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The Elements of Applied Avalanche Forecasting Part II: The Physical Issues and the Rules of Applied Avalanche Forecasting

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Abstract. This paper (Part II) constitutes the second of a two part series to define the seven elements of avalanche forecasting. Part I contains the first four elements which are needed to present the human issues. This paper contains the last three elements which deal mostly with the physical issues and their use in the decision-making process. Some basic rules of applied avalanche forecasting are included here, for the first time, to illustrate physically based principles which are used in applied avalanche forecasting and their link to data analysis and decisions. Since the seven elements of applied avalanche forecasting are strongly connected, the reader should consult Part I (this journal issue) as a prelude to the present paper. Part II contains sections about data and information, scale issues in time and space, decision making and errors and physical rules of applied forecasting. Since all seven elements of applied avalanche forecasting are connected, Part II does not stand alone.

Key words: snow avalanche forecasting, physical factors, decision-making, decision errors

1. Introduction

Avalanche forecasting is defined as prediction of current and future snow instability in space and time relative to a given triggering level for avalanche initiation. Applied avalanche forecasting is concerned with such predictions when decisions are made which affect risk to humans or property. There are two broad aspects to applied avalanche forecasting: the elements (I–IV) most closely connected with the human issues which were largely dealt with in Part I of this treatise and the elements most closely connected to the physical issues which are contained in this paper (Part II) and the decision-making process. None of the elements of avalanche forecasting are completely separate so that both parts of this treatise must be utilized to give a comprehensive picture of applied avalanche forecasting.

This paper contains the elements (V–VII) dealing with the information which goes into making a forecast, the time and spatial scales for applied avalanche forecasting and a description of decision-making for use in operations and backcountry travel and some rules of applied avalanche forecasting which are physically based. As with Part I, this paper is not about how to forecast avalanches. Instead, when combined with Part I, this paper contains a comprehensive overview of applied avalanche forecasting and all its features.

V. Information: types and relation to informational entropy

1.1. INFORMATION TYPES

Information necessary for avalanche forecasting consists of two types: a) singular information: information specific to the case at hand (the present situation and in the near future) and b) distributional data: information about similar situations in the past. For both of these types of data, the forecaster includes information not only about instability in the snow cover but the information is integrated with terrain, the type of trigger anticipated and incremental changes by snow and weather.

(a) Singular data or information (case information or data) is specific to the case in question. One should always have an opinion about the state of instability of the snow cover before attempting potentially risky activities in snow avalanche terrain (LaChapelle, 1985; McClung and Schaerer, 1993). Relevant singular information might be completely lacking in the case of potential instabilities in new snow at the beginning of a forecast period, which makes it essential to acquire such information. Bayes Rule states: Posterior Probability $\propto$ Prior Probability $\times$ Likelihood. Singular information contributes to the likelihood if avalanche forecasting is viewed as a Bayesian process: any forecast would be greatly limited in accuracy without it. One reason that linear time series models (e.g., Salway, 1976) have not been successful as forecasting tools is that linear time series techniques do not properly include the present (initial) conditions (Tong, 1997) which contain important singular information.

(b) Distributional data or information (or base-rate data) consist of knowledge about the distribution of outcomes in similar situations in the past and they are usually more general than singular. Such information could initially constitute the Prior Probability if avalanche forecasting is viewed as a Bayesian process. Here there is a strong link to experience with avalanches and terrain. Inexperienced people may have an extremely limited (or non-existent) view of distributional information related to terrain at a location. Examples of distributional information may include general rules of thumb from experience integrated together (not used separately) to help make decisions (Munter, 1999), nearest neighbours or non-parametric discriminant analysis of multivariate data (Buser *et al.*, 1987; McClung and Tweedy, 1994) calculated by computer to compare similar situations from the past with current data, or previous information about instability including experience with similar terrain features and snow conditions known to the forecaster.

If there are no current observations then all assessments must be based on previous experience or other information: the Prior in Bayes Theorem and the Prior is used as the Posterior Probability. Bayesian techniques are introduced here only as an example for combination of data types; there are other alternatives (Pearl, 1988; Leung, 1997). If both previous information (e.g., the Prior) and current observations, (e.g., the Likelihood), are available then Bayes Theorem could be used to arrive at the Posterior which is the Prior for the next update. Use of this Bayesian procedure could be done formally using computer forecasting techniques (McClung and Tweedy, 1994) or through an informal, judgemental combination of likelihood and prior without the use of computers or formal statistical methods as is typically done in back-country forecasting.

It is essential to combine both data types in an objective manner with respect for uncertainty to avoid biases in forecasting. Failure to use distributional information can result in bias. Failure to use singular data can cause errors and inaccurate forecasting.

1.2. RULES OF APPLIED AVALANCHE FORECASTING RELATED TO DISTRIBUTIONAL INFORMATION

In Appendix A, some Rules of Applied Avalanche Forecasting are listed, based on experience (distributional information) that may be helpful to integrate singular and distributional data for making physical inferences about slab avalanches. In practice, an avalanche forecaster does not formally distinguish between singular and distributional data in the analysis; the information is combined naturally in the integrative inductive reasoning process. Normally, singular data are collected to make a forecast and then combined with distributional data (McClung, 2000).

1.3. INFORMATION RANKING: INFORMATIONAL ENTROPY

Single data elements about the snowcover may be ranked according to their informational entropy defined as: their relevance and ease of interpretation (a measure of the uncertainty or entropy) with respect to estimating instability. The concept of informational entropy forms a strong link between data and human perception. Informational entropy applies to singular data and it gives a framework for targeted sampling. LaChapelle (1980, 1985) and McClung and Schaerer (1993) have explained this ranking system in detail. Following LaChapelle (1985), three classes of data may be defined (see Figure 1) : III. Snow and weather data measured at or near the snow surface; II. Snow-pack factors primarily revealing snowpack structure necessary for avalanches; I. Stability factors dealing with loads applied to the snowpack to reveal instability. Data elements are classified into this ranking scheme with the highest entropy data in Class III, lowest in Class I and intermediate in Class II. A report of wind speed and direction (Class III) is not nearly as easy to interpret as cracking of the snow cover under skis (Class I) which implies wind conditions have higher informational entropy. High entropy (Class III) data are highly correlated (McClung and Tweedy, 1994). An important advantage of

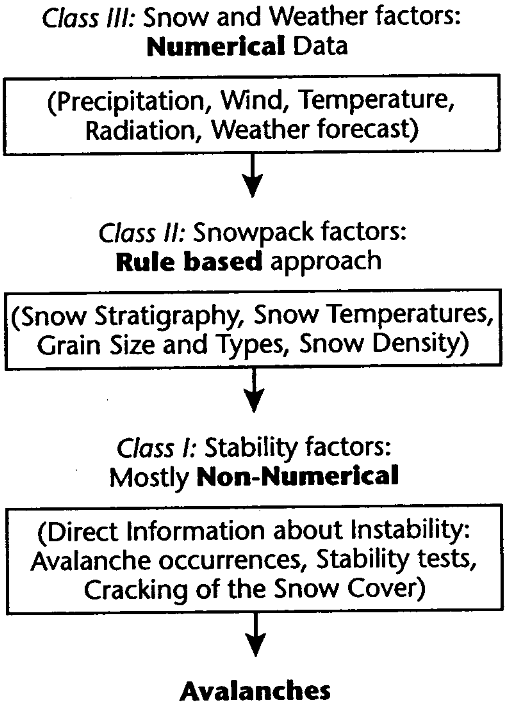


Figure 1. Informational entropy of data elements in three classes [after LaChapelle, 1985; McClung and Schaerer (1993)] for interpreting instability. The lower the class number the more relevant and more easily interpreted are the data. For models, Class III data are mostly numerical, Class II data more easily handled in a rule based approach (McClung, 1995) or subjectively and Class I data usually provide direct evidence.

computerized forecasting is to include such correlations in multi-variate estimates. This is a task not possible for humans without the aid of computers except for a few variables.

1.4. WEIGHTING DATA: RANKING WITHIN AN ENTROPY CLASS

Informational entropy classification alone is not sufficient to explain the usefulness of a datum. There is an asymmetry in the *weighting* and **use** of data and their implications about instability. Within an informational entropy class, if a datum displays positive information about instability it is considered more important in the forecasting process than one with information which is negative with respect to instability. Therefore, it is necessary to discuss weighting (importance attached) and use of data within an informational data class.

One can view a probability scale in terms of a pictorial representation of weighting data. For example, observations of avalanche occurrences (high probability of instability elsewhere) are considered much more important than information indicating a lack of occurrences and, therefore, people attach more weight to the former.

Figure 2 shows a linear probability scale (Press, 1989) but the scale need not be linear. If the probability (or percent probability or chance) of avalanching is high, as indicated by a datum, there may be high certainty of the outcome. However, in the middle range, there may be uncertainty about whether a datum says anything about avalanching and it may not contribute useful information. Similarly, if the probability is low, the datum may say something about stability with little information about instability. (Figure 2). Targeted data sampling (Part I) is concerned with seeking data which reveal important information about instability.

VI. Scales in space and time

Avalanche forecasting is practised on different spatial and temporal scales (McClung, 2000). The mix of readily available data depends on the scale (Figure 3) and to be truly effective the information used should match the scale of the problem (Haegeli and McClung, 2000). Figure 3 depicts the forecasting scale in relation to typical informational entropy classes of data which are gathered by the forecasters.

1.5. SPATIAL SCALE

LaChapelle (1980) and McClung and Schaerer (1993) discuss three basic operational spatial scales (Figure 3) as: synoptic-scale (e.g., forecasting for a region of a mountain range $>10^4$ km^2) (Ferguson *et al.* 1990; Stucki *et al.*, 1998); meso-scale (e.g., typical for a highway avalanche area or a ski area $>10^2$ km^2); micro-scale (e.g., forecasting for a given avalanche path or terrain feature <1 km^2). Normally as the spatial scale decreases, the difficulty of the forecasting problem increases and the need for accuracy increases (McClung, 2000). This is probably due to two reasons: (1) the need to integrate terrain, local features and their influences on snow deposition patterns becomes more important as the scale decreases; (2) as the scale decreases the forecasting problem moves from one of a more general nature to one which becomes highly specific. In practice, increased difficulty at smaller scale is compensated for by obtaining more low entropy data at the smaller scale. For example, to ski a given slope one would not be wise to rely on information solely developed for a synoptic scale without true relevance to the slope in question (McClung, 2000). Thus, effective forecasting on the micro-scale must be done by personnel present at the time with relevant data appropriate to the micro-scale. Any information (including synoptic scale) is useful in arriving at a micro-scale forecast, but use of large scale information (such as Public Danger Scale bulletins) not supplemented by both singular and distributional information at smaller scale is probably a significant source of back-country deaths and accidents (McClung, 2000).

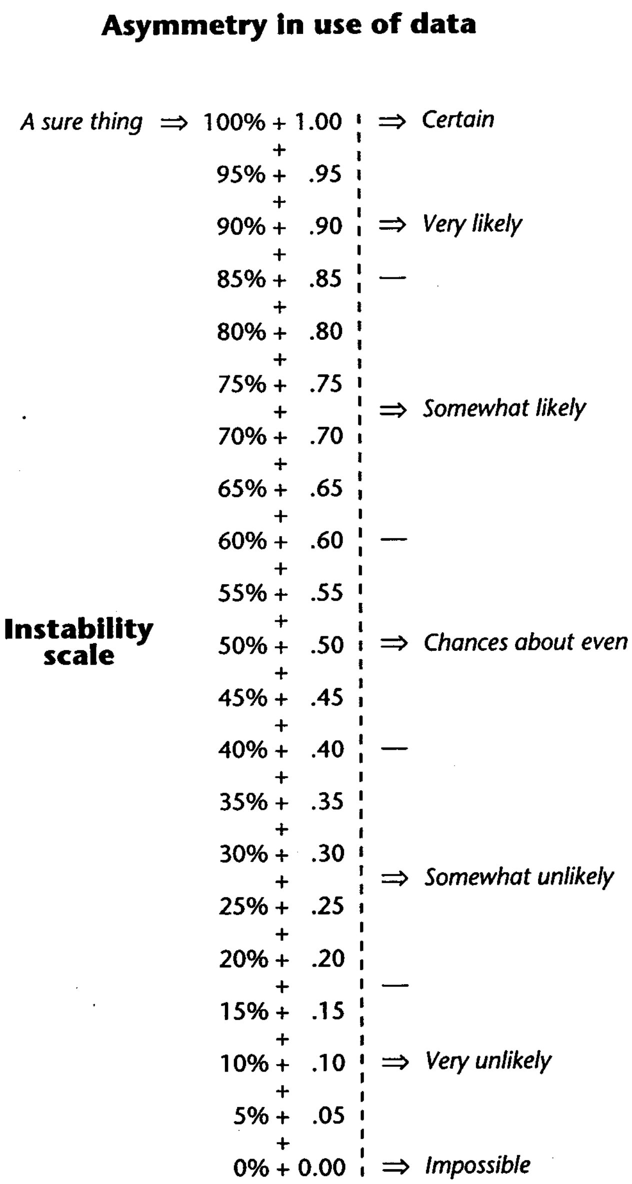


Figure 2. Linear scale for instability (after Press, 1989). A datum which shows high certainty of instability is more valuable than if instability is not revealed. The scale is written in both language descriptors as well as probability and percent probability to emphasize it applies to both numerically based forecasts as well as judgemental ones which are not based on computer analysis.

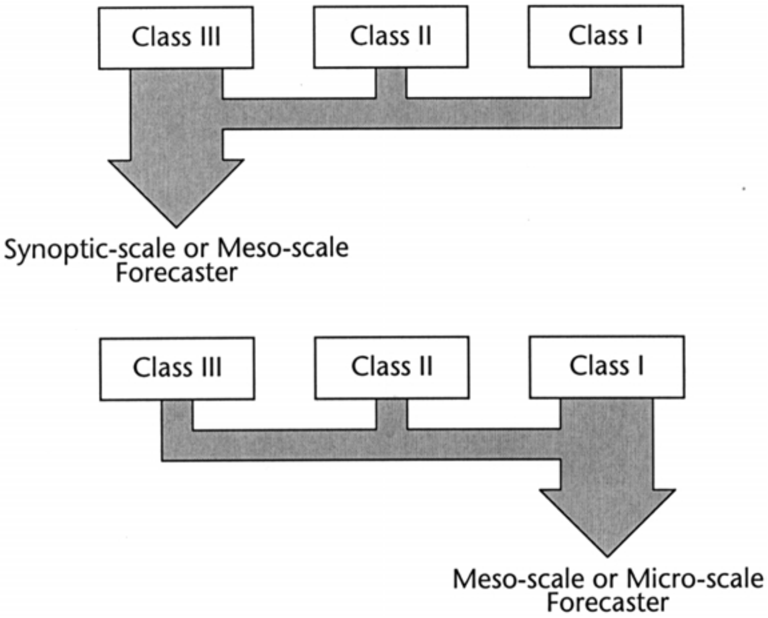


Figure 3. Scale of forecasts (synoptic, meso-scale or micro-scale) with typical principal data flow according to informational entropy class. Forecasters at all scales often use data from all three entropy classes.

1.6. TEMPORAL SCALE

The accuracy of avalanche forecasting also depends on the temporal scale which in reality is combined with the spatial scale. A 'now cast' being an estimate of the current instability is much easier to determine than a forecast and a 'nowcast' is usually much more accurate. Forecasts have increasing uncertainty as time scale into the future increases. Since future weather conditions can strongly influence avalanche conditions, the effect of temporal scale is directly linked to the problem of chaos in weather forecasting and its effect on the residual uncertainty. Thus, avalanche forecasting shares the time scale problem with weather forecasting: as the scale in time increases into the future, uncertainty and lack of accuracy increase. Rich Marriott's question remains: "How can you forecast avalanches if you can't forecast the weather?" The answer is: it is possible but in practice, one must often make allowances for the increasing uncertainty in decisions that arise. McClung (2000) presents an approximate system for classifying forecasts based on temporal and spatial scales and data available.

VII. Decision-making

Decision-making is a very important element of applied avalanche forecasting because it implies action which can have important and sometimes costly consequences. Decision-making provides an answer to the question: Given the information, what action should be taken? Decision-making is strongly related to the other elements of avalanche forecasting including the reasoning process and human perception. It may also be related to risk and its perception through a Risk-Decision Matrix (e.g., Figure 1; Part I). The description of decision-making here is given in outline form for brevity. Actual decision-making is very complex for a problem involving avalanche forecasting and a complete discussion of it would be lengthy and inappropriate here. Avalanche forecasting decisions can be viewed in outline form as an analysis with a series of basic steps: (1) Data Collection and Integration (including Singular and Distributional Information); (2) Analysis including consideration of informational entropy, uncertainty and sampling errors and asymmetry in data use and accounting for variations in human perception and estimation; (3) Objective and, if possible, a Collective Decision in one of three general categories: (A) Go (e.g., open ski terrain, open transportation routes, proceed through back-country ski terrain, remove a warning for synoptic scale forecasts); (B) No Go; or (C). Seek more relevant information which will help resolve the uncertainty to place the decision in (A) or (B).

A collective decision is usually better than one made by a single person and helps to resolve biases (Makridakis, 1990). A decision based on more than one estimate can be more reliable than a single one (LaChapelle, 1980). Further, in order to make consistent decisions about avalanche forecasts, the decision-making process should be formalized as this is a primary method to eliminate biases (see Appendix A; part I). An assessment of risk and decisions in avalanche forecasting is strongly influenced by human perception (see Part I) including all its elements: targeted education and experience, biases and data sampling. There is always an irreducible, residual risk in avalanche forecasting problems involving human variations, variations of the temporal and spatial variability of the snow cover and incremental changes due to snow and weather which must be accounted for.

In Appendix B, decision making is outlined in simplest terms related to Hypothesis Testing from the perspective of the Operational Risk Band (ORB) introduced in Figure 1, Part I of this treatise. The primary result is to relate correct decisions to errors. A correct decision is shown to be one that is not too conservative nor too much on the side of risk and this is how experienced avalanche forecasters should make their decisions.

2. Summary

Information and data used in applied avalanche forecasting may be either numerical, symbolic or of judgemental form. Bayes Rule provides a flexible framework for combining these classes of information but a Bayesian strategy is not the only possibility for doing so.

Information and data may be classed according to their influence on human perception in interpreting instability. Further, data are weighted within a data class (I, II, III) according to what they reveal about instability.

Applied avalanche forecasting is a multi-scale problem both in space and time. These scale issues strongly affect the relevance and accuracy of forecasts as data and information from different scales are used (McClung, 2000; Haegeli and McClung, 2001).

The rules of applied avalanche forecasting (Appendix A) form a partial basis for physical expectations about slab avalanche occurrences. Such rules cannot be used separately: they result from experience and, as such, they constitute distributional information rather similar to terrain and general snow climate. Optimal avalanche forecasting must include singular data as well as distributional data.

Most of the examples in this treatise have been concerned with back-country skiing. However, the concepts are meant to apply to avalanche forecasting in a fairly general sense. For synoptic scale (office-based) forecasts, the link between the forecasts and decisions is often not an action-oriented risk analysis in the same sense as field-based forecasting since the synoptic-scale forecast is often passed to the local field-based forecasters who may use the synoptic forecast as part of their decision-making analysis.

Terrain and general snow climate (McClung and Schaerer, 1993) are important in avalanche forecasting but, by themselves, they give information about general expectations and, as such, form part of distributional information. I have not included these as separate elements of avalanche forecasting because they, like the rules of applied avalanche forecasting, provide only general expectations and rather *static* information about instability is implied (Haegeli and McClung, 2001). Avalanche forecasting is presented here and in Part I as *dynamic* (McClung, 2000) rather than static. Terrain, however, is an implicit, integral part of every element. Some examples are listed here:

- Terrain induces variations in snow deposition patterns and therefore it is part of the definition and the goal.
- Terrain is implicit in the human factors (experience; data sampling) and is an important element of distributional data.
- The reasoning process must include terrain in both the inductive reasoning flow as well as rules formed by deductive reasoning.
- Terrain is linked to scales in time and space by data sampling as the forecast changes from the general (synoptic scale) to the specific (micro-scale).
- Terrain must be included in decision-making for determination of which terrain is to be opened or used for human movement.

Correct decisions in avalanche forecasting should fall within the Operational Risk Band (ORB): not too risky nor too conservative. Errors accrue for either of the latter kinds of decisions but the costs differ. The decision process outlined in Appendix B is a first attempt to describe it in simplest form. Actual decisions are much more complicated as they involve the entire process as outlined under element VII: decision making. Decision making is an essential element of applied avalanche forecasting because formalized decisions are needed to resolve human biases (Part I: Appendix A).

Appendix A: The Rules of Applied Avalanche Forecasting

The following are rules developed mainly from experience (observations) about avalanche forecasting combined with physical principles and they are stated here for physical expectations about slab avalanches rather than loose snow avalanches (see McClung and Schaerer, 1993, for a discussion of the differences). When integrated together using experience, they constitute part of the input to interpret data. No simple rule used independently will be of much use in forecasting avalanches. These rules constitute primarily distributional or base-rate data and they must be integrated with terrain knowledge (which is itself distributional data) and singular data in practice.

1. At most places, at most times, the snow cover is stable with respect to normal triggering forces. Notes: The state of instability of the snow cover is highly dynamic so this rule may not be useful at a particular time. Most places and most times may not be of use depending on the scale of the problem. In back-country forecasting, we want to know something about **this** place and **this** time. This rule of thumb is true but it, like others of its kind, cannot be used alone.

2. Observationally, there are two basic situations in avalanche forecasting:

A – Absolute instability (widespread natural avalanche releases)

Corollary to A: The natural release of avalanches occurs only a very small percentage of the time, typically a few hours each winter.

B – Conditional instability (finite trigger required to initiate future avalanching)

Corollary to B: The potential for avalanche release by external triggers can persist for long periods of time. The typical length of time is closely related to climate for the particular winter. Both of these basic observational situations (A and B) may be understood as elements of a continuum of situations. The first where the avalanche probability with respect to a given critical triggering level is high (the critical triggering level is low and unstable imperfections in weak layers are widely available) and the second where the avalanche probability for avalanching is low (the critical triggering level is high or unstable imperfections are not very common). The higher the critical triggering level or the more scarce unstable imperfections are, the more difficult is the perception problem.

3. All snow and weather conditions that depart from normal are suspect as possible precursors of avalanching. Incremental changes in instability associated with snow and weather conditions are a principal source of uncertainty in avalanche forecasting (e.g., in the Goal: Part I) and the additional uncertainty associated with unusual combinations of factors should be anticipated.

4. Any process that rapidly alters the mechanical or thermal state of the snow cover can lead to avalanching. The most important rapid mechanical and thermal changes are:

- Loading by precipitation, wind drift or people
- Rapid temperature changes
- Sudden thaw

– Percolation of liquid water into cold snow
Corollaries to 4:

A. The proximate cause of most dry slab avalanches is overloading.
B. The proximate cause of most wet snow avalanches is internal changes in snow properties.

Note: Besides being the weakest natural material snow has two other important physical properties which distinguish it from rock or soil: its properties are highly temperature and rate dependent. Rapid temperature changes in dry snow most importantly affect the slab material stiffness (not strength) (McClung,1996). When snow warms or becomes wet, strength decreases. Also, a critical deformation rate must be exceeded before failure is likely in dry snow (Salm, 1971).

5. Any snow grains formed at high rates at the surface or in the snow cover have potential to set the stage for future avalanche formation. Examples include: surface hoar and kinetic forms (faceted snow, depth hoar, and radiation recrystallization). See McClung and Schaerer (1993) for details about these forms. These grains have two important properties: (a) the potential for long persistence in the snow cover and (b) anisotropy with respect to deformation: relatively weak in shear and stronger in compression (McClung and Schweizer, 1999). Most skiing accidents can be attributed to the presence of these forms (Jamieson and Johnston, 1992).

6. The winter history of a given path is an important determiner of instability. The missing layers may be as important as the ones present for assessing instability or lack of it. For new snow instability, the winter history is usually not important except, for example, in early season when ground roughness features around shallow snow can prevent slab formation.

7. The exposed snow surface breeds instability, for weathering tends to affect the bonding of the next snowfall adversely. The longer is the period of weathering, the poorer is the subsequent bond.

Important alterations of the exposed snow surface are:
- surface hoar formation
- radiation recrystallization and near surface facets
- sun crust
- rain crust
- freezing rain or rime
- revision by wind including wind crust
- temperature changes.

8. The most common cause of direct-action (instability in new snow), dry soft slab avalanches is overloading often accompanied by a high precipitation rate.

9. The most common cause of dry climax avalanches (instability in old snow) is failure of a buried layer of crystals produced under conditions of high growth rate: surface hoar, faceted crystals, depth hoar, radiation recrystallization.

10. Conditions leading to the formation of wet snow avalanches by radiation in the spring are governed by the **net** radiation balance of the snow surface. The net balance includes both long and short-wave components (sunlight). Direct sunlight

warms the snow cover making wet snow avalanches possible but thin cloud cover may provide a greenhouse effect to prevent long wave radiation escape to inhibit cooling.

Appendix B: Types of Errors in Avalanche Forecasting and Relation to Decision-Making and Risk

In Part I of this treatise, it is argued that decisions related to applied avalanche forecasting should lie within a risk band (the Operational Risk Band or ORB) and there are two types of decision errors which produce decisions outside the ORB. In this appendix, the concept is related to decision-making in avalanche forecasting in the simplest way by considering two mutually exclusive hypotheses about instability of the snow cover for two possible sets of these hypotheses. Thus, by analogy to statistical decision theory, two mutually exclusive hypotheses are defined: the null hypothesis (H_0) (the least likely one according to the forecaster) and the alternate hypothesis (H_a) (the most likely one). The alternate hypothesis is the converse of the null hypothesis. The formation of the null and alternate hypothesis depends upon an opinion mostly formed by the inductive reasoning process described in Part I including human perception and its variations.

Consider two scenarios for hypotheses about the state of the snow cover.

Scenario I: H_a: The snowpack is stable (with respect to the activity contemplated and the triggering level)

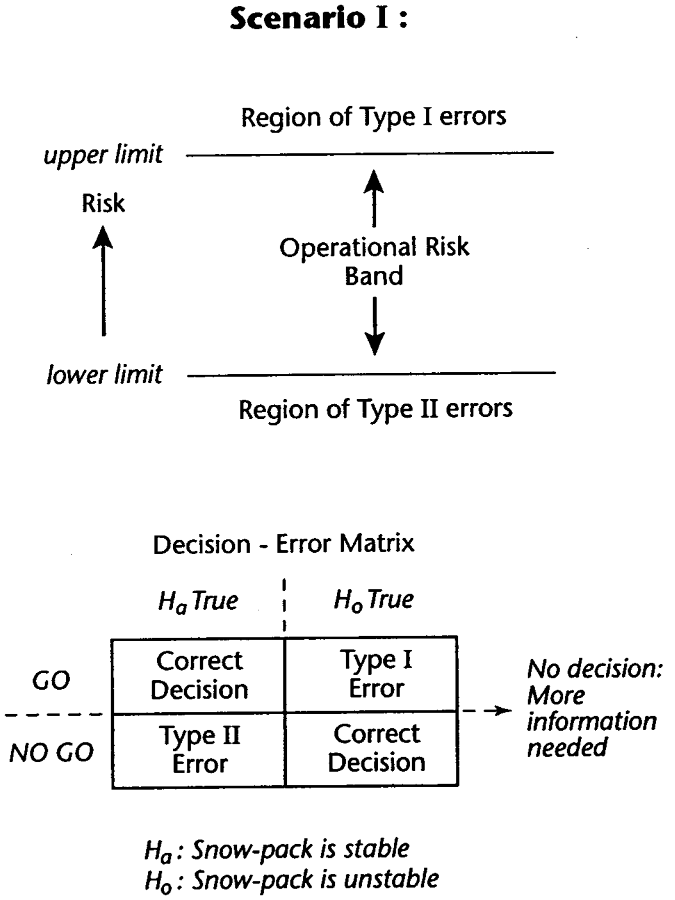
H_0: The snowpack is unstable

Comments: Generally, the decision would be to proceed (called GO) with respect to the activity. Perception could be poor: for example evidence might not have been uncovered with respect to any instability present, or instability might be highly localized and difficult to access, particularly if random sampling is used. Since the snow-pack is stable at most times and most places there is often a strong tendency for the *a priori* information (in a Bayesian sense) to favour an assessment (an alternate hypothesis) that the snow-pack is stable. This constitutes a rule of thumb which is an important bias to be dealt with in avalanche forecasting. Application of rules of thumb in avalanche forecasting is akin to applying static risk assessment to a risk problem which is dynamic in character; serious errors are bound to occur sooner or later.

Description of errors:

Type I: Reluctance (or failure) to claim the snow-pack is unstable unless hard proof is at hand. Typical costs: Death, injury, destruction. *Comment:* upper limit (near Target Risk) of ORB exceeded (Figure 1 of Part I).

Type II: Failure to open facilities or commence back-country travel when it turns out to be appropriate. Typical costs: excessive delays in opening facilities,



	H_a True	H_o True
GO	Correct Decision	Type I Error
NO GO	Type II Error	Correct Decision

Figure 4. Risk and decisions for an alternate hypothesis (H_a) that the snow-pack is stable (Scenario I). This is the most common alternate hypothesis associated with dangerous errors leading to injury or death (Type I errors).

ski runs; travelling objectives not met. *Comment:* Excessive prudence is implied; lower limit of ORB crossed. Figure 1 of Part I relates the ORB and the errors to a schematic and a decision-error matrix. Figure 4 shows the hypotheses, errors and decisions in a simple diagram from for Scenario I.

Relation to risk: The analysis indicates the snow-pack is stable. In such a situation it is possible for undiscovered instability to exist which can imply moderate to high risk from poor perception. It is also possible that the snowpack is stable implying low risk. Since the possibilities range from low to high risk (high variability) there is ample room for errors to occur and for human biases to interfere.

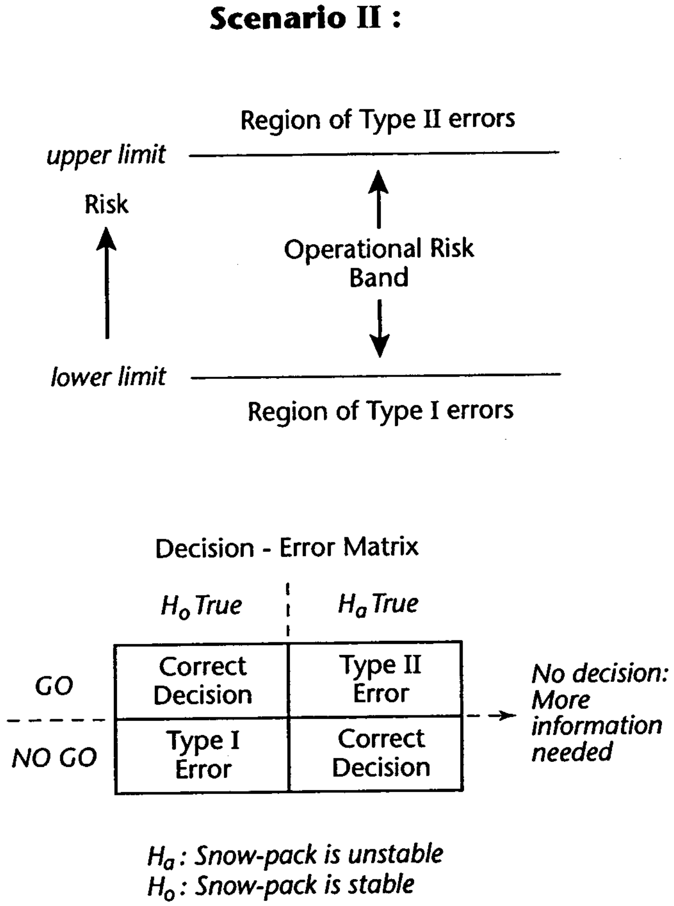


Figure 5. Risk and decisions for an alternate hypothesis (H_a) that the snow-pack is unstable (Scenario II). The null hypothesis, if true, can lead to excessively conservative decisions if terrain is not opened for occupance or movement of people in or through avalanche terrain (Type I error). In this case, a Type II error is more serious. Opening terrain for which the most likely hypothesis is that the snow-pack is unstable can occur for in-experienced forecasters or people with high propensity for taking risks.

Scenario II: H_a: The snowpack is unstable.

H_0: The snow pack is stable

Comments: Generally, the decision would be not to proceed (called NO GO). Perception may be good with easily recognizable instability in the snow cover or perception may be poor with no good information about instability.

Description of errors:

Type I: Failure to claim the snowpack is stable unless hard evidence is at hand. Typical costs: Excessive delays in opening facilities or ski runs; objectives not met.

Comment: May imply excessive prudence; lower limit of ORB crossed. Typically, this error is made by inexperienced forecasters or government officials with poor perception who fear liability if terrain or facilities are opened.

Type II: Failure to retreat or close facilities when it turns out to be appropriate. Typical potential costs: death, injury, destruction. This error may result from excessive propensity for risk-taking.

Comment: Upper limit of ORB is exceeded. Figure 5 shows the hypotheses, errors and decisions in a simple diagram. Relation to risk: The perception is that the snowpack is unstable: a situation that differs from the normal state of affairs. This could imply that perception is good and there is positive evidence about instability. In such a situation, the risk-related perception would most likely be low or moderate at most, for an experienced person due to good perception (see Table I; Part I) and the likely exercise of prudence unless risk propensity or biases interfere. Figure 5 relates scenario II to a schematic and the risk-decision matrix.

Accident statistics (McClung, 2000) show that Scenario I describes the situation for which most accidents occur in skiing: people trigger the avalanches themselves with an hypothesis that the snow-pack is stable with respect to the activity they are contemplating given the triggering level; human perception may be fair or poor. Accident statistics show most serious mistakes occur when instability is difficult to locate and perception about it is poor (McClung, 2000).

Scenario II applies only occasionally for inexperienced forecasters or people with a high propensity for taking risks. This scenario illustrates a principle of applied avalanche forecasting related to decision making: competent decisions should not involve too much risk nor should they be too conservative.

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