LOCAL VERIFICATION OF THE SWISS AVALANCHE BULLETIN

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ABSTRACT: Verification is a difficult yet important part to improve avalanche forecasting. During winter 1996/97 verification activities took place for the area of Davos (approx. 200 km^2). At ISSW '96 a prototype GIS-application LAWIPROG was presented to visualise the verbal avalanche bulletin of the Swiss Federal Institute for Snow and Avalanche Research (Davos). For evaluation of the verification LAWIPROG was used.
All observed avalanches in the test area were recorded and classified. Moreover, mountain guides, ski patrol teams and private mountaineers were asked to report their observations concerning the snow pack and avalanche situation with a standardised questionnaire. The observed avalanches were introduced to the GIS-database and analysed for spatial characteristics. All this information was combined in order to estimate the „real" avalanche danger in the form of a subjective verification. LAWIPROG was enhanced with functionalities to visualise the difference between the forecasted bulletin and the effective situation verified in situ. For each bulletin a map was calculated which shows where the bulletin is either accurate, too high or too low. Additionally, the difference between bulletin and verification can be visualised using a circle diagram where variations in exposition and altitude are emphasised. Concerning only the overall hazard level, in the test area 88% of the days the bulletin and the verification matched. Tendencies in which aspects and at what altitudes the bulletin was either too low or too high can be recognised.

KEYWORDS: avalanche forecasting, GIS, verification, visualisation

1. INTRODUCTION

One task of the Avalanche Warning Service of the Swiss Federal Institute for Snow and Avalanche Research (SLF, Davos) is the publication of an avalanche bulletin. The bulletin itself provides a forecast for the next day and is only an approximation of reality. In order to improve the forecast quality of the avalanche bulletin verification techniques are required. This is not an easy task as only a minority of slopes can be evaluated for snow stability. Föhn and Schweizer (1995) describe the principal difficulties of verifying the avalanche danger, e.g. the fact that lower hazards can not be verified with observation of avalanche occurrences.

In this study the verification is based on detailed information provided by mountain guides, ski patrol teams and mountaineers. The verification activities took place during winter 96/97 for the region of Davos (Harvey, 1997). LAWIPROG was used for comparison of the bulletin and the verification. Although LAWIPROG calculates high resolution GIS maps, it is not correct to interpret the result as avalanche danger for individual slopes in the field. The national bulletin gives an overview of the distribution of the avalanche danger for a larger area.

2. DATABASE AND TECHNIQUE OF VERIFICATION

2.1 *Database*

In addition to the daily snow and weather data which are used for the bulletin the following (independent) data were collected.

- *Avalanche observations:*
  Stoffel et al. (1997) analysed the spatial distribution of avalanche activity. In a similar way avalanche observations were reported systematically by the ski patrol teams of the resorts surrounding Davos. Moreover, staff member of SLF performed special obser-

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vation tours, where also snow profile inspections and snow stability tests were done. During the verification period (winter 1996/97) 235 avalanches were observed. They were introduced to the GIS-database and analysed for spatial characteristics.

- *Subjective Assessment:*
  Mountain guides, ski patrol teams and - on a voluntary basis - private mountaineers were asked to report their observations and judgements concerning the snow pack and avalanche situation with a standardised questionnaire. 148 questionnaires were evaluated.

2.2 *Technique of verification*

Depending on the avalanche danger degree the daily amount of information varied a lot, a fact that made verification more difficult on some days than on others.

On 8 days during the whole verification period we had no additional information like questionnaires, observations or snow stability tests (e.g. 20.1.97). These days were characterised by a low hazard level (one exception) and stable weather. With the assumption of no great change on the avalanche situation the verification of these days was taken from the day before. On the other days there was always some sort of additional information (16.2.97 was a day with a lot of additional information: 5 questionnaires, 2 snow profiles, 9 observed avalanches). The verification of these days was usually done every two weeks by following steps:

1. Examination of snow and weather data and personnel notices
2. Examination of questionnaires
3. Analysis of observed avalanches
4. Analysis of snow stability tests

All expert judgements on the avalanche situation (1.-4.) were compared with each other and weighted. Finally a subjective decision was made on the supposed avalanche danger.

For the comparison of the bulletin (forecast) and the verification (supposition) the four main components were analysed and compared with each other: hazard level, aspect, altitude and slope.
Example for bulletin (B) and verification (V) (see also visualisation in Figure 1):

	Hazard level	Aspect	Altitude	Slope
B:	moderate	NW-SE	>1800	steep slopes
V:	moderate	W-SE	>2000	steep slopes

3. ANALYSIS AND EVALUATION WITH LAWIPROG

Core of the analysing process is the calculation of high resolution GIS maps (1:25'000) representing the bulletin as well as the verification. At ISSW '96 the GIS prototype LAWIPROG for the visualisation of the (verbal) Swiss avalanche bulletin was presented (Leuthold et al. 1996). LAWIPROG calculates a map which visualises either the predicted or the verified danger level. From a high resolution digital terrain model (cell size 25 m) the data for slope, aspect and altitude were derived. Together with the hazard level the critical values for aspect, slope and altitude are weighed according to expert rules and then transformed into a map by a multiplicative model. All spatial modelling is done in the raster module GRID of the GIS Software ARC/INFO.

For each day of the verification period two maps were calculated visualising the bulletin and the verification. To compare bulletin and verification the two maps were subtracted in all unique cell points, thus indicating where the bulletin is either to high or to low or where it fits the verification (Figure 1).

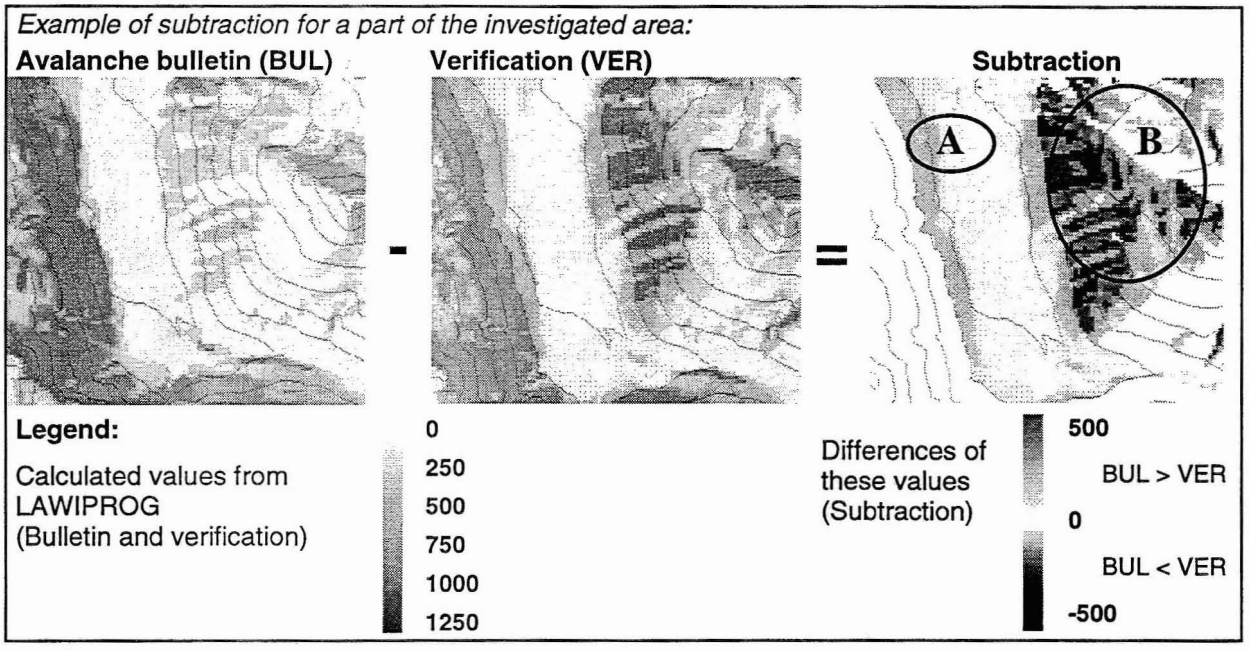

Figure 1. Comparison of bulletin (forecast) and verification (reality). The values from 0 to 1250 for bulletin and verification are calculated from a multiplicative model from LAWIPROG, Leuthold et al. (1996). Linear scale from 0 = very low danger to 1250 very high danger. Subtraction: **A** = Area where the bulletin is to high, light gray (orig.: green colour). **B** = Area where the bulletin is to low, dark gray (orig.: red colour).

All calculations were made for the map of Davos (scale 1:25'000). Red zones (dark gray) show cells were the bulletin was lower than the verification, green zones (light gray) show where it was higher. To compare the differences systematically a procedure was introduced to LAWIPROG which transfers the results of the subtraction into a circle diagram, similar to Giraud (1992) (Figure 2). The circle diagram is divided up into 16 aspects and altitudes from 1800 - 3000m and shows the differences in exposition, slope, altitude and hazard level. For the transformation the value of each cell in the circle diagram is calculated by the mean of the corresponding cells in the calculated map.

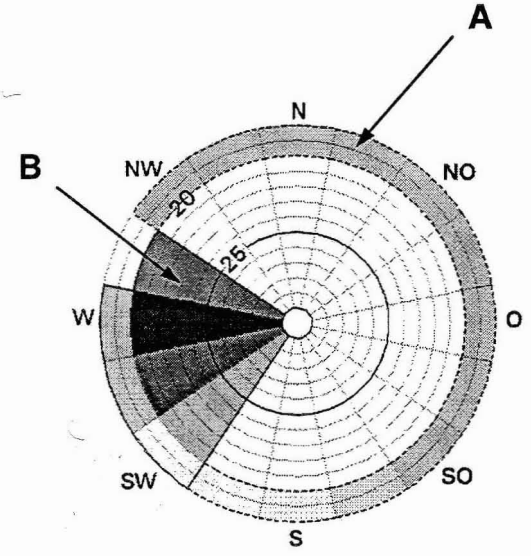

Figure 2. Circle diagram visualising the differences between bulletin and verification (the numbers describe the altitude level in hundred meters). A and B correspond to the areas in Figure 1.

4. RESULTS

For each day of the verification period (December-March) a circle diagram was generated from the calculated maps. As a result, for every day, it can be recognised which factors of the bulletin were judged wrongly and how big the difference to the verification was.

Concerning only the overall hazard level, in the test area 88 % of the days the bulletin and the verification matched (Figure 3).

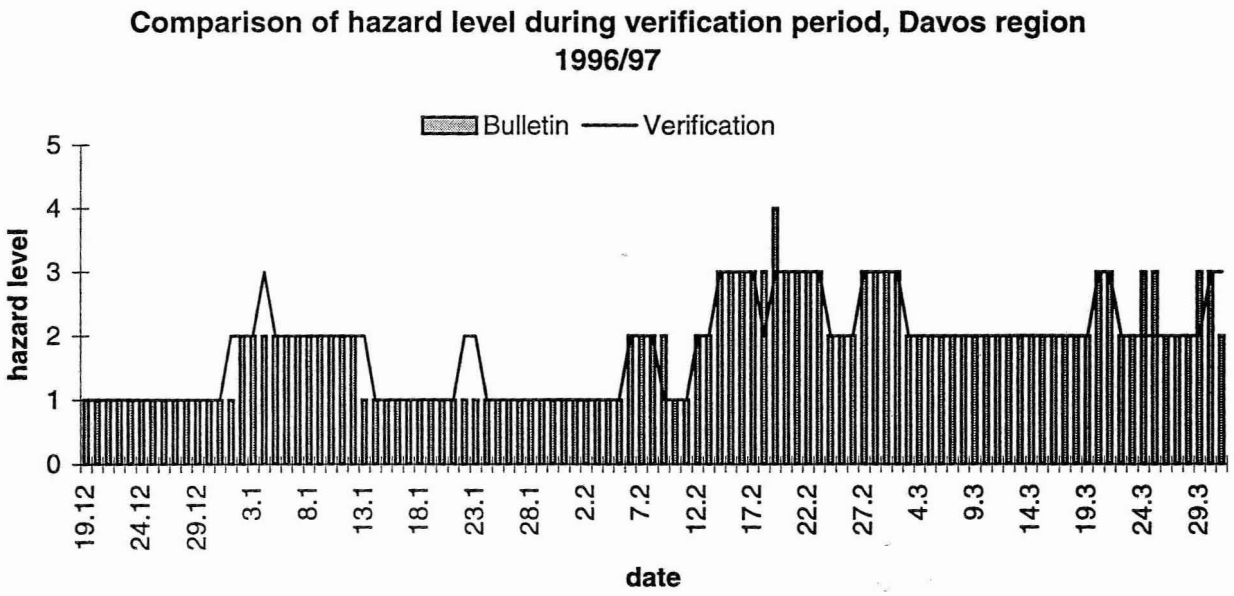

Figure 3. Hazard level in the bulletin and the verification.

Usually the comparison of bulletin and verification is done separately either for hazard level, altitude or aspect but never combined with each other. With the circle diagram we have now the possibility to compare hazard level, altitude and aspect of bulletin and verification all together. The circle diagram allows quick and easy diagnosis for forecasters where bulletin and verification did not match. A tendency of differences can be analysed: E.g. in which aspects and at what altitudes was the avalanche bulletin too high or too low?

For that purpose all circles, from days where the hazard level was the same, were added together in two groups: bulletin too high and bulletin too low. Tendencies where the bulletin was often too low during the verification period can be observed in western expositions (Figure 4, left). For altitudes below 2200 meters the bulletin was often too high (Figure 4, right).

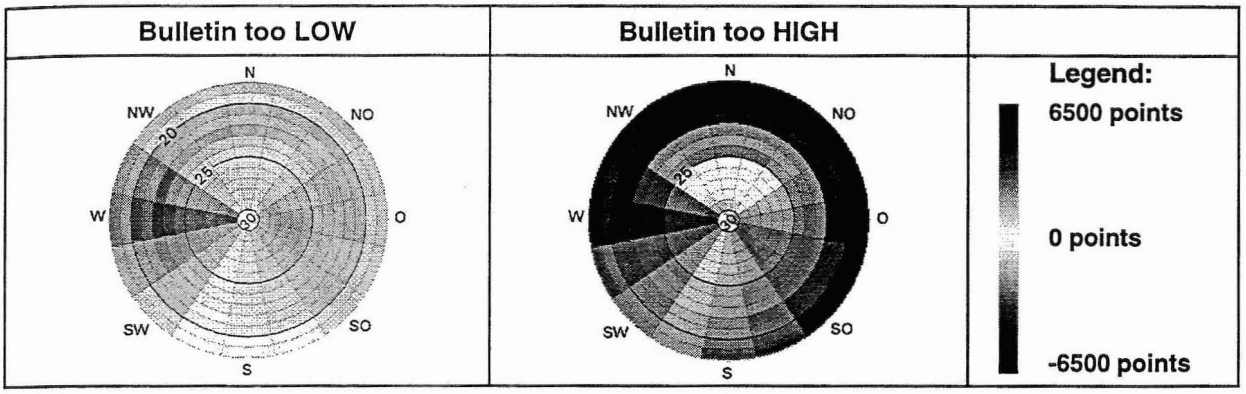

Figure 4. Added differences of all calculated values from LAWIPROG, where hazard level of bulletin and verification was equal: from days where the bulletin was too low (left) and from days where the bulletin was too high (right). The predicted bulletin describes a greater area than the verification, therefore the range for altitude and aspect can also be wider. This can be one reason for bigger differences in the circle diagram on the right.

5. CONCLUSIONS

Local verification as done in this study requires daily observations and judgements from people outside. This amount of information is only possible for relatively small investigation areas and can not be done for the whole of Switzerland. Even for the study area around Davos occasionally sparse information occurred. Although for the test area hazard levels of the bulletin and the verification often matched, the bulletin was generally too low for western aspects and too high for altitudes below 2200 m.

The extended LAWIPROG for verification offers the opportunity to visualise two different bulletins. Any difference of the four main components from the bulletin can be visualised on a map or as a circle diagram. This can support an avalanche forecaster in comparing two different types of bulletins (e.g. verified and predicted bulletin). Further, bulletins computed by hazard models can be compared with each other or with a predicted bulletin.

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7. REFERENCES

Föhn, P.M.B. and Schweizer, J. 1995. Verification of avalanche hazard with respect to avalanche forecasting. In: Proc. Int. Symposium: Sciences and mountain, Chamonix, France, May 30-June 3 1995, p151-156.

Giraud, G. 1992. MEPRA, an expert system for avalanche risk forecasting. In: Proc. ISSW, Breckenridge, Colorado, USA, 1992, p97-104.

Harvey, S. 1997. Verifikation des Lawinen-bulletins im Raum Davos (Winter 1996/97). Eine Auswertung mit GIS. Eidg. Inst. für Schnee- und Lawinenforschung, Interner Bericht Nr. 711.

Leuthold, H., Allgöwer, B., Meister, R. 1996: Visualization and Analysis of the Swiss avalanche bulletin using GIS. In: Proc. ISSW Banff, Canada, 1996, p35-40.

Stoffel, A., Meister, R., Schweizer, J. 1997. Spatial Characteristics of avalanche activity in an alpine valley - A GIS approach. In: Proc. Int. Glaciological Society, Int. Symposium on Snow and Avalanches, Chamonix, France, 26-30 May 1997, p329-336.