PROJECT ALBINA: A CONCEPTUAL FRAMEWORK FOR A CONSISTENT, CROSS-BORDER AND MULTILINGUAL REGIONAL AVALANCHE FORECASTING SYSTEM

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ABSTRACT: About 29 forecasting centers in the European Alps assess the regional avalanche danger for their area on a regular basis and inform the public through regional avalanche bulletins. However, if for example Tyrolean recreationists would like to enjoy backcountry skiing in the Province of Trento, they very often encounter a linguistic problem - unless someone from their group speaks fluent Italian. Since communication is a major part of effective avalanche warning, consistency in the communication of avalanche danger is essential to ensure the greatest value for the users. Only recently, a comparison between neighboring avalanche danger forecast systems revealed different possible factors of inconsistency: (1) varying size of the warning regions, (2) differences in language and culture, (3) operational constraints in the production and distribution of the avalanche danger bulletin and (4) different interpretations of the avalanche danger levels. In order to foster the efforts in harmonizing warning production and communication and consequently increase the value for backcountry recreationists, three forecasting centers within the European Avalanche Warning Services (EAWS), namely Tirol from Austria as well as South Tyrol and Trentino both from Italy, teamed up with the main goal to develop and implement a conceptual framework in line with EAWS standards and best practice. The conceptual framework focuses on objects notoriously known to be potential sources of inconsistency when assessing and communicating avalanche danger across forecasting borders: e.g. (1) avalanche danger assessment and forecasting production, (2) timing and validity of publication and (3) effective geo-communication. We will present this generally valid approach for connecting various avalanche forecasting centers without undermining their territorial sovereignty. The framework contains operational workflows across borders among avalanche forecasters, concepts of self-improvement and a discussion on how to standardize exchange of experiences between forecasters. Starting with the winter season 2018-2019 Tirol, South Tyrol and Trentino will operationally use the presented framework accessible under avalanche.report and hence increase the consistency of forecasting products and the value for the users.

KEYWORDS: avalanche warning services, avalanche forecasting, communication.

1. INTRODUCTION

In order to prevent fatalities caused by snow avalanches, avalanche warning services (AWS') throughout the world publish avalanche forecasts and advisories to inform local authorities and the general public. The standards for publishing avalanche forecasts and structuring the information in the warnings have been developed over the years with the aim to provide the users with a product that is as effective as possible. In Europe, almost all avalanche warning services (N = 29) use commonly developed best-practices and standards on assessing and communicating avalanche danger (EAWS, 2017b). A 5-level, ordinal avalanche danger scale with its definition, the European Avalanche Danger Scale (EADS), represents hereby the core information for all avalanche warning services within the group of the European Avalanche Warning Services (EAWS).

Although EAWS puts increased effort in harmonizing avalanche danger assessment, Techel et al. (2018) demonstrated that based on avalanche danger level assessment only, there are major differences in published avalanche danger levels. Especially across borders of neighboring forecasting centers differences are significant when danger levels *1-Low* and *4-High* were assessed. It is everything, but straight forward to explore objectively the reasoning behind these differences, since multiple factors influence the

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assessment of the avalanche danger level. Possible reasons may range from real differences in snowpack stability or avalanche activity to differences in interpreting and applying definitions and recommendations of the EADS and other tools developed within the EAWS.

Though following the best-practices by EAWS, products from the different AWS' vary considerable in degree of detail, use of text, symbols and graphics, degree of advice provided, validity, timing of publication, and spatial (extent, elevation dependency) and temporal resolution (Burkeljca, 2013). Basically, the danger level is the parameter, which is used in the most similar way; all other parameters are communicated in a very diverse way (Techel et al., 2018). However, communication is a major part of effective avalanche warning and therefore consistency in the communication of avalanche danger is essential to ensure the greatest value for the users.

In order to foster the efforts in harmonizing warning production and communication and consequently increase the value for backcountry recreationists, three forecasting centers within the European Avalanche Warning Services (EAWS), namely Tirol from Austria as well as South Tyrol and Trentino both from Italy, teamed up with the main goal to develop and implement a conceptual framework in line with EAWS standards and best practices.

According to Murphy (1993), assuring consistency is paramount for high-quality forecasts. Therefore, the conceptual framework behind the common avalanche forecasting system focuses on objects notoriously known to be potential sources of inconsistency when assessing and communicating avalanche danger across forecasting borders. Here, we will present our concept with special focus on how the three avalanche warning services will handle (1) avalanche danger assessment and forecasting production, (2) timing and validity of publication and (3) effective geo-communication. Lanzanasto et al. (2018) discuss the accompanied technical framework for solving the conceptual context in more detail.

2. CONSISTENCY, QUALITY AND VALUE IN FORECASTING

We based our conceptual framework on the thoughts made by Murphy (1993) regarding the goodness of forecasts in general. According to Murphy (1993) a good forecast must fulfill a high degree of consistency, quality and value (Table 1). Consistency describes two facts: First, the consistency between what the forecaster assesses or judges in her mind (forecasters are assumed to be feminine in this manuscript) and the way she expresses her judgment. In the optimal case both, thoughts and published judgment of the forecaster are identical. However, sometimes system requirements or e.g. standardized text limit the forecaster in expressing her judgment. The second type of consistency is the consistency among forecasters themselves, i.e. that a forecaster in Italy assesses the avalanche danger in the same way as her colleague in Austria is doing it.

Table 1: Names and definition on types for goodness according to Murphy (1993).

Type	Name	Definition
1	Consistency	Correspondence between forecast and judgment
2	Quality	Correspondence between forecast and observation
3	Value	Incremental benefits of forecasts to user

Forecast quality is defined as match between forecast and observation (Table 1). What sounds fairly easy at the beginning is actually not possible for avalanche danger forecasting, since verification of forecast quality is only possible in some circumstances and for some aspects of the EADS. There is e.g. no objective measure for release probability, a decisive part of the EADS. However, it is possible to assure high quality simply by achieving a high degree of consistency (Murphy, 1993).

The value of a forecast (Type 3 in Table 1) relates to the benefits individuals and/or institutions experience when the forecasts are used to guide their decision-making process. Of course, different user groups treat this value differently, since their decisions may have a different set of consequences. Users of avalanche forecasts are divided mainly in two groups: recreationists and local authorities. Values to both user groups have to be addressed when publishing regional public avalanche forecasts and therefore good avalanche forecasting must fit the needs of both. Murphy (1993) concludes again that a high degree of consistency will assure high value, but concurrently he points out that a high degree of value depends to a certain amount on the user itself.

The theoretical framework of Murphy (1993) led us in designing the concept of a consistent, cross-border and multilingual regional avalanche forecasting system. In the following we address especially the elements that helped to increase consistency and value of our common avalanche forecast.

3. TOWARDS CONSISTENT WORK-FLOWS AND SYSTEM SETTINGS

We addressed consistency in two manners: First we investigated the various system settings of the three avalanche warning services and tried to bring them to one common basis which is in line with all EAWS standards and best-practices. Within this process we focused especially on creating the conceptual framework in a way that never prevents the forecaster in expressing her judgment, i.e. offer all possibilities in line with EAWS standards to express the judgment of the forecasters. Secondly, we defined a common workflow on how to assess avalanche danger, i.e. we tried to assure that the judgment, which evolves in the forecasters head follows state-of-the-art evaluation and assessment procedures.

4. CONTENT-BASED STRUCTURE OF AVALANCHE FORECASTS

In EAWS (2017a), the content and structure of public avalanche forecasts are defined. Consequently, the contents of the avalanche forecasts are structured according to the so-called information pyramid (Figure 1a): Generic, but very important information comes first. In each lower level of the pyramid, the information becomes more detailed. Of course, with increasing depth of information, the requirements for avalanche technical skills of the users increase. Even though the information pyramid represents a core standard in EAWS, at present, no avalanche warning service in Europe has implemented this structural concept it its purest form – mostly because of technical constraints. Until now, in Tirol, for example, two Typical Avalanche Problems have been assigned together with aspect and elevation information to the entire State, but the avalanche danger level was assessed for two different elevations in 12 different sub-regions. Also e.g. in Switzerland there are scale breaks within the use of the information pyramid below the level of the danger description (Figure 1a), since the description of the snowpack is only available for the scale of entire Switzerland and not for the dynamically grouped micro-regions. These temporal and/or spatial scale breaks may lead to misunderstandings when communicating avalanche danger to the user. Therefore, we attempted to implement the structure of the information pyramid in its purest form into our concept. Accordingly, we had to slightly adopt the structure of the pyramid (Figure 1b) and performed detailed analyses on spatial and temporal scale (see below). The main purpose was to follow the approach of Switzerland by using micro-regions that may be grouped to larger regions with the same avalanche conditions, but stay completely consistent with the structure of the information pyramid.

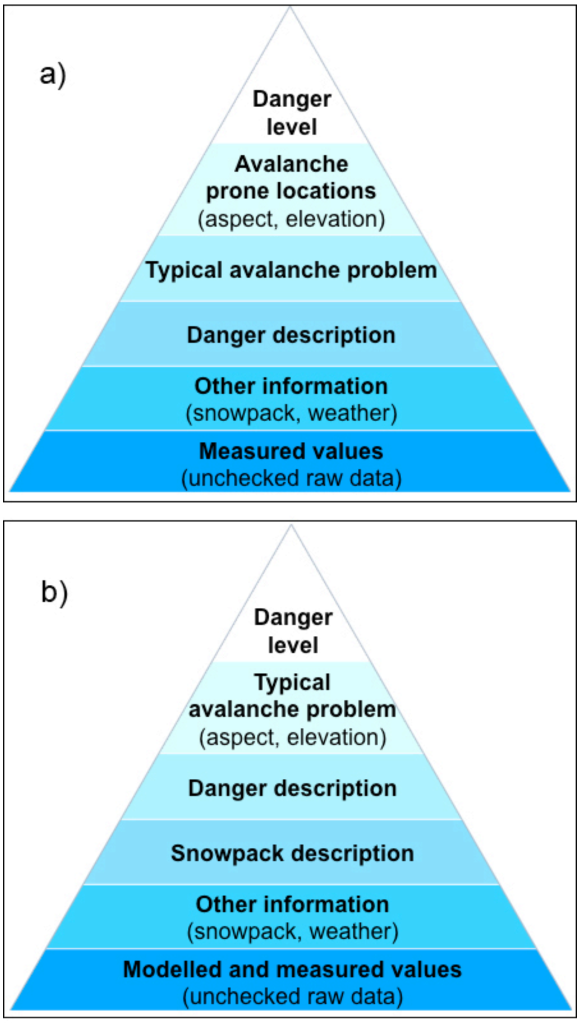

Figure 1: Official EAWS informatin pyramid (a) and the slight adoption (b) made to fullfill the needs of avalanche.report.

4.1 Analysis of warning regions

Most avalanche warning services communicate their danger ratings along a cartographic representation. Warning regions are geographically clearly specified areas permitting the forecast user to know exactly which regions are covered by the forecast. Generally, warning regions correspond to the minimal spatial resolution of a regionally forecast avalanche danger level, and are therefore recommended to have a size of about 100 km^2 or larger (EAWS, 2017b). For our three warning services, the size of individual warning regions varied considerably (median area Tirol: 970 km^2, median area South Tyrol: 680 km^2, median area Trentino: 290 km^2), thus the representation was not consistent among the

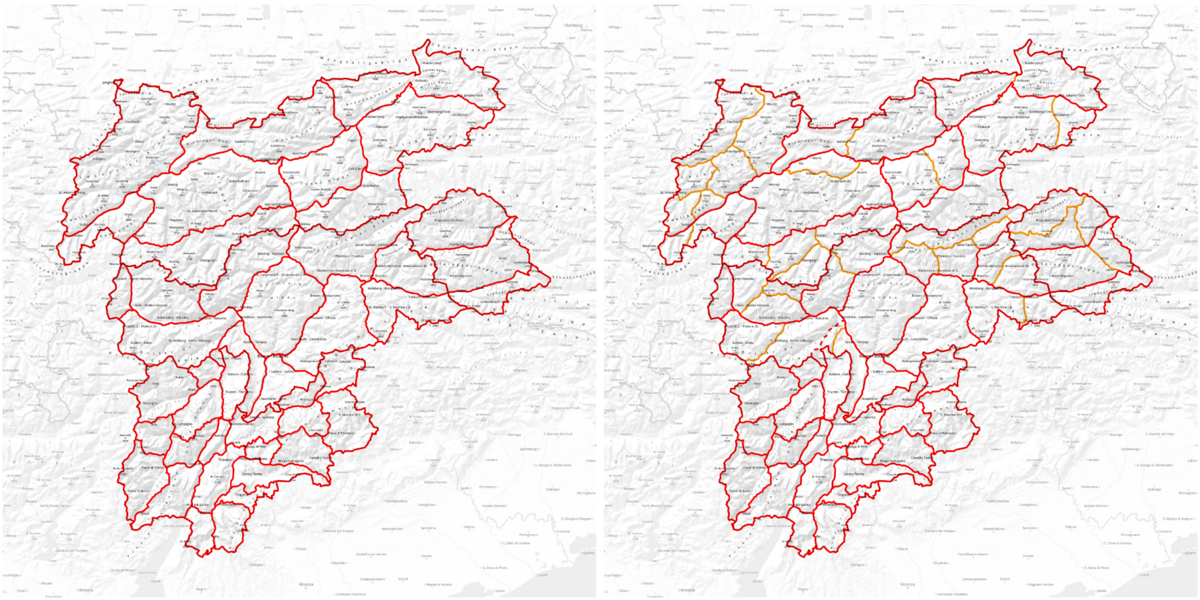

Figure 2: Warning regions of Tirol, South Tyrol and Trentino before (left) and after (right) the revision of their shape, extent and size. Revision was based on expert's opinion and a cluster analysis on winter precipitation. Especially along the Main Divide the number and size of the warning regions were adopted.

three warning services. Techel et al. (2018) could show that the larger a warning region, the higher the variability within these regions and suggested to introduce smaller warning regions. On the other side, effective avalanche forecasting is always subject to time constraints. Consequently, a high degree of spatial granulation comes with high costs in terms of time, since the forecaster has to address all levels of the information pyramid for the chosen degree of granulation. Therefore, newly introduced spatial extents and sizes of warning regions must follow a best-value approach. Until now, extent and shape of warning regions were chosen based on the forecasters experience. Here, we decided to include also a more objective way and performed a cluster analysis based on spatially distributed data of modeled daily 24-h new snow sums. We used the winter seasons 2011-2012 until 2016-2017 into the analysis. Modeled daily 24-h new snow sums were derived from the forecasting model SNOWGRID (Olefs et al., 2013). The cluster analysis was based on the concepts of misclassification errors versus the cost of increasing number of classes. We chose the number of classes, which had the lowest overall misclassification value and the lowest number of classes. For exact details of the cluster analysis, see Laternser (2002). The results of the cluster analyses were then discussed in several workshops with the forecaster, compared to the expert's opinion and finally resulted in an increased number of smaller warning regions for Tirol and South Tyrol (Figure 2). In Trentino, forecaster worked already with a set of smaller warning regions and thus a more detailed subdivision was not necessary according to our best-value requirements. In Tirol the formally 12 regions were subdivided in 29 new warning regions (median area 345 km^2), in South Tyrol the used 11 regions were subdivided in 20 new warning regions (median area 292 km^2). Together with the 21 existing warning regions of Trentino, the entire area of the Euregio is now represented with 70 warning regions. Hence, regions became much smaller. For and effective forecasting regions may be interactively grouped and within one chosen set of merged regions, the forecasters may assess avalanche conditions consistent to all necessary levels of the information pyramid (Lanzanasto et al., 2018).

4.2 Timing and validity

A consistent workflow presumes a consistent timing of publication and validity. Issuing time, temporal validity and publication frequency of the forecasts varied between all three forecast centers: Tirol issued daily at 07:30 a now-cast which was valid for the next hours (until the afternoon), South Tyrol issued a forecast at 16:00 for the next day, however, forecasts where assessed only every second day, except for the weekend. Trentino published on three days a week a mixture of now cast and forecast. Publishing time varied between 11:00h and 13:00h and lead-time was up to 72 hours. All of the forecast centers had the possibility to update their forecast product when conditions changed

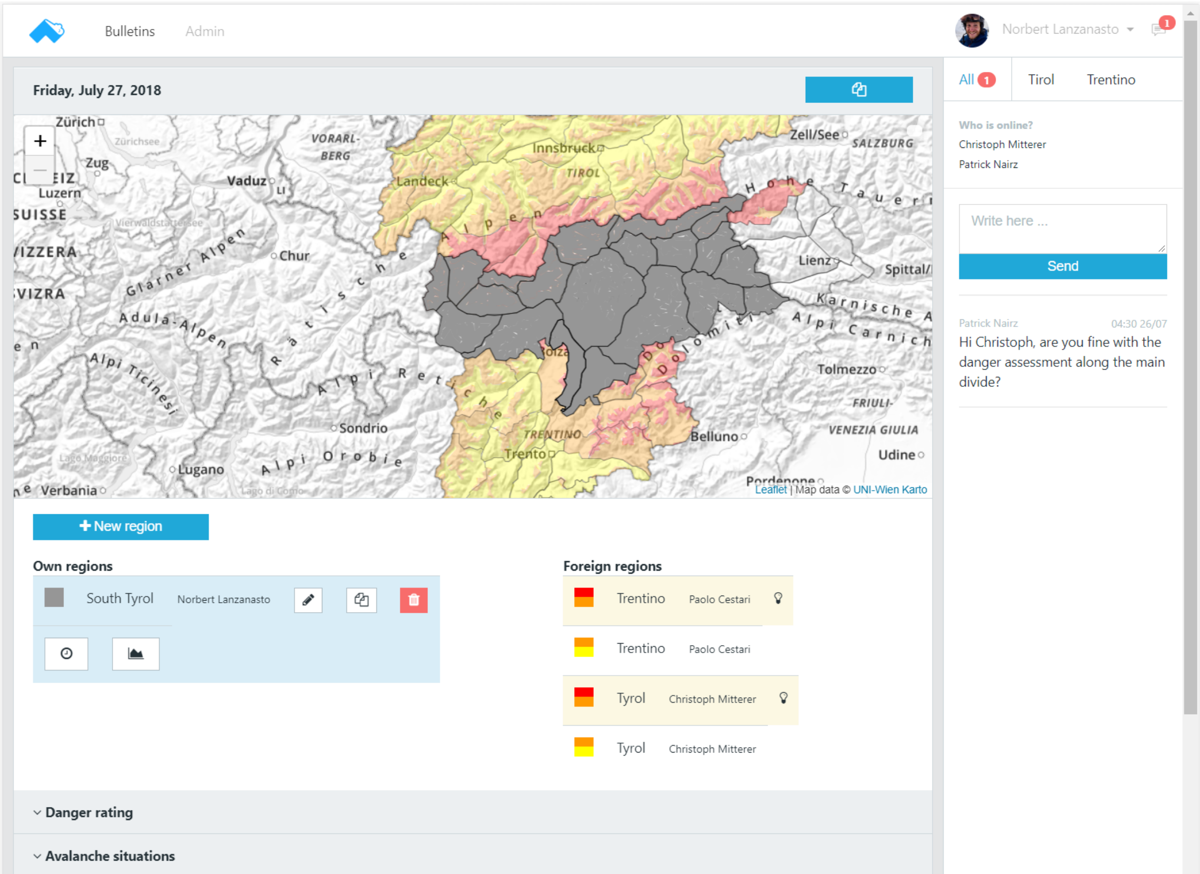

Figure 3: Overview of the software application allowing the forecasters to assess and communicate the forecast avalanche danger. The software is aligned an effective workflow for assessing avalanche danger across borders of forecasting centers.

significantly. We unified timing of publication and validity. Now all three avalanche warning services publish at 17:00h a forecast which is valid for the next day (0-24h). In addition, an optional, but announced update at 08:00h for the day as now cast is possible. Again, if conditions change dramatically, every warning service may adjust the forecast without any announcement. However, neighboring avalanche warning services will arrange shortly before a special update is published.

4.3 *The forecasters' workflow*

During several workshops we discussed best-practices and standards by the EAWS. Especially the definitions of the EADS and the use of the EAWS-Matrix (EAWS, 2017b) were compared in detail to other ideas and approaches (Müller et al., 2016). The group of forecasters finally agreed on a common workflow that is fully based on EAWS standards. The core tool of the workflow is the EAWS-Matrix and the workflow itself follows the inverse direction of the information pyramid (EAWS, 2017a). The web-based application to communicate the avalanche danger was streamlined according to this workflow (Lanzanasto et al., 2018). Figure 3 gives an overview on the streamline of the workflow starting with assessing avalanche danger level, followed by avalanche problems with spatial characteristics, avalanche danger description and snowpack evaluation. The workflow is applied to warning regions, which experience equal avalanche situations. Warning regions may dynamically be grouped to larger regions representing the avalanche situation – an approach very similar to the concept used in Switzerland.

5. CONSISTENCY AND VALUE IN COMMUNICATION TO USER

Before the age of Internet, avalanche forecasts were communicated in written format or broadcasted via radio stations. With the use of the Internet, avalanche warning services started to communicate their avalanche forecasts in a mixed way with graphs, maps and text explanation (Russi et al., 1998). Communicating in a mixed content form is still valid and also the products within the ALBINA project combine text with graphics and maps. Figure 4 gives an overview of the website avalanche.report, which is one of the main results of the project. The user may explore the different avalanche conditions with an interactive map on danger levels for the

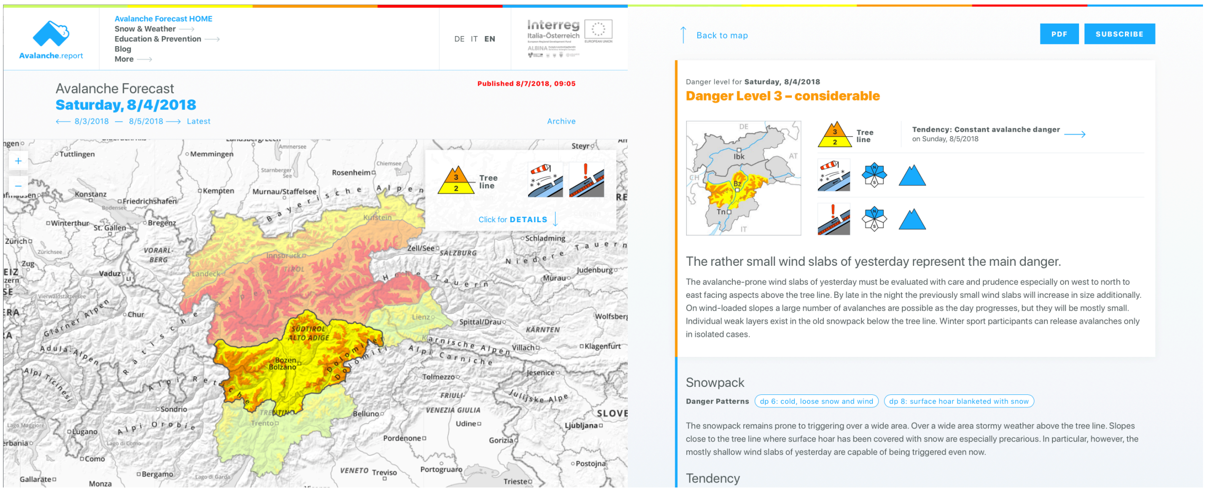

Figure 4: Combinations of interactive maps and text content are used to fully describe the avalanche conditions. User must interact and select a region (left screenshot) and click for details reported as a mix of text, graphs and maps (right screenshot).

entire area of Tirol, South Tyrol and Trentino (Figure 4 left). By selecting a region of interest, the user is provided with more detailed information on prevailing avalanche conditions. Since detailed information is too complex for visual communication only, it is described with a mix of text, graphs and maps (Figure 4 right).

5.1 Text-based communication

The official languages in the participating avalanche warning services Tirol, South Tyrol and Trentino are German and Italian. Therefore, we must communicate the avalanche forecast at least in these two languages. In a first step, we explored the possibilities of using fixed text blocks, which automatically describe the avalanche danger based on the chosen field within the EAWS-Matrix. However, end user demand for more detailed information, also within the more standardised format of the avalanche forecast (Pielmeier and Winkler, 2012). This is not applicable with fixed explanations. Therefore, we decided to use the Swiss-made catalogue of phrases for avalanche danger forecasting (Winkler et al., 2013). Because this catalogue of phrases is limited to a small sublanguage, the system is able to automatically translate sentences from German into the target languages French, Italian and English without subsequent proofreading or correction. In order to fulfil our needs, we added Italian as source language and expanded the catalogue by six new sentences. In this way, our forecaster can describe the avalanche situation and the snowpack structure still in a very variable and detailed way, though without the need for any translation service or proofreading in non-native languages. Our textual communication follows the requirements by the user and concurrently offers the highest degree of consistency when expressing avalanche danger and describing the prevailing structure of the snowpack.

5.2 Map-based communication

By incorporating spatio-temporal information and cartographic expertise into the overall conceptual framework, relevant facts can be depicted in an even more effective and visually understandable form. The focus of the map-based communication approach within the scope of the project lies towards the development of a multidimensional, spatio-temporal information system. Information channels to the user include a web-based, interactive online portal as well as demand-driven analog products, mainly in the form of static maps for various purposes. The online portal will allow the analysis and presentation of avalanche relevant information from multiple sources in a unified and contemporary visualization and representations format. Furthermore, methods and concepts for the visualization and communication processes have been examined with regard to topics like cartographic information access, usability and effective visual information retrieval.

As example on the methods and applied concepts for visualization we report on the evolution of he graphical representation of elevation based danger levels, which was a critical conceptual issue. There is no clear EAWS guideline saying wether the graphical representation of the avalanche danger level allows for an elevation dependency. In fact, members of EAWS use mainly two approaches, i.e. with and without the possibility to assign to different elevations with a danger level (Techel et al., 2018). To satisfy both approaches, we implemented the graphical

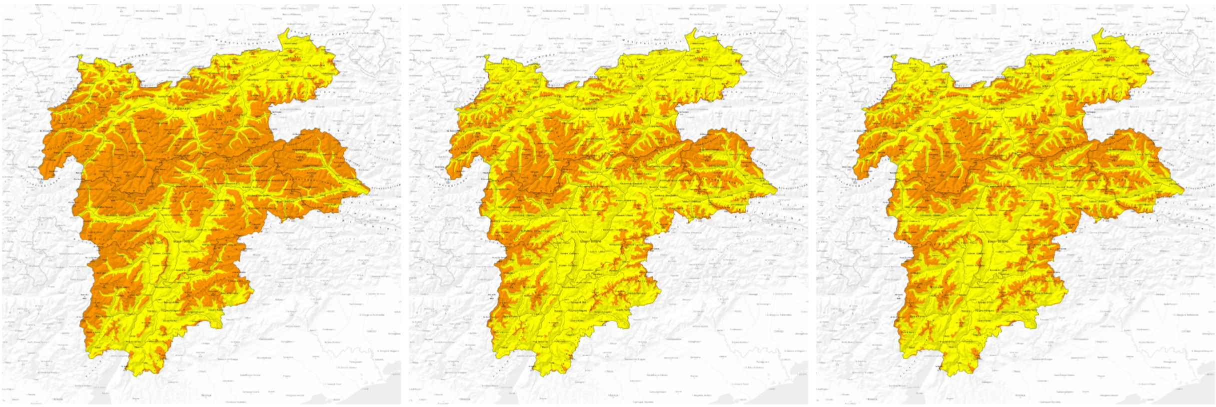

Figure 5: Case study for assessing avalanche danger (2-Moderate and 3-Considerable) for two elevation bands with different thresholds: 1500m (left), forest border/tree line (center) and individual elevation threshold based on the single warning region (right).

representation by means of two elevation bands. In a first step, two overall threshold approaches, using the 1500m contour line and the tree line were used as the basis of the evaluation of the delimitation – regardless of the reported threshold for elevation dependence within the text (Figure 5 left and middle). However, this led to confusing representation of the elevation threshold, especially for days with high and low laying elevation breaks. Therefore we analyzed historical elevation (minimum, median and mean elevation) breaks for avalanche danger for each region delimited them individually (Figure 5 right).

5.3 *User-group specific products*

As discussed above, user facing different decision-making problems may find the same set of forecasts of quite different value. In the case of avalanche danger forecasting, this is confined by two very different user groups: local authorities (so-called avalanche commissions) and backcountry recreationists.

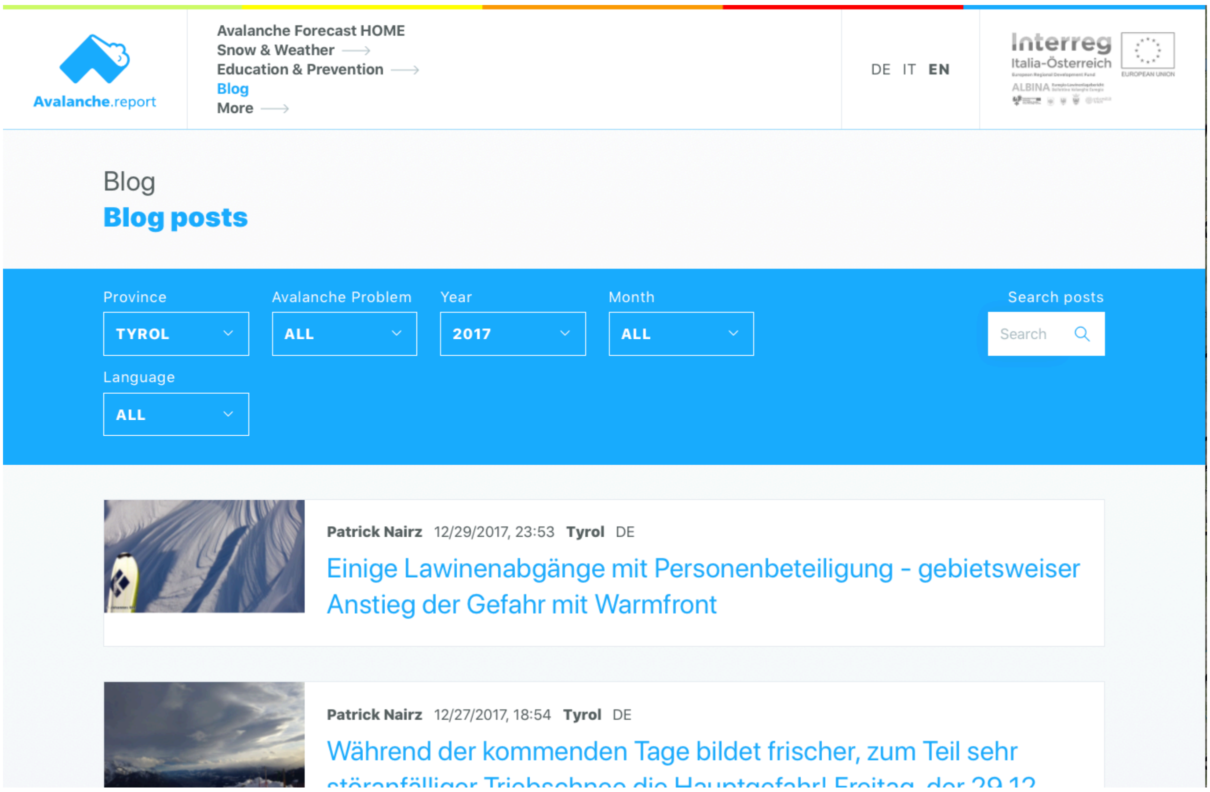

Figure 6: Example of blog posts on avalanche.report. Blogs may be filtered according to Province / State, year, language and Typical Avalanche Problem.

In addition, when following EAWS best-practices and standards, avalanche forecasts become very standardized and often forecasters do not have the possibility to address the needs of the various end users by e.g. describing in high detail the occurrence of a persistent weak layer or the raising of a catastrophic situation. To address exactly those different needs of the diverse user groups, we will accompany the avalanche forecast with two additional products: a forecasters blog and the possibility of special, detailed alerts for local authorities. The forecasters blog is already implemented, while the special alerts for local authorities are still in development. Within the blog post, avalanche forecasters may address especially backcountry recreationists with an unstandardized way of communication. Forecasters may use different language, graphs, pictures, videos, etc. to better explain the current and future avalanche situation (Figure 6).

6. CONCLUSION

We presented our way towards a conceptual approach in harmonizing the assessment and communication of avalanche danger for three neighboring avalanche warning services in Europe, namely Tirol in Austria and South Tyrol and Trentino in Italy. Within the project ALBINA, we had the opportunity to address objects notoriously known to be potential sources of inconsistency when assessing and communicating avalanche danger across forecasting borders: e.g. (1) avalanche danger assessment and forecasting production, (2) timing and validity of publication and (3) effective geo-communication. We built our conceptual framework around the suggestions on goodness of forecasts by Murphy (1993). In order to assure a high degree of consistency we implemented a common and streamlined workflow in assessing avalanche danger, a new set of smaller warning regions, which may be grouped dynamically according to the prevailing avalanche and snowpack situation. We harmonized timing and validity of avalanche forecasting products and offer a new, consistent set of products, which accompany the classical avalanche forecast on a regular basis. Starting with the winter season 2018-2019 Tirol, South Tyrol and Trentino will operationally use the presented framework accessible under avalanche.report and hence increase the consistency of forecasting products and the value for the users.

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