Review of *How dynamic are ice-stream beds?* by Damon Davies et al.

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1 General comments

This paper presents highly valuable results of measurements of subglacial topography evolution, performed by repeat radar measurements on Pine Island Glacier (I am not qualified to evaluate the instrumental procedure and data processing). As outlined in the manuscript, this type of data set only exists for a few locations, and is useful for our understanding of subglacial bed dynamics under changing ice-flow conditions.

The manuscript is well written, and the aim and results are presented in a concise and comprehensible manner. The manuscript clearly deserves publication in *The Cryosphere*. Before publication, I would appreciate if the authors consider the following points:

- Highly relevant to the study area of this manuscript, Sergienko and Hindmarsh (2013) demonstrated large spatial variability in subglacial shear stress inferred from surface-velocity inversion. I would find it very interesting if it was possible to put these results into context of the locations of the proposed "high-shear-stress ribs". I would expect subglacial sediment transport to be low in the areas where stress inversions shows low subglacial friction, regardless of assumed till rheology. Unfortunately it appears that the study area of Sergienko and Hindmarsh (2013) is closer to the grounding line than the site that is investigated here—is that correct? In any case, do your findings present arguments for or against the prior results of localized traction?

- The paper makes several references to changes in ice-surface elevation. If there is any change in bed conditions (bed topography or basal traction), this change should be expressed by a change in surface topography. Opposite, if the bed doesn't change, it should not result in a surface expression. I think it would be very interesting if you could plot surface-elevation profiles at the same points as you have data for the subglacial topography. In case internal reflectors are identifiable and comparable between surveys, a study of these would also bolster the grounds for interpretation.

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- Strain distribution in deforming beds is a very important and highly controversial topic, tightly connected to the discussion of till rheology. Our understanding of subglacial till fluxes is still lacking, but of primary importance to ice-stream stability, landform development, and glacier physics (Blankenship et al., 1986; Boulton and Hindmarsh, 1987; Alley, 1989; Jenson et al., 1995; Engelhardt and Kamb, 1998; Iverson et al., 1998; Truffer et al., 2000; Iverson and Iverson, 2001; Nygård et al., 2007; Damsgaard et al., 2013; Damsgaard et al., 2016). In till-transport models subglacial sediment flux is dependent on stress and sliding velocity. By coupling sediment transport with a formulation of mass balance (e.g. Exner equation, Exner (1925), Paola and Voller (2005), Fowler (2010), and Kyrke-Smith and Fowler (2014)), ice acceleration by itself will cause a net erosion of the subglacial bed. The nature of subglacial till advection is highly relevant, for example, for theories of drumlin formation (Hindmarsh, 1998; Fowler, 2000; Schoof, 2007; Fowler, 2010). I would find it useful if the results presented in this manuscript are further discussed with relation to implications for till rheology and subglacial advection. I have further elaborated in specific comment 12 below.

I have further comments below, tied to specific page and line numbers. Further referencing, as suggested, may be beneficial to readers less familiar with the topic.

2 Specific comments

1. P1L13: How are you doing on the abstract word count relative to journal limits? If you have space, I suggest adding further motivation with something along the lines of: *"An especially poorly observed parameter is sub-decadal stability of ice-stream beds,* ***which may be important for subglacial traction, till continuity, and landform development.****"*.

2. P1L37: It might be worth mentioning previous studies that hypothesize that large subglacial till fluxes can cause fast build-up of grounding-line wedges, potentially stabilizing ice streams against sea-level rise (e.g. Alley et al., 1989; Alley et al., 2007).

3. P1L40: I suggest also citing Cuffey and Alley (1996) and Alley (2000) which discuss till generation, transport, and associated effects on subglacial beds.

4. P2L1–6: I think it would be helpful to distinguish between soft and hard-bed processes in this paragraph. The cited studies with larger fluxes (e.g. Motyka et al., 2006) discuss reworking of soft beds, while studies with smaller rates (e.g. Hallet et al., 1996) discuss hard-bed erosion. This may not be immediately clear to an outside reader.

5. P2L8–14: Along the lines of my point in "General comments" above, maybe cite and discuss the subglacial stress inversion by Sergienko and Hindmarsh (2013) here.

6. P2L36–39, Table 1, P5L23–24: In several places the text suggests that surface-lowering data is present in Table 1, but the table only includes surface velocities. Is it possible to include the surface-elevation changes in the table?

7. P3L34–P4L2: (I'm a non-expert in glacial radar). Do the same reasons make it impossible to interpret changes in basal reflectivity? As far as I know, changes in the reflectivity have the potential to be an indicator for changes in water content at the ice-bed interface.

8. P5L6–7 and P5L20–21: You previously mentioned that the applied methodology does not make it possible to constrain *absolute* changes in bed elevation, just changes in roughness relative to the mean topography. To me it seems highly unlikely that the bed should have undergone uniform erosion or deposition, but you might want to mention this caveat when presenting the results nonetheless.

9. P6L7–10: Thick porous sediment layers are not necessarily associated with deep active deformation (Damsgaard et al., 2016). See also discrepancy between Blankenship et al. (1986) and Engelhardt et al. (1990).

10. P6L25–27: Minchew et al. (2017) (previously cited in the manuscript) suggests that variations in basal water pressure are likely less important than variations in ice-internal stresses, due to relatively weak rigidity of the RIS ice-stream shear margins. This finding contrasts with the interpretation by Thompson et al. (2014) and Rosier et al. (2015).

11. P6L34–36: It is not immediately clear to me how a dynamic hydrological system would increase sediment transport or erosion. Are you talking about ice-contact subglacial sediment transport or fluvial sediment transport in subglacial sheets or channels (e.g. Alley et al., 2003; Fowler, 2010; Kyrke-Smith and Fowler, 2014)?

12. P7L8–11: Viscous till models and their pressure-dependent fluxes imply that there is no steady-state bed topography if the bed is not planar, as sediment transport would always be larger on the stoss side of bed bumps than on the lee side (Hindmarsh, 1998; Fowler, 2000; Schoof, 2007). Modeling studies indicate similar pressure dependence of till flux for Coulomb-plastic materials (Damsgaard et al., 2013). If there is such a pressure dependence, where increasing normal stress on the bed increases deformational depth, this bed-altering process excludes interpretation (3), *"...subglacial till flux is in a steady state wherein sediment transport is active but is not altering the shape of the bed."*.

13. P7L23–28: It might be worth mentioning that the site of Alaska is very unusual and that the reported erosion rates by Motyka et al. (2006) are not likely to occur for long. The dynamics of this setting have been further analyzed in Brinkerhoff et al. (2017).

14. P7L40–42, Figure 5: To the untrained eye, it also appears like there has been localized erosion at a distance of 7.6 to 8.0 km. Does this change fall within the bounds of

uncertainty? If not, I think it would make sense to discuss it together with the changes between distances 8.5 to 9.1 km.

15. Figure 1: It took me a moment to realize that the contour lines in panel b are the "dashed lines" referred to in the caption, as the dashes are too small to be apparent on screen and in print. Is it possible to make the dashes and the spacing between them longer?

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