Iceland hotspot history. Nat. Geosci., 9(5), 366-369, 2016. doi: 10.1038/NGEO2689.

Shapiro, N. M. and M. H. Ritzwoller. Inferring surface heat flux distributions guided by a global seismic model: particular application to Antarctica. Earth Planet. Sci. Lett., 223(1-2), 213-224, 2004.

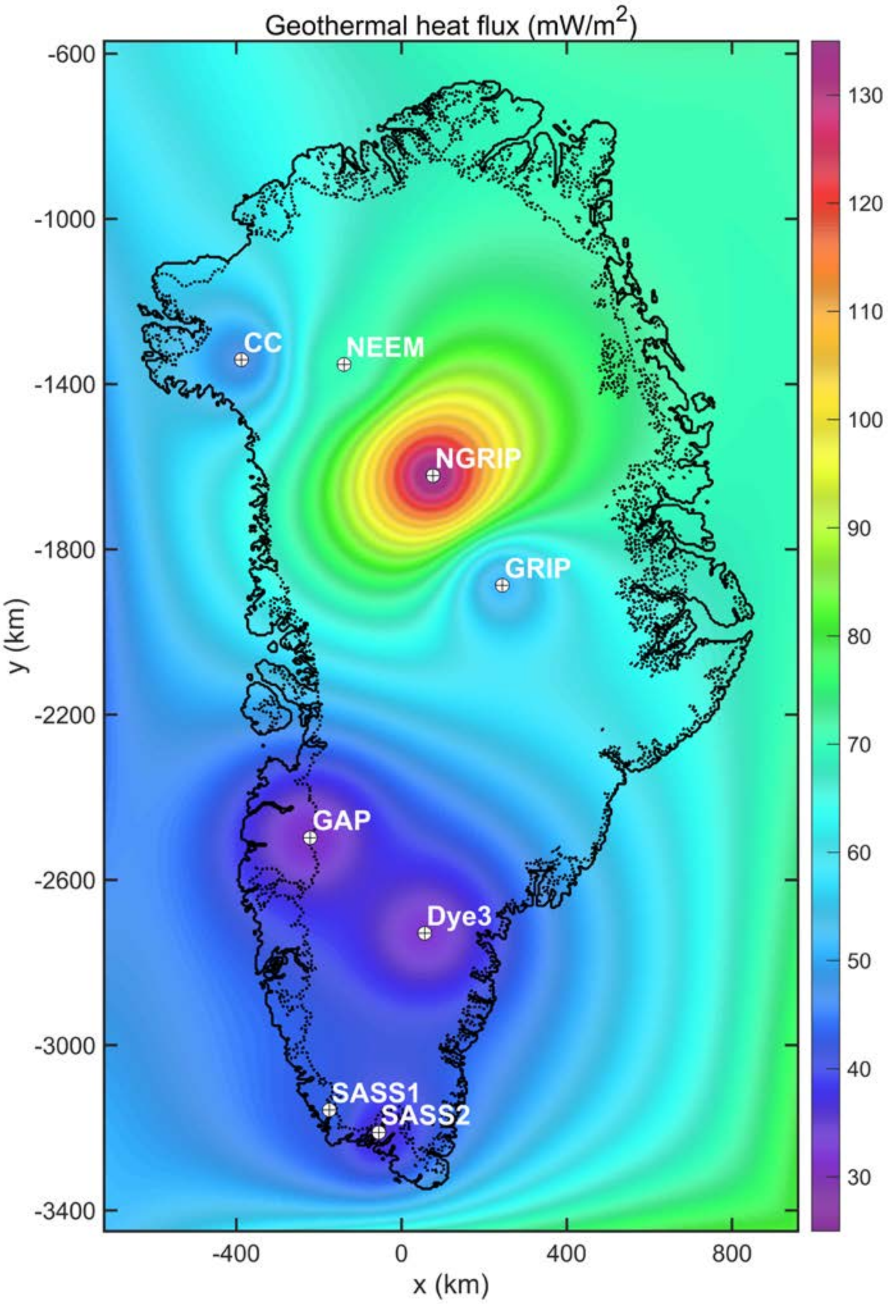

Figure 1. GHF map (in mW/m^2) constructed by iteratively matching observed and simulated basal temperatures at the five ice core locations GRIP, Dye 3, Camp Century, NGRIP and NEEM. The rock-borehole sites SASS1, SASS2 and GAP are also shown. Solid black line: land margin; dotted black line: ice margin.