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Estimating subglacial geothermal flux by a combination of shallow borehole temperature, englacial vertical strain-rates and inverse modelling: Application to the site selection in the quest for the oldest ice

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Ice domes in the interior of East Antarctica are ideal candidates in the quest for the longest continuous record of climate in polar ice. They are in areas with low surface precipitation, low horizontal advection and large ice thickness. However, the age of the ice near the bottom of the column is very sensitive to subglacial thermal conditions as they can promote basal melting and the loss of the bottommost and oldest ice. The biggest unknown in the basal heat balance is the geothermal heat flux, it can be derived from remote sensing but at a much larger scale that the spatial bedrock variability and it is not applicable for this problem.

In order to estimate geothermal heat flux, we propose to first extract borehole temperature in the top hundreds of meters of depth using a combination of thermistors and distributed temperature sensing (DTS). Second, record the variation of stable isotope using a rapid access ice drill (RAID), again in the top hundreds of meters, in order to stablish a relation between the new site and an already analysed ice core to estimate the temporal variations of surface temperature and accumulation. Third, measure vertical flow advection near surface by monitoring the displacement of radar layers with a phase-sensitive frequency modulated continuous wave radar (ApRES); and finally use an adjoin-based inverse method, that accounts for the temporal variations of surface mass balance and temperature and propagate uncertainty from measurements and model unknowns, to estimate basal temperature and geothermal heat flux.

We first validate our method by sampling the already existing full-depth borehole temperature at EPICA Dome C. We also validate our DTS system at Talos Dome where there is no previous borehole temperature but basal conditions are well established. And finally, we use preliminary measurements from a 450m depth borehole temperature measurement near Dome C, in a location known as Little Dome C, current candidate as ideal site for the Beyond Epica Oldest Ice project, to estimate basal conditions and the suitability of the site in the quest for the oldest ice.

Our simulations, the tests at Talos Dome and Dome C, and the reanalysis of EPICA Dome C records suggest that our DTS system is able to record within the mC precision estimating the target geothermal heat flux with 0.5 mW m-2 uncertainty when combined with englacial vertical strain-rate information and 2 mW m-2 uncertainty without. We also show preliminary results from our analysis of the data extracted at Little Dome C. (The DTS records of the top 450m and ApRES englacial strain-rate data from have just arrived from the field at the time of writing this abstract.)