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Extreme variation in basal thermal conditions of the central Greenland Ice Sheet due to anomalous lithosphere structure

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At the Earth's surface, heat fluxes from the interior are generally insignificant when compared with fluxes from the sun and atmosphere; however, in areas permanently blanketed by ice these become very important. Modelling studies show that they are key to understanding the internal thermal structure of ice sheets and the distribution of melt water at their bases, information which is crucial for planning deep ice drilling campaigns and climate reconstructions. Unfortunately, the challenging conditions in ice-covered regions make measurement difficult in exactly the places where it is needed most. Until now, proxy methodologies have been considered best for determining geothermal heat flux (GHF) beneath ice sheets. Our method is to use a novel interdisciplinary approach, integrating a time-evolved climate-ice-lithosphere coupled model with a wide range of data such as direct ice-core measurements, past climate reconstructions and indirect estimates of the lithospheric thermal state. Here we show that the oldest (and thickest) part of the Greenland Ice Sheet (GIS) is strongly thermally influenced by both GHF increasing from west to east and glaciation-induced perturbations of the thermal structure of the upper crust. A pronounced lateral gradient in GHF across the Summit region of the GIS is due to anomalously thin lithosphere, which has only about 25 to 66% of the thickness typical for Archaean to early Proterozoic areas. Our findings suggest that the thermal basal conditions of the present-day central GIS are characterized by surprising rapid lateral variations in ice temperatures of up to 12ºC along relatively small distances of 100 to 150 km. We reveal two areas of rapid basal melt in central Greenland, only one of which was previously predicted by ice-penetrating radar measurements and age-depth relations from internal layering (Fahnestock et al. [2001]). The endothermic phase transition associated with rapid basal ice melt is found to increase subglacial heat flow in the uppermost layers of the crust by a factor of three to values well above 100 mW/m2.

Fahnestock, M., Abdalati, W., Joughin, I., Brozena, J. & Gogineni, P. High geothermal heat flow, Basal melt, and the origin of rapid ice flow in central Greenland. Science 294, 2338–2342 (2001)