

**“RISK, RESEARCH AND INNOVATION” PROJECT ON WET-SNOW AND GLIDE-SNOW
AVALANCHES IN AOSTA VALLEY (NW ITALIAN ALPS): THE EXPERIMENTAL APPROACH.**

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ABSTRACT: In the framework of the “Risk, Research and Innovation” project carried out by the Mountain Risk Research Team, the glide-snow avalanches are studied. As the wet-snow avalanches, the glide-snow avalanches are highly dangerous because of the large possible involved volume of snow and the difficulty of forecasting their release.

Before the '60s, these phenomena have only partially attracted the scientific interest but afterwards the knowledge on formation and processes related to wet-snow and glide-snow avalanches has grown significantly. Particularly, the role of free water at the snow/soil interface has been analyzed as key factor responsible of the gliding rate and the acceleration of the gliding snowpack.

The experimental approach on the analysis of formation of glide-snow avalanches is based on the set-up of four test sites within the Monterosa Ski resort in Aosta Valley (NW Italian Alps) during summer 2013.

The snow gliding of the snowpack, which can possibly results first into the formation of glide cracks and then to avalanche releases is monitored in two test sites. Glide shoes, temperature and water content sensors are installed at the snow/soil interface to monitor the processes. A third test site is devoted to the test of innovative sensors for snow humidity and density measures. The last test site is dedicated to the evaluation of the effectiveness of different protection measures with respect to the risk related to wet-snow avalanches. The paper describes the test sites, the objectives of the research and shows some preliminary data.

KEYWORDS: snow gliding, snow water content, monitoring test sites, snow/soil interface, avalanche risk assessment.

1 INTRODUCTION

Wet snow avalanches, including the gliding ones (Jones et al., 2006; Mitterer and Schweizer, 2012), currently represent a major point of uncertainty in

forecasting activities because of the difficulty of release prediction. (Peitzsch et al., 2012; Reardon and Lundy, 2004). Interest in this type of avalanches is more and more increasing because these phenomena, in the last years, seems to have been enhanced by the climate change dynamics that could lead to a warmer and wetter snowpack (Lazar and Williams, 2008) and to a rise in frequency of wet avalanches, though no clear trend has been identified yet.

Moreover, the high destructive potential due to the large involved volume of snow, the high impact

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pressure they can develop on buildings, forest, infrastructures, such as for example a lift mast, and the difficulty to manage the problem with the common systems of artificial triggering - wet and glide-snow avalanches do not react positively to such measures and therefore are more difficult to manage than dry snow avalanches - put this type of phenomena under the focus of the avalanche risk assessment, both for the public administration and for the ski resort.

For this reasons, the monitoring of glide cracks formation and evolution - aiming at a better understanding the role of free water at the snow/soil interface as a main factor that characterizes the gliding process - together with the testing of new sensors able to measure the water content in the snowpack, represent essential steps towards glide-snow avalanche risk assessment (Ceaglio et al., 2012; Peitzsch et al., 2012).

In this work the objectives of the research, a description of the test sites, and some preliminary data, with a specific focus on the experimental approach, are shown.

2 THE PROJECT AND ITS OBJECTIVES

The Mountain Risk Research Team - MRR Team (established in the framework of the "Call for the creation and development of Research Units" - DGR n. 1988 dated 26/08/2011) is a multidisciplinary research unit with a scientific-technical core, integrated with the legal and social aspects, in the field of natural hazards in mountain environment. In particular, the MRR Team, which includes universities, research institutes and a ski enterprise of Aosta Valley is developing the Operational Project "RRI - Risk, Research and Innovation".

The scientific and technological objectives pursued in this project by the MRR Team are (1) to develop tools for monitoring and prediction of wet-snow and glide-snow avalanches and (2) to define a procedure (best practice) of risk management in terms of safety and cost reduction in the Alpine ski-resort Monterosa Ski. In details, the project aims at proposing:

Objective 1: an innovative management tool to analyze weather, snow and soil parameters and to identify the driving factors for wet-snow and glide-snow avalanches and possibly to find threshold values for such parameters.

Objective 2: innovative management tool to support Monterosa Ski technicians by introducing a new technique for the artificial triggering of wet-snow avalanches in the Plan of Actions for the Artificial Avalanche Triggering (PIDAV).

Objective 3: innovative management tool that supports Monterosa Ski technicians in the activities of construction and maintenance of the ski slopes, with a specific focus on the best practices to reduce the soil erosion.

3 DESCRIPTION OF THE SITES

Four test sites have been installed during Summer 2013 within the Monterosa Ski resort (Fig.1), at the head of the Lys and Ayas Valleys, on the Monte Rosa Massif (Aosta Valley, North-western Italian Alps). The experimental sites are focusing on objective one and two, to improve knowledge on snow humidification and glide-snow and wet-snow avalanches mechanisms.



Fig. 1. Skirama of the Monterosa Ski resort and localization of the test sites active since winter season 2013/14.

- 1) Pista Nera: glide-snow avalanche release area (Gressoney-La-Trinité, 2230 m asl, ESE, 40°) located upstream of the "Pista Nera" ski run.
- 2) Sant'Anna I: glide-snow avalanche release area (Gressoney-La-Trinité, 2120 m asl, E, 36°) located downstream of the cable car arrival to Sant'Anna.

3) Sant'Anna II: flat area, located near the cable car arrival to Sant'Anna (Gressoney-La-Trinité, 2170 m asl, 360°), close to the daily and weekly snow study plots of the Avalanche Warning Service (MOD 1 and MOD4 AINEVA).

4) Pista Larici: wet-snow avalanche release and track area above the "Pista Larici" ski run (Ayas, 2100 meters asl, WNW): the interference of wet-snow avalanches, especially in spring conditions, makes the site critical from a logistical point of view (Frigo et al., 2013).

The sites "Pista Nera" and "Sant'Anna I" are designed to monitor the gliding process - eventually resulting first into the formation of glide cracks and afterward into glide-snow avalanche releases - and to study its most important driving factors. The devices include two glide-snow shoes (Fig. 2) for each site, temperature and water content sensors in the soil (at different depths: 5-15 cm) and in the basal snowpack layer (Fig. 3).



Fig. 2. Glide-snow shoes (Sommer®).



Fig. 3. Water content reflectometer (CS616) and temperature sensors (T107) at the snow/soil interface (Campbell).

All sensors are connected through buried cables to data-loggers located in safe positions outside the release area (Fig. 4). Moreover a web-cam (Courtesy of Consorzio Turistico Gressoney Monte Rosa) is continuously monitoring the possible glide cracks formation and evolution of the site "Pista Nera".



Fig. 4. Collecting data system: datalogger (Campbell), solar panel and battery.



Fig. 5. "Sant'Anna II" test site during the installation of sensors.

The third test site “Sant’Anna II” is devoted to testing electromagnetic sensors (e.g. Kovacs et al. 1995) (WCR - Water Content Reflectometer) for snow density and water content measure, important key variables for snow-gliding phenomena (Fig. 5).

Moreover snowpack characterization associated to the water content measures using a portable reflectometer (CS616 sensor) are performed weekly. The effectiveness of different protection actions, such as for examples innovative wood defense structures, artificial release measures, with respect to the risk related to wet-snow avalanches, are monitored in the last test site, “Pista Larici” (Fig. 6).



Fig. 6. Artificial avalanche triggering at “Pista Larici” site with DaisyBell® system.

Sensors for humidity and temperature (*iButton*®) at the snow/soil interface and in the soil are herein installed. Moreover, snow profile characterization and water content measures using a portable reflectometer (CS616 sensor) are performed weekly.

4 PRELIMINARY RESULTS

At the end of the winter 2013-2014, in the sites set up to monitor the gliding process, “Pista Nera” and “Sant’Anna I”, three glide-snow avalanche events have been observed and successfully recorded by the snow gliding shoes and by the data-loggers (Fig. 7). The first two events occurred late in Autumn, after the intense snowfalls registered

between 19 and 22 November that brought more than 1 m of new snow in the sites.

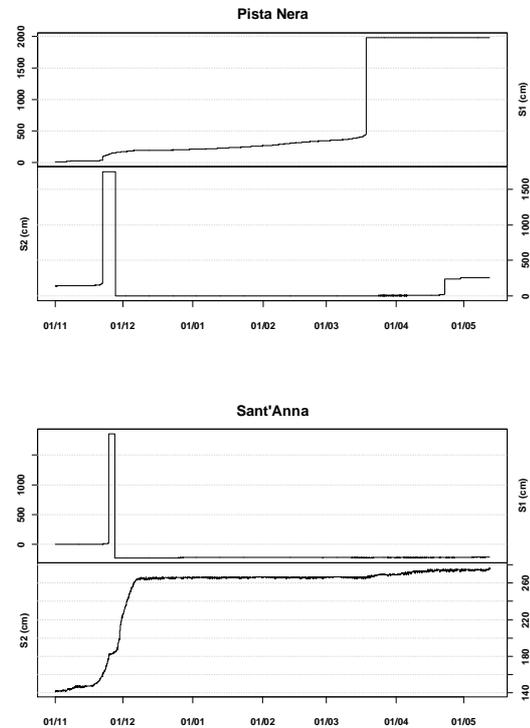


Fig. 7. Gliding movements (cm, cumulated) registered in the sites “Pista Nera” and “Sant’Anna I” during the winter season 2013-2014 by the glide snow shoes (S1 and S2).

The first avalanche occurred at 11.06 p.m. of 21 November during the apex of the snowfall (“Pista Nera” site - Fig. 8); the second event occurred in



Fig. 8. Glide-snow avalanche occurred in the site “Pista Nera” on 21 November 2013.

“Sant’Anna I” once the snowfall was over, at 6.35 p.m. of 24 November, after the first sunny and warm day (Fig. 9).



Fig. 9. Glide-snow avalanche occurred in the site “Sant’Anna I” on 24 November 2013.

The third event occurred on 18 March at 2.00 pm in “Pista Nera” after a prolonged time period of good weather (absence of snowfalls since 5 March), rise in temperature and snowpack settlement (Fig. 10).



Fig. 10. Glide-snow avalanche occurred in the site “Pista Nera” on 18 March 2014.

Besides this registered event, since March 7, a glide crack became visible and gradually larger until the middle of March: between 16 and 18, other three glide-snow events occurred, but were detected only by the web-cam as they didn’t involve the glide-shoes.

About the test site “Sant’Anna II” and “Pista Larici”, several snow profiles were performed and the collected data were associated with water content measures (Fig. 11) in order to validate the sensor systems.



Fig. 11. Snowpack characterization data associated with water content measures.

Particularly, a first calibration curve to adapt CS616 water content reflectometer to estimate the snow density and water content has been implemented and it is now in a testing phase. Finally, many artificial avalanche releases were carried out in the site “Pista Larici”, also trying innovative methods still in a testing phase, but without any avalanche release.

5 DISCUSSION AND CONCLUSIONS

The effectiveness of Operational Project “RRI-Risk, Research and Innovation” of the Mountain Risk Research Team can be confirmed by this first year of the project in developing tools for monitoring and prediction and in defining a procedure (best practice) of risk management in terms of safety and cost reduction.

We have shown that the development of new strategies in the mitigation of risk due to wet-snow and glide-snow avalanches cannot avoid a multidisciplinary approach and a strict cooperation between researchers, technicians and operators of the ski-resort areas.

Analyses of the data collected during the past winter are now in progress, with the aim of finding threshold values for the driving factors of such phenomena and therefore to provide a valuable early-warning tool to the security personnel of Monterosa Ski for the management of the ski slopes. New data collection will be carried on and implemented during the upcoming winter season 2014-2015. The preliminary analyses point out the relevance of the cross-correlation of the different data set of the observed physical snow parameters

(depth, temperature, water content, etc.) to get robust relationships with the observed gliding phenomena.

Future analysis, methods and procedures that will be identified to manage the risk of glide-snow and wet-snow avalanches for the ski resorts will be the basis for the management of this kind of dangers also in other anthropic environments, specifically roads and villages.

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