Avalanche research, education and forecasting in Svalbard, Norway – A roadmap provided by an expert workshop in Longyearbyen, April 2013

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ABSTRACT: The mountainous landscape around Svalbard's main settlement Longyearbyen is snow covered for 8-10 months per year. Infrastructure is built in avalanche prone terrain, and an increasing number of inhabitants and tourists use the high relief landscape for winter recreation. This has led to an increase in both fatal and non-fatal avalanche accidents in the past 15 years, demanding improved focus on avalanche science, education, and forecasting. In response to this, we organized an international expert workshop in Longyearbyen, in April 2013 with 14 invited avalanche researchers and professionals from around the World. The goal was to review past and current avalanche research, education, and forecasting efforts in Svalbard, and based on these to provide recommendations and a roadmap for future efforts. In this paper, we present future key directions and priorities in the areas of research, education and forecasting. Our future research topics are location unique, but the results of which have worldwide implications. We also discuss the creation of a graduate level snow and avalanche course at the University Centre in Svalbard (UNIS), answering the demand for well-trained snow and avalanche professionals and scientists. Finally we discuss the implication of a regional avalanche forecasting service, which could be integrated into the Norwegian system.

KEYWORDS: Avalanche research, avalanche education, avalanche forecasting, Svalbard, Norway

1 INTRODUCTION

The Svalbard archipelago is located between 76° and 81°N in the Norwegian High Arctic. The mountainous landscape around Svalbard's main settlement Longyearbyen is snow covered for 8-10 months per year. As a result of this combination of factors, snow avalanches occur frequently, resulting in a hazard to infrastructure and people. In the last 12 years, avalanches have caused four fatalities, and in addition buried and injured people and destroyed infrastructure. With Longyearbyen township ever growing in its confined space of the Longyeardalen (Figure 1), and increasing numbers of tourists visiting Svalbard in winter, more infrastructure loss and avalanche accidents are anticipated unless immediate action is taken.

Therefore, basic knowledge about the topographical and meteorological triggers of snow avalanches in Svalbard are timely and crucial. Such knowledge can be used to instigate further in-depth progress in avalanche research, education and forecasting.

In this paper, we briefly review and summarize recent avalanche research and forecasting efforts in Svalbard. We then introduce the outcome of our workshop, which took place 23-26 April 2013 in Longyearbyen, with the goal to provide a roadmap for future professional avalanche work in the three above-mentioned topics.

2 SVALBARD – TOPOGRAPHY AND METEOROLOGY

The mountainous area around Longyearbyen is comprised of flat lying sedimentary bedrock, which form plateau mountains that are intersected by U-shaped valleys. These plateau mountains rise to an elevation of about 500 m a.s.l. with some alpine peaks reaching above 1000 m a.s.l.

Meteorology in the Svalbard area is highly influenced by ocean currents and air masses of different thermal character. Especially in winter, an alternating pattern of high and low-pressure systems can lead to daily air temperature fluctuations. Low-pressure systems result in snowstorms and occasionally in mid winter rain-on-snow events.

In general, however, Svalbard is relatively dry, with a mean annual precipitation amount of around 190 mm water equivalence. Mean annu-

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al air temperatures are currently -2.0 °C at sea level (2012) (Met.no, 2013). Average annual wind speeds are in the order of 5 m/s, prevailing from the SE during winter (Christiansen et al., 2013).

Figure 1: Longyearbyen, Svalbard's main settlement situated at the mouth of the valley Longyeardalen, flanked by up to 500 m high plateau mountains. The group of houses at the left end of Longyeardalen (circled) is the settlement Nybyen, which is particularly prone to cornice fall avalanche activity.

3 CURRENT AND PREVIOUS SNOW AND AVALANCHE RESEARCH IN SVALBARD

3.1 Snow climate

Snow depth distribution measurements were conducted at different locations in Svalbard at a local scale (Winther et al., 2003). These studies commonly related snow depth variability to redistribution by wind, as no high vegetation exists in Svalbard. Jaedicke and Sandvik (2002) modeled wind governed snow distribution and its effect on glacier mass balance, as well as on the location of glaciers.

A detailed classification of the snow climate and its main characteristics was presented by Eckerstorfer and Christiansen (2011a). They found a cold and thin snowpack, with a persistent depth hoar base and a middle part comprised of ice layer – facets combinations. These results are a confirmation of earlier studies by eg. Gerland (2001).

3.2 Cornice fall avalanches

Cornices and resulting cornice fall avalanches were recognized as geohazards in Longyearbyen (Figure 2) by the Norwegian Geotechnical Institute (NGI) in the early 2000 (Hestnes and Sandersen, 2000). It was suggested to construct snow fences on the plateaus, some distance away from the ridge to prevent cornices from forming, however, these plans were never put in to action.

During a three years avalanche monitoring project (2006-2009), Eckerstorfer and Christiansen (2011b) found that 45.2 % of all avalanches in a 17 km^2 large area around Longyearbyen were cornice fall avalanches. This finding triggered a number of detailed process studies focused on cornice development and failure. Researchers investigated; timing and speed of cornice accretion during the first seasonal snowstorms (Eckerstorfer et al., 2013); formation of cornice tension cracks as a prerequisite for dramatic failure during sudden air temperature rises (Vogel et al., 2012); and occurrence of cornice fall avalanches predominantly at the end of the snow season in June and July (Eckerstorfer and Christiansen, 2011b).

Figure 2: Two cornice fall avalanches on the plateau mountain Gruvefjellet, flanking Longyeardalen on its eastern side. The left avalanche was natural, the right one artificially triggered. Both cornice falls released 14 May 2012 and crossed the road between Nybyen and the main town of Longyearbyen.

3.3 Slush and wet slab avalanches

Slush avalanches are a typical avalanche type for the maritime High Arctic setting and were of interest to German, Polish and Swedish geomorphologists between the 1970s and 1990s. In particular, the German researchers made substantial contributions in their papers to the understanding of the release mechanism of slush avalanches due to snowmelt or heavy precipitation supersaturating the snowpack until a total loss of strength (Scherer et al., 1998).

More recently, Eckerstorfer and Christiansen (2012) studied two wet avalanche cycles, resulting from mid winter rain-on-snow events. Avalanches in these two cycles, January 2010 and March 2011, were extreme in their sizes and runout distances and released due to 1 in 100 year record monthly precipitation and air temperatures. However, no correlation between the frequency and magnitude of such extreme meteorological conditions and warming climate conditions was found. Moreover, the frequency and duration of low-pressure systems were found to be the dominating controls (Eckerstorfer and Christiansen, 2012).

3.4 Snowpack stability and its variability

Avalanche prone slopes in Svalbard are typically devoid of high vegetation and exhibit irregular ground topography. Thus, the connection between wind deposition and in-fill of these slopes and the topography is crucial to understand. Eckerstorfer et al. (submitted) found that the shallowest zones on slopes coincide with the weakest spots. However, later in the season when ground irregularities are levelled out, these shallow spots are very difficult to identify, thus knowing the terrain is crucial when using it for small scale avalanche forecasting.

4 CURRENT AVALANCHE EDUCATION IN SVALBARD

The University Centre in Svalbard (UNIS) is currently not running any courses focusing specifically on snow and avalanche related topics. There are only three courses taught at the Arctic Geology and Technology Departments that include snow and avalanche studies, and these courses only contain a few hours on this topic within their curriculum. However, avalanche awareness is part of the mandatory winter safety course for all new bachelor students at UNIS. In recent years, there have been a number of public avalanche awareness talks and the avalanche group from the local Red Cross offers courses for members and companies. So while basic avalanche education opportunities are available, there is a distinct lack of more advanced, science based, avalanche education and training.

5 CURRENT AVALANCHE FORECASTING IN SVALBARD

During the last three winters, the local Red Cross in Longyearbyen have issued a non-public, weekly avalanche bulletin for a mountain road leading to the company K-SAT's facilities on one of the plateau mountains. The bulletin is used as a decision-making tool for when to close the road due to unacceptable high avalanche danger. No other avalanche forecasting, or public avalanche forecasting is currently undertaken in Svalbard.

6 DISCUSSION

Using the research efforts undertaken to date as starting point, the three interrelated topics of, avalanche research, education and forecasting were discussed during the expert workshop. This was complimented with several field trips into the local surroundings to help the participants familiarize themselves with the local issues and snow and avalanche setting (Figure 3).

6.1 Future avalanche research

A gap analysis showed that there are a number of key areas with high research potential in Svalbard. These topics are location unique, or prevalent to the Svalbard location, but have potentially wider significant implications globally.

The key areas identified were; (1) Snow and avalanche spatial variability in an Arctic and wind-dominated landscape; (2) Cornice dynamics and cornice fall avalanches; (3) Mid-winter slush avalanche events; and (4) Snow and avalanches in a changing climate.

While each of these topics will require independent research questions and projects many of the methods and data required for these topics are inter-related. Among the collective needs for these research themes are a robust continuing database of snow, weather, and avalanche observations (Eckerstorfer et al., 2008). There is also a need for transferring these data into different official databases, such as Regobs.no by the Norwegian Water Resources and Energy Directorate (NVE) or eklima.no by the Norwegian Meteorological Institute (Met.no). Additional to these datasets, a more complete understanding of the processes involved in the release, timing of release and spatial extent of different kinds of avalanches is required. This will require a combination of traditional field based surveys and new, innovative, remote sensing techniques. Such remote sensing techniques should include; (1) Unmanned aerial vehicles (UAV) that allow for high-resolution, site and time specific data collection; (2) Terrestrial laser scanning (TLS) for repeated scanning of slopes to depict the temporal evolution of the snowpack's spatial variability; and (3) Satellite-based remote sensing, using the advantage of Svalbard's location in the polar orbit of satellites.

6.2 Future avalanche education

There was general agreement during the expert workshop that too few university-level courses on snow and avalanches exist. However, the need for snow and avalanche training to educate future researchers is quite clear.

The University Centre in Svalbard (UNIS) offers courses at all levels, with up to 60 % field component. With easy and quick winter field access, and the potential of inviting specialists to teach on courses, a UNIS course focusing on snow and avalanches is an attractive and feasible proposition. The workshop therefore strongly recommended for UNIS to develop a dedicated and intensive 3-4 weeks snow and avalanche science course at the master level, focusing on field learning methods.

Following these recommendations from the workshop, a trail version of this course is now being planned for the spring of 2014. It will then most likely become a formal part of the UNIS curriculum in the Arctic Geology Department from spring 2015. More information about this course can be found on the UNIS website (www.unis.no) under courses. This course will be tailored to the location, focusing on local snow and avalanche issues, but will also provide a strong physical and mathematical basis to understand snowpack and avalanche dynamics. Unique to this course, is the very high field component that will ensure that students can actively collect and analyse robust field data, but at the same time understand the processes and theory behind the observations taken. Topics covered will include snow stratigraphy, snow testing / sampling, snow hydrology, snow geophysics, avalanche physics and dynamics, as well as avalanche engineering and hazard mitigation.

6.3 Future avalanche forecasting

The discussions on avalanche forecasting identified two key points, which are; (1) Including Svalbard into the Norwegian Avalanche Center (varsom.no) or inventing a Svalbard specific forecasting model; and (2) Assessing the feasibility of different avalanche mitigation measures in Longyearbyen.

Since January 2013, NVE is issuing avalanche bulletins three times a week for selected areas in mainland Norway. A minimum of two observers work 2 x 4 hours per week and receive basic avalanche course training, financed by NVE. Third parties fund additional observers and infrastructure beyond this set amount. Svalbard is currently on a list of potential forecasting regions in 2013/2014, however, the interest of third parties to co-finance an avalanche forecasting service in Svalbard is crucial for it to come into existence. Such cooperation partners could be UNIS, the local mining company, the local authorities and the tourist industry. On the other hand, the model of two observers working 25 % of their time for a potential forecasting center was challenged by some of the experts. Avalanche forecasting was seen by some as a 100 % job that needs full commitment. Thus, funds from NVE and local companies could also be funnelled into at least one 100 % position, which would strengthen the role of such a person in the community.

Regarding the feasibility of avalanche mitigation measures in Longyeardalen, the discussions lead to the conclusion that there is one particular avalanche problem. The cornices in the Nybyen part of town pose a clear risk, and cheap but effective mitigation measures such as snow fences or wind baffles on the plateau could be useful. This was already suggested by NGI in a number of reports during the last 30 years, but to date, no action has been taken. Despite such mitigation work, avalanche engineering research projects would be also a feasible step in the future.

Figure 3: Participants of the expert workshop on a ski touring excursion to the Larsbreen glacier in the Longyeardalen valley to familiarize themselves with the local setting.

7 CONCLUSION

Longyearbyen, Svalbard's main settlement is located in avalanche prone terrain. A number of fatal accidents, infrastructure loss, together with a growing population and rising tourism make avalanche research, education and forecasting timely and important. Therefore, the expert workshop established recommendations for future snow and avalanche research, education and forecasting in Svalbard:

- Research:
  - Re-start database on field-based avalanche observations and include these data in official national and potentially international databases.
  - Improve climate and snow observations by expanding the current network.
  - Focus on research that is unique to the location, but has wider implications (e.g. slushflows, cornice dynamics, avalanches and climate change)
  - Process based research on snow and avalanches
  - Improve process understanding of cornice dynamics
- Education:
  - Develop an intensive, highly field-based graduate snow and avalanche course at UNIS.
- Forecasting:

- Include Svalbard as a region for the avalanche forecasting by NVE or adjust the NVE model towards a Svalbard specific model
- Consider passive avalanche control to minimize cornice development in Longyearbyen.

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