The Cryosphere Discussions

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Review of Obase et al.: 1D temperature and age modeling at Dome Fuji

Anonymous Referee #3

Referee comment on "A one-dimensional temperature and age modeling study for selecting the drill site of the oldest ice core near Dome Fuji, Antarctica" by Takashi Obase et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-204-RC3, 2022

Obase et al. present results for a 1D ice and heat flow model. The goal is to inform site selection for a new core site near Dome Fuji, targeting ice older than the ~700 ka limit of the previous core. The goals of the paper are to: 1) identify parameter combinations that approximately match the Dome Fuji depth-age and borehole temperature relationships and thus can be used for predicting depth-age relationships in the vicinity; 2) identify the primary constraints on the basal ages, which they determine is ice thickness; and 3) apply the model to the radar line that stretches from the previous ice core site to a potential new site, North Dome Fuji.

I am providing only a brief review because I am concerned about the treatment of the basal thermal state in the model. In Figure 5, a change in the geothermal flux of 5 mW m-2 (from 55 to 60 mW m-2) yields a change in the average melt rate of ~2.5 mm/yr (from my eyeballing of the averages). This is too large. It should be about 0.5 mm/yr since 1 mW m-2 can melt approximately 0.1 mm/yr of ice. The caluclation is below:

the melt rate (M) equals the geothermal flux (G) divided by the latent heat (L) and the density of ice (ρ)

M = G / L / ρ = 0.001 (W/m2) / 334000 (J/kg) / 917 (kg/m3)

So I'm confused why the values in Figure 5 change so much for the modest increase in geothermal flux. I checked this with a model run of my own transient 1D ice and heat flow model with forcings for EDC based on AICC2012. The attached figure shows that modeled melt rate agrees with the calculation above – each 1 mW m-2 of excess geothermal flux causes approximately 0.1 mm/yr of basal melting.

I wonder if the Obase model has a problem with the basal boundary. It sounds like the temperature gradient is being set directly as the ice-rock boundary, instead of in the bedrock well below.

Unfortunately, the basal melt rate is the controlling factor on the depth-age, such that an error would affect the entire manuscript. I am not sure, but it looks like this problem is also affecting the depth-age relationship in Figure 6.

I initially wondering if there was some nonlinearity model that would amplify the basal melt rate in response to a change in geothermal flux. The basal melt rate affects the vertical velocity. But this has the impact of steepening the basal temperature gradient, allowing more of the heat to be conducted away rather than used to melt basal ice. So that works in the opposite direction. And the model run I performed suggests that there is not a significant non-linearity.

The manuscript addresses an interesting problem of calculating the temporal variations in the basal melt rate and the impact on the depth-age relationship. However, I think the authors need to provide further support that they are calculating the basal melt rate accurately before the remainder of the manuscript is evaluated.

Please also note the supplement to this comment:
https://tc.copernicus.org/preprints/tc-2022-204/tc-2022-204-RC3-supplement.pdf