Answer to Interactive comment on "Submarine melt as a potential trigger of the NEGIS margin retreat during MIS-3" by Ilaria Tabone et al.

Anonymous Referee #2

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The objective of the study is to test whether submarine melt (ocean warming) could be the primary cause of the ice margin retreat of NEGIS during MIS3 and MIS1 that was recently documented by Larsen et al 2018 using radiocarbon dating of reworked shells in historical (LIA) moraines. It uses the GRISLI-UCM 3D ice-sheet-shelf model to simulate the influence of submarine melt using a variable amount of melt rates. I am not an expert in ice sheet modelling and cannot evaluate if the model set-up is state-of-the-art, but the description of the model set-up is easy to follow and understandable. It also seems to be realistic melt-rates that have been used to force the model. The manuscript is generally well-written, and the model-data comparison provides new and interesting knowledge about the potential effect of ocean warming and submarine melt on the evolution of NEGIS. However, there are a few places where minor revision is warranted. These are listed below.

We are grateful to the reviewer for their positive evaluation of our work. Answers to their specific comments are reported below.

Page 1

Title: I am not aware of the TC politics on using abbreviations in the title, but I would avoid using them. The title could be changed to: Submarine melt as a potential trigger of ice margin retreat of the Northeast Greenland Ice Stream during Marine Isotope Stage 3.

Title changed to: "*Submarine melt as a potential trigger of ice margin retreat of the Northeast Greenland Ice Stream during Marine Isotope Stage 3.*"

L1: Remove "area"

Done.

L5: Why is this a conundrum? – this should be explained in more detail.

We agree that this paragraph needs clarification. We changed it to: "*Alongside, a recent study suggests that the NEGIS grounding line was 20-40 km behind its present-day location for 15 ka during Marine Isotope Stage (MIS) 3. This is in contrast with Greenland temperature records indicating cold atmospheric conditions at that time, expected to favor ice-sheet expansion. To explain this anomalous retreat a combination of atmospheric and external forcings has been invoked. However, the ocean was not brought into play. Here we investigate the sensitivity of the NEGIS to the oceanic forcing during the Last Glacial Period (LGP) using a three-dimensional hybrid ice-sheet-shelf model. We find that a sufficiently high oceanic forcing could account for a NEGIS ice-margin retreat of several tens of km, potentially explaining the recently proposed NEGIS grounding-line retreat during MIS-3."*

L9: MIS-3 = Marine Isotope Stage 3

Changed accordingly.

Page 2

L11-: change to.. . . ..even retreating 70 km behind its present-day position from 7.8-1.2 ka during most of the mid- and late Holocene and 20-40 km from 41-26 ka during Marine Isotope Stage 3 (MIS-3, c. 60-25 ka).

Combining this and other reviewers' suggestions this sentence has been changed to: "*Around 41-26 ka BP during Marine Isotope Stage 3 (MIS-3, c. 60-25 ka) the NEGIS front was ca. 20-40 km farther* *inland than today, then advanced by more than 250 km toward the shelf break at the Last Glacial Maximum (LGM) and retreated again during the last deglaciation, at ca. 70 km behind its present-day position, where stopped most of the mid-and late Holocene (7.8-1.2 ka BP). "*

L12: Stage NOT state

Changed accordingly. It was a typo.

L20: change to (LIG, c. 128-116 ka)

Changed accordingly.

Page 5

L15: change to (c. 116 ka)

Changed accordingly.

Page 6

L20 and L24: I guess it should be the last 45 ka?

We agree with the reviewer, L20 was "45 kyr". Changed accordingly. In L24, however, we were actually meaning "35 kyr" since we were referring to the evolution of the submarine melting forcing, which by construction is cut off at zero at 35 kyr.

L34: change to mid- and late Holocene

Changed accordingly.

Figure 1: I would make the inset map bigger and outline NEGIS – maybe as a panel next to the diagram. It would also be useful if the LIG, MIS3, LGM, Holocene time periods are as shown as vertical bars.

These suggestions have been taken into account when producing the new Fig. 3 (old Fig. 1). The inset map has been substituted by a new stand-alone figure zoomed on the analysed sector showing the location of the outlet glaciers, the observed present grounding-line position, the LGM reconstructed grounding-line positions (max and min), PD observed surface velocities, offshore bathymetry and the onshore ice cover (new Fig. 2).

Figure 3: I would suggest making the figure bigger as it is difficult to see the details in the maps. Maybe an outline of NEGIS could be placed on top of the velocity fields? It would also be valuable for the discussion if the LGM reconstruction of Funder et al and the minimum reconstructions (MIS-3 and MIS1) of Larsen et al could be shown on the maps.

New Fig. 4 (old Fig. 3) is now bigger; the arrows indicating the PD grounding line have been replaced by a thin black curve and the snapshots have been named by the time they represent. Also, the reconstructed LGM extent from Funder et al., 2011 (based on Evans et al., 2009; Arndt et al., 2015, 201; Winkelmann et al., 2010) is added to each snapshot for comparison. Since the minimum extent during MIS-3 provided by Larsen et al. (2018) is inferred from only a couple of locations close to ZI and SG, tracing a 2D prospect of the grounding-line position during MIS-3 would be hard from the limited information on the retreat coming from that work, we decided to not include the MIS-3 minimum reconstruction on the map.

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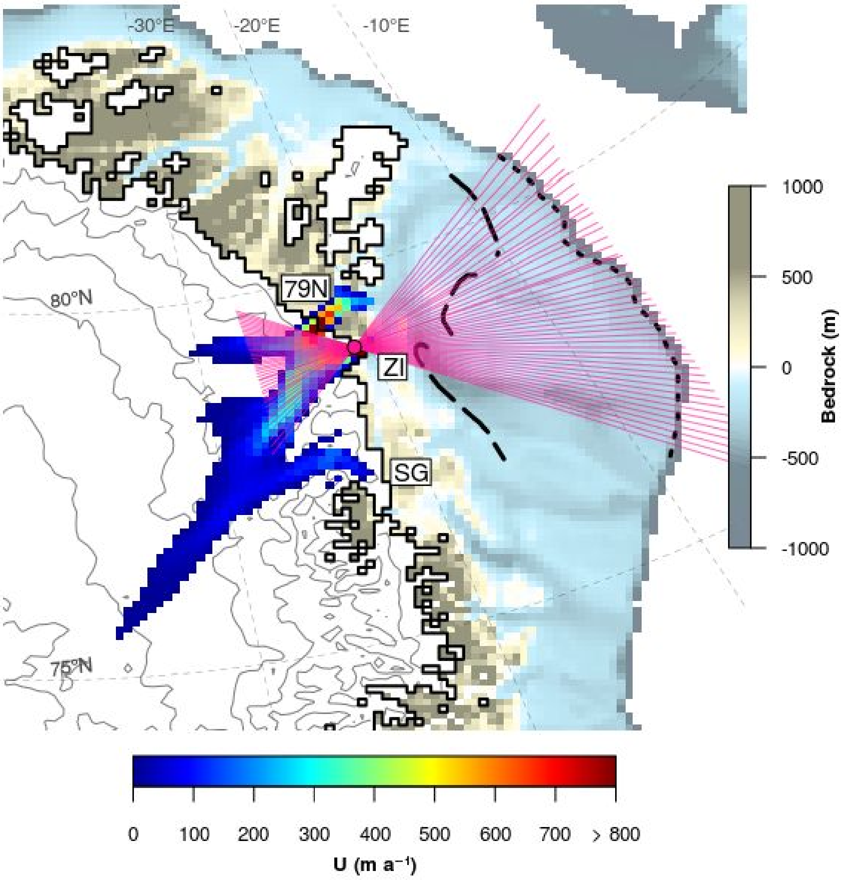
Evans et al., 2009. Marine geophysical evidence for former expansion and flow of the Greenland Ice Sheet across the north-east Greenland continental shelf. *Journal of Quaternary Science: Published for the Quaternary Research Association,* 24, 3 (2009): 279-293.

Funder, Svend, et al. "The Greenland Ice Sheet during the past 300,000 years: A review." *Developments in Quaternary Sciences*. Vol. 15. Elsevier, 2011. 699-713.

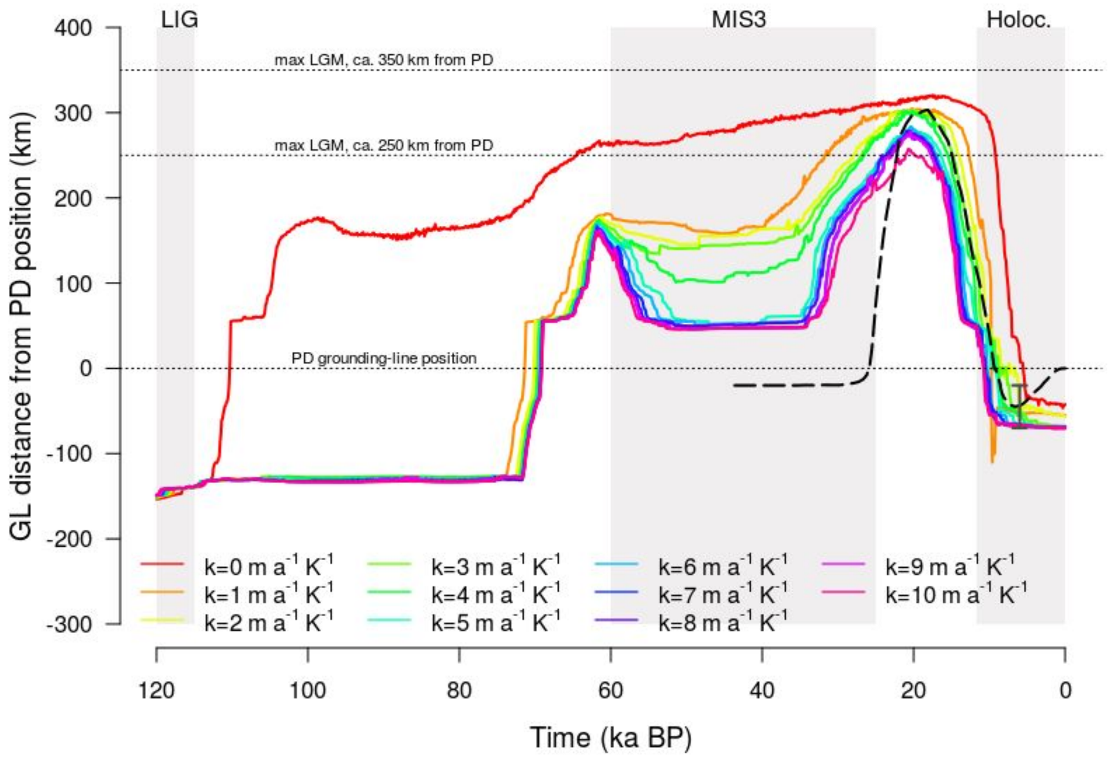
Larsen et al., 2018. Instability of the Northeast Greenland Ice Stream over the last 45,000 years. *Nature communications* 9.1 (2018): 1872.

Winkelmann et al., 2010. Submarine end moraines on the continental shelf off NE Greenland–Implications for Late glacial dynamics. *Quaternary Science Reviews,* 29, 9-10 (2010): 1069-1077.

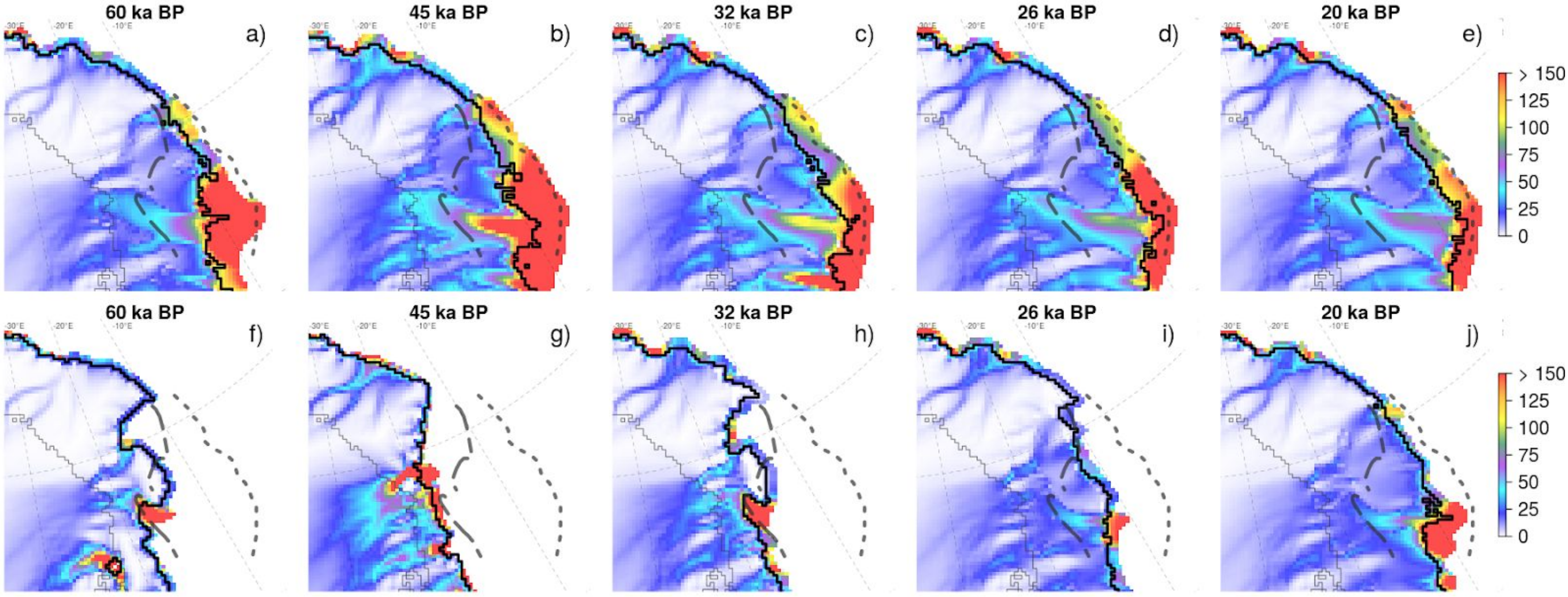
FIGURES:



New Fig. 2. Map of the NEGIS sector showing the location of its three outlet glaciers (79N, ZI and SG), the observed present grounding-line position (solid black line), the observed present surface velocities (from Joughin et al., 2018), the offshore bathymetry and the onshore ice cover (both from Schaffer et al., 2016) and the maximum (dotted black line) and minimum (dashed black line) grounding-line positions reconstructed for the LGM (Funder et al., 2011). The 48 transects used to calculate the evolution of the grounding-line position are shown in purple.



New Fig. 2 (old Fig. 1). Evolution of the NEGIS grounding line relative to its observed present-day position for the set of experiments. The grounding-line distance has been calculated along 48 transects which follow approximately the flow direction of NEGIS ZI glacier towards the shelf break (Fig. 2). Dashed black line shows the reconstruction by Larsen et al. (2018). Shaded regions represent the time periods relative to the LIG, MIS-3 and the Holocene. The three dotted curves show the PD NEGIS grounding-line position (0 km), the maximum (300 km +- 50 km) expected advance of the northeastern part of the ice sheet at the LGM according to Funder et al. (2011) and Larsen et al., (2018).



New Fig. 4 (old Fig. 3). Snapshots of U (m a−1) in total absence of submarine melting (a-e) and in presence of active orbital-driven oceanic forcing (κ = 8 m a−1 K−1 , Bref = 8 m a−1) (f-j) at different times along MIS-3 and the LGM. The black line represents the position of the simulated grounding line. Grey thin solid line represents the observed PD grounding-line position (Schaffer et al., 2016). Maximum (dotted black line) and minimum (dashed black line) grounding-line positions reconstructed for the LGM (Funder et al., 2011) are also shown.