Reply to William Armstrong (RC1)

Review of “Brief communication: Hydrologic connectivity of a tidewater glacier characterized with Sentinel-2 satellite images – a case study of Nordenskiöldbreen, Svalbard” (tc-2022-54) by Jan Kavan & Vincent Haagmans

Summary
The authors lay out the issue that field measurement of glacier hydrology is difficult, yet significant computing & remote sensing expertise is often needed to ingest the large volumes of freely available satellite data. The authors therefore ask the question, “can one, without expert knowledge of processing remote sensing data, use Sentinel-2 imagery to study a subject as dynamic as the hydrological system of a tidewater glacier?” The authors manually digitize Sentinel imagery to characterize the areal extent of sea ice, supraglacial lakes, and sediment plumes as they evolve over the melt season of several years. The authors demonstrate that Sentinel is a useful tool for glacier hydrology surveillance, but don’t really ask or answer any science questions that advance the field other than “how do these things vary?”. I don’t see any serious flaws in the study, but think the study generally illustrates something that is already well-known (i.e., that satellite data, and particularly high spatial & temporal resolution data, is useful for glacier research). The study could be strengthened by framing their research around a process-based question about glacier hydrology. However, that is something of a value judgement/opinion, and think the manuscript could be publishable after addressing the following major & minor comments, constituting what I think are “minor revisions”.

Major Comments
1) In Section 2, you lay out a lot of background on previous work conducted on Nordenskiöldbreen, but never state “why this glacier”. Why is this your study site? Are there reasons to expect that this is a better/worse site for a Sentinel case study than any other Svalbard glacier (or global glacier, for that matter)?
REPLY: Good point, this core question was not addressed by the authors. A paragraph has been added at the end of the introduction:
‘The tidewater glacier Nordenskiöldbreen was selected as a study subject due to the combined availability of local meteorological records from the shores of an adjacent bay, Petuniabukta, and a significant body of literature focused on the glacier. Moreover, a rather dry continental climate ensures a relatively high number of clear sky days compared to the coastal regions of Svalbard. Hence, a sufficient number of Sentinel-2 images can be used to illustrate the seasonal dynamics of the glacier system. Finally, over a decade of combined local field experience around the study site supports the interpretation of observations.’

2) On L96 you state that “the areal extents of sea ice, sediment-laden meltwater plumes, and selected supraglacial lakes were quantified using Sentinel- 2 satellite false-color images” but give no criteria for how you are going to define these features? What image interpretation cues are you using to say something is sea ice vs. icebergs, do you consider frozen supraglacial lakes, etc.?
REPLY: Thanks for this question, it was somehow obvious for us, but certainly not for the reader. We included a more detailed description of how the features were delimited. In fact, both supraglacial lakes and sea ice cover are very contrasting features and easily visually detectable. The supraglacial lakes did not freeze, they all drained before the below zero temperatures arrived in mid September. Also there were no lakes before May/June when they started to fill in with meltwater. In the case of icebergs, there were usually only a few of them incorporated within the sea ice cover. Delimitation of sediment plumes is of course more complicated as the boundary between the plume and clear sea water is not always so clear - in the corrected manuscript we use improved methodology that we tested in a

different location of Svalbard ad which was published recently in Kavan et al. 2022 (10.3390/w14121840)

3) Use of transition words like “furthermore” sometime seem out of place/incorrect. “Furthermore” implies that you’re building on a previous argument, but “additionally” seems like a better transition word (you’re often just adding more information, not necessarily “building a case”) > for example L78.
REPLY: The transcript was scanned for similar cases as on L78 and if necessary reworded.

Minor Comments
L24: Need a citation to support that subglacial discharge is generally the primary mechanism for meltwater export.
REPLY: We believe that this is supported with the following sentence (also with references).

L43: Perhaps worth noting that the tidewater glaciers disproportionately contribute to Svalbard glacier area/mass flux/mass loss (if true).
REPLY: Tidewater glaciers in Svalbard contribute disproportionately to the Svalbard glacier areal cover. Has been added to the manuscript as: ‘About 15% of the glaciers on the Svalbard high-Arctic archipelago are of the tidewater type, yet these make up as much as 60\% of the glacier-covered area (Blaszczyk et al., 2009)’

L45: O’Neel et al. (2015) would be a good reference to support this statement > doi: 10.1093/biosci/biv027
REPLY: Thank you for the suggestion. It has been included.

L53: Svalbard glaciers are retreating significantly faster than other Northern Hermisphere glaciers? If so, “faster” is missing from this sentence.
REPLY: This does not necessarily seems to be the case (e.g. Kochtitzky and Copland, 2022) and therefore ‘faster’ was not included

L63: Unclear > your evidence that the glacier is partly land terminating is that there’s no crevasses? Can you not just see land in the images? There are other ways to get crevasse free ice.
REPLY: You are right, we adjusted the sentence to “Presently, the southern and northern margins and the center of the glacier front (on Retreat Island) are land-based, as derived from satellite imagery through the absence of crevasses and also from in situ observation where the bedrock appears beneath the glacier masses.”.

L64: Can you provide a little more information about what these “morphological features” are?
REPLY: These are mostly ice-cored moraines close to the centerline and fluted surfaces close to the margins - this was added to the text.

L68: Incorrect period after “m” in 30 – 60 m a-1
REPLY: The period was removed.

L98: Surely given the magnitude of previous work done on this glacier, someone has quantified the melt season and you don’t have to just assume a start/end date? Or can you use meteorological data to identify when temperatures go above 0 °C on average?
REPLY: This assumption was used just to define the period for gathering the satellite images, but in general it corresponds to the meteorological data from the area (station in Petuniabukta close to sea level). The sentence was adjusted “Images covering the ablation season as derived from the meteorological observation in Petuniabukta(15 May – 30

September) with cloud coverage smaller than 20% were extracted and checked for their suitability."

L112: Is there any temperature offset between the two met stations? Do you correct for it?
REPLY: The offset is 0.48°C for mean daily temperature during the summer season (warmer conditions in Petuniabukta), the coefficient of correlation is 0.94. We did not correct for it as the offset is rather small and we use the air temperature more as an illustration of the processes. It would be worth correcting when using for modeling purposes etc. We add the information on the offset.

Fig 3b: How is sea ice concentration defined?
REPLY: The sea ice cover is compact, a single borderline between open water and sea ice is very clear. We add a more precise definition of the sea ice coverage in the methods section.

L128: The sentence starting with "probably" should be combined with the previous sentence – it is not a complete sentence.
REPLY: Thanks for noticing this, it was corrected.

L134: How do you know the water came from snow on the mountains and isn't locally sourced glacier melt?
REPLY: You are right, it was meant that it could be ALSO from the snow on the nunataks, the missing "also" was added.

L137: Can you see surface streams in the imagery? That could help you rule out surface connection between the lakes accounting for the synchronous timing. I suspect your latter hypothesis (separated systems responding to a shared forcing) is the most likely.
REPLY: We cant see any surface streams on the images actually (which can also mean that these are too small for the 10m resolution). From a field experience we did not observe any surface outflow from a Nordenskiold Lake, for sure there was a huge moulin in the center of the lake connecting the lake to subglacial network. We did not reach the other supraglacial lakes. It is thus hard to make any final conclusion on that.

L139: Clustered how? Spatially or by their behavior? This is also discussion, not results.
REPLY: The referenced lakes clustered spatially. Yes, we have the subchapter defined as "Results and Discussion" to facilitate interpretation of our outcomes.

L163-165: You should note that you can also use microwave remote sensing to see through clouds, coarser resolution traditional satellites (e.g., MODIS), or cubesats (e.g., Planet) to get around these cloud & temporal sampling issues.
REPLY: Again, a good point. We will elaborate on this and compare our Sentinel-2 dataset to other comparable publicly available satellite remote sensing products. The question is whether these will capture well the sediment plumes.

L166: Subglacial discharge may not make it to the fjord surface if: 1) the flow is hyperpycnal due to high suspended sediment load, or 2) the upwelling discharge plume reaches neutral buoyancy below the surface (e.g., Donald Slater papers). These limitations should be acknowledged in using plumes as your sole proxy for subglacial discharge. (Recurring at L193).
REPLY: In general, you are right. In this specific case, we are pretty sure the sediments reach the surface as the outflow from the subglacial channel is near-surface or basically on the surface as the front of the glacier is currently almost landbased. It is quite different from

what is known from massive greenlandic tidewater glaciers for example. We add an explanation to the text.

L189: Citation or more justification needed that the discharge conditions would inhibit vertical water movement.
REPLY: We used the bathymetry mapping (Baeten et al. 2010 doi:10.1144/SP344.15) to illustrate the shallow marine environment. The photo from the field to illustrate near surface outflow from the subglacial channels may be used as well.

L198: Strange to say maximum temp is approximately 10 °C and then say 17 °C in the following sentence. Please clarify different metrics or simply statements.
REPLY: We agree, the sentence was modified to "The maximum values of approximately 10°C were usually observed during late July in the past years."

L206: This finding could also suggest that subglacial hydrology acts as a flow integrator over these timescales.
REPLY: Thanks for this idea, we tried to include that in the text.

L212: "Massive" is subjective, and you don't actually quantify subglacial discharge > reword.
REPLY: Sentence was rewritten as: 'Lake drainage is promptly accompanied by significant subglacial runoff expressed through vast meltwater plumes visible on the surface of Adolfbukta near the subglacial drainage outlet in the southern part of the glacier front'

L231: This is stylistic, but I would suggest the conclusion have a "wrap up" sentence instead of ending with this specific example of air temp-plume area relationship.
REPLY: Good idea, we will add a couple sentences as a 'wrap up' (as also suggested by Reviewer 2) and put the work in a bigger context.

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