The Cryosphere

Discussions

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Interactive comment on "Consistent CryoSat-2 and Envisat Freeboard Retrieval of Arctic and Antarctic Sea Ice" *by* Stephan Paul et al.

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Overview and general comments

The authors present algorithm development from the latest iteration of the ESA Sea Ice Climate Change Initiative, which is working toward producing a consistent long-term climate record of sea ice thickness for both polar oceans. The paper focusses on improving the surface classification methodology for both CryoSat-2 (CS2) and Envisat using multiple waveform parameters and more advanced statistical techniques, and then uses these results to tune the Envisat retracking threshold in order to minimize the observed freeboard difference relative to CS2. This is a somewhat similar approach to 'correcting' the Envisat sea ice freeboard as taken by Guerreiro et al.

(2017), where they adjusted the Envisat freeboard based on a fit between pulse peakiness and the CS2/Envisat freeboard difference. While there are studies similar to the present manuscript in the literature, the methodological development within the ESA SICCI warrants publication, as presumably further development will follow and eventually data will be delivered to users who will want to know how it was produced.

I do have some suggestions/comments that I think will improve the manuscript:

1) Sections 2.3.2 and 2.3.3: I am not familiar with these statistical techniques, and I don't think the wider polar altimetry community will be either, unless there have been other publications on these techniques within the context of polar altimetry? There is a lot of jargon (specialist terms e.g., "k-means", "clustering", "decision trees", "trained forests", etc.) and sentences that are nonsense without specialist knowledge, for example, how does a "decision tree" in a "trained forest" cast a "vote"?! I am imagining woodland creatures and some kind of election! While I appreciate that I could follow the references you have provided to textbooks etc, I think the manuscript would be greatly improved if you could provide a more intuitive explanation of these procedures, as well as some relevant equations and figures if applicable, including specific examples of how this applies to altimeter waveform classification. In particular, I think this is important because this seems to be one of the major developments in the paper, so I think readers should be able to gain an intuitive picture of what is happening in your processing in order that they might develop/reproduce what you have done. The schematic in Figure 1 is sort of useful but there is still a lot of jargon, and it's not clear to me what is happening at each stage.

2) How are your results affected by just using a fixed retracking threshold for Envisat lead waveforms, rather than including lead and floe waveforms in the tuning/fitting procedure? The reasoning for retracking near (or at) the maximum power for lead waveforms is equally valid for CS-2 and Envisat, i.e., specular scattering from leads reduces the effective footprint to the size of the lead, which in turn gives you a return which is close to the transmitted pulse (convolution with a delta function rather than the flat-

surface impulse response). Using a single retracker for all CS2 waveforms and essentially two separate retrackers for Envisat leads and floes represents an inconsistency with your approach that I don't feel is justified.

3) Related to this, I appreciate that your fitting procedure is essentially try to match the Envisat freeboard to the CS2 freeboard by tuning the Envisat retracking threshold. But couldn't you simply skip a stage here and fit the Envisat waveform parameters (LEW/sigma-0) to the CS2 freeboard directly?

4) Section 3.1: You get a better match with the surface type classification than in SICCI-1, but isn't this by construction? Haven't you tried to match the number of waveforms classified as leads and floes for the two satellites, or have I misunderstood something? Further, I wouldn't necessarily expect there to be agreement between the number of leads/floes detected by the two instruments, simply because of the different footprints – from physical/geometric arguments I would expect far more 'ambiguous' waveforms in the Envisat data. More encouraging is the broad spatial agreement between the lead/floe distributions.

5) Section 3.2: Similarly, isn't the small observed difference in freeboard by construction? Here, I think the manuscript would be greatly improved by comparison of the two satellites with independent radar freeboard measurements, e.g., by combining the IceBridge laser and snow radar.

Specific comments

The title is clunky, I would suggest "Consistent retrievals of Arctic and Antarctic sea ice freeboard from Envisat and CryoSat-2"

Page 1, Line 2: I suggest "...estimation over recent years, however, precursor..."

Page 1, Line 13-15: "cover" should be "extent". Also, join the sentences "...Meier et al), while Antarctic sea ice extent..."

Page 1, Line 15-16: I suggest the following "...(Turner et al). Arctic sea ice is also

thinning, as observed by..."

Page 1, Line 24: I suggest "...that measurement of sea ice thickness at circumpolar scales in both polar regions..."

Page 2, Line 4: really this type of processing dates back to at least Laxon (1994), "Sea ice processing scheme at the EODC".

Page 2, Line 5: I'm not really familiar with the term "run-time" within the context of altimetry, could you explain or use a more familiar term.

Page 2, Line 6-7: "so accurate that...", this isn't really the case for individual lead/sea ice measurements due to speckle noise. Also, explain explicitly that this elevation difference is termed the freeboard, otherwise the next sentence might not make sense to people unfamiliar with this term.

Page 2, Line 9-11: "not true" – I'm aware of all the studies on this (including some of my own work!), but I would still argue that such a strong statement on this issue is still not possible. I would suggest "When estimating sea ice thickness from radar altimeters, it is often assumed that...", and you should provide a more extensive list of studies that might suggest otherwise.

Page 2, Line 18: I believe the Envisat altimeter was Radar Altimeter 2 (RA-2)?

Page 4, Line 32: Is this filtering important? How many waveforms are removed?

Page 4, Line 33-Page 5, Line 1: Do you also apply a land mask filter? Are the inbuilt land surface type flags accurate enough to catch all land contaminated waveforms?

Page 5, Line 4-8: I think what you are saying is that distinguishing leads is essential in order to estimate the instantaneous sea level anomaly along track?

Page 5, Line 9-14: Before this paragraph you should explain why it is possible to distinguish leads and floes to begin with i.e., explain the different surface scattering characteristics. Otherwise, this paragraph is not clear.

Page 5, Line 12: "footprint of 2km", this is the pulse-limited footprint. "increase up to 10km (Chelton et al.)", I don't think Chelton was talking about off-nadir ranging to leads, he was talking about the effect of significant wave height on the pulse limited footprint, which is fundamentally different i.e., strong off-nadir backscatter in the case of leads vs. large surface roughness in the case of high SWH.

Page 5, line 18: "sea ice backscatter", you mean $\sigma\hat{}0$?

Page 5, Line 29: young, thin ice areas, cause specular reflections, you should add a citation.

Page 5, Line 10-31: surely the rejection rate could be decreased as well?

Page 9, Line 24-Page 10, Line 3: This is all rather unclear to me.

Page 10, Line 1; Figures 2-5: Show the pulse peakiness maps as well, also show the multi-year ice mask for comparison.

Page 11, Line 2: Why disregard PP in the fitting procedure? Presumably you tried different iterations but discarding PP gave you the best result?

Page 12, Line 3-11: The fitting procedure is not clear to me at all. What are you fitting to what? What is the "x-y" plane? Perhaps a diagram/Figure could help to illustrate this?

Figure 10: Could you change the x-axis scale to $\sim$ -25cm to $\sim$ 40cm to make the figure clearer

Page 16, Line 26-34: Could the difference with Guerreiro be explained by the speed of light propagation correction, or do you both apply it in the same way?

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