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Interactive comment on "Rapidly-changing subglacial hydrology pathways at a tidewater glacier revealed through simultaneous observations of water pressure, supraglacial lakes, meltwater plumes and surface velocities" *by* Penelope How et al.

Anonymous Referee #2

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Summary This manuscript presents a combination of field and satellite observations of borehole water pressure, supraglacial lake area, ice velocity and plume extent at Kronebreen, Svalbard. These observations are combined with surface melt, runoff and subglacial hydropotential modelling to infer spatial and temporal variations in the glacier's subglacial drainage system, and the relationships between these variations and ice flow. The manuscript presents a useful, multi-faceted dataset, but currently the analysis of the data is simplistic and not fully supported by the evidence presented (for

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example, suggestions that tides influence the timing of plume pulses). As a result the conclusions are rather vague, and less significant than they could be. Also, it seems as though from the outset that hydrology was identified as the principal control on ice dynamics, and other potential factors have been ignored.

Main points

1. No attempt is made to investigate alternative controls on ice velocity apart from variations in subglacial hydrology. This is especially pertinent for the early season 'flushing event' which causes the up-glacier drainage of the supraglacial lakes. 2. The borehole water pressure gradually decreases while ice velocity is increasing, which does not tie in with your explanations of ice motion being controlled ' by the location of efficient/inefficient drainage and the position of regions where water is stored and evacuated from' (pg. 1) 3. The description of seasonal variations in ice flow (i.e. that the speedup is constrained to the southerly part of the near-terminus region) does not seem to be supported by the example velocity images shown. It would be useful to produce some plots showing relative changes in ice velocity, so that the reader can see the justification for the discussion. 4. Assertions made in the discussion should be backed up with data and results. For example the suggestion that tides influence the timing of plume pulses (but there are many other similar examples as detailed in the specific comments below).

Specific points (by page and line number)

P2, L3: Data are plural. 'data is' should be 'data are'

P2, L16: This strikes me as a bit of a strange statement; what is a 'pressure environment'? Presumably you mean basal water pressure and effective pressure?

P2, L20: How rapid? Maybe better to specify several hours etc.

P2, L23: Presumably the statement about 'inefficient evacuation of meltwater' relates to the fact that the basal hydraulic system at the terminus is not at atmospheric pressure

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so the along-glacier hydraulic gradient is less steep? It would be worth clarifying this.

P2, L26: In terms of land-terminating glaciers on ice sheets, this description is only really applicable to the marginal 20 km or so. Further up-glacier, maximum ice flow typically occurs later in the overall melt season (i.e. later than the onset of melting at the margin), once melt has commenced at higher elevations. It may be worth specifying that you are referring to land-terminating valley glaciers here?

P2, L28: What exactly do you mean by 'subglacial drainage re-organisation'?

P2, L30: 'Ice velocity records indicate similarities to land-terminating glaciers'. Do you have a reference for this statement? And do you mean the terminus region of tidewater glaciers of further inland?

P3, L6: 'The drainage of supraglacial lakes provides an additional meltwater input into the subglacial environment'. The use of 'additional' here is a little odd - additional to what? I assume you mean in addition to the drainage of surface meltwaters before they accumulate into lakes, but this is not obvious from the previous paragraphs.

P3, L15: You need to make clear that this phenomenon has been observed in the terminus region (last 20 km) of a single tidewater glacier in Greenland. As written, you risk suggesting that such drainage is as common or prevalent as the up-glacier progression of lake drainage with time, which is not the case.

P3, L18: 'terminus' should be 'near-terminus'

P3, L16: Wat exactly are 'Subglacial transient pressure waves'? How do these control up-glacier progression of lake drainage? This requires more explanation and a reference.

P3, L21: What is 'the bed system'? Better to avoid these vague terms and simply describe what you actually mean, which you do in the next-but-one sentence. Also, I'm not quite sure what the point of this sentence is 'This has largely been studied in inland and near-terminus settings'. Are there other 'settings' from which such observations

are missing?

P3, L23-24: 'long periods of time'. Be more specific - days, weeks, months, years, decades? I assume decades based on the Tedstone reference but this would not be obvious to someone unfamiliar with the literature.

P3, L26: How do these 'long residence times' tie in with observed reductions in ice surface uplift and velocity about 24 h after a lake drainage?

P3, L27: Would not injection of water into a distributed system or a small channel also be capable of causing uplift?

P3, L28: I think there are too many 'systems' mentioned in these introductory sections. It gets a bit confusing after a while.

P4, L5: I think you need to note here that Slater et al (2017) used photographs from a time-lapse camera rather than satellite images. Also, time-lapse is also temporally intermittent - it is the frequency of that intermittency that is important!

P5, L15: This sentence is convoluted: 'Kronebreen retreated $\sim$1 km between 2011 and 2016' would say the same more succinctly.

P6, L7: The GPS position errors seem quite large. Why not post-process them using for example TRACK software? Also, it is not mentioned anywhere how these positional errors affect your measurements, of, for example, supraglacial lake area.

P6, L10: 'data was' should be 'data were'

P6, L16-17: How did you avoid falsely identifying shadows and sediment-rich ice as lakes (both also have a high contrast with bare ice)?

P8, L32: Seems like a word is missing before 'which'. Could it be 'campaigns'?

P9, L8: 'but more central and nearer to the glacier's central flow line' should be 'but nearer to the glacier's central flow line'

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P9, L21-23: Both sentences are pretty much repeated from the first paragraph of this section.

Figure 2: It would be useful to also put the dates along the top x axis.

P11, L6-7: Or more accurately, fill enough that water is visible in the TL imagery...

P11, L22-23: 'Modelled melt production has a diurnal pattern with a maximum in the day and minimum at night' – I think this is well enough known that it is not necessary to report here.

P11, L27: The bracket after the units shouldn't be superscript.

P11, L29-31: Some repetition from previous paragraph re diurnal variations etc.

P12, L6: It would be informative to outline these on the velocity plots in Figure 5

P12, L16: Based on Fig. 2, it seems like the melt season lasts through until mid-way through September. I therefore do not think it is correct that the velocities were consistent for this period.

P13, L3: They definitely coincide (inasmuch as the temporal frequency of the TSX data allows), so do you mean 'possibly caused by'?

P13, L3-4: This is a bit vague. Ok, at the near-terminus centreline, velocities are higher in September than in the pre-melt season period, but at the other two ROIs they are broadly the same as before the melt season.

P13, L7: But despite this, there is actually very little variation in borehole water pressure (as shown in fig. 2). Perhaps the borehole is actually not that well connected to the regional basal hydrological system?

P14, L26: 'supraglacial lakes' should be 'supraglacial lake area'

Figure 5: It is difficult to distinguish between no data (transparent) and >2.4 m/d (partly opaque white?). Could the colour scale be changed to make this clearer? It is not

currently clear where the down-glacier extent of good data is.

P16, L11 (and throughout): 'upward-propagating' should be 'upglacier-propagating' (otherwise suggests vertical propagation).

P16, L18-19: 'This implies that meltwater is present at the bed and is enhancing basal lubrication '. Why is this necessarily the case? You should refer to another dataset - e.g. basal water pressure etc. to support this statement. What is to say that the acceleration is not due to a reduction in buttressing at the calving front?

P16, L21-22: And all other glacier catchments assuming a normal lapse rate...

P16, L23: So do you think that basal frictional melt is an important factor for accounting for the remaining meltwater at the bed?

P16, L25-26: No, it only indicates that theoretically this is the expected route of subglacial water, not the configuration of the drainage system.

P16, L30-31: Can you not easily quantify this from your hydropotential analysis? This would be a useful addition.

Figure 6: Based on the size of the subglacial catchments (N bigger than S), why is the southern plume expression so much more extensive? What date is the plume extent from?

P17, L3-4: Might this indicate that the drainage is linked to a perturbation at the calving front? For example, an acceleration and consequent longitudinal stretching related to a calving event or break-up of seasonal cover adjacent to the glacier?

P17, L4: 'upglacier-propagating'

P18, l8: What exactly does 'spatially discrete' mean in this context?

P18, l23: But if the plume is periodically visible, does this not suggest that the basal water is also purged periodically? Do you see a difference in velocity between times

when the southern plume is and is not visible?

P20, L14-15: Could it not be that the volume of meltwater is just insufficient for the plume to either reach or be visible at the fjord surface?

P20, L18: 'upglacier-propagating'

P21, L15: 'unexpectedly absent during periods of high runoff'. Suggesting more distributed outflow of meltwater at the grounding line?

P21, L18: 'varies over only a small range' (it does vary)

P21, L22-23: 'The precise timing of each outflow is possibly controlled by marine dynamics such as tidal level.' Do you see any evidence for cyclicity on the frequency of tides? Otherwise, what evidence is this statement based upon?

P21, L25-26: 'The trigger for the release of this water could be related to this hydraulic pulsing'. This seems a little too speculative.

P22, L11: 'The key difference at Kronebreen, and other tidewater glaciers, is the high hydraulic base-level. . .' should be 'The key difference at Kronebreen, and other tidewater glaciers, compared to land-terminating glaciers, is the high hydraulic base-level. . .'

P22, L15-16: You should say why 'a stable drainage system cannot exist in this region'; presumably because the high velocities preclude the formation of persistent channels?

P22, l24: What do you think causes the 'glacier-wide transient low-pressure wave that is initiated near the terminus', and what evidence do you have to support this assertion?

P22, L29: What does 'This' refer to?

P23, L8: 'due to the difference in ice thickness'. Be more specific, it is not just the difference, but the fact that the ice is shallower that is key here. Also, you should state that the thinner ice leads to slower creep closure rates, meaning that channels are easier to open and maintain.

P23, L10-11: You should be clear that you are referring here to the mean melt rate for the entire submerged ice front rather than the localised melt rate (which is likely to be greater for more spatially-focused discharge).

P23, L13: I'm not sure I agree with this statement. From Fig. 5 it looks like there is also a speedup at the northern part of the tongue. Could you provide a relative change in velocity map to evidence your assertion?

P23, L20: What exactly is mean by 'consistent' here? Spatially consistent (if so this is different to the results presented in this paper), temporally consistent?

P23, L27-29: This sentence seems contradictory - please clarify...

P24, L9: It might be worth also referencing Doyle et al. (2015), Nature Geoscience who saw a similar effect at a land-terminating glacier in west Greenland.

P24, L27: Or indeed that it is something other than meltwater that triggers this initial speed-up - e.g. a calving event, break up of sea ice etc.

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