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Monitoring the Continuous Surface Motion of Glaciers by Low-Cost GNSS Receivers

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The motion of a glacier is usually monitored by episodic geodetic observations that are carried out during the summer. During winter observations are much more difficult due to harsh weather conditions and the remote location of glaciers in general. Based on such observations the glacier surface velocity is estimated as the mean displacement rate between the positions of the different observation epochs. Alternatively remote sensing about surface displacements can be collected from space or air, but they also capture only one finite time interval. It is therefore very often difficult to estimate the seasonal behavior of a glacier or to detect sudden changes.

The position estimation with Global Navigation Satellite System (GNSS) like GPS or GLONASS is today widely used in smart phones, traffic control and many other devices. To keep the costs of these sensors at a minimum they usually provide only code observations. However, some of these cheap receivers deliver also phase data, which are the key element for precise geodetic positioning. Analyzing the phase data of the Low-Cost GNSS sensor in combination with a nearby geodetic reference station allows the estimation of relative positions with an accuracy of a few centimeters.

In the summer 2013 we started an experiment with two sensor systems on the glacier Vernagtferner in Austria. Each system consists of a single board computer, a GNSS receiver and solar powered energy supply. Data were collected each day for two hours. The data were analysed together with the data of a GNSS reference station, which is located in the vicinity of Vernagtferner glacier. The coordinates for each day were estimated with accuracies better than one centimetre, while the coordinate time series are very consistent. One of the sensors was placed on a stake which was drilled into the ice. Here we could observe very slow horizontal motion of about 0.3 m/a, while the height was not changing significantly. The second system was attached to a framework which is placed on the surface of the glacier. Here we observed continuously the melting process of the glacier surface during the ablation season 2014, which reduced the glacier elevation at this location by 2 m.

A similar experiment was also applied on the glacier Mýrdalsjökull in Iceland. Even though the experiment did not last over the entire winter we could observe a significant difference in the motion of the glacier. During the summer the resulting horizontal velocity was almost 22 m/a, while the average over the entire year was estimated to 13 m/a.