Classification in Avalanche Forecasting

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SUMMARY

Classification is an important first step in understanding and ultimately modelling processes in science. This also applies to the process of avalanche forecasting. Avalanche forecasting is the prediction of current and future snow instabilities in space and time relative to a given triggering (deformation energy) level. The goal is to minimise the uncertainty of these instabilities with regard to the temporal and spatial variability of the snow cover, any incremental changes in snow and weather conditions, and any variations in human perception and estimation (McClung, 1998). As any other prediction, avalanche forecasting is highly dependent on the type of input data, on which the prognosis is based. Therefore it seems reasonable to base a classification of avalanche forecasts on an analysis of the spatial and temporal scale of the used data.

Data used to forecast avalanches consist of two general types: 1) *singular or case data* about the specific situation at hand, and 2) *distributional data* and information about situations in the past (McClung, 1999). Distributional information are not measured to make the current forecast, but they enter the decision-making process as experience. Examples are calculations of nearest neighbours (Buser, 1987) or discriminate analysis (McClung and Tweedy, 1994). Individually, these types can further be classified according to their informational entropy: the relevance and ease of interpretation for predicting avalanche occurrence (McClung and Schaerer, 1993). The three classes are: *Class III: Snow and weather data*: measured at or above the surface, mostly numerical; *Class II: Snowpack factors*: data from snow pit analysis, mostly non-numerical; and *Class I: Stability factors*: data such as stability tests or observed avalanche occurrence which give direct information about past and present avalanche activity, non-numerical character. In general, the lower the number of the class, the lower the informational

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entropy (uncertainty) with respect to the actual avalanche process and therefore to the prediction. Along with this decrease in entropy goes a decrease in scale over which the measured data are representative of as well as an increase of needed resolution. These data properties have strong implications on the value of the resultant forecast.

Singular data are most intimately related to the current and future state of the snowpack and possible avalanche occurrence. Hence the grouping of avalanche prediction is based on the presented classification of this type of data (McClung, 1999). Following the ideas of Lambe (1973), the forecasting predictions are placed into three main categories in terms of availability and informational entropy of singular data.

Type A is a true forecast, where the probability of avalanche occurrence is determined before the incremental changes in weather and snow conditions have happened. In this case, all three data classes are purely predicted. This type of forecast depends heavily on the accuracy of weather forecasts and, as such, they contain the inherent uncertainty of the weather prediction as well as the uncertainty of the subsequent stability forecast process. The only input are current Class III data, and therefore this forecast can only be valid on the synoptic scale (e.g. significant portion of a mountain range). The French SAFRAN-CROCUS-MÉPRA system (Giraud et al., 1998) is an example of such a forecast.

Type B forecasts are made while the incremental changes are happening or after they have taken place. Now it becomes possible to measure and observe the characteristics of the situation in question and the time range of the forecast becomes much smaller than in Type A. In this case Class III data are generally measured and Class II and I can be partially observed. Almost all initial (early morning) forecasts in ski and highway operations are of this type: snow and weather observations are taken and sometimes preliminary stability tests are performed in a snow profile, but often avalanche occurrence is not yet scanned for.

Through extensive snow pack analysis and scanning for avalanches during the day, more Class II and I data are getting available for the prediction process. This allows making more detailed and more accurate spatial forecasts. These predictions are classified as *Type B1*. Type B forecasts are generally applied to mesoscale areas. Examples include individual mountain passes or ski resorts.

Type C predictions are sought when forecasts are made for the micro-scale (e.g. individual terrain features), and therefore they are the ultimate goal of every forecast process. They are made after the incremental changes in snow and weather conditions have taken place, extensive data sampling has been made, avalanche occurrences have been scanned, and skiing has been performed. At this stage the forecaster has so much low entropy information at hand, that profound predictions can be made on the microscale (e.g. individual ski run or terrain feature). This type of forecast is generally used in helicopter skiing and backcountry travelling.

The presented sequence of avalanche predictions from Type A to Type C reflects the evolutionary character of the forecasting process. As time proceeds, more information with lower entropy is added to the decision-making process. This goes hand in hand with an increase in the spatial and temporal resolution of the forecast.

A model backcountry traveller begins a trip at home with synoptic information, like the public avalanche bulletin. Once arrived at the destination, he or she tries to get more information about the current avalanche situation by asking locals about past avalanche activity and/or analysing the first snow pit. With this additional information in mind, the forecast is updated and refined. When finally travelling in avalanche terrain, continuous searches for clues about potential instabilities are made and the micro-scale forecast improves steadily.

As a next step, the classification of avalanche prediction could be used to group currently used avalanche forecasting models. This might reveal insights about their validity and limitations with respect to the spatial and temporal scale of the data used. In order to produce accurate and useful results, avalanche forecast models must proceed the same evolutionary path from large scale, high entropy data down to smaller scale and low entropy information.

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References

Buser, O., M. Bütler, and W. Good. 1987. Avalanche Forecast by the Nearest Neighbour Method. *IAHS Publication (Proceedings of the Davos Symposium: Avalanche Formation, Movement and Effects, Sept. 1986),* **162**, 557-569.

Giraud, G., E. Brun, Y. Durand, and E. Martin. 1998. SAFRAN/CROCUS/MÉPRA Models as a Helping Tool for Avalanche Forecasters. *25 Years of Snow Avalanche Research at NGI, Voss, 12-16 May.* Norwegian Geotechnical Institute (NGI). 108-112.

Lambe, T. W. 1973. Predictions in Soil Engineering. *Geotechnique,* **23**(2), 149-202.

McClung, D., and P. Schaerer. 1993. *The Avalanche Handbook*. Seattle, WA, The Mountaineers. pp 272.

McClung, D. M., and J. Tweedy. 1994. Numerical Avalanche Prediction: Kootenay Pass, British Columbia, Canada. *Journal of Glaciology,* **40**(135), 350 - 358.

McClung, D. M. 1998. The Seven Elements of Avalanche Forecasting. *International Snow Science Workshop, Sunriver, OR, Sept. 27 - Oct. 1.* ISSW. 426.

McClung, D. M. 1999. Predictions in Avalanche Forecasting. *International Symposium on the Verification of Cryospheric Models, Zurich, Switzerland, August 16-20.* International Glaciological Society (IGS). in press.

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