Experiments with remote sensing in the context of avalanche warning and detection

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INTRODUCTION

In many mountain regions of Norway snow avalanches pose a risk to road and railway passengers as well as tourists, skiers and others during the winter season. Each year, snow avalanches hit populated areas and parts of the transport network, leading to the damaging of buildings and infrastructure, sometimes also to the loss of lives. Much of the country is remote and knowing exactly where avalanches are likely to take place or have taken place is a challenge for the authorities. Earth observation satellites, therefore, represent a potentially important source of information.

Two Norwegian projects carried out by NGI and NR have investigated and experimented with the potential of using remote sensing for avalanche warning and detection: The Norwegian Space Centre (NSC) supported project "Improved Avalanche Warning Using Satellite Data" (2008-2010) and the European Space Agency (ESA) funded project "Avalanche Inventory for Decision Support and Hind-cast - AvalRS" (2008–2011).

MEASURING WEAK LAYER FORMATION

Snow variables of importance for weak layer formation and which might be retrieved by using remote sensing data include snow grain size, snow surface temperature and snow wetness. The temporal development of these variables will, under special conditions, also be essential, like, for example, the formation of surface hoar. Such a surface phenomenon could later result in a weak layer within the snow pack.

The project carried out for NSC demonstrated that snow surface properties, related to the subsequent formation of weak snow layers in the snowpack, could be measured in satellite data of moderate resolution during the accumulation season (Solberg et al., 2009; Solberg et al., 2010).

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We applied the MODIS sensors (on board the Terra and Aqua satellites) for snow parameter retrieval. In situ measured surface snow grain characteristics were compared to snow grain characteristics as derived from multispectral data from the MODIS satellite sensor. The study showed that parallel in situ snow measurements and snow analyses exploiting data from MODIS are possible for the selected test sites in Norway. We found two cases where the satellite-retrieved snow surface temperature and snow grain size evolution indicated formation of surface hoar. Unfortunately, we lack in situ measurements for those cases, while a skiing tourist observation at the same time in a nearby mountain area confirmed extensive surface hoar formation. As the weather conditions where the same in both regions, this is a strong indication that the remote sensing results were correct.

DETECTING AVALACHES

The avalRS project carried out a pilot study and demonstration showing that pattern recognition methodology could be used for the detection of avalanches using very-high resolution (VHR) optical satellite data (Frauenfelder et al., 2012 Larsen et al., 2011).

We explored the use of imagery from high-resolution (HR) and very high-resolution (VHR) satellite sensors. HR included SPOT 2 and 4, and VHR included Quickbird and test data from an airborne optoelectronic pushbroom scanner (data courtesy of Leica-Geosystems, Heerbrugg, Switzerland and Y. Bühler, SLF, Switzerland). Only VHR imagery (≤ 2.5 m spatial resolution) gave suitable results. Similar VHR sensors are currently available on, e.g., the WorldView, Ikonos, Orbview, GeoEye, SPOT-5 and Pléiades satellites.

The key part of the detection algorithm is a texture segmentation step, which distinguishes the avalanches from other objects such as smooth and rugged snow, trees and rock. Two

different approaches are investigated: a method based on grey-level co-occurrence matrices (GLCM), and a method based on directional filters.

The algorithms are developed and trained on a Quickbird image of a Norwegian mountain area which contains several avalanches. The segmentation algorithms detect parts of all avalanches. The directional filter method was also tested and validated on another Quickbird image, covering a different scene in Norway.

The GLCM approach gives a higher rate of false detections than the directional filters approach, but maps the outline of the avalanches better. A brief demonstration of feature extraction shows that context and shape of detection objects may provide important information to further enhance the performance by reducing the number of false detections and refining the outline. From this case study, we believe that avalanche mapping in VHR optical images is possible in general.

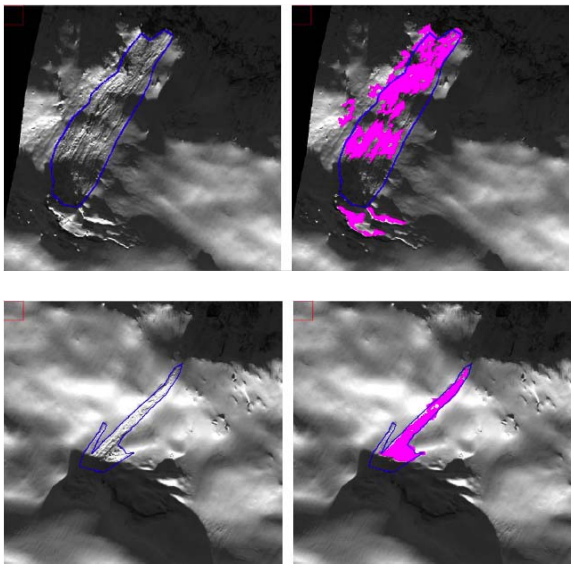

FIGURE 1. Two avalanches in Hellesylt, Norway, acquired by Quickbird on 16 April 2005. Left: avalanches outlined manually in blue on the panchromatic image. Right: detected segments are overlain in pink.

CONCLUSIONS

Avalanches rank among the most significant natural hazards in the snow-covered mountains of the world. Avalanches endanger not only transport links and settlements, but also tourists who visit ski resorts and back-country mountain regions during wintertime. During recent decades, an estimated 250 causalities per year worldwide have been reported as a direct result of snow avalanches (Schweizer, 2008).

We have presented results of experiments using satellite remote sensing to measure the formation of surface hoar and detection of recent avalanches. Strong evidence was found for observations of surface hoar based on the combination of snow surface temperature and snow grain size development. Further work aims at establishing a snow grain evolution model. The model will be used as an input to the avalanche forecasting model.

In our study of detecting avalanches, we have showed that automatic detection and mapping of occurred avalanches in VHR optical imagery is possible. The study also showed that such data could be used to add important information to validate avalanche forecasts, something which could lead to significantly improved forecasts. We think that an operational service for such inventory and verification purposes could be turned into practice once the remaining algorithm challenges have been overcome.

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