Remote assessment of avalanche risk

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In cooperation with a Swiss research team, geographers of Ludwig-Maximilians-Universitaet (LMU) in Munich have developed a novel measuring system relying on two different physical methods that promises to enhance forecasting of avalanches and spring floods. The method combines GPS and radar to measure snow properties also on the slopes.

Accurate forecasting of avalanches, and the risk of flooding in Alpine catchment areas during the spring thaw, primarily requires time-resolved data on snow volumes and the levels of liquid water in the snow cover. A research group led jointly by Professor Wolfram Mauser and Franziska Koch in the Department of Geography at LMU, and Dr. Jürg Schweizer and Lino Schmid at the WSL Institute for Snow and Avalanche Research (SLF) in Davos, has now developed a system that combines two distinct modes of measurement and, for the first time, permits continuous and non-destructive monitoring of the relevant parameters of the snow. The new method, which is described in the journal *Geophysical Research Letters*, can in principle be used in difficult terrain, such as avalanche-prone slopes.

In the journal *Sensors*, LMU researchers recently reported a technique, which allows the liquid water content (LWC) of the snow cover (and thus the onset of the spring thaw) to the continuously determined using low-cost GPS receivers designed to detect microwave radiation emitted by the satellites of the Global Positioning System. Essentially, the strength of the signal detected below the snowpack allows one to deduce the LWC of the overlying snow cover. "The weaker the signal, the wetter

the snow," Wolfram Mauser explains. "On the basis of these data, it is then possible to provide more reliable forecasts of wet-snow avalanches and the potential for flooding caused by meltwater. Since the GPS signals are freely available and the receivers are cost-effective and easy to install, it should be feasible to set up a monitoring network to facilitate early warning of flooding."

Non-destructive data acquisition below the snowpack

The LMU team has now compared the data obtained with their method with information collected by their Swiss colleagues at the SLF with the help of a ground-penetrating radar system, which measures the time taken for a radar signal to be reflected back to its source. Both systems were installed for two winter seasons at a test site on the Weissfluhjoch near Davos, at an altitude of 2540 m. Before the first snow fell, the upward-looking radar system in its protective case was buried below the snow cover and two GPS antennas (each 4×4 cm) were also positioned under the snowpack. Over the course of the winter months, in which the area was completely covered in snow, they monitored the data transmitted by the two systems. "The GPS and the radar-based instruments are among the first systems that are capable of monitoring the liquid water content continuously and non-destructively by applying external measured snow depth. The two systems provided consistent results for the moisture content of the snow cover with high temporal resolution, and also enabled us to determine the point in early spring at which the snow begins to melt during the day and freezes again at night," says Franziska Koch.

Moreover, the data obtained by the ground-penetrating radar system and the GPS-based method could be combined to yield values for three essential snow parameters of the snow. In this way, the snow water equivalent (i.e. the volume of water that results when a given volume of snow melts), snow depth and the LWC can be monitored continuously

by this novel combination without relying on external measurements. "The great advantage of this approach is that both systems are installed under the snow cover. This means that they can also be deployed for direct measurement of the important snow parameters on potentially hazardous slopes where avalanches are possible. That is something no conventional measuring technique can do," says Koch. Up to now, avalanche forecasting has been based on measuring the depth of the snow pack with the aid of sensors attached to poles, which can easily be destroyed if an avalanche occurs. Other monitoring systems can be used only on level terrain and, for obvious reasons, manual data acquisition cannot be carried out in acutely endangered areas. The researchers are now working on ways to determine snow volumes from the GPS data alone.

More information: "A novel sensor combination (upGPR – GPS) to continuously and non-destructively derive snow cover properties," *Geophysical Research Letters*, DOI: 10.1002/2015GL063732

"Measuring Snow Liquid Water Content with Low-Cost GPS Receivers," *Sensors*, DOI: 10.3390/s141120975

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