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Rockfall alarm system in Vissoie, Val d'Anniviers

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Abstract

The Val d'Anniviers is one of the major valleys of the canton of Valais in Switzerland. Well known for its winter sports opportunities and for the villages of Grimentz and Zinal, the valley is accessible by a vertiginous road exposed to a wide range of gravitational hazards. Though the Route d'Anniviers is protected by multiple galleries, severe events can still impact the road. In March 2024, a series of rockfall led to heavy accumulation of debris atop a road gallery at the entrance of the valley. A week later, on the 29th of March, bigger blocks hit the road and perforated the gallery. To avoid complete isolation, an alternative route was opened from the other side of the valley. An alarm system needed to be installed to increase the safety of workers during the gallery renovation as well as part of a long-term mitigation plan. Geoprevent was mandated on the 10th of April by the local authorities and installed a rockfall Doppler radar on the 22nd of April. This high-end technology permits to detect rockfalls in real-time. In addition, the rockfall Doppler radar was coupled with traffic lights and an alarm horn permitting to close the road and alarm of incoming rockfalls in real-time. SMS and email alarms are also sent in case of events, and both the radar data and live footage from the added pan-tilt-zoom remotely controllable camera are visible from Geoprevent's online dataportal. This paper looks into the different technologies involved in the alarming system in Vissoie and investigates the main challenges faced during its operation.

Keywords

Radar, Rockfall, Alarm system.

1 Introduction

Mountainous regions frequently expose infrastructure such as roads, railways, and buildings to Alpine mass movements, including landslides and rockfalls (Hungr et al., 2014), mudflows (Jacquemart et al., 2015), and ice or snow avalanches (Margreth et al., 2017). Historically, where feasible, structural mitigation measures—such as tunnels, galleries, dams, protection walls, or protective forests (Holub et al., 2008; Stoffel et al., 2005)—have been implemented to prevent or reduce damage. In recent years, advances in electronic monitoring technologies, including trigger lines, radar systems, and motion or seismic sensors (Geoprevent, 2023), have enabled the development of organizational measures such as the automatic closure of roads or railways. These systems can provide a cost-effective alternative to structural protection, provided that the lead time between event detection and impact is sufficient for users to evacuate the hazardous area. Meier et al. (2016, 2017) demonstrated that Doppler radar systems can be effectively integrated into local alarm systems to automatically close roads or railways following the detection of ice or snow avalanches and rockfall events. A Doppler radar was installed in Val d'Anniviers in April 2024. Val d'Anniviers is one of the major side valleys of the canton of Valais in Western Switzerland. It is famous for its ski resorts and charming mountain villages such as Grimentz and Zinal. The valley is accessible through an exposed road carved within and along cliffs. Many segments of the road are protected from rockfalls with retention nets and galleries. However, big boulders can still cause damages, as was the case on the 29th of March 2024 where big boulders hit and perforated the Galerie des Croisettes. In order to increase the safety of road users and of the workers excavating the debris accumulated on top of the gallery, the Doppler-based alarm system was installed in April, a few days after being ordered by the local commune and the road authorities.

2 Rockfall Doppler radar setup

The Doppler radar was installed on the opposite side of the valley to guarantee a good visibility on the instable cliff. In addition, the radar is located slightly lower than the cliff, optimizing the use of the doppler effect. This is because the radar performs best when movement is made towards the antennas, in the line of sight. The Doppler radar is mounted on a concrete block to ensure stability throughout the year. A 230V cable connects the radar to a nearby farmhouse, providing a stable 24/7 power source. The system is composed of the radar head, external antennas, and a PTZ controllable camera (Figure 1). The choice for external antennas is based on the typical longer range these provide. While internal antennas would permit to monitor a wider area, external antennas provide a narrower angle but reach a longer range. Here the instability is located in a narrow couloir stretching right above the road gallery, a case for which the external antennas are perfectly adapted for. The distance from the radar location to the upper part of the monitored cliff is of ca. 1 km.



Fig. 1 Hardware of the Doppler radar system with monitoring camera, radar head and event camera.

3 Data acquisition and visualization

The radar scans its field of view by transmitting a frequency-modulated continuous wave (FMCW) signal across a 50 MHz bandwidth at approximately 10 GHz. Moving objects are detected using the Doppler effect, whereby the difference in frequency between the emitted and received signals is measured. Objects moving within the radar's field of view reflect signals with frequency shifts that depend on their velocity. The time-of-flight information between the radar and the moving object allows to locate the moving objects within the radar's field of view. Measurements are performed every second, and detected objects are continuously tracked until they either stop moving or leave the radar's field of view. The system operates independently of weather conditions and ambient light. Figure 2 illustrates a rockfall trajectory together with associated metadata and event images as displayed on GRAVX™, Geoprevent's data portal. Information on all detected events is stored and can be visualized through this platform.

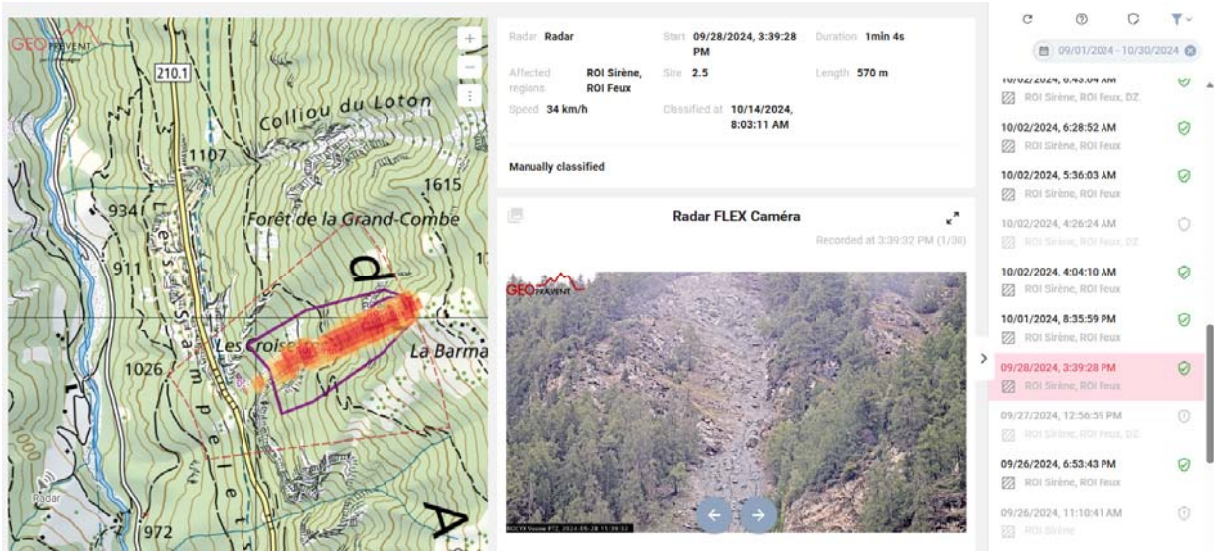


Fig.2 Screenshot of the GRAVX platform displaying rockfall events through video and projection on map, as well as key characteristics (speed, size, length, duration).

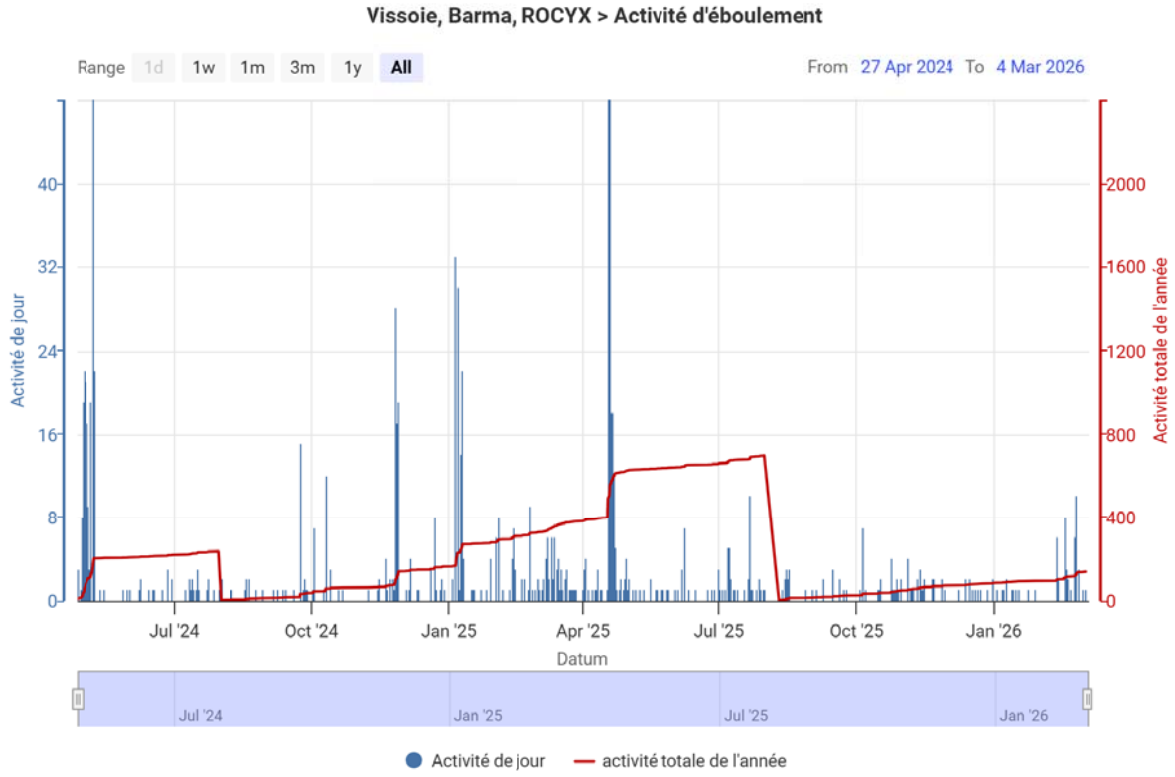


Fig. 3 Rockfall activity measured since the radar installation. In total more than 1090 events have been detected.

Table 1. Summary of the main characteristics of the ROCYX rockfall radar.

Characteristics	**ROCYX rockfall radar**
Functionality	- Localization, tracking and mapping of rockfalls
Sensitivity	- 0.1m3 at 100m,1m3 at 1 km
Coverage	- Range: up to 4 km - Coverage: several km2, depending on antenna
Weather	- Independent of weather
Limitations	- Rockfall area needs to be visible from the radar position - Reflections (e.g., from rockfall protection nets)
Alarm system	- Possible
Activity monitoring	- Possible

4 Alarming with the ROCYX doppler radar

4.1 Traffic lights

The Doppler radar permits near real-time detections of events and is therefore also a key element of alarm systems. The type of alarming device needed is highly dependent on the exposed people and their activity. To increase the safety of road users, traffic lights permit to close the road before a rock hits. As part of the alarm system the traffic lights must have both reliable power supply and communication with the rockfall radar. Here, the traffic lights communicate via radio link and are solar powered.



Fig. 4 Traffic lights with solar panels ensure the road is closed in case of rockfall.

4.2 Alarm horn

In this case, the alarm system complements and already existing protection infrastructure: the gallery. As was seen in March 2024, the gallery doesn't guarantee protection against bigger blocks, nor does it protect all exposed segments of the road, hence the need for the complementary alarm system. Nevertheless, the gallery still protects the road from smaller rockfalls, leading to regular accumulation

of material on top of the gallery. This material needs to be excavated in the summer in order to ensure the performance of the gallery. The excavation is a risky operation, as workers and machines are located under the cliff instability. There, alarm horns with flashing lights are activated in case of a rockfall. These alarm horns are supplied with 230V cable power and communicate with the radar via radio signal for a faster transmission. These characteristics make the alarm horn mobile, which is highly practical due to the dynamic nature of construction sites.



Fig. 5 Mobile alarm horn for construction workers.

4.3 SMS/e-mail alerts

In addition to on-site alarming, the ROCYX rockfall radar also triggers sms/e-mail alerts in case of event. The recipients' lists for these alerts are editable on the GRAVX platform by the customer. Different alerts can be sent out depending on the trajectory of the event, featuring key information such as event's size, location, and duration. These alerts give road managers and local authorities the opportunity to be react to events in near real time. A typical reaction could for instance be to take remote control of the alarming device (e.g., traffic lights).



Fig. 6 SMS alert of rockfall in Vissoie.

5 Conclusion

The ROCYX rockfall radar, combined with traffic lights, alarm horn, and SMS/e-mail alerts permit to increase the safety of both road users and construction workers exposed to rockfalls on the Croisettes gallery. Through this safety increase, road management and construction plan coordination can be optimized. Additionally, data regarding the rockfall activity can be used to manage the risk related to construction works activities on site and optimize the timing of such activities.

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