PREDICTING THE AVALANCHE DANGER LEVEL FROM FIELD OBSERVATIONS

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ABSTRACT: As public avalanche forecasts are done for large regions, backcountry travelers cannot simply rely on the bulletin as local conditions may be different from the forecasted level of danger. It is therefore imperative for backcountry travelers to make their own observations and assess the hazard. This procedure is equivalent to verifying the danger level. During the last eight winters 312 field observations including a snow profile with a stability test, observations on snow surface quality, drifting snow, signs of instability, avalanche activity, and an estimate of the local danger level were made by experienced researcher and forecasters near Davos (Switzerland). We preliminarily analyzed whether the danger level can be estimated based on the occurrence of signs of instability. Whereas the danger level 'Considerable' was frequently associated with whumpfs, shooting cracks and recent avalanching, the analysis revealed that the danger level can rarely be determined based on these observations only. For example, a whumpf is neither a necessary nor a sufficient condition for the danger level 'Considerable' – but of course still a serious sign of instability. With additional information, in particular from the snowpack, a better discrimination between the danger levels seems possible.

1. INTRODUCTION

The avalanche danger prevailing in a region cannot be measured, but estimated at best. Estimates of regional avalanche danger are fairly accurate. Depending on – among other things – the size of the forecast area the regional avalanche forecast is probably correct in 60-90% of the time (e.g. Jamieson et al., 2006) – though 'correct' is not the right word in our context. As we cannot measure the avalanche danger, we can also not accurately verify the forecast. Nevertheless, as the forecasted danger does not always match the actual conditions, it is imperative for backcountry travelers to make their own observations and either assess whether the forecasted danger level (public bulletin) is right or, if no public bulletin exists, estimate the danger level independently. If recreationists are not capable of making their own assessment, they need to consider a wider margin of safety.

After a day of backcountry travel, experienced professionals often know quite well whether the forecast was right or not. They seem to have a pattern in their mind of, for example, what's 'Considerable' danger. If all the observations fit one of the memorized patterns, that one is the corresponding danger level. But, what are the key observations? Can we reliably estimate the danger level based on a few simple observations? For example, if a skier triggers a whumpf, this is an indication that a skier might trigger an avalanche. Skier triggered avalanches are often observed when the danger level is 'Considerable'. Spontaneously releasing slab avalanches are typical for the danger level 'High' (e.g. Jamieson et al., 2009; Schweizer, 2003). On the other hand, if no such signs of instability are observed, is the danger level necessarily 'Moderate' or 'Low'? In fact, previous research on verifying the regional danger level suggested that the danger levels 'Moderate' and 'Low' can only be verified by several snow stability tests (Schweizer et al., 2003).

Jamieson et al. (2009) explored the relation between simple field observations and the local danger level. One of their classification trees predicted 'Considerable' danger if either recent slab avalanching, shooting cracks or whumpfs were observed on a day when the regional forecast was 'Considerable'. A similar analysis using snowpack observations revealed that whereas the stability test scores were correlated with the verified danger level, the regional forecast was still a better predictor than any single stability test (Bakermans et al., 2010).

Recently, Munter (2009) presented a checklist type of tool that allows one to estimate the danger level based on 20+ observations.

The aim of this study is to characterize the danger levels 'Low', 'Moderate' and 'Considerable' based on a few observations and hence to preliminary assess whether these danger levels can be predicted based on a well defined, limited number of observations.

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2. DATA AND METHODS

In the winter of 2001-2002 we started to complement a snow profile record with observations that should facilitate the interpretation of the profile in the context of operational forecasting. These observations were initially entered into a generic text field and included specific, additional information on:

1) Profile site,
2) Snow cover characteristics at profile site, and
3) Stability test results;

furthermore observations made on the way to and from the profile location on:

4) Snow surface properties,
5) Drifting snow,
6) Whumpfs and shooting cracks, and
7) Recent avalanche activity; and finally an
8) Estimate of the local avalanche danger.

For the present study, we have compiled 312 profiles from the SLF snow profile database. Profiles to be selected had to be complete and recorded by an experienced observer; and snow conditions had to be dry.

Almost 90% of the profiles were collected near Davos (Switzerland). All profiles were observed on slopes (modal aspect: north, median slope angle: 34°, median elevation: 2465 m a.s.l.) and included snow stratigraphy (grain type and size, snow hardness index), observed according to the ICSSG (Fierz et al., 2009), snow temperature and a rutschblock test (RB) (e.g. Schweizer, 2002).

Profiles were classified into profile type and stability according to Schweizer and Wiesinger (2001). Furthermore, the threshold sum, the RB score and RB release type were combined to yield an alternative estimate of point stability (Schweizer et al., 2008).

In the present analysis we will only consider the presence or absence of whumpfs, shooting cracks, and recent avalanching (<24h), and the local danger estimate. For analysis, intermediate values of the local danger were rounded to the next full danger level (e.g. 2- to 2: Moderate, 2-3 to 3: Considerable, 3+ to 3). Finally, the dataset was completed with the regional danger level as forecasted in the public bulletin. This rating was occasionally not available since observations were made in early winter before the bulletin period started.

3. RESULTS

The dataset was fairly well balanced in respect to stability and local danger estimate. Observers rated the danger level in 25% as 'Low', in 40% as 'Moderate', in 33% as Considerable' and in 2% as 'High'.

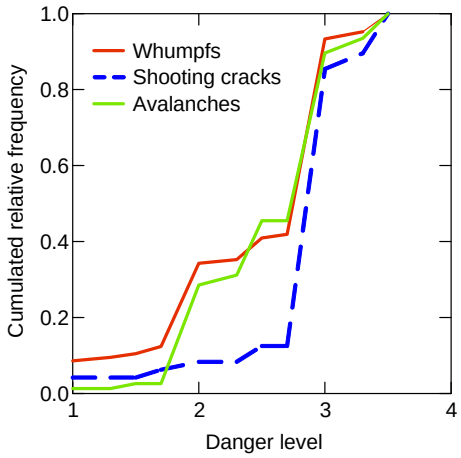

Figure 1: Cumulated relative frequency of whumpfs, shooting cracks and recent avalanching vs. avalanche danger.

The frequency of whumpfs, shooting cracks and recent avalanching were significantly different for the various danger levels (Figure 1).

Whumpfs were observed on about one third of the days. In two thirds of those cases the danger estimate was 'Considerable' or higher; in 27 out of 105 cases it was 'Moderate', and in about 10% of the cases it was 'Low'.

On only 15% of the days shooting cracks were reported. On those 48 days, observers rated the avalanche danger as 'Considerable' or higher in 92% of the cases. On two days each, they estimated the danger as 'Low' or 'Moderate'.

Slab avalanches within the last 24 hours were reported on 77 days. The danger rating on those days was 'Low' on 1 day, 'Moderate' on 23 days (30%), and 'Considerable' or higher on the remaining 53 days (69%).

On the other hand, when the danger was rated as 'Considerable' (or higher), whumpfs were observed on 63%, shooting cracks on 41%, and avalanches on 49% of the days (Table 1). On days when the danger was rated as 'Moderate', whumpfs were triggered on 22% of the days, shooting cracks were rare (<2%), and avalanches were observed on about every fifth day (18%). When observers rated the danger as 'Low', they still recorded occasionally whumpfs (on 13% of the days), but very rarely shooting cracks or avalanches (on 2 days and on 1 day, respectively).

All three signs of instability were most frequently observed when the danger level was rated 'Considerable'.

Table 1: Frequency of signs of instability for the danger levels 1 to 4

Danger level	*N*	Whumpfs	Shooting cracks	Avalanches
1: Low	79	13%	2.6%	1.3%
2: Moderate	125	22%	1.6%	18%
3: Considerable	103	63%	41%	49%
4: High	5	100%	100%	100%

1-10% very unlikely, 11-33% unlikely, 34-66% about as likely as not, 67-90% likely, >90% very likely

However, the absence of these signs was not related to a single danger level. In the case of no signs of instability, the danger level is likely (about 90%) not 'Considerable', but lower – how low cannot be concluded. A preliminary analysis with a different dataset using the forecasted danger level has shown that the uncertainty might well be higher (about 15-25%). Therefore strictly downgrading the danger level from 'Considerable' to 'Moderate' simply based on the absence of whumpfs (or other signs of instability), cannot be recommended based on our preliminary analyses.

The two types of stability variables and the RB score were all three significantly ($p < 0.0001$) negatively correlated with the local danger level: -0.53, -0.41. -0.40.

If the stability, or more generally the existence of a potentially critical weak layer, was considered, the danger level 'Low' could be characterized. If there were no signs of instability and no critical weakness ('good' or 'very good' stability), the danger level was 'Low'. However, the classification accuracy for this danger level was only 55%.

4. CONCLUSIONS

In terms of classifying (or verifying) the danger level based on signs of instability, we can only make the following two conclusions:

1) If shooting cracks are observed, the danger level is 'Considerable'.

2) If no signs of instability are observed, the danger level is likely either 'Moderate' or 'Low'.

The uncertainty for the second conclusion is higher than for the first one. Observing a whumpf only does not allow one to conclude that the danger level is 'Considerable' as in more than one third of the cases the danger was rated as 'Moderate' or even 'Low'. However, when a whumpf in combination with recent avalanching was observed, the danger level was often (84%) rated as 'Considerable'. To differentiate between the danger levels 'Low' and 'Moderate' other observations preferable on snowpack layering or stability are required. Overall, for our dataset, on only 15% of the days (when shooting cracks were observed) the danger level could be estimated based on signs of instability.

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