THUMBS-UP FOR ANALYTIC SNOWPACK ASSESSMENT – PUTTING NEW EAWS STANDARDS INTO PRACTICE

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ABSTRACT: Snowpack stability tests, snow profiles, and process-based analysis of terrain features and weather help avalanche professionals in assessing avalanche danger and depicting it on a temporal and spatial scale. Apart from the incidence of avalanche-prone slopes and potential avalanche size, snowpack stability is the main factor for assigning a given avalanche danger level. Last year the EAWS (European Avalanche Warning Services) sharpened their definitions of the terms used in avalanche forecasting and subdivided snowpack stability into four classes. The resulting new standards were put into practice by all the members of the EAWS last winter. At the Bavarian Avalanche Warning Service they were introduced both in training courses and in operational services. All avalanche forecasters, observers, and avalanche commissioners now use them in order to assess and communicate avalanche danger.

Approximately fifty observers regularly collect snowpack information in the Bavarian Alps and forward it to the Avalanche Warning Service. In addition, avalanche commissioners permanently evaluate snowpack stability in order to assess avalanche hazards to public infrastructure such as roads and ski resorts. They monitor a total of 650 avalanche plummet paths and record their findings and all avalanche incidents in the web app LA.DOK (Avalanche Documentation and Communication Tool). Comparing observation data from winter season 2022/23 we found that the snowpack stability tests ECT (Extended Column Test) and KBT (Kleiner Blocktest, “small block test”) are both suitable for directly designating, on the spot, the test result of a certain snowpack stability class. It is crucial to distinguish between fracture initiation and crack propagation to determine whether a slab can be unleashed and how much impact would be necessary to trigger it. Characteristics of slab and weak layer help to estimate potential avalanche size. Determining a weak layer´s snow grain type and size helps to predict the persistence of that layer. In order to obtain comparable results we developed a catchy method with the help of which observers and commissioners can adequately communicate and classify their test results in a standardized way. It works using your thumbs: thumbs up implies “safe situation” (no avalanche to be expected), thumbs down “immediate danger” (avalanches can release anytime). Left thumb represents fracture initiation, right thumb crack propagation. The combination of left hand and right hand leads you directly to one of the four stability classes. In the short period of one winter season we found high acceptance of this descriptive method within our diverse community which confirms its applicability. Our vision of the future is that more and more winter sports enthusiasts will now share their observations in the selfsame way and thus make their findings beneficial to everyone by contributing to avalanche warning through shared information.

KEYWORDS: avalanche, snowpack, stability, risk management, EAWS

1. INTRODUCTION

The Association of European Avalanche Warning Services (EAWS) has optimized the matrix for determining the avalanche danger level (Müller et.al, 2023). The two distinct matrices for additional loading and natural triggering were merged. What formerly was known as “likelihood of an avalanche triggering” is now characterized in the valid EAWS-matrix by four snowpack stability classes and their frequency depicted (Fig. 1). The EAWS matrix is primarily a decision-making tool for avalanche forecasters. In order to determine the danger level they rely on a sufficient amount of information regarding snowpack stability in outlying terrain.

For winter sports enthusiasts it is particularly important to know whether avalanches can be triggered by additional loading of the snowpack and if so, how much loading. In other words: is there a danger of a slab avalanche if I ski this slope? The four new stability classes supply concrete evidence to answer this question: “very poor stability” means that a slab avalanche could trigger by

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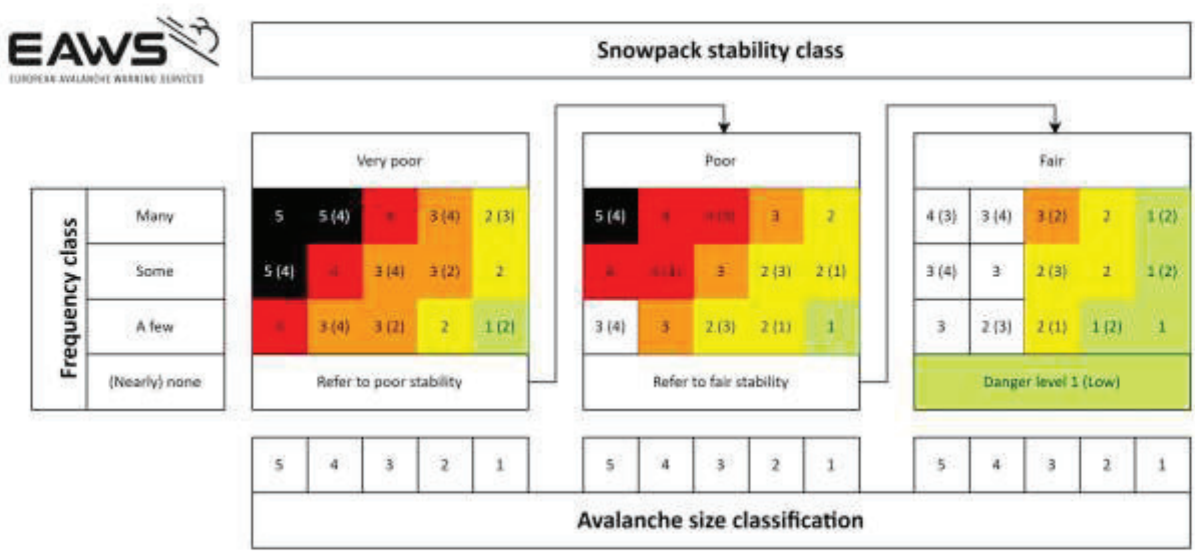


Figure 1: The EAWS-matrix (EAWS, 2023) for determining the danger level by means of avalanche size (scale at bottom), incidence of dangerous spots (scale at left) and stability classes (scale at top). These are “very poor,” “poor,” “fair” and “good.” Good stability automatically means Danger Level one, so this fourth stability class is not specifically mentioned.

itself, in other words an avalanche is possible even without additional loading of a winter sports enthusiast. “Poor stability” means that a slab could be triggered by minimum additional loading, for example, the weight of one sole skier. If it is possible for a slab to trigger only by large additional loading such as a group of skiers not maintaining safe distances between each other, one speaks of “fair stability”. ”Good stability“ means that an avalanche is generally unlikely to trigger. Since snowpack stability is subject to a high degree of variation across the terrain, the assigned value is a far-reaching one and should be understood as a guideline in the Avalanche Bulletin. In order to obtain a professionally reliable assessment of one single slope, snowpack tests and/or snowpack profiles are recommended.

There are many tests to assess the danger of a dry-snow slab. At the Bavarian Avalanche Warning Service the “small block test” (KBT) (Lawinenwarndienst Bayern, 2023) has proven most useful. Internationally, the ECT (Simenhois and Birkeland, 2006, 2009) has proven more practical than the elaborate “Rutschblock” (RB) test (Birkeland and Chabot, 2012). Until very recently, however, there has been no simple, one-step method which leads directly from test result to the stability class. Initial investigations to this end have been carried out by Techel et al. (2020a, 2020b). The test interpretations which have thus far been published were developed in a scientific context and are only of limited use in practice.

2. ANALYTIC SNOWPACK ASSESSMENT

Determining snowpack stability is an integral part of analytic snowpack assessment to judge slab avalanche danger. Analytic snowpack assessment is based on data and facts of the snowpack which must be gathered on-site. That means it is of great importance to dig into the snowpack. A scheme of how analytic snowpack assessment is done is depicted in Fig. 2.

2.1 *Process-based analysis*

Of central importance is the selection of a suitable site for conducting the test, which also assures the selfsame state of the snowpack on other parts of the slope. For this, profound understanding of the processes by which the snowpack has been generated and transformed is essential. For so-called **process-based analysis**, well-founded expertise of snow and avalanches is indispensable.

2.2 *Look into the snowpack*

The phrase **“Look into the snowpack”** focuses all the knowledge which can be obtained through an intense examination of the snowpack layering which will permit a reliable judgment of avalanche danger in that place, including a snowpack test. Form and size of snow grains in the weak layer, the sequence of layers inside the snow cover and characteristics of the “slab” are important subjects of examination.

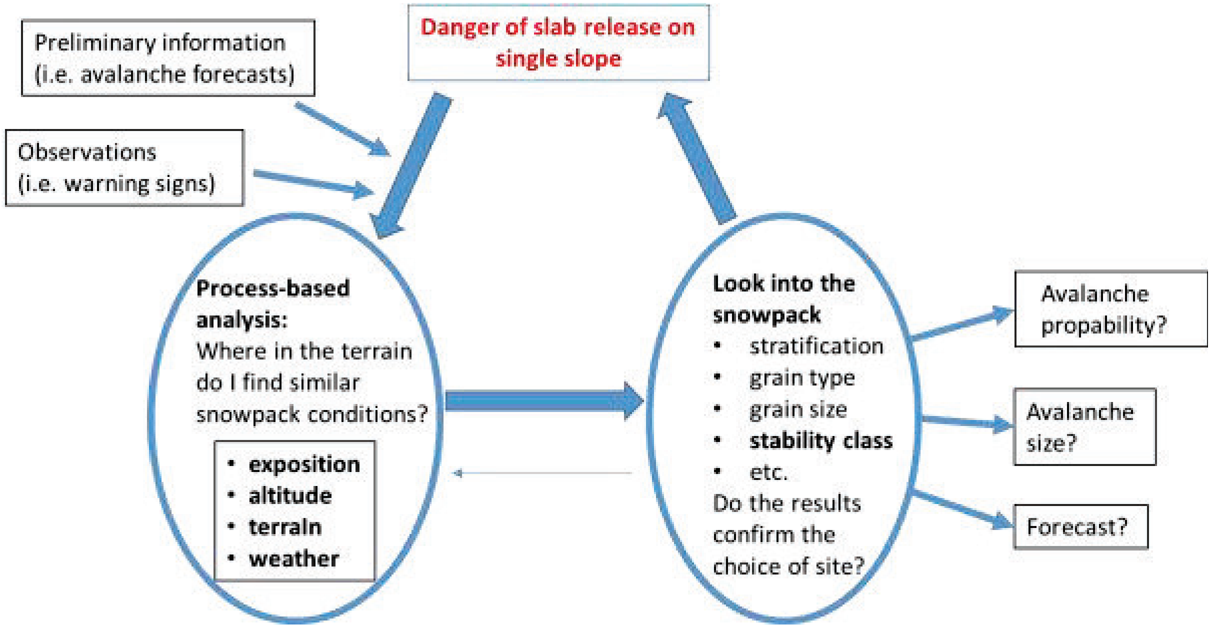


Figure 2: Diagram of an analytical assessment of slab danger

2.3 *Method of procedure*

First, a safe and representative testing site for assessing the single slope in question is selected. The spot must have snowpack conditions comparable to those over the slope. The snow depth should be below average. The Look into the snowpack then gives us information about the snowpack layering: Is there a combination of slab and weak layer? If there is, what characteristics do these two layers have and how is potential triggering and propagation of a fracture to be rated? What were the processes which led to this snowpack layering? And finally, can it be assumed that these processes also took place throughout the slope under examination? If the last question can be answered with "yes," an assessment of the danger on this slope is possible.

2.4 *Assessing the stability class with ECT/KBT*

Snowpack tests generally predicate the likelihood of a crack initiating and propagating in the snowpack. Apart from the fundamental prerequisites for slab avalanches (slope steepness >30° + the presence of a slab and a weak layer inside the snowpack + additional loading / triggering impulse), these are the two factors which ultimately decide the possible triggering of an avalanche and its potential size. Through the newly developed thumb-method, the results of both snowpack tests ECT and KBT can be translated into one of the four stability classes in a graphic and memorable way (Fig. 3).

- First thumb (left hand): the loading level which would unleash a crack is an indicator of the tendency of the weak layer to fracture (crack initiation). In the ECT, the repeated-digit numbers 11 and 22 help to order the test results in the three categories "crack initiation likely," (=thumb points down); "crack initiation possible (=thumb points sideways) and "crack initiation unlikely" (=thumb points up). In the KBT, these are the three levels at which the test block is knocked (light, medium, strong).

- Second thumb (right hand): the type of fracture is an indicator of whether the crack can propagate inside the weak layer. ECT results showing utter crack propagation (ECTP) correspond to smooth crack surfaces of the KBT (=thumb points down), ECT results showing partial crack propagation (ECTpp) are like roughly-hewn crack propagation of the KBT, corresponding to medium (=thumb points sideways) and ECT results without crack propagation (ECTN), like KBT results with stepped crack surfaces, can be seen as an indicator that the fractures do not propagate inside the weak layer (=thumb points up).

- The thumb-method leads over a combination of both thumb positions to one of the four EAWS stability classes.

2.5 *Examples*

Ex. 1: If in the ECT upon the 15th strike ("medium thumb position for crack initiation") a fracture without propagation is generated ("good" thumb position for crack propagation) (ECTN15@30) this results in good snowpack stability:

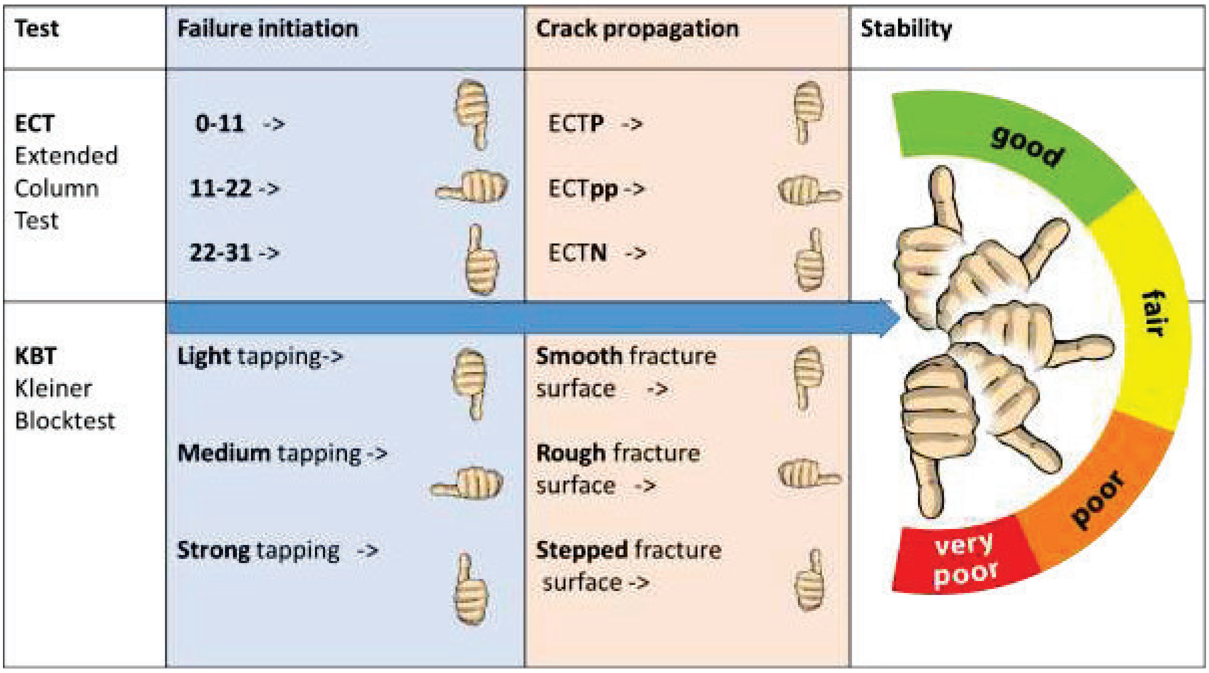
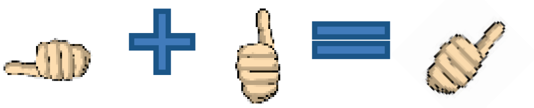
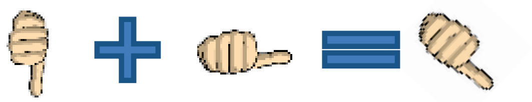


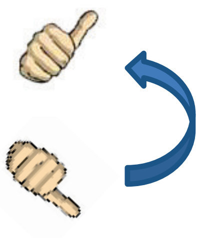
Figure 3: The thumb position, arrived at through a combination of crack initiation and crack propagation and the resulting snowpack stability class.



Ex. 2: If in the KBT upon light tapping ("poor" thumb position for crack initiation) a rough-hewn break at 80cm depth ("medium" thumb position for crack propagation) is generated (KBT light+rough@80), this results in poor snowpack stability:



Since with KBT the knocks are made from the side in the immediate area of the weak layer, weak layers can also be found at great depths inside the snowpack. These, however, are often difficult to trigger, even if they collapse upon light tapping. With the KBT, snowpack stability in these cases can be corrected by a half-level of the thumb position in case the layer of snow on top of it is thick and hard. That would mean in the case of Example 2:



3. DATA AND RESULTS

During the winters 2021/22 and 2022/23 snowpack tests were conducted at a total of 77 locations in Germany, Austria and Switzerland. In each place, one KBT and one ECT test was dug at the same site. The slope steepness gradients (between 5 and 40°), aspect and altitudes (between 800 and 3000 metres above sea level) of the test sites were quite varied, as were the stabilities which resulted (Table 1).

Table1: Resulting stability classes using the thumb-method for the 77 ECTs and KBTs.

Stability class	good	fair	poor	Very poor
ECT	58	14	2	3
KBT	54	8	4	11

If you look at the resulting stability classes, around two-thirds of the test results were similar. If you additionally consider tests that resulted in the same stability class but found different weak layers as unequal, approximately half of the test results were similar (Table 2). Eleven times testing the snowpack with KBT found poorer stability for the same weak layer than the ECT and six times the ECT found poorer stability than the KBT.

Table 2: Comparison of snowpack stability classes and weak layers resulting from ECT and KBT. KBT=ECT stands for similar results, KBT<ECT stands for one class "poorer" stability with KBT and ECT<KBT vice versa. ECT≠KBT stands for minimum two stability classes difference or completely different weak layers.

	Number of tests
KBT=ECT	36
KBT<ECT	11
ECT<KBT	6
ECT≠KBT	24

In addition, the following observations were made:

- When there were several weak layers at one site, they were found more reliably with the ECT.
- If the weak layers were located deeper inside the snowpack (more than 50cm), in one third of the cases (7 out of 21) they were found only with the KBT.
- The KBT tends to result in slightly poorer stability classes if applying the thumb-method.

4. DISCUSSION

Over the course of the last few winters members of the Bavarian Avalanche Warning Service intensively tested, discussed and analyzed the advantages and disadvantages of both snowpack tests, ECT and KBT. The biggest distinction in carrying out the tests is the direction the test block was loaded from: with KBT from the side, with ECT from above. This appears to be a plausible explanation for the somewhat different test results.

- The KBT test tends to produce somewhat "poorer" stability classes. This result is relativized when the depth of the weak layer and the characteristics of the slab on top of it are taken into consideration.
- Weak layers which lie deeper inside the snowpack are found more easily with the KBT. Whether this plays a role in risk assessment can only be determined by deeper looks into the snowpack and process-based analysis. Deep lying weak layers might be harmless for winter sports enthusiasts however will be important for avalanche commissioners, as these layers might cause problems when heavy loaded by new snow.
- If the two tests deliver different results, as a rule one of the two tests uncovers a potential weak layer which is "overlooked" by the other test. With the help of additional knowledge which the competent tester obtains through a look into the snowpack, together with an understanding of the processes taking place inside the snowpack, in most cases these disparities can be explained.

An analytical approach to the theme of avalanche danger which includes both a look into the snowpack and process-based analysis, leads ideally to a clear-cut picture of the danger of an avalanche triggering and its potential magnitude. These two aspects of slab avalanche danger are the major focal points when it is a matter of taking suitable measures to deal with that peril in the context of a risk-conscious decision-making process. For the work of the Avalanche Commission, or for producing an Avalanche Warning Bulletin, an additional aspect is also required, namely, a forecast of the immediate future.

5. CONCLUSION

The new EAWS-matrix and the definitions of snowpack stability which lie at the foundation of that matrix have been successfully tested and introduced by the Bavarian Avalanche Warning Service. To achieve this goal, uniform communication in our training program and our warning reports was of great significance. In order to school snowpack analysis apprentices on-site, the thumb-method proved to be of great value. It makes possible a catchy and memorable depiction of snowpack test results as they relate to crack initiation, crack propagation and, ultimately, snowpack stability. It is particularly suitable for snow experts and groups in making analytical decision-making processes clear, vivid and accessible to all participants. Initial data and assessments of results show that the thumb-method is suitable for determining and communicating the class of snowpack stability in a uniform way despite varied snowpack stability tests. A combination of different types of tests (in our case, ECT and KBT) appears the most reliable method of finding all weak layers and being able to determine snowpack stability as depicted by the four stability classes.

In future, the results of snowpack tests which are undertaken by the Bavarian Avalanche Warning Service will be assigned clearly to one stability class and depicted as we have shown (Fig. 4) in the cockpit of the avalanche and documentation tool LA.DOK. This eases the work of avalanche

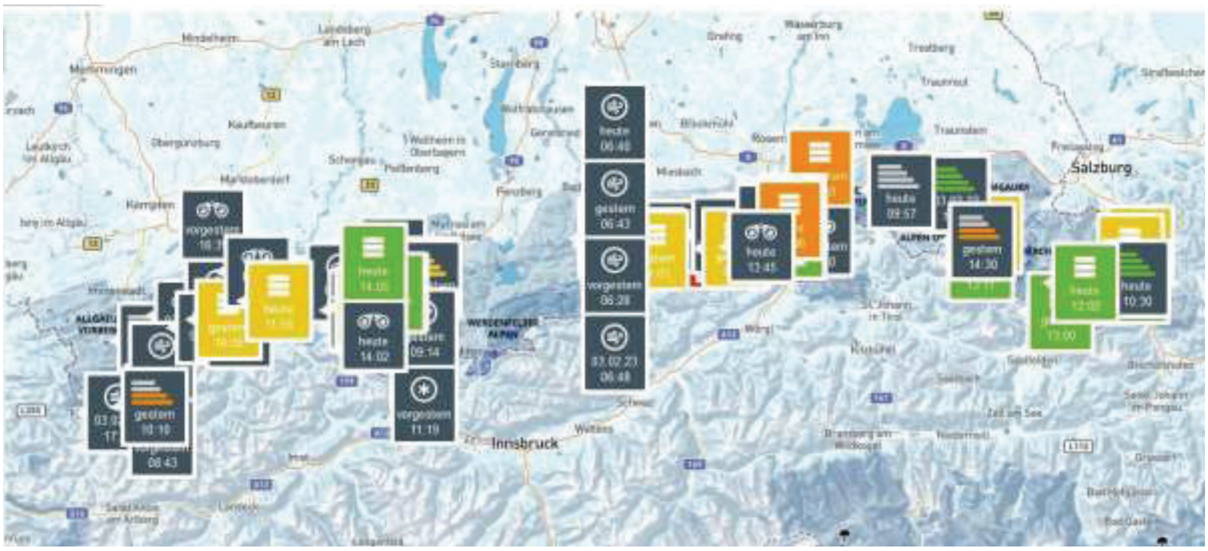


Figure 4: Depiction of test results for the Bavarian Alps in the four colors of the snowpack stability classes via the Cockpit of LA.DOK.

forecasters in their task of determining a danger level for one particular region. An additional input is made available to the public through the descriptive thumb-method which has the potential of further improving communication of avalanche danger.

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