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The Cryosphere Discussions

Interactive comment on "Geophysical evidence for soft bed sliding at Jakobshavn Isbrae, West Greenland" *by* A. E. Block and R. E. Bell

Anonymous Referee #1

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This paper presents some interesting findings suggesting deep sediments in the main trunk of Jakobshavn Isbrae. While the results are intriguing and I believe there is some thickness of sediments in the trough, there are several points that need be addressed.

My main concern, which is echoed below, is that there are large unexplained anomalies on the north side, which are not that much different than the trough anomalies. Some attempt should be made to adjust the model with a different density model to account for these anomalies. Being near sea level it is unlikely that these are sediments. For example, the t34 northern anomaly is almost identical in magnitude to the T44 trough anomaly. Though the T34 anomaly remains unexplained and is not sediment, we have 2000-m of sediment to explain the similar size anomaly in T44. I do think there is some amount of sediments, but a 3000-m trough deep trough is hard to imagine and difficult

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to explain (in fairness a 1500 m deep trough is fairly remarkable too). I would like to see this paper published, but not before more work is done to clear up the north side anomalies. There also some sharp disconintuites in the residuals. For example, on left side of T44 vs right side. Also where T44 and T34 show much less of anomaly relative to the surrounding pattern. Why is this? The actual data look reasonably continuous. Is there a problem with the model?

There is also a theme throughout the paper that entire community has considered that motion is entirely due to internal deformation over a hard bed. For example in the abstract it state "Earlier studies of basal processes minimized basal slip as a fast flow mechanism." This simply isn't true and the paper should reference the literature better, rather than relying on a single paper. For example, Thomas JGlac 2004, estimates a basal shear stress of 50 KPa (ie. Taub « Taud) and assumes the glacier moves largely by ice shelf dynamics (i.e., sliding).

Specific comments

Introduction "The main trunk of the glacier is joined by 2 other branches, one from the north that merges near the 2008 grounding line and one from the south, that merges 25 9 km upstream". Normal it is considered that there is a north branch and a main trunk (aka south branch). I don't see any other branch. "After the disintegration of a 15 km long floating ice tongue in 1998." The disintegration of the tongue and speedup began in 1998. Its wasn't until several years later that most of the tongue was lost. It would be good to cite Luckman's Jakobshavn paper here.

" Ice Bay" I am not aware of this as being a defined place name needing to be capitalized.

4. Constraining Gravity Signals "The signal from empty crevasses that penetrate 1 km into the ice sheet and create 10% free space is less than -5 mGal." This is about 10 times deeper than crevasses are expected to propagate. Its fine to assume a much deeper depth for evaluating the sensitivity, but it would be worth noting so people don't

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get the impression the crevasses are actually this deep.

5.1 Inland profiles “This interpretation is consistent with seismic reflection results that suggest the trough shoulder is bedrock but the center of the trough is lodgement till or compacted sediment (Clarke and Echelmeyer, 1996).” Actually, their results suggest either lodged sediments or a “fluidized” bed. Because they thought deformation dominated they assume the former, but you suggest high sliding, which would more indicate the latter.

5.1.1. Minimum. . . “If an additional low density body is modeled at the surface next to the sediment, the resulting sediment prediction will be shallower by 10–30%. It is also possible, though not modeled here, that the trough is immediately above a low density body between 19 and 49 km inland (T19–T49). In this case, our minimum estimate for sediment thickness could still be too large.” I would really like to see a solution where a lower density rock is used to match the gravity on the north side with this rock extending beneath the trough (you do something like this on one of your fjord profiles). Maybe use a rock density model to take out the northside anomaly first, then go back and add sediment to take out the trough anomaly (some of which would be fixed with the lower density rock under the trough). As long as there is a north-side anomaly where there should be no sediment and which is not that much less than the trough anomaly, it’s hard to attribute the full trough anomaly to sediments. I think seeing such a solution a MUST HAVE for this work to be published. Which model is best is subject to interpretation, but the reader should see both.

5.3 Sediment Description “Given the 30m crossover error, there could be $\pm$100m of additional sediment.” This may be true outside the trough, but the data are likely to be considerably worse inside the trough. Furthermore, this is at the crossovers on a grid, and the interpolation should lead to larger overall between the grid points. I doubt thickness errors could explain the full sediment thickness, but the uncertainty is certainly greater than presented here.

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6. Discussion “while the center line is underlain by lodgement till and/or sediments within the density range of 2000–2500 kgm−3” See earlier comment with respect to their assumption of lodgement till.

“Although set in a Proterozoic basement, the trough is 25 sediment filled as the result of the deposition of glacial material over the past 2.7MY as the Greenland ice sheet waxed and waned.” This statement is a little to unequivocal given that the point of the paper is to establish the presence of sediment. A qualifier such as may have or likely would be appropriate for this conjecture.

“We also consider the sediments to be wet because the entire trough is below sea level and connected to the outlet fjord.” I don’t doubt the bed is wet, but that doesn’t necessarily follow from it being below sea level (tills can freeze). Furthermore, you could be looking at a few meters of dilated wet tills on top of hundreds of meters dry lodged sediment.

“these studies repeatedly find that basal sliding is relatively unimportant along Jakobshavn’s flow line (Clarke and 10 Echelmeyer, 1996; Luthi et al., 2002).” Here would a good to append to this sentence while other studies suggest a weak bed where sliding dominates (Thomas, 2004).

“The velocity of the glacier has been attributed to the trough itself because its geometry concentrates geothermal heat, contributing to warm englacial temperatures.” While the trough thicknesses do contribute, it is the strong internal shear heating that produces the warm englacial ice. See Funk et al Journal of Glaciology, Vol. 40, No. 136, 1994.

The whole discussion on shape factors doesn’t full take into account the role of lateral drag. Its not at all clear the shape factor treats this properly. If a weak bed sliding dominates as you suggest, then taub should be small (<50KPa).

“Our results strongly suggest that basal slip is an important component of motion along the majority of Jakobshavn Isbrae 25 and that basal slip is restricted to where the sub-

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glacial trough is filled with sediment." It would be good to append to this the following . . . consistent with earlier estimates of a weak bed (Thomas, 2004) and seismic estimates of sediment (Clarke and Echelmeyer). It by no means diminishes the findings from this work by acknowledging the earlier work by others.

Interactive comment on The Cryosphere Discuss., 5, 339, 2011.