FORECASTING THE FATAL LONGYEARBYEN AVALANCHE. POSSIBILITIES AND CHALLENGES

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ABSTRACT: One of the main questions after the fatal avalanche in Longyearbyen in December 2015, where two persons perished and eleven houses were destroyed, was whether an active avalanche warning system would have identified the upcoming danger. At the time of the catastrophe, no avalanche warning was in operation. Observation routines established in the early 90ties were discontinued. The forecasted and observed weather is compared with 42 years of meteorological data from Longyearbyen airport. Similar weather conditions are identified and corresponding records of avalanche events clearly states that alarm bells should have sounded. The analysis showed that heavy snowstorms usually occur with westerly winds, while avalanches on the hillside leading to the fatal avalanche are associated with winds from Southeast. Minor precipitation and critical wind causes minor avalanches almost annually, while the fatal event in 2015 occurred due to a rare combination of intense precipitation and wind from Southeast. After the fatal avalanche on Saturday morning, larger parts of the settlements below west facing mountain sides were evacuated. Norwegian Geotechnical Institute managed to establish a fully manned avalanche warning service within Tuesday evening. A month later replaced by regional forecasts. The lessons learned from this work will be helpful in future local avalanche warning for settlements.

KEYWORDS: avalanche accident, forecasting, storm weather, wind measurements

1. INTRODUCTION

All fatal avalanches in settlements are rare events mostly associated with unfortunate combination of snow properties both in the release areas, path and runout zones, strong winds and heavy snow precipitation. On 19 December 2015, a fatal avalanche hit the settlement of Longyearbyen in the high Arctic. Eleven houses were destroyed with 25 people trapped, 10 injured and two dead. Events of this size have not been reported earlier in the settlements short history. The only reported fatal event being a major slushflow from a side valley in 1953 (Ramsli, 1953). This paper analyses the weather conditions that lead up to the fatal avalanche and describes shortly the ad hoc avalanche forecasting service that was established.

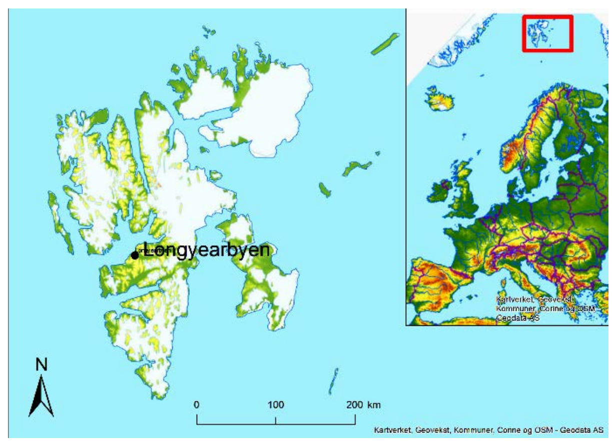

Fig. 1: Location of Longyearbyen in the Arctic.

1.1 Topography

Longyearbyen is located at 78º north and is an isolated town with approximately 2000 inhabitants during winter (Fig. 1).The town was established in 1906 in a side valley of the wide Advent Valley in the center of Spitsbergen. The site was chosen due to its close location to the coal mine that gave birth to the settlement. Buildings and houses have been moved in the valley from the location of one coal mine to another, but since the 1970's almost all new buildings were established close to the mouth of the valley. The available space for buildings and houses has always been limited to a small strip of land between the river and the mountains on both sides of the valley. The town is surrounded by steep mountain sides reaching up to almost flat plateau mountains. These plateaus give an almost endless fetch for drifting snow (Vogel et al., 2012).

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1.2 Climate

Longyearbyen is located in an arctic desert climate. The observed annual precipitation at the airport is less than 200 mm in the period 1976 – 2016 (Fig. 2). The climate on Svalbard has changed significantly in recent years. The annual mean temperature has increases by 3 °C since 1990. Especially the winter temperatures have increased with 2-3 °C per decade. This leads to more frequent warm spells with rain in the winter. Also the amount of precipitation has increased by 20-30% in Longyearbyen since 1990 (Vikhamar-Schuler et al., 2016). There is generally little snow on the ground. The maximum snow height at the airport was 56 cm in 1986-04-26 (snow height data is missing 1995-2008). Due to the lack of vegetation, wind speeds are high and drifting snow is almost always apparent (Jaedicke and Sandvik, 2002).

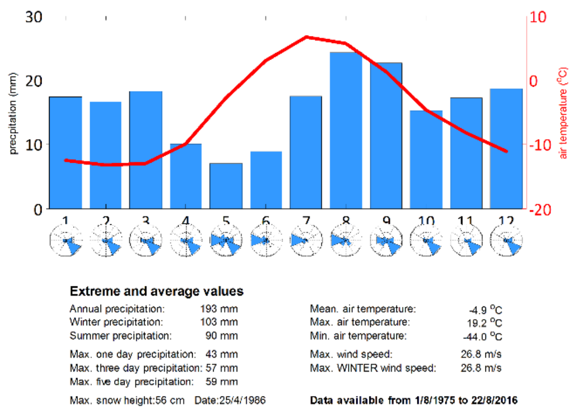

Fig. 2: Climatic overview from the meteorological station at Longyearbyen airport (registering since 1975).

2. MATERIALS AND METHODS

For this study, data from weather stations in Longyearbyen as well as meteorological maps and weather forecasts prior to the event have been used. The meteorological station Longyearbyen (station nr. 99860) was located from 1911 to 1976 in the town and was then moved 3.5 km northwest to the airport (station nr. 99840). In recent years, the University Centre in Svalbard has established five weather stations around Longyearbyen of which the stations "Gruvefjellet" (464 masl) and "Adventdalen" (15 masl) have been used in this analysis. The location of the stations in relation to the avalanche from 19th December 2015 is shown in Figure 4. Weather maps and records of the meteorologists forecast were kindly provided by the Norwegian Meteorological Institute.

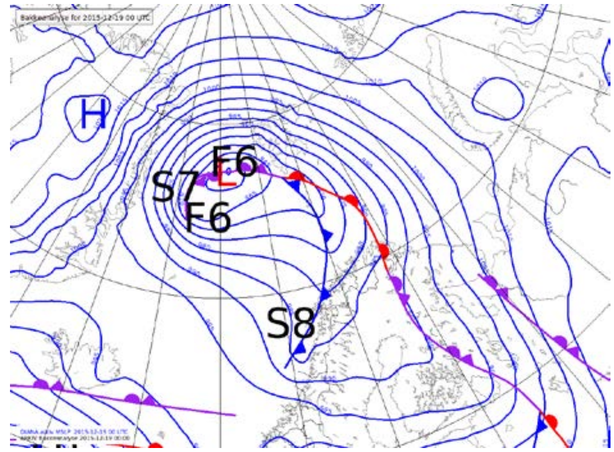

Fig. 3: Synoptic situation during the night before the avalanche (2015-12-19 00:00)

3. RESULTS

3.1 Storm weather

Starting on 17th December 2016 an intensive low pressure formed by two separate low pressures joining paths in the Norwegian Sea. The centre of the system increased in intensity while it moved towards the Svalbard archipelago (Fig. 3). The low pressure system was followed closely by the meteorologists and on the 17th December at 11:45 a first weather awareness warning was issued for the Svalbard Islands. The warning was "*Spitsbergen: On Friday evening storm from east, night to Saturday possibly hurricane force. Locally gusts up to 40-45 m/s. Saturday morning decreasing wind, first in southern parts.*" The highest wind speeds were measured during the night from the 18th to 19th December. The lowest pressure of 966 hPa was measured on 19th December at 06:00.

The storm prior to the fatal avalanche started on 17th December 2016 around 12:00 and ended in the morning of the 19st December, approximately three hours prior to the avalanche. Dominating wind direction was from east and wind velocities up to 25 m/s and gusts up to 30 m/s were measured at the airport. The mean temperature during the storm was -5.8 °C, with a maximum of -0.6 °C and minimum of -15.3 °C before the storm started. The temperature increased from -12 °C to -2 °C within 24 hours. The wind velocities at the at the mountain station Gruvefjellet were in the same range as at the airport. The valley station Adventdalen south-east of the town recorded the highest wind velocities with 26 m/s and with gusts up to 33 m/s.

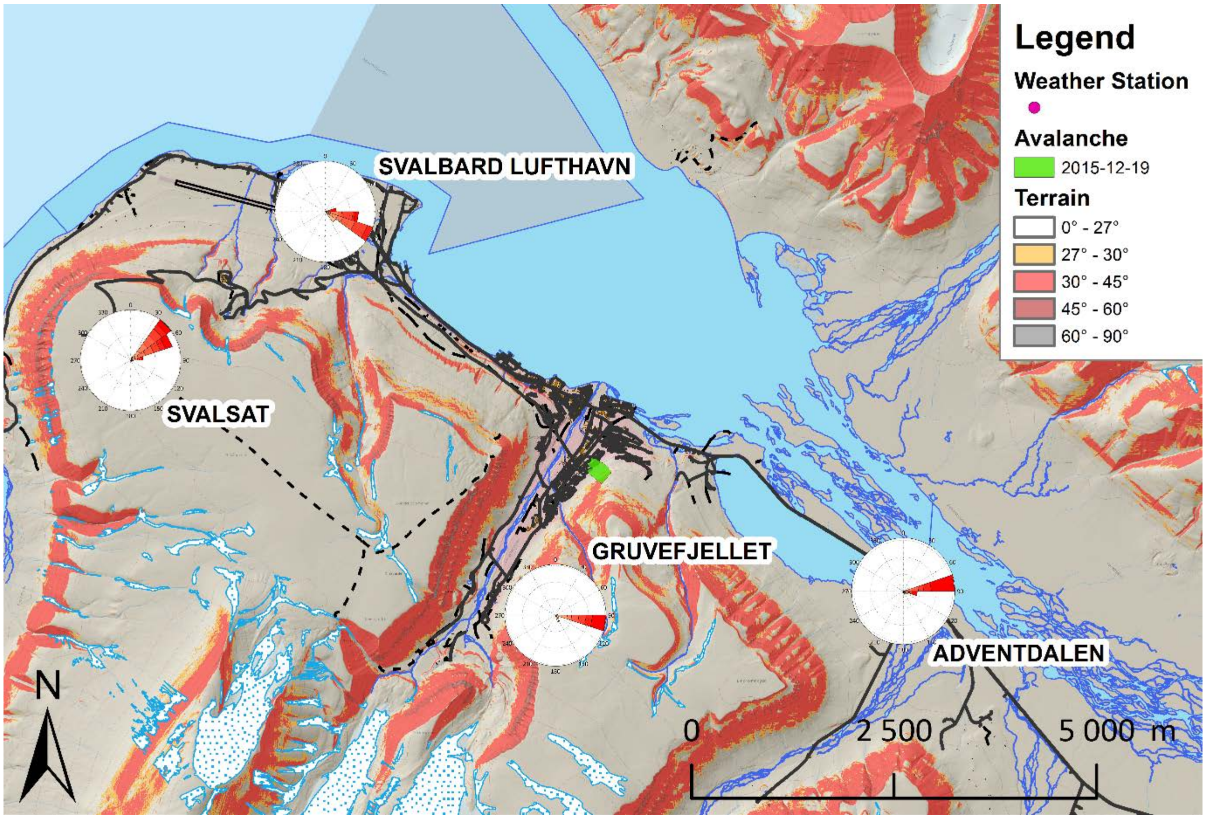

Fig. 4: Position and wind rose of the weather stations used in the analysis for the period 17th to 20th December 2015.

The wind roses from the storm are shown on the map in Figure 4. The unofficial observed storm precipitation was approximately 30 mm, while the official record shows 18 mm in the morning on the 19th. Reliable snow precipitation measurements in these wind speeds are almost impossible. The meteorological forecast model HIRLAM 12 predicted a total of 45 mm for Friday 18th and Saturday 19th (Meteorological Institute, 2016).

For the establishment of early warning routines, Hestnes and Bakkehøi (1992) and Hestnes (1993) showed the weather situations that lead to earlier minor avalanche events in the mountain side behind the now destroyed houses. Within three winter seasons, there were four avalanches. All of them accompanied with relative moderate winds from south easterly directions and limited precipitation (maximum prior to an avalanche was 16.6 mm in 5 days).

Searching the 40 years of weather observations from the airport with the criteria of negative temperatures, winds over 10 m/s and precipitation over 10 mm in 24h, 22 episodes are found. Most of them with wind direction from southwest which is the prevailing wind direction accompanied by most precipitation. Only 2 of those events have wind directions from southeast, one in 2006-11-04 and the fatal event in December 2015. Increasing the criteria to the 18 mm as observed on the morning of the 19th December, only the event of the fatal avalanche remains.

Considering the results from Hestnes and Bakkehøi (1992) and Hestnes (1993), with much less precipitation or wind being sufficient to lead to an avalanche release (using 5 mm and 5 m/s as criteria), 32 episodes with south easterly winds are found (Fig. 5). Slightly less than one event annually in average.

3.2 Avalanche forecasting

After the fatal avalanche, the most exposed sections of the town were evacuated and an avalanche forecasting system was in demand for the settlement, as the previous system was suspended (Hestnes et al. 2016). NGI operates a client based avalanche warning service issuing avalanche warnings for exposed settlements, infrastructure or building sites. The service starts every autumn in

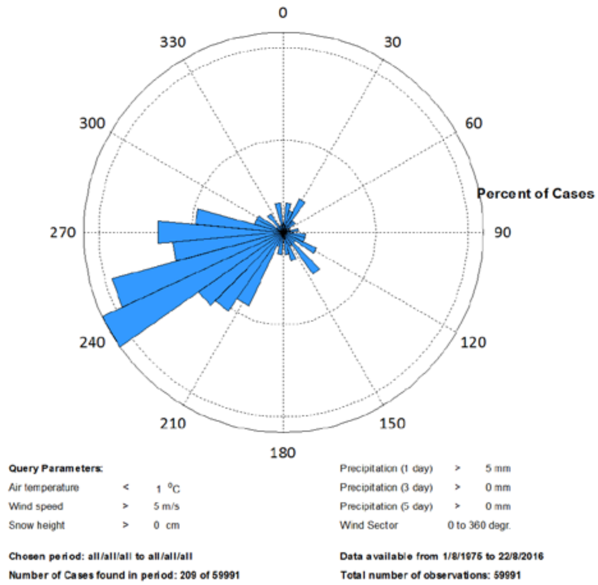

Fig. 5: Wind direction at Svalbard airport in minus degrees Celsius, wind > 5 m/s and 24 hour precipitation > 5 mm. 32 out 209 events show wind from south east.

December and covers from 5-10 specific locations all over the country. To accommodate that projects are changing from season to season, a general GIS based IT system was established (Jaedicke et al., 2014) where all available information on weather and snow is updated hourly for the whole of Norway. Additional, site specific weather stations can be included in the system. Based on this system, a forecasting service for Longyearbyen was established within 36 hours after the fatal avalanche. The legal arrangements took some more time to organize, such that the first avalanche forecast was issued in the morning of the 23rd December. The forecasts were based on weather observations from the four weather stations, local field observations and weather forecasting. Daily local avalanche forecasts for the settlement were issued until the end of January when the public operated national forecasting expanded from the mainland to cover the entire region around Longyearbyen and local avalanche service was abandoned.

4. DISCUSSION

The available weather data on the storm is sufficient to get an impression of the conditions that lead to the fatal avalanche. All weather stations around Longyearbyen reported wind more than 20 m/s wind and the dominating wind directions was from south east during the entire storm. The report of the Norwegian Meteorological Institute on the storm event (Meteorological Institute, 2016) concludes that no wind extremes were reached and that wind velocities above 25 m/s occur in average every 3.5 years. This analysis does not take into account the combination with precipitation (18 mm) and wind from south east. Such events are extremely rare and have to be considered as an extreme weather event.

5. CONCLUSION

The forecasting models predicted as much as 45 mm with violent storm from south east. Considering the weather conditions during earlier avalanches in this location and the rareness of presented storm event in comparison with 40 years of weather observations, this avalanche event would have been easily forecasted if an avalanche forecasting service would have been in place.

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