THE EYE IN THE SKY: AVALANCHE MAPPING FROM SPACE

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ABSTRACT: The Seward Highway in Alaska has over one hundred avalanche paths spread out along a 150 km major transportation corridor, which traverses three different avalanche climatic regimes. This coupled with a small staff can make avalanche debris detection and mapping difficult. With the use of satellite imaging we may have a reliable means of detecting and recording avalanche deposits. During the winter of 2016 the Seward Highway recorded an unprecedented amount of glide avalanche releases. Using both optical and SAR data we can accurately detect avalanche debris, further aiding in mitigation strategies and avalanche hazard management.

KEYWORDS: glide avalanche, remote sensing, Sentinel satellites, transportation corridor

1. INTRODUCTION

Recent developments in remote sensing data collection techniques are producing data at previously unprecedented and unimaginable spatial, spectral and temporal resolution. The advantages of using remotely sensed data vary by topic, but generally include safer evaluation of unstable and/or inaccessible regions, spatially continuous and multi-temporal mapping capabilities (change detection) and automated processing possibilities. Recent studies show that space-borne optical sensors as well as radar (Synthetic Aperture Radar/SAR) can be used to detect and map avalanche debris (cf. Larsen et al., 2010; Lato et al., 2012; Malnes et al., 2015; NGI, 2015; Wiesmann et al., 2001).

Here we present the use of remote sensing data for avalanche debris detection, exemplified by results from a case study along the Alaskan Seward Highway (Fig.1).

We use both high-resolution optical imagery from the Landsat-8 and Sentinel-2 satellites, as well as SAR data from the Sentinel-1 satellite. The data analysed covers the period from December 2015 to June 2016.

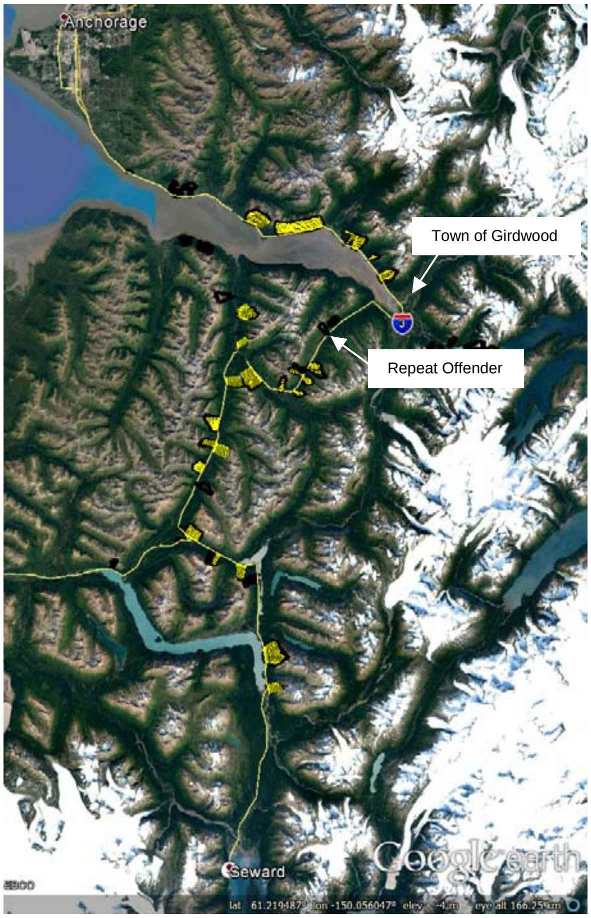

Fig. 1: Map section showing Seward Hwy between Anchorage and Seward (to the south) and Homer (to the west), including some of the most notorious avalanche paths. Map source: Google Earth and Alaska Department of Transportation.

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2. GLIDE AVALANCHE CYCLE

Glide avalanches are a common sight during the winter in Southcentral Alaska. Typically, they form in the early winter or during the spring melt. Early winter glide avalanches are a function of warm moist snow laid on an unfrozen ground. Spring-melt glide avalanches have the most recognizable release mechanisms being increased solar radiation and an isothermal snowpack. During the winter of 2015/16 glide avalanche occurred the entire winter. Many mid-winter glide avalanches did not follow usual characteristics and there were no discernible release mechanisms.

The Seward Highway Avalanche Program has a robust 32-year avalanche occurrence dataset. The winter of 2015/16 produced more recorded glide avalanche releases than all the years combined in the dataset. From March 4 to April 14, a total of 44 glide avalanche releases were recorded in paths that affect the Seward Highway (cf. examples in Figs. 2-4). This number is likely lower than the actual number of avalanches occurred, due to the difficulty in identifying and cataloguing each release. The majority of these glide avalanches occurred along a 16 kilometre stretch of highway west of the town of Girdwood, Alaska (location given in Fig. 1). In addition, a considerable amount of glides were observed further south along the Seward Highway, around the "Repeat Offender" path. Fortunately, in many of the avalanche paths that tend to represent a high risk to the highway, there was no winter snowpack below 300 meters anymore. The glide avalanches that did release quickly stopped due to the lack of snow to entrain and due to the surface roughness in the track of the paths. Those glide avalanches that ran >800 meters were in confined tracks and deposited only considerably small amounts of debris.

Operationally, the glide avalanches did not affect the transportation corridor. None of the glide avalanches reached the road. If there would have been a normal snowpack below 300 metres, the likelihood that some of the glide avalanches would have reached the highway would have been increased. Because of the unusually high number of releases, we were not able to get an accurate count of all the glide avalanches.

Fig. 2: “Sneaky Peat” path #975, release on 23-MAR-2016. Image source: Alaska Department of Transportation (AKDOT) image.

Fig. 3: “Supermans" path #945, release on 10-APR-2016. Image source: AKDOT image.

Fig. 4: "Reuben B." path #928, release on 14-MAR-2016. Image source: AKDOT. For release on 23-MAR-2016, see https://vimeo.com/160299691

3. METHODS AND RESULTS

We used optical imagery from the Landsat-8 and Sentinel-2 satellites to detect avalanche debris. Due to the spatial resolution of these data (15 metres per pixel for Landsat-8, 10 metres per pixel for Sentinel-2) automatic detection algorithms which earlier have been successfully applied to very-high resolution satellite imagery (e.g. Larsen et al., 2010; Lato et al., 2012) do not work well enough. We therefore detected and mapped the avalanches by visual inspection in the optical imagery.

For the period of observation, December 2015 to June 2016, there were several Landsat-8 scenes with sufficiently low cloud cover available to allow avalanche detection (cf. Fig. 5). The Sentinel-2 data, however, were affected by cloud cover and we found no scenes in our areas of interest that were analysable. It has to be mentioned that this is purely coincidental and not due to any inherent differences between these two sensors.

A large drawback of optical methods is their dependency of clear sky conditions and good illumination. We therefore used radar data from the Sentinel-1 satellite as well. Synthetic aperture radar (SAR) data enables avalanche detection and mapping also during bad weather conditions or during periods with polar night. While optical imagery interpretation is quite intuitive even for people without image interpretation training, the recognition of avalanche debris in SAR data is less straight-forward. However, when SAR data is processed adequately and the results are properly illustrated, also SAR-derived avalanche mapping is possible. We applied some basic pattern recognition techniques to the SAR data in order to highlight the avalanche debris.

Figure 5 shows an example of an image sequence from both Landsat-8 and Sentinel-1 for the area near the Repeat Offender avalanche path (path #699). Yellow polygons in the figure indicate avalanche paths that have historically affected the highway. The sequence shows that there is no avalanche activity in path #699 between January 21, 2016 and February 2, 2016, while some small avalanches can be seen to the west (lower-left corner of panel a) and in the valley NW of path #699. In this SAR change detection the avalanche debris is visible as light-green blotches. SAR change detection between early February and early March (not shown) does not show considerable avalanche activity. This is supported by a Landsat-8 scene from March 6, 2016 (panel b) without any obvious avalanche debris deposits. From observations by AK-DOT we know that this situation drastically changed by mid-March, with a large number of glide avalanches during the following weeks. This can be seen in the Landsat-8 image from April 7, 2016 (panel c), as well as from the SAR change detection between data from March 21, 2016 and April 14, 2016 (panel d). Later imagery (panels e and f) mainly shows the continuous snow depletion throughout spring time. By the end of June (not shown) the area is almost snow free. The same type of analysis was applied to other important avalanche paths, such as the "Holiday" path (#912) near Girdwood.

4. CONCLUSIONS

The use of satellite images to map deposits and avalanche releases would greatly benefit the Seward Highway Avalanche Program. It takes several hours to visually inspect each avalanche path in the transportation corridor. At times this task cannot be accomplished for several days after an avalanche event. Being able to remotely detect and record avalanche releases would aid in mitigation strategies. Having a small staff, it is common practice to focus mitigation work on those areas which are seen as the most hazardous. With accurate records of release/deposits the avalanche program would be better informed on areas that have not released and, thus, would be receptive to active mitigation measures.

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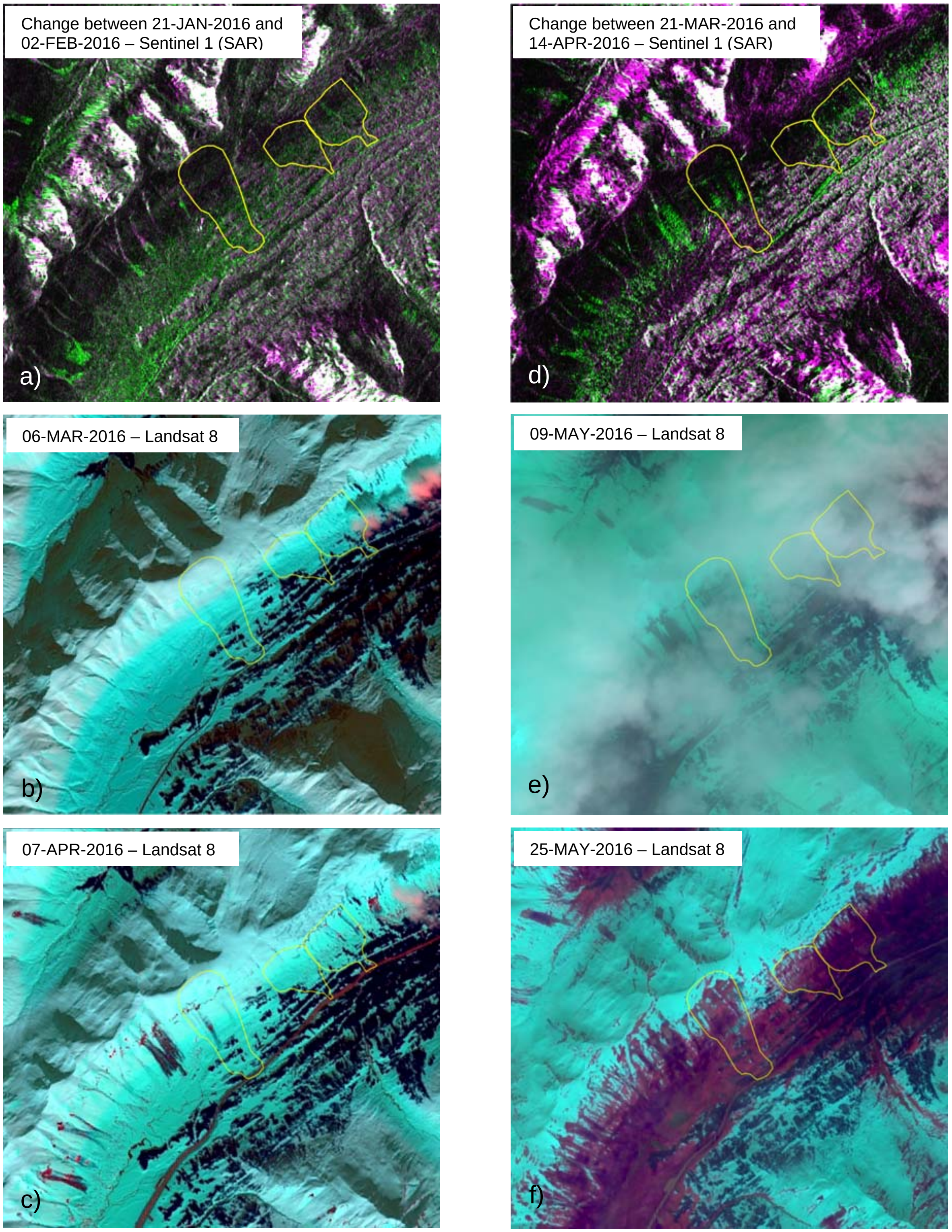

Fig. 5: Satellite data sequence along Seward Hwy, with "Repeat Offender" #699 path in the image centre (outlined by yellow polygon). Yellow polygons indicate avalanche paths that have historically affected the highway. a) no avalanche activity in path #699, however some small avalanches (visible as light-green blotches) to the west and north-west of path #699; b) no significant avalanche activity; c) and d) numerous glide avalanche occurrences at between early March and early April; e) and f) continuous spring melt snow depletion. Sources: Landsat-8 data by Copyright ©NASA Earth Observatory / Landsat-8. Sentinel-1 data by Copyright ©European Space Agency, 2016.