Åknes Report 04 2010

Hegguraksla in Tafjorden: Monitoring and data analysis

Summary

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Title	Hegguraksla in Tafjorden: Monitoring and data analyses
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Summary:

Documentation, analysis and interpretation of data are important parts of the quality routines for Åknes/Tafjord Early Warning Centre. This report presents the scenarios and data analysis of the existing monitoring systems. It is a base for the established advisory group for the Åknes/Tafjord Early Warning Centre.

Monitoring is performed at two instabilities at Hegguraksla with volumes of between 0,4 and 1 mill m^3. Additional volume will be entrained during a possible event, and a collapse will lead to a dangerous tsunami.

The sites are instrumented with a ground-based radar measuring the distance to reflectors, crackmeters and tiltmeters. The monitoring data so far indicate fairly stable conditions, although a sub-millimetres scale widening of a crack is indicated at the upper instability. Longer time series is needed before firm conclusions can be made.

Content

Introduction

Documentation, analysis and interpretation of data are important parts of the quality routines for operative early-warning systems. This report is a part of the documentation procedures and is an important base for evaluation by the established advisory group for the Åknes/Tafjord Early Warning Centre. The report presents the rock avalanche scenarios, data series and analysis of the existing monitoring systems, as well as planned new instrumentation. The instability at Hegguraksla consists of two blocks that are located in Tafjorden in the inner part of Storfjorden (Figure 1). It is near the site of the last major rockslide of Storfjorden, which occurred in Langhammaren in 1934 and created a tsunami that killed 40 people. Investigations have been performed in the entire Tafjord area by the University of Lausanne and the detailed investigations at Hegguraksla were carried out in connection with a PhD study (Oppikofer, 2010). Based on this, monitoring of the unstable blocks started in 2004.

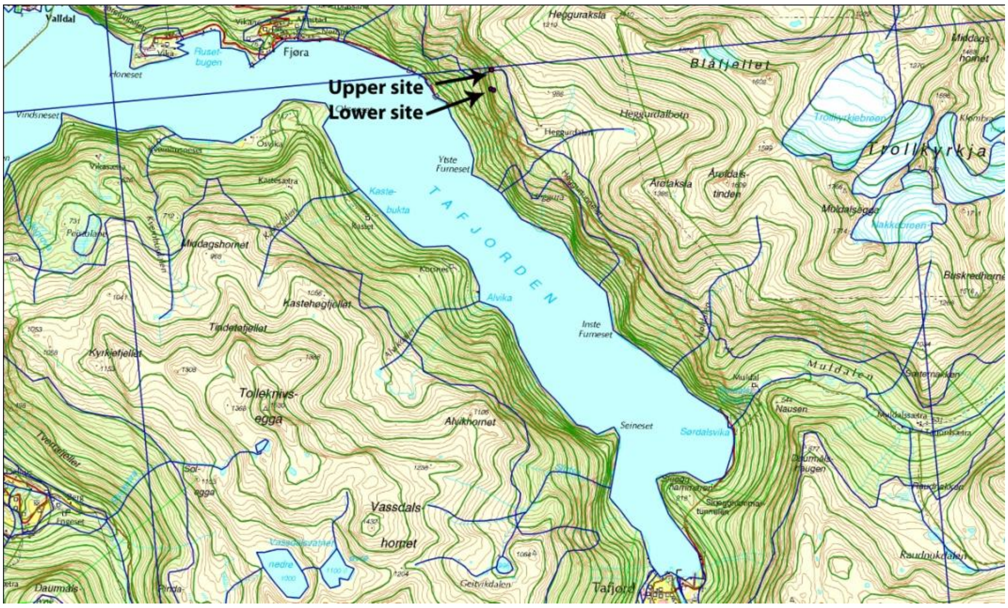

FIGURE 1: THE POSITION OF THE TWO INSTABILITIES AT HEGGURAKSLA IN TAFJORDEN, INNER STORFJORDEN.

Geology and scenarios

The work of Oppikofer (2010) included geological mapping, the use of air-based LIDAR and of ground-based LIDAR in selected areas. The scenarios for tsunami modeling were based on these investigations. Figure 2 shows a photo of the two unstable blocks, described below.

Upper instability

The upper instability is a 250 m high column composed of two lithologies; orthogneisses in the lower part and augengneisses in the upper part (Oppikofer, 2010). A large open NNE-SSW-trending fracture acts as back-crack, and this fracture can be followed further to the south and is marked in the field by a small escarpment. Oppikofer proposed two alternative interpretations of the geometry (Figure 3). The volume estimates for the unstable blocks is 0,8 and 1,0 mill m^3 for the two alternatives respectively. Large problems due to difficult atmospheric conditions were affecting the LIDAR measurements (Oppikofer, 2010), and conclusions of possible movements cannot be drawn from these investigations.

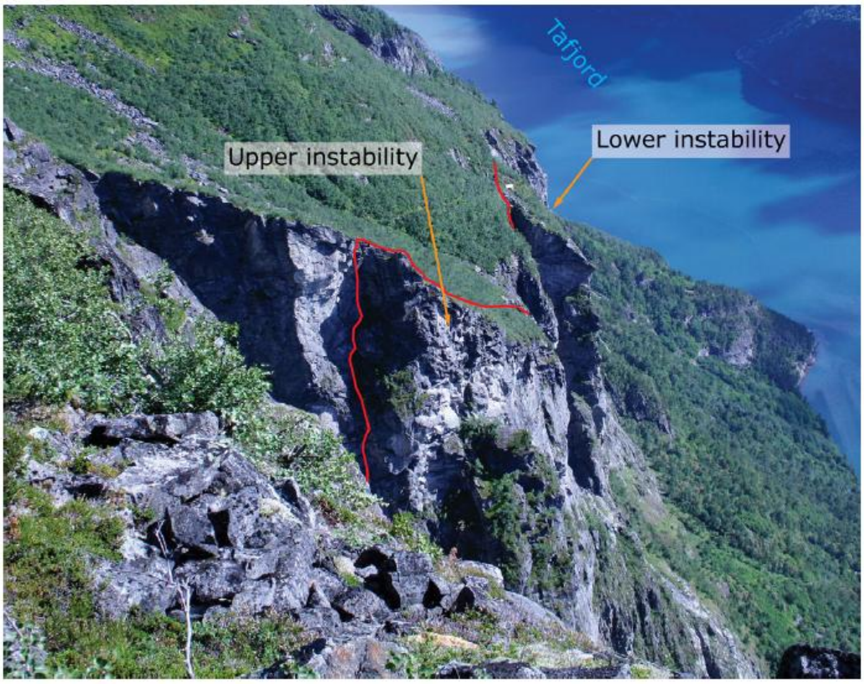

Figure 2: View to the southeast of the two monitored instabilities at the front of the Hegguraksla unstable area (from Oppikofer, 2010).

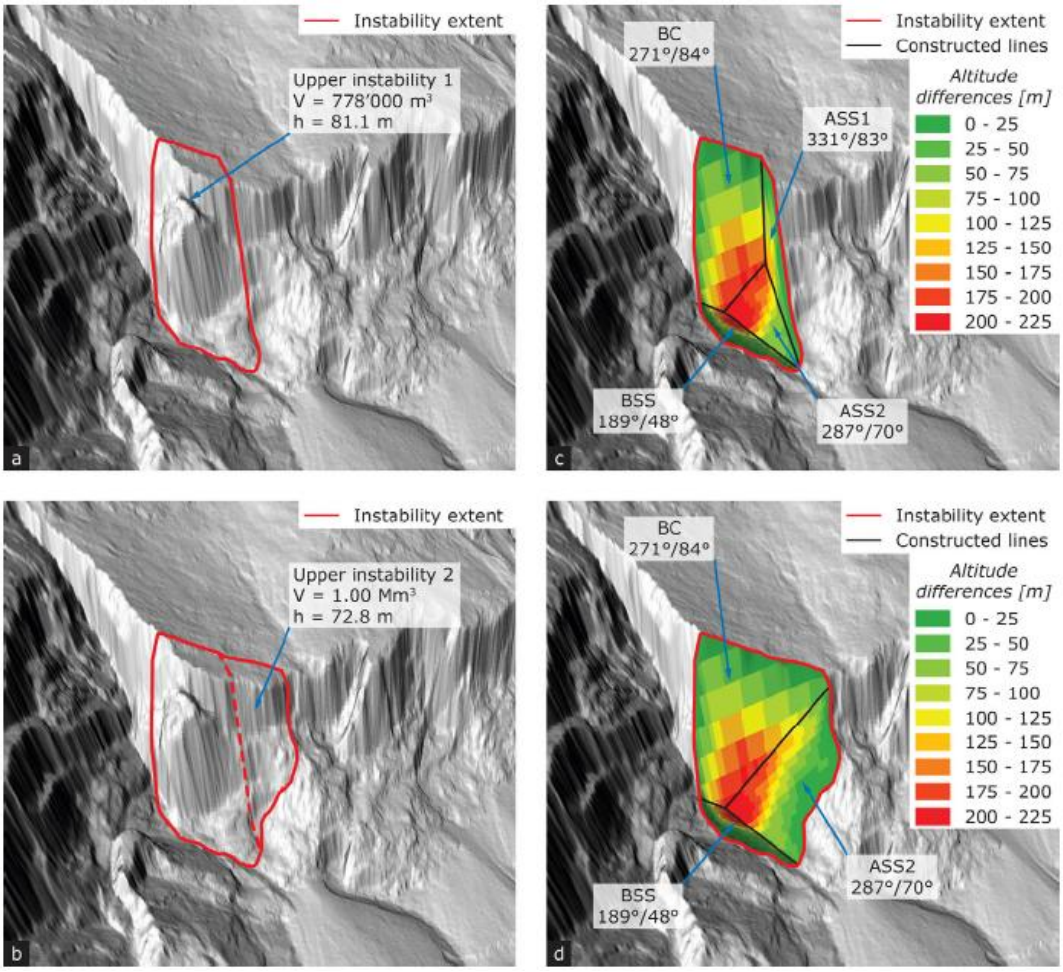

Figure 3: 3D representations of the Hegguraksla area (from Oppikofer, 2010). A & B: two possible geometries of the unstable blocks; C & D: Basal failure surface as the base for volume estimations.

Lower instability/block

The lower instability is characterized by a large opening along a back-crack in the northern part (Figure 2). The opening is probably mostly developed by rockfall activity along the highly fractured zone. The back-crack is not visible in the continuation to the south. Water seepage has been observed at the base of the instability (Oppikofer, 2010). The volume of the lower instability has been estimated to be 0,4 mill m^3 (Figure 4). Good results were obtained from repeated LIDAR measurements, but a possible movement on the site is smaller than the resolution of the method. A rockfall that occurred between the two datasets from 2007 and 2008, above the open crack, was documented by this method (Oppikofer, 2010).

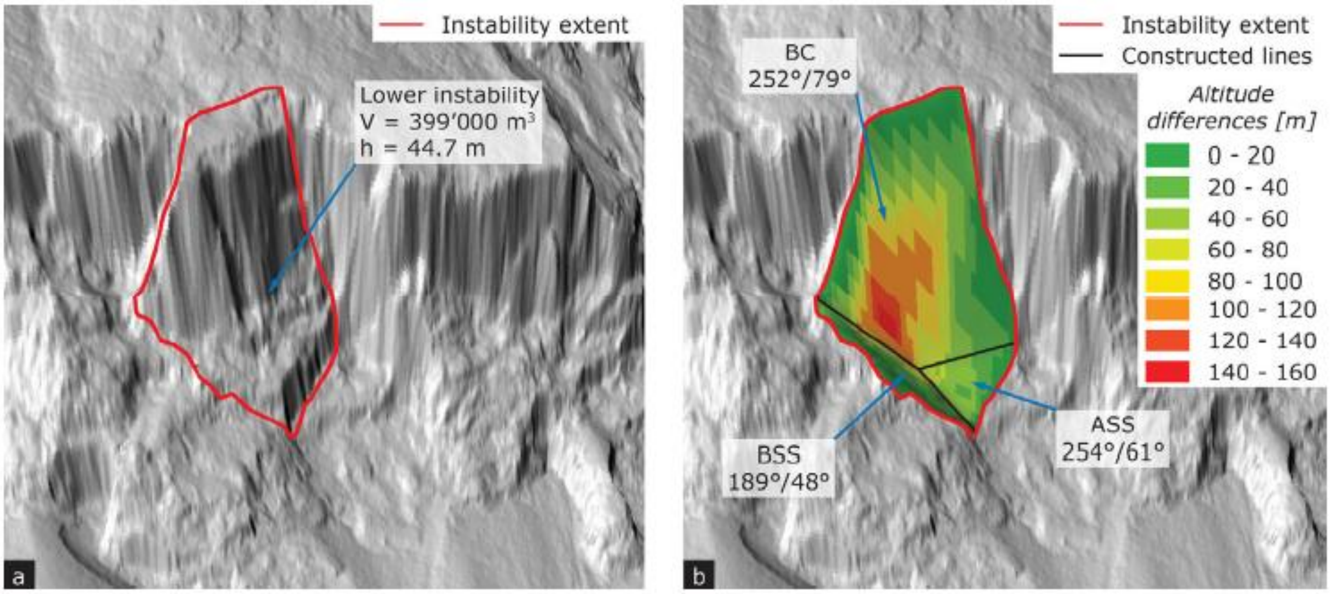

FIGURE 4: 3D VIEWS OF THE LOWER HEGGURAKSLA INSTABILITY (FROM OPPIKOFER, 2010): A) PRESENT TOPOGRAPHY AND INSTABILITY EXTENT; B) ALTITUDE DIFFERENCES BETWEEN THE CONSTRUCTED BASAL FAILURE SURFACE AND THE TOPOGRAPHY (UP TO 143 M).

Instrumentation and data analysis

Hegguraksla is less instrumented compared to Åknes. At the upper instability it consists of three crackmeters (Figure 5) and two tiltmeters, while the lower instability is instrumented with two tiltmeters. These instruments are online and send data using GSM to Åknes Early Warning Centre. A ground based radar system that measures the displacement of a set of reflectors has been established by the company ISPAS. One reflector is placed on each instability and one at the stable rock behind each instability. Additional reflectors are placed further uphill, in an area were there have been mapped structures that could be related to large-scale detachments, but there are no fresh signs of movements. The data are presented through a web-interface, and is part of the operational monitoring at the Early-Warning Centre.

Crackmeters

Three crackmeters are installed at the Upper instability. Data from 18th of November 2008 to the 21th of May 2010 is shown in figure 6. Crackmeter 2 and 3 show both a pronounced seasonal cycle, with expansion during winters and contraction during summers. The maximum width of the cracks was greater in the winter 2009-2010 than in the winter 2008-2009. This may either indicate different conditions during the two winters or a general widening of the cracks that is overprinted on a seasonal pattern; however the widening of both crackmeters from one winter to the next was less than 1 mm (Figure 6).

FIGURE 5: CRACKS AND INSTALLATION OF CRACKMETERS AT HEGGURAKSLA.

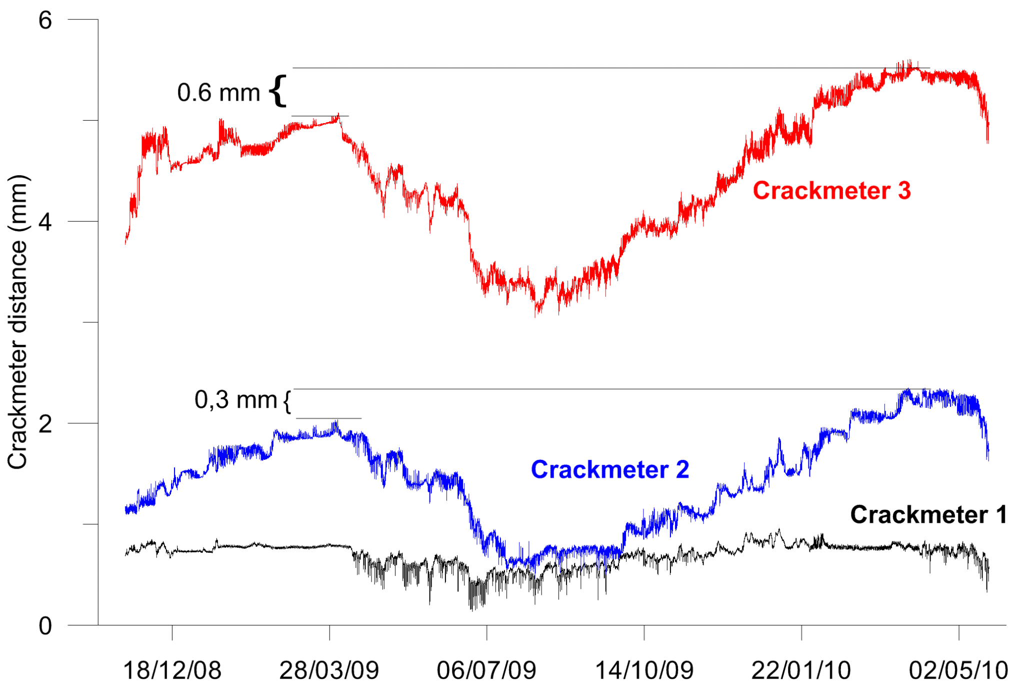

FIGURE 6: CRACKMETERS 1, 2 AND 3, UPPER INSTABILITY, HEGGURAKSLA. EXPANSION IN WINTERS AND CONTRACTION IN SUMMERS ARE SEEN.

Tiltmeters

The tiltmeters have recorded changes in tilt in two directions for two places on both Upper and Lower instability of Hegguraksla; the measuring period is between 18th of November 2008 to 21th of May 2010. The A-axis is parallel to the dip of the slope and the B-axis perpendicular. At both sites tiltmeter 1 is located at the stable backwall and tiltmeter 2 in the instability.

Upper instability

The tilt of tiltmeter 1 is strongly influenced by a sudden event in March 2010, where the tilt changed in A-axis from c. 6 mm/m to 60 mm/m and in the B-axis from -13 mm/m to -3 mm/m (Figures 7 & 8). The event took place over time and may be caused by the displacement of a loose rock, but this need to be followed up more carefully in the field. There are no other indications that there should be movement on this part. Tiltmeter 2 appeared much more stable during the first year but quite unstable since the summer 2009 (Figures 7 & 8).

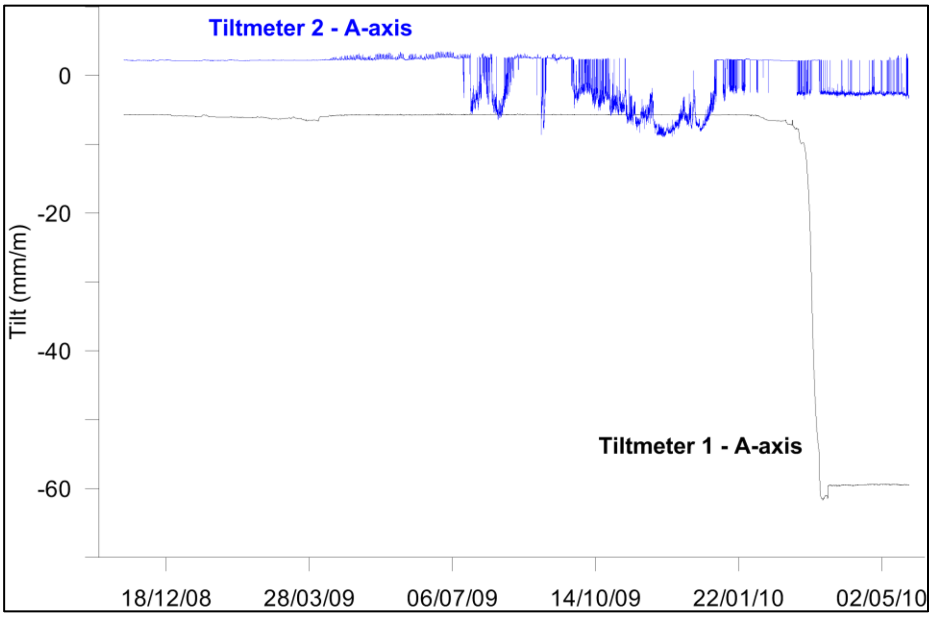

FIGURE 7: UPPER INSTABILITY, HEGGURAKSLA: TILTMETER 1 AND 2: A-AXIS

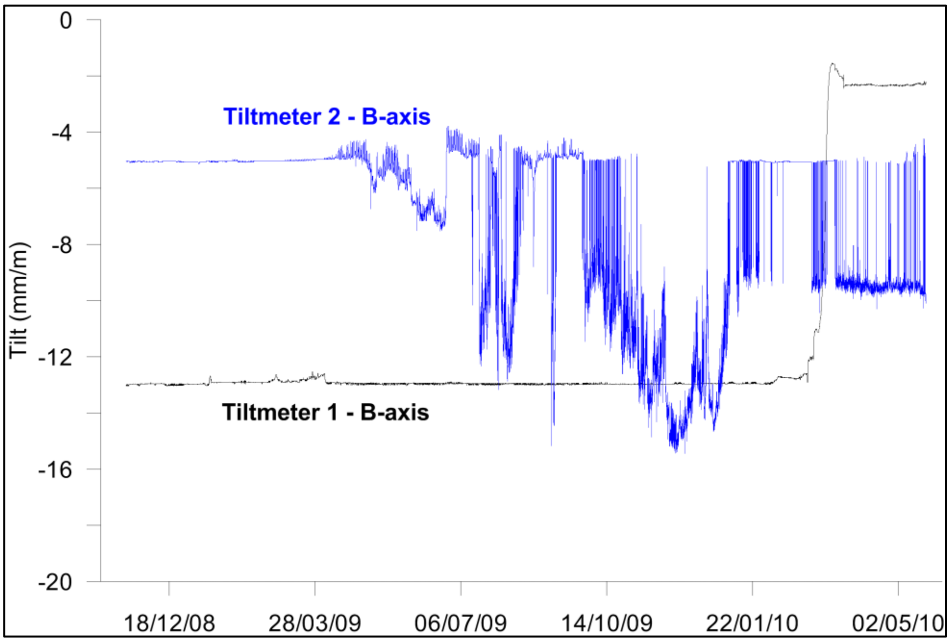

Figure 8: Upper instability, Hegguraksla: Tiltmeter 1 and 2: B-axis.

Lower instability

Tiltmeter 1 seems to display a seasonal fluctuation, in particular in the B-axis (Figures 9 & 10). Tiltmeter 2 displays some large jumps, which may indicate that the rock in which it is placed is not stable enough.

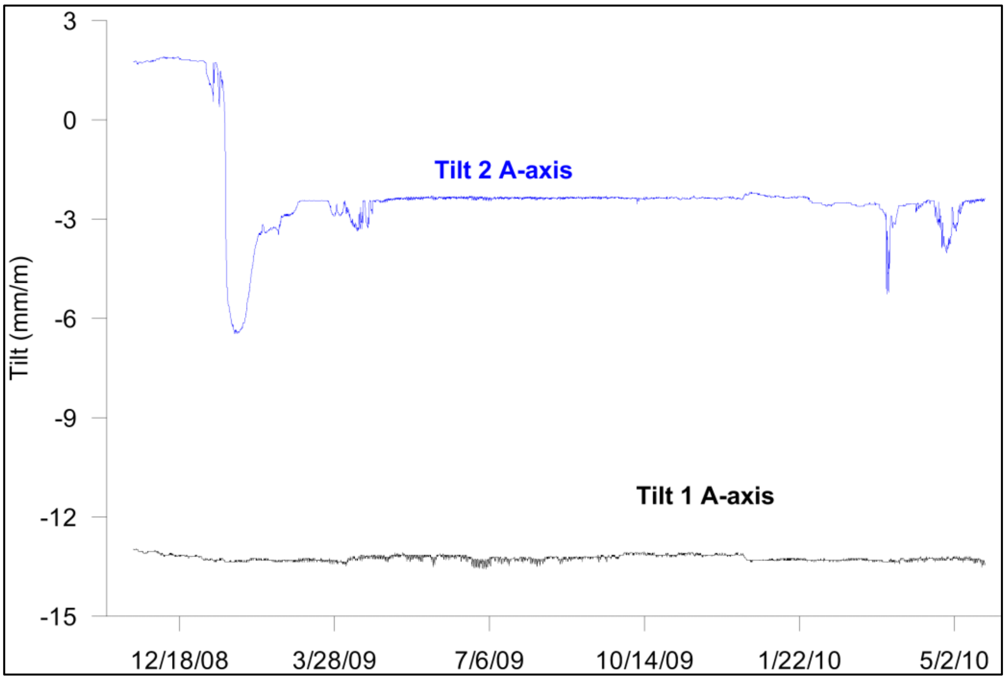

Figure 9: Lower instability, Hegguraksla: Tiltmeter 1 and 2: A-axis.

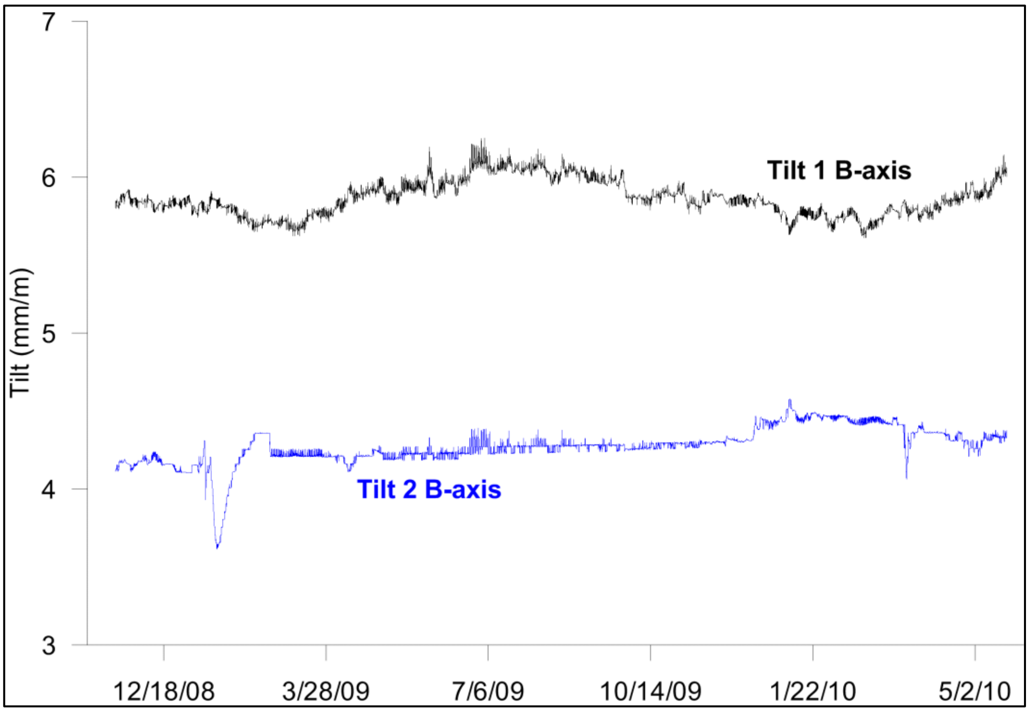

Figure 10: Lower instability, Hegguraksla: Tiltmeter 1 and 2: B-axis.

Radar measurements

Radar reflectors were placed in 2004, but there have been a series of problems related both to the foundation of the reflectors and to the radar system. Therefore, long-term series cannot be used before the spring 2010. The location can be seen on the photographs in Figure 11, where site 2 is the Upper instability, and Site 1 is the Lower instability. Site 3 above is most likely stable.

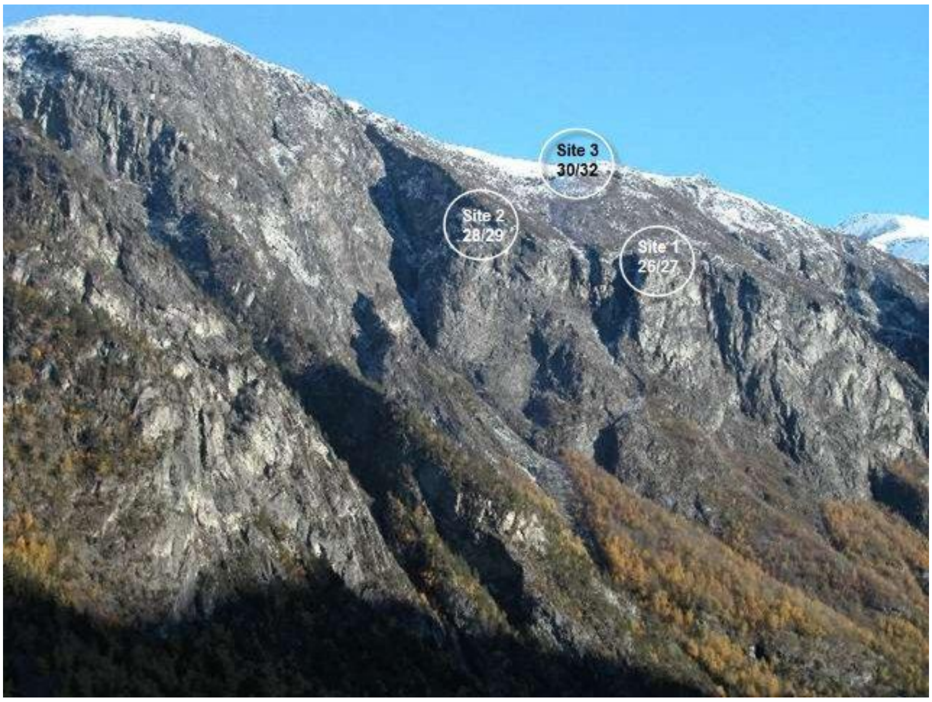

Figure 11: Photo showing the location of the radar reflector sites. Site 2 corresponds to Upper instability and Site 1 to Lower instability.

The system should now function better, but we see many jumps (1 - >5mm) in the data (Figure 12). The jumps do not reflect true movement of the rock wall, but rather different atmospheric conditions between the reference and moving reflectors. There also occur some larger jumps of more than 15mm. A Longer time series is necessary before we can properly evaluate possible movement and the system reliability and performance.

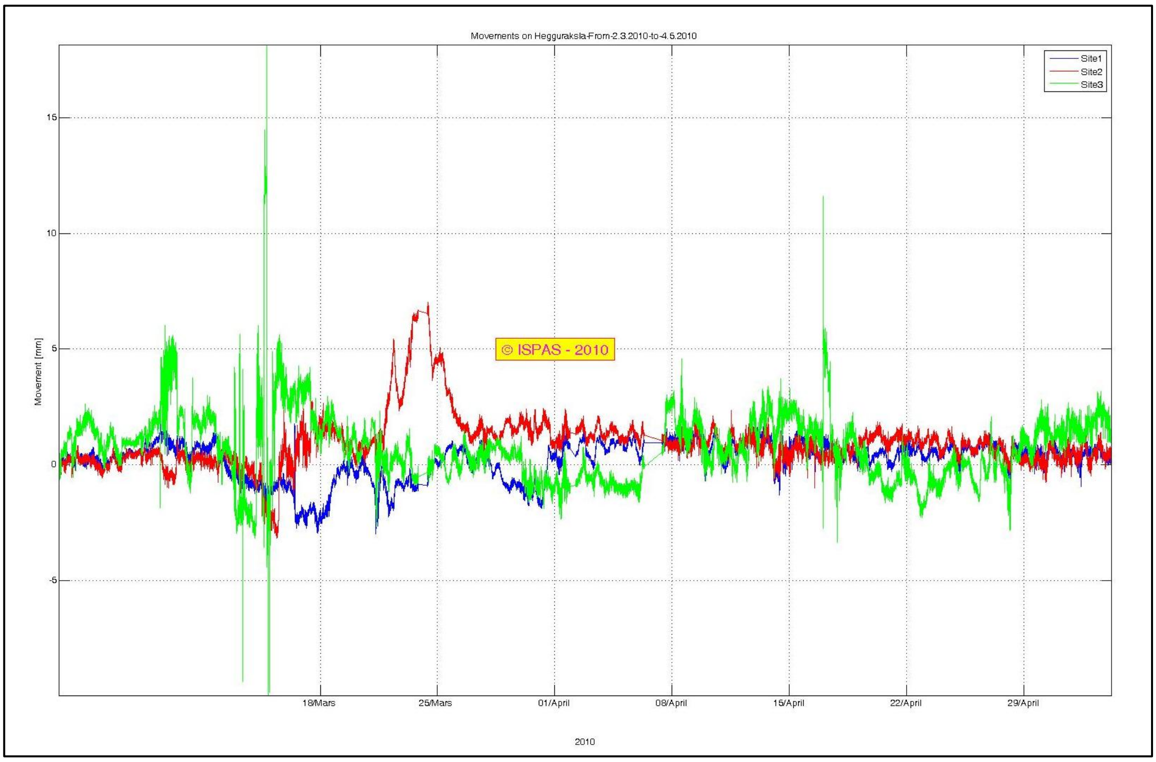

FIGURE 12: RADAR MEASUREMENTS AT SITE 1 (BLUE), SITE 2 (RED) AND SITE 3 (GREEN).

Comparison and evaluation of the data

The experienced problems with the radar instrumentation mean that we have no long and reliable time series for analysis. At the moment it does not appear that the tiltmeters provide enough reliable information of displacement of the mountainside. Movement may be too small to be picked up by the tiltmeters or overprinted by other factors that may influence the readings, such as humidity. The crackmeters of the upper instability record a clear seasonal signal of expansion in the winter and contraction in the summer. This suggest that the expansion may be caused by the growth and expansion of ice in the cracks. During two consequtive winters a small overall widening of the cracks was measured (less than 1 mm), but this may reflect unusual conditions during one of these particular winters). The crackmeters appear to be reliable, but they are placed only at the Upper Instability. The instrumentation of Hegguraksla should be supplemented with at least a couple of extensometers, as experience from Åknes has given us greater confidence in these instruments. At least one or two extensometers need to be placed at the lower instability.

Conclusions

The investigations show two instabilities at Hegguraksla with volumes of between 0,4 and 1 mill m^3. Additional scree material will be entrained during a possible rock avalanche event, which will cause a dangerous tsunami.

The sites have been instrumented with a ground-based radar measuring on reflectors; crackmeters and tiltmeters. Apart from the crackmeters, we have so far not obtained reliable timeseries of displacement measurements, and it is therefore premature to analyze the displacement characteristics of the instability, although annual sub millimeter scale displacement is indicated in the upper instability. Longer time series is needed before firm conclusions can be made.

A few extensometers will be established at the two instabilities in 2011 in order to increase the redundancy of the monitoring.

References

Oppikofer, T. 2010: Detection, analysis and monitoring of slope movements by high-resolution digital elevation models. PhD thesis, University of Lausanne.