Persistent Slab Avalanches

Introduction

Persistent slab avalanches are caused by a cohesive slab of snow losing its bond to an underlying weak layer that strengthens slowly or not at all over time. These weak layers can remain unstable and primed for human triggering for weeks after burial and often catch backcountry recreationists when they least expect it, on clear and calm days. Persistent slab avalanches are tricky to manage because they can be triggered by light loads with very little warning and they often release above the trigger, making it difficult to escape if you are the trigger.

Development

Persistent slabs form when a persistent weak layer becomes buried and remains unstable after the normal storm snow or wind slab instabilities associated with storms have subsided. Some persistent slabs become deep persistent slabs if the weak layer doesn't strengthen for extended periods of time.

Time of the Season:

Persistent slabs can form at any point in the season, although they are more likely in fall, winter, or early spring before the end of regular storms and prior to the onset of melt- freeze cycles.

In a colder than normal spring, persistent slabs can continue to form until the late spring melt begins.

Weather Patterns:

Persistent slabs are often associated with the same weak layers as deep persistent slabs (in fact, in most cases it is a persistent slab that lasts, which forms a deep persistent slab problem later in the winter). So rain on snow events and shallow early season snowpacks combined with clear, dry spells often result in persistent slab formation in association with facet/crust layers and basal facets or depth hoar. In addition, clear, dry, cold spells during the winter can produce facets at or near the surface which then become the failure layer for a slab that forms on top. Especially in the interior mountain snow climate, calm clear dry weather is often associated with the formation of surface hoar, which is another very common weak layer associated with persistent slabs.

Rain on snow events produce a wet surface layer. If this wet surface is buried by snowfalls before it freezes, development of facet on crust layers is common. Facet/crust layers can also develop if the surface freezes first and is then buried by subsequent snowfalls, but in general weak layers that develop under the latter conditions are not as severe. In either case, faceting above and/or below crusts is exacerbated if a clear, dry spell occurs after initial formation of a facet on crust layer but before it is deeply buried.

Basal facets and depth hoar form when a shallow, early-season snowpack is subjected to a period of clear, dry weather. This creates strong temperature gradients in the snowpack, which in turn promote development of facets and depth hoar layers at or near the ground.

Surface faceting occurs when a strong temperature gradient is generated at or near the surface of the snowpack.

Surface hoar is the winter equivalent of dew and it forms during periods of clear weather when there is sufficient water vapour in the air in conjunction with a snow surface that is below the surrounding air's dew point. It's a good bet you'll find surface hoar where fog banks and layers of cloud come into contact with mountainsides but it often forms even in the absence of fog or clouds.

Persistent slab problems occur when facet/crust layers, basal facets and depth hoar, surface facets, or surface hoar are buried by snowfalls but are not buried deeply enough to be considered deep persistent slabs. Persistent slabs are more likely to develop if the initial snowfalls burying the layers are low density, light accumulations of cold snow.

Snow Climates:
Persistent slabs are uncommon (although not unheard of) in maritime climates. Warm temperatures, high density snow, large storm snow accumulations, and regular storm snow slab avalanche activity tend to prevent formation of or eliminate any persistent weak layers in the early season.

Persistent deep slabs are common in an interior mountain climate where weather conditions are conducive to the formation of facet/crust combinations, surface faceting, and surface hoar. Occasionally, basal facet/depth hoar layers do form in the interior but this is not a common situation.

Persistent slabs are very common in continental climates. Rain on snow events which might create facet on crust conditions and surface hoar formation are less common in these climates, but long periods of cold, dry weather that occur throughout the winter are highly conducive to basal facet and depth hoar formation and surface faceting. This produces layers that may not be buried deeply enough to become deep slabs but which, nonetheless, are extremely persistent.

Spatial Distribution:
The persistent weak layers that underlie a persistent slab can be widely distributed or quite isolated. How widespread a problem will be depends entirely on the weather pattern that created it. For example, if a rain on snow event is widespread, the weak layer that subsequently develops can span entire ranges, whole regions, or even multiple climatic zones. Conversely, isolated areas of facet on crust or basal facets/depth hoar are common if the snowpack and weather conditions that produce them are localized events.

Similarly, the extended periods of early season clear dry weather required to form basal facets and depth hoar may be widespread or localized depending on the winter in question and the geographic region.

Conditions conducive to surface faceting are often localized. It is not uncommon, however, for surface facets to span multiple ranges and even multiple climatic zones.

Surface hoar formation are generally isolated or localized, often limited to specific bands of elevation. Contrary many other weak layers, surface hoar commonly forms and persists more at lower elevations than higher. However, in extreme cases, surface hoar can span elevation bands and even multiple ranges or even multiple climatic zones.

Avalanche Activity Patterns

Seasonal Timing and Persistence:
Persistent slab activity shows little preference for seasonal timing—any time a persistent grain is buried, the potential for persistent slab avalanches exists.

Because the grains that form the weak layers are extremely resistant to strengthening, these problems often persist for weeks in deep snow climates (where they tend to become deep persistent problems after longer periods of burial). In shallow snow climates the problem can persist months or even an entire season where there's often not enough accumulated snowfall to bury them deeply enough that they become a deep slab problem.

Size and Propagation:
When the weak layer that underlies the slab is widely distributed, it's common to see wide propagations where most or all of start zones clean out. In these situations, fracture lines can run great distances, may propagate across terrain features that generally stop fracture lines in other types of avalanches, and in extreme circumstances can connect multiple avalanche paths. These slides sometimes overrun significant terrain features in the track or runout zone destroying mature timber and lengthening or widening existing paths.

Spatial Distribution and Variability:
Persistent slab avalanches are common at all elevations. In some cases, they are a greater (or at least a longer-lived) problem at lower elevations where lesser snowfalls and more wind sheltered terrain prevent them from strengthening due to overburden weight and they remain shallow enough to be sensitive to triggering for long periods of time. Persistent slabs are common on all aspects and show little preference for specific terrain features.

Persistent slab avalanche activity is often variable in distribution over terrain. That is, one mountain range, one drainage, one mountain, one slope on a mountain, a given elevation, or a particular aspect may have a persistent deep slab problem while adjacent ranges, drainage, mountains, slopes, elevations, or aspects do not.

The factors that drive variability include the weather pattern than caused the problem in the first place and the amount of avalanche activity on the weak layer soon after burial. The more widespread the weather pattern and the less avalanche activity on the layer early in its lifespan, the more widespread persistent slab activity will be and vice versa.

Persistent slab avalanches, especially when the weak layer is surface hoar, can occur on surprisingly low angle terrain or can pull surprisingly far back onto flat terrain above steeper slopes. In extreme cases, even slopes with average inclines as little as 15 degrees can slide.

Triggering:
In the earlier stages of a persistent slab instability, avalanches tend to be very easily triggered and are of limited size. As a persistent slab instability evolves and the weak layer becomes more deeply buried, avalanches become more difficult to trigger but they are deeper and have larger propagations, increasing their destructive size potential. In the late stages of a persistent slab instability avalanches may be difficult to trigger, but areas of instability capable of producing avalanches with very large destructive potential lingers. At this stage slides can propagate through terrain features.

Remote triggering, especially from shallow or weak spots in the snowpack is common. In deep snowpacks, layers that become resistant to triggering are generally buried deeply enough that they become deep persistent slab problems.

Certain weather conditions promote increased sensitivity to triggering:

- Accumulations of wind driven snow or new snowfall at a rate of 3-5cm per hour (3mm/hour water equivalent) or more.
- Rainfall of any amount.
- Total snowfall accumulations of 30-50cm or more (30mm of water equivalent) in a 12 hour period or less.
- Strong solar radiation or warm temperatures making the surface of the snowpack noticeably denser or moister.
- Air temperatures warming at a rate of 3°C per hour or more, especially if the temperature rises above 0°C as a result.

If more than one of these weather conditions occur together, the effect is greater than the sum of its parts. When weather conditions are conducive to increased sensitivity to triggering, lighter triggers, such as a single skier, may be enough to tip the balance and trigger an avalanche.

Recognition and Assessment in the Field

Avalanche Activity:
In the initial phases of activity, persistent slabs may be difficult to distinguish from storm snow avalanches or wind slabs. Technically, the initial round of avalanching on a persistent layer could be considered storm snow or wind slabs rather than persistent slabs. The exact point at which a storm snow or wind slab problem should considered a persistent slab is a somewhat academic argument.

There does come a point, however, when general agreement is reached and a persistent slab problem is declared. If a layer continues to perform after the initial loading associated with a storm has ended or if storm snow or wind slab avalanche cycles have ended and the next round of activity occurs on the persistent layer, then it's time to call a spade a spade. Certainly if a layer goes dormant then reawakens it must be considered persistent in nature. Wider propagations and significant remote triggering are also clues that the problem is more along the lines of a persistent slab rather than something purely wind or storm related.

A lack of avalanche activity is not a reliable indicator of potential hazard, especially in the later stages of a persistent slab instability. Persistent slab avalanches often occur in cycles consisting of dormant periods where only a few isolated avalanches occur for periods of time interspersed with periods of activity where a number of events are clustered in a relatively short time frame. Dormant periods are generally associated with periods of benign weather. Persistent slabs often "wake up" or reactivate when weather changes occur (see Triggering above).

Snowpack Layering, Tests, and Observations:
Persistent slab avalanches are characterized by 40-150 centimetres of cohesive snow over a persistent weak layer of facets, facet and crust combinations, depth hoar, or surface hoar.

Facets are angular grains with the look and feel of sugar crystals. They bond poorly to each other and to the layers above or below. Depth hoar grains are larger, hollow, cup- shaped, and often have striations visible to the naked eye on close inspection. Thick basal facet and depth hoar layers often pour out like grain when exposed in a snow profile pit wall. Facet on crust layers can be much more subtle. The crusts are generally relatively easy to identify, consisting of icy or crunchy, hard layers often created by freezing rain or consisting of snow that has been wetted by rain or melting, then refrozen. However, the associated facet layers can be very thin, sometimes so thin that they are not visible to the naked eye, especially in the case of inexperienced observers. The faceted grains in persistent weak layers are often relatively small compared to basal facets. Surface hoar layers can also be quite difficult to see or find by the inexperienced observer. These layers can be very thin—if the grains are lying flat, they may show only as an interface between layers that is too thin to measure.

Standard tests such as the shovel compression test and rutschblock test are well suited to testing persistent weak layers. Fracture character is generally considered a better indicator of propagation potential while the actual loading step at which failure occurs better indicates the potential of initiating failure. Since propagation is the deciding factor in a slab avalanche, practitioners often pay less attention to the number of taps with a compression test or the amount of force exerted on a rutschblock and more attention to whether a sudden planar or sudden collapse failure (pops or drops) occurs. Any persistent weak layer displaying a pop or drop character is suspect regardless of how much force it took to initiate failure. The propagation saw test (PST) has proven to be a fairly reliable indicator of whether a deeply buried weak layer might propagate if failure occurs. It should be noted that the PST does not quantify the force or load required to trigger an avalanche, it only indicates the likelihood that a fracture will propagate if triggered.

It should be noted that, while thick weak layers are more easily identified and appear more fragile, thin weak layers are often more unstable than thick ones and should not be discounted.

Ski cutting or any other form of testing that places a person on an actual avalanche slope are not recommended—even on small terrain features. Watch for signs of instability while travelling, such as whumpfing, cracking, and avalanches on similar slopes. These observations are a clear signal that conditions are at a critical state. However in the case of a known or suspected PWL, the absence of whumpfing or avalanches should never be interpreted as evidence that a layer is not active.

Surface Conditions:
Surface condition is not indicative of persistent slab avalanche potential. Because the underlying layer persists for extended periods of time, it's possible that almost any surface condition could be experienced in this avalanche character type.

Risk Management Strategies

In the early stages, risk management is similar to managing storm snow or wind slab problems. However, in the latter stages of a persistent slab cycle, after the more predictable activity associated with early loading has passed, risk management tends to become more complex and starts to look similar to deep persistent slab issues. The cyclical nature of the problem, the potential for wide propagations, and the prospect of remote triggering contribute to high uncertainty and low confidence making persistent slab instabilities difficult to assess, predict, and manage. As the time frame of persistence reaches weeks, appropriate risk management relies on making decisions based on what you know about a slope, its history of avalanche activity over the season, slope use patterns (e.g. compaction), and/or stabilization (avalanche control) measures. In the absence of local knowledge the only reasonable way to manage your risk is by leaving a wide safety margin wherever a persistent slab is known or suspected to exist.

Timing:
Choosing the time of exposure can reduce risk when persistent slabs are a concern.

- Avoid exposure to deep persistent slabs when weather factors likely to increase sensitivity to triggering exist:
  - Snowing, especially >3cm/hour.
  - Wind-loading.
  - Raining.
  - Strong solar radiation or air temperatures high enough to make the surface of the snow feel moist or wet.
  - Temperatures rising at more than 3°C/hour, especially if the temperatures are going above zero.
- It takes time for persistent slabs to adjust to stress from changes in weather.
- Wait at least 36-48 hours after significant weather changes.
- On clear days, warming and solar radiation can quickly destabilize slopes or cornices above, which might then trigger a persistent slab. Even when in the shade in the valley below or on a "cold" slope such as a north or east aspect, keep looking up and don't underestimate how early the sun or warming temperatures might be affecting slopes or cornices far above.
- There's less tendency to stop and reassess current, local conditions in good weather. Stay alert and don't miss changes happening around or above you.

If any of the above factors is at play, and especially if more than one are a potential, you should very carefully examine your motivation for exposing yourself to slopes where persistent slabs are known or suspected to exist. It is strongly recommended you back off and go to slopes where persistent slabs are not an issue. Or choose low angle, simple terrain that is not exposed to slopes above. If you feel you must expose yourself to slopes that might contain persistent slabs, give them several days to adjust to new stresses before reconsidering them as an objective. Consider using those several days to obtain as much information as possible from credible local sources about the slope you want to tackle and continue to question your motivation.

Human Factors:
It has been noted that:
- People are more willing to push into bigger, steeper, more complex terrain when the weather is good.
- People ride more aggressively on blue-bird days.
- People tend to discount their intuition or "gut feel" more on blue bird days. If something doesn't feel right, they are more willing to push on a clear warm day than on a cold, foggy, snowy day.
- Examine your own motivation and that of others in your group. Check out this article: http://www.mec.ca/AST/ContentPrimary/Learn/Snowsports/AvalancheSafety/HumanFactors.jsp.
- Assess the training and experience of your party.
- Use a decision making process or tool like the Avaluator™ to aid in trip planning.
- Ensure all members of the party play an active role in all aspects of planning, preparation, and execution of the trip.
- Talk to the others in your party. Listen to what they have to say. Respect their concerns. Make sure lines of communication remain open between all members of the party at all times.
- Use the information in this discussion and from regional avalanche forecasts to assess general conditions for the area where you will be.
- Talk to credible local experts such as guides, ski patrollers, avalanche professionals, etc. to get a handle on local conditions.
- Avoid making snap decisions in the field that put you at risk for triggering a persistent slab avalanche, especially in the later stages of a persistent slab instability when the slab becomes thicker and stronger. Because there are often no visible signs of instability related to persistent slab avalanche conditions, it is easy to be lulled into a false sense of security while in the field.
- Generally, the best decisions regarding persistent slab avalanches are made during planning and prior to going out in the mountains. When dealing with a known or suspected persistent slab instability, it is not a good idea to let the lack of signs of instability lead you to choose to travel on more aggressive terrain than originally intended.

Terrain:
Especially in the latter stages of development, persistent slabs are associated with high uncertainty and low confidence. With persistent slabs don't ask: "Will it slide?" Rather you should ask: "If it slides, what will happen to me or my partners?" This approach leads to greater margins for error and more conservative terrain choices, which are the best way to manage the risk presented by persistent slabs. Be conservative when choosing terrain and manage your group carefully. For example:
- Take a more conservative overall approach when dealing with persistent slab problems.
- Use a slope assessment tool or process like that provided by the Avaluator™ to assess each slope before you expose yourself to avalanche terrain (www.avalanche.ca/cac/pre-trip-planning/trip-planner).
- Avoid areas where the snowpack is shallow (less than 200cm on average).
- Avoid terrain where the snowpack depth is variable (shallow areas mixed with deep areas).
- Avoid slopes that have rocks and scattered trees sticking out of the snow.
- Avoid steep unsupported terrain features especially if there is a pronounced convexity.
- Minimize or eliminate exposure to terrain traps.
- Stay on slopes that are less than 30o incline.
- In cases where highly sensitive surface hoar is the issue, avoid slope greater than 20 degrees incline.
- Stay on simpler terrain (www.avalanche.ca/CAC_Avaluator_TerrainRating).
- Avoid avalanche start zones and tracks if possible.
- If you must travel in or through start zones or tracks, go one at a time from safe spot to safe spot.
- Spread out or go one at a time when travelling in or through avalanche runout zones.
- Regroup only in safe areas where avalanches will not start or where terrain features or ground cover provide protection, such as:
    - High points.
    - Ridges above start zones.

- Dense timber well away from the sides or bottom of the track or runout zone.
- During the later stages of a persistent slab instability when the slab becomes thicker and stronger, be especially cautious about approaching or travelling near terrain breaks where very low angle terrain steepens because persistent slab avalanches in this condition can pull very far back onto low angle terrain and potentially carry a person over the edge onto the adjacent slopes below.

USE AT YOUR OWN RISK

Mountain travel is dangerous and can involve exposure to avalanches and other hazards. The advice and decision guidelines provided in this field book cannot eliminate these hazards, but they can help you understand and manage them. This field book is no substitute for training, experience, and choosing skilled and responsible travel partners.

To find an avalanche training course near you, visit www.avalanche.ca.

CITATION

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