Supplementary Information

Millennial-scale migration of the frozen/melted basal boundary, western Greenland ice sheet

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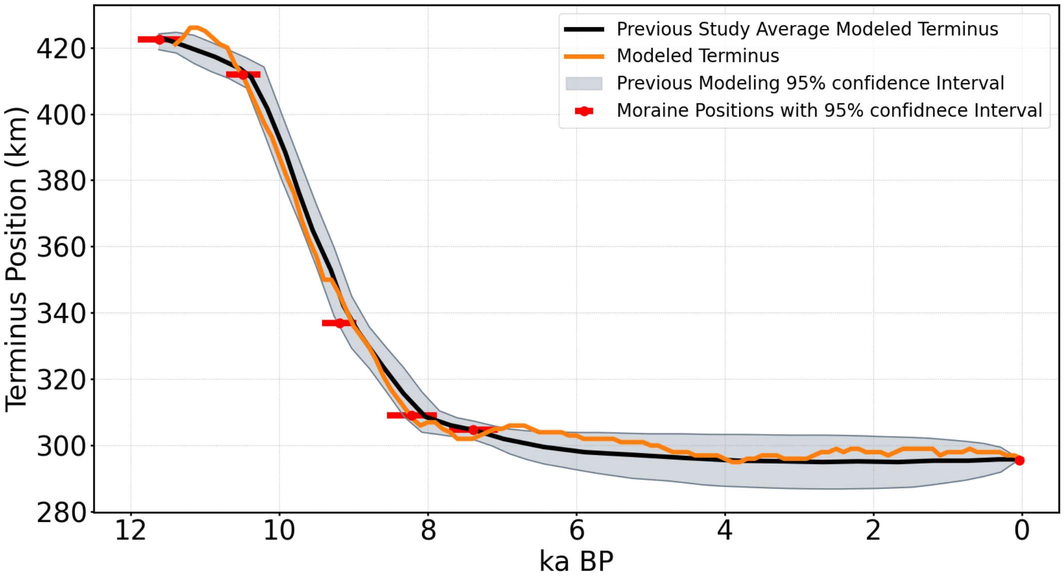

Fig. S1: Comparison of our modeled terminus retreat (orange), with mapped moraine history including 95% confidence intervals (red), and prior modeling studies (black) with 95% confidence intervals (gray region).

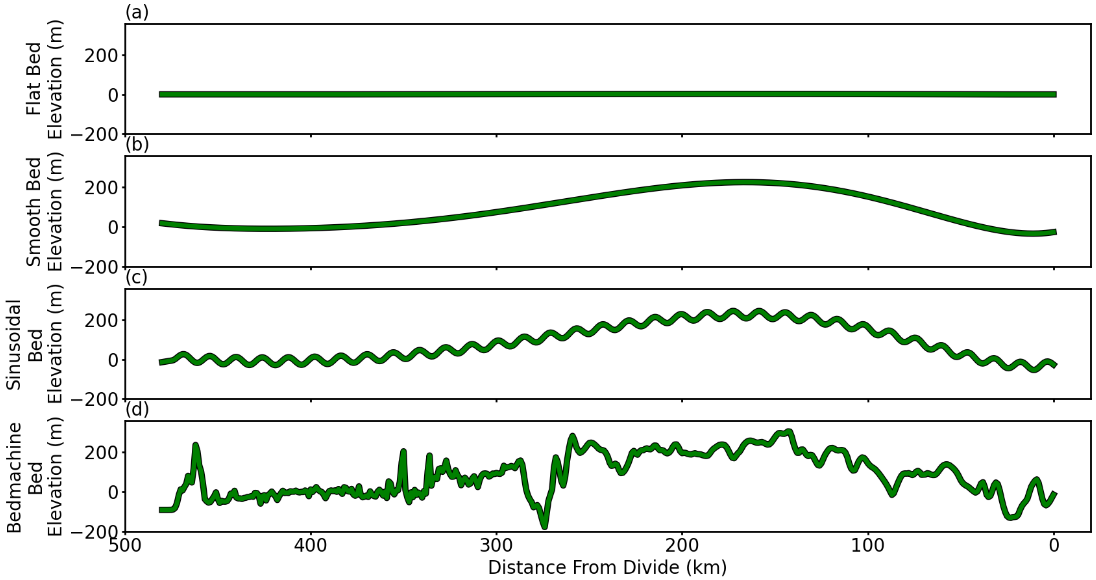

Fig. S2: The four bedrock configurations used to test the sensitivity of the model to the prescribed bedrock topography. The four configurations are as follows: (a) Flat – All topography is removed. (b) Smooth – A polynomial fit to the Bedmachine data for this location. (c) Sinusoidal – a 20 meter amplitude 14 km period sine wave added to the smooth bed. (d) Bedmachine – The data used in the manuscript. These four configurations were chosen to determine the variation in the solution from flowline scale topography, and kilometer scale features in the topography.

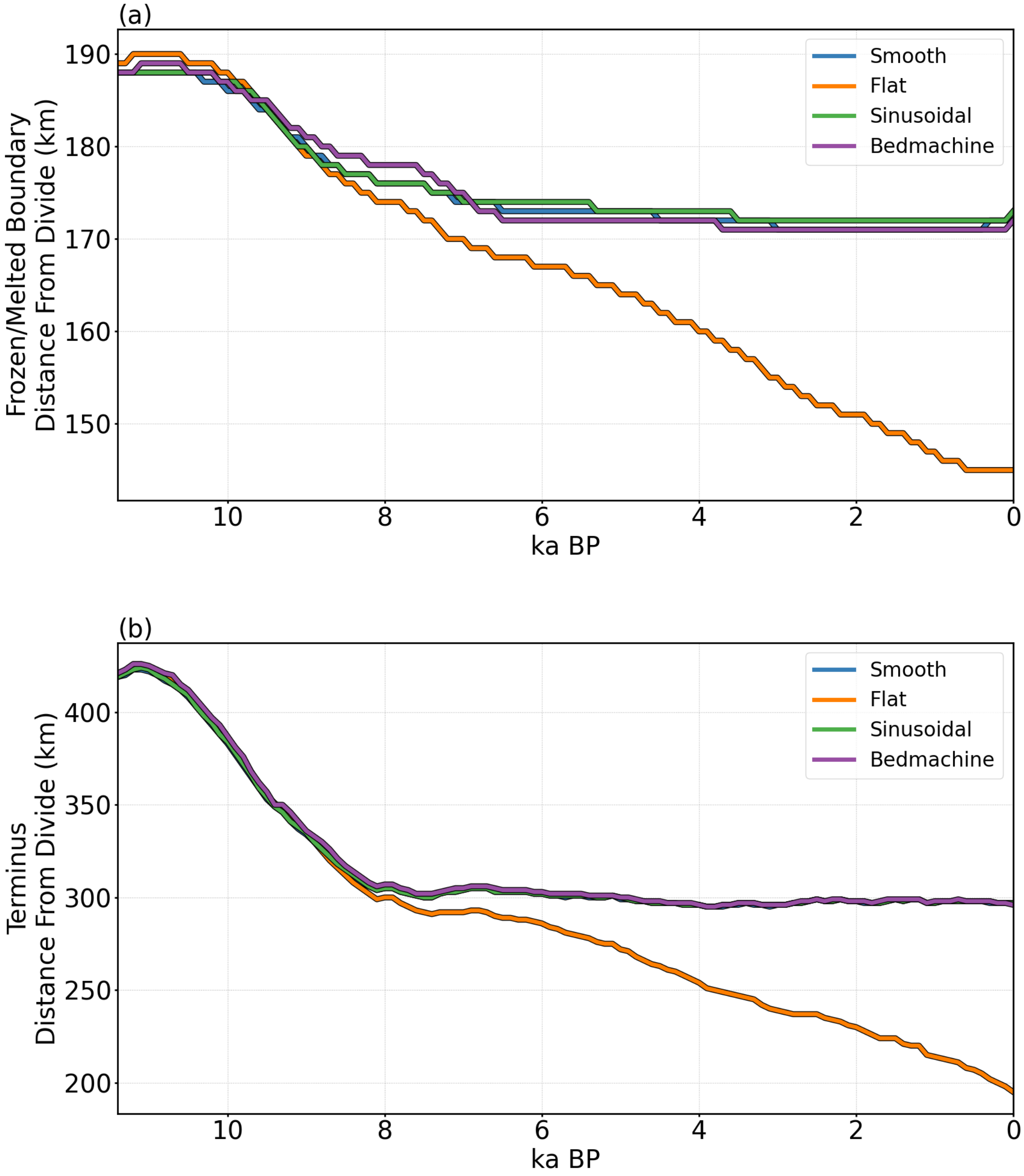

Fig. S3: The frozen/melted boundary (a) and terminus (b) evolution for each bedrock configuration (Fig. S2). Models were run with the same initial ice sheet surface elevations. Each model run was then forced with the same precipitation and temperature forcing. Significant deviation in the results from the Bedmachine bed only occurs with the removal of all topography. When all topography is removed there are significant impacts on the surface mass balance. This is the result of increased ablation at the terminus since the terminus position is generally at a lower elevation during the retreat. As a result, there is increased terminus retreat, which in turn causes more frozen melted boundary migration.

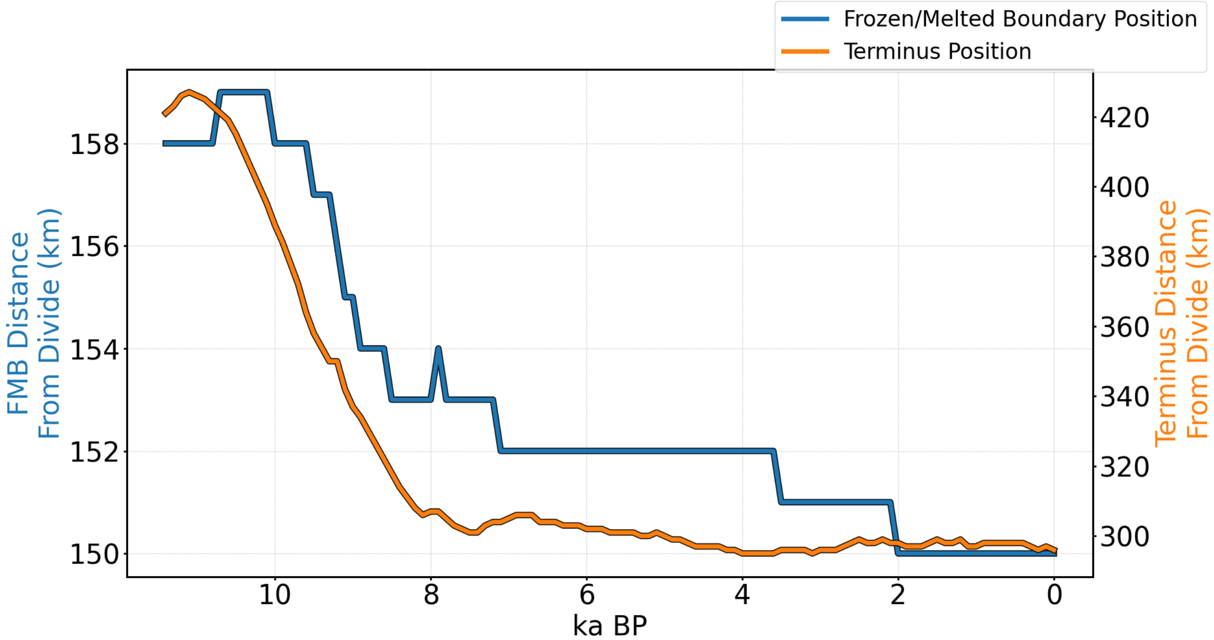

Fig. S4: 50 mW m^{-2} model run location of the terminus and frozen/melted boundary over the course of the simulation, plotted on the same time scale to highlight the correlation (or lack of) between terminus and frozen/melted boundary movement. At this heat flux, frozen/melted boundary migration is still well correlated with terminus movement, but net movement has been significantly reduced.

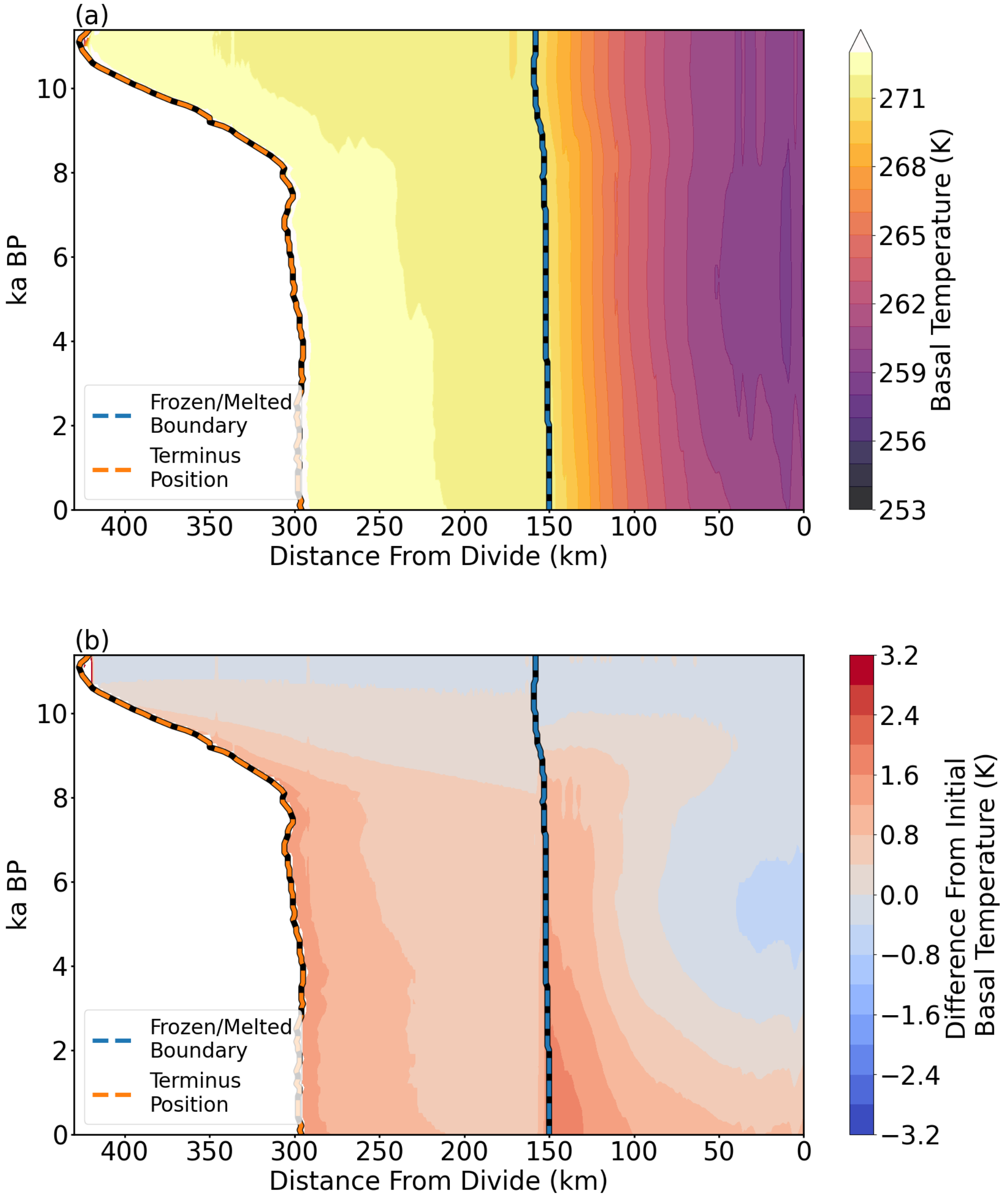

Fig. S5: 50 mW m^{-2} model run basal temperature (a) and change in temperature from initial basal temperature (b) along the retreating ice sheet transect. The dotted orange line highlights the terminus position, and the dotted blue line indicates the frozen/melted boundary position. At this heat flux, the frozen/melted boundary still sits in a region that experiences warming mostly driven by changes in frictional and strain heating.

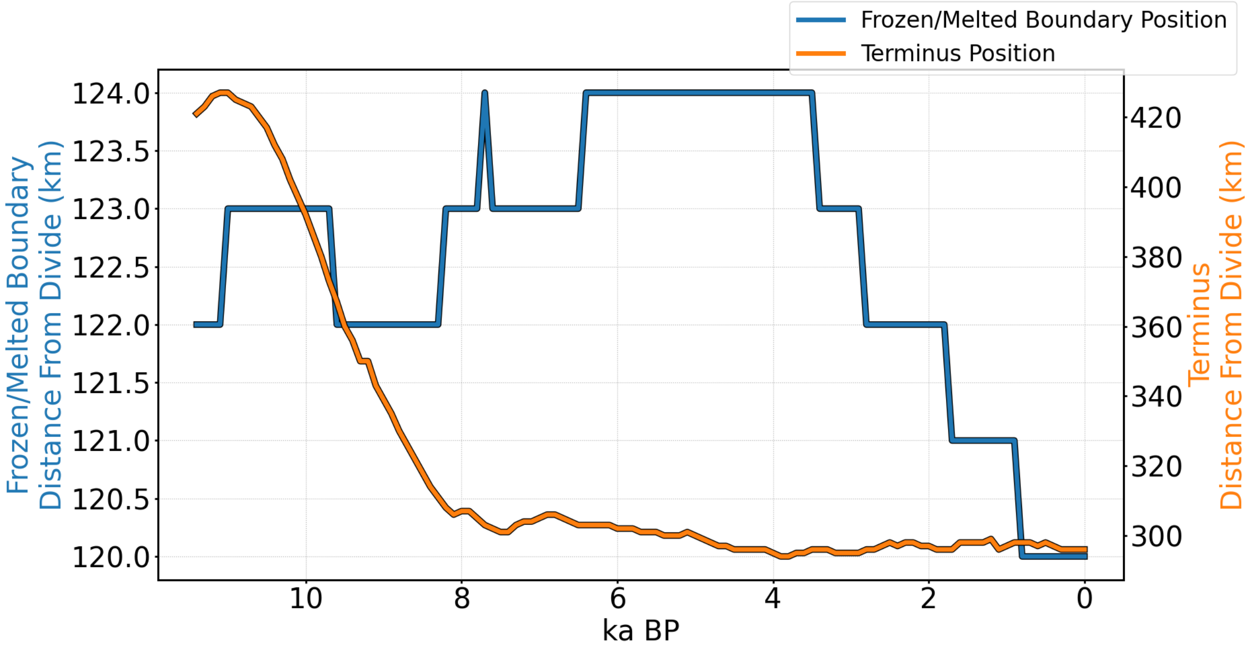

Fig. S6: 70 mW m^{-2} model run location of the terminus and frozen/melted Boundary over the course of the simulation, plotted on the same time scale to highlight the correlation (or lack of) between terminus and frozen/melted boundary movement. At this heat flux, frozen/melted boundary migration is not well correlated with terminus movement, and movement has been significantly reduced.

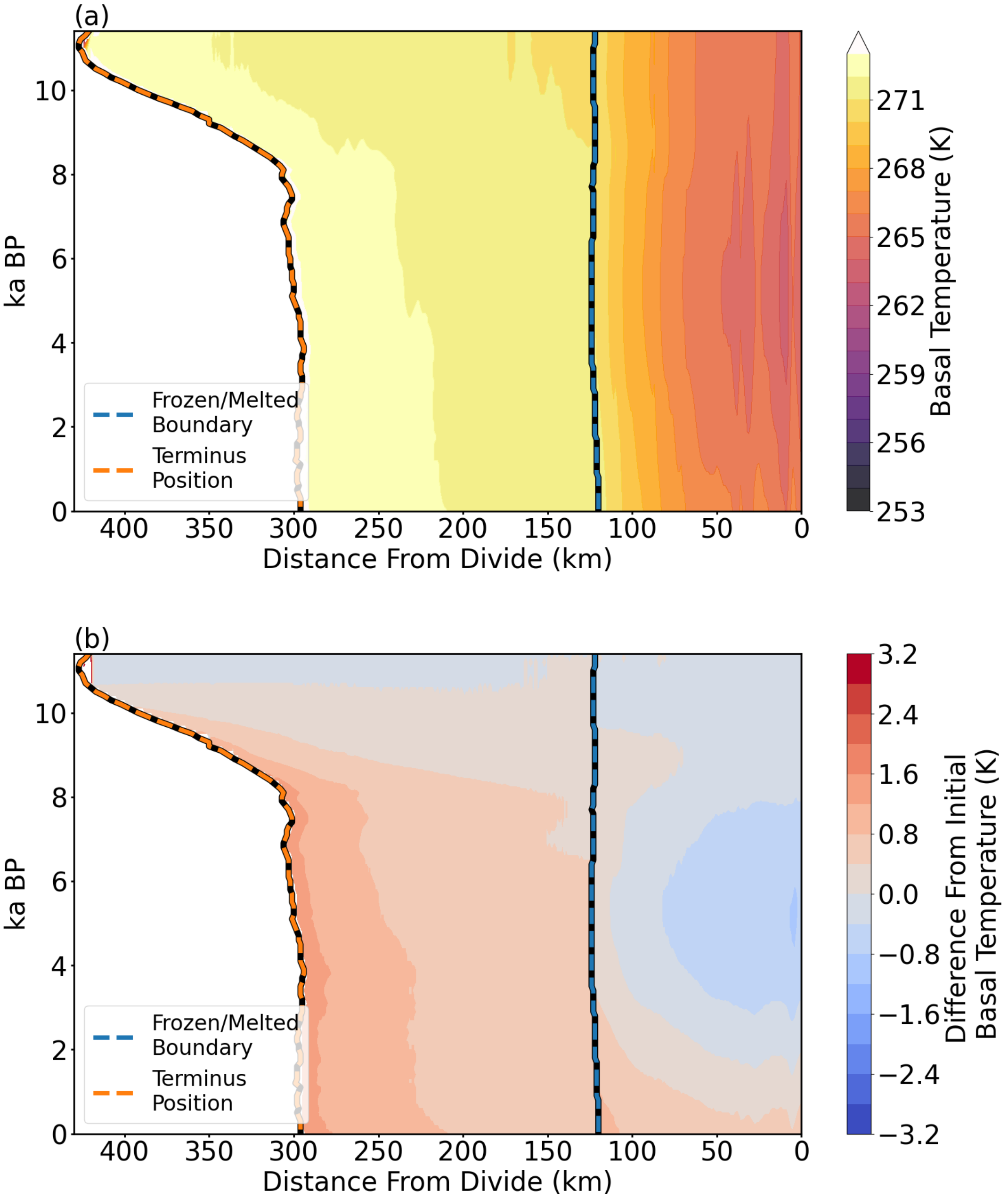

Fig. S7: 70 mW m^{-2} model run basal temperature (a) and change in temperature from initial basal temperature (b) along the retreating ice sheet transect. The dotted orange line highlights the terminus position, and the dotted blue line indicates the frozen/melted boundary position. At this heat flux, the frozen/melted boundary sits in a region that experiences temperature changes that are less influenced by changes in frictional and strain heating.

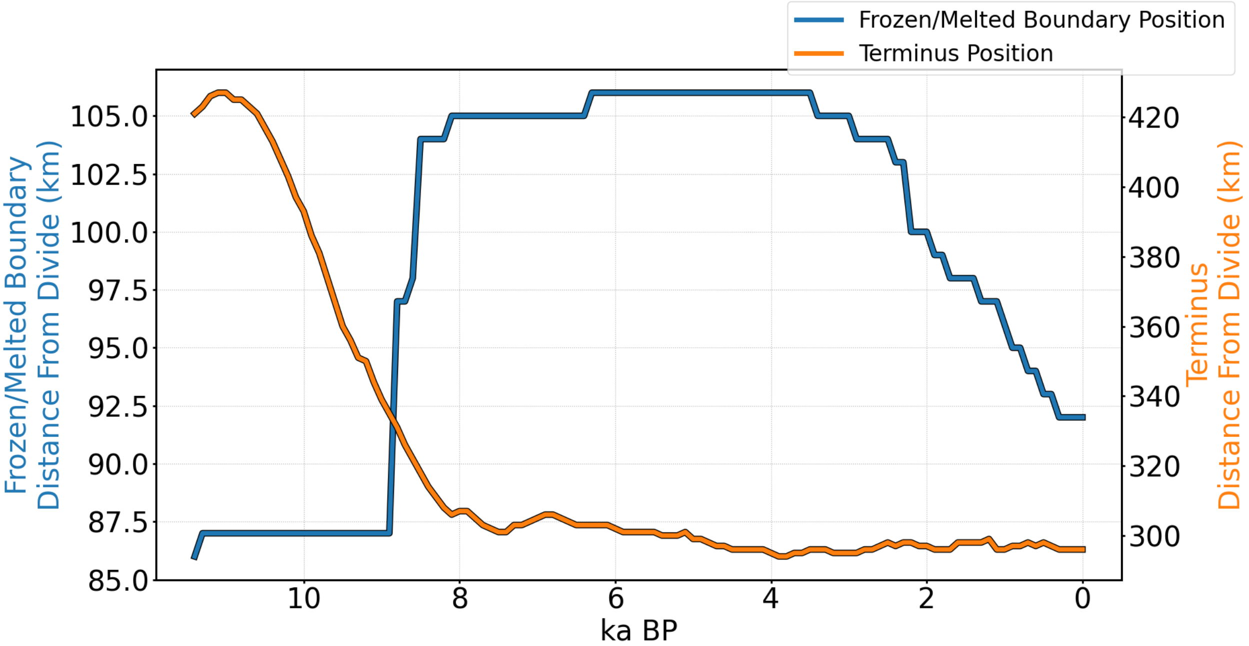

Fig. S8: 80 mW m^{-2} model run location of the terminus and frozen/melted boundary over the course of the simulation, plotted on the same time scale to highlight the correlation (or lack of) between terminus and frozen/melted boundary movement. At this heat flux, frozen/melted boundary migration is no longer well correlated with the movement of the frozen melted boundary. The frozen melted boundary is located near enough to the divide such that changes to the frictional and strain heating are small that they no longer control the movement of the frozen melted boundary.

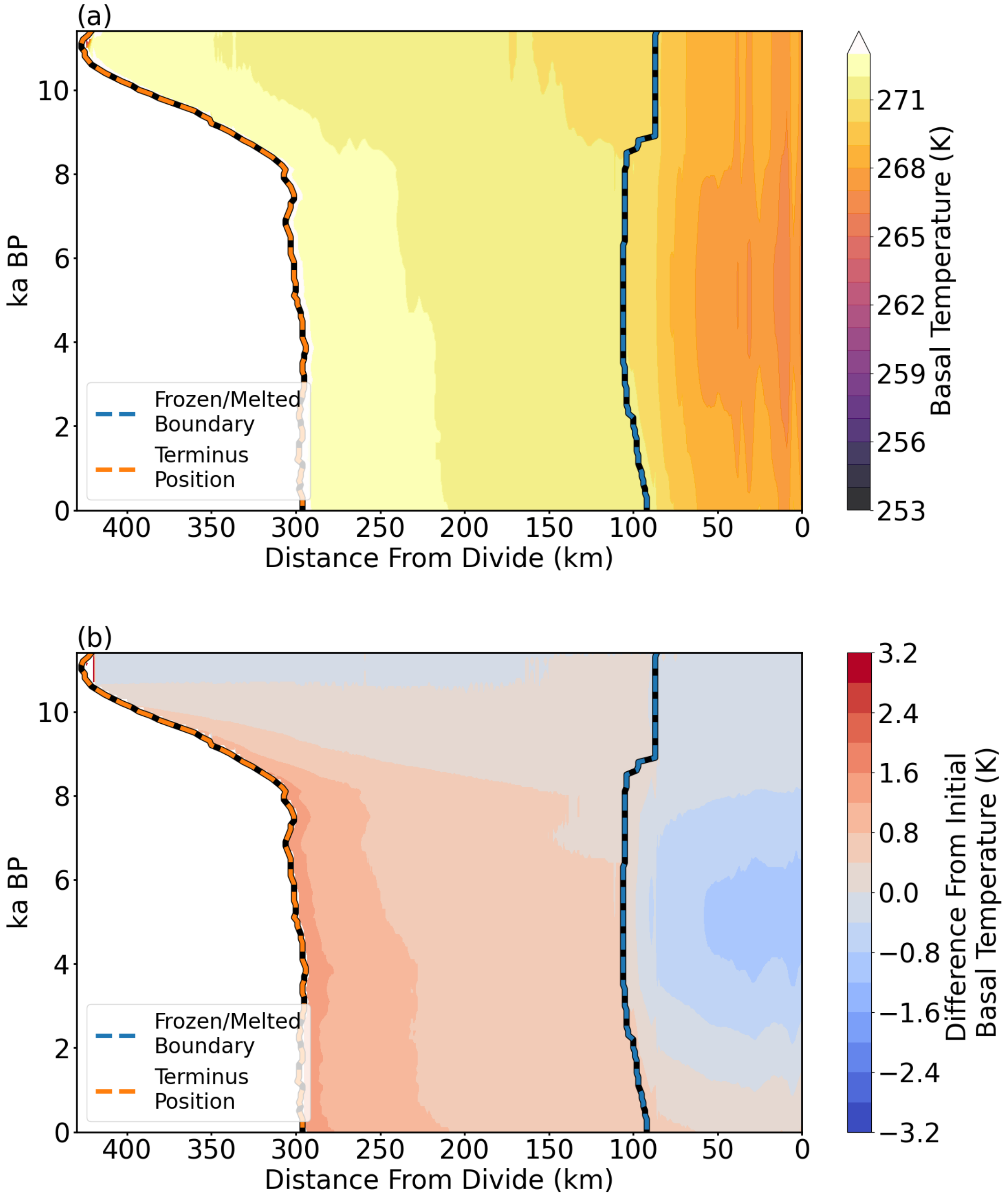

Fig. S9: 80 mW m^{-2} model run basal temperature (a) and change in temperature from initial basal temperature (b) along the retreating ice sheet transect. The dotted orange line highlights the terminus position, and the dotted blue line indicates the frozen/melted boundary position. At this heat flux, the frozen/melted boundary sits in a region that experiences temperature changes that are not influenced by changes in frictional and strain heating. The position is also moves significantly as a result of the cooling that occurs.