ANALYSIS OF A SPONTANEOUS AVALANCHE EVENT BASED ON THE OBSERVATIONS OF THE LONG-TERM ECOLOGICAL RESEARCH NETWORK IN MATSCH/MAZIA, ITALY.

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ABSTRACT: Identifying the precise timing and the meteorological conditions of natural avalanches is important for avalanche triggering prediction. However, it is not so common to have meteorological records in locations close to avalanches. In the framework of the LTER (Long-Term Ecological Research) network, in Matsch/Mazia valley (South Tyrol, Italy), a dense network of microclimate stations for environmental monitoring and for ecological studies has been installed. In this catchment, the winter 2017-2018 was characterized by above-average snowfall. We focus on an event occurred on the January 4th 2018, when several spontaneous avalanches were released near a station, which registered meteorological parameters before and during the event. Moreover, close to the station every winter snow profiles are determined, to calibrate snow height and precipitation sensors. This presentation shows how the collected weather data allow identifying the time and meteorological conditions of this spontaneous avalanches release. Moreover, snow profiles and simulations using the SNOWPACK model were performed, to better investigate the snow layers characteristics and snow properties. We found good agreement ($R^2 = 0.92$ for snow depth) between SNOWPACK simulations and observations. Results suggest that the avalanche was likely caused by snow overload and a loss of cohesion due to rapid temperature increase. The obtained data show the value of micrometeorological observations to monitor natural avalanche release conditions.

KEYWORDS: avalanche, weather stations, meteorological data, LTER, SNOWPACK model.

1. INTRODUCTION

While there are numerous large avalanches continuously monitored, it is not so common to have detailed meteorological records in locations close to small, natural avalanches, especially in forested areas. Moreover, for natural avalanches it is difficult to record the precise triggering time. For this reason, an accurate reconstruction of the meteorological and nivological conditions during a spontaneous avalanche event may provide useful information for better prediction of avalanche triggering.

In this extended abstract, we take advantage of "LTER Matsch/Mazia", to analyze the nivological conditions of the winter 2017-2018, which was characterized by above-average snowfall. We use the data of this LTER site to analyze the avalanches naturally released in January 2018 near a microclimatic station, called M4s. We describe the weather conditions and we compare manual snow profiles, collected during the winter, with a simulation with the SNOWPACK snow model (Bartelt & Lehning, 2002).

2. AIMS

The aim of this analysis is to take advantage of an unexpected avalanche event hitting a LTER meteorological station to detect avalanche timing and to recognize critical weather parameters for spontaneous avalanches. Moreover, we aim at understanding the snow metamorphisms processes leading to snow instability with the help of manual snow profiles and snow surveys. Finally, for a deeper analysis of stability and snow structure, a simulation with a snowpack model was performed. For this purpose, a physically-based model as SNOWPACK, able to track the snow properties and layers is required, with the advantage to have a modelled profile close in time to avalanche release event.

3. STUDY AREA AND STATIONS

"LTER Matsch/Mazia" is a mountainous research area managed by Eurac Research (BZ, Italy) and

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part of the worldwide network of sites LTER (Long-Term Ecological Research). The area is located in Matsch/Mazia valley in the northern Italian Alps. The valley extends over 90 km^2 from 950 m a.s.l. of the town of Schluderns to 3738 m a.s.l. at the top of Weisskugel. The valley is one of the driest region of the Alps with an average of 525 mm of precipitation per year (at 1600 m a.s.l.). The valley is also suited for parameterizing hydrological models due its closed catchment. Since 2009, a network of 18 microclimate stations has been installed. 5 main stations create an altitudinal transect from 1000 m a.s.l. to 2700 m a.s.l..

The focus of this paper is on station M4s (Figure 1), a station configured for hydrological studies, placed at 2000 m a.s.l. at the bottom of a steep convex hillside, partially covered by a Swiss stone pine forest. Since 2015, the station measures relative humidity and air temperature with a sensor Rotronic HC-2S3, direct and diffuse solar radiation with a DeltaT BF5, wind speed and direction with a Gill Windsonic4, snow height with a Campbell Scientific SR50A and precipitation with a heated weighting bucket Ott Pluvio2. The sensors are managed by a logger Campbell Scientific CR1000, having a sampling time of 1 minute and a logging time of 15 minutes. Data are transmitted to a central server.

Heavy snowfall, cold temperature and strong wind characterized the days before the January 4th 2018. Advection of warm air changed quickly weather and snow condition and in the afternoon of 4th of January, when at least four avalanches were released at a distance of maximum 500 m from the station. The largest one was already registered in the historical avalanches inventory of Province of Bozen (http://gis2.provinz.bz.it/geobrowser/). Other smaller ones were released on the top of the hillside and flowed down on small channels inside the forest. The picture in Figure 2 gives an overview of the avalanches area and of the avalanches flow tracks..

4. DATA AND METHODS

The avalanche was released from the top of hillside, flowed down on a small channel passing through a forest and deposited snow and debris near the M4s station without valuable damage. Sensors installed measured this event. Through a quality check process recognizing outliers, we aim at identifying the exact time of the event. Weather data preceding avalanche release were analyzed in order to observe avalanche related events, for example finding cold periods, strong wind events, heavy snowfall etc. Moreover, a simulation with SNOWPACK was performed for an analysis of snow grains and layers at the time when avalanche occurred.

Figure 1: *Picture of station M4s, composed by a meteorological station, a snow height sensor, a weighting pluviometer and an atmospheric deposition sampler. Above the station on August 24th 2017, below on January 15th 2018, after being hit by a powder avalanche.*

Figure 2: *Overview of the avalanches tracks (highlighted in red) surrounding M4s (indicated with a yellow star).*

The meteorological data were taken into account with the purpose to analyze the causes of avalanche release in order to characterize weather preceding avalanche (Jöbstl et al., 2013).

In particular, we observed air temperature, relative humidity, precipitation and wind for the ten days preceding the avalanche release (Conlan & Jamieson,2013). The 48 hours before avalanche were analyzed with particular attention. Plotting data time series, we detected particular or anomalous events, for example extreme cold, rapid air temperature increase or heavy precipitation

4.1 Nivological Data

During winter, we carried out several snow pits, to collect useful data for sensor calibration and model validation. The surveys follow AINEVA procedures (Cagnati, 2003); in particular, we collected data of snow temperature, grain characteristic and density. Furthermore, snow surveys are shared with the Hydrographic office of Province of Bozen, given the importance of these data for avalanche forecast and risk management.

4.2 SNOWPACK modeling

To better understand snow properties, we performed a simulation with SNOWPACK, a 1D physical model developed by WSL Institute for Snow and Avalanche Research SLF (Bartelt & Lehning, 2002). The model solves 1D partial differential equation for mass, energy and momentum conservation and models heat transfer, water transport, vapor diffusion and mechanical deformation, and it simulates snowpack and ground surface behaviour. SNOWPACK treats snow as a porous material composed by ice, water and air. The model takes meteorological data as input after preprocessing them with Meteo-IO (Bavay & Egger, 2014). This tool checks values, fill gaps and generate missing parameters. The output of the model is a detailed structure of the snowpack. The model parametrization was selected comparing manual snow pits carried out during the winter season.

The model was validated against snow height and the best model parametrization shows a coefficient of determination R^2= 0.92.

5. RESULTS

5.1 Detection of avalanche timing

The avalanche occurred on January 4th, depositing debris on the station, as confirmed by local people who were in the area the day after. Sensors were dirty and recorded several outliers (Figure 3). We observed that temperature stopped increasing and, at the same time, the relative humidity stayed on saturation for several hours. The weighting pluviometer recorded a sudden increase of level in the bucket, without a precipitation increase, while the ultrasonic snow height sensor seemed to be obscured by snow particles. These facts are consistent with a powder slab, where a powder cloud deposited snow on the air temperature/RH sensor shield, on the snow height sensor and on the pluviometer. Based on the observed anomalies, the time of avalanche release was estimated between 4 PM and 4:15 PM.

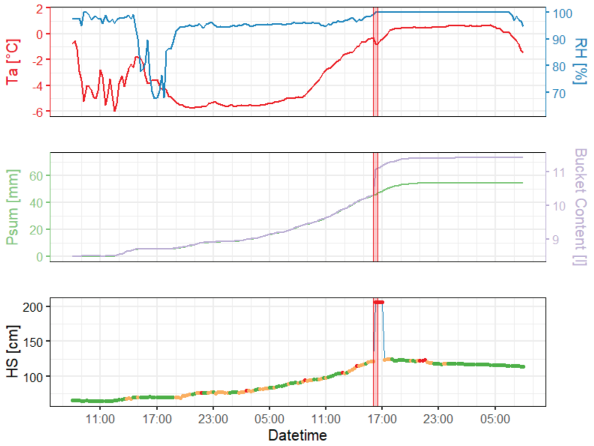


Figure 3: *Time series of air temperature (Ta), relative humidity (RH), cumulated precipitation (Psum), bucket content, snow height (HS) with quality classification from January 3rd 2018 at 8 AM to January 5th 2018 at 8 AM. Red boxes highlight the time of avalanche release, between 4 PM and 4:15 PM of January 4th 2018*

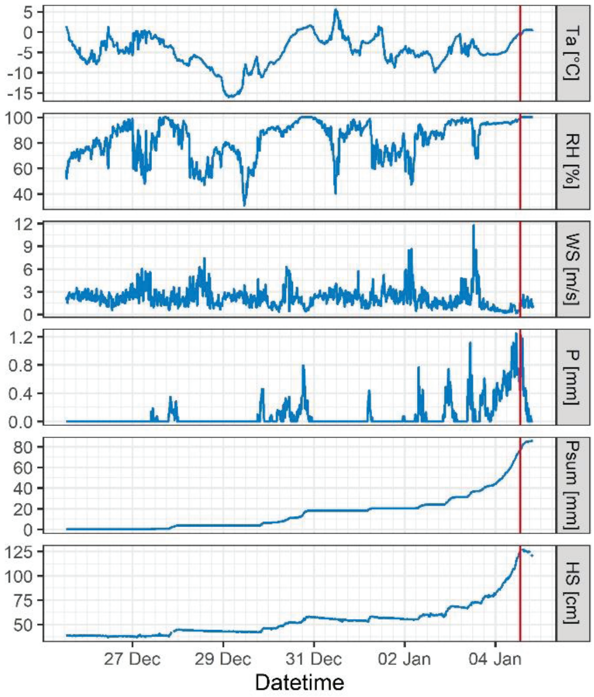


Figure 4*: Meteorological data on M4s station from December 25th 2017 to January 4th 2018.Red line highline avalanche release of January 4th 2018 at 4 PM*

5.2 Analysis of weather condition

The weather conditions preceding the avalanche were characterized by heavy snowfall and by advection of moist and warm air, which caused a rapid temperature increase and an increase of relative humidity. The day preceding the avalanche, the temperature started from -6 °C at 8 AM to reach 0 °C at 4 PM, with an increment rate of 0.75 °C/h. At the same time, 50 cm of fresh snow were deposited on the pre-existing snowpack.

Figure 4 shows the time series of air temperature (Ta), relative humidity (RH), wind speed (WS), precipitation intensity (P), accumulated precipitation (Psum) and snow height (HS) for previous 10 days. This period was characterized by 82 cm of new snow, cold periods with temperature of -16.1 °C and -9.9 °C alternated with a warm period, where the maximum temperature of 5.6 °C was reached. Worth to be mentioned is the strong wind on January 3rd, as described in Climareport (Hydrographic office of Province of Bozen/Bolzano, 2018). Our sensor measured a wind gust of only 12 m/s (breeze for standard wind classification), but this value is likely underestimated, since the sensor height of 2 m does not respect WMO Guidelines.

5.3 *Simulation of snow structure*

Meteorological data (Ta, RH, WS, P, solar radiation) were also used as input to simulate snow properties by using the SNOWPACK model. The purpose is to understand how snowpack evolves over time, especially before an avalanche release. The output of the simulation is a virtual snow profile showing grain shape and stability information. SNOWPACK indicates 82 cm of fresh snow on a weak layer at 43 cm, composed of incorporated surface hoar. Below this layer, faceted crystals and depth hoar grown during the cold periods were observed (Figure 5).

The simulated snow layers structure and grain type's distribution generally agree with the observations. In particular, the survey executed on January 15th , the first possible date to reach M4s in safety, fits very well with snowpack model results, indicating a similar layer structure, as shown in Figure 6.

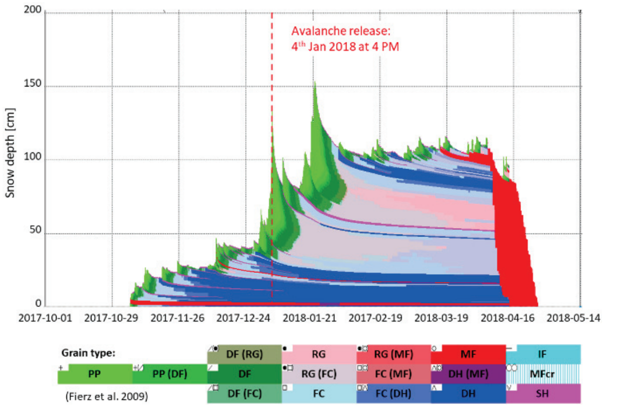
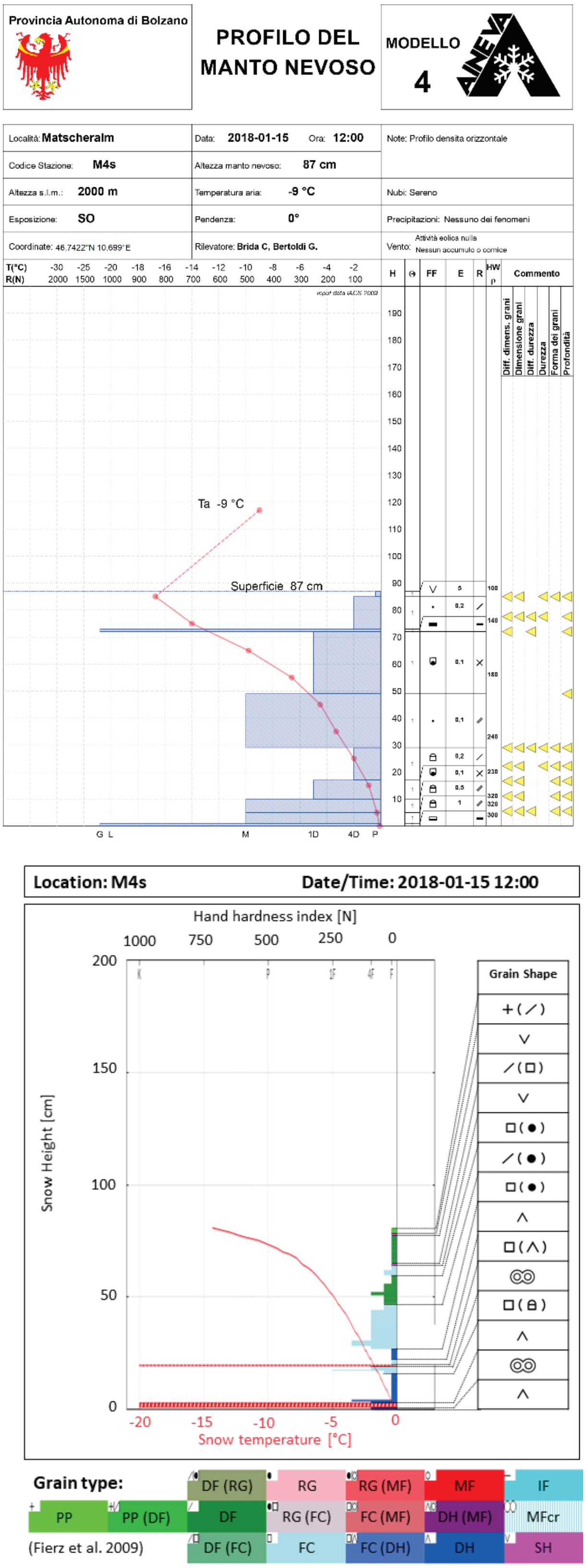


Figure 5: *SNOWPACK simulation on M4s station for the winter season 2017- 2018*


Provincia Autonoma di Bolzano
PROFILO DEL MANTO NEVOSO
MODELLO 4

Località: Matscheralm
Data: 2018-01-15 Ora: 12:00
Note: Profilo densità orizzontale
Codice Stazione: M4s
Altezza manto nevoso: 87 cm
Altezza s.l.m.: 2000 m
Temperatura aria: -9 °C
Nubi: Sereno
Esposizione: SO
Pendenza: 0°
Precipitazioni: Nessuno dei fenomeni
Coordinate: 46,7422°N 10,699°E
Rilevatore: Brida C, Bertoldi G.
Vento: Attività eolica nulla, Nessun accumulo o cornice

Location: M4s
Date/Time: 2018-01-15 12:00

Figure 6: *Above, the snow profile observed on January 15th 2018. Below, the grain shape profile resulted from SNOWPACK simulation for the same date is reported.*

Simulation and snow profiles were taken on the bottom of hillside, quite far from avalanche release zone, which is likely more wind exposed than station area.

Figure 6 shows the snow pit profile, on January 15th 2018, both manually measured and simulated with SNOWPACK.

6. CONCLUSION

This analysis aimed at exploring the possibility to use

This analysis aimed at exploring the possibility to use mountain LTER sites for studying snow processes, and how it is possible to understand the exact avalanche timing and infer avalanche characteristic from an accurate analysis of meteorological data.

In this extended abstract, we focused on a natural avalanche that hit, but not destroyed, a meteorological station in the Alps, where regular snow surveys are taken.

The avalanche deposited debris and powder on sensors and was detected very well in our data quality check system, estimating the release of a powder between 4 PM and 4:15 PM on January 4th 2018.

A weather analysis shows two cold periods during the days preceding the avalanche event. The first period could be the cause of growing of faceted crystals and depth hoar when there is little snow on ground; the second promotes the formation of surface hoar. The heavy snowfall combined with the strong wind created a slab, broken by snow overload and rapid temperature increase.

The simulation with SNOWPACK model gives us an overview of snow layers characteristics and evolution. In particular, when we focus on the avalanche event, we identify the presence of a weak layer as the possible reason of avalanche release. The snow instability conditions have been also confirmed by the local avalanche degree risk level 4 (Avalanche bulletin of the Province of Bozen).

In conclusion, it is worthwhile highlighting the importance of recording snow and meteorological conditions at the avalanche release time. Recognizing critical parameters can improve local avalanche forecasting or the efficiency of artificial avalanche release. LTER sites, distributed all over the world, can provide many high quality data for ecology as well as, science field. Data of climate stations, models and surveys contribute to create a database of snow properties and avalanche events. Moreover, collected data could be useful for calibration of precipitation sensors and for validation of hydrological models.

7. ACKNOWLEDGEMENTS

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