Toward better decision tools for the management of frequent avalanches

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ABSTRACT: Avalanche safety personnel often face with the problem of whether to close a road or a ski-resort exposed frequently to avalanches. Such decisions are often difficult, due to the lack of local and specific forecast on the possible evolution of weather and snowpack characteristics, as well as their influence on avalanche dynamics and forecasted runout distances. To fill this gap, the STRADA project was founded, providing strategies and tools for the management of natural risks. Avalanches were monitored at different full-scale test sites and the corresponding snowpack characteristics were indirectly determined using the numerical models SNOWPACK and Alpine3D. The combined analysis of these data has shown the importance of knowing the snowpack distribution and characteristics to define release areas and runout distance. This new knowledge, combined with the best practice and the best tools for avalanche simulation, such as the numerical model RAMMS, allow to improve risk mitigation strategies for routes and ski-resorts management. In synthesis, for the management on roads and ski resorts we propose three potential strategies: (1) monitoring and definition of basic criteria: it is important to know local snowpack conditions along the entire path, also including previous avalanche activity; (2) simulation of avalanche scenario: numerical avalanche models can be applied to assess different hazard scenarios with respect to different snowpack conditions as model input; (3) simulation of snow cover scenario: the snowpack in an entire basin is simulated using numerical models such as SNOWPACK and Alpine 3D, both in terms of forecast and real time scenarios.

KEYWORDS: STRADA, frequent avalanches, management, routes, ski-resorts, strategies

1 INTRODUCTION

Small and medium avalanches, often characterised by low return periods, present notable problems for technicians and administrators who have to manage their effects on anthropized lands, especially those within ski-resorts and along roads and railway lines. Risk assessment and related decisions are often difficult due to the lack of both specific local forecasts – in relation to the possible evolution of weather and snow conditions and to their influence on the avalanche dynamics as well as on an accurate forecast of the runout distances. Actual risk management techniques also lack specific procedures and performance indicators which can be used by both technicians and administrators.

Figure 1. Regional route n. 44 (Aosta valley, Italy) (photo courtesy of UNV Aosta Valley).

To overcome this shortcoming, at the start of 2010 the STRADA project was set up. The project dealt with the impact of climate change on avalanches, springs and lakes, in a uniform and detailed way, taking into consideration the dif-

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ferent elements of territorial planning and management.

Specifically, as part of activity 4 regarding the analysis of small and medium avalanches, the project has proposed new methods to combine the most advanced technical knowledge in modelling and best practice in the snow cover sector with the best tools for the simulation of avalanche dynamics. These methods were used in the creation of risk mitigation strategies for the management of means of routes and ski-resorts.

The first part of the project aimed to investigate how the evolution of the climatic situation can influence the behaviour of small and medium avalanches. It was ascertained, that the effects caused by climatic variables on orographically complex territory like the Alps are still not very clear, and the current global (GCMs) and regional (RCMs) climate models are still not effective enough to simulate the consequences of changes in the avalanches physical variables. When the global backdrop is confirmed, some general assumptions can be made. With the current uncertainty, the processes that have caused the anomalous events observed in the last few years, that is, the occurrence of avalanches prematurely in the winter season and the intense avalanche activity well into the spring have not yet been understood. These events could be an indicator of a variation in the physical properties of the snow cover, influenced by climate change. Therefore, in the long term it could have an impact on the avalanche danger, as well as on the rules for the relative risk management.

Although the causes are not up for debate, the relevant variation of the main parameters and, especially of the air temperature (in its average, minimum and maximum values) might suggest variation in the intensity, type, spatial and altitudinal distribution of snow fall (Table 1) for the near future (source CIPRA 2002), with possible direct effects on the rheology, frequency and runout distance of avalanches and indirect effects on the duration and spatial distribution of the seasonal snow cover. In particular, an increase in the air temperature will influence the type and quantity of solid precipitation (snow crystal type, new snow density, intensity and limit of snowfalls), the snow cover evolution (density, humidity and liquid water content, metamorphism and development of weak layers) and, therefore, the type of avalanches. In some cases, a greater liquid water content of the snow cover might reduce the friction of the avalanche and therefore favour a longer runout distance.

Elevation m	Current Snow Volume 10^9 m^3	Future Snow Volume 10^9 m^3	Change in Volume Future-Current
500	6–8	0–0.5	98–100% loss
1000	15–20	0.2–1	95–98% loss
1500	28–35	8–12	65–70% loss
2000	40–50	20–28	50–60% loss
2500	30–38	18–22	40–45% loss
3000	8–10	8–10	<5% change
3500	2–3	2.5–3.5	15–20% gain
4000	0.8–1.2	1.0–1.4	15–20% gain

Table 1: Estimates of Changes in the snow volume in the Alps between the baseline 1961-1990 climate and a climate scenario based on the IPCC ‘A’2’ Greenhouse Emission Pathways by 2100 (Beniston, M. 2012).

The evolution of the climate in the last few years may have a direct influence on the avalanche dynamics ,which can be analyzed thanks to the development of tools such as RAMMS (Christen et al., 2010), SNOWPACK and Alpine 3D (Lehning et al., 2006; Lehning et al., 2008). Those tools are continually being improved through research, thanks also to their use at different full-scale test sites, such as Vallée de la Sionne (VDLS, Valais, Switzerland) and Seehore (Fig. 2, Aosta Valley, Italy) (Maggioni et al., 2013; Barbero et al., 2013).

Figure 2. View of Seehore test site after avalanche event of 26 February 2013 (photo courtesy of A. Welf).

2 OUTCOMINGS OF THE PROJECT STRADA

The STRADA project has identified the importance of knowing the snow cover distribution as a fundamental prerequisite for the identification of risk mitigation strategies. Given this, one of the main activities of the STRADA project has been to identify typical conditions of snow distribution in avalanche sites, and therefore to associate these conditions with the avalanche events themselves. In order to achieve this aim, it has been fundamental to find an appropriate method for obtaining the snow cover distribution with high temporal and spatial resolution. Two numeric models have been used: SNOWPACK, a single-dimensional model capable of recreating the complex structure of snow cover on a point scale, and Alpine3D (Fig. 3), a three-dimensional atmospheric model, capable of recreating the snow cover distribution and structure with high spatial distribution, on a local scale, starting with data gathered at the meteorological stations (Lehning et al., 2006; Lehning et al., 2008, Bavay et al., 2009).

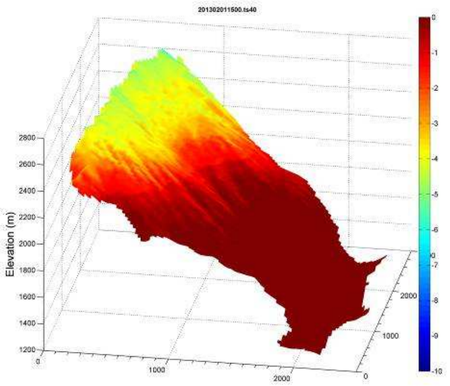

Figure 3. Alpine 3D simulation. The figure shows the temperature of the snowpack, 40 cm below the snow surface, on the site of VDLS - CH (Figure courtesy of SLF-DAVOS).

Numerous snow distribution scenarios studied at the VDLS experimental site (Steinkogler et al., unpublished data) enabled us to note that the snow cover characteristics can vary greatly and unexpectedly from one event to another, and particularly within the water basin, where large temperature gradients can be observed between the starting and the runout zones. This means that snow data collected only, for example, in the starting zoneì are not so much representative of the entire avalanche path. These scenarios can be compared to the registered avalanche activity at the site to check the statistical link between snow cover features , such as, for ex. new snow depth, total snow depth and snow temperatures, with the runout distance of the corresponding avalanches. That link allows the creation of simple practical rules for improving management of the risk for routes and ski-resorts.

The snow cover scenarios can then be used for the recreation of avalanche scenarios through use of the avalanche dynamics model RAMMS (Christen et al., 2008), modified to take into account the properties of the snow cover along the path (Fig. 4).

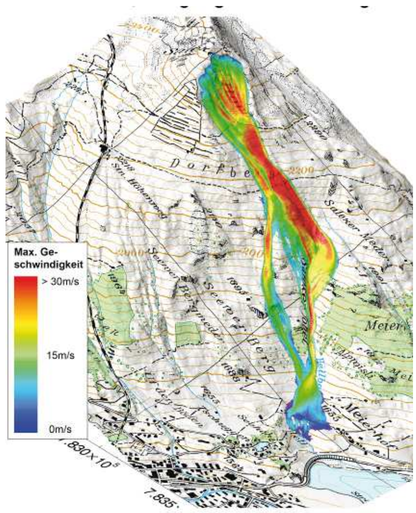

Figure 4. RAMMS simulation on the site of Dorfberg in Davos - CH (Figure courtesy of SLF-DAVOS).

In contrast to an only terrain based model, the new models will integrate the snow cover influence on terrain morphology. To run the new models the user has to provide information about the current snow cover scenario. Based on the input, new algorithm for the definition of release zone, developed in the project STRADA, allows to calculate different release areas for the same terrain depending on the different snow cover distribution. Thus, it will fulfil the requirements of practitioners, which observe varying release area locations and extent in their daily work without disposing of an instrument capable of capturing this behaviour. Taking into account the snow cover along the avalanche track, will allow to associate runout distances to the real snow cover characteristics.

Thus, it might now be possible to define snow cover - avalanche scenarios in order to obtain more realistic run-out distances related to terrain and snowpack characteristics.

3 STRATEGIES

The strategies identified in the STRADA project are divided into different types and priority levels, which require, in order to be used in the practice, the implementation of policies and investments with a time frame of at least 15-20 years. It is necessary to simplify and homogenize the legislation, to increase the general knowledge of the area as well as of its main parameters, to have a better understanding of the processes and to implement the quality and quantity of data feeding the numerical models in the experimental and calibration phase (developed as part of this project). Accurate hazard forecastingand estimation of the resulting risk, in fact, require a reference framework and local knowledge of expected events, resulting from as more continuous as possible monitoring of the snow cover conditions along the entire avalanche path. This monitoring should be made following predetermined operational protocol, which ensures the recording and integrity of the data gathered (in compliance with standardised methods and encoding) and, in the case of manual surveys, from the integrity of the operators.

In the future, it might be possible to set up a database for the definition of return periods, type, dynamics and runout distances of avalanches, as well as to define event thresholds, reference scenarios and better performance of the numerical models.

In the absence of resources, the management of ski-resorts or routes can take place on the basis of simple, empirical rules based on historical knowledge of local characteristics of the snow cover distribution and structure. Nevertheless, this approach exposes technicians with the job of its management, to take on a notable amount of responsibility that is not backed up by objective criteria in the case of arbitration. As we have already highlighted, effective risk management, also requires a framework of knowledge of the zone. When this framework is absent or limited, the STRADA project has developed and perfected methods of spatial and morphometric analysis of the zone, which allow the identification, as a preliminary step, of the potential starting zone and, if possible, also the delineation of the maximum runout distance.

Figure 5. Cover of the text drawn up at the conclusion of the STRADA project, containing the strategies for the management of small and medium avalanches (Chiambretti et al., 2013).

In synthesis, for the management of avalanches on roads and ski-resorts, in the STRADA project, three potential strategies are proposed:

- Monitoring and definition of basic criteria. It is important to know local snow cover conditions along the entire avalanche path, also including previous avalanche activity. Thus, avalanche safety personel need a strategy to monitor the avalanche site. Attention should be primarily given to important variables such as new and total snow depth and snow temperatures. The data should be recorded in order to create an historical dataset. In a second step, it should be possible to develop a criteria based on the recorded data to establish for which snow condition (i.e. a threshold snow depth value) the avalanche can reach a specific location.
- Simulation of avalanche scenario. Unfortunately for the not well known areas the empirical criteria cannot be used. Hence numerical avalanche model, as RAMMS, can be applied to assess different hazard scenarios with respect to different snow cover conditions as model input. This approach needs a lot of input data at the local scale, therefore a preliminary calibration on well documented avalanche paths (such as for example the avalanche test sites) is necessary. Later, the same approach could be used in less documented sites.
- Simulation of snow cover scenario. The snowpack in an entire basin is simulated using numerical models such as SNOWPACK and Alpine 3D, both in terms of forecast and real time scenarios. This approach would allow to predict the snowpack condition in advance for large areas with high spatial resolution. Avalanche simulation may be run parallel to asses avalanche hazard. This approach is still in its developing phase.

4 CONCLUSIONS

At the conclusion of the STRADA project, in July 2013, three potential levels of strategies have been defined: they are based both on the observation of the conditions characterizing an avalanche basin and on developing models, currently used in the study of snow and avalanches. These strategies range from the scale of individual basin to the scale of the valley.

The next step involves the application of these strategies on roads or ski-resorts management, in order to test them in different territorial realities and to elaborate the most plausible scenarios, in support of local governance.

Such application aims at the definition of management rules in the local and regional contexts (local avalanche committee, technical committees, etc..) which include different types of protection measures, possibly the temporary closure of the infrastructure, in order to operate the artificial triggering of avalanches endangering them. This can reduce the closure time of roads or ski resort.

In fact, the prolonged closure of a road or a ski resort is a big issue in the Alpine areas and determines strong impact in a mountain region, from the social context and the tourism point of view, which are reflected on the economic fabric of the valley, in terms of lost revenue and jobs.

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