WINTER 2013/2014 ON THE ITALIAN ALPS – ANALYSIS AND LESSON LEARNED ABOUT AVALANCHE RISK TREATMENT AND MANAGEMENT STRATEGIES

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ABSTRACT: Winter 2013/2014 in Italy was the second warmest since 1800. At low elevation it was characterized by frequent as well as abundant rainfalls (>62% above the average value for the reference period). At high elevations (above 1500 m a.s.l.), on the other hand, the winter season recorded remarkable amounts of snow on the Italian side of the Alps: exceptional values of snow cover, up to more than 800 cm, has been cumulated at 2000 m a.s.l. (around twice the long-term average) and fresh snow fell for single event up to 150 cm/24 h. During December and January the snowpack was composed, at its deepest levels, by persistent weak layers and slippery interfaces covered by subsequent heavy snowfalls which led to a short but intense period of instability (several provoked avalanches). As such weak base was covered by fresh snow, it no longer exerted any influence on the triggering of avalanches. Subsequent snowpack instability was first focused in the uppermost snowpack layers due to the weakening effects of further periods of precipitation and finally was extended to the whole thickness due to the exceptional overload and percolation of liquid water. A critical avalanche situation prevailed for an extraordinarily long period along all the Alps. Spontaneous avalanches reached mountain huts, ski slopes and ropeways as well as roads and small villages. Avalanche protection measures were severely damaged and artificial avalanche release, in spite of their extensive use, were not always satisfactory in reducing the risk. Several insights arise from this recent experience.

KEYWORDS: Italian Alps, Winter 2013-2014, Avalanche criticalities

1. INTRODUCTION

During the last winter, the northern and central regions of Italy experienced a persistent and intense climatic anomaly: precipitations (liquid and solid) were extremely abundant - reaching in some regions cumulated values (Dec., Jan. and Feb.) ever observed during the last 90 years - and temperatures were mild, with positive anomalies more intense and widespread in the minimum values other than in the maximum. The quarterly averages of the Tmin remained almost anywhere above the climatic norm. These climatic anomalies affected the snowpack which was, usually, thin on the Apennines (due to the high temperatures and frequent rains), but locally very or exceptionally thick on the Alps.

These particular climatic conditions have been associated with persistent abnormalities in the large-scale atmospheric circulation which involved most of the Northern Hemisphere compared to climate 1961-2000.

In this context, during the last winter (from mid-Dec. to early Mar.), these Italian regions have often been affected by perturbed systems (one every two days or so) connected to the North-Atlantic deep depressions, associated with lows and secondary cyclogenesis over the western Mediterranean. These systems conveyed moist and mild air masses which have led to frequent and extensive cloud cover and large amounts of precipitation (commonly solid only above 1000-1200 m of elevation).

Overall, throughout Italy precipitations twice the norm have fallen, but the maximum cumulated precipitations (liquid and solid) were reached on the eastern Alps and the northern Apennines with quarterly amounts from two to five times above the average value (A.A., Gruppo di Lavoro ArCIS, 2014).

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The largest peaks of precipitation were recorded in the Friuli-Venezia Giulia Region, where the cumulated values over three months exceeded 2500 mm (a value 4 to 5 times larger than the climatic norm for the reference period and a new record. over the last 50 years for Jan. and Feb.).

In this region, the accumulated HN has reached, locally, values of 1567 cm, with an average HS of 400 cm at 2000 m of altitude. In the Dolomites area, accumulated HN has reached values of 635 cm (Arabba - Veneto Region - 1630 m above sea level) and up to 800 cm (Primiero - Trento Province - 2000 m above sea level). In the Central Alps (Lombardy Region) this value has exceeded 400 cm at 1800 m of altitude and in the western Alps (Valle d'Aosta Region and Piemonte Region) the accumulated HN at 2000 m of altitude was variable between 200 and 300 cm (Valt and Cianfarra, 2014; A.A., Servizi Valanghe AINEVA, 2014).

2. ANALYSIS

A dimensionless SAI index (Standardized Anomaly Index) has been used to investigate the magnitude value anomalies: this Index has been compared with annual or seasonal average values of the individual stations.

2.1 HN – height of new snow, depth of snowfall

The seasonal cumulated HN value, expressed as SAI Index and calculated throughout all the Italian Alpine regions, indicates a value higher than the 0.90 percentile and therefore the 2013-2014 winter is defined as "extreme or rare" for its snowfall amounts (Fig. 1). Only the 1950-1951 winter shows higher values.

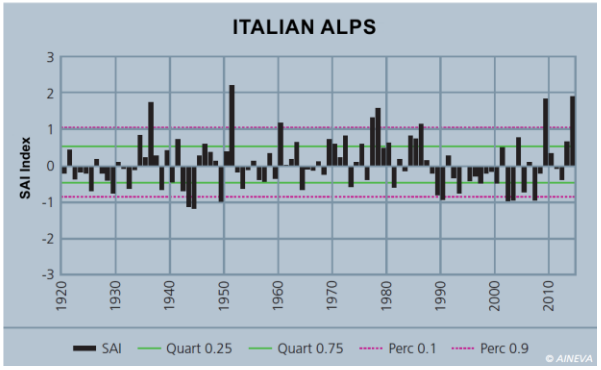

Fig. 1: seasonal cumulated HN on the Italian Alps [SAI Index] for the period 1920-2014 [after Valt and Cianfarra, 2014].

The analysis of the 3 main areas of the Alps (Western, Central and Eastern – Fig. 2) highlights a great diversity of cumulated HN in the three sectors (Fig. 3, 4, 5).

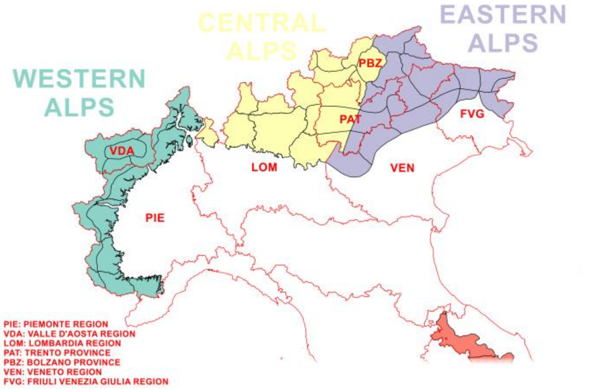

Fig. 2: main area of the Italian Alps, homogeneous forecasting zones (black) and regions (red).

In the western Alps (from the Ligurian Alps to Lake Maggiore), the SAI index was higher than the 3rd quartile and for the period 1985-2014 it was only lower than 2008-2009, 2003-2004 and 1985-1986 winters – (Fig. 3).

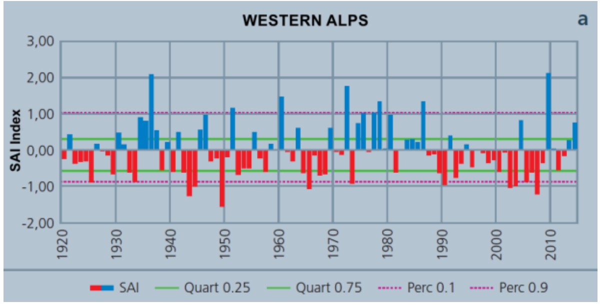

Fig. 3: seasonal cumulated HN on the Western Alps [SAI Index] for the period 1920-2014 [after Valt and Cianfarra, 2014].

In the central Alps (from Lake Maggiore to the Adige river), the SAI Index was the second from 1930 onwards, preceded only by 1936, and by being higher than the 0.90 percentile this winter is classified as "extreme or rare" (Fig. 4).

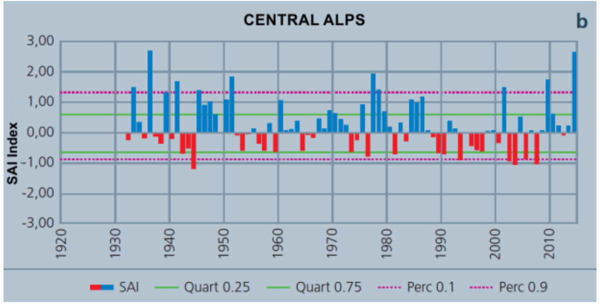

Fig. 4: seasonal cumulated HN on the Central Alps [SAI Index] for the period 1920-2014 [after Valt and Cianfarra, 2014].

Even in the eastern Alps (from the left bank of the Adige river up to the Julian Alps), the SAI Index was higher than the 0.90 percentile, confirming the this winter season may be classified as a "rare and extreme", like winter 1950-1951, which recorded an higher value (Fig. 5).

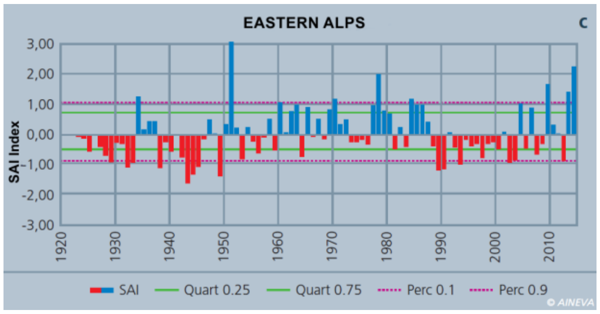

Fig. 5: seasonal cumulated HN on the Eastern Alps [SAI Index] for the period 1920-2014 [after Valt and Cianfarra, 2014].

The analysis shows values above average reference (1975-2009) for the cumulated HN values (on a monthly basis for the three different alpine areas), but to a different extent depending on the domain (Fig. 6).

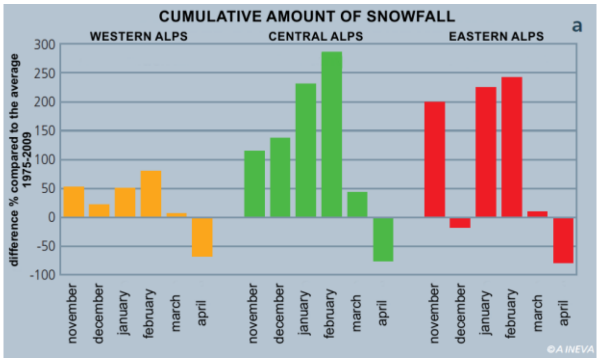

Fig. 6: cumulated HN on a monthly basis [difference %] compared to average values for the period 1975-2009 [after Valt and Cianfarra, 2014].

In the western Alps, the cumulated HN value was higher than the average reference (between Nov. and Feb.).

In the Central Alps, the cumulated HN value was much higher than average and has increased from Nov. to Feb.. In the eastern Alps, the cumulated HN value was above average in the months of Nov., Jan. and Feb., while in Dec. (due to the high elevation of the freezing level) the value was around average.

For the three sectors, the cumulated HN values of Mar. were around the norm, while in Apr. they were significantly lower than the average reference (1975 – 2009) - (Valt and Cianfarra, 2014).

2.2 *HS – height of snowpack, snow depth*

The average index value of the HS was 117 cm (calculated for the Italian Alps for the Nov. – Apr. period over a altitudes range of 1,500 up to 2,500 m a.s.l.) - (Fig. 7).

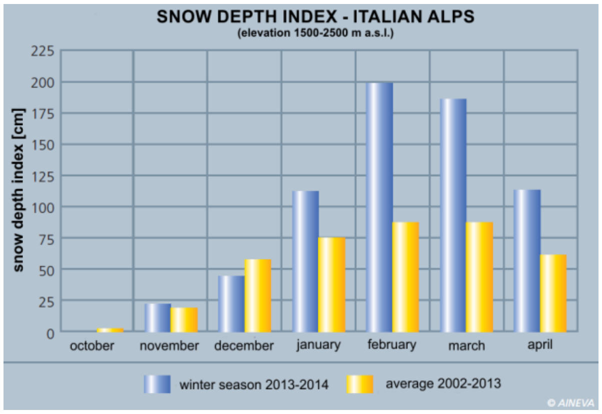

Fig. 7: index of average HS for winter 2013-2014 drawn, by month, on a selected data set of 20 representative stations above 1500 m of elevation. The index is compared with average value for the period 2002-2013 [after Valt and Cianfarra, 2014].

Such value was the second one, in average, between 2002-2013 and was preceded only by the 2009 value of 138 cm. The same indices calculated for the Feb. and Mar. were also higher than 2009 ones, while Dec. 2008 and Jan. 2009 values were higher than this season (Valt and Cianfarra, 2014).

2.3 *Winter and snowpack evolution*

The 2013-2014 winter season showed a similar trend, in all areas of the Alps, but characterized by different intensities of some snowfalls. Several snowfalls occurred, during the last decade of Nov., to create the snowpack base, followed until Christmas, by a long period of good weather and mild temperatures. During the second decade of Dec. the Alps were reached by an intense snowfall characterized by higher freezing level in the eastern Alps. On Dec. 26th, the western sector has suffered heavy snowfalls, while the precipitation of 5th-6th and 14th-20th Jan. 2014 were more intense onto the central Alps and onto the piedmonts. Such snowpack evolution, characterized by alternations of “cold” and “warm” intense snowfalls, favored the development of persistent basal weak layers (MFpc, MFsl, FCxr, DHxr) and slippery interfaces (crusts - MFcr, IFil, IFrc) followed by a short but intense period of instability. The snowfalls of 30th Jan. to 10th Feb. were particularly more intense on the eastern Alps, on some areas of the Central Alps and in the northern part of the western Alps. In the latter area, the strong south-easterly wind of Feb. 6th, accompanying the precipitation, highly contribute to increase the accumulated fresh snow. Subsequent snowpack instability was first focused in the uppermost snowpack layers due to the weakening effects of several periods of precipitation but gradually it was extended to the whole thickness due to the exceptional overload and percolation of liquid water towards the ground. The snowfalls from Feb. 26th to Mar. 5th, have affected the Alps, being more intense onto the Western Alps, with snow even at 400-600 m elevation. A period of strong warming and subsequent snowpack ablation, thus significantly increasing the percolation of liquid water towards the ground, followed the latter snowfall event until the new 22nd-26th Mar. precipitations which were more intense onto the central Alps. On 4th-5th Apr. a new intense snowfall affects only the Maritimes Alps (SW sector) followed by new precipitation episodes all over the Alps on the 19th-21th and 27th-30th Apr.. The winter season has also been characterized by a snowfall event mixed with the Sahara Desert's dust (19th Feb. 2014) that has colored the landscape, of all over the Alps, with amber – red tone. Depending on the altitude and exposure, along this horizon, a melt-freeze crust further developed allowing the growth of faceted crystals above and below the crust itself (Fig. 8).

Fig. 8: Sahara's desert dust coloring the landscape and concentrated into the MFcr layer [courtesy Autonomous Province Bolzano and ARPA Piemonte, 2014].

On this diffuse and often weak layer, in the weeks immediately following, several small and medium-sized (sometime large) surface avalanches detached. After the first decade of Mar., this horizon has enhanced, due to its low albedo, the absorption of heat in the snowpack and its strong wetting, thus favoring the full depth and gliding avalanches.

The snowpack duration has been strongly influenced by the mild winter temperatures which favored heavy rains at low altitude. During the period Dec. – Apr., in the elevation range between 800 and 1500 m a.s.l., the snow cover duration has been 50 days shorter than the period 1961-1990 average (110 days) while, above 1500 m of altitude, it was 2 days longer than the average (145 days) - (Fig. 9).

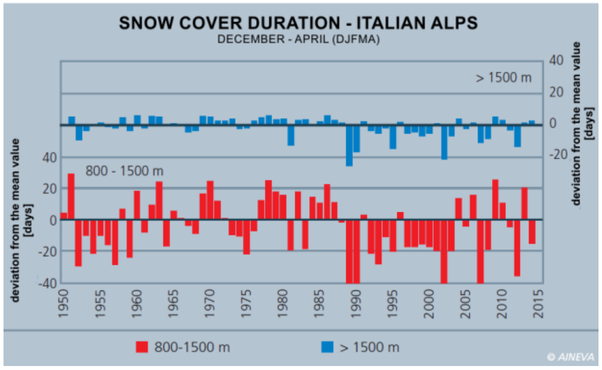

Fig. 9: snow cover duration calculated as a standard deviation from the mean value (period 1961-1990) for two altitude ranges: 800-1500 m (8 stations) and above 1500 m (8 stations) - [after Valt and Cianfarra, 2014].

During the period Mar. – Apr., in the elevation range between 800 and 1500 m a.s.l., the snow cover duration has been 9 days shorter than the period 1961-1990 average (36 days) while, above 1500 m of altitude, it was 2 days shorter than the average (58 days) - (Valt and Cianfarra, 2014; A.A., Servizi Valanghe AINEVA, 2014).

2.4 *Avalanche activities and danger levels*

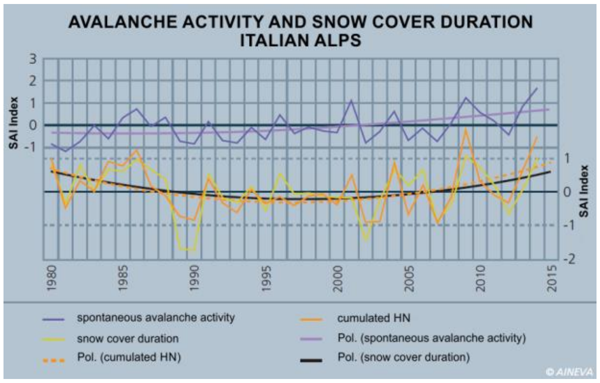

Fig. 10: Avalanche activity index compared with snow cover duration and cumulated HN [SAI Index] for each winter (period 1980-2014) onto a data set of 12 significant stations - [after Valt and Cianfarra, 2014].

The winter season has been characterized by frequent avalanche activity from late Dec. to late Apr.. Due to succession of snowfalls and continued basal snow cover instability, a high number of days with avalanches occurred in almost all regions. In general, the SAI Index analysis of daily avalanche observations (avalanches present, versus avalanches absent), has shown the highest value since 1980 – (Fig. 10).

By examining the daily observations data (Fig. 11), using the AINEVA's Model 1 codes (many medium-sized avalanches – cod. 3 group L1; single large natural avalanches – cod. 4, group L1) it is observed that along all the winter season was characterized by spontaneous avalanche activity and especially during the periods: 27th Dec.; 7th Jan.; 2nd-6th Feb. (intense snowfalls); 16th-24th Feb. (snowfalls and wind); 10th-16th Mar. (major rise in temperature); 5th-13th Apr. (new rise in temperature); 20th-22nd Apr. (snowfalls). The spontaneous avalanche activity can be compared with the number of avalanche accidents.

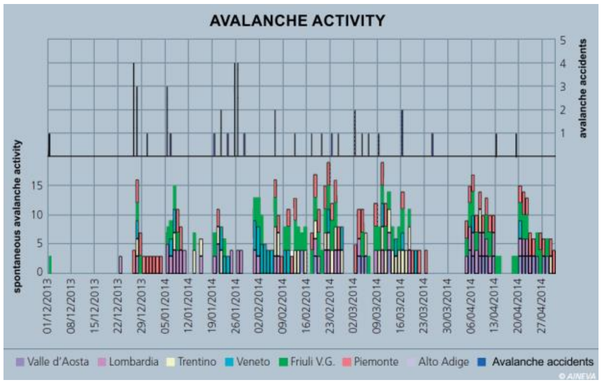

Fig. 11: Days with significant avalanche activity (winter 2013-2014) broken down by region and avalanche accidents - [after Valt and Cianfarra, 2014].

The highest concentration of accidents occurred: 26th-27th Dec.; 5th Jan. (during a snowfall mixed with rain); 25th–26th Jan. (after a snowfall with wind); 6th Feb.; 2nd and 16th Mar. (snowfalls with wind) – (Fig. 11).

Along the Italian Alps, considering the 47 forecasting zones, the avalanche danger levels were used with the following percentages (Fig. 12):

- 1 – low (23%);
- 2-moderate (37%);
- 3 – considerable (34%);
- 4 – high (6%);
- 5 – very high (1%).

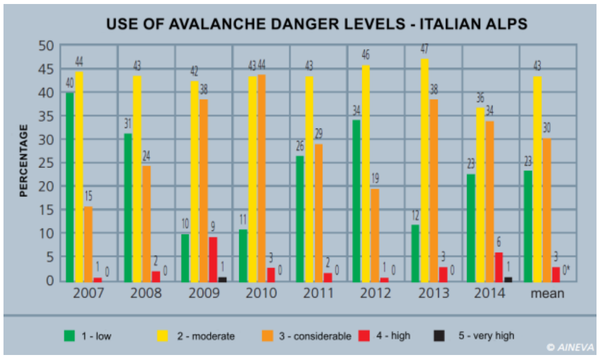

Fig. 12: % usage of danger levels in the 7 regional avalanche bulletins during the last 8 winter seasons and mean value - [after Valt and Cianfarra, 2014].

In Veneto and Friuli Venezia Giulia regions the danger level 5 – very high was used for the first time since the 5 degrees danger level scale is used (since 1994).

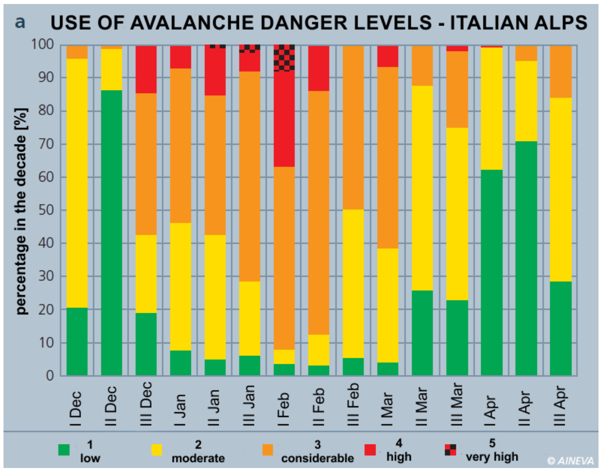

Fig. 13: % usage of the danger levels in the 7 regional avalanche bulletins (47 AINEVA's forecasting zones) for the different winter decades - [after Valt and Cianfarra, 2014].

The figure 13 shows the utilization percentage of the avalanche danger levels for the different winter decades both in total and for each macro areas (Fig. 14, 15, 16).

The danger level 1 – low was often issued in Dec., and then it was increasingly used by the end of Mar. to mid-Apr.. The danger level 2 – moderate was scarcely used especially during the first two decades of Feb. and mainly in the western and central alpine sectors. The danger level 3 – considerable was often issued between the third decade of Dec. and the first of Mar.. The danger levels 4 – high and 5 – very high have been issued more often between the third December's decade and the second February's decade - (Valt and Cianfarra, 2014; A.A., Servizi Valanghe AINEVA, 2014).

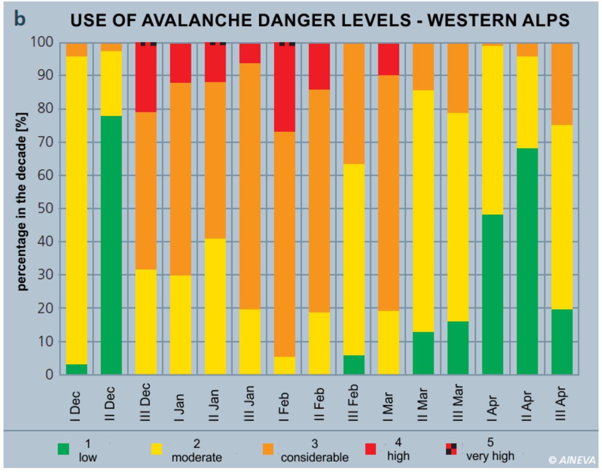

Fig. 14: % usage of the danger levels in the western Alps regional avalanche bulletins (17 AINEVA's forecasting zones) for the different winter decades - [after Valt and Cianfarra, 2014].

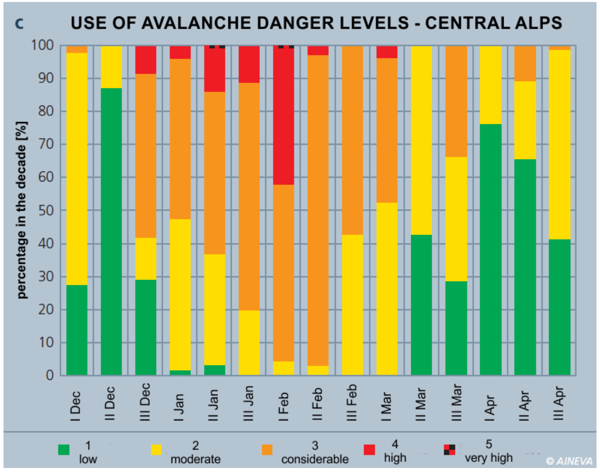

Fig. 15: % usage of the danger levels in the central Alps regional avalanche bulletins (17 AINEVA's forecasting zones) for the different winter decades - [after Valt and Cianfarra, 2014].

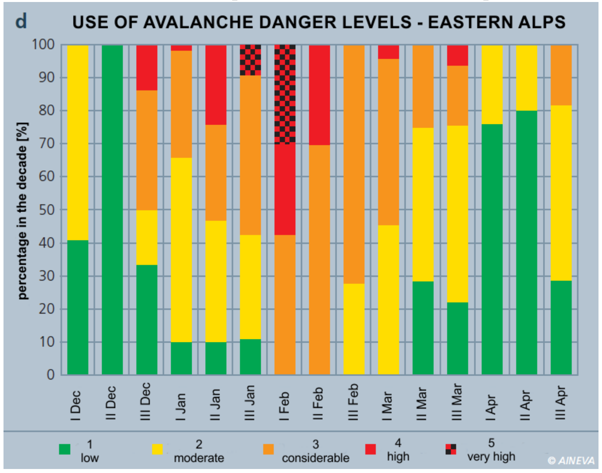

Fig. 16: % usage of the danger levels in the eastern Alps regional avalanche bulletins (21 AINEVA's forecasting zones) for the different winter decades - [after Valt and Cianfarra, 2014].

3. AVALANCHE CRITICALITIES

The spontaneous avalanche activity was a common phenomenon which characterized this incredible season. The heavy snowfalls, often mixed with rain up to 2000 m of elevation, have piled up onto unfrozen ground (up to 1800-2200 m of elevation due to mild temperatures). This has promoted a strong snowpack humidification, especially in the basal layers closer to the ground and also due to a lack of significant night-time irradiation, thus encouraging a widespread avalanche activity with medium, large and very large-sized events, mainly full-depth, gliding, and several surface-layer avalanches.

Fig. 17: farmhouse partially damaged, the 6th Feb. 2014, by the avalanche at Pillhof - Moos in Passeier - [courtesy Bolzano Province, 2014].

The avalanche activity has been very common especially on southerly aspects, on steep grassy slopes, with events that have affected entire slopes reaching down to the valley floor and thus causing major damage to infrastructure (roads, power-lines, mountain huts, farmhouses and ropeways) as well as woods which, during the past decades, had covered the old avalanche paths (Fig. 17).

The full depth and gliding avalanches were more frequent during the period 13th-25th Feb. and during the first two decades of Mar.. In the release areas, such avalanches have scraped the turf (dragging down the grass, bushes, young trees, earth, stones and locally starting significant surficial landslides), and severely damaging the snow supporting structures.

Many roads on the valley floors and on the main mountain passes were closed for avalanche danger for several days (up to a maximum, in the Dolomite area, of 70 days - Passo Rolle and 83 days – Passo Fedaia – Fig. 18) and during several events numerous vehicles (16) have been involved albeit without serious consequences.

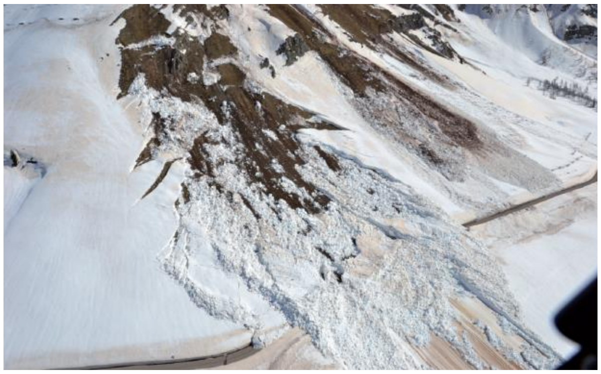

Fig. 18: national road n°. 50 at Passo Rolle interrupted the 16th Mar. 2014 by several large full-depth and gliding avalanches - [courtesy Trento Province, 2014].

Several insights arise from this recent experience - (A.A., Servizi Valanghe AINEVA, 2014).

3.1 *Management of avalanche criticalities*

The management of avalanche criticalities along roads, hamlets and ski areas, was carried out by local avalanche commissions or by groups of professional technicians (depending on the organizational model adopted by each region) in close collaboration with regional or provincial forecasting offices. Those activities were mainly observations, data measurements, local avalanche forecasting, monitoring and management interventions (road or ski area closures, evacuations of residential areas, artificial triggering of avalanches).

Several avalanche criticalities (loose dry snow avalanches or surface-layer slab avalanches) were handled properly and timely, especially those in which the scenario was easy to detect and monitor (heavy snowfall with quick HS increase, significant wind activity with slabs formation). In these scenarios, the more effective management measures were temporary closure of road or ski slope stretches and possible threatened buildings evacuation). Avalanches artificial triggering has given, often, satisfactory results; especially when weather conditions have allowed its timely execution. However, due to frequent poor or prohibitive weather conditions (several too close snowfalls, extended cloud cover) or too high amounts of fresh snow, employment and effectiveness of such management measures were, often, hampered. Many other avalanche criticalities (full-depth avalanches or gliding avalanches) have been poorly managed because the scenario appeared more difficult to detect, forecast and monitor (due to either the strong humidification and/or lubrication of the snowpack at its base or to its exceptional thickness). Many of these avalanches, in fact, occurred in unusual times or during poor visibility conditions and it was hardly to predict the pore saturation in liquid water capable of triggering avalanches or to increase the gliding speed. In such scenarios, the only most effective management measures were prolonged road or ski slope stretches closure and possible threatened buildings evacuation. Quite often, such measures were taken only after the partial detachment of some avalanches. Avalanches artificial triggering, by any means, has often proved totally ineffective due to the high snowpack thickness and its significant plasticity able to absorb artificially induced stresses - (A.A., Servizi Valanghe AINEVA, 2014).

4. CONCLUSIONS

Gained experience highlights that the full-depth avalanches or gliding avalanches, both in terms of forecasting and management possibilities, still require whether in-depth studies about formation and initiation mechanisms or the development of more effective management solutions. This will still require time and significant resources by the international scientific and technical community.

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