WHICH BUILDINGS ARE AT RISK? MEET ALARM: AN AUTOMATED WORKFLOW LINKING AVALANCHE RUNOUT MODELLING TO BUILDING RISK ASSESSMENT FOR EMERGENCY MANAGEMENT IN NORWAY

Leonie Kommerell[1]*, Håvard Boutera Toft[1], Gustav Pless[1] and Karin Bergbjørn[1]

[1]*The Norwegian Water Resources and Energy Directorate, Oslo, Norway*

ABSTRACT: During periods of high/extreme avalanche hazard, decision makers need to identify which buildings may be exposed and where field assessments or evacuations should be prioritised. In many parts of Norway, this assessment is challenging because detailed avalanche hazard-zone maps or site-specific warning services are not available. The Avalanche Location Alert Risk Method (ALARM) is therefore being developed as a supplementary tool for periods of high or extreme avalanche danger. ALARM is an automated workflow that combines terrain analysis, potential release-area identification and avalanche runout modelling to assess the exposure of relevant buildings. It uses inputs from the regional avalanche forecast, such as elevation band, aspect and avalanche problem, to identify relevant release areas and models how far dry-snow avalanches could run in different scenarios. The output is a list of exposed buildings, together with maps of modelled avalanche runouts and estimated impact pressures. The aim is to enable experts to focus their time and resources on the most exposed buildings that may require field assessment or evacuation. ALARM provides a catalogue of five precomputed standard scenarios for each of Norway's avalanche forecast regions, excluding Svalbard. It also enables event-specific modelling for selected regions when the standard scenarios are insufficient. The workflow is intended as a decision-support tool and not as a replacement for expert judgement, local knowledge or detailed hazard-zone mapping. Validation against historical events and official hazard zones is ongoing; the present paper therefore demonstrates the method, national-scale implementation and computational feasibility rather than predictive accuracy. Approximately 30,000 simulations can be processed within four hours for a selected region, indicating that ALARM may eventually support time-critical avalanche emergency management once validation is complete.

KEYWORDS: Avalanche exposure, Emergency management, Potential release areas, Runout modelling, Decision support, Building prioritization

1. INTRODUCTION

Snow avalanches threaten lives, roads, buildings, and other infrastructure in many parts of Norway, especially where steep slopes lie close to settlements. Using the national avalanche hazard indication maps (AHIM), Toft et al. (2026) estimate that 150,000 buildings could be exposed to avalanches. Hazard-zone maps, regulations for new developments, mitigation measures, and site-specific avalanche warnings provide important risk-management measures. However, AHIM describe long-term susceptibility rather than the current snow and weather situation, and detailed hazard mapping is resource-intensive and available only for a subset of locations. As a result, many buildings in avalanche-prone terrain still lack a systematic assessment of exposure.

For emergency preparedness, this creates a practical problem: during a large avalanche cycle, it can be unclear which buildings should be evaluated or which occupants should be considered for evacuation. Decisions must often be made with limited field observations, under changing conditions, and across large areas. They therefore rely heavily on the judgement of avalanche experts and local decision makers. ALARM addresses this issue by providing a consistent initial screening of buildings that may be exposed under a given avalanche scenario. The workflow identifies potential release areas using an adapted implementation of the potential release area (PRA) algorithm from Veitinger et al. (2016), simulates dry-snow avalanche runout with AvaFrame's com1DFA model (AvaFrame, 2026a), and compares the modelled runout impact pressures with the positions of relevant buildings. The model output is a map and a priority list that can help experts narrow down the set of buildings requiring assessment.

This paper describes the model components of ALARM and demonstrates its large-scale application across all forecast regions in Norway, excluding Svalbard. A case study from Oldervik in Troms, Northern Norway, illustrates how the model can combine information from the avalanche forecast with information on individual

* Corresponding author address:
Leonie Kommerell, Norwegian Water Resources and Energy Directorate 0301 Oslo, Norway;
tel: +47 22 95 95 95;
email: leko@nve.no

building exposure. Validation against large avalanche events and detailed avalanche hazard mapping is still ongoing. The results should therefore be interpreted as a demonstration of the model workflow and its computational feasibility, not as a validated operational product.

2. METHODS

ALARM supports two complementary modes of operation. The first mode uses a national catalogue of five standard parameter scenarios that have already been precomputed for all 23 avalanche forecast regions on the Norwegian mainland. These scenarios provide results that can be filtered by elevation and aspect according to the current regional avalanche forecast. The second mode allows users to start a new, configurable run for a selected region if the precomputed scenarios are not sufficient. Both modes follow the same five-step workflow and produce a building-level exposure list that can be traced back to the relevant release areas and runout-model outputs.

2.1 *Module 1 – Potential Release Area (PRA) Calculation*

PRAs are identified from a 5 m digital elevation model (DEM) resampled by the Geological Survey of Norway (NGU) from the national 1 m elevation model provided by the Norwegian Mapping Authority (Kartverket, n.d.). Where available, the workflow also uses the NIBIO SR16 forest raster. Following the fuzzy-logic approach of Veitinger et al. (2016), ALARM treats slope angle as a graded suitability score rather than a simple yes/no threshold. Terrain with slope angles from 28° to 60° is evaluated together with wind exposure, curvature, and surface roughness. These factors are combined into a suitability score between 0 and 1 for each raster cell, where higher values indicate terrain that is more suitable for release-area formation. The PRA calculation is adapted from the method used in Toft et al. (2024). Forest cover is represented by stem density from the SR16 dataset (NIBIO, 2019); higher stem densities reduce the suitability score to account for the stabilizing effect of forest on the snowpack (Bebi et al., 2021).

Cells above the upper threshold form the polygon cores, or seeds. These seeds are then expanded into adjacent terrain where suitability scores exceed a lower growing threshold. This approach produces release areas bounded by terrain form rather than by a single binary cutoff. A minimum-area threshold removes isolated noise while retaining small release features. The module can produce either a binary PRA raster, where cells above a selected suitability score are assigned a value of 1 and retained as PRAs, or a continuous PRA raster, where each cell keeps its suitability score between 0 and 1. The raster selected by the user is then converted to vector PRA shapefiles containing area, elevation, and slope attributes.

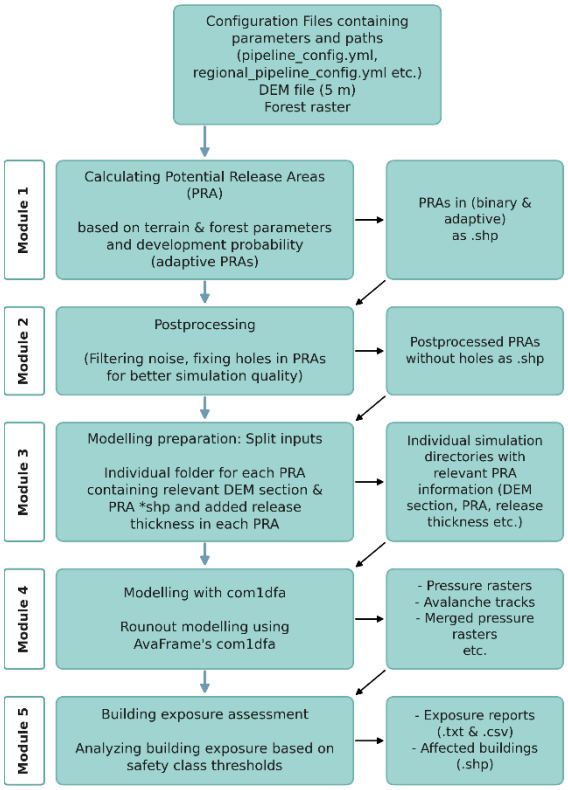


Figure 1: Overview of the ALARM 2.0 workflow. The five sequential modules derive potential release areas, prepare and simulate avalanche runout, and combine the model outputs with building data to produce building-level exposure results.

2.2 *Module 2 – Postprocessing*

PRA polygons produced in Module 1 may contain internal holes representing locally unsuitable terrain such as flat areas or dense vegetation that cannot be processed directly by com1DFA. Simply filling all holes would incorrectly turn unsuitable terrain into release areas and could make the simulated runouts too large. ALARM therefore applies a size-based cleaning step. Small holes below a configurable threshold are filled, while larger holes are opened by cutting a very narrow corridor, approximately 3–15 cm wide, from the hole to the outside boundary of the polygon. This corridor is negligible compared with the 5 m raster resolution, but it removes the invalid interior ring while keeping the polygon area effectively unchanged. The module outputs cleaned PRA polygons with their original attributes and a record of the processing applied.

2.3 Module 3 – Modelling Preparation

Input preparation for modelling builds on AvaFrame's regional com7Regional module (Oesterle et al., 2025). Because simulation runtime increases with the number of terrain cells processed, each PRA is simulated on a clipped DEM rather than on the complete regional DEM. For every PRA, the AvaFrame module creates a separate simulation folder containing the corresponding PRA shapefile and DEM subset. In ALARM, com7Regional has been modified so that the buffer adapts to the PRA size and is applied mainly in the downhill direction. Based on internal implementation tests, the buffer around each DEM subset scales from 250 to 1,500 m depending on DEM size. Buffering is also directional: a full buffer is retained downslope, whereas the upslope buffer is reduced; symmetric buffering is used where terrain direction cannot be resolved. Internal tests indicated that this directional clipping reduced the processed terrain area by approximately 40% without removing the downslope domain required for the simulations.

Each PRA is then assigned a release thickness representing the depth of snow assumed mobilized at release. This value is set in the ALARM configuration. A multi-thickness option allows the same PRA to be simulated with several release thicknesses without repeating the PRA calculation. Other model parameters are also defined in the ALARM settings and passed to the AvaFrame modules.

The module outputs a folder structure in the format expected by com1DFA. Each folder contains a clipped DEM, the corresponding PRA shapefile, and the assigned release-thickness configuration.

2.4 Module 4 – Runout Modelling with com1DFA

Avalanche runout is simulated with AvaFrame's com1DFA module using the SamosAT friction model implemented in AvaFrame (Oesterle et al., 2025). For each simulation, the model produces peak rasters of maximum impact pressure, flow velocity, and flow thickness. These rasters are used in the building exposure assessment in Module 5.

com1DFA was selected because it is open source, physically based, produces the peak-pressure outputs needed for building assessment, and can be integrated into an automated regional workflow. A fork of AvaFrame 1.12 was developed for ALARM to run simulations in parallel, reduce the amount of stored output, and make the relevant model settings easier to adjust while preserving compatibility with existing AvaFrame workflows.

2.5 Module 5 – Building Exposure Assessment

For each simulation, cells with simulated peak pressure above the configurable threshold of 0.1 kPa are merged into an avalanche-track polygon and linked to the source PRA through a unique identifier. The threshold is used to remove low-pressure numerical noise when converting peak-pressure rasters into polygons. Track attributes include polygon area, mean and maximum peak pressure, and median PRA elevation.

The merged modelled peak-pressure raster is combined with building geometries and building categories. Building geometries were obtained from the Geovekst FKB-Bygning dataset, with data status from November 2025 (Norwegian Mapping Authority, 2025). For each building, the model identifies the maximum simulated peak pressure within a user-defined buffer around the building. This value is then compared with screening criteria for the corresponding building category, informed by the safety classes in the Norwegian building code (Norwegian Directorate for Building Quality, 2017). Buildings that exceed these criteria are flagged as potentially exposed. The outputs include per-building records and a ranked summary of potentially exposed buildings, including residential buildings and buildings associated with many residents or critical functions. The results are intended for prioritization and do not constitute a regulatory compliance assessment or a substitute for site-specific avalanche forecasting.

2.6 Scenario-based application

To process large regions efficiently, ALARM divides each analysis area into 10 × 10 km tiles with a 1 km overlap. The full workflow, from Module 1 to Module 5, is run for each tile and parallelized across tiles and available CPU cores. Tile-level peak-pressure results are then merged by keeping the highest value at each grid cell. Individual PRAs and avalanche tracks are preserved so that each result can be traced back to its source.

As a national baseline, ALARM has precomputed five standard parameter scenarios for each forecast region (Table 1), spanning moderate to extreme snow conditions and alternative PRA delineation strategies. The scenarios vary three parameters: the PRA dual thresholds, where 80/60 represents stricter delineation and 75/55 represents more permissive delineation; the proximity-grouping distance, which allows nearby PRAs to be modelled together and represents greater re-

lease-propagation potential; and release thickness. Additional parameter combinations can be processed for individual regions if needed.

Table 1: Parameter variation in all five scenarios modelled over the 23 warning regions.

Scenario	***Thresholds***	***Proximity grouping***	***Release thickness***
A	80/60	0 m	1.2 m
B	80/60	0 m	1.8 m
C	80/60	100 m	2.3 m
D	75/55	0 m	2.3 m
E	75/55	150 m	2.3 m

The five scenarios are interpreted as an ensemble of plausible conditions, not as an ordered risk scale. At this stage, the most appropriate parameter combination cannot yet be selected confidently for each region. Using a common scenario set therefore preserves national comparability and represents uncertainty in PRA delineation, release propagation, and release thickness. In addition to the national catalogue, users can configure and process several custom parameter combinations for an individual region in a single run.

3. PRELIMINARY RESULTS

ALARM was applied to all 23 avalanche forecast regions on the Norwegian mainland that receive daily forecasts. Each region was processed under all five standard scenarios (Table 1), covering approximately 214,435 km². The full national run was completed on a server with 48 CPU cores and approximately 300 GB RAM and took about three weeks. In total, 3,838,337 individual avalanche simulations were performed across all regions and scenarios. This demonstrates that the workflow can process large and varied terrain at national scale. To show the outputs in more detail, the following section presents Oldervik in Tromsø municipality (Figure 2) as a case study.

Tromsø municipality in Northern Norway covers a land area of 2,474 km². Oldervik was selected for the case study because recent hazard-zone mapping provides a basis for comparison (NVE, 2024), and because documented avalanche events have repeatedly blocked access roads and led to evacuations in and around the village. These events are particularly well documented because a site-specific avalanche warning is in place. These characteristics make Oldervik a relevant test site for examining whether ALARM produces exposure patterns that practitioners can interpret and use during a known avalanche situation.



Figure 2: Position of Oldervik in Tromsø municipality in Northern Norway (Basemap: Open Street Map).

The case study scenario was based on the avalanche warning issued for the Tromsø forecast region on 18 March 2025 (Figure 3), when the danger level was 4 (high). Repeated snowfall and periods of strong northwesterly winds had deposited approximately 50–60 cm of new snow locally during the preceding five days. The forecast identified a wind-slab problem above 300 m a.s.l., with expected avalanche size 3 and locally size 4, as well as a wet loose-snow problem. Because ALARM currently focuses on dry dense-flow avalanches, the wind-slab problem was selected to define the scenario. The reported northwesterly winds were then used to identify the corresponding leeward release aspects.

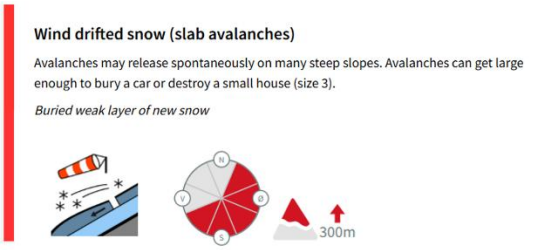


Figure 3: Excerpt from the avalanche forecast issued for the Tromsø forecast region on 18 March 2025 (Varsom, 2025).

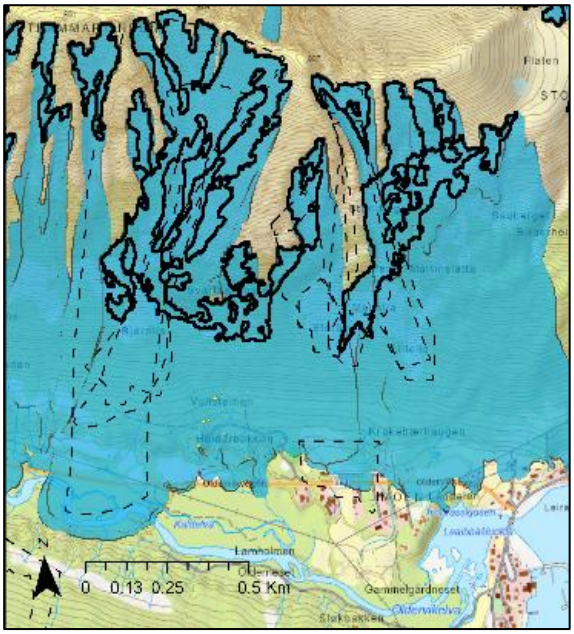


Figure 4: Modelled avalanche tracks in Oldervik under Scenario E after filtering shown in blue. The dashed lines outline registered past snow avalanche events. Basemap: GeocacheBasis (Geodata AS et al., 2026).

The first step in the case study was to retain only PRAs above 300 m a.s.l. on leeward aspects consistent with loading by the reported northwesterly wind. The filtered PRA set was then used to select the corresponding avalanche tracks and potentially affected buildings in Oldervik (Figure 4). Buildings were then ranked from highest to lowest modelled impact pressure. For the three most exposed buildings, Table 2 reports the contributing source PRA or PRAs, estimated impact pressures, and the median elevation and aspect of the originating PRA. Building identifiers are partially redacted for publication.

Table 2: Three buildings with the highest modelled exposure under the selected avalanche scenario in Oldervik.

Building ID	***Relevant PRAs***	***Peak pressure (kPa) at building***	***PRA elev. (m a.s.l.) and aspect***
xxxx844	593, 214	136.5	505 – S
xxxx278	593, 214	84.2	505 – S
xxxx274	593, 214	49.8	505 – S

In an operational setting, this ranked building-level output could help emergency responders decide where to start. Instead of treating all potentially affected buildings as equally urgent, responders could prioritise site inspections and evacuation assessments for buildings with the highest modelled exposure. Figure 5 shows the spatial distribution of potentially affected buildings near Oldervik and identifies the three highest-ranked buildings listed in Table 2. Together, the table and map translate the model output into a practical priority list for expert review and field deployment.

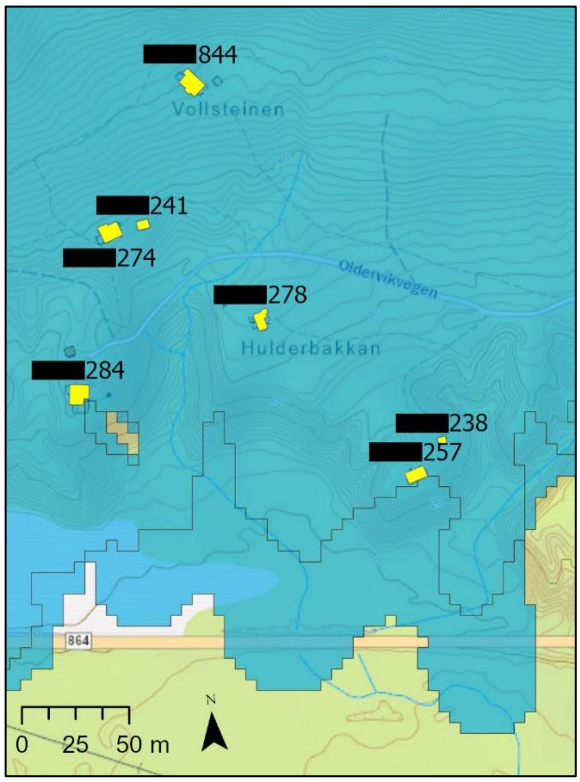


Figure 5: Detail view of the highest-priority buildings (numbered, corresponding to Table 2) and additional potentially affected buildings near Oldervik, Tromsø. Avalanche tracks and estimated impact pressure are shown for the applied scenario based on the 18 March 2025 warning and release areas leeward of the reported northwesterly wind. Basemap: GeocacheBasis (Geodata AS et al., 2026).

A large dry-slab avalanche was reported near Oldervik during the same warning period (RegObs, 2025), providing a relevant event for subsequent validation work.

4. DISCUSSION

The preliminary results show that ALARM is technically scalable. Across all 23 mainland forecast regions and five scenarios, the workflow completed 3,838,337 simulations. The approximate three-week runtime shows that nationwide scenario precomputation is feasible. At a more targeted regional scale, about 30,000 simulations can be processed within four hours on the tested computing setup. This suggests that regional calculations could be feasible within time frames relevant to an evolving avalanche situation. How-

ever, predictive accuracy still needs to be quantified through the systematic validation described below.

By design, ALARM's runout modelling targets dry dense-flow avalanches using com1DFA's SamosAT friction model. Wet-snow and powder-snow processes are not represented in the current version. Avalanche forecasts often list several avalanche problems at the same time, as in the case study above, where both wind-slab and wet loose-snow problems were active. In such cases, ALARM addresses only the wind-slab problem, and the results should not be interpreted as a complete hazard picture for the day. Extending coverage to other avalanche types may become feasible as wet-snow-capable modelling options within AvaFrame/OpenNHM develop further, including com1DFA's wet-snow friction option and NGI's experimental MoT-Voellmy module (AvaFrame, 2026a, 2026b). Simulated peak pressure is a modelled, relative quantity rather than a measured pressure. It depends on simplifying assumptions in the model, such as friction parameters, and should therefore be used to compare exposure across buildings and scenarios rather than as an absolute value for structural design. The five standard scenarios applied in the nationwide run form a precomputed ensemble representing plausible variation in PRA delineation, release propagation, and release thickness; they are not a ranked severity scale. For a given event, users can first filter this catalogue by elevation band and aspect and then interpret differences between the resulting exposure lists using local knowledge and professional judgement. If the standard ensemble does not adequately represent the situation, a tailored regional simulation can be generated with adjusted parameter settings. This combination of rapid access to precomputed results and flexible regional processing is consistent with ALARM's role as a decision-support tool rather than an automated source of a single correct answer.

Systematic validation against recorded avalanche events and detailed hazard-zone mapping is ongoing and is not yet available. The present output should therefore not be used for operational decision-making. Instead, it constitutes a preliminary research dataset for testing the internal consistency of the workflow and identifying model sensitivities. The next phase will assess whether modelled PRAs correspond to observed release areas, whether simulated runout reproduces documented avalanche extents, and whether the resulting building ranking identifies locations that were actually exposed. It will quantify true positives, false positives, and false negatives at both avalanche-path and building level. This distinction is important for practitioners: false positives could generate unnecessary field inspections or evacuations, use limited response resources inefficiently, and reduce user confidence, whereas false negatives could leave exposed buildings unidentified and lead to potentially severe consequences. Only after accuracy has been validated across multiple documented events and regions should ALARM outputs be considered for operational use in decision-support settings.

Establishing this evidence base across multiple regions is therefore the immediate next step. ALARM adapts the AutoATES 2.0 PRA calculation (Toft et al., 2024), originally developed to support terrain assessment for recreational travel, toward building-level, condition-dependent exposure assessment. Related work within CAIROS also supports operational avalanche decision-making, but focuses on harmonizing workflows, training, and tools for avalanche commissions in the European Alps (Winkler et al., 2024). ALARM's scenario-based outputs are tied to specific snow and weather conditions and can therefore provide more targeted, condition-dependent guidance during active avalanche cycles, complementing static hazard-zone mapping. ALARM is not intended to replace detailed hazard-zone mapping, which remains the appropriate basis for land-use regulation where available. Its intended role is to support rapid, expert-led assessment during avalanche emergencies, particularly where detailed hazard-zone mapping or a site-specific warning is unavailable.

5. CONCLUSION AND OUTLOOK

This paper presents ALARM, an automated workflow that combines terrain-based release-area modelling, physics-based runout simulations, and building-level exposure assessment. It demonstrates ALARM's application across all 23 avalanche forecast regions on the Norwegian mainland. The nationwide results show that precomputing a five-scenario catalogue is computationally feasible, while the Oldervik case study illustrates how filtered results can help experts prioritise which buildings to inspect and, if necessary, consider for evacuation during large avalanche cycles. The demonstrated capacity to process approximately 30,000 simulations within four hours further indicates that regional modelling is feasible for urgent situations not covered by the nationwide precomputed scenarios. Accuracy remains to be established through systematic validation.

Planned validation will follow the dependency structure of the workflow. Because PRA delineation controls all downstream modelling, it will be validated first. This will involve manual comparisons with observations and with slopes that have

well-documented avalanche histories. Validation of runout modelling and building-level exposure will follow once PRA validation is sufficiently advanced.

Beyond validation, planned work includes refining the scenario ensemble for individual regions. As validation results become available, some regions may need additional scenarios tailored to local conditions, while unrealistic parameter combinations may be removed. Future versions may also extend ALARM's runout modelling to other avalanche types, such as wet-snow avalanches, if suitable modelling options mature within AvaFrame. More broadly, ongoing work will help clarify the extent to which Norwegian municipalities need an automated avalanche decision-support tool and whether ALARM, in its current or future form, can meet that need.

Once validated, ALARM could provide systematic, condition-driven decision support for avalanche emergency management across Norway. Its main value would be to extend consistent building-level screening to areas where detailed local mapping or event-specific assessment is not available.

ACKNOWLEDGEMENTS

We thank colleagues at the Norwegian Water Resources and Energy Directorate (NVE) for helpful discussions during the development of ALARM 2.0. We are grateful to José Santiago Pullarello at the Geological Survey of Norway (NGU) for sharing the resampled 5 m DEM. We also thank the Norwegian Avalanche Association (NORSKRED) for supporting Leonie Kommerell's participation at ISSW 2026 through the Young Snow Professional Award.

REFERENCES

AvaFrame, 2026a. com1DFA theory: friction model and wet-snow friction type option, AvaFrame documentation, https://docs.avaframe.org/en/1.9/theoryCom1DFA.html, last access: 17 August 2026.

AvaFrame, 2026b. com9MoTVoellmy: NGI MoT-Voellmy, AvaFrame documentation, https://docs.avaframe.org/en/latest/moduleCom9MoTVoellmy.html, last access: 17 August 2026.

Bebi, P., Bast, A., Helzel, K., Schmucki, G., Brozova, N., and Bühler, Y., 2021. Avalanche protection forest: From process knowledge to interactive maps, in: Protective Forests as Ecosystem-based Solution for Disaster Risk Reduction (Eco-DRR), edited by: Teich, M., Accastello, C., Perzl, F., and Kleemayr, K., IntechOpen, https://doi.org/10.5772/intechopen.99514.

Geodata AS, Kartverket, Geovekst and the municipalities, and OpenStreetMap, 2026. GeocacheBasis (Geocache_UTM33_WGS84) [MapServer service], Geodata Online, https://services.geodataonline.no/arcgis/rest/services/Geocache_UTM33_WGS84/GeocacheBasis/MapServer, last access: 17 August 2026.

Kartverket, n.d. Høydedata: Nasjonal detaljert høydemodell [dataset], https://hoydedata.no/LaserInnsyn2/, last access: 17 August 2026.

NIBIO, 2019. SR16 – Norsk skogressurskart, Norwegian Institute of Bioeconomy Research, https://kilden.nibio.no, last access: 17 August 2026.

Norwegian Directorate for Building Quality, 2017. Regulations on technical requirements for building works (TEK17). Lovdata, https://lovdata.no, last access: 17 August 2026.

Norwegian Mapping Authority, 2025. FKB-Bygning (Common Map Database – Buildings), Version 5.0 [dataset], Geonorge, https://kartkatalog.geonorge.no/metadata/fkb-bygning/8b4304ea-4fb0-479c-a24d-fa225e2c6e97, last access: 17 August 2026.

NVE, 2024. Hazard zone assessment for avalanches and landslides in steep terrain – Tromsø Municipality. External Report 16/2024, Norwegian Water Resources and Energy Directorate, https://publikasjoner.nve.no/eksternrapport/2024/eksternrapport2024_16.pdf, last access: 17 August 2026.

Oesterle, F., Wirbel, A., Köhler, A., Neuhauser, M., Fischer, J.-T., and Granig, M., 2025. AvaFrame: The Open Avalanche Framework (Version 1.12) [computer software], https://docs.avaframe.org, last access: 17 August 2026.

RegObs, 2025. Avalanche incident registration 4210486, Tromsø, 18 March 2025, https://regobs.no/registration/4210486, last access: 17 August 2026.

Toft, H. B., Sykes, J., Schauer, A., Hendrikx, J., and Hetland, A., 2024. AutoATES v2.0: Automated Avalanche Terrain Exposure Scale mapping, Nat. Hazards Earth Syst. Sci., 24, 1779–1793, https://doi.org/10.5194/nhess-24-1779-2024.

Toft, H. B., Nicolet, P. S., and Humstad, T., 2026. Snow avalanche exposure and consequences in Norway. Extended abstract submitted concurrently to the International Snow Science Workshop (ISSW 2026); unpublished.

Varsom, 2025. Avalanche warning for the Tromsø forecast region, 18 March 2025, https://www.varsom.no/en/snow/forecast/warning/Troms%C3%B8/2025-03-18, last access: 17 August 2026.

Veitinger, J., Purves, R. S., and Sovilla, B., 2016. Potential slab avalanche release area identification from estimated winter terrain: a multi-scale, fuzzy logic approach, Nat. Hazards Earth Syst. Sci., 16, 2211–2225, https://doi.org/10.5194/nhess-16-2211-2016.

Winkler, M., Gasperi, A., Schwarz, J., Hesselbach, C., St. Clair, A., Griesser, S., Benigni, S., Gaddo, M., Munari, M., Genswein, M., Mitterer, C., Fischer, J.-T., Adams, M., and Riedl, H., 2024. Project CAIROS: Harmonizing avalanche commissions' workflow, training and tools. In: Proceedings of the International Snow Science Workshop, Tromsø, Norway, 2024.