Determination of the avalanche danger level in regional avalanche forecasting

EAWS Working Group Matrix and Scale, updated in May 2025, accepted by EAWS General Assembly in June 2025.

The EAWS recommends using the definitions and related terms and classes to describe avalanche danger presented in this document. The following sections define the avalanche danger level and the contributing factors: snowpack stability, frequency distribution of snowpack stability and avalanche size. An avalanche danger level can only be issued for an area of a certain size. The chapter Setting the spatial and temporal frame provides terms and guidelines for this process. We conclude with the workflow and the EAWS Matrix that should be applied to determine the avalanche danger level. The appendix provides further details and examples on our considerations and work process.

Avalanche danger

Definition:

> Avalanche danger is the potential for an avalanche, or avalanches, to cause damage to something of value (Staham et al., 2018).

Avalanche danger level

Definition:

> The avalanche danger level is a function of snowpack stability, the frequency distribution of snowpack stability and avalanche size for a given unit (area and time). There are five avalanche danger levels: *5-Very high, 4-High, 3-Considerable, 2-Moderate, 1-Low*.

Technical description of avalanche danger levels

Table 1 provides the technical description of the avalanche danger levels. This description provides the link between the European avalanche danger scale and the EAWS Matrix.

Danger level	**Technical description**
Very high / Extreme	Natural avalanches occur in many locations. Avalanches can be very large and extremely large.
High	Avalanches can be triggered by people in many locations. Natural avalanches occur in some or many locations. Avalanches can be large or very large.
Considerable	Avalanches can be triggered by people in some [or many] locations. Natural avalanches can occur in nearly none to some locations. Avalanches can be medium-sized or large.
Moderate	Avalanches can be triggered by people in a few [or some] locations. There are typically nearly no or at most a few locations where natural avalanches can occur. Avalanches can be medium-sized.
Low	There are nearly no [or at most a few] locations where avalanches can be triggered by people or occur naturally. [Stability is often fair or good.] Avalanches are generally small, but can be medium-sized.

Table 1. Technical descriptions of avalanche danger levels, based on how factor combinations and danger levels have been used in European avalanche forecasts. These descriptions have been reviewed in light of recent research and the current European Avalanche Danger Scale (EADS).

Setting the spatial and temporal frame

The following spatial scales must be considered when determining the avalanche danger level for a region.

Forecasting domain

A forecasting domain is the area of responsibility of an avalanche warning service issuing public avalanche forecasts. The forecasting domain is generally static for a service/operation.

Micro-region

Micro-regions are the smallest, geographically clearly defined areas used for avalanche danger assessment. They are static. They allow the forecast user to know exactly which area is described. They may be delineated by administrative boundaries; describe climatologically, hydrologically, or meteorologically homogeneous regions; or may be based on orographic divisions, or a combination of these.

Reference unit

A reference unit is the smallest spatial-temporal entity at which an avalanche danger level can be assessed. A reference unit can be delineated by different elevations and/or aspects within a micro-region (Figure 1). It must still be large enough to include a variety of avalanche terrain such that issuing an avalanche danger level makes sense. The reference unit needs to be defined and remain consistent within a warning service (and ideally across warning services).

Warning region

A warning region is an aggregation of micro-regions, where avalanche conditions are considered similar and are assessed with the same danger level, critical aspects, and elevations where the danger and the avalanche problems prevail, and the danger description. The way they are aggregated can vary from day to day. A warning region is smaller or equal to the forecasting domain and larger or equal to a micro-region.

Resolution

The spatial-temporal resolution used to assess avalanche danger depends primarily on the availability of relevant and reliable data in a sufficient spatial density and temporal frequency. Therefore, the resolution of avalanche danger assessment will vary between warning services. Typically, the following elements characterize the spatial-temporal resolution used to determine the avalanche danger level:

- the size of the micro-regions within a forecasting domain (Figure 1a),
- the resolution of elevation and/or aspect (Figure 1b and c), and
- the temporal subdivision within the valid period of a forecast (e.g., in the morning/evening, Figure 1d).

The resolution of these elements defines the lowest spatial and temporal units at which a forecaster can issue an avalanche danger level, which we refer to as **reference unit**.

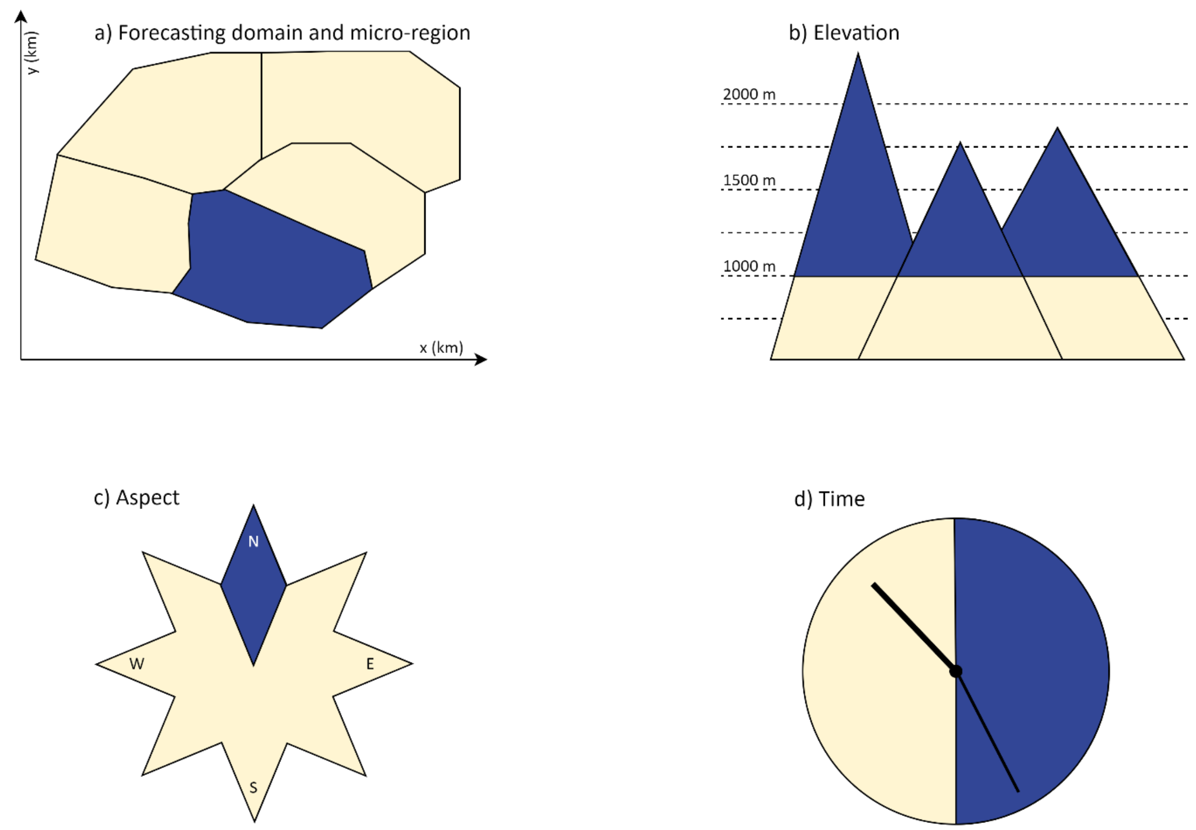

Figure 1: Typically, a reference unit can be characterized by the combination of the smallest subdivisions for the elements: (a) the smallest geographical entity (the micro-region) within a forecasting domain, (b) the resolution of elevation and (c) aspect, and (d) a temporal subdivision. In the figure, exemplary sub-divisions are highlighted. Here, the size of a single micro-region defines the spatial extent, elevation is resolved in 100 m increments, but is assessed as above (and below) an elevation threshold, the aspect is split into eight parts, while the temporal subdivision allows a distinction between morning and afternoon. The combination of the elements highlighted in blue, would be the reference unit, the smallest spatial-temporal entity at which the avalanche danger level can be assessed.

Snowpack stability

Definition:

> Snowpack stability is a local property of the snowpack describing the propensity of a snow-covered slope to avalanche (Reuter and Schweizer, 2018). Snowpack stability is described using four classes: *very poor*, *poor*, *fair,* and *good*.

The guiding questions are: "How easy is it to trigger an avalanche?"

Remarks

1. Depending on the avalanche type, snowpack stability is described by:
    a. Failure initiation, crack propagation and slab tensile support (slab avalanche) (Reuter and Schweizer, 2018)
    b. Loss of strength/bonding (loose-snow avalanche) (e.g., McClung and Schaerer, 2006)
    c. Loss of basal friction and slab tensile and/or compressive support (glide-snow avalanche) (e.g., Bartelt et al., 2012).
2. Since snowpack stability is a local property, it is inversely related to the probability of avalanche release. Snowpack stability describes the snowpack to fail given a specific trigger (Statham et al., 2018), as for instance a person skiing a slope. Table A-1 in Appendix A provides an overview of synonymous terms from the literature. It differs to avalanche occurrence probability which depends on scale and is the result of stability and its distribution (frequency of triggering locations) for a given area (Schweizer et al., 2020).
3. The term *local* refers to a point which ranges in size from a potential trigger location or stability test to a starting zone.
4. All snowpack stability assessments may refer to either the future (forecast) or the present (nowcast), based on observations or models. For example, if the snowpack stability in a release area is considered fair today and a layer of new snow is expected by tomorrow, the stability of tomorrow's snowpack — including the new snow layer — must be reassessed. It is likely that stability will have decreased to *poor* or even *very poor* by that time.

Table 2: Stability classes, and the type of triggering typically associated with these classes. For more examples relating to these classes refer to Figures A1 – A3 in Appendix A.

Stability class	How easy is it to trigger an avalanche?
very poor	Natural / very easy to trigger
poor	Easy to trigger (e.g., a single skier)
fair	Difficult to trigger (e.g., explosives)
good	Stable conditions

Frequency distribution of snowpack stability

Definition:

The frequency distribution of snowpack stability describes the percentages of points for each stability class relative to all points in avalanche terrain. Thus, the frequency f for all points with stability class i (n_i) compared to all points (n) is $f(i) = n_i/n$. The frequency distribution of snowpack stability is described using four classes: *many*, *some*, *a few*, and *none or nearly none* (Table 3).

Remarks

1. The frequency distribution of snowpack stability refers to multiple points (i.e., stability tests, snowpack models or potential triggering locations) or avalanche starting zones.
2. The frequency must be assessed for a warning region which must be equal to or larger than the reference unit.
3. In theory, the definition asks for a percentage. In practice, however, this is often impossible to determine precisely as the frequency distribution must often be inferred from sparse data. Percentages or thresholds for *many*, *some*, *a few,* or *none or nearly none* differ depending on the measurement/evidence used or available. For instance, the percentage of slopes that produce spontaneous avalanches might be lower than the percentage of points with stability tests that indicate *very poor* stability though both may be called *many*.
4. Appendix B provides a brief overview of research related to frequency distributions of snowpack stability.

Table 3: Classes of frequency for snowpack stability.

Frequency class	Description	Evidence (e.g., observations)
many	Points with this stability class are abundant.	Evidence for instability is often easy to find.
some	Points with this stability class are neither *many* nor *a few*, but these points typically exist in terrain features with common characteristics (i.e., close to ridgelines, in gullies).	Evidence exists but is not always obvious.
a few	Points with this stability class are limited in number. Despite their scarcity, they are considered relevant for stability assessment.	Evidence for instability is hard to find.
none or nearly none	Points with this stability class do not exist, or they are so rare that they are not considered relevant for stability assessment.	

Figure B-1 illustrates the concept of frequency distribution for an idealized case.

Avalanche size

Definition:

Avalanche size describes the destructive potential of avalanches.

The guiding question is: "How large can avalanches become?" Estimates are made based on Table 4.

Table 4: Description of classes of avalanche size. For a more detailed description see EAWS (2022).

Size	Name	Destructive potential
1	**Small**	Unlikely to bury a person, except in run out zones with unfavorable terrain features (e.g., terrain traps).
2	**Medium**	May bury, injure, or kill a person.
3	**Large**	May bury and destroy cars, damage trucks, destroy small buildings and break a few trees.
4	**Very large**	May bury and destroy trucks and trains. May destroy fairly large buildings and small areas of forest.
5	**Extremely large**	May devastate the landscape and has catastrophic destructive potential.

Forecasters must estimate the largest avalanche size to be reckoned with under the given or expected conditions — that is, the largest size class that can occur if an avalanche is triggered or released. For example, for a situation that could be described as: **"If avalanches release, they may reach up to size 3."**. Avalanches of size 1, 2, and 3 are to be reckoned with, whereas size 4 and 5 avalanches are not expected. We therefore assign size 3 as the avalanche size to be used in the matrix (see Table 5 below).

Table 5: Overview of avalanche size classes and description of expectation of occurrence.

Avalanche size	If avalanches occur, this size class is...
5	Not expected
4	Not expected
3	To be reckoned with
2	To be reckoned with
1	To be reckoned with

Workflow to determine the avalanche danger level

The workflow describes the path from assessing the avalanche problems to setting the avalanche danger level for a warning region. All relevant avalanche problems must be considered, and their snowpack stability, frequency and avalanche size evaluated. Generally, the highest resulting danger level will be communicated for the given warning region. Exceptions occur for example when two avalanche problems combine in a way that the number of triggering locations is considerably higher than for an individual problem alone leading to a higher danger level.

Table 6: Workflow to determine the avalanche danger level. See also chart in Appendix E.

Task		Explanation and remarks
1	**Assess which avalanche problems are present.**	Choose from the avalanche problems defined by EAWS (EAWS 2022)
	If no avalanche problems are present, the avalanche danger level is 1-Low.	
2	**For each identified avalanche problem, assess the locations (elevation, aspect) and the time of day when the problem is present.**	
3	**For these locations and times assess the classes of snowpack stability**.	Snowpack stability is related to the question: “What does it take to trigger an avalanche?” Often, the locations with the lowest snowpack stability are decisive.
4	**For these stability classes, assess the frequency.**	The frequency is related to the question “How frequent are points where avalanches can release given the trigger specified in step 3?”
5	**Assess the avalanche sizes.**	Avalanche size is related to the question: “How large can avalanches become?” Often, the largest avalanche size to be reckoned with is decisive.
	If snowpack stability, frequency, or avalanche size vary considerably between aspects, elevations, or during the forecast period, repeat steps 3 to 5 to identify the locations and times with the most severe combination of these three factors.	
6	**Refer to the EAWS Matrix and obtain the danger level for the combination of snowpack stability, frequency and avalanche size determined in steps 3-5.**	
	Repeat steps 2 to 6 for other avalanche problems that are present.	
7	**Choose the highest danger level obtained in step 6.**	

EAWS Matrix

The matrix is used to determine the avalanche danger level based on snowpack stability, the frequency of said snowpack stability, and avalanche size. It is most suitable to assess dry-snow avalanche problems (new snow, wind slab, persistent weak layer). Experiences from the first three seasons after its introduction showed that for wet-snow and glide-snow avalanche problems, that relate to very poor stability (Appendix A), there was a tendency to assign a lower danger level for the same combination of stability, frequency, and size, compared to dry-snow avalanche problems.

The design of the matrix builds on the recognition that the frequency of locations with the weakest snowpack stability is often decisive for determining the avalanche danger level (Techel et al, 2020a). This concept is reflected by displaying three separate panels for the stability classes *very poor*, *poor*, and *fair*, which are connected by arrows from left to right (Figure 2). For each stability class, combinations of frequency (y-axis) and avalanche size (x-axis) are summarized in a separate panel. The layout reflects the intended logic: the forecaster begins in the upper left with the most severe conditions and systematically eliminates unreasonable combinations. By progressing through the matrix, the user arrives at the cell that best represents the expected conditions.

To assign a danger level with the matrix, forecasters start with the lowest stability class (i.e. *very poor*) and determine the frequency of such locations. If these locations do not exist, or are so rare that they are not considered relevant for the danger assessment process (class *none or nearly none*, Table 3), the assessment moves to the next stability class, as indicated by the arrows in Figure 2. This process is repeated for locations with *poor* stability, and if necessary, with *fair* stability. If snowpack stability is assessed as *good*, the danger level is automatically set to 1-Low, regardless of the values of the other two factors. In some situations, it may be necessary to consider both the lowest and the next-lowest stability class, particularly when the latter is considerably more frequent than the former. In this case, two stability-frequency combinations may be taken into account. In the final step, forecasters select the largest avalanche size class that must be reckoned with given the observed or anticipated conditions. While stability and frequency are linked, the assessment of avalanche size is independent.

The combination of selected stability, frequency, and avalanche size classes results in one, or occasionally two, matrix cells indicating the danger level that best represents the situation within a region. However, as the survey results, which was the basis for developing the matrix, did not always yield a clear danger level consensus for a given factor combination (Figure 2), the matrix displays either one or two danger levels. Displayed are the respective integer values of the danger levels . The value that is not in brackets in Figure 2 represents the danger level, which reflects the most common and average response among forecasters, and consequently determines the cell's color. If the interquartile range of responses included a second, distinct danger level, this level is displayed in brackets. By including a second danger level, the matrix intentionally retains the variation in expert opinion. For example, for the combination *very poor –some – size 3* (Figure 2), the matrix shows a 3-Considerable and a 4-High in brackets. As illustrated in Müller et al (2024), 34% of the forecasters favored a danger level other than 3-Considerable for this combination. Matrix cells are left uncolored if fewer than 70% of respondents provided a danger level estimate (Müller et al., 2024).

	Snowpack stability class														
Frequency class	Very poor					Poor					Fair				
Many	5	5 (4)	4	3 (4)	2 (3)	5 (4)	4	4 (3)	3	2	4 (3)	3 (4)	3 (2)	2	1 (2)
Some	5 (4)	4	3 (4)	3	2	4	4 (3)	3	2 (3)	2	3 (4)	3	2 (3)	2	1 (2)
A few	4	3 (4)	3	2	1 (2)	3 (4)	3	2 (3)	2	1	3	2 (3)	2 (1)	1 (2)	1
(Nearly) none	Refer to poor stability					Refer to fair stability					Danger level 1 (Low)				
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
	Avalanche size class														

Figure 2: EAWS Matrix updated 2025.

Appendix

Appendix A: Snowpack stability

Figures A-1 to A-3 provide an overview of the relation between the snowpack stability classes and typical phenomena or observations.

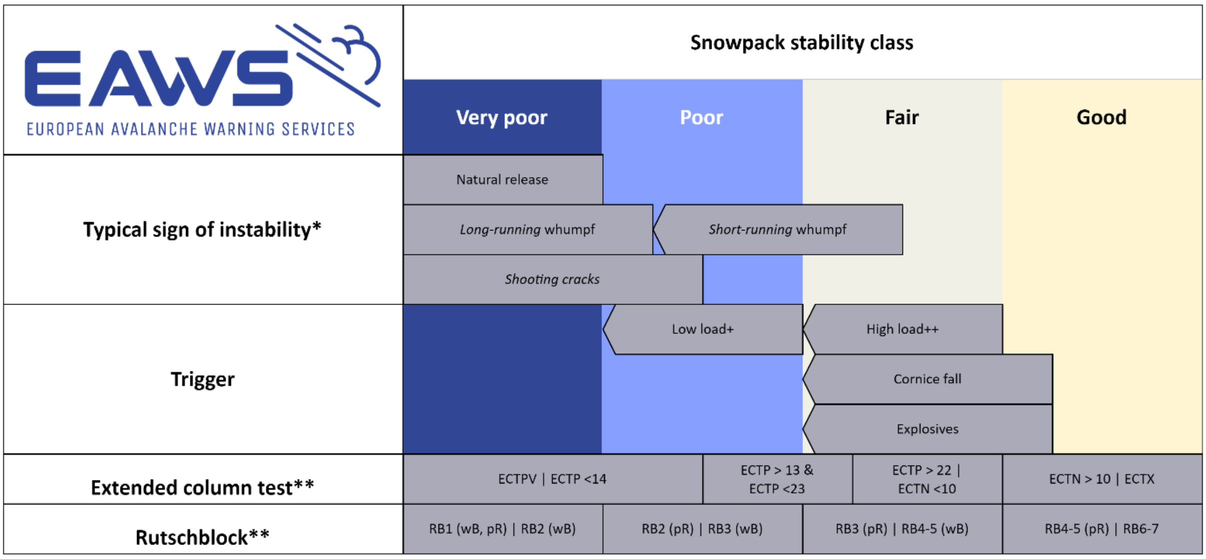

Figure A-1: Common evidence or indications for snowpack stability classes focusing on dry-snow slab avalanches. Arrows indicate that existence towards lower stability classes is imperative. Natural avalanches are a clear indication for the class very poor, while a low and a high additional load are considered approximately equivalent to poor and fair stability. Observations and stability test results should be regarded as indicative only. Abbreviations: Extended Column Test (ECT), Rutschblock (RB), whole block (wB), partial release (pR). ∗Schweizer et al. (2021), ∗∗Techel et al. (2020)a, +single skier not falling, ski-cut, ++single skier falling, group of skiers, person on foot.

For wet-snow stability and glide-snow stability, the separation between fair and poor is often difficult. Wet snow avalanches most often release naturally and are therefore connected to the class *very poor*. Observations will often only provide a tendency towards either *good* or *very poor* stability (Figures A-2 and A-3). Stability tests generally work poorly in wet snow. If they indicate *very poor* stability, they should still be considered but not otherwise.

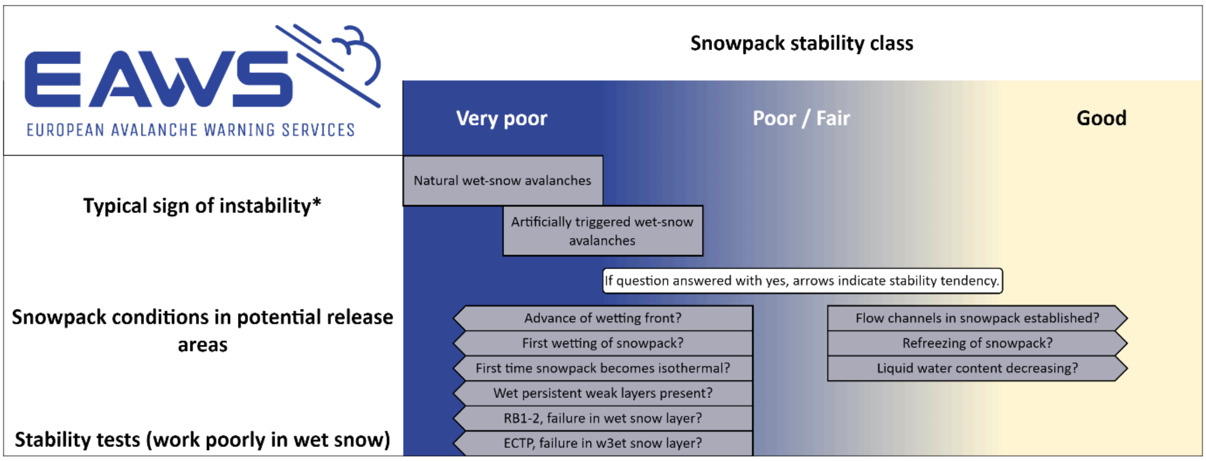

Figure A-2: Common evidence or indications related to wet-snow stability. If no liquid water is present in the snowpack, wet-snow avalanches are not possible.

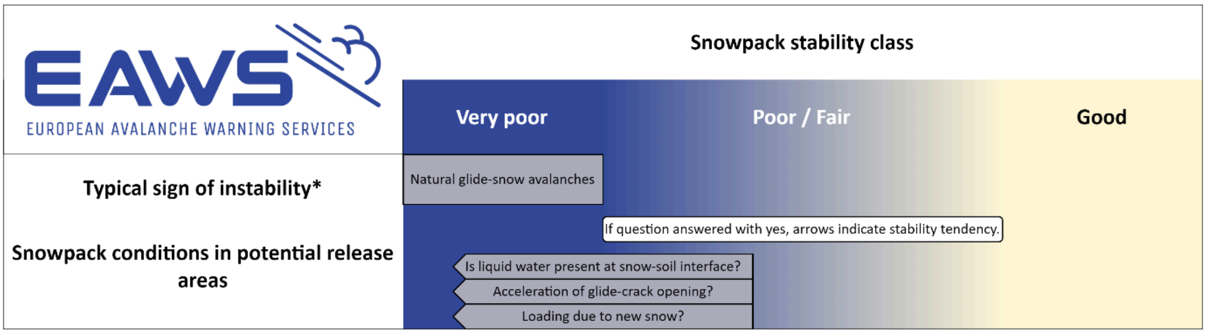

Figure A-3: Common evidence or indications related to glide-snow stability. Glide-snow avalanches are not possible if there is no liquid water present at the snow-spoil interface.

We compare the classes for snowpack stability to other stability classifications in the literature. See Table A-1.

Table A-1: Overview of class labels describing snowpack stability and a comparison to terms describing sensitivity to trigger from the Conceptual Model of Avalanche Hazard (CMAH). We neglected columns from the CMAH that included a spatial component, because we think stability and its corresponding frequency should be decoupled.

Snowpack stability (EAWS)	**Snow stability (AAA, 2016)**	**Sensitivity to triggers (Statham et al., 2018, Table 5)**			
		Sensitivity	**Human triggers**	**Explosive triggers**	**Cornice triggers**
Very poor	Very poor	Touchy	Triggering almost certain	Any size	Any size
Poor	Poor	Reactive	Easy to trigger with ski cuts	Single hand charge	Medium
Fair	Fair	Stubborn	Difficult to	Large	Large trigger explosives
Good	Good – very good	Unreactive	No avalanches	and air blasts	No slab from very large cornice fall

Appendix B: Considerations when assigning classes of frequency distributions of snowpack stability

Figure B-1 illustrates the concept of frequency distribution. It shows an idealized case.

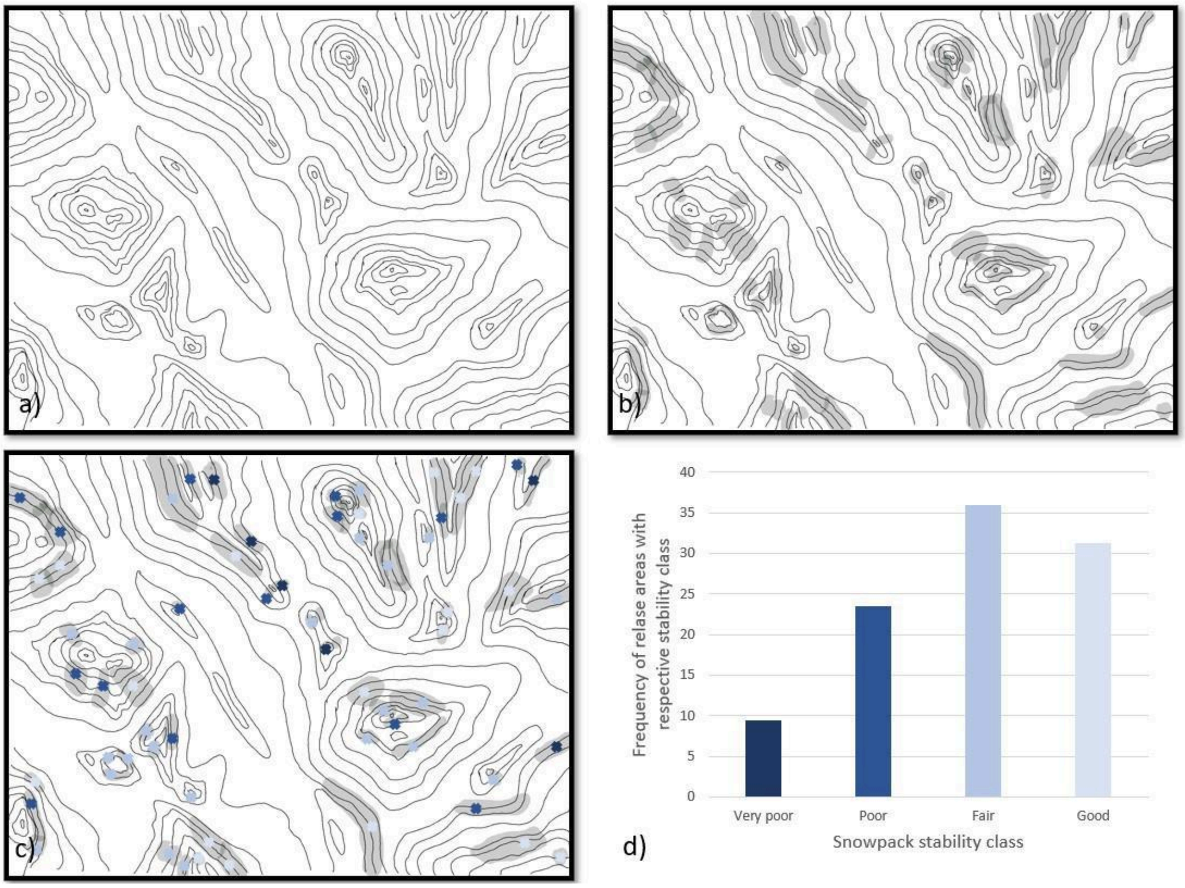

Figure B-1: Illustration of frequency distribution. We consider a hypothetical and idealized scenario where a stability assessment for points within starting zones is available. Here, our micro-region is defined by the contour map in panel a). For sake of simplicity, we choose the reference unit to be equal to the micro-region. Thus, considering all points in the starting zones within the region independent of elevation, aspect or other possible subdivisions (Panel b). Panel c) shows the stability class assessed in each point. Panel d) shows the resulting frequency distribution of these stability classes. Generally, the frequency of the weakest stability class, in this case very poor, needs to be considered to determine the avalanche danger level.

The challenge of assigning percentages or defining thresholds between frequency classes, has been widely discussed but no clear answer exists yet.

Few forecasters or avalanche workers have access to sufficiently comprehensive and evenly distributed data across relevant release areas within the regions they assess. As a result, assigning a frequency distribution class remains largely based on expert judgment and experience for the foreseeable future. We believe that substantially more data, combined with targeted verification campaigns, is needed before reliable thresholds can be established.

In the following paragraphs, we list several studies that have attempted to quantify the frequency distribution of snowpack stability in various ways. The values presented represent the best available estimates but are based on different datasets and approaches; they cannot be directly compared or combined to uniformly define class thresholds. Further studies of this type are needed to provide reliable percentage estimates for the frequency distribution of snowpack stability.

Stability tests (Rutschblock):

Frequency classes derived by Techel et al. (2020)b for the frequency of the Rutschblock stability class *very poor*:

- ***None or nearly none: 0%***
- ***a few*: >0% - <4%**
- ***some or several*: 4% - 20%**
- ***many*: >20%**

Avalanche activity:

Avalanche mapping using airborne imagery and remote sensing enabled quantitative comparison of widespread avalanche activity during three periods with danger level 5-Very high (1999, 2018, 2019) across the Swiss Alps. Based on the avalanche area defined by the 100-year return period, 17% of the area was active in 1999, 11% in 2018, and 6% in 2019. These values may represent the frequency class *many* in the classification of snowpack stability.

Based on a 15-year dataset of manually mapped natural avalanches in the Davos region, Switzerland, the following frequency classes were obtained using the approach described by Techel et al. (2020b), assessing the proportion of potential release areas that were active (i.e., where avalanches occurred):

- ***a few*: <0.02%**
- ***some*: 0.02-2.2%**
- ***many*: >2.2%**

Note, this mapping approach has a comparably low detection rate (Hafner et al. 2021). As a rough estimate, the class thresholds may be too low by a factor of approximately 2. This study is not published.

Table B-1: Classes of frequency for distribution of snowpack stability and a comparison to terms describing spatial distribution according to the Conceptual Model of Avalanche Hazard (CMAH)

Frequency class	**Description**	**Evidence (e.g., observations)**	**Distribution (CMAH)**	**Spatial density (CMAH)**	**Evidence (CMAH)**
many	Points with this stability class are abundant.	Evidence for instability is often easy to find.	**widespread**	The avalanche problem is found in many locations and terrain features	Evidence is everywhere and easy to find
some	Points with this stability class are neither *many* nor *a few*, but these points typically exist in terrain features with common characteristics (i.e., close to ridgelines, in gullies).	Evidence exists but is not always obvious	**specific**	The avalanche problem exists in terrain features with common characteristics	Evidence exists but is not always obvious
a few	Points with this stability class are limited in number. Despite their scarcity, they are considered relevant for stability assessment.	Evidence for instability is hard to find.	**isolated**	The avalanche problem is spotty and found in only a few terrain features	Evidence is rare and hard to find
none or nearly none	Points with this stability class do not exist, or they are so rare that they are not considered relevant for stability assessment.				

EAWS
EUROPEAN AVALANCHE WARNING SERVICES

References

AAA American Avalanche Association. Snow, weather and avalanches: observation guidelines for avalanche programs in the United States. Technical Report, American Avalanche Association, 2016.

Bartelt, P., Feistl, T., Bühler, Y., Buser, O., 2012. Overcoming the stauchwall: Viscoelastic stress redistribution and the start of full-depth gliding snow avalanches. Geophysical Research Letters 39. doi:https://doi.org/10.1029/2012GL052479.

CAA, 2014. Observation guidelines and recording standards for weather, snowpack and avalanches. Canadian Avalanche Association. NRCC Technical Memorandum No. 132.

EAWS, 2022. Standards: Avalanche problems. URL: https://www.avalanches.org/standards/avalanche-problems/. last access: 13 May 2022.

Hafner, E.D., Techel, F., Leinss, S., Bühler, Y., 2021. Mapping avalanches with satellites – evaluation of performance and completeness. The Cryosphere 15, 983–1004. URL: https://tc.copernicus.org/articles/15/983/2021/, doi:10.5194/tc-15983-2021.

Schaerer, P. and McClung, D. (2006) The Avalanche Handbook. 3rd Edition, Mountaineers Books.

Müller, K., Techel, F., and Mitterer, C.: An updated EAWS matrix to determine the avalanche danger level: derivation, usage, and consistency, Nat. Hazards Earth Syst. Sci. Discuss. [preprint], https://doi.org/10.5194/nhess-2024-48, in review, 2024.

Reuter, B., Schweizer, J., 2018. Describing snow instability by failure initiation, crack propagation, and slab tensile support. Geophysical Research Letters 45, 7019 – 7029. doi:10.1029/2018GL078069.

Schweizer, J., Mitterer, C., Reuter, B., Techel, F., 2021. Avalanche danger level characteristics from field observations of snow instability. The Cryosphere 15, 3293–3315. doi:10.5194/tc-15-3293-2021.

Statham, G., Haegeli, P., Greene, E., Birkeland, K., Israelson, C., Tremper, B., Stethem, C., McMahon, B., White, B., Kelly, J., 2018. A conceptual model of avalanche hazard. Natural Hazards 90, 663 – 691. doi:10.1007/s11069-017-3070-5.

Techel, F., Müller, K., Schweizer, J., 2020a. On the importance of snowpack stability, the frequency distribution of snowpack stability and avalanche size in assessing the avalanche danger level. The Cryosphere 14, 3503 – 3521. doi:10.5194/tc-2020-42.

Techel, F., Winkler, K., Walcher, M., van Herwijnen, A., Schweizer, J., 2020b. On snow stability interpretation of extended column test results. Natural Hazards Earth System Sciences 20, 1941–1953. doi:10.5194/nhess-2020-50.

Data sets referred to in Appendix

Schweizer, J., Mitterer, C., Techel, F., Stoffel, A., Reuter, B., 2020b. Snow avalanche data Davos, Switzerland, 1999-2019. doi:10.16904/envidat.134.