Verification of avalanche bulletins by questionnaires

Bernhard Brabec and Thomas Stucki
Eidgenössiches Institut für Schnee- und Lawinenforschung/Lawinenwarnung und Prävention
Flüelastrasse 11
CH-7260 Davos-Dorf

ABSTRACT

The paper describes how avalanche bulletins (regional and national) are being verified by means of questionnaires in Switzerland. At the beginning of winter 1996/97 a set of four questionnaires has been introduced:

- Questionnaire A: „Personal judgement of avalanche danger"
- Questionnaire B: „Observations of avalanches without personal or material damage"
- Questionnaire C: „Observations of avalanches with people caught but without material damage"
- Questionnaire D: „Observations of avalanches with personal and/or material damage"

About 10 000 of these questionnaires have been distributed to the public, 500 have been returned during the winter 1996/97. This means twice as many returns as for previous winters. Questionnaires B,C and D can be used for the verification of the higher hazard degrees. Questionnaire A is the most frequently returned and can be used for all degrees of hazard. Therefore it is the subject of our evaluation. The questionnaires are used on a daily basis for the construction of the bulletin if they were returned in time. Therefore we cannot talk of an independent verification in a strict sense. At the end of the winter a comparison between questionnaires and bulletins has been done. The questionnaires allow to define a degree of hazard for 8 expositions and 4 height zones (1500-2000m, 2000-2500m, 2500-3000m and >3000m). Therefore we compare a set of 32 segments of every questionnaire to the bulletin. The overall estimation for Switzerland shows that about 64% of the feedback are in agreement with the bulletin, 32% differ by 1 degree of hazard and 4% by 2. The symmetric distribution of differences indicates that the degree of hazard is neither systematically over- nor underestimated. The distribution varies heavily between regions, height levels and expositions. For the region Davos a detailed verification using additional own field observations has been done and is compared to the verification based on questionnaires.

INTRODUCTION

The verification of the avalanche danger and thus avalanche bulletins has concerned avalanche warning services for decades (Judson and King 1985; Elder and Armstrong 1986; Kindschi and Meister 1987; Föhn 1992; Remund 1993; Meister 1994; Föhn and Schweizer 1995; Meister 1996; Stucki 1996; Cagnati, Valt et al. 1997; Harvey 1997; Stucki and Brabec 1997). On the one hand the development of forecasting models has raised the need for precise target variables, on the other hand warning services want to control the quality of their bulletins. Verification has to fulfil the following requirements to be an objective method:

1. independence of the product (bulletin) to be verified
2. independence of the person doing the verification
3. independence of the number of observations available (should only influence the quality of the result)
4. independence of the region where the method is applied

None of the methods proposed by now fulfils all of the above requirements. In general avalanche hazard degrees cannot be verified objectively because they cannot be measured in the field and have no definition in physical mathematical terms that can be deduced from objective field measurements. Basically three different verification methods can be applied (Meister 1994):

1. additional measurements and field tests
2. avalanche accident analyses
3. observations by skiers

Field tests and measurements have the disadvantage that a transformation has to be found between measurement and hazard degree, e.g. an avalanche activity index has to be linked to hazard degrees. Avalanche accident analyses show that even big accidents often depend on chance occurrences. Observations of skiers include the problem of dependence from the bulletin and subjectivity of the observations. SLF has decided to continue its tradition (Kindschi and Meister 1987; Meister 1994) to keep in touch

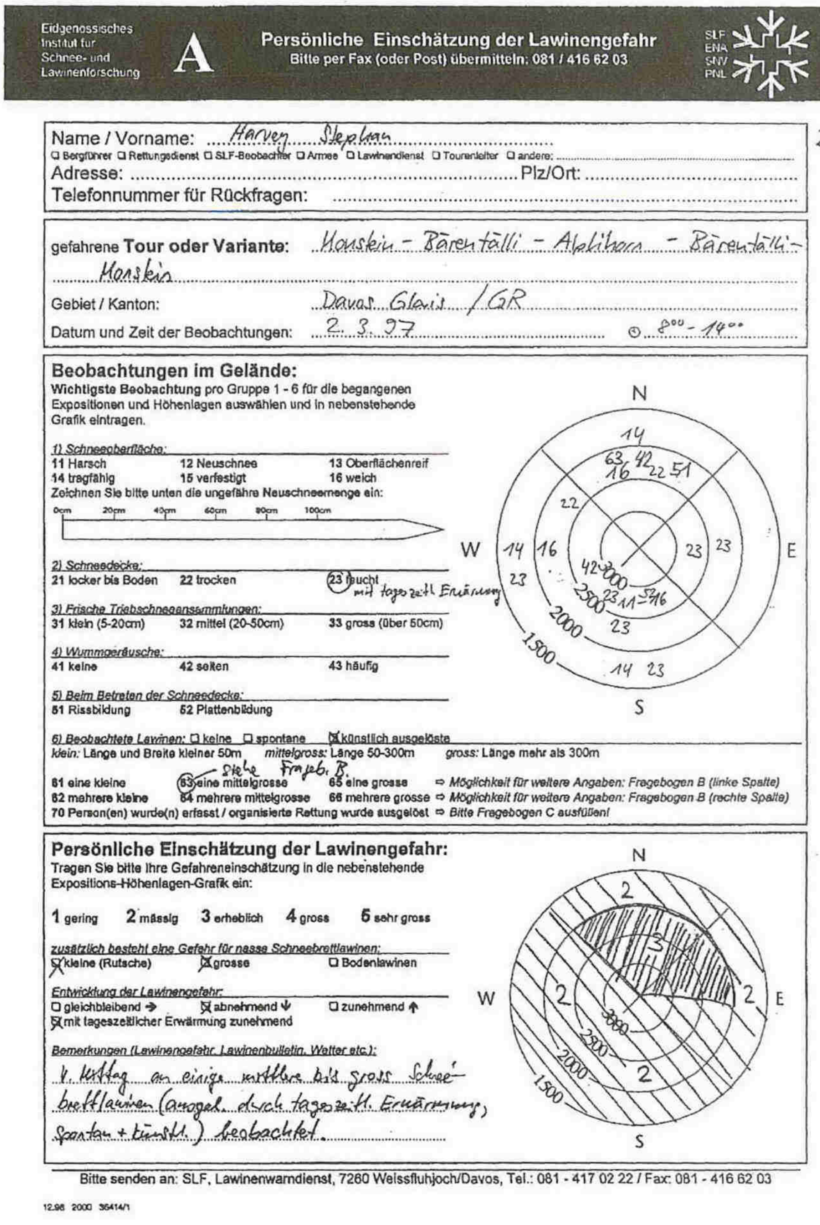
with users of avalanche bulletins and motivate them to deliver feedback to the institute in 1996. The old questionnaires have been revised and a new set of four questionnaires introduced (Stucki 1996):

- Questionnaire A: „Personal judgement of avalanche danger"
- Questionnaire B: „Observations of avalanches without personal or material damage"
- Questionnaire C: „Observations of avalanches with people caught but without material damage"
- Questionnaire D: „Observations of avalanches with personal and/or material damage"

The main goals of the new questionnaires were:

- increase of the feedback (from 190 in 1995/96)
- construction of an observer's network: People regularly making field observations are searched who fill out questionnaires on a nearly daily basis. In region 5 two such mountain guides are already in good contact with SLF.
- clear distinction between questionnaires.
- coordination with existing databases and information sources.

Questionnaires B, C and D contribute to the verification of the higher hazard levels of the European Avalanche Hazard Scale (Meister 1994). Avalanche observations alone are too rare to be used for a daily verification and cannot distinguish hazard levels „low“ and „ moderate“. Therefore this study has been based on questionnaire A.


Eidgenössisches Institut für Schnee- und Lawinenforschung

A

Persönliche Einschätzung der Lawinengefahr
Bitte per Fax (oder Post) übermitteln: 081 / 416 62 03

SLF ENA SNV PNL

249

Name / Vorname: Harvey Stephan
❑ Bergführer ❑ Rettungsdienst ❑ SLF-Beobachter ❑ Armee ❑ Lawinendienst ❑ Tourenleiter ❑ andere:
Adresse: ... Plz/Ort: ...
Telefonnummer für Rückfragen: ...

gefahrene Tour oder Variante: Monstein - Bärentälli - Alplihorn - Bärentälli - Monstein
Gebiet / Kanton: Davos Glaris / GR
Datum und Zeit der Beobachtungen: 2. 3. 97 ⌚ 8⁰⁰ - 14⁰⁰

Beobachtungen im Gelände:
Wichtigste Beobachtung pro Gruppe 1 - 6 für die begangenen Expositionen und Höhenlagen auswählen und in nebenstehende Grafik eintragen.

1) Schneeoberfläche:
11 Harsch 12 Neuschnee 13 Oberflächenreif
14 tragfähig 15 verfestigt 16 weich
Zeichnen Sie bitte unten die ungefähre Neuschneemenge ein:
0cm 20cm 40cm 60cm 80cm 100cm

2) Schneedecke:
21 locker bis Boden 22 trocken (23) feucht mit tageszeitl. Erwärmung

3) Frische Triebschneeansammlungen:
31 klein (5-20cm) 32 mittel (20-50cm) 33 gross (über 50cm)

4) Wummgeräusche:
41 keine 42 selten 43 häufig

5) Beim Betreten der Schneedecke:
51 Rissbildung 52 Plattenbildung

6) Beobachtete Lawinen: ❑ keine ❑ spontane ☒ künstlich ausgelöste
klein: Länge und Breite kleiner 50m mittelgross: Länge 50-300m gross: Länge mehr als 300m
61 eine kleine (63) eine mittelgrosse – siehe Frageb. B. 65 eine grosse ⇨ Möglichkeit für weitere Angaben: Fragebogen B (linke Spalte)
62 mehrere kleine 64 mehrere mittelgrosse 66 mehrere grosse ⇨ Möglichkeit für weitere Angaben: Fragebogen B (rechte Spalte)
70 Person(en) wurde(n) erfasst / organisierte Rettung wurde ausgelöst ⇨ Bitte Fragebogen C ausfüllen!

N W E S
14 63 42 16 22 51 22 14 16 23 23 23 42 3000 2500 23 11 - 51 16 2000 23 1500 14 23

Persönliche Einschätzung der Lawinengefahr:
Tragen Sie bitte Ihre Gefahreneinschätzung in die nebenstehende Expositions-Höhenlagen-Grafik ein:

1 gering 2 mässig 3 erheblich 4 gross 5 sehr gross

zusätzlich besteht eine Gefahr für nasse Schneebrettlawinen:
☒ kleine (Rutsche) ☒ grosse ❑ Bodenlawinen

Entwicklung der Lawinengefahr:
❑ gleichbleibend → ☒ abnehmend ↓ ❑ zunehmend ↑
☒ mit tageszeitlicher Erwärmung zunehmend

Bemerkungen (Lawinengefahr, Lawinenbulletin, Wetter etc.):
... spontan + künstl.) beobachtet.

N W E S
2 3 2 2 2 3000 2500 2000 1500

Bitte senden an: SLF, Lawinenwarndienst, 7260 Weissfluhjoch/Davos, Tel.: 081 - 417 02 22 / Fax: 081 - 416 62 03

12.96 2000 36414/1

Figure 1: NR 249 of Questionnaire A.

DESCRIPTION OF QUESTIONNAIRE A

Questionnaire A is used for sending observations made in the field to SLF. A second part of the questionnaire (see lower part of figure 1) is used for the personal judgement of the avalanche hazard. Observations and hazard levels can be defined for 4 height levels (1500-2000m, 2000-2500m, 2500-3000m and >3000m) and 4 expositions (N,E,S,W). Several users have used 8 expositions (NNE, ENE, ESE, SSE, SSW, WSW, WNW, and NNW). An additional part at the top of the questionnaire contains administrative data about the person (including her profession) and about the tour done.

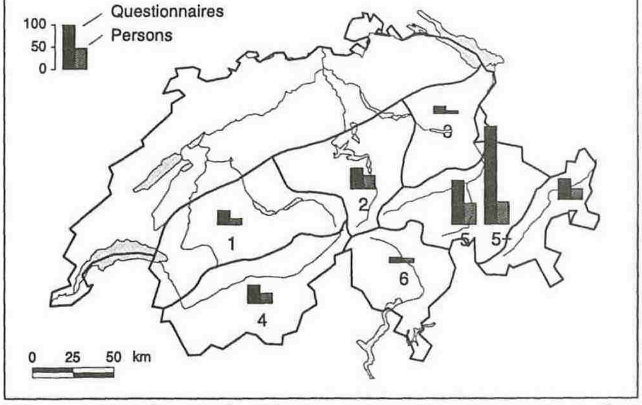


Figure 2: Regional distribution of questionnaires A send to SLF: for region 5 117 questionnaires sent in by 3 mountain guides have been taken out. Region 5+ contains those as well.

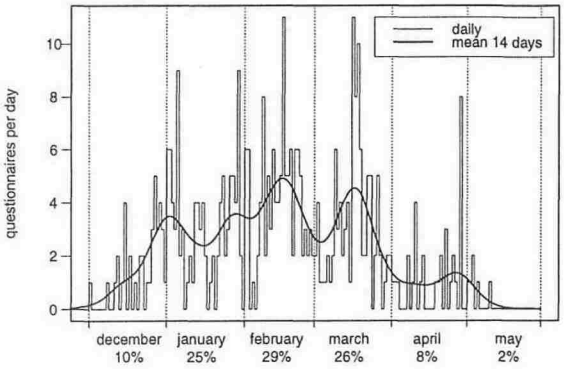


Figure 3: Temporal distribution of feedback.

FEEDBACK

During the winter 1996/97 about 10000 questionnaires (A-D) have been ordered at SLF and distributed. About 500 of those were sent back till the end of the winter by skitourists, mountain guides and avalanche safety personnel. Although this means that only 5% of the disseminated questionnaires came back, the amount of questionnaires has been doubled compared to the winter before. At the beginning of the campaign in 1987 (Kindschi and Meister 1987) 44 sheets have arrived at SLF.

Figures 2 and 3 show the temporal and spatial distribution of questionnaires A returned, all together 388 out of 4000. The first feedback arrived on the 1st of December, the last on the 10th May. During these 121 days 106 persons participated in the campaign. On 44 days there was no feedback. Motivation to send in a questionnaire seems to increase with higher hazard levels.

COMPARISON TO BULLETIN

The comparison between avalanche bulletins and questionnaires was done in two steps:

1. On a daily basis the information given in the questionnaires was used for the construction of the next bulletin if they were sent back in time. Therefore the questionnaires and the bulletin are not independent. On the other hand the bulletin is also used for planning a tour and therefore influences people.
2. At the end of the winter a statistical comparison between questionnaires and bulletin was done which is discussed in the following part.

To compare the questionnaires to the avalanche bulletins published by SLF during the winter 1996/97 a common data structure for questionnaires and bulletins had to be defined. Therefore the questionnaires as well as the bulletins were registered in a relational database. In the Swiss avalanche bulletin only the highest hazard degree is given for a specific region and day. Height and exposition of the most critical terrain parts are defined in addition, e.g. for the example of figure 1 the avalanche bulletin was hazard degree considerable for expositions from West to Southeast higher than 1800 meters (see figure 4). For

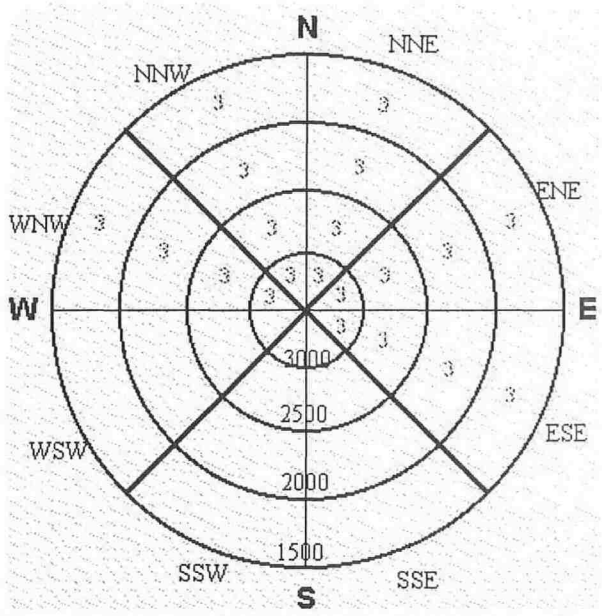


Figure 4: Avalanche bulletin for the questionnaire of Figure 1: hazard level considerable (3) for expositios from West to Southeast above 1800 meters. The segments are equal defined as for the questionnaires.

questionnaires it is not unlikely to have more than one hazard degree.

For the comparison between bulletin and questionnaires two distance measures were defined.

d1: For each of the 32 segments (8 x 4) the difference is calculated if both segments are defined, e.g. for questionnaire NR. 249 of figures 1 and 4 (see table1).

Table 1: Distance measure d1 for example NR 249

N.A. stands for NOT AVAILABLE

exposition	height	bulletin	quest.	d1
NNE	1500-2000	3	2	1
ENE	1500-2000	3	2	1
ESE	1500-2000	3	2	1
SSE	1500-2000	N.A.	2	N.A.
SSW	1500-2000	N.A.	2	N.A.
WSW	1500-2000	N.A.	2	N.A.
WNW	1500-2000	3	2	1
NNW	1500-2000	3	2	1
NNE	2000-2500	3	3	0
ENE	2000-2500	3	3	0
ESE	2000-2500	3	2	1
SSE	2000-2500	N.A.	2	N.A.
SSW	2000-2500	N.A.	2	N.A.
WSW	2000-2500	N.A.	2	N.A.
WNW	2000-2500	3	2	1
NNW	2000-2500	3	3	0
NNE	2000-2500	3	3	0
ENE	2000-2500	3	3	0
ESE	2000-2500	3	2	1
SSE	2000-2500	N.A.	2	N.A.
SSW	2000-2500	N.A.	2	N.A.
WSW	2000-2500	N.A.	2	N.A.
WNW	2000-2500	3	2	1
NNW	2000-2500	3	3	0
NNE	>3000	3	3	0
ENE	>3000	3	3	0
ESE	>3000	3	2	1
SSE	>3000	N.A.	2	N.A.
SSW	>3000	N.A.	2	N.A.
WSW	>3000	N.A.	2	N.A.
WNW	>3000	3	2	1
NNW	>3000	3	3	0

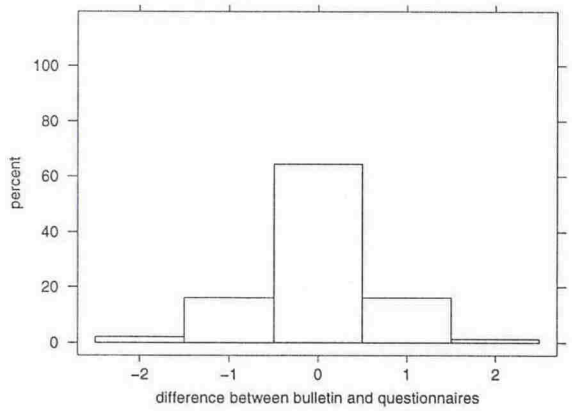


Figure 5: Comparison between avalanche bulletin and questionnaires for d1. 2210 segments could be evaluated. 64% of the questionnaires are in agreement with the avalanche bulletin. The amount of over- and underestimation is about 18%.

Note that for the evaluation 8 expositions and 4 height levels are used. The numbers 1 to 5 are assigned to hazard degrees low to very high. The distance measure allows to distinguish between different expositions and heights but has the disadvantage that questionnaires do not contribute equally to statistics, e.g. questionnaires completely different from the bulletin (no segments equal) get completely lost. Questionnaire NR 249 contributes with 9 segments having difference 0 and 11 segments having difference 1 to statistics.

d2: Equally to the bulletin for each questionnaire only the highest hazard level is counted and compared. Thus questionnaires contribute equally but one extreme segment changes the result. For questionnaire NR. 249 we get a difference d2 of 0. The information of

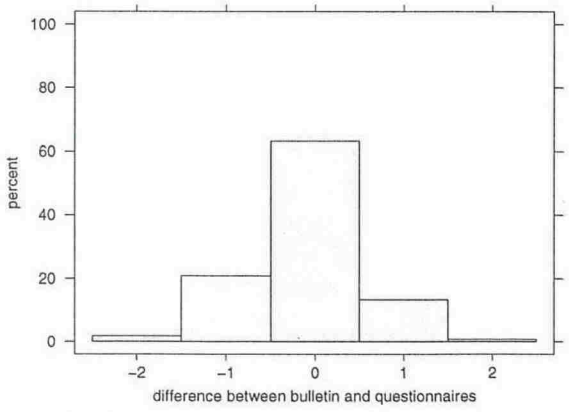


Figure 6: Comparison between avalanche bulletin and questionnaires for d2. 388 questionnaires could be evaluated. 63% are in agreement, 23% indicate underestimation and 14% overstimation of the hazard degree in the bulletin.

exposition and height gets lost.

The two distance measures have been applied to the complete uncorrected dataset. Figures 5 and 6 show the results. The symmetric distribution shown in figure 5 indicates that the bulletin is in $^2/_3$ of the time in agreement

Table 2: regional variability of feedback cursive numbers mark regions with little feedback (<30 questionnaires)

Region			*underestimation*		*agreement*		*overestimation*	
#segm		*#quest*	*of the avalanche bulletin*					
			d1 %	*d2 %*	*d1 %*	*d2 %*	*d1 %*	*d2 %*
1	*101*	*28*	*36*	*18*	*55*	*53*	*9*	*29*
2	240	42	12	12	70	76	18	12
3	*61*	*14*	*26*	*36*	*70*	*57*	*4*	*7*
4	250	38	25	29	48	50	27	21
5 +	1240	210	13	21	71	68	16	11
6	*71*	*10*	*20*	*30*	*48*	*60*	*32*	*10*
7	10	42	33	33	49	50	18	17

with user opinion and that the estimation is neither to high nor too low. Figure 6 shows a similar amount of agreement but the distribution is skewed towards underestimation. This graph is similar to the results from 1987 (Kindschi and Meister 1987) concerning the agreement but different concerning the skewness. In 1987 25% of the questionnaires indicated overestimation, 15% underestimation. The agreement for single regions (see figure 1 and table 2) varies between 48 and 76%. The difference between d1 and d2 is the higher the less questionnaires have been returned for a region (table 2). For different heights and expositions the results varied a lot because the amount of feedback was

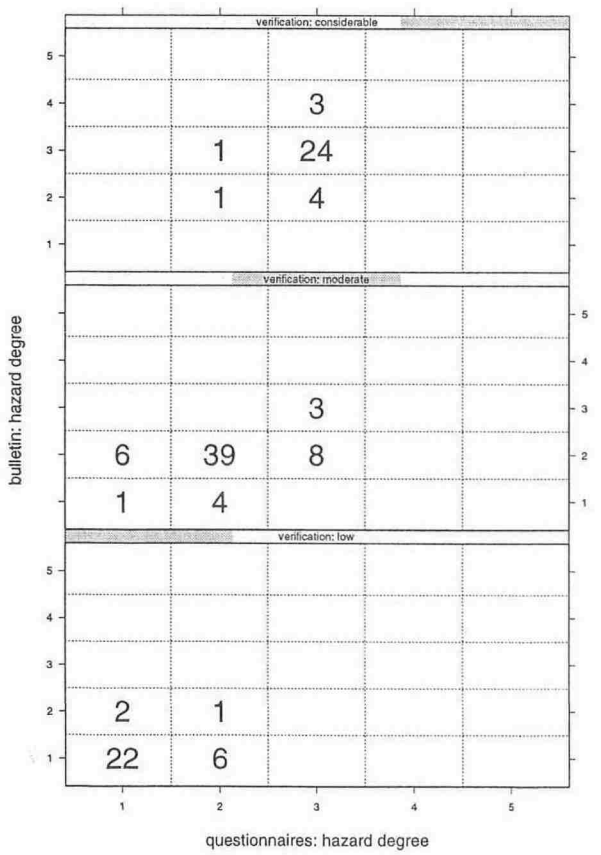


Figure 7: Comparison between bulletin, questionnaires and verification. Each subgraph contains all questionnaires of one hazard degree of the verification. Verification increases from low to considerable from bottom to top.

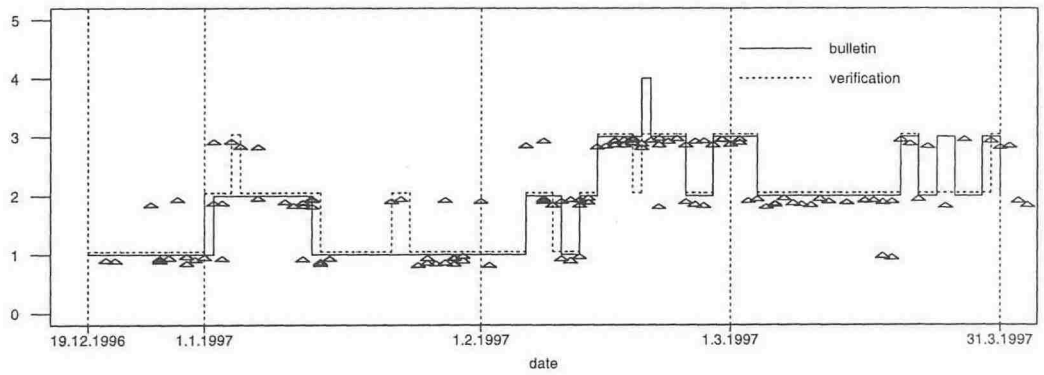


Figure 8: Bulletin and verification in Davos; triangles indicate questionnaires

often very small.

REGIONAL COMPARISON FOR DAVOS

For Davos, where SLF is situated, Harvey (Harvey 1997) has verified the avalanche hazard every day using data from observers, automatic stations, snow profiles, observed avalanches, personal contacts, questionnaires A and B and his own judgement between December 21st 1996 and march 31st 1997. This verification has been compared to the national bulletin and the questionnaires of the area (130). Distance was measured using d2. Figure 7 shows the difference between questionnaires and bulletin given the verification. Figure 8 shows verification and bulletin in a timeseries-graph. Each questionnaire is represented by an overlaid symbol.

Figures 7 and 8 show that questionnaires can be used as a rough indication of a verification but that they are not sufficient: On the one hand questionnaires vary around verification in each of figure 7's subgraphs, on the other hand Figure 8 shows situations where questionnaires are in contradiction to verification, e.g. 18th February. Therefore field tests have to complement them.

CONCLUSIONS

The proposed questionnaires are a useful mean to get feedback to an avalanche bulletin from skitourists, mountain guides and avalanche safety personnel. In Switzerland questionnaires have become increasingly important also during bulletin construction during the last 10 years and a network of observers sending in questionnaires is under construction. The aposteriori verification of hazard degrees by questionnaires would be possible if questionnaires were filled out perfectly, hazard level assignment an objective task and the questionnaires not used for bulletin construction.

REFERENCES

Cagnati, A., M. Valt, et al. 1997. A field method for avalanche danger level verification. *International Symposium on Snow and Avalanches, Chamonix.*

Elder, K. and B. Armstrong 1986. A quantitative approach for verifying avalanche hazard ratings. *Davos Symoposium, Davos, IAHS.*

Föhn, P. M. B. 1992. Stability evaluation for a sloping snowpack. *European summer university - Snow and avalanches, Chamonix.*

Föhn, P. M. B. and J. Schweizer 1995. Verification of avalanche danger with respect to avalanche forecasting. *Int. Symposium: Sciences and mountain - The contribution of scientific research to snow, ice and avalanche safety, Chamonix.*

Harvey, S. 1997. Verifikation des Lawinenbulletins im Raum Davos (Winter 1996/97)
Eine Auswertung mit GIS, *Eidg. Institut für Schnee- und Lawinenforschung.*

Judson, A. and R. M. King 1985. An Index of Regional Snow-pack stability based on natural slab avalanches. *Journal of Glaciology* 31(108): 67-73.

Kindschi, J. and R. Meister 1987. Positives Echo auf die Aktion "Lawinenbeobachtung". *Die Alpen* 63(11): 462-463.

Meister, R. 1994. Country-wide avalanche warning in Switzerland. *International Snow Science Workshop, Snowbird*, Utah.

Meister, R. 1996. Das Lawinenbulletin und seine Aussagemöglichkeiten. *Schnee- und Lawinenforum, Davos, Eidgenössisches Institut für Schnee- und Lawinenforschung.*

Remund, J. 1993. Verifikation der regionalen Lawinengefahrenprognose. ETH Zürich.

Stucki, T. 1996. Neue Fragebogenreihe des SLF. *Die Alpen*(11): 29-31.

Stucki, T. and B. Brabec 1997. Fragebogenaktion des SLF. *Die Alpen* 12/1997d: 17-19.