

## Avalanche risk management in Winter 2012/13 in Monterosa ski resort – Aosta Valley (IT)

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**ABSTRACT:** Monterosa Ski is one of the most important resorts in the North/West Italian Alps. Extending through three valleys in two regions (Aosta Valley and Piedmont - IT), Monterosa Ski begins at 1.332m in Brusson, crosses Champoluc-Frachey, rises up to the 2.727m of Colle Bettaforca, embraces Gressoney-La-Trinité and Gressoney-Saint-Jean (1.818m), climbs up to the 2.971m of Passo dei Salati, reaches the 3.275m of Punta Indren and backs down to 1.212m of Alagna Valsesia (Piedmont), in the shadow of many 4000m peaks of Castore (4.226m), Lyskamm (4.532m), P.ta Gnifetti (4559m) and Punta Dufour (4633m) with 180km in 67 ski runs served by 37 lifts (capacity is over 50000 people/hour) and 150 km linked by 35 lifts in the Aosta Valley (IT).

Presenting the actors (qualification, know-how and expertise of the staff and its management), the available devices and the planning of avalanche risk management, the paper shows, beyond the decisions taken, how fundamental is the analysis of the critical snow and weather conditions of the two valleys leading the decision-making on the avalanche artificial release solutions (gas-based fixed, gas/explosives mobile systems, etc ... ) and, subsequently, when to re-open the ski runs.

As an example, the paper presents some critical snowpack stability situations solved by using artificial avalanche release including episodes induced by wind and wet snowpack.

**KEYWORDS:** ski resort, avalanche, risk management.

### 1 INTRODUCTION

Monterosa Ski resort is one of the largest ski resorts in Italy. It is about 180 km of ski-slopes (170 km with artificial snow-making tools and 150 km in Aosta Valley) and 37 lifts (capacity is over 50,000 people/hour.) and 67 ski slopes (41 red, 20 blue 6 black ski-runs), developed along three valleys: Ayas and Gressoney in Aosta Valley and Alagna in Piedmont. It starts at 1.332 m in Brusson, crosses Champoluc-Frachey, rises up to 2.727 m of Colle Bettaforca, embraces Gressoney-La-Trinité and Gressoney-Saint-Jean (1.818 m), climbs up to the 2.971 m of Passo dei Salati, reaches the 3.275 m of Punta Indren and backs down to 1.212 m of Alagna Valsesia (Piedmont), in the shadow of many 4000 m peaks of Castore (4.226 m), Lyskamm (4.532 m), P.ta Gnifetti (4559 m) and Punta Dufour (4633 m). Next winter, it will joint also the

Champorcher ski area (Fig. 1, in yellow).

Monterosa Ski has been a dynamic resort for 30 years where innovation and its projects make skiing there a continuous discovery: each year, it accommodates 1.000.000 people.



Figure 1. Localisation in Aosta Valley (IT) of the Monterosa Ski resort. In yellow, the new part in Champorcher valley that it will be added since next Winter 2013/14.

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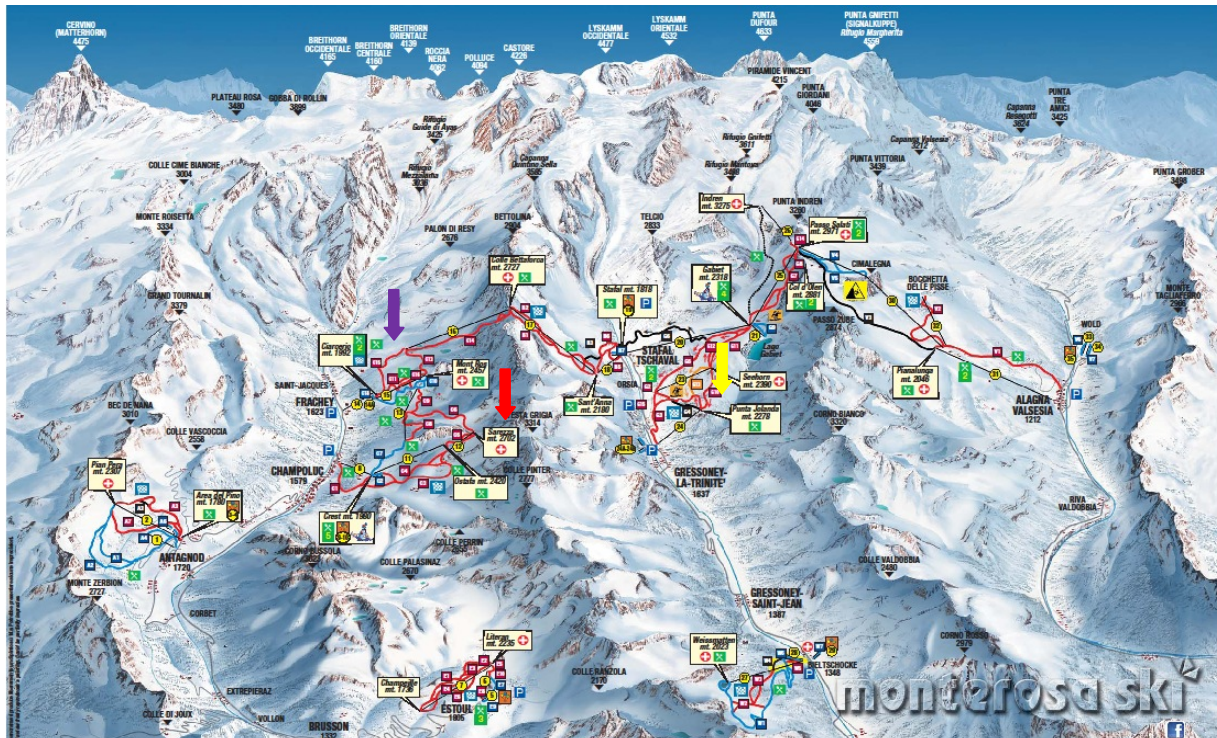


Figure 2. Skirama of Monterosa Ski resort. The arrows localises the examples of avalanche risk management reported in this paper.

## 2 AVALANCHE RISK MANAGEMENT

The avalanche risk management passes through a lot of aspects: monitoring, analysis of local snow and weather conditions, assessment, information, etc ... The paper tries to resume the available tools and resources in Monterosa Ski resort to manage the avalanche risk.

The ski resort is developing in 5 mountainsides in 3 Valleys from 1200 m to 3800 m asl (Fig. 2) and more than 100 identified avalanche basins. It is easy to understand the difficulties to manage diverse types of snowpack instabilities related to the altitude: low (below 2000 m), medium (between 2000 to 3000 m) and high (above 3000 m) to reach in time all the corners of the ski area, securing it and, subsequently, opening it.

Since 2005, to manage the avalanche risk, Monterosa Ski is equipped by PIDAV (Action plan to artificially trigger avalanches, as in France and Swiss) and PISTE (Action plan to temporarily suspend the exercise of ski resort) continuously updated depending on the purchase of innovative avalanche release techniques, qualifications, changes in the ski area (new tracks, dismantling lifts, etc ...).

A small part in Monterosa Ski in Gressoney and Alagna valleys is devoted to freeride and it is usually managed with information diffusion at ticket offices, lift departures by informative panels and website.

### 2.1 Monterosa Ski Team

Considering the wide territory of Monterosa Ski, the avalanche risk management has been divided in three sectors, one for each valley, in which a specialised technical team works. The team is composed by:

- in Ayas valley: one ski-run manager, 12 ski-patrollers (pisteurs secouristes) (four authorized to use explosives), 4 policemen and 14 snow groomers;
- in Gressoney valley: one ski-run manager, 10 ski-patrollers (pisteurs secouristes) (four authorized to use explosives), 3 policemen and 12 snow groomers;
- in Alagna sector: one ski-run manager, 4 ski-patrollers (pisteurs secouristes) (four authorized to use explosives), 2 canine units and 5 snow groomers.

Each member of the team has been trained and qualified for his special job. Therefore the national and regional qualifications obtained are:

- regional course for ski-run manager;
- regional course for ski-patroller;
- AINEVA course 2A – snow & avalanche observer;
- AINEVA course 2B – artificial avalanche trigger expert;
- AINEVA course 2C – operational director;
- AINEVA course 2D – safety head;
- License to manage and use explosives with fire and electric triggers;

- Mountain guides course – geo-morphological observer;
- Soccorso Alpino Valdostano courses - helicopter rescue;
- first aid license BLS – BLSD – BTLS – BPLS;
- AVIF courses for rescue on ski-lifts.

## 2.2 Available devices and tools

In its area, Monterosa Ski presents 5 active defence fixed structures (snow umbrellas and snow bridges) at Passo dei Salati (2970 m), St. Anna (2170 m), P.ta Telcio (2830 m), Colle Sarezza (2717 m) and Gabiet (2340 m), and 2 types of artificial fixed avalanche devices: 4 Gaz-Ex® at Colle Sarezza (the first Italian installation) and one Avalex® at Col d'Olen (2880 m, the first Italian installation in 2004). The four 3mc Gaz-Ex® are installed powered by a single deposit for the safety of 15.000 sqm total surface.

About artificial mobile trigger devices, Monterosa Ski employs explosives and DaisyBell®. The explosive employed is dynamite or emulsion available in sticks with 40 mm diameter, 400 mm long and 670 g weight. The charge is packed with a weight between 4 and 5 kg (n. 6 - 7 sticks in a burlap sack) and armed with n. 2 detonators with length greater than 1 m. To assure the immediate availability of the explosive, the Resort built a warehouse to store explosives, necessarily supervised h 24 as imposed by Italian laws (Frigo et al., 2012).



Figure 3. The “carica Vassale” to manage artificial avalanche release with explosives using helicopter (Vassale et al., 2004).

To release avalanche with explosives from helicopter, Monterosa Ski developed and patented in 2004 the VAS1 technique (Fig. 3) in which, thanks to a mechanical tool, explosive contained in a carton is dropped from helicopter and activated when it touches the snowpack. The system, too complicate to manage, has now been replaced since Winter 2012/13 by an inno-

vation operative procedure to launch explosives from helicopter. The PH-procedure is developed by Pellissier Helicopter (IT) in collaboration with Monterosa S.p.a. and authorized by ENAC.

After 2 testing years by Monterosa ski-run managers, in 2009 DaisyBell® is bought by Resort. The collaboration with TAS is now continuing to test the Daisy Track Manager and the Cornicheur tool. With DaisyBell®, Monterosa Ski secures about 140.000 m<sup>2</sup> of avalanche surface in about 2,5 h.

Table 1. Artificial avalanche release in Monterosa Ski resort: explosives vs DaisyBell®

Winter	Explosive [kg]	DaisyBell® [n. shot]
2008/09	5.000	/
2009/10	500	617
2010/11	1.000	403
2011/12	2.000	537

## 2.3 Timetable of avalanche risk assessment

In Monterosa Ski, snowpack, weather, snowdrift and avalanche daily observations coupled with the knowledge of the territory and its behaviour under diverse conditions together with acquired experience and passion for this job lead to some major daily steps to manage avalanche risk in a ski resort:

1. continuous monitoring of the weather conditions thanks to the comparison between local webcam, manual and 9 automatic weather stations spread on Resort area and available on-line;
2. check out the regional avalanche bulletin and information exchange with regional Avalanche Warning Service and other ski resorts in Aosta Valley;
3. continuous monitoring of snowpack conditions with observations and field tests to assess its stability;
4. if it is necessary, request the authorizations to use explosives, order and store them in the warehouse;
5. preparation of charges and/or DaisyBell® and activation of Gaz-Ex®;
6. adopt the avalanche risk management procedures given by PIDAV;
7. evaluation the results of operational choices to open lifts and slopes.

## 4 AVALANCHE RISK MANAGEMENT EXAMPLES

Below, three particular avalanche risk management examples in Monterosa ski resort.

#### 4.1 Col Sarezza (2700 m asl)

The first example is the Col Sarezza (Fig. 2, red arrow). It's a strategic point in the Monterosa Ski in Ayas valley: it connects the ski slopes in Champoluc with ones of Frachey.

To make the link always accessible & safe and to protect the tracks, the lift and the snow cannons by avalanches, the site was equipped with two types of fixed defence systems: n. 4 Gaz-Ex® and 4 lines of snow bridges (Fig. 4).

In this case, the problem is about the efficiency of defence systems: in some cases (the formation of wind slabs or cornices) fixed devices do not ensure the complete safety of the tracks and the arrival station of the lift. That's why ski-patrollers exploit a "mixed method": the first part of reclamation occurs, remotely, thanks to Gaz-Ex®. After the monitoring of the snowpack stability around the snow bridges area, if it is still instable, the artificial release with mobile systems (DaisyBell® or explosives) is activated.

#### 4.2 P.ta Seehore (2570 m asl – NW aspect)

The P.ta Seehore avalanche basin is cleaned by ski-patrollers to secure the "Collegamento Gabiet" ski run that links the P.ta Jolanda lift to Gabiet slopes (Fig. 2, in yellow).

Since 2009, this slope is becoming the test site of Aosta Valley to study the dynamics of artificially small/medium avalanches (Barbero et al., 2013; Maggioni et al., 2013; Segor et al., in this issue).

To artificially release avalanches at P.ta Seehore, PIDAV indicates triggers by DaisyBell® and explosives from helicopter.

In 2011, the second major snowfall of the season operates on Gressoney, Ayas, Champorcher valleys and the central one (Rava, 2011). The automatic weather station at Gabiet lake (2380 m asl), close to experimental site, accumulates 60 cm of the fresh snow from 28<sup>th</sup> Feb to 1<sup>st</sup> March, plus 53 cm from 3<sup>rd</sup> to 4<sup>th</sup> March, adding 48 cm during the 12<sup>th</sup> March. By the 17<sup>th</sup> March the fresh snow fall is 1m that leads the snowpack thickness to the maximum of the season, equal to 277 cm.

In March, the average of the minimum temperatures ranging between -1 and -7 °C, while the maximum between +13 and +18 °C at 1500 m, +8 and +13 °C at 2000 m and +5 to +7 °C at 2500 m (Fig. 5) together with a moderate/strong winds from E aspect (March 16<sup>th</sup>) and N-NW (17<sup>th</sup> and 18<sup>th</sup> March).

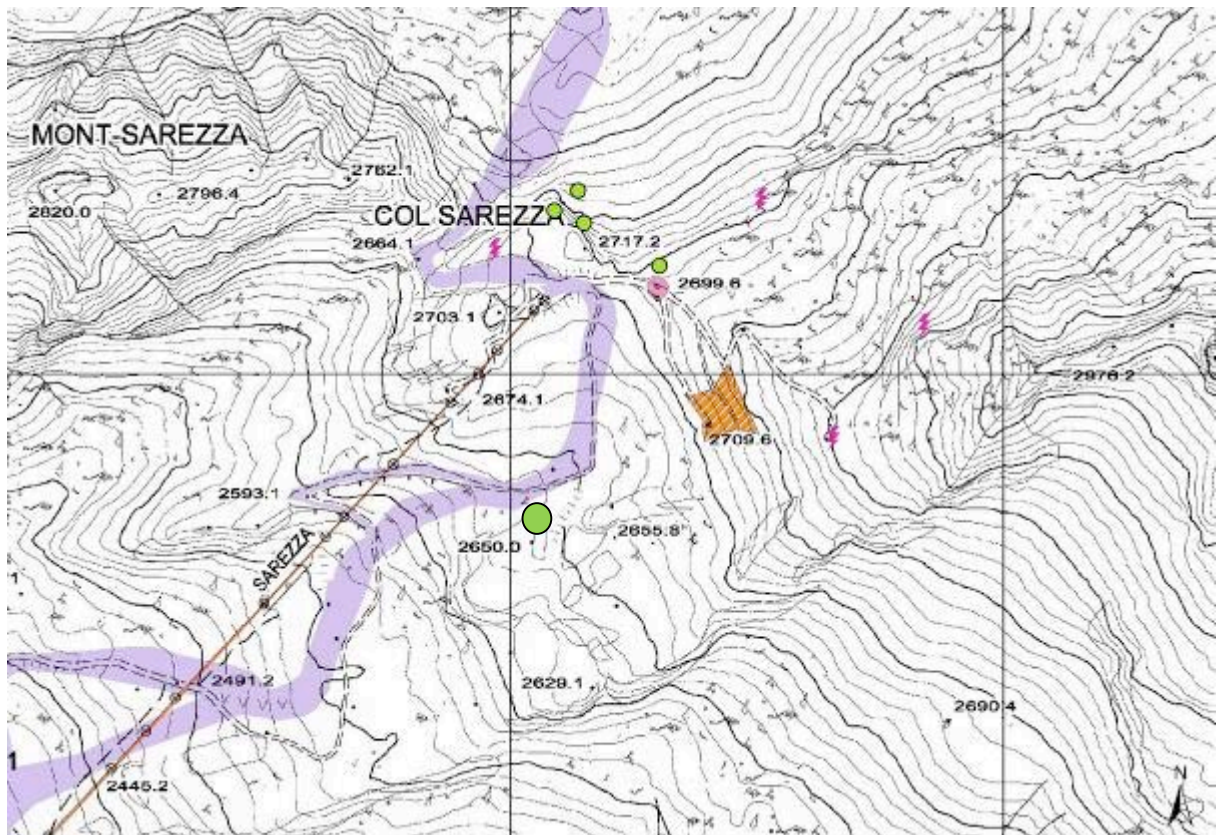


Figure 4. Col Sarezza (in pink: Gaz-Ex (lightning) and their small shelter (circle); in orange, the snow bridges area; in green: the mobile release points; in violet: the ski slopes).

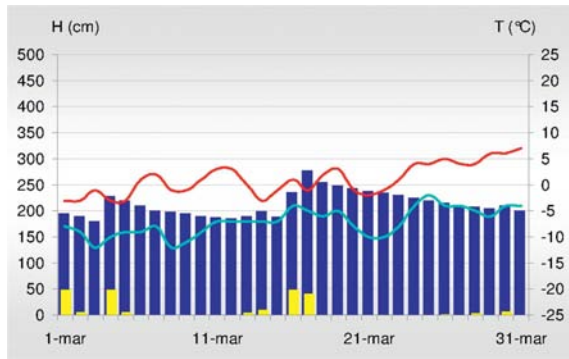


Figure 5. Snow height, maximum and minimum temperature in March 2011. Data from automatic weather station at Gabiet Lake - 2380 m (RAVA , 2011).

The chronology of events on March 2011:

**16-17 March** The precipitation began on 15<sup>th</sup> March in the afternoon brings 50-60 cm new wet snow up to 2000 m accompanied by moderate winds which formed new accumulations above 2200 m. Many natural avalanches are reported at all aspects and in the morning of 17<sup>th</sup> and P.ta Seehore shows two tracks of natural loose avalanches in orographic left-side (no-impact with the instrumented obstacle, Fig. 6). At the same time, with one shot of DaisyBell®, a large slab avalanche is released from the slope close to the test site that reaches the “Collegamento Gabiet” ski run. The density of the snow in the deposition zone was 340 kg/m<sup>3</sup>. The avalanche danger regional level in Gressoney territory was 4-strong.



Figure 6. P.ta Seehore test site: in white the small sluff artificially released with the 3<sup>rd</sup> shots. On the left, two loose avalanches naturally released probably between 16 and 17 March (RAVA, 2011a).

**18 March at 08:30 am** The last snowfall added to the snowpack up to 60-70 cm of new snow at 2000 m and during night, negative temperature helped the refreezing of the snowpack. To clean the basin, three explosive shots from helicopter (Carica Vassale, in Fig. 7 in blue) detonated close to the P.ta Seehore ridge: only the third shot (on the right in Fig. 7) caused a small sluff which grazed the obstacle.

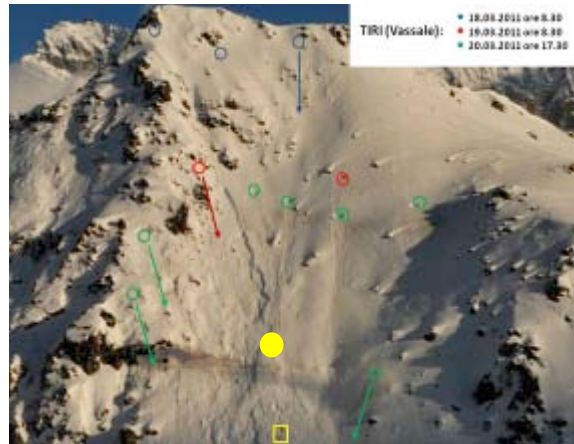


Figure 7. Shots done from 18<sup>th</sup> to 20<sup>th</sup> March 2011 to clean P.ta Seehore avalanche basin. The arrows indices the release; in yellow the position of the instrumented obstacle before (circle) and after (square) the event of 19<sup>th</sup> March 2011 (RAVA, 2011a).

During the day, the snow is dry above 2300 m, and strong winds from N-NW are drifting the recent loose snow. Many natural medium-large avalanches are reported at all aspects and stability tests performed show weaknesses in the snowpack both between the fresh snow surface layers and inside the old moistened snow. The avalanche danger regional level was stable on 4-strong.

**19 March at 08:30 am** Thanks to the continuous monitoring of the snow & weather conditions, a new sluffs released from basins with the same exposition of P.ta Seehore are noted coupled with a snowdrift accumulations along the slopes at lower altitude by the ridge. In the morning, a new try to trigger the P.ta Seehore avalanche is done by two detonations by explosives (Fig. 7 in red) at lower altitude from the usual one. The first shot causes a trigger of a large slab that leans the obstacle and drags it 26 m downstream in N-NO direction (RAVA, 2011a). The avalanche erodes 120 cm of the snowpack along the slope downstream the obstacle, invades and cross the ski run (Fig. 8). The second shot, at the

same altitude in the center of the slope, does not cause any avalanche.

The unusual avalanche release zone is individuated on the west of the basin at 2500 m asl with a wind slab thickness ranged from 60 to 100 cm and 340 kg/m<sup>3</sup> of density. The predefined weak link between the obstacle and its foundation is broken to safe the structural integrity of the last one under extreme events (Barbero et al., 2013). As expected, the foundation has not damaged while serious damage has been reported by load transducers and connecting cables.



Figure 8. P.ta Seehore basin – 19 March 2011 events with the “Collegamento Gabiet” ski run. The position of the obstacle before (in red) and after (in yellow) the avalanche (Photo: A. Welf).

#### 4.3 The “Larici” ski run (2000 m asl – SW aspect)

The SW slopes close to Larici ski run is cleaned by ski-patrollers to safety get back skiers to Frachey (Fig. 2, violet arrow): the “Larici” is the track to come back to Gressoney valley for skiers staking in Ayas valley. It is one of the new ski runs of Monterosa Ski etched and made in Winter 2006/07 to replace an old lift. The problem is due to small wet avalanches that slip from these slopes, overrun the track by 400 m (Fig. 10) and damage snow cannons and safety nets. The slopes are a sparse and stony forest with 45 - 60° of inclination. To manage this problem, two methods are used coupled with the continuous monitoring of the snow and weather local conditions: i) temporary closure of the track; ii) artificial release with DaisyBell® & explosives

from helicopter or from the ground. Usually, the release is anticipated by rapid temperature changes during the day or small sluffs release.

In the first 10 days of April 2013, several snowfalls accumulate a lot of snow rapidly drifted by wind on E slopes. From 10 April, a tropical weather for North Africa brings dry air and spring temperatures: 14<sup>th</sup> April, the freezing level reaches 3700 m asl. The combination of high temperature & sun humidifies the snowpack up to 3500 m and saturates it below 2500 m asl leading to a strong avalanche activity (RAVA, 2013) throughout the Aosta Valley:

- small and medium-sized surface avalanches of recent wet snow from the steep sunny slopes and rocky bars at all aspects;
- gliding avalanches (full-depth slabs) from the sunniest slopes below 2200 m;
- slab avalanches, mainly from the N and E aspects with 50-100 cm thickness (involving also the deeper layers) induced by low (skiers) or high (artificial triggering) overloads.

The most critical condition is linked to the N and E aspects (the less sunny), still very full of very unstable snow, not yet metamorphosed towards spring type (recent loose snow on faceted crystals or glass) and fully humidified, at least up to 2800 m. The degree of danger level is 3-considerable on the whole Region.

In Ayas valley, the 12<sup>th</sup> April, the snowpack presents 140 cm of thickness by 2000 m. Considering the given snow & weather conditions and the avalanche activity, the Larici slope (Fig. 9) is supposed instable and from 10<sup>th</sup> April is under monitoring.

Some DaisyBell® shots on 11<sup>th</sup> don't provoke avalanche trigger, but on 12<sup>th</sup> around 03:30 pm small sluffs is releasing from the slopes. The track is immediately closed and cleaned by 37 DaisyBell® shots that release several small wet



Figure 9. Sluffs on 12<sup>th</sup> April 2013 on the Larici slope (Photo: A. Prola).

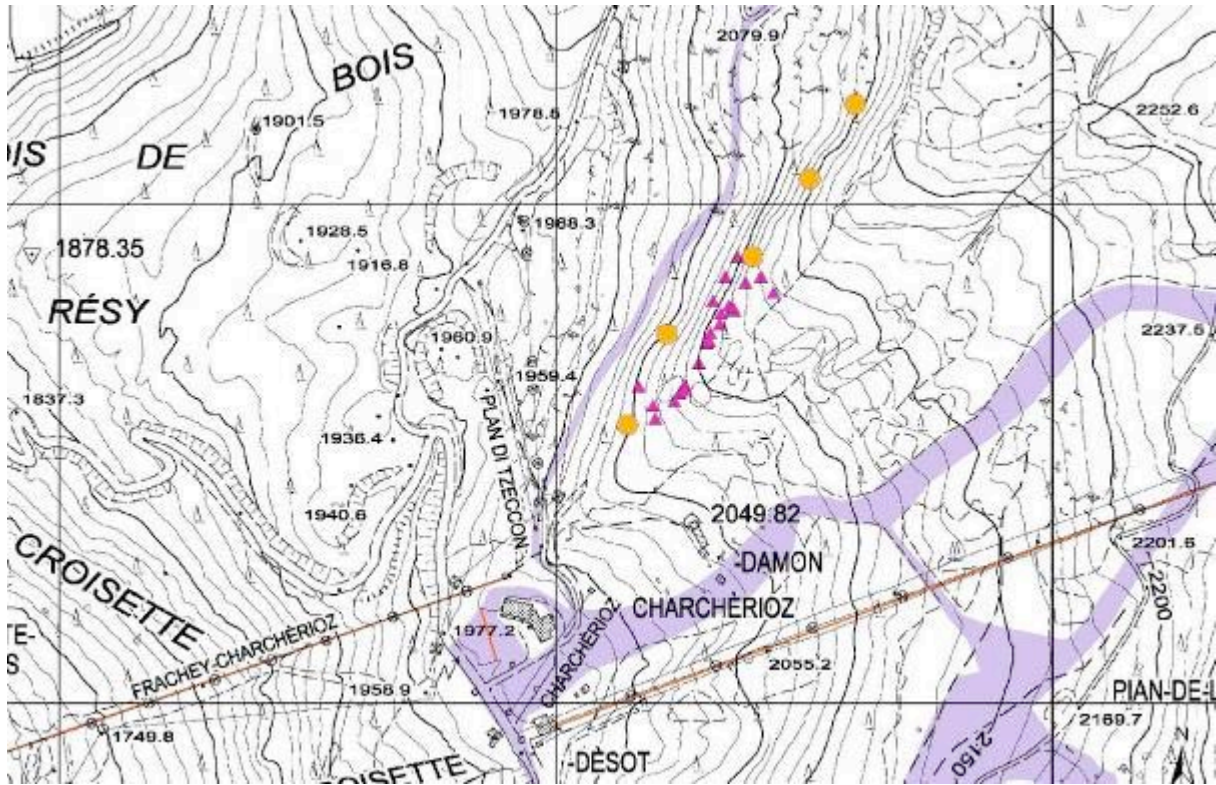


Figure 10. La Larici (in yellow the shot points from PIDAV; in pink, the DaisyBell® shots in 12<sup>th</sup> April 2013; in violet: the ski slopes).

avalanches invading the track and uprooting safety nets (Fig. 9). The 13<sup>th</sup> to assure the safety of the track, some other shots by explosives are done but nothing comes off.

## 5 CONCLUSIONS

In a wide resort as Monterosa Ski on the basis on the avalanche risk management there is the knowledge of territory, its local meteorology (i.e., local winds) mixed with the high professionalism together, passion for this job and curiosity to innovative instrumentation and equipment: the desire to decrease avalanche risks and making more safe the resort impose to improve the knowledge on avalanche. That's why, Monterosa Ski is always interested in technological innovation applied to the management of ski slopes and avalanche risk. Many research collaborations and innovation carried out with universities (University of Torino, Politecnico di Torino, ISPRA, Alpine Institute Angelo Mosso, etc ...), technical bureau (AWS, ARPA, AINEVA) and specialized firms underline the company's commitment. Some examples are the collaboration in ALCOTRA projects (DynAval, RiskNat, MAP<sup>3</sup>) to support the researchers in situ and driving them in the real issues in the field; the participation as a partner in MRR Team to study

release tools (DaisyBell®, Daisy track Manager and Cornicheur® for TAS, the development of VAS1 and the PH-procedure).

The paper rapidly reports unusual examples of risk management in ski resort to underline the problems and the decision making to make safe one day of fun for people.

## 7 ACKNOWLEDGMENTS

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## 8 REFERENCES

- Avalanche Bulletin of Aosta Valley - March 2011
- Avalanche Bulletin of Aosta Valley - April 2013
- Barbero, M., Barpi, F., Borri-Brunetto, M., Bovet, E., Chiaia, B., De Biagi, V., Frigo, B., Pallara, O., Maggioni, M., Freppaz, M., Ceaglio, E., Godone,

- D., Viglietti, D., Zanini, E., 2013. A new experimental snow avalanche test site at Seehore Peak in Aosta Valley (NW Italian Alps) — Part II: engineering aspects. *Cold Regions Science and Technology* 86, 14-21.
- Frigo, B., Barbero, M. and De Biagi, V., 2012. A CBA of artificial avalanche release devices in ski resort: Monterosa Ski (AO- Italy) case study. 2012 International Snow Science Workshop, Anchorage, Alaska, pag. 662 – 665.
- Frigo, B., Chiaia, B. Cardu, M., Giraudi, A., Godio, A., Rege, A., 2010. Experimental analysis of snowpack effects induced by blasts. 2010 International Snow Science Workshop, pag. 66 – 71.
- Frigo, B., Chiaia, B. Cardu, M., 2011. Snowpack effects induced by blasts: experimental measurements vs theoretical formulas. 2012 International Snow Science Workshop, Anchorage, Alaska, pag. 943 – 947.
- Maggioni, M., Bovet, E., Buehler, Y., Godone, D., Bartelt, P., Freppaz, M., Chiaia, B and Segor, V., 2013. Influence of summer and winter surface topography on numerical avalanche simulations. This issue.
- Regione autonoma Valle d'Aosta, Assessorato opere pubbliche, difesa del suolo e edilizia residenziale pubblica, Direzione assetto idrogeologico dei bacini montani, 2011a. Experiment test site P.ta Seehore: events on 18-19-20 March 2011. Internal report Winter 2010/11, DynAval project.
- Regione autonoma Valle d'Aosta, Assessorato opere pubbliche, difesa del suolo e edilizia residenziale pubblica, Direzione assetto idrogeologico dei bacini montani, Ufficio Neve e Valanghe, 2011. Rendiconto nivo-meteorologico. Inverno 2010-2011, pagg 181.
- Regione autonoma Valle d'Aosta, Assessorato opere pubbliche, Direzione assetto idrogeologico dei bacini montani, Ufficio Neve e Valanghe, 2013. Rendiconto nivo-meteorologico. Inverno 2012-2013. (in press).
- Segor, V., Pitet, L., Maggioni, M., Frigo, B., Freppaz, M., Chiaia B., Bovet, E., Ceaglio, E., Welf, A., Dellavedova, P. 2013. The experimental snow avalanche test site at Seehore peak in Aosta Valley (IT): MAP<sup>3</sup> ALCOTRA project. This issue.
- Vassale, R. and Turcotti, P., 2004. La carica Vassale, Neve e Valanghe, n. 53.