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Anomalies in the vertical ice motion of Vatnajökull, Iceland: Hydraulic jacking versus strain-uplift

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We analyse InSAR data from the ERS1/2 tandem mission of the glacier outlet Skeiðarárjökull in Vatnajökull, Iceland, to study vertical surface movements of the ice surface. We study 35 interferograms in the period from May 1995 to March 2000 from both ascending and descending orbits. In these interferograms we observe high variability in the radar line of sight (los) velocity which is predominantly caused by variability in the glacier flow. We introduce a simple method for subtracting the contribution of surface parallel motion to the los-velocity. The residual shows vertical motion caused by vertical straining of the ice and bed separation due to the hydraulic action of pressurised, subglacial water. The study reveals an area, where spatial anomalies in the vertical motion are frequent. Its location is above the estimated subglacial course of the river Skeiðará at the most over-deepened part of the glacier. There we observe between 10-20 cm/day uplift during high velocity events accompanying rainstorms and one jökulhlaup and a subsequent slower subsidence ($<$10cm/day). Three DGPS-station where mounted on the glacier in the spring 2006, SKE1 at the location of the observed anomalies and SKE2 approximately on the same flow line 3 km down-glacier. At SKE1 we observe up to 50 cm/day uplift consequent to speed-up events during rainstorms where the horizontal velocity was up to 10-fold the minimum of 30 cm/day. Such events never triggered more than $\sim$5 cm/day uplift in the other station. To estimate vertical motion caused by strain we use as a first approximation a velocity

field, deduced from ERS1/2 InSAR data of ascending and descending orbits, and scale to fit the horizontal velocity observed at SKE1 and SKE2. By using the 2-dimensional continuity equation we calculate that 1/3 to 1/2 of the uplift observed at SKE1 during speed-up events could be due to strain, leaving the remain to bed separation. However, we do observe correlation between the flow direction at the stations and the flow velocity indicating that the ice-flow diverges less to the sides during high velocity events. By skewing the velocity field slightly so that it represents better the horizontal flow direction during speed-up events (change of around 5° at SKE1) the estimated uplift due to strain becomes significantly higher suggesting that the entire uplift observed at SKE1 may be explained as strain due to increased horizontal ice-flow. We conclude that our simple calculations do not exclude bed separation due to hydraulic uplift as a possible source for some of the anomalies observed in the vertical motion both in the InSAR and in the DGPS-data. However, we emphasis that our observations illustrate the difficulties of identifying the source of anomalies in vertical glacier motion derived from InSAR data and spatially limited GPS-data during high velocity events. Setup of 4 GPS-stations in a strain diamond with the 5^{th} station in the centre is needed for rigorous result.