Preliminary measurements and survey of snowdrift at the seehore avalanche test site - Aosta Valley (IT)

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ABSTRACT: In high elevation areas drifting snow influences the snowpack spatial distribution and consequently its stability. The amount of snow drifted from the windward side and accumulated on the leeward side is not only a function of wind conditions but it also depends on the snowpack characteristic.

One of the aim of the project MAP[3] "Monitoring for the Avalanche Prevision, Prediction and Protection" – P.O. ALCOTRA Italy/France (Alps) 2007-2013 is to better understand the influence of snowdrift on the snow spatial distribution in the leeward side of a ridge, where avalanches naturally or artificially occur.

To achieve this aim, in Summer 2012 the Seehore avalanche test site in Aosta Valley (Italy) was implemented with a snow and weather station installed on the ridge at 2570m asl in order to measure wind speed and direction, snow depth and drifted snow at different heights above the ground.

In case of avalanche release, snowpack properties and release features are recorded by field surveys. Laser scan measurements and photogrammetry are also performed to get information about the spatial distribution of the snowpack, with a special focus on the release zone.

This paper presents the design and the installation of the system and the first results of the measurements. As the experimental device was fully operational only for four months during winter 2012-2013, in this paper we focus on two specific events: 1) snowdrift event without snowfall, 2) snowdrift event with concurrent snowfall before an artificially released avalanche in the study site.

More work is planned for the future, in particular concerning the avalanche release and snowpack features in respect to snowdrift conditions. This new experimental test site presents a great potentiality to advance in this research topic, due to its small size and relatively easy logistic in the data recording.

KEYWORDS: snowdrift, avalanche release zone, experimental data, NW Italian Alps.

1 INTRODUCTION

In high elevation areas drifting snow influences the snowpack spatial distribution and consequently its stability. The additional load produced by the drifted snow might be critical for slab avalanche release. In literature, the snowdrift phenomenon has been approached in different ways: a) for the snow avalanche experts the main goal is to study the slab properties related to the wind/snow cover interaction in order to identify the location of potential avalanche release areas; b) for meteorologists and experts in wind properties the process itself is interesting and the aim is to understand the physical mechanism and possibly to model it.

Among the first approach, Foehn (1988) and Conway and Abrahamason (1984), from measurements taken at the crown face of slab avalanches, attributed differences in shear strength to slab geometry formed by wind. Bair at al. (2010) also found no crown transects with regular snow depth, suggesting that the transect shape is dominated by upwind terrain features and their interaction with the wind.

The more meteorological and modelling approach was followed for ex. by Gauer (1998), Mott and Lehning (2010) and Vionnet et al. (2012), who developped a model for the snowdrift and validate it with the help of data recorded at experimental snowdrift test sites. However, in these kind of work, the results did not combine the snow loads produced by the snowdrift to potential avalanche release zone.

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To our knowledge, there exist no experience that integrates the two research subjects taking advantage from experimental data. In the experimental test site of Seehore in Aosta Valley (Nort-western Italian Alps), we therefore aim at:

- study the wind field and the snowdrift around a complex mountaineous terrain;
- estimate the snow cover redistribution due to snowdrift;
- relate snow loads due to the wind action to the location of avalanche releases.

The aim of this paper is to present the experimental test site and the preliminary results obtained from the analysis of the data registered during the first operative season (winter 2012-2013). It is an ongoing project that started last winter and will last at least for another season.

2 STUDY AREA

The Seehore test site (45°51'05"N; 07°50'34"E) is located at the head of the Lys Valley, near the village of Gressoney-La-Trinité on the Monte Rosa Massif in the North-western Italian Alps. It is within the MonterosaSki resort and usually avalanches are triggered for the safety of the ski run that crosses the bottom of the slope (Fig. 1). It belongs to the authority Regione Autonoma Valle d'Aosta and is operative since winter 2009-2010 for the study of avalanche dynamics, flow/obstacle interaction and release processes The slope has an altitude difference of about 300 m (2570 to 2300 m asl) and faces toward NNW. At 2420 m asl an instrumented obstacle is placed for the measurement of the avalanche impact forces (Maggioni et al., 2013 and Barbero et al., 2013; Segor et al., this issue).

Figure 1: Winter view of Seehore peak from North-East (photo: A. Welf). The insert shows the geographical location of the test site.

In winter 2012-2013 the test site was implemented for the study of the influence of the snowdrift processes on avalanche release.

3 DATA COLLECTION

In order to measure the snow and meteorological variables necessary for the study of the snowdrift process, in Fall 2012 a snow and weather station were installed on the ridge, at 2570 m asl. The station is composed by (Fig. 2):

- 1 anemometer and 1 wind vane placed at 600 cm above the ground;
- 1 snow depth sensor placed at 530 cm above the ground;
- 4 snowdrift sensors (Wenglor YH08NCT8 LASER) placed at variable heights above ground (+110, +210, +310 and +550 cm). These sensors measure the number of particles that cross a laser beam and have being used by other authors in different study sites (e.g. Naaim-Bouvet et al., 2012).

The measurements are locally recorded every 10 minutes by a data-logger and also sent through a transmission system to the Politecnico of Torino.

Beside the above parameters measured up at the ridge, other snow and weather parameters are recorded in the surrounding. An automatic and a manual weather stations are placed at about 2400 m asl less than 1 km apart from the site. Snow depth, air temperature and precipitation are automatically recorded every 30 minutes, while new snow height and density, air temperature, snow cover surface characteristics and weather conditions are manually recorded daily at 8 am.

Moreover, in case of avalanche release, more data are collected by field work, namely snowpack physical properties, snow cover distribution via manual probing and/or laser scanning, and release zone characteristics.

Figure 2: Snow and weather station placed on the ridge at 2570 m asl at the Seehore test site (photos: M. Maggioni).

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4 DATA ANALYSIS

From the recorded data, we first characterize the test site in term of wind conditions.

new snow data taken manually every morning near the study site.

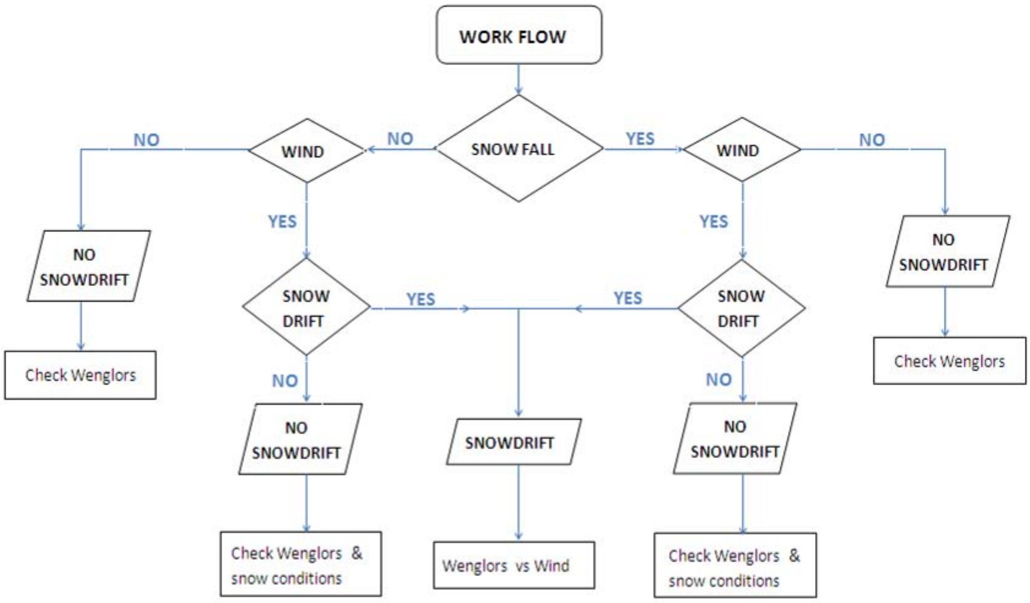

Figure 3: Work flow for the extensive data analysis.

Then, different analysis are performed: extensive analysis on the whole database and more specific ones on particular periods.

The work flow is shown in Fig. 3, where it is evident that the first important distinction is between periods of snowfall and of no snowfall. Within these two subsets, the analysis of snowdrift with respect to wind and snowpack properties is done.

In particular, we analyse the possible relation between the Wenglor count at different heights above the ground and the wind speed.

In this work we do concentrate on specific periods, while the extensive analysis of the whole database is planned for the future. In particular, we focus on the periods:

- 24th – 26th of February 2013: snowdrift event with concurrent snowfall, before the avalanche artificially triggered on 26th of February 2013;
- 20th March 2013 (01:19 - 07:49 pm): snowdrift event without concurrent snow fall.

To identify the different events, we first have to distinguish between the snowfall and no snowfall periods. This is already an issue, because their definition cannot be achieved simply checking the snow depth data from the snow gauge. In fact, sometimes the strong wind blowing during a snowfall can falsify the snow depth automatic records (as found for ex. by Bellot et al., 2011). In our case, we can trust more the

5 PRELIMINARY RESULTS

In this section we first characterize the wind conditions at the Seehore test site and then analyze the two specific selected events.

5.1 Wind conditions at Seehore test site in winter 2013

The system was fully operational only in the period 15th February – 3rd May 2013. We can use only those data to describe the wind conditions at the site, that therefore are related only to the last season and cannot be used to characterize the prevalent wind field at the site.

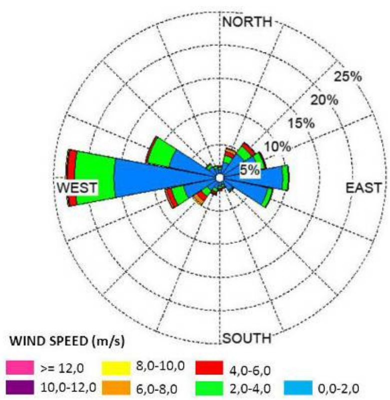

Figure 4. Distribution of the wind speed and direction (hourly averaged values) at Seehore (15th Feb - 5th May 2013).

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Unfortunately, there are no AWSs in the surrounding that can be used for this aim, as the wind field around the Seehore peak is a lot influenced by the local topography.

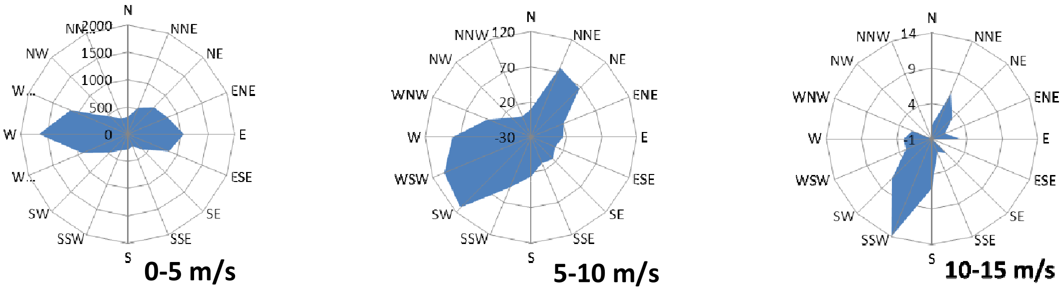

Figure 5. Wind directions for different wind speed classes at Seehore (2nd Feb – 5th Mar 2013).

Fig. 4 shows that, in those 4 months, the prevalent wind direction was W-E and the maximum speed around 16 m/s (but with prevalent direction SSW-NNE). Most of the data (93.8%) lies in the wind speed class 0-5 m/s, 5.7% in the class 5-10 m/s (Fig. 5). If we consider only the periods when the lowest wenglor (W4) counted more than 100 particles per 10 min (considered as a threshold to identify a snowdrift period), the prevalent wind direction was again W-E but the data distribute slightly differently within the classes: most of the data (78.3%) still lies in the wind speed class 0-5 m/s but more data are within the class 5-10 m/s (20%) Note that Seehore test site faces toward NNW, therefore the wind sector that favours the snow load on the slope range from SW to E.

The winter 2012/13 was characterized by several episodes of snowdrift (even with high wind speed, around 10m/s) linked to intermittent snowfalls.

5.1 Snowdrift event with concurrent snowfall before the artificially triggered avalanche on 26th of February 2013

On 26th of February 2013 (9.40 am) an avalanche was artificially released with explosives at the Seehore test site (Fig. 6) after a period of snowfall with concurrent wind blowing mainly from WSW, with an average velocity (on the period 24th – 26th February) of 3 m/s (peaks up to 10 m/s, Fig. 7).

The cumulative new snow measured at the manual station was 52 cm, while the AWS and the snow gauge up at the ridge registered about 40 cm of new snow (determined as the difference between the snow depth at the beginning and at the end of the snowfall), as well as the manual snow pit (Fig. 8).

The snow distribution on the ground before the avalanche triggering was measured with a laser scan campaign (Fig. 9), that was repeated after the avalanche release for avalanche mass balance purposes. Here we are interested in the snow cover distribution before the triggering in order to recognize areas of additional snow load

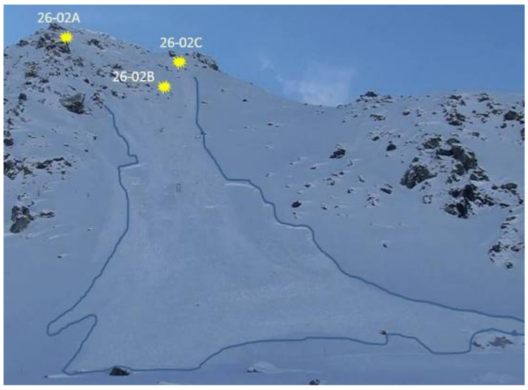

Figure 6. Overview of the avalanche triggered on the 26th of February 2013. In yellow the triggering points: shot 26-02A released the large avalanche that triggered two secondary releases along the path; shot 26-02B had a negative result and shot 26-02C released only a small sluff.

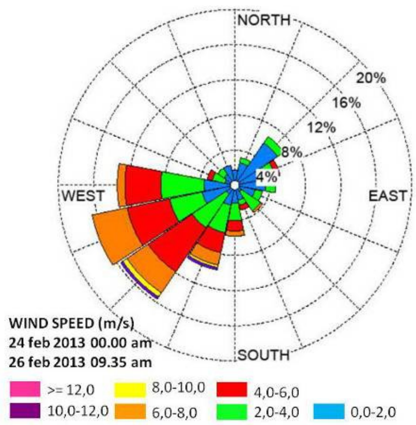

Figure 7. Distribution of the wind speed and direction at Seehore (raw data in the period 24th feb 00.00 am - 26th feb 09.35 am 2013).

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probably due to wind actions. For example, there are two evident areas at around 2550-60 m asl with a snow depth higher than the surrounding ones (Fig. 9); there, the avalanche was artificially triggered.

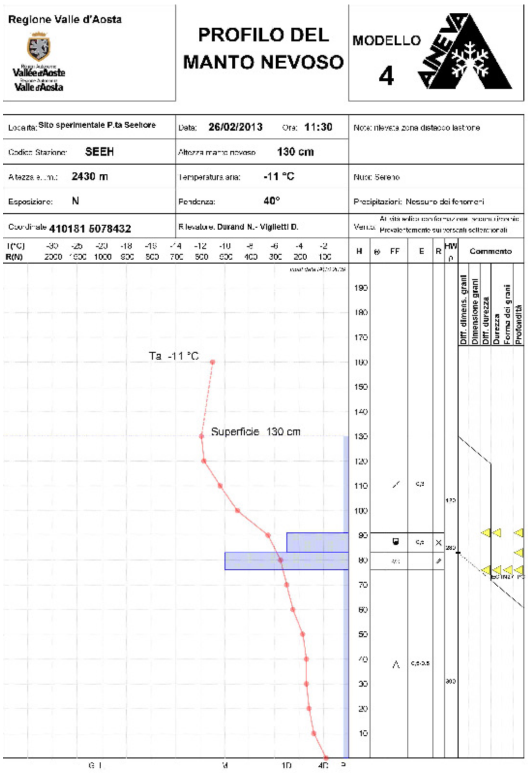

Figure. 8. The snowpack profile at 26th of February 2013 closed to the avalanche release zone shows a 40 cm of fresh snow on a 10 cm thick faceted rounded particles - RGxf and 10 cm melt-freeze crust - MFcr (Fierz et al., 2009).

The wenglors measured particle numbers up to about 85000 in 10 minutes at the lower position (W4 in Fig. 10). The relation between the counts shows that the highest values were gene-rally recorded from wenglor 4 (W4 at +110 cm), then wenglor 1 (W1 at +550 cm) and then wenglor 3 (W3 at +210 cm). Tab. 1 shows the correlation (always highly significant, $p < 0.001$) between the variables: W4 is the wenglor with the highest correlation with the wind speed, probably due to the fact that the flux closed to the snow surface is larger than at higher heights above the ground.

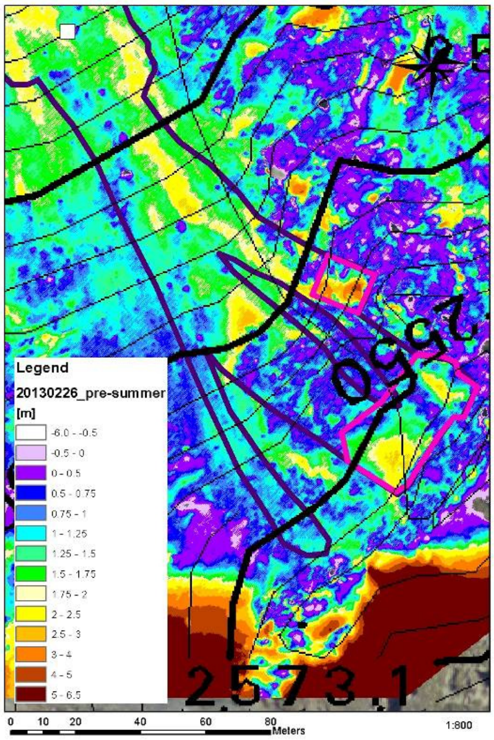

Figure 9. Snow cover distribution in the release zone on 26th of February 2013 before the avalanche triggering. The blu line outlines the avalanche perimeter, while the pink ones the release areas used to back-calculate the event (see Maggioni et al., this issue).

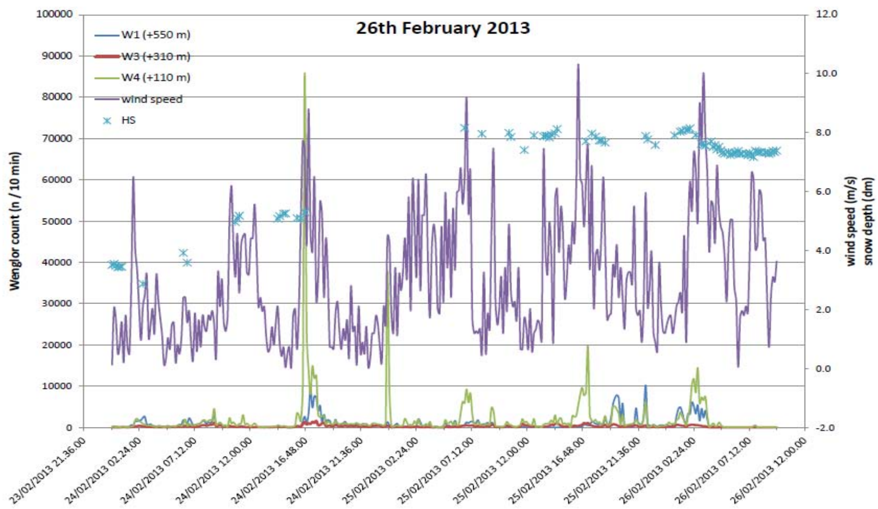

Figure 10. Wenglor count, wind speed and snow depth registered from the instruments placed up at the Seehore ridge.

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	w1	w3	w4	speed
w1	1.000	0.560	0.321	0.202
w3	0.560	1.000	0.522	0.248
w4	0.321	0.522	1.000	0.341
speed	0.202	0.248	0.341	1.000

Table 1. Correlation between the wenglors and the wind speed ($p < 0.001$).

5.2 Snowdrift event without concurrent snowfall

The specific snowdrift period considered here occurred on the 20th of March 2013 from 01:19 to 07:49 pm.

After the snowfall from 23rd to 26th of February (that imposed the artificially avalanche release described in section 5.1), a new snowfall from 27th to 28th of February (about 20 cm) and other feeble one from 16th to 19th of March (about 25 cm) built a snowpack in which 30 cm of fresh snow based on around 30 cm of rounded grains LGlr (Fierz et al., 2009).

Fig. 11 shows the trend of the three wenglor counts and the wind speed during the snowdrift event: wenglors draw the same trend, i.e. counts increased when the wind speed relatively decreased, reaching the low/medium speed range (from 5 to 10 m/s, ideal for snowdrift phenomena) from 06:19 to 07:19 pm. All the wenglors were significatively mutually correlated ($p < 0.05$), while no correlation was found between the wenglors and the wind speed (Tab. 2).

Note that, in this snowdrift event, the wind speed is high in comparison to the average value at Seehore ridge, reaching peaks of about 12.5 m/s with NNE prevailing directions (Fig. 12).

	w1	w3	w4	speed
w1	1.000	0.628	0.866	0.196
w3	0.628	1.000	0.356	-0.066
w4	0.866	0.356	1.000	0.242
speed	0.196	-0.066	0.242	1.000

Table 2. Correlation between the wenglors and the wind speed.

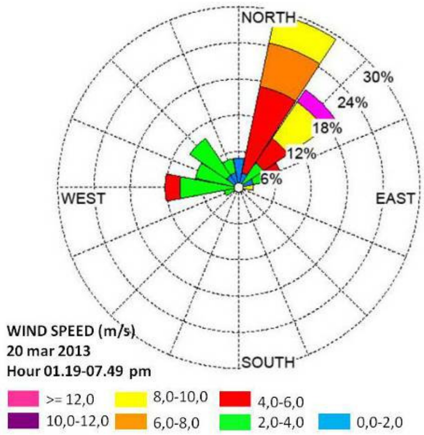

Figure 12. Distribution of the wind speed and direction at Seehore (raw data on the 20th of March 2013, from 01:19 to 07:49 pm).

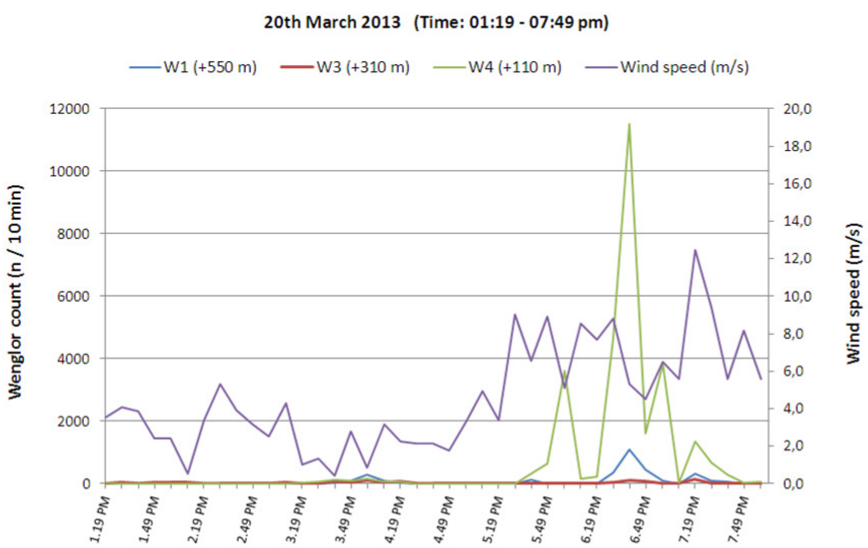

Figure 11. Wenglor count and wind speed registered at the Seehore ridge during a snowdrift event without snowfall (Time: 20th March 2013, from 01:19 to 07:49 pm).

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6 DISCUSSION AND CONCLUSIONS

In this paper we presented a new test site for the study of the snowdrift over a complex mountain topography and of the snow load on potential avalanche terrain. As it was operational only for 4 months last season, we then presented only results from specific periods.

In terms of wind conditions, the Seehore test site seems to be not very windy, with wind speed similar to other surrounding AWSs placed on ridges and considered not windy (personal communication by G. Contri). As, in reality, in the release zone of the Seehore avalanche test site, we observed snow loads due to wind, we think that the interaction of the steep topography with the wind field plays a key role in understanding the recorded data. We will go deeper in this research with measurements of the wind speed around the peak an possibly modelling the wind field.

From our preliminary analysis we did not found any trend between the wenglor counts and the wind speed, neither with nor without concurrent snowfall, as instead found by Naaim-Bouvet et al. (2012) for period of snowdrift without snowfall. We definitely need a larger dataset to say something more about this relation. We will also check the wenglor functionality at different air temperature, as we recently discovered that the sensors might have problems at temperatures lower than a certain threshold (ranging between -10 and -15 °C) that is different for each sensor. This is the main problem to be solved now in our analysis, before being able to give correct interpretation of our data and coming to some conclusions.

In the future, we will analyze the whole dataset with extensive analysis, in order for ex. to find a relation between the snowpack properties and the snowdrift events. As Li and Pomeroy (1997), we would like to search for a relation between the threshold velocity for snowdrift and the snow properties, mainly the age of the snow at the surface of the snowpack, snow density and temperature. We cannot take advantage of snowpack models until yet (the approach followed for ex. by Lehning et al., 2000 and Vionnet et al., 2012), but we hope for future collaborations in order to obtain further information to be used in our analysis.

A great improvement would come from laser scan campaigns made three times at the test site: 1) before and 2) after a snowdrift event and 3) after the avalanche triggering, in order to follow the snow cover redistribution and relate this to the location of avalanche release areas.

In case of snowfall we will also check if the highest wenglor is able to count the falling snow particles, depending on the wind speed.

To conclude, the main innovation in our experimental test site is the combination of snowdrift measurements in an avalanche test site. This peculiarity makes us able to study possible relation between snowdrift, snow load on release zone and the potential avalanche triggering. Until now we only have one registered event, therefore we hope in the future to get more data in order to achieve this goal, which has a practical application for avalanche experts.

7 AKNOWLEDGEMENTS

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8 REFERENCES

Bair, E.H., Birkeland, K.W., Dozier, J., 2010. In situ and photographic measurements of avalanche crown transects, Cold Regions Science and Technology, 64(2), 174-181.

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.

Bellot, H., Trouvilliez, A., Naaim-Bouvet, F., Genthon, C., Gallée, H., 2011, Present weather sensor tests for measuring drifting snow, Annals of Glaciology, 52(58), 176-184.

Conway, H., Abrahamson, J., 1984. Snow stability index. Journal of Glaciology 30, 321–327.

Fierz, C., Armstrong, R.L., Durand, Y., Eychevers, P., Greene, E., McClung, D.M., Nishimura, K., Satyawali, P.K. and Sokratov, S.A. 2009. The International Classification for Seasonal Snow on the Ground. IHP-VII Technical Documents in Hydrology n. 83, IACS Contribution n. 1, UNESCO-IHP, Paris.

Maggioni M., Durand N., Frigo B., Pallara O., Freppaz M., Dellavedova P., Segor V., Naaim-Bouvet F., Bellot H. Preliminary measurements and survey of snowdrift at the Seehore avalanche test site – Aosta Valley (IT). International Snow Science Workshop (ISSW 2013), Grenoble Chamonix-Mont-Blanc, France, October 7-11, 2013. pp. 126-133

Föhn, P.M.B., 1988. Snowcover stability tests and the areal variability of snow strength. Proc. 1988 Intl. Snow Sci. Workshop, Whistler, B.C. Canada, pp. 262–273.

Gauer, P., 1998. Blowing and drifting snow in Alpine terrain: Numerical simulation and related field measurements. Ann. Glaciol., 26, 174–178.

Lehning, M., Doorschot, J., Bartelt, P., 2000. A Snow drift index based on SNOWPACK model calculations. Ann. Glaciol. 31, 382–386.

Li, L., Pomeroy, J., 1997. Estimates of threshold wind speeds for snow transport using meteorological data. J. Appl. Meteorol. 36, 205-213.

Maggioni M., Bovet, E., Dreier, L., Buehler, Y., Godone, D., Bartelt, P., Freppaz M., Chiaia, B.2, Segor V., 2013. Influence of summer and winter surface topography on numerical avalanche simulations. This issue.

Maggioni, M., Freppaz, M., Ceaglio, E., Godone, D., Viglietti, D., Zanini, E., Barbero, M., Barpi, F., Borri-Brunetto, M., Bovet, E., Chiaia, B., De Biagi, V., Frigo, B., Pallara, O., 2013. A new experimental snow avalanche test site at Seehore peak in Aosta Valley (NW Italian Alps) - Part I: conception and logistics. Cold Regions Science and Technology 85, 175-182.

Mott, R., Lehning, M., 2010. Meteorological modelling of very high resolution wind fields and snow deposition for mountains, Journal of Hydrometeorology, DOI:10.1175/2010JHM1216.1.

Naaim-Bouvet, F., Bellot, H., Naaim, M., 2010. Back analysis of drifting snow measurements over an instrumented mountainous site. Ann. Glaciol. 51 (54), 207–217.

Naaim-Bouvet, Bellot, H., Nishimura, K., Genthon, C., Palerme, C., Guyomarc'h, G., 2012. How to detect snow fall occurrence during blowing snow event? Proceedings, 2012 International Snow Science Workshop, Anchorage, Alaska.

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). This issue.

Vionnet, V., Guyomarc'h, G., Bouvet, F.N., Martin, E., Durand, Y., Bellot, H., Bel, C., Puglièse, P., Occurrence of blowing snow events at an alpine site over a 10-year period: observations and modelling, Advances in Water Resources (2012), doi: http://dx.doi.org/10.1016/j.advwatres.2012.05.004