

## Anonymous Referee #2

Review of tc-2018-230 Spatiotemporal Distributions of Icebergs in a Temperate Fjord: Columbia Fjord, Alaska by S. Neuhaus et al

### General comment

The paper analyzes the distribution of icebergs within the Columbia fjord using high resolution (0.5 m) visible satellite images (10 covering a 8 months period in 2013). Classical image processing tools (from Matlab) are then used to detect and estimate the size of the icebergs within the fjord. The results are validated by comparison with manual analysis for selected scenes. The results of the images analysis are then used to compute the time/space distribution of iceberg and the evolution of the distribution of the icebergs' size in time and location within the fjord. The analysis reveals the complex distributions of the iceberg within the fjord as well as the seasonal variability related to the glacier calving rate.

The results are of interest and are worth publishing. However, the motivation of the study should be stated more clearly and if the implication for the future of Greenland icebergs (if kept) should be better justified.

The study is also limited to 8 month and 10 images where certainly much more are available. I know that image processing is quite hard and fastidious but at least the authors should justified why they limited their study to this short data set. Paragraph 4.3 and 4.4 need to be better focused on real results and not on quite shallow general discussions. The distribution of volume and the evolution of the size distribution are important results by themselves. I think that the study could also be improved if simple computation of freshwater flux using ice volume and classical melting law were conducted and presented.

*Authors' Response: We would like to thank the reviewer for their comments.*

*We would like to thank the reviewer for drawing to our attention the fact that our discussion of Columbia Fjord as a potential future Greenlandic fjord is too general. We have made sure to address this in our revisions. Instead of justifying our study by presenting Columbia Fjord as a potential future Greenland fjord, we have focused our manuscript on the more specific implications of our results. We have amended section 4.4 so that it is now a more detailed comparison of our findings to measurements which have been previously published in papers covering the topic of icebergs in fjords.*

*We have also worked on section 4.3 to make it less general and more focused on our results. We have done this by adding estimated iceberg melt from melt equations published in Bigg et al. (1997), as well as presenting salinity profiles taken inside Columbia Fjord during our study period by the US Geological Survey.*

## Specific comments

Page 1 line 8 outlet=> outlet

*Authors' Response: We appreciate the reviewer catching this typo. We have corrected it.*

- Page 1 line 20: Coloumbia==> Columbia

*Authors' Response: We appreciate that the reviewer caught this typo as well. We have corrected it.*

- Page 1 line 20 Considering the difference of temperature between Greenland and PWS water and the different conditions of the Greenland fjords this remark is certainly way to general.

*Authors' Response: We recognize that our comparison of Prince William Sound in Alaska and fjords in Greenland was far too general. We are currently working on correcting this.*

- Page 3 lines 15-20. For people not familiar with WorldView Satellite explain why there are sometimes two images from the same satellite at the same time. The sentence on the hundredths of second separation is quite useless.

*Authors' Response: We agree that there should be an explanation of why the WorldView Satellite would take two images only minutes apart. The images were taken for the purposes of DEM creation using stereo imagery. We have thus added in a few sentences in Section 2.1 explaining this. We have also removed the sentence mentioning "hundredths of a second" because it is unhelpful.*

- Page 3 line 23 and following; As the study fully relies on the detection and analysis of the WW1 images, it is important to at least present an example of detection (on an image detail) at best to provide the analysis of all images in Supplementary Information.

*Authors' Response: To give readers a better idea of what we have done, we have added in an example of iceberg detection to figure 2, as well as adding in a sentence referencing said figure.*

- Page 4 lines 23-26. It is not explain what is the difference between a and b images ( see my previous comment). If this is related to different viewing angle it is important to precise it as it might explain the different result (that could be due to a difference in effective resolution). I don't understand the November 19 case (not enough information). There again it could be related to viewing angle and specular reflection on open water (wild guess as we don't have the data and there are not freely accessible).

*Authors' Response: Because on a few instances there were two sets of stereo images taken, we had two images taken on the same day. We labelled these images 'a' and 'b' respectively. We have now added in a few sentences distinguishing 'a' and 'b' images to the text, as well as mentioning that the difference in iceberg identification could be due to viewing angle. Changing the angle at which we view the ocean changes the reflectivity of the ocean, which could therefore affect which pixels were identified as ice versus water.*

- Page 4 line 32. Why May 06 (a b) is not included? Provide explanation. reference to figure 4 should be included.

*Authors' Response: Omitting May 06a from the figure was a mistake on our part. We have fixed this by adding the icebergs from May 06a into figures 4a and 4b. We have also added references in the text to these two figures.*

- Page 5 line 13-14, The sentence is not very clear. The pdf is computed on the following bins.

*Authors' Response: We have re-worded this sentence to make it less confusing.*

- Page 5 & 2.4. This paragraph presents two methods of estimation of the iceberg volume from the satellite iceberg area (which might be different from the waterline cross-sectional area if the water is very clear). A is not a proxy.

*Authors' Response: We do not use waterline cross-sectional area as a proxy for iceberg volume as we actually calculate iceberg volume using two different methods. We have removed the mention of using waterline cross-sectional area as a proxy.*

- Page 6 line 7-. I think the authors recompute the albedo using fixed ocean and ice value to eliminate solar angle and atmospheric influence but it is not stated.

*Authors' Response: Yes, we calculated the albedo using this method in order to avoid issues with atmospheric interference as well as the angle at which solar radiation hits the ocean. We have added in a sentence stating this more clearly.*

- Page 6 line 18-20 Where is the 95% coming from. Figure 4 and 5 don't present proportion but numbers and area. Figure 4 should use a log colorscale to reveal more details of the distribution within the fjord.

*Authors' Response: 95% of all the icebergs identified in this study had a waterline cross-sectional area less than or equal to  $100 \text{ m}^2$ . As this is not readily discernible from the figure, we are amending it, as well as re-wording the text to make this more clear. We have also changed the colorscale of figure 4 to be logscale in order to emphasize iceberg distributions in the fjord.*

- Page 6 line 20-24. I don't understand the purpose of this remark. It is part of the detection and analysis method and should be treated there.

*Authors' Response: We have moved this to the methods section.*

- Page 6 line 25. Please mention figure 6 from the beginning of the &.

*Authors' Response: We have added in a reference to figure 6 in the first sentence of the paragraph.*

- Figure 6. For May 6 b and Jul 11 there are only estimates for the proximal zone certainly because of the partial coverage. Is it really necessary to keep those two images as they don't really bring any special information/results.

*Authors' Response: Despite the fact that there is incomplete coverage for the fjord on May 06b and July 11, we believe there is value in representing the partial data in the figure. The power-law exponents for these two dates show agreement with the power-law exponents in the proximal zone for the other dates in the same seasons.*

- Page 7 line 13-15. The comparison of the thickness for a given A using 2 and 3 explains completely the difference observed in Table 3. What is important to note here is that the variations of the total volume, and percentage of volume for large icebergs are very similar using the two formulas although they give very different iceberg thickness (this is certainly due to the strong impact of the power-law distribution of the distribution of the ice volume).

*Authors' Response: This is a very good point. We are now addressing this in the text.*

- Page 7 line 19. The summer increase of albedo could implies that the fragmentation is increasing in warmer waters.

*Authors' Response: This is an interesting point. We have added a sentence addressing this into the discussion section.*

- Page 7 line 21-25. It is important to explain in detail the computation of the residence time.

*Authors' Response: We have clarified our computation of iceberg residence time by stating our methods more explicitly.*

- Page 8 line 23-25 In fact power-law and lognormal are quite similar and power-laws (which do not converge (tend to infinity in 0) ) can be used to approximated the tail of lognormal distributions.

*Authors' Response: This is an interesting point, and something we are working to address in the manuscript.*

- Page 9 line 7-17 Two recent studies one from Bouhier et al (<https://doi.org/10.5194/tc-12-2267-2018>) and one from Crawford et al (<https://doi.org/10.1029/2018JC014388>) presented size distributions of pieces resulting from icebergs fragmentation with slope close to -1.5 (i.e. the mid fjord summer slope). The two studies mentioned that this -1.5 slope is in general associated to fragile fragmentation and could in this case indicate that during summer month the main driver of the size distribution within the fjord is the fragmentation.

*Authors' Response: We very much appreciate the reviewer bringing these two studies to our attention. We have used their findings, as well as those from other studies of iceberg fragmentation, to expand on brittle fragmentation. We agree that the power-law exponents we find in this study indicate that there is more brittle fragmentation of icebergs during the summer months than the spring or fall. We have added in a number of sentences to the discussion on this topic.*

- Page 9 line 26-27 In fact when computing power-law distribution there is always some problem with the tail of the distribution just because the numbers of samples is too low.

*Authors' Response: The reviewer makes a very good point. We have added in a sentence explaining this in the methods section where we first mention removing the tail of the distribution to achieve a better fit.*

Page 9 line 30. This is a direct consequence of the power law distribution.

*Authors' Response: We agree with this point, and have added in a statement pointing this out in the manuscript text.*

- Page 9-10 &4.3 This paragraph is not very clear and don't present any significant results. It could be of interest if the volume of ice and melting law were used to estimate the fresh water flux from each image.

*Authors' Response: We recognize that this paragraph is too general and does not present significant results. We have re-worked this paragraph to focus more on results, and have created a new figure accompanying this paragraph comparing iceberg keel depths to salinity profiles in the fjord to visually represent the contribution of freshwater from icebergs at various points along the fjord length. In addition, we have made estimations of iceberg melt using an equation from Bigg et al. (1997), which we were able to use by making assumptions about fjord conditions and iceberg velocity.*

- Page 10 &4.4 There is no data in winter in your study.

*Authors' Response: In the arctic, the sea ice maximum extent is reached in March. Because there is no sea ice present in our March imagery, we made the assumption that there was no significant sea ice present in the fjord.*

- Page 11 line 1 Where is 11% mélange coming from (not from Table4).

*Authors' Response: We calculated the mélange by subtracting the total number of ice pixels by the number of ice pixels that are identified as part of an iceberg. We have included our calculations of mélange into the methods section.*

- Page 11 line 14-15. The computation of the iceberg surface is not obvious. It should be given (in annex).

*Authors' Response: We agree that we do not explicitly explain our calculations of iceberg surface area. We are adding the explanations of iceberg surface area calculations into the methods.*

- Page 12 line 4-6. The -1.5 slope could indicate that there is more fragmentation during summer.

*Authors' Response: We agree with the reviewer on this point. We have therefore edited this sentence to include brittle fragmentation.*