Taylor and Carr present an assessment of supraglacial pond evolution in the Everest region of Nepal over a ~2.5 year period using Sentinel-2 imagery. As they detail, the region has seen extensive research investigating glacier hydrology and supraglacial pond dynamics. For this reason, I would expect the paper to offer new insight into the changes in this area, rather than a simple extension of previous studies by a few years. They suggest the need for a new method of ranking glaciers based on their stage of lake development (which a novel aspect of the paper) but this is not adequately supported by the results. A spatio-temporal assessment of pond evolution needs to consider the change at specific ponds/pond basins, e.g. the recent work by Benn et al. (2017). Similarly, grouping pond change into elevation bins is problematic in the study region because of the low gradient nature of the glaciers. Other studies have opted for distance based metrics e.g. Thompson et al. (2016). Nonetheless, it is not clear which DEM (or the date) was used in the paper for the elevation groupings. Objectives 2 and 3 have been addressed in other studies, so again there are limited insights here. The spatial resolution of the imagery used (10 m/ 100 m^2) does not allow the authors to address how many ponds were smaller than 100 m^2 for their Objective 2.

My main concern is the lack of detail and errors in the methodology e.g. lack of an uncertainty assessment, and justifying and specifying the use of a thermal band for pond classification, when Sentinel-2 does not have a thermal band, and nor would it be suitable for pond classification. This naturally leads to questioning the robustness of the results over such a short timeframe when previous studies have shown large intra- and inter-annual variation in pond coverage. To highlight this, I have shown the pond data for 2016 and 2017 on Khumbu Glacier from Watson et al. (2018), which was derived from 0.5 m and 3 m resolution imagery respectively. In both cases, the total pond area reported by Taylor and Carr for the same years is approximately double that of Watson et al. (2018), so further investigation is required. There are Taylor and Carr classified ponds that I see no evidence of in the raw imagery (I have provided an example on Khumbu Glacier). There are also issues in the discussion, where the authors refer to ponds in the 'high accumulation zone' despite glacier accumulation zones not appearing in the study.

Conclusions of rapid pond expansion discussed in the context of outburst flood hazards is a sensitive issue in a region where $7 million was recently spent on glacial lake hazard mitigation work. Therefore, I believe it would be unfortunate (and potentially problematic) for residents to be unnecessarily alarmed or misled based on these results. The authors should improve their methodology and demonstrate that the results are robust. For the reasons outlined above and detailed below, I cannot recommend publication in The Cryosphere and I have rejected the paper on this basis.

I have detailed specific problems below and I hope the authors would use this to help prepare a substantially revised study, which I would gladly read. The authors could include comparisons to the reference datasets of Watson et al. (2018) in their study, which can be provided on request. The authors should also ensure that the results are communicated in a way that considers the sensitive nature of glacier hazards.

Kind regards,

C. Scott Watson

General comments

Objectives:

- Objective 1: this is difficult to address over such a short time scale in your study (December 2015 to April 2018). Recent work has shown that in some cases pond coverage is expanding in the region; however, the takeaway message from Watson et al. (2016) was that pond coverage was expanding in

some locations but there was large annual and inter-annual variation. Seasonal pond expansion was especially large. Therefore making conclusions based on less than three years of data is problematic.

- Objective 2: 100 m^2 is the pixel area of Sentinel-2 imagery so you cannot state what proportion of ponds were less than this without subpixel analysis or use of validation data. Nonetheless, the issue is already addressed in detail by other studies e.g. Salerno et al. (2012), Miles et al. (2016), Watson et al. (2016) and Watson et al. (2018). Your results are not discussed in the context of these studies. Without using subpixel analysis or a validation dataset, you cannot perform this objective.
- Objective 3: this was recently addressed by Salerno et al. (2017) and Watson et al. (2017a) for these specific glaciers. Your findings should be discussed in the context of previous studies.

Methods:

- There is no uncertainty assessment in the pond or cliff classification so it's not clear what is statistically significant and what isn't. This could be carried out using commonly used +/- one or half pixel uncertainties in the classification.
- There is no information regarding how the Maximum Likelihood Classification (MLC) was carried out (number of training sites, distribution, validation etc).
- The authors state they used bands 5 and 7 but no justification is given. They state they used band 7, which is incorrectly referred to as a thermal band, because 'thermal wavelengths are absorbed by water bodies so their addition aided the classification substantially'. References should be provided. Nonetheless, this is concerning because Sentinel-2 does not have a thermal band.
- The single reference used to support the Maximum Likelihood Classification '(Tiwari et al., 2016)', specifically state that they did not use the method for classifying water because there were 'no prominent water bodies' in their study. The conference paper was focused on classifying debris cover from clean ice.
- It is not clear how many ponds were manually classified vs classified using MLC. Figures 3 and 4 show a clear difference in the appearance of pond outlines, with many appearing very smooth and rounded but few displaying edges suggestive of a pixel classification. There are also many ponds that have been classified outside of the glacier masks.
- Please provide detail about how/if the frozen or partially thawing nature of the pond surfaces in April would affect the classification. Provide examples of the underlying imagery used. Currently all examples are hidden by the glacier masks or the pond polygons. A separate figure should be added showing the classification procedure. The images 2016-2018 are progressively later in April, could this lead to larger ponds in the later images?
- Please provide detail on the ice cliff digitization, perhaps on the same figure as the pond classification.
- Please provide detail on the elevation bands. I'm not clear how they were derived or what they correspond to. Perhaps add a figure in the supplement.
- Glacier names: I can't find reference to Pangbung and Sumna Glaciers. International Centre for Integrated Mountain Development and other publications refer to them as Bhote Kosi Glacier and Melung Glacier.

Results:

For comparison, I have taken the published data of Watson et al. (2018) for Khumbu Glacier in 2016 and 2017. The reference datasets were derived from 0.5 m resolution Pleaides imagery (Nov 2016) and from 3 m resolution PlanetScope imagery (Nov 2017). These are not directly comparable with the April data of Taylor and Carr, but nonetheless should have a similar pond area since both datasets are outside the melt season. November 2016 should also be comparable to April 2017, since ponds may have shrunk over the winter, but not expanded. I have also included the pond area delineated using a NDWI classification applied to Sentinel-2

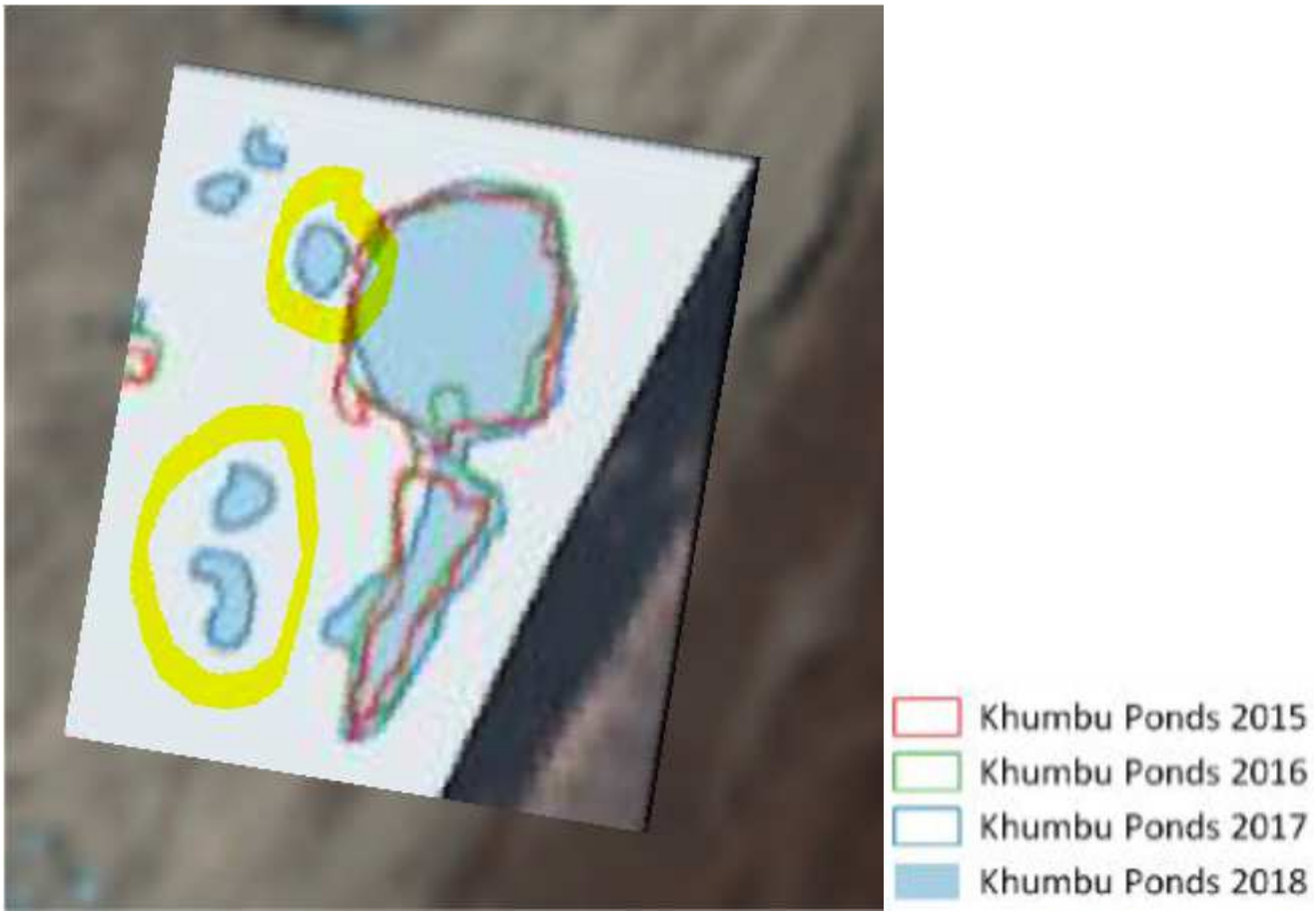
imagery (Nov 2016 and 2017). The reference dataset was also derived for other glaciers in your study, so consider requesting this from the authors or collaborating with one of the several research teams that has data in this region. The classification of Taylor and Carr Khumbu Glacier contains approximately double the ponded area compared to that of Watson et al. (2018). In the case of two instrumented ponds on Khumbu Glacier Watson et al. (2017b), water levels were observed to be rising in mid-late April (see their Fig. 6), so the difference between pre- and post-monsoon water levels requires investigation.

	Watson et al. (2018) (November) Reference dataset	Watson et al. (2018) (November) Optimised Sentinel-2 classification	Taylor and Carr (April)
Glacier (date)	Pond area (m^2) (number)	Pond area (m^2) (number)	Pond area (m^2) (number)
Khumbu (2016)	195,100 ± 17,000 (287)	197,700 (188)	369,168 (165)
Khumbu (2017)	191,500 ± 76,000 (211)	180,300 (172)	427,386 (225)

Missing ponds:

I cannot distinguish between the 2017 (blue outlines) and 2018 (blue fill) on Khumbu Glacier (Figure 3). Nontheless, I have taken a distinct area of ponds and compared the Taylor and Carr classification with the Sentinel-2 imagery they used in the study (I have screenshotted band 8, 4, 3 false colour composites). I cannot see evidence of the yellow highlighted ponds in either of the two Sentinel-2 images that the classification should be based on (2017 or 2018).

Taylor and Carr Figure 3 classification overlaid on Sentinel-2 imagery:



18 April 2017:

23 April 2018:

With transparency:

Specific comments

L8. ‘which can potentially represent a hazard’

L12. Is this the same chain identified by Watson et al. (2016)?

L15. Clarify ‘general theory’

L16. Does this affirm the conclusions of Watson et al. (2018)?

L42-43. The Watson et al. 2016 ref doesn’t belong here.

L55. ‘and presence of ice cliffs’

L96-97. ‘high’ is not specific.

L110. In the abstract you state the resolution is 10 m. Here you state <10 m.

L117 ‘minimize’ to be consistent with American English. Check for consistency throughout.

L118. Specify the two tiles used in the mosaic.

L120. Use ‘non-glacier’ instead of ‘land’?

L120-121. There are clean ice areas on Khumbu and Ngozumpa Glaciers within your debris mask. Add the RGI citation.

L124. ‘semi-automatically’

L125. How many training sites? Distributed how? Did you aim to just include pure pond pixels or mixed pixels also?

L126-128. Band 5 is not the NIR band, nor does 7 have a thermal wavelength. Sentinel-2 does not have a thermal band.

L136. Do you mean the ASTER GDEM, or an ASTER DEM product (e.g. AST14DEM)? Specify the citation and date for whichever was used.

L139. What is the uncertainty in this velocity product? On Fig.7 you show velocities of 2 metres per year down to less than 0.5 metres per year. Detail how this can be resolved in a 120 m spatial resolution product.

L140. Specify what type of bands. Elevation, distance?

L141. Specify how the cliffs were mapped. As polygons e.g. Herreid (2018)? Or lines e.g. Watson et al. (2017a). The former requires fine resolution imagery/ DEM so it’s not clear how this was done on Sentinel-2 imagery, especially when resolving steeply-sloping cliffs. What was the uncertainty in the delineation?

L157. ‘markedly’

L174. Remove the decimal point. 456 m

L175. Remove the decimal places from ‘1,493,142.68’

L191-193. I'm not sure why this comparison is made. As a proportion of the glacierised area, pond coverage on Lhotse Shar and Imja were similar (Fig. 9) and you show the area of Lhotse Shar to be approximately three times that of Imja.

L204. How was the average slope calculated and does it related to the full study glacier (including clean ice), or the smaller mask that you are using?

L207-209. Clarify what you mean by '10 equal elevation bands' in section 2.4 and how this varies glacier to glacier. Consider a methods figure showing the process.

L217-218. Accumulation zones are not part of your glacier mask so this is incorrect.

L221. What do you mean by 'higher frequency ponding'? Is this the same as 'numbers of ponds' used in the previous sentences. If so perhaps change for consistency.

L222. Define what you are calling a 'break in slope'. Some glaciers e.g. Nuptse and Khumbu have similar 'steps' in the elevation profile in Fig.5 but no labeled break in slope. Does this relate to local slope, or the glacier gradient?

L234. Add a space between units here and throughout and be consistent with the figure axis label.

L246-247. The percentage change is actually quite small, so could this be within levels of uncertainty?

L245. Be consistent with the number of decimal places.

L247. Remove space. '3.3 %'. Check throughout.

L248. Remove '-' in ice-cliff and be consistent throughout.

L249. Do you mean they covered an additional 1.6% of the glacier surface area?

L254-255. This is text for the discussion.

L259. You need to give the reader some information in the text regarding what these stages mean. 'ice-dammed' what?

L260. Space between units.

L263. Fig. 10b does not detail the ablation zone. 'Ablation zone' and 'accumulation zone' need to be specifically detailed in the context of the study and figures in order to discuss them.

L278-281. There is an assumption made here that Lhotse Glacier is going to develop a proglacial lake, so you need to detail why. There is a small village (Chukhung) nearby, and they would likely be very concerned to hear these results.

L283. Could precipitation have caused the pond expansion trend observed? i.e. could 2018 have seen more snowfall than 2017 or 2016?

L292-294. How prevalent are crevasses on the study glaciers?

L296. Provide a reference here. I think (Benn et al., 2012).

L301. This may be true, but the reader cannot tell unless you present an analysis of how individual ponds have changed.

L307. But only if the expanded pond area is suitably aligned.

L311. You are 'suggesting' things that have already been detailed in the references. The reader wants to know what has changed. What is your study showing that's new? Are these velocities different from previous studies, or does your data demonstrate the same thing and reaffirm those studies?

L321. 'could be due to the formation of new ponds in addition to pond coalescing' is not specific. What do your specific data show?

L323. Where do you show that ice velocities are higher on the smaller glaciers? This is not consistent with my understanding.

L330. What about weather, which is more relevant to your study time scale?

L334. I'm not sure you've made a specific comparison in terms of pond area/number?

L336. This does not suggest seasonal variations have limited impact. Your data do not show this. It suggests that you expect the trend you found to exceed any seasonal variation.

L338-350. This is problematic because there is an assumption that Sentinel-2 can observe the full size distribution of ponds. Salerno et al. (2012), Watson et al. (2016) and (2018) deal with the issue of pond omissions/ commissions using satellite imagery of variable resolution and include even finer-resolution imagery as ground truth (~ 3 m or less). Therefore, I don't think this section adds anything new. Nonetheless, this paragraph should refer to these previous studies.

L340. 100 m^2 is the pixel area of Sentinel-2 imagery so you cannot state what proportion of ponds were less than this without subpixel analysis or use of validation data.

L342. There is no supplementary Figure 4.

L350. Watson et al. (2018) also provided a pond-by-pond comparison of the role of fine resolution vs coarser resolution imagery.

L355. 'large number of ponds coincided with slopes of 2-4°'. This analysis is not presented. Is it based on the ASTER DEM?

L357. Slope or gradient. Terminology needs to be clarified since local slope, and glacier-scale slope/ gradient, have very different meanings and roles.

L363. 'We suggest' should be referring to a new interpretation, not something widely known. 'Affirm' or 'confirm' should be used when your results support already published works. This should be changed throughout the paper.

L373-375. How does this compare with Watson et al. (2016)? Has the spatial distribution of ponds changed significantly?

L381. 'promotes'

L395. The correct Watson reference for ice cliff melt is Watson et al. (2017c).

L404. Watson et al. (2017a) found cliffs 20-40 m in top edge length to be most prevalent in the region, which indeed suggests that Sentinel-2 can observe some of the larger cliffs, but the uncertainty will be large. The main issue is that the surface of steeply sloping cliff topography is not resolved unless using a 3D surface.

L414. Your study was less than 4 years. December 2015 to April 2018.

L449. Why are ponds classified outside the mask on Supplementary Figure 2?

L485. Specify the ESA usage statement/citation for Senitnel-2 data.

Figure 1. Can you add the rest of the glacier outlines and specify debris vs clean ice. Specify UTM grid zone 45N. Suggesting changing the inset to lat lon.

Figure 2. Incorrect units (km^2).

Figure 3. There are some ponds outside the glacier outline. Are these included in the calculations? I can't see a clear different between 2017 and 2018 outlines in some cases (e.g. on Khumbu Glacier).

Figures 5-8. Graph scales vary between glaciers, which makes visual comparisons difficult.

Figure 6. 'glacier elevation/slope at 10% glacier area distance bands'. These need detailing in the study and you should show them on Figure 1.

Figure 7. Change the velocity label to 'm yr^{-1}' or 'm a^{-1}' with superscript,

Figure 10. There appears to be some issue with the pond outlines on the lower panel. I suspect glaciers west of Nuptse have pond outlines (with a line thickness), whereas those west of Nuptse have a filled polygon but no outline, making the ponds look less prominent. Check and correct if required. Label the panels. Did this influence your interpretation of the potential for catchment microclimates?

Figure 11. Very similar to Table 3. Condense to a table or Figure.

Supplement:

Figure 1. Units are incorrect.

Figure 2. State the imagery date.

Table 2. Specify the full imagery date.

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