Snow and weather conditions study for the avalanches on the Lautaret pass road (French Alps)

Daniel Goetz
CNRM-CEN/GAME (Météo-France, CNRS), Saint-Martin-d'Hères, France

SUMMARY: This study aims at characterizing snow and weather conditions typical of avalanche events on the Lautaret pass road. Historical data of avalanche observations were compared to the corresponding snow and weather conditions. In a first step, historical series of avalanche observation and corresponding snow and weather conditions were studied statistically. No obvious correlation was found between avalanche frequency and snow and weather conditions. Thus, in a second step, we performed an expert analysis of each day with one or more avalanches (73 days). To this aim, modelled snow and weather data (French analysis models Safran-Crocus-Mepra) and local human observations were used. The study period was restricted to winters from 1983/84 to 2005/2006, to reach a large sample of information about snow and weather conditions. Our results characterize the avalanche activity according to the path or to the family of paths, variations in the number of avalanches during the period, and the avalanche frequency during the winter season. We also determined 5 types of on-the-road avalanches (recent snow avalanches, slab avalanches with and without snowfall, wet snow avalanches with and without rain), and relationship between on-the-road avalanches and level of avalanche hazard (forecasted by Meteo-France). Finally, we proposed expert forecast rules, mainly intended for avalanche forecasters in charge of the Lautaret pass road supervision.

KEYWORDS: avalanches - Lautaret pass road - snow and weather conditions - climatology - expert rules.

1 INTRODUCTION

The road going through the Lautaret pass (2058 m a.s.l.) links Grenoble to Briançon in the central area of the French Alps (figure 1). In winter this road is subject to avalanche hazards along a section of about 30 km. Therefore, the county council of Hautes-Alpes department, who is in charge of the security of the Lautaret pass road, solicited a study of the features of the avalanches and of the nivometeorological conditions favouring the avalanches in this area.

2 STUDIED AREA AND AVALANCHES DATA

The Lautaret pass road follows a westerly-easterly direction and reaches a maximum altitude of 2058 m a.s.l. at the pass. The 30 km long section exposed to avalanches presents a westerly stretch (on Grenoble side) ranging from 1100 m a.s.l. and the pass, and an easterly stretch (on Briançon side) between the pass and 1600 m a.s.l.. The altitudes of avalanche departure areas vary significantly along the route, between 1600 m a.s.l. and 3200 m a.s.l., and their aspects are oriented either to the south or to the north (roughly).

Figure 1. Location map of Lautaret pass (2058 m a.s.l.), in the middle of the French Alps.

This study used observation series of avalanches occurring in avalanche-prone paths (corridors and other areas) threatening the Lautaret path road. These paths have been listed and regularly surveyed for a long time (since the early XXth century) by the National Forest Office of the Hautes-Alpes. These data have been centralized and archived by the Cemagref of Grenoble.

Corresponding author address:
Daniel Goetz, Centre d'Études de la Neige,
1141, rue de la Piscine
F-38400 SAINT-MARTIN-D'HERES, France;
tel: +33 (0)4 76 63 79 26; fax: +33 (0)4 76 51 53 46
e-mail: Daniel.Goetz@meteo.fr

The avalanche data file lists the following data for each observed avalanche : date and hour of departure (time slot), name of the site, departure and arrival altitudes, features of the avalanche (shape in the departure zone, snow quality at the departure and at the arrival, surface-layer or full-depth avalanche, aerosol or not, dimensions of deposit, snow and weather conditions during the 3 previous days (simplified), reason of departure, victims, damages or reached places, various comments).

3 STATISTICAL PROCESSING

A statistical distribution of several nivometeorological variables for the days with and without avalanche(s), respectively, was performed from French numerical models Safran-Crocus-Mepra. These models respectively analyse weather conditions in mountain, simulate the snowpack evolution, analyse its stability (Durand and al., 1999). The outputs are meteorological variables (wind speed and direction, temperature, rain and snow precipitation amount in 24 h and in 3 days) and snow variables (snow depth, instability index calculated for recent snow avalanches and for wet snow avalanches). These outputs concern the average altitude of avalanche departure. This kind of statistical repartition (example in figure 2) shows that each variable affects avalanche departures, but does not reveal any obvious correlation.

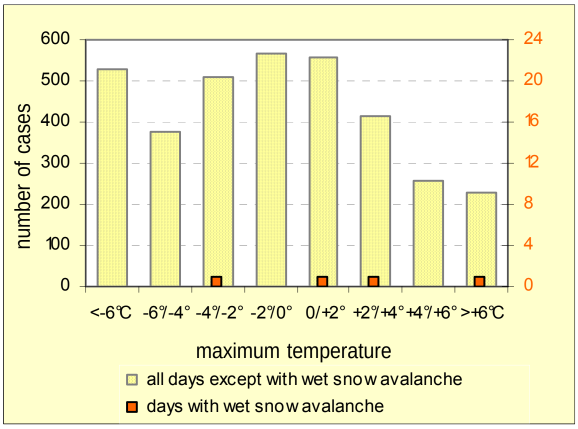

Figure 2. Value distribution of daily maximum temperature at an altitude of 2400 m in a south-westerly 40° gradient slope in the massif of Thabor (Safran data modelled during winters, from 1981/82 to 1999/2000).

Thus, a criterion of avalanche(s) occurrence was defined for each of the 3 main types of natural avalanches (recent snow avalanches, wet snow avalanches with rain, wet snow avalanches without rain). This criterion consists in an sequence of interlinked tests on the value of several snow and weather variables (10 to 12 variables according to the avalanche type). The contingency tables (avalanche(s) occurrence with respect to the criterion) were not satisfactory. In these tables, the rate of non-detection is null or very weak, but the rate of false warnings is very large (example in figure 3).

RECENT SNOW AVALANCHES	days **with** avalanche(s)	days **without** avalanche(s)	total
criterion **respected** (occurrence)	0,5%	23,4%	23,9%
nonrespected criterion (nonoccurrence)	0,0%	76,1%	76,1%
total	0,5%	99,5%	100%

Figure 3. Contingency table for recent snow avalanches down to the Lautaret pass road (1982/83-1999/00 period).

Two explanations can be given about these results. First, avalanche observation may be irregular (some avalanches may not be reported). Second, the Safran-Crocus-Mepra nivometeorological variables may be quite rough (due to weather stations situated 7-20 km away from the studied area).

As a consequent of these results, the study was redirected to an expert snow and weather conditions analysis of each listed situation leading to one or more avalanches down to the road. 73 of such situations occurred from winter 1983/84 to winter 2005/06.

4 EXPERT ANALYSIS

The analysis used all available data of observation. Observations consist first in human observations performed twice a day (at 08 h and at 13 h) at the nearest snow and weather stations. They also consist in observation data contained in the daily snow and avalanche forecast and also in the weekly summary snow and weather report, both written by the snow and weather centres of Briançon and Grenoble.

4.1 Climate results

The number of avalanches of all the 35 studied paths were counted to identify the more active ones and the less actives ones, all along the 30 threatened kilometres of the road.

A chronological view through the 23 winters of the studied period brings out the winters characterized by a lot of avalanches and the winters characterized by few avalanches.

The distribution of the avalanches during the winter months enables to identify the winter periods the most subject to avalanches (figure 4).

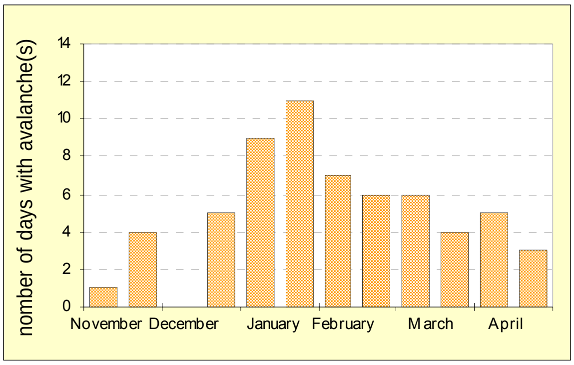

Figure 4. Distribution of the number of days with avalanche(s) down to the Lautaret pass road during the winter months (1983/84-2005/06 period).

4.2 Expert results

4.2.1 Avalanche types

The expert analysis first consisted in a detailed analysis of the snow and weather conditions before and during each avalanche spell. This analysis was subsequently exploited to determinate the type of each avalanche, using also avalanches observation information. The definition of theses types of avalanches was inspired by the standard classification in 3 main types (recent snow avalanche, wet snow avalanche, slab avalanche). However, our detailed analysis rather led to distinguish 5 types, reflecting better the reality of avalanches that happened along the Lautaret pass road. These 5 types are: recent snow avalanche, slab avalanche with snowfall, slab avalanche without snowfall, wet snow avalanche with rain, wet snow avalanche without rain.

This classification provided information on what type(s) of avalanche occurs in each corridor, what is (are) the type(s) of avalanche predominating for the whole threatened section (figure 5), how the avalanches are spread out over the winter months concerning each of the 5 identified types of avalanche (figure 6).

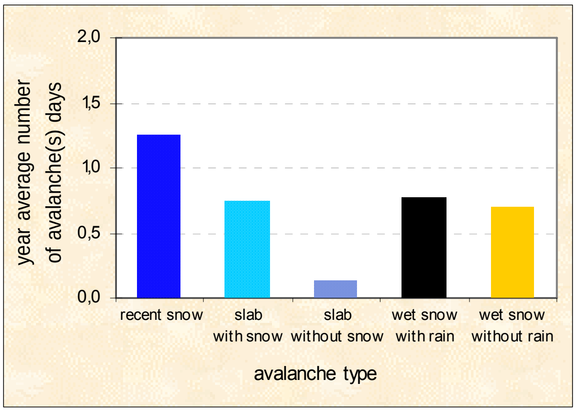

Figure 5. Year average number of days with avalanche(s) according to the type of avalanche (average for 1983/84-2005/06 period).

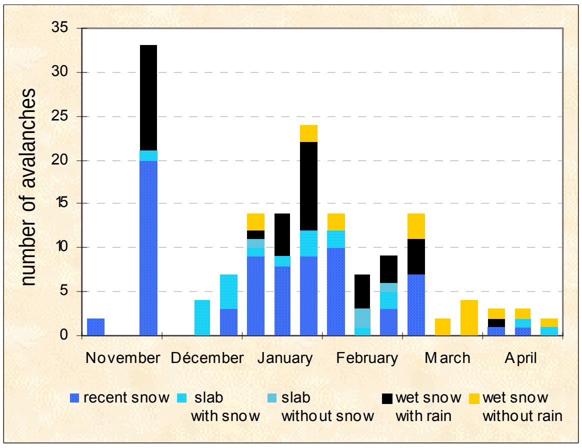

Figure 6. Over the winter months avalanches distribution concerning each of the 5 identified types of avalanche (1983/84-2005/06 period).

4.2.2 Avalanches and forecasted hazard level

An avalanche hazard forecast covers the Lautaret pass area. The weather centres of Briançon and Grenoble write daily reports during the winter months. These forecasts use the European Avalanche Danger scale (5 levels) and is made at the "massif" level (a "massif" is an ~ 600 km^2 mountainous area with an homogeneous climate (Ancey and al., 1998)). The Lautaret pass is located in a crossroads of several massifs, and its road runs across 3 massifs: Grandes Rousses, Oisans, Thabor.

We studied the correlation between forecasted hazard level and avalanches that drained down (or near) to the road. Noteworthy, this hazard level corresponds either to a natural hazard or to an accidental one (the announced hazard level is the highest of both cases), whereas avalanches that drained down to the road are mostly natural avalanches.

This study first shows that the number of days with avalanches (globally very small: 1,5% of the days during the winter period - 1 November to 31 May) unsurprisingly increases with the forecasted hazard level (figure 7). However the number of avalanches decreases when the hazard level is 5, maximum, because of a very limited use of this level. To eliminate the influence of the rate of use of the hazard levels, we calculated for each hazard level the rate of avalanche days among all days corresponding to a given hazard level. This rate increases very strongly with the highest hazard levels (figure 8).

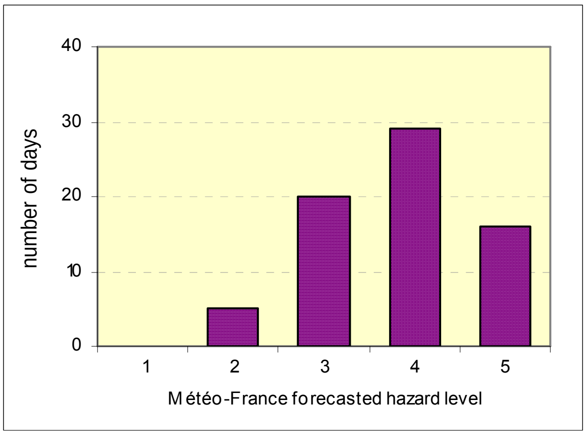

Figure 7. Number of days with avalanche(s) down to the Lautaret pass road according to avalanche hazard level (forecasted by Météo France) (1983/84-2005/06 period).

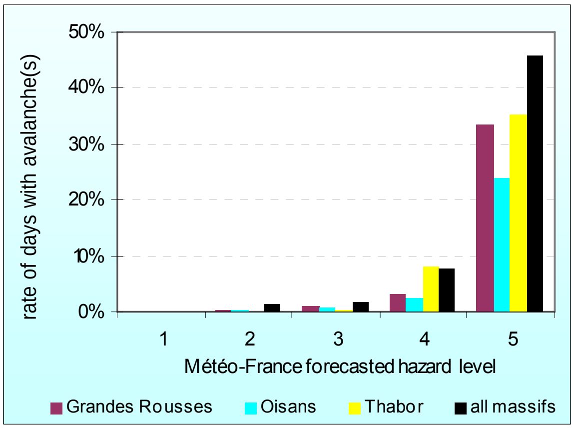

Figure 8. Avalanche(s) days rate among all days corresponding to a given hazard level, for each of the 5 hazard levels, which are forecasted in the 3 by the road crossed massifs (1983/84-2005/06 period).

On the other hand, the distribution of the number of avalanche days according to the hazard level depends on the avalanche type. Recent snow avalanches occur almost only when hazard level is 4 or 5, in the same ratio (figure 9). The probability of slab avalanches with snowfall steadily increases with the hazard level. Slab avalanches without snowfall are rare and occur for middle-range hazard levels. The distribution of wet snow avalanches with rain is very close to the one of all avalanches together (cf. figure 7). Wet snow avalanches without rain statistical distribution distinguishes itself by a maximum when hazard level is 3 (figure 10).

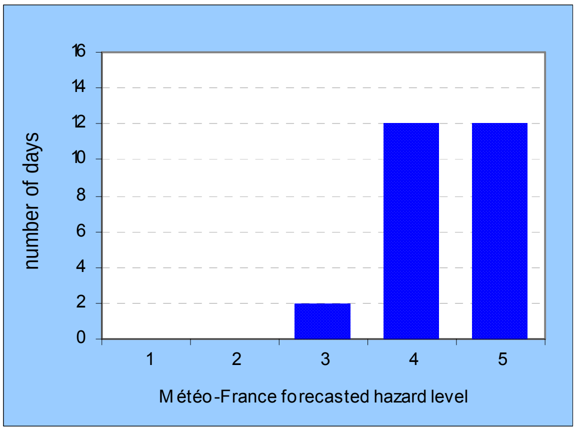

Figure 9. Number of days with recent snow avalanches down to the Lautaret pass road according to the forecasted hazard level (1983/84-2005/06 period).

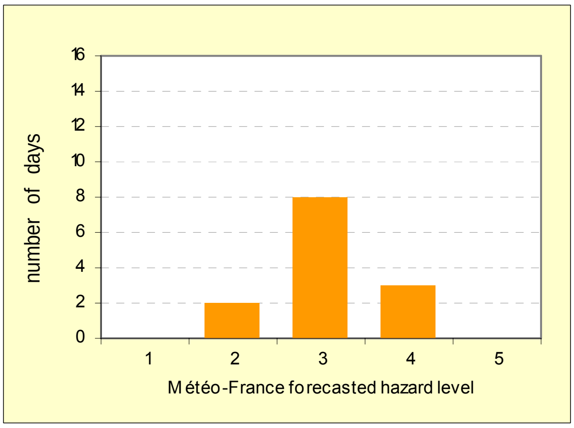

Figure 10. Number of days with wet snow avalanches without rain down to the Lautaret pass road according to the forecasted hazard level (1983/84- 2005/06 period).

4.2.3 Expert rules

The results about correlations between avalanches going down to the Lautaret pass road and nivometeorological conditions were not satisfactory (cf. part 3). The study thus established expert rules to forecast these avalanches according to these snow and weather conditions.

However, the 35-studied paths each have few avalanche events during the studied period. For that reason, they were merged into 12 homogeneous families concerning their location, altitude and aspect of avalanches departure and flowing zones. This was possible, although the paths have various altitudes and aspects, and are located in 3 different massifs (Grandes Rousses, Oisans, Thabor).

Nivometeorological analysis of all cases presenting avalanche(s) reaching the road area were summarized for each family. Subsequently, expert rules to forecast the hazard level of such avalanches were determined (see an example figure 11).

1°) RECENT SNOW AVALANCHES:

b) Oisans:

▪ *C and D families paths:*
(from 9 cases)

Favourable snow and weather conditions:

- snowfall: variable (from 40 cm in 2 days to 1 m in 4 days)
- wind (level 3000 m): either NW to N or S to SW quite strong to violent (60 to 100 km/h)
- 0°C level: not very distinguishing (800 to 2000 m)
- snowpack: usually good
- forecasted hazard level : 3, 4 or 5

Figure 11. Expert rules for recent snow avalanches in C and D families paths (Oisans massif).

These rules are similar to already known ones. Thus, they do not seem to be very much of use to avalanche forecasters, especially as the values of snow and weather variables, which appear in theses rules, often cover large ranges. Value distribution of the "recent snow amount" variable at the time of recent snow avalanches is a good example of that: this variable is not very distinguishing, even so it is possible to point out a threshold around 60 cm (figure 12).

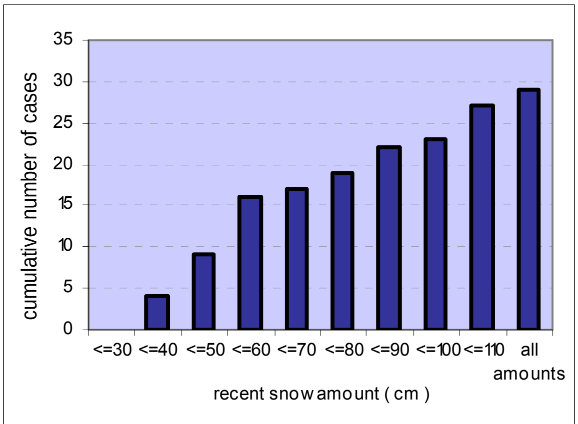

Figure 12. Snowfall distribution at the time of recent snow avalanches down (or near) to the Lautaret pass road (1983/84-2005/06 period).

The expert study also brought out more general expert rules about three of the five avalanche types (see an extract figure 13). Experienced avalanche forecasters most probably know these rules too (Villecrose et al., 1999).

6°) ADDITIONAL EXPERT RULES: *(extract)*

b) Wet snow avalanches with rain:

Two aggravating elements can be considered, in addition to the expected precipitation:

- the upper part of the snowpack is a thick recent snow layer, just before the spell of milder weather;
- there is such a snowpack in medium altitude and near to the road slopes.

Figure 13. Supplementary expert rules for hazard forecast of avalanches down to the Lautaret pass road (extract).

5 CONCLUSION

A clear contribution of the study concerns climatology of the avalanches that go down to the Lautaret pass road, their different types and their relationship to the forecasted avalanche hazard level.

The practical significance of the expert rules that were established is quite limited, because these rules are quite vague, many of them are general and in principle avalanche forecasters already know them.

Two things can explain these limited results. On the one hand the area, in which the Lautaret pass road is located, presents complex climatic characters because it is a north-south and east-west climatic crossroads. On the other hand local snow and weather conditions are not known in detail (because weather stations, human or automatic, are not located inside the studied area but on its periphery).

This study about a vast and busy avalanche-prone area enabled nevertheless to increase the knowledge of this natural phenomenon, which widely proved in the past its danger potential.

6 ACKNOWLEDGEMENTS

The author thanks the county council of Hautes-Alpes department who financed a good part of the study. He also thanks the unnamed reviewers who improved my English.

7 REFERENCES

Ancey, C. et alii, 1998. Guide neige et avalanches. ANENA-Édisud, Grenoble, France, 335 p.

Villecrose, J., Coléou, C., Giraud, G., 1999. Février 99 dans les Alpes du Nord. Note de centre n°14 du Centre d'Études de la Neige, Météo France, Grenoble, France, 86 p.

Durand , Y., Giraud, G., Brun, E., Mérindol, L. , Martin, E., 1999. A computer based system simulating snowpack structures as a tool for regional avalanche forecast. J. Glaciol., 45, 469-485.