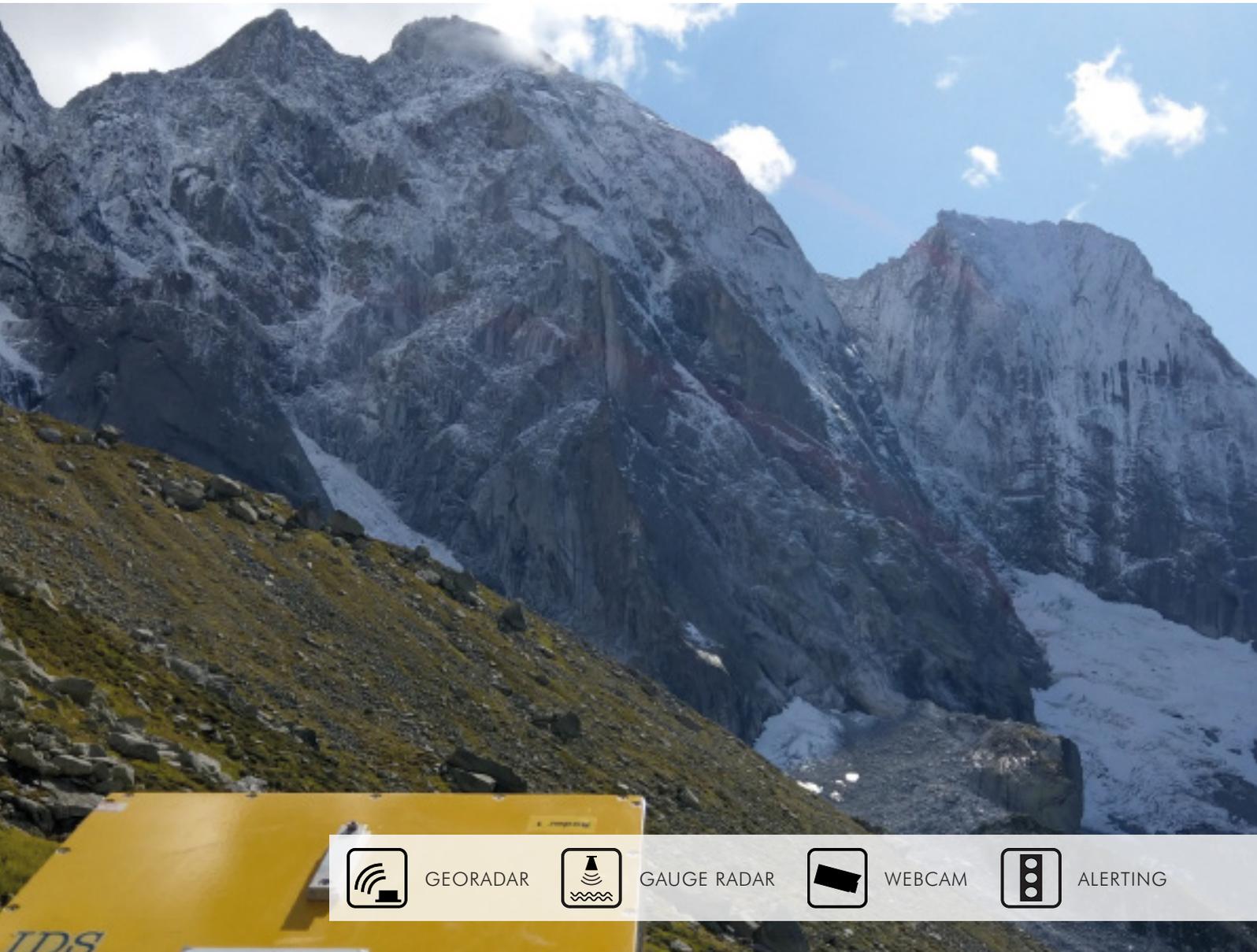


ROCK AVALANCHE AND DEBRIS FLOW ALARM SYSTEM BONDO



GEORADAR



GAUGE RADAR



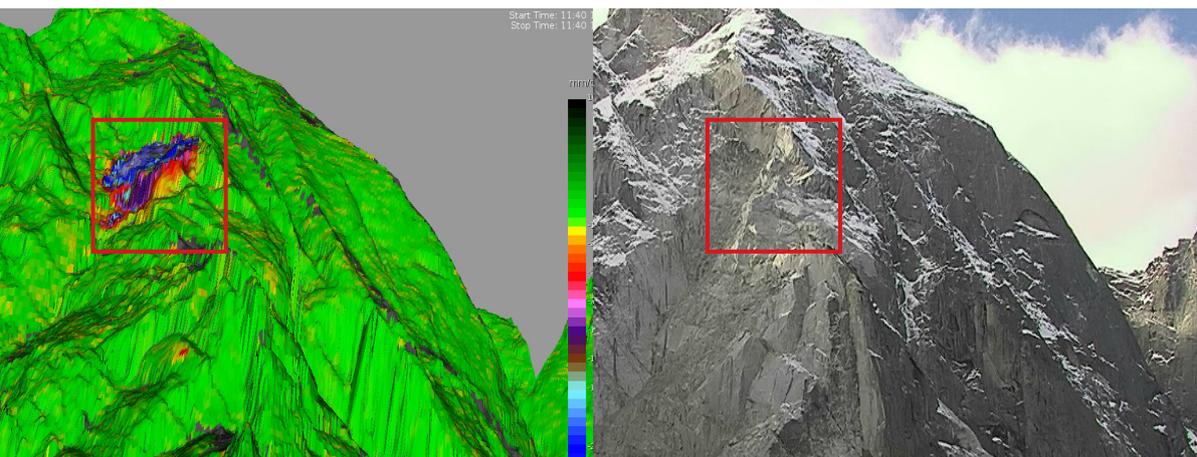
WEBCAM



ALERTING

Comprehensive rock avalanche monitoring at Pizzo Cengalo and debris flow alarm system with automatic road closure in Bondo village.





Title Page: Georadar to monitor Pizzo Cengalo.

Figure 1: Deformation analysis by interferometric georadar of Pizzo Cengalo on September 14, 2017. Collapse was correctly predicted for the night of September 15, 2017.

CHALLENGE

On August 23, 2017, a large rock avalanche occurred on the north-east face of Pizzo Cengalo near the border of Switzerland and Italy. Approximately three million m³ of rock detached impacting the glacier below and formed a powerful debris flow carrying huge boulders as far as the village Bondo. The debris flow triggered our alarm system and automatically closed several roads in the vicinity of Bondo. The alarm system in combination with a large catch basin prevented casualties and extreme damage in the village. Several additional rock collapses in the following weeks caused a similar cascade of events, however of a smaller scale. Unstable material remained on the mountain and further collapses remain to be expected. Clean-up operations in the danger zone demanded for quick extension of the measurement and alarm system to increase warning time.

SOLUTION

The existing alarm station (station A) was repaired and extended. In addition, we installed a second alarm station upstream (station B) allowing increased warning times. Station A provides approximately two minutes and station B approx. four minutes warning time before the debris flow

reaches the village. The clean-up area and bypass road were equipped with traffic lights, alarm horns and worker beacons. The mobile alerting devices can be moved any time or made permanent once the works are completed.

Additionally, we set up a warning system to monitor Pizzo Cengalo around the clock by georadar (station C). The interferometric georadar continuously scans the rock face and detects smallest surface movements on a scale from millimetres per year to meters a day. The radar operates reliably at a safe distance in all weather and visibility conditions. Automated deformation analysis identifies acceleration areas within the rock face and enables early recognition of potential instabilities. Collapse estimations can be drawn from analysing the inverse velocities of critical rock areas combined with expert judgement. Event predictions including approximate timings have proved correct in several cases, e.g. for the rockfall event of September 15, 2017, with expected failure at night. The georadar warning system allows to plan and implement appropriate protection measures early (e.g. evacuation) and guarantee safety for the village.

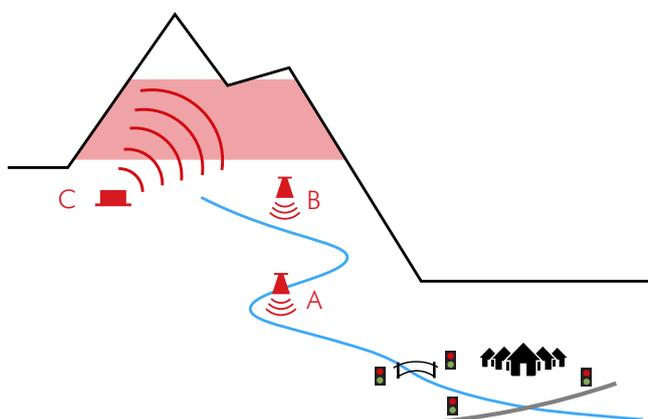


Figure 2: Debris flow alarm stations (A, B) with gauge radars, webcams and alert and rock avalanche warning system (C) with georadar and webcam.



Figure 3: Gauge radar station (station A) across the Bondasca river with several meters debris flow deposits in August/September, 2017.