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The Cryosphere Discussions

Interactive comment on "Increased glacier runoff enhances the penetration of warm Atlantic water into a large Greenland fjord" *by* A. J. Sole et al.

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Sole et al (2012) provide a detailed examination of the heat flux into and out of the KF and the resulting amount of subglacial melt of KG and the role of KG subglacial runoff in that process. KG is one of the three large Greenland outlet glaciers with detailed oceanographic observations. The authors reach a critical conclusion that supports the ongoing evolution and quantification of the role and interaction of warm ocean water penetrating at depth to reach marine outlet glacier termini, and glacier runoff. The following sentence from the paper is of such importance that it warrants publication of the paper. "Along-fjord heat transport towards KG increases significantly with both glacier runoff and coastal water temperature. A doubling of glacier runoff produces a 29% (48 %) amplification of mean annual (summer) heat transport towards the KG

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terminus, increasing estimated mean annual (summer) submarine melt rates from 211 to 273 (842 to 1244)myr−1." There is certainly room for improvements in the model going forward, but this is another step in quantification of the glacier runoff reinforcing AW circulation to the glacier front process, that deserves our attention.

This paragraph reviews three recent papers that highlight the evolution of the concept of glacier runoff enhancing the penetration of warm AW to marine calving glacier termini in Greenland, and how Sole et al (2012) adds to this discussion. Straneo et al (2011) observed for Helheim Glacier, Greenland that the melting circulation within the fjord and at the ice front is influenced by seasonal runoff from the glacier and by the fjord's externally forced currents and stratification. Rignot et al (2012) identified a positive feedback with glacier runoff, "A doubling in subglacial runoff should increase subaqueous melt by 25% according to the model simulations." Note this compares well to the 29-48% increase modeled here. Straneo et al (2012) further found that examination of oceanic water properties identified the melting by AW and the influence of subglacial discharge on water properties in the summer. Straneo et al (2012) found that KG was quite complex, warranting a detailed examination, and that KG had higher volumes of glacier runoff modified water in the upper circulation zone and less of a PW signature than other glaciers. The complexities of the circulation system outlined in the papers above, are impossible to model based on existing field data alone. Sole et al (2012) use an appropriate ocean model combined with one of the richest fjord data sets in Greenland to further quantify and discern the complexities of the fjord circulation at KG.

The critical result of Sole et al (2012) provides a more detailed quantification of glacier runoff, and the potential role of glacier runoff in the net flow of warmer AW to the glacier face. Numerous papers have identified the acceleration of marine terminating outlet glaciers in southeast, southwest, and northwest Greenland during the past decade. This acceleration and retreat has coincided with increased melting and hence glacier runoff. The mechanism of glacier runoff strengthening the circulation of AW to the glacier front provides a mechanism for the similar response of so many glaciers. The glaciers are scattered across a wide enough region that the actual oceanic conditions at the fjord mouths are less likely to have changed as similarly.

The anonymous reviewer #1 observes that “It was shown in (Straneo 2010, Nature Geosci.) that vigorous wind-driven baroclinic currents flush Sermilik Fjord in a matter of days. As a result of this externally forced ‘intermediary circulation’, Straneo concludes that water properties in Sermilik Fjord track sub-seasonal changes of water properties on the shelf. If KF, which like Sermilik lacks a shallow sill, is flushed so rapidly by external forcing that the water properties in the fjord always essentially match shelf properties (with a lag of no more than a few weeks) then it is hardly possible for subglacial discharge to enhance the penetration of shelf waters.” I disagree with this analysis. The citation is true, but is now an outdated result. Straneo et al (2010) was a preliminary result based on data from just 2008, whereas Straneo et al (2011) relied on data from two more field season and their conclusion as noted above does not support the rapid baroclinic flushing model. Instead Straneo et al (2011), Straneo et al (2012) and Rignot et al (2012) support the highly stratified basic circulation described by Sole et al (2012) with glacier runoff volume as an important component.

Specific Comments:

4863-13: Relatively synchronous acceleration of most marine terminating outlet glaciers even the ones that are not large should be emphasized.

4864-14: A table indicating the characteristics of the various water masses be useful. This would ideally include both shelf water characteristics and the various in fjord water mass characteristics. Figure 9 provides a useful depiction of the modeled general circulation. I would rather this simple depiction be early in the paper

4867-12: Do acquisitions in September lead to any bias?

4868-15: Is the melt season duration long enough ((Figure 3c- 60 days) given the results from recent years, with extensive June melt? Note Figure 2a from the Tedesco et al (2012).

4686-18: Beyond this paper having a temporally varying glacier runoff input to the model would be useful, as the large melt spikes seen in 2012 for example would certainly alter the glacier runoff impact on circulation. What would such amazing spikes in melt and runoff as in July 2012 due to the circulation of AW? Of course the lag in the runoff and the dampening of this spike are difficult to identify currently.

4872-15: Peak in intermediate flow?

4873-15: Figure to illustrate this?

4873-18: The wind driven importance relates to the observations of Christofferson et al (2011), should be referenced.

4875-13: How does the runoff calculated here compare to Mernild et al (2012) for Sermilik Fjord per unit area? This should be used for comparison.

4875-16: Provide quantities from the other studies for comparison. The reported here seem high.

4877-21: What is the likely difference between KF and Sermilik Fjord?

Figure 9: This could benefit from being more detailed in terms of illustrating not just the basics but also the water mass characteristics in a fashion like Straneo et al (2011) Figure 2b and c.

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