Avalanche

- What is avalanche
- Notable avalanches
- Causes
- Contributing factors
    - Terrain
    - Snow structure and characteristics
    - Weather
- Avalanche avoidance
    - Prevention
    - Safety in avalanche terrain

What is avalanche

An avalanche is a flow of snow down a mountainside, though rock slides and debris flows are also sometimes called avalanches. Avalanches are one of the biggest dangers in the mountains for both life and property.

Many factors contribute to Avalanches. Point-release avalanches occur when the weight of the snowpack exceeds the shear strength within it, and are most common on steeper terrain. In fresh, loose snow the release is usually at a point and the avalanche then gradually widens down the slope as more snow is entrained, usually forming a tear-drop appearance. This is in contrast to a slab avalanche. Slab avalanches account for around 90% of avalanche-related fatalities, and occur when there is a strong, stiff layer of snow known as a slab. These are usually formed when snow is deposited by the wind on a lee slope. When the slab fails, the fracture, in a weak layer, very rapidly propagates so that a large area, that can be hundreds of meters in extent and several meters thick, starts moving almost instantaneously. The third starting type is a slush avalanche which occurs when the snowpack becomes saturated by water. These tend to also start and spread out from a point.

As avalanches move down the slope they may entrain snow from the snowpack and grow in size. The snow may also mix with the air and form a powder cloud. An avalanche with a powder cloud is known as a powder snow avalanche. The powder cloud is a turbulent suspension of snow particles that flows as gravity current. Powder snow avalanches are the largest avalanches and can exceed 300 km/h and 10,000,000 tones of snow, they can flow for long distance along flat valley bottoms and even up hill for short distances.

Notable avalanches

A large avalanche in Montroc, France, in 1999, 300,000 cubic meters of snow slid on a 30 degree slope, achieving a speed of 100 km/h (60 mph). It killed 12 people in their chalets under 100,000 tons of snow, 5 meters (15 feet) deep. The mayor of Chamonix was convicted of second-degree murder for not evacuating the area, but received a suspended sentence.

On May 31, 1970 the Ancash earthquake caused a large avalanche from Huascaran, resulting in the destruction of the town of Yungay and the death of at least 18,000 people.

During World War I, approximately 50,000 soldiers died as a result of avalanches during the mountain campaign in the Alps at the Austrian-Italian front, many of which were caused by artillery fire. However, it is very doubtful avalanches were used deliberately at the strategic level as weapons; more likely they were simply a side effect to shelling enemy troops, occasionally adding to the toll taken by the artillery. Avalanche prediction is nearly impossible; forecasters can only assert the conditions, terrain and relative likelihood of slides with the help of detailed weather reports and from localized snowpack observation. It would be almost impossible to predict avalanche conditions many miles behind enemy lines, making it impossible to intentionally target a slope at risk for avalanches. Also, high priority targets received continual shelling and would be unable to build up enough unstable snow to form devastating avalanches, effectively imitating the avalanche prevention programs at ski resorts.

Causes

Snow avalanches occur when the load on the upper snow layers exceeds the bonding forces of a mass of snow (bonding to layer beneath, horizontal internal stability, support from anchors such as rocks and trees, stress support from top or bottom of slope). A low timber line will exaggerate the threat because trees help hold snow in place and slow it down once it begins moving.

Contributing factors

All avalanches are caused by an over-burden of material, typically snowpack that is too massive and unstable for the slope that supports it. Determining the critical load, the amount of over-burden which is likely to cause an avalanche, is a complex task involving the evaluation of a number of factors. These factors include:

Terrain

Slopes flatter than 25 degrees or steeper than 60 degrees typically have a low risk of avalanche. Snow does not accumulate significantly on steep slopes; also, snow does not flow easily on flat slopes. Human triggered avalanches have the greatest incidence when the snow's angle of repose is between 35 and 45 degrees; the critical angle, the angle at which the human incidence of avalanches is greatest, is 38 degrees. The rule of thumb is: *A slope that is flat enough to hold snow but steep enough to ski has the potential to generate an avalanche, regardless of the angle.* However, avalanche risk increases with use; that is, the more a slope is disturbed by skiers, the more likely it is that an avalanche will occur.

The four variables that influence snowpack evolution and composition are temperature, precipitation, solar radiation, and wind. In the mid-latitudes of the Northern Hemisphere, more avalanches occur on shady slopes with northern and north-eastern exposures. However, when the human triggered incidence of avalanches are normalized to mid-latitude rates of recreational use, no significant difference in hazard for a given exposure direction can be found.. The snowpack on slopes with southern exposures are strongly influenced by sunshine; daily cycles of surface thawing and refreezing create a crust that may tend to stabilize an otherwise unstable snowpack, but the crust, once it has been fractured, may detach itself from the underlying layers of snow, slide, and promote the generation of an avalanche. Slopes in the lee of a ridge or other wind obstacle accumulate more snow and are more likely to include pockets of abnormally deep snow, windslabs, and cornices, all of which, when disturbed, may trigger an avalanche.

Convex slopes are more dangerous than concave slopes. The primary factor contributing to the increased avalanche danger on convex slopes is a disparity between the tensile strength of snow layers and their compressive strength.

Another factor affecting the incidence of avalanches is the nature of the ground surface underneath the snow cover. Full-depth avalanches (avalanches that sweep a slope virtually clean of snow cover) are more common on slopes with smooth ground cover, such as grass or rock slabs. Vegetation plays an important role in anchoring a snowpack; however, in certain instances, boulders or vegetation may actually create weak areas deep within the snowpack.

Snow structure and characteristics

The structure of the snowpack is a strong predictor of avalanche danger. For an avalanche to occur, it is necessary that a snowpack have a weak layer (or instability) below the surface and an overlying slab of snow. Unfortunately, the relationship between easily-observed properties of snow layers (strength, grain size, grain type, temperature, etc.) and avalanche danger are extraordinarily complex; consequently, this is an area that is not yet fully understood. Furthermore, snow cover and stability often vary widely within relatively small areas, and a risk assessment of a given slope is unlikely to remain valid, accurate, or useful for very long.

Various snow composition and deposition characteristics also influence the likelihood of an avalanche. Newly-fallen snow requires time to bond with the snow layers beneath it, especially if the new snow is light and powdery. Snow that lies above boulders or certain types of plants has little to help anchor it to the slope. Larger snow crystals, generally speaking, are less likely to bond together to form strong structures than smaller crystals are. Consolidated snow is less likely to sluff than light powdery layers; however, well-consolidated snow is more likely to generate unstable slabs.

Weather

Weather also influences the evolution of snowpack formation. The most important factors are heating by the sun, radiational cooling, vertical temperature gradients in standing snow, snowfall amounts, and snow types.

If the temperature is high enough for gentle freeze-thaw cycles to take place, the melting and refreezing of water in the snow strengthens the snowpack during the freezing phase and weakens it during the thawing phase. A rapid rise in temperature, to a point significantly above the freezing point, may cause a slope to avalanche, especially in spring. Persistent cold temperatures prevent the snow from stabilizing; long cold spells may contribute to the formation of depth hoar, a condition where there is a pronounced temperature gradient, from top to bottom, within the snow. When the temperature gradient becomes sufficiently strong, thin layers of "faceted grains" may form above or below embedded crusts, allowing slippage to occur.

Any wind stronger than a light breeze can contribute to a rapid accumulation of snow on sheltered slopes downwind. Wind pressure at a favorable angle can stabilize other slopes. A "wind slab" is a particularly fragile and brittle structure which is heavily-loaded and poorly-bonded to its underlayment. Even on a clear day, wind can quickly shift the snow load on a slope. This can occur in two ways: by top-loading and by cross-loading. Top-loading occurs when wind deposits snow perpendicular to the fall-line on a slope; cross-loading occurs when wind deposits snow parallel to the fall-line. When a wind blows over the top of a mountain, the leeward, or downwind, side of the mountain experiences top-loading, from the top to the bottom of that lee slope. When the wind blows across a ridge that leads up the mountain, the leeward side of the ridge is subject to cross-loading. Cross-loaded wind-slabs are usually difficult to identify visually.

Snowstorms and rainstorms are important contributors to avalanche danger. Heavy snowfall may cause instability in the existing snowpack, both because of the additional weight and because the new snow has insufficient time to bond to underlying snow layers. Rain has a similar effect. In the short-term, rain causes instability because, like a heavy snowfall, it imposes an additional load on the snowpack; and, once rainwater seeps down through the snow, it acts as a lubricant, reducing the natural friction between snow layers that holds the snowpack together. Most avalanches happen during or soon after a storm.

Daytime exposure to sunlight can rapidly destabilize the upper layers of a snowpack. Sunlight reduces the sintering, or necking, between snow grains. During clear nights, the snowpack can strengthen, or tighten, through the process of long-wave radiative cooling. When the night air is significantly cooler than the snowpack, the heat stored in the snow is re-radiated into the atmosphere.

Avalanche avoidance

Due to the complexity of the subject, winter traveling in the backcountry (off-piste) is never 100% safe. Good avalanche safety is a continuous process, including route selection and examination of the snowpack, weather conditions, and human factors. Several well-known good habits can also minimize the risk. If local authorities issue avalanche risk reports, they should be considered and all warnings heeded. Never follow in the tracks of others without your own evaluations; snow conditions are almost certain to have changed since they were made. Observe the terrain and note obvious avalanche paths where vegetation is missing or damaged, where there are few surface anchors, and below cornices or ice formations. Avoid traveling below others who might trigger an avalanche.

Prevention

There are several ways to prevent avalanches and lessen their power and destruction. They are employed in areas where avalanches pose a significant threat to people, such as ski resorts and mountain towns, roads and railways. Explosives are used extensively to prevent avalanches, especially at ski resorts where other methods are often impractical. Explosive charges are used to trigger small avalanches before enough snow can build up to cause a large avalanche. Snow fences and light walls can be used to direct the placement of snow. Snow builds up around the fence, especially the side that faces the prevailing winds. Downwind of the fence, snow buildup is lessened. This is caused by the loss of snow at the fence that would have been deposited and the pickup of the snow that is already there by the wind, which was depleted of snow at the fence. When there is a sufficient density of trees, they can greatly reduce the strength of avalanches. They hold snow in place and when there is an avalanche, the impact of the snow against the trees slows it down. Trees can either be planted or they can be conserved, such as in the building of a ski resort, to reduce the strength of avalanches.

Artificial barriers can be very effective in reducing avalanche damage. There are several types. One kind of barrier (snow net) uses a net strung between poles that are anchored by guy wires in addition to their foundations. These barriers are similar to those used for rockslides. Another type of barrier is a rigid fence like structure (snow fence) and may be constructed of steel, wood or pre-stressed concrete. They usually have gaps between the beams and are built perpendicular to the slope, with reinforcing beams on the downhill side. Rigid barriers are often considered unsightly, especially when many rows must be built. They are also expensive and vulnerable to damage from falling rocks in the warmer months. Finally, there are barriers that stop or deflect avalanches with their weight and strength. These barriers are made out of concrete, rocks or earth. They are usually placed right above the structure, road or railway that they are trying to protect, although they can also be used to channel avalanches into other barriers. Occasionally, earth mounds are placed in the avalanche's path to slow it down.