The Cryosphere Discussions

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Comment on tc-2021-203

Anonymous Referee #1

Referee comment on "Seasonal evolution of Antarctic supraglacial lakes in 2015–2021 and links to environmental controls" by Mariel C. Dirscherl et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-203-RC1, 2021

Manuscript Review: Cryosphere Discussions

Seasonal evolution of Antarctic supraglacial lakes in 2015-2021 and links to environmental controls

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Summary:

In this study the authors combine observations from SAR (Sentinel 1) and optical (Sentinel 2) satellite imagery to generate a record of Antarctic supra-glacial lake coverage with high spatial and temporal resolution. The record covers six Antarctic ice shelves between 2015 and 2021. Three of the ice shelves are located on the Antarctic Peninsula (George VI, Wilkins, Bach) and three are located in East Antarctica (Amery, Nivilsen, Riiser-Larsen). The authors use machine learning to identify lakes from imagery, with the machine learning methods described in two previous papers (Dirscherl et al., 2020 & 2021). The authors investigate the coverage and reoccurrence of the lakes and perform a statistical analysis of the correlations between lake coverage and atmospheric conditions and global climate indicators.

For the Antarctic Peninsula ice shelves, they find peak lake coverage in January, with the largest lake coverage in the 2018-2019 and 2019-2020 seasons. The most significant

correlation is found for George VI Ice Shelf where lake coverage is positively correlated with air temperature, with a lag of approximately 14 days. There appears to be a negative correlation of lake coverage with the Southern Annual Mode for the Antarctic Peninsula ice shelves.

For the East Antarctic ice shelves, there is a less prominent peak in lake coverage, with coverage extending from late December to early February. Furthermore 2020-2021, saw the smallest lake coverage for these East Antarctic ice shelves. Positive correlations are observed for temperature and solar radiation with a range of lag times.

The manuscript is a natural progression from the two previous papers describing the machine learning methods. Here these methods are applied to 6 years' worth of data from 6 Antarctic ice shelves, thereby providing one of the most (if not the most) comprehensive records of recent Antarctic supra-glacial lake coverage. The analysis is thorough and generates a set of noteworthy/interesting conclusions. However, my one major criticism is that the results and discussion sections are a bit of a jumble, this is mainly due to the volume of information the author tries to convey. This could be addressed by adding more structure to the text, possibly by splitting it into six sections for each ice shelf and limiting the text to reporting the significant results with the figures contain extra details.

This work makes a worthwhile contribution to the field and I feel it will be of interest to many in the glaciology community.

I have included a commented PDF as part of my review. Here I include some more detailed points that require addressing:

Comments:

- Use of term average:
  - At times I was confused by the use of average, which in some contexts refers to: the mean of the data included in the bi-weekly value; the spatial average over the ice shelf; or the mean of multi-year data. It would be good to clarify what is mean each time average is used.
  - Secondly average is used in the abstract and conclusion with reference to the mean values from the 6 years of data. However, on first reading this gives the impression

that it is a long-term record. Saying something is above or below the average, when that is only based on 6 years of data lacks the long-term context. For instance, it may be the case that 2015-2016 was a high lake year in comparison to the 20 years beforehand, but not in comparison to the following 5 years. This point needs to be considered throughout the text when reporting differences between annual results.

- If I am interested in an ice shelf not included in this investigation what can I learn from this paper? Are there any general statements that can be applied to all lakes following the evidence generated here?
- How are datasets (Sentinel 1 & 2) combined? What is the time resolution of the pre-aggregated data? Is this consistent for each bi-weekly value? How does the performance with each dataset compare? i.e. are same lake features identified? Are there any differences? How does this impact your results?
- This new combined dataset is a great contribution to the field and this is not emphasized enough in the main text. It would be great if the usefulness of the new dataset could be highlighted more, i.e. 2D dynamics of lakes, lake geometries, etc. But maybe this is the focus for future papers?
- It would good to add details about how machine learning training data was generated and how classification was tested. Are there any feature that might be missed?
- Transport of meltwater:
  - You say that water is transported across the ice shelf (and I believe you) but what evidence do you have of actual water movement? It would be really interesting to see the flow of meltwater and subsequent growth of lakes in a time series.
  - You say that there is a lag between melt and lake growth where water has been transported across the shelf. How far has meltwater been transported? Can you investigate the lag between ERA5 data where the melt is formed and the formation of the lake?
- Figure 5: It's difficult to make out colours representing over 2 or 3 years of reoccurrence. This is possibly due to the small areas where lakes are frequently present. It would be good if bigger map plots were available, possibly in a supplement? There's so much great data here, it's a shame not to be able to see it more clearly.
- Results section: As mentioned earlier, the results section can be difficult to read in places because there is so much information about 6 different ice shelves. One way to make this easier to read would be to have a small section dedicated to each one, and then use the discussion to summarise similarities and differences between them. It would also be helpful to only report the statistical significant results and point the reader to the figures for more details.
- Correlation analysis sections: Again these two sections are difficult to read because there is so much information. I like figure 6 – maybe it would be good to use this figure to guide the reader through the results. Similarly with Figures 7 and 8, but possibly here you can be more selective about what plots you choose to show, leaving the others to the supplement.
- Similarly the discussion section includes a lot of repetition of the results section and frequently jumps from one ice shelf to another and back again – this could be trimmed down.
- Comparison with large-scale climate indicators such as:
  - DMI: Lines 589-591: I don't understand what is meant by this sentence.
  - SAM: Line 429: "correlation with annual SAM (Table 1) indicates a significant negative linear relationship (r=-0.82*) over George VI Ice Shelf." This is the only

significant correlation identified. Can you draw any API-wide conclusions from this?

I found it difficult to discern the take away conclusions about the interaction with these climate indicators. Lines 642-652 do discuss this, but the explanation is very vague, with few references to other studies that have thoroughly investigated these dynamics.

- Melt-albedo feedbacks (Line 678): not sure whether you have mentioned any particular examples of this from your results. It would be great to see some examples.
- Table 2: "Local controls" how have you determined these correlations? It's easy to miss this in the text, so it would be good to have a dedicated results section on this (similar to point above).
- Buried lakes: This is mentioned in the conclusion and abstract, but not in the main text. How important/common are they? Where are they found? Is this one difference between sentinel 1 & 2? Are you missing them in Sentinel 2? How does this impact your results?
- ERA5-Land climate reanalysis – you haven't included any discussion on the potential shortfalls of using this data. For instance, are small scale effects around blue ice or exposed bedrock included? How does this impact your results?

Minor Comments:

Line 101-102: Use of space when quoting numerical values to separate thousands from hundreds, i.e. 10 000. (i) I'd usually choose to use a comma; 10,000. (ii) I'd apply this to 1,000 and 10,000. I'm not sure what the formatting choices of the journal are.

Line 287-288: "We observe a rapid onset of supraglacial lake formation in late January" Fig 3 shows that the peak lake coverage is in late January not the onset of lake formation.

Line 292-293: "More specifically, lake extents during the 2019-2020 and 2020-2021 melting season were above average during their peak and slightly below average in parts of early 2019-2020 and late 2020-2021" Does this imply faster than usual lake formation? Do you think this is a result of shallower lakes?

Line 371: "lakes spreading across Nivlisen Ice Shelf": Can you detect whether this spreading is occurring in time? i.e. lakes spread during melt season or lakes spread year on year?

Line 377: “average and maximum air temperature” What average is this? The spatial average across the whole shelf? The average of the aggregated data? The multi-year average?

Lines 429-434: It might be easier for the reader if you only report the significant results in the text, as otherwise there is too much information to take in.

Line 613: I don’ understand what you mean by “north(-easterly)”

Line 638 -639: “firn air depletion potentially contributing to facilitated melt in 2020-2021” do you mean lakes rather than melt?

Line 665: “latitudinal flow stripes” I don’t think latitudinal is the best word to use here as the structure of the flow stripes is so complex. I suggest just removing latitudinal.

Line 667: “surface slopes” do you mean low surface slopes?

Line 781: Include reference to: Gilbert, E., & Kittel, C. (2021). Surface Melt and Runoff on Antarctic Ice Shelves at 1.5°C, 2°C, and 4°C of Future Warming. Geophysical Research Letters, 48(8), 1–9. https://doi.org/10.1029/2020GL091733

Lines 803-804: Example of how you are using your short record to talk about anomalous years, without any context of long-term values.

Line 807: “record low lake coverage” same as point above.

Line 808: “Lateral meltwater transport” where is the evidence for water flow/movement?

Line 829: “Reduced firn air content” How is this measured? Are you inferring this from the records of low snow accumulation?

Figure 1: “the large lake feature at the western grounding line was excluded from analyses”

I’m not sure what is meant here. (i) This is not mentioned anywhere else in the text. (ii) It is not clear what feature/lake you are referring to. (iii) What impact does excluding this area have on you results?

Figure 2: Looking at Figure 2e I wonder how much of this region is classified as a lake? There seems to be a high bright patch of open water and then an elongated drainage pathway. In the main text there is no discussion about meltwater volumes and how this might affect correlations with temperature and radiation, etc.

Figure 5: As mentioned above, visibility of plots could be improved.

Please also note the supplement to this comment:
https://tc.copernicus.org/preprints/tc-2021-203/tc-2021-203-RC1-supplement.pdf