The Cryosphere Discuss., 7, C1461–C1465, 2013
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The Cryosphere Discussions
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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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Received and published: 15 August 2013

We thank Reviewer 2 for taking time to read and provide valuable comments on our paper. We have copied the comments and each concern of Reviewer 2 below and have addressed each concern.

First point, Reviewer 2: The paper submitted by Engram et al. is generally well written, the image analysis methodology is sound and the interpretation of the results is correct; however, it falls short of a paper deemed acceptable for publication as a "Research Article" in The Cryosphere.

Response to first point: We believe that our organization of the important points in this

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paper has caused some confusion, but are glad that Reviewer 2 found it well written and that the reviewer validates our image analysis methodology. We disagree with the reviewer however, that our study is not sufficient for a research article. Below we provide more details on why this paper is a valid research study.

Second point, Reviewer 2: The finding that L-band is not very useful for differentiating between floating and grounded ice is shown but is something that one should expect, based on what we already know about radar interaction (at both C- and L-band frequencies) with lake ice that contains bubbles of various sizes. Previous work has clearly shown that both C-band (VV and HH) and X-band are very useful for differentiating floating ice from grounded ice, and this (C-band) has formed the basis of approaches for monitoring the evolution of lake ice from floating to grounded ice conditions. Ice cover on shallow lakes has been documented to contain a large volume of tubular bubbles, particularly in late winter/early spring (March-April) on the Arctic Coastal Plain of Alaska (e.g. Jeffries et al., 1994) and other similar coastal areas of the Arctic/sub-Arctic.

Response to second point, Reviewer 2: We believe it is not sufficient to simply expect that L-band is not very useful. We could not find any detailed study of the L-band radar response from floating and ground lake ice in the literature. Hence, we do believe that establishing L-band radar cross section information and determining the main scattering processes at the L-band wavelength are worthwhile, relevant, and new. We do not believe that indisputable evidence of L-band being less useful than the shorter wavelength of C-band to distinguish floating from grounded lake has been provided in the past. In fact, an early publication (Elachi et al., 1976) reported that uncalibrated airborne L-band radar appeared to show a bigger contrast between floating and grounded ice than the much shorter X-band wavelength and that the longer wavelength of L-band might be a better indicator than X-band for floating and grounded lake ice. We added the following text to the end of our literature review, ”After a thorough literature search, we could not find any detailed reports that characterized L-band cali-

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brated 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."

To better highlight our main research findings and emphasize their relevance, we changed the order of our discussion to start with floating ice instead of with grounded ice.

Third point, Reviewer 2: . . .the last paragraph of 4.1 (pp11-12) is somewhat irrelevant to the original goal of the study (L-band, as the title of the paper suggests), as are the last two paragraphs of section 4.3 (pp 15-16) and the first paragraph of the "Conclusions" (p. 16).

Response to third point: Reviewer 2 is correct: we here included information that is not relevant to the characterization of L-band SAR from lake ice when we noted that some of the lakes that have previously frozen to the bottom now have floating ice all year, and some of the lakes that previously supported floating ice now freeze to the bottom. We included this information as it was an important issue with regard to our methodology, since we sampled some lakes as examples of floating ice some years and as examples of grounded ice other years. We consider our studied lakes as naturally variable and thus the change in their status of ground to floating or vice versa are useful background information to be considered in our study. However, it is beyond the scope of our paper to include detailed lake ice regime changes in our discussion and conclusion. In our revised paper we will remove these paragraphs (last paragraph of 4.1, last two paragraphs of section 4.3 and the first paragraph of "Conclusions") from the discussion and conclusion. We will retain mentioning the shifting lake ice regime in the method section as it is relevant to our study. We will add a new reference to a comprehensive study of recent changes in thermokarst lake ice regimes on the Alaska Arctic Coastal Plain (Surdu et al., 2013 http://www.the-cryosphere-discuss.net/7/3783/2013/tcd-7-3783-2013-discussion.html).

Fourth point, Reviewer 2: Reviewer 2 states that lack of field observations (bubble type,

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density, location of bubbles at various depths within the ice volume, rocky bottoms or not, fully frozen sediments or not) around the time of at least one of the space-borne SAR acquisitions make the interpretation of results very speculative.

Response to fourth point: We disagree with the reviewer that certain field observations (location of bubbles at various depths within the ice volume, rocky bottoms or not, fully frozen sediments or not) are important to interpret L-band SAR backscatter intensity from grounded and floating lake ice. If the scattering mechanism that we saw for L-band were double-bounce or volumetric scattering, then it would be important to conduct field work to determine the layering of different types of bubbles that could cause such scattering behaviors. But with roughness as the dominant scattering mechanism from lakes with floating ice, layers of bubbles included in the ice could not play a main role in backscatter, or else the intensity would not decrease when the ice froze to the lake bottom. Since L-band backscatter intensity from grounded lake ice was very low and was statistically the same for both study regions, we did not consider field observations of lake-bottom substrate type and degree of frozen sediments to be of vital importance to interpret L-band grounded ice results.

For our characterization of L-band backscatter intensity from grounded and floating lake ice, the most important field measurement was to determine if the lakes (or portion of the lakes) froze to the lake bed or not. We did measure ice thickness and grounded ice during our field campaign in April 2009, which was commensurate with satellite acquisitions. To highlight that our field measurements were concurrent with SAR acquisitions we added text to our methods section to read, “We identified areas of grounded and floating ice on the NSP study lakes using our April 2009 ice thickness field measurements from four of the lakes in conjunction with April 2009 SAR imagery.”

For our knowledge of whether or not the lakes on the Alaskan Arctic Coastal Plain froze to the bottom, we relied on previously published field measurements, and on C-band SAR.

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Other field work included extensive ebullition bubble surveys in both geographic regions in the early winters of 2008 and 2009 to determine ebullition activity and resulting bubble density, which can affect the roughness of the ice/water interface under floating ice. To highlight our field observations of ebullition bubbles, we have revised the labels on Figure 6 to include results from field surveys to read, " High ebullition (11.1% bubble area)" and "Low ebullition (5.1% bubble area)".

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