Monitoring a rockslide in development

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INTRODUCTION

Alert levels rose to the highest, creating national headlines, when high deformation rates and acceleration was measured in the Mannen rock-slide, Norway. A ground-based radar (InSAR) registered movement up to 60 mm/day and a total displacement of 300 mm during one month in the fall of 2014. A failure of the rock slope, being located 1200 m above the valley floor, would pose a potential risk for houses, farms and other infra-structure such as roads, power supplies and a railroad.

BACKGROUND AND METHOD

Mannen is one of the high risk objects for cata-strophic failures in Norway. Since 2009, Mannen has been permanently monitored by Åknes/Tafjord Beredskap IKS, which now is a part of The Norwe-gian Resources and Energy Directorate. The dis-placements rates are about 20 mm/year in the fastest moving areas and a failure can affect 30 properties by direct impact. It poses a greater danger if the underlying river gets dammed by the landslide masses, and is followed by a dam collapses leading to flooding of the downstream area. Be-tween the 17th and the 25th of September 2014 a ground-based radar (InSAR) was installed at a new location to measure deformations in areas that formerly had not been covered by the permanent monitoring system of Mannen.

RESULT

The data showed that part of the rock slope moved 45 mm during the eight days of measurement. The moving area was 6000 m² which is only a small fraction of the defined scenarios of Mannen, and for this reason it was named „Veslemannen" (The small man"). During a heavy rainfall the 21 th of September 2014 displacements rates increased dramatically, giving displacement rates that were five to ten times greater than the initial speed. In landslide monitoring acceleration is used to predict when a failure is likely to occur. Due to the in-creased and rapid displacement rates the radar was reinstalled the 6th of September 2014 and meas-urements have continued ever since. In the time that followed the displacement rates increased several times and several acceleration phases were registered. The acceleration was at its greatest after a heavy rainfall the 28th of September 2014 when the speed was over 80 mm/day in the fastest moving area. At this time it was expected that a failure would occur shortly. People had been

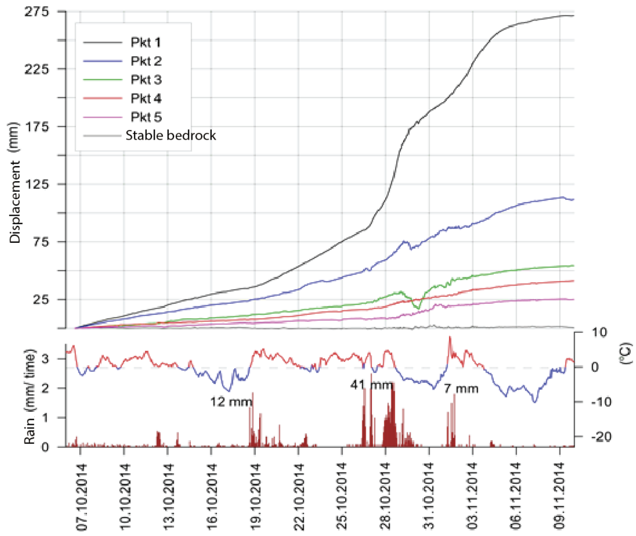

Figure 1. Registered movement between the 6th of October 2014 and the 9th of November 2014 in five points in the moving area and a reference point outside the moving area.

evacuated some days earlier. At the 29th of Sep-tember the temperature sank below 0°C and the precipitation came as snow. This made the rock slope slow down. The speed decreased and contin-ued to do so during the winter. Ground-based radars have difficulties measuring in snow covered terrain and new instruments, including three extensometers, a LiDAR-scanner and two geo-phones were installed to have an adequate moni-toring system throughout the winter. That allowed people to return to their homes. During the summer and fall of 2015 the movement has picked up, and it has been several periods of acceleration. These have been linked to snowmelt and rainfall events, demonstrating that the controlling factor for the instability is water. There are no indications showing that the larger scenarios of Mannen are affected by the movements in Veslemannen.

CONCLUSION

This case illustrates the importance and value of monitoring unstable rock-slopes. Monitoring makes it possible to detect deformations, follow the movement and give a prediction of when a failure is likely occur. People can be evacuated before a failure to prevent loss of lives. Nature is dynamic, and conditions affecting the slope stability can change, making prediction of failures challenging. Moving rock slopes can slow down and not fail, as it did in this case. The monitoring system can in these situations make it is safe for people to return to their homes and they can be evacuated again if there are new indications showing that a failure is likely to occur.

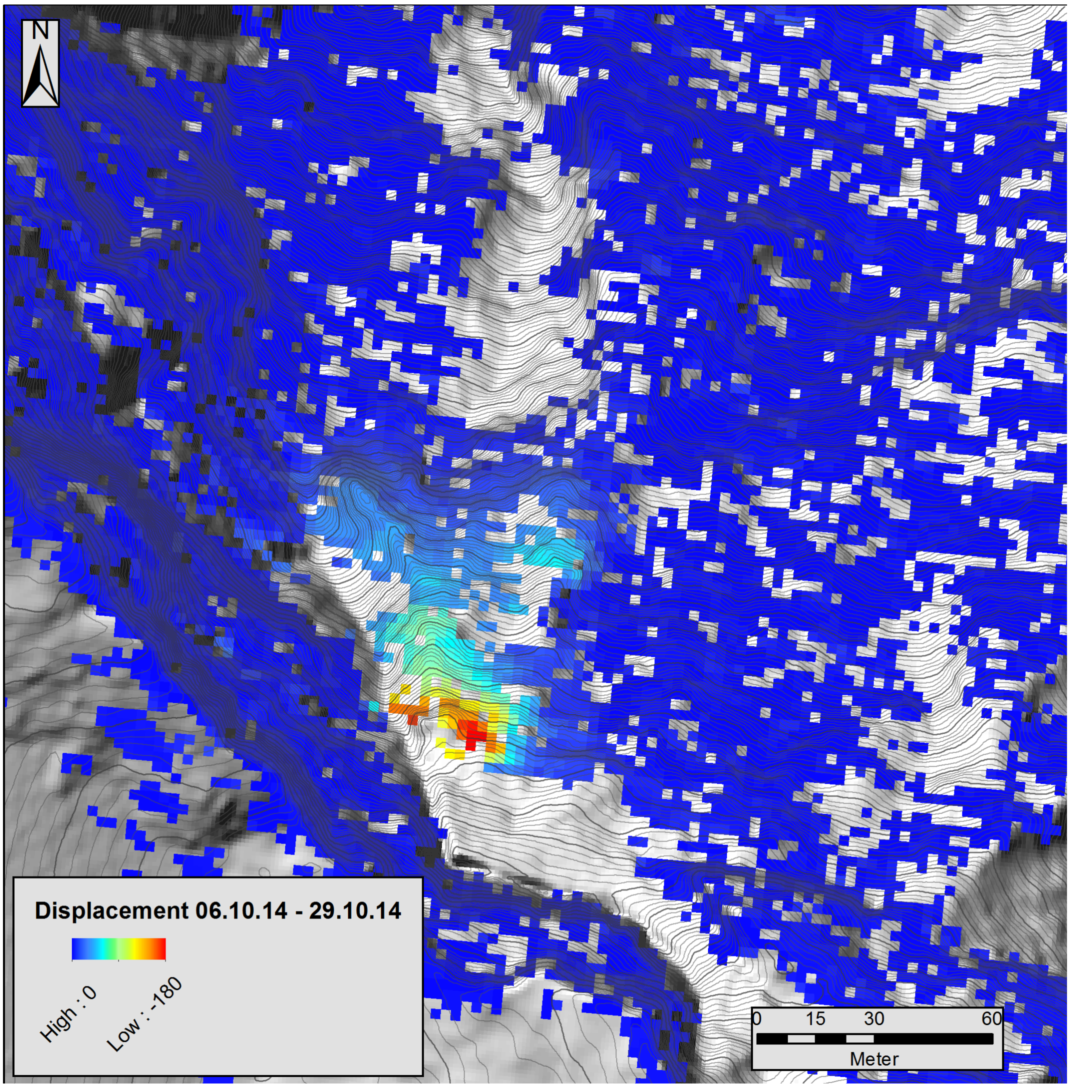

Figure 2. A georeferenced cumulated radar image from the second campaign show that the displacement is greatest in the upper part of the moving area.

KEYWORDS

monitoring; Rock-slope failure; Veslemannen; InSAR

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