RAPPORT

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Avalanche warning in Svalbard

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Avalanche warning in Svalbard

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Cover photo: Avalanche debris observed by a Red Cross rescue group in the Polar Night.

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Abstract: Svalbard has an extensive avalanche problem and seven people died in avalanches from 2000 to 2018. To mitigate the problem, the Norwegian Avalanche Warning Service included public avalanche warnings for Svalbard on Varsom.no in February 2016. To assist evacuations by local authorities, local warnings for Longyearbyen were started as a temporary measure days after the fatal accident in December 2015, when an avalanche hit ten buildings. This report presents the methods, organisation, and results associated with establishing the two avalanche warning services on Svalbard. We discuss lessons learned in terms of collaboration, risk management, specific challenges in the Arctic, due to climate changes and the event of an avalanche hitting two buildings in February 2017.

Key words: Avalanche warning, risk management, climate change, Varsom.

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Preface

Avalanches pose a significant problem in Svalbard, and the fatal accident in 2015 triggered a rapid establishment of avalanche warning services for both the public and local authorities in Svalbard. This report describes the methods applied for warning and risk management from 2015 to the beginning of 2019, and discuss aspects related to rapid climate change, uncertainty, and arctic challenges.

The report was written by Rune V. Engeset, Markus Landrø, Martin Indreiten, Karsten Müller, Odd A. Mikkelsen and Knut I. A. Hoseth, based on the experience from establishing avalanche warning services for the public and local authorities in Svalbard.

The authors work for the Norwegian Water and Energy Directorate (NVE), the University Centre in Svalbard (UNIS)/Arctic Safety Centre (ASC) and UiT the Arctic University of Norway (UiT)/Centre for Avalanche Research and Education (CARE).

The work was presented at the Arctic Safety Conference in Longyearbyen, Svalbard on 13-15 May 2019.

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Summary

Svalbard has an extensive avalanche problem and seven people died in avalanches from 2000 to 2018. To mitigate the problem, the Norwegian Avalanche Warning Service included public avalanche warnings for Svalbard on Varsom.no in February 2016. To assist evacuations by local authorities, local warnings for Longyearbyen were started as a temporary measure days after the fatal accident in December 2015, when an avalanche hit ten buildings. This report presents the methods, organisation, and results associated with establishing the two avalanche warning services on Svalbard. We discuss lessons learned in terms of collaboration, risk management, specific challenges in the Arctic, due to climate changes and the event of an avalanche hitting two buildings in February 2017.

Highlights:

- Public avalanche warnings for Svalbard started in February 2016, on Varsom.no
- Local avalanche warnings started immediately after the December 2015 avalanche
- Rapid climate change, short residential history and changing populations posed specific challenges
- Increasing field-based activities (academia and tourism) and avalanche-exposed settlements render avalanche warnings important for risk management in this high-Arctic society

1 Introduction

1.1 Svalbard

Svalbard is a Norwegian archipelago, located in the Arctic Ocean between 74 and 81 degrees North and 10 and 35 degrees East. Svalbard has an arctic climate, but significantly warmer temperatures than other areas at the same latitude. Ocean currents and sea ice extents play an important role as a climate regulator. About 60 % of the archipelago is glacier-covered, and there are many mountains and fjords. Many of the mountains are table shaped or with jagged peaks. Non-glaciated ground has permafrost, with an active layer of 1-2 meters depth.

The administrative centre and main settlement in Svalbard is Longyearbyen, with a population of about 2200 people. Longyearbyen is managed by Longyearbyen Community Council (Lokalstyret), who has many of the same responsibilities as a municipality (utilities, education, cultural facilities, fire brigade, roads and ports). The town is also the seat of the Governor of Svalbard (Sysselmann), who represents the Norwegian government in exercising its sovereignty over the Svalbard archipelago.

Previously, coal mining was a key activity, but lately research and tourism have become important industries with the University Centre in Svalbard (UNIS) playing an important role.

The Norwegian Water Resources and Energy Directorate (NVE) is the national authority for energy, water resources and avalanches, and contributes to the prevention of accidents and damages from floods, landslides and avalanches in Svalbard. NVE is responsible for the public warning services for floods, avalanches, landslides and ice. However, local authorities are responsible for the safety of citizens locally. Citizens' safety is to a large part the responsibility of the individuals themselves, when it comes to recreational activities.

1.2 Avalanches and avalanche danger in Svalbard

Svalbard has an extensive snow avalanche problem ("snow avalanche" is referred to as "avalanches" from this point on in this report). Avalanches pose a threat to roads, ski lift, snowmobile tracks, airport, infrastructure, and buildings, including houses, apartment buildings, schools, hotels, and restaurants. Avalanche risk is inherent to field-based activities such as backcountry skiing, snowmobiling, and dog sledging. Researchers, students, and travel operators have to consider avalanche risk when planning and conducting field-based activities. Since 2000, seven people have died in five avalanches: Five on snowmobiles (4 February 2001, 22 March 2004, 15 March 2009, 24 January 2015) and two in buildings (19 December 2015).

Based on its location, it could be reasonable to assume a typical maritime snowpack and associated avalanche problems, but that is not the case for Svalbard. Most avalanches are dry slab avalanches, but also loose snow avalanches, wet snow avalanches, slush avalanches and cornice falls are common. Large areas with loose dry snow in combination with strong winds often create significant snowdrift. Thus, wind slabs are a common avalanche problem in Svalbard. Another common avalanche problem are persistent slabs, as persistent weak layers often develop in the snowpack due to cold and dry winters with a thin snow cover with a large vertical temperature gradient. This avalanche problem is overrepresented in fatal accidents in Svalbard. However, also warm spells and rain occur during winter and wets the snowpack. Thus, wet slabs, wet loose and slush avalanches are avalanche problems to be aware of, despite the high latitude. Eckerstorfer and Christiansen (2011) described the avalanche situation in Svalbard and the Longyearbyen area in more detail.

1.3 Avalanche warnings

The goal of avalanche forecasting is to provide warnings to people at risk with information about the avalanche conditions at hand (diagnosis) and how this may change in the near future (prognosis) in order for the users to manage the risk and avoid accidents and damages. A very important side effect of avalanche warnings is that the users and the society at large become avalanche aware. Forecasters produce warnings based on an analysis of data on avalanche history, snowpack stability, weather, and topography to predict the future avalanche danger and activity (LaChapelle, 1980, McClung, 2002). Information on avalanche danger is important for risk management, a concept introduced as a systematic approach for dealing with natural hazards (Bründl and Margreth 2015). The avalanche danger is a function of the likelihood and the size of expected avalanches (Statham et al, 2017, EAWS MOU, 2017).

NVE and UNIS launched a public avalanche warning service for Svalbard in February 2016, after a 17-days test period in April/May 2015. UNIS carried out the field observations and NVE the forecasting. Since then, public warnings are published daily for the region Nordenskiöld Land from the beginning of December to the end of May, based on 2-3 observations weekly. For the rest of Svalbard and the rest of the season, warnings are only issued for danger level 4 or 5. These warnings are based on no or few observations, and therefore heavily dependent on the weather forecast. The public warnings are issued as part of the operations of the Norwegian Avalanche Warning Service (Engeset, 2013) and are available on Varsom.no (the warning with all its contents) and Yr.no (avalanche danger level only) for the regions shown in Fig. 1.

The 19 December 2015 accident prompted a local warning in Longyearbyen, launched a few days after the accident. These warnings were initiated as a temporal measure to provide the information required for managing the evacuation of buildings, the prohibition of residence and traveling bans by Sysselmann and Lokalstyret. Initially, this service was run by Norwegian Geotechnical Institute on a contract with NVE.

Another local warning has been run by the Kongsberg Satellite Services in cooperation with the Red Cross, to assess the danger of avalanches on the road to Platåfjellet, where the SvalSat satellite ground station is located.

1.4 Objectives

The objectives of this report is to explain the avalanche problem in Svalbard, describe how the two different avalanche warnings services were established an operated as risk mitigation and management measures, and to discuss lessons learned from the forecasting and risk management process.

Fig. 1. Map of Norway and Svalbard with warning regions shown in red (regular daily warnings at all danger levels) and gray (warnings only at danger level 4 and 5).

2 Materials and methods

This report is based on data and experiences from 2015 to 2019. The analysis was based on data from regobs.no, varsom.no, internal and external evaluations, and the experiences of the authors, who have been involved in observations, forecasting, risk management, and evaluations.

2.1 Public avalanche warning

Methods and organisation used in Svalbard are the same as for the 21 regions on mainland Norway. Observers use predefined routes, to take care of their own safety and to get high-quality data from relevant snow in relevant terrain. Landrø et al. (2016) described in the procedures and methods applied.

Forecasters use the standards defined by the European Avalanche Warning Services (EAWS, www.avalanches.org). The forecasters and observers base much of their work on the Avalanche Danger Assessment (ADAM, an updated version of the system described in Müller et al., 2016), the Avalanche Problem Solver (APS, a system in development and described in Müller et al., 2018) and the Systematic Snow cover Diagnosis (described in Kronthaler et al., 2013, and Müller et al., 2015).

The forecasters produce a public regional warning daily, which is valid for the next two days. In the morning, the forecasters assess the situation and evaluate if there are significant changes to the avalanche danger of the current day. If needed, the current day warning is updated and republished before 10:00 in the morning. The main elements in the public regional warning (Fig. 2) is described in more details in Engeset et al. (2018), and includes in a prioritised reading order (an inverted pyramid, cf. EAWS information pyramid described at www.avalanches.org):

1. Daily avalanche danger level of the region, including a time series of several days
2. Main message, which typically addresses what is the main problem and what is our main management advice to the user
3. Emergency alert, an alert to preparedness authorities and others of the expected occurrence of size 3 or larger avalanches that are released naturally (spontaneously) in the region
4. Avalanche problems (1-3), including what is the weak layer (if any), properties of sensitivity, geographical distribution, expected avalanche size, and management advice for this specific problem and danger level
5. Avalanche danger assessment (in Norwegian only)
6. Snow and avalanche history (in Norwegian only)
7. Weather forecast used for the avalanche warning
8. Regional map
9. Observations last three days from Regobs.no

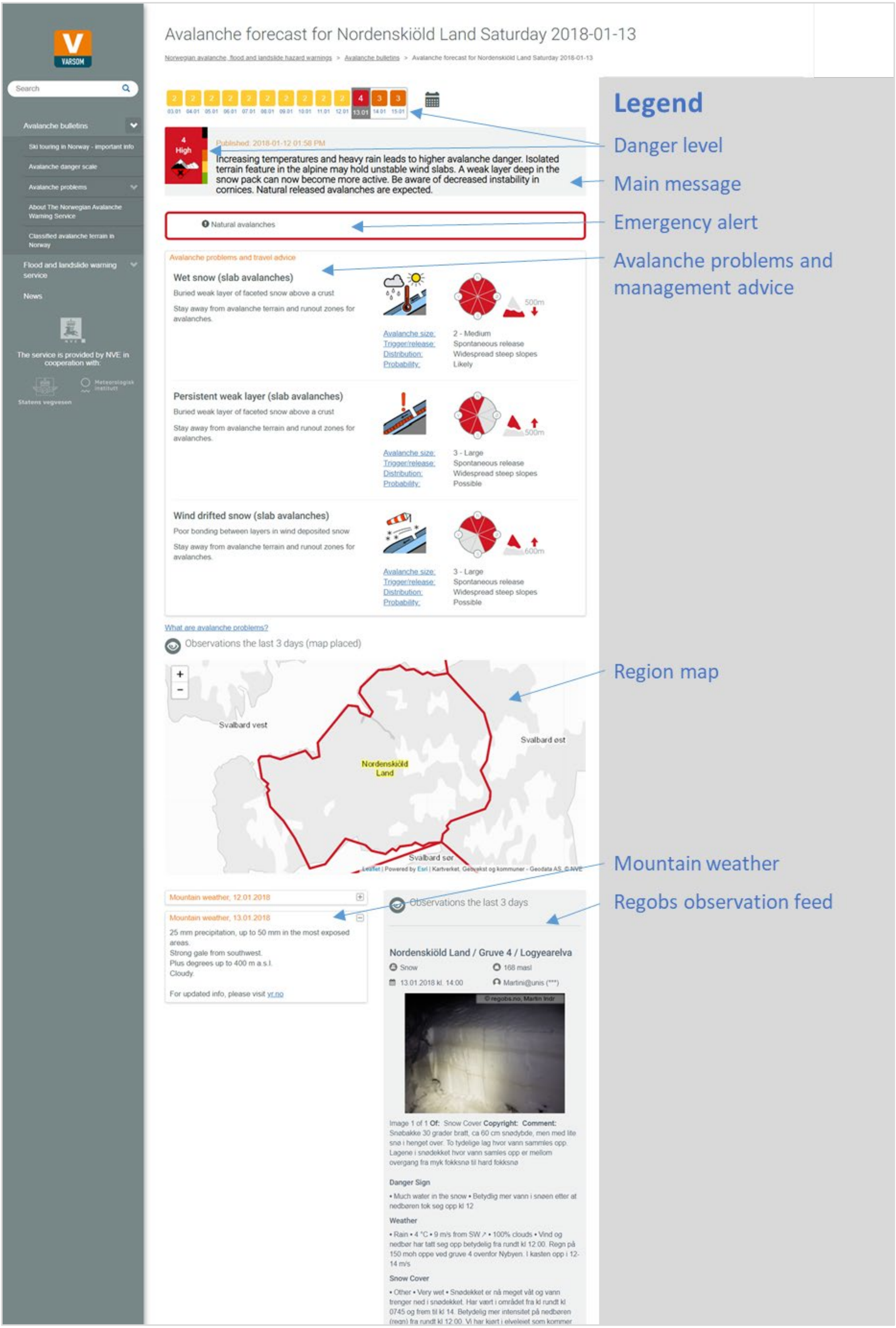


Fig. 2. Screen dump of an English verion of a public regional avalanche warning. The different elements are annoted and explained using blue text and arrows.

One of the four regional forecasters on duty every day, analyse the situation for Svalbard and produce the warnings. If danger level 4 or 5 is expected during the coming two days, the warnings are published before 10:00 in the morning. Until February 2019, the regional forecaster before 10:00 in the morning, if a local warning was required.

Until February 2019, the public avalanche forecasters' job included considering if a local warning was needed in addition to producing the regional warnings. They had to consider if natural release of avalanches size 3 or larger was expect in the region Nordenskiöld Land. If so, the NVE Northern branch (regional office) was alerted. They tasked a dedicated forecaster to produce local avalanche warnings for Longyearbyen. Sysselmann, Lokalstyret, and local observers could also trigger local warnings, when necessary. The design is illustrated in Fig. 3.

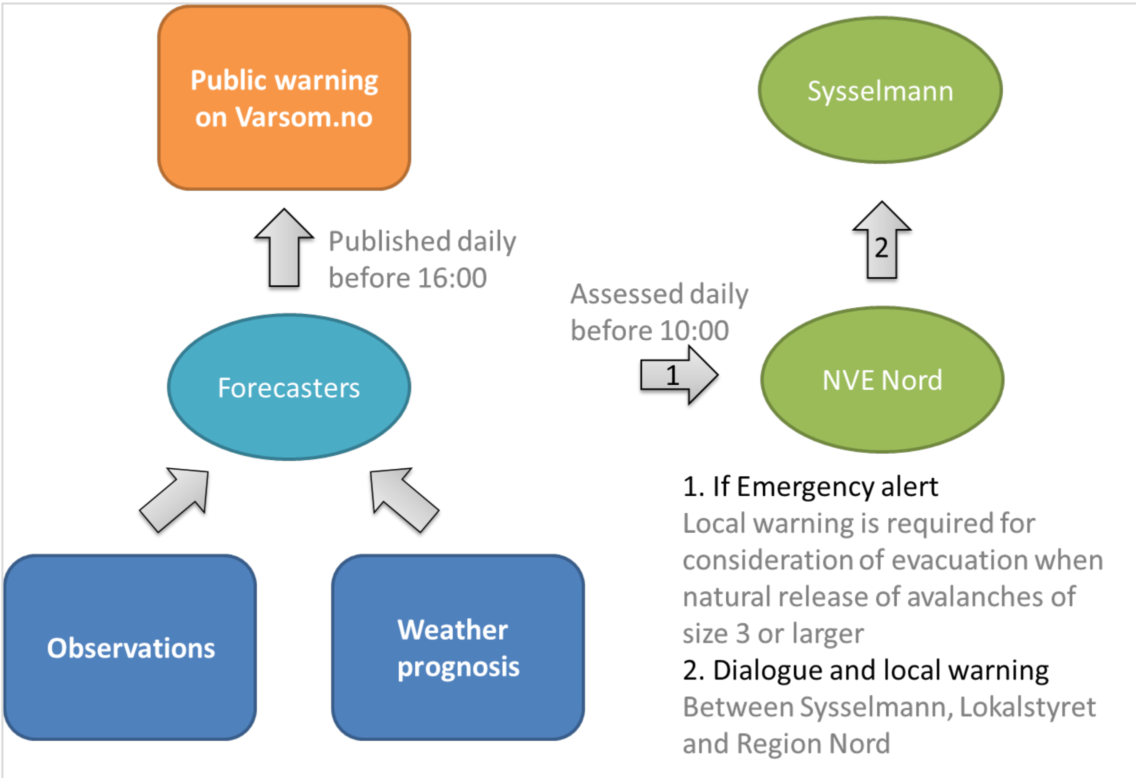


Fig. 3. Design of systems, where the regional warning service triggers the local warning service.

2.2 Local avalanche warning

Local warnings used observations in and around Longyearbyen (2-3 observations weekly at fixed locations, laser scanning, and automatic stations), as well as regional observations. The local warning provided a description of the current situation and a forecast (typically for the next 24 hours) for 23 avalanche paths threatening houses. To get the best possible description of the current situation, the observers would aim to choose the optimal pre-defined observation trip, based on the current avalanche problems and weather. Local warnings were issued daily (or more frequently) until the situation normalised.

NVE had three forecasters available for issuing local warnings. In case of a shortage of NVE personnel, the Norwegian Geotechnical Institute (NGI) or Skred AS assisted NVE in issuing the local warnings. From the end of December 2015 to the end of January 2016, NGI carried out the local warnings. In February 2019, Skred AS took over the local warnings in collaboration with UNIS on a contract with NVE and Lokalstyret, respectively. From this point in time, the triggering of the start local warnings became part of the job Skred AS was doing.

The local warnings were sent to Sysselmann, with a copy to Lokalstyret and NVE, and were not published to the public. Sysselmann managed the situation with regards to evacuations, travel bans and dialogue with the population in collaboration with Lokalstyret.

The local warning was published using the template illustrated in Fig. 4 and Fig. 5 shows an example of a warning. An explanatory note in the warning describes the forecast, its use, and limitations in more detail: *"This local warning describes the probability of avalanches reaching predefined buildings during the period the assessment is valid for. It is the responsibility of Sysselmann to assess and carry out evacuation and traffic bans. Middle and high probability will normally trigger the need for evacuation and/or traffic bans. The warning is based on available information at the point in time the assessment was carried out, and it will always be uncertainty related to the development of the weather and snow conditions during the period of validity. The user of the warning is himself/herself responsible for managing the uncertainty associated with the warning. Even at low probability, avalanches may reach avalanche-prone buildings. The warning is based on observations on www.regobs.no and the available weather prognosis at the point in time the warning was produced. Extra observation may be requested from UNIS, if further observations are required." (unauthorised translation from Norwegian).*

The forecasters use a baseline document to produce the local warnings, where all relevant avalanche paths are described according to the following structure:

1. Avalanche path number
2. Object(s) at risk
3. Area in square kilometres
4. Release area maximum steepness, aspect, and elevation interval
5. Avalanche problems including cornices, which typically are causing natural release. Includes typical weather and snow conditions causing a release
6. Description of avalanche path and runout areas, including objects (buildings, roads, etc.) at risk
7. Photos, RAMS model simulations, etc.

Fig. 6 shows an example of how the avalanche paths are described.

Skredbanevarsel - vurdering av skredfare mot bebyggelsen i Longyearbyen

Sendt til: Sysselmannen på Svalbard (snoskredvarsling@sysselmannen.no)

Kopi til: skredvarsling@lokalstyre.no, snoskredvarsling@nve.no, beredskap@nve

Gjeldene for dato: 07.12.2018 00.00 til 07.12.2018 00.00

Etter henvendelse fra: Navn/institusjon

Utarbeidet av: Velg et element.

Kontaktperson i Velg et element.: Navn

Dato: Dato.; Klokkeslett: Klikk her for å skrive inn en dato.

Gjeldene for dato: 07.12.2018 00.00 til 07.12.2018 00.00

Etter henvendelse fra: Navn/institusjon

Utarbeidet av: Velg et element.

Kontaktperson i Velg et element.: Navn

Dato: Dato.; Klokkeslett: Klikk her for å skrive inn en dato.

Anbefalt tiltak:

Oppsummer kort situasjonen og beskriv hvilke tiltak anbefales.

Denne lokale vurderingen beskriver sannsynlighet for snøskred mot definert skred bebyggelse i perioden vurderingen gjelder for. Det er Sysselmannens ansvar å vurdere og utføre evakuering og ferdselsforbud. Normalt utløser middels og høy sannsynlighet for skred evakuering og/eller ferdselsforbud. Vurderingen er basert på tilgjengelig informasjon på det tidspunktet vurderingen er gjort og det vil alltid være usikkerhet knyttet til utviklingen i vær- og snøforholdene i gyldighetsperioden. Brukeren av varslet er selv ansvarlig for å håndtere usikkerheten i varslet. Selv ved lav sannsynlighet kan det likevel ikke utelukkes at det går snøskred som kan treffe skredutsatt bebyggelse.

Vurderingen er basert på observasjoner fra www.regobs.no og gjeldende værprognose på det tidspunkt vurderingen er utstedt. Om observasjoner er mangelfulle kan ekstra observasjoner bestilles fra UNIS. Denne vurderingen sendes til snoskredvarsling@nve.no for loggføring.

Beskrivelse av nåsituasjonen for aktuelle skredbaner:

Relevante snø- og værobservasjoner i regObs og fra stasjonene rundt byen.

Værprognose lagt til grunn for vurderingen:

Skriv inn værprognosen for angitt varslingsperiode.

Skredfarevurdering for bebyggelse:

Tekst som beskriver ventet utvikling og skredproblemer som kulepunkter: Problem – sannsynlighet – tilleggsbelastning - skredstørrelse.

Treffsannsynlighet mot bebyggelser som kulepunkter i kategoriene «lav/middels/høy». F.eks. Nybyen: Treffsannsynlighet mot bebyggelse for de neste 24 t vurderes som lavt.

Hva skal til for å stabilisere situasjonen og hva skal til for å forverre situasjonen?

Usikkerheter:

Beskriv usikkerheten knyttet til varslet.

Kvalitetssikring:

Varslet er lest og kvalitetssikret av: Klikk her for å skrive inn tekst.

Beskriv usikkerheten knyttet til varslet.

Observasjoner fra regObs som er lagt til grunn for vurderingen:

Legg inn regObs-lenker. F.eks. http://www.regobs.no/Registration/118737.

Assessment of avalanche danger for Longyearbyen buildings

To:
Copy:
Period of validity:
Requested by:
Produced by:
Contact person:
Issued date and time:

Recommended action:

Explanatory note:

Description of the current situation at relevant avalanche paths:

Available weather prognosis:

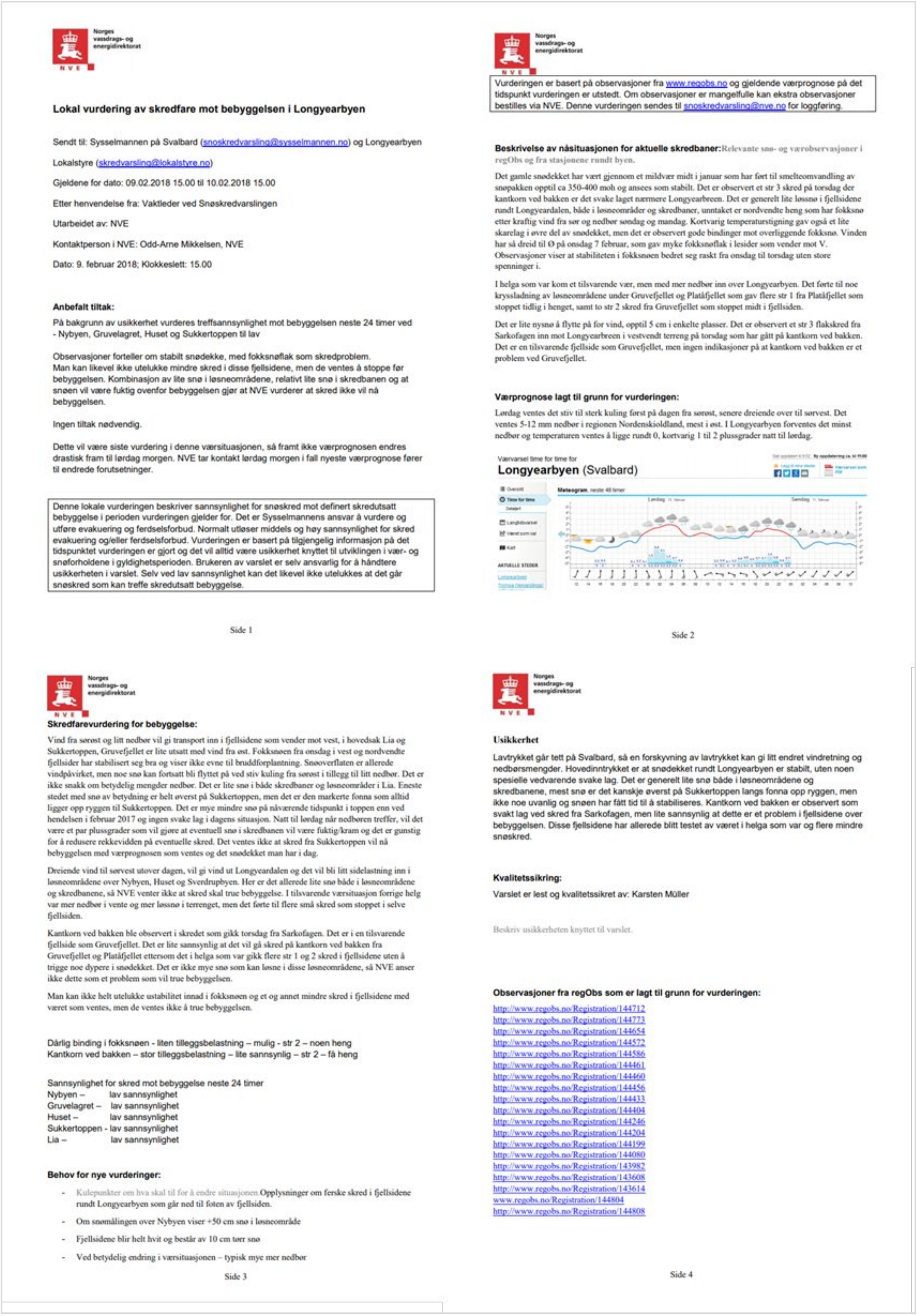
Avalanche assessment for the avalanche paths:

Description of uncertainty:

Quality control:

List of Regobs observations used:

Fig. 4. The template for local avlanche warnings (in Norwegian; English translation in grey box).



Norges vassdrags- og energidirektorat
NVE

Lokal vurdering av skredfare mot bebyggelsen i Longyearbyen

Sendt til: Sysselmannen på Svalbard (snoskredvarsling@sysselmannen.no) og Longyearbyen Lokalstyre (skredvarsling@lokalstyre.no)

Gjeldene for dato: 09.02.2018 15.00 til 10.02.2018 15.00

Etter henvendelse fra: Vaktleder ved Snøskredvarslingen

Utarbeidet av: NVE

Kontaktperson i NVE: Odd-Arne Mikkelsen, NVE

Dato: 9. februar 2018; Klokkeslett: 15.00

Anbefalt tiltak:

På bakgrunn av usikkerhet vurderes treffsannsynlighet mot bebyggelsen neste 24 timer ved
- Nybyen, Gruvelagret, Huset og Sukkertoppen til lav

Observasjoner forteller om stabilt snødekke, med fokksnøflak som skredproblem.
Man kan likevel ikke utelukke mindre skred i disse fjellsidene, men de ventes å stoppe før bebyggelsen. Kombinasjon av lite snø i løsneområdene, relativt lite snø i skredbanen og at snøen vil være fuktig ovenfor bebyggelsen gjør at NVE vurderer at skred ikke vil nå bebyggelsen.

Ingen tiltak nødvendig.

Dette vil være siste vurdering i denne værsituasjonen, så framt ikke værprognosen endres drastisk fram til lørdag morgen. NVE tar kontakt lørdag morgen i fall nyeste værprognose fører til endrede forutsetninger.

Denne lokale vurderingen beskriver sannsynlighet for snøskred mot definert skredutsatt bebyggelse i perioden vurderingen gjelder for. Det er Sysselmannens ansvar å vurdere og utføre evakuering og ferdselsforbud. Normalt utløser middels og høy sannsynlighet for skred evakuering og/eller ferdselsforbud. Vurderingen er basert på tilgjengelig informasjon på det tidspunktet vurderingen er gjort og det vil alltid være usikkerhet knyttet til utviklingen i vær- og snøforholdene i gyldighetsperioden. Brukeren av varslet er selv ansvarlig for å håndtere usikkerheten i varslet. Selv ved lav sannsynlighet kan det likevel ikke utelukkes at det går snøskred som kan treffe skredutsatt bebyggelse.

Side 1

Norges vassdrags- og energidirektorat
NVE

Vurderingen er basert på observasjoner fra www.regobs.no og gjeldende værprognose på det tidspunkt vurderingen er utstedt. Om observasjoner er mangelfulle kan ekstra observasjoner bestilles via NVE. Denne vurderingen sendes til snoskredvarsling@nve.no for loggføring.

Beskrivelse av nåsituasjonen for aktuelle skredbaner: Relevante snø- og værobservasjoner i regObs og fra stasjonene rundt byen.

Det gamle snødekket har vært gjennom et mildvær midt i januar som har ført til smelteomvandling av snøpakken opptil ca 350-400 moh og ansees som stabilt. Det er observert et str 3 skred på torsdag der kantkorn ved bakken er det svake laget nærmere Longyearbreen. Det er generelt lite løssnø i fjellsidene rundt Longyeardalen, både i løsneområder og skredbaner, unntaket er nordvendte heng som har fokksnø etter kraftig vind fra sør og nedbør søndag og mandag. Kortvarig temperaturstigning gav også et lite skarelag i øvre del av snødekket, men det er observert gode bindinger mot overliggende fokksnø. Vinden har så dreid til Ø på onsdag 7 februar, som gav myke fokksnøflak i lesider som vender mot V. Observasjoner viser at stabiliteten i fokksnøen bedret seg raskt fra onsdag til torsdag uten store spenninger i.

I helga som var kom et tilsvarende vær, men med mer nedbør inn over Longyearbyen. Det førte til noe kryssladning av løsneområdene under Gruvefjellet og Platåfjellet som gav flere str 1 fra Platåfjellet som stoppet tidlig i henget, samt to str 2 skred fra Gruvefjellet som stoppet midt i fjellsiden.

Det er lite nysnø å flytte på for vind, opptil 5 cm i enkelte plasser. Det er observert et str 3 flakskred fra Sarkofagen inn mot Longyearbreen i vestvendt terreng på torsdag som har gått på kantkorn ved bakken. Det er en tilsvarende fjellside som Gruvefjellet, men ingen indikasjoner på at kantkorn ved bakken er et problem ved Gruvefjellet.

Værprognose lagt til grunn for vurderingen:

Lørdag ventes det stiv til sterk kuling først på dagen fra sørøst, senere dreiende over til sørvest. Det ventes 5-12 mm nedbør i regionen Nordenskioldland, mest i øst. I Longyearbyen forventes det minst nedbør og temperaturen ventes å ligge rundt 0, kortvarig 1 til 2 plussgrader natt til lørdag.

Værvarsel time for time for
Longyearbyen (Svalbard)
Meteogram, neste 48 timer
Lørdag
Søndag
Aktuelle steder

Side 2

Norges vassdrags- og energidirektorat
NVE

Skredfarevurdering for bebyggelse:

Vind fra sørøst og litt nedbør vil gi transport inn i fjellsidene som vender mot vest, i hovedsak Lia og Sukkertoppen, Gruvefjellet er lite utsatt med vind fra øst. Fokksnøen fra onsdag i vest og nordvendte fjellsider har stabilisert seg bra og viser ikke evne til bruddforplantning. Snøoverflaten er allerede vindpåvirket, men noe snø kan fortsatt bli flyttet på ved stiv kuling fra sørøst i tillegg til litt nedbør. Det er ikke snakk om betydelig mengder nedbør. Det er lite snø i både skredbaner og løsneområder i Lia. Eneste stedet med snø av betydning er helt øverst på Sukkertoppen, men det er den markerte fonna som alltid ligger opp ryggen til Sukkertoppen. Det er mye mindre snø på nåværende tidspunkt i toppen enn ved hendelsen i februar 2017 og ingen svake lag i dagens situasjon. Natt til lørdag når nedbøren treffer, vil det være et par plussgrader som vil gjøre at eventuell snø i skredbanen vil være fuktig/kram og det er gunstig for å redusere rekkevidden på eventuelle skred. Det ventes ikke at skred fra Sukkertoppen vil nå bebyggelsen med værprognosen som ventes og det snødekket man har i dag.

Dreiende vind til sørvest utover dagen, vil gi vind ut Longyeardalen og det vil bli litt sidelastning inn i løsneområdene over Nybyen, Huset og Sverdrupbyen. Her er det allerede lite snø både i løsneområdene og skredbanene, så NVE venter ikke at skred skal true bebyggelse. I tilsvarende værsituasjon forrige helg var mer nedbør i vente og mer løssnø i terrenget, men det førte til flere små skred som stoppet i selve fjellsiden.

Kantkorn ved bakken ble observert i skredet som gikk torsdag fra Sarkofagen. Det er i en tilsvarende fjellside som Gruvefjellet. Det er lite sannsynlig at det vil gå skred på kantkorn ved bakken fra Gruvefjellet og Platåfjellet ettersom det i helga som var gikk flere str 1 og 2 skred i fjellsidene uten å trigge noe dypere i snødekket. Det er ikke mye snø som kan løsne i disse løsneområdene, så NVE anser ikke dette som et problem som vil true bebyggelsen.

Man kan ikke helt utelukke ustabilitet innad i fokksnøen og et og annet mindre skred i fjellsidene med været som ventes, men de ventes ikke å true bebyggelsen.

Dårlig binding i fokksnøen - liten tilleggsbelastning – mulig - str 2 – noen heng
Kantkorn ved bakken – stor tilleggsbelastning – lite sannsynlig – str 2 – få heng

Sannsynlighet for skred mot bebyggelse neste 24 timer
Nybyen – lav sannsynlighet
Gruvelagret – lav sannsynlighet
Huset – lav sannsynlighet
Sukkertoppen - lav sannsynlighet
Lia – lav sannsynlighet

Behov for nye vurderinger:

- Kulepunkter om hva skal til for å endre situasjonen. Opplysninger om ferske skred i fjellsidene rundt Longyearbyen som går ned til foten av fjellsiden.
- Om snømålingen over Nybyen viser +50 cm snø i løsneområde
- Fjellsidene blir helt hvit og består av 10 cm tørr snø
- Ved betydelig endring i værsituasjonen – typisk mye mer nedbør

Side 3

Norges vassdrags- og energidirektorat
NVE

Usikkerhet

Lavtrykket går tett på Svalbard, så en forskyvning av lavtrykket kan gi litt endret vindretning og nedbørsmengder. Hovedinntrykket er at snødekket rundt Longyearbyen er stabilt, uten noen spesielle vedvarende svake lag. Det er generelt lite snø både i løsneområdene og skredbanene, mest snø er det kanskje øverst på Sukkertoppen langs fonna opp ryggen, men ikke noe uvanlig og snøen har fått tid til å stabiliseres. Kantkorn ved bakken er observert som svakt lag ved skred fra Sarkofagen, men lite sannsynlig at dette er et problem i fjellsidene over bebyggelsen. Disse fjellsidene har allerede blitt testet av været i helga som var og flere mindre snøskred.

Kvalitetssikring:

Varslet er lest og kvalitetssikret av: Karsten Müller

Beskriv usikkerheten knyttet til varslet.

Observasjoner fra regObs som er lagt til grunn for vurderingen:

http://www.regobs.no/Registration/144712
http://www.regobs.no/Registration/144773
http://www.regobs.no/Registration/144654
http://www.regobs.no/Registration/144572
http://www.regobs.no/Registration/144586
http://www.regobs.no/Registration/144461
http://www.regobs.no/Registration/144460
http://www.regobs.no/Registration/144456
http://www.regobs.no/Registration/144433
http://www.regobs.no/Registration/144404
http://www.regobs.no/Registration/144246
http://www.regobs.no/Registration/144204
http://www.regobs.no/Registration/144199
http://www.regobs.no/Registration/144080
http://www.regobs.no/Registration/143982
http://www.regobs.no/Registration/143608
http://www.regobs.no/Registration/143614
www.regobs.no/Registration/144804
http://www.regobs.no/Registration/144808

Side 4

Fig. 5. An example of a local warning issued on 9 February 2018.

Snøskredbaner som truer bebyggelsen rundt Longyearbyen

Det er bebyggelsen under Sukkertoppen, Haugen, Nybyen, Sverdrupbyen, Huset og Skjæringa.

Skjæringa

2 skredbaner
Barnehage, museet? og kirke

Figur 1: Løsneområder og bratthet ovenfor Skjæringa. Brattheten vises i farger, grønn:28-35 grader, gul:35-45 grader, rød: 45-55 grader.

Figur 2: Løsneområder ovenfor Skjæringa og modellering av snøskred med 0,5 meter snødybde i RAMMS, størrelse S, returperiode 10 år.

Skredbane 1

11000 m2

Bratthet: 33 grader

Eksposisjon: Ø

Løsneområdet er mellom kote 100 og 150 moh

Skredproblem: Fokksnø, vedvarende svake lag og temperaturstigning og/eller regn.

Løsneområdet kan beskrives som jevnt bratt, litt brattere i toppen før den slaker noe ut. Over 35 grader i toppen, mellom 35 og 30 i nedre del. Mest utsatt med vær fra SV til NV. Lite utsatt for sideladning/kryssladning. Det er kjent at det har gått skred her tidligere, men ikke nådd bebyggelsen. Faresonekartlegging vurderer at 1000 års skred kan treffe bebyggelsen.

Truer kirke, gamle barnehage og barnehagen.

Skredbane 2

14000m2

Bratthet: 36 grader

Eksposisjon: Ø

Løsneområdet mellom 120 moh og 200 moh

Skredproblem: Fokksnø, vedvarende svake lag og temperaturstigning og/eller regn.

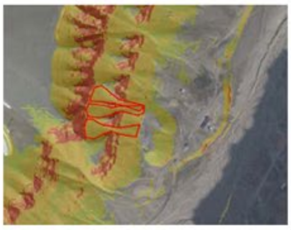
Mest utsatt med vær fra SV til NV. Lite utsatt for sideladning/kryssladning.

Jevn løsneområde med liten ruhet og ujevnheter. Lite utsatt for sideladning/kryssladning.

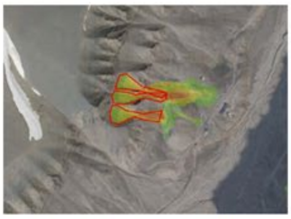
Fellestrekk for løsneområde 1 og 2: Sannsynlighet for utløsning er lik på skredbane 1 og 2. Løsneområde 2 er litt brattere enn løsneområde 1 og har litt mer fallhøyde. Løsneområdet 1 er litt brattere i toppen og har enkelte mindre ujevnheter som fører til litt større oppsamling av snø. Løsneområde 2 har mindre ujevnheter i terrenget. Det vurderes at skredbane 1 og 2 har lik sannsynlighet for skredutløsning.

Sverdrupbyen

3 skredbaner
Restaurant og fritidsbolig



Figur 5: Løsneområder og bratthet ovenfor Sverdrupbyen. Brattheten vises i farger, grønn:28-35 grader, gul:35-45 grader, rød: 45-55 grader.



Figur 6: Løsneområder ovenfor Sverdrupbyen og modellering av snøskred med 0,5 meter snødybde i RAMMS, størrelse S, returperiode 10 år.

Skredbane 5

5000 m2

Bratthet: 38 grader

Eksposisjon: Ø

Løsneområdet mellom 180 moh og 340 moh

Skredproblem: Skavelnedfall, regn og fokksnø

Skredbane 6

5800 m2

37 grader

Eksposisjon: Ø

Løsneområdet mellom 180 moh og 340 moh

Skredproblem: Skavelnedfall, regn og fokksnø

Skredbane 7

6500 m2

Bratthet: 38 grader

Eksposisjon: Ø

Løsneområdet mellom 180 moh og 340 moh

Skredproblem: Fokksnø og regn (Ingen skaveldannelse på toppen)

Fellestrekk

Skredbane 7 truer restauranten. Skredbane 5 og 6 truer fritidshus og større trolig «ubebodd rekkehus». I terrenget ovenfor restauranten er det en liten haug, med en kort flate på som kan føre til at mindre skred kan stoppe og dele seg litt. Store skred bryr seg ikke om denne flaten. Terrenget er noe under 30 grader opp til 250 moh der man treffer på klippebånd på 50 høydemeter som blir kuttet av brede renneformasjoner langs hele fjellsiden, likt som ved Huset. Terrenget her oppe er omtrent 37 grader bratt. Over klippene er det litt mer åpent terreng, men fortsatt avgrensede forsenkninger for hver enkelt løsneområdet. Over 350 moh blir det brått mye brattere med klippeparti og mindre renner til topps. Det dannes ofte skavler på toppen ovenfor løsneområde 5 og 6. Løsneområde 7 er ikke truet av skavelnedfall.

Det er ikke kjent hvilken skredbane som løsne først. Skredproblemet her er først og fremst fokksnø, skavlnedfall og nedbør som regn.

Skavler bygger seg opp på vær fra SV-NV når det er snø tilgjengelig. Løsneområdene kan få påfyll av snø når det ikke blåser for mye, slik at snøen også faller ned. Typisk opp til frisk bris. Løsneområdet er utsatt for kryssladning av vindtransportert snø. Ofte S og N vind som blåser opp og ned dalen.

Vedvarende svake lag som kantkorn kan dannes, vanskelig å ha kontroll på. Rim ventes ikke å dannes grunnet ofte urolige vindforhold i løsneområdet.

Fig. 6. An excerpt from the document describing the avalanche paths for the avalanche warning in Longyearbyen.

3 Results and discussion

3.1 Manual observations

A total of 1556 manual field observations were submitted on the snow and avalanches module of Regobs (www.regobs.no). Of these, 19 included incidents/accidents, 108 avalanches, 674 danger signs, 454 avalanche activity, 862 weather, 761 snow cover, 453 instability tests, 541 snow profiles, 445 avalanche problems, and 476 avalanche danger assessments. Fig. 7 shows the geographical spread of observations.

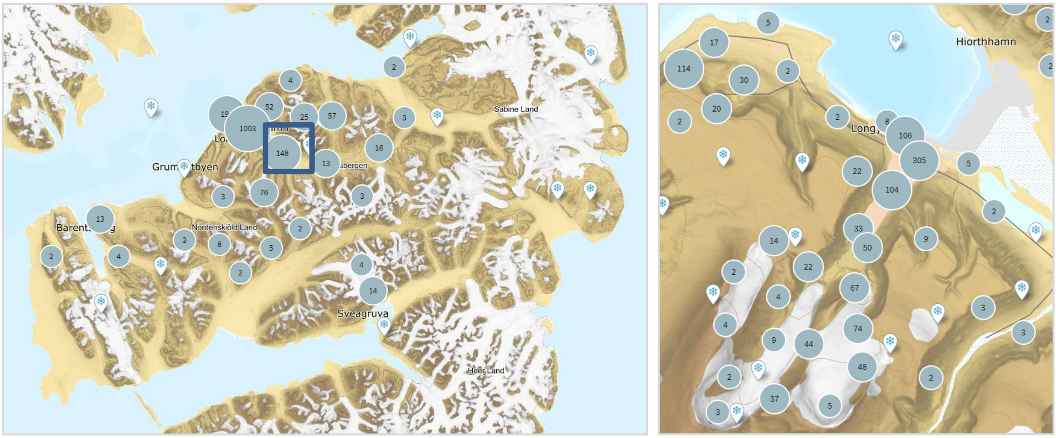


Fig. 7. Map of snow and avalanche observations within the Nordkiold Land region (left) and Longyearbyen area (right).

Based on the 23 avalanche paths threatening houses or infrastructure, expedient observation routes had to be identified. This was done in cooperation between the local observers and the leaders of the NVE observation corps. The focus was to obtain relevant snow and avalanche information while safeguarding the observer's safety. The fact that there are periods of Polar Night, the possibility of encountering polar bears and the observers being out on their own, added extra elements that had to be taken into consideration.

A total of seven different observation routes with associated observation points were pre-defined. Not unlike the "playlist" that some Heli-ski operations use to mitigate avalanche risk given the current avalanche conditions. Five of these observation routes were targeted at snow avalanche observations and two at slush avalanches. All pre-defined routes were documented in what is called an observation trip description. Here each route is described with regard to terrain classification (ATES, Statham et al., 2006), observations beyond standard ones that are particularly interesting on the specific trip (i.e. amount of entrainment snow below the release areas), locations for seasonal profiles and test sites, and critical decision points when exposed to avalanche terrain.

Routines for evaluation of these routes were established to ensure high quality, relevant observations, and a high degree of observer safety. All involved avalanche forecasters had access to the observation trip description. Thus, having insight in the specific points of interest and challenges of each trip.

Before heading out on an observation trip, the observers registered which trip they were heading out on, what they would be looking for and an estimate of when the observations could be expected to be submitted and made publicly available on Regobs.no and Varsom.no. This was done via the Regobs app. Thus, the forecasters knew when an observer was out and was given a pre-indication of what the observer supposed to be the current avalanche problem. In our opinion, this system has provided relevant, high-quality observation and prevented accidents amongst the observers.

In addition to manual observations in town and at pre-defined observations routes, UNIS staff carried out laser scanning of the avalanche slopes (Holt et al., 2018). Data was shared with the forecasters and other observers using Regobs. The data provided very useful information on the snow cover depth and distribution in the release areas and in the avalanche path. It provided insight into a number of key questions, such as cornice formation (are the cornices getting larger and will they break off?), changes in snow depth in the start zones (how large is the loading of new and wind-drifted snow?), amounts and changes in the avalanche paths (how far will avalanches run and how large will they be?). The strength of the laser scanning was that it could easily get data from locations where automatic instruments and manual observations could not be used due to safety and terrain concerns. However, it could not be used during periods of poor laser visibility, which is often the case during storms with elevated avalanche danger.

3.2 Automatic observations

Snow data for Longyearbyen is limited due to the short history of avalanche forecasting and observing in the area. Therefore, field observations of the snowpack and spatial distribution in avalanche prone slopes is important data for the forecasters. The Arctic winter with Polar Night lasting from November to February can hinder direct visual observations of snow and avalanche conditions. It is also a challenge due to safety for the observers to move into avalanche terrain without visibility of the slopes.

To get more data and additional information, UNIS installed three automated snow-monitoring stations in avalanche release areas above exposed infrastructure for the winter season 2017/18. The stations were founded by Lokalstyret and put into operation by UNIS. The stations measured air temperature, humidity, snow depth, snow surface, and ground temperature. The stations had a high power requirement, and as a result, were only able to transmit data four times per day.

The main target for the stations is to measure snow depth and accumulation. Drifting snow from the fetch areas on the plateaus, which surround Longyearbyen, can build up slabs during a short time period on avalanche prone slopes, especially during storm events.

For the winter season 2018/19, the stations were replaced with a new type of station (Fig. 8) developed in cooperation between Telenor Svalbard and UNIS. These stations use the Low Power Wide Area Network technology (LPWAN). The new sensors give near real-time access to snow depth data and allow forecasters or other users to monitor snow depth changes in the avalanche release areas during storm events. The experience from this winter season tells us that the automated snow stations, together with local weather stations provide an additional resource for hazard management decisions during times of increased avalanche danger.

Another set of automatic weather and snow observations stations were upgraded or established by the Norwegian Meteorological Institute (MET) as part of the investment to extend the national observing network for avalanche forecasting (Brækkan et al., 2018). These stations included:

- 9870 Adventdalen at 15 m asl.: wind, precipitation, snow depth, surface temperature.
- 99843 Platåberget III at 450 m asl.: wind, precipitation, snow depth, surface temperature, short wave radiation.
- 99762 Sveagruva II at 50 m asl.: wind, precipitation, snow depth, surface temperature, soil temperature.

In 2018, the NVE established gamma ray, snow depth and flow cap sensors at Platåberget to measure the snow water equivalent, snow depth and wind-transported snow.

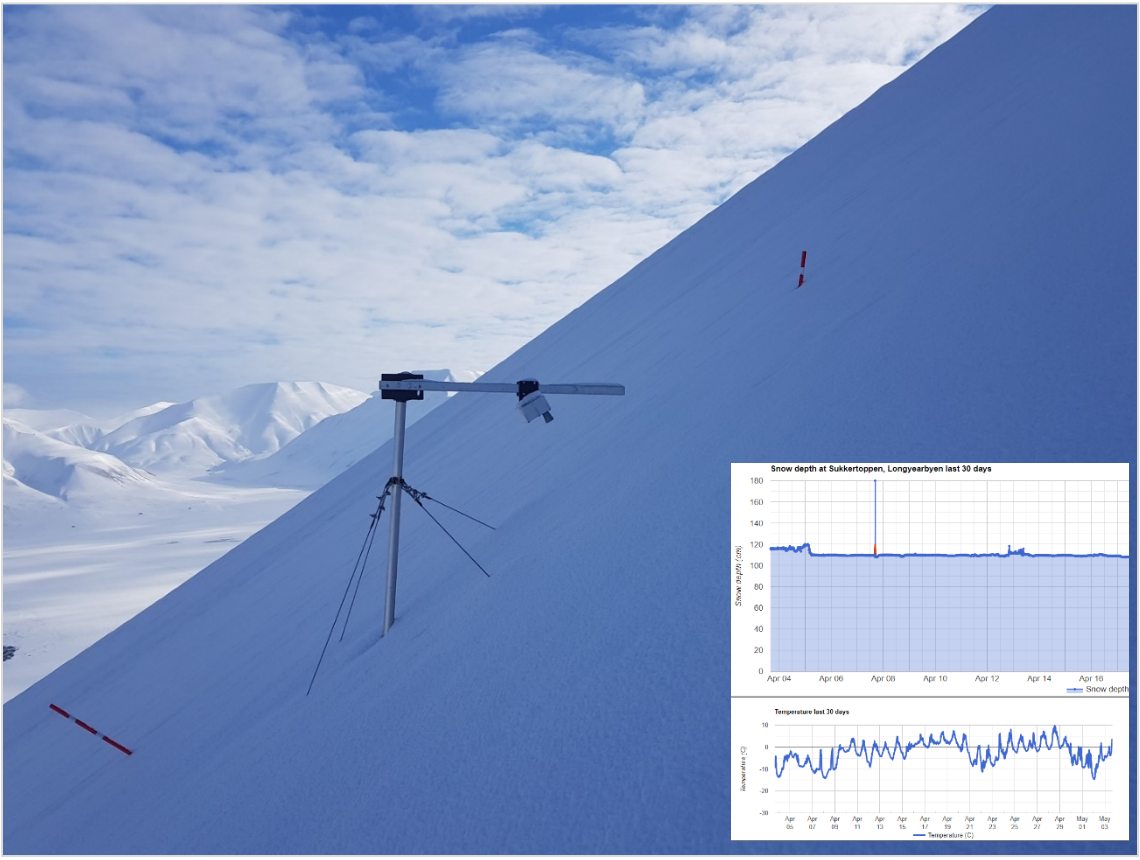


Fig. 8. An automatic snow observation station in the release area at Sukkertoppen (inset example data plot for some of the data form the station). Photo: Martin Indreiten.

3.3 Avalanche warnings

From the first official regional warning was issued on 21 January 2016 and up to the end of April 2019, 640 regional warnings were published for Nordenskiöld Land and 34 for the other three regions which are used only at danger level 4 or 5. Fig. 9 shows the entire time series of danger levels from the regional warnings and Table 1 shows the number of warnings at different danger levels. The most common danger level, 2-Moderate, is twice as frequent as 3-Considerable.

A total of 44 warnings forecasted release of natural avalanches of size 3 or larger and were tagged as an Emergency alert. This was also the criteria for activating the local warnings before February 2019. In addition to these warnings, 17 regional warnings were issued during the test period from 22 April to 9 May 2015. All test warnings were danger level 2-Moderate and had wind slabs and/or persistent slabs as the avalanche problems.

The warning data confirms that persistent weak layers (persistent and deep persistent slabs) and wind-drifted snow (wind slabs) are the two most common avalanche problems, by far (Table 2). Although persistent layers are more frequent than wind-drifted snow in the warnings, the forecasters on duty choose to communicate the wind slab problem twice as the principal problem. In terms of how many avalanche problems the forecasters choose to publish as relevant, 48 warnings (7.5 %) had three problems, 189 (29.5 %) had two problems and as many as 403 (63.0 %) warnings had one problem only.

With regards to local warnings, the Governor received 39 written and five at-location local warnings during a total of 17 periods from the accident in December 2015 to the end of January 2019.

Table 1 Number of avalanche warnings at different danger levels and number of warnings triggering emergency alerts. The total number of warnings for Nordenskiöld Land region was 640.

	Number of warnings	
Danger level	Nordenskiöld Land	Other regions
1	17 (3,7 %)	-
2	467 (73 %)	-
3	152 (24 %)	-
4	5 (0,7 %)	18
5	0	-
Emergency alert	44 (6.9 %)	-

Table 2 Number of avalanche problems used in the Nordenskiöld Land regional warnings. #1 means that the problem featured as the most prominent problem in the warning, and so on.

Avalanche problem	#1	#2	#3	Total	Total
Wind slab	400	117	8	525	42 %
Storm slab	57	7		64	5 %
Dry loose	0	2		2	0 %
Wet slab	10	4		14	1 %
Wet loose	6	15		21	2 %
Persistent slab	174	381	36	591	47 %
Deep persistent slab	9	31	4	44	3 %
Sum				1261	

Fig. 9. Time series of regional danger level from the four seasons 2016-2019. The avalanche danger level (1-5) is on the y-axis and time (dates) on the x-axis.

3.4 User statics

The user statistics of Varsom.no (Table 3) show that during the five first months of the 2018-2019 season, the page with the Nordenskiöld Land warning region was read more than 10 000 times in Norwegian, and nearly 3 300 times in English. In other words, about 25 % of the time, users preferred the English version. This makes sense, as Longyearbyen has a population of about 2200 people, of which about 30 % have a non-Norwegian point of registered residence. Another relevant explanation is that a large part of the UNIS students are not able to read Norwegian. Nearly 50 000 tourists visit Svalbard per year, and some of these used the warnings directly on self-catered tours or indirectly on organised tours.

Another fact is that the total number of page views nearly doubled from the previous season. This season, the users spent on average 3 minutes per page warning page read in Norwegian, about double the time spent on the English version. As mentioned previously, the Norwegian version contains more details as text, which may explain this difference. The English version of the warning page is the fourth most popular region in Norway, after Lyngen, Tromsø and Lofoten, while it is number 14 on the list of Norwegian versions.

On 3 April 2019, a new Varsom Regobs app was released. This new app replaced the two old Regobs and Varsom apps, and it is in both English and Norwegian. This is a significant improvement for non-Norwegian users, as the warnings and user-provided observations will be available in English.

Table 3 User statistics from Varsom.no from the two previous seasons. Data from Google Analytics.

	Pageviews		
	Views	**Views per day**	**Avg. time (min)**
Dec 1, 2018 - May 1, 2019			
Norwegian	10 207	68	3.0
English	3 278	22	1.4
Total	13 485	89	
Dec 1, 2017 - May 1, 2018			
Norwegian	4 794	32	2.3
English	1 992	13	1.1
Total	6 786	45	
Change from 2018 to 2019			
Norwegian	113 %		34 %
English	65 %		21 %
Total	99 %		

The avalanche warning is used by snowmobile and skiing recreationalists. It is used by UNIS for their field activities, both student courses, and fieldwork, and by researchers and academic staff. The Regobs system is used during courses, as well as a data collection, storage, and retrieval system for master and Ph.D. students. Varsom is also used as a pedagogical tool by UNIS, to teach students about avalanches and to raise the awareness of this type of hazard. Hazards, such as polar bears may be more commonly known to students arriving in Svalbard for the first time, although avalanches have killed more people than the polar bears historically.

The avalanche warning is used by the tourist industry, where the danger level is used to decide on which activities are to be suspended, and when are mitigating measured required to proceed.

Local authorities (Sysselmann and Lokalstyret) use the regional warnings to communicate the avalanche danger, raise avalanche awareness, close/open snowmobile routes and to considering the avalanche risk during rescue missions.

Several free avalanche awareness seminars, open to the population of Longyearbyen, may have contributed to increased awareness in general and thereby also interest in obtaining snow and avalanche information from the warning service and Varsom. Also, avalanche courses targeted at specific user groups, such as snowmobilers, and courses offered to the Longyearbyen population in general, has led to a high degree of avalanche awareness in this community.

3.5 Discussion

Public and local warnings were established quickly. This was possible due to four factors: (a) NVEs experience and operational capacity for regional forecasting on the mainland, (b) NGIs experience and local forecasting capacity on mainland, (c) local observers had already received basic training from the test period, and (d) local Sysselmann, Lokalstyret) and national (NVE, MET) authorities, as well as the local partner UNIS, promoted this development. Recruitment and training of observers were crucial, as was collaboration with UNIS and end users. Site-specific challenges included the Polar Night that places special demands on equipment (night vision) and measures to safeguard the observer's work (pre-planned observation routes).

An evaluation of the local warning (Landrø et al., 2017) concluded that a short/clear message with detailed documentation of the assessment ensures effective communication during a situation and allows for analysis afterward. It was recommended to pay more attention to uncertainty due to climate change and limited observational history. This is in particularly important in Svalbard, as its climate has changed significantly over the past decades and changes will continue (Bilt et al., 2019, Hestnes et al., 2016). It was recommended to have a more formal method for quality assurance due to reliance on a few experts in the warning process. Another improvement point that was pinpointed was to be even more aware that severe wind in combination with even small amounts of loose snow may cause a very rapid increase in avalanche danger. This is partly due to the plateau shape of the mountaintops surrounding Longyearbyen, representing very large catchment areas.

The regional warning has improved civil preparedness and avalanche competence/ awareness in Norway and probably prevented loss of lives (Hisdal et al., 2017). This is probably also the case in Svalbard, as it is much used and has increased avalanche awareness in Svalbard.

4 Conclusions

The avalanche awareness in Svalbard increased significantly during the past five years, mainly due to the fatal accident in 2015 and the launch of regional avalanche warnings for the public and local warnings for the local authorities.

Observers, forecasters, and production/distribution systems were quickly in place due to the experiences and infrastructure on the mainland and locally, but site-specific training and adjustments were required. Rapid climate change, short turnover cycles for personnel and users, and a short history of settlements and avalanche awareness, all contribute to uncertainties and challenges that were specific to Svalbard.

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