CONSISTENCY IN REGIONAL AVALANCHE FORECASTS: A LOOK ACROSS BORDERS

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ABSTRACT: Consistency in the way avalanche hazard is communicated in avalanche forecasts is essential to avoid misinterpretations by users utilizing bulletins issued by different warning services, for example, when backcountry recreationists travel across national or regional borders. Comparing avalanche forecast products in the European Alps, we note differences in the forecasts in respect to their issuing times and the duration the forecast is valid, but also in the spatial scale of the warning regions underlying the forecasts. Furthermore, variations exist in the way elevational gradients or temporal changes in avalanche hazard are communicated. Further, when exploring the use of the five-level ordinal European Avalanche Danger Scale, which is used by all warning services in the Alps, some differences appear. These are most obvious at danger levels *4-High* and *5-Very High*. These inconsistencies confirm the need to further harmonize the issued forecasts and the way avalanche hazard is communicated to increase consistency in the forecast products, and hence reduce misunderstandings for the travelling user.

KEYWORDS: avalanche forecasting, avalanche danger level, consistency, European Avalanche Warning Services

1. INTRODUCTION

The group of the European Avalanche Warning Services (EAWS) strives to provide society with efficient and accurate avalanche forecasts in order to reduce “the loss of lives and damages due to avalanches” (EAWS, 2017). To achieve this goal, EAWS has developed common standards, including guidance on criteria, structure and graphical output of forecast products (EAWS, 2017).

National or regional avalanche warning services (AWS) issue regional avalanche forecasts (also called bulletins or advisories) throughout the winter. Their main purpose is to inform and warn the public about the avalanche hazard and they therefore represent an important product to increase public avalanche safety. The bulletins provide information on the current and near-future snow and avalanche situation in a specified territory.

Already 25 years ago, the avalanche warning services operating in the European Alps and Pyrenees agreed on a common danger scale: the European Avalanche Danger Scale (EADS; SLF, 1993; EAWS, 2018a). The EADS is an ordinal, five-level scale, focusing on avalanche danger, with categorical descriptions for each danger level describing snowpack (in)stability, avalanche release probability, expected size and number of avalanches and the likely distribution of locations where avalanches may occur (EAWS, 2018a). A danger level is typically issued for areas larger than 100 km2, and describes expected conditions at time scales of 6 to 24 hours (Techel and Schweizer, 2017).

Today, the EADS has become an integral part of avalanche forecasting in Europe. It is used by the AWS of the European countries (except Sweden). The EADS is also the binding guideline used by forecasters to determine the danger level in a region.

Further efforts to increase coherence included the introduction of a common, standardized language to describe avalanche conditions (including translations into nine languages; EAWS, 2018b), or the use of a common avalanche size classification (EAWS, 2018b). Furthermore, EAWS members

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are encouraged to summarize typical avalanche situations using the concept of the typical avalanche problems (EAWS, 2018c).

With this study we intend to provide the producers and users of avalanche forecasts with a summary highlighting some of the main differences between avalanche forecasting products in the Alpine countries. Furthermore, we graphically explore the (spatial) consistency in the use of the danger levels, focusing on the upper and lower end of the danger scale.

1.1 Avalanche forecast products in the European Alps: There are differences!

Avalanche bulletins are available in all the countries in the Alps. Links to the websites of the national and regional warning services, and their products, are provided on www.avalanches.org, the official website of the EAWS.

Generally, there is one forecast center responsible for a specific region, and hence only one forecast product valid. The exception is the Italian Alps, where often more than one warning service issues a forecast covering (in parts) the same area.

The time of publication and the temporal validity of the forecasts vary: forecasts may be published in the morning (for instance in some federal states in Austria), during the early or late afternoon (as for instance in France, Italy and Switzerland). They may be valid for the day the forecast is issued (in some federal states in Austria), or may be forecasts for up to 24 to 30 hours after publication. Finally, some warning services regularly update the forecast in the morning (e.g. in Switzerland).

Regional avalanche forecasts are issued for clearly specified regions, so-called warning regions (shown in Fig. 1). Often the regions' limits are visibly outlined in map-based bulletins. However, sometimes these regions are aggregated to larger regions with the same danger (as in Valle d'Aosta (VDA) or in Switzerland (SWI)). The size of the warning regions used in a forecast impacts the communication of the avalanche danger, as it defines the lowest spatial resolution available for the graphical communication of avalanche conditions. The size of these warning regions varies depending on the warning service, from those with regions being smaller than 200 km^2 (as in SWI, VDA or Trentino (TRE)) to about 2000 km^2 (as in Styria (STE) or in Lombardy (BOR)).

1.2 Concepts to communicate changes in danger level with elevational gradients and changes during the day

All warning services provide information on the most avalanche prone aspects and elevations. However, three different concepts are used:

- Only one danger rating is indicated, which describes the danger in the most avalanche prone elevations (e.g. in Switzerland, often in Italy).
- Two danger ratings can be indicated, above and below a specified elevation (in France, in Austria, in Bavaria (BAY)).
- Three danger ratings are published for the elevation bands 'below' and 'at' tree line and 'alpine' (in Livigno (LIV)).

All warning services inform users about temporal changes in the danger level during a forecast period. This may be done using icons, a number of danger maps or in text form.

2. DATA AND METHODS

To explore the use of the danger levels in the Alps, we rely on data from four winters (2011-2012 – 2014-2015: 477 forecast days) and from 23 of the 30 potential forecast centers. We calculated the proportion a danger level was forecast during these four winters. Figure 1 shows a map of the regions and forecasting centers concerned.

The data are described in detail in Techel et al. (in review).

3. RESULTS

Fig. 2 shows the distribution of published danger levels across the European Alps. Danger levels *2-Moderate* and *3-Considerable* are forecast about 80% of the time, regardless whether we consider the forecast danger level valid in the first time-step, often corresponding to the situation in the morning (Fig. 2a), or the highest danger level issued (Fig. 2b).

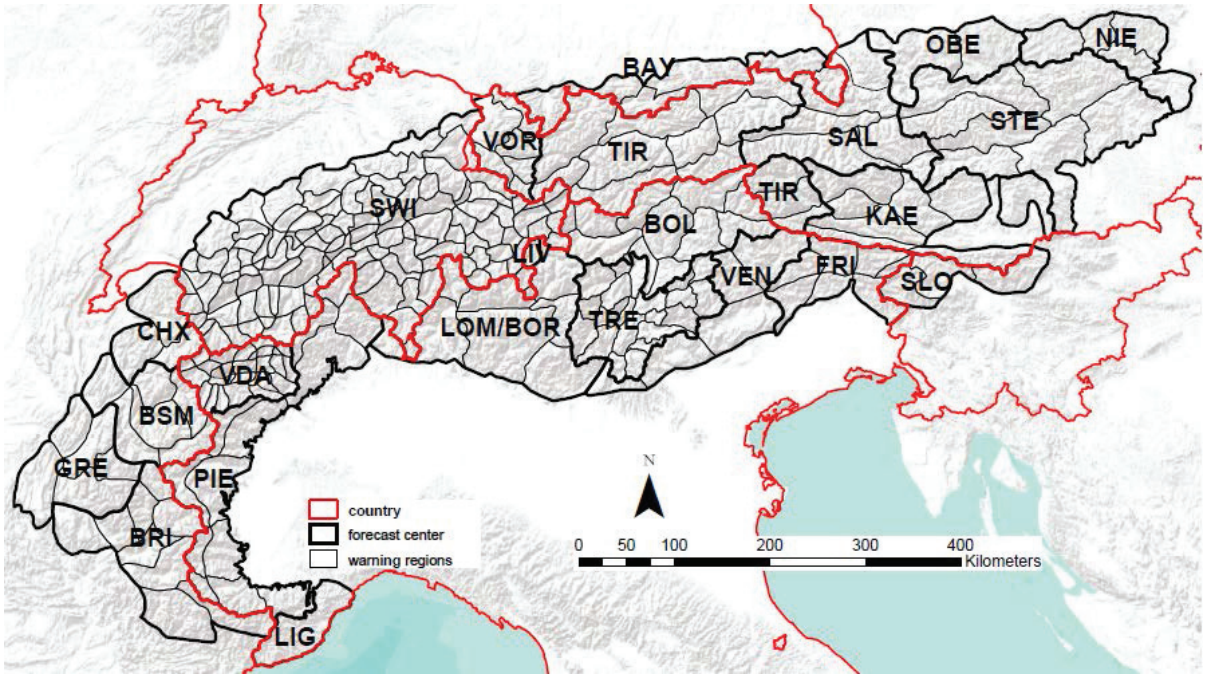

Fig. 1: Map showing the relief of the European Alps (gray shaded background) with the outlines of the individual forecast centers (bold black outlines, three-letter abbreviations) and the warning regions, the smallest geographically defined regions, used in the respective avalanche forecasts (thin black outlines). The national borders of the Alpine countries are outlined in red. In the Italian Alps, where two avalanche warning services provide forecasts (AINEVA and Meteomont Carabinieri), the warning regions shown generally follow AINEVA. Exception is LIG (Meteomont Carabinieri). The forecast domains of LOM (AINEVA) and BOR (Meteomont Carabinieri) are identical, however, the three warning regions for BOR are not shown on the map. The forecast domain LIV is superposed onto parts of LOM/BOR (map source: ESRI, 2017). Note that the map captures the situation and partitioning during the period under study.

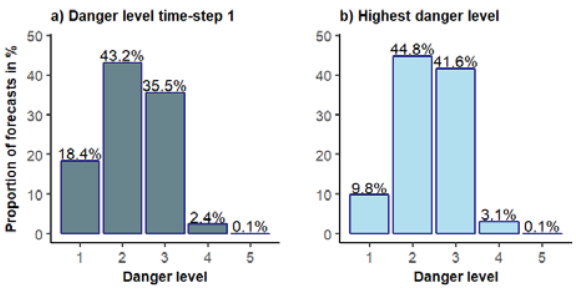

Fig. 2: Frequency distribution of the forecast avalanche danger level per day, (a) for the danger level forecast in a first time-step (often corresponding to the morning) and (b) the highest danger level (often in the afternoon). Mean values are shown for all the warning regions in the Alps taken together.

However, differences are even more pronounced when comparing danger level distributions from different warning regions in the Alps. Exemplarily, this is shown for the proportions of forecasts at the lower and upper end of the danger scale (Fig. 3). Danger level *1-Low* is forecast most frequently in regions with lower elevations along the Northern and Southern rim of the Alps, but particularly often in the lowest-lying regions in the East, where in some cases more than 50% of the forecasts have danger level *1-Low* (Fig. 3a). In contrast, the higher danger levels *4-High* and *5-Very High* correspond not only to regions with higher elevations but are also more frequently issued in parts of France and Italy (particularly in the Briançon (BRI), Piedmont (PIE) and Lombardy (LOM) forecast domains), while SWI and VDA stand out for comparably low usage of these danger levels despite having similarly high mountain ranges as their immediate neighbours.

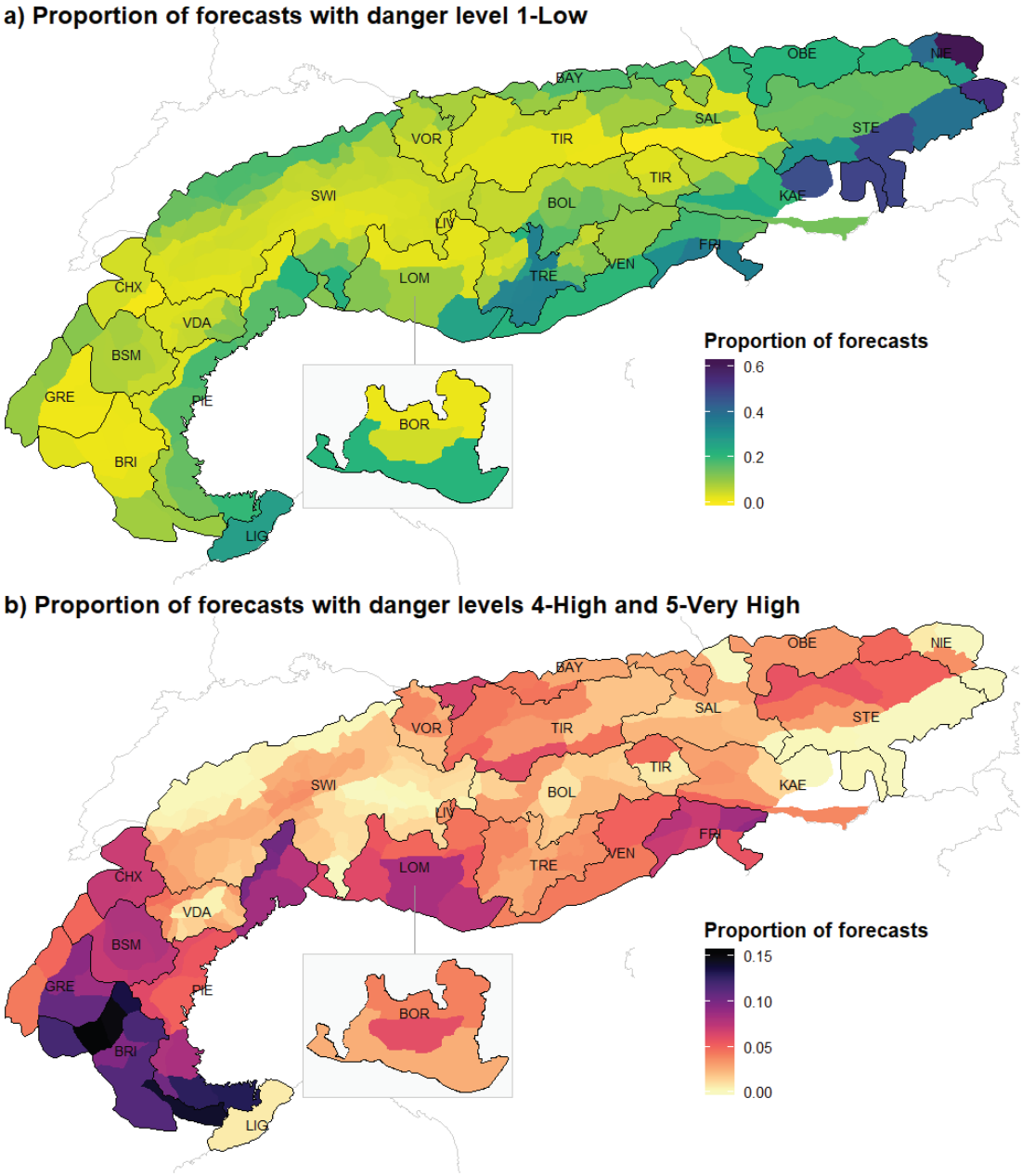

Fig. 3: Maps showing the proportion of forecasts with (a) danger level *1-Low* and with (b) danger level *4-High* or *5-Very High*. The colour coding corresponds to the respective proportion of forecasts and is optimized for readability. Black lines outline boundaries of forecast center domains. The forecast centers LOM (AINEVA) and BOR (Meteomont Carabinieri) both provide forecasts for the province Lombardy. BOR is shown as inset.

4. DISCUSSION

4.1 The use of the danger levels: some inconsistencies

Visual interpretation of Fig. 3a shows large-scale patterns of lower and higher proportions of danger level *1-Low*. Often, similar values are found in neighboring regions across forecast center boundaries, indicating a rather consistent use of this danger level across the Alps.

In contrast, the use of the two highest danger levels is considerably more heterogeneous (Fig. 3b): national or forecast center boundaries often coincide with an abrupt change in the frequency of

these danger levels. Of note are the relatively large differences between SWI and VDA compared to their neighbors in the West and South. Furthermore, frequencies of danger levels *4-High* and *5-Very High* in the BRI forecast domain are particularly high (up to 15% of the days). The difference between SWI and VDA and its neighbors in the West and South can, at least partially, be explained by the size of the warning regions, which are much smaller in SWI and VDA (Fig. 1). This in turn may affect the danger level communicated in the forecasts, particularly for danger levels *4-High* and *5-Very High*. Assuming that a warning service wants to communicate the highest danger rating for a warning region, SWI and VDA have the chance to combine the regions affected, while other warning services will have to generalize at a greater spatial scale (for details refer to Techel et al., in review).

4.2 *Intermediate danger levels*

As shown in Fig. 2, danger levels *2-Moderate* and *3-Considerable* are forecast more than 80% of the time. However, these danger levels not only span a wide range of avalanche situations ranging from conditions when natural avalanche release is possible on many slopes to situations when avalanches may be triggered only in some slopes and by additional loading. This demonstrates clearly, and is emphasized by the EAWS, that the danger level by itself is insufficient to describe in detail the current conditions. Therefore, and particularly at these danger levels, additional information provided in the forecasts like the dominant avalanche problem and the danger description will provide valuable information (Engeset et al., in review).

5. CONCLUSION

We have shown that differences exist in avalanche forecast products and in the way the danger level is communicated, but also in the frequency the higher danger levels are issued. With the EAWS being committed to enhance the communication and awareness of the avalanche danger to all user groups (EAWS, 2017), and considering the large numbers of winter sport recreationists and professionals travelling to different countries for leisure activities[1], we emphasize the need to further harmonize forecast products and the application of the danger scale. Users, when reading bulletins issued by other warning services, should be aware that differences in the forecast products might exist.

A full description of the data, methods and the results of the study, including an in-depth discussion can be found in Techel et al. (in review).

[1] Avalanche accident statistics show that many of the victims died outside their country of citizenship or residence, as for instance in Switzerland where 35% of the victims were citizens of different countries (Zweifel et al., 2012), while 10% of the Swiss citizens who died in avalanches died outside Switzerland (Winkler et al., 2016)).

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