WINTER 2016-2017 SNOWFALL AND AVALANCHE EMERGENCY MANAGEMENT IN ITALY (CENTRAL APPENNINES) - A REVIEW

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ABSTRACT: The winter of 2016-2017 set a new record for snowfall and avalanches activity for Central Appennines of Italy (Marche, Abruzzo and Molise regions). Tens of destructive avalanches were reported during the 3rd week of January 2017 from several locations across the area. Several hamlets and infrastructures were menaced or hit by those events and in the Rigopiano site an hotel was totally destroyed with a death toll of 29 victims. This paper describes the general scenario which produced such events, how Italian avalanche technicians operated during the emergency aiding the Civil Protection in managing the situation and the subsequent scenario analysis. High resolution satellite images highlighted hundreds of avalanche events with impressive soft slab and loose snow avalanches which deposited massive piles of snow, woody debris and rocks in the tracks and in the runout zones creating fresh trimlines or widening the existing historical avalanche paths. Such disturbing events left behind many mature downed trees and extensive areas of vegetation damage, providing a unique opportunity to improve our knowledge of local avalanche spatial distribution and magnitude which was otherwise scarce and of poor quality.

KEYWORDS: winter 2016-2017, avalanche emergency management, Central Appennines.

1. INTRODUCTION

The beginning of winter season 2016-2017 in Italy was characterized by the persistence of a positive anomaly of the 500 hPa geopotential, located between the British Isles and Scandinavia. This intense block configuration was replaced, in Jan. 2017, by a negative anomaly centred on southern Italy which produced large snowfalls causing a disruption of primary services and producing serious damage and inconvenience to the population with tragic consequences too. Numerous large and very large avalanches released during such event of intense solid precipitation all along the Central Appennines including the one which produced the complete destruction of the Rigopiano Hotel and others which menaced or hit tens of hamlets and other infrastructures. Such scenario involved the Italian Civil Protection system in a demanding situation to handle such emergency.

2. WEATHER SCENARIO

Between January 15th and 16th 2017, a stationary and extremely intense long-wave trough well developed at mid and high atmosphere levels favoured a blocking configuration between the Azores's Anticyclone and a low-pressure area extended from Scandinavia to the Tyrrhenian Sea (fig. 1). Such configuration attracted cold maritime air from the Arctic over the Tyrrhenian Sea. The divergence associated with the jet stream trajectory further amplified its intensification and even colder continental air was moved, with an antizonal pattern, from Russia and Balkans towards the Adriatic Sea (fig 2).

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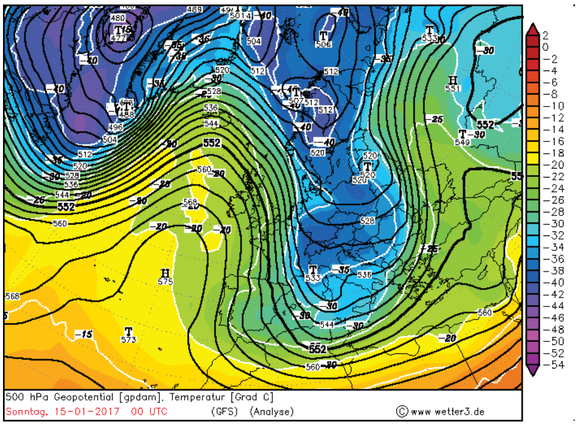

Fig. 1: Geopotential [hPa] and temperature [°C] at 500 hPa at 00 UTC on Sun. 15th Jan. 2017 (GFS model – source www.wetter3.de).

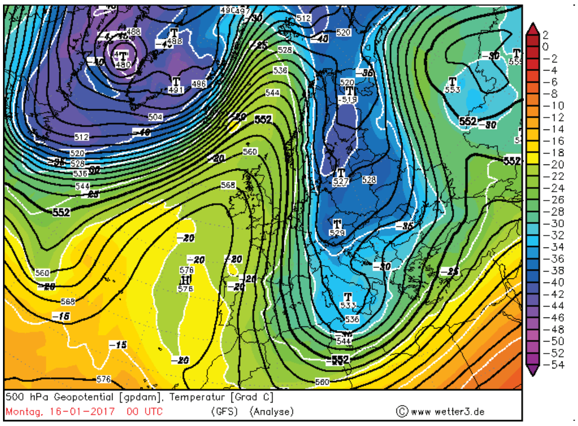

Fig. 2: Geopotential [hPa] and temperature [°C] at 500 hPa at 00 UTC on Mon. 16th Jan. 2017 (GFS model – source www.wetter3.de).

A strong vorticity advection, along the ascending branch of the trough, favoured a further worsening of precipitations on the Adriatic Sea area starting from Mon. 16th Jan.

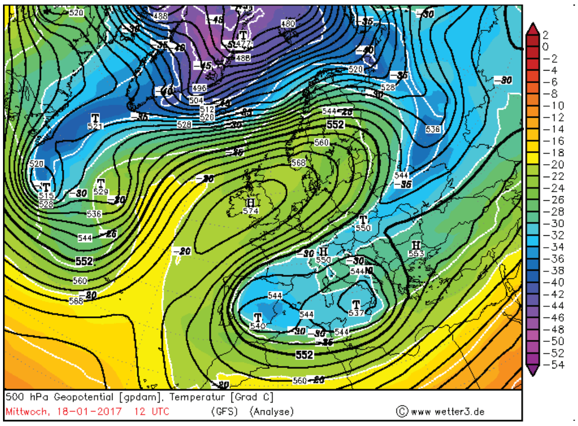

Fig. 3: Geopotential [hPa] and temperature [°C] at 500 hPa at 00 UTC on Wed. 18th Jan. 2017 (GFS model – source www.wetter3.de).

Meanwhile, the Azores's Anticyclone was gradually shifted towards the British Isles thus promoting, since from Tue. 17th Jan., a new block structure of the "high over low" type (fig 3). Such evolution reinforced a stationarity cyclonic structure over the southern Tyrrhenian Sea, characterized by a strong divergence and vorticity advection at all elevations.

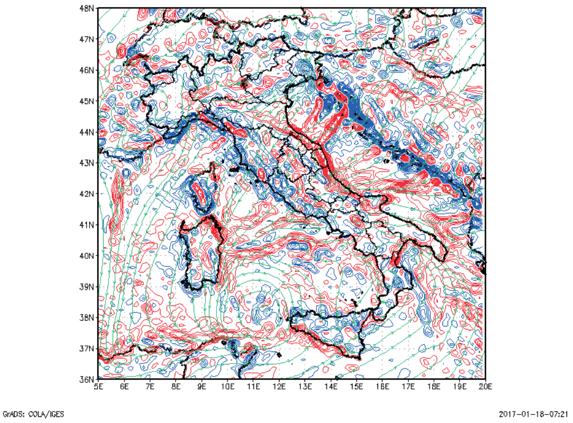

Fig. 4: flows and convergence (in red ascending motions, in blue descending motions) at 1000 hPa at 00 UTC on Wed. 18th Jan. 2017 (source ECMWF 0125).

Therefore, the interaction of very cold and strong N-E winds, entering from the Dinaric Alps, with the warm waters of the Adriatic Sea and the forced uplift against the Central Appennine range determined a marked convergence at low elevations (fig 4) and prolonged "stau" conditions which generated persistent heavy precipitations (solid above 200–300 m asl due to the low elevation of the freezing level) over the hills and mountains of Marche, Abruzzo and Molise regions lasting up to the 19th Jan..

At the end of the snowfall, the fresh snow cumulated values proved to be abundant over the whole Middle Adriatic sector, with higher values over the Abruzzo and the southern parts of Marche regions. The snowfalls covered an area of about 4.300.000 he. The average snowfall cumulated values at 1.500 m of elevation, for the period 15th–18th Jan., were between 150-300 cm on the eastern side of the Appennine range and around 100-150 cm on the western ones. Locally, such values were up to 500 cm due to the orography and wind activity (figs 5 and 6).

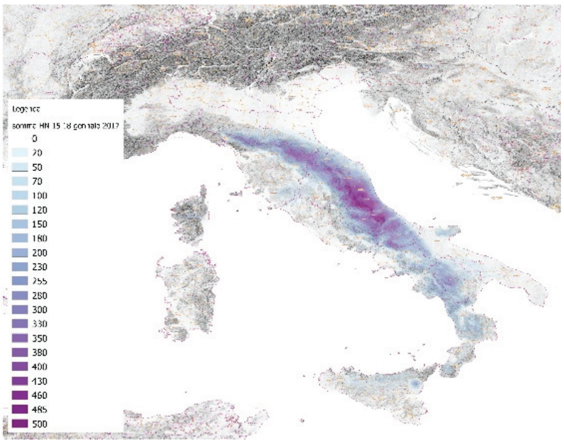

Fig. 5: fresh snow cumulated values [cm] for the period 15th – 18th Jan. derived from Moloch model (CNR-ISAC) and compared with the satellite images MODIS Snow Cover (Terra - MOD10/Aqua - MYD10) and Soil Moisture Active Passive (SMAP) "Snow Mass 9 km" (NASA Catchment Land Surface Model [source: https://worldview.earthdata.nasa. gov/].

Fig. 6: Campo Imperatore area (AQ) on the Gran Sasso d'Italia Massif as seen from the helicopter the 27th Jan. The slopes are blanketed by significant soft slab deposits with surficial wind dunes up to 3–6 m high [source AINEVA - photo Chiambretti].

The snowfalls at higher elevation (above 800 m) were characterized by a reduced density due to low Ta. Below such elevation, the new snow density presented more standard values. During the snowfalls of 16th Jan. the strong convective vertical motions gave rise to intense snow showers also accompanied by a short but widespread episode of “graupel” (PPgp) precipitation which constituted an unstable layer within the newly formed snowpack. The reduced density, the relevant snowpack thicknesses and the widespread presence of the PPgp layer maintained the snowpack in latent instable conditions for several days.

3. AVALANCHE ACTIVITY

A rapid and preliminary analysis of high-resolution satellite images (Google Earth Pro) has enabled us to identify the perimeter of 511 large and very large (extreme) avalanche events which released in the sectors most affected by the rapid accumulation of intense snowfall (fig 7).

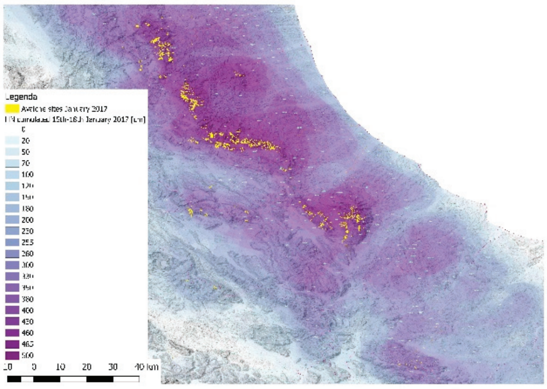

Fig. 7: identified avalanche sites (in yellow) of the Jan. 2017 event and fresh snow cumulated values for the period 15th – 18th Jan. derived from Moloch model (CNR-ISAC) and compared with the satellite images MODIS Snow Cover (ref. as in fig. 6).

The areas mainly affected by the avalanche activity were the Sibillini Mountains, the Laga Mountains, the Gran Sasso d'Italia Massif, the Majella Massif and the Matese Massif.

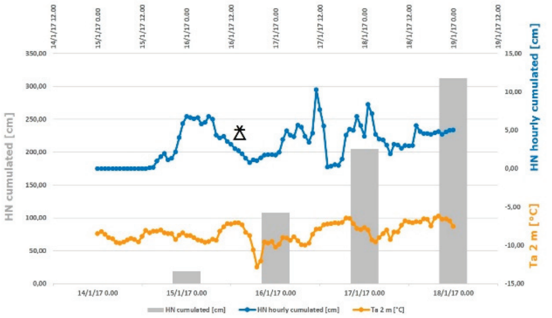

Fig. 8: HN and Ta mean hourly value, HN mean daily cumulated values for the Central Apennines area at 2.000 m from synoptic models.

The avalanche activity climax happened, mainly, during 17th and 18th Jan. and it was found to be concomitant with the reach of the cumulate "plateau" of the snowfall precipitation (fig. 8). Only in the areas closest to the epicenter of the seismic shakes of 18th Jan., the avalanche events were “seismically induced” before the achievement of maximum values. Those events were mainly triggered by localized collapses of rock masses from the steepest rock walls.

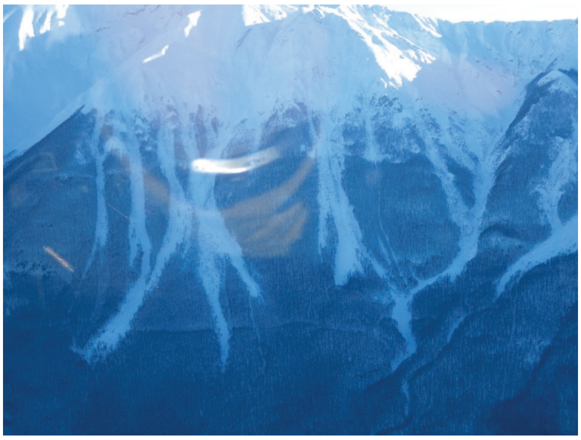

Fig. 9: Eastern slopes of the Gran Sasso d'Italia Massif as seen from the helicopter the 27th Jan. Several large avalanches have opened large trimlines in the woods. [source AINEVA - photo Chiambretti].

Many of these avalanches reached the valley's bottom seriously damaging the woods (fig 9) and were characterized by high velocity and impact pressures and by unusual long run-out distances due to reduced snowpack density and to frequent entrainment, along the track area, of trees, rocks and debris which increased their mass and speed. Most of such avalanches can be categorized as soft slabs or loose snow types which rapidly developed as bipartite flows (dense flow and powder component) giving rise to very complex phenomena with a high destructive power.

Many events reactivated well known avalanche sites, often extending the track sections or creating coalescence between sites (fig. 9). 110 of such events hit or menaced roads, isolated buildings or hamlets, ski areas and a dozen caused serious damages including the complete destruction of the Rigopiano Hotel (fig. 10). After the 19th Jan. only at low elevations a significant avalanche activity persisted and it was initially characterized by thousands (it is an estimate) of sluffs, small avalanches and sometimes medium dry slab avalanches or glide avalanches or, in the final stages, by full depth wet slabs on grassy slopes and road embankments which created many road disruptions. At even lower elevations, the sudden snowpack melting induced by the progressive rise in temperatures and rain, started during the late 18th Jan. afternoon, generated floods along rivers and several landslides and mud-flows.

Fig. 10: a room of a house hitted by an avalanche in Foce di Montemonaco (AP). The windows and doors of the 1st and 2nd floor on the exposed side were smashed and snow and debris were powerfully injected inside all rooms. Fortunately, the village had already been evacuated [source CFM PC Regione Marche and AINEVA - photo Chiambretti].

In addition to the locality of Rigopiano (Municipality of Farindola-PE), other 30 localities had buildings/infrastructures hit or isolated by avalanches.

4. EMERGENCY MANAGEMENT

Such relevant snowfall amounts produced the complete isolation of several hamlets and villages, the partial or total interruption of almost the whole roads system (both main and secondary roads at medium and high elevations) as well as power or telephone lines disruptions. At lower elevations (down to 200 m asl) plantations were seriously affected by the heavy snow cover and farm's livestock stables, and several buildings roofs (including houses, sports facilities, industrial warehouses, supermarkets etc often already damaged by the earthquakes) collapsed due to the snow load.

The gravity and the vastness of the snow and avalanche emergency scenario, forecasted by the bulletins in the previous days, were evident during the late afternoon of the 18th Jan. as soon as the Rigopiano Hotel disaster was confirmed and notices about the other avalanche events were gathered.

The National Dep. of Civil Protection (DPC) requested, on the 19th Jan., a support to the technicians of the avalanche warning services of the

Alpine Regions coordinated by AINEVA. AINEVA's emergency support activities and on-site technical-scientific assistance immediately began with a first deployment of its technical director and one technician soon followed by ten others from Lombardia, Veneto, Valle d'Aosta, Friuli Venezia Giulia and Trento regions. The twelve forecasters worked in Marche, Abruzzo and Molise regions affected by the emergency for ten days and the technical director was then appointed by the prosecutor to carry out surveys and inquires in the Rigopiano's disaster area for a total of thirty continuous service days. Joint inspections teams operated on the field; they were composed by technicians of the following services: AINEVA, Civil Protection Multirisk Functional Centers (CF), Meteomont Service and National Alpine and Speleological Rescue Corps (CNSAS) teams. Seven other technicians of the Autonomous Province of Trento supported, via 24h web-conference, the DPC and the CF of the Marche, Abruzzo and Molise regions in the coordination and management of the emergency. On Jan. 21st, a Technical Table was opened, at the Operational Coordination Center (COC) of Penne (PE), where joint teams of technicians were requested to support the assessment of the residual avalanche hazard and risk and to evaluate the safety procedures of the rescue operations on the Rigopiano disaster area as well as assessing the local avalanche danger and hazard for hamlets and roads in central Italy (Marche, Abruzzo, Molise Regions and a small sector of Lazio Region). The technicians were dispatched to the localities where a local assessment of avalanche danger and hazard was necessary. The main issues which forecaster technicians daily confronted with were:

- total or partial lack of updated and reliable avalanche maps or cadastres not allowing a preliminary assessment of the sites;
- lack of reliable data from Meteomont's automatic and manual stations;
- poor local data or observations (lack of local avalanche commissions or qualified technicians);
- strong limitations on the use of helicopters due to the persistent bad weather conditions;
- accountability conflicts between institutions not always easily resolved;
- evolution from a lack of avalanche risk awareness to a media-fueled hysteria;
- locally bad management of snow removal from roads mainly due to budget cuts.

Such issues imposed to all technicians to close the information gap thanks to the direct execution of surveys/observations despite the persistent conditions of poor visibility thus exposing them to high potential risk and work overload. Only their high level of experience and professionalism enabled these issues to be overcome successfully and effectively, allowing the achievement of the expected results.

The emergency management involved 9.000 rescuers and technicians [including regional Civil Protection services, Civil Protection aid and rescue convoys, staff of the Nat. Dep. of Civil Protection, Fire Brigade, National Volunteer Alpine and Speleological Rescue Corps (CNSAS), Guardia di Finanza Mountain Rescue Teams, Armed Forces and Police Corps, etc.] and more than 5.000 vehicles and special equipments employed in the following activities:

- snow removal from hundreds of kilometers of main roads and inhabited areas;
- restoration of power and telephone lines;
- transport and delivery of basic necessities to the most isolated places and the evacuation of sick or distressed people.

Only for the Rigopiano site the rescue operation used daily, on average, 347 rescuers.

ACKNOWLEDGEMENTS

We would like to acknowledge Daniele Moro[1], Valerio Segor[2], Gabriele Amadori[1], Sergio Benigni[3], Luigi Bonetti[4], Gianluca Tognoni[3], Alvise Tomaselli[5] and Renato Zasso[5] for their contributions to write this article.

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