AVALANCHE WARNING SWITZERLAND CONSEQUENCES OF THE AVALANCHE WINTER 1999

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Abstract: During the last few years the Swiss avalanche warning service has undergone a major development in terms of utilization of communication and information technology. The collection and compilation of meteorological and snow data as well as the broadcast of the avalanche danger information have been automatized to a large extent, making extensive use of internet technology.

Besides the traditional text-based avalanche bulletins, graphical products have been introduced in order to increase attention of the younger customer segment, particularly freeriders. A variety of special charts and maps (national and regional avalanche danger, snow and new snow maps) is produced and made available via internet. Additionally, compact information packages can be obtained via SMS or WAP.

However, as the avalanche winter 1999 has shown, proper communication of high quality avalanche information is not sufficient for an efficient handling of avalanche crisis situations. While the warning system itself worked well in 1999, problems occurred (i) due to the non-uniform level of education and organization of avalanche security services, and (ii) due to the insufficient or sometimes missing communication between different security persons and organizations. These problems have been addressed in a joint project with the federal authorities. First, a concept for unified education of local and regional avalanche security services has been elaborated and is now being realized in an ongoing series of courses. Second, an internet-based information tool (content management system) has been developed together with an external partner. It supports the different security services (road, railway, police, ski stations, etc.) in rapid mutual information about the situation and organisational steps. The tool has undergone a successful pilot operation in the second part of the winter 2001-2002 in the region of Davos-Klosters.

Keywords: avalanche bulletin, avalanche countermeasures, avalanche forecasting, avalanche warning, communication

1. Introduction

Within the framework of "Avalanche Warning CH 2000" (Russi et al. 1998) the Swiss avalanche warning system has undergone a major development in the last few years, making extensive use of modern developments in information and communication technology.

A network of automatic stations for the measurement of meteorological and snow parameters has been built up. Their data, together with those of a dense network of human observers, form the basis for the daily avalanche forecasting for the Swiss Alps, issued by the SLF.

Strong attention has been paid to communication aspects. Quick and easy access to the information is crucial for the ski tourists as well as for the security services. Therefore the information is broadcasted, as far as possible, on all public platforms, such as radio/TV, phone, internet, SMS, WAP, etc.

The first two months in the year 1999, with a partly catastrophic avalanche situation, have been a hard test for the warning systems as well as for the people and organisations involved in crisis management. While in general the warning system and preventive measures turned out to work well, some deficiencies became apparent in this extreme situation on the side of the security and crisis management services. First, the performance in the different villages and regions has shown to be strongly dependent on the amount of experience that could be gained in "normal" winters. Second, the communication *between* the different security organisations in critical situations in some cases turned out to be unsatisfactory. It became clear that a good "downward" information flow from the warning service to the security

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services is important, but also the "lateral" information flow between the partners in crisis management.

The above deficiencies were approached in the project "Interkantonales Frühwarn- und Kriseninformations-System" IFKIS (Intercantonal Early Warning and Information System), carried out by SLF on request by the Swiss Forest Agency BUWAL. The results are presented in this paper.

The paper is structured as follows. In section 2 we give a short description of the basis for the SLF avalanche forecasts. Section 3 contains a summary of the daily products of the SLF avalanche warning service. The information delivered by SLF forms the basis for the local operational decisions of security services. Traditionally, the SLF is not involved in the operational decisions. Section 4 describes an exception from this rule. Following a fire catastrophe in the Gotthard tunnel and its subsequent closure in mid October 2001, SLF was asked for on-site expertise and consulting concerning the winter opening of the Gotthard mountain pass road. The actions and experiences are summarized in section 4. In section 5 we present the results of the project IFKIS and the consequences drawn from the avalanche winter 1999.

2. The basis for the avalanche warning

2.1 The measurement and observation network

The network for the compilation of data for the avalanche danger forecast consists largely of two parts:

a) *Automatic station network.* The main part is formed by the IMIS network (*I*ntercantonal *M*easurement and *I*nformation *S*ystem), including around 75 automatic stations measuring snow height, snow and air temperatures, humidity, radiation, and wind. The IMIS network has been continuously extended since 1996 and is being completed in 2002, up to minor modifications and extensions. The stations are operated by solar energy, because they are located close to potential avalanche release zones and therefore in most cases outside the range of the electric power network.
In addition to the measured data the new snow height is calculated by the numerical model SNOWPACK (Lehning et al. 1999; Fierz and Lehning 2001), using the difference between snow height and theoretically evaluating the snow settlement.
The IMIS network is supplemented by the ENET, a smaller network of 11 automatic stations, built and operated together with MeteoSwiss. The measured parameters are the same as at the IMIS stations, but the ENET stations are located close to mountain stations where external power supply is available. This allows for additional sensor equipment, such as ventilated radiation sensors or heated wind sensors.

b) *Human observer network.* The observer network consists of around 200 people reporting the relevant meteorological and snow parameters and avalanche observations on a daily basis. Some of them make flat field snow profiles twice a month. Part of the observers have a prescribed measurement program and are not necessarily experts for estimating the local danger. A second part, the so-called *Geländebeobachter* (slope observers) with avalanche expert know how (guides, members of security services, etc.) provide their evaluation of the local danger level and personal observations by using a special questionnaire on Internet or fax.

The automatic and the human observer network are of complementary nature. They are both indispensable and can not replace each other.

Besides the data discussed above, weather forecast and the comparison of the output of different meteorological models are, of course, of central importance for the forecasting of the avalanche danger.

2.2 Data transfer

The data transfer from the automatic stations (measurement interval 30 minutes) has been described earlier in detail (Russi et al. 1998). It is made in wireless form from the measurement station to a relay station and then via the public phone lines.

The data taken by the human observers, in contrast, are transferred to SLF via Internet (operational since winter 2001-2002).

All the data are automatically included in the central SLF database, from where they can be accessed and processed on one hand by the avalanche warning service, and on the other hand for a series of internal and external applications, e.g. the evaluation of preventive measures.

2.3 Model input to forecasting

There have been continuous efforts at SLF to apply the understanding of the physical processes in the snow pack as an input for the avalanche danger forecast. The numerical simulation tool SNOWPACK (Lehning et al. 1999, Lehning 2001) is in operational use for the daily calculation of the new snow height at the locations of the automatic stations. In addition the tool calculates various snowpack indices for the

daily use in the forecasting process (Lehning et al. 2000; Dorschoot et al. 2001). Present efforts are directed towards numerical extraction of snowpack stability information from the model calculations.

3. The SLF avalanche warning products

3.1 Information for the public

Information bulletins for the public are produced twice a day. At 5 pm the main ("evening") bulletin covering the entire Alpine area of Switzerland is published. It consists of the four modules "General", "Short term development", "Forecast of the avalanche danger for the next day", and "3-Days Tendency. The bulletin is published in German, French, and Italian. It is broadcasted via Radio, phone, fax, a series of newspapers, and internet. The latter has become a very important medium, with a hit rate of around 2 Mio. per winter.

On Internet the text bulletin is accompanied by series of special information maps, including e.g. the danger level, snow height, new snow, etc. An example is shown in Figure 1.

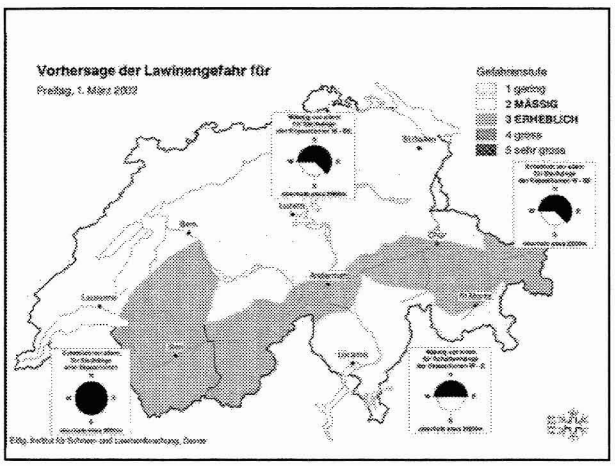

Figure 1. The avalanche danger on 1 March 2002.

In the following morning, the evening bulletin is updated using latest station and observer data and the new weather forecast of MeteoSwiss, for publication in form of a series of regionally resolved morning bulletins at 8 pm. In contrast to the text based evening bulletin, the morning bulletins are dominated by a graphical display of the spatial distribution of danger levels. The regional resolution and use of graphics guarantees easy readability and interpretation.

The evening and morning bulletins have quite different target groups. While the evening bulletin provides the basis information for, e.g., ski touring on the next day, the morning bulletins are intended for off-piste skiers in ski resorts.

The morning bulletins are also displayed in ski stations (preferably in "waiting areas" in the ski lift stations), often together with the so-called "Freeride Check-Point", a table containing general information on precautionary measures and an explanation of the danger levels.

3.2 Information for security services

Besides the publicly available information, the security services, responsible for traffic lines, buildings and other infrastructure have access to additional information.

First they can access the data from the automatic stations via the Windows based software tool InfoBox. Besides the bare data, the InfoBox provides also appropriate processed information, such as 3-day plots of the evolution of relevant snow and meteorological parameters. SNOWPACK results are also available in the InfoBox. The InfoBox is widely used by security services throughout the Swiss, but also the Austrian, German, and Italian Alps.

An important support tool for the security officials is the "Early Warning" (Frühwarnung) function. In case of an imminent critical situation an early warning message is released via the InfoBox, indicating the critical regions, see Figure 2. The criterion for an early warning message is very restrictive, namely a high probability that the next 72 hours will bring at least 1m of new snow and the avalanche danger will increase to level 5 ("very large"). If the snowfall is not predicted to lead to danger level 5, then an "Information Heavy Snow Fall" is generated. These informations are accompanied by an SMS or pager alert (according to individual preference) with a request to consult the InfoBox for details.

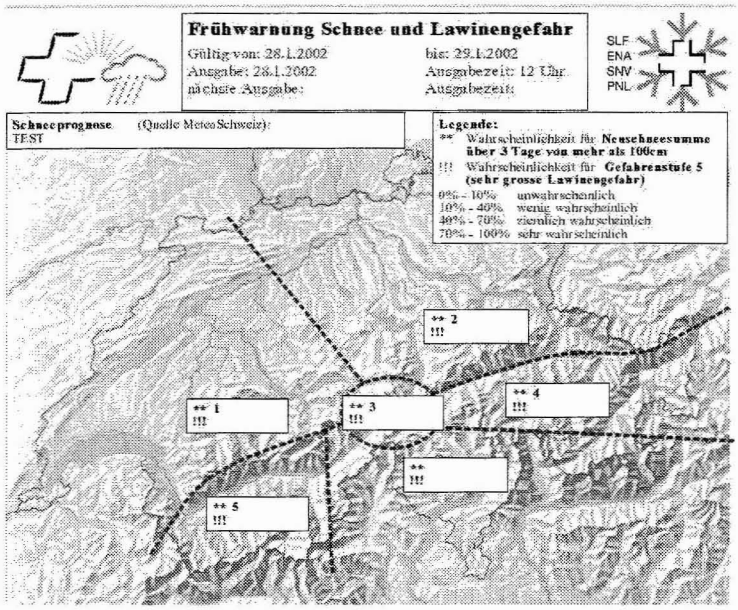

Figure 2. Early warning message to security services.

3.3 Computer-assisted local support: NXD-2000

As mentioned in the introduction, SLF provides the basic information for the local operational decisions, but in general no on-site decision support ("Einzelhangbeurteilung"). However, a Nearest Neighbour based computer tool is available for this purpose. The Nearest Neighbour approach, developed some time ago by Buser (Buser 1989) has been implemented and improved in the tool NXD-2000 by Gassner (Gassner 2000). The tool has been installed at about 30 sites in- and outside Switzerland, e.g. in Snow Basin, Utah, for the Olympic Winter Games 2002.

NXD-2000 does not provide the user with a forecast, but with a "structured memory" of similar situations in the past. The forecasts or the decisions, respectively, have to be made by the user himself. At present all NXD users have their local databases. A further planned development is to use these local data as an additional daily information for the SLF forecasters. This information, although highly local and selective, could be very valuable.

4. On-site decision support by SLF: The Gotthard tunnel fire catastrophe

The traditional philosophy of SLF has been to provide the basic general information supporting the security services, but not to be involved in any local operational decision. One of the main reasons is to maintain the role as an independent instance, e.g. in case of an accident with legal consequences.

While SLF will in general not refrain from this principle in future, it provided local decision support as a consequence of the fire catastrophe in the Gotthard tunnel in mid October 2001. The Gotthard tunnel is at the heart of the main North-South car traffic lines through the Swiss Alps. Therefore its closure after the fire posed major traffic capacity problems, particularly in view of the imminent winter. One of the envisaged solutions was the winter opening of the Gotthard mountain pass road. While providing a valuable alternative regarding capacity, the winter opening posed major problems from the point of view of avalanche danger.

The responsibility for control and maintenance of national highways is on the cantonal level. While the authorities on the north side (Canton Uri) are very experienced with avalanche situations, the south side (Canton Ticino) requested support from SLF for an eventual winter opening of the mountain pass road.

A risk analysis (SLF 2001, Margreth et al. 2002) clearly showed that a permanent opening of the road during a normal winter could not be envisaged, but only a delayed winter closure. After the political decisions in favour of this proposal had been made, the following measures had to be taken:

a) Elaboration of a security concept
b) Local extension of the measurement and observation network with engagement of local specialists

c) A special daily avalanche bulletin for the Gotthard region
d) SLF experts on the spot in critical situations.

Fortunately the snow and avalanche situation during most of the time until the reopening of the tunnel, just before Christmas 2001, was very favourable. There were only two short periods during which the situation required the presence of SLF experts. However, the experience for all the experts involved (warning, measurement network, risk analysis) has been a very valuable one.

5. Consequences of the avalanche winter 1999

5.1 The avalanche winter 1999

In the first two months of 1999 three subsequent periods of heavy snow fall lead to a catastrophic situation in the French, Italian, Swiss and Austrian Alps. In the time between 27 January and 25 February the total snowfall locally exceeded 5 meters, corresponding to a reoccurrence interval of 80-100 years in some regions. 17 people were killed in the Swiss Alps. Direct damages amounted to 437 million Swiss Francs, indirect damages to 328 million (SLF 2000, Noethiger et al. 2002).

The avalanche winter 1999 has been a hard test for all people and organisations involved in warning and crisis management. While the information flow from the SLF warning service turned out to work well, a series of problems occurred on the level of the local and regional security services. They can be grouped into two parts:

a) Inhomogeneity of education level. While the officials in regions with frequent avalanche threats could in general cope with the situation, the management of the crisis at other places was sometimes unsatisfactory.
b) Partly inefficient communication between different local security officials or services, leading sometimes to inconsistent measures ("open railway line parallel to a closed road").

These problems were approached in the project IFKIS (*I*nterkantonales *F*rühwarn- und *K*risen-*I*nformations-*S*ystem), which was carried out by SLF on request of the Swiss Forrest Agency BUWAL. In the following two sections we describe the conclusions drawn from this work.

5.2 Education and training concept

The SLF has traditionally offered courses and information material for people in charge of security tasks. Following the analysis of the avalanche winter, there was the widespread desire to define and achieve a generally valid and accepted standard for local avalanche experts.

Within the frame of the IFKIS project, the SLF developed a modular education and training course program. In order to secure general support, the course program has been developed in close interaction with the cantonal authorities.

There are two course levels A and B:

Level A courses are attended by members of security services whose task is the preparation of information for the decision makers.

Level B are attended by people in leading positions of security organisations and authorities (decision makers).

Both the A and B level contain a general (basic) part. In addition the course level A is split into three modules 1 – 3 for subsequent specialisation. These are

Module 1. Snow- and avalanche observation (mainly for the SLF-observers).

Module 2. Estimation of the local avalanche danger (making of slope profiles, transmission of data, etc.).

Module 3. Estimation of the risk for objects (housing, traffic lines, etc.).

The main goals of the courses are shortly summarized in Table 1.

The courses are held according to the needs, usually in the beginning of the winter. Very positive experience could be gained during the last two years.

5.3 Information system

The second deficiency showing up during the 1999 avalanche crisis was the difficulty to conduct an efficient communication between the different security officials (roads, railway, housing, etc.) in critical situations. It was often difficult to sufficiently quickly exchange information on new events and enforced (or cancelled) measures. The most widespread medium, the phone, is not always the optimal communication system, because the two (or more) partners have to be available simultaneously. There was a clear desire for an additional, more flexible communication platform.

As a consequence of this situation, SLF together with the Alpines Sicherheits- und Informationszentrum (Alpine Security and Information Center) ASI in Landeck, Austria, developed an Internet based action information system (Massnahmen-Informations-System, in the following abbreviated as MIS). The MIS allows security officials to inform each other

about the actual state in their responsibility area. A first version of the system had been developed by ASI in response to similar communication problems after the avalanche catastrophe in Galtür in February 1999. The MIS has a usual Internet browser interface and is therefore very widely accessible. A typical part of the user surface is shown in Figure 3. Access control (selective if necessary) is done via passwords protection. The tool is based on a Content Management System, allowing an easy and efficient administration of documents of different type.

Table 1. The principal goals of the SLF course program for avalanche experts. In addition to the general part, the course A contains 3 modules for further specialisation. Course B has no modules.

	Level A	Level B
Basic part	*Weather*: Knowledge of the generally available Meteo products and ability to interpret them in view of the avalanche danger. *Snow*: Knowledge of the basic snow forms an the most important parameters influencing the snowpack stability. Ability to make snow profiles and interpret the corresponding snow profile plot. *Avalanche danger*: Knowledge of all SLF information and ability to interpret them in view of his or her needs. Knowledge of the factors responsible for avalanche formation and ability to estimate the actual local avalanche danger.	*Weather*: Like level A, in addition Ability to interpret synoptic maps. Ability to use and interpret the InfoBox and observer data. *Snow*: Knowledge of the basic snow forms an the most important parameters influencing the snowpack stability. Ability to interpret snow profiles. *Avalanche danger*: Knowledge of all SLF information, concerning the InfoBox, and ability to draw the appropriate conclusions. *Measures*: Ability to estimate the actual risk potential by using the danger map. Knowledge of the artificial release methods, advantages, disadvantages, and the legal situation. Ability to recommend appropriate measures.
Module 1 (Course A)	- Ability of correct data compilation, including flat field profile, and internet transfer to SLF. - Ability to estimate the local avalanche danger level.	
Module 2 (Course A)	- Ability to make a slope profile and to transfer the results into a danger level estimation. - Ability to extract the relevant information for the SLF warning service. - Ability to give basic instructions to beginners.	
Module 3 (Course A)	- Knowledge of protection measures. - Ability to recognize need of organisational measures and their documentation.	

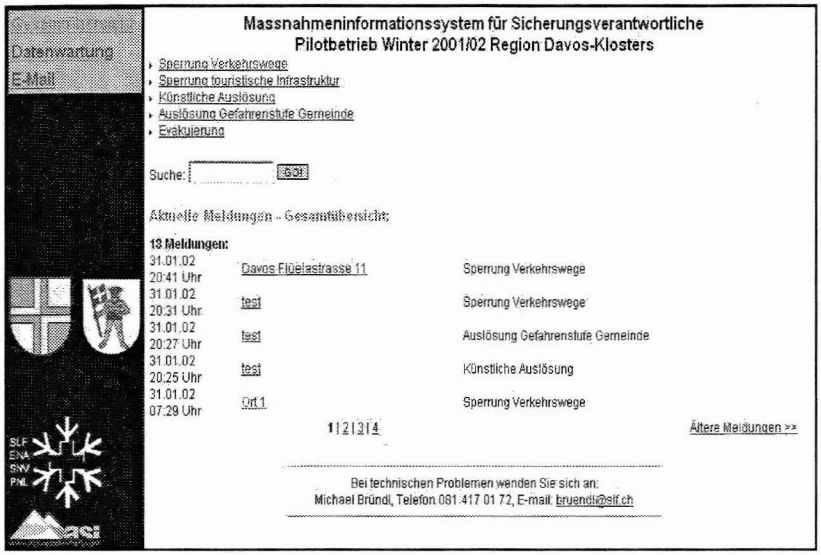

Figure 3. A part of the information platform MIS.

The system has passed a successful pilot operation in the region of Davos and and Klosters, two ski resorts in the Eastern Swiss Alps. Participating organisations were the local tourism offices, road authorities, the regional railway company, the police departments and the security services of the local ski stations. The pilot operation will be continued during winter 2002-2003. In order to guarantee an optimal information flow the MIS will be linked to local communication systems, such as the touristic information system.

The intention for future development is to include further regions. Although MISs covering different regions may be interlinked to some degree they will basically stay autonomous, reflecting the fact that even extreme avalanche crisis situations like 1999, are of local or at most regional nature concerning crisis management.

6. Conclusions and Outlook

6.1 The information system

Besides the continuous efforts to improve the forecasting quality, the emphasis in the last years has been put on the rapid and universal availability of the warning information for the users. This means that all the public platforms, such as radio/TV, phone, fax, internet, etc., are used, with the information type and content varying according to the possibilities of the platform.

In critical situations, not only the "downward" information flow from the warning service to the public and the security services is important, but also the "lateral" information exchange between the different involved services. This has become particularly clear during the avalanche winter 1999. In order to improve the situation, the following needs were identified: a) A high and education level of the involved partners, with homogeneous standards, and b) appropriate information channels. As described in this paper, SLF has focused its efforts in both direction the last years. The further development of the action information system MIS and its installation in different regions will be an important future step.

6.2 Application to other natural hazards

The snow avalanche measurement systems and warning procedures bear a high potential for other natural hazards, such as hydrological hazards, landslides, or rock fall. The extension and adaptation of the present system to other natural hazards will be an important future challenge.

7. References

Buser, O., 1983. Avalanche Forecast with the Method of Nearest Neighbours. Cold Regions Science and Technology, 8 (1983), 155-163.

Doorschot, J., N. Raderschall and M. Lehning, 2001. Measurements and one-dimensional model calculations of snow transport over a mountain ridge, *Ann. Glac.*, 32, 153 - 158.

Fierz, C. and M. Lehning. 2001. Assessment of the microstructure-based snow-cover model SNOWPACK: thermal and mechanical properties. *Cold Reg. Sci. Technol.*, 33, 123-131.

Gassner, M. , 2000. An Improved Avalanche Forecasting Program Based on the Nearest Neighbour Method. Proceedings of the 12th International Snow Science Workshop, Big Sky, Montana, USA, 2000.

Lehning, M. , Bartelt, P. Brown, B., 1998. Winter Operational Use of a Snowpack model for the avalanche warning service in Switzerland. Proceedings of the NGI, Nr. 203, 169-174.

Lehning, M., Bartelt, P., Brown, R.L., Russi, T., Stöckli, U., Zimmerli, M., 1999: Snowpack Model Calculations for Avalanche Warning based upon a new Network of Weather and Snow Stations, *Cold Reg. Sci. Technol.,* 30, 145-157.

Lehning, M., Doorschot, J., Bartelt, P., 2000: A Snow Drift Index Based on SNOWPACK Model Calculations, *Ann. Glac.,* 31, 382-386.

Lehning, M., C. Fierz and C. Lundy. 2001. An objective snow profile comparison method and its application to SNOWPACK. *Cold Reg. Sci. Technol.*, 33, 253-261.

Lehning, M. , Doorschot, J.J.J., Raderschall, N., 2002. A 3d model for snow drift and snow cover development in steep alpine terrain. Proceedings of the 13th International Snow Science Workshop, Penticton, Canada, this issue.

Margreth, S. , 2002. Winter Opening of High Alpine Pass Roads – Analysis and Case Studies from the Swiss Alps. Proceedings of the 13th International Snow Science Workshop, Penticton, Canada, this issue.

Noethiger, C.J., Elsasser, H., Bründl, M., Ammann, W.J. 2002. Indirekte Auswirkungen von Naturgefahren auf den Tourismus – Das Beispiel des Lawinenwinters 1999 in der Schweiz. Geographica Helvetica, Heft 2 (2002), 91-108.

Russi, T. , Ammann, W., Brabec, B., Lehning, M., and Meister, R. 1998. Avalanche Warning Switzerland 2000. Proceedings of the 11th International Snow Science Workshop, Sunriver, Oregon, USA, 1998.

SLF 2000. Der Lawinenwinter 1999, SLF.

SLF 2001. Offenhaltung des Gotthardpasses im Winter 2001/2002. SLF Expert Report 2001.32. Authors: S. Margreth et al.. SLF Davos.