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Interactive comment on "Characterization of L-band synthetic aperture radar (SAR) backscatter from floating and grounded lake ice in arctic Alaska" *by* M. Engram et al.

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We thank Reviewer 1 for taking time to read and comment on our paper and will respond to each of his/her comments, copied below.

First point, Reviewer 1: This manuscript provides a nice comprehensive review of previous lake ice studies and for the most part is fairly well-written.

Response to first point: The motivation for writing this paper was the lack of previously published results for L-band SAR backscatter from lake ice in the literature. We therefore thought a literature review was very important, but we failed to point out the lack of studies using L-band calibrated SAR in the history of lake ice research. In our revised

paper we add to our Introduction, "After a thorough literature search, we could not find a report that characterized L-band calibrated SAR backscatter intensity from floating and grounded lake ice to follow the early promise that Elachi et al. (1976) reported from uncalibrated L-band airborne radar".

Second point, Reviewer 1: However, the major concern I have with this manuscript is its lack of new, and more importantly useful, information with respect to remote sensing theory, techniques and/or approaches.

Response to second point: Reviewer 1 is partly correct, in that we used some accepted and established remote sensing techniques, such as sampling and averaging SAR pixels using ArcMap, to report the intensity of L-band backscatter from floating and grounded lake ice. We used C-band SAR as an indicator of floating and grounded lake ice which is a well established remote sensing technique, as we note in our Methods section. But we disagree with Reviewer 1 that our study lacked new valuable additions to remote sensing, because some aspects of our remote sensing analysis were new: quad-pol decomposition of any SAR has never been used to examine floating and grounded lake ice before and it provided valuable knowledge of scattering mechanism. Our statistical comparison of floating and grounded lake ice intensities for two very different geologic regions, using identical SAR instruments, provided valuable results. No study of grounded versus floating lake ice has been performed for the Seward Peninsula before. The remote sensing techniques and approaches that we used were not the main point of our article. We will highlight the usefulness of our observations to the scientific community, as indicated below.

Third point, Reviewer 1:The authors find that L-band is not an improvement over C-band for differentiating between floating lake ice and grounded lake ice, clearly shown in Figure 4. This is the main result of the paper and this result does not contribute to the development of new remote sensing information (i.e. theory, techniques, or approaches) from what was previously already well established in the literature.

Response to third point: In light of these comments by Reviewer 1, we see that we need to better highlight the main focus of our paper to align our main point with our title, "Characterization of L-band synthetic aperture radar (SAR) backscatter from floating and grounded lake ice in arctic Alaska". Although we state that our main point is the comparison of the usefulness of L-band to that of C-band SAR to determine floating and grounded lake ice regimes, we maintain that this study contains other new information, in addition to the comparison of the utility of C- and L-bands, to significantly add to what is well-established in the literature. While our comparison of L-band to C-band for two different regions is generally of scientific interest, for utility and for insight into scattering properties of lake ice, we also highlight 1) L-band SAR's average backscatter intensity, 2) report that the T11 polarimetric element is the dominant response from floating ice for L-band SAR, indicating roughness as the scattering mechanism, and 3) find that there was a difference in backscatter values for floating ice between different geographic regions.

To re-focus the paper, we re-wrote the abstract to read, "Here, we examine calibrated L-band (23.6 cm wavelength) single- and L-band quadrature-polarized SAR return from floating and grounded lake ice in two geographic regions in Alaska. Our primary goal was to characterize L-band backscatter intensity values for a variable set of Arctic lakes, scattering mechanism, and spatial variability for floating and grounded lake ice, and to compare L-band radar return to that of C-band(5.6 cm wavelength) SAR which is already well documented in the literature. We report the backscatter intensity of single-polarized floating lake and grounded ice from each region (-13 dB and -16 dB for floating ice from the northern Seward Peninsula and Arctic Coastal Plain respectively, -19 dB for grounded ice). We report the dominant backscatter return from lake ice for L-band SAR is the T11 polarimetric element, indicating that roughness is the dominant scattering mechanism. L-band SAR backscatter from floating ice was different for our two study regions. C-band SAR showed far greater contrast between floating and grounded lake ice, making it the preferred wavelength for identifying lake ice regimes, and also indicating that L-band does not detect the targets that cause

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higher backscatter from floating ice in C-band VV SAR. Furthermore, since L-band is sensitive to ebullition bubbles trapped by lake ice (bubbles increase backscatter), this study helps to elucidate potential confounding factors of grounded ice in L-band from methane studies of floating ice."

That the T11 component is dominant, indicating that backscatter from floating ice shows roughness scattering behavior, is a new finding and we point it out in our Results and Discussion sections. Many previous C-band lake ice studies postulate double-bounce as the scattering mechanism for SAR from floating lake ice, in which SAR is reflected from the ice-water interface, then reflected again from small tubular bubbles in the ice. To more strongly highlight this new information, we changed the order of our Discussion section to start with our polarimetric decomposition from floating ice. Our discussion paper has already been cited by Surdu et al. (2013), that roughness is the dominant scattering mechanism for L-band SAR from floating ice: http://www.the-cryosphere-discuss.net/7/3783/2013/tcd-7-3783-2013-discussion.html

Our conclusion that L-band is a less powerful indicator of floating ice than the shorter C-band is also new and useful information. Our findings are contradictory to an initial report from the seventies (Elachi et al., 1976) of the possible superiority of L-band over the shorter X-band to distinguish floating from grounded lake ice. To emphasize this point, we added the following text to our introduction, "After a thorough literature search, we could not find any report that characterized calibrated L-band calibrated SAR backscatter intensity from floating and grounded lake ice to follow the early promise that Elachi et al. (1976) reported from L-band airborne radar." Additional evidence of the usefulness of this information is that our discussion paper has already been cited by Surdu et al. (2013), in support of choosing C-band wavelength for a long-term study of lake ice freezing to the bottom: http://www.the-cryosphere-discuss.net/7/3783/2013/tcd-7-3783-2013-discussion.html

Fourth point, Reviewer 1: I think this paper will have little value to the scientific community simply because it is a proof of concept study that show L-band is not an improve-

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ment over C-band. “If” L-band was an improvement over C-band, then this study could find a place in the literature but that is not the case.

Response to fourth point: We disagree with assigning less importance to a negative result compared to a positive result. Knowing that a certain wavelength and polarization is sensitive to a target in addition to knowing that a different wavelength and polarization is not sensitive can provide new information about the scattering mechanism of the target. Microwave scattering is a complicated process and knowing which SAR parameters provide a low intensity response (and in what range) can add to the larger picture of understanding microwave/lake-ice interactions. We added the following text to section 4.1 of our discussion to emphasize this point, “Because L-band intensity is lower than C-band backscatter from floating ice, and L-band’s dominant scattering mechanism is roughness, our findings could lead to a better understanding of C-band microwave interaction with lake ice.”

We addressed the availability of SAR data and added the following text to the Introduction and background section, “It is important to characterize L-band SAR intensity values from known floating and grounded lake ice, in addition to the established work published in C-band, in case L-band acquisitions are the only available SAR data for a certain region and observation time.”

The motivation for this paper was the noticeable absence of studies on L-band SAR response to lake ice in the published literature. There is no previous publication which reports the backscatter intensity of calibrated L-band SAR from floating and grounded lake ice. We needed a numeric threshold to exclude grounded ice in an L-band SAR image during a geospatial comparison of lake ice to ebullition bubble field measurement, and found no such characterization for either JERS-1 or PALSAR in our literature search. To emphasize this point, we added this text to the conclusion, “The average backscatter intensity of L-band HH SAR is -13 dB for floating ice from the northern Seward Peninsula, -16 dB from floating lake ice on the Arctic Coastal Plain, and -19 dB for grounded ice from both regions.”

Interactive comment on The Cryosphere Discuss., 7, 2061, 2013.