# On the use of high-frequency radar technology in alpine mass movement monitoring: principles and performance within torrential activities

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## 1. Introduction

In order to investigate distinct mechanism and parameters (e.g. velocity) supplementary to alpine mass movements and as decision tool for passive protection measures, a reliable monitoring system is required. The main objective of our research project is to illustrate the principles and the potential of an innovative radar system and its versatility as an automatic detection system for alpine mass movements. The high frequency radar device was already successfully tested in Ischgl/Tyrol in combination with artificial snow avalanche release in order to verify a successful avalanche release (Kogelnig et al., 2012).

To this end we investigate the practicability of the system itself, regarding the usability under real test conditions, the prospective use as a standalone warning system and furthermore we analyze the gained data from the radar device.

## 2. Principles of the radar device

The presented radar device operates on a pulsed-wave Doppler method. In this connection, short pulses withconstant high frequency are emitted by a directional antenna that also samples the echo in distinct time intervals, corresponding to distance intervals, so called "range gates" (Fig. 1). In the case of detecting alpine mass movements, a travel time analysis of the echo signal is performed, i.e. the apparent difference in distance of the reflected radar signal due to the motion of the targets relative to the radar device, yields a velocity spectrum/distribution within the width covered by a range gate.

**Fig. 1: Principle of the pulsed-wave Doppler radar device**

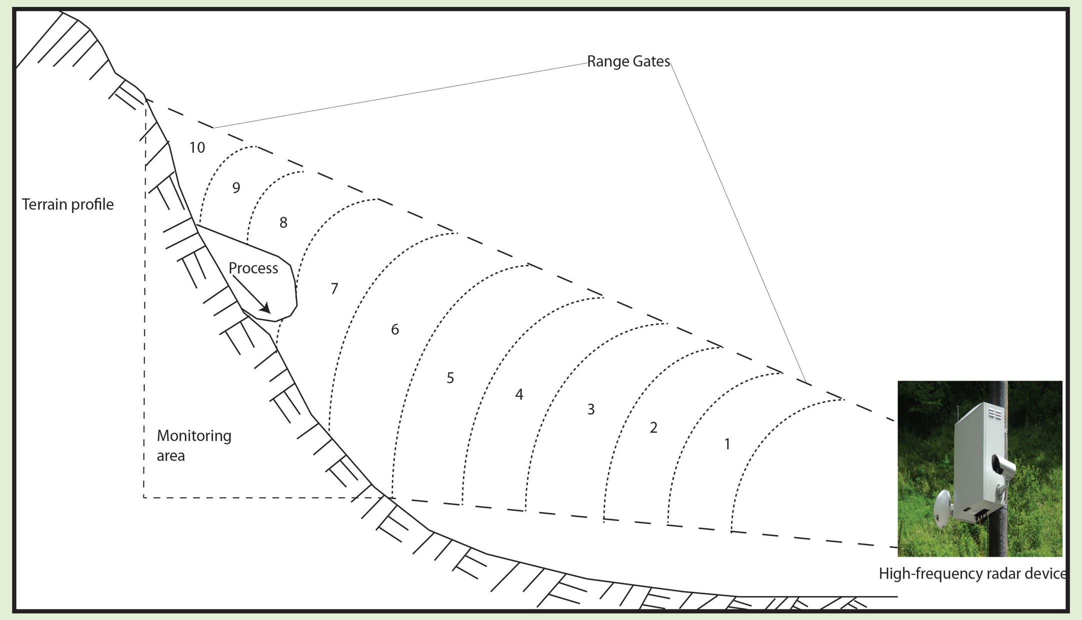
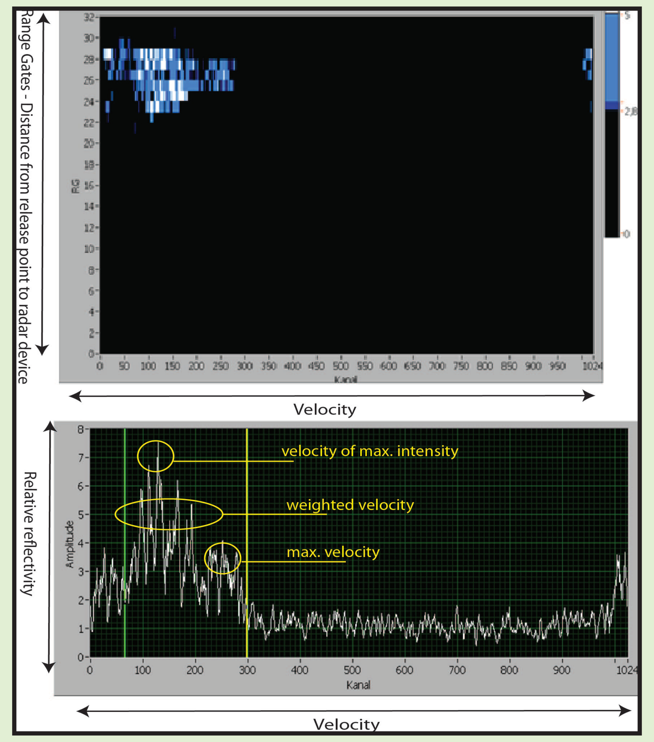



**Fig. 2: Sketch of analyzing PC software**




The analizing software uses the intensity of the reflected radar signal, to give a rough estimate of the mass movement size (Kogelnig et al., 2012). Additionally installed cameras with high resolution provide visual data of the monitoring area.

Fig. 2 represents an example of the software, showing the velocity spectrum of an artificial released snow avalanche from 15.02.2012 at the "Grosstal-Lawine" in Ischgl (Tyrol/Austria).The lower part of the sketch figures out the relation of the relative reflectivity and the avalanche front velocity within a distinct range gate. Information of higher importance is marked with a yellow circle. The sketch on the upper side shows the position of the avalanche and its velocity distribution at a certain time step.

## 3. Case Study

The catchment area of Lattenbach (Fig. 3) torrent (47° 8'N, 10° 31'O) is about 5.3 km$^2$ and receiving stream is the river Sanna. The mainly south-east exposed catchment has its tectonic borders between Silvretta nappe and the Northern Limestone Alps, whereby spacious mass movements arise and viscous debris flows occur frequently. In case of debris flows the receiving stream can be dammed up and overflow buildings on the banks upstream. Events are recorded over hundred years ago, which is why this specific torrent had been monitored intensively by the Institute of Mountain Risk Engineering, University of Natural Resources and Life Sciences-Vienna, over the last couple of years (Hübl et al., 2004). Together with the radar device, two ultrasonic measuring sensors are installed at this certain torrent cross section to provide data of the water level. The obtained data was coupled with the hydrological computations of runoff discharge, based on the recorded rainfall data by the precipitation gauge located within the catchment area.


**Fig. 3: Overview of case study area**

The aim of the monitoring system (Fig. 3) is to improve a better knowledge about debris flow triggering conditions, obtaining threshold values (i.e. precipitation and water level increase) for an event warning system and to provide data (i.e. velocity distributions and photogrammetric information) or further scientific analyzes. With the stored data, threshold values and hazard indicators can be achieved.

## 4. Experiences from the first trial season

As the radar device was installed in early 2012 at Lattenbach torrent, just data from this year is available. The summer season of 2012 was characterized with heavy thunderstorms and massive rainfall events in Austria, causing the occurrence of several debris flows, though our monitored torrent showed only one small event (Fig. 4), causing no harm but thes et of an alarm signal This is why we mainly focused our investigation on further useful applications of the radar system. As it is now the current status of research, the device is not only able to detect alpine mass movements, but also is capable to take over the task of measuring the water level (Fig. 5) and may be used as a weather radar, detecting heavy precipitation events (Fig. 6).

**Fig. 4: Event interpretation**

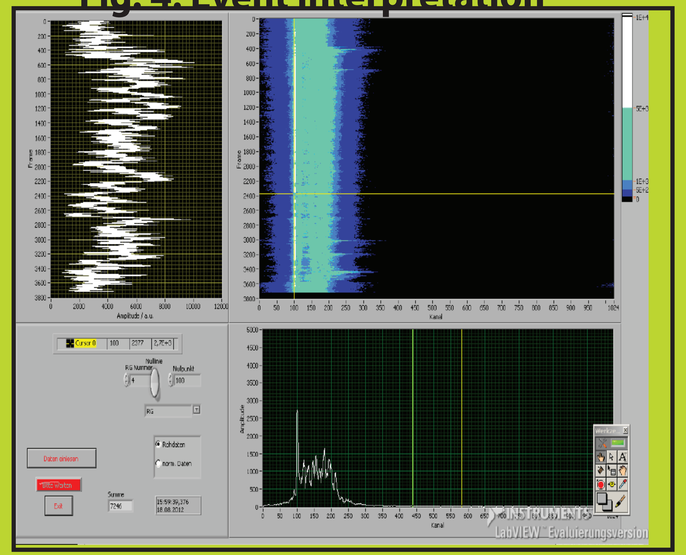


Fig. 4 illustrates the sampled data, plotted every 10 minutes, from Lattenbach torrent throughout September '12. On the x-axis the velocity and on the y-axis the point of time is being plotted, showing remarkably high velocities around frame 3.500, representing the date of the event. An alarm signal was set due to expedience of the automatic detection parameter threshold.

**Fig. 5: Measurement of water level**

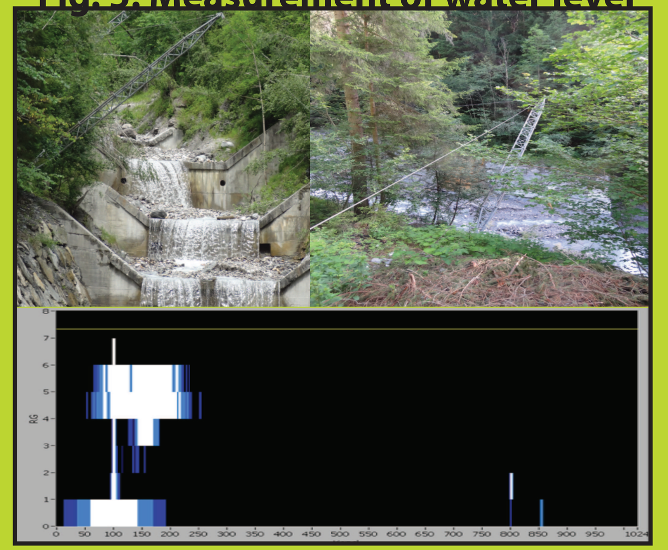


Fig. 5 shows a distinct amplitude peak close to value 200 on the x-axis, correlating with the speed of the flowing water. The peak-position provides information about the current velocity and the area beneath the peak shows the relative reflectance, correlating with the water quantity.

**Fig. 6: Application as weather radar**

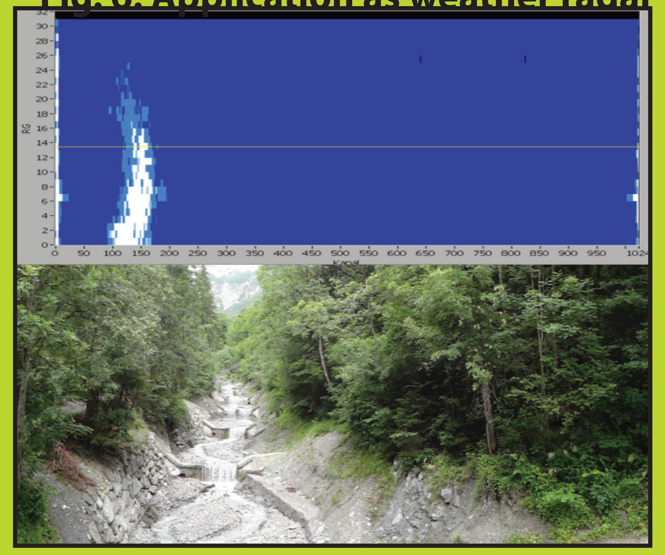


Fig. 6 presents a sketch of a heavy rainfall event recorded at the 20th August 2012 at 21:30 pm, where remarkably high reflectance, interspersed throughout almost the whole monitoring area, of huge water droplets was detected.

## 5. Conclusion

The experiences of the first trial in summer 2012 in monitoring the Lattenbach torrent and the experiences gathered after the first winter in Ischgl in detecting snow avalanches in combination with artificial avalanche release systems by Wyssen (Kogelnig, 2012) showed the high integrated potential using radar technology in monitoring of alpine mass movements. Fig. 2 demonstrates the already given possibilities in analyzing the gained radar data from snow avalanches with the current analyzing-algorithm. Further examples on the use of radar technology in snow avalanche research can be find in Gauer (2007a,b), Rammer (2007) and Jörg (2012).

As our current studies proof, it is not only possible to detect moving masses under realistic test conditions measuring its velocities and intensities, but also comparing and assessing water level changes based on data generated by ultrasonic devices. Furthermore, reliable detection of heavy rainfall events with the same system is possible, with just little adjustments of the corresponding PC software. At present strong efforts are made to investigate a correlation function of the radar data's relative intensity to either the process intensity and/or its magnitude.

Nevertheless the practicability and functionality of the radar device could be proofed, although no actual debris flows event could be monitored so far, it is crucial to calibrate the automatic detection parameters according to several events. Especially environmental conditions (i.e. wind vortices, tree movement under the influence of wind, heavy rainfall, etc.) may be the cause on one hand of false alarms and on the other hand the reason for bad data quality. The challenge is still to define proper thresholds of automatic detection parameters in that way they will not trigger an alarm due to environmental circumstances, but that already smaller torrential events may be detected and reported. Moreover it is essential to develop analyzing algorithms for each monitoring function and to examine whether or not the different measurement applications do not influence each other in a bad manner.

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