WIDESPREAD WET AVALANCHES BUT A SAFE ROAD: THE MARCH 2025 WET SNOW CYCLE IN HARDANGER AND LESSONS FROM SITE-SPECIFIC FORECASTING ON E134 HAUKELIFJELL

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ABSTRACT: On 4–5 March 2025, an extensive wet avalanche cycle struck the Hardanger region of western Norway, closing multiple roads through avalanche debris, slush flows and debris flows, and prompting red-level warnings from Varsom.no. E134 Haukelifjell, a major mountain pass connecting western Norway to the rest of the country, experienced the same meteorological forcing and snowpack conditions but remained open throughout the event. This paper documents the forecast-decision-action sequence behind that outcome, in the first season that site-specific avalanche forecasting and active avalanche control operated together on this road. An Orange alert level was issued two days ahead of the peak of the event, prompting preventive blasting at Pepparstein on 4 March that released a size 3 avalanche before the heaviest rainfall arrived, substantially reducing the load on the starting zone. Much of the precipitation subsequently forecast as snow fell instead as rain, further stabilizing the remaining snowpack, and no avalanches reached the road at any point. SNOWPACK simulations illustrate the wet snow processes involved but served as supporting context rather than as the basis for operational decisions, which relied on field observations, weather forecasts, and structured risk assessment. The case illustrates how early alert level elevation, well-timed preventive control, and continuous tracking of the precipitation phase transition can together keep a mountain road open during a regionally severe avalanche event.

KEYWORDS: wet avalanche, site-specific forecasting, avalanche control, road safety, SNOWPACK, Hardanger

1. INTRODUCTION

Wet avalanche cycles pose a particular challenge for the management of mountain roads in the maritime snow climate of Norway's west coast. Wet avalanche cycles are driven by rapid energy inputs – rain, warm air temperatures, and solar radiation – that can overwhelm a snowpack across large areas within hours. The transition from a stable, refrozen snowpack to widespread release can be sudden and extensive, leaving little time for reactive road management.

On 4–5 March 2025, a major wet avalanche cycle struck the Hardanger region, triggering avalanches and other slope hazards across virtually all known paths. Varsom.no issued red-level warnings for avalanches, flooding and debris flows. Other roads in the region were closed by avalanche debris or by debris flows. However, E134 Haukelifjell — one of the main road connections between western Norway and the rest of the country — remained open throughout the event. This paper documents how site-specific forecasting and preventive avalanche control, operating together for the first time on this road, achieved that outcome.

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2. STUDY AREA: E134 HAUKELIFJELL AND THE HARDANGER REGION

2.1 *The Hardanger Region*

The Hardanger region encompasses the inner fjord arms and surrounding mountain areas of Hardangerfjorden in western Norway, with steep valley sides rising from fjord level to plateaus exceeding 1,700 m asl. The snow climate is strongly maritime, with Røldal among the snowiest inhabited locations in Europe. Frequent rain-on-snow events and pronounced temperature variability drive repeated melt-freeze cycles, producing a snowpack dominated by melt forms (MF) and melt-freeze crusts (MFcr). Precipitation decreases rapidly eastward across the region. E134 Haukelifjell lies within Hardanger, at its eastern margin near the main watershed. While sharing the same general maritime snow climate, snowpack conditions there — particularly snow depth and the frequency of rain at high elevations — may differ from the deeper, more westerly fjord areas.

2.2 *E134 Haukelifjell*

The road E134 Haukelifjell crosses the southern part of the Hardangervidda mountain plateau,

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reaching a maximum elevation of 1,085 m asl. The mountain pass is approximately 25 km long and crosses nine avalanche paths distributed across three sub-areas: Austmannalia (west-facing, ~860–900 m asl.), Bergsstølen–Midtlæger (south- to southwest-facing, ~900–1,085 m asl.), and Pepparstein (north-facing, 990–1,330 m asl., constituting the highest starting zone). Roughly half the paths can produce destructive size 4–5 avalanches reaching the road; the remainder produce smaller size 1–2 events that can nonetheless affect traffic. Five of the nine paths are equipped with a total of nine Wyssen avalanche towers, for preventive avalanche control.

2.3 Site-Specific Avalanche Forecasting and SNOWPACK Modelling

Site-specific avalanche forecasting for E134 Haukelifjell was established in the 2024–2025 winter season, its first year of full operation. Avalanche bulletins providing an alert level for each of the three sub-areas were issued four times per week, together with recommendations for preventive control. The four alert levels (green, yellow, orange, red) carry structured recommendations for maintenance work and traffic handling, addressed to the road owner and maintenance crew (Orset & Frekhaug, 2024). Alert levels are determined through a structured risk assessment following modified EAWS methodology, applied to site-specific consequence matrices for each avalanche path (Eckerstorfer et al., 2026).

Alert level		Road operation	Traffic handling
Red	Critical	No stopping or presence at avalanche site	Road closed
Orange	Demanding	Stay in vehicle only at avalanche site	Convoy travel with risk assessment; traffic not stopped in avalanche site
Yellow	Moderate / uncertain	Limit time outside vehicle	Convoy travel through avalanche site; road remains open
Green	Normal	Normal operation	Open road

Figure 1: Alert levels and associated road operation and traffic measures (simplified from the internal alert level action table).

Forecasters were informed by several weather stations and snow depth measurement sites along the pass, supplemented by weekly field observations from a local snow observer. The physics-based snow cover model SNOWPACK (Lehning et al., 2002) was run for two points at different elevations — approximately 900 m asl. (Austmannalia) and 1,300 m asl. (Pepparstein). SNOWPACK was primarily forced with in-situ sensor data (air temperature, relative humidity, rain rate, solar radiation, wind speed, snow depth) and supported by MEPS ensemble forecast data for short-range forward simulations. A parametrization with doubled wind erosion yielded the best results at Pepparstein, compensating for the strong wind exposure of the open, vegetation-free mountain pass.

3. THE MARCH 2025 WET SNOW CYCLE

The March 2025 wet snow cycle across the Hardanger area is documented through observer reports in the crowd sourcing observation platform Regobs.no (Engeset et al., 2018), regional hazard forecasts from Varsom.no (Engeset, 2013), and gridded precipitation analyses from seNorge.no. Conditions at E134 Haukelifjell are reconstructed in greater detail using weather station data, the SNOWPACK simulations, field observations and the site-specific forecast bulletins.

3.1 Snowpack Preconditioning

The 2024–2025 winter at Haukelifjell was characterized by a succession of mild weather episodes that repeatedly reset the snowpack through wet snow metamorphism. The season started with limited snow accumulation, and several mild periods before mid-January produced successive MFcr layers at all elevations. By late February the snowpack consisted primarily of MF and MFcr layers, with a persistent weak layer of facets below a crust active above roughly 1,100 m asl. Snowpack below 900 m asl. was fully saturated. Snow accumulation was below normal for the area and season.

Several small wet avalanche events up to size 2 in late February signaled the snowpack's increasing susceptibility to wet avalanche release. SNOWPACK simulations captured the succession of melt-freeze episodes and formation of MFcr layers well. The WSI wet snow indicator tracked the progressive wetting of the snowpack through late February. This gave forecasters a physically consistent picture of the snowpack's trajectory toward conditions susceptible to wet slab avalanche release.

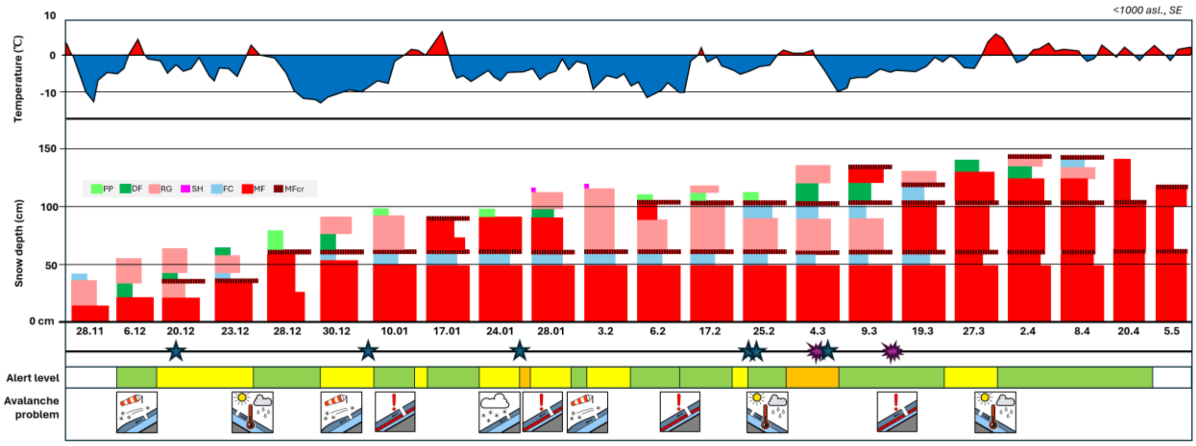

Figure 2: Generic season snowpack profile for E134 Haukelifjell, winter 2024–2025, representing conditions at <1,000 m asl. in south–east-facing terrain. Air temperature, alert levels and avalanche problems are shown as well. Stars indicate notable avalanche activity, blasting operations are indicated by the burst symbols. The March 2025 wet avalanche cycle is visible around 4–9 March.

3.2 Meteorological Forcing

Two successive Atlantic low-pressure systems crossed southern Norway on 4–5 March 2025, producing the most intense weather episode of the winter at Haukelifjell. The systems had been forecast several days in advance. From 4 March, Varsom.no issued orange warnings for flooding and debris flows (60–80 mm/24h, locally 80–120 mm) and an orange extreme rainfall warning (80–120 mm/24h, locally up to 150 mm). MET Norway's forecast called for 30 mm on Monday 3 March, 40–55 mm on Tuesday 4 March, and up to 50–55 mm on Wednesday 5 March for the wider region.

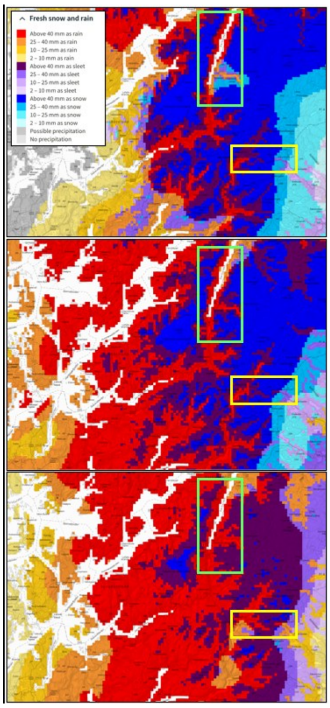

Figure 3: Daily precipitation amount and phase for the wider Hardanger region in western Norway on 3, 4, and 5 March 2025. The transition from snow on 3 March to heavy rain (>40 mm/day) on 4–5 March is clearly visible across the Hardanger region. Data source: seNorge.no.

Precipitation at Pepparstein (1,300 m asl.) arrived in two main pulses. The first pulse began around 06:00 on 3 March and continued through the afternoon, depositing the bulk of the approximately 45 cm of new snow that accumulated in the 30 hours preceding the main rain event. Temperatures at Pepparstein remained between −1 and 0°C throughout the snowfall phase, keeping precipitation as snow up to at least 1,300 m asl. The second and heavier pulse arrived from approximately 06:00 on 4 March and continued through 5 March. By midday on 4 March, temperatures at Pepparstein had risen marginally above 0°C, marking the transition to rain in the upper starting zones. Accumulated precipitation at Pepparstein over the full 1–6 March period reached 161 mm.

Wind at Pepparstein was dominated by westerly flow during the event, leading to cross loading of the Pepparstein starting zones and forming wind slabs above roughly 1,000 m asl. Wind slabs were the primary avalanche problem identified in the site-specific forecasts ahead of the rain transition. The combination of sustained westerly gale-force winds, approximately 45 cm of new snow, and then a transition to heavy rain with plus degrees reaching all release zones by Wednesday evening constituted the full meteorological forcing of the March 2025 event. Much of the precipitation that had been forecast as snow arrived instead as rain — a factor that proved somewhat decisive for road safety.

3.3 Snowpack Response

At 1,300 m asl., SNOWPACK simulations showed the fresh wind deposited snow from 3 March and earlier formed FC layers undergoing wet snow metamorphism within hours of rain onset on 4 March. The WSI indicator W (first wetting) flagged free water penetration into the fresh snow almost immediately; within approximately 12 hours, the new snow had been converted to MF. Free water then percolated downward until encountering MFcr layers, which acted as temporary capillary barriers. As rain and warm temperatures continued through 4–5 March, these MFcr layers dissolved — allowing free water to reach weakly bonded MF layers in the lower snowpack. The WSI F indicator (full-depth isothermal) signaled the onset of conditions susceptible to full-depth wet slab release. Field observations from this period indicate comparable snowpack development across the wider Hardanger region, though the exact pace of this sequence elsewhere is uncertain.

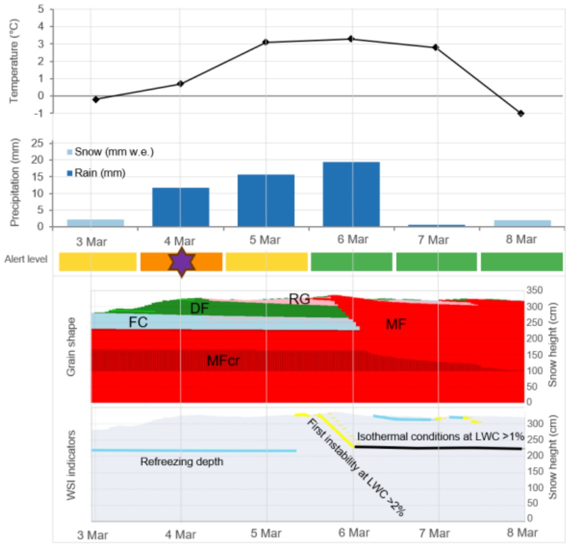

Figure 4: Meteorological conditions, alert level and SNOWPACK simulation output at Pepparstein (1,300 m asl.), 3–8 March 2025. Purple star marking the preventive avalanche control at Pepparstein on 4 March. SNOWPACK simulations illustrating grain shape and wet snow indicators.

3.4 *Observed Avalanche Activity*

The March 2025 cycle was the most extensive recorded in the Hardanger region during winter 2024-25. Avalanches released from all aspects across virtually all known paths. In the Røldal area, wet loose avalanches of size 2 were observed from all aspects on 4–5 March, along with wet slabs and cornice failures reaching size 3 on east-facing terrain. A multitude of size 4 avalanches, possibly even reaching size 5 were confirmed across the Hardanger region, especially in and around Sørfjorden. Several transitioned into slush flows and debris flows extending well beyond typical deposition zones. Multiple roads in the region were closed as a preventive measure. At E134 Haukelifjell, a size 1 wet slab was found at Pepparstein on 14 March with an estimated release date of 5 March. No avalanches of any size reached the road, and E134 remained open throughout the event.

4. FORECASTING, BLASTING, AND ROAD SAFETY

4.1 *The Forecast Sequence*

The operational sequence that kept E134 open is documented in the site-specific forecast bulletins issued in the days surrounding the event. On 2 March, with heavy precipitation and gale-force winds forecast, the forecasting team issued the following alert levels:

- Sunday 2 March: Yellow alert level
- Monday–Tuesday 3–4 March: Orange alert level

The avalanche assessment cited two concurrent problems: wind slab formation above ~1,000 m asl. combining with an active persistent weak layer (PWL) above 1,100 m asl. Natural size 3 avalanches were expected at Pepparstein, with avalanches potentially reaching the road. Rising temperatures were flagged as an additional concern, as they would raise the wet avalanche elevation and transition the hazard from wind slab to wet snow.

The 3 March bulletin maintained Orange for Tuesday–Wednesday 4–5 March, with forecast precipitation of 30 mm Monday, 40 mm Tuesday, and 50 mm Wednesday.

Figure 5: Examples of avalanche activity: a) Slush flow deposits along a creek. b) Wet slab and slush flow deposits. c) Multiple size 4 wet slab avalanches that transition into debris flows and slush flows in Sørfjorden. d) Slush flow that started as a wet slab avalanche. e) Multiple wet slab and wet loose snow avalanches. f) Cornice fall that triggered a wet slab avalanche. g) Wet snow conditions at roughly 1,300–1,500 m asl. Data source: Regobs.no

4.2 *Preventive Blasting*

On 4 March, with alert level Orange in effect and conditions at the threshold of alert level Red, the road owner executed preventive blasting at Pepparstein. All three towers at Pepparstein were fired in sequence, releasing a size 3 avalanche. The timing was critical, as the blasting removed substantial snow mass from the Pepparstein starting zone before the most intense rainfall arrived on 4–5 March. This meant that the snowpack at Pepparstein entering the peak of the cycle was substantially less loaded than it might have been.

4.3 *Return to Green and Road Safety Outcome*

The 5 March bulletin already issued a return to Yellow for Wednesday 5 March and Green for Thursday–Friday 6–7 March. The bulletin noted that wet avalanche danger was expected to decrease — no avalanches were expected to reach the road. By 6 March, all sub-areas were Green, remaining at the lowest alert level through the following week.

E134 Haukelifjell remained open throughout the event. No avalanches reached the road during the most severe weather episode of the winter. This outcome stands in contrast to the broader Hardanger region, where multiple roads were either preventively closed or closed by avalanche debris or by debris flows. The key elements in the outcome were: (1) Orange alert level issued two days ahead of the peak forcing, allowing time to plan and execute control; (2) preventive blasting on 4 March releasing a size 3 avalanche at Pepparstein before the heaviest rain arrived.

Across the full operational avalanche control record from 2021 to 2026 (Pepparstein was equipped with avalanche towers before site-specific avalanche forecasting started), 27 blasting operation dates are documented at Pepparstein. Only three produced recorded avalanches of size 3. The March 2025 event was the first wet or transitional avalanche produced by the control system at Pepparstein.

5. DISCUSSION

5.1 *Forecast-Driven Preventive Control*

The March 2025 event illustrates that continuous site-specific avalanche forecasting enables improved road safety management. Throughout the season, the forecasting service tracked snowpack and weather conditions at E134 Haukelifjell and issued alert levels with recommendations for preventive action. The road owner was not obliged to follow the recommendations but was strongly advised to act on them. The March event showed what happens when they do.

Orange alert level was issued on 2 March — two days before the peak of the event — creating the operational space for the road owner to plan and execute blasting under controlled conditions on 4 March. The forecasters did not simply flag danger at a single point in time; they tracked the evolving hazard continuously, correctly anticipating the transition from wind slab to wet snow conditions and maintaining appropriate alert levels through the peak of the event.

The value of this setup is further illustrated by a contrasting episode earlier in the season. On 25 January 2025, the forecasting service recommended avalanche control at Orange level for Pepparstein. The road owner assessed the risk as acceptable and did not proceed. A natural size 1 avalanche with runout halfway to the road was observed the following day. In March, the same recommendation was acted upon promptly, and the road remained open throughout the most severe weather event of the winter. The difference in outcome was not in the quality of the forecast — both assessments were sound — but in the decision to act on it. This underlines that the forecasting service and the road owner together form a system: the forecasting service provides the best possible situational awareness and recommendations, but the road safety outcome ultimately depends on the road owner's willingness to act on them.

5.2 *SNOWPACK as Operational Support*

SNOWPACK provided useful background context for understanding the snowpack's preconditioning through the winter and the wet snow processes during the event, but it was not the primary driver of operational decisions. The forecasters' Orange alert level on 2 March was based on the snowpack field observations, and the weather forecast — not on the SNOWPACK output. SNOWPACK's main contribution was as a physically consistent narrative tool: it helped forecasters understand why the snowpack was behaving as it was, particularly regarding MFcr dissolution and free water movement.

6. CONCLUSIONS

On 4–5 March 2025, the Hardanger region experienced an extensive wet avalanche cycle that closed multiple roads and produced numerous size 4 avalanches. E134 Haukelifjell experienced the same meteorological forcing and snowpack conditions yet remained open throughout.

This case illustrates three operational principles for avalanche risk management on mountain roads: (1) early alert level elevation — two days ahead of the peak — creates the operational space for proactive control before conditions become too dangerous to act; (2) preventive blasting is most effective when executed at the threshold of natural release, before the main forcing arrives; (3) in maritime snow climates, the precipitation phase transition from snow to rain can be as consequential as the total precipitation amount, and forecasters need to track it in real time.

The Technology for Natural Hazard Management project (Statens Vegvesen, 2026), in its first operational season on E134 Haukelifjell, demonstrated that the integration of site-specific forecasting and active control infrastructure can keep a major mountain road open during a regionally severe avalanche event.

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