Meltwater Dynamics Beneath Skeiðarárjökull from Continuous GPS Measurements and Seismic Observations

Matthew J. Roberts [1], Eyjólfur Magnússon [2, 3], Rick Bennett [4], Halldór Geirsson [1], Erik Sturkell [3], Helgi Björnsson [3], Finnur Pálsson [3], Helmut Rott [2], and Alexander H. Jarosch [3]

(1) Physics Department, Icelandic Meteorological Office, Bústaðavegur 9, 150 Reykjavík, Iceland (2) Institute of Meteorology and Geophysics, University of Innsbruck, A–6020, Austria (3) Institute of Earth Sciences, University of Iceland, Sturlugata 7, 101 Reykjavík, Iceland (4) Department of Geosciences, University of Arizona, Tucson, AZ 85721–0077, U.S.A.

C31A–1232

1. Background

Glacier and ice-sheet motion is dominated by the amount of meltwater within subglacial drainage. Velocity estimates from remotely-sensed data illustrate the variability of glacier flow in response to factors ranging from intense rainfall to glacial surges. Such time-dependent data illuminate the subglacial extent of pressurised water, but the exact timing, duration, and strength of the forcing is often unknown.

2. Motivation

Here we present initial results from measurements of surface movement in the lower ablation zone of Skeiðarárjökull (1,380 km^2): the largest piedmont glacier of the Vatnajökull ice-cap, Iceland. (Figure 1). In April 2006, motivated by frequent floods and regional-scale seismicity from the glacier, we deployed three continuous, high-accuracy global positioning systems (GPS) on Skeiðarárjökull (Figure 2).

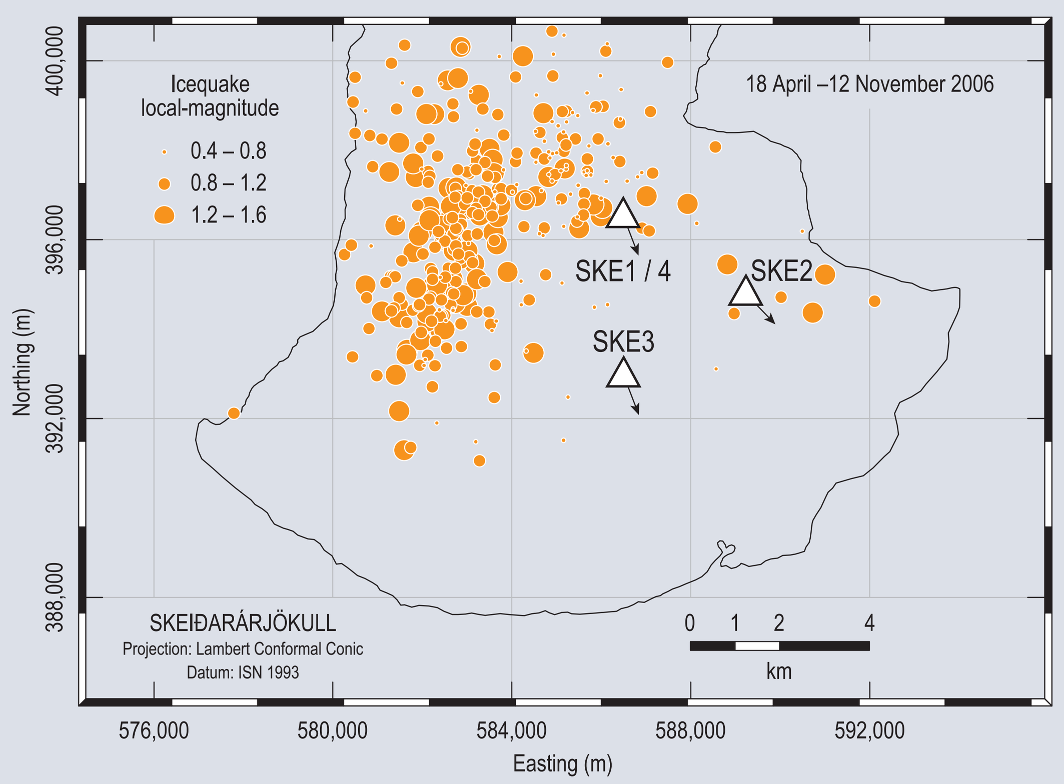


Figure 2: Location of GPS stations on Skeiðarárjökull and icequake epicentres registered during the study period by the *SIL* seismic network (Figures 1 and 4B). Note that the arrows illustrate the direction of station movement but not the magnitude – see Figure 6 for vector data.

3. Methods

To enable long-term observations, we devised a broad, low antenna platform, which comprised four aluminium supports designed to be embedded partly into the glacier surface (Figure 3). Each GPS receiver was powered by a 12 V battery connected to a 50 W solar panel.

The array had an initial station-to-station distance of 3 km, with the uppermost GPS station located 8 km from the glacier terminus - in a region where ice thickness exceeds 400 m and icequakes are common (Figure 2). Data, sampled at 15-s intervals, were processed alongside permanent stations in Iceland's national GPS network.

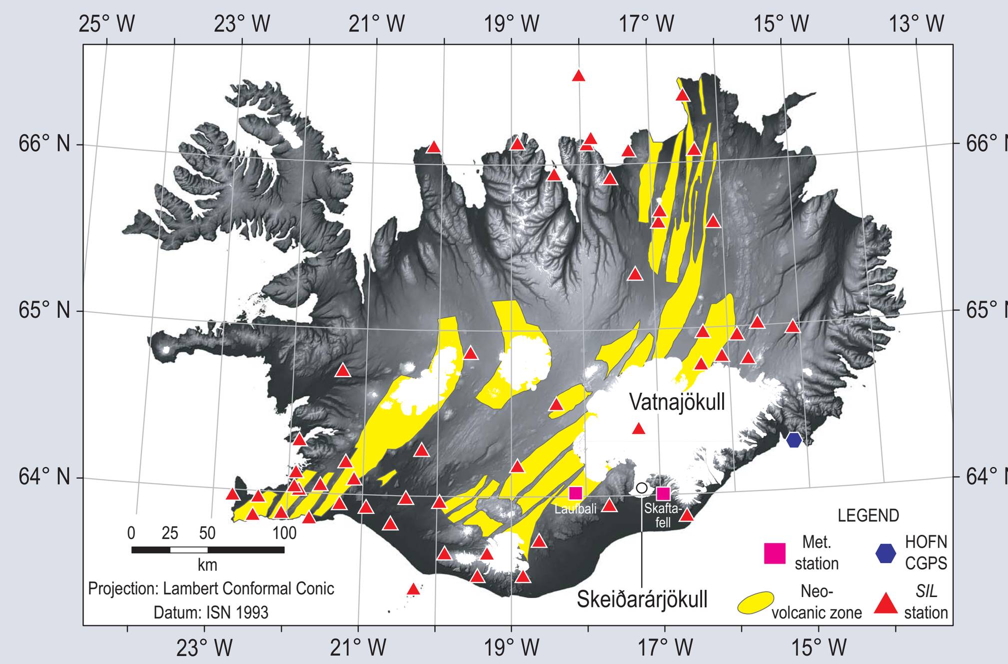
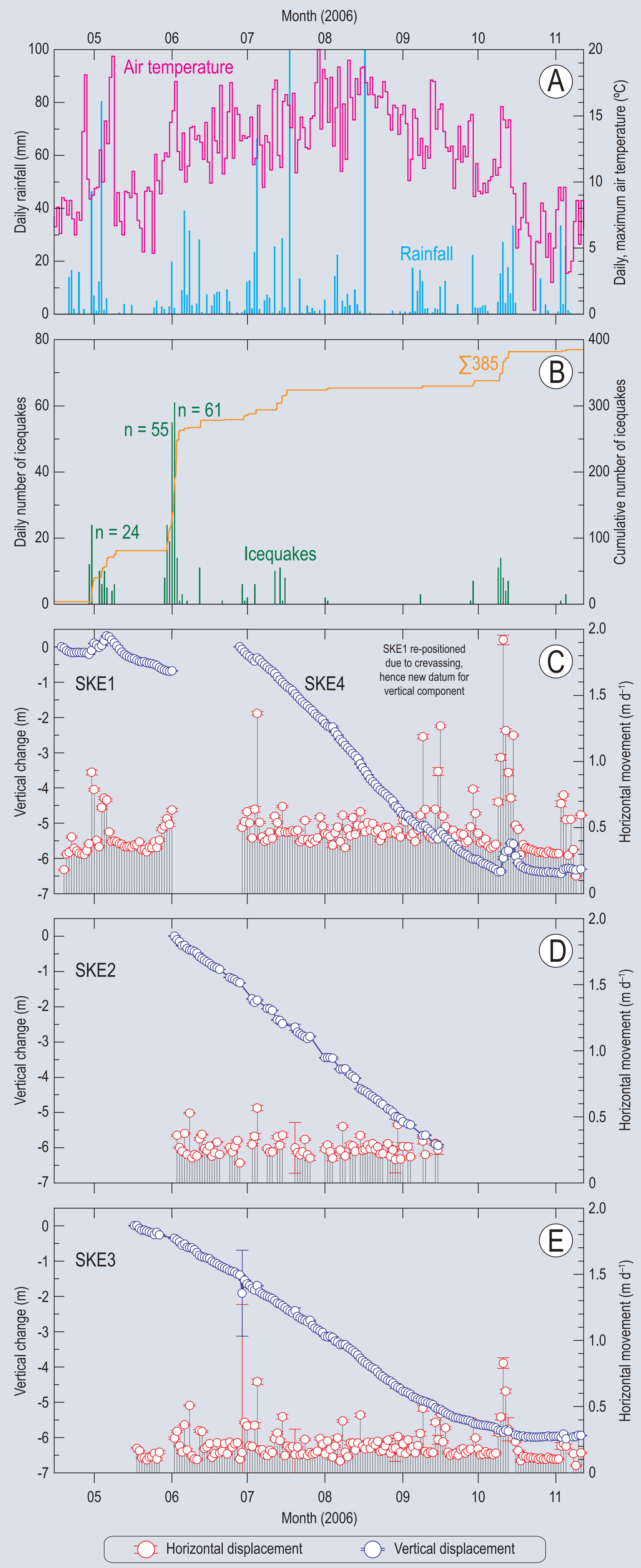


Figure 1 (left): Skeiðarárjökull and the *SIL* seismic network, utilised here to monitor seismicity from the glacier. For more information about the *SIL* network, visit: http://hraun.vedur.is/ja Note also the location of the CGPS reference station used in this study and the position of meteorological stations near to Skeiðarárjökull.



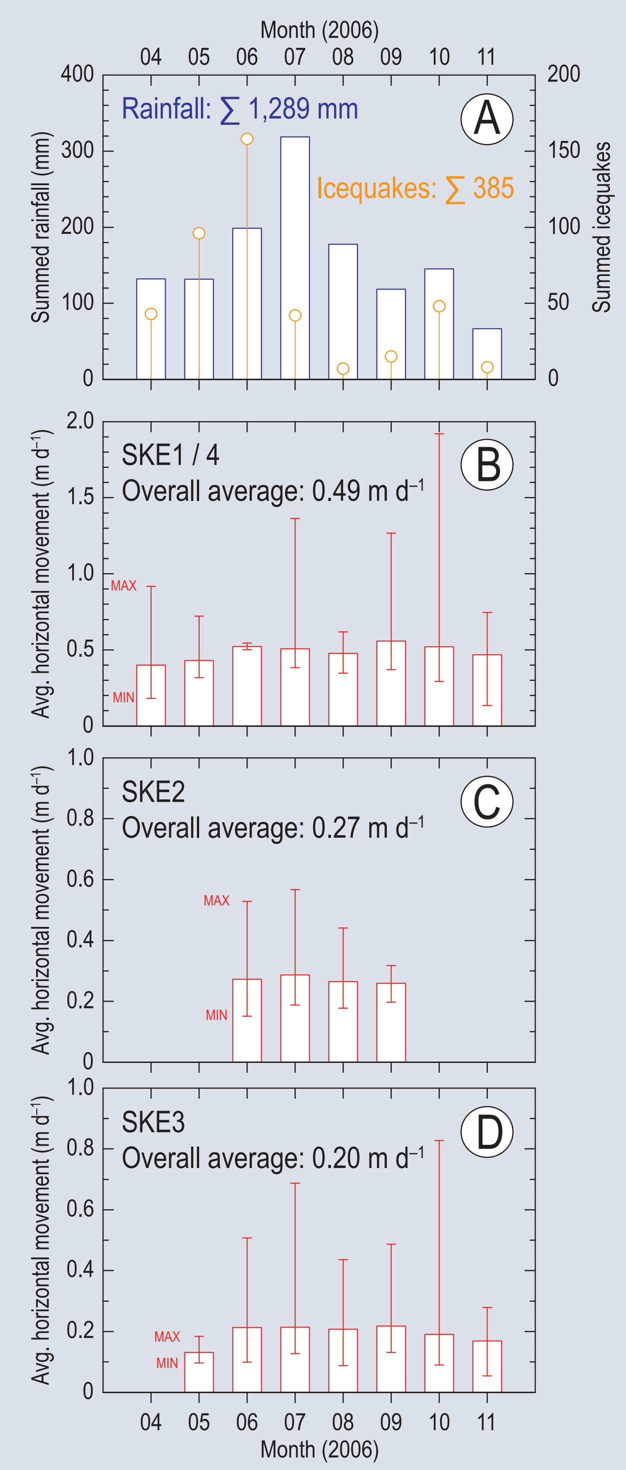


Figure 5 (above): (A) Monthly, summed rainfall in Skaftafell (Figures 1 and 2) and monthly number of icequakes in Skeiðarárjökull (Figures 2 and 4). (B – D) Daily, horizontal movement of the GPS stations as monthly averages. Note the change-of-scale in (B).

4. Results

Within the study period, horizontal velocities varied from 0.05 m d^{-1} (SKE3) to 1.92 m d^{-1} (SKE4); the highest displacement rates occurred during intense rainfall and were often accompanied by glacier seismicity and temporary uplift of the ice-surface (Figures 4 – 7).

Figure 4 (left): Stacked, time-series plots of rainfall and air temperature data from Skaftafell (A); icequake activity in Skeiðarárjökull (B); and movement of the three GPS stations (C–E). Geodetic data were processed relative to CGPS station HOFN, sited 100 km east of Skeiðarárjökull (Figure 1). Each GPS data-point represents a 24-hour solution based on satellite data collected continuously at 15-second intervals. Note the interdependence between intense rainfall and increased displacement rates. For the location of Skaftafell (90 m a.s.l.), see Figure 1.

Figure 3: GPS stations on Skeiðarárjökull. Each station was equipped with a *Trimble NetRS* receiver and a *Zephyr* geodetic antenna.

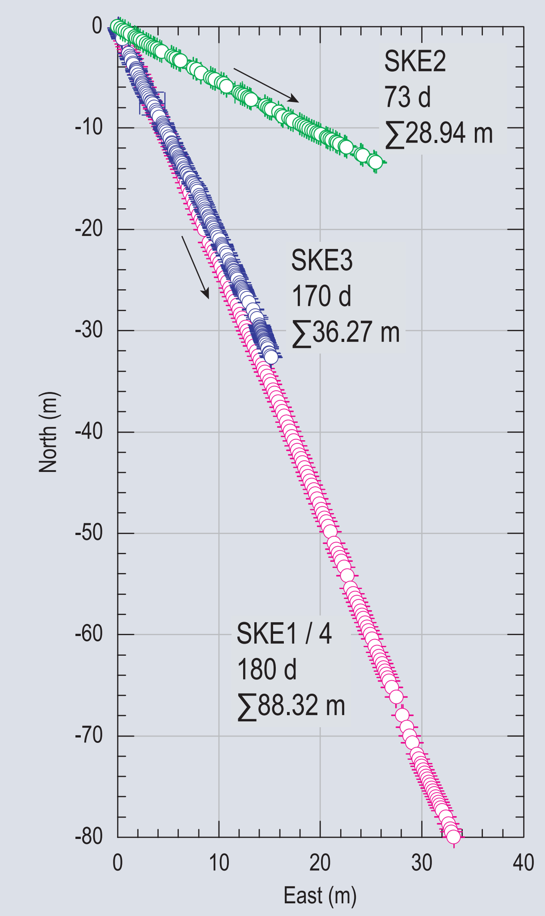


Figure 6 (above): Total horizontal vector, based on 24-h solutions, for each GPS station. See Figure 8 for data on angular motion.

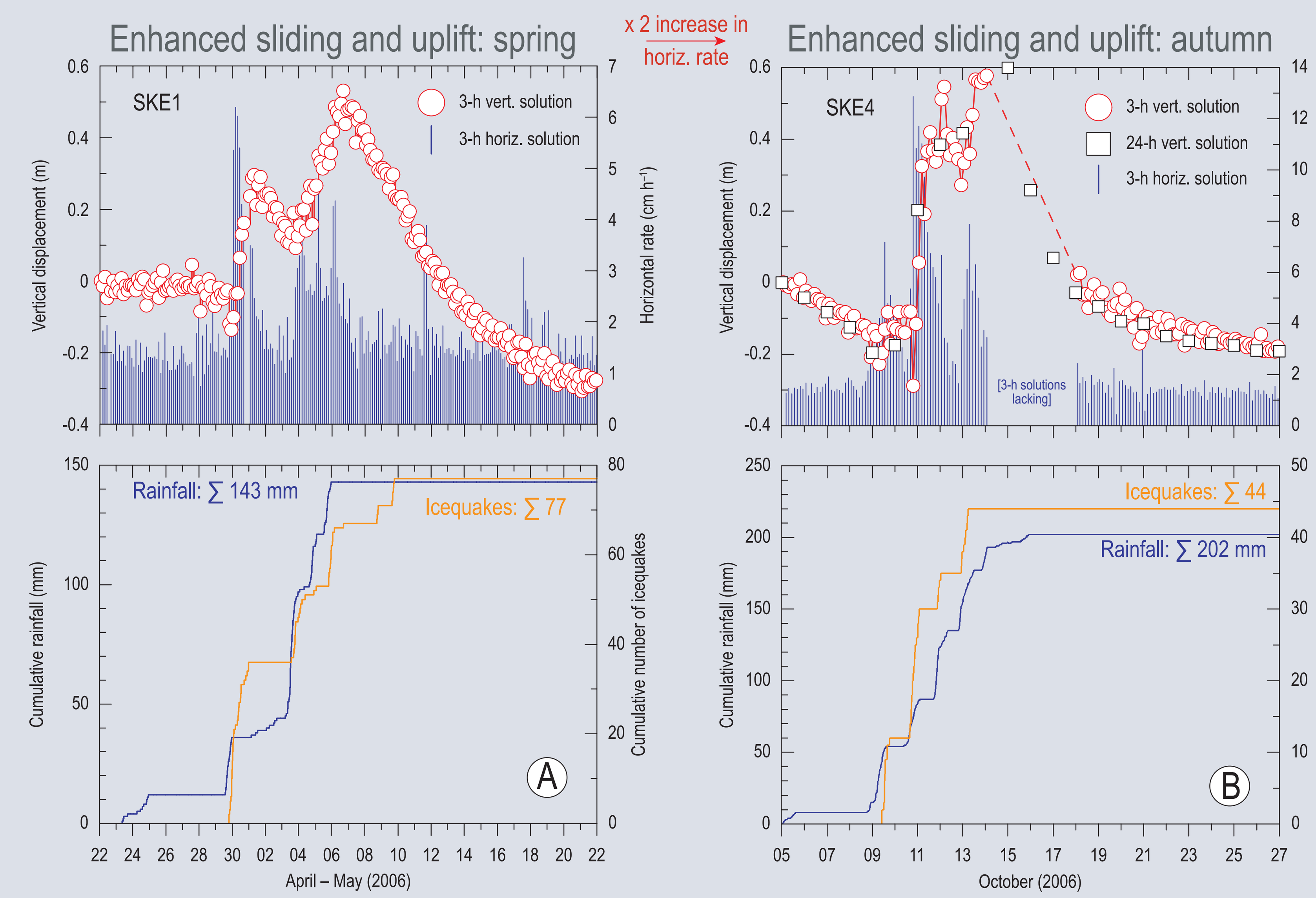
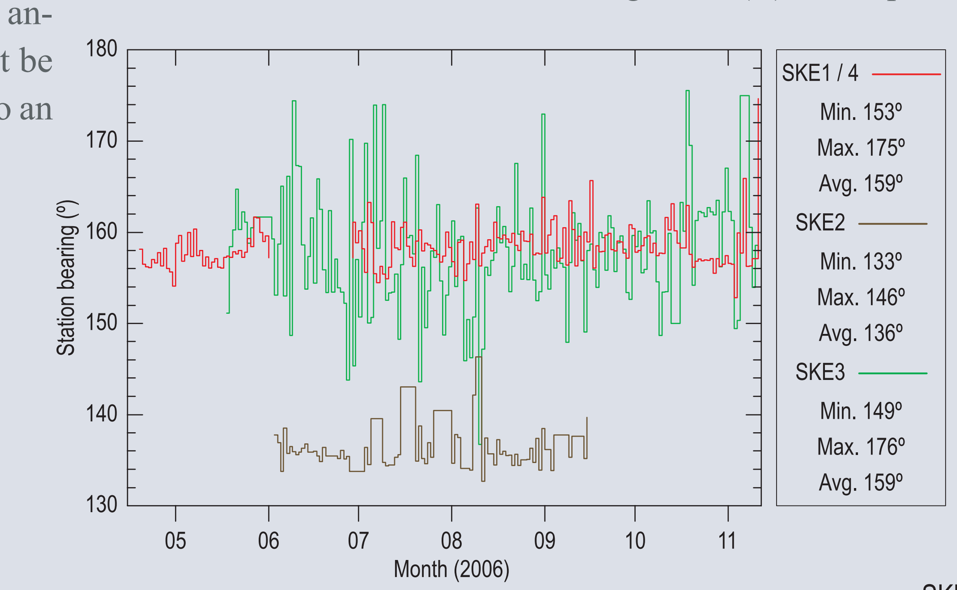


Figure 7 (above): Glacier response during spring and autumn rain storms. (A) Increased horizontal movement at SKE1 and subsequent vertical uplift of the ice surface. Note the period of sustained ice-surface uplift in association with rainfall at Laufbali (~490 m a.s.l.), sited 44 km west of Skeiðarárjökull (Figure 1). The return – 18 days later — to the vertical datum from 29 April implies that meltwater was released slowly from beneath the glacier. (B) Site repsonse at SKE4 to intense rainfall over Skeiðarárjökull.

Figure 8 (lower right): Angular variation in station motion based on 24-h GPS solutions. Larger angular variations at SKE3 might be due to the station's proximity to an ice divide.

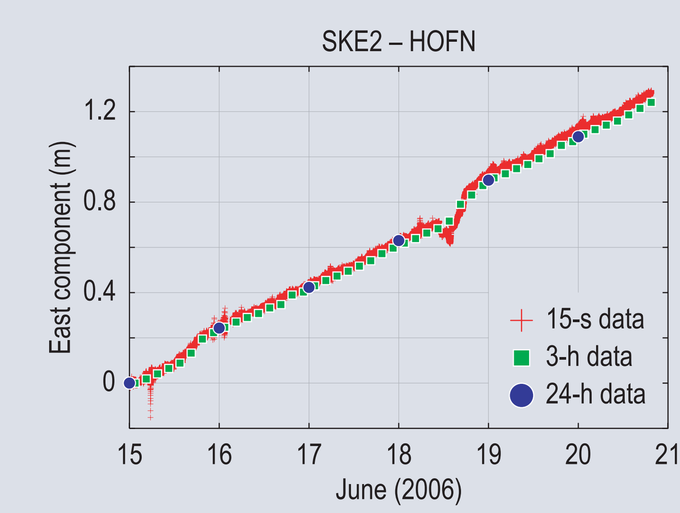


5. Conclusions

In combination with local meteorological data our geodetic and seismic observations show that Skeiðarárjökull is remarkably sensitive to variations in meltwater input to the glacier bed. Seemingly, transient changes in sliding rate – forced by hydraulic jacking of the glacier base – can take place over large areas of the glacier bed during intense rainfall.

6. Future Work

Kinematic processing of GPS data to allow further constraint on the timing of velocity changes due to rainfall; these data, along with existing focal parameters, will help to elucidate icequake source-mechanisms.



E-mail: matthew@vedur.is