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The Cryosphere Discussions

Interactive comment on "Grounding zone subglacial properties from calibrated active source seismic methods" *by* Huw J. Horgan et al.

Anonymous Referee #1

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The authors present an active seismic study in the grounding zone of the Whillans Ice Stream. Although their seismic methods are interesting, the paper needs a lot of work. Basic hypotheses (i.e., the influence of tides) about their findings are unexplored. Their clustering analysis is threadbare. Most lacking is the intellectual context. Other groups (besides folks from Penn State) do work on Whillans and it would benefit progress in the field if the authors showed more interest in interacting with these other lines of inquiry. Despite these criticisms, I do think that a significantly modified manuscript could meet publication standards in the Cryosphere.

Data, Methods, Results

First major point: the clustering warrants more detail. How was the number of clusters chosen? It would be useful to see an L-curve analysis to persuade the reader that

three is a reasonable number. Were error bounds included in the cluster analysis? It would be interesting to do so. It would also be interesting to see the clustering carried out with Vs included for the following reason. A reasonable null hypothesis would be that there exist two clusters: grounded and floating. These two clusters should be mainly distinguished by Vs. Perhaps the results indicate that grounding zone is more complicated than this simple picture?

2D scatter plots of the clustering results should be shown to demonstrate the validity of the underlying method. See https://scikit-learn.org/stable/modules/clustering.html. Different clustering methods work well with different structures in the data and it's not clear that K-Means is the right choice for this application.

Second major point: Were the shots all fired at the same phase of the tides? See the work by Victor Tsai and others about tidal grounding line migration. Perhaps this is why Line 1 appears to have not hit the ocean cavity? Perhaps the ice was in contact with ocean sediments during the time of acquisition.

Other points:

It would be useful to also report Q values.

Figure 4 (and elsewhere), What are the units of source size?

What is the symbol R_b? The text only defines R_{bInt} and R_{b10}.

Table 4. Does the plus/minus range indicate one standard deviation?

Discussion, Conclusions

I found the discussion to be quite narrow. Whillans is a complex, interesting, and unusual system. The ice stream is decelerating and is expected to be a major stabilizer of Antarctic ice loss. Yet when we go to probe the nature of the deceleration, we see that ice flow is quite bizarre and exhibits a remarkable large scale stick-slip motion. Despite this fascinating situation, the most that the authors can offer in terms of the

implications for ice flow is the already-established point that "The rapid transition in basal properties indicates that the full Stokes equations are likely to be needed to be solved if the ice flow velocity field is to be accurately." The authors also mention the Walker 2013 paper. As written, this paper could be submitted to a seismology-focused journal like BSSA. As indicated in the next section of the review, it would be nicer to see closer integration with other lines of inquiry.

References

27 out of 49 of the citations in this paper are to the Penn State group. Of the other 22 citations, the average citation age is in the mid 1990's and none are about the Whillans Ice Stream.

I'm surprised to see no mention of any of the numerous modeling studies that have been carried out on Whillans:

Bougamont, Marion, Slawek Tulaczyk, and Ian Joughin. "Numerical investigations of the slow-down of Whillans Ice Stream, West Antarctica: is it shutting down like Ice Stream C?." Annals of Glaciology 37 (2003): 239-246.

Goldberg, D., C. Schoof, and O. Sergienko (2014), Stick-slip motion of an Antarctic ice stream: The effects of viscoelasticity, J. Geophy. Res. Earth Surf., 119, 1564–1580, doi:10.1002/2014JF003132.

Lipovsky, B. P., and E. M. Dunham (2017), Slow-slip events on the Whillans Ice Plain, Antarctica, described using rate-and-state friction as an ice stream sliding law, J. Geophys. Res. Earth Surf., 122, doi:10.1002/2016JF004183.

Sergienko, O. V., D. R. MacAyeal, and R. A. Bindschadler (2009), Stick–slip behavior of ice streams: Modeling investigations, Ann. Glaciol., 50(52), 87–94.

Similarly for the observational studies of other groups,

Beem, L. H., et al. "Variable deceleration of Whillans Ice Stream, West Antarctica."

Journal of Geophysical Research: Earth Surface 119.2 (2014): 212-224.

Stearns, Leigh A., Kenneth C. Jezek, and Cornelis J. Van Der Veen. "Decadal-scale variations in ice flow along Whillans Ice Stream and its tributaries, West Antarctica." Journal of Glaciology 51.172 (2005): 147-157.

Walter, J. I., E. E. Brodsky, S. Tulaczyk, S. Y. Schwartz, and R. Pettersson (2011), Transient slip events from near-field seismic and geodetic data on a glacier fault, Whillans Ice Plain, West Antarctica, J. Geophys. Res., 116, F01021, doi:10.1029/2010JF001754.

Other shelf/stream papers besides the Penn State Walker et al 2013 paper:

Tsai, Victor C., and G. Hilmar Gudmundsson. "An improved model for tidally modulated grounding-line migration." Journal of Glaciology 61.226 (2015): 216-222.

Sayag, R., and M. Grae Worster. "Elastic dynamics and tidal migration of grounding lines modify subglacial lubrication and melting." Geophysical research letters 40.22 (2013): 5877-5881.

Finally, it is somewhat glaring that there are no citations to the WISSARD project on the Whillans Ice Stream. The authors mention basal "ponding". Other grounds call these ponds subglacial lakes:

Tulaczyk, Slawek, et al. "WISSARD at Subglacial Lake Whillans, West Antarctica: scientific operations and initial observations." Annals of Glaciology 55.65 (2014): 51-58.

Carter, S. P., H. A. Fricker, and M. R. Siegfried. "Evidence of rapid subglacial water piracy under Whillans Ice Stream, West Antarctica." Journal of Glaciology 59.218 (2013): 1147-1162.

Siegfried, Matthew R., et al. "A decade of West Antarctic subglacial lake interactions from combined ICESat and CryoSatâĂŘ2 altimetry." Geophysical Research Letters

41.3 (2014): 891-898.

Note that I'm not saying the authors need to cite every one of these papers. Rather, it would simply be nice to see a little bit more interaction with the rest of the intellectual community on topics of interest.

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