

We thank the reviewer for their careful and helpful comments.

In the response, referee comments are in *italics*, our replies are in normal font, and the revised text is in [light blue](#).

Major Comments

As the authors said, they took the accumulation rate and age depth relationship from Vostok ice core which is 700 km away from Kunlun station. It may have large difference from the real relationship at Kunlun station. Hence it may cause large uncertainty in the optimal value of parameter p and the modelled age, as it is a key function in this 1D pseudo-steady-state age model. So I am wondering how the modelled age at Kunlun station would change if another accumulation rate and age depth relationship is taken? For instance, use the accumulation rate and age depth relationship at the Dome Fuji or Dome C. I also would like to see the plot of normalized vertical velocity. Please add this plot at Kunlun station. Also, it would be interesting to compare the normalized vertical velocity with Zhao et al. (2018).

Reply: Thank you for this comment, we have now tested different ice core chronologies (age-depth relationship and accumulation history) as input.

The simulation remains stable down to a depth of ~2600 m. Below this depth, the simulated ages depend on the chronology used. This may be due to the isochrones being relatively shallow, which leaves the model poorly constrained in the lower part of the ice column, as discussed by Chung et al. (2023) and Wang et al. (2023). Among the available ice core chronologies in East Antarctica, Vostok is the closest to Dome A and was used to date the isochrone constraints. Therefore, for consistency we use the Vostok accumulation variations.

Furthermore, our simulated vertical velocity near the bed is lower than that reported by Zhao et al. (2018). This may be because Vostok is not located on a typical ice divide. In such regions, horizontal advection is non-negligible, whereas our 1D pseudo-steady-state model assumes purely vertical compression. This simplification may introduce discrepancies in the simulated vertical velocity, especially in the basal ice.

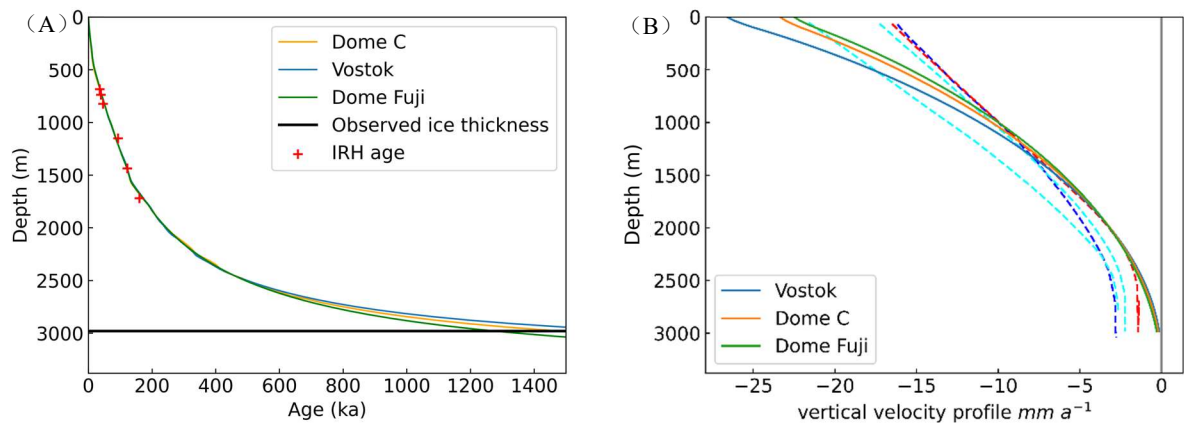


Figure R1. (A) Age - depth relationship at Kunlun Station. Dome C, Vostok (Bouchet et al., 2023) and Dome Fuji (Oyabu et al., 2022) denote different ice core chronologies. (B) Vertical velocity profile at Kunlun Station. The solid line represents our simulation, and the dashed line represents the simulation of Zhao et al. (2018).

Minor Comments

Line 1, what do you mean by ‘high precision’? Why do you think your model is a high precision model?

Reply: Thank you for your comment. As we believe that the 1D model performs reasonably well at Little Dome C, the previous wording may have appeared somewhat subjective. We have removed it.

-Line 19, there are two commas.

Reply: Done.

-Line 21, add ‘of’ after the last ‘age’.

Reply: Done.

-Line 24, It need to point out the model limitation, which may bring large uncertainty to this result.

Reply: We have added a sentence to explain the model limitation. “...older ice and higher age density. However, due to the limited availability of deep radar isochrones, the deep ice remains less well constrained than shallower ice, which may result in larger uncertainties in the simulated age of the oldest ice.”

-Line 25, ‘Isoinv1D model’ is only used here. But you use ‘1D pseudo-steady-state model’ in section 3. Use the same name.

Reply: Done.

-Line 37, change 'simulations' to 'projections'

Reply: Done.

-Line 52, what is 'NP' ? Provide its full name when it first appears.

Reply: Done. NP refers to the North Patch area in Dome C (Chung et al., 2023). The revised text is “Simulated ages exceeded 2 Ma at another more promising old ice location, [the North Patch \(NP\) \(Chung et al., 2023\)](#).”

-Line 56, it is hard to understand this sentence '... the maximum ice age is defined as ice characterized by an age density of 20 kyr/m.'

Reply: We have rephrased this to “[...the maximum ice age is defined as the age at the depth where the age density reaches 20 kyr m⁻¹](#)”.

-Line 65, 'a full Stokes coupled heat equation model' is wrong description. Full Stokes model includes the heat equation.

Reply: Done. We have revised it to “[a Full Stokes model](#) showed that”.

-Line 70, it is not clear what do you mean by 'these factors' . The main uncertainty comes from GHF. 'greater uncertainty' , why do you use 'greater' , than what?

Reply: We have rewritten these sentences as this also caused confusion for Reviewer 2. We are comparing the GHF representation in the Zhao et al. (2018) with that of IsoInv1D. From Line 68, the new sentences are:

“[Their models are constrained by surface velocity measurements and prescribed GHF. However, GHF is spatially variable, and surface velocity observations are sparse. The constant GHF may lead to significant uncertainty in the age of deep ice. By contrast, our approach offers three advantages: \(1\) the 1D steady-state model does not explicitly include parameters for GHF and surface velocity, it avoids the uncertainties inherent in their estimation; \(2\) It is constrained by dated IRHs, which have a stronger constraints on age-depth structure; and \(3\) The model has been successfully applied in multiple regions, especially at EDC and LDC where the model has been validated.](#)”

-Line 71, Provide the full name of 'IRH' when it first appears.

Reply: Done.

-Line 73, 'supportf' is a typo

Reply: Done.

-Line 85-87, avoid to use 'light blue' and 'dark blue' in the main text. They should only appear in figure captions. Remove the lightm. Use C21DA and C21KL instead.

Reply: Done.

-Line 92, is it Luo et al. (2023) or Luo et al. (2022)?

Reply: Thank you for pointing out this error. It is Luo et al.(2022).

-Line 94-96, for some reason, the font size of the subscripts for the variables in the text and in the equations is too large.

Reply: Done.

-Line 120. It is not correct that '... cannot quantify the melting rate.'

Reply: Thanks for your comment. We have removed it. The revised sentence is "The latter is used to judge basal melting from temperature and vertical heat flux."

-Line 126, why do you make this assumption?

Reply: The steady-state age is calculated at the radar measurement points, and the true age is calculated using the ratio $r(t)$ between the average accumulation and the true accumulation from ice cores. We therefore assume $r(t) = 1$ for ages exceeding the maximum ice core age as we have no accumulation variations for ice older than this. This approach follows similar treatments in the literature (Chung et al., 2023; Wang et al., 2023).

-Eqn (4), check if you missed H_m .

Reply: Thanks, we have added H_m in the text.

-Eqn (5), use parentheses that match the formula height.

Reply: Done.

For all the equations, double check the variables if they are scalar or vector. Vectors

should be in bold.

Reply: Done. We have bolded vectors in the text.

Page 6, the subscript of H_m in this page looks odd.

Reply: Done.

-Line 157-158, what do they mean by ‘4 km, 18 km, and 44 km’? Are they distance from somewhere? Please describe them accurately.

Reply: We have revised it and corrected the value error of “18 km”. The revised sentence is “**Simulated ice ages near the bed are relatively old at distances of 4 km, 13 km, and 44 km from the C21 KL start point, which is located near the center of C21DA. These sites correspond to regions with low basal melt rates.**”

-Line 181. I do not understand this sentence ‘Near and north of Kunlun Station, a larger maximum ice age corresponds to greater ice sheet thickness.’

Reply: We now refer to areas shown in Fig. 4A and have corrected the sentence to reflect this. “**In areas B and C (Fig. 4A) the larger maximum ice age is explained by a greater ice thickness, as shown in Fig. 3 (C).**”

-Line 184, I assume you mean Fig. 3 A?

Reply: Yes, that is Fig. 3 A. We have corrected it.

-Line 223, add ‘as Sun et al., (2014)’ after ‘the same methodology’.

Reply: Done.

-Line 226-228, avoid to use words like ‘blue curve’ in the main text. Replace them with scientific description.

Reply: Done.

-Line 230-232. Rephrase this long sentence.

Reply: We have rephrased this sentence. “**This differs significantly from the simulations of Zhao et al.(2018). This discrepancy likely arises from the lack of IRH constraints at the base of the ice sheet. The deepest IRH is less than 60% of the ice-sheet thickness at Kunlun Station with an age of 161 ka. This is significantly shallower and younger than IRHs used in other**

studies with this model (Chung et al., 2023; Wang et al., 2023).

-Line 233. *There is something wrong in this sentence. 'this figure is 200 m' ?*

Reply: We have rephrased this to "...while in the Greenland Ice-core Project (GRIP), this value is 200m."

-Line 248-249. *I do not agree with this sentence. Do you have similar cold surface temperature and low geothermal heat flux in Dome A?*

Reply: We have revised this for clarity "In Dome A, where the surface is extremely cold and ice thickness is large, the latter mechanism may dominate. This is supported by our simulation results, which show no clear relationship between ice thickness and basal melt rate."

-Line 291, *do not use subjective words such as 'successful' .*

Reply: We have revised the sentence to "..., which incorporates horizontal ice advection and lateral divergence along a flowline, allowing more realistic estimates of ice age and thinning function. ..."

-Line 294-310. *Please rephrase the conclusion paragraph. The wording needs to be improved. For instance, you cannot say "The method obtained parameters ". Is this '8 km south' correct? It is said '8 km southwest' in section 4.2.*

Reply: Thanks for your suggestions. '8 km southeast' is the correct description. We have revised the conclusion paragraph. The new paragraph is

"We applied the 1D pseudo-steady-state model from Chung et al. (2023) to simulate the age of the C21 radar lines. Using six IRHs dated from the Vostok ice core as constraints, we propagated the Vostok age-depth relationship to the Dome A radar survey lines and derived the corresponding ice age and time-averaged accumulation rate.

Figure 4. (A) shows that ice exceeding 1 Ma is concentrated in three regions: the area around Kunlun Station (Area B) and ~8 km southeast (Area A), and ~5 km north of Kunlun Station (Area C). These regions exhibit higher age uncertainty than other areas but are characterized by greater ice thickness, lower basal melt rates ($<1 \text{ mm yr}^{-1}$), and age densities below 20 kyr m^{-1} . At Kunlun Station, under ideal conditions, the simulated maximum ice age is $1737 \pm 223 \text{ ka}$, with an age density of $\sim 8.2 \text{ kyr m}^{-1}$ and a basal melt rate of 0.14 mm yr^{-1} . Considering basal melting and previously observed distributions of older ice, we adopted a conservative estimate of $909 \pm 113 \text{ ka}$ at 200 m above the bedrock, consistent with the 650–830 ka range reported by Zhao et al. (2018). Areas A and C exhibit higher maximum age density than area B, with particularly elevated values in parts of area C.

These results indicate that drilling in both the Kunlun Station region (Area B) and the northern region (Area C) could yield ice cores older than 1 Ma. This provides some guidance

for prioritizing promising drilling targets near Dome A and supporting ongoing international efforts to recover ice exceeding 1 Ma.”

-Line 305. Rephrase this sentence ‘These differences are likely due to the simplified yet effective modelling framework adopted here, which allows the integration of more spatially explicit radar-derived age constraints’. Both this study and Zhao et al. (2018) used the same radar-derived age constraints. Maybe you write ‘The variation in results is mainly due to different methods.’

Reply: We agree with the sentence “The variation in results is mainly due to different methods”. However, these sentences were logically unsuitable in the new revised paragraph Line 294-310, so we have removed them.

-For the figures: There are only one or two numerical values on the longitude and latitude lines in the maps. It is not easy to read the map. For all the maps, add numerical values to all the longitude and latitude lines. Besides, for all the maps, add the scale bar. The text and numbers on the figures need to be enlarged.

Reply: Done.

-Figure 1. I would label C21DA for the dark blue line and C21KL for the dark blue line, to be consistent with what you said in the caption. It is hard to see the two intersections of AWI with C21KL. Are the two points ‘S’ and ‘N’ necessary to show? Give the reason why you need to label them. If you need to, I suggest to use other letter to represent them, because S and N can easily be confused with south and north. I do not think it is correct ‘...and the black lines represent surface elevation contours.’ There are no surface elevation contours. You did not say anything for the inset figure. The label of 'Vostok' could be smaller. There are black lines in the inset box, what are they? Describe it in the figure caption. The sub-caption of the figure is not needed, remove it. Put the unit ‘m’ into parentheses.

Reply: We have revised the color: light blue for C21DA and dark blue for C21KL. We have removed the ‘S’ and ‘N’ points. We have added the surface elevation contours in meters (black lines).

-Figure 2. It is hard to match this figure with figure 1. You have stretched the four triangles into a straight line. Where is your starting point? And the direction? Where is Kunlun station? Mark it.

Reply: We have corrected the color of C21DA and C21 KL. C21KL (dark blue) is stretched into a straight line, starting from the endpoint of C21 KL near the center of C21DA. We have also changed the caption for Fig. 2 to “[Cross-section of the C21KL survey line \(dark blue line in Fig. 1\)](#)”.

-Figure 3-6. Much of the figure domain is useless and not interesting; the spatial extent of the plot can be reduced. This legend for ‘Kunlun station’ is not needed. Say it in the caption and remove the red star legend. Remove the sub-captions of the figure. Please them at the

colorbar. Put the units into parentheses. Change the units like 'mm/yr' to 'mm yr⁻¹'. The text and numbers on the figures need to be enlarged. Circle the same optional area in Figure 4b as in Figure 4a.

Reply: Done.

-The figure 4 caption is unclear, such as 'A is the 8 km area southwest of Kunlun Station, B is the Kunlun Station area, and C is the 5 km area north of Kunlun Station.' . Please improve it, to be consistent with the main text. You may say 'Area A is 8 km southwest of Kunlun Station, ...' . You can combine figure 4 and 5 into one figure.

Reply: The sentence has been revised to be more consistent with the text. "Area A is located 8 km southwest of Kunlun Station. Area B surrounds the Kunlun Station. Area C is located 5 km north of Kunlun Station."

Figure 7. Replace the legend 'Age-depth scale' with 'this study' . Add a subplot to show the vertical velocity.

Done.

Reference:

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