SAFETY CONCEPT "LIESGELE AVALANCHE", A HIGH RESOLUTION APPROACH TO SUPPORT DECISION MAKING OF AVALANCHE COMMISSIONS AND TO ANALYZE THE USAGE OF PROTECTION MEASURES

Alexander Prokop[1, 2]*, Clemens Schekulin[3], Josef Pichler[1], Reinhard Kaplanski[1]

[1]Department of Civil Engineering and Natural Hazards, BOKU, University, Vienna, AUSTRIA

[2]Snow Scan Research, Engineering, Education GmbH, Vienna, AUSTRIA

[3] ÖBB-Infrastruktur AG, Praterstern 3, 1020 Vienna, AUSTRIA

ABSTRACT: In April 2009 an avalanche event at the Liesgele avalanche track in Carinthia, Austria, destroyed an electrical tower and stopped only 100 m away from the railway track. This event finally motivated the local avalanche commission to invest in an analysis, using new high resolution approaches to support their decision making. The analysis manly investigated under what meteorological condition (manly snow drift events) what fracture height and release mass is to be expected and what run out distance of the avalanche is reached in the different scenarios from the 5 present release areas. Different tools were applied to fulfill that goal: 1) An meteorological station was built to assess meteorological conditions on site 2) terrestrial laser scans ensured high resolution spatial snow depth mapping of the avalanche release area, the avalanche track as well as the deposition zone 3) 3-dimensional atmospherical modeling using ARPS (Advanced regional prediction system) analyzed wind flows that are responsible for snow drift events 4) extreme value analysis determined the return period of extreme snow heights at the release areas 5) Dynamic avalanche modeling using SAMOS, ELBA+ and RAMMS determined possible run out scenarios. The analysis gave the avalanche commission a fundamental knowledge about the events that are expected under certain scenarios in the future. Already in winter 2014 this knowledge had to be applied (the railway track had to be closed for 5 days) due to massive snow heights in the release area with a return period of approximately 50 years.

KEYWORDS: avalanche modeling, wind field modeling, terrestrial laser scanning, decision making

1. INTRODUCTION

Avalanche-dynamics models are used in land-use planning and for the design of protection measures. One of the important input parameters for such models is the mass of snow that is released within the avalanche starting zone. However, the snow cover distribution in mountainous terrain is known to be highly influenced by the local wind field. Snow transport and deposition behaviour due to snow drift and blowing snow is not the only but the main reason for the variable snow depth distribution at avalanche release zones. So far one averaged snow height (and snow mass) value accounts for the avalanche release zone as an input value for dynamic avalanche models. This value is estimated by extreme value statistics of 1 dimensional snow height measurements from automated measurement stations in close proximity to the avalanche release zone, e.g. Gumbel (1958). Additionally, Salm et. al (1990) accounts for the influence of the topography on the snow height distribution, since the determining, parameters of slab thickness are new snow height, slope angle and snow drift. The user-guide for the widely used dynamic avalanche model AVAL-1D 1.3 (SLF, 2005) suggests accounting for snow drift by adding an additional 0.3 – 0.5 m to the value of the slab thickness. As those simple approaches do not account for the variable snow cover distribution within the avalanche release zones, the Swiss guidelines (Magreth, 2007) recommend that snow height is measured manually or with snow gauges before designing protection constructions. For this purpose 25 – 100 measurements per hectare are suggested. As those measurements are often dangerous and inaccurate when compared to al-

* *Corresponding author address:*
Alexander Prokop, Snow Scan Research Engineering, Education GmbH, Vienna, AUSTRIA
tel: +43 69912030823
email: SnowScan@gmx.at

ternative methods (Prokop et. al, 2008) terrestrial laser scanning (TLS) is used in this study to measure the variable snow depth distribution within the avalanche release zones. TLS is an affordable method of gaining 3-dimensional high resolution snow height data (Prokop, 2008a). In addition to the spatial snow height measurements, wind field modelling is carried out in order to understand the process of extreme snow drift events. The method of combining wind filed modeling and spatial snow height measurement was previously used for the design of snow fences to mitigate the effect of snow drift events by encouraging snow accumulation in defined areas and preventing snow accumulation in hazardous areas (Prokop and Delaney, 2010) and for avalanche forecast purposes (Prokop, 2008b). However, the presented methodology additionally uses extreme value statistics to determine the spatial snow depth distribution. Potential slab thicknesses can therefore be estimated with a high resolution approach and make estimation of the model input parameter and the design of protection constructions and blasting spots within avalanche release zones more accurate.

2. LIESGELE AVALANCHE TRACK

In April 2009 an avalanche event at the Liesgele avalanche track in Carinthia, Austria (figure 1), destroyed an electrical tower and stopped only 100 m away from the railway track.



Fig. 1: Location of the “Liesgele avalanche track”

For safety concerns on the 4th of April 2009 another avalanche was triggered by blasting actions launched from a helicopter (figure 2).



Fig. 2: Avalanche release area and consecutive avalanche after blasting launched from the helicopter.

3. METHODOLOGY

3.1 Meteorological and snow pack condition

An automated measurement station at the area of interest delivers important data describing meteorological and snow conditions. Even though this data is measured only at the point the station is positioned, it is necessary in order to acquire input data for wind field modeling (or to validate the model) and for knowledge of snow pack conditions.

3.2 Wind field modeling

While the meteorological station provides wind parameters only at the point of measurement, the mesoscale atmospheric model ARPS (Advanced Regional Prediction System) was used for the 3-dimensional modeling of micro scale airflow within the test site (Xue et al., 2000a, 2000b). To fulfill the requirements of this work, a very high horizontal resolution of 5 m was found to be sufficient to

reproduce the characteristic flow features in the complex terrain (Mott and Lehning, 2010). The vertical resolution varies between 1.3 m near the ground and 60 m in the upper layers of the atmosphere. Correlations between the wind field and snow heights refer to the first layer above ground. The model run was initialized by different atmospheric profiles using analytical functions. The flow fields were computed until they reached a stationary state.

3.3 Snow Depth Mapping

The Riegl LPM-321 (www.riegl.com) laser-scanning device was used for the current study. For the method of measurement the reader is referred to Prokop (2008a) and Prokop (2009). Post processing of the data was carried out according to Prokop and Panholzer (2009). The measurement resolution was greater than 0.3 m (average horizontal point spacing smaller than 0.3 m). Accuracy of the measurements achieved is within a range of 0.1 m, determined by reproducibility tests. Laser measurements were executed for two overall seasonal snow height distributions in April 2008 and April 2009.

3.4 Extreme value statistics

For extreme value statistics of the snow height according to Gumbel (1958) snow height data from five meteorological stations in close proximity to the test area were used. The data was adapted to the elevation of the test area. The extreme value statistics were completed for the 3 days new snow sum and the overall seasonal snow height. The statistical series was sufficient enough to extrapolate events with a 150-year return period.

3.5 Dynamic avalanche modeling

Dynamic avalanche modeling using SAMOS, ELBA+ and RAMMS determined possible run out scenarios. Through the high-resolution picture of the spatial snow depth distribution it was easy for the operator to define the area of slab release for dynamic avalanche modeling. The snow height input value for dynamic avalanche modeling remains estimated, as spatial snow height data only exist for two years. However, the data provides detailed information for a more accurate estimation for the snow height input value.

4. RESULTS

The 3-dimensional wind simulation delivered important information. The predominant, on a macro scale, northwest and west winds are combined with heavy snowfall the greatest contributor of snow to the avalanche release area.

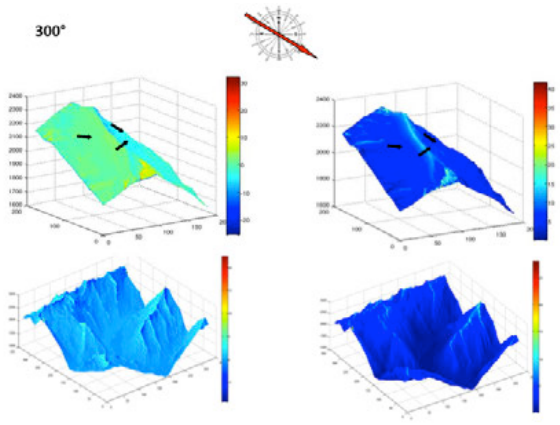

Fig. 3: Simulated vertical and horizontal wind speed from a wind direction of 300°.

This was also confirmed by the results of terrestrial laser scanning, the main problematic areas are visible in figure 4.

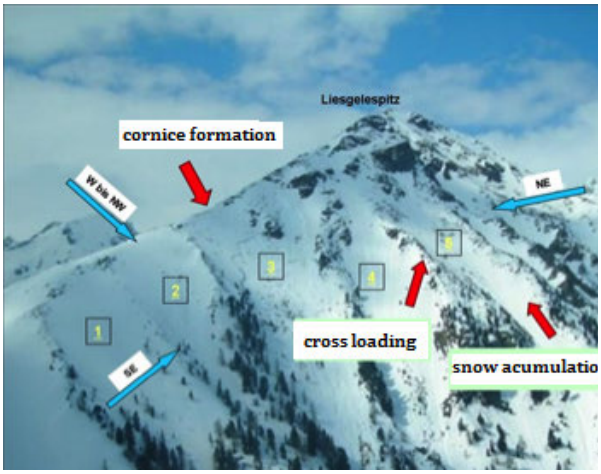

Fig. 4: Snow distribution patterns analyzed by wind field modeling and snow depth mapping via terrestrial laser scanning

Together with the extreme value analysis a good definition of fracture height and release area for dynamic avalanche modeling was possible. This was conducted using SAMOS, ELBA+ and RAMMS. Possible run out scenarios are visible in figure 5.

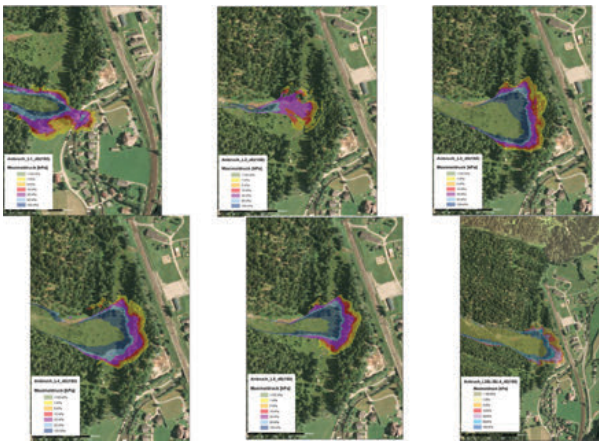

Fig. 5: Run out scenarios modeled using SAMOS

5. DISCUSSION AND CONCLUSIONS

A high-resolution approach consisting of wind field modeling, spatial snow height measurements extreme value statistics is presented to analyze the spatial snow height distribution at a particular avalanche release zone. Potential dimensions of extreme slab releases are investigated. Traditional extreme value statistics for determining extreme snow heights using snow height data from regional stations are not accurate enough to describe the amount of snow within a particular avalanche release area. Therefore the use of such extreme snow height values is questionable input data for dynamic avalanche modeling as well as for the dimensioning of protection constructions and blasting actions. The presented methodology facilitates a detailed picture of the snow cover dimensions at an avalanche release zone, therefore detailed instructions for avalanche protection measures could be given to authorities. The analysis gave the avalanche commission a fundamental knowledge about the events that are expected under certain scenarios in the future. Already in winter 2014 this knowledge had to be applied (the railway track had to be closed for 5 days) due to massive snow heights in the release area with a return period of approximately 50 years.

ACKNOWLEDGEMENTS

The work was funded by ÖBB-Infrastruktur Betrieb AG, INFRA.service, Naturgefahren-Management, 9500 Villach. Thanks to DI. Clemens Schekulin and DI.Christian Rachoy for funding this project. Moreover, thanks to RIEGL (www.riegl.com) for supporting this project.

REFERENCES

Gumbel, E.J., 1958. Statistics of extremes. NewYork, Columbia University Press, 4th edition 1967, 375 p.

Margreth, S., 2007. Lawinenverbau im Anbruchsgebiet. Technische Richtlinie als Vollzugshilfe. Umwelt-Vollzug Nr. 0704. Bundesamt für Umwelt, Bern, WSL Eidg. Institute für Schnee- und Lawinenforschung SLF, Davos 136 p.

Mott, R,, Lehning, M., 2010: Meteorological Modeling of Very High-Resolution Wind Fields and Snow Deposition for-Mountains. J. Hydrometeor, 11, 934–949.doi: 10.1175/2010JHM1216.

Prokop, A., 2008a. Assessing the applicability of terrestrial laser scanning for spatial snow depth measurements, Cold Regions Science and Technology 54, pp.155-163.

Prokop, A. 2008b. Combining wind field modeling with spatial snow depth measurements for avalanche forecast purpose. In Proceedings of the International Snow Science Workshop, Whistler, BC, Canada, 21-27 September 2008. International Snow Science Workshop Canada Inc., BC Ministry of Transportation, Victoria,Canada, pp. 523-527.

Prokop, A., Schirmer, M., Rub, M., Lehning, M.,Stocker, M., 2008. A comparison of measurement methods: terrestrial laser scanning, tachymetry and snow probing, for the determination of the spatial snow depth distribution on slopes. Annals of Glaciology 49, pp.210 – 216.

Prokop, A. 2009. Terrestrial laser scanning for snow depth observations: an update on technical developments and applications. In Proceedings of the International Snow Science Workshop, Davos, Switzerland,27 September – 2 October 2009. Edited by J. Schweizer, and A. Van Herwijnen.Davos, Switzerland, pp. 192-196.

Prokop, A., Panholzer, H., 2009: Assessing the capability of terrestrial laser scanning for monitoring slow moving landslides. Nat.Hazards Earth Syst. Sci., 9, 1921 -1928.

Prokop, A., Delaney, C.M., 2010. A high resolution approach to defining spatial snow height distribution in avalanche release zones for dynamic avalanche modeling. In Proceedings of the International Snow Science Workshop 2010, p 839-845.

Prokop, A., Rana, L., Delaney, C., Zott, F. (2010): Sicherheitskonzept Thomaseck; IAN Report, Institut für Alpine Naturgefahren, Universität für Bodenkultur – Wien (unpublished)

Riegl, 2010. http://www.riegl.com

Salm, B., Burkard, A., Gubler, H., 1990.Berechnung von Fliesslawinen. Eine Anleitung für den Praktiker mit Beispielen, Mitteilung Nr. 14, Eidg. Institut für Schnee und Lawinenforschung, Weissfluhjoch/ Davos.

SLF, 2005: AVAL-1D. Numerische Berechnungvon Fliess- und Staublawinen (Dynamic avalanche modelling software).

Xue M, Droegemeier KK, Wong V., 2000a.The advanced regional prediction system (ARPS) -a multi-scale nonhydrostatic atmospheric simulation model. Part I: Model dynamics and verification, Meteorology and Atmospheric Physics.75:161 -193.

Xue, M., Droegemeier, K. K. and Wong, V, 2000b. The Advanced Regional Prediction System (ARPS) Part II: Model physics and applications. Meteorology and Atmospheric Physics. 76: 143 -165.