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The Cryosphere Discussions

Interactive comment on "Arctic lead detection using a waveform mixture algorithm from CryoSat-2 data" *by* Sanggyun Lee et al.

Anonymous Referee #3

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Summary

The paper proposes a novel waveform mixture analysis to detect leads, adopting the concept of linear mixture analysis that is widely used in the field of hyperspectral image analysis. The authors conclude that this method shows a better performance in detecting leads than previous methods. Moreover, spatiotemporal patterns and interannual variability of Arctic-wide lead fractions are discussed.

General Comments:

The method looks interesting, though I am not really sure if it really outperforms other existing methods. Following the given explanations is not easy and the discussion is sometimes superficial. I try summarize my major concerns:

1) The given results/figures do not sufficiently support the conclusions in the paper. For example, in the Conclusions section, the authors state that "The lead dynamics based on monthly lead fraction maps were examined with the Arctic Atmospheric and oceanic circulations". Where is this shown? I am also not sure if the differences between the considered algorithms are statistically significant; nor if the evaluation with MODIS images is sufficient, since the resolution is about 250 m, meaning that smaller leads detected with CryoSat-2 might be missed. See also the specific comments below.

2) The method description in the paper lacks more detailed information in the methodical part. The methods/algorithms are explained very briefly, e.g. "N-FINDER", "MATLAB toolbox for linear unmixing with the interior point least square algorithm". Although the authors refer to literature sometimes, these methods should be explained in more detail, since they are essential for understanding the study. Specifically, in the beginning, it should be explained what "endmembers" are and what they represent. The same applies to the "abundance fraction". Moreover, the authors do not show explicitly how the abundance fraction is derived. Additional figures explaining intermediate steps would be very helpful for understanding.

3) The selection of the end members needs more explanation. Where are the 48 collected CryoSat-2 orbits located? A map would be very helpful here. Also, I wonder how this approach deals with different ice types, given that first-year ice waveforms are different from multiyear ice waveforms? Reading section 3.1, it sounds like only first-year ice waveforms have been considered? The next issue is the nonlinear mixing as mentioned correctly. Due to the specular reflection, a lead (of a certain size) will always dominate the waveform. This is even more the case for the Doppler SAR processed waveforms. How is this handled in the WMA?

4) One of the objectives is to "investigate the relationship between Arctic lead fraction and thermodynamics and ice dynamics". However, this is discussed just very briefly in Section 5.3. As mentioned above, a thorough examination of the linkage to atmospheric forcing and ice dynamics is not shown.

The issues, listed above, should be addressed by the authors. Moreover, some sentences are unclear or imprecise (see specific comments). Taken together, these omissions mean that major revisions are needed.

Specific Comments:

P1L22. "sea ices" - the plural of sea ice sound odd.

P2L27: "could make near surface temperature up to a 3.5 K" - this sentence is confusing and should be rewritten. I suppose you mean that an increase in lead fraction leads to an increase in near-surface temperature of up to 3.5 K?

P3L5: "CryoSat-2 takes an advantage of SIRAL to detect smaller leads (e.g., $\sim$ 300 m)" - why should the lead size relate to the Doppler beam footprint (300 m)? The actual size of the lead might be smaller, since the specular return from the mirror-like lead surface will dominate the waveform, also if the illuminated surface is a mixture of sea ice and lead.

P3 Section 2.1: It should be clearly written which data are used here (I suppose level 1b). Which Baseline has been used (C?)? Which period is considered?

P3 Section 2.2: Same as above: Which data product version has been used? Which period?

P5L5: "vectors" -> vector

P5L21: What do you mean with "CryoSat-2 files"? An orbit file?

P5L25: "Waveforms from March to April between 2011 and 2014 were compared to those from January to May, and October to December between 2011 and 2016 (not shown), resulting in little difference between them" - Why do you separate between the two periods (January-May, October-December)?

P7L18-26: The MODIS resolution is about 250 m. What about smaller leads (< 250 m)? Due to their specular surface, they could be detected by CryoSat-2, but not with

MODIS. Therefore, I wonder how representative this evaluation is?

Figure 2: An overview map with the locations of the MODIS images would be helpful.

Figure 3: Unit is missing. Percentage?

P9L7: "The areas around the coast line" - To me it seems that lead fraction is higher at the ice edge and in the marginal ice zones, like Barents Sea?!

P11L10-12: I would argue that this conclusion is not valid: You average over one month, so leads are also propagating, opening and closing during that period. Certainly, when you have large ice drift, like in the Beaufort Gyre. Therefore, the standard deviation might not be reflect the uncertainty here.

Figure 6: Unit is missing. Percentage?

Figure 6: Why do you get these orbit patterns in the sea ice fraction maps, certainly in February 2011?

P17L3-5: "In addition, this study showed the high inter- annual variability of Pan-Arctic lead fractions in recent years (i.e., 2011-2016), which implies that sea ice becomes more vulnerable to atmospheric and oceanic forcing." - How does the interannual variability of lead fractions imply that sea ice becomes more vulnerable to atmospheric and oceanic forcing? This is not clear to me.

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