OPTIMIZING ROAD MANAGEMENT WITH DOPPLER RADAR FOR AUTOMATIC AVALANCHE DETECTION AT I-70

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ABSTRACT: The road over Loveland Pass leads traffic below the Seven Sisters avalanche paths. that are subject to regular avalanche control missions using RACS. In March 2022, a Doppler radar for automatic avalanche detection was installed as a pilot project. The radar scans the slope at distance and allows to cover several paths simultaneously at safe distance. The radar system provides data, such as start distance, avalanche length, front speed and maps the avalanche precisely, providing the operator with the exact location of the event. The system provided CDOT with crucial information about avalanche activity and added great value to the RACS operations.

KEYWORDS: Doppler radar, Long range, Avalanche detection, Road safety, Loveland Pass.

1. INTRODUCTION

The I-70 is the main connection from Denver through the Rocky Mountains to the west. Two lanes in both directions guarantee people and goods transport on this important axis. Below Loveland pass, the road passes through the Eisenhower tunnel, avoiding the windy road over the pass, located at an elevation of 3.655 m a.s.l. (ca. 12.000 ft.). For safety reasons, hazardous goods are not allowed to go through the tunnel and need to be transported over the pass using Highway 6 all year around (see Figure 1). If the pass is closed, the Colorado Department of Transportation (CDOT) needs to close the tunnel regularly for traffic, allowing only dangerous goods at certain times. This causes significant traffic jams and highlights the importance of Loveland Pass in keeping traffic moving along this corridor through the Rocky Mountains.

Figure 1: Overview of the situation at the junction of I-70 and Highway 6. Avalanches form the 7 Sisters hit the road just after the intersection.

2. THE 7 SISTERS AVALANCHE PATHS

The road over Loveland Pass is snow covered in winter and several Remote Avalanche Control Systems (RACS) along the way as well as hand charges guarantee a safe passage. On the east side of Loveland Pass, next to the Loveland ski resort, the avalanche paths called 7 Sisters demand regular avalanche work by the CDOT avalanche program in collaboration with the Colorado Avalanche Information Center (CAIC). Therefore, a RACS was installed in the start zone of the 7 Sisters, comprising of 11 Gazex exploders and 4 control shelters in 2016 (Deems et al., 2016). In average about 20 avalanche control sessions are conducted every winter.

3. AVYX DOPPLER RADAR SETUP

For the test winter, an AVYX Doppler radar was installed to detect avalanches running in the 7 Sisters Paths. The radar head, a remote controllable PTZ camera as well as the control cabinet were installed at an existing camera pole along I-70 about 4-5m above ground (see Figure 2). At this location, line-power and cellular service was available.

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Figure 2: Installation of the AVYX Doppler radar at a camera pole of CDOT along I-70. The radar head and remote controllable PTZ camera were installed about halfway to the top at 4-5 m of elevation, the control cabinet just above the snow surface.

The applied radar unit had a 30° vertical and 30° horizontal opening angle. With this hardware, 5 of the avalanche paths were covered from the release zone to the road. To optimize the operation for CDOT, two different regions of interest (ROI) were defined. The upper zone refers to the start zone of avalanches; an avalanche passing this zone is of interest for avalanche technicians to identify the need to perform avalanche control. Also, forecasters can validate their forecast with the information. The lower ROI is located just above the road. This zone provides an indication if an avalanche hit the road or came close-by, respectively. This information is important for the snowplow crew to act quickly after the road was blocked with snow.

4. AVYX DOPPLER RADAR FUNCIONALITY

The Doppler radar permanently emits electromagnetic waves that are reflected from objects it interacts with. If an object moves towards or away from the radar, the waves are reflected with a different frequency. Proprietary and trained algorithms allow distinguishing an avalanche from other objects. Due to two receiving antennas at the radar head, the location of the avalanche can be mapped in detail.

With this technology, avalanches can be detected in a few seconds and responsible operators are informed in quasi-real time (Meier et al., 2016). In numerous locations in the Alps and Scandinavia, these systems are connected to traffic signals, gates and beacons to alarm people and operate a road fully automated (Meier et al., 2018; Persson et al., 2018).

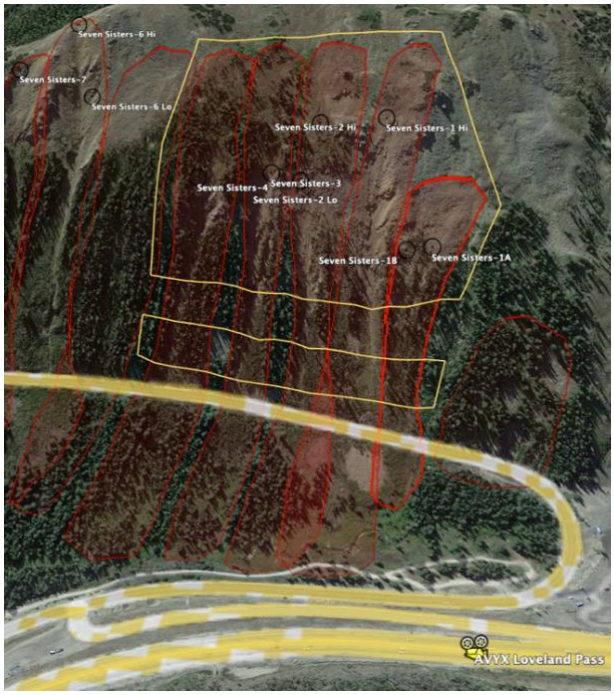

Figure 3: Setup of AVYX Doppler radar for avalanche detection of five paths at 7 Sisters (red polygons. The radar was installed along I-70, two ROIs were defined, one for avalanche activity measurement, another one for road interactions (yellow polygons). The Gazex exploders are marked with black circles.

5. AVALANCHE DETECTION RESULTS

Between March 10 and June 18, 2022, 40 avalanches were detected. 23 of them occurred during 7 avalanche control missions on March 10, 18, 30, April 13, 18, 24 and May 21. 16 avalanches occurred spontaneously, while one was triggered by a snowboarder. The 7 Sisters avalanche paths are located just outside the Loveland ski area.

5.1 Data visualization

All data is locally processed and transferred to the GRAVX online portal, where the involved users from CDOT and CAIC can access the results and remote control the PTZ camera. Each avalanche event is mapped at its precise location. Additionally, avalanche characteristics, such as time of

occurrence, duration, front speed and size estimate are calculated based on the event (see Figure 4). A series of event images help visualizing the event if it occurs in good visibility. The interface also allows for communication between the users and the radar experts in case of questions.

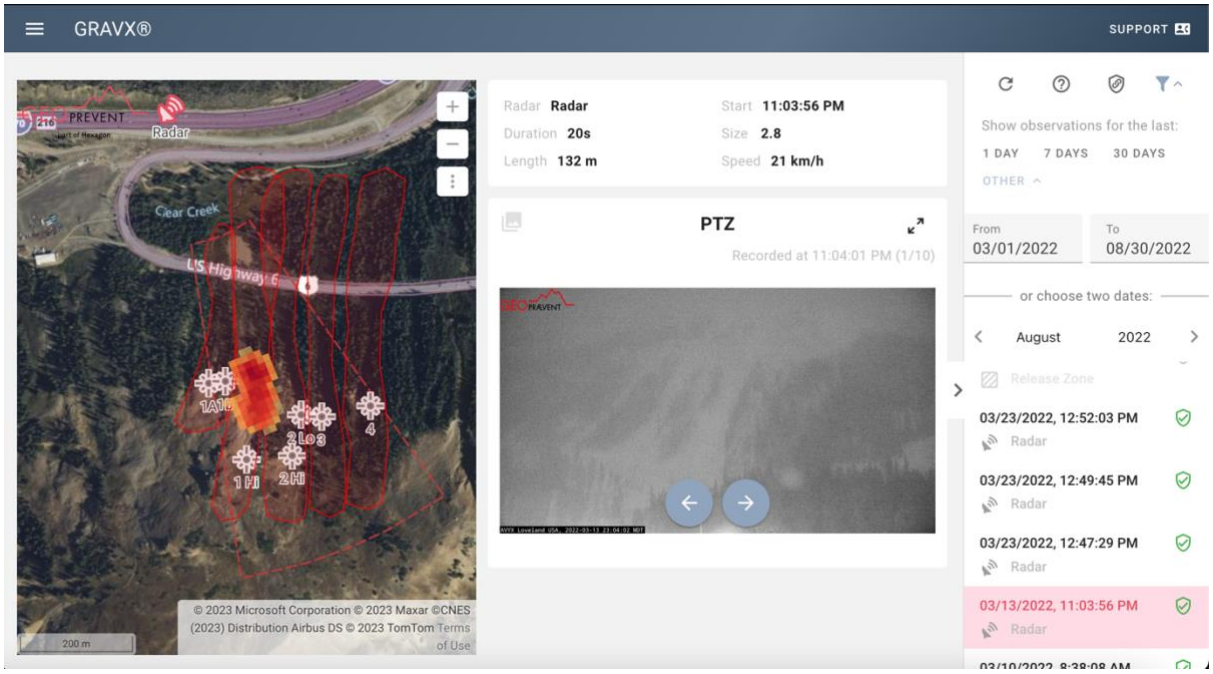

Figure 4: GRAVX online portal for data visualization and remote control of PTZ camera. On the right side, avalanche events are historically ordered. With a filter, events of interest can be found easily. If selected, information such as start time, event duration, front speed, avalanche length and avalanche size estimate are shown (center). Below, a series of events taken during the event. Using the arrows, users can swipe through the collection. On the very left of the portal is the avalanche map. It shows the radar with its field of view (dashed line) the red/orange heatmap corresponds to the avalanche activity integrated over the time of the event (here 20s). In the background are the registered avalanche paths and the Gazex exploders.

6. DISCUSSION

To the knowledge of the radar user, there is no indicator that an avalanche would have been missed in the 3 months of measurement. As this was the first time measured at the current location, detection parameters were set to high sensitivity to detect every movement at the site. This allows to detect also small slabs, that stop again after 30m. Further, trucks on the road, snow drifts and skiers are also detected. This is needed to make sure no avalanche important to the local avalanche security operation is missed.

After a run-in period, sensitivity and algorithms are optimized to the current situation, that only movement of relevance to the user is detected. At Loveland, this will be applied for a future application.

Sensitive detection algorithms allow to look deeper into the avalanche characteristics. As an example, a triggered avalanche during the control mission of March 30, 2022: The avalanche flew in two pulses, that run slightly shifted in time in the same avalanche path (see Figure 5). Both pulses are detected by the radar and can be analyzed in detail in the radar data.

Beside precision and accuracy, reliability is a key point in detection, making Doppler radars to widely applied technology for alarming systems (Meier et al. 2018; Persson et al., 2018)). Having reliable detection and a low number of false positive alarms is of crucial importance if Doppler radars are connected to automated traffic signals or gates. Experience demonstrate that local road users have a low tolerance if a road is unnecessarily kept closed.

Figure 5: An avalanche event triggered by a Gazex exploder during an avalanche control mission on March 23, 2022. The two avalanche pulses are well visible on the selected event images. The two avalanche fronts can be well determined in the avalanche data.

7. CONCLUSIONS

CDOT and CAIC relied on the system to provide real time information on the 7 Sisters avalanche paths. The camera functionality in combination with the radar system added a significant value to the winter operation at Loveland Pass. The intuitive user interface made it easy to navigate through the data and use the radar system.

8. ACKNOWLEDGEMENT

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