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Interactive comment on "Large-scale integrated subglacial drainage around the former Keewatin Ice Divide, Canada reveals interaction between distributed and channelised systems" *by* Emma L. M. Lewington et al.

Flavien Beaud (Referee)

flavien.beaud@gmail.com

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In the proposed manuscript titled: Large-scale integrated subglacial drainage around the former Keewatin Ice Divide, Canada reveals interaction between distributed and channelized systems, by Lewington et al, the authors present a map of landforms associated with subglacial water flow in the Northwestern sector of the Laurentide Ice Sheet. In previous work (Lewington et al., 2019), the authors developed an automated method to extract such landforms from Digital Elevation Models (DEMs), method which they apply here to a sector of the Laurentide Ice Sheet. A motivation for this work is

to analyze different landforms together and recognize their intertwined nature. This is a welcome advance in glacial geomorphology enabled by the availability of the Artcic-DEM, as studies of such landforms tend to overlook these interconnections. The authors perform a comprehensive mapping effort of the landforms and the relationships they find between different landforms will be essential in improving our understanding of their formation. I have a few points of concern, however, before this study can be published. The main concern is the proposed mechanism of formation of these landforms as a result of hydraulic changes in the vicinity of a main drainage channel. My second concern is that the presentation of the manuscript both in the text and the figures should be improved. In summary, I believe that the work presented is significant and, pending revisions, is publishable in The Cryosphere. Note that this general comment is associated with an annotated pdf of the manuscript where detailed comments can be found.

Scientific comments:

Generally, the literature cited is quite extensive, however, I think that the recent (past 5 years) literature on glacial processes has been a bit overlooked. For example, one the main point of the paper relies on the interactions between a subglacial channel and its surrounding drainage, topic that has been discussed a fair bit in recent papers (see Hoffman et al., 2016, Nature Communication; Stevens et al., 2015, Nature; Rada and Schoof, 2018, The Cryosphere; Andrews et al., 2014, Nature). While some of these papers are cited, their findings are not related in enough details. In terms of sediment transport, bedrock erosion and tunnel valleys and esker formations a few recent numerical modelling papers also offer some valuable insight as to how to interpret the landforms of interest here and their results should be discussed (see Beaud et al., 2016 Earth Surface Dynamics; Beaud et al., 2018, ESPL and JGR, Delaney et al., 2019, JGR). While a number of these paper are my research, I am not aware of any other study quantifying both sediment transport and bedrock incision by subglacial water flow. More details are listed in the commented pdf of the manuscript. The current manuscript does not provide enough evidence to substantiate the claim that the pressure fluctuations between a subglacial channel and its surroundings are responsible for the formation of subglacial landforms shaped by water. I think that there is, in fact, more evidence to show that the lateral migration of subglacial channels is a better candidate than the extent of the 'variable pressure axis'. The variable pressure axis idea is used to describe a temporary phenomenon, and a reversal in pressure gradient with respect to steady state conditions. As described in Hubbard et al. (1995), the water that flows outward from the channel during a pressure peak will subsequently flow back towards said channel. This mechanism cannot explain a net transport in either direction. A similar idea that does not involve the pressure gradient reversal is that channels tap into the surrounding distributed system within a distance that is linked to the hydraulic conductivity of the distributed drainage system (Hewitt, 2011, JoG; Hewitt, 2013, EPSL; Werder et al., 2013, JGR). This idea is used by Delaney et al. (2019, JGR) to explain the transport of material created by subglacial erosion toward a main channel, or by Hewitt and Creyts (2019) to determine the spacing of eskers. The size of the sediment transported in a distributed system is thought to be relatively small (Beaud et al., 2016, Earth Surface Dynamics), and may not be adequate to transport the sediment of the size found in the targeted landforms. It is common to find gravel if not boulders in the till. The flow forming these landforms should thus be able to transport such sediment. To explain the transport of significant amount of sediment or clasts of large size, floods resulting from lake drainages are often involved. However, for a single lake drainage to create a flood throughout a channel until it exists the glacier, the lake size has to be particularly large. For example, on the Greenland ice sheet lake drainages are unlikely to create large flood through a single channel as they are spread across a drainage catchment and may not drain at the same time (e.g. Bartholomew et al., 2012; Fitzpatrick et al., 2014). However, single drainage event will affect the bed in the vicinity (few kms) of the lake location (Stevens et al., 2015, Nature). Beaud et al. (2018, EPSL) further discusses the efficacy of floods of various magnitude to incise bedrock, and find that seasonal meltwater production is more likely to produce landforms like tunnel valleys.

To remove sediment or incise bedrock and form a negative-relief meltwater corridor, the water flow has to be able to produce shear stresses that are sufficient to transport coarse sand and gravel which are typical from glacial till. Therefore, the water flow velocities have to be sufficient and there should be enough accommodation space for these particles to be transported. Sediment transport in a macro-porous sheet has been modeled by Creyts &al. (2013, JGR) and sediment transport capacity in a network of connected cavities is discussed in Beaud et al. (2016 ESurf). In either study, the size of sediment that can be readily transported in a distributed system is small, i.e. on the order of size of coarse sand. I believe there is a strong body of evidence to suggest that the lateral migration of a subglacial channel across a melt water corridor is responsible for its formation. Gulley et al. (2012, JoG) find that the location of moulin has a large control on the location of the drainage channel and as a result of moulin advection, the said drainage channel changed paths from one year to the next. In the tunnel valley review presented in Kehew et al. (2012), there is ample evidence that the fill of tunnel valleys is constituted of numerous smaller individual channels, hinting a migration rather than a process occurring in a channel surroundings. Experiments of water flow under pressure over a sediment bed, show the braided nature of the resulting sediment channels (Catania and Paola, 2000, Geology) or the migration of single sediment channels (Lelandais et al., 2016, JGR). Finally, in this study, eskers are not necessarily at the center of a MWcorridor, whereas, in an isotropic medium and following the proposed VPA theory, they should. In an anisotropic medium, they should still be systematic characteristics on either side of a drainage channel likely dependent on the conductivity or the roughness of the substrate in this area. In summary, I believe that the VPA origin of landforms should be dropped, unless the authors are able to provide convincing evidence that it can produce sediment transport and bedrock erosion. However, I believe the author can make a strong case for subglacial channel migration being the responsible for the width of MWcorridors. Such migration has seldom been studied and the present study could thus open the door for the use of MWcorridor width as a proxy for glacial conditions. It is likely that the migration is limited by a combination of bed topography, ice surface topography, effective pressure (ice overburden minus water pressure) and location of moulin. In addition, the spacing between MWcorridor is a more complete description of the esker or channel spacing proposed by Hewitt (2011) and Hewitt and Creyts (2019). Thus, the current results could actually be used to infer more robustly the spacing of drainage networks and thus inform the conductivity of the distributed drainage networks that should be used in numerical models.

Presentation:

Title change: the title should be modified to something that focuses more on the method and results than the interpretation of the results. Throughout the text there is copious use of comparatives, but they are not always compared to something specific. In general, please try to quantify these comparisons with numbers so that they are less subjective. It seems a bit weird to put eskers with splays and eskers at odds during the explanations. These are both positive relief features in opposition to the other negative relief landforms. Also, it seems circular to say that esker with splays are connected to eskers, since their name suggests they are eskers too. Please add some explanation of these choices in the manuscript. Many of the figure display text that is too small, or the maps show an area that is too large to see features clearly. Many figure panels also lack letters to reference them. Please add some to make the figure more intelligible. At the beginning of paper show examples of the different landforms and their manifestation on the DEM. I understand this is was the point of the Lewington et al., 2019 paper, but it is necessary to show this here again. Define splay around the esker in more details.

Best, Flavien Beaud

Please also note the supplement to this comment:
https://www.the-cryosphere-discuss.net/tc-2020-10/tc-2020-10-RC2-supplement.pdf

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-10, 2020.