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Project title: SLIDER: Subaqueous Landslide dynamIcs anD infrastructure resiliencE in lochside enviRonments

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Project short report:

The project aims to improve understanding of landslide runout on steep nearshore subaqueous slopes beside modified lochside infrastructure in the western Scottish Highlands. These settings are important for strategic transport routes, where limited space between steep valley sides and loch margins can require engineering solutions such as embankments, cuttings or viaducts.

This work focuses on the Wades Bridge Bank subaqueous landslide at Loch Lomond, where historical A82 road embankment construction was associated with slope failure and long runout across the loch bed. The study location and interpreted landslide reference zones are shown in Figure 1a. Earlier modelling by Finlayson et al. (2023) provided a useful first-order reconstruction, but did not explicitly test the influence of material remoulding and hydrodynamic effects that may be important for subaqueous landslide behaviour. BingCLAW modelling (Kim et al., 2019) was therefore undertaken as part of the Geo-INQUIRE Transnational Access project through by Dr Finn Løvholt and Dr Steven Gibbons at the Norwegian Geotechnical Institute, Oslo, to explore whether these processes improve simulation of the interpreted runout pattern and landslide footprint.

For current modelling, the source material and the channel material are both present at the start of the simulation, as shown by the initial slide-thickness field in Figure 1b. The channel material is assigned a higher initial yield strength than the source and is allowed to weaken through remoulding during the simulation. This is not a true dynamic bed-entrainment model. Instead, the approach should be interpreted as a preloaded weak or remouldable channel-layer proxy for source-triggered mobilisation of material along the runout path.

The current model setup includes a source/scarp zone with an initial depth of 5.0 m, equivalent to approximately 19,360 m^3. The channel zone has an initial depth of 2.5 m, equivalent to approximately 93,280 m^3. The combined initial source-plus-channel volume is therefore approximately 112,640 m^3, which is broadly comparable to the interpreted total event volume.

A sensitivity test was carried out indicating that residual yield strength and remoulding coefficient strongly influence runout, deposition pattern and velocity. The parameter set was selected using two main diagnostic criteria. First, an equivalent channel-only simulation should not self-mobilise strongly, as this would imply that the preloaded channel layer is unrealistically unstable without source triggering. Second, a source-only simulation should not reproduce the full mapped footprint, as this would imply that the channel material is unnecessary. The selected source-plus-channel parameter set is therefore considered a plausible preliminary calibration because it reproduces the broad runout pattern while retaining a physically interpretable role for source-triggered channel mobilisation. However, the selected parameter set should not be treated as unique. Similar runout patterns may be produced by different combinations of source strength, channel strength, residual strength and remoulding rate. This equifinality means that the current results should be interpreted as a preliminary calibration rather than a definitive parameter solution.

The tested parameter set used an initial source yield strength of 5 kPa, an initial channel yield strength of 10 kPa, a residual yield strength of 0.5 kPa, and a remoulding coefficient of 1×10^{-3}. Full definitions of the parameters are provided by Kim et al., (2019).

The time-series outputs show a coherent staged movement pattern. At the initial frame, material is present in both the source and channel zones, with negligible velocity and surface change. By approximately 60 s, movement is concentrated in the upper source area and along the channel (Figure 2a) with velocity around 2 m/s (Figure 2b). The corresponding surface-change pattern shows early evacuation and deposition within the upper channel system (Figure 2c). The slide thickness around 170s extend into the lower lobe (Figure 2d), whilst the velocity field is largely reduced, indicating that active movement is becoming limited (Figure 2e). The surface-change pattern at this stage shows evacuation and thinning in the source and central channel, with deposition concentrated towards the distal footprint (Figure 2f). This is consistent with transfer of material from the steep nearshore slope towards a lower-gradient depositional area.

Future work should compare the present BingCLAW remouldable-channel approach with models that include explicit entrainment processes, and also explore whether an entrainment formulation can be implemented.

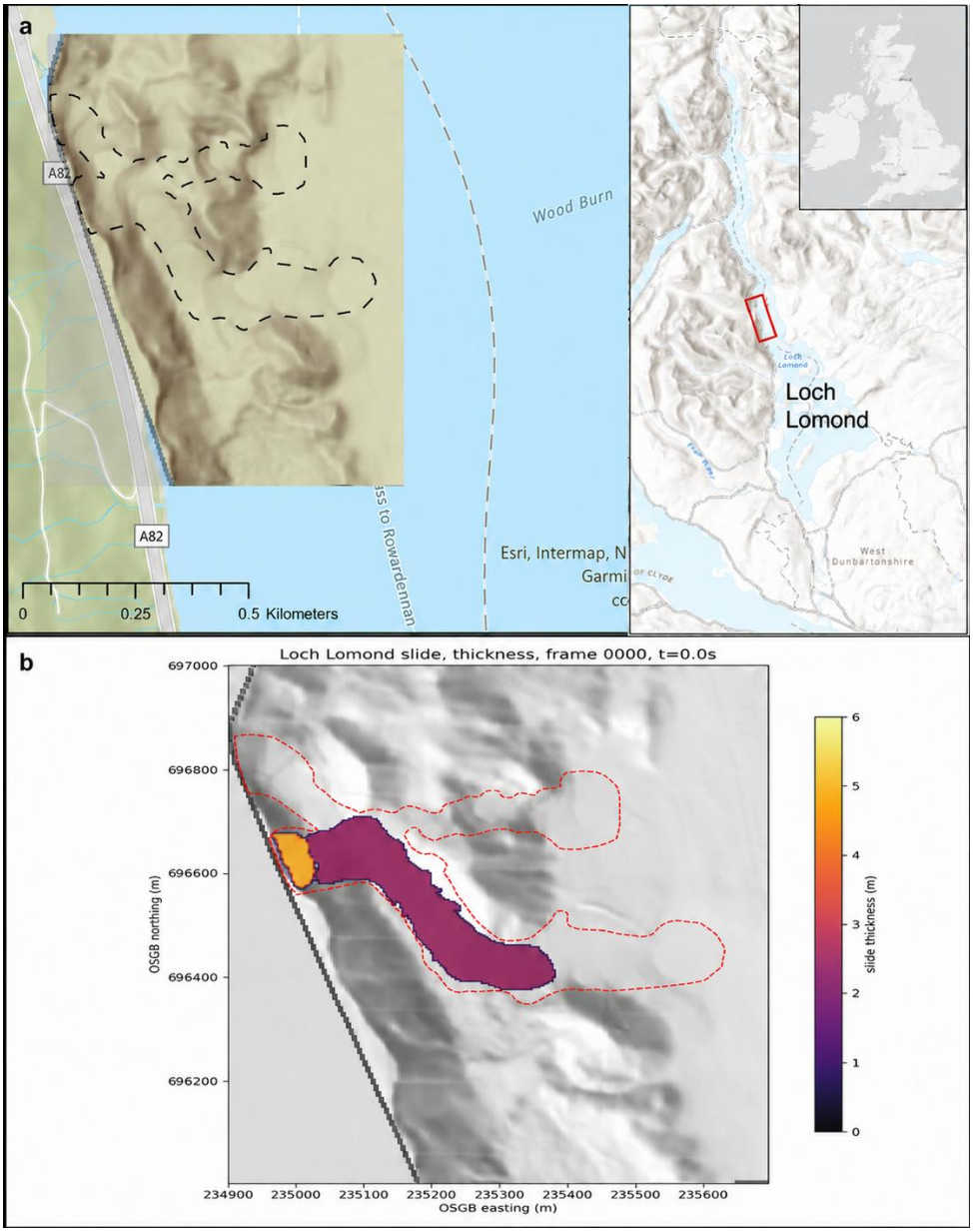

Figure 1: Study location and initial BingCLAW model setup
(a) Location map showing the A82 lochside setting, regional inset, bathymetric data and interpreted landslide reference outlines. (b) Initial slide-thickness field at t = 0s, showing the prescribed source/scarp material and preloaded remouldable channel material used to test source-triggered mobilisation. Red dashed outlines show interpreted landslide/footprint reference zones; colours show slide thickness. (Basemap source: Esri, Intermap, NASA, NGA, USGS; Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community) ((Contains British Geological Survey materials ©UKRI 2026)

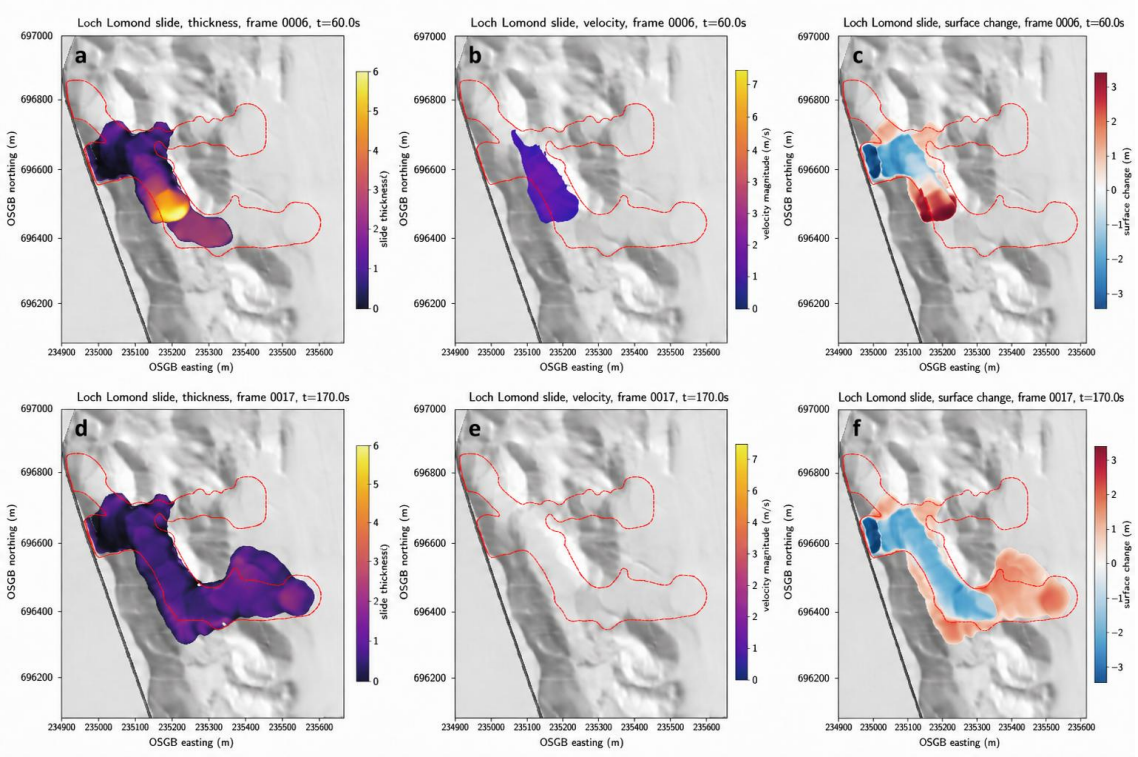

Figure 2: BingCLAW model outputs at t = 60 s and t = 170 s
Panels show: (a) slide thickness at 60 s, (b) velocity magnitude at 60 s, (c) surface change at 60 s, (d) slide thickness at 170 s, (e) velocity magnitude at 170 s, and (f) surface change at 170 s. Red dashed outlines show interpreted landslide/footprint reference zones. By 60 s, active movement is concentrated in the upper source and channel; by 170 s, the slide thickness extends into the lower lobe, velocity is largely reduced, and surface change shows evacuation along the source/channel with deposition towards the distal footprint. (Contains British Geological Survey materials ©UKRI 2026)

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