THE NEW CHALLENGE IS NO MORE TO IMPROVE PREDICTION, BUT TO BETTER MANAGE THE UNEXPECTED.

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ABSTRACT : While researchers are devoting their efforts for decades to improve avalanche forecasting, it still appears that the victims are almost always surprised: they either did not expect at all an avalanche at the time, or they never imagined they were of such magnitude. However, it is sometimes the best professionals who are involved, the ones who should have avoided the accident completely, or limit its severity, if they had been aware of the danger.
To minimize the effect of surprise, current methods of risk reduction are not fully satisfactory. On the contrary, assuming that the avalanche is predictable, they reinforce the user sometimes in dangerous beliefs. Therefore we explored the idea of "bounded vigilance model" proposed by Ian McCammon in 2009. Thus, on the basis of simple, measurable and debatable parameters, the objective is to determine which mode of vigilance is required: relax mode, concerned mode, alert mode or... hazardous mode. The goal is no longer to predict the avalanche (which does not generally occur), but to be better prepared for the unexpected. From here, there are clearly opportunities for danger avoidance, risk reduction or reconsidering the entire project.
I have adopted this practice for helping decision making during cross-country skiing, track-setting for ski mountaineering races ... or for risk management on the access roads to the biggest ski resorts in the Alps. This is also taught in the training of French guides and ski instructors.

1. INTRODUCTION

With the development of means of observation and calculation, and the advent of methods and communication tools, it became possible to plan in detail a road trip of several hundred kilometers ... as well as describing the parameters of the next hurricane threatening New York. So we all get used to forecasts that we want to be both accurate and sure. However, based on 736 avalanches we have described and recorded in our online database (30 of them precisely studied in the context of expertise in court), it appears that the avalanche is a large surprise to most of those who are victims, whether amateurs or professionals.

➢ A ski instructor: "*We had already made several runs in this area, without detecting any sign of instability."*

➢ A guide: "*What surprised me the most? The scale of the thing! I figured it could trigger and I had anticipated, but not so big, not from above! The all mountain in the face! ! !* ".

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➢ A specialist in risk management: "... *I noticed that two types of cases are associated with the most striking surprises: beliefs ("I never thought it possible"), and gaps in the collection and use of information.* "

In 2009, Ian McCammon, alerted us about the limitations of teaching and peremptory methods of avalanche risk reduction. He advocated instead a "bounded vigilance model" based on simple observations, but carefully selected. It is this approach that we tried to develop, by associating it with a strong warning against the prospect of being able to predict the avalanche without error (a belief that we should abandon).

To respond to a request from the National School of Ski and Mountaineering (ENSA, Chamonix), I proposed the basis of a program to help ski instructors to determine their true "level of vigilance". The foundations of this approach (figure 3) are presented here.

2.WHAT ARE THE LIMITS TO PREDICT AVALANCHES?

Acceptance of uncertainty seems a prerequisite for managing avalanche risk. At least three

reasons prohibit indeed an accurate view of the situation: the spatial variability of the snowpack, the complexity of the trigger mechanism of slabs, and the wide variety of sizes of avalanches possible for apparently similar configurations.

2.1 Snowpack

The great variability of the snowpack on a slope is obvious, sometimes just within a few meters, at least in the French Alps. For two main reasons:

- ➢ The effect of wind that erodes or accumulates snow because of the slightest changes in slopes,
- ➢ The avalanches, that also add or remove meters of snow on slopes which, precisely, we are interested in.

The use of an avalanche probe can easily allow to check the differences of thickness, which necessarily lead to differences in stratigraphy, mainly because of varied temperature gradients. We had already checked this fifteen years ago, by measuring snow depth every 5 m on a square of 50 m x 50 m in an area submitted to avalanches (from less than 1m to more than 3m).

These observations are now specified with new automatic stations installed in France, to help manage avalanche risk above the roads. Whereas a single snow depth is not satisfactory, we implemented seven stations carrying two measures of snow depth at a few tens of meters away (www.isaw.ch). This allows to judge the importance of transport of snow by the wind, to see that the same area can be alternately subjected to erosion and accumulation, and that even a bump can be the site of significant accumulations.

These findings lead naturally to doubt the interest of stability tests for purposes of prediction, whatever they are. This had been already suggested B. Jamieson and C. Campbell in 2004, with 62 Rustchblocks performed in the same slope ... and sometimes conflicting results of two contiguous tests.

2.2 Stability

Progress in understanding the triggering mechanism of slabs especially allow to understand its complexity. For example, assuming an avalanche triggered by propagation of a crack under the slab (and then into the slab) involves the manifestation of phenomena that are impossible to anticipate and monitor.

Yet it is probably these mechanisms that lead to surprising phenomena such as remote triggering, the triggering of slabs of old snow or post-control avalanches (as presented for instance by M. Ferrari during ISSW 2010).

2.3 Size of the avalanches

The Swiss have laid the basis of a relationship between the risk level of European scale and size of the expected avalanches, illustrated in the educational CD "White Risk". The North Americans have clearly formalized it in the new scale of public avalanche risk. These initiatives were expected because the size of avalanches feared is the major criterion that can lead to evacuating buildings, closing lines of communication ... or adjusting the distances between skiers.

Yet again, the forecasts are fragile. It is not uncommon for a small avalanche to trigger a much larger one (or not!), or that a same site produces avalanches 30 m or 500 m wide in conditions that appear similar.

3. BACK TO PARAMETERS DICTATED BY COMMON SENSE

January 5, 2012: For the third time in the winter, heavy snow fall reach the northern Alps. The slopes were leveled by previous snowfalls and common sense dictates that access to several large resorts in Savoie had to be closed. Many agreed, but two of them refused, on the basis of expert opinion. It is not until several medium-size avalanches reached the roads that decision to close them to traffic was taken. Only luck allowed to avoid any casualty.

If one refers to the interesting study of P. Höller in 2010, we can imagine that better decisions for security would have been taken 80 years ago! Indeed, most of the parameters determining the

avalanche danger had already been identified in the 1930s: slope angle, new snow depth, and even weak layers. Since then, critical values have been specified (eg inclination threshold) and important phenomena have been understood (functioning weak layers for example). However, it is regrettable that the status of "specialist" is often used to push the limits that mountain common sense had correctly assessed.

Since the ability of a decision-maker to manage too many parameters is limited, and that the parameters are little tangible, I suggest with I. McCammon to retain only a few simple, measurable and debatable indicators. Inventing nothing compared to the precursors of the 1930s, I would suggest these:
➢ Inclination of the slope (threshold of 30 °),
➢ Recent Avalanches,
➢ Recent overloads (rain or snow)
➢ weak layers buried
➢ Melting.
Of course, the risk level must also be taken into account if it has been assessed by a proficient service.

No statistics to justify that choice (!) but some confidence in the laws of physics and several decades of measurements and observations (either on snowpacks that have not produced avalanches, or on accident sites). The aim is to remind the decision-maker to focus FIRST on common-sense information. These are the ones which will determine the true level of vigilance in which people should be and also those on which we will be questioned by the judges in case of trouble.

3. FOUR VIGILANCE MODES

Reading many accounts as part of expertise in court showed me that avalanche victims lacked simple and clear benchmarks to assert their exposure to danger. I do not know yet serious accidents involving mountaineers on alert mode. Each time, the risk is either ignored (the leader can be focused on another hazard), or significantly underestimated. Intuition is clearly insufficient, and the decision aid methods are not infallible. The accumulation of experience works pretty well to be

aware of avalanches small and medium: the experienced mountaineer felt collapses, observed triggered slabs elsewhere, or triggered himself a slab by ski cutting. It is quite different for very large slabs, which sometimes start without any previous signs.

The main obstacle to learning from experience is the relative scarcity of avalanches. When all observable conditions are met for the avalanche to occur, usually nothing happens. The mountaineer both experienced and lucky becomes less and less suspicious, until the day ... However, when the young aspirant guides are back on the field, after I have shown them many examples of avalanches, are often "terrorized" without reason (moderately steep terrain, old snow, etc..). There is thus a need to try responding in new ways (figure 1).

Once the indicators selected are well identified, trained and experienced mountaineers do not usually encounter difficulties estimating quickly the true mode of vigilance required. Tests during two seasons with the aspirant guides from Sweden and Great Britain were very positive. However, it was necessary to build a simple grid containing values for the indicators. This grid is not issued from statistics either! These indicators are being developed with teachers from ENSA (Chamonix). They are of course intended to be criticized and improved (figure 2).

It is easy to understand this method with caricatured situations:
➢ Skiing with less than 20 cm of new snow on slopes less than 30 ° while there is no melting and that the danger level is estimated at 1 or 2 should lead to relax mode (but with a normal vigilance for detecting an eventual change of situation).
➢ Skiing with more than 50 cm of new snow on a slope over 30 ° while the danger level is estimated at 4 or 5 clearly requires an awareness of hazardous mode.

When you are at the foot of a slope over 30 ° and a buried weak layer allows a possible fracture propagation, it is perhaps less obvious to realize that the alert mode is required and that you have to manage the risk.

This illustrates how crucial prior theoretical training is, especially about the metamorphism of snow, the trigger mechanisms of slabs and use of available information. The matter is not to reduce the work of preparation and observation, on the contrary. The rationale of the method is to better focus on what is a priority, in the aim to generate the appropriate level of vigilance. So keep probing, digging, measuring inclinations, study maps, read the bulletins!

Then the choice is often possible between danger avoidance and risk management, which should be taught not by snow scientists, but by specialists in how to behave in snowy mountain.

4. CONCLUSION

Clearly, despite the efforts of researchers, the local forecast of the occurrence of an avalanche is almost never possible (will the slab be triggered here and now?). This is why we must deal with the element of unpredictability, often leading to taking safety margins, which may seem unnecessary. Our room for improvement is in reducing the exposure to danger, and not in the details of our forecast, which runs into limits which will be difficult to push: incomplete knowledge of triggering mechanisms of slabs and, especially, inability to obtain all necessary information.

The goal is to bring the mountaineers (or the consultants) to a suitable level of vigilance, on the basis of simple indicators, at each stage of reflection "3x3". Then everyone is free to avoid danger or to manage his risk-taking, but knowingly. This should limit the number of avalanche accidents and especially their seriousness. Indeed, it seems that many serious accidents are caused not by an error in the details of risk management (alert mode needed), but a failure in taking into account the danger (relax mode inappropriate).

5. AKNOWLEDGMENTS

6. REFERENCES

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"Relax" mode _(green)_	No alarming indicator has been identified. Unless unexpected findings, the route is completed as planned. The leader is alert to the possible reporting of danger he would not have anticipated. NORMAL VIGILANCE
Concerned mode _(yellow)_	Indicators to check priority have been identified (accumulations by wind, or melting, for example), check their level (how much new snow depth increases under my skis?) anticipation of modification of track or route, rather than switch to "alert mode". DANGER AVOIDANCE.
Alert mode _(red)_	Indicators show that an avalanche can take away or hit someone in the group. We must therefore organize to limit the damage (distance between participants, safety islands), and possibly consider an escape route (without increasing the danger). RISK REDUCTION
Hazardous mode _(black)_	A lucid analysis would show that the best precautions can not reasonably limit the consequences of an avalanche. The probability of multivictimes and / or death is high. NEW ANALYSIS ; ALTERNATVE

Figure 1. Four modes of vigilance based on observed indicators, and guidelines of behavior: normal vigilance, avoidance of risk, risk reduction or new analysis.

Indicators			
Recent avalanches	none	accidental small and medium	large and / or spontaneous
New overloads: Rain or snow	<about 20 cm	>about 20 cm	>about 50 cm
Weak layers	None	existing under new snow (directly below, or deeper)	thick and continuous under new snow (directly below, or deeper)
Melting	few cm under surface	more than about 15 cm	more than about 30 cm
«danger level »	1 ou 2	3	4 ou 5

Minimum level of vigilance engendered - slope angle			
In an incline of 30 degrees or more	concerned mode	alert mode	hazardous mode
Immediately downstream of an incline of 30 ° or more	"relax" mode	concerned mode	alert mode
Further downstream of an incline of 30 ° or more	"relax" mode	"relax" mode	concerned mode
Note: in case of poor visibility, the level of vigilance must be generated similar to that adopted for the slope angle of 30 ° or more (because it can be navigated without having anticipated).			
The identification of downstream traps (cliffs, crevasses, obstacles, etc..) must also produce an adaptation of the level of vigilance.			

Figure 2. Bounded vigilance charts, appropriate to the terrain (positioning in relation to slopes steeper than 30°), and benchmarks for indicators.
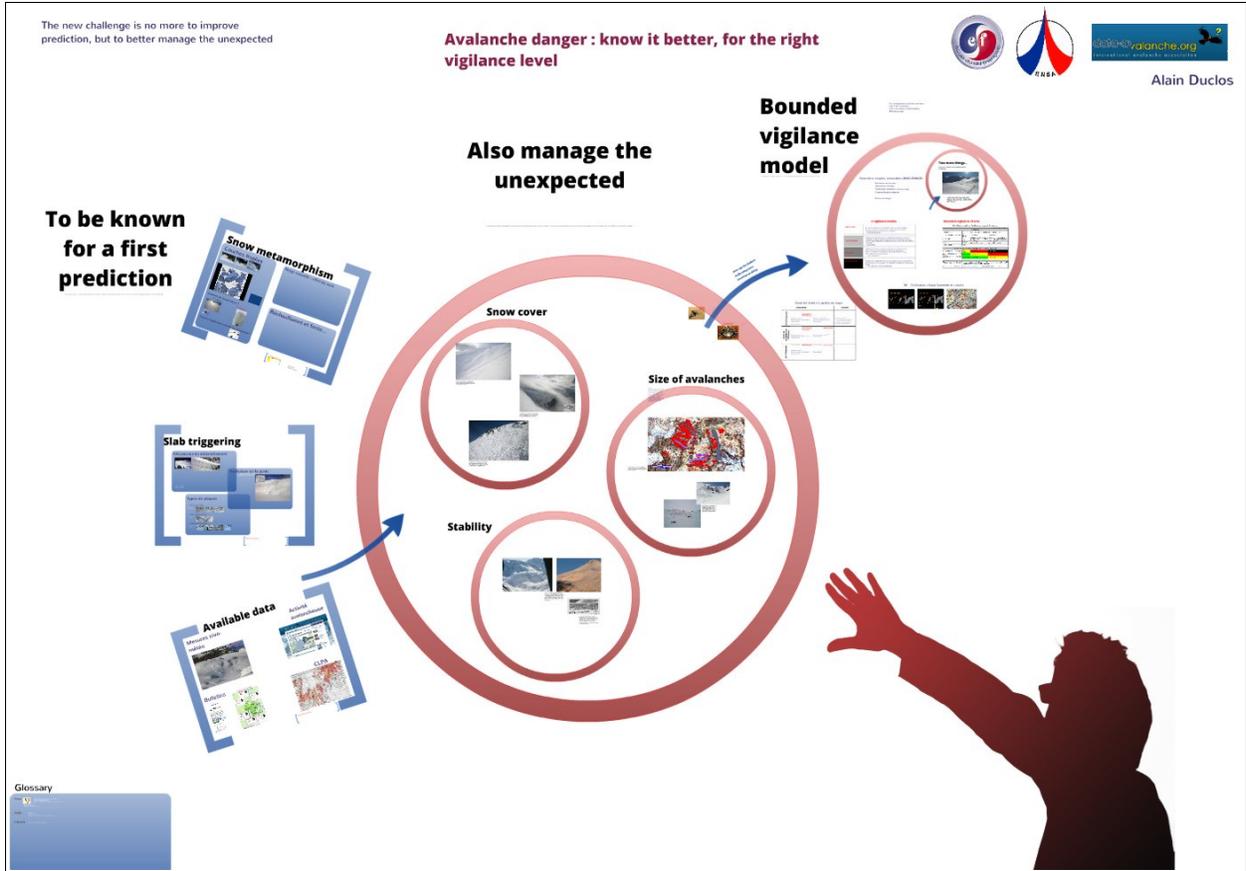
Figure 3. Frame of the new "Snow and avalanche" program provided by the National School of Ski and Mountaineering (Chamonix).