DESTRUCTIVE AVALANCHES IN THE MEDITERRANEAN REGION

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ABSTRACT: In the winter of 2016 - 2017, in the heart of the Mediterranean (Apennins – Italy), during a period of abundant snowfalls, large and very large destructive avalanches occurred in anthropized areas, such as Rigopiano, where a big hotel was buried, 29 people were killed and only 11 people were rescued. Avalanches of these characteristics and dynamics are not spatially and temporally isolated episodes, but fall within a historical series of avalanches that confirms the presence of a dangerous area in the heart of the Mediterranean region. It moreover suggests a connection with the climate change registered in the last decades and encourages in-depth analysis as well as a permanent supervision and evaluation of avalanche danger in the Mediterranean area.

KEYWORDS: avalanche danger, avalanche dynamics, Apennins, Rigopiano, climate change.

1. INTRODUCTION

As is known, mountain areas are fragile and complex ecosystems and thus extremely sensitive to climate changes. Studies undertaken in these areas are therefore considered of greater interest to better understand the global change and even more the local one, which directly affects the social and economic development of mountain areas (e.g. Romeo, 2001 a and b). Melting glaciers, poor snowfalls, irregular precipitation, rising temperatures and different thermodynamic genesis cause increasing uncertainties for touristic, recreational and sporting activities, as well as problems regarding water supply and safety in relation to the natural hazard strictly connected to such a change (e.g. Romeo, 2002). The Apennines are known as the mountain area rising all along the Italian peninsula, in the heart of the Mediterranean area and with the southernmost glacier of Europe (Gran Sasso d'Italia, 2910 mt). Owing to their geographical position they can be considered valuable indicators for snow and avalanche phenomena particularly influenced by these changes (e.g. Fazzini and Romeo, 2011, Fazzini et al. 2005). As regards snow and avalanches, Apennines have always been considered less important than the Alps, even if data collected over a period of 60 years by the State Avalanche Service of the ITALIAN FOREST SERVICE (nowadays METEOMONT CARABINIERI*) show respectable winter seasons of primary importance also for the public safety (e.g. Romeo, 2005; Romeo et al., 2008). Data and information about avalanches collected since 1957 have always shown a wide spread over the territory and frequent avalanche activity on Apennines, with phenomena of relevant size (even size 4 or 5 by the EAWS classification) and destructive effects. Gliding avalanches, nowadays of greater importance on the alpine ares, have always been evident on the Apennines, where proper attention has always been given to this phenomenon. The above-mentioned analysis, related to the latest winters (2005/2006, 2011/2012 and 2016/2017) characterised by abundand snowfalls, well spread medium or large, and in some cases, destructive avalanches, has shown the dangerousness of Apennines and highlights that a possible trend of such extreme phenomena could be expected to increase, if confirmed by further studies and analysis.

2. SNOWFALLS TIME SERIES ANALYSIS AND SAI INDEX

The SAI Index (Giuffrida and Conte, 1989), computed from seasonally cumulated snow fall, is used for the snowfall analysis of this study (Mercalli et al., 2003). Usually, these analysis are conducted considering a high number of measurement stations; for instance, to calculate the SAI Index of the Southern side of the Alpine range, more than 80 historical stations have been used (Valt and Cianfarra, 2018). Concerning Apennines, Gazzolo and Pinna (1973) described snowfalls during the four-year period 1923-1973. However, many measurement stations have been abandoned due to high management costs. In 1978 the METEOMONT snow and weather measurement network of the Avalanche Service - STATE FOREST SERVICE was implemented and Romeo et al. (2004 and 2008) perform first the analysis of snowfalls on central Apennines from 1978 to 2003 and to 2007. More recently, Valt et al.(2016) tried to describe

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Apennines snowfalls through the SAI Index using 24 measurement stations all over the area from Emilia Romagna to Molise region. Valt's et al (2016) work has been integrated with data from the last two winter seasons. Gradually some additional time series have been added and the database improved. However, the SAI Index referring to the whole Apennine range must be considered still experimental. The winter season 2016-2017 has been characterised by little snow in the Northern part of the Apennines and on the most part of the Tirrenic side. On the contrary in the central part of the mountain range, especially on the Adriatic side, unusually heavy snowfalls have been registered.

First SAI Index elaborations for the whole Apennines (Figure 1) show an average snowy winter season.

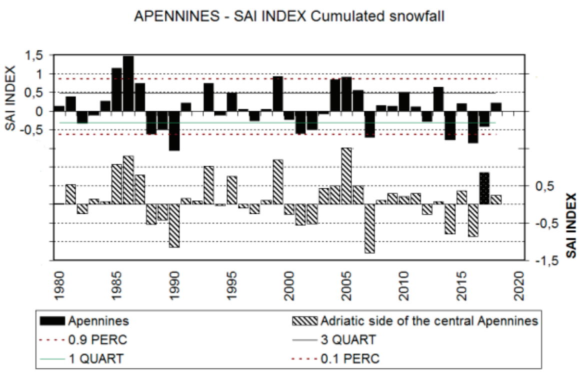

Figure 1: SAI Index of cumulated fresh snow for the central Apennines, Adriatic side.

However, an accurate analysis of the still active measurement stations, although with a limited time series from 2013 to 2018 (data available on line), shows how much central Apennine is snowy. Monthly snowfall for January 2017, compared to the 2013-2018 average, is shown in Figure 2. As can be seen, distribution of measurement stations with above average snowfalls (graphic symbol triangle) is highly concentrated. In the period between the 16th and 18th of January 2017, the sum of cumulated fresh snow, was higher than 100-150 cm. Many values have been estimated on the basis of the average depht of snow on the ground because many measuerement sites couldn't be reached. The average value of the depth of snow on the ground in January 2017 for each station is shown in Figure 3. These values confirm, in an even more pronounced way, the central Apennine area's great snowfall.

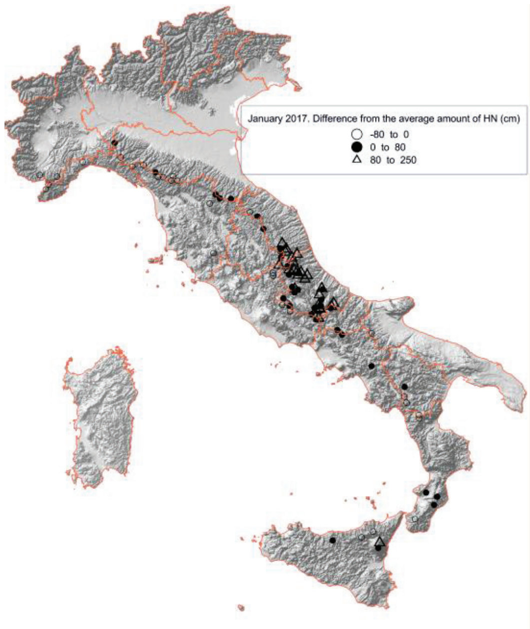

Figure 2: January 2017, difference from the average amount of fresh snow (cm)

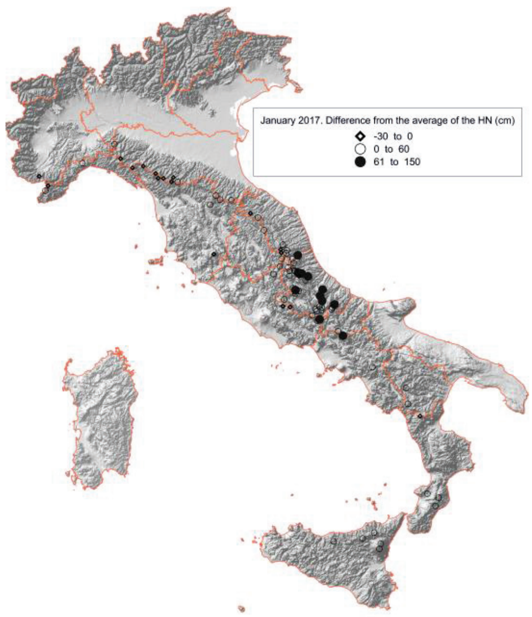

Figure 3: January 2017, difference from the average depth of snow on the ground.

3. HISTORICAL DESTRUCTIVE EVENTS IN THE APENNINES (MEDITERRANEAN BASIN)

The Italian Avalanche Service operated by the STATE FOREST SERVICE (nowadays METEOMONT CARABINIERI) was established in 1957 upon the request of the FAO (UN) Forestry Department and the Institute for Snow and Avalanche Research (SLF) of Davos. It represented the first systematic and harmonised system of avalanche data collecting in Italy. Throughout this activity, on the Apennines (a mountain range that extends from Liguria to Calabria) about 3.000 size 3 or bigger avalanche events (EAWS avalanche size classification, www.avalanches.org) were registered up to today. 377 of these were size 4 avalanches (volume of the detached mass between 10.000 and 100.000 cubic meters), and 39 size 5 avalanche (volumes over 100.000 cubic meters).

Figure 4: Distribution of size 4 and 5 avalanches.

All the size 4 and 5 avalanches have resulted in many victims (total 103) or damages: soil erosion, destroyed forests, damaged structures and infrastructures (houses, hotels, power lines, cableways). Regions involved were: Liguria (Brandolini p. et al., 2017), Emilia Romagna, Marche, Lazio, Abruzzo, Molise and Basilicata (see Figure 4). Anyway, the most severely and frequently affected regions were those in the central Apennines (Marche and Abruzzo).

Figure 5: Avalanche of Bolognola, 1930 (photo Balelli)

Most of the registered events occurred in the period from January to March during the years 1930, 1934, 1945, 1969, 1970, 1984, 1986, 1990 (December), 1998, 2006, 2011, 2013, 2015 and 2017. A possible increasing trend of destructive events can be noticed during the last decade. The most devastating events with the greatest number of casualties were: Bolognola (Marche region) in 1930 with 19 dead, Bolognola again in 1934 with more 19 dead (Figure 5 and 6), Pigna (Liguria region) in 1945 with 5 dead, Mendatica (Liguria region) in 1971 with 2 dead and town centre devastated, Stazzema (Tuscany region) in 1984 with 4 dead, Rigopiano (Abruzzo region) in January 2017 with a destroyed hotel and 29 dead (Figure 7).

Figure 6: Avalanche of Bolognola, 1934 (photo Balelli)

As the numbers demonstrate, during certain weather and snow conditions, can be registered a wide presence of dangerous and sensitive sites where size 4 or size 5 avalanche events (potentially destructive, capable of destroying forests and buildings and devastating the landscape, or everything found on their way) are likely to occur.

Figure 7: Avalanche of Rigopiano, 2017

Data analysis allows identification of events with flows capable of crossing terrains with small slope angle (below 3°),and with a destructive potential capable of destroying buildings and parts of forests (size 4 avalanches), of reaching the valley floor, devastating the landscape and expanding for 3 kms or more (size 5 avalanche).

4. AVALANCHE EMERGENCY OF JANUARY 2017

During the period from 16th to 25th January 2017, abundand snowfalls above 1000 mts all over central Apennines provoked a state of emergency with civil protection needed for many isolated settlements and the high avalanche danger in the regions of Marche, Lazio, Abruzzo and Molise. Phenomena were particularly intense and widespread in Abruzzo, mostly on the Gran Sasso mountain range, that owing to its geographical position, was directly affected by the atmospheric circulation effects coming from the Balkans, producing heavy snowfalls and strong winds. The snow stratigraphic profile performed on 20th January 2017 in Rigopiano (eastern side of Gran Sasso range – Abruzzo) shows in detail, as a text to to decipher, snowfalls and temperatures regarding that period and the relative transformation of the snow grains and the layers (Figure 8).

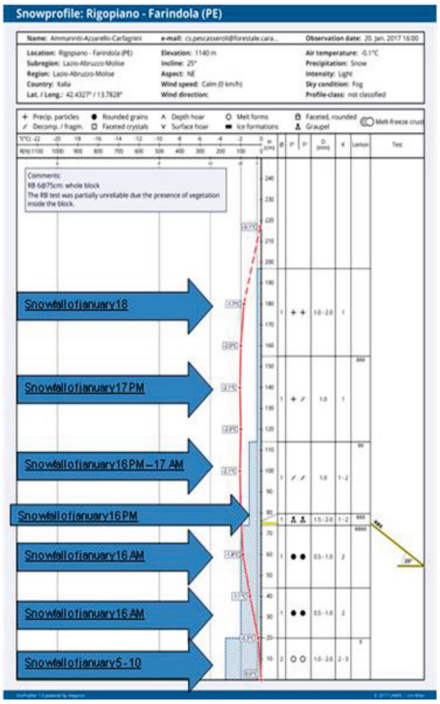

Figure 8: Snowprofile of January 20th, 2017.

The first snowfalls, followed by low temperatures (due to create a bottom layer) occurred between 5th and 10th January, with first 50 cm of cumulated fresh snow at 1200 mts. A second series of heavy snowfalls with moderate to strong winds, associated with low temperatures (from -18°C to -7°C) occurred during the period from 16th to 18th January with over 2 m of cumulated snow within three days and widespread avalanches all over the Gran Sasso North-Eastern side (Figure 9).

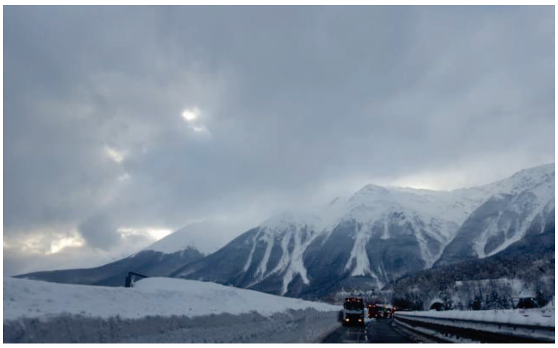

Figure 9: North -Eastern side of Gran Sasso - 20.01.2017

At the beginning of January, the thermal regime shows very low temperatures (minimum -18°C at 1200 m), sharply rising on 14th January (minimum -7°C) with maximum temperatures approaching 0°C between 17th and 18th January.Weak to moderate, locally strong, wind (always coming from the same directions (North-East, North-West) perfectly intercepted the Gran Sasso range favouring massive deposit of wind-drifted snow and cornices. On January 18th 2017 the highest numebr of avalanches was registered all over the Gran Sasso range: 206 avalanches between size 3 and 5, over a total area of 2700 ha, 520 ha of destroyed forest, 100.000 m^3 of snow-felled trees (whose age was between 60 and 40 years) for a total of 100.000 tons (Fagus sylvatica L.). Most avalanches provoked damages to woods, and also to roads and remote uninhabited refuges. In Rigopiano one single avalanche buried a big hotel hosting 40 people: 29 of them were killed and 11 rescued from the snow-covered wreckage (Figure 10). In Ortolano one house was involved with one victim.

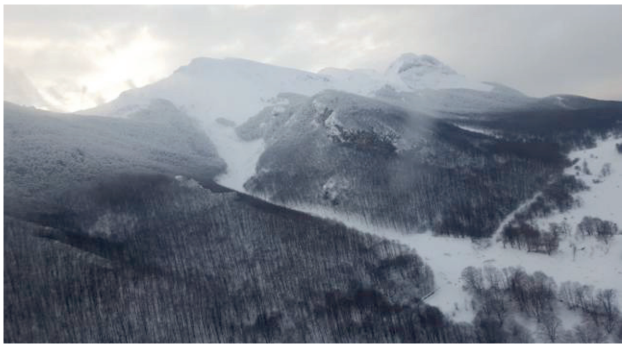

Figure 10: Rigopiano avalanche overview.

Even if the avalance events occurred with different effects on a wide area which includes 4 Apennine regions, the Rigopiano avalanche was widely reported in the media for the high number of victims during a single event. Also, for this reason, many anlyses and studies have been performed about this avalanche to understand its cause and dynamic. In these work a dynamic study was carried out using the model RAMMS (RApid Mass MovementS) developed by the Institute for Snow and Avalanche Research of Davos (Christen e al., 2010). The avalanche module is based on a single-phase, two-dimensional dynamic modeling providing the solution of the conservation of mass and momentum equations using a TVD scheme (Total Variation Diminishing) which is applicable to an unstructured triangular grid from the digital terrain model. Single or multiple release areas are easily specified using GIS type drawing features. It can also give information about the drag effect. Furthermore, this software is linked to a GIS interface able to load different input informations and return the main avalanche parameters into a spatial and organised model. The first results of RAMMS model simulation carried out with input data by METEOMONT CARABINIERI Service confirm all the destructive potential of Rigopiano avalanche (Figure 11).

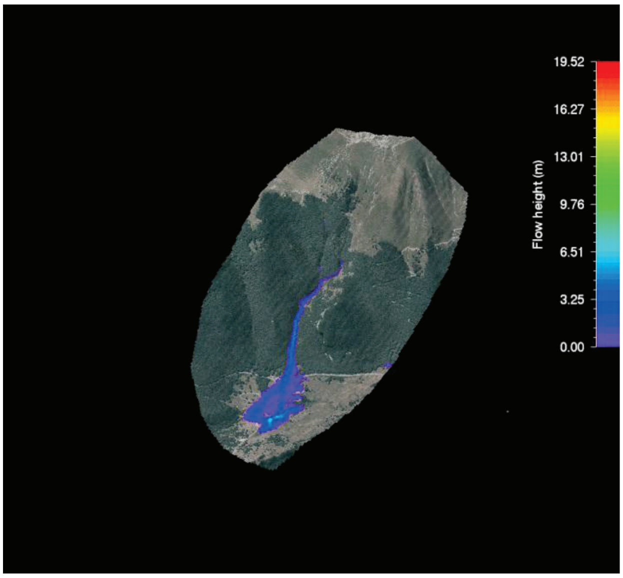

Figure 11: Rigopiano avalanche simulation carried out with RAMMS modeling.

5. CONCLUSION

The Apennines are formed by a series of mountain ranges extending 1300 km in lenght along the Italian peninsula, between 37 and 40 degrees north, in the Mediterranean area. The amount of fresh snow may vary considerably from the northern, central and southern part of the mountain range. The same value can even change from the Tirrenic to the Adriatic side, with the eastern sector usually more snowy than the western one. First elaborations of SAI snow index, highlight very much snowy seasons, alternated with other drier periods. However, as happened in January 2017, snowfalls can be very much intense in a single sector (central Apennine facing Adriatic sea, in this case) causing severe problem due to avalanches, as already happened in the past and like numerous reports of big avalanches over the time, especially in Gran Sasso mountain massif, can testify. In January 2017over 200 large size avalanches, occurring after the intense snowfalls of the period 16th -19th January (80-200 cm of fresh snow), have been reported. Rigopiano avalanche was not a time and place limited and isolated event, but represents historical, widespread and frequent avalanche activity in the heart of the Mediterranean, whose dangerousness for avalanches can be confirmed. It would also suggests a possible connection with the climate change of the last decades and calls for further consideration and studies on the Mediterranean area, where greater interest and closer attention in terms of monitoring, as well as better evaluation and management of avalanche danger would be recommended. In this regard, the Mediterranean mountain, lying on the southern border of the geographical area that limits the european perennial snows, could assume the relevant role of sensitive indicator for the climate changes and their effects on avalanches, also for more continental European mountain areas.

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