Interactive comment on "Linking glacially modified waters to catchment-scale subglacial discharge using autonomous underwater vehicle observations" by L. A. Stevens et al.

Anonymous Referee #2
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This manuscript is well articulated and shows interesting, uniquely detailed ocean observation near a glacier ice front. In my view, the use of plume theory and model is slightly overstretched (i.e. plume theory can be made consistent with the observations, but hardly explains or quantifies much of it), but the comparative analysis remains interesting nonetheless. Overall, I only have minor comments (see below) that should be easily answered by the authors, so I recommend the manuscript for publication after minor corrections.

Thank you for your detailed and helpful comments on the manuscript. We give a full point-by-point response to each concern and comment below.

Specific comments
4585, Line 8-10: confusing sentence, maybe reformulate?

Sentence has been reformulated to read, "We find evidence of two main types of subsurface glacially modified water with distinct properties and locations that are consistent with runoff discharged at two separate locations along the grounded margin."

4586, Line 22: needed → need

Disagree. The noun in this sentence is "ocean property and plume measurements needed to inform and validate model simulations and theory", and "are lacking" is the verb.

4586, Line 22: It is fair to say that observations help to develop theoretical approaches, but observations are not required for that specific reason. So the lack of theories is not directly imputable to the lack of observations.

Yes, that is a fair statement. We do not state that the lack of theories is due to the lack of observations. Rather, we suggest that while theoretical approaches are often developed in absence of observations, acquiring observations is useful for both the intrinsic value of observations of the system, and for the ability to test and validate theoretical approaches.

4587, Line 27: I am just curious: were the operation 'high-risk' because of the potential for calving? Presumably, a probability density function of the calving frequency could help reducing that risk. Was such a pdf available to you?

The operations were high-risk due to the actively calving ice front, and the challenges we encountered operating an untethered autonomous underwater vehicle that relied on acoustic communications navigation methods in an acoustically 'loud' environment. A probability density function of calving frequency was not available, though real-time observations of calving location and frequency during the field campaign did inform us of the more active regions of the terminus.

4588, Line 12: Only CTD and turbidity? Did the ADCP not work properly?

As noted (4588, line 25-16, 4589 lines 1-5), AUV navigation was problematic in the fjord. This was a minor issue for the characterization of water properties, but caused significant challenges in converting the ADCP data from vehicle-relative to earth-referenced velocities. Thus, although the ADCP worked properly, earth referenced velocity data were not available for analysis. We have attempted to make this clear by deleting the original sentence referenced by the reviewer (4588, line 11-12) and adding two sentences after 4589, line 5: "Although a minor issue for the localization of water properties, the navigation challenges and track-line deviations caused significant uncertainties in the conversion from vehicle-relative to earth-referenced velocities. As a result, only measurements from the CTD and ECO Triplet are presented here."

4589, Line 24: 3m → 3.2-3.6m, or alternatively, change the vehicle speed to 1.5m/s

We regret that we do not fully understand the intent of this recommendation. The AUV speed during a mission was not constant, but varied from about 1.6 to 1.8 m/s. The vehicle sensors do not all sample at the same rate, but a common time base where all sensors could be compared was desired. Thus, CTD and ECO data were interpolated and averaged to 2 s intervals. As noted by the reviewer, and as implied by "~3 m" in line 23, the spatial resolution of this 2 s time series was not constant, but varied from about 3.2 to 3.6 m.

Perhaps the reviewer feels that stating the spatial resolution of the 2 s time series as "~3 m" is misleading since the average value is more like 3.4 m. We have modified line 23 to read: "Temperature, salinity, and turbidity measurements were interpolated to 0.5 s and then averaged over 2 s to obtain smoothed, along-track data for all sensors on a common timebase with along-track resolution of 3.2–3.6 m (based on typical vehicle speeds that ranged between 1.6-1.8 m s^{-1})."

4590, Line 6: remove comma after CTD casts and change 'and RBR' → 'an RBR'

This sentence has been modified to read: "Several shipboard CTD casts, collected using an RBR XR 620 CTD during the field campaign, are presented to supplement the REMUS CTD observations (Fig. 6)." The following sentence was also modified to clarify that these were shipboard casts (*changes in italics*): Eight *shipboard* CTD casts were taken along the R1 transect (Fig. 3), 8 casts were taken along cross-fjord sections in the outer SF (>10 km from the SS terminus) (triangles 10 in Fig. 7a), and 3 casts were taken roughly at the R5 midpoint, northeastern end, and southwestern end (Fig. 3)."

4590, Line 15: how can there be a 2.5m error in depth measurements between CTD cast and REMUS observations?? That is way beyond the accuracy of the pressure sensors.

As stated (4590, line 16-17), the RBR CTD was calibrated before and after the field work. Implied, but not stated, is that the REMUS CTD did not benefit from pre and post deployment calibration. An out-of-date REMUS pressure calibration was assumed to be the reason for the relatively large offset. We have revised 4590, lines 15-17 to read: "The RBR XR 620 CTD was calibrated before and after the fieldwork, but the REMUS CTD was not. REMUS measurements were therefore adjusted by 2.5 m to match the CTD observations, and this offset is assumed to have remained constant throughout the campaign."

4590, Line 20: 'a REMUS ADCP'. Why 'a'? How many ADCP units were mounted (the expression 'dual' in the description section is unclear)? If there were more than one ADCP, maybe replace 'a' with 'downward looking'.

There is one ADCP system, which includes both upward and downward looking transducer heads. The ADCP description (4588, lines 9-10) has been modified (*changes in italics*) to read: "REMUS environmental sensors included … a Teledyne/RDI dual *(upward and downward looking)* 1200 kHz Acoustic Doppler Current Profiler (ADCP)." The sentence on bathymetry (4590, line 20) now reads "Detailed bathymetry … was obtained through depth measurements from a shipboard single-beam depth sounder, a shipboard ADCP, and *the REMUS downlooking ADCP in bottom-track mode* (Fig. 3)."

4592, Line 20-24: Very hard to read, please rephrase.

Have reworked this paragraph to aid reader comprehension. Paragraph now reads: "To first order, subglacial catchments are defined by ice sheet surface and bed topography, which governs subglacial hydraulic potential at the bed (Cuffey and Patterson, 2010). Gradients in subglacial hydraulic potential at the ice-sheet bed do not completely dictate subglacial meltwater pathways due to the constantly evolving subglacial hydraulic system over the summer melt season (Andrews et al., 2014; Chandler et al., 2013; Hewitt et al., 2012; Schoof, 2010), but subglacial hydraulic potential gradients are likely the dominant regional factor. This is supported by recent modeling studies, which find a strong topographic control of channelized subglacial meltwater routing over Greenland Ice Sheet outlet glaciers (Banwell et al., 2013; Palmer et al., 2011)."

4593, Line 15 and Figure 7, caption: bedmap → bed map?

Bedmap has been changed to "bedrock elevation map" at all instances in the manuscript (L227, L246, L248, Fig. 4, and Fig. 7).

4596, Line 16: I (think I) understand why GMW1 is likely coming from an area of higher runoff than GMW2 (larger subglacial flux>larger buoyancy forcing>shallower equilibrium depth), but I am not sure the sentence and the connection is clear enough for the average reader. I guess you could refer the reader to section 4.3 where this link is more clearly explained.

Have added a reference to see section 4.3 to guide reader.

4601, Line 3: why only 2 primary subglacial discharge? Aren't the observations potentially missing D3? I generally agree that a case can be made for D3 to be of minor contribution, but don't really see a need to dismiss it either.

We only suggest two primary subglacial discharge locations here, as discharge through D1 and D2 combined account for >90% of the total meltwater runoff from the catchment. As we have presented information on D3 in section 4.2, we do not think we need to go into detail on D3 in the discussion section.

4605, Line 24: similarly, unless otherwise explained, I would suggest stating: 'For this system, we observed AT LEAST two, . . .'

Changed start of sentence to "For this system, we observe at least two".

4605, end of paragraph: I totally agree with the authors. I might add however that the time variability of the subglacial discharge might also lead to modifications in the nature of the discharge distribution at the ice front (say, from 2-3 distinct point discharge to a more distributed discharge?). Please feel free to add a sentence relaying this additional thought, or not...

We have added two additional sentences in this paragraph to further qualify that this methodology is suitable when the subglacial drainage system near the ice/ocean interface is assumed to be channelized. The new sentences reads: "Our survey interval was limited to peak summer conditions, when one would expect channelized subglacial discharge. Observations during other times of the year, in particular prior to and during the onset of meltwater runoff early in the melt season, as well as towards the end of the melt season when runoff is reduced again, would be useful to more fully characterize the seasonally evolving magnitude and type of subglacial discharge in this environment."