Review of Topology and pressure distribution reconstruction of an englacial channel by L. Piho et al., submitted to TC

General comment

The study is a methodological contribution that presents a new method to map the topology of supra and en glacial flow and retrieve the water pressure along flow. Such method will benefit to the investigation of glacial hydrology and its influence on ice dynamic. The paper well presents the method and its limitations. However, the purpose of the work is not clearly articulated and it lacks a wider comparison with other methods (dye tracing, GPR, seismic, satellite observations) that would help to highlight the benefits of this new methods. It also lacks information on what kind of observation are currently needed by the glacial hydrology community and how this new method may contribute to provide such observation.

I think that the proposed method are valid and suitable as well as very original and will bring new and useful information about glacial hydrology, at relatively low cost and easy deployment. It is therefore important for such method to be shared with the glaciological community.

I support the publication of this manuscript on the condition that the authors highlight (1) the advantages and limitations of their method (e.g., water pressure measurements, applicability to other setups, to subglacial environments …) (2) how their method finds its place in the current methods used to observe and model glacial hydrology and the associated challenges. Such changes might necessitate major revisions and to revisit the structure of the discussion and conclusion sections as well as to provide some changes on the introduction. See comments below for more details.

My comments on the manuscript (annotated pdf) and below are aimed at highlighting where changes could be made to improve the clarity of the manuscript.

1. Does the paper address relevant scientific questions within the scope of TC?

This paper addresses the challenge of observing the glacial hydrology system and measuring its properties. Our capability to understand the response of ice sheets and glaciers to increasing surface melt relies on our capability to understand how surface meltwater influences ice dynamics. When reaching the bed and the subglacial hydrology system, meltwater can modulate glacier basal sliding by modulating basal water pressure. The configuration and properties of the subglacial drainage system are therefore key parameters that influence glacier dynamics. However, because of its inaccessibility this system is yet poorly known, and its properties are

often obtained indirectly (through GPR observations, seismic measurements or surface velocity changes) or at a local scale (borehole measurements). The capability to observe such system, and especially access to the water pressure conditions and the system geometry is therefore a limiting factor towards a better understanding of the glacier dynamics.

The goal of this paper is to propose a new method to map the topology of supra and englacial channels as well as measure the water pressure along these channels. The authors do not directly address the question of the influence of surface meltwater on ice dynamics, but propose a new way to map glacial hydrology paths and retrieve associated water pressure. The contribution of this paper is mainly a methodological contribution to the observation of glacial hydrology geometry and parameters.

In this study, the authors have mainly observed supra-glacial channels that could have been mapped by satellite imagery, the main benefit of this new method is therefore his potential to map en and sub glacial water flow that are otherwise difficult to map. However, a detailed discussion on how the method could be applied to such environments is lacking. Such discussion would really strengthen the contribution of this paper.

2. Does the paper present novel concepts, ideas, tools, or data?

The novelty of this paper lies on the proposed methodology. The authors present a method to retrieve the position (x,y) of drifters sent into en- and supra-glacial channels and measure the water pressure along the way. The drifters were already presented in a previous paper by the same authors and the novelty of the current contribution resides on the evaluation of the inertial measurement unit to retrieve the traveled distance. They validate the obtained results against independent observation with an error of c. 10 %, which is reasonable giving the precision of other methods to map englacial channels (e.g. GPR). The evaluation of the pressure measurements is limited by the fact that the instrumented channels were mainly at atmospheric pressure.

3. Are substantial conclusions reached?

The main conclusion of this paper is that submersible drifters can be used to map the 2D topology of englacial and supra-glacial channels. It yet remains unsure how such method could be applied to map subglacial hydrology channels, but this paper present a first and crucial step in this direction. The main conclusion is therefore a conclusion on a methodological feasibility. Within the scope of such methodological conclusion, I would expect to have some discussion on how this method can be coupled with other methods and also on how other groups could access to such technology. This would help the reader to better capture the contribution of this paper and the benefits and limitations of the presented method.

4. Are the scientific methods and assumptions valid and clearly outlined?
   Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

   Evaluating the choice of Hidden Markov models lies outside of my competences, but I find that the methods are well explained and the assumption clearly stated.

   There is, however, missing details on the noise removal part (2.4). Indeed the authors present their filtering procedure without giving all the values and parameter they used to do so. This should be added to allow a reproduction of the results. In addition, the terminology is sometime unclear (terms such as “overall, noisy”) and the authors should ensure to have an appropriate and consistent terminology throughout the text.

5. Are the results sufficient to support the interpretations and conclusions?

   The authors argue that their method allow to retrieve water pressure along flow path, but given the chosen setup (mainly free flow), it remains difficult to assess the extent to which drifters could be used to conduct subglacial water pressure measurements. I suggest to better discuss this aspects to allow the reader to have a clear view on the current capability of the method. In addition, one of the main difficulty that is encountered with such sensors is their retrieval. While it might be relatively easy for supra-glacial flow (as investigated here), it might be a limiting factor when investigating subglacial and englacial water flow. I would like to have a discussion on how such method could be efficiently used to map subglacial water flow, and what problems might be encountered, and how the authors suggest to face such problems. This will help to support the use of such method in the future for glacial investigation in different setups.

6. Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

   Yes.

7. Does the title clearly reflect the contents of the paper?

   From the title, one might expect to find a bit more on the pressure distribution, for which only a little part of the text is dedicated to. This is mainly due to the fact that the authors investigate free flowing channels, with very little changes in water pressure (some eddies and step pools). I would suggest to remove the term pressure from the title and focus on the topology, which is the strong outcome of this paper. I would also like to see in the title an information about the method/instrument used for the reconstruction.

8. Does the abstract provide a concise and complete summary?

   The abstract is overall concise and provide a good summary of the paper. The penultimate sentence is however too speculative as they concern subglacial investigation of water pressure, which is not discussed in the manuscript. The last sentence is also speculative, as it suggests that the proposed method allow to reconstruct previously unexplored subsurface fluid paths, which is not supported by the current study as the mapped path where already known. I suggest rephrasing these sentences and, if kept, to better discuss these aspects on the manuscript, otherwise their remain too speculative.

9. Is the language fluent and precise?

   The language is fluent, but sometime lacks of precision. I have suggested to have a consistent terminology when referring to water path as well as avoiding terms such as “overall, thereby” that are not precise and bring some confusion on the text.

10. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

    Yes.

11. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?
    Is the overall presentation well structured and clear?

    The overall presentation is well structured, and the figures are quite clear. I suggested minor edits in the figure (scales of the picture, flow direction, missing legends) that can easily be adjusted. The structure of the discussion and conclusion is a bit confusing as new results are presented in these sections.

    I suggest to clarify the introduction, as well as the discussion and conclusion sections.

    The introduction does only give a brief description on the actual state of knowledge on the glacial hydrology dynamics, the current challenges and the current observational methods. Key physical parameters needed for modelling are not presented, which makes difficult to understand which parameters are important to measure. The description of the current observational methods lacks details on pro/cons of each method and therefore makes difficult to understand the benefit of this study. I suggest to add more details on the physical principles of glacier hydrology as well as on the current method. This would help the reader to understand the current challenges are how this study might contribute to address them. It is indeed difficult to understand now what is the aim of this study. I understand that this is a first step to show the potential of using drifters, but I suggest to better describe the current challenges. One half of the

introduction is dedicated to details on the drifters and limitations of previous study, which is nice to see how this study contribute to the use of drifters. However, I found this a bit unbalanced compared to the first part of the introduction. I suggest to rephrase and to better include the scope of this study within the wider frame of glacial hydrology investigation. I understand that the paper aims at a methodological contribution, it such case I suggest to better detail the current methodological limitations of existing methods.
The aim of this paper is not yet clear from the introduction.

I suggest to have a discussion on:
1) the methods benefits and limitation. Under which condition such method could be used to investigate sugblacial water flow? Which retrieval rate do you expect? What are the conditions for this method to be applicable?
2) how your observation can help to better understand glacial hydrology. Can they be used as input parameters in models, or to validate the outputs. Can they challenge actual hydrological models? Can the observed topology can help better understand the formation of glacial pathways?
3) discuss how actual methods can be complemented by your method. Your method mainly gives a temporal snap shot with a good spatial resolution, how could you combine it with GPR that have similar spatial resolution or with dye tracing that give information on the drainage characteristic or with seismic that give you a long term picture ? I find such discussion important as the paper aims at a methodological contribution.

Now the discussion only discusses the uncertainty and outcomes of the presented method, but it misses the comparison with the wider picture.

The conclusion presents new results and new calculations that should be moved to the result or the discussion section. I suggest having a Conclusion and Perspective section (with point 3 of the discussion), where you summarize the main finding and also how the variable you observe can be used in hydrological models. Since your study aim at a methodological improvement, I think it would be relevant also to explain how such sensors could be used by other teams and also what are the differences/complementarity with other similar sensors.

12. Are the number and quality of references appropriate?

Yes. It however lacks some references on the current models and assumtpions used in glacial hydrology, such as:

- Werder, M. A., Hewitt, I. J., Schoof, C. G., & Flowers, G. E. (2013). Modeling channelized and distributed subglacial drainage in two dimensions. *Journal of Geophysical Research: Earth Surface*, *118*(4), 2140-2158.
- Hewitt, I. J. (2013). Seasonal changes in ice sheet motion due to melt water lubrication. *Earth and Planetary Science Letters*, *371*, 16-25.

- de Fleurian, B., Werder, M. A., Beyer, S., Brinkerhoff, D. J., Delaney, I. A. N., Dow, C. F., ... & Sommers, A. N. (2018). SHMIP The subglacial hydrology model intercomparison Project. *Journal of Glaciology*, *64*(248), 897-916.

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Hill, T., & Dow, C. F. (2021). Modeling the dynamics of supraglacial rivers and distributed meltwater flow with the Subaerial Drainage System (SaDS) model. *Journal of Geophysical Research: Earth Surface*, *126*(12), e2021JF006309.

I have also noted some mis-citations in the manuscript concerning seismic studies (see anoted pdf).

13.Is the amount and quality of supplementary material appropriate?

I would like to see the satellite imagery used to derive the channels topology as well as some picture of the channels itself to support arguments proposed by the authors in the manuscript such as:

“ Glacier drainage systems do, however, evolve and change rapidly over the years. ”
“However, the sharp turn of the river after the canyon exit is visible on the satellite imagery and can be matched to the topology of the reconstructed path.”
“We revisited the englacial channel on 19 Aug. 2020 and deployed a GNSS enabled surface drifter to gather a GNSS path of the now melted-out channel.”