Measurements of seasonal surface velocity variations by continuous GPS measurements on the Hofsjökull ice cap in central Iceland

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Introduction and data

Variations in the subglacial hydrological system are likely to be the main cause for ice velocity variations that have been observed on many glaciers in recent years in connection with increased surface melting caused by climate warming (Rignot and Kanagaratnam, 2006; Bell, 2008). The relationship between subglacial hydrology and ice velocity variations is being investigated as a part of the Nordic Toppforskningsinitiativet SVALI project. One of the study areas is a partly glaciated watershed on the north side of the Hofsjökull ice cap in central Iceland where two hydrometric stations are located near the ice edge (Fig. 1, right panel). In order to investigate the seasonal variations in the surface ice velocity on the northern flank of Hofsjökull a continuously recording GPS-station (Fig. 1, left panel) was operated from Mai 2011 to September 2011. The GPS-station was located at the lower edge of a relatively flat area at an elevation of about 1300 m a.s.l., near the equilibrium line of the glacier (Fig. 1, right panel). Recordings were made at 15 s intervals and the data are processed kinematically relative to a fixed station near the ice edge. Results from preliminary processing for vertical and horizontal displacements, filtered with medina filters with a window of: 3 hours and one day are shown on figure 2. Ice surface velocities deduced from daily horizontal displacements are also shown on figure 2.

Precipitation and temperature data from an automatic weather station located in the highland, ~10 km north of the glacier, is shown on figure 2 for comparison. Hourly river discharge measurements from two hydrometric stations are also presented on figure 2 for comparison. One of the stations is located in the river Vestari-Jökulsá, draining the part of the glacier that the GPS-station was located on but it is ~40 km down river from the glacier margin. The other one is located in the highland, ~15 km down river from the glacier, but it is in Austari-Jökulsá that is draining an adjacent part of the glacier.

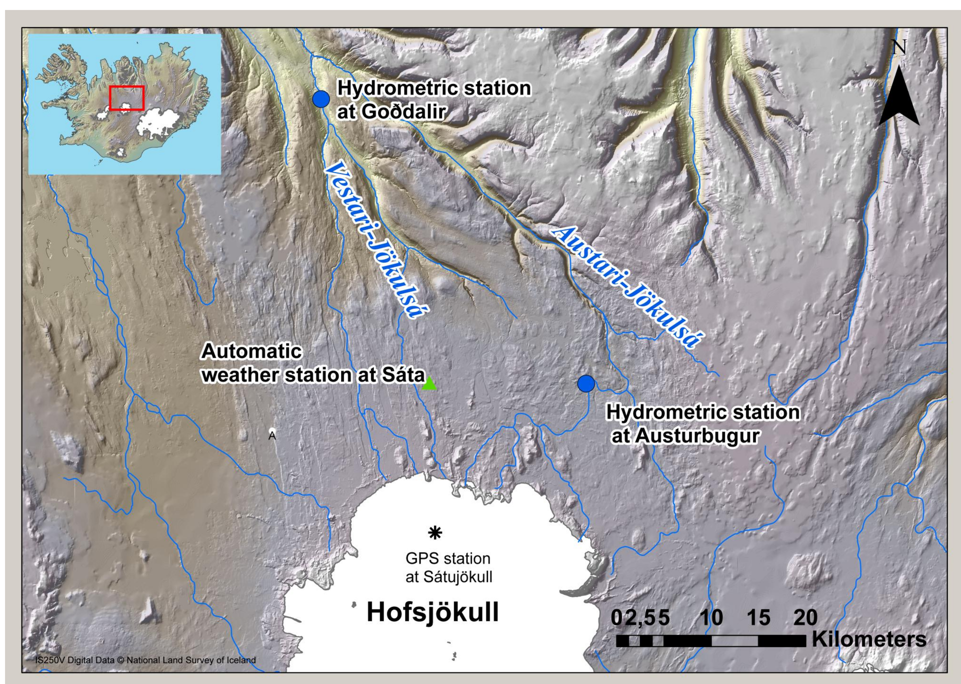

Figure 1. Left panel: Instrument setup on Sátujökull. GPS receiver, GPS antenna, solar panel and batteries are all located on specially designed quadropod. Right panel: Location of GPS station, automatic weather station and hydrometric stations.

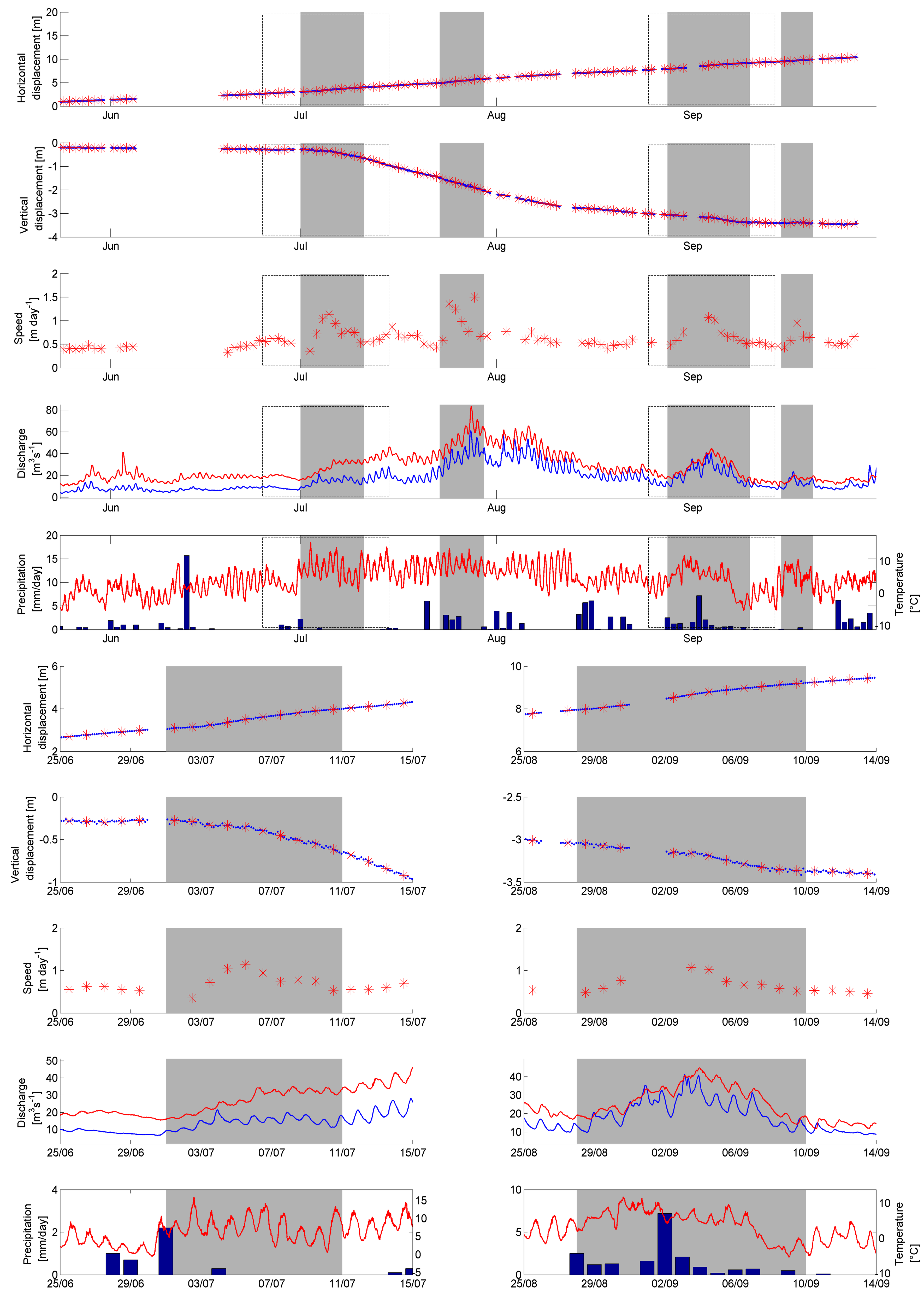

Figure 2. Panel 1 and 2, vertical and horizontal displacements measured on Sátujökull, filtered with medina filters with a window of: 3 hours (blue dots) and one day (red stars). Panel 3, ice surface velocities deduced from daily horizontal displacements. Panel 4, discharge in nearby glacial rivers, Vestari-Jökulsá at Goðdalir is shown in red and Austari-Jökulsá at Austurbugur is shown in blue. Panel 5, meteorological data from a nearby automatic weather station, Sáta. Precipitation shown as blue bars and temperature as a red curve. Periods of increased surface speed are marked with gray background. A zoom in on the two periods defined with black broken lines on the top five panels are given in the lower five left and right panels.

Preliminary results

Four periods of increased surface speed are identified, indicated with grey background on figure 2. An increase in river discharge is observed during all four periods. The events of increased surface speed do therefore all seem to be connected to increased hydrological activity, either caused by increase in melt or rain events.

The first event in the beginning of July seems to be connected with the onset of summer melting on the glacier caused by sharp temperature increase on the 30 June. Vertical lowering, caused by the melting, is observed and river discharge increases during the following days. The increase in ice surface speed is sharp but dose only last for three days. After that the speed decreases in five days to a similar value as before the event. This might presumably be connected to a subglacial water accumulation caused by increased water input, from surface melt, to an ineffective distributed subglacial hydrological system. But subglacial accumulation of water has been observed or inferred at many locations on large and small glaciers and found to be associated with substantial increases in ice flow velocities (e.g. Fudge and others, 2009; Magnússon and others, 2011). The effectiveness of the system might then quickly be increased by formation of basal channels to match the increased input and surface speed is lowered again.

Slow but steady increase in melting for the middle of July, seen from increased river discharge and surface lowering, does not cause any considerable surface speed variations and the subglacial hydrological system might therefore be able to adapt simultaneously this change. A considerable increase in surface velocity is observed for 24 to 29 July. A rain event on the 24 to 26 of July might strain the adaptability of the subglacial hydrological system and cause this increase.

During late August, increase in surface speed is observed again. Input into the subglacial hydrological system from surface melt was probably low the week before this event as temperatures, horizontal lowering and river discharge were low. The subglacial hydrological system might have been adjusted to this low input and is therefore not able to transport the increased input from rain, but considerable amount of rain is observed during this period. This would cause water accumulation that might cause the increase in surface speed.

Fourth event of increased surface speed is observed in the later half of September coinciding with increased temperatures, that increase melt and thereby input into the subglacial hydrological system with similar effects as before.

Small or no effect on ice surface speed of a number of rain events in August and a considerable rain event on the 21 of July compared to the rain events discussed above is noteworthy and needs further considerations.

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