Avalanche Danger Patterns – a new approach to snow and avalanche analysis

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ABSTRACT: In recent years, backcountry winter sports far removed from secured ski slopes have undergone a surprising upsurge. Connected with this boom are heightened challenges for the individual avalanche warning services to generate up-to-date warnings and publish them via modern information technology. On a parallel track, the unified and standardized European Avalanche Danger Scale has devised a variety of decision-making strategies which enable users to rapidly make a decision for or against a given undertaking in outlying terrain.

An additional innovative development now thrusts the importance of classic snow and avalanche analysis back onto center stage: the concept of so-called 'Avalanche Danger Patterns'. By that is meant that a specific overall situation, i.e. a certain combination of natural factors, is the direct cause of avalanche risk. In other words: a clearly defined weather situation leads to distinct and clear-cut effects in the snow layering, which in turn lead to a corresponding threat of avalanches.

In Tyrol we have been working with 'The 10 decisive danger patterns' for three years now. The idea of danger patterns is the perfect counterpart to a variety of decision-making strategies and has already received an overwhelming echo of popular approval, ensuring that these patterns will continue in the future to play an important part in our daily avalanche forecasts.

KEYWORDS: danger pattern, threat of avalanches, danger level, avalanche bulletin, avalanche warning service

1 INTRODUCTION

In 1993, after years of intense talks and ongoing consultations, the European Avalanche Danger Scale was perfected to its final form and introduced to the public (Mair 1998).

In the years which followed, a number of decision-making strategies were devised based on this danger scale, e.g. the reduction method of Munter, 'stop or go' method of the Austrian Alpine Club, snowcard of the German Alpine Club. These strategies found quick acceptance and are used daily by many people (Mair, 2004). However, one particular shortcoming was pointed out again and again, particularly by experienced winter sports participants and pros: that when such strategies are consistently applied, the themes of 'snow' and personal observations receive far too little attention.

The Avalanche Warning Service of Tyrol holds about 50 lectures each winter, given by a wide range of experts, e.g. mountain guides, mountain rescue squads, ski instructors, students, younger pupils, backcountry ski tourers, snowboarders, freeriders, etc.

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One question repeatedly gets posed, namely whether simply coupling of a day's danger level to the orographical factors, e.g. slope direction and gradient, plus details relating to participants, e.g. size of group, distance maintained between skiers, how heavily frequented the given slope is, is not in the end too short-sighted. In particular the danger level published for any given day in the avalanche bulletin was frequently thought to be used as a method of exerting pressure upon potential sports participants (Mair 2008).

2 THE IDEA OF DANGER PATTERNS

Out of this dilemma, backed up by the long-ranging experience of 25 years working in the avalanche warning service, including analysis of hundreds of avalanche accidents, a new idea was born:

Avalanche accidents rarely are coincidences. In most cases by far, the course of events is clearly predictable: the weather leads to the snow layering; the snow layering leads to the avalanche situation; the consequences are avalanche accidents utterly typical of that given situation. Behind this process, a certain scheme is always at work, in other words a 'pattern' prevails, a recognizable combination of factors.

The next step in the process was the attempt to typecast such 'avalanche danger patterns'. The red thread through the complex variations was the normal unfolding course of a winter season, from the first snowfall in early winter to snowmelt in springtime.

The question which had to be answered was: what was the classic, expected danger pattern at each given point of time in the season? The answers ultimately crystalized into 10 danger patterns, which were subsequently published in the book “Avalanche - recognizing the 10 decisive danger patterns’ (Mair and Nairz 2010). In the following parts of this paper, the term ‘danger pattern’ will be abbreviated as ‘gm’ (from the German term ‘Gefahrenmuster’).

There was also an additional question which was fascinating, namely, how frequently did a certain danger pattern occur in the course of a winter? That, in turn, revealed how ‘urgent’ it was. Through the analysis of hundreds of avalanche accidents over a quarter of a century, 5 danger patterns emerged in a descending scale of frequency, in which gm.5 (snowfall after a long period of cold) was responsible for 25% of all avalanche events down to gm.9 (graupel covered with snow) responsible for only 2% (see figure 1).

In order to present danger patterns in the best possible light, we made everything as easy as possible to grasp at a quick glance and very close to real life practice. Thus each single gm is defined as simply and clearly as possible in terms of of physical-snow, then associated to its seasonal and altitude-specific occurrence, and illustrated with striking examples of accidents. The overall picture is then rounded out by a number of practical tips.

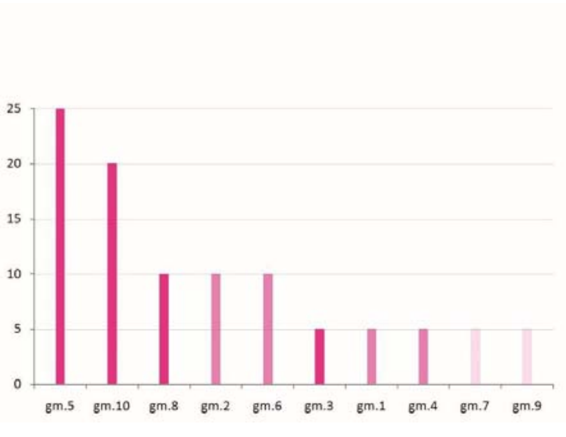

Figure 1. The immediacy of individual danger patterns (frequency of occurrence as percentage of avalanche events)

3 THE TEN AVALANCHE DANGER PATTERNS IN DETAIL

3.1 gm.1 Early winter, ground-level hoar

(Please note: this pattern was originally called ‘The second snowfall’, but since it can also occur later in winter it has been re-named).

This pattern addresses the highly frequent occurrence when there are rather light spells of initial snowfall in late autumn and early winter. The snow tends to remain on the ground particularly on shady slopes due to the low air temperature and increasingly transforms to faceted crystals or depth hoar.

A classic weak layer is thereby formed for subsequent snowfall. This element, which is very trigger-sensitive inside the snowpack, can also be the cause of avalanches later in winter, especially when in springtime the upper layers of the snowpack become thoroughly wet. In principle, there are but two relevant layers inside the snowpack: the lowermost weak layer and the bonded snow on top of it (see figure 2).

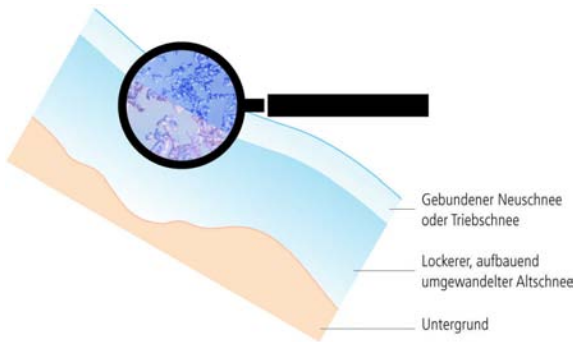

Figure 2. Depth hoar near the ground from early winter, covered over with bonded snow

3.2 gm.2 Gliding snow

The most important feature of full depth snowslides is the lack of a weak layer; the entire snowpack glides along the surface of the earth. The essential factor is a smooth ground surface, e.g. grass-covered slopes, a slope gradient of more than 20% and water in liquid form, i.e. temperatures around 0° at the point of contact between earth surface and snow.

Full depth snowslides have another unusual feature, namely, the moment of their release is extremely difficult to predict and they cannot be artificially triggered. As indicator for the pending threat of full depth snowslides, so-called glide-cracks, fishbone-shaped openings in the snow surface, tend to form (see figure 3).

Figure 3. Glide cracks announce the threat of full depth snowslides

3.3 gm.3 Rain

Rainfall numbers among the classic alarm signals in snow and avalanche analysis. After long periods of rainfall, the avalanche danger always increases. On the one hand, rain adds great weight to the snowpack; on the other, the rainwater destroys the crystal bonding inside the snow cover and its firmness thus decreases.

One advantage of this gm is that rain can be easily recognized by non-experts. In addition, the situation generally tends to stabilize rather swiftly, in case the temperatures drop after the rain comes to an end. Rainfall can occur in all aspects, obviously more often at lower altitudes (see figure 4).

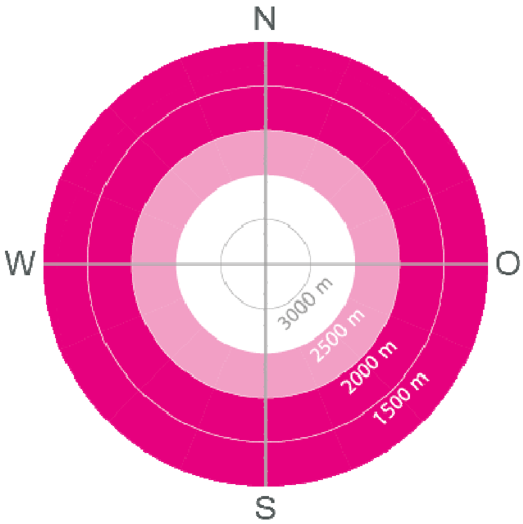

Figure 4. Rainfall is a problem in all aspects, at lower altitudes in particular

3.4 gm.4 Cold after warm / warm after cold

This danger pattern numbers among the syndromes which are more complex. What is meant is that either cold new fallen snow gets deposited on top of a relatively warm old snow-pack; or relatively warm snow falls atop a cold old snowpack. In both cases it leads to large thermal gradients and movement of water vapor inside the snowpack which in turn favour the formation of faceted, unbonded snow crystals. In other words, the treacherous part is that with a certain delay (about 1-3 days) thin weak layers are formed inside the snowpack. Moreover, it is a process which cannot be observed from outside (see figure 5).

Figure 5. Diagram of water vapor transport and expansion of a weak layer in a cold-after-warm situation

3.5 gm.5 Snowfall after long enduring cold

The 'classic' among danger patterns, responsible for about a quarter of all avalanche events. Long periods of cold always lead to highly disparate temperatures inside the snowpack and as a consequence, to faceted crystal formation. This leads to thin, unbonded layers of faceted snow crystals forming, usually after about 1-2 weeks. At the next snowfall, these weak layers provide the perfect impetus for slab avalanches. Large-scale avalanches are often the result in such cases (see figure 6).

Figure 6. Large-scale avalanche through new fallen snow after long period of cold

3.6 gm.6 Cold, loose new fallen snow plus wind

Wind numbers among the major avalanche-enhancing factors, along with rain. "Wind is the architect of avalanches," as the proverb runs.

Wind always makes an impact by facilitating snow transport, whether freshly fallen or long deposited snow. The 'snowdrift' which forms as a result is the sign of danger par excellence, above all others. With some experience, signs of wind in outlying terrain can be easily recognized, e.g. through cornices, wind swirls and drifted gullies and bowls (see figure 7).

What is far more difficult, however, is to recognize a snow layer's borderline. Frequently, loosely packed snow falls first, and later on the wind comes up. Thereby, a bonding problem of these highly varied snow layers occurs at the borderline of the freshly fallen and the drifted snow. Ordinarily borderline bonding improves rather rapidly. That means that the gm.6 threat persists for a shorter time than gm.5.

Figure 7. Far ranging snow transport beneath a cloudless sky

3.7 gm.7 Shallow snow areas surrounded by deep snow areas

(Note: this pattern was originally named 'shallow snow areas in winters with heavy snowfall.' But since there are also deep snow zones during winters with little snowfall, the name has been changed.)

The major problem with this danger pattern can be put in a nutshell: highly varied snow depths in a small area.

On the one hand, the snowpack's thermal gradients and its consequent metamorphosis to faceted snow crystals are more intense in a shallow snow cover than in a deep one. On the other, a potentially weak layer is covered by less snow in a shallow snowpack, making it easier to trigger (see figure 8). It is the transition areas from deep to shallow snow which are critical. This phenomenon helps to explain why - quite contrary to the general opinion - deeply drifted gullies and bowls are often less prone to triggering than broad ridges adjacent to them where the snow is shallow.

Figure 8. In the middle of the gully, a weak layer is well covered and not prone to triggering. At the edges, triggering an avalanche is far more likely.

3.8 gm.8 Surface hoar covered with snow

Apart from rain and wind, surface hoar covered with snow numbers among the classic alarm signals in avalanche lore. What matters here is knowing how these visually beautiful but highly trigger-sensitive snow crystals are formed (see figure 9). Only following a night of clear skies full of outgoing radiation, in which the snowpack surface is colder than the surrounding air, can surface hoar form. Numerous large-scale avalanches which cannot be otherwise explained by meteorological or physical-snow causes are a clear indicator of gm.8.

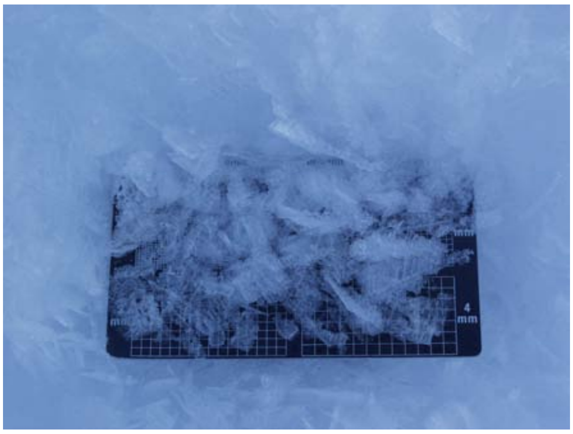

Figure 9. Surface hoar can give rise to extremely fragile crystals several centimeters large, an ideal weak layer for subsequent snowfall

3.9 gm.9 Graupel covered with snow

Graupel covered with snow is the danger pattern which occurs least frequently of all. The reason for that is that graupel typically forms during periods of showers, which are seldom in winter (see figure 10). Furthermore, graupel usually occurs over small surface areas, which prevents large-scale avalanches from triggering as an indicator, as in gm.8.

However, precisely because of its rarity and small-area quality, graupel covered with snow is a booby trap for experts, the cause of surprises even for experienced winter sports participants.

Figure 10. Graupel forms during continuous rise and fall inside a shower cell, causing the graupel pellets to increase in size

3.10 gm.10 Springtime situation

The last of the ten danger patterns is the springtime syndrome. This is distinguished by meteorological parameters of temperature, humidity and radiation, all three of which greatly increase in springtime, making the snowpack more and more isotherm, ultimately turning it thoroughly wet. This ordinarily begins in April and is quite different from the so-called 'early' springtime situation, which can occur even in February.

A major feature of the springtime situation is the increasing frequency of avalanches, often climaxing in large ground and valley avalanches (see figure 11). For winter sports participants the situation is generally easy to evaluate: following a night of clear skies when the surface crust of the snowpack is capable of bearing loads, good conditions prevail for backcountry skiiing tours. As of late morning, the snowpack rapidly loses its firmness and the danger rises - potentially as much as three danger levels!

Figure 11. Massive wet snow avalanches in spring can also endanger residential settlements

4 THREE YEARS OF PRACTICAL EXPERIENCE

The ten decisive danger patterns have been in use for three years at the Avalanche Warning Service of Tyrol (Mair and Nairz, 2011).

The echo from the population is enormously positive. Not only has this idea been introduced to an interested public in hundreds of lectures, but the book outlining the foundations of the analysis is already in its fourth printing. Furthermore, there are published translations in Czech, Italian and Russian.

Above all else, the motto of 'lessons from experience put into practice' is what reaches sports participants and is considered user friendly. Thus, in the daily avalanche warning bulletins, the current danger pattern (up to 3) is published. The high level of feedback has forced us to conclude that the danger patterns have attained almost a higher level of usefulness among various groups than the danger level itself, for pros an even greater value.

5 CONCLUSIONS

Nowadays, avalanche patterns are used in other countries as well, e.g. Bavaria, Switzerland, where efforts are made to depict where the main problems lie at a given time, e.g. inside the snowpack, at the borderline of old snow and new fallen snow, etc.

Tyrol's Avalanche Warning Service is commited to promoting the use and the knowledge of this danger pattern system to the Working Group of the European Avalanche Warning Services (EAWS) so that the idea can be pursued and harmonized internationally. The high degree of interest on the part of winter sports lovers is a strong argument to continue on this path.

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