

**WHICH OBS FOR WHICH AVALANCHE TYPE?**

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**ABSTRACT:** At the 2004 ISSW, Roger Atkins proposed that—early in the terrain selection process—backcountry travellers could identify which *types* of avalanches were likely, e.g. wind slab, persistent slab, wet avalanche. These avalanche types are analogous to a set of scenarios in traditional risk analysis. Variations on Atkins’ approach have been incorporated into some public bulletins. The types of avalanches that dominate the danger ratings are called Avalanche Types/Characters/Threats/Concerns/Situations/Problems by different groups. The latest Swiss brochure for recreation in avalanche terrain suggests different observations for the four different types of avalanche situations. To determine which observations are best for which types of avalanches, a field study was conducted in the winters of 2008-09 and 2009-10 in the Coast Mountains, Columbia Mountains and Rocky Mountains of western Canada. On each field day, an experienced field team rated the local avalanche danger, identified two dominant Avalanche Types and observed a standard set of over 20 quick field observations. The quick observations included avalanches, wind transported snow, snowfall, etc. For correlation analysis, we focussed on two distinct classes of Avalanche Types: 1) Persistent Slabs, as well as 2) Wind Slabs combined with Storm Slabs. While some observations correlated with the local danger when either class of avalanches dominated the danger rating, other observations correlated best when only one of these two classes dominated the local danger rating. These results may help bulletin writers recommend that recreationists focus on certain local observations for better informed decisions.

1. INTRODUCTION

For decades, risk analysts for natural hazards have identified distinct scenarios (or potential events) which threaten something of value e.g. property or infrastructure. For each scenario, the probability of the natural event affecting the thing of value and the expected consequences are estimated (Kaplan and Garrick, 1981).

Mitigation, if required, typically focuses on the scenarios with the highest risk (combination of probability and consequences). If the probability and consequences for each scenario can be quantified, the risk for the can be graphed as in Figure 1. If either the probability or consequence can only be ranked (not quantified), the scenarios are usually presented in a risk matrix (e.g. Ahrens, 2008, p. 22-24). The scenarios

with the highest risk (or unacceptable risk) can be targeted for mitigation. This established approach to risk analysis has been used for long-return period avalanches that can affect property (e.g. Wilhelm, 1998). The same concept is also used informally by guides, forecasters and experienced recreationists, who often focus on one or two types of avalanches

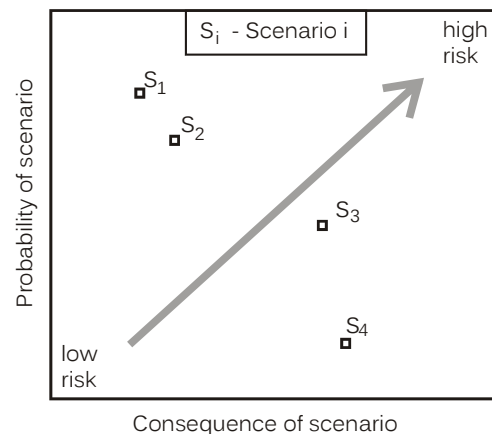


Figure 1: In this graph, Scenario 3 has the highest risk and could be targeted for mitigation.

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(scenarios) when assessing the risk on the terrain being considered for the current day.

For many years some Swiss guides and avalanche educators have proposed asking: "What is the main danger today?" On most days, it can be decided whether it is either a *New Snow*, and *Old Snow*, or a *Wet Snow* situation.

Once the situation is recognized, the mitigation strategy can be adapted (Wassermann and Wicky, 2003). Stephan Harvey has further formalized this approach, called it pattern recognition and added one more situation: *Wind Driven Snow*, when an increased avalanche danger often prevails (Harvey, 2008).

In parallel with the Swiss development of Avalanche Situations, at the 2004 ISSW in Jackson Hole, Roger Atkins proposed that the probability and consequences be assessed separately for different types of avalanches, e.g. wind slab, persistent slab, wet avalanche, so the decision makers could focus on the one or two scenarios (Avalanche Types) that posed the greatest risk. Some of his avalanche characteristics incorporated terrain, e.g. wind slabs near ridge tops.

Atkin's concept was used by the Avalanche Danger Scale Project, which was a Canada-US part of the multi-agency project called Avalanche Decision Framework for Amateur Recreationists 2 (ADFAR2). Starting in 2005, the committee of mostly forecasters took a fresh look—actually fresh look after fresh look—at the forecasting process. When they finally had a consensus, the Avalanche Type was a key component of their

conceptual forecasting model (Statham et al., this volume). Definitions for the different types of avalanches have been developed. These definitions were the basis for incorporating Avalanche Problems into Canadian avalanche bulletins (Klassen, 2010).

Most recently, Avalanche Type been used as the central theme in a field book for decision-making in avalanche terrain published by the Canadian Avalanche Centre (Klassen et al., 2010). The field book contains templates for recording the relevant observations and facilitates decisions when preparing for and travelling in avalanche terrain.

The concept of Avalanche Type has been and will continue to be applied at various scales. At the slope scale, experienced forecasters and guides can visualize certain types of potential avalanches on the terrain. At the regional scale, some avalanche forecast centres have started to use one, two, or occasionally three Avalanche Types in their public bulletins. Although there is as yet no consistent terminology (Table 1), the concept has caught on and is now used in various applications.

When updating the popular Swiss avalanche awareness brochure "*Caution – Avalanches!*" the idea of Avalanche Situations was merged with the reduction method with the classical 3x3 framework (Harvey et al., 2009). For each of the four Avalanche Situations a number of key observations are proposed to help recreationists focus on the most important observations for the day (Table 2).

Table 1. "Avalanche Type" terminology and some applications

Source	Application	Name for type of avalanche of concern: type classes
Avalanche Danger Scale Project/Committee (Statham et al., this volume)	Forecasting & forecasting courses	Avalanche Character: loose dry; loose wet; wet slab; storm slab; wind slab; persistent slab, deep persistent slab; cornice falls.
Utah Avalanche Center, USA	Public bulletins	Avalanche Threats: storm snow; persistent slab; wet avalanche; cornice fall.
SLF Davos, Switzerland (Harvey et al., 2009)	Awareness brochure	Avalanche Situations: new snow; wind driven snow; old snow; wet snow.
Canadian Avalanche Centre, Revelstoke, BC, Canada (Klassen et al., 2010)	Public bulletins, field book, awareness courses	Avalanche Problem (formerly Primary Avalanche Concern): loose dry; loose wet; wet slab; storm slab; wind slab; persistent slab, deep persistent slab; cornice falls.

Table 2. Typical signs for four distinct avalanche situations (from the Swiss brochure *Caution – Avalanches!*)

Avalanche Situation	Typical signs and relevant observations
New Snow	Amount of new snow (critical new snow depth is reached), <b>recent slab avalanching</b> . Further observations: air temperature evolution and wind during snowfall, type of snow surface prior to snowfall
Wind Driven Snow	Signs of drifting snow, hard packed or soft, varying ski pen when breaking trail, slabby surface layers, <b>recent slab avalanching, cracking</b>
Old Snow	Weak layers in the snowpack (simple snowpack tests often useful), <b>whumpfs</b>
Wet Snow	Rain, overcast during night, air temperature well above 0°C, strong insolation, deep ski/foot penetration, <b>natural avalanching</b> (slab or loose snow)

Alarm signs are marked in **bold**.

Early experience with this scheme suggests that on some days it is difficult to distinguish between *new snow* and *wind driven snow*. Also, the debate continues about whether to explicitly recommend digging when *old snow* is the dominant avalanche situation. On the other hand, the emphasis is not on digging when either *new snow*, *wind driven snow* or *wet snow* is the primary avalanche situation.

The relevant observations for each Avalanche Type in Table 2 are based on experience and an understanding of the processes that form the different types of potential avalanches. Haegeli and Atkins (this volume) also present key observations from a survey of experienced avalanche professionals. For this study, we set out to use field data (independent of theory or experience) to identify some key observations when different types of avalanches were dominating the danger rating.

## 2. METHODS AND DATA

Since the winter of 2007, the Applied Snow and Avalanche Research group at the University of Calgary (ASARC) has been rating the local avalanche danger and making a standard set of over 20 observations (e.g. Jamieson and Haegeli, 2008; Appendix A). Starting in the winter of 2009, we began daily rating the top two Avalanche Types, so we could assess which observations were “best” for the various types of expected avalanches. This paper summarizes the results from the winters of 2008-09 and 2009-10.

On most field days in the winters of 2008-09 and 2009-10, ASARC’s field teams in the Coast Range, Columbia Mountains and Rocky Mountains, rated the local avalanche danger, made over 20 standard observations (Appendix A), and identified the two most important

Avalanche Types (Table 1). For this study we used only the Avalanche Type with the greatest importance—based on its contribution to the danger rating. If the two avalanche types had equal importance (50:50), we used the one recorded as Avalanche Type 1.

Many of the observations were made *before* and *after* the decision point, i.e. when the team reached treeline. For each observation, e.g. blowing snow, we used the *before* or *after* observation that was more conducive to higher avalanche danger. So, if we observed blowing snow in the morning but not in the afternoon, we used the morning observation.

For most of the observation variables, the specific observation values could be ordered from the least associated with avalanching to the most. For example, the observations for blowing snow were ordered: none, at ridge, below ridge.

Appendix A shows that we rated the local danger for one, two or three elevation zones: below treeline, treeline and alpine. We used the treeline rating, except in four cases in which we did not rate the local avalanche danger at treeline, in which case we used the below treeline rating.

In a few cases in which the precipitation was rain, we treated the precipitation rate as missing.

This resulted in the dataset shown in Table 3. Each case is a record of one field team travelling on touring skis in a specific area on a given day.

We excluded Loose Avalanche and Wet Avalanche types from the analysis since there were too few cases. Also because of limited cases, we combined Storm Slab with Wind Slab, and combined Deep Persistent Slab with Persistent Slab.

Table 3. Number of cases by Avalanche Type

Avalanche Type	No. of cases
Persistent Slab	82
Deep Persistent Slab	17
Wind Slab	42
Storm Slab	18
Loose Snow Avalanche	10
Wet Snow Avalanche	8

### 3. PRELIMINARY RESULTS

Spearman rank correlations between the local danger rating and the ordered observations are shown in Table 4. Correlations for which  $p < 0.05$  are marked in **bold**. Correlations for which  $p < 0.01$  are marked in **bold italic**.

#### 3.1 Observations that correlated when either class of Avalanche Type was important?

When either Wind Slab/Storm Slab Avalanches or Deep/Persistent slab avalanches dominated the danger rating, the observations that correlated with the local avalanche danger were: slab avalanches, whumpfs/shooting cracks, clumps of snow falling off trees (tree bombs), deep ski penetration, snow height (snowfall) from in last 24/48 h, and air warming to 0°C (negative) (Table 4). The negative correlation prompted a second look at the data: when the air temperature reached 0°C (usually spring time), the avalanche danger was mostly Low or Moderate.

#### 3.2 Observations that correlated when storm snow or wind slabs were important?

In addition to the observations mentioned in the previous paragraph, the snowfall rate, increased hand shear depth and absence of a surface melt-freeze crust correlated with the local avalanche danger when storm snow or wind slabs dominated the danger rating (Table 4). The key variables include the following observations of current or recent snowfall: snowfall rate, accumulated snowfall in the last 24/48 hours, as well as deep ski penetration.

#### 3.3 Observations that correlated when deep/persistent slab avalanches were important?

In addition to the observations mentioned for both classes of Avalanche Types, low hand shear resistance, pinwheeling, and snow surface cracking at skis correlated with the local avalanche danger when Deep/Persistent Slab

Avalanches dominated the local danger rating.

## 4. DISCUSSION

The observations proposed by the Swiss avalanche awareness brochure *Caution – Avalanches!* (Harvey et al., 2009) and the Canadian Avalanche Centre field book (Klassen et al., 2010) are supported by the correlations in Table 4. For a New Snow Avalanche Situation, recent slab avalanches and new snow amount correlated with the local avalanche danger. For an Old Snow Avalanche Situation, whumpfs correlated with the local avalanche danger. Some correlations such as the one between pinwheeling and the local danger when Deep/Persistent Slabs are important, are difficult to explain and may not be significant in a larger, more balanced dataset.

For Deep/Persistent Slabs, fewer observations correlated with local danger than for Storm Snow and Wind Slab Avalanches, which is consistent with the greater forecasting challenge for persistent slabs. See also the limited relevant observations in Table 2 for the Old Snow Avalanche Situation.

Research often yields unexpected results. When ASARC's morning stability evaluation was expanded to include identification of the one or two most important Avalanche Types, one of us (Jamieson) expected the usual response to increased paperwork. Instead, the field staff liked the focus that Avalanche Type provided to the morning safety meeting and has retained it. The Avalanche Type is just one part of the rethinking of the forecasting (Statham et al., this volume) that has become popular with ASARC's field staff.

## 5. SUMMARY

Several regional forecast centres have adopted the concept of Avalanche Character/Type/Threat/Concern/Situation/Problem for use in their public bulletins. This concept is consistent with the scenarios in traditional risk analysis. Harvey (2008) has proposed specific observations for certain classes of Avalanche Situations. For this study, we analysed a dataset of 159 cases (location-days) in which over 20 observations were made and the local avalanche danger was rated. When the dominant Avalanche Type was either Storm

Table 4. Rank correlations with local avalanche danger for two combined classes of Avalanche Type

	Wind/Storm (n = 60)	Deep/Persistent (n = 99)
<b>Avalanche observations</b>		
Recent loose avalanche(s)	0.05	-0.14
Recent slab avalanche(s)	<b>0.41</b>	<b>0.46</b>
<b>Passive snowpack observations</b>		
Shooting cracks, whumpfs	<b>0.37</b>	<b>0.27</b>
Snow surface cracks at skis	0.22	<b>0.25</b>
Pinwheeling (today)	0.08	<b>0.32</b>
Overnight freeze after thaw	-0.15	0.05
Snow clumps falling from trees	<b>0.34</b>	<b>0.25</b>
Deposits of drifted snow	0.19	0.17
Thickness of surface crust	<b>-0.31</b>	-0.17
Wind scouring/sastrugi	-0.10	-0.04
<b>Active snowpack observations</b>		
Avg. ski penetration	<b>0.68</b>	<b>0.49</b>
Ski pole probing in top 50 cm	-0.13	-0.04
Hand shear resistance	0.20	<b>0.32</b>
Hand shear depth	<b>0.33</b>	0.14
<b>Weather observations</b>		
Snowfall rate	<b>0.45</b>	0.14
Typical wind speed	0.18	0.16
Blowing snow	0.15	0.17
Cloud cover	0.15	0.17
Snow height last 24 h	<b>0.55</b>	<b>0.21</b>
Snow height last 48 h	<b>0.63</b>	<b>0.39</b>
24 h change in max. air temperature	0.02	0.18
Air warming to 0°C	<b>-0.42</b>	<b>-0.24</b>

Avalanches or Wind Slabs, the observations that correlated (and were consistent with knowledge of avalanche formation) included recent slab avalanches, snowfall rate, snow clumps falling from trees (usually indicative of wind or warming), deep ski penetration and snow height from the last 24/48 hours. When the dominant Avalanche Type was either Deep Persistent or Persistent Slab, the observations that correlated (and made sense) included recent slab avalanches, whumpfs/shooting cracks, deep ski penetration and increased snow height from the last 24/48 hours.

Further field studies are planned. There are other observations that correlated in this study and may benefit from analysis of a larger

dataset. However, any recommended observations should be consistent with the current understanding of the processes that form the different types of avalanches.

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Appendix A - Tip sheet for research observations

ASARC RSO Field Observations 2011									
Date	Location					Profile: Y N			
Raters: LL, CK	Bulletin readers:					Bulletin writers: LL			
<b>Field Observation</b>	<b>Before decision( min)</b>					<b>After decision point only</b>			
# loose av in motion	SVM 0 1 2 3+	N 0 1 2 3+	SVM 0 1 2 3+	N 0 1 2 3+	SVM 0 1 2 3+	N 0 1 2 3+	SVM 0 1 2 3+	N 0 1 2 3+	SVM 0 1 2 3+
# slab av in motion	SVM 0 1 2 3+	N 0 1 2 3+	SVM 0 1 2 3+	N 0 1 2 3+	SVM 0 1 2 3+	N 0 1 2 3+	SVM 0 1 2 3+	N 0 1 2 3+	SVM 0 1 2 3+
recent loose av.	<24 24-48 none	<24 24-48 n	<24 24-48 none	<24 24-48 n	<24 24-48 none	<24 24-48 n	<24 24-48 none	<24 24-48 n	<24 24-48 n
recent slab av.	<24 24-48 none	<24 24-48 n	<24 24-48 none	<24 24-48 n	<24 24-48 none	<24 24-48 n	<24 24-48 none	<24 24-48 n	<24 24-48 n
# whumpf/shooting cr	0 1 2 3+		0 1 2 3+		0 1 2 3+		0 1 2 3+		0 1 2 3+
cracking at skis	None Occ. Freq.		None Occ. Freq.		None Occ. Freq.		None Occ. Freq.		None Occ. Freq.
# pinwheel slopes tdy	0 1-2 3+		0 1-2 3+		0 1-2 3+		0 1-2 3+		0 1-2 3+
current tree bombing	None Occ. Freq.		None Occ. Freq.		None Occ. Freq.		None Occ. Freq.		None Occ. Freq.
wind deposits	none < 24 24-48		none < 24 24-48		none < 24 24-48		none < 24 24-48		none < 24 24-48
surface condition	dry fresh settled sticky		dry fresh settled sticky		dry fresh settled sticky		dry fresh settled sticky		dry fresh settled sticky
Other _____	wind stiff M/W coarse		wind stiff M/W coarse		wind stiff M/W coarse		wind stiff M/W coarse		wind stiff M/W coarse
	crust ____ cm sup Y N		crust ____ cm sup Y N		crust ____ cm sup Y N		crust ____ cm sup Y N		crust ____ cm sup Y N
snowfall rate	0 <1 1 2 3+ LR MR+		0 <1 1 2 3+ LR MR+		0 <1 1 2 3+ LR MR+		0 <1 1 2 3+ LR MR+		0 <1 1 2 3+ LR MR+
wind speed	C L M S+		C L M S+		C L M S+		C L M S+		C L M S+
blowing snow	none below @		none below @		none below @		none below @		none below @
wind scouring/sastrugi	none < 24 24-48		none < 24 24-48		none < 24 24-48		none < 24 24-48		none < 24 24-48
avg ski penetration	cm					cm			
ski pole probe (top 50 cm)	obv WL hard over soft		obv WL hard over soft		obv WL hard over soft		obv WL hard over soft		obv WL hard over soft
	buried crust incr. resist		buried crust incr. resist		buried crust incr. resist		buried crust incr. resist		buried crust incr. resist
hand shear (top 40 cm)	E M H NR   B RP SP		E M H NR   B RP SP		E M H NR   B RP SP		E M H NR   B RP SP		E M H NR   B RP SP
	↓ approx. ____ cm		↓ approx. ____ cm		↓ approx. ____ cm		↓ approx. ____ cm		↓ approx. ____ cm
average sky	⊙ ☉ ⊕ ⊖ ⊗		⊙ ☉ ⊕ ⊖ ⊗		⊙ ☉ ⊕ ⊖ ⊗		⊙ ☉ ⊕ ⊖ ⊗		⊙ ☉ ⊕ ⊖ ⊗
HN24 cm	HN48 cm	Ta change since yesterday ~ °C							
Ta warming to 0 °C Y N		overnight freeze after thaw Y N No thaw							
Av type 1: L Wet Wind Strm Prst Deep					Av type 2: L Wet Wind Strm Prst Deep				
yymmdd: 071205 FC on CR					yymmdd: 071205 FC on CR				
Loc: Alp TL BTL					Loc: Alp TL BTL				
shelt, lee nr ridges ...					shelt, lee nr ridges ...				
unreact stub tchy v tchy   wide loc isol					unreact stub tchy v tchy   wide loc isol				
v unl poss. 50:50 likely v likely					v unl poss. 50:50 likely v likely				
Sz: 1 2 3 4 5					Sz: 1 2 3 4 5				
Imp: 1 2 3 4 5 6 7 8 9 10					Imp: 1 2 3 4 5 6 7 8 9 10				
Loc danger	Pre-dig LL CK	Post LL CK	Why change?		Comments				
	ALP	c c c c			CK: 071205 pop in CTX2 at TL				
	TL	c M c c			good skiing, no cracking BTL				
	BTL	M M M M							

Initials: LL wrote the current bulletin. CK neither read nor wrote it.

record observations before and after the decision to enter or not enter more serious terrain than the ascent route. Note minutes of ski travel.

**in motion** => an av you observed running  
**SVM** = triggered by skier/sled/cat. N = Natural

due to stiff surface snow

slopes with today's pinwheels

**dry fresh** usually F; **settled** usually 4F

avg. thick, **supportable**, where present ignore isolated conditions.

numbers for cm/h of snowfall, LR, MR for light, mod rain.

use basket end for ski pole probe

hand shear test: ~30 x 30 cm; cut back and sides with hand or ski pole. Rate **Easy, Mod, Hard, No Result**. Also note character: **Sudden Planar, Resistant Planar, Break**

approx. change in max. temperature from yesterday to today (neg. if cooler today)

record Y or N only if melting occurred on the previous day, or **No thaw** if no melt occurred on the previous day

See examples of the two types of avalanches. **L** = Loose. Others are slabs. **Deep** = deep prst. Use ellipses to show a range. For location, use arrows and notes. **stub** = stubborn. **tchy** = touchy. **wide** = widespread. **loc** = localized. **isol** = isolated. **unl** = unlikely. **imp** = importance: how much it dominates the danger ratings.

rate BTL, TL and/or ALP if you can do so with confidence. Observers, LL and CK, must **independently** rate the local danger pre-dig (typically post site selection) and post-dig (typically back at the trailhead). If > 2 observers, group by ratings, e.g LL CK/JO. If any ratings change while/after digging, note who changed their rating and the primary cause(s) e.g. profile, RB, CT, rumble, wind, etc.

**Additional notes:**

- Except for the danger rating, more than one of the given options can be circled, if necessary.
- Observations of current and recent avalanche activity made within the last 10 km of travel to the start of tour (either by car/heli/sled) should be included.
- Note and explain uncertainty in any observations and to assist subsequent interpretation by someone else.