Earth Syst. Sci. Data Discuss.,
https://doi.org/10.5194/essd-2020-99-AC1, 2020

Open Access Earth System Science Data Discussions

Interactive comment on "High-resolution mapping of circum-Antarctic landfast sea ice distribution, 2000–2018" *by* Alexander D. Fraser et al.

Alexander D. Fraser et al.

adfraser@utas.edu.au

Received and published: 19 August 2020

(Responses separated into general comments to Reviewer 1, "R1A" and "R1B" as main issues, then "1)", "2)", etc for specific minor comments)

General comments to Reviewer 1: We thank Reviewer 1 for their encouraging preamble and very careful review of the manuscript. We generally support all Reviewer 1's suggestions and recognise that they will improve the manuscript. All comments are specifically addressed below, and will be incorporated into the revised manuscript.

R1A: Description of methods: - I am not confident I understand what you have done strictly based on this manuscript. As I think it would be good if this paper stands by itself, I am suggesting that you spend some more time elaborating on

Printer-friendly version

Discussion paper

the methods.

We are happy to provide more details in this section. As you identified, we tried to make the manuscript as concise as possible, but acknowledge that more detail in this section would be a wise way to spend words.

- For instance, it is not clear to me how you create the composites. Could you be clearer in terms of this being a mosaic of overlapping imagery or if you are considering just one acquisition for each location and this being a composite of the two channels. Either way, it would be helpful with a couple of sentences addressing how they are created and the number of images typically incorporated.

One thermal infrared composite image was created (from Channel 31), regardless of the time of year. During times of sufficient sunlight, a visible (Channel 01) composite image was also created. So to answer your question, it is a mosaic of overlapping imagery – in fact, two mosaics of overlapping imagery in periods of sunlight (one for reflectance, one for brightness temperature). In line 132 we state that 600 images are incorporated into the composite images for each 15 day period, but we are happy to elaborate on this in the text by saying that these 600 images are separated into 6 regions of 100 images. Without this regional consideration, we found that there is a concentration of images in one or more particular regions based on cloud conditions, since we rank and select the 600 least cloudy granules.

- The steps in the methods are quite clear in of themselves, but it would help if the outcome of each steps is described as well.

This is a great idea, and will increase the clarity of explanation. We will add this in the revised document.

- This is how I interpret your initial steps: - For any given location and for all 15-day periods in your dataset, you download all available images and create multiple composite images based on available channels (how do you do this?).

Not quite, and sorry for the confusing/insufficient explanation. We download all (approx. 1,800 per 15 day period) cloud mask ("MOD/MYD35" product) granules covering the Antarctic coast. We then grid these, partition into six regions around the coast, and rank each group to select the top 100. For these 600 timestamps, we then download the calibrated radiance data ("MOD/MYD02") from which composites and the other processing steps are conducted. We will include this deeper description in the revised manuscript.

- Hence, for this location, you have several images (how many roughly?)

The composites for each region (of approx. 60 degrees longitude width) have 100 input images. Note that the "regional" consideration is dropped after the cloud mask product has been gridded, i.e., the MOD02 product is gridded to the circumpolar grid. Of course, these are not cloud-free views of the surface for all pixels of each MOD02 granule. Again, we are happy to include more detail on this.

- Then you detect the edges in all these composites resulting in multiple 1 km resolution (binary datasets?) indicating locations of edges in each composite.

That's correct – as mentioned in line 142, composites undergo edge-detection. However, edges are also computed for each input granule, as mentioned in lines 139 and 140, resulting in multiple 1 km resolution binary datasets indicating edges in each granule (not composite). Reviewer 3 suggested a flow chart. I think this would be a great complement to the description in the text and Fig 1, so we will produce this, and cross-reference Figure 1's individual panels from this chart.

- Then you sum the binary datasets and thus higher numbers more strongly indicate persistent edges at the timescale of 15 days. By doing this you reduce the number of composites down to one product?

That's right. Well, not quite one product, but we vastly reduce the input images by this process. We retain the Canny vs Sobel edges in separate summary images, for

example.

- You then multiply the edges with the median-filtered composite. But which one, if you have multiple composites for this region?

That's right. This is Step 6 detailed in line 146. Only the (summed) Canny edges are used in this process to construct the edge probability map. This is because the Canny edges have excellent localisation.

- Also, please spend a sentence on describing how this results in confidence as opposed to just the edge product.

That's a good idea. Since both the summed Canny input map and the gradient-median-filtered composites and non-binary, their product is also non-binary and so gives a fine-grained measure of confidence. Using four adaptive thresholds (based on the histrogram of the value of the product of these two maps), we assign four broad confidence classes to edges.

- What is the range of values prior to normalization?

Good question. I haven't thought to check, because the normalised product is so much more useful when deploying this algorithm across the whole continent. The lower range is 0 (no Canny edges * a zero value for the median-filtered composite image). The upper range is typically the product of 60 Canny edges (a particularly obvious edge with frequent, clear views of the surface throughout the whole period in both Terra and Aqua MODIS) and a composite gradient-median-filtered value of around 5, for the infrared case, or 0.75, in the visible channel case. The IR value is higher due to the numerical value of the brightness temperature difference between cold ice and warm water being much higher than the difference in reflectance of a dark vs light surface. But these details are helpfully abstracted away thanks to the normalisation.

- Finally, the result is a product of landfast ice edge with 1 km spatial and 15-day temporal resolution. However, how do you eliminate lower confidence edges

based on the histogram analysis?

Edges with a lower confidence than the lowest threshold (which is 98

- If you could attempt to clear up any of misunderstandings and make this a little easier to follow, it would be great. I suggest a figure where the reader can associate each step with a figure panel (or alternately a schematics). Basically, modifying Figure 1 to incorporate the other steps as well

Thanks – this is a good suggestion. We also note that Reviewer 3 suggests a flow diagram. We think that a clearer explanation, as you outlined, plus the flow diagram will help greatly.

R1B:

Specific points: -At line 190 you describe: "In the case of a manually-extracted ice edge pixel, it reflects the sum of the ice edge change plus the digitisation error." And you seem to imply that there are no errors in this data?

I think you meant to type that this implies that there is no error in the automatic digitisation, is that right? This (that the auto-determined pixels have no error) was our initial assumption – since the Canny edge localisation is very good – however you're right - we have implicitly ignored any sub-pixel digitisation error with this assumption.

Performing a quick random point simulation, I can see that the sub-pixel error averages to zero, but has an RMS value of 0.288 px. It could be argued that this value is a better one to use here. In the revised manuscript we plan to incorporate this number into the error analysis.

- Could you elaborate about this in the manuscript and discuss the accuracy of the Canny edge detection in general based on your pixel spacing and in terms of misclassification in the case of slow moving non-stationary ice in fjords

Misclassification of melange as fast ice probably occurs in a few limited regions around

the coast. We haven't mentioned this in the manuscript because it probably occurs in such limited regions as to be negligible on a circum-Antarctic scale. But I agree that it's worth noting this caveat in the revised manuscript. Another related error is in regions of densely-packed icebergs, which we pointed out in line 215, so this would be a good place to discuss melange misclassification.

- and stationary drifting ice pinned between icebergs or by onshore winds over consecutive 15-day periods? I suggest as before to move some of this discussion into either a discussion section or as a subsection to the methods section and discuss caveats a little more deliberately.

Yes, as you indicate, both issues are probably present to some extent. Regarding the drifting sea ice pinned between grounded icebergs, we have experienced this but only in limited areas in the Antarctic (e.g., visible from stations but at a spatial scale much smaller than one km, our pixel size). Regarding the ice temporarily advected against the shore or existing, genuine fast ice, we still believe that 15 days is long enough to preclude most of this ice from consideration. The coastal flow is generally offshoreward to westward (Turner and Pendlebury, 2001). Blocking anticyclonic pressure systems do occur in southern midlatitudes and these can result in persistent onshoreward winds in particular regions of the Antarctic coast, although the residence time for such systems is rarely longer than one week (Massom et al., 2004). We plan to edit the text to discuss both caveats.

Refs:

J. Turner; S. Pendlebury (Eds.) The International Antarctic Weather Forecasting Handbook, British Antarctic Survey, Cambridge, UK. ISBN: 1855312212, 2001.

R. A. Massom; M. J. Pook; J. C. Comiso; N. Adams; J. Turner; T. Lachlan-Cope; T. T. Gibson. J. Climate (2004) 17 (10): 1914–1928

- You define landfast ice as stationary for 15 days as opposed to earlier 20 days.

A 3-week timeframe is to my knowledge more common. Why did you make this choice and how will this impact the analysis and the potential misclassification of temporarily stationary pack ice etc.

As above – the circumpolar trough generally permits swift passage of low-pressure systems from west to east. Blocking events can occur north of the ice edge, but these rarely persist more than one week, so 15 days is probably sufficient to exclude this except for extreme cases. Discussion to be added in the text.

- Is the manual delineation very labor intensive e.g. is it sometimes difficult to determine where to draw the line with potentially large consequences for the ice extent? Do you have suggestions for how to mitigate this or how your approach could be improved in the future resulting in a larger than 58% success rate?If you could discuss this slightly in the manuscript, that would be very interesting.

The manual delineation ranges from being relatively straightforward (in the case of high quality composite imagery, where few judgement calls need to be made) to quite labour intensive (in the case of heavy cloud obscuring the surface, resulting in ambiguous fast ice edge delineation, and requiring the use of the previous and next 15 day period's composite imagery for guidance). On occasion, such judgement calls have the potential to significantly impact a single period's fast ice extent retrieval in a limited region.

We have taken steps to mitigate this here compared to our earlier work (e.g., by now considering edges visible even under thin cloud; by including more MODIS data per 15-day period). Multisensor fusion would help alleviate this to some extent (we used AMSR-E in our previous work) but limits the time period able to be considered (e.g., AMSR-E was launched 2.5 years after Terra MODIS). Here, our approach is still limited by poor MOD35 cloud mask product accuracy at times. We are interested in implementing state-of-the-art machine-learning cloud masking to mitigate this (e.g., Paul and Huntemann, The Cryosphere Discussions, 2020). This improvement may lead to

an automation percentage in excess of the 58% reported here.

I agree that this kind of discussion is a great addition to the manuscript, and we plan to incorporate it in the revised version.

Ref: Paul, S. and Huntemann, M.: Improved machine-learning based open-water/sea-ice/cloud discrimination over wintertime Antarctic sea ice using MODIS thermal-infrared imagery, The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-159, in review, 2020.

- Could you even provide some speculation into whether other sensors could enhance the analysis?

Yes – as above, AMSR-E has been used to complement this technique in our previous work (Fraser et al., 2010, which was purely manually-digitised), although it isn't clear how the multisensor fusion could be achieved in the framework of the present paper. Again, we would like to reiterate that few sensors match the very long observational lifetime of MODIS, so a multisensor fusion becomes less attractive in this sense.

- I realize and appreciate that you have written a quite concise paper and don't want to delve too much into the details. However, I suggest some more clarity and elaboration around these two points.

We agree that some more detail in these sections would be a useful addition at the cost of a few sentences.

R1 - Minor comments:

1) Line 65 - 74 move to discussion

Yes, I can see how it fits well in the discussion.

2) Line 78: I don't see the "in prep" reference in the bibliography. If not included there, take out.

Yes, this is still in prep so we will remove it from here.

3) Table 1: Avoid the word very as in "very high"

OK.

4) Line 81: Replace "the new" with something like "the fast ice time series presented here" to make it clear that it is not a new one described in Table 1.

Good idea.

5) Line 95: Can you clarify how the composites are created? Do you mean creating a mosaic or merging the channels?

Yes, addressed in the main comment above.

6) Line 97: Is this manual updating done every year and for the entire coastline? Is this labor intensive if to be done with necessary accuracy?

Yes, every year for the entire coastline, using the two MOA products (produced in 2004 and 2009) as a baseline. It is relatively quick in comparison to the manual parts of fast ice retrieval. Detail to be added to the text.

7) Line 112: "layer of clouds"?

OK

8) Line 115: Here as well as prior in the manuscript, the use of parenthesis could be toned down by reformulating.

Thank you – we note that Reviewer 2 has recommended a parenthesis overhaul too. We will revisit all occurrences in line with these comments.

9) Line 123: Again, not sure if parenthesis is needed here.

As above.

10) Line 126: I am not familiar with the plural form "cloud". Clouds?

Yes, will be changed as with comment 7).

11) Line 125: You have already said this. Take out.

Thank you.

12) Line 133: Missing oxford comma

Will be inserted.

13) Line 139 and 140: It would be great if you could elaborate here on what you mean by summing edge products. Do you just sum binary pixel values of edge/no edge?

That's correct. Detail to be added to the text.

14) Line 139: Do you mean successive 15-day periods, meaning several periods? If so, how many?

Sorry, this sentence was explained terribly! Thank you for picking it up. Will be changed from "and sum over successive 15-day periods." to "and summed within the current 15-day period." Same for the following dot point.

15) Line 142: Try to limit redundancy, you have already stated that the composites are cloud-free

Thank you, will be changed.

16) Line 143: Could you provide a short explanation for the Median filter. For instance, what is this gradient value range? Is there a threshold used to determine whether the edge is stationary and for how long?

Partly addressed in the response to your main comment above, but to explicitly answer here: The gradient of the median of the composites ranges from 0 to around 5 (for the Channel 31 thermal IR brightness temperature composite) or 0.75 (for the Channel 01 reflectance composite). There is no consideration of time-scale finer than the

compositing window of 15 days, since few regions are spoiled for cloud-free imagery throughout the entire 15 day window. The adaptive threshold is applied only to the product of the Canny summed edges and the gradient-median-composite images.

17) Line 148: Is this something you define. If so, make that clear. Otherwise, please provide reference.

Yes, this is our original algorithm. Will be made clear.

18) Line 162: In the methods section below Line 162 looks like the start of a discussion to me. I recommend creating a discussion section and placing much of this there. Some of it also belongs more in the introduction perhaps.

Thanks – we will reconsider the placement of this content.

19) 185: Like before, no need for parenthesis

I guess you mean 187 – thanks.

20) Line 215: Missing space

Thank you.

21) Line 244: What indicates this in the plot? The discontinuity in the plot?

Ah, no – apologies for the confusion. Regions with low automation fraction indicate this. Will be made clear. Reviewer 4 also wondered about the discontinuities. These will now be described in the figure caption.

22) Line 248: What do you mean with edges vary? The detected edges or the actual ice edge? You mean vary over time when the ice edge is assumed constant? Please explain better.

Thanks – in hindsight I can see that we can explain this better. We will elaborate to clarify.

23) Line 263: Please be consistent with the use of notations for in-line lists e.g.

1, a, or i.

Thanks – we will review these for consistency in the revised document.

24) Line 266: Missing space

Thank you.

25) Line 271: Please clarify this sentence as it is not clear what you mean by complexity dataset and linkages between what.

The dataset we refer to is a dataset of Antarctic coastal margin complexity and configuration, though I agree it doesn't read particularly well as written. Will be clarified.

Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2020-99, 2020.

Printer-friendly version

Discussion paper