Decision-making on Variable Risk Terrain

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ABSTRACT

The likelihood of severe injury or death increases when avalanche victims encounter strong destructive forces within moving debris, and/or they impact with injurious or fatal terrain features such as trees, cliffs, and deep gullies along the avalanche path. This paper proposes a scale for determining the level of potential risk of severe injury or death as these factors vary from one avalanche path to another. The intent of this risk scale is to provide a decision-making tool to help both recreational and professional backcountry travelers determine the need to minimize site-specific uncertainty about snow stability when contemplating travel onto avalanche terrain.

INTRODUCTION

By far, the largest number of avalanche fatalities occurs among backcountry skiers and mountaineers. Tragically, the number of fatalities in these groups is increasing over the long term. This trend suggests the need for additional and/or improved methods and tools to help backcountry travelers correctly analyze site-specific avalanche risk.

Conventional wisdom once taught that all that was needed for an avalanche to occur is snow on a slope and a trigger. Avalanche safety education and backcountry forecasting techniques have advanced well beyond offering such vague generalities. Over the years, clearer parameters have been identified for observing elements of weather, snowpack, and terrain that contribute to avalanche probability on a given slope.

While being able to forecast avalanche probability is important, by its nature any such forecast involves some level of uncertainty. Given this fact, a modicum of caution in choosing a safe route in avalanche terrain has always begged the question, "What are the potential consequences of being caught in an avalanche on this slope?". The answer depends on three factors; 1) the potential for dynamic forces within the avalanche to injure or kill, 2) the number of potentially injurious and/or fatal terrain features with which the avalanche victim may come into contact on the ride down, and 3) the time, skills, and tools required to conduct a successful rescue as determined by the final burial depth and/or size of the search area.

Existing "hazard rating" scales classify the size of and destructive forces for specific avalanche events and are useful for land-use planning. Existing "stability rating" scales classify general trends in snowpack stability during times of uncertainty and are useful for assessing the potential for avalanches to occur over a broad geographic area. However, neither scale classifies the specific risks presented by the terrain features and configuration of a given avalanche path. This paper proposes the stepped Avalanche Terrain Risk (ATR) Scale which the authors believe can provide an additional tool to aid backcountry travelers in the decision-making process for variable risk terrain.

Along with the ATR Scale, advisory recommendations for minimizing uncertainty and taking precautions to maximize personal safety at each risk level are offered. It is intended that the ATR Scale and the associated advisories be used in conjunction with existing "stability rating" scales so as to provide a more complete methodology for the decision-making process in the backcountry. It is hoped that, used together, the ATR Scale and the stability forecast will provide a logical, structured approach to data gathering and route selection when the possibility of fatigue, environmental pressures and/or the excitement or confusion of immediate circumstance might cloud better judgment.

DEFINITIONS AND ASSUMPTIONS

"Risk", defined in Webster's New World Dictionary, College Edition (1966), is "the chance of injury, damage or loss". The concept of "risk" will be used throughout this paper with "chance" being expressed in terms of probability, with "injury" and "damage" being defined as severe personal injury, and with "loss" being defined as loss of life.

A widely documented reason that backcountry travelers are severely injured or killed in avalanches is that they lack the knowledge, skills, and means necessary to recognize potentially weak snowpack conditions, and/or to conduct a successful rescue after the fact. It will be assumed, therefore, that users of the ATR Scale have a basic avalanche education, i.e. they have successfully completed a Level 1 (or equivalent) avalanche safety course, and that they are equipped with the basic tools necessary for conducting slope measurements, snow stability tests, and avalanche rescue. It also will be assumed that users are both competent in accurately assessing their own limits and capabilities, and that the "goal" of the touring group is to minimize risk insofar as this is practical.

AVALANCHE HAZARD AND SNOW STABILITY RATING SCALES

Numerous types of rating scales and systems for describing snow stability and potential avalanche hazard have been adopted throughout the world. There has been difficulty in arriving at a consensus in the wording of these systems. Different mountain regions appear to have rating scales to serve their unique purposes and philosophies. Recent efforts by European and North American countries to standardize their stability rating categories and terminology into the "Unified Scales" are testimony to the difficulties encountered when trying to agree on a universal system. Despite the apparent disparity in rating systems, each is useful and provides important information. Examples of some of the various rating scales and systems are described below.

AVALANCHE HAZARD RATING SYSTEMS

Several countries including Canada and Switzerland have adopted hazard rating systems which categorize the effects on people and property after an avalanche has started. For example, the Canadian system (Table 1), describes the size of an avalanche by the type and magnitude of potential destructive forces.

Such a rating system provides useful information for engineers and land-use policy makers, but does not directly address the question of relative risk of potentially severe injury or death to backcountry travelers attempting to negotiate a particular avalanche slope.

Table 1. Canadian Reporting System

Size	Description	Typical Mass	Typical Path Length	Typical Impact Pressure
1	Relatively harmless to people	<10t	10 m	1 kPa
2	Could bury, injure, or kill a person	10^2 t	100 m	10 kPa
3	Could bury a car, destroy a small building, or break a few trees	10^3 t	1000 m	100 kPa
4	Could destroy a railway car, large truck, several buildings, or a forest with an area up to 4 hectares	10^4 t	2000 m	500 kPa
5	Largest snow avalanches known; could destroy a village or a forest of 40 hectares	10^5 t	3000 m	1000 kPa

SNOW STABILITY RATING SCALES

In past years, many countries also adopted snow stability rating scales which attempted to describe general trends in overall stability of the snowpack. Typical of these systems are those of the U.S., Canada, France, and Switzerland. The U.S. scale is presented in Table 2 as an example.

Table 2. U.S. Stability Rating Scale

Low Hazard: Mostly stable snow. Avalanches are unlikely except in isolated pockets on steep snow-covered slopes and gullies.

Moderate Hazard: Areas of unstable snow. Avalanches are possible on steep snow-covered open slopes and gullies.

High Hazard: Mostly unstable snow. Avalanches are likely on steep snow-covered open slopes and gullies.

Extreme Hazard: Widespread areas of unstable snow. Avalanches are certain on some steep snow-covered gullies. Large destructive avalanches possible.

None of these systems fully addresses the risk of strong avalanche forces or potentially injurious terrain features to which a person may be exposed if caught in an avalanche on a particular slope. For example, the U.S. "Low Hazard" and "High Hazard" ratings represent two different levels of snow strength. Both indicate a potential for areas of weak snow to exist, and either could represent a high potential risk or a low potential risk of severe injury or death for backcountry travelers depending on the length of slope or the number large trees or rock outcrops on the slope they intend to access. Such general warnings of potential instability are clearly helpful in assessing of overall snowpack conditions, but backcountry travelers obviously need to consider more than this to determine the level of risk they are facing in any site-specific situation.

AVALANCHE RISK AND DANGER SCALES

Adopted by most of Europe at the Meeting of Avalanche Services held in Wildbad Kreuth, Bavaria in 1993, the Unified Avalanche Risk Scale attempts to identify potentially hazardous backcountry situations and recommends action to avoid those situations. More recently avalanche forecast and information centers in the United States and Canada have adopted modified versions of the European model. The U.S. Avalanche Danger Scale is represented in Table 3 as an example. While these scales still lack a ranking scale for potentially injurious or fatal terrain features on an avalanche slope, they do go a step further than previous scales by expressing the need for increasingly better evaluation and route selection techniques on higher risk slopes.

DIFFICULTY RATING SCALES FOR OTHER TYPES OF MOUNTAIN RECREATION

In the process of developing a rating scale that addresses the relative risks specific to a given avalanche slope, the authors examined various difficulty rating scales that are commonly used in other mountain activities. The rating scales used for mountaineering and for rivers were found to contain useful formats for evaluating risks present in their respective environments as well as for the skills needed to deal with those hazards. These scales are represented in Table 4 and Table 5 respectively.

TABLE 4. CLIMBING RATING SCALE

Class 1 - Cross-country hiking, hands not needed.

Class 2 - Scrambling, hands helpful, rope not needed but probably carried to assure party safety.

Class 3 - Easy climbing, scrambling with use of hands, elementary climbing technique helpful. Rope should be available and may be desired by an inexperienced climber.

Class 4 - Roped climbing with belaying. Belays may be anchored using either natural anchors or climbing hardware. Some moves may be difficult and could be Class 5 except for the security of short pitches, or natural protection such as trees, shrubs, and rock horns.

Class 5 - Roped climbing requiring protection such as runners, artificial chocks, and pitons, as well as belays.

TABLE 3. U.S. AVALANCHE DANGER SCALE (1996)

Danger Level (& color) (what)	Avalanche Probability and Trigger (why)	Degree & Distribution of Avalanche Danger (where)	Recommended Action (what to do)
Low (green)	Natural avalanches very unlikely. Human triggered avalanches unlikely.	Generally stable snow. Isolated areas of instability.	Travel is generally safe. Normal caution advised.
Moderate (yellow)	Natural avalanches unlikely. Human triggered avalanches possible.	Unstable slabs possible on steep terrain.	Use caution in steeper terrain on certain aspects (defined in accompanying statement).
Moderate to High (orange)	Natural avalanches possible. Human triggered avalanches probable.	Unstable slabs probable on steep terrain.	Be increasingly cautious in steeper steeper terrain.
High (red)	Natural and human triggered avalanches likely.	Unstable slabs likely on a variety of aspects and slope angles.	Travel in avalanche terrain is not recommended. Safest travel on windward ridges of lower angle slopes w/o steeper terrain above.
Extreme (red w/black border)	Widespread natural or human triggered avalanches certain.	Extremely unstable slabs certain on most aspects and slopes. Large destructive avalanches possible.	Travel in avalanche terrain should be avoided. Travel confined to low angle terrain well away from avalanche path run-outs.

Class A - Roped climbing with an artificial assist, such as stepping on a piton or climbing a chain of slings or pre-tied stirrups.

TABLE 5. RIVER RATING SCALE

Class 1 - Slow-moving water with few or no obstacles. Easy to read, easy to paddle.

Class 2 - The water is faster and the river makes a few bends. Rocks, holes, and waves are present but recognizable from upstream and easily avoided. Requires basic white water skills.

Class 3 - The current is faster yet, and rocks, waves, and holes increase in both number and size. Routes are fairly apparent, but shore scouting is advisable. A reliable roll is highly recommended. Your white water skills should be in good shape.

Class 4 - The water is difficult, big, or both. Holes and waves may be quite big, and finding a clean route will require some detective skill. Should you get off-line, there is a possibility of getting trashed. Scouting is mandatory for all but the best paddlers. A solid roll is a necessity.

Class 5 - Class 5 is essentially the upper limit of what can be run without serious risks, even by experts. Scouting is a must. The rapids are exceedingly complex and turbulent. Holes may be very large and nasty. You have to be "spot-on" to run Class 5 water. The price for not being exactly where you want to be can be high.

Class 6 - Basically unrunable. Niagara Falls, for example, qualifies quite admirably for a Class 6 rating. Someone claiming to run Class 6 water either is suicidal or, more likely, has overrated the water.

Neither scale specifically addresses relative risk, but the concept is implicit in each. For the purposes of describing avalanche terrain risks, the river scale was found to be the closest match. It was observed that the same sorts of features that can cause severe injury or death in rivers compare favorably to similar features on avalanche paths. These include rocks, trees, drops, deep holes, strong hydraulic forces and late rescue for river environments; and rocks, trees, cliffs, deep burials, avalanche forces and late rescue for avalanche paths. The ATR Scale, therefore, assigns levels of relative risk of severe injury or death to site-specific avalanche terrain using the river scale as its model.

IDENTIFICATION OF SPECIFIC AVALANCHE TERRAIN RISK FACTORS

Avalanche slopes have a variety of configurations from short test slopes of ten to twenty meters to entire mountain sides having a thousand meters or more in vertical drop. In addition, avalanche slopes vary in the number and type of potentially injurious or fatal terrain features. Some slopes may be confined with rock outcrops, cliffs, gullies, benches, and individual trees or stands of trees, while others may be unconfined and relatively smooth from the starting zone to the runout.

In considering the basis for the ATR Scale, slope length was found to be a potentially significant factor. The length of the avalanche slope effectively determines the distance (or time) over which one may be exposed to potentially injurious avalanche forces and terrain features. It follows from this that the risk of injury or death (R) increases as the magnitude of forces (F) generated by the moving debris, and the number of potentially injurious terrain features (S) with which the victim may come into contact increase over the length of the slope (x). Restated, the greater the distance (or time), over which a victim could encounter potentially injurious avalanche forces and/or terrain features, the greater the opportunity for such encounters will be, and thus the greater the probability of severe injury or death. This relationship is expressed in Figure 1.

Figure 1. $R = F(x) + S_1(x) + S_2(x) + \ldots + S_n(x)$

Internal forces within the moving avalanche are not constant as debris runs from the top of the path (T) to the bottom (B). Nor are the number of contacts with potentially injurious terrain features necessarily constant over the path length. Considering such variability, a more accurate way of expressing Figure 1 is represented in Figure 2. (In both equations, only terrain features aligned along the descent path are considered. Features located across the slope at a given elevation present no more risk than a single feature because the probability of contacting more than one is zero.)

Figure 2. $R(\%) = {}_T\int^B F(x)dx + \sum_{i=1}^{n}\{{}_T\int^B S_i(x)dx\}$

Note that slope length only addresses the potential for severe injury or death from internal forces and from contact with obstacles, not for deep burial. Care must be taken when considering slope length, not to overlook the fact that a deep burial is not dependent on slope length. Both a deep release on a short slope and/or a shallow release above a creek bed can cause death from a deep burial.

THE AVALANCHE TERRAIN RISK (ATR) SCALE

Assigning specific values to avalanche force and terrain feature variables could be very difficult if not impossible before the actual avalanche event occurs. In any case, assigning such values is not the purpose of this paper. Of greater importance is understanding the relationship of these variables to the probability for severe injury or death. The proposed ATR Scale attempts to express this relationship. Each risk level increases with the increasing probability for destructive avalanche forces (i.e., long-running avalanches), the increasing probability for contact with potentially injurious terrain obstacles, and/or the decreasing probability for a successful rescue.

Most human triggered avalanches have crown depths of less than 1.5 meters. Therefore, in assigning a risk level to a slope, a slab depth of approximately 1.5 meters or less should be assumed. The elements listed in each class level are independent considerations, one or all of which, when compared, may provide a sufficient foundation for assigning the appropriate risk level to the slope being considered. The ATR Scale is represented in Table 6.

TABLE 6. AVALANCHE TERRAIN RISK SCALE

Class 1

- no injury or deep burial is likely; self rescue is highly probable

  small potential starting zone -minimal destructive forces (less than 15 meters of vertical)
- no potentially injurious terrain features
- small, consistent runout (no deep burial potential)

Class 2

- shallow burial potential only; rescue is highly probable
- small potential starting zone
- small destructive forces (15 to 50 meters of vertical)
- no potentially injurious terrain features
- gradual, consistent runout (no deep burial potential)
- small deposition area for beacon search

Class 3

- deep burial potential; rescue is questionable
- moderate sized starting zone
- moderate destructive forces (50 to 100 meters of vertical)
- no potentially injurious terrain features
- abrupt transition in flat or depressed runout
- moderate sized deposition area for beacon search

Class 4

- deep burial and/or severe injury is probable; rescue is doubtful
- large potential starting zone
- large potential destructive forces (more than 100 meters of vertical)
- potentially injurious terrain features on less than 50% of slope
- large deposition area for beacon search

Class 5

- deep burial, severe injury and/or death is virtually certain; rescue is highly improbable
- large or multiple potential starting zones at various elevations
- potentially devastating destructive forces (more than 200 meters of vertical)
- potentially injurious terrain features on over 50% of slope
- large or multiple deposition areas for beacon search

ATR SCALE ADVISORY RECOMMENDATIONS

The higher the ATR Scale classification, the greater the need to minimize the uncertainty of snowpack stability. Another way to express this is to say that the greater the probability of severe injury or death in the event an avalanche occurs on a given slope, the more important it is to have a high level of confidence that the snowpack is strong enough to support the weight of one individual or the entire touring group before they venture onto the slope.

It is worthwhile reiterating that the ATR Scale is intended for use by individuals whom it is assumed have adequate education, competence and equipment to be in the backcountry, and that the touring group wishes to minimize the risk from avalanches as much as is practical. The advisories in this section are also based on these assumptions and are offered to assist in the evaluation of snow stability and to prepare for the potential risks of proceeding onto the slope.

Class 1 Advisory: Minimizing uncertainty of snowpack stability is not necessary. Minimal precautions are needed. These slopes are often used as test slopes to help assess the snow strength on higher risk slopes with similar aspects at similar elevations. Some notion of the potential for the snowpack to fail is helpful. Precautions necessary to help avoid injury from a simple fall in that event should be taken. The risk of severe injury or death from deep burials on Class 1 slopes is effectively zero.

Class 2 Advisory: Minimizing uncertainty of snowpack stability is helpful. The precautions listed for Class 1 slopes as well as standard personal precautions for potential burial are recommended. These would include potential victims securing openings in clothing, loosening pack and pole straps. At least a ski pole test or hand test of snow layering and some notion of the potential for the snowpack to fail is advised. The group should be prepared for a shallow burial rescue. Rescue skills should be good. The risk of severe injury or death from deep burials on Class 2 slopes is low.

Class 3 Advisory: Minimizing uncertainty of snowpack stability is advised. At least one representative shear test should be conducted before accessing the slope if there is a reasonable question concerning snow strength. If shear tests or other indicators suggest potential failure planes, the group should expect and be prepared for a potentially deep burial rescue. Rescue skills should be very good. The risk of severe injury or death from a deep burial on Class 3 slopes is moderate.

Class 4 Advisory: Minimizing uncertainty of snowpack stability is necessary. One or more representative shear test(s) should be conducted whether or not weakness is evident or suspected. Special attention should be given to potentially variable snowpack stratigraphy across the starting zone. Representative shear tests should be conducted before accessing the slope if variable conditions in the starting zone are suspected. Knowledge of performance history under a variety of snowpack conditions including those that exist at the time is helpful. Rescue and evacuation skills and preparedness should be excellent. The risk of severe injury or death from deep or lengthy burial, impact with obstacles, and/or strong avalanche forces on Class 4 slopes is high.

Class 5 Advisory: Minimizing uncertainty of snowpack stability is essential. Numerous representative shear tests in all potential starting zones are advised on a periodic basis throughout the winter to document changes in snow stratigraphy. A performance history under a variety of snowpack conditions including those that exist at the time should be known. Representative shear tests should always be conducted prior to venturing onto the slope. Ready access to advanced life support and rapid evacuation should be available. Preparation for body recovery is advised. The risk of severe injury or death from deep or lengthy burial, impact with obstacles, and/or strong avalanche forces on Class 5 terrain is extremely high.

DISCUSSION

The ATR Scale is intended to help quantify the risk level of the terrain being considered by the touring group. It is not intended in any way to help determine the level of acceptable risk for the group. Each group must determine for itself the level of risk that is acceptable to achieving its desired goal.

When using the ATR Scale, asking the fundamental question, "What are the potential consequences of being caught in an avalanche on this slope?" is the first step. If the answer is that a person would, without doubt, be violently tumbled, contact a potentially injurious terrain feature, and/or end up in a deep or lengthy burial, then the slope is a Class 5. If the answer to the question is that the chances are not certain, but better than 50% that one or more of those things will happen, then the slope is a Class 4. If there is no exposure to a long-running avalanche or potentially injurious terrain features, but a deep burial is probable, then the slope is a Class 3. If the slope is relatively short, there are no potentially injurious terrain features, and only a shallow burial is likely, then the slope is a Class 2. And finally, if the chances of being hurt or buried are negligible, the slope is a Class 1. In the recreational setting, it is advisable that each individual know and understand the goals of his or her group. These goals should be discussed and agreed to before the trip starts and as frequently as necessary en route. One errant member can cause strife within the group at critical times. He or she can also seriously jeopardize the safety of the group through careless or daring acts which either harm others or create the need for a rescue and evacuation. The ATR Scale can be used as one means of agreeing on the group goals by discussing the risk level that is most appropriate for the occasion.

Professional mountain, touring, and heliski guides are charged with setting and maintaining the goals and safety parameters for their groups. However, it is very important that guides communicate the risk levels to their clients so that the clients can make an informed decision as to whether or not to accept those risks. The ATR Scale is a useful tool for this purpose. Likewise, it can help guides avoid unwanted risk levels in the face of common environmental factors such as fatigue, client pressures, logistical failures, tempting incentives, or management pressures. As with any system designed to safeguard public safety, it should be noted that the ATR Scale, or any other system used in an atmosphere of indifference, complacency, or incompetence will eventually fail with catastrophic results.

CONCLUSION

The attraction of a long, steep run after a fresh snowfall can be overwhelming to both recreational and professional skiers and snowboarders. The anticipation of an exciting descent all too often causes terrain risk and considerations of safety to be trivialized or ignored completely. Likewise, blind dedication to the goal of attaining the summit on a climbing expedition is a powerful incentive in the face of decreasing odds of success. It is believed that the ATR Scale will improve backcountry travelers' abilities to assess the comparative risk presented by avalanche terrain. It is also hoped that the corresponding advisories will be a useful supplement for minimizing uncertainty.

The ATR Scale provides a logical methodology for prioritizing the steps needed to identify variable risk terrain. Snow stability scales are intended to aid in the process of decision-making during times of snowpack strength uncertainty. When used with the ATR Scale, the combined systems produce a synergy of improved risk analysis and offer a more complete system than either offers alone.

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REFERENCES

Fredston, J. and Fesler, D., 1995, Snow Sense, Alaska Mountain Safety Center, Inc., Anchorage, Alaska (116 p)

McClung, D. and Schaerer, 1993, The Avalanche Handbook, The Mountaineers, Seattle, Washington (271 p)

Perla, R. and Martinelli, M., 1978, The Avalanche Handbook, Agricultural Handbook 489, U.S.D.A. Forest Service (254 p)

Ferber, P. (ed.), 1975, Mountaineering; The Freedom of the Hills, Third Edition The Mountaineers, Seattle, Washington (478 p)

Conger, S., 1994, (From the Editor) "Unified Avalanche Risk Scale", The Avalanche Review, Vol. 12, No.6, Salt Lake City, Utah.

Tilton, Buck, 1992, The Basic Essentials of Avalanche Safety, ICS Books, Inc., Merrillville, Indiana (68 p)

U'ren, S. B., 1990, Performance Kayaking, Stackpole Books, Harrisburg, Pennsylvania (184 p)

Meister, R., Country-wide Avalanche Warning in Switzerland, Proceedings of the ISSW'94., (pp 58 - 79)

Schweitzer, J. and Fohn, P., Two expert systems to forecast the avalanche hazard for a given region., Proceedings of the ISSW'94., (pp 295 - 309)

Bolognesi, R., Buser, O., Good, W., Local Avalanche Forecasting in Switzerland: Strategy and Tools. A new approach..., Proceedings of the ISSW'94., (pp 463 - 472)

Fredston, J., Fesler, D., and Tremper, B., The Human Factor - Lessons for Avalanche Education, Proceedings of the ISSW'94., (pp 473 - 487)

Woodmecey, J., and Shick, J., Avalanche Forecasting for Helicopter Skiing Operations in the United States., Proceedings of the ISSW'94., (pp 527 - 531)

Elder, K. and Armstrong, B., A quantitative approach for verifying avalanche hazard rating., Avalanche Formation, Movement and Effects, IAHS Publication No. 162 (1987)., (pp 593 - 604)

Bohnenblust, H. and Troxler, C., Risk Analysis - Is it a useful tool for the politicians in making decisions on avalanche safety?, Avalanche Formation, Movement and Effects, IAHS Publication No. 162 (1987), (pp 653 - 664)

Armstrong, B. and Williams, K., (1986), The Avalanche Book, Fulcrum Inc., Golden, Colorado (231 p)

LaChapelle, E. (1985), The ABC of Avalanche Safety, Second Edition, The Mountaineers, Seattle, Washington, (112 p)

Holler, P., What do Ski Mountaineers Know About Snow Cover and Avalanche Formation?, Proceedings of the ISSW'92., (pp 270 - 272)

Meiklejohn, B., "Safe Skiing" Backcountry Skiing in Avalanche Terrain., Proceedings of the ISSW'90., (pp 97 - 110)

Birkeland, K., Brown, R., Hansen-Bristow, K., The Spatial Variability of Snow Strength on Potential Avalanche Slopes., Proceedings of the ISSW'90., (pp 115 - 129)

Kobe, K. and Jenkins, M., Hazard Perception and Preparation by Cross-country Skiers in Utah., Proceedings of the ISSW'9o., (pp 130 - 140)

Burr, E., North Cascade Helicopter Skiing Risk., Proceedings of the ISSW'88., (pp 87 - 90)

Tremper, B. and Ream, D., Utah Avalanche Forecast Center User Survey and Formats for Avalanche Advisories., Proceedings of the ISSW'88., (pp 241 - 250)

LaFeuille, J. and Pahaut, E., Avalanche Forecasting and Communication: Experiences in Avalanche Hazard Scales., Proceedings of the ISSW'88., (pp 251 - 258)

Dexter, L. and Armstrong, B., Avalanche Frequency and Magnitude Determination for Ski Touring Operations., Proceedings of the ISSW'88., (pp 1 - 7)

Harrison, W. and Wiegele, M., Engineer and Practitioner: A Combined Effort in Avalanche Hazard Forecasting., Proceedings of the ISSW'88., (pp 116 - 123)

Sutherlnd, L. and McPherson, H., Management of Avalanche Risk Faced by Backcountry Skiers., Proceedings of the ISSW'86. (pp 1 - 5)