

Author comments: Generating synthetic fjord bathymetry for coastal Greenland

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Review by: R. Timmermann

We thank the reviewer for their supportive comments and have made corrections in line with the provided suggestions, much improving the original manuscript.

1. *page 2, l. 5-6: The “physically unrealistic morphologies” in the Bamber et al. (2013) dataset have also been recognized by Schaffer et al. (2016) when putting together RTopo-2 – although the approach to overcome the issues there was much more heuristic than what is presented in this paper. Still, you may want to add the Schaffer et al. (2016) work to the list of studies aiming for an improved representation of Greenland fjord topography in a bed-to-bathymetry DEM.*

This new compilation is now acknowledged in the new manuscript. We now include:

“...towards the ice sheet margins. The development of the RTopo-2 provides another response to the limitations of Bed2013 within fjord regions, with improvements being made by including new observational data (Schaffer et al., 2016)”

2. *page 3, l. 9: I couldn’t do much with the word “acknowledged” here.*

We have removed “acknowledged” from the sentence.

3. *page 3, l. 25: I suspect that the “and,” at the end of the line was not intended to be there. I think this can nicely be two separate sentences.*

This now reads: “...variogram function (Deutsch and Journel, 1998). Using this it is possible...”

4. *page 4, l. 18: I suggest to make it “low-resolution” (because it makes it easier to see that the “large” belongs to “datasets”, not to “resolution”)*

We agree. This has now been altered to read: “...are apparent in low resolution datasets particularly...”

5. *page 5, l. 127: “a flat spectra” sounds wrong to me*

By ‘flat spectra’ we simply mean that there is a regime where that the power spectral density is (near) independent of frequency. These term is in common usage in signal processing, and we see no problem with the usage here. However, for clarity we now say: “flat region of the power spectra”

6. *page 7, l. 5: It’s actually a path integral of a constant number (most likely One), isn’t it? “Along-track distance” or just “length” would be simple words for it.*

We now use the term “path length” instead of “path integral”.

7. *page 7, l. 16: I’ll have to admit that I could not do much with the word “transform” here.*

This has now been rewritten to read: “...we calculate the distance of all locations between land/ice and ocean within the channel (d), from which the...”

8. page 7, l. 24: manor -> manner

Done.

9. page 7, l. 30-34: *It is clear that some of the potential paths have to be removed along the track, but I'll have to admit I fail to understand the explanation why step 4 does this job the way it is supposed to be. Any chance to put this into some simple descriptive words illustrating the idea and the reasoning?*

The lack of transparency of this step was also highlighted by reviewer 1, to whom we responded with the following:

The referee is correct to note that these parameters are somewhat arbitrary. Ultimately, they are chosen so that at least one path is found for each fjord, but not many more. We plan to formalise this process for the final DEM product

Essentially, what we are doing here is solving a optimization problem many times to find the optimal paths between a large set of start- and end-points, then choosing a subset of the them such that there is only one path between each pair of close start and end points. We have complicated the process somewhat by attempting to carry out the path generation and selection at the same time, in order to avoid the large number of paths that we would otherwise need to consider.

The predefined distance interval is a simple finite difference parameter, and is picked so that there are enough nodes on a path to resolve it – this would be the same however we implemented the above. The ideal (but unattainable) value would be zero.

The relationship between child and parent edges is chosen to be small enough allow the path to turn quickly enough to follow the channel, and large enough so that the minimum radius of curvature is of the order of one channel width. The ideal value would be 2π , and restricting it simply anticipates the expectation that paths containing many loops will ultimately be rejected. In other words, this keeps paths close to the locally optimal direction, but allows some latitude so that branches can form.

The angle between new paths ($\pi/24$) is another finite difference parameter – we cannot consider the continuum of angles spanning $(-\pi/6, \pi/6)$. Again the ideal value would be zero and we reduce it progressively until the same (or similar enough) set of paths are generated.

The values $|x-x_i|, |y-y_i| < 16$ km are chosen to identify similar paths. The first two are chosen such that one of a set of seeds is identified within a small number of generations, if the paths that start from from them appear to be converging.

The condition $|a-a_k| < \pi/8$ is also chosen to identify similar paths. The angle must be greater than zero to allow branches to form from paths which are identical up to the point of the branch, and persist provided they arrive at distinct end point. A smaller angle reduces the number of branches in play at any one generation.

We have added additional text to section 3.1 to add further clarity.

10. page 8, l. 7: I think the explanation for step 7 is easier to understand if the words “When considering the length of all complete paths,” are removed and the sentence simply starts with “Where ...”.

Done.

11. page 9, l. 17: I think there should be no comma after “parameters”.

Removed.

12. page 13, l. 22: I suggest to remove the paragraph break here. Maybe the sentence in l. 20-22 can be rewritten to clarify that the improvement is an improvement compared to Bed2013, with OBS1516 as a reference what the targeted truth is.

The paragraph break has been removed and this has now been rewritten:

“Considering centreline profiles for all fjords, we illustrate the improvements made to the general elevation profile of each fjord (Fig. 12) relative to those present in Bed2013, by considering the general agreement between the synthetic geometry and OBS1516.”

13. page 14., l.1: I think “provided” or “presented” is better here than “illustrated”

We now use presented.

14. page 15, l. 10: “_at_ a significant distance” ?

We now write “...at a significant distance...”

15. page 16, l. 21: “high-frequency” ?

We now ensure all uses of “high frequency” are hyphen-free.

16. page 16, l. 34: should it be “_for_ Bed2013” ?

Yes – this is now corrected.

17. caption to Figure 5: Even with the electronic version in front of me, the “Please refer to the online version of this article to make use of references to colour.” bit fails to make sense to me.

This has been removed.

18. caption to Figure 8: I suggest to make it “along-transect” at both locations

Done.

19. Figure 9: The figure shows that SynthBCAO and SynthOBS give very similar results, which is good and demonstrates the ability of the method. However, I miss a possibility to directly compare to the OBS1516 data. Would it be possible to replace the grey area in panel a, which just indicates data coverage, by the OBS1516 elevation data? Keeping the extent / data coverage information of course (white areas remain white).

Yes – this is now implemented.

20. caption to Figure 11: *I am sure the last sentence can be formulated in an easier way (still making the point to be made)*

We have reworded this to:

“Positive differences (red) occur where the subtrahend is deeper than the minuend, with negative differences (blue) occurring where the subtrahend is shallower than the minuend.”

21. *In general, I miss a statement (e.g. in the Summary) on how many manual steps are required during the procedure. Manual steps are mentioned at several locations in the manuscript, but I wonder how much work it would be to do this for, let's say, entire Greenland.*

We have added this to the end of the discussion:

“This paper provides a proof of concept routine for constructing geomorphologically realistic fjord geometry in the absence of observations. Actual implementation of the presented routine for large regions (e.g. the Greenlandic coast) would require manual intervention in so far as (i) identifying a seed elevation at the head of the channel and (ii) defining an end zone (e.g. the fjord mouth). Step (i) could be achieved by using a nearest neighbour approach to acquire the nearest elevation to a given seed location. A solution to step (ii) could be by using an observation density grid where the end zone is identified as being a location with an observation density greater than a chosen value. In addition to this, the values necessary to prevent the development of closed circuit artefacts would have to be adapted to the width of the fjords for which the method is implemented.”

In addition to the changes made in response to the above comments, we have made some additional amendments.

Fig. 10: We have adjusted the panels and the coverage in (a) is now slightly more restricted than was presented in the original manuscript – the new coverage does not affect any of the analyses within the presented manuscript other than the reported statistics with regard to differences between Bed2013 and OBS1516 (section 4.1). We have also corrected the description of the under- and over-estimates indicated by the colour scale bar.

Fig. 13: Improved resolution