Experiences on a storm causing avalanche cycles in south-west Norway

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ABSTRACT: Southern Norway has the 2nd and 3rd longest fjords in the world, respectively the Sognefjorden and the Hardangerfjorden, cutting deep into the old Caledonian Mountain Range. The Caledonides are striking from north to south along the Scandinavian Peninsula, including Norway and Sweden. There are several peaks reaching 2000 m asl. Low pressures coming from the North Atlantic Ocean causes frontal and orographic precipitation along the coast and in the western parts of the mountain range. Several areas in the mountains of western Norway have an annual precipitation exceeding 4000 mm, while the climate is much drier in eastern Norway and Sweden. During winter time, this results in heavy snow falls and severe avalanche related problems on minor and major roads located along fjords and in the mountains. The Sondre storm cycle in January 2008 caused heavy snow fall and strong winds in the mountains of southern Norway. This resulted in several avalanches blocking all road connections between the 2nd largest city, Bergen, on the western coast and the capital, Oslo, on the eastern coast. Many of the avalanches had an extremely long run out distance. A mountain cabin, located several hundreds of meters away from the mountain foot, was moved by an avalanche and cars were trapped in between avalanches for up to two days.

KEYWORDS: Orographic precipitation, Road administration, Storm cycle, Case study

1 INTRODUCTION

Norway is a long and thin country, situated between latitudes 58N and 71N, on the western part of the Scandinavian Peninsula. It´s geographical position is comparable to Alaska, Greenland and Sibir. There are 5 million inhabitants and the country has an extensive public road network, totally 55.000 km of national highways and county roads in addition to 38.000 km of municipal roads.

An old mountain range, the Caledonides, is striking from north to south along the Scandinavian Peninsula, mostly in the Norwegian part. It has several peaks higher than 2000 m asl. The mountain range is deep incised of fjords in the west, thus making the coast line of Norway extremely long and mostly very steep. Southern Norway has the 2nd and 3rd longest fjords in the world, respectively the Sognefjorden (203 km) and the Hardangerfjorden (179 km). The Sognefjorden is situated to the west of Norway's highest mountain area, Jotunheimen, crowned by Galdhøpiggen (2469 m asl).

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During winter time, large amounts of snow fall result in severe avalanche related problems on minor and major roads situated along fjords and in the mountains. The heavy snow fall and strong winds in the mountains of southern Norway during the Sondre storm event in January 2008 resulted in high avalanche activity. All road connections between Oslo and Bergen, including the E16, were blocked by avalanches. Many of the avalanches also had an extremely long run out distance.

The Norwegian Public Roads Administration (NPRA) is responsible for the management and safety on national highways and county roads. This includes forecasting and protection against snow avalanches. The daily surveillance is performed by maintenance personnel supported by NPRA´s geologists or by consultants.

2 CLIMATE AND DOMINATING WEATHER SYSTEMS IN SOUTH-WESTERN NORWAY

Warm seawater from the Mexican Gulf is transported across the Atlantic Ocean to the Norwegian coast by the North Atlantic Current (NAC). Additionally, the mountainous Norwegian coastline is being overrun by warm, moist air, entering from the North Atlantic Ocean in the west.

These phenomena are the reasons why Norway has a rather mild climate in spite of its northern location. The annual temperature along the Norwegian coast varies between -3ºC on Finnmarksvidda in the north and +8º C on Karmøy in the south-west. In the mountains of southern Norway, the annual temperature in some areas decreases to around -8ºC.

The weather system, combined with the long mountain range, has important implications on precipitation and wind in Norway. Warm and moist air from south, south west or west meet cool, polar air (The Polar Front) in the Atlantic and thus low pressure cells arise. Figure 1 shows a low pressure reaching the coast of south-west Norway. The low pressures consist of two front systems; a warm front followed by a cold front. At the warm front, warm and moist air is forced up over cooler air and makes vapour condensating to intense frontal precipitation.

Figure 1. Low pressure cell, reaching the South western Norwegian coast from the North Atlantic Ocean. (Photo: Erik Kolstad, Bjerknes Center for Climate Research)

Additionally, the orographic effect, forcing warm and moist air to rise above the mountain range and thus cooling the air, gives reason to huge amounts of precipitation in the coastal region, shown in figure 2.

The power of the low pressure cells controls the wind strength, which in turn controls the amount of warm and moist air being forced over the mountains. Frontal and orographic precipitation are the main factors responsible for the wet climate of the western parts of the Norwegian mountains. In some mountain areas the precipitation exceeds 4000 mm annually. During a situation with dominating westerlies (the most

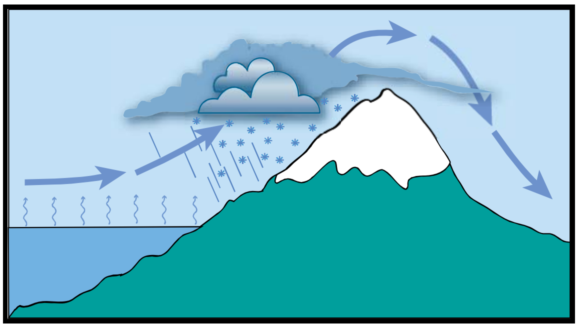

Figure 2. Warm and moist air forced up across a mountain range causes cooling of the air and resulting orographic precipitation.

normal winter situation), the amount of precipitation in south-west Norway depends directly on the power and numbers of low pressure cells.

3 THE SONDRE STORM EVENT AND ITS IMPLICATIONS ON THE ROAD SYSTEM IN SOUTHWESTERN NORWAY

The western region of Norway is showed in figure 3. Key localities are marked in the figure. E16 is the main road interlinking the 2nd largest city, Bergen, on the western coast and the capital, Oslo, on the eastern coast. The highest elevated part of this road runs over a mountain pass situated in the border area between the

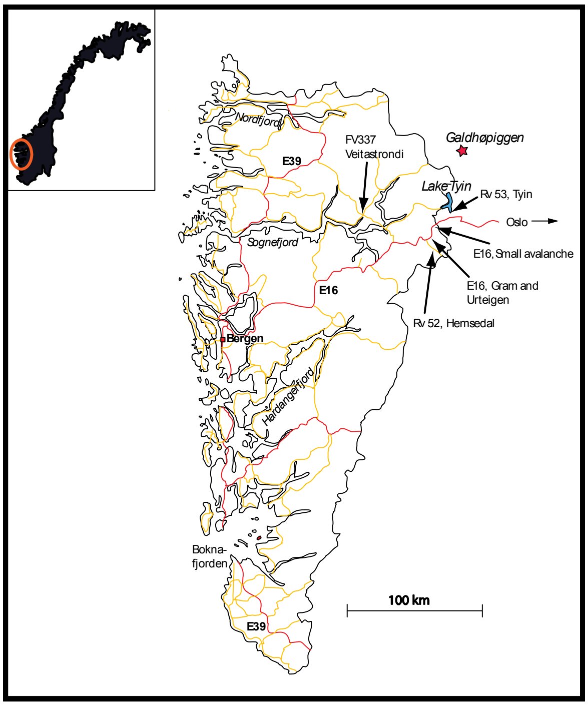

Figure 3. The Western Region of Norway, according to the organization of NPRA. The arrows show the location of several avalanche events in this region during the Sondre storm cycle.

western and eastern regions.

In southern Norway, a storm cycle named the Sondre storm event took place from late evening on Thursday the 24th to early morning on Saturday the 26th of January in 2008. Meteorological data for 10 days, including this period, is presented in figure 4. The data are sampled at the Maristova (precipitation), Sognefjellhytta (wind) and Finsevatn (temperature) weather stations. Maristova is at 806 m asl and is situated close to the avalanches on E16. The Sognefjellhytta is at 1413 m asl, in a mountain area some distance further north while Finsevatn on 1210 m asl is some distance to the south, but on about the same elevation as the release areas of the avalanches on E16. Figure 4 shows a high amount of precipitation in addition to strong winds during the Storm. During 24-27 January, about 65 mm precipitation was recorded at Maristova, most of it during the first period of the storm. Assuming that 1 mm precipitation corresponds to 1 cm of snow, this means 65 cm snowfall. The highest wind speed measured at Sognefjellhytta, 23 m/s, was measured on the 24th of January. The temperature at around 1200 m asl was decreasing during the storm and increased to around zero degrees after it.

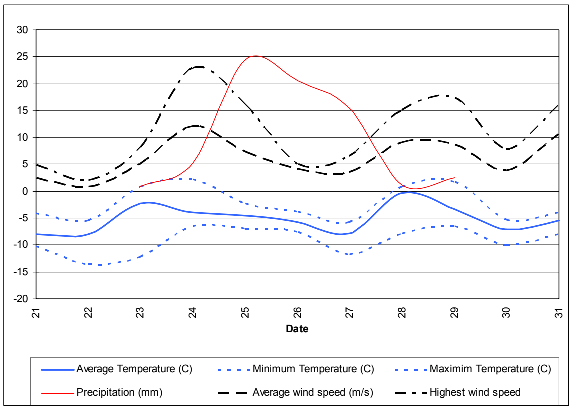

Figure 4. Weather observations during the Sondre storm cycle. The graph shows temperature, precipitation and wind speed, as observed at representative weather stations in the area.

The most powerful part of the storm happened during daytime Friday 25th of January, 2008. The western coast of Norway was in particular strongly affected with Gail winds, high tides and big waves. Further inland, strong winds, combined with heavy snowfalls, led to difficult driving conditions. Due to strong snow drift and avalanche danger, all mountain roads between west and east in Norway had problems during the day. In the early afternoon all mountain passes, except the E16 main road between east and west, were closed. In the western parts also local mountain roads had to close.

At about 4 pm, a large slab avalanche hit the E16 west from the mountain pass and covered the road in a length of more than 100 metres; the avalanche is well known and is named "Gram" (shown in figure 5). Typically, this avalanche has a return period of 5 years. Police and rescue personnel searched through the avalanche the same evening, but pulled out after advice from the NPRA. Bad weather, darkness and the fact that there are two release areas running out in the same avalanche path made the rescue operation too dangerous. No cars or persons were found during the search.

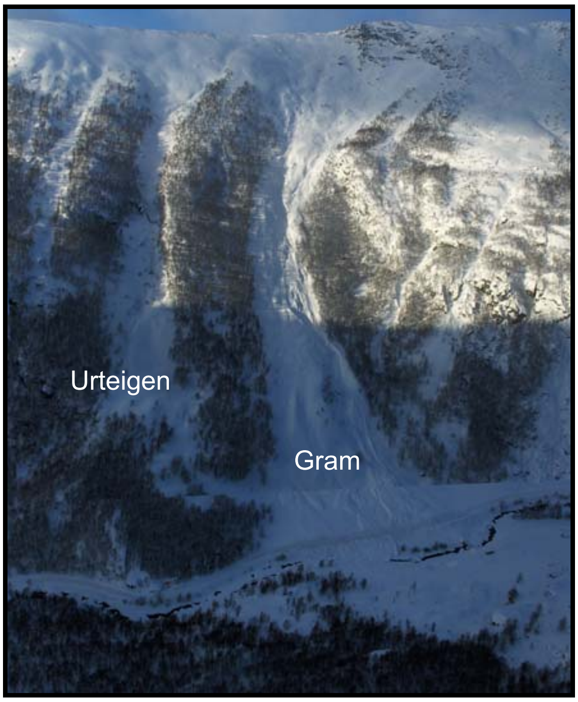

Figure 5. The Gram avalanche is in the center of the figure and Urteigen avalanche is to the left. On this figure, the road is already cleared after it was hit by the Gram avalanche. The following day, the Urteigen avalanche also hit the road, as shown in figure 8. (Photo: Kristian Kjesbu, NPRA, 25th of January)

On the eastern side of the avalanche, several cars had to turn around. These cars had passed the last turning point before the road was closed, thus a ploughing truck was sent to assist them. About 10 km from the cars, the ploughing truck ran into a small avalanche and got stuck. The situation was very hostile. It was clear that the NPRA could not assist the people in the cars. Luckily, there was also a local summer hotel, situated between the avalanches, which could open for hosting the people.

All roads between east and west were now closed, all train traffic had to stop due to avalanche danger and almost no airplanes could take off from the western parts of Norway. The west and east were almost entirely separated from each other.

The next morning, Saturday 26th of January, the large avalanche at Gram could be inspected. The weather was slightly better, and the forecast was calm weather until the early afternoon.

The road Rv 52 over Hemsedal mountain, also a mountain pass road between west and east, was inspected. Due to clouds, release areas could not be inspected. In spite of doubts, this road was opened for controlled traffic for a short while. The weather condition was getting worse and soon a small avalanche blocked this road. The traffic was stopped just before a large avalanche, which totally blocked the road. Luckily, there were no cars in the avalanche area.

At the same time the E16 main road opened at Gram and the connection between east and west was re-established, after more than 24 hours closure. All the other roads interlinking west and east were still closed. The local mountain roads in addition to some roads close to sea level could not open this day.

The next day, on Sunday 27th of January, the weather condition was improved. Clearing and reopening of the mountain passages started. Better weather condition allowed for a short aerial inspection of the affected areas. Large avalanches with extreme run out distances were observed. At the local mountain s road Rv 53 Tyin–Årdal, an avalanche had passed over the road and displaced a private mountain cabin, located 350 m away from the mountain foot at the Tyin Lake (see figure 6). The release area for this avalanche is located 200 m over the valley floor.

Figure 6. On Sunday the 27th, extreme avalanches overrun the road and reached a recreation village at the Tyin Lake. (Photo: Svein Helge Frækaland, NPRA, 27th of January)

Monday 28th of January, the temperature rose above zero degree up to an elevation over 1000 m asl. This resulted in another avalanche cycle. Figure 7 shows a big avalanche cutting the road connection off to the small community of Veitastrondi. This avalanche had a thickness of up to 8 m on the road. During this mild weather, also the E16 main road was once again closed. The avalanche at "Urteigskreda" ran as a wet slab avalanche. Such a big avalanche had not occurred here for 30 years (see figure 8). Luckily, there were no cars or personnel injured, but the road was closed for the rest of the day. The release area of the Urteigskreda avalanche, shown in figure 5, is close to the release area of the Gram avalanche.

Figure 7. An avalanche slide through a gully at Veitastrondi. The avalanche covers the whole avalanche fan at the end of the gully. (Photo: Njål Farestveit, NPRA)

Figure 8. The Urteigen avalanche hit the road on Monday 28th. Observe the man standing on the avalanche! (Photo: Njål Farestveit, 28th of January NPRA)

4 EXPERIENCES AND IMPLI-CATIONS AFTER THE SONDRE STORM CYCLE

Powerful low pressure cells lead to frontal and orographic precipitation in the form of snow during winter season in the mountains of southwest Norway. This situation often results in one or more avalanche cycles. The first avalanche cycle is triggered of heavy snow falls and strong wind, while later increase in temperature combined with rain may cause an additional cycle, consisting of wet slab avalanches.

After the Sondre storm cycle and similar situations in other places, the NPRA had to improve the plans for transporting people through avalanche risk areas. The plans also include rescue operations of people who are trapped in avalanche areas. This has led to stricter limitations on the number of cars driving at a time along with ploughing trucks. It has also resulted in better preparedness of crawler trucks in avalanche exposed areas, in the case there is need for evacuating of people.