

## ***Interactive comment on “Multi-modal sensing drifters as a tool for repeatable glacial hydrology flow path measurements” by Andreas Alexander et al.***

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We would like to thank Elizabeth Bagshaw for reviewing our manuscript and providing helpful and constructive feedback, which will help to improve the current manuscript.

In the following we respond to the comments and outline how we will address these in the revision of the manuscript.

Referee comments are presented in ***bold and italic***, and our replies follow directly thereafter.

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### **General comments**

***This paper gives a comprehensive account of a challenging experiment to assess the repeatability and usability of data collected by a drifting sensor. It should be noted that experiments including field testing of new engineering techniques in extreme environments are exceptionally challenging, and the authors should be congratulated on their successful deployment. The paper is well-written, and gives a comprehensive review of much of the supporting literature.***

Thank you for this positive overall judgment.

***However, the scope of the paper is somewhat confusing to the reader, since the problem is framed as a subglacial experiment, yet the data are confined to the supraglacial environment. This in no way invalidates the results, but I believe that the paper would be more appealing to the target audience if the supraglacial scope were made clear from the first paragraph and in the abstract. The subglacial deployment may be the ultimate goal of the project, but the current state of the science and engineering is limited to the supraglacial. I advise that the introductory paragraphs and abstract are focussed on supraglacial literature, with some additional references as necessary (for example, Decaux et al 2019 cited later). The subglacial material can then be moved to later in the discussion, to make clear how the supraglacial results can be utilised and developed in the future.***

We agree. The scope of the current iteration of this manuscript was obviously not made clear enough, as also noted by referee 2. The subglacial deployment is indeed the goal of this project, but not part of this manuscript. We believe therefore that the focus should not be supraglacial alone but on the overall range of potential applications

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of the drifter technology. We will shorten and rephrase the introduction and the abstract accordingly to make the scope of the manuscript clearer and avoid confusion for the reader.

In order to understand the data, which can be acquired with the proposed drifter technology, it was crucial for the study to address practical goals associated with determining the suitability of the method for wider implementation:

The first goal was to conduct a comprehensive statistical assessment of repeated field deployments to determine the limits of the proposed methods, and to determine the expected measurement performance of the devices for future studies. The second was to investigate the multi-modal drifter time series and its relation to the physical conditions experienced along the flow path. Finally, the third goal was to determine possible linkages between flow path geometry and time series signals to identify distinct properties of channel geometry. This can either be achieved by using supraglacial channels or englacial/subglacial channels whose length and geometry are known a priori.

***I like the use of statistics to validate the sensor performance, and the realism in relating the statistical results to logistical practicality. However, the actual purpose of the paper is not entirely clear in this iteration – is it an engineering test, a sensor validation exercise, or does it reveal a previously unknown glaciological phenomenon? All of these are valid outcomes, but the introduction and particularly the abstract should be better focused to demonstrate that experimental purpose to the reader. The paper could also be shortened by moving some of the tables to supplementary info (see below).***

The current paper does not show any previously unknown glaciological phenomena. The focus is to demonstrate the general feasibility, provide a statistical performance assessment, and to validate the data produced by the sensors. We concur with the

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reviewer's comment, and will reformulate the introduction and the abstract to make this clear. We will also shorten the manuscript by moving some of the figures and tables to the supplementary material, following the reviewer's suggestions.

### **Specific comments**

***Figure 1: please could you include a labelled photo of the sensors? It would be great to see them in a bit more detail.***

We thank the reviewer for this suggestion. We will add a labeled photo of the sensors.

***Figure 2: Place names are illegible on the map, and the features of the glacier need some labels in c).***

The notice of this error is appreciated. We will improve the figure and add additional labels in c).

***It would be useful to know where the net was situated, for example, and perhaps have some accompanying photos of the deployment/recovery sites.***

We will add this information in the manuscript/ on the figure.

***Could you comment on the feasibility of the net recovery in a larger system, and if the sensors are destined for the subglacial system, on the robustness of the net methods with debris and bedload transport in the flow?***

This is an excellent question. Our current net method seems to us to be at the moment only feasible for smaller systems. The main problem with the net method is the clogging of the net with ice on supraglacial channels. Similar problems occur in

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front of subglacial systems where the additional bedload transport also clogs the net. High discharge and flow velocity make the installation and handling of the nets difficult as well. We will add a comment about this in the manuscript.

***Table 1: Could transmission distance (if relevant) be a separate column rather than a comment?***

Transmission distance is only mentioned once in the comment for the Smeets et al. (2012) reference. Making a separate column, would contain a majority of empty entries for the other references. So we would prefer to leave it as it is.

***P3, L23: Is 500 Euro truly low cost? This is a subjective term.***

Agreed. This is a subjective term and we will remove this.

***P10, L20: Please include an estimate of the range of discharge variability.***

We did not measure it, so any estimation would be wrong. We will add an according comment.

***Figure 3 doesn't really add much to the paper, it could be removed to save space without detriment, since the workflow is not unusual and is described in the text.***

Agreed, we will remove this figure.

***P12, L25: please define the 'features of subglacial channels'***

A more detailed definition will be provided. In our context, features of subglacial channels include step-riser, glide and chute sequences, and the associated signals in the multi-modal time series data (e.g. sudden change in linear acceleration)

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which correspond to these morphological sequences. In addition, features can also correspond to changes in the local pressure field, indicating regions where the total water pressure increases or decreases along the flow path.

***Figure 4 and Tables 3 and 5 may be better placed in supplementary info, since their content is only of interest to a very specific audience and the paper is rather long.***

We will move them to the supplementary info.

***Table 4 and P14, L7: what is the 'required size' for a subglacial deployment? Unclear how these measurements are extrapolated to the subglacial system: just because the drifter can move through an open supraglacial stream doesn't necessarily infer that it will pass through the subglacial environment.***

This number was inferred from the deployment of drifter dummies with the same size and buoyancy than the real drifters through englacial systems. We will clarify this in more detail.

***Figure 10: Can other sensor data be added to this figure? It would be very useful to see the accelerometer data plotted alongside. The IMU accelerometer method is really exciting, so if the data could be demonstrated alongside the pressure and photographs, it would really contribute something valuable to the field.***

Thanks for this suggestion. We will add additional IMU data to the figure.

***P25, L11-25: What were you hoping to determine with this dataset? It seems that you have proven that the technology and the sensor set work (which is great!), so can you relate this to the flowpaths? How do the data relate to visual ob-***

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***servations? If you hope to use this to visualise subglacial systems, then it is important to relate the sensor data (of which you have a considerable quantity) from the supraglacial system to visual observations where you can. Then you can demonstrate how this might be used in the subglacial environment. 'We need more data' seems a bit of a cop-out! What precision do you need to obtain scientifically useful data?***

We were hoping to show the repeatability of the dataset. This step is an important first step (and the focus of this study) towards retrieving information about subglacial drainage from our drifters. We were also attempting to do what you are pointing out here, but having only thirteen data points and no channel geometries (due to temporal and man-power constraints) seems not very convincing to us to make conclusive statements about the signal features of certain channel geometries. We will however elaborate more on this topic to improve clarity.

***P26, L26: What is 'satisfactory performance'? This is very subjective. What did this experiment hope to achieve, and did you do it? Was it field testing of the casing, the transport method, or of the sensor performance, or of the usefulness of the data to characterise the supraglacial flowpath? Or of future subglacial deployment? Please be specific – this is an excellent engineering test, but subjectivity in appraisal should be avoided.***

Thanks for pointing this out. We will remove any subjectivity and clarify the scope of this experiment.

***Table 6 isn't terribly useful.***

We will remove it.

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Interactive comment on The Cryosphere Discuss., <https://doi.org/10.5194/tc-2019-132>, 2019.