APPLYING THE GROM SCORE ON SNOW PROFILES FROM HUMAN-TRIGGERED SLAB AVALANCHES AND FIELD OBSERVATIONS IN VAL D'ARAN, PYRENEES

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ABSTRACT: Since the start of the Aran Avalanche Warning Service in 2004, efforts have been made to record data on avalanche and snowpack characteristics from reported human-triggered slabs occurred in the valley and nearby. Such dataset is an important part of a larger dataset from the whole Eastern Pyrenees, which has been object of several investigations on the typical characteristics of human-triggered slabs in the Pyrenees and the Pyrenean structural indexes. In the present study, we focus on the subset of data from Aran Valley and nearby valleys to characterize the human-triggered slab avalanche characteristics in the Aran forecasting region, featured by an oceanic snow climate. Finally, we rate the snow pits with the new Grom Score method to assess the stability based on structure, strength, and propagation criteria. Results help us to emphasize the most prone conditions for human-triggering in Aran Valley, but also test the Grom score method for better communication and practical stability assessments.

KEYWORDS: Snow stability, avalanche forecasting, avalanche communication, Pyrenees

1. INTRODUCTION

Avalanche forecasting is a fundamental part of the safety for winter backcountry practitioners. Being able to clearly communicate the information provided by the avalanche warning services is essential, not only the contents of the avalanche danger bulletins but also the data collected obtained in the field that complement this information. Transmitting the degree of instability of a slope from snowpack observations, stratigraphic snow profiles and stability tests has always been a challenge for avalanche forecaster and communicators. The great spatial and temporal variability of the snowpack means that the representativeness of specific observations in a slope is limited, and they must be analyzed with caution.

A snow profile can be analyzed into three factors related to slope stability: strength, structure and energy (Sharaf and McCammon, 2005). Richards et al. (2023) modify these terms and refer to strength, structure and propagation, which are more easily interpretable in the field observations. For practical purposes, strength (fracture initiation) and propagation can be determined more or less directly from stability tests such as the Rutschblock Test (RB), Extended Column Test (ECT) and Compression Test (CT). In this sense, investigations such as Birkeland et al. (2023) describe the advantages and limitations of these most widespread tests within the scientific and recreational community and more specifically the studies of Techel et al. (2020a and 2020b) give a very detailed interpretation of the ECT results. On the other hand, the structure is determined by the layering and characteristics of the layers constituting the snowpack. McCammon and Schweizer (2002) proposed a stability rating system of the snow profiles using 5 easily identifiable parameters (the so-called "lemons") that Moner et al. (2008) adapted with data from the Eastern Pyrenees and Bacardit et al. (2016) reviewed with an enlarged data set.

The recent work of Richards et al. (2023) proposes the "Grom Score", a new classification method that considers the three elements of stability (strength, propagation and structure) using the results of the ECT and the stratigraphic characteristics of the snowpack. The method simplifies the structural parameters of McCammon and Schweizer (2002) from 5 to 3 criteria called PHD (Persistent weak layer / Hardness difference / Depth of the weak layer) in a way that facilitates its classification and communication (Figure 1). In addition, the strength and propagation score are easily determined from the ECT results.

The proposed method was tested on more than 6600 observations (snow profile with ECT) from the SnowPilot.org database. This public database comes from observations of both professionals (forecasters, patrollers and guides) and trained recreational users. The results obtained, although with quite a few nuances, are quite coherent and it is presented as an effective communication tool.

This work aims to validate the method proposed by Richards et al. (2023) using two datasets from the Val d'Aran avalanche center (Pyrenees-

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Spain). The data used is exclusively generated by snow professionals so that a greater methodological consistency is expected. The goal is to test the Grom Score as a snowpack stability interpretation tool and can be used as a communication tool between forecasters and users in the Pyrenees. Furthermore, the Grom Score could be integrated in the avalanche skills training programs for recreationist and professionals.

	Rating	Description	Score
Strength	Difficult	Tap score 21-30-ECTX	3
	Moderate	Tap score 11-20	2
	Easy	Tap score 0-10	1
Propagation	ECTX	ECT provided no failure	3
	ECTN	ECT provided no propagation	2
	ECTP*	ECT provided full propagation	1
	ECTPV*	ECT fails with full propagation on isolation	0
	* If ECTP structure ≤ 1		
	* If ECTPV structure = 0		
Structure	Good	Weak snow on top of strong snow, lacking a weak layer	3
	Fair	Strong snow on top of weak snow, greater than a meter deep and lacking a PWL	2
	Poor	Strong snow on top of weak snow, PWL is present	1
	Very Poor*	All lemons or PHD factors are present with PWL	0
	*If PWL than structure ≤ 1		

Figure 1: Summary table of the application of the Grom Score according to Richards et al. (2023).

2. DATA AND METHODS

The Val d'Aran is a small county in the Norwest of Catalonia, Spain, located in the Central Pyrenees on its Northern slope. This aspect provides an Atlantic climate different from the other mountain areas of Catalonia and Spain (Figure 2). Since the start of the Aran Avalanche Center in the 2003-2004 season, the responsible avalanche forecasters have systematically collected data from the snow cover both for the avalanche forecast and for the investigation of unstable slopes. These latter data constitute an extensive database of human-triggered slabs from the Pyrenees which have been the subject of several studies (Moner et al. 2008 and Bacardit et al. 2016).

The data used in this work is extracted from two different datasets. The first comes from the human triggered slab avalanche database (HU-TRI) that has been carried out in the Eastern Catalan Pyrenees since the winter of 2003-2004 (Moner et al. 2008 and Bacardit et al. 2016). This database collects snow profiles on unstable slopes where human-triggered slabs have occurred, or woumpfs or shooting cracks have been observed. From this dataset, snow profiles from Val d'Aran and nearby valleys have been extracted (Figure 2) using the same well-trained forecasters or observers. Observations without ECT, have been discarded. The selected data includes 103 snow profiles from 2007-2008 to 2023-2024 winter seasons.

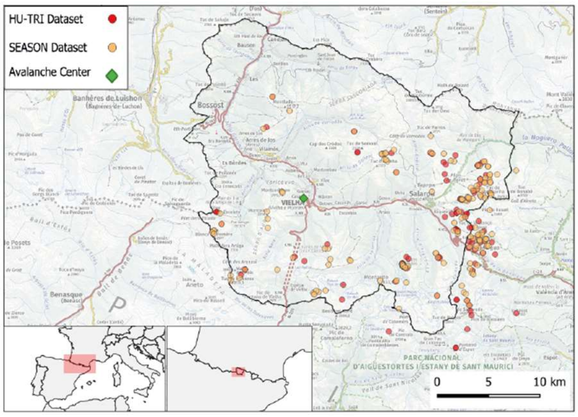

Figure 2. Study area with the location of the snow profiles of the two datasets. Location of the Aran Avalanche Center is also indicated.

The second dataset includes observations made by the forecasters in the daily work to assess the snowpack stability (SEASON) from the 2020-21 to 2023-24 winter seasons. The data have been extracted from CAAML files plotted using the software https://niviz.org/. For this dataset, two filters have been applied too. Snow profiles without ECT have been discarded. A second, snow profiles from wet-snow conditions have also been discarded, as it was done in the work by Richards et al. (2023). Though there are some studies on ECT results still including wet-snow profiles (Techel and Pielmeier, 2009), the application and performance of the ECT in wet snowpacks still lacks further research (Schweizer and Jamieson, 2010). The most recent study reviewing the ECT is still focused in dry-snowpacks only (Birkeland, et al. 2023). The SEASON dataset finally contains 163 snow profiles which also include the records of the HU-TRI dataset for the same seasons.

The two datasets contain location data (slope, orientation and altitude) and stratigraphic characteristics of the snowpack (crystal form and hardness of the weak layer, hardness of the slab layer and depth of the weak layer).

In addition, in the SEASON dataset, the stability evaluation ("Poor"," Fair" and "Good") of the related slope done by the forecaster "in situ" after performing the snow profile with test, has also been included and used. For this study, each slope has also been rated as stable or unstable according to Techel et al. (2020).

The Grom Score of each snow profile has been calculated using the methodology proposed by Richards et al. (2023) exactly. In cases with more than one ECT result in a profile, the lowest value has been selected. Finally, in cases with ECTX results, the weak layer that gives a lower structural score has been chosen (Figure 1).

Once the Grom Scores have been calculated, the results have been related to the type of the weak layer (persistent or non-persistent). Moreover, for the SEASON dataset, the Grom Scores have been related to the slope stability (stable or unstable).

3. RESULTS AND DISCUSSION

3.1 Human-triggered slab avalanche dataset

The HU-TRI dataset corresponds entirely to "unstable" slopes, and therefore it is expected to get low results. In the overall sample, 83% correspond to values equal to or less than 4, obtaining values 2 and 3 in 52% of the cases (figure 3).

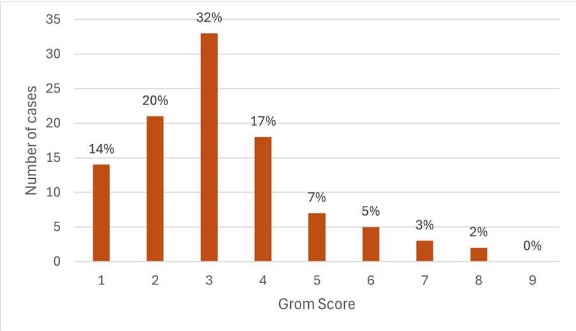

Figure 3: HU-TRI Dataset with the number of cases for each scoring result. N= 103.

The character of the weak layer (persistent versus non-persistent) has an important weight in the Grom Score. In this dataset, 82% are related to a persistent weak layer (PWL). This agrees the finding by Bacardit et al (2016) with an enlarged data set of human-triggered slabs of the whole Eastern Pyrenees for the last three decades. Snow profiles with a PWL have 87% of the scores between 1-4 while those with a non-persistent weak layer contain 68% of the scores in this range. The number of cases with scores of 5 and higher are very low, as expected in a sample of unstable slopes (figure 4). The score of 9 is not recorded in any observation and 8 only in two cases with a non-persistent weak layer.

3.2 SEASON Dataset

In this dataset containing the snow profiles of the last 4 winter seasons, a more widespread distribution of the scores is expected. Though the typical goal of the field observation trips is to potentially find the instability, throughout in the whole winter season there are periods of time in which unstable layers are rare and difficult to find.

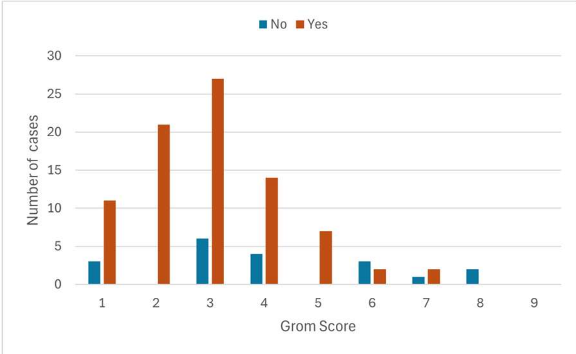

Figure 4. HU-TRI Dataset with scores rated by the presence of a persistent weak layer (Yes) or without (No).

Regarding the stability assessment of the slope assigned by the forecasters, the high scores are clearly related to "Good" stability evaluation (Figure 5). Likewise, slopes with a "Poor" rating clearly correspond to Grom Scores of 4 or less (84%). Scores of 2 and 3 are obtained in the most cases of unstable slopes and no scores of 8 and 9 are obtained in "Poor" slopes.

Figure 5. SEASON Dataset with the slope stability assessment ("Poor", "Fair" and "Good"). The numbers inside the columns correspond to the number of cases for each result.

In this dataset, 121 cases are rated as stable, and 42 cases are unstable (Figure 6). The base rate for unstable profiles is thus 26%. The profiles classified as unstable show 74% of Grom Scores between 1 and 4, but still 21% with scores of 5 or more. Only those profiles scored with values of 1 to 3 are below the base rate. Therefore, an unstable profile with a score lower than 4 is likely to be unstable.

This result towards the lower scores is more acute in this study than by Richards et al. (2023) and can be explained by different causes. Firstly, it could be related to particular characteristics of the winter seasons to which the data refer. In the Pyrenees, the 2022-23 and 2023-24 seasons have recorded snow depths well below the climatic averages. The second reason may be due to the lack of information related to the profiles studied. Only data from the CAAML files have been included, whereas additional information on signs of instability usually recorded in the field notebooks is not always transferred the snow profile plot.

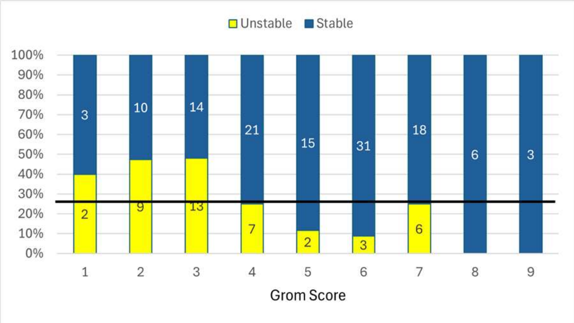

Figure 6. SEASON dataset with profiles classified as “Stable” or “Unstable”. The black horizontal line represents the base rate of the unstable profiles.

Finally, the stability assessment assigned by the forecaster has been analysed as function of presence or absence of a PWL. The snow profiles with a PWL, show lower Grom scores than those without a PWL (figures 7a and 7b). This is because the Grom Score method is developed to obtain a lower score when a PWL is present. In the last 4 winter seasons, there are no cases with scores of 8 or 9 with a PWL present. Moreover, cases without a PWL show higher scores, and only few profiles with scores lower than 5.

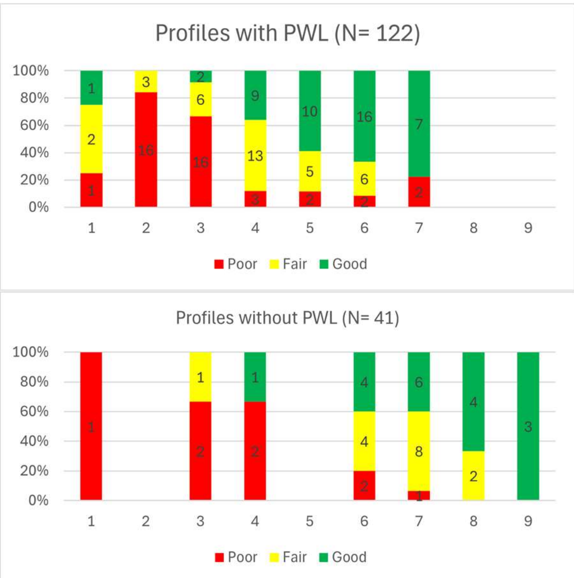

Figure 7. SEASON Dataset with scores shown separately in profiles with PWL (top) and without PWL (bottom)

4. CONCLUSIONS

In this study, the Grom Score method proposed by Richards and collaborators have been applied with snow profiles from the Central Pyrenees. The scores calculated from two datasets (HU-TRI and SEASON) are comparable to those from the original study, with 80% of the cases from slopes with a “Poor” or “Unstable” stability evaluation with scores between 1 and 4. Therefore, the method is tested and verified as a valuable tool to assess the snowpack stability from field snow profiles.

The study highlights the importance of always carrying out an ECT together with the stratigraphic profile. Given the important weight that the result of this test has, both in the assessment of the fracture initiation and propagation, it is highly recommended to perform a second ECT to verify the result of the first test.

With the data analysed here, the Grom Score is a valuable tool to clearly and easily communicate stability evaluation from field observations based with a stratigraphic profile and ECT. This is useful both for professionals and all users with less experience and/or training to interpret rough snow profiles.

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