A CASE-STUDY OF HIGH LOAD HUMAN-TRIGGERED AVALANCHE ACCIDENT IN L'ESTANYÓ (ANDORRA): LESSONS LEARNED AFTER CONDITIONS ANALYSIS

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ABSTRACT: Two different groups ok skiers planned to descent the south-west face of Estanyó peak at 2.550 m altitude. They had different objectives, the first group (9 persons) with a professional discipline mind-set, and the second group (5 persons) with recreational objective. The second one included large variety of ski levels within the group members.

On the 5th of March 2024, a large-size dry slab was triggered by the 11th of the 14 skiers involved in the accident. It was the first days of the season that the snow and weather conditions were winter typical. Furthermore, it was the first day of the season that was possible to ski typical routes that this unusual dry winter were not possible to ski.

The human factor played an important role, too. Safety feeling by previous skiers was in place. The good organization and travel habits of most skiers were crucial for the successful-end of this story, as nobody was completely buried, even if the avalanche deposit was divided by two parts.

This is the highest number of involved skiers in an avalanche accident in the Pyrenees since 2014.

In this paper, we review the snowpack analysis and the avalanche forecast difficulties for this kind of situations. As avalanche forecasting service: how can we identify and predict the avalanche problem on this particular aspect, either as wind slab or persistent weak layers? Therefore, decision-making of the users, would have changed?

KEYWORDS: avalanche accident, avalanche matrix, avalanche problems, persistent weak layers.

1. AVALANCHE DESCRIPTION

At around 13:00 hours (local time) on the 5th of March 2024, an avalanche was triggered by a high additional load on the south-western slope of the Estanyó peak. The top starting zone was located at 2,600 metres and the weak layer caused a large propagation crosswise along 150 meters (fig 1).

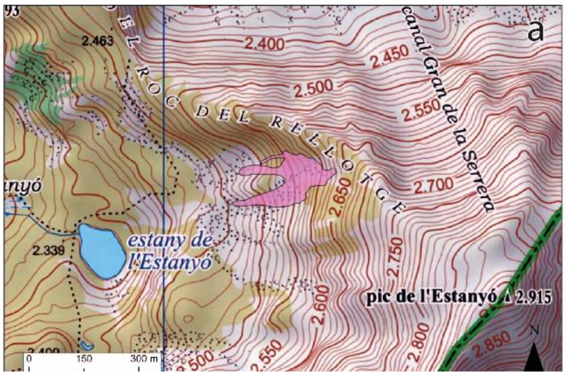

Figure 1: Avalanche location and total extinction

Approximately the volume of snow mobilised was 7.000 m³, therefore, the avalanche size according to the scale proposed by the EAWS would be 2.5. Once the avalanche was triggered, the avalanche deposit split in two due to a small spine that characterises that slope, a fact that reduced its destructive potential. The avalanche danger level was 3 in north zone (fig 2) with wind slab and new snow avalanche problems.

2. WEATHER AND SNOW CONDITIONS

There is an automatic weather station (AWS) near to the avalanche. The weather station is at 2.290 m in a north face and Figure 3 shows the weather conditions during the previous days to the accident. All weather data are from this AWS. Until February 23th the snowpack was very thin in an extremely dry winter season.

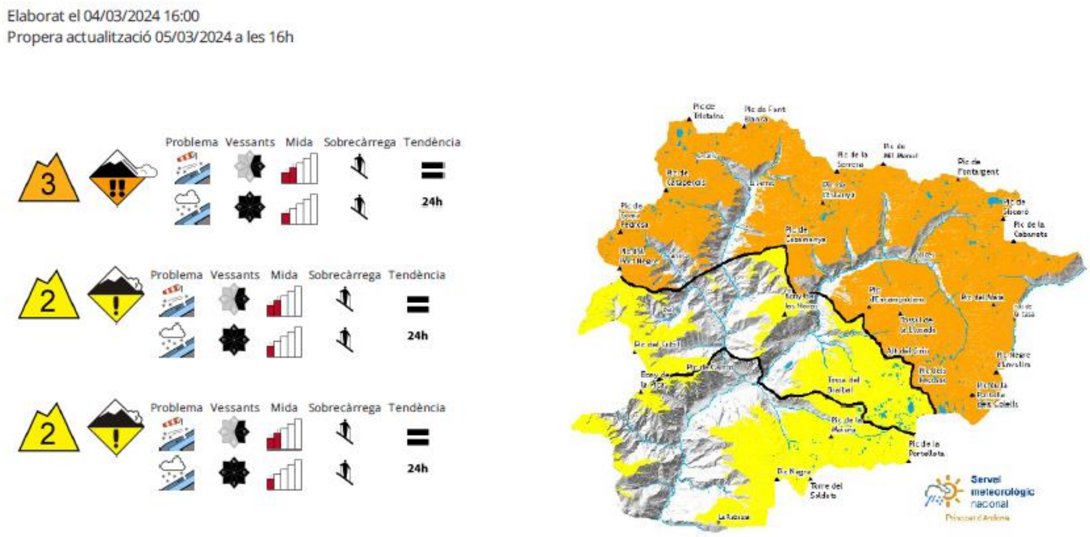

Figure 2: Avalanche bulletin for the 5th of March 2024, The avalanche bulletin is made the day before at 16h.

The snow conditions since 23th February changed drastically, especially in the northern area of Andorra, where the accident happened. There were several light snowfalls before a larger snowfall that accumulated 60 cm on the 27th of February. It should be noted that both the snowfall of the 23th and the 27th included round snow. The snowpack thickness on the 28th was 1.45m. At the end of the snow episode and especially on the 28th, it was accompanied by a strong NW wind of up to 29km/h (8m/s) (Fig. 4). Immediately after, there was a small weather window that allowed temperatures to rise on the 29th with a maximum of 5.2 °C and a progressive compaction of the snowpack during the 4 following days. From the 2nd March, the arrival of an atmospheric depression with a southwest flux, caused instability across the country and up to 44cm of new snow accumulated. As the day progressed, winds turned NW with 30km/h on the 3rd, as shown in Figure 4.

From the 4th onwards, as the centre of low pressions moved eastwards, high pressure moved in, with temperatures rising from -10.6 °C minimum to +3 °C maximum. Even so, instability was maintained in the north of the country due to the passage of a low pressions area at high altitude. The following days, atmospheric stability began to gain ground, bringing widespread clear skies but keeping temperatures low. The 5th of March, snowpack was distributed as shown in Figure 5.

Figures 3 and 4 show weather data 12 days before the accident. It was during these days that the slab that caused the accident was configured.

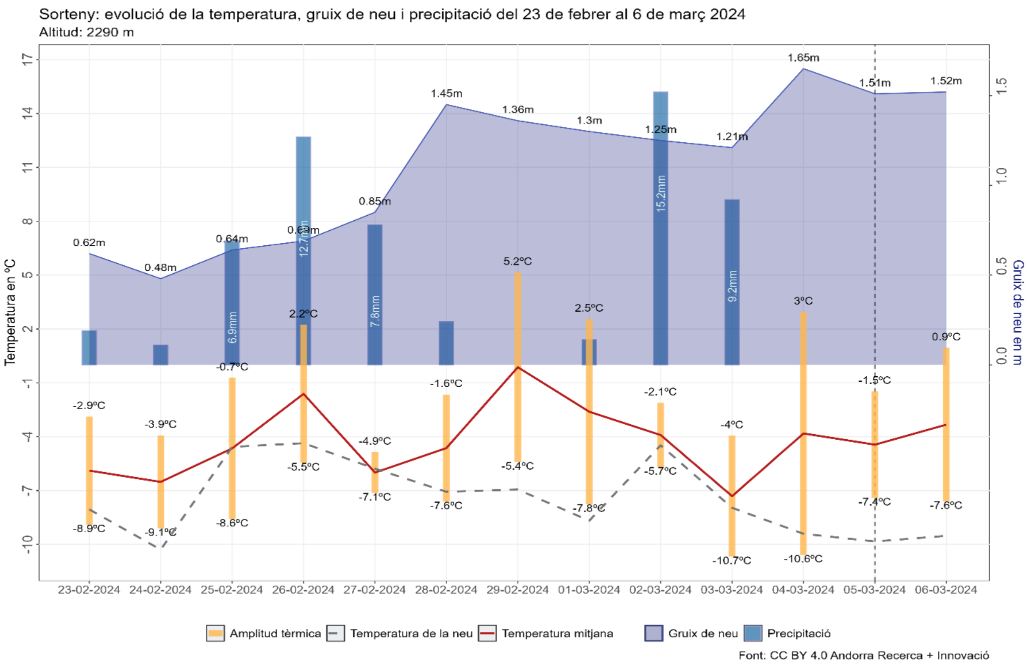

Figure 3: weather conditions evolution 12 days before the accident. Legend: snowpack accumulation (blue area), the equivalent amount of precipitation (blue columns), temperatures with their amplitude (yellow columns), air temperature (red line) and snow surface temperature (intermittent grey line).

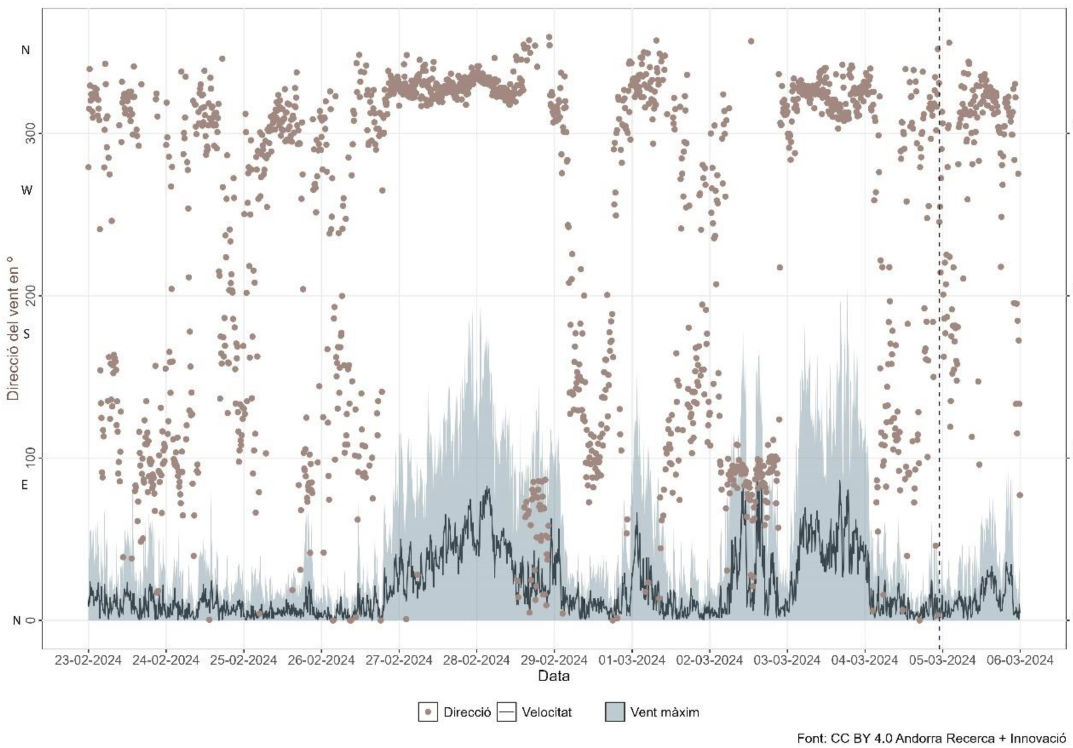

Figure 3: wind intensity and direction evolution 12 days before the accident.

Snowpack stratigraphy on the 5th of March (the day of the accident) is shown in Figure 5. On the left (5a), a snow profile made the day after the accident from one flank of the scar. At this point, the slab was resting on a layer of between 3 and 8 cm of 3 mm round snow that had fallen at the beginning of the first episode (23/02), which was also resting on a large 1-finger hardness (Fig. 7a and 7b). Below these layers there was a crust of re-icing, the only snow remaining before the snowfalls of the 23th February. At other points of the scar in the immediate vicinity where this profile was made, above the crust there were facets measuring between 1 and 2 mm and there was no round snow or the lower fine-grained layer. On top of this layer, which acted as a weak layer, there were large, recognisable particles and particles in two layers separated by a re-icing crust formed on the 29th February and 1st March. These two layers were visually recognizable at

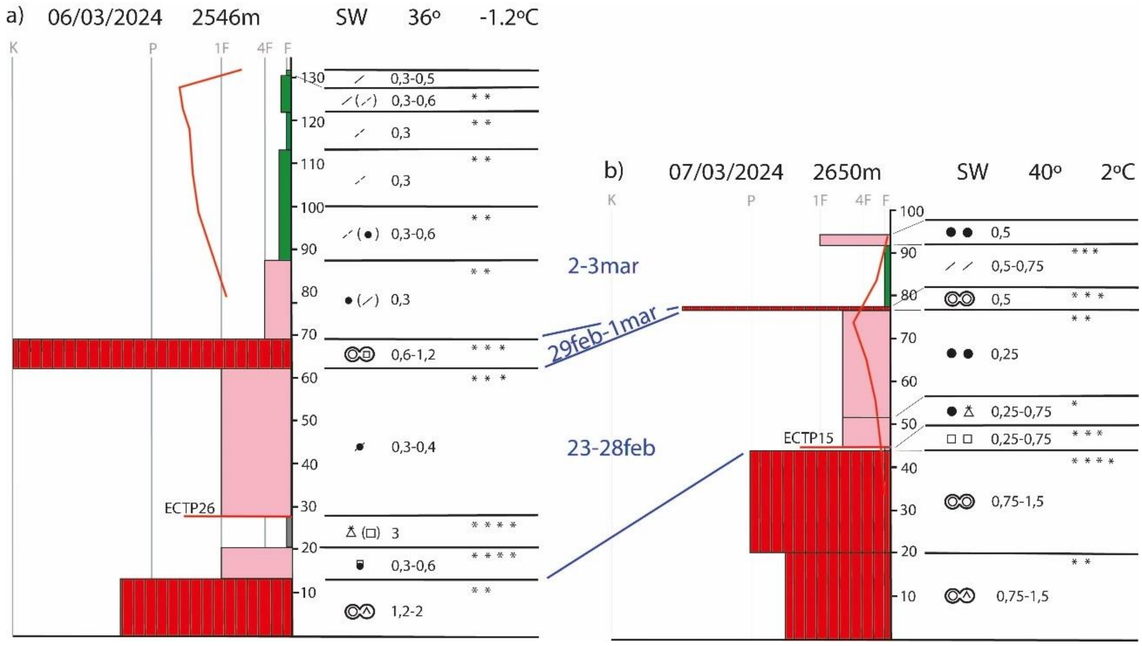

Figure 4: accidental slab snow profiles, 5a performed the day after the accident (6th of March) and 5b two days after the accident (7th of March).

the scar, and caused the avalanche deposit to consist of larger hard slab blocks on one side and a smaller, softer deposit on the other.
Figure 5b shows another snow profile made above the avalanche scar two days after the accident. Here, above the crust at the base, a thin 1 cm layer of small facets was found, and above it the structure was similar: a package of large till and recognisable particles, with a crust - in this case much thinner - in between. At this point, however, there was less snow accumulated especially during the last episode above the second crust, partly due to compaction during the last 24 hours and the effect of the wind. The ECT test at this point was ECTP15 with evident propagation.

3. THE SLAB PROPAGATION, THE ACCIDENT AND THE FORECAST

After an extremely dry winter, the light snowfalls between the 23th and 27th of February configured the weak layer. Furthermore, the round snow was added as an ingredient to increase the instability of the weak layer. The thin winter snowpack below the light snowfalls with low temperatures caused a large temperature gradient within the snowpack, that generated a metamorphism of this thin new snow layer which became covered since 28th.
The slab accident involved two big snowfalls (27th February and 3th March) and its origin was the weak layer visible in snow profiles (Figure 5) and caused the ECTP's.
There are two key points to avoid an accident. One is the correct and safe conduct during the ski activities: security distance between members (it was interrupted by a member of another group), correct/good interpretation of terrain and avalanche evidences (the slab was clearly the only non-drifted and self-interpretation of the snowpack stability is very important for in-site decision-making (analysis and formation is essential to transit the mountain).
The other key point is to avoid an accident is the main one: the avalanche bulletin. First of all, the danger level for the day of the accident was 3, chosen as shown in Figure 6. In terms of danger level and popular opinion it was a correct danger level. But in terms of avalanche problems and aspects the bulletin wasn't sufficiently accurate. Furthermore, after the accident, the forecasters discovered that our knowledge of snowpack was poor, or very poor due to few and short field trips to analyse the snowpack stability and their distribution the previous days to the accident. The predictors didn't know the existence of weak layer below the first big snowfall (27th). Our consideration was that with 4-days compaction the eventual weak layer was ended their activity and the main problem was with wind drifted snow during the last snowfall (3th).
These 12 days period completely changed the snowpack conditions and we did only two field observations during this period. Furthermore, we couldn't analyse some slab accidents due to intern limitations combined with few weather windows. One of this two observations was made in 4th, but was a representative observation? Was a representative site? At the moment, we thought the answer was yes. We analyse this further in the following section.

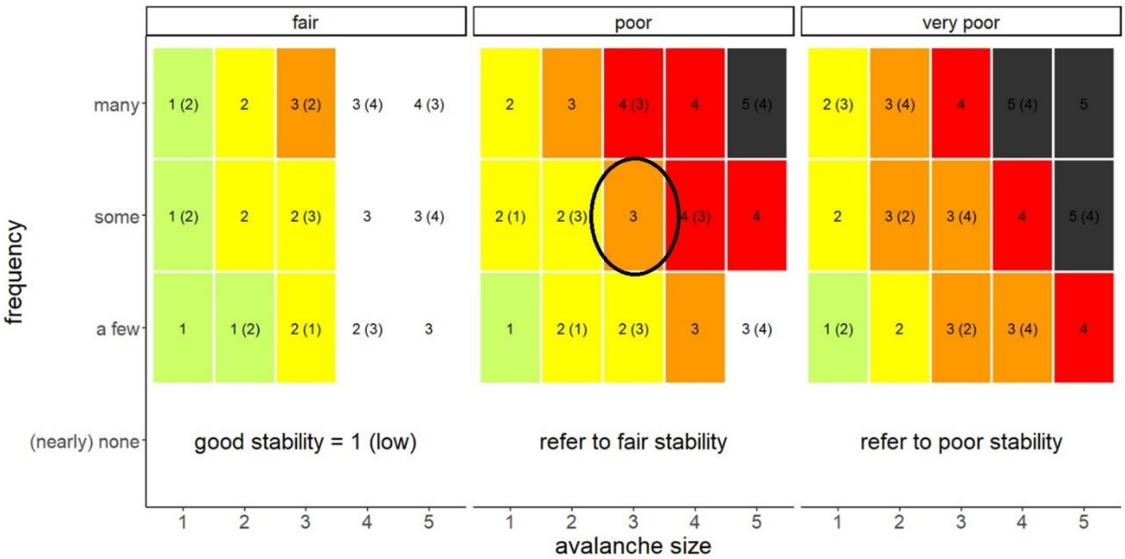

Figure 5: option chosen to establish level 3. Poor stability, in some potential avalanche release and maximum avalanche size of 3.

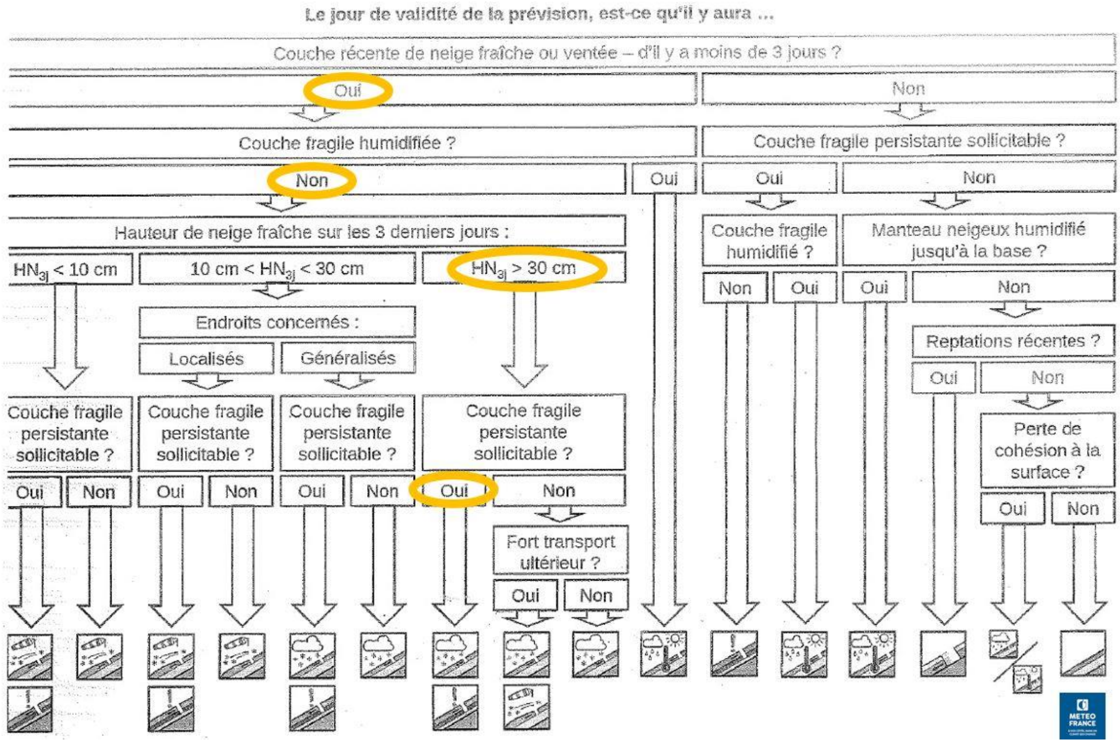

Figure 6: eventual decision-making to choose the avalanche problems for the 5th of March if we had known the presence and activity of weak layer.

4. THE FORECAST DECISION-MAKING

The danger level for the 5th of March was assigned like shown in Figure 6, and the avalanche problems was chosen omitting the weak layer that caused the accidental avalanche, but if we had known about the presence and activity of the weak layer, the problems would have been new snow and weak layers, as shown in the Figure 7.

The accident occurred around 13:00 h, but as a forecast service we knew about the avalanche at 15:50. The new bulletin for the 6th of March was already drafted and prepared to be published at 16:00 h. As we see that frequency of poor stability class was every day more difficult to find, we descended the frequency as “few”. Furthermore, until before the avalanche we didn’t have had any avalanche of size 3, either natural or accidental, so we decided to change also the avalanche size expected. Our bulletin was ready to be published with avalanche danger level 2 (Figure 8).
But when we knew about the avalanche accident, we immediately changed the danger level and added some details in bulletin, like main aspects and other description details. Our first reaction was “we don’t know why this accidental avalanche have happened”. During the next days, when we analysed the avalanche slab and performed more field observations, we understood which was the lacking knowledge or information about the snowpack: the we had not identified the weak layer.
Finally, after 3 days, we went back to the decision chosen in Figure 8, but with the field observations we discovered that it was has been logical to choose this option the 5th even if the accident. The only thing that would have been missing would have been to explain it properly.

5. CONCLUSIONS

This situation has highlighted the importance of having quality field observations for a good avalanche bulletin. On the other hand, as users, we must be aware that it will not always be possible to go out to the field to get to know the terrain and to be able to accurately disseminate the danger, which is why decisions on the ground are also very important. And finally, to make good decisions on the ground, it is essential to have good training, practice and to choose good hiking partners.
Fortunately, no personal injuries are to be regretted in this accident and, at least as a forecasting service, we should take this as experience to make better quality bulletins. In a season where conditions changed suddenly in a few days, and with mountaineers who are more driven by desire than by lucidity, we must be able to collect the necessary data to have all the information and be able to make the right communication decisions.

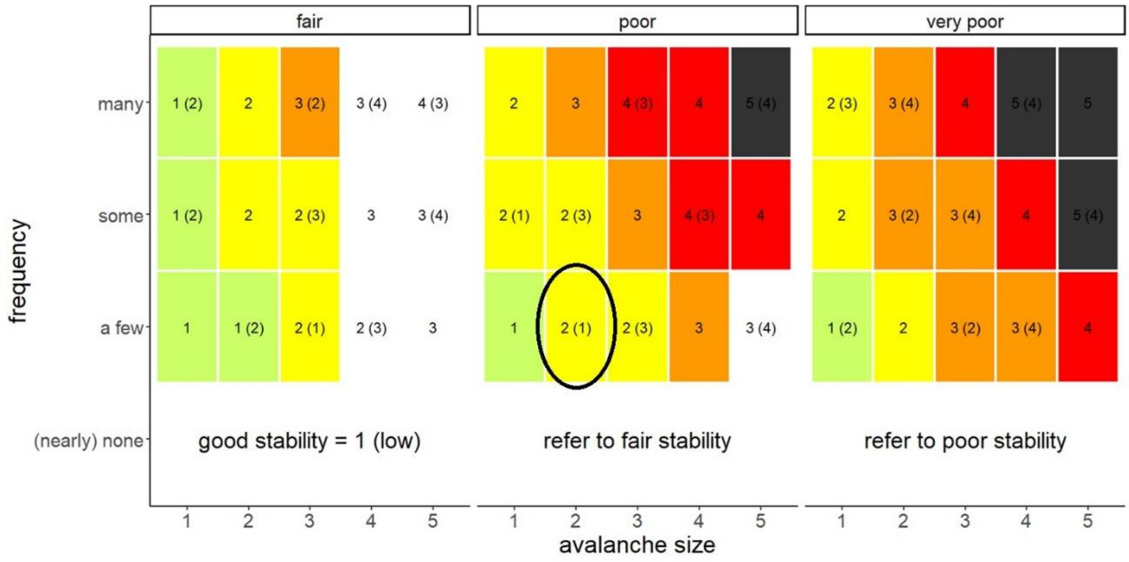

Figure 7: option chosen to establish level 2. Poor stability, in a few potential avalanche releases and maximum avalanche size of 2. This avalanche danger level wasn't published, when we knew the accident, we changed the decision.

We can also rely our decisions in technology. Numerical models of snow cover are becoming increasingly reliable. Figure 9 shows the snowpack modelling for the day of the accident (SAFARN-Crocus-MEPRA in the left and snowpack in the right) clearly shows a faceted layer below compacted layers, compatible with the weak layer that caused the accidental slab. At the right side, another modelling, from snowpack, that shows also the eventual weak layer.

ACKNOWLEDGMENTS

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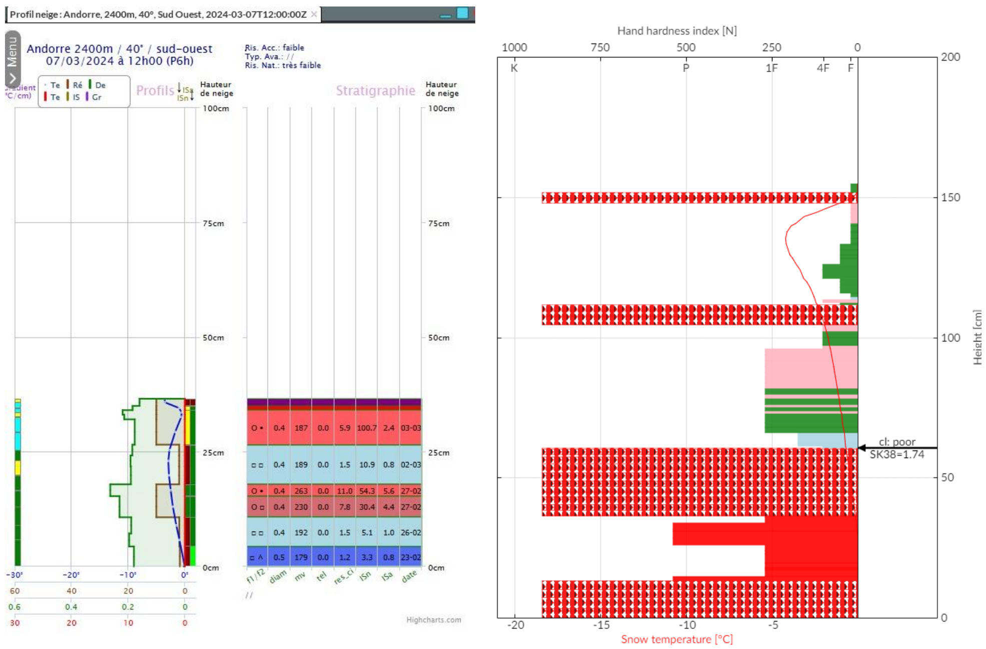

Figure 8: snowpack modelling

for always being willing to discuss about communication of avalanche danger level and avalanche problems.

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