Dear Madam/Sir

An author's response was uploaded on March 18. No further changes were required for the final upload and that response (text included below) has therefore not changed.

I would like to ask the editorial staff to please check that:

- The name "Smith-Johns**e**n" (in title) is correctly spelled (with an "e" in the last syllable)
- The author **Julien Westhoff** is listed. He was accidentally not listed in the earliest version of the manuscript.

Yours faithfully,

Paul Bons

Response already uploaded on March 18, 2021:

Reply to comments on "Comment on "Exceptionally high heat flux needed to sustain the Northeast Greenland Ice Stream" by S. Smith-Johnsen et al., The Cryosphere, 14, 841–854, 2020"

We thank the two reviewers for their encouraging remarks regarding our comment and their suggestions to improve the manuscript. We also sincerely apologise that neither we, nor the reviewers and editorial staff of The Cryosphere noticed the spelling mistake in the first-author's name. The reviewers and the authors themselves all point out two issues with our comment:

1) The authors also published another paper (Smith-Johnsen et al., 2019 - *actually 2020*) that explored the effect of variation in geothermal het flux (GHF) on the modelled ice flow at NEGIS.

Reply: This paper was submitted before Smith-Johnsen et al. (2020a) and is referred to in paper under consideration. Smith-Johnsen et al. (2020b) only considered GHF-scenarios with a maximum of about 135 mW/m^2 (Greve, 2020b). As we write in our comment, GHF values below ca. 150 mW/m^2 are geologically feasible. In the discussion section of Smith-Johnsen et al. (2020b) the authors refer to higher GHF-values "*We use five GHF maps to define the uncertainty bounds in the sampling studies, however, GHF values 10 times higher have been suggested for the NEGIS region (Fahnestock et al., 2001). These were not included here, as they are local findings and not spatially distributed maps, and by excluding these high values, we underestimate the ice flux uncertainties*". The authors do not write that these values are unrealistic, only that these would increase the uncertainty.

2) The paper by Smith-Johnsen et al. (2020a) does point out at various points in the text that it is a modelling study and the authors also mention that the geothermal heat flux (GHF) is "exceptionally" high.

Reply: In our comment, when citing the authors, we did include the caveat "*In our model experiment, ...*". At the very end of the conclusions, the authors write: "*Hence, the minimal heat flux value needed to initiate the ice stream in our model is 970mW/m^2, as proposed by Fahnestock et al. (2001). This magnitude is too high to be explained by GHF alone, and we suggest that processes such as hydrothermal circulation may locally elevate the heat flux of the area*". This final conclusion does not convey the message that this is a "mere" modelling study to show what the effect of a very high GHF would be and that the high

heat flux is questioned, but instead that the GHF alone cannot provide the necessary heat, and that therefore other processes may be needed instead, such as hydrothermal circulation. In our comment we discuss various processes (including hydrothermal circulation) that could be invoked to elevate the effective heat flux that reaches the bedrock surface and come to the conclusion that it is geologically unlikely that any could raise the value to anywhere near 970 mW/m^2.

Whether the authors are aware of, or even in their paper discussed the issues with very high or exceptional heat fluxes is not the main point here. The title of the Smith-Johnsen et al. (2020) paper conveys a strong, clear and unambiguous message: "*Exceptionally high heat flux needed to sustain the Northeast Greenland Ice Stream*". It is this "take home message" (without ifs or buts) that we take exception to and we think the reviewers support us in expressing our concerns through our comment.

Changes made (new text in red font):
Throughout: Correct spelling mistake in first author's name; again apologies for that.

Line 15: Reviewer Holschuh: Ultimately, the work of Smith-Johnsen et al. is not enough for you to conclude that NEGIS does not require elevated geothermal flux. You can, however, conclude that the melt rates must be lower than those proscribed in Smith-Johnson et al. This could be fixed with a simple change to line 15: "Thus, fast flow at NEGIS must be possible without the extroardinary melt rates invoked in Smith-Johnson et al."
Action taken: Following the suggestion by Reviewer Holschuh, we replaced the original sentence "NEGIS is thus formed and controlled by some other, yet unknown, process" with "Fast flow at NEGIS must thus be possible without the extraordinary melt rates invoked in Smith-Johnsen et al."
Line 22: Reviewer Holschuh: This quotation contains the operative words: "in our model experiment". It is important that proper emphasis is applied to that aspect of their conclusions.
Action taken: The original text was: "They conclude that *"In our model experiment, a minimum heat flux value of 970 mW m^{-2} located close to the East Greenland Ice-core Project (EGRIP) is required locally to reproduce the observed NEGIS velocities, giving basal melt rates consistent with previous estimates. The value cannot be attributed to geothermal heat flux alone and we suggest hydrothermal circulation as a potential explanation for the high local heat flux"*. To emphasise that this is based on a model experiment, we changed this to: "They conclude that *"... a minimum heat flux value of 970 mW m^{-2} located close to the East Greenland Ice-core Project (EGRIP) is required locally to reproduce the observed NEGIS velocities, giving basal melt rates consistent with previous estimates. The value cannot be attributed to geothermal heat flux alone and we suggest hydrothermal circulation as a potential explanation for the high local heat flux"*. It should be noted that this statement is preceded by the caveat *"In our model experiment"*. "
Line 95-99: Reviewer Holschuh: suggests replacing the last sentences with: "Given that the extraordinary heat flux invoked in Smith-Johnson et al. (2020) cannot exist at NEGIS, there must exist some other weakness in the NEGIS system that enables fast flow that is not captured by their model. While we cannot rule out a supporting role for geothermal flux at NEGIS, the flux required to produce extreme basal melt invoked by Fahnestock et al., and Smith-Johnson et al. is geologically implausible, leaving open many questions about the dynamics of the NEGIS system." **Reviewer Ebbing** also suggests rewording these sentences.
Action taken: We took some of the suggested text from the reviewer and merged that with the original text: "Even though the extraordinary heat flux invoked in Smith-Johnsen et al. (2020) cannot exist at NEGIS, their model results are definitively useful. They indicate that some other weakness exists in the NEGIS system that enables the fast

flow, most likely with a supporting role of geologically plausible heat fluxes. The studies by both Fahnestock exwwt al. (2001) and Smith-Johnsen et al. (2020) thus highlight the exciting challenge still ahead to truly understand ice streams such as NEGIS and ice-sheet dynamics in general." Two references were removed accordingly.

Other edits:

- Missing reference to Rezvanbehbahani et al. (2017) added to reference list.
- Author J. Westhoff was accidently omitted from the author list and now added.

References for this reply:

Greve, R.: Geothermal heat flux distribution for the Greenland ice sheet, derived by combining a global representation and information from deep ice cores, Polar Data J., 3, 22–63, 2019.

Smith-Johnsen, S., de Fleurian, B., Schlegel, N., Seroussi, H., and Nisancioglu, K.: Exceptionally high heat flux needed to sustain the Northeast Greenland Ice Stream, The Cryosphere, 14, 841–854, doi:10.5194/tc-14-841-2020, 2020a

Smith-Johnsen, S., Schlegel, N.-J., de Fleurian, B., and Nisancioglu, K.: Sensitivity of the Northeast Greenland Ice Stream to Geothermal Heat, J. Geophys. Res.-Earth, 125, e2019JF005252, 2020b