Response to Reviewer Comments

RC1:
Remarks:
1) Improve description of modeling methods
2) Improve presentation of model results

--- Accommodate these general remarks via explicit treatment of specific comments ---

Specific Comments:
1. line 13: There are many missing hyphens between words, such as 'one dimensional'should be 'one-dimensional'.
Fixed.

2. line 14: I suggest 'compaction' instead of 'burial'.
Changed.

3. line 38: I think that it is worth stating that these percentages are area and not volume.
Done.

4. line 68: the two-dimensional extension deserves much more explanation!
We have expanded the paper methods to include a more robust description of our horizontal ice flow implementation.

5. line 71: I suggest adding a paragraph describing the road map for the paper.
The final paragraph on the introduction, starting line 66, has been expanded to provide a clear statement of purpose and objectives.

6. line 77: could add 'as well as compaction and advection', given that this is the topic of the paper and these clearly influence the density and thermal structure. This would strengthen the topic sentence.
We have rewritten the first two sentences of this section. However, we have kept the advection discussion in the second sentence because we see this as a modifier on the primary physics of densification.

7. line 84: 'rather' would be a good addition after the comma.
This section has been rewritten.

8. line 91: It makes sense that the one-dimension advection does a good job approximating the two-dimensional solution because the downstream gradients are small (viz. Hewitt and Schoof, 2017). The important issue, however, is that the one-dimensional advection does not include downstream transport of moisture, which is likely to be very important and is not included in the two-dimensional implementation described in the supplement, correct?

This is true. This manuscript is focused exclusively on the role of horizontal ice flow, impacts the full percolation zone. Horizontal routing of meltwater is an outstanding topic of research for the field and is beyond the scope of this work.

9. line 97: this paragraph is confusing as it makes it sound like the authors implementedeverything in FEniCS — is this true?
Yes, the model physics are simulated within the finite element package FEniCS.

10. line 120: why wasn't the Community Firn Model (Stevens, 2018) used? It contains several implementations of meltwater percolation through firn and is open source(https://github.com/UWGlaciology/CommunityFirnModel).
The model of Stevens (2018) does not include horizontal advection of the firn column. We therefore developed our own code to include horizontal transport from ice flow. As described in the text, we tested our model against other models based on the FirnMICE experiments and found favorable agreement.

11. section 2.3: I think it would be very valuable to write to out the equations in a general way, so that it is clear (1) what advance the authors have made and (2) how the advance is implemented operationally. In other words, I suggest writing the density ρ evolution equation as dρdt=f(ρ,T,...), (1)where the right-hand side is given by Reeh et al. (2005) etc. is a function of the temperature T. Then, the authors could state that they will add downstream ice advection u as ∂ρ∂t+u∂ρ∂x=f(ρ,T,...),(2)and state that this advection process occurs explicitly (my assumption), where the upstream density is advected downstream at each time step.
In our expansion of the paper's methods, we have included general equations for the densification rate of change and heat transport. These are foundational to our model implementation, which we now describe in more detail in section 2.14.

12. section 2.3.1: I suggest including some of the figures from the supplement in the main text to demonstrate how the models work.
We have moved much of the supplemental text to the manuscript body to better communicate the model mechanics. Regarding the results of the synthetic experiments, we have edited Figure 2 to show the influence of advection on simulated air content because this illustrates the primary process with which the papers is concerned. Including plots from all sensitivity tests in the manuscript body would also oblige us to describe the results from each in detail, with negative consequences for the clarity of the manuscript. We therefore have distilled these results to their most important points in the text, and leave figures of all sensitivity tests in the supplemental for interested readers.

13. line 276: 'for much another reason' should be 'for another reason'.
Fixed.

14. line 282: typo as there should be parentheses around the figure reference, i.e. '(Figure5b)'.
Fixed.

15. line 302: ‘x’ should be ‘x’.
Fixed.

16. line 335: simulations produce data. How do I access the simulations? Also, I suggest putting Leone in parentheses to match the other funding acknowledgments.
This section has been edited and expanded to address these issues.

17. line 378: error in title
Fixed.

18. figure 1: is this figure useful/insightful?
We believe that is important to demonstrate to the reader the regions of the ice sheet which have relevance to the findings of this paper: this figure shows where high melt in the accumulation zone is coincident with relatively high horizontal displacement. In addition, this figure shows the locations of our study transects.

19. figure 2: I suggest addressing the dot, solid, and dot-dash lines within the caption. Also, an additional figure showing the two-dimensional results for the different models shown in figure 2 could be very useful (i.e. figure 3 but for the figure 2 simulations).
We have addressed the dot, solid, and dot-dash lines in the figure caption. A two-dimensional example from a sensitivity test would be useful only inasmuch as it would clarify how the sensitivity tests are performed (the results are best summarized in the figures that are already included). We have therefore improved description of the sensitivity testing in the revised manuscript methods.

20. figure 3: it would be helpful to label the subfigures on the actual figure. For example, the transect name could be put next to the letter, i.e. ’(a) EGIG line’ and topography, pore close-off depth, and differences could be labeled on the respective panels.
We have edited the figure panel labeling following these suggestions.

21. figure 4: I suggest converting this plot to either 3 panels, one for each model, or 4panels, one for each transect. Currently, it is impossible to decipher.
We have broken the figure in to four panels (one for each transect) to better facilitate comparison of the different infiltration schemes.