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Editorial

Snow avalanche formation and dynamics

Snow avalanches — a type of fast-moving mass movement — occur in snow covered mountain areas throughout the world and may cause property damage and loss of life as they interfere with human activities. Within the last ten winters (1996–1997 to 2005–2006) about 1020 people were killed in the European Alps by avalanches. Worldwide, the number of fatalities per year is estimated to about 250. Economic costs due to property damage can be considerable. In Switzerland, for example, the direct and indirect costs of the avalanche disaster in February 1999 amounted to about EUR 500 million. Due to avalanche protection works constructed in recent decades, the damage to infrastructure and residential areas has been reduced, so that today most of the fatalities involve personal recreation on public land (Jamieson and Stethem, 2002; Schweizer et al., 2003).

Whereas the population and recreation pressure in many regions of the European mountains is still increasing, the financial means for avalanche protection works appear to be declining. Cost–benefit considerations increase the relevance of temporary protection measures such as road closures. However, preventive measures heavily rely on reliable avalanche forecasting; i.e. the prediction of location and time of avalanche occurrence.

Since snow avalanches are rare events — as are many other natural hazards — possibilities to study their causes and dynamics with field observations are limited. Moreover, due to the complexity of avalanches, many processes are not amenable to laboratory or numerical studies. Nevertheless, a better understanding of the underlying processes is considered as a prerequisite for improved prediction.

The General Assembly of the European Geosciences Union (EGU) in Vienna, 15–20 April 2007, included — within the Natural Hazards Division — two sessions on “Snow avalanche formation and dynamics” with a total of 27 contributions. This Special Issue of Cold Regions Science and Technology contains six papers based on EGU contributions.

Remote sensing of the cryosphere is a very active research topic. Data acquired by satellites are essential to obtain, for example, the snow cover extent which is an important input for climate models as well as for hydrological applications. Many snow related applications are based on the reflectance properties of snow in the near-infrared band (e.g. Tedesco and Kokhanovsky, 2007). Whereas, data from space-born instruments have rarely been applied for avalanche research, ground-based remote sensing techniques have been extensively explored, especially in the last couple years. Terrestrial laser scanning (TLS) has created the most interest. The potential for its application as well as the limitations is now described in two contributions (Prokop, 2008—this issue; Schaffhauser et al., 2008—this issue). These two studies and a complementary one (Prokop et al., in press) clearly show the applicability of terrestrial laser scanning. The application of TLS for snow depth sounding will certainly provide useful data for the development and validation of both 3D snow drift and runoff-models. An accuracy of about ±10 cm at a distance of several 100 m to the target has been achieved in several independent studies. Airborne laser scanning has already successfully been applied to assess the mass balance of large avalanche events (Sovilla et al., 2006).

On most days during the winter, the avalanche forecasting services that issue public bulletins have to focus on dry-snow instabilities potentially triggered by recreationists. This prompted the idea to introduce the load by a skier into the stability index approach (Föhn, 1987). Though it is accepted today that the limit-equilibrium approach is a rather poor model of snow slab release (it has been superseded by models based on fracture mechanics), it is currently the only model used for forecasting. Habermann et al. (2008—this issue) attempted to improve the skier stability index by including the snowpack layering. However, the correlation between the modified stability index (that included slab and substratum properties) and stability test results did not improve. Their results obtained with a highly simplified finite element model, suggest that less stress penetrates through stiffer slabs and thus fracture initiation is less likely, while other studies (Heierli and Zaiser, 2008; Sigrist and Schweizer, 2007; van Herwijnen and Jamieson, 2007) show that, once initiated, fractures under stiffer slabs have a high propagation propensity.

A tragic recreational accident in the Connaught valley near Roger Pass (Columbia Mountains of western Canada) in February 2003 has triggered several research projects. To indicate to recreational backcountry users the terrain that can be affected by large spontaneous avalanches at times of elevated danger, Delparte et al. (2008—this issue) developed a statistical runout model to map avalanche extent in a GIS. Based on avalanche records of over 40 years, an alpha-beta runout model (Lied and Bakkehøi, 1980) was adapted for the Roger Pass area in Glacier National Park.

Cappabianca et al. (2008—this issue) describe a comprehensive approach to avalanche risk mapping, which was pioneered in Switzerland in the early 1960s and has since been developed over the last 30 years in many other countries in Europe and North America. However, the criteria (e.g. the threshold impact pressure) relevant for a given risk zone vary widely. In particular in the European Alps, these different criteria, which may well exist between two adjacent valleys, are hard to justify. A harmonized approach seems essential. However, harmonization is challenging as already small changes in procedure may change the hazard maps causing considerable economic consequences for land owners. The procedure proposed by Cappabianca et al. (2008—this issue) combines statistical analysis of snowfall records, iterative simulations of avalanches dynamics (using a 1D dynamical model) and empirically based vulnerability relations. Using an example in the eastern Italian Alps, different avalanche protection

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scenarios were considered that show the effect of avalanche defence structures in the starting zone on the risk level in a village at the valley bottom.

An essential element of a quantitative risk assessment is the impact pressure to be expected at a given location in the runout zone. Thibert et al. (2008—this issue) report on a full-scale experiment to measure avalanche impact pressure on an instrumented structure in an avalanche path at the Col du Lautaret test site (southern French Alps). The principal difficulty when determining the impact pressure is the fact that the structure modifies the avalanche flow. This makes a numerical simulation approach challenging. Therefore, flow–structure interaction is mainly investigated experimentally. The avalanche pressure was determined inversely from the elastic bending modes of the structure. A preliminary relation was found for the velocity dependence of the impact pressure. Further experiments are needed with different avalanche characteristics to confirm these results. However, it seems clear that the impact pressure is underestimated under most flow conditions if determined with a simple hydraulic expression where the pressure is proportional to the density and the square of the flow velocity. This has been previously pointed out by Gauer et al. (2007) and Sovilla et al. (2008) based on measurements from two other full-scale test sites: Rygfonn (Norway) and Vallée de la Sionne (Swiss Alps), respectively.

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