AVALANCHE TERRAIN EXPOSURE SCALE MAPPING IN THE PYRENEES: AN EXPANDING PROJECT

Montse Bacardit[1]*, Sara Orgué[2], Ivan Moner[1], Jordi Gavaldà[1], Aina Margalef[3], Marc Pons[3], Gerard Olm[2], Rocío Hurtado[2], Pablo Huelin Rueda[2], Albert Piqué Badia[2], Miguel Ángel Clavero[4], Luis Masgrau[5]

[1] *Centre de Lauegi, Consell Generau d'Aran (CGA), Val d'Aran, Spain*
[2] *Freelance Avalanche Technician, Pyrenees*
[3] *Centre d'Estudis de la Neu i la Muntanya d'Andorra (CENMA-IEA), Sant Julià de Lòria, Andorra*
[4] *Campaña Montaña Segura, Federación Aragonesa de Montañsimo (FAM), Spain*
[5] *Gobierno de Aragón (DGA), Aragón, Spain*

ABSTRACT: The Avalanche Terrain Exposure Scale (ATES) was developed by Parks Canada in 2004 to inform backcountry users about the exposure to avalanche danger of winter mountain itineraries in their National Parks. Nowadays, ATES maps have become a popular tool for trip planning in Western Canada, Alaska and New Zealand. In 2011, the ATES was first applied for a pilot area in Val d'Aran, Central Pyrenees, and after 8 winter seasons, ATES zoning for Val d'Aran is fully completed and ready for the upcoming 2018-19 winter season. In recent years, other areas in the Pyrenees have also started to rate their avalanche terrain using the ATES zoning methodology: Tavascan, Canfranc and Benasque in the Spanish Pyrenees, and several valleys in Andorra. Here we present the current results of the overall ATES mapping in the Pyrenees, which represents an expanding project at a mountain range scale.

Since ATES maps in the Pyrenees are expanding and becoming commonly used for trip planning amongst recreationists and practicionists, it is important to pool the doubts that have emerged amongst professionals involved in the terrain classification. Understanding and applying the three rating models in the same way can be of great help to produce functional and homogeneous ATES maps between zones across the Pyrenees. The discussion generated can also be useful for other mountain ranges where the ATES zoning is currently spreading out.

KEYWORDS: avalanche terrain; exposure; zoning; risk management; trip planning

1. INTRODUCTION

The Avalanche Terrain Exposure Scale (ATES) was first implemented in 2004 to rate backcountry recreational trips according to its overall exposure to avalanche terrain (Statham, 2006). It was initially conceived to classify an individual itinerary or drainage, but it was soon applied as a classification system for zoning backcountry recreation areas (Campbell and Marshall 2010) using methods described by Campbell et al. (2012). The ATES spread out beyond National Parks to other Canadian mountain ranges, as well as Alaska and New Zealand mountains. The ATES was promptly considered by backcountry recreationists as a valuable avalanche safety tool. More recently, the ATES has been implemented in worker safety operations in project sites or access roads (Campbell and Gould, 2014).

The ATES was originally presented as a two-model tool: The Technical Model (v1.04) was designed for terrain rating purposes and skilled users to interpret avalanche terrain, while the Public Communication Model (v1.04) was intended to easily communicate the same concepts to a less skilled audience (Statham, 2006).

However, the Technical Model shows a high degree of subjectivity and a certain amount of redundancy within and between the eleven terrain parameters, many of which are defined qualitatively. It also poses a challenge when ATES zoning by means of Geographic Information Systems (GIS) (Campbell and Gould, 2014).

A new practical ATES Zoning Model was proposed by Campbell and Gould (2014) with the premises to be accessible (no need for specialized computer programs), simple, compatible with the Technical Model v1.04, applicable for trip planning, and based on the analysis of previously zoned terrain from two primary avalanche terrain parameters: slope incline and forest density. The authors do not propose the Zoning Model to substitute the Technical Model but consider the need to designate a model and standards to establish homogenous and comparable methodology and criteria.

From the 2011-2012 winter season onwards, the ATES was established in Val d'Aran,

Central Pyrenees, being the first implementation in Europe (Gavaldà et al. 2013). On a first stage, the terrain was rated using the Technical Model v1.04. On a second stage, the practical Zoning Model was firstly tested to assess compatibility with the previous model and afterwards adopted as the main tool to classify the terrain. The ATES zoning for Val d'Aran is today fully completed and ready for the upcoming 2018-19 winter season.

In recent years, other areas in the Pyrenees have also started to rate their avalanche terrain directly using the practical ATES Zoning Model: Tavascan, Canfranc and Benasque in the Spanish Pyrenees, and several valleys in Andorra. At the same time, the Canadian ATES zoning methodology has been employed for safety projects in other European alpine countries, such as Norway, Sweden and Switzerland.

In this paper we present the current results of the overall ATES mapping in the Pyrenees, which represents an expanding project at a mountain range scale. We show the methodological variations amongst Pyrenean professionals developing ATES ratings and the ATES communication strategies in order to reach the wide range of users. We want to deliver the experience we have acquired over the years zoning with both the Technical and the Zoning Models in our particular snow climate. Certainly, there is the need to apply accurately and precisely the methodology to produce functional and homogeneous ATES maps between zones across the Pyrenees and all other mountain ranges in the world where the ATES zoning is currently spreading out.

2. ATES MAPPING IN THE PYRENEES

In the Pyrenees, several mountains belonging to Spain and Andorra countries have already been zoned using the ATES (Figure 1), achieving a total of 910 km^2. Simple, Challenging and Complex terrain compute respectively for the 27%, 34% and 34% (Table 1). The ATES zoning has been applied at different spatial extent with varied terrain use. From the side-country of single ski areas, the backcountry accessing and around mountain huts, to all avalanche terrain included in a whole valley (i.e. drainage). Large areas, like Aran or Andorra valleys (Canillo, Ordino, La Massana and Encamp commons) display more balanced proportions between the three terrain classes. Small areas such Tavascan, Astún and Candanchú ski areas, and Benasque with Llauset and Renclusa mountain huts show a larger proportion of Challenging and Complex terrain. The reason could be that ski resorts and mountain huts in the Pyrenees are generally located beyond the treeline and in the alpine, with a high relative extension of open, steep terrain and/or exposed accesses.

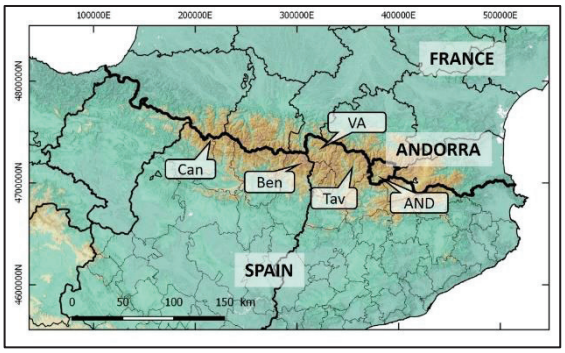

Figure 1. Location of the ATES sites in the Pyrenees. AND, Andorra; VA, Val d'Aran; Tav: Tavascan; Ben: Benasque; Can: Canfranc.

The ATES zoning in the Pyrenees is currently expanding to new sites: ski areas interested in promoting the side-country accompanied with safety information; mountain huts with frequented backcountry of the Aragonese Mountaineering Federation (FAM); or other Andorran valleys to complete the ATES map of the national backcountry terrain. Moreover, ATES zoning has caught the interest of some Spanish Natural and National Parks. A chief reason is to manage park accesses and visitors in winter, when any place in the park is less frequented and more remote. Therefore, we can expect to see the extension of the ATES zoning in more Pyrenean mountain spaces in the near future.

Table 1. Summary of terrain zoned using ATES in the Pyrenees. Terrain use: BC = backcountry; SC = side-country. Terrain class: 1 = Simple. 2 = Challenging. 3 = Complex.

Site	Terrain use	Terrain zoned (Km^2)	Terrain class (%)		
			1	2	3
Val d'Aran	BC SC	563	30	33	37
Tavascan ski area	SC	8	8	31	61
Canfranc: Astún – Candanchú ski areas	SC	18	18	55	27
Benasque: Llauset – Renclusa mtn. huts	BC	127	10	40	50
Andorran valleys	BC SC	195	31	33	36
Total		910	27	34	39

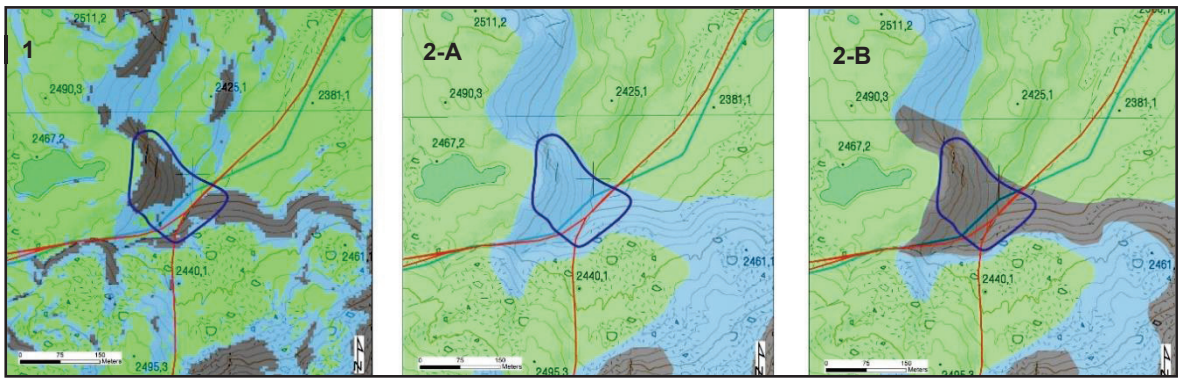

Figure 2. Circ dels Pessons bowl, Andorra. Polygon: feature of concern. Polylines: typical routes. 1: Preliminary zoning using automatic GIS "slope+forest density" analysis; 2-A: the whole terrain feature is rated as Challenging. 2-B: the same piece of terrain rated as Complex beside a piece of Challenging terrain.

3. METHODOLOGICAL CONSIDERATIONS

3.1 Zoning versus Technical Model

To our experience in having used both ATES rating models, the Zoning Model based on 5 quantifiable criteria with established threshold values, is more clear, functional and less redundant. The preliminary terrain classification founded on the first dual parameter (slope and forest density) is relatively easy and objective to get before field surveys.

In the Pyrenean ATES sites, manual preliminary zones using a high-resolution terrain model, topographical maps and aerial imageries have been obtained for Val d'Aran, Tavascan, Canfranc, Benasque and some Andorran valleys, whereas automatic GIS analysis has been applied for some other Andorran valleys as well as Canfranc.

The other 4 parameters are successively analyzed and applied to refine the polygons with a decreasing order of priority. In this second stage, field validation and expert judgement are as necessary as in the Technical Model.

In Canfranc, a computed combination of parameters improved with the involvement of a specialist technician for assessment and calibration tasks is applied at four stages of the process. This ensures a better adjustment of the model to local conditions at the time that controls the human subjectivity. Zones with same characteristics are rectified at a basin scale avoiding the use of different criteria of the method for each problematic spot.

We found that the Zoning Model is mostly consistent with the Technical Model. But there are two relevant differences in quantifiable variables which, to our opinion, can result in discordant results between methods.

- Slope incline varies with forest density. The new thresholds are more restrictive, especially in open zones. Terrain is rated towards more Challenging or Complex.

- Interaction with avalanche paths criteria in the Zoning Model (Avalanche frequency in the Technical Model) changes substantially. As an example, Complex terrain is 1:1 ≥ size 3 in the Technical Model, whereas it is 1:1 > size 3, which is interpreted as 1:1 = size 4 in the Zoning Model. This fact particularly affects runout zone ratings.

3.2 Scale of polygons

The ATES zoning methodology can be applied at a variety of spatial scales but zones should be drawn at a basin-scale of 100 – 1000 m. Moreover, a 10-20 m polygon overlap is allowed to express uncertainty related to ATES zones (Campbell et al. 2012). According to the same authors, zones produced are entirely terrain-based and completely independent of trips or routes, and therefore not useful for route finding. However, close attention should be given to common routes and high-use areas: what we call the "polygon function", a helpful approach when choosing the appropriate polygon scale and boundaries.

Figure 2 shows one example for polygon scale choice with distinct rating results in Circ dels Pessons bowl, Andorra. After automatic preliminary zoning in which a mosaic of too small polygons is obtained, the polygon scale is extended. In option 2-A the whole terrain feature is fitted into a single Challenging zone, whereas in option 2-B, a Complex zone is delineated over the larger Challenging zone. Field survey allowed to check that despite the steepness of this piece of open terrain, there are no start zones with ≥ Size 2 potential and the depression is "only" a burial type terrain trap. Thus, option A is undertaken.

Figure 3 provides a second example for polygon scale option with regard to its function in the head of the Lliterola Valley (Renclusa hut, Benasque). In option 1, a small scale is adopted and the terrain is rated with larger polygons. In option 2, a large scale is chosen and the terrain is rated with smaller polygons. Both options are within the 100 – 1000 m basin scale. Option 2 is finally selected, being more functional in terms of terrain class resolution in this highly used alpine pass.

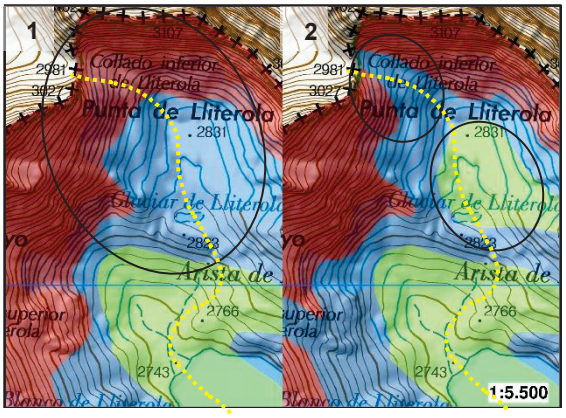

Figure 3. Head of the Lliterola Valley, Renclusa hut, Benasque, Spain. Black ellipses: features of concern. Dotted line: typical route. 1: larger polygons result in higher class ratings. 2: smaller polygons allow lower class ratings.

In Canfranc, areas smaller than 1,600 m^2 (or even 2,500 m^2) were removed. This polygon threshold is due to the importance given to some isolated pieces of terrain and the proper perception expected by users (Figure 4).

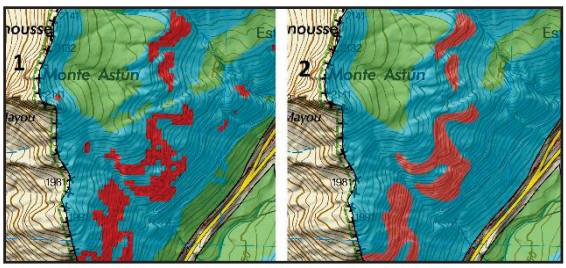

Figure 4. Monte Astún ski area surroundings, Canfranc. 1: halfway computing zoning. 2: zoning after lasts specialist interventions and small areas removing.

3.3 *Special terrain*

So far none of the ATES sites in the Pyrenees have used the Class 0 ("Non-avalanche terrain"). However, "special terrain" types have been the object of interesting discussion amongst professionals.

- "Not-practicable terrain", i.e. extreme terrain, very steep, not useful to progress. In the preliminary zoning, it is rated as Complex. But in the final zoning, we distinct three types with different classification results: 1) very steep terrain in dense coniferous forest; 2) very steep terrain in dense deciduous forest; 3) very steep terrain in rocky area. For these three types of "non-practicable terrain": 1) it is typically not rated as Complex, because starting zones are very small and the undergrowth act as effective anchor of a typical thin snowpack; 2) it is mostly rated as Complex, with some exceptions. Deciduous trees typically have a thicker snowpack and undergrowth is less effective as anchor; 3) it is rated as Complex terrain, despite the fact that starting zones are very small but it is potentially traumatic, fatal terrain.

- "Variable terrain": lakes with non-durable ice cover, dams with variable water level are not assigned with a polygon category, despite the fact that they are bounded with ATES rated terrain (see Figure 5 as an example).

Pieces of "special terrain" must reach the minimal scale size to be considered as distinct features with respect to the surrounding terrain.

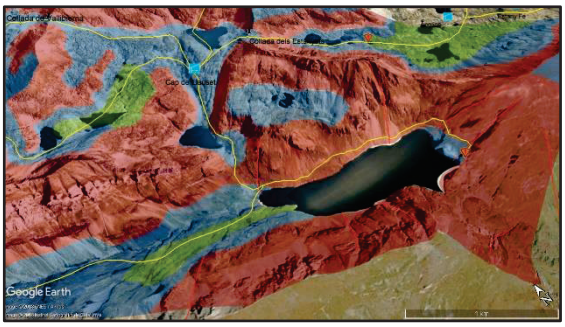

Figure 5: ATES zoning in Llauset mountain hut. Note that Llauset dammed lake is "variable terrain" and has not been rated.

3.4 *Overall objectivity/subjectivity and coincidence amongst professionals*

In the zoning process, the initial pieces of rated terrain are objective elements and shouldn't present differences among individuals. This agrees with a high precision of ~30 m proposed by Campbell and co-authors (2012).

However, defining polygon transitions and, above all, choosing the polygon scale demand expertise and become tremendously subjective.

In an individual survey to professionals involved in the ATES zoning in the Pyrenees (n=10), we agree that a 75% of the mapping extent is objective and a 25% is subjective, which implies the need to take decisions under the expert criteria. We have also asked about the zoning consistency (coincidence) among individuals of a same mapping team: it ranges between 85 and 95% in the results after field surveys and final zoning. Since it is only possible to deliver

a unique ATES map, in cases of not coincidence, priority was given to the final zoning by the most experienced individual.

4. COMMUNICATION TOOLS

The output of the ATES zoning in the Pyrenees has been using similar means at all sites. Maps and complementary terrain information can be visualized online and in all ATES sites but Andorra freely downloaded from websites (Table 2). ATES panels are set in the most popular trailheads in all sites but Canfranc. Moreover, the travel advice in the local avalanche advisories issued by the Aran Avalanche Centre (Val d'Aran) and Alurte (Canfranc) contain specific terrain class concepts and recommendations for trip planning according to the well-known decision support tool Avaluator™ Trip Planner (Haegeli et al. 2006). This piece of information is key to engage the public to use the ATES ratings and maps, and the Avaluator™ matrix. Both tools have become an important part of the avalanche training programs by ACNA (the Spanish Avalanche Association) and EDNA (the Andorran Avalanche Association). Students learn to understand and identify the exposure and complexity of avalanche terrain, and trip planning is organized using the Avaluator™ tool. In addition, avalanche awareness talks have been undertaken to present the ATES projects to the local public, authorities and safety stakeholders.

Table 2. List of Pyrenean ATES sites and short URL to websites.

ATES site	Short URL to website
Val d'Aran	https://goo.gl/XvYBbw
Tavascan	https://goo.gl/QgbHfa
Canfranc	https://goo.gl/u5p6hg
Benasque	https://goo.gl/QM1b7h
Andorra	https://goo.gl/MejPXF

5. CONCLUSIONS

Since the first ATES zoning experience in Val d'Aran in 2011, near 10^3 km^2 of avalanche terrain have already been rated using the ATES zoning methodology in the Spanish and Andorran Pyrenees. ATES maps are becoming a key part of safety projects promoted by local governments, ski centers, mountaineering federations and natural protected areas.

Through diverse ways of effective communication and dissemination, ATES maps and Avaluator™ decision support tool are increasingly used for winter recreationists and avalanche professionals using the backcountry and sidecountry of controlled areas. We expect to see the ATES zoning rapidly spreading out to new areas in the Pyrenees, which are going to connect the already existing ATES maps.

Several avalanche professionals from distinct organizations are involved in the ATES terrain classification in the Pyrenees. We all have opted for the practical Zoning Model instead of the Technical Model due to its more practical application. However, expert advice is still inevitable and poses difficulty to produce objective, consistent and uniform ATES maps across sites and professionals involved.

As previously remarked by authors involved in the Technical and Zoning Models, there is a need for making consensus on the methodology and designation of a single model to obtain the ratings.

ACKNOWLEDGEMENT

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REFERENCES

Campbell, C. and Marshall, P. 2010. Mapping Exposure to Avalanche Terrain. International Snow Science Workshop. Squaw Valley, CA, USA.

Campbell, C., Gould, B. and Newby, J. 2012. Zoning with the Avalanche Terrain Exposure Scale. International Snow Science Workshop. Anchorage, AK, USA.

Campbell, C. and Gould, B. 2013. A proposed practical model for zoning with the Avalanche Terrain Exposure Scale. International Snow Science Workshop. Grenoble, France.

Campbell, C. and Gould, B. 2014. An ATES Zoning Model. The Avalanche Journal, 107.

Gavaldà, J., Moner, I. and Bacardit, M. 2013. Integrating the ATES into the avalanche information in Aran Valley (Central Pyrenees). International Snow Science Workshop. Grenoble, France.

Gould, B. and Campbell, C. 2014. Modern snow avalanche terrain mapping for industrial projects. Conference on Geohazards. Kingston, ON, Canada.

Haegeli, P., McCammon, I., Jamieson, B., Israelson, C., and Statham, G. 2006. The Avaluator – a Canadian rule-based avalanche decision support tool for amateur recreationists. International Snow Science Workshop. Telluride, CO, USA.

Statham, G., McMahon, B. and Tomm, I., 2006. The Avalanche Terrain Exposure Scale. International Snow Science Workshop. Telluride, CO, USA.