

Interactive comment on “Melting and fragmentation laws from the evolution of two large southern ocean icebergs” by Nicolas Bouhier et al.

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[british,english]article

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Reply to referee's comments

February 13, 2018

The authors wish to thank referee 1 who spent time to correct many grammar and spelling mistakes and to provide us with many useful comments.

Anonymous Referee #1

Received and published: 14 December 2017

GENERAL COMMENTS:

This manuscript presents an interesting analysis of the decay of two large icebergs, as tracked from satellite imagery and from altimetry. The ice bergs both decrease in size over time. The data products together show thickness and horizontal extent of the ice bergs, so the investigators are able to distinguish mass loss due to melt (change in thickness) vs fragmentation (changes in surface area). Results show that fragmentation is the major source of mass loss for large ice bergs. The study then assesses the details of melting and fragmentation. The authors compare two melt models, one associated with thermodynamics and a second based on thermodynamics, and find that the turbulent thermodynamic model better represents the observations. They then

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examine the statistics of fragmentation by looking at pdfs of ice berg sizes. I particularly appreciate the assessment of the results in the context of both melting and fragmentation theories.

The analysis is thorough and the results are likely to attract broad interest. However, it will require more careful editing prior to publication. My detailed comments follow:

I have reviewed the list of 15 questions in the instructions for reviewers, and of these questions, only a handful raise concerns, as follows:

(5) Are the results sufficient to support the interpretations and conclusions? For the most part results are sufficient. It would be preferable to include formal uncertainty estimates in the figures, where possible.

(11) Is the language fluent and precise? As noted below, the language could be improved.

(12) Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? As noted below, mathematical symbols have suffered from a font substitution problem, which should be corrected if possible in future pdf versions.

We checked the pdf and did not find any font substitution. May be the problem comes from the referee printer?

SPECIFIC COMMENTS:

(1) For this assessment of time series of iceberg properties, assessment of uncertainty are important and should be included. In particular, some of the quantities in Figures 4 and 5 should be plotted with uncertainties. Others might be OK with uncertainties indicated in the figure caption.

We introduces the uncertainties estimates provided in the previous study (Tournadre et al 2015). We choose not to include the uncertainties in the plot because it overloads the figure.

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(2) The summary raises some interesting points about possible overestimates in previous studies of freshwater flux due to icebergs. But I haven't found a clear estimate of freshwater flux in this study. Is it possible to provide a concrete number?

We provide general estimates in the text.

(3) Mathematical notation is not type-set with embedded fonts. My print out has "square root" symbols in place of "less than or equal" and "greater than or equal" signs for the inequalities on line 6 of p. 2. Likewise, vectors in equation (3 have lost their arrowheads in my printout. For a journal that people read from downloaded pdfs, this is especially challenging. I admit that the cryosphere models are outside my domain of expertise, and I have trusted the authors on these and have not attempted to work through the background literature to evaluate their appropriateness.

I think the problem comes from the reviewer's printer or computer. We check carefully the pdf on the TC website and did not find any problem with the math and equations.

DETAILED COMMENTS:

(4) References are not cited correctly in many places, and a number of references that should be in the main text have been embedded in parentheses. This needs to be proofread carefully for citation style.

We check the reference and remove unnecessary parentheses.

(5) The writing, while generally OK, includes passages that are difficult to understand. I cannot possibly identify everything, and I encourage the authors to locate a native English speaker who can help them proofread in detail.

We has the manuscript proofread by a Canadian colleague.

(a) Here is my suggested rewriting of the abstract:

The evolution of the thickness and area of two large Southern Ocean icebergs that have drifted in open water for more than a year is estimated through the combined

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analysis of altimeter data and visible satellite images. The observed thickness evolution is compared with iceberg melting predictions from two commonly used melting formulations, allowing us to test their validity of large icebergs. The first formulation, based on a fluid dynamics approach, tends to underestimate basal melt rates, while the second formulation, which considers the thermodynamic budget, appears more consistent with observations. Fragmentation leads melting as the major process responsible for the decay of large icebergs. Despite its importance, fragmentation remains poorly documented. The correlation between the observed volume loss of our two icebergs and environmental parameters highlights factors most likely to promote fragmentation. Using this information, a bulk model of fragmentation is established that depends on ocean temperature and iceberg velocity. The model is effective at reproducing observed volume variations. The size distribution of the calved pieces is estimated using both altimeter data and visible images and is found to be consistent with previous results and typical of brittle fragmentation processes. These results are valuable in accounting for the freshwater flux constrained by large icebergs in models.

Changed. Thank you for the time taken to rewrite the abstract.

(b) p. 1, lines 17 and 18. What is meant by "buffer"? What is meant by "diffuse"? Should it be "diffusive"?

Changed to reservoir

(c) Language is in places too informal, with the use of contractions. For example, line 9 of p. 2: "can't" should be "cannot" in formal writing.

Corrected

(d) p. 2m lines 23-25. Change wording and punctuation to clarify: " identified three styles of calving during the drift: "rift calving", which corresponds to the calving of large daughter icebergs by fracturing along preexisting flaws; "edge wasting", the calving of numerous small edge-parallel, sliver-shaped small icebergs; and "rapid disintegration",

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which is characterised by the rapid calving of numerous icebergs."

Changed

(e) p. 2, line 34. "allow to" → "allow us to"; also p. 9, line 20. (It's a transitive verb.) Likewise for p. 4, line 19. "enables" → "enables us"

Changed

(f) "ones" should not be used as a substitute noun in a comparison. For example, on p. 4, just before heading 2.2, you can say "For example, B17a was sampled by 152 altimeter passes during its drift and C19a by 258 passes." The word "ones" is unclear and non-standard English. Another example on p. 9, line 17: "measured one" → "measured loss".

Changed

(g) p. 9, line 3. Does it take several years for the iceberg surface temperature to depend on the ablation rate? Or should this say, "Icebergs can sometimes float for several years. After initial adjustment, the iceberg surface temperature depends on the ablation rate."

changed to "Icebergs can sometimes drift for several years. During its travel the iceberg's surface temperature will depend on the ablation rate. "

(h) p. 1, line 16. Rewrite to say, "However, their melting accounts for less than 20% of their mass loss, and the majority of ice loss (80%) is achieved through breaking into smaller icebergs (Tournadre et al., 2016)."

Changed

(i) p. 1, line 21. The word "between" doesn't seem clear hear. Perhaps the authors mean, "differ in their basal ice-shelf and iceberg melting" or "achieve different relative balances of basal ice-shelf and iceberg melting"?

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Changed to "Global ocean models including iceberg components show that basal ice-shelf and iceberg melting have different effects on the ocean circulation."

(j) p. 2, line 13. "law" → "laws" (k) p. 3, line 10. Capitalize "Southern Ocean"

Changed

(l) p. 3, line 11. Not clear if this is a singular or plural noun. To clarify perhaps, "area, size, and shape have been estimated".

Changed

(m) p. 3, line 14. By saying "that drifted", this implies that there are a number of other icebergs that drifted for more than two years in the South Pacific. I think the meaning would be clearer if "that" were replaced with "and".

Changed

(n) p. 3, line 15. "a relatively small 200 km² one drifting" → "relatively small (200 km²) and drifted"

Changed

(o) p. 3, line 15. To clarify the distinction between the plums and the big icebergs, say "both large icebergs".

Changed

(p) p. 3, line 5(2nd case). "confronted to" → "confronted with".

Changed

(q) p. 4, line 21. "small icebergs location" → "small iceberg locations". (The word "iceberg" is used as an adjective, and nouns used as adjectives are nearly always singular.)

Changed

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(r) p. 4, line 8. "ones" → "passes" (s) p. 4, line 20. "constrains" → "constraints" (t) p. 4, line 18. "as iceberg" → "as an iceberg"

Changed

(u) p. 5, line 17. Try "For each image with good cloud cover and light conditions"

Changed

(v) p. 5, line 28. "proxy of" → "proxy for"

Changed

(w) p. 9, line 4. Try "can theoretically warm up to" (x) p. 9, line 9. "shows" → "show" "ones" → "velocities"

Changed

(y) p. 9, line 10. "thus considered as" → "treated as"

Changed

(z) p. 9, line 17. "one" → "loss" (aa) p. 9, line 25. Try "The second model parameter T_i (see Figures 6-c and 7-c) varies between $-20 \pm 7.1^\circ\text{C}$ and $-0.6 \pm 0.6^\circ\text{C}$ for B17a, with a $-10.9 \pm 7.1^\circ\text{C}$ mean for B17a. For C19a, it is between $-9 \pm 0.6^\circ\text{C}$ and $1 \pm 0.6^\circ\text{C}$, with a $-10.6 \pm 5.8^\circ\text{C}$, although the model sometimes fails to converge to realistic iceberg temperature, i.e. for $T_i < 0^\circ\text{C}$. This occurs"

Changed

(bb) p. 9, line 34. "fail" → "fails" (cc) p. 11, line 29 Try "calving of icebergs from glaciers or ice shelves"

Changed

(dd) p. 12, line 13. "exist" → "exists"

Changed

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(ee) p. 12, line 17. "We investigate this matter by progressively including the dependence on environmental parameters"

Changed

(ff) p. 12, line 23. "ones" -> "loss"

Changed

(gg) p. 13, line 13. Clearer wording perhaps: "tested but brought no improvement".

Changed

(hh) p. 13, line 35. Missing superscript for km²

Changed

(ii) p. 13, line 17. "fragments" -> "fragment"

Changed

(jj) p. 14, line 22. "in open ocean" -> "in the open ocean"

Changed

(kk) p. 14, line 22 "relatively" -> "are relatively"

Changed

(ll) p. 14, line 24. "get" -> "obtain" (The word "get" sounds too colloquial for formal writing.)

Changed

(mm) p. 14, line 29 Try "the first is more dynamically based, and the second results from a thermodynamic balance"

Changed

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(nn) p. 15, line 7. "chose to carry" -> "carried", "find out which" -> "identify the", "parameters are more likely to" -> "parameters that likely favour"

Changed

(oo) p. 15, line 23 onward. I'm not sure what is meant by this discussion. Change to "small iceberg bias". Does the "them" in "To include them" refer to small or large icebergs? The context suggests large icebergs, but the wording implies small icebergs. The word "still" should be removed.

Changed to "As a consequence, it is believed that the current modelling strategies suffer from a "small iceberg bias". To include large icebergs in models requires to ascertain that the previous modelling strategies are still valid for large icebergs. We also ought to gain more knowledge on how these bigger bergs constrain a size transfer to produce medium to small pieces via fragmentation. Eventually, these smaller pieces are those that account for the effective fresh water flux in the ocean."

(pp) p. 15, line 5-7. I would remove the "On the one hand" /"On the other hand" structure. It's a bit informal and doesn't clarify the meaning. The second sentence can begin "It also has demonstrated"

Changed

Anonymous Referee #2

Received and published: 20 December 2017

This paper presents an assessment of two different melting model approaches for icebergs during their drift and introduces an empirical fragmentation law developed from observations for the fracturing processes during iceberg drift. In principle, this is an interesting story with potential for improving models of freshwater input into the Southern

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Ocean by iceberg melting. However, the manuscript needs some work before publishing. A main problem is a lack of structure, which makes the line of thought hard to follow for the reader.

The manuscript contains a lot of different types of observational data, models, model results, so that it might have been better to divide the story into two manuscripts.

Melting and fragmentation are closely linked and we think it is important to conduct a joint analysis of the two processes in the same paper.

The introduction is rather long and detailed, but at the same time is lacking a clear line of thought. It should be more concise, and more importantly make the contribution or the potential of the presented approach to larger research goals more clear.

The introduction might be a little bit too long but we think that it is important to give a precise general context and to show why it is important to better understand and model the melting and fragmentation of icebergs. If the referee has any suggestions as to improve the introduction we are willing to include them.

The rest of the manuscript does not follow the usual methods/ results/ discussions structure. After the introduction a “data” section follows, after which already the results from the iceberg observations are presented.

We think that we do follow the general/usual structure of method/results/discussion. Data are generally considered as an integral part of the “method” section as they are the base of the study. Section 3 that describes the evolution of the two icebergs can also be considered as part of the “method” section.

Then one melt model is introduced, and the results presented, before the second model approach is described. This is not good for the reading flow. My suggestion for a better structure would be to clearly divide the paper in two parts, 1. Melting, 2. Fragmentation, and follow a classic methods/ result / discussion structure in each of the separate parts. The introduction and an additional joint discussion then should make it clear how these

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parts belong together. In the first part you could have a “methods” chapter where the remote sensing data and their analysis is described, and the two melt approaches as well as the explanation that you are assessing and comparing their performance. Then present the melt results from observations, and the model results. Followed by a discussion of all three results. In a second part the fragmentation model could be explained. In this way the paper could be made more concise and clearer.

We don't really see how this structure is really different from the one we used. The “method” section consists of the data set used and the description of the evolution of the two icebergs, i.e. the basis of the study. The melting and fragmentation are then analyzed in the two following sections. We introduce a discussion subsection in the melting and fragmentation sections.

The summary is too long and repetitive, and contains parts which should be mentioned before in a discussion. In my view it would be necessary to thoroughly rework the structure of the paper in order to communicate the actual value of the study.

We shorten the summary.

Language: There are problems with punctuation, grammar and expressions in some places, which need a revision and maybe a read-through by a native speaker.

Using referee 1 comments we did our best to correct the text. It was also proof-read by a native speaker.

Figures: The labels on the axes should appear as the same font size, and should not overlap as in figure 4. I would suggest including a table with the fitting parameters for the fragmentation law, instead of printing the equations into the figure. Where possible I would place the panel labels outside of the main plot area and without a frame.

Changed

Specific comments:

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Title: the title is not an adequate description of the content, as previously established melt models are being assessed, and a new empirical law for fragmentation is presented. Southern Ocean is a name and should be written with capital letters.

[It is true that the melting and fragmentation laws are not treated in the same way in the paper but we don't think the title is misleading.](#)

Page 1, line16: "melting accounts for less than 20 % of their mass loss" This is only true for the final stages of decay, as most large tabular icebergs keep their shape quite well during drift. This expression is also a bit misleading, as in the end all mass is lost due to melting, as also the smaller icebergs do melt.

[The Tournadre et al \(2015\) clearly shows that the melting of large icebergs that transport most of the ice volume is limited compared to the breaking during their all life-cycle. It is a truism to say that ultimately they all melt.](#)

Page 3, line 13: please insert the web-address of the BYU data base as a reference.

[We gives the BYU and NIC web-address in the Acknowledgments section.](#)

Page 5, line 15: insert "Here," in front of the second sentence to make it clear that now you are talking about your study and no longer about the BYU data.

[Changed](#)

Page 5, line 37: "Due to lack of a better alternative. . .SST is used": I understand that the ocean temperature at the base of the iceberg, i.e. in about 300m depth, is not easy to obtain, but it would be necessary to at least discuss this as an error source and get some data from models to estimate the difference possible between the temperature at the surface and at depth.

[We include a reference to a paper by Merino et al \(2016\) that analyzed the difference between surface and 0-150 m mean temperature. \(Merino et al, "Antarctic icebergs melt over the Southern Ocean : Climatology and impact on sea ice", Ocean Modelling](#)

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[\(2016\), 99--110\).](#)

Page 6, line 9: I think SI units are standard for TC.

[cm are SI units .](#)

Page 7, first paragraph: Something that is completely missing here is the influence of firn compaction or changes in density along drift. This can have a substantial effect on the freeboard of an iceberg, while no mass is lost. This should be explained and an error should be estimated for this. There is also no information about which mean density has been assumed and why.

[The firn densification is discussed in details in §4 and in annex A. Section 3 describes the data and the observed melting of the icebergs.](#)

The units in this and the following paragraphs are not displayed correctly in the pdf.

[We checked the pdf on the TC web site and did not find any problem with the display of units.](#)

Page 10, line 16: "melt rate"

[Corrected](#)

Page 10, last paragraph: here methods, results and discussion are all mixed up in one single paragraph.

[See general reply](#)

Page 11, line 18: "melt rate"

[Corrected](#)

Page 12, first paragraph: here also all in one paragraph: first discussion and interpretation of results ("highest correlation is obtained for. . .), and only after this a reference to the figure where the data is shown. This is confusing to read. First describe the results, then interpret and discuss them

C14

Page 12, line 17-19: This paragraph is unclear, are there words missing? (“volume loss depending”?)

Changed to “We investigate this matter by step, by progressively including the dependence to environmental parameters in a simple model of bulk volume loss.”

Page 13, first paragraph: As the model is derived by fitting the observations, it should not be a surprise that there is a good correlation.

99.8% is better than a good correlation and it is not obvious that the same model can be apply to both icebergs with such a high correlation.

It would have been interesting to discuss the meaning of the fit parameters, and why they are different for the two icebergs.

The parameters are not significantly different that is what authorize to define a common model between the 2 icebergs.

In my view a useful empirical model should be able to reproduce the fragmentation of different icebergs with the same parameters.

That's exactly what is demonstrated in this section: the same model reproduces well the fragmentation of both iceberg.