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Subglacial Heat Flow Measurements in Greenland and Antarctica

Gary Clow (1), Edwin Waddington (2), Robert Hawley (3), and Dorthe Dahl-Jensen (4)

(1) USGS, Denver, USA, (clow@usgs.gov), (2) Earth and Space Sciences, University of Washington, Seattle, USA (edw@uw.edu), (3) Earth Sciences, Dartmouth College, Hanover, USA (robert.hawley@dartmouth.edu), (4) Centre for Ice and Climate, University of Copenhagen, Denmark (ddj@gfy.ku.dk)

Estimates of geothermal flux can be derived from temperature measurements in boreholes in polar ice sheets. The USGS Borehole Logging System (Clow, 2008) measures borehole temperatures at 1 mK resolution and repeatability. We have obtained the current temperature-depth profiles at GRIP, at GISP2, and at North GRIP in Greenland, and at Taylor Dome and at Siple Dome in Antarctica.

Because the thermal properties of ice are generally more uniform and better known than those of other rocks, the flux into the basal ice is readily estimated from the basal temperature gradient, and these fluxes may provide useful estimates of the long-term tectonic geothermal flux. We have calculated this heat flux into the basal ice at GRIP, GISP2, Taylor Dome, and Siple Dome. Because basal melting (e.g. at NGRIP, Greenland) or basal freezing (e.g. at BYRD Station, Antarctica) introduces a local energy sink or source, the basal gradients in the ice at those ice-core sites are poor proxies for geothermal flux.

The polar regions have experienced larger glacial-interglacial temperature swings than the rest of the planet, so climate transients may cause the heat flux into the basal ice today to differ substantially from the long-term geothermal flux. Then, the geothermal flux can be extracted only by solving a geophysical inverse problem to simultaneously obtain estimates of surface temperature history and geothermal flux. The forward algorithm is a transient thermal model that uses a surface temperature history and geothermal flux to produce estimates of the modern temperature-depth profile.

Ice flow introduces advective heat transport in addition to diffusive transport. Therefore, the forward algorithm must incorporate ice flow and its variations through time, in order to use data from the full depth range.

Estimates of geothermal flux were derived in this way at GISP2 by Cuffey and Clow, (1996, JGR) and at GRIP (Dahl-Jensen et al., (1998, Science). We have solved a geophysical inverse problem using the spectral decomposition method to obtain estimates of geothermal flux at Taylor Dome and Siple Dome. Because both sites are close to ice divides, and are thought to have undergone little thickness change in the Holocene, we used a 1-D ice-flow/heat flow model with constant ice thickness for the forward algorithm. Uncertainties in vertical advection contribute the largest source of uncertainty in geothermal flux.

Clow, G.D. 2008. USGS polar temperature logging system, description and measurement uncertainties, USGS Techniques and Methods 2-E3, 24pp. http://pubs.usgs.gov/tm/02e03