Insight into Slab-Avalanche Triggering:
A Combination of Four Phenomena in Series

Story by François Louchet and Alain Duclos

Tragedy struck the small village of Aussois in the French Alps on February 14, 2005, when a huge hard-slab avalanche caught and fatally wounded a well-known local avalanche worker. Pompon, a local IFMGA-certified mountain guide and ski patroller with about 20 years of professional avalanche experience, triggered the fatal avalanche in a wide bowl called Les Balmes. The upper section of the 300-meter-wide bowl is divided into several separate gullies or thalwegs which can normally be controlled individually with hand charges from above. Apparently intending to view the negative results of the first shot placement on his familiar control route, or perhaps to test the snow resistance, Pompon slid slightly out onto a convex slope measuring less than 30 degrees on the upper fringes of the second gully. Strong winds the day before had loaded Les Balmes with a significant amount of snow, and the avalanche Pompon triggered was much bigger than expected. His partner watched the quasi-simultaneous release of the entire bowl as the massive avalanche carried Pompon more than 600 vertical meters and mortally wounded him. He died a few months later after suffering a deep coma.

This casualty tragically illustrates how an avalanche specialist, with a perfect knowledge of the field, might eventually be trapped by a larger-than-expected slab-avalanche release. Both rupture mechanics and statistical physics can bring new insight into this problem. These theoretical approaches perfectly fit field observations. They explain why some unexpected avalanches may release and also, more commonly, why nothing happens even when most conditions for triggering seem to be met.

A few basic concepts

Avalanche-release phenomena may be classified into two main categories: spontaneous and artificially triggered ones. Spontaneous failures are of a ductile nature. They result from a strain rate increase during snow creep or reptation, up to a critical point at which failure suddenly occurs. We shall focus here on accidental and artificial avalanches. Such failures occur within a much shorter time scale, correspond to a rapid change in the controlling parameters, and are of a brittle nature. Any physical evolution process needs a driving force, which may or not be balanced by a resistance. In order to understand the phenomenon, we need to identify both the driving force and the resistance.

• Driving force:

A process is likely to occur spontaneously if it contributes to a decrease in the energy of the system down to a stable state. In the avalanche problem, the available energy stems from the snow weight. The weight of a skier (some 80 kg) is extremely small as compared to the weight of the snow involved in the avalanche-triggering mechanism (several millions of kg).

• Resistance:

The reason why the snow cover remains on mountain slopes is snow cohesion, which provides resistance to rupture. This is not the case for water, which would immediately flow downslope as it has no cohesion. Snow cohesion contributes in keeping the snow cover in a metastable state . Two types of resistance have to be overcome in order to release an avalanche: i) the shear resistance of the bonding between the slab and the older snow substrate, known as weak layer; and ii) the rupture stress of the cohesive slab. The local action of a skier may gradually damage the weak layer, which is more similar to a brittle house of cards than to ball bearings. It may also contribute to opening a crown crack across the slab thickness. Therefore, the skier's action only deals with possible changes in the resistance of the weak layer or of the slab and not with the driving force.

A simple sketch of the system

In the case of accidental or of artificial triggerings, both the cohesive slab and the weak layer behave as elastic/brittle bodies; they may deform elastically under stress and fail in a brittle way if the stress exceeds a threshold value. The elastic/brittle slab is represented in the above diagram as a series of blocks linked by brittle springs, which can extend or contract depending on the stress they experience or split into parts if the stress exceeds a threshold value. In a similar way, the slab is connected to older snow by elastic/brittle bonds, represented as some kind of flexible and brittle flat house of cards, which might fail and collapse if the stress is large enough. Based on the above-mentioned properties we can detail the different steps involved in the avalanche-triggering chronology.

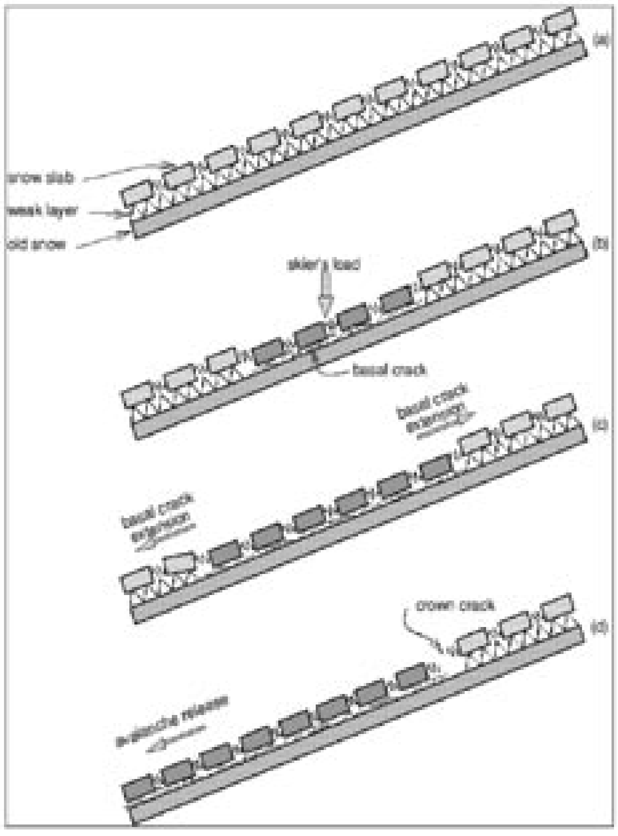

Fig 1: (a) A slab on a weak layer may be seen as a series of blocks linked by elastic/brittle springs lying on a collapsible house of cards; (b) the skier's load may collapse part of the house of cards (basal crack); (c) driven by either the skier's action or the snow weight, the basal crack may extend; (d) when the extension of the basal crack is large enough, the weight of the hung part of the slab initiates a crown crack at the top, resulting usually in the avalanche release.

A Combination of Four Steps In Series

We propose that accidental or artificial avalanche release stems from four mechanisms:

1. collapse of the weak layer that results in the nucleation of a basal crack,
2. propagation or expansion of the basal crack
3. opening of the crown crack at the upper rim of the basal crack
4. expansion of the crown crack, which leads to the avalanche release.

These mechanisms operate in series; if any single one does not occur, the avalanche is not released.

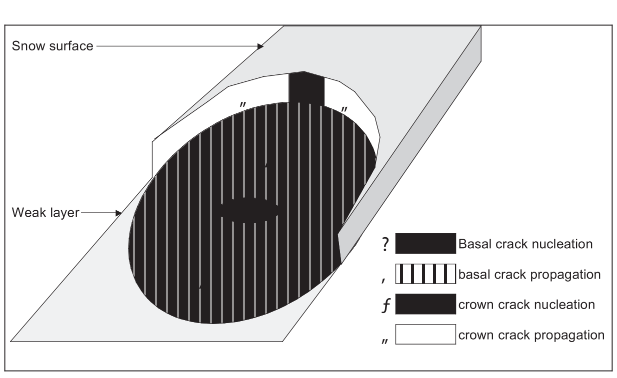

Figure 2: Four successive steps involved in avalanche release.

1. Basal crack nucleation

On a slope, the weak layer experiences both the shear (parallel to the slope) and compression (perpendicular to the slope) components of the slab weight, both of which increase with its depth and density. The weak layer may be damaged when the load locally exceeds its mechanical resistance. The weight of a skier or a snowmobile does not significantly increase the total load experienced by the weak layer, but this load is applied on a very small surface (e.g. ski bases), and results in a significant pressure that may cause local damage of the weak layer. An explosive has a similar effect. Depending on the nature of the weak layer, the resulting collapse of these zones reduces their shear resistance to almost zero. The damaged zone or basal crack then extends along the skier path. The weak layer may also collapse on flat ground. In which case the whole slab weight is now along its compression component.

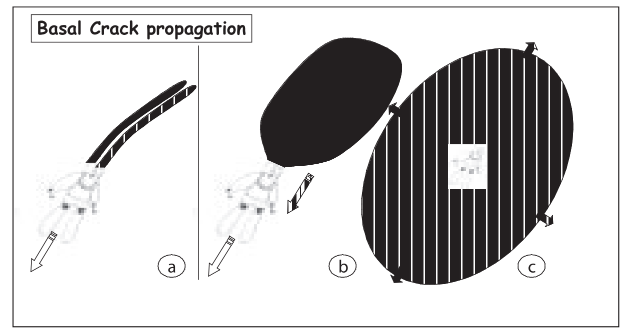

Fig 2: Basal crack propagation. (a) A weak layer covered by a shallow slab made of fluffy snow may collapse only along the ski track without further expansion; (b) the bending of a stiffer slab under the skier helps a wider collapse of the weak layer, resulting in a wider basal crack (artificial growth); (c) reaching a critical size, the crack may extend rapidly under the load of the snow itself (spontaneous growth).

2. Basal crack expansion

Basal crack expansion may result from one of two different mechanisms:

a. Owing to the gradual damage produced by the skier's additional local pressure, a crack may extend step-by-step in an area around the skier's path.
b. A crack initiated by the skier might extend over much larger distances under the effect of the snow weight itself.

On a slope, the driving force consists of the compressive and shear components of the stress due to the slab weight. In other words, it results from the energy release experienced by the slab as the weak layer collapses. The skier's weight has no more effect at this stage, as the involved snow mass is enormously bigger.

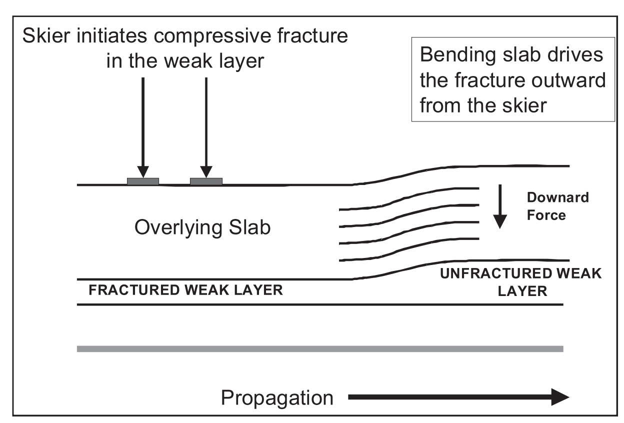

Fig 4: Diagram showing the collapse of the weak layer and expansion of the basal crack. The overlying slab is bent, providing the downward force to progressively fracture the weak layer.

More precisely, such a spontaneous propagation of an existing crack obeys a specific law, known as Griffith's criterion. In spite of possible modifications related to slab geometry and stiffness, Griffith's criterion basically states that under a given stress, a large crack is more likely to expand than a small one. This is also the case for a sheet of paper that tears off more readily if it contains a large crack. Spontaneous propagation takes place when the product of the stress by the square root of the crack size exceeds a threshold value Kc, called fracture toughness. Spontaneous propagation of the basal crack only occurs if the crack reaches a critical size—the larger the load, the smaller the critical size. Beyond this critical size, the energy release rate of the slab can no longer be balanced by the resistance to slab propagation; the basal crack extension velocity is now much faster. Velocities of the order of 20 m/s have been reported.

C) Crown crack nucleation:

As the basal crack extends along the slope, the slab weight that was balanced by the weak layer resistance is now transferred into the slab itself at the crack rims. It takes the form of a tensile stress at the top cross section of the slab, where the freed part of the slab is hung. This stress turns into a compression stress at the bottom rim and into shear stresses on both sides. All these stresses obviously increase with the weight of the hanging part of the slab or the basal-crack size. The snow-failure stress is usually smaller in tension than in compression, the shear failure stress being between these two. Therefore, as for basal crack nucleation, a crown crack nucleates

Continued next page ➡

SLAB TRIGGERING

continued from previous page

at the top of the basal crack when the tensile stress in the slab reaches a threshold value.

Since two different basal crack growth mechanisms can operate, we expect two different types of avalanche triggering to occur *(below)*.

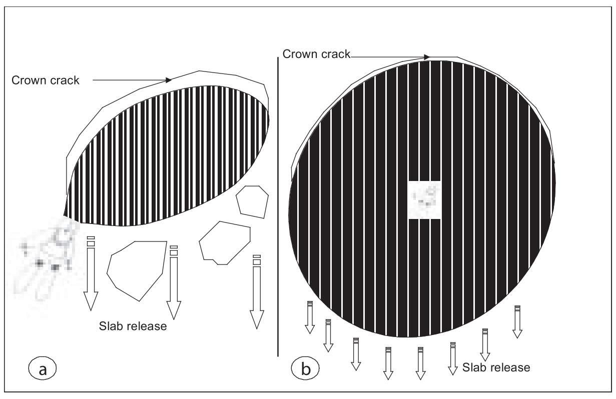

Fig 5: a) subcritical triggering: the starting zone is limited roughly to the area damaged by the skier; b) supercritical triggering: crown crack opening occurs at a large distance from the skier.

Subcritical triggering:

In this case, the basal crack gradually extends step by step in an area around the skier's path. At some stage of this extension, the tensile stress experienced by the slab at the upper rim may exceed the slab rupture stress. The starting zone is limited to the area actually damaged by the skier, who is likely to be located at the boundary of this zone when the avalanche is released. This scenario might happen when the slab cohesion is low. A small-size basal crack is sufficient to reach the slab-tensile-rupture stress. The cut made by the skis in the soft slab may also help the slab failure along the skier's path. By contrast, with stronger slabs, the slab-rupture stress may not be reached, the crown crack does not open, and the skier gets out of the hazardous area without triggering the avalanche.

Supercritical triggering:

Now the slab is significantly stronger (i.e., crown crack opening becomes more difficult), and/or the driving force for basal-crack expansion is larger (i.e., the slab is heavier). The basal-crack size may reach the critical value for spontaneous expansion before a crown crack can open. At this point, the basal crack starts expanding with a significantly larger velocity. Crown-crack opening occurs a short time later, often at quite a large distance from the skier, when the weight of the freed part of the slab has become large enough to trigger the failure of the tough slab. The starting zone is much bigger than in the previous case, and the skier is trapped somewhere in the middle of it. In some conditions, it may result in a "bang" at slab failure. A simple calculation (Louchet 2001 b) shows that supercritical triggering is favored by large slab weights and that conditions for its occurrence are more readily met on slopes around a universal angle of 35.3˚.

4. Crown crack expansion and avalanche release

With some modifications, Griffith's criterion may also apply to the crown crack. If the tensile load is large enough to nucleate an incipient crown crack, it will necessarily be large enough to propagate it, as the increasing crack size requires a decreasing propagation stress. The crown crack grows very rapidly (brittle failure), until the stress concentration at its tips reaches the shear-failure stress on both sides. The bottom rim usually fails in turn at this stage as the whole slab weight is now transferred to it, and the avalanche is released. In most cases, the nucleation of the crown crack is immediately followed by its expansion and by the avalanche release.

For the weak layer, the slab rupture threshold may have scattered values. An incipient crown crack usually appears at one of the weakest places. Its subsequent propagation may meet a tougher zone, which may hinder its growth. In this case, the basal crack goes on extending up further. We often observe stable incipient crown cracks.

III) The theory explains avalanches which are released...and those which are not

In this section, we discuss several field situations and examples of avalanche release from real life, in the light of the four basic steps developed above. We show in these examples that the conditions for avalanche release require that all four conditions be fulfilled. If even one of them is not, the avalanche will not be triggered.

Are huge snow accumulations favorable or unfavorable for avalanche release?

A thick snow cover may favor basal-crack expansion. This is true for natural, artificial, or accidental triggerings. But basal-crack nucleation by a skier or by explosives is impossible if the involved slab is too thick, due to poor pressure transmission to the weak layer. This is probably why accidental releases are more frequent during early winter: weak layers are easily formed during this period and frequently covered with shallow slabs. Basal cracks are therefore more likely to be nucleated.

Avalanche professionals sometimes deplore the poor efficiency of artificial triggerings in spite of huge snow accumulation. Often the snow depth is probably too large to allow artificial triggering, and not large enough to drive a natural avalanche release.

Why should skiers cross a hazardous area one after the other rather than in groups?

This recommendation is supported by at least two reasons. The first reason is that if an avalanche catches one of them, the others might successfully conduct a rescue. The second reason is based on a situation where the weight of a single skier is insufficient to nucleate a basal crack, like on a thick slab, but the combined weight of several skiers crossing the area simultaneously may be large enough to nucleate it.

On shallower slabs, a single skier may nucleate a basal crack (step 1), gradually expand it on a limited area (step 2), and get out from the hazardous zone without triggering an avalanche. In this case, crown-crack nucleation (step 3), could not occur because the hung part of the slab was too small or not heavy enough to open the crown crack. If a second skier, then a third one, and so on, cross the same zone along slightly different paths, the corresponding basal cracks may merge, resulting in a unique crack that may be large enough to either directly open a crown crack (step 3, subcritical mode) or expand it in an unstable way before opening a large crown crack far above (step 3, supercritical mode). The resulting triggering would not depend on whether skiers have crossed the zone together or one after the other. A reasonable recommendation to minimize the risk might be to cross the dangerous area successively and along the same path, although by doing this, the skiers could disturb the weak layer due to deeper penetration of the slab by the successive skiers.

Why are most avalanches observed on slopes around 35˚?

There is a general agreement that the most favorable slopes for avalanche triggering are around 35˚. This observation may be explained using the above considerations. A limited basal crack width (as in Figures 3 a or b) that remains smaller than the critical size for spontaneous expansion (step 2, subcritical mode), may result either in a limited starting zone or in no triggering at all. By contrast, if the basal crack is wide enough (or the critical size small enough), the resulting spontaneous expansion cannot be stopped (step 2, supercritical mode) unless stratigraphy changes. Indeed, the tensile stress experienced by the slab at the upper crack tip continuously increases until the slab-rupture stress is reached, and the crown crack opens (step 3). The avalanche is more likely to be released at this stage, as compared to the case of a limited subcritical growth (step 4).

As the supercritical scenario is favored for slopes around 35˚, avalanches are expected to be preferentially triggered on such slopes and not around the classical 45˚ expected from simple mechanical arguments . This particular observed feature is a strong argument in favor of our present approach.

Why are tough slabs often associated with large avalanches?

The tougher the slab, the more difficult crown-crack nucleation is. This is probably why tough-slab avalanches are usually big. The amount of elastic energy stored in such big slabs can be huge. Sudden release at crown-crack opening may result in an impressive "bang."

Why do crown cracks often open at outcrops or trees?

It is frequently observed that the crown crack starts opening (step 3) at an outcrop or a tree or even on a ski or surf track. These features act as weak points in the slab, which help crown-crack nucleation. The same mechanism takes place at convexities. Such weak points play a dual role: they facilitate slab triggering through crown crack nucleation, but they prevent large-scale propagation of basal cracks, which may have resulted in the release of very large slabs. In other words, large slab avalanches are likely to be found on wide and smooth slopes without weak points or field heterogeneities like trees, sparse rocks, or outcrops.

Why are some avalanches triggered on flat ground?

The propagation of the basal crack (step 2) helps us to understand accidents occurring on gentle slopes, neighbored by slopes steeper than the fateful 30˚. The victims are responsible for the nucleation of the basal crack, which may gradually expand to the steeper slopes. At this point, the driving force is more efficient, and the basal crack may become unstable and propagate rapidly in the supercritical mode, triggering one or several slabs.

Why do "whumpfs" on steep slopes not necessarily result in avalanche release?

Sometimes a whumpf is clearly felt on a rather steep slope (step 1), but without any further consequence. This case may correspond to a weak layer of small dimensions (blown out by the wind as it still was at the surface or swept out by a previous avalanche), at the boundaries of which the basal crack propagation stops (step 2) before reaching the size necessary for unstable propagation or for directly opening a crown crack (step 3) and releasing the avalanche (step 4).

IV) Snow cover variability and triggering scenarios:

The different triggering scenarios therefore depend on the spatio-temporal variability of the snow mechanical properties, which are involved during the four successive steps of the triggering process. The snow cover is most often heterogeneous in thickness and/or mechanical resistance. For this reason, the type of basal crack left along the skier's path may vary: for example from the case of Figure 3a to that of Figure 3b, or worse, that of Figure 3c. This may be the case for instance if snow evolves from fluffy to stiff. Another example is that of an artificial crack growth under a shallow slab (Figure 3b) that can quickly turn to the case of Figure 3c if the slab thickness becomes locally larger. This scenario is especially threatening for experienced mountaineers, who usually pay close attention to the snow condition under their skis but are less aware of the danger due to the snow variability in the neighborhood. In both cases, a slope that seems to be quite safe may suddenly be swept out by a spanning avalanche.

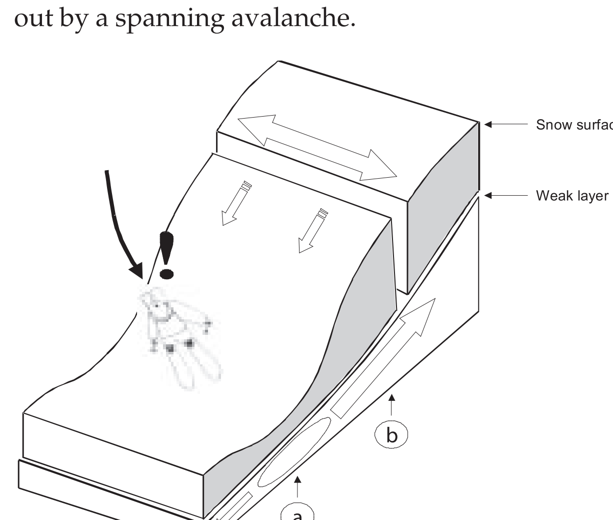

Fig 7: A particularly hazardous situation is found when a slightly loaded slope (where a skier can easily nucleate a basal crack (a)) is bounded by a more loaded and steeper slope. Both the larger load and the steeper slope favor basal-crack expansion and further crown-crack opening.

Experienced skiers sometimes succeed in triggering slab avalanches without being caught in them. It may happen indeed that a skier triggers an avalanche of limited size. Most of the time, this is a subcritical triggering. The tensile stress in the slab resulting

Continued on page 19 ➡

After seeing this brochure for a pneumatic baseball-pitching machine, Atwater joined forces with its inventor, Frank Parsoneault, to create the first Avalauncher.

dollars). In comparison, Peters sold his last guns for under $1200. While the U.S. and Canadian gun are both designed for Avalanche Control System's 82.55mm shell, the French Launcher shoots an 83mm round that is almost 6' in length. In addition to its pricy gun cost, the French Launcher charges $170 for its projectile. Its binary explosive, which is mandated to become inert within a short time period, drives the total shot cost up even more.

Another gun that deserves mention here is the LOCAT. This is a compressed gas weapon that operates up to 3000 pounds per square inch (psi) - compared to the 400-450 psi max pressures of the previously mentioned Avalaunchers. The higher pressure not only allows greater range, but also the ability to use a military-style detonator. The LOCAT pricetag is a staggering $190,000. Reserved for only those with the deepest pockets, LOCAT ironically stands for Low Cost Artillery Trainer.

With its ability to place several pounds of high explosives up to 2000 yards away, the Avalauncher continues to be a viable tool for avalanche-mitigation work today. Its effectiveness is due to the hard work and foresight of many men and women, not all of whom have been mentioned. There are some interesting prospects for the future of the Avalauncher and I hope to cover those in a later article.

Special thanks for help in this article go to Pete Peters; Monty Atwater, Jr; Mark Parsoneault; Ron Perla; Ed LaChapelle; Jerry Nunn; Paul Hauk; and Marty Schmoker.

John Brennan tells TAR that he has wanted to write this story for a while. After his son was born last April 15, his wife and mother-in-law suggested he take a road trip to research the article, as typically he's laid off after the ski season ends around Easter and doesn't start back on summer trails until around June 1. His goal was to meet the key players in the history and development of the Avalauncher face-to-face. He covered just under 3000 miles and five states in seven days and additionally was able to get small ski tours in each of the states he passed through. ❄

SLAB TRIGGERING

continued from page 14

from the collapse of the weak layer on a limited area is large enough to open a crown crack just above. The avalanche is released, but the skier can escape if able to control his or her trajectory. This is likely to occur with weak and shallow slabs made of loose snow.

Slope cutting usually works, but not always. This could be the reason why Pompon was caught while trying to trigger the bowl of Les Balmes. A slab avalanche may occasionally largely exceed the usual size most often seen on a particular slope. This is the nature of a supercritical triggering. The collapsed part of the weak layer spontaneously and rapidly extends in all directions. The crown crack may open far above the skier, who gets trapped in the middle of a huge triggered slab that may reach widths up to several hundred meters. Escape is impossible, and the outcome is usually fatal. This scenario is more likely to take place when a slab is composed of tough and heavy snow. Being aware of the existence of these two fracturing modes is fundamental for practitioners, as predicting which one of these two is likely to occur is risky, even if the supercritical mode is favored by a continuous weak layer, a heavy, thick, and tough upper snow layer, and slope angles around 35˚.

The layout procedure for triggering devices, like gas exploders, should also take into account these two different scenarios: the separation between two neighbor devices is different depending on whether sub or supercritical avalanches need to be triggered. Frequent subcritical triggerings probably hinders the release of large slabs, whereas optimizing supercritical triggerings may lead to unexpected consequences, owing to the uncontrolled size of the avalanche.

V) From a basic understanding towards a possible prediction?

Despite the large variety of observed avalanche phenomena, their understanding does not require as many models, but may be described by using a few simple concepts. Too simple of an approach, based on a balance between a global snow resistance and a supposed overload due to the skier, would not be able to describe the variety of observed triggerings. By contrast, such a variety of behaviors can be easily accounted for on the basis of the four-step scenario described above.

The final result in terms of avalanche occurrence and size may vary drastically, depending on the way in which these processes are connected. Human action modestly appears limited to a local change in the weak layer resistance, which may nevertheless lead to quite different scenarios depending on the local and global snow cover properties. The snow cover is such a complex system, with such a large spatio-temporal variability, that a deterministic prediction of avalanche release turns out to be impossible. It would require an army of patrollers measuring snow properties all day long, and a slight uncertainty in these measurements might lead to totally different behaviors.

Our ignorance can be dealt with in terms of randomness. Field measurements show that starting zones obey a specific size distribution, taking the mathematical form of a power law, also known as a "scale invariant" distribution. This means that there are many small avalanches and a few big ones. But the ratio between the number of avalanches of different sizes is perfectly well defined, and there is no characteristic avalanche size.

We demonstrated using cellular automata simulations (Faillettaz et al. 2004) that such scale invariance can be reproduced, provided random values are used for rupture thresholds. The consequences are twofold:

- Scale invariant size distributions obtained from field measurements are a signature of the random nature of the snow cover, confirming the necessary use of statistical approaches.
- Introducing disorder leads to a perfectly well-defined statistical organization, which provides some hope of "personalized" avalanche prediction using cellular automata fitted on particular gully topographies.

In the meanwhile, we believe that the basic concepts and mechanisms developed in this paper will be of some help in improving decision-making for professionals and practitioners through a better understanding of the possible underlying mechanisms.

Acknowledgements:

Future innovative developments of the present approach in terms of avalanche forecasting will certainly rest on the statistical simulations developed during PhD work by Jérôme Faillettaz, who is gratefully acknowledged. The authors would also like to thank Bruce Jamieson for permission to reproduce a figure and Henry Schniewind for critically reading the manuscript. They also invite your comments and insight; contact information is provided at the end of each bio.

REFERENCES

Faillettaz J, Louchet F. and Grasso J-R., 2004. Two-threshold model for scaling laws of non-interacting snow avalanches, *Physical Review Letters*, vol 93, no 20, pp 208001-1 - 208001-4.

Fohn P.M.B.,1987. The stability index and various triggering mechanisms, in Salm B. and H. Gubler, eds., *Avalanche Formation, Movement and Effects*, International Association for Hydrological Sciences, publ. 162 (Symposium at Davos 1986), pp 195-211.

Griffith A.A., 1920. *The phenomena of rupture and flow in solids*, Philos. Trans. R. Soc. London, Ser. A, vol 221, pp 163-198.

Gubler H. and Bader H-P., 1989. A model of initial failure in slab avalanche release, *Annals of Glaciology*, vol 13, pp 90-95.

Heierli J., 2005. Solitary fracture waves in metastable snow stratifications, *Journal of Geophysical Research*, vol 110, pp 1-7.

Johnson B., Jamieson B. and Johnston C., 2000. Field data and theory of human triggered whumpfs and remote avalanches, Proc. ISSW 2000, Big Sky (Montana), pp 208-214.

Johnson, B.C., Jamieson B. and Stewart R.R.. 2004. Seismic measurement of fracture speed in a weak snowpack layer, *Cold Regions Science and Technology*, vol 40(1-2), pp 41-45.

Louchet F., 2000. A simple model for dry snow slab avalanche triggering, Comptes Rendus Acad. Sci. Paris, *Earth and Planetary Sciences*, vol 330, Pages 821-827.

Louchet F. 2001 a. Creep instability of the weak layer and natural slab avalanche triggerings, *Cold Regions Science and Technology*, vol 33, pp 141-146.

Louchet F., 2001 b. A transition in dry-snow slab avalanche triggering modes, *Annals of Glaciology*, vol 32, pp 285-289.

Louchet F., unpublished results.

Louchet F, Faillettaz J., Daudon D., Bédouin N., Collet E., Lhuissier J. and Portal A-M., 2002. Possible deviations from Griffith's criterion in shallow slabs, and consequences on slab avalanche release. (XXVI General Assembly of the European Geophysical Society, Nice (F), march 25-30, 2001). *Natural Hazards and Earth System Sciences*, vol 2, nb 3-4, pp 1-5.

Narita H., 1983. An experimental study on tensile fracture of snow, *Contrib. Inst. Low Temp. Sci.*, Ser. A, volume 32, pp 1-37.

François Louchet graduated as an engineer from Ecole des Mines and has a PhD in Solid State Physics. He is a professor of Physics of Condensed Matter at the University of Grenoble (France). He began trying to understand avalanche release after watching a huge slab avalanche release during a trek in the Galibier district, French Alps, in February 1997. He recently joined the Grenoble department of Glaciology to develop new research topics on dynamical aspects of deformation and fracture and physics of complex systems. He can be reached at: Laboratoire de Glaciologie et de Géophysique de l'Environnement UJF/CNRS, BP96 – 38402 Saint Martin d'Hères, France, louchet@lgge.obs.ujf-grenoble.fr

Alain Duclos is an engineer who received a PhD in Geography from Grenoble University with the goal of learning more about slabs. He spent many years as an IFMGA mountain guide and ski patroller. He presently heads the ALEA company, which is dedicated to avalanche risk mitigation and expertise, in Aussois (Savoie), and is committed to road protection in the Savoie region. He can be reached at: ALEA Sarl, 73500 Aussois, France, a.duclos@wanadoo.fr ❄