We thank Reviewer 2 for their comments on our paper. Their suggestion to expand on the ice-dynamic impact had led to us carrying out additional ice velocity analysis for the 2015 drainage event using feature tracking of radar (Sentinel 1a) satellite data. The results suggest a slowdown in ice flow during the drainage event, and we have now included this in the paper through the addition of a figure, and methods, results and discussion. Our responses can be found below. Reviewer comments are in black and replies in blue.

On behalf of all co-authors,

Kind Regards,

Stephen Livingstone

Reviewer 2

General Comments

The manuscript is well written and reports on some very interesting observations. The main shortcoming is a complete lack of the investigation and discussion of ice dynamical effects. While a numerical study is clearly outside the scope of this paper, the DEM and satellite velocity data products could be easily investigated to answer some important questions.

A subglacial lake of a lateral extent of twice the ice thickness will strongly affect the surface topography and the ice flow field. Is there any evidence of a flat surface over the lake (this should be readily visible form the DEM)? Is the surface structure changing after the drainage events, e.g. a downstream bulge, or crevasse zones?

In terms of a surface expression of lake drainages, unlike in other examples of Greenland subglacial lake drainages, we do not see any evidence of a compressional zone or increased lateral crevassing at the downstream end of the lake (see Figure 1 below which shows hillshaded surface topography before and after the 2015 drainage event). The only evidence seems to be lowering of the surface above the lake, which you can see by the shadow at the downstream (left-hand) end of the lake. The ice surface above the lakes is also not flat (Figure 1). We suggest a number of reasons why this could be the case: (1) the relatively modest thickness of ice (approx. 400 m beneath lake 2) and small predicted size of lakes (<1 km^2), which are likely maximum estimates given the influence of bridging stresses and the viscosity of the ice on the transmission of the effects of lake drainage to the surface; (2) unlike subglacial lakes observed elsewhere (e.g. Antarctica and further from the margin beneath the Greenland Ice Sheet) these are in a relatively confined outlet lobe and close to an ice-dammed lake. Due to the relatively deep depressions and lakes at the lateral ice margins, the ice flow in part 'peels' off to either side of the main glacier trunk. This creates a complex pattern of crevassing that may hide the (relatively subtle for the reasons outlined above) influence of the lake; (3) if the bed was relatively rough, coupled with the small sizes of the lakes, the bed would have a large effect relative to the lake, whereas in Antarctica where lakes are often an order of magnitude larger, the lake 'slippery spot' may dominate; and (4) complex surface hydrology, emergence of debris-rich layers at the surface and localised meteorological factors (katabatic winds moving emergent dust around, and strong solar insolation with resulting albedo variations) results in a complex ice surface topography with almost ubiquitous 4-5 m relief that is independent of crevasse formation.

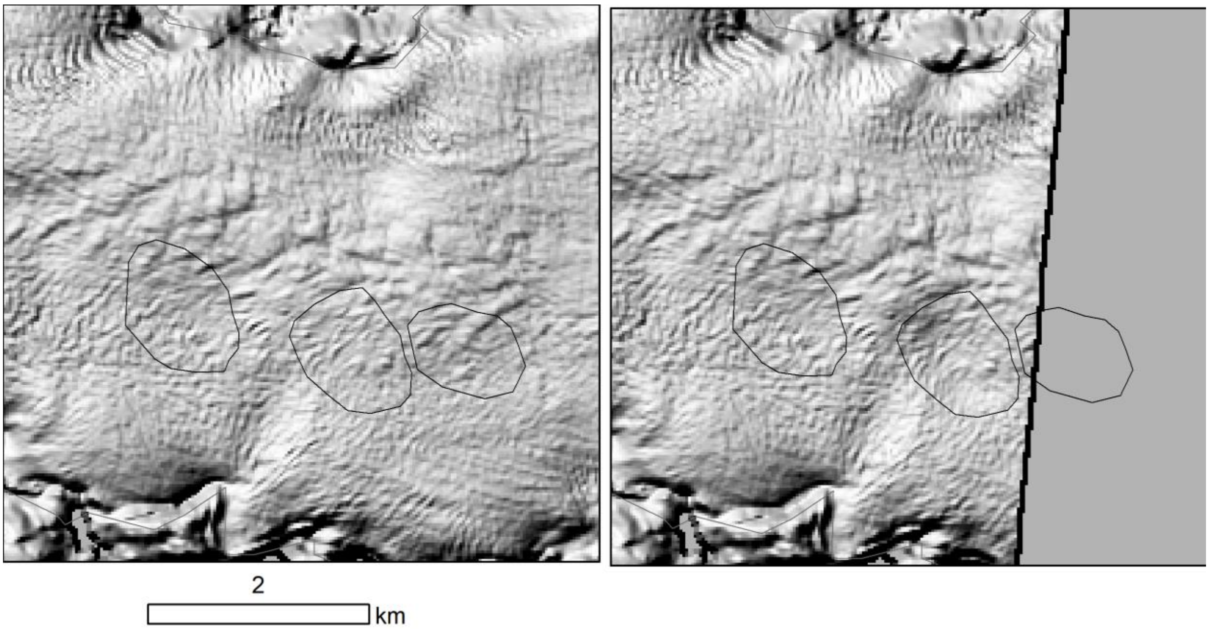

Figure 1: ArcticDEM hillshaded DSMs before (2nd August) and after (21st September) the 2015 subglacial lake drainage event. The lake that drained during this period is the middle of the polygons. The drainage is picked out by a drop in ice-surface elevation. Note how the surface is not completely flat.

The ice flow field would also be greatly affected by uncoupling from the bed of such a big area. Is there indication of increased lateral crevassing, or a compressional zone including a surface bulge at the downstream end of the lake? Are ice velocities higher over the area of the subglacial lake? Are velocities changing during drainage and refilling?

Good point. Although we could not identify an increase in lateral crevassing, compression (e.g. a surface bulge) or locally higher velocities over the subglacial lakes, we did identify an ice-dynamic response during the 2015 drainage event, although this is complicated by a regional slowdown that occurred during the same time. We used Sentinel 1a radar data (12-day repeat image pairs) to calculate ice velocity from feature and speckle tracking (adopting the same method published in Tuckett et al., (2019)). Anomalies were calculated relative to the 2015 winter mean, and revealed a distinctive and abrupt slowdown to winter values immediately downstream of the lake (relative to upstream, where values were positive) over the period during which it drained. We believe this is the first evidence for a net slowdown in ice flow following a subglacial lake drainage and have therefore added in a new methods section as an Appendix to detail the ice velocity methods; combined figures 1 and 2 (which focus on ice-surface elevation change) and added a new figure 2 where we show the ice velocity anomalies; and expanded both the Observation and Discussion sections to include a description of the ice velocity response and then some discussion on why a net slowdown is possible in the context of these lakes. We think this has added substantially to the paper, so thank the reviewer for his suggestion.

Tuckett, P.A., Ely, J.C., Sole, A.J., Livingstone, S.J., Davison, B.J., Melchior van Wessem, J., Howard, J. Large and rapid accelerations of Antarctic Peninsula outlet glaciers driven by surface melt. Nature Communications, 2019.

Minor comments
26 "channel melt rates" (it is important to distinguish this from surface melt).

Done

33 "surface melt water"

Not all water in subglacial lakes will be from surface melting (e.g. basal frictional and geothermal melting) and we therefore prefer to leave this as just meltwater.

41 This is somewhat problematic, as the lakes are at the ice bottom, which is not above the ELA. Their locations are at positions in the accumulation area, where the *surface* is above the ELA, or simply, above the EL.

Good point. We have rephrased as per the reviewers last suggestion, EL.

62 Were these anomalies stable in space, or moving with the ice?

Yes, good point, these anomalies are stable in space, i.e. they do not migrate down ice through time. We have added this point to the methods and observation section – *"Timeseries of relative elevation change for each anomaly, which are not advected towards the margin, were calculated from sub-annual ArcticDEM DSMs by subtracting the mean ice-surface elevation of the anomaly from the mean elevation of a 500 m buffer around it (Fig. 1b)."*

72 An indication of the ice thickness above these features is needed.

Rough ice thicknesses for each anomaly have been added to the descriptions.

115 The change in surface elevation is only discussed in terms of subglacial water storage. Another cause could be ice compression by horizontally convergent ice flow. Can this be ruled out by the surface velocity field?

If we understand you correctly, we do not think this likely for a number of reasons. (1) the anomalies are all circular to ovoid in form, which is consistent with a ponded water body rather than horizontally convergent ice flow, which we might expect to produce a more flow-parallel, linear feature; (2) horizontally convergent ice flow would produce the rise in ice surface but does not account for the drop in elevation; (3) the drop in elevation in the 2015 example coincides with an outburst flood and proglacial sediment accumulation, which we suggest must have been caused by a rapid drainage event; and (4) the anomalies are stable in space (i.e. they do not migrate down ice).

Figure 1: Years are barely readable. Better underlay the numbers by white background. Also describe in the caption that the "ice dammed lake (white background)" is visible on the surface.

We have extended the caption to mention the ice-dammed lake. We have added a white background to all the numbers and text.

Figure 2: The black line should be broken at 2011, as the anomaly might have been much lower than suggested by the line.

We have made the line dashed at 2011 to indicate that the anomaly could have been much greater, and also added a comment in the caption. Note this is now Figure 1b to account for the new ice dynamic work and figure.