Stagnant ice and age modelling in the Dome C region, Antarctica
Review 1 response

We thank the reviewer for the time and effort for evaluating our manuscript. Below, our response is in blue and changed text in the manuscript in blue italic:

Reviewer comments
Author comments
Additional/modified text passages from manuscript

Review of "Stagnant ice and age modelling in the Dome C region, Antarctica" by Aildasa Chung et al.
This paper examines the age of the ice interior of Dome C using a 1D ice flow model combined with radar imagery. Chapter 2 describes the 1D ice flow model based on Parrenin et al. (2017) with the incorporation of mechanical ice thickness and stagnant ice. A method for optimizing unknown parameters (precipitation, flow parameters, and mechanical ice thickness) using the ages from radar imagery are described. Chapter 3 describes a method for detecting basal units and age layers from radar images, and their correspondence to the age profile from the EDC ice core. In Chapter 4, the 1D model results are validated against the age and vertical velocity profiles of the LDC or EDC, and the correspondence between the stagnant ice distribution. The results of the 1D model regarding spatial distribution of stagnant ice are compared with radar images. Chapter 5 examines uncertainties from the ice flow model and radar datasets.

Overall, I think the paper is of sufficient quality to be accepted. Below are some questions and suggestions for minor revisions.

We have rearranged the results section following suggestions from another reviewer. This rearrangement has changed figure numbers, sections number and line numbers. We have tried include new numbers in our response so it is easier to find the revisions.

We first present evidence from observations of the stagnant basal layer – the ApRES vertical velocity profiles at EDC and LDC, then the basal unit seen in the LDC-VHF radar survey. We then compare our numerical model with and without inverted bedrock depth, in order to show that a model which allows for a stagnant ice layer is more appropriate, at least in the Little Dome C region. Having shown that the stagnant ice model is more appropriate, we then present the melting/stagnant ice, p parameter, accumulation rate, age and age density results for all four areas of interest around Dome C. Finally, we present the results at single locations- EDC for comparison to experimental ice core data, and LDC predictions for the current Beyond EPICA and MYIC drill sites.

L43: I understand that "stagnant ice" refers to ice masses with a minimal flow. Meanwhile, I think it would be meaningful to describe a definition of "stagnant ice" in this study.
Definition added new line 79:

We label this ice "stagnant" as the best fit thinning profile of the 1D model does not pass below H_m, though from observations we can see that ice continues to depth Hobs, so we infer a vertical ice flow velocity of 0 for this layer.

L80: Is r(t) exactly the same as in Figure 2 of Parrenin et al. (2017)? If so, I recommend citing the figure.
Suggestion accepted

L83: "temporally-averaged" accumulation? And, is it averaged over the last 800,000 years?
New line 86 changed to:
temporally averaged value over the last 800 ka

L87; Actual basal melting should be determined thermodynamic, so I think this formulation is one assumption. Does this formulation come from a condition of no discontinuity in the vertical velocity at the observed bedrock?
Basal melting can be determined thermodynamically and kinematically. We opt for the kinematic approach, truncating the vertical velocity at the observed bedrock.

L90: Name of the software?
New line 98:
For this model, we use the Python module SciPy's least-squares optimisation with the Trust Region Reflective algorithm.

Equation 5: What is the definition of σiso? And also, write out the term "reliability index" in the description of equation 5 as the term is used later (Figure 12 and Section 5)
New line 104:
The depths and ages of isochrones are diso respctively and χiso, σiso is the age uncertainty and χmod is the modelled age.
New line 110:
If the model is a good fit, then the "reliability index" σR is close to 0.

L110: Any introduction for MYIC?
MYIC now mentioned in the introduction new line 28:
The Australian Antarctic Division (AAD) have also selected a drill site at LDC for their Million Year Ice Core (MYIC) project.

Table 3: "DC-LDCRAID2", "DC_LDCRAID", "DC_LDC_DIVIDE", and "DC_PNV09B" are not mentioned in the text. Which panel in Figure 2 does these names correspond to?
Radar line names have now been removed from Table III as they did not add any useful information for the reader. The radar lines are not fully visible in Fig. 2 as we focus on LDC where the majority of the radar survey took place for panels (b) and (c).

L203: Total ice thickness at EDC?

New line 315: We are referring to the total ice thickness at the point in the radar closest to EDC.

The closest point to EDC in the LDC-VHF dataset is 178 m away with a total ice thickness of 3239 m.

L208: High melting area in the lower left of the figure may not be reliable, according to Figure 12. It may be hard to explain why there's considerable basal melting where the bedrock elevation is relatively high.

New line 286, line added to reference former fig 12 (now Fig 6):

There is significant melting predicted around the edges of the LDC relief, especially on the western side of LDC and across the Concordia trench (Fig. 2a), where Fig. 6a shows that the model is less reliable

Figure 5: Where does this transect correspond (on the map)?

Now Fig. 7: Labels A and B now show transect on the map and the caption has been extended to describe this.

A radar transect in the LDC-VHF dataset which passes diagonally across Patch B from A to B in panel (b).

Figure 6: The caption in Figure 6b would be "p=3.6, and stagnant ice=0" based on sentences.

Suggestion accepted

L272: Confused, because according to figure 6, the p=3 for LDC. Why does figure 8 have a more significant value of p? This may come from different radar/ApRES velocity measurement datasets. Please discuss this.

Former Fig. 8 (now Fig. 10) shows the modelled p parameter which for LDC is higher than the ApRES fit at LDC - former Fig 6a (now Fig. 3a).

Now added to the discussion:

The different p values for the model and the ApRES at both LDC and EDC could be due to the depths of the constraints used for both fits. The maximum ApRES measurements, excluding the basal reflections, are 2145 m at EDC and 2017 m at LDC. For the 1D model, the deepest isochrone constraint at EDC is 2740 m for DELORES (now Table II) and 2826 m for LDC-VHF (now Table III). Deeper constraints have a larger effect on the p parameter than shallower ones. Therefore, the constraints which are 600-800 m deeper for the 1D numerical model, strongly affect the modelled p value.

Figure 7: High precipitation areas in the upper left corner might be less reliable, according to Figure 12.

New Fig. 9. Surface accumulation is mainly constrained by the sallowest isochrones, so it should be a robust feature even if the reliability index is not so good.

Table 4: What are the values of p and a in these modeling results?

p and a have now been added (now Table V)

L325 For this discussion, I think it's necessary to refer to Parrenin et al. (207) (Equations 4-5), which discusses the relationship between basal deformation and the value of p

When Lliboutry (1979) developed their numerical scheme, p was initially calculated depending on the vertical temperature gradient and ice sheet thickness (Eqs. 4 and 5 of Parrenin et al. 2007). However, this theoretical value of p is not compatible with the mechanics of a divide and does not take into account basal sliding. Therefore, for our case at LDC, the best course of action for us is to invert p as there are too many unknowns to calculate it.