



EGUsphere, referee comment RC1
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Review of Montelli and Kingslake

Anonymous Referee #1

Referee comment on "Geothermal heat flux is the dominant source of uncertainty in englacial-temperature-based dating of ice rise formation" by Aleksandr Montelli and Jonathan Kingslake, EGU sphere, <https://doi.org/10.5194/egusphere-2022-236-RC1>, 2022

Review of Montelli and Kingslake: "Geothermal heat flux is the dominant source of uncertainty in

englacial-temperature-based dating of ice-rise formation

Montelli and Kingslake use an inverse approach to estimate the uncertainty in determining the age of grounding at ice rises from the englacial temperature profile. They apply this technique to Crary Ice Rise – the primary location where this technique of dating the grounding of the ice shelf has been applied. The authors conclude that the uncertainty in geothermal flux is the primary source of uncertainty; given the uncertainty in geothermal flux, particularly in the Ross region, this is an important conclusion.

The technique is similar to previous work using borehole temperature profiles to infer past temperature but is instead oriented towards inferring the timing of grounding in the ice-sheet to ice rise transition. Therefore, the past histories are assumed to be defined, and the modern parameters are assumed to be unknown – essentially a reversal of the assumptions used for in the borehole thermometry work. The manuscripts does a good job of exploring many sources of uncertainty, although quite a few more remain. The work is a useful contribution and improves our understanding of the limitations of ice-rise grounding from englacial temperature profiles.

The paper is mostly well organized with clear descriptions and illustrations of the model set up. However, the choice of vertical velocity profile is not clear. For instance, what is the Dansgaard-Johnson kink-height being used? And I think a value of "n" of 3 is being used for the Lliboutry approximation, but this is often employed because different choices of "n" allow a wider range of vertical velocities than the D-J approximation (e.g. Kingslake et al., 2014). The shape of the vertical velocity likely can vary a lot for these types of scenarios – an ice shelf should have a nearly linear vertical velocity while an established divide will be highly non-linear, and typically represented with "n" significantly less than 3.

The paper also seems primarily focused on Ross-like locations. Most ice rises have accumulation rates much greater than 0.1 m/yr. I think the paper would benefit from specific discussion of how well englacial temperature profiles would constrain timing of grounding in other locations than the Ross and Filchner Ronne – where the accumulation rates are greater. This would provide guidance of where it is promising to obtain englacial temperature profiles and where it is unlikely to be useful. My guess is that higher accumulation rates shorten the timescale that regrounding can be inferred for.

The paper should also discuss the impact of horizontal advection on the temperature profile. When can the effects of the upstream flow – starting with thicker ice, colder temperatures, and different accumulation rates (West Antarctica has weird accumulation gradients so it's not obvious that being higher and colder also means less accumulation) – be safely neglected. A few forward runs based on Mercer Ice Stream and Crary would be useful to discuss this potential uncertainty qualitatively. It would be beyond the scope of the paper to include this in the inversion. I also wonder if the forward modeling in Figures 5 and 6 could be restricted to the thinner ice sites. Are there examples of 2500m thick grounding events (L405 suggests ice rises are general much thinner).

The paper should also be clear about the thermal properties being used. Regarding Table 1: I'm a bit confused by the values the authors have chosen for ice which I think is because the heat capacity and thermal conductivity values are switched. The heat capacity is chosen as 2.3 J/kg/K yet Cuffey and Paterson (2010) give the range of values between 0 and -50C as 2097 to 1741 J/kg/K. The factor of 1000 notwithstanding, the chosen value does not fall within this range. Similarly for the thermal conductivity, the authors give 2000 W/m/K yet the Cuffey and Paterson range is 2.1 to 2.76 for 0 to -50C. It seems like

the authors switched the values. The heat capacity of bedrock (assuming that the thermal conductivity of bedrock is actually the heat capacity) seems too low as well. Also, the authors should at the very least discuss the uncertainty of these values and the uncertainty of not treating them as temperature-dependent. It seems like this will be an important enough source of uncertainty to include in a paper about the uncertainty of dating ice rise formation with the englacial temperature profile, but maybe it isn't.

Overall, this manuscript is a valuable contribution that improves inferences of past ice sheet behavior. That the code for the inversions will be made publicly available is an asset that can be applied beyond this specific application (it didn't look the like the github link was active yet, but I wouldn't expect it to be before the paper is accepted).

Minor comments

L294: The example of accumulation is not surprising. Most analyses will use a percent change in accumulation rate rather than a fixed amount. This better reflects the variability in climate.

Figures 3 and 4 – It would be good to label all of the axes even if all of the axes in a column or row are the same.

Fig. 5 caption is long and very repetitive. It seems like this 5 scenarios text could be shared with only the differences articulated each time.

Fig. 5 C – check values. Most heat fluxes are given in $W m^{-2}$, so I think you should stay consistent with that.

Update Neuhaus reference

L 388-390 – It might be worth mentioning here that in addition to cooling effects from groundwater, you might also expect heating effects from friction during the regrounding. There is likely to be a very complicated and stressful (pun intended, sorry) time period when grounding occurs.

L412-416 – ApRES vertical velocity constraints were used at Dome C to improve inferences of past temperature change. It's pretty buried in a complicated paper, but it highlights the point being made: Buizert et al., 2021, Science, "Antarctic surface temperature and elevation during

the Last Glacial Maximum"

L445 – delete "comprehensive" or modify it with "most comprehensive yet