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Interactive comment on "Detecting methane ebullition on thermokarst lake ice using high resolution optical aerial imagery" *by* P. R. Lindgren et al.

Anonymous Referee #2

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Review of 'Detecting methane ebullition on thermokarst lake ice using high resolution optical aerial imagery' By Lindgren et al.

This manuscript describes a new method for analyzing spatiotemporal dynamics of methane ebullition over lake ice and quantifying emissions using optical aerial imagery. The method analyses are described in context with a previously published ebullition/seep size quantification system and used to quantify emissions from an Alaskan thermokarst lake over two years. The authors found some interesting spatiotemporal variability between the two years, but it may have been impacted by surveying too soon after ice on. They also found a striking inverse relationship between ebullition emission and distance from the eroding shore. Overall, the method described seems to be useful

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for quantifying ebullition dynamics over non-snow covered lake ice in difficult to reach areas and I feel it should be published; however, I fear it will be a challenge for readers to truly understand the methods, which will prevent them from fully appreciating the results of this analysis. I, therefore, recommend this paper for publication only after a thorough re-evaluation of the writing as per my comments/suggestions and that of other reviewers.

General comments:

1 – The methods section would benefit from a summary paragraph, particularly one that describes the sampling strategy with which methods were used where and how. The methods is long and difficult to follow at times. I feel portions of it could be placed in a supplemental methods section. See specific comments for some suggestions. I also suggest how to split some sections for easier reading.

2 – 'Tiny-type' seeps do not add much to your story at all. Is this necessary?

3 – The results/discussion section has some very long sections that can be re-classified into more self-standing sections to help the reader follow along. I make specific suggestions below as to how to do this. I strongly urge the authors to consider these suggestions as the reader does tend to get bogged down with many details and perhaps lose the main point of each paragraph.

4 – Section 5 should start with the positives, then discuss the negatives.

5 – Section 6 (conclusions) should lose the values and not repeat the abstract and results. The conclusion could be more concise and simply highlight the author's main points and their role in the big picture.

Specific comments:

P7450, L5 – what does 'multi-temporal' mean exactly?

P7450, L9-11 – 'Our aerial imagery thus...' sentence is confusing. How does the aerial

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imagery capture the events that occurred before image acquisition? I guess you mean that since the bubbles are frozen in ice that the image is capturing those events, but I think you should make this clearer. However, I think this sentence could also be left out.

Why is 'hotspot' capitalized? I think this is unnecessary and looks strange.

P7454, L13-end – It is not usual to reference a figure in the introduction already. Is this necessary? I believe this whole paragraph could be moved to the methods as a sort of summary of your very complicated methods section. And you can replace this paragraph here with a much shorter version of what you will describe without the use of the figure.

P7456 – Your methods are highly complicated to follow and I strongly suggest starting with a summary paragraph. You should list what the next methods sub-sections will be describe and be very specific as to the sampling strategy as you used multiple methods at different times and different years. Here you can specific in regards to when you sampled in terms of ice on/off and snow cover as this was not immediately obvious throughout the methods. A summary paragraph here will really help the reader through the methods.

P7456, L6 – how did you survey here? By plane?

P7456, L18 – 'Tiny-type' sounds a bit informal. I understand that since you already have an 'A-type' that going smaller requires a new term. However, you also don't quantify the emissions from this tiny-type so you can use what you like in terms of a name. How about 'sub A-type' or 'diffuse' or 'mm-sized'? And again, the 'tiny-type' bubbles were not used much at all in the analysis and perhaps it can be left out entirely.

P7456, L27 – the 60-80% CH4 in the bubbles is from the unpublished citation too, I presume. You should cite 'unpub' again.

P7457, L4 – 'of the lake area' – add the 'a' at the end of 'are'

P7458 – In general, I think these few paragraphs are very difficult to follow. I strongly urge the authors to perhaps shorten it to only the most useful information and put the rest in a supplemental methods section. I found Fig. S1 to be very useful in understanding the classification system; however, the figure caption for S1 is much easier to understand than the text in the manuscript. I suggest using the figure caption wording and expanding to what is necessary in the main text of the manuscript.

P7460-7462 – I suggest splitting section 3.4 into three sub sections. There is too much information in this whole section, which requires subdivision to help the reader follow and there are natural places where this could occur. The first section should still be 'interpretation of image classification results'. The second section will discuss how you determined spatial patterns and start at P7461, L14 and could be expanded a bit most likely. The third section will discuss how you determined temporal patterns and starts at P7461, L21. However, this section definitely has too much information. It could shortened and details moved to a supplemental with a flow chart figure to help support the reader in understanding the methods.

P7461 – better explain 'training samples' and 'field-collected seep location data' – I was not sure what you meant by this.

P7461, L17 – cite 'Fig. 1' after '1949 aerial image'

The results/discussion section 4.1 is difficult to follow even with the subdivisions. I believe sections 4.1.1 and 4.1.2 can be divided into three separate sections (4.1, 4.2 and 4.3) with further subdivisions when necessary.

Section 4.1 should keep the title 'Relationship between bubble patch brightness and field-measured methane flux' and could be divided into four sub-sections (4.1.1, 4.1.2, 4.1.3) potentially. First is the first paragraph. Second would be the second paragraph where you discuss the limitations of the classification method. The third section would be the third paragraph (P7464, L3) discussing individual seep type difficulties, but divided into two paragraphs with the first paragraph discussing A and B-types and the

second paragraph discussing C-type. The fourth section would be the last paragraph of the section discussing Tiny-type seeps, but perhaps this paragraph is not necessary at all since this is more or less the only time it is discussed or used.

P7463, L18-19 – I do not really understand how you were able to come to any final numbers or conclusions if 'an absolute discrimination of individual seep type was difficult'. So how did you overcome this then? You must have in order to report final values but I am lost trying to figure out exactly how. It should be made immediately aware to the readers; otherwise, your method appears not to work based on this statement.

P7464, L8 – 'B-type seeps were also difficult to map' – is this because it was difficult or because they were not there? You should qualify this statement by explaining briefly at the end of this sentence why it was difficult, which leads to the next sentence/topic.

Section 4.2 would then begin with current section 4.1.2 discussing 'classification of bubble patches'.

But then Section 4.3 should deal with the 'estimation of whole-lake methane flux' and begin at P7466, L16.

P7465, L7-8 – This first sentence is very confusing. How does 2012 have two accuracies?

P7465, L9-11 – How did the classifier work best for A-type seeps when B-type or C-type seeps were misidentified as A-types? What is 'commission'? You mean 'omission'? Is any of this misidentification/omission data anywhere to be seen in the manuscript? Did you correct for these errors? How? It is fine that the method doesn't work perfectly, but if you had to do manual corrections, then you should state how you did here as well as how you even knew that the seeps were misidentified. I am still not clear on that.

P7466, L13-15 – Did you correct for this potential misidentification of hotspots as C-types? It is fine if you did not, but you should state that in regards to your final numbers.

Section 4.4 would be 'spatial distribution of bubble patches in relation to thermokarst-

lake margin'

P7467 – I really like this relationship with emission and the distance from the lake margin; however, I kept wondering what the depths were from the margin to the center as well. Can you also put that data in the text?

Section 4.5 would be 'Multi-year (2011-2012) comparison of bubble patch characteristics'

P7468, L7-10 – You use '(a), (b)' etc here in the text, which is confusing when looking at Figure 6, which has two panels labeled 'a' and 'b' but what you want the reader to see are the images labeled '(i)' and '(ii)', etc. . .. so you should change this in the text.

Figure 6 – why is 2012 so much brighter than 2011? When first reading this section, that question stuck with me unanswered for a while. I believe later you give an explanation but I think you should address it sooner.

Figure 7 – I feel the panels should be reversed (i.e., panel C should be A and then A and B should become B and C, respectively). Then you can reference the figure panels in the text. P7468, L26 – you should reference the pressure time series, and P7468, L 28, you should reference the bubble-patch images.

P7469, L7 – I believe a sub-section of 4.5 should start here (4.5.1) where you discuss these deviations and Figure 8. In general, this paragraph was a bit difficult to follow. It could use some re-writing. I also feel a new paragraph should start at P7469, L20 with sentence 'Based on our DGPS data'.

P7470, L15-18 – 'Increased brightness' sentence is difficult to understand. How does the increased brightness of 2012 matter to the 2011 data?

P7470, L22 – what hypothesis are you referring to?

Section 5 is a nice section outlining the benefits and limitations of your method; however you should reverse the order in which you discuss things. You should discuss the

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benefits first (it's always good to start positive and the title of the section also states 'benefits' first) and the limitations/challenges second. Therefore, start the section with L25 of P7471 with the sentence 'Despite these challenges', but of course delete the 'Despite these challenges' part because you will not have discussed them yet in this new order. Also, The second paragraph on P7472 (L19) can be added to the first paragraph to make just one paragraph for benefits. As well, the second paragraph discussing challenges could also simply be one paragraph by combining sentences on P7471,L22-25 with the previous lines.

Conclusions – I feel this section should be shortened. I was tempted to say to even forget it since you could sum up everything in the previous section. However, since your method is complicated and the results and discussion are combined, I feel that a conclusion section summing your main points is necessary. Although, I suggest that you leave out any numbers, particularly ones that are already in the abstract and the results/discussion section. Try to keep to the main points without values, but then discuss how your results and the method fit into the big picture. Why is this method necessary? This is already discussed in the last paragraph, I believe. But you also must be careful not to make this section redundant with the benefits of the previous section. The conclusion should focus on how the results from this method will help advance knowledge in the big picture (i.e., global methane budgets), while the previous section focused on the immediate benefits of the method in terms of evaluating flux.

Table 1 – Why are the references there? Is it that the ground surveys are from the previously published work? IT should be made clearer in the caption.

Table 2 – clarify in the caption what 'overlapping threshold', 'total', 'as one patch', 'in a cluster of patches' means. Put in the column headings that these are 'N'.

Figure 3 – change the caption text slightly to be clearer: 'Significant differences ($p < 0.05$ at 95% CI) based on PC1 mean brightness values were found between C- and A-type seeps, Hotspot and A-type seeps,…. For 2011 and …. For 2012.'

Figure 4 – the descriptions of the (i), (ii), etc images are somewhat better here in the caption than in the main text. Consider aligning the text and caption somehow.

Figure 6 – descriptions in the caption for (i), (ii) etc are also better here in the caption than in the main text. Again consider aligning the two descriptions.

Figure 7 – reverse panels – Make C become A.

Figure 8 – This figure is slightly difficult to understand. The main text might describe it better than the figure caption. Make sure the reader can understand both.

Supplemental figures in the supplemental should be labeled 'S1', 'S2', 'S3', as is written in the manuscript text, and Table should be labeled 'T1' and placed before the figures in the supplemental.

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