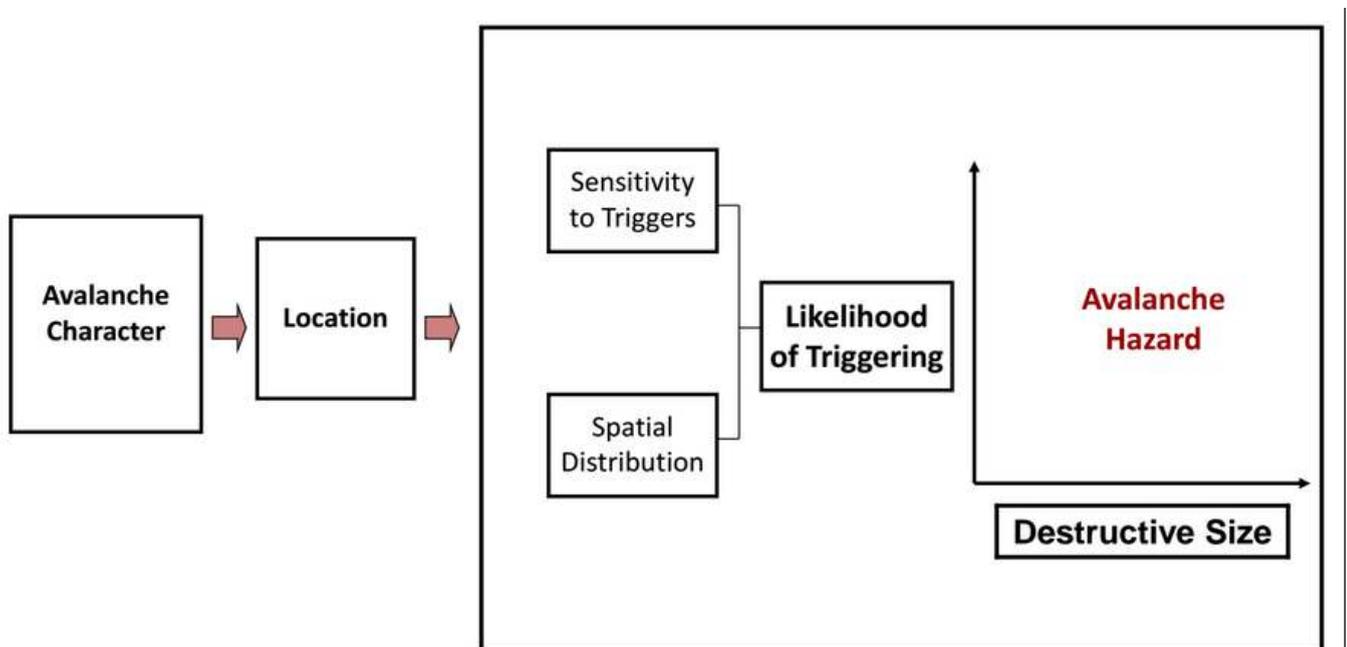


# Avalanche Skills Course 2 Supplement

This resource is intended to supplement the Mountain Safety Council Avalanche Skills Course 2 Participant Workbook.

## Conceptual Model of Avalanche Hazard

This conceptual model of avalanche hazard identifies the key components of avalanche hazard and structures them into a systematic, consistent workflow for hazard and risk assessments. This is used to communicate the risk in avalanche forecasts and can be applied at any scale in space or time



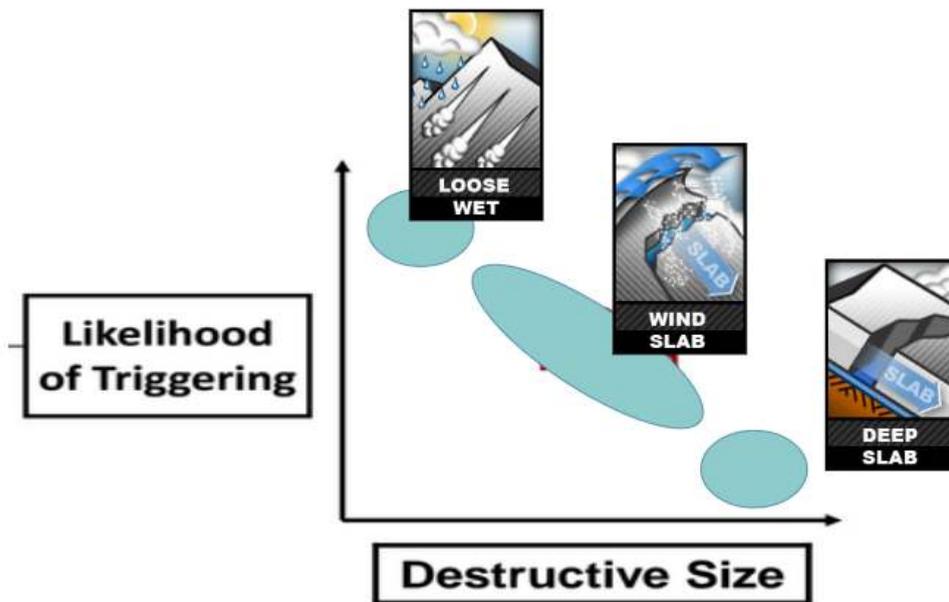
### *Avalanche Character*

Avalanches are categorised by their character. Primary characters include slab or loose, wet or dry. These are divided into sub-classifications. Characters are used within avalanche forecasts to provide more information on where the danger is likely to exist, how to identify the problem, and how to manage the risks. Different characters will exhibit different parameters on the size and extent of the problem, what terrain to favour or avoid, which observations are most useful, the expected size of the avalanches, perceptibility to triggering, and how long the problem is likely to persist.

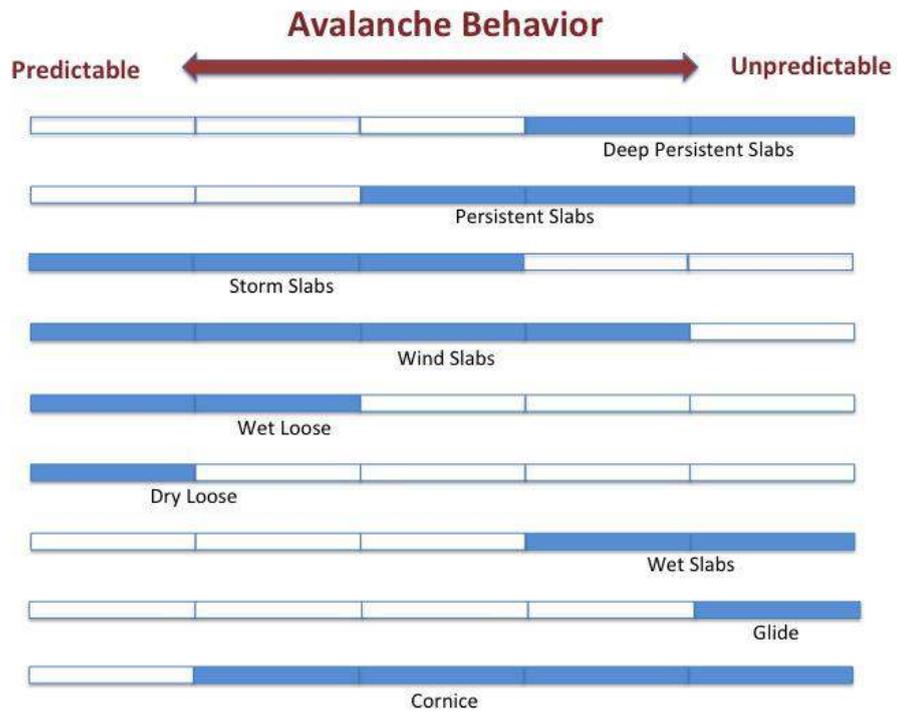


Character	Weak Layer / Interface	Slab Properties	Persistence	Weak Layer Location	Propagation Potential	Relative Size Potential
<b>Loose Dry</b>	Various (no cohesion)	None	Hours/days	Near the surface	Down slope entrainment	R1-2
<b>Loose Wet</b>	Various (no cohesion)	None	Hours/days	Any level	Significant down slope entrainment	R1-3
<b>Wind Slabs</b>	DF, PP	4F-K Wind transported	Hours/days	Upper pack	Terrain feature	R1-3
<b>Storm Slabs</b>	PP, DF	F-P Soft -stiff	Hours/days	In or just below storm snow	Path	R1-4
<b>Wet Slabs</b>	Various	4F-P Wet grains	Hours/days	Mid pack to deep	Path	R1-5 (climax)
<b>Persistent Slabs</b>	PWLs such as SH, FC, CR, FC/CR combo	4F-P Stiff-Hard	Weeks/months	Upper to mid pack	Path to adjacent paths	R2-4
<b>Deep Persistent Slabs</b>	PWLs such as DH, FC, CR, FC/CR combo	1F-K Hard	Weeks/months	Deep or basal	Path to adjacent paths	R3-5 (climax)
<b>Cornices</b>	~	~	Months w/ short peaks	~	~	~
<b>Comment</b>	Typical failure plane	Typical kind of slab	Typical duration of instability	Relative to HS	Typical expectation	Typical range of size relative to path

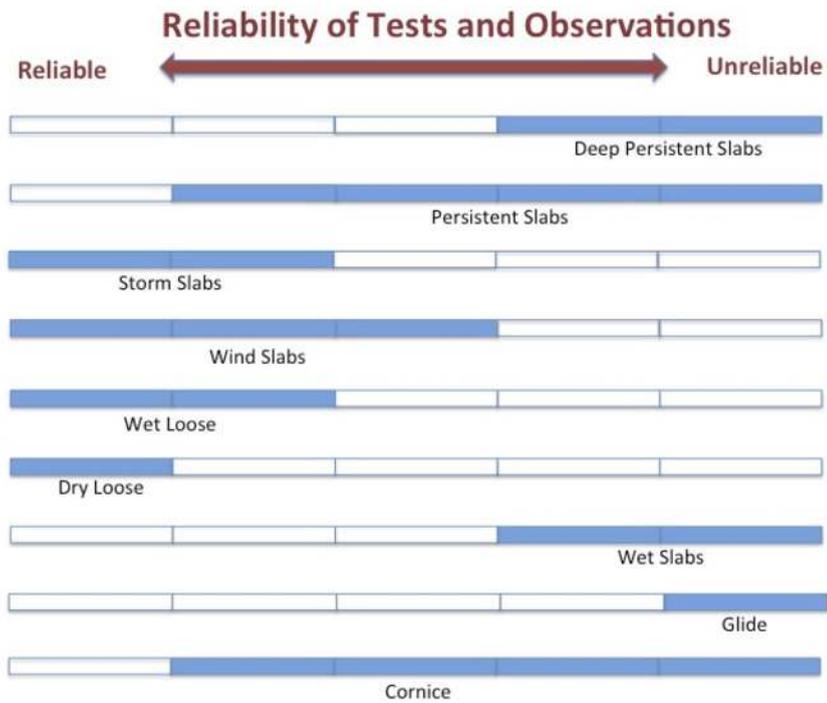
Relationship of Avalanche Likelihood, Size and Character



Predicability

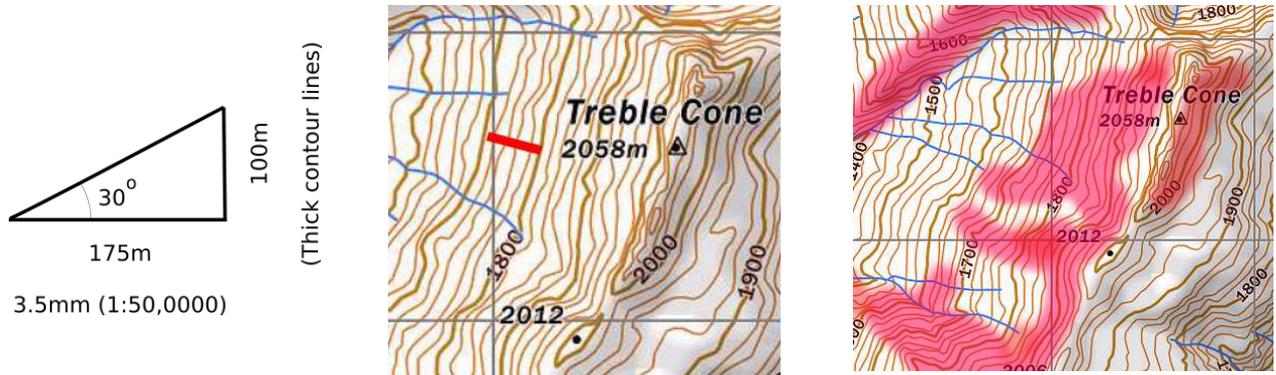


Reliability of Tests and Observations

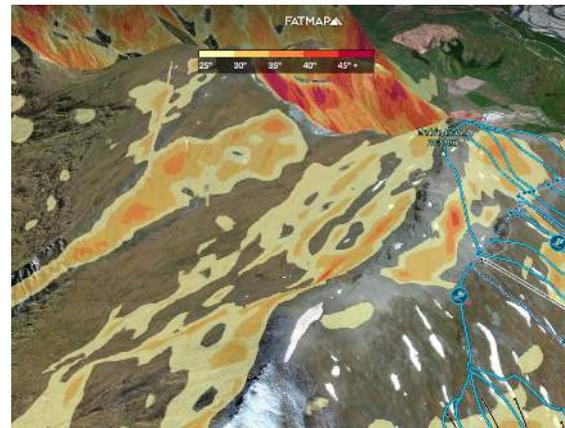


# Terrain Assessment

## Assessing Slope Angle Using a Topomap



Websites and smartphone apps such as Fatmap® provide powerful tools for assessing avalanche terrain. These can be used as a guide to identifying the complexity of avalanche terrain using terrain overlays that highlight slope angles between 30° and 45°.



## Applying Avalanche Danger to the Terrain



Avalanche Terrain between 30 and 45 degrees

Avalanche Danger applied to Terrain



# Avalanche Assessment

## Information Gathering

Gathering information about previous and current weather and observations of the snow surface or snowpack structure can provide an indication of an avalanche danger being present. Take particular note of observations that are contrary to the perceived avalanche danger forecast, indicating that the actual conditions might not match those that were forecasted.

## Signs on the Surface (Class 1)

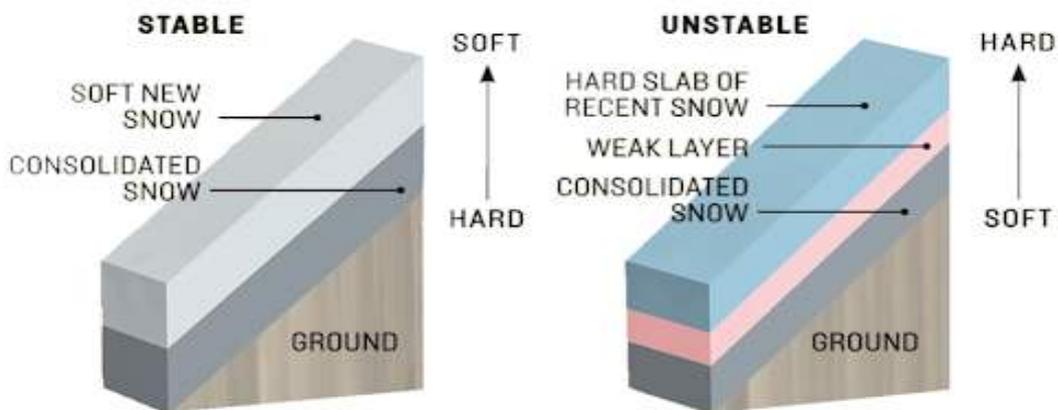
<b>Recent avalanche activity</b>	<p>Noted relative to Angle, Aspect and Altitude Evidence of recent avalanches will give good evidence of a current potential avalanche danger. Slab avalanches that have been released within the last 48 hours are very significant since the instability that caused them will most likely still exist in other slopes with similar terrain characteristics. Evidence of slab avalanches can remain for many days or even weeks.</p>
<b>Signs of Instability (cracking, whumpfung, pin-wheeling)</b>	<p>Signs of snowpack instability include shooting cracks, 'whumpfung', pinwheels, or glide cracks. Weak layers within a layered snowpack are sometimes so unsupportive that when they are walked or skied over them they will suddenly settle making a 'whumpfung' sound. This can occur on flat or low-angle slopes where there is no avalanche danger but it does indicate similar snowpack conditions in avalanche terrain and may even remotely trigger avalanches on adjacent slopes. Sometimes they are accompanied by cracks appearing on the snow surface. On steeper slopes, this sudden settling can trigger avalanches.</p>
<b>Snow surface conditions</b>	<p>What evidence does the snow surface give on current and previous weather. Scoured, smooth, sun-affected?</p>



### Signs in the Snowpack (Class 2)

<b>Snowpack test results</b>	CT or ECT
<b>Layer properties</b>	Snowpack structure ‘Lemons’. Layer of greatest concern. Upside down or rightside up.
<b>Snow depth</b>	Threshold depths on sunny and shady slopes
<b>Penetrability</b>	Is snow available for transport. If there is loose snow that can be shifted by the wind then there does not need to be new snow for there to be new loading.
<b>Blowing snow</b>	Any time snow can be seen blowing off ridge tops then there is likely new snow loading.

#### Upside down or Rightside Up



#### Snowpack Structure ‘Lemons’

The presence of a number of these ‘Lemons’ in the snowpack structure can be an indication of instability.

- Weak layer depth <1m
- Weak layer thickness <10cm
- Difference in hardness >1 step
- Difference in grain size >1mm
- Weak layers grain type (Facets, Surface Hoar etc.)



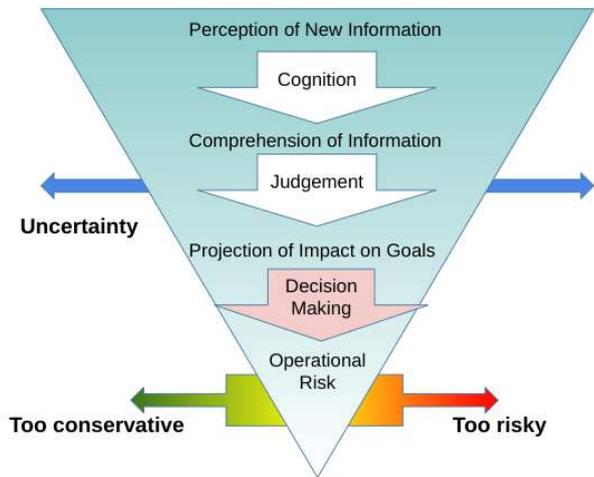
**Weather (Class 3)**

<b>Loading (precipitation)</b>	Avalanche danger will increase whenever additional weight is added to the existing snowpack. This could include new snow, rain, and particularly wind (see below). The additional load may overload, or bring the snowpack close to overloading, weakness within the old snow, or at the boundary between the new and old snow.
<b>Wind direction and strength</b>	<p>One of the most common causes of avalanches in NZ, is wind. Moderate winds with new snow or snow available for transport can result in a meter or more of freshly loaded snow on the lee side.</p> <p>Along pronounced ridges running perpendicular to the wind direction, snow will often form into cornices, often overhanging the lee side. Any obvious cornice formation should be regarded as an indication of likely wind slab formation on the lee side. Cornices should also be given a wide berth as they can fracture a long way back from the crest.</p>
<b>Rapidly rising temperatures</b>	<p>If the upper snowpack is wet due to the warming effects of the sun, above freezing air temperatures, or rain, especially if the change has been rapid, then the snow can become unstable. These problems are commonly an issue during the afternoon in late winter.</p> <p>Rain will add warmth to the snowpack tending the temperature of the snow towards 0°C. Rain events are common in NZ and whilst people tend not to be travelling in the mountains while it is raining, travelling immediately after a rain event should be avoided, giving the snow time to settle and refreeze.</p>
<b>Solar radiation</b>	Sun on snow has a big effect, especially during late winter and spring. Snow warming from the sun will be aspect-related. Slopes facing North will be hardest hit.



## Situational Awareness and Decision Making

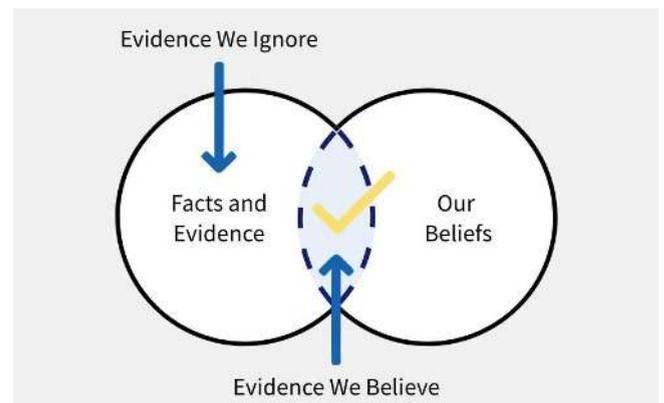
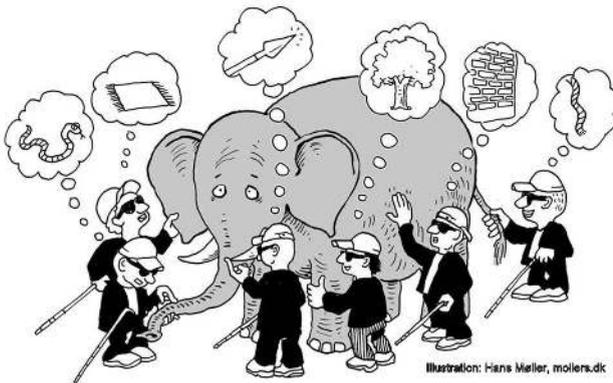
### Perception



Accessing and recognising the information that is available to make good decisions about avalanche risk depends on maintaining situational awareness.

This includes all the observations we can make about the avalanche hazard including the perception of what information is available, beneath our feet, from above, and the consequences below.

### Comprehension



One or two pieces of sensational information may distract from other critical data or reasoning or cause you to be distracted from making a realistic assessment. We can often also fall into the trap of ignoring or dismissing information that conflicts with pre-established opinions or augmenting and prioritising any information that confirms those opinions. This is known as Confirmation Bias.

### Projection on Goal

Purely rational decisions would involve weighing all alternatives. This is always limited by the amount of available time and information. In our decision-making, we need to be cognitive of any inherent uncertainty, how much information is available and the quality of the information.



While people strive to make rational choices, human judgment is subject to cognitive limitations.

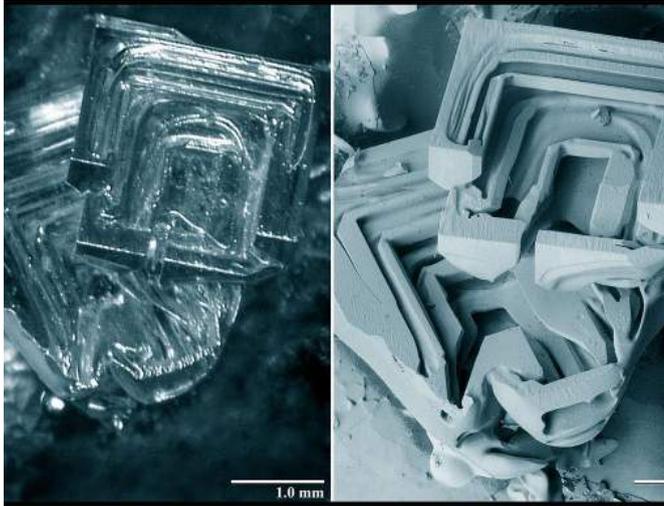
We need to be and apply this to the margin of error within our decision-making. This ensures that risk is kept within acceptable levels whilst acknowledging differences between the actual and perceived risk. During times of higher uncertainty then it is appropriate to maintain a wider margin of safety and be conservative with decision-making.



## Snowpack

### *Dry Snow Metamorphism: Temperature Gradient*

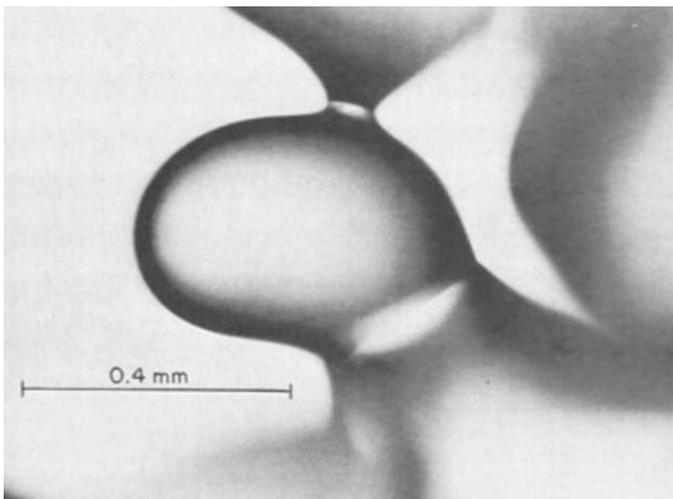
Temperature gradient drives the processes of Rounding or Faceting



A HIGH temperature gradient forms WEAK snow ( $1^{\circ}\text{C} / 10\text{cm}$  or more)

Deposition creates angular shapes which are less cohesive (sugary)

Faceting (Weak)



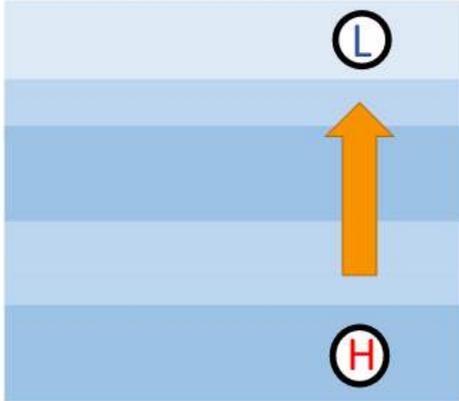
A LOW temperature gradient forms STRONG, WELL BONDED snow (less than  $1^{\circ}\text{C} / 10\text{cm}$ )

Minimal vapor movement encourages bonding between grains of snow

Rounding (Strong)



SNOW SURFACE -10° C COLD = LOW PRESSURE



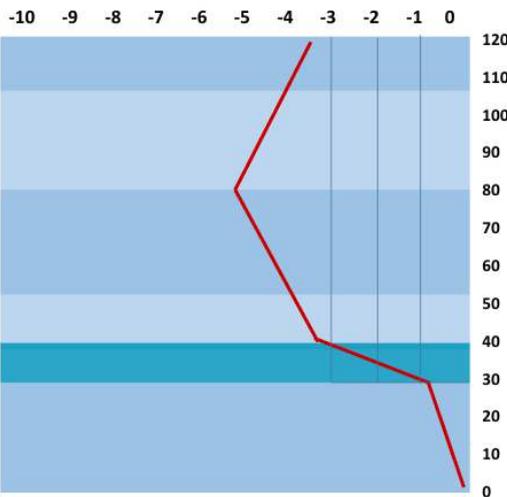
GROUND 0° C WARM = HIGH PRESSURE

Water vapor travels through the snowpack...

...from areas of H pressure...

...to areas of L pressure.

Generally upwards from ground

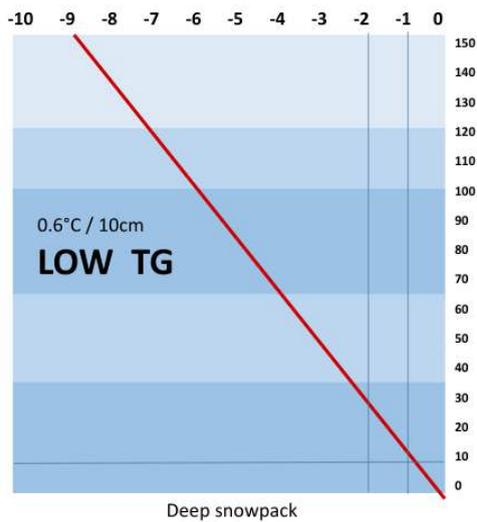


Both **LOW TG** and **HIGH TG** may exist in different parts of the same snowpack

A **High TG** can often be found around crusts

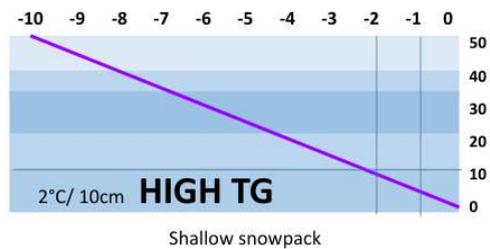
← **HIGH TG**

← **LOW TG**

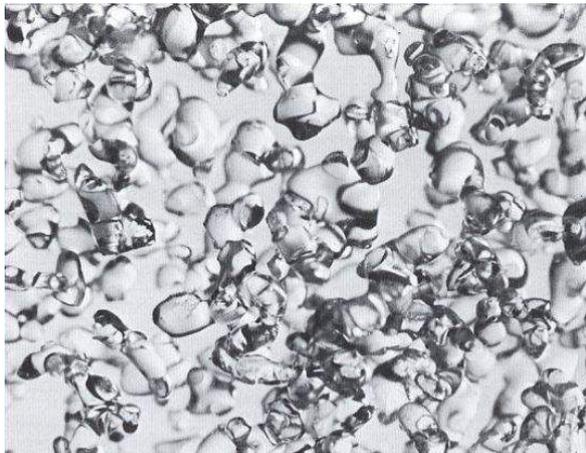


### DEEP vs SHALLOW Snowpack

1°C change or more over 10cm is considered a **HIGH** TEMPERATURE GRADIENT



## Wet Snow Metamorphism: Melt Freeze



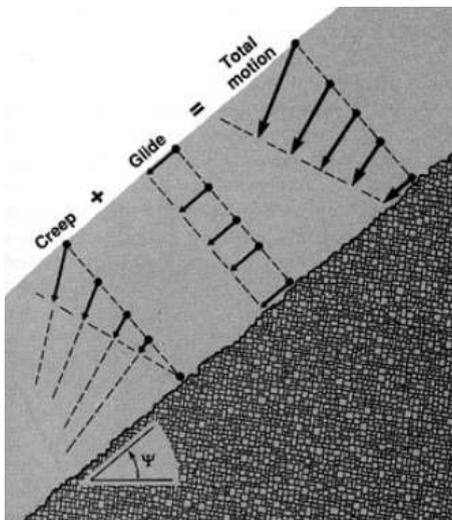
Melt-Freeze Metamorphism occurs when the snowpack is warmed by sun, temperature or rain

This forms rounded grains joined by liquid water

In melt phase - moist or slushy snow - can be weak and incohesive

In frozen phase - ice layers or crusts - snow is generally strong and well bonded

## Creep and Glide



### Creep

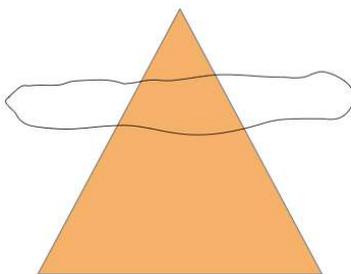
The snowpack is always creeping due to metamorphism and its high porosity

### Glide

The entire snowpack slips over the ground or at an interface such as an ice layer

Glide cracks sign of instability for potential wet slab

## Surface Hoar



Moisture in the air is deposited on the cold snow surface (like dew)

A fragile, feathery form on the surface which may become a weak layer when buried

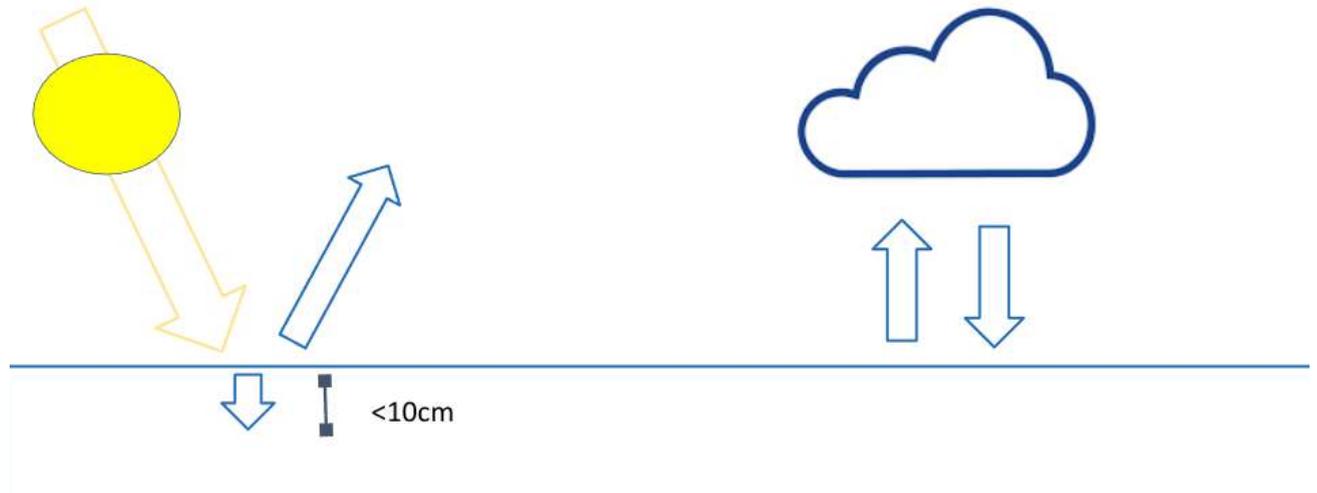
Surface hoar generally forms at night with clear skies, light wind and some humidity



### *Heat Exchange at the Snow Surface*

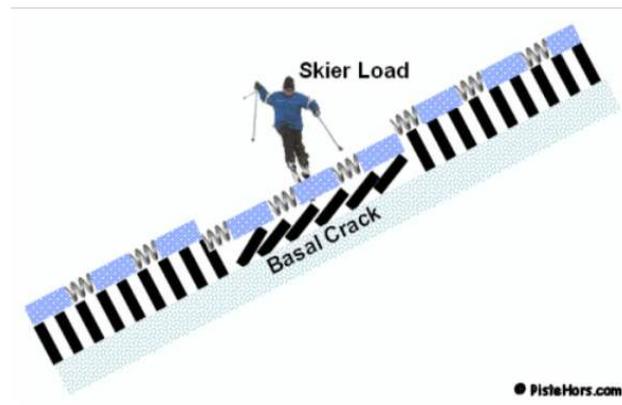
Clear skies will allow radiation to reflect back into the atmosphere resulting in a significant cooling of the top 10cm of the snowpack, regardless of the ambient air temperature.

It this results in a high temperature gradient, it will result in near-surface faceting.

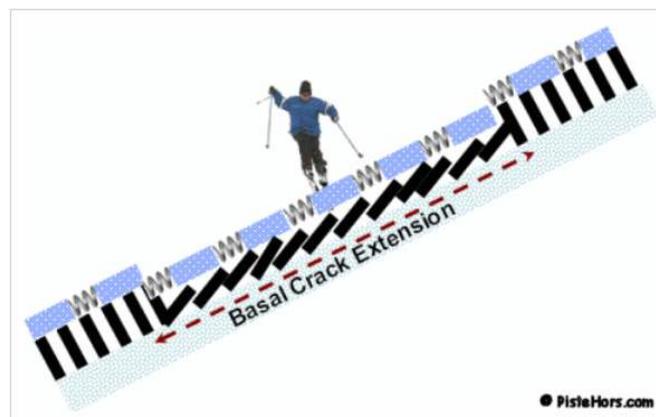


## Fracture Mechanics

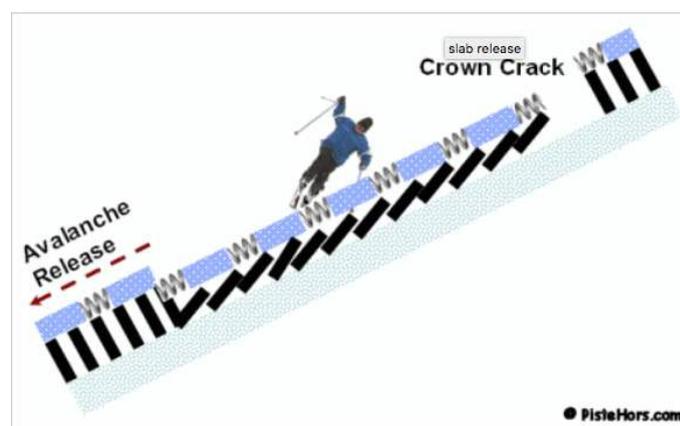
### Initiation 'Snap'



### Fracture Propagation 'Crackle'



### Slab release 'Pop'



# Managing Human Factors

## *Planning*

Good decision-making can be supported by thorough planning. This includes reviewing and understanding the weather and avalanche forecast and analysing terrain and possible routes to determine what areas may be safe or dangerous.

We are particularly interested in the previous 24-48 hrs of weather and the forecast for the time we are in the field. This includes:

- Wind strength and direction
- Precipitation type and amount
- Temperature at different elevations

This information is used to form a picture of what conditions to expect, what information to target to confirm or challenge this picture, and where would be good points to gather this information. These are all important considerations when planning routes. Timing is also often critical as patience will allow for danger to reduce after, for example, new snow, rain, or wind.

Trip plans should identify critical decision points (time or location) and have contingency plans in place. This pre-loads decision-making so you are not having to make things up in the field when you may be tired, cold, wet, or subject to other heuristic traps.

You should understand your group's goals, experience, abilities, strengths, weaknesses, and risk acceptance level so that you can choose objectives appropriate to the group and match expectations and approaches before going into the field.

Finally, at the end of your day, you should reflect on your planning, decisions during the day and observations in the field to apply any learnings into preparing for your next day in the backcountry.





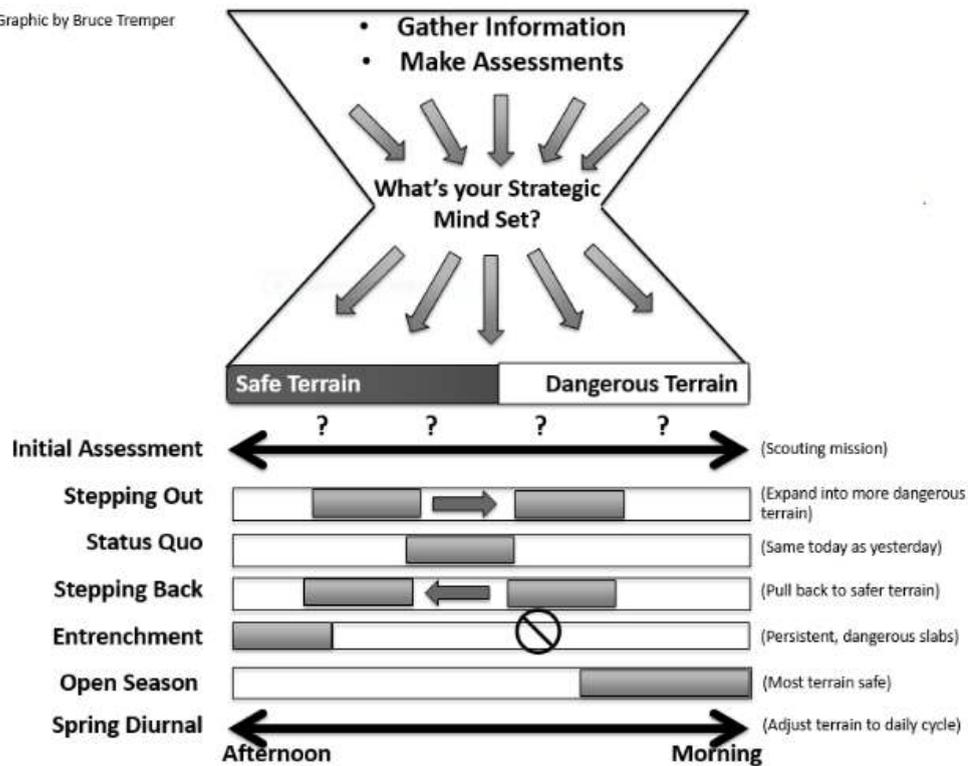
## Communication

It is always important to communicate well within your group. Communication should ideally be conducted in a safe and comfortable place, out of weather, and with hoods down. Well-matched teams should be able to share observations and opinions, encourage discussion, and make consensus decisions where everyone can have a veto. Often nominating a 'devil's advocate' can help to test any safety critical decision.

## Mindset

Identifying a common group mindset for any trip, helps align decision-making. This should be agreed upon daily by the group somewhere warm, dry, and comfortable before you head out. A group mindset helps to look at the facts and information without outside influences like awesome snow, perfect conditions, and weather (hot, cold, windy, snowy) affecting your thought process. Mindset is a mental attitude or disposition that would evolve from hazard assessment, local knowledge, and personal level of risk acceptance, perception of conditions, terrain, and level of uncertainty or confidence in the forecast. These can include keeping it mellow, avoiding avalanche terrain, checking things out, or acknowledging improving confidence in an assessment of conditions.

Graphic by Bruce Tremper



### ***Discipline and Safe travel techniques***

Following a disciplined and systematic approach to your planning, preparation, and travel in the backcountry will minimise your exposure to risk. Whilst we try and make good assessments of avalanche danger, we have to recognise that we can be wrong, and safe travel discipline will prevent us from getting caught out if taking shortcuts.

The terrain you choose will greatly affect your safety in avalanche terrain. Avalanche involvements are mostly triggered by another member of the party so regardless of the perceived avalanche danger, discipline in applying the precautions of safe travel techniques will further mitigate any risk when traveling in avalanche terrain.

Space out so that no more than one person is exposed to avalanche hazards at one time. The spacing will therefore vary depending on the complexity of the terrain and the size of avalanche paths.

Maintain visual contact at all times. This may mean positioning a spotter for blind pitches of skiing and looking back to the last person skiing the slope.



Regroup in safe spots or islands of safety that are not exposed to hazards from above or have terrain traps below. These depend on the nature and expected size of the current avalanche danger.

Choose safe routes that are low angle or follow ridges.

Follow good communication protocols within your group. Communication will be more difficult with bigger groups, when fatigued, or when environmental conditions are challenging.

Before entering avalanche terrain, identify escape routes that can be followed in the event of an avalanche to attempt to get you out of and away from any further danger.

