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The Cryosphere
Discussions

Interactive comment on "Reduced glacier sliding caused by persistent drainage from a subglacial lake" *by* E. Magnússon et al.

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Authours reply to comments by M. Pelto

Comment 1:
566-5 and Figure 3: The velocity rate on transect I remains low for the entire study period versus during the pre-jökulhlaup period;however, the velocity is consistently increasing. Does this signal an evolution of tunnel drainage system back towards a distributed drainage system? If so how long will this take? For transect II velocities returned to pre-jökulhlaup values by 2000. Does this reflect a quicker transition in subglacial drainage, or that less of a distributed drainage system existed in this region initially? If the former is true is the quicker transition due to greater ice velocities and

ice thicknesses?

The variability in the observed velocity at transect I after the jökulhlaup is too low to allow any interpretation on the evolution in the subglacial drainage system at this location. Much of the observed fluctuation may not reflect actual velocity changes but atmospheric signals in the InSAR data, which cause errors in the velocity estimates. The referred trend in the velocity is unclear since the observation of the highest post-jökulhlaup velocity at transect I is from the early part of the period (blue line), and the velocity close to the minimum is also observed near the end of the period (red line). The cause of the quicker transition at transect II is not clear. We however argue that the reduced drainage from the lake Grímsvötn during the later part of our study (as Figure 5 indicates) is more likely to maintain the basal water pressure low underneath the smaller glacier section (transect I) than the larger one (transect II). One may also point out that during the slow-down at transect II the glacier area north east from it remained at the pre-jökulhlaup velocity ($\sim$1 m d^{-1}). This may have caused geometrical changes in the ice mass that were large enough to produce negative feedback on the subglacial water pressure, hence changing basal sliding towards its former state.

Comment 2:
567-8: Is there any discharge estimates for the outlet stream or is this braided system to difficult to monitor?

The river Skeiðará is braided and its discharge is difficult to monitor. We know however that typical winter discharge is 15-80 m^3 s^{-1}, while summer discharge is 200-400 m^3 s^{-1} (Snorrason et al., 1997). Using estimated ablation in the drainage area above the two transects in 1996-1999 (Björnsson and Pálsson, 2008) we derive that typical summer discharge passing transect I were 30-40 m^3 s^{-1} while the corresponding value for transect II were 200-300 m^3 s^{-1}. We are however not able to predict the winter discharge at the two transects.

Comment 3:
569-1: Winter conductivity provides a fingerprint for leakage conditions, are any values available for pre-1996 when a different subglacial drainage network existed? I would like to see more conductivity data if it is available.

The conductivity in the river Skeiðará was measured on sub-daily basis the month before the jökulhlaup in November 1996. The observations showed values of 60-120 μS cm^{-1} (Snorrason et al., 1997) with the highest values observed the last days before the jökulhlaup.

Comment 4:
Figure 5: Shows water accumulation rates in Grímsvötn. A table or figure is needed that focuses on the leakage rate determined for the same time periods, not just the accumulation rate. The leakage rate is the key focus of the paper.

To clarify this Figure 5 was modified as shown in this reply. The hatched area of the graph indicates the expected range of water accumulation (6$\pm$3 m^3 s^{-1}) in Grímsvötn during winters, assuming no leakage, based on the pre-jökulhlaup InSAR observations.

Comment 5:
Magnússon et al., (2005) indicate a large ice balance transfer between 1986 and 1998

into the region of 1500-1300 m from further upglacier, as determined by surface elevation changes. This suggests enhanced flow in the upper region of the glacier prior to and or during the jökulhlaup period. Is this important to the following velocity reduction at transect I and the shortened duration of velocity reduction at transect II? Is the reduced surface elevation gradient that resulted important? Since 1998 how has the surface elevation evolved? If it is a slow thickening is this not would be expected do to reduce velocities and a tunnel drainage system?

The area of large balance transfer between 1986 and 1998 observed in Magnússon et al. (2005) took place in the western outlets of Vatnajökull outside ice divides of Skeiðarárjökull outlet and are due surges in 1992 to 1995 (Björnsson et al., 2003). A similar pattern but with less balance transfer was observed at Skeiðarárjökull during the same period (Magnússon, 2003). This was due to a surge of the Skeiðarárjökull outlet that occurred in 1991 (Björnsson, 1998). Comparison of DEMs from 1998 and from 2004 (Berthier, 2005) indicates that the area south of Grímsvötn is thickening by 1-2 m yr-1. It should however be stated that thickening is expected in this region regardless of the observed slowdown since Skeiðarárjökull is a surge type glacier.

Comment 6:
In January 1997 ice flow observed to flow into the Gjalp Cauldron at 0.08 m/day-0.25 m/day (Gudmundsson, 1997). Is this a local short term phenomenon that does not impact the longer term velocity reduction on transect I?

There is no direct link between the ice motion towards Gjálp, 10 km north of Grímsvötn, outside the ice divides of Skeiðarárjökull and the decrease in motion at transect I, other than the indirect common trigger of the unrest in 1996, the Gjálp eruption. The ice motion towards Gjálp was toward the centre of the depression formed in the glacier during the eruption. We however conclude that the decrease in motion at transect I on the Skeiðarárjökull outlet was most likely related to the leakage from Grímsvötn, a consequence of the jökulhlaup that followed the eruption.

Comment 7:
Gudmundsson (1997) and Aldsdorf and Smith (1999) identify velocities not altered regionally across the ice cap by the Gjalp event. Were these studies to broadly focused on overall ice cap velocities to note the significant declines? Gudmundsson (1997) also note the development of the tunnel drainage network did not induce widespread sliding during the eruption phase. Clarify that it is this same system that has remained developed in the upper reach of the glacier. Gudmundsson (1997) and Aldsdorf and Smith (1999) identify velocities not altered regionally across the ice cap by the Gjalp event. Were these studies to broadly focused on overall ice cap velocities to note the significant declines?

Gudmundsson et al., (1997) correctly state that no rapid sliding on regional scale was associated with the eruption. The ice motion of Skeiðarárjökull was not monitored during the jökulhlaup in November 1996. Alsdorf and Smith (1999) work with very few data but if the figures in their paper are studied thoroughly the InSAR data from Skeiðarárjökull shows lower velocity after the Gjálp event than before. The InSAR data obtained before Gjálp event is however obtained during a jökulhlaup in the river Skeiðará in March 1996 which caused the velocity on Skeiðarárjökull to be unusually high at that time (Magnússon et al., 2007).
The water draining from Gjálp, drains into the lake Grímsvötn before leaking down underneath Skeiðarárjökull. Hence, there is no direct link between the subglacial drainage systems at the two places.

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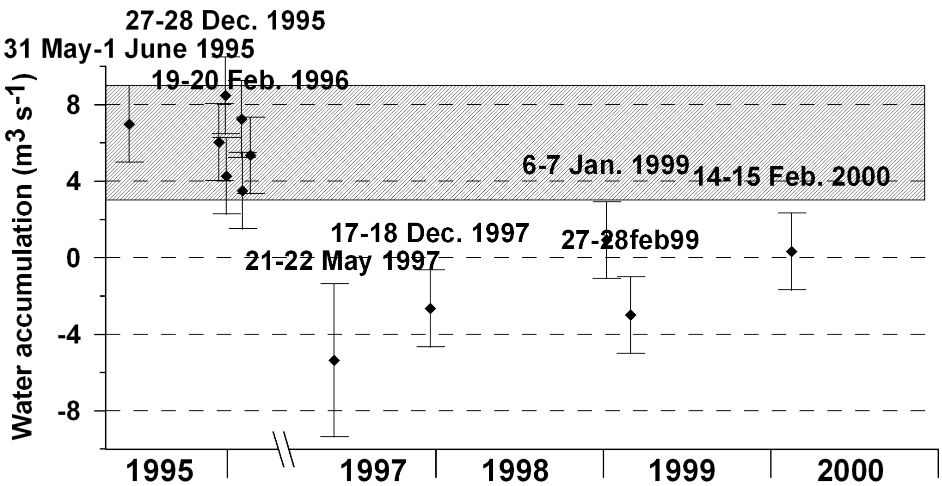

Fig. 1. Fig. 5 reviewed.