SAFETY ACADEMY
GUIDE BOOK SNOW
BASIC AVALANCHE KNOWLEDGE

ORTOVOX

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GUIDE BOOK SNOW

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This small handbook on avalanche assessment aims to provide or reinforce **INITIAL BASIC KNOWLEDGE**, and to help establish an understanding of the **LAWS OF NATURE**. Along with practical avalanche training, it explains important links between the **SNOWPACK AND AVALANCHE DANGER**!

You will never be able to fully eliminate risk while **FREERIDING** or on a **SKI TOUR**. However, the aim is to be able to quickly recognize dangers, estimate risks, and take suitable measures. In this way you can carry out sensible **RISK MANAGEMENT** and take **CONSIDERED ACTION** to ensure you'll enjoy your sport for a long time to come.

We wish you safe, enjoyable tours!
Your **TEAM ORTOVOX**

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01. AVALANCHE BASICS

AVALANCHES ARE DIVIDED INTO THREE DIFFERENT TYPES

1. SLAB AVALANCHE

When a weaker layer in the snowpack fails a fracture may cross the slope to release a slab avalanche. A characteristic crown is formed. **95**% of all avalanches are slab avalanches. They are responsible for 98% of deaths caused by avalanches.

2. LOOSE SNOW AVALANCHE

Loose snow release at a point – contrary to a fracture line. Dry loose snow avalanches require a **SLOPE ANGLE OF 40**°, wet loose snow avalanches start to slide at lower gradients. 2% of avalanche victims die due to loose snow avalanches.

3. GLIDE SNOW AVALANCHES

Glide snow avalanches cannot be triggered by skiers. They release due to a loss of friction on a film of water on the ground. In most cases, a characteristic "**MOUTH-SHAPED GLIDE CRACK**" forms on the slope. It is not possible to predict when they will slip.

FORMS

Each of these avalanche types can be further differentiated: For example, if it is wet (18%) or dry (82%). 5% of slab avalanches release spontaneously. 95% are triggered artificially – by people or blasts.

Photos: LWD Tirol (left) & Ralf Hochhauser (right)

SKIER-TRIGGERED AVALANCHES

SKIER AVALANCHES ARE THOSE TRIGGERED BY A SKIER

99%

of avalanches triggered by recreationists are almost exclusively dry, slab avalanches.

In over 90%

of cases, an avalanche is triggered by the first person entering the slope.

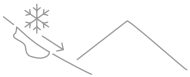
The larger the

AVALANCHE

the lower the chance of survival.

The average fracture thickness is

45 – 50 cm



The typical skier-triggered avalanche is

50 – 70

m wide and has a path three times as long.

10%

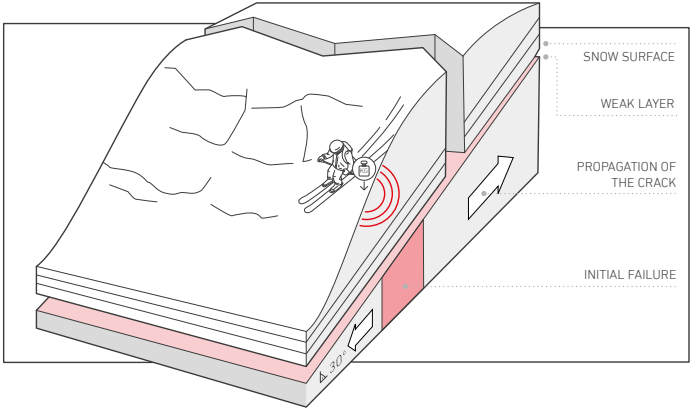
are remotely triggered.

The average slope angle of the steepest slope section is

38°

HOW WE TRIGGER SNOW SLABS?

ALL SNOW SLABS NEED FOUR "INGREDIENTS"



1. LAYERS Well-bonded snow on top of a **WEAK LAYER**. The "slab" mostly consists of wind-drifted snow, i.e. small, round, degraded crystal shapes. In contrast, the weak layer mostly consists of large, faceted snow grains.

2. FAILURE INITIATION The load of a skier may be enough to fracture a weak snow layer in the snowpack underneath – no matter if skinning or skiing.

3. CRACK PROPAGATION The initial crack can start spreading out from the skier, if the weak layer is present all across the slope and the slab is sufficiently thick with well-bonded snow to support crack propagation.

4. STEEPNESS The snow slab will only slip if the slope steepness is over 30°.

Illustration: in the style of Alain Duclos

02. AVALANCHE FACTORS 3×3

WEATHER CONDITIONS, TERRAIN, PEOPLE

3 FACTORS – weather conditions, terrain, people – are used together to estimate avalanche danger and aid decision-making. This takes place on **3 LEVELS**: When planning at home, in the mountains, and on the specific slope itself. Information and expertise regarding the 3 factors has become increasingly precise, judgements more accurate, and decisions more appropriate!

	CONDITIONS		TERRAIN	PEOPLE
	WEATHER Unfavorable: A lot of new snow along with wind and cold temperatures.	SNOWPACK A slab avalanche will only form if a weak layer is present underneath an unfavorable slab.	TERRAIN Steep, 30° or more, mostly virgin. Often in hollows and on homogeneous slopes.	HUMAN Up to 95% of snow slabs are triggered by skiers. Over 90% of these by the first skier...
REGIONAL (tour planning)	Avalanche bulletin Weather report Personal reports Different types of weather in succession		Map Inclinometer Guide / specialist literature Personal reports	Group size & ability Motivation (Peer) pressure Responsibility, etc.
LOCAL (choice of route)	Snow depth, new snow Wind signs and temperature Triggered avalanches Whumpf sounds Personal reports		Do my expectations correspond to the actual terrain? Assess on sight Binoculars Personal reports	State of mind on the particular day Mood within the group Are other people on the slopes? Competition with others? Pressure to succeed? Motivation?
ZONAL (individual slopes)	Visibility Double-check filter 1 and 2 What is different than expected? Wind signs: Windward or leeward? Factors: Check individual slope		What is above/below me? Steepest part of the slope Slope aspect Elevation, proximity to ridges Slope shape	How many people are on the slope? Committed to a goal? Driven by others' behavior? Motivation? Every group member's mood and form on the day

illustration: in the style of SLF.ch

WEATHER CONDITIONS

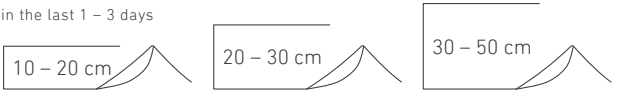
PRECIPITATION

Precipitation creates and influences the snowpack over the course of the winter. Initially, the new snow layer can be poorly bonded to the old snow layer. Therefore, avalanche danger typically increases during or shortly after fresh snowfall.

NEW SNOW is also an additional load for the layer of old snow. Rain also constitutes an additional load, and warms and infiltrates the snowpack. The amount of **NEW SNOW**, **TEMPERATURE AND WIND** are the main factors for the development of avalanche danger during a period of precipitation.

CRITICAL AMOUNT OF NEW SNOW

in the last 1 – 3 days



in unfavorable conditions

in average conditions (mixture of favorable / unfavorable)

in favorable conditions

UNFAVORABLE CONDITIONS

- Strong wind (around 50 km/h or 31 mi/h)
- Low temperatures
- Unfavorable snowpack structure (snow hardness variations? weak snow surface buried?)
- Uniform and weakly bonded older snow buried

FAVORABLE CONDITIONS

- No or little wind
- Temperatures just below 0° C, especially when snow starts falling
- Rain turning into snow
- Irregular old snowpack, well compacted

WIND

The wind is said to be the "**ARCHITECT OF AVALANCHES**". New snow makes it particularly easy for the wind. The wind mechanically shreds the snow crystals and deposits them in the form of wind-drifted snow in wind-sheltered places.

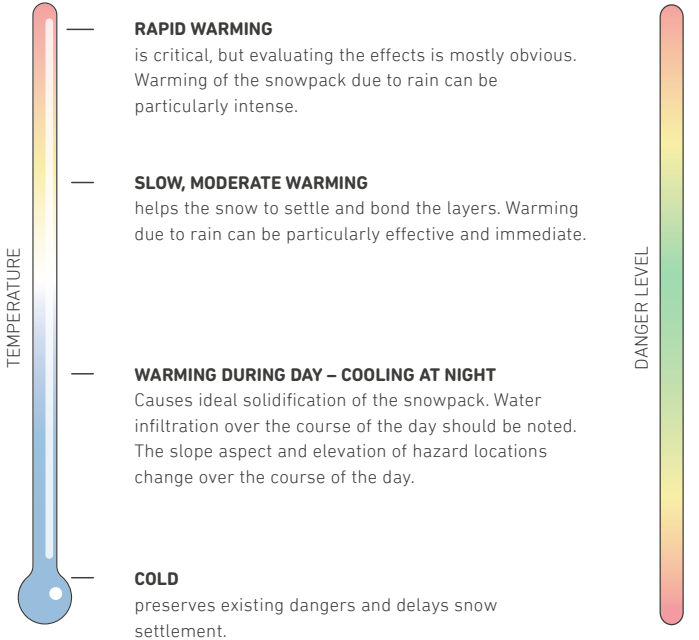
BEAR IN MIND

Try to avoid recent wind slab that often form in gullies, troughs, and bowls, as snowdrifts accumulate there. Just as dangerous are areas on the lee side of ridges, as well as the cornices above them that are in danger of breaking off.

Photo: Hansi Heckmair

WARMING

The temperature influences the snowpack, the transformation processes within and, in particular, the **TOPMOST SNOW LAYERS** (30 – 50 cm). Air temperatures and solar warming, but also rain are influencing factors.



RAPID WARMING
is critical, but evaluating the effects is mostly obvious. Warming of the snowpack due to rain can be particularly intense.

SLOW, MODERATE WARMING
helps the snow to settle and bond the layers. Warming due to rain can be particularly effective and immediate.

WARMING DURING DAY – COOLING AT NIGHT
Causes ideal solidification of the snowpack. Water infiltration over the course of the day should be noted. The slope aspect and elevation of hazard locations change over the course of the day.

COLD
preserves existing dangers and delays snow settlement.

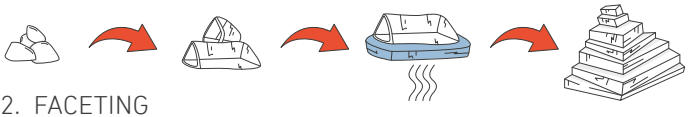
SNOWPACK

TRANSFORMATION PROCESSES

Snow is "alive". The crystals in a snowpack change constantly as a result of **PRESSURE**, **WATER VAPOR DIFFUSION AND MELT-FREEZE** metamorphism. Snow is highly porous and consists primarily of air, ice and a small amount of liquid water. There are three transformation processes in the snowpack:

1. ROUNDING

Wind and thermodynamic processes form small, rounded crystals.
The perfect slab.



2. FACETING

Strong temperature gradients (typically in cold nights with clear skies) create large, faceted crystals. Often the perfect weak layer.

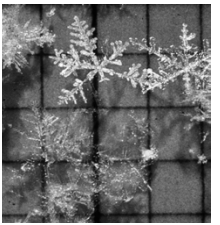
3. MELT-FREEZE METAMORPHISM

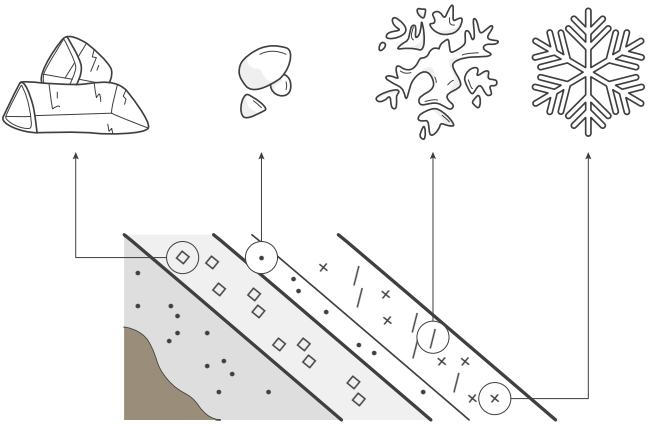
Large, coarse snow grains form when snow melts and refreezes.
Thawing weakens the snowpack, while freezing stabilizes.

illustration: in the style of EAWS

WEAK LAYER

A typical **WEAK LAYER** consists of faceted and, therefore, **RELATIVELY LARGE CRYSTALS**. There are many cavities (air) in the layer and few contact points (sinter bridges) between the crystals. Surface hoar or faceted snow grains form a long-lasting weak layer (over weeks) once they're buried. New snow can also form weak layer but that weak layer may "heal" within a day or two, depending on temperature.





□ = Angular crystals formed by faceting. Often the perfect weak layer.
● = Small, round snow grains formed by rounding. Often the perfect slab.
／ = Wind-broken parts of new snow, often elongated shapes.
Good characteristics for forming a slab.
+ = New snow – can form a slab, but can be initially too soft.

TERRAIN

SLOPE STEEPNESS

AS A GENERAL RULE:

- A slope angle of 30° and above can result in a slab avalanche.
- The **STEEPER** the slope, the more likely there will be an avalanche.
- The higher the **DANGER LEVEL**, the more slopes have poor stability.
- Irrespective of the danger level, the average slope angle of skier-triggered avalanches is the same (approx. 38°).
- The **STEEPEST PART** of the slope is used to determine the slope angle; the area should measure at least 20 m×20 m.

RULE OF THUMB:

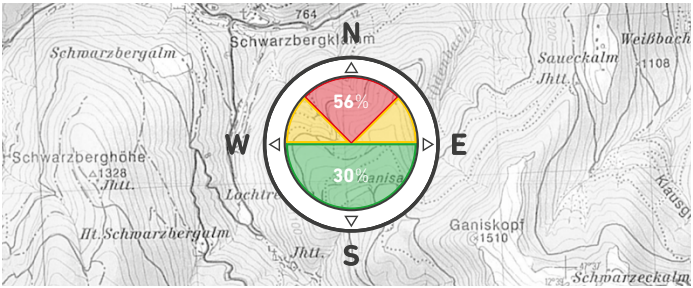
5	Backcountry skiing, free riding and snowmobiling are **GENERALLY NOT RECOMMENDED**.	
4	• **AVOID SLOPES STEEPER THAN 30°** • Even in flatter areas, bear in mind the possibility of natural avalanches from catchment areas above.	
3	For all slopes specified in the avalanche bulletin: • **AVOID SLOPES GREATER THAN 35°**; • Ride slopes over 30° one by one. Keep your distance from each other during the ascent.	
2	• Avoid the extremely steep terrain listed in the avalanche bulletin. • In hazard locations listed in the avalanche bulletin that are over 30°: Keep your distance from each other when ascending, and descend one by one.	
1	Apart from extremely steep terrain, conditions **GENERALLY SAFE** from avalanches.	

illustration: avalanches.org

SLOPE ASPECT AND ELEVATION

There are often hazard locations at particular slope aspects and elevations. There are around twice as many avalanche accidents on north-facing slopes as on south-facing slopes. However, the number of people travelling per aspect is unknown.

The reason for the high number of **ACCIDENTS ON NORTHERN SLOPE ASPECTS** could be conditions favoring weak layer formation such as delayed snow settlement. Powder also lasts longer on north-facing slopes, which might mean they are also busier. However, in some situations, south-facing slopes can also be more dangerous than north-facing slopes.



Avalanche danger usually increases at higher elevations, as there will be more new snow, the wind is usually stronger and the air temperature is often lower.

NOTE

Avalanche problems describe the type of avalanche danger at different aspects and elevations. Therefore, the information in the avalanche bulletin is particularly important (see page 18).

SLOPE SHAPE

The slope shape also influences avalanche formation. Avalanche accidents are particularly frequent at **LARGE**, **HOMOGENEOUS AND SLIGHTLY CONCAVE** slope shapes as well as wide gullies and hollows. Accidents in convex or rugged terrain are less common.

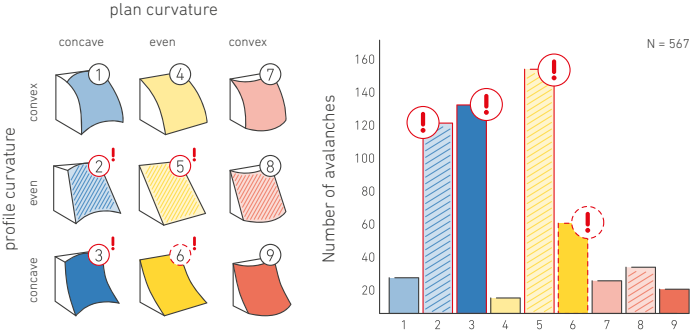
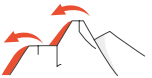


Image: Vontobel et al, International Snow Science Workshop 2013, Analysis of different slope shapes and their link to avalanches initiated by skiers. Left-hand image shows various slope shapes. Right-hand image shows the distribution of avalanche releases; N = 567 skier avalanches investigated; most avalanche releases can be attributed to slope shapes 2, 3 & 5 at a distance, shape 6 too).

TYPICAL AREAS WITH WIND SLABS

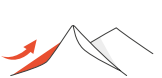
Wind-drifted snow is often found on the leeward side close to a ridge, just below steep sections, in concave slope shapes or, at the foot of rock faces , but can also be found at transitions in the terrain on the windward side.

Leeward side of ridges



Steep slopes below terraces and plateaus

Hollows and gullies



At the foot of rock faces or steep sections

illustration: in the style of SLF.ch

TERRAIN AND CONSEQUENCES

The terrain plays a decisive role when it comes to **BURIAL DEPTH** or mechanical injuries. This is why we talk about "**TERRAIN TRAPS**".
Along with the amount of snow that is moving, it is primarily the shape of the terrain and potential obstacles in the avalanche path that determine the consequences of an avalanche!

Photo: Ben Reuter

RISK FACTORS FOR SERIOUS CONSEQUENCES IN THE PATH OF AN AVALANCHE ARE:

- Steep slopes, steepness level → fall and mechanical injuries ●
- Rocks, trees → mechanical injuries resulting from collision ● ●
- Ditch, course of a stream, hollow in the outflow area → runout zone, threat of deep burial ● ●
- Crevasse in the runout area → risk of fall and also a large runout zone
- Large slopes (>60m) above → the larger the slope above, the deeper the burial

BEAR IN MIND

Even "minor" consequences (e.g. injuries) can have severe impacts in the wrong situation (poor weather; remote area, late in the day)!

PEOPLE

Avalanche hazard locations don't pose a problem themselves – but we may create a problem by approaching the areas.

SIZE OF THE GROUP

Large groups can pose a problem. Often they move slower. Even if they don't, spreading out to reduce the consequences, can create communication issues and take a lot of time, which makes larges group hard to handle from a guide's perspective.

ABILITY

Solid skiers can keep to the specified routes in the mountains and can avoid falls in spicy sections where a single fall may to much and trigger a slab. With good ability, dicey sections can be quickly passed one by one while keeping the necessary distance from other skiers.

GROUP HOMOGENEITY

A motivated group sharing the same goal with a about the same skill level and speed ambitions is less likely to experience tension and conflict.

Photo: Max Drager

GROUP PHENOMENA

- We often feel safer in a group than we do alone: This makes us more confident and open to risk → group polarization
- Large groups often have **NO CLEAR DECISION-MAKING STRUCTURE**. The person who argues loudest can mostly assert themselves.
- Motivated people often argue to their own ends: Other people's skepticism is afforded less importance.

DECISION TRAPS

- Exhaustion reduces our attentiveness.
- Other people influence our decision.
- The desire for exclusivity and photos for social media influences our behavior.

PRESSURE AND PROJECTION

- Social desirability means we do not ask uncomfortable questions.
- Our own motivation or the fulfillment of external desires render objective decision-making more difficult.

It is helpful to remind ourselves of these phenomena again and again when it comes to avalanche decisions making. An **OPEN GROUP DYNAMIC**, transparent debate and an ear for the "quiet voices" in the group can also help taking good decisions in difficult moments. Bailing off doesn't stand for defeat, but means success – particularly in mountain sports!

NOTE

According to analyses, most avalanche accidents seem to be driven by "human factors" besides insufficient evaluation of the avalanche situation. These human factors are mostly psychological in nature – they influence our decisions.

03. AVALANCHE BULLETIN

THE 5 DANGER LEVELS

The avalanche bulletin is published daily in the relevant months, and sometimes even twice daily. Along with the regional danger level for an area, an elevation or over the course of the day, additional information regarding avalanche problems and dangerous areas are important for winter athletes. Therefore, a quick glance at the danger level is insufficient.
The foundation for all trip planning is accessing and processing all information found in the avalanche bulletin.

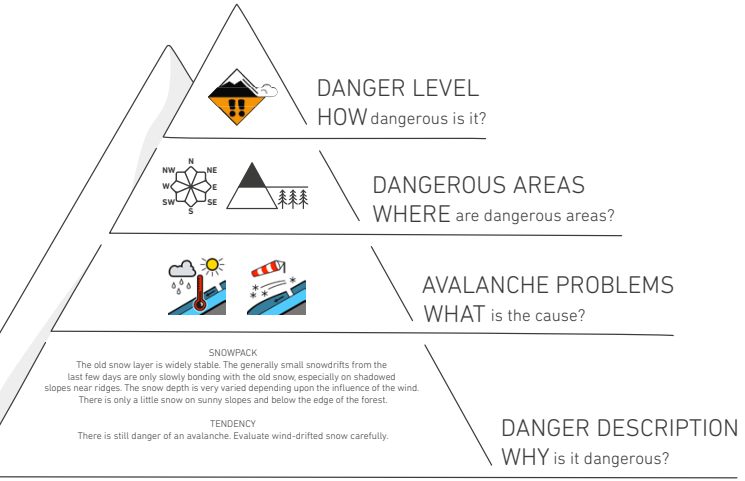


Image: Avalanche bulletin information pyramid, where the position corresponds to its importance – the most important information comes first. In the style of IFALP

Credit: avalanches.org

DANGER LEVEL

A danger level always refers to an area of at least **100 km²**. A danger level does never refer to a particular aspect of a mountain, let alone a single slope. Avalanche dangers do not increase linear with the levels.
THREE PARAMETERS are key for the danger level: In particular, the frequency of dangerous areas and the stability of the snowpack are of decisive importance. The expected size of avalanches can also play a role.

EUROPEAN AVALANCHE DANGER SCALE				
	DANGER LEVEL	**ICON**	**SNOWPACK STABILITY**	**LIKELIHOOD OF TRIGGERING**
5	Very high Very rarely forecast, approximately 1% of avalanche fatalities		The snowpack is **POORLY BONDED AND LARGELY UNSTABLE IN GENERAL**.	Numerous **VERY LARGE** and often **EXTREMELY LARGE** natural avalanches can be expected, even in moderately steep terrain*.
4	High Forecast for a few days in winter, approximately 10% of avalanche fatalities		The snowpack is **POORLY BONDED ON MOST STEEP SLOPES***.	Triggering is likely, even from low additional loads**, on many steep slopes*. In some cases, numerous **LARGE** and often **VERY LARGE** natural avalanches can be expected.
3	Considerable Forecast for approximately 30% of winter, 50% of avalanche fatalities		The snowpack is **MODERATELY TO POORLY BONDED ON MANY STEEP SLOPES***.	Triggering is possible, even from low additional loads**, particularly on the indicated steep slopes*. In certain situations some **LARGE**, and in isolated cases **VERY LARGE** natural avalanches are possible.
2	Moderate Forecast for approximately 50% of winter, approximately 30% of avalanche fatalities		The snowpack is **ONLY MODERATELY WELL BONDED ON SOME STEEP SLOPES***; **OTHERWISE WELL BONDED IN GENERAL**.	Triggering is possible, primarily from high additional loads**, particularly on the indicated steep slopes*. **VERY LARGE** natural avalanches are unlikely.
1	Low Forecast for approximately 20% of winter, approximately 5% of avalanche fatalities		The snowpack is **WELL BONDED AND STABLE IN GENERAL**.	Triggering is generally possible only from high additional loads** in isolated areas of very steep, extreme terrain*. Only **SMALL** and **MEDIUM** natural avalanches are possible.

AVALANCHE PROBLEMS

WHAT IS THE CAUSE?

The avalanche bulletin also uses icon(s) and/or text to describe the main problem(s). Usually, descriptions of five different avalanche problems provide the user with information about what to be aware of.

NEW SNOW

WHAT?	Characteristics	The avalanche problem is related to current or most recent snowfall. The amount of additional loading by new snow onto the existing snowpack is the crucial factor of the **NEW SNOW** problem. How critical the loading is depends on various factors such as temperature or characteristics of the old snow surface. **REMOTE TRIGGERING POSSIBLE**.
	Expected avalanche types	▷ Dry-snow slab avalanches ▷ Dry-loose snow avalanches ▷ Natural and human triggered avalanches
WHERE?	Spatial distribution	Generally widely present and often in all aspects.
	Position of weak layers in the snowpack	Usually at the transition to the old snow surface, but sometimes in the new snow layers and sometimes also deeper in the old snowpack.

WIND-DRIFTED SNOW

WHAT?	Characteristics	The avalanche problem is related to **WIND-DRIFTED SNOW**. Snow can be transported by wind with or without a concurrent snowfall. **REMOTE TRIGGERING UNLIKELY**.
	Expected avalanche types	▷ Dry-snow slab avalanches ▷ Natural and human triggered avalanches
WHERE?	Spatial distribution	Highly variable but typically on **LEEWARD SIDES** in gullies, bowls, near distinct changes in slope angle, behind ridge-lines or other wind-sheltered locations. More common above treeline.
	Position of weak layers in the snowpack	Usually at the transition to the **OLD SNOW SURFACE** or within the windslab layer due to variation in wind speed and variation during storm cycle, but occasionally also deeper in the old snow cover.

PERSISTENT WEAK LAYERS

WHAT?	Characteristics	The avalanche problem is related to the presence of persistent **WEAK LAYERS IN THE OLD SNOWPACK**. These weak layers typically include buried surface hoar, depth hoar or faceted crystals. **REMOTE TRIGGERING POSSIBLE**.
	Expected avalanche types	▷ Dry-snow slab avalanches ▷ Mostly human triggered avalanches; natural avalanches are rare, mainly in combination with other avalanche problems
WHERE?	Spatial distribution	The avalanche problem can be widespread or quite isolated. It can exist in **ALL ASPECTS**, but is more frequent on shady, wind sheltered slopes.
	Position of weak layers in the snowpack	Anywhere in the old snowpack, often deep in the snowpack. However, when deeply buried triggering becomes increasingly hard.

GLIDING SNOW

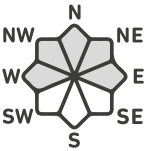
Cannot be triggered artificially and is of little relevance to winter athletes.

WET SNOW

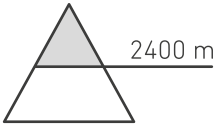
WHAT?	Characteristics	The avalanche problem is related to **WEAKENING OF THE SNOWPACK** due to the presence of liquid water. Water infiltrates the snowpack due to melt or rain. **REMOTE TRIGGERING VERY UNLIKELY**.
	Expected avalanche types	▷ Wet-snow slab avalanches ▷ Wet loose snow avalanches ▷ Mainly natural avalanches
WHERE?	Spatial distribution	When sun is the main cause, distribution of the problem is mostly depending on aspect and elevation. All aspects are affected in the event of rain on snow.
	Position of weak layers in the snowpack	Anywhere in the snowpack

WHERE ARE DANGEROUS AREAS

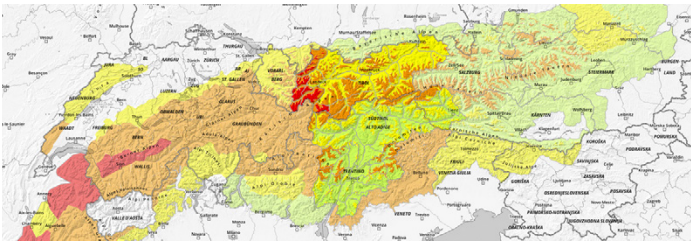
Good avalanche bulletins give the user spatial information: Where the dangerous areas are and what avalanche problems are to be expected there. Along with the **ELEVATION AND THE SLOPE ASPECT**, the avalanche bulletin also describes the **AFFECTED TERRAIN**, e.g. gullies and hollows, transition points from lots of snow to little snow, behind slope edges or close to a ridge, at shadowed slopes or in the sun.



Dangerous areas go from west through north to east



Dangerous areas are found above 2,400 m



Credit: avalanches.org

Experienced users collect information on avalanche problems from the **BULLETIN** and add to them or correct them using their **OWN OBSERVATIONS** in the mountains. A matrix can be helpful in this regard...

PROBLEM	ASPECT	ELEVATION	DESCRIPTION
New Snow 	n/a	n/a	n/a
Wind-drifted snow 			▷ Extensive snowdrift accumulations ▷ Can be triggered by individuals in some areas ▷ Medium size ▷ Covered with fresh snow / difficult to identify ▷ Whumpf sounds / cracks in the snowpack
Persistent weak layers 			▷ Avalanche triggering possible in isolated cases, particularly with high additional load ▷ Quite large
Wet snow 			▷ Likelihood of triggering increases throughout the course of the day ▷ Wet loose snow slides ▷ Small and medium snow slabs ▷ On very steep (>35°) sunny slopes

04. TOUR PLANNING

AVALANCHE RISK MANAGEMENT

D × **C** - **M** = **R**

In order to turn information and knowledge about avalanches into sensible decisions during planning and while in the mountains, we need a decision-making **STRATEGY**. This will help us come to the most precise possible assessment of our **RISK**. Bear in mind: Mountains represent a dangerous environment, where we bear responsibility for any consequences. There is no absolute safety: We can only reduce the risk to a level we are comfortable with by assessing it and coming to a decision. The **D**-**C**-**M**-**R METHOD** has established in snow science in recent years. It follows the equation:

D	× **C**	- **M**	= **R**
for danger stands for the probability of avalanche release.	for consequences estimates the outcomes of a burial.	describes the measures we can possibly take to reduce the probability of avalanche release or the consequences.	The result is the risk.

The **D**anger must first be recognized (see p. 26) and then evaluated according to the probability of its occurring. In addition, we can consider the four factors for a snow slab and evaluate these (cf. p. 30).

As it is not easy to evaluate the potential for avalanche initiation or crack propagation, it can be simpler to observe the **SLOPE ANGLE**, which correlates to the probability of **AVALANCHE RELEASE**.

The **C**onsequences depend upon the **TERRAIN** (terrain traps) and the extent of the **SNOW SLAB** (mass).

By maintaining intervals for load reduction and taking care where they leave their tracks as they traverse the ridge, the ski touring group in the picture are minimizing the likelihood of triggering an avalanche. And there is a maximum of one to two people in the "danger zone" – this makes consequences less severe in the event of a snow slab avalanche.

Measures (e.g. intervals for load reduction) can **REDUCE** the probability of avalanche release, particularly for avalanche problems that require a large additional load to induce a release (often persistent weak layers). If avalanches can be triggered by a lower additional load (often wind-drifted snow, for example), these measures are less effective. However, they often **REDUCE** the consequences (safe assembly points) because "only" one person can be buried in the avalanche and, therefore, all other members of the group can begin rescue measures.

The **R**isk should be reduced to a sensible level. Every group should evaluate the risk that is acceptable to them. If the **DANGER IS 0** or the consequences are largely harmless, the risk is very low. Two sliders make the link clearer. If both are very "high", the risk is no longer acceptable.

Assessment:
+ = good
0 = neutral
- = poor
- = very poor

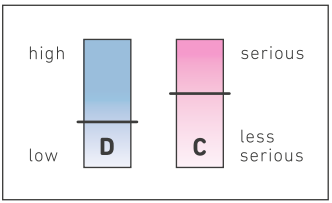


Photo: Hansi Heckmair

RECOGNIZING DANGEROUS AREAS

DETERMINING SLOPE STEEPNESS USING THE MAP

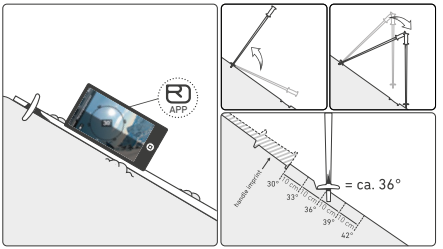
Digital maps often provide a slope gradient layer that uses **COLOR CODING** to indicate the steepness of the terrain.

Steepness can be determined from paper maps using a slope ruler.

Photos: Max Dräger

DETERMINING SLOPE STEEPNESS IN THE MOUNTAINS

In the mountains, slope steepness must be estimated **FROM A DISTANCE** – otherwise you will already be in the middle of the slope...
This requires a little practice. Estimate the steepness of slopes at slopes that are not dangerous and then check to see how close your estimates are. Steepness can be measured in two ways:



1. Using an **INCLINOMETER** on your cell phone or the Ortovox app (under "Tools").

TIP

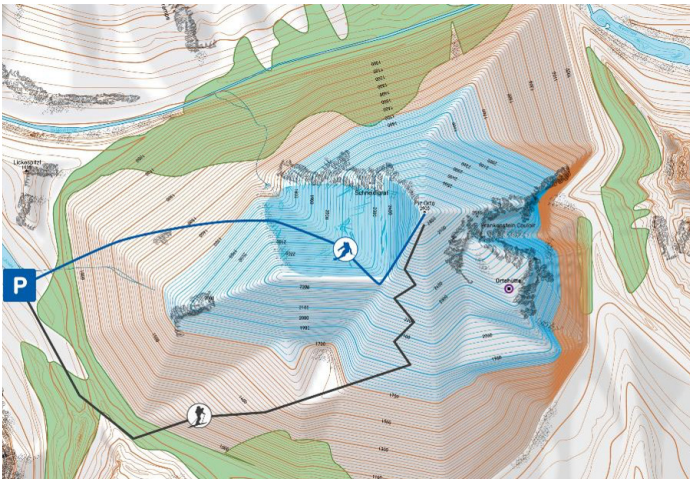
Place your cell phone on a ski or a ski pole.

2. **THE POLE METHOD**. It is important that both ski poles are set to the same length. One pole is placed at the relevant location pointing downhill the slope and then lifted so that there is a visible **IMPRINT IN THE SNOW**. The second pole is held out with the grip against the grip of the first, and serves as a **PENDULUM**. If the second pole meets the end of the imprint in the snow exactly, the slope is 30° (equilateral triangle). If it extends beyond the imprint towards the valley, the slope is steeper. Each additional 10 cm corresponds to about 3° additional slope angle.

FINDING THE CRUX SLOPES

We take three steps in order to identify cruxes during the planning phase:

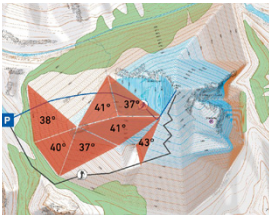
1. We mark all steep slopes **ABOVE 30**° along and above our route as potential cruxes.
2. We limit our selection to slopes that fit the description of avalanche prone locations as mentioned in the avalanche forecast (core zone) – ≥40° slopes can be selected, even if they are not in the core zone.
3. If remote triggering and spontaneous avalanches are unlikely*, we limit our selection to the slopes that we traverse or ski down – and do not include slopes above our route.



* Remote triggering is typical with persistent weak layers or new snow problems. In these cases, slopes above the intended rout need to be considered. If snow drifts (or wind slabs) are the only problem, remote triggering is rather rare. Remote triggering of wet slabs is rare. Avalanche forecasts usually address the frequency of natural avalanches if it is relevant.

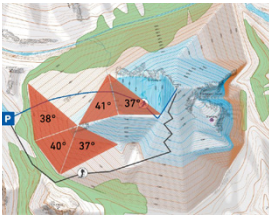
PROCEDURE:

After marking all steep slopes over 30° on or above our route, we consider the information we've collected from the avalanche bulletin (cf. page 23).
Using the information from the example avalanche bulletin, we can predict a wind slab problem for the crux in the picture. We can rule out a temperature problem because of the elevation, and persistent weak layers are rare on this aspect.



1. STEP:

Identify potential crux slopes (steeper than 30°) along and above the route.



2. STEP:

Limit your selection of crux slopes according to the information from the avalanche report. (hazard locations)

3. STEP:

Is remote triggering possible? If remote triggering can be ruled out or is highly unlikely, slopes steeper than 30° situated above the planned route (adjacent areas) can be omitted. In our example there are three slopes left as crux slopes.

CRUX CHECK

"IS THE TRIP OK?"

Because **RISK** is always calculated from Danger × Consequences, we should evaluate our cruxes using that formula.
When considering the link between danger and consequences, the **CRUX CHECK** tool can be of help. As it can be difficult to evaluate snow layers or assess the probability of avalanche release and crack propagation, slope steepness can be a helpful proxy. Because the steeper the slope, the more likely it is that there will be an avalanche.
We assign the appropriate **STEEPNESS CLASS** to our cruxes and then answer the questions about the consequences.

	D	**LIKELIHOOD OF TRIGGERING**	**+C**	**CONSEQUENCES**	**=R**	**RISK**
SLOPES IDENTIFIED WITH THE "CRUX FINDER"	≥ 40°	Slopes steeper than 39°		□ Sizeable slope? □ Large release volume? □ Terrain traps? □ No safe spots?		Extreme terrain is always considered a critical crux.
	≥ 35°	Slope angle 35°-39°		□ Sizeable slope? □ Large release volume? □ Terrain traps? □ No safe spots?		With 1 or more check the crux is critical
	≥ 30°	Slope angle 30°-34°		□ Sizeable slope? □ Large release volume? □ Terrain traps? □ No safe spots?		With 2 or more checks the crux is critical
	< 30°	Runout zones?				

THE CONSEQUENCES ARE EVALUATED USING FOUR QUESTIONS:

- ☑ "Is **THE SLOPE LARGE**?" We evaluate whether a release would result in a serious burial.
- ☑ "**IS MUCH SNOW GOING TO MOVE**?" In other words: How much snow will come down? The more snow, the deeper and more serious a burial could be.
- ☑ "Are there **TERRAIN TRAPS**?" that could make the consequences of a burial worse? I.e. ditches below that could lead to larger burial depths or obstacles such as precipices, rocks or trees that could lead to injury.
- ☑ "Are there **SAFE GROUPING SPOTS**?" We can avoid multi-person burials using suitable **GROUPING SPOTS** or sensible group organization. Because the more people that are buried, the lower the chances of survival.

For example, let's take a look at slope 1 from our example on page 29: The slope steepness is between 35° and 40°. At several hundreds vertical meters high, it's a large one. Skiing from the top of the slope, a couple of turn witll takes right into the middle of that large slope.
The runout is unfavorable as the slope leads to a hollow/gully. Chances of getting hurt in the avalanche path are low, but the unfavorable runout in combination with the size of the slope should be rated as critical.
Measures such as skiing along the planned route one at a time do not really make sense in this case, because the slope is large and in the end there is no safe grouping spot.
Terrain traps such as ditches or rocks in the runout area are not apparent from the map. As the slope immediately flattens above and below, and as we could ascend it one by one from right to left, only one or a maximum of two people would be in the danger area.
That makes two negative answers for the consequences. According to the table, that means we are dealing with a "critical crux". We should always plan an **ALTERNATIVE** for "critical cruxes" in case we cannot proceed when on the slope.

ESSENTIAL KIT?

EMERGENCY AVALANCHE EQUIPMENT

A **COMPLETE SET OF EMERGENCY AVALANCHE EQUIPMENT** enables you to locate and save your friends in case of emergency. The individual standard emergency equipment must **ALWAYS** be carried when you are outside the secured skiing area.

CHECKLIST

Individual Emergency-Equipment

☑ AVALANCHE TRANSCEIVER
3 antennas and a flagging function are standard.

☑ Shovel
A clearing function saves you invaluable time.

☑ Probe
A quick and stable quick assembly system is essential.

Extended Emergency-Equipment

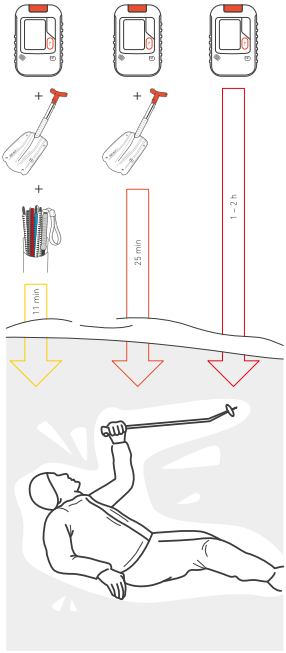
☑ Avalanche Airbag
An airbag system can reduce the burial depth.

☑ Helmet
Should always be worn when on tour.

Emergency-Equipment for Groups

☑ First-Aid Kit and Bivi bag
Can save lives and make emergencies more bearable.

☑ Mobile Phone
You can alert the rescue by dialing 112 (Europe) / 911 (US)



Emergency equipment cannot prevent an avalanche or potential burial.

Photos: Max Dräger

05. ON THE SLOPES

AVALANCHE TRANSCEIVER PARTNER-CHECK

At the starting point of the tour, the transmitting and receiving function on **ALL AVALANCHE TRANSCEIVERS** should be checked:

- The leader checks all other group members using the group check function.
- For devices without a group check function, all participants should switch their device to "search" while the leader remains on "send".
- The group should then switch to the "send" function and the leader carry out a check, with each group member passing the leader 5 – 10 m apart.

On a trip we should continuously reassess, adapt or amend our assumptions from the tour planning phase. We must remain attentive with all our senses (sight-hearing-touch), and suitable visibility conditions are essential!

SIGNS OF INSTABILITY

It is often difficult to judge avalanche danger in the mountains. Signs of instability are an unmistakable indication of acute local avalanche danger.
The three signs of instability are:

- Recent avalanches
  A recent avalanche is a clear indication of an unfavorable and unstable snowpack. The more recent the avalanche, the greater the danger of additional slab avalanches on surrounding slopes with the same or similar aspect.
- Shooting cracks
  Shooting cracks appear as cracks propagating outwards through the snowpack under the weight of a person or machine. They often leave a visible fracture and different levels to the sides of the fracture behind.
- WUMPF Sounds
  When a weak layer collapses, the air inside the snowpack escapes making that noise.

NOTE

Other signs of danger that can typically influence avalanche danger during an ascent are strong precipitation, particularly rain, strong wind, and a rapid rise in temperature.

Photos: LWD Tirol

WIND SIGNS

RECOGNIZING WIND-DRIFTED SNOW

„THE WIND IS THE ARCHITECT OF AVALANCHES."

This old saying contains a lot of truth. Because the wind produces the perfect wind-drifted snow slab. If the wind-drifted snow is fresh, there is a weak layer below, and the slope is steep enough, there is acute avalanche danger. That's why we should ensure we can recognize wind-drifted snow and read the wind direction in the snow.

Signs of danger:
Hard rime forms on summit crosses, rocks and ski-lift pylons, for example. Hard snow is blown against an obstacle where it then accumulates.

The **WIND ERODES** the surface snow on the windward side and deposits it on the leeward side, leaving sastrugi. The sastrugi **ALWAYS** point into the wind.

SNOW CORNICES show the prevailing wind direction over a long period of time. They are good signs of wind activity, especially on ridges and sharp terrain edges. Cornices always grow **WITH THE WIND**, as dangerous wind-drifted snow is deposited on the leeward side.

SNOW BANNERS are clear signs of strong wind activity. The snow is blown from the windward side to the leeward side.

Photos: Max Dräger

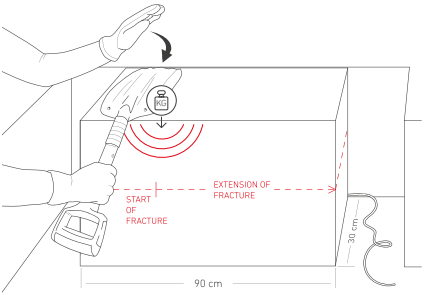
ON THE SLOPE

EVALUATING THE PROBABILITY OF AVALANCHE

The relevant questions regarding the four "ingredients" of a snow slab (see p. 4) are:

- ☑ Is there a weak layer with a slab on top (**LAYERS**)
- ☑ and can I disturb this (**INITIATION**)?
- ☑ If yes: Is the slab on the weak layer prone to **PROPAGATION**
- ☑ and is the slope **STEEPNESS** sufficient for there to be a slide (> 30°)?

A snow profile can help provide information on the layer. A compression test can tell us whether and how easily we can initiate the weak layer. The ECT (see illustration of extended column test) gives us information about the ease of propagation of the slab in combination with the weak layer.



NOTE

Because these questions take time and expertise to answer, most skiers will rather base their decisions on simple observations they make in the terrain.

EVALUATING THE PROBABILITY OF AN AVALANCHE

- A lack of signs of instability is the basis for entering a steep slope. If you have observed any signs of instability, you should always stay on the flat (under 30°).
- Given that in 90% of cases the first person causes the slope to release, existing tracks are an important sign, but no guarantee. Be more cautious with persistent weak layers. It is often not the first person that causes the slope to release here.
- Is there an acute avalanche problem? Can you recognize fresh wind-drifted snow? Have persistent weak layers been forecast? Is there a temperature or new snow problem?
- Steepness can be the final indicator. The "preferred angle" for snow slabs is between 35 – 40°!

The likelihood of triggering is often uncertain, and we have to live with this "unclear knowledge". Evaluations of --/-/0/+ and a mental risk slider can help us reach a decision.

Slope steepness evaluation

< 30° = +

30°-31° = 0

32°-34° = -

> 35° = --

Photo: Max Draeger

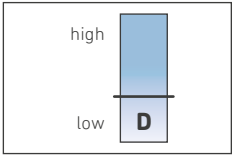
Simple danger evaluation:

no signs of instability (0)

no tracks (0)

new snow three days old, hardly any wind, old snow foundation is good (+)

slope steepness 34° (-)



The danger slider is in the bottom to middle here

ESTIMATING THE CONSEQUENCES

The four questions about consequences are our "standard construction kit" for risk assessment. Compared to the likelihood of triggering an avalanche, an evaluation is often easier. Symbols can be helpful for the individual questions, such as --/-/0/+

- ☑ "**IS THE SLOPE LARGE**?" The severity of a burial depends upon the height of the slope above me.
- ☑ "**IS MUCH SNOW GOING TO MOVE**?" The more snow begins to move and the heavier it is (wet snow, hard snow), the deeper and more serious a burial will be.
- ☑ "Are there **TERRAIN TRAPS**?" Ditches, obstacles or slopes in the avalanche path in particular can make the consequences more serious.
- ☑ "Are there **SAFE GROUPING SPOTS**?" We have to avoid multi-person burials. The more people are buried, the lower the chances of survival.

It is worth noting your personal risk appetite and motivation in the context of the group!

- ▷ What consequences am I and my buddies prepared to live with?
- ▷ What do we need to rule out (skiing first lines)?
- ▷ When will need to bail or change plans? (Detour, next hut cannot be reached)?
- ▷ Be aware that you should not sugarcoat the situation because you don't want to miss out!

Photo: Hansi Heckmair

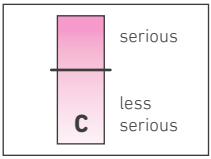
EXAMPLE: HOW WOULD THE SKIER (ABOVE IN THE PICTURE) RATE THE SLOPE?

The slope is large. Currently the person is still at the upper end. However, the situation is different further down. Triggering this slopes almost certainly means serious burial for the skier. (-)

There are 30 cm of new snow – the old snowpack below is stable according to the avalanche bulletin (0)

The outflow area is not particularly dramatic; there are no ditches, rocks or steep precipices. (0)

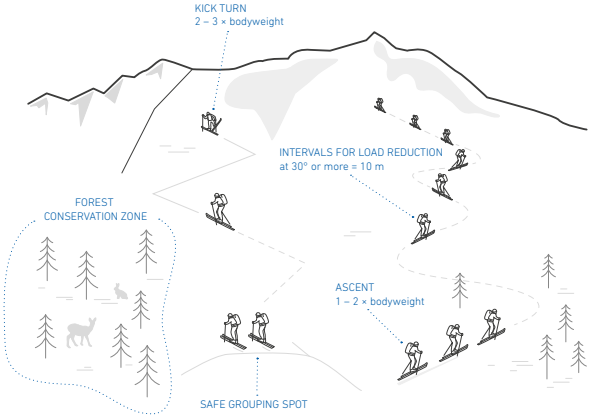
If there are good, safe skiers in the group, they can ski down the entire slope to the flat, one by one. (+)



The consequences slider is in the middle here

Photo: Max Draeger

MEASURES DURING THE ASCENT

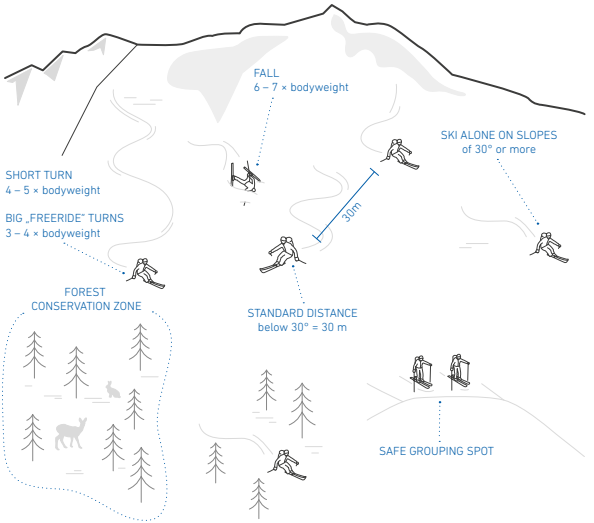


- Actively watch out for **SIGNS OF INSTABILITY**
- Use terrain relief such as flats and ridges
- **STAY AWAY** from dangerous slopes and terrain traps
- Spread out when you skin up steep slopes
- Go around fresh **SNOWDRIFTS** and **ACCUMULATIONS OF COMPACTED SNOW**
- Traverse steep slopes as high as possible
- Constantly estimate slope steepness
- Be considerate of other groups and coordinate with them

NOTE

If you are unsure of the danger level, a snow profile and snowpack tests may get you more information on the snowpack. If you are still unsure about safety, choosing an alternative route to stay in level terrain below 30° are the only good decisions!

MEASURES DURING DESCENT



- Ride steep slopes one by one
- Choose safe assembly points
- Agree on the order of descent: weaker skiers should be in the middle of the group
- Only ride all at the same time if conditions allow for
- In case of doubt, skiers should descend **ONE BY ONE**.
- Members of the group should **WATCH OUT FOR ONE ANOTHER**.
- In the forest, ride with your buddy: every two group members are responsible for each other and do not let each other out of their sight

NOTE

Falls and jumps impact the snow cover with **6 – 7 TIMES BODY WEIGHT** and should be avoided particularly in ridge areas and steep sections!

06.RESCUING YOUR COMPANION

AVALANCHE ACCIDENT

The chance of survival in the **FIRST 15 MINUTES** is relatively high at 90%, but after that drops drastically.

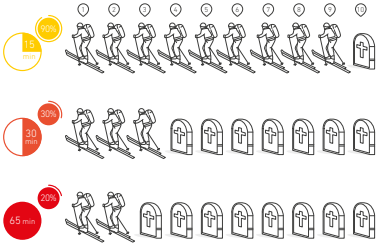


Image: in the style of SLF.ch; The chance of survival of fully buried people depending upon the duration of burial

Only with:

- complete emergency equipment
- a fast rescue operation
- and lots of training do you have a realistic chance of rescuing the victim.

HELP FROM COMPANIONS

- If an accident was observed, memorize the **POINT OF DISAPPEARANCE** and call professional search and rescue without delay.
- All helpers **SWITCH THEIR TRANSCEIVERS** to **SEARCH** or **STANDBY**
- If there are several helpers, one alerts the rescue service (eu 112 / us 911).
- If you have nobody to help or no signal for an emergency call, rescuing your buddy there and then is the highest priority!
- The search area starts at the **POINT OF DISAPPEARANCE** or at the **AVALANCHE CROWN**.

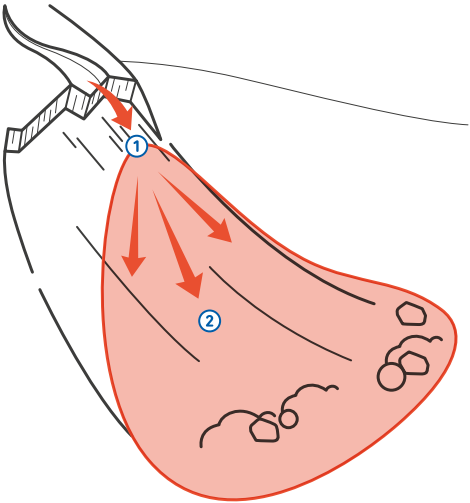
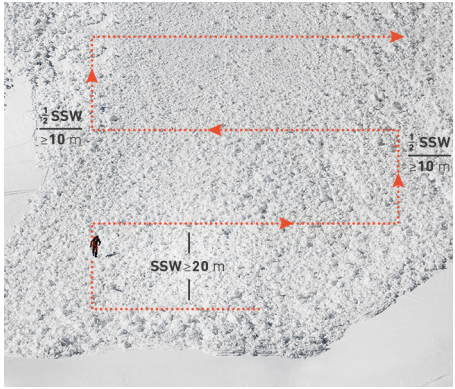


Photo: Max Dräger

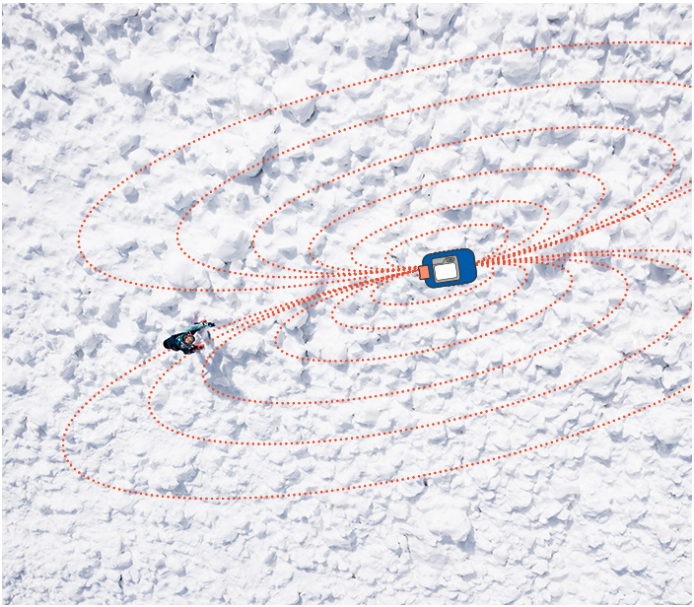
SEARCHING FOR BURIAL VICTIMS

SIGNAL SEARCH

- First, you should search the avalanche deposit with your **EYES AND EARS** for objects or partially buried victims.
- At the same time, start the signal search.
- Depending on the number of helpers, the avalanche deposit is searched in **PARALLEL** (search strip width max. 20 m, or 64 ft), or by **MEANDERING** with one person searching.



Photos: Max Dräger



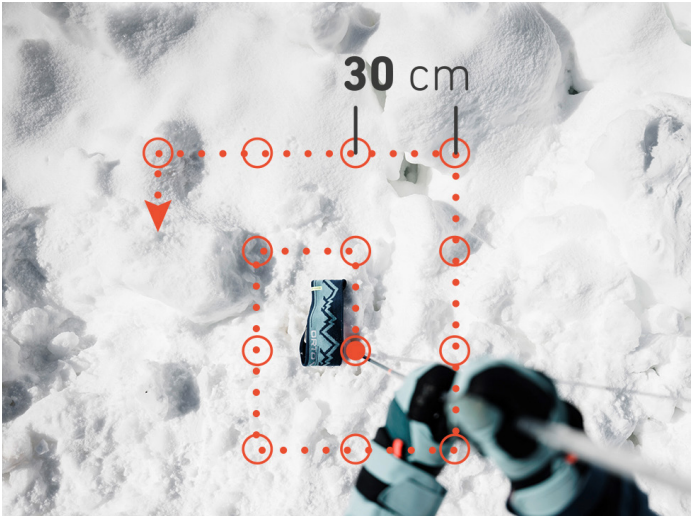
COARSE SEARCH

- Modern, digital 3-antenna avalanche transceivers will show you the direction.
- You just have to follow the **DIRECTION ARROW**.
- Distances that get smaller indicatet that you are getting closer to the victim.
- If the indicated distance increases: Turn 180° and go in the opposite direction! Good devices will actively prompt you to turn around.

FINE SEARCH

- When **2 – 3 METERS** (6 – 10 feet) away from the victim, hold the device as **CLOSE** as possible **TO THE SNOW SURFACE** and search **CROSSWAYS** until you find the lowest value.
- The value displayed equates to the victim's depth.
- You should ideally **MARK THIS POINT** using crossed poles and a shovel.

Photos: Max Dräger



PROBING LOCATION

- Mark the point with the smallest distance measurement (with crossed ski poles, shovel etc.) Starting from this point, probe the area systematically from **INSIDE TO THE OUTSIDE** in the 25cm (~10 in) grid spacing shown.
- The probe remains in place and is used for **ORIENTATION** purposes.

TIP

Always probe at a **90° ANGLE** to the surface of the snow.

DIGGING

- Read the victim's **DEPTH** from the probe and walk down the slope by this figure and start shoveling in a V-shape.
- If there are several helpers, two people stand at the front and shovel the snow backwards. The third stands behind and clears the snow away. **CHANGE POSITIONS AFTER ONE MINUTE**.
- The positions should be taken as follows: **CUT OUT BLOCKS**, **SHOVEL** and **CLEAR SNOW AWAY**.

TIP

SHOVELS with a **CLEARING FUNCTION** can save valuable time here.

Photos: Max Dräger

FIRST AID IN AN AVALANCHE ACCIDENT

After locating and probing for the buried person, it is time to start shoveling. When shoveling, always speak loudly to the person as they may be able to hear you. Always avoid making comments that could cause the buried person additional worry or stress.

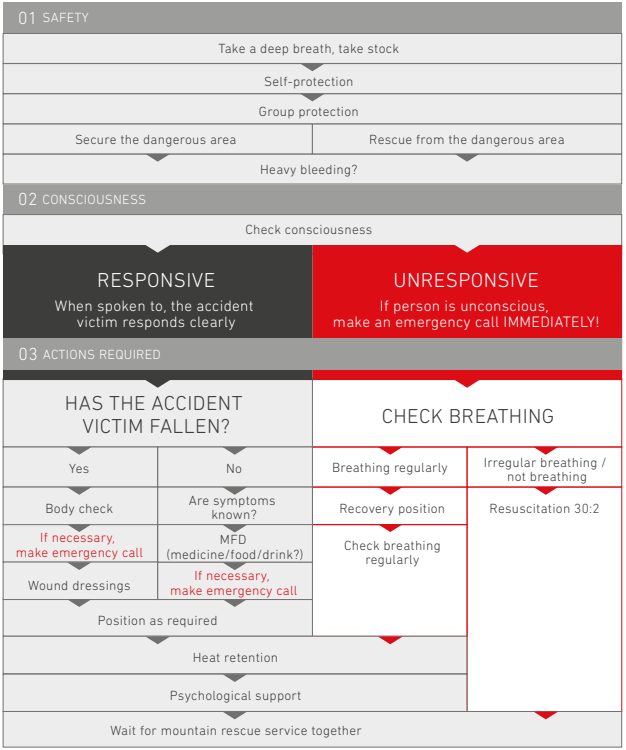
As soon as your shovel has reached the person:

- Check the direction the head is facing
  The main issue is lack of oxygen
  There is an acute risk of suffocation!
  Therefore, the faster the head and respiratory paths are freed,
  the better the chances of survival
- Continue shoveling briskly but **CAREFULLY** until you reach the victim's head
- Carefully uncover the victim's face

EMERGENCY MANAGEMENT

FIRST AID ALGORITHM

The alpine first aid algorithm serves as a guideline while providing assistance. This way, the first responder can be sure they do not forget any medical measures.



RESPONSIVE & BREATHING

If you have freed the buried person and they are **BREATHING** unaided, the focus should be on **KEEPING THEM WARM** and treating any potential injuries.
When positioning the victim, the mound made from shoveling will provide good wind-protection until evacuation is possible by a professional rescue team. The accident victim should be cared for until the mountain search and rescue team arrive.

UNRESPONSIVE

If the person does not react when you directly address them or gently shake them, but is **BREATHING**, put them in the **RECOVERY POSITION**.
However, if they are **NO LONGER BREATHING**, begin **RESUSCITATION IN THE RATIO 30:2** immediately and constantly **CHECK** their condition.

EMERGENCY CALL DO I HAVE RECEPTION?

YES

EURONOTRUF 112
USA 911
Bergrettung AT 140

ECHO SOS

NO

1. Switch your cell phone to the lock screen or turn on your phone without unlocking it.
2. Press the emergency call button or enter your PIN.
3. Dial 112 or press "Emergency Call". Is the number dialing?

NO

YES

EMERGENCY CALLS NOT POSSIBLE!

- Save the GPS coordinates of the accident site.
- Change location.
- Ensure accessibility!

MAKE AN EMERGENCY CALL

PROFESSIONAL MOUNTAIN SEARCH AND RESCUE

In the case of an avalanche accident, immediately notify the professional rescue team via **EMERGENCY CALL**. The emergency call will go to the emergency control center where all necessary rescue services (mountain rescue service, helicopter, canine unit, etc.) are alerted and coordinated. The mountain search and rescue team have many rescue methods at their disposal in addition to avalanche transceiver search. The quicker the emergency call is made, the quicker the professional rescue team can provide support. The mountain rescue service's director of operations coordinates all rescue services. Along with the avalanche transceiver search, these include important resources such as **AVALANCHE RESCUE DOGS**, the **RECCO DETECTOR** ® and **DRONES**. The rescue services systematically search and mark the avalanche. If no signal can be found or there is uncertainty about the number of buried people, additional avalanche search chains are used.

LEGAL NOTICE

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SMART DECISIONS ARE

BASED ON KNOWLEDGE.

WOULD YOU HAVE KNOWN?
Accumulation of drifting snow in areas near the ridge.

GET LIFE-SAVING KNOWLEDGE IN THE DIGITAL SAFETY ACADEMY LAB SNOW, OUR E-LEARNING PLATFORM FOR AVALANCHE PROTECTION.

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When you go off-piste and onto unsecured terrain, you need in-depth knowledge about how to reduce risks and perform an avalanche victim search. Secure a place on a course and get yourself prepared for an emergency.
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TAKE PART NOW AND TRY THEM OUT!