Geo-INQUIRE installation: BingClaw - Model for simulating dynamics of cohesive landslides (TA2-532-1)

Project title: Seismic response and multi-scale cohesive landslide dynamics with BingClaw

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Project acronym: LANDQUAKE

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Project report:

Quantitative landslide runout prediction is necessary for understanding landslide dynamics, estimating landslide risk, and developing landslide hazard mitigation plans. Calibrating model parameters and uncertainty qualification are crucial for numerical simulations. We sought to evaluate the cohesive landslide model (BingClaw) and compare it with the run-out data for the field event of the 24.5 Mm^3 Baige landslide in 2018 (Liu et al., 2021). The Baige event was particular in the sense that it is a rockslide that took place on a steep slope, impacting the river basin in the valley below the rock slope release. Specifically, we sought to test the model's potential for soil mechanics and capacity to capture dynamic runout and deposition morphology using different values of input parameters.

Under the visit, the BingClaw code was set up for the Baige River topography. Numerical simulations were carried out to hindcast the landslide run-out distance, through the different values of the key rheological parameters such as the yield strength of the flowing rock material. The initial volume is shown in Figure 1. We carried out a range of sensitivity analyses, investigating effects of how the material yield strength and dynamic consistency μ (analogous to viscosity for Newtonian Fluids) affected the landslide dynamics and run-out distance. In Figure 2, we show a selected number of snapshots from these sensitivity analyses. The parameters used for the analysis is shown in Table 1.

It was found that the model was capable of simulating the landslide dynamics and final run-out distance. This is indicated by the comparisons with the landslide footprints given by the yellow markers in Figure 2. It must be noted that this includes also these markers indicate sediments transported downstream by the current, and that the initial landslide run-out was contained closer to the impact area. In fact, the simulations using a yield strength τ_y=150kPa seems to match this initial run-out distance best (which can be confirmed by inspection of Figure 2a in Liu et al., 2021). Using lower yield strengths, the landslide overshoots the observed run-out data on the opposite side of the river basin. For the lower yield strength of 30kPa the simulation reaches the boundary of the domain, triggering in this case a model instability terminating the simulation.

It is noted that the time dependent landslide output could in principle also provide also input to tsunami simulations. However, given that BingClaw is cohesive, there were some limitations in terms of matching the detailed three-dimensional distribution of the rock masses, even if the run-out distance could be matched through sensitivity studies of the material yield strength. The setting for the Baige landslide case was also quite challenging, with a large volume landslide impacting a shallow river basin. Hence, it was not possible to incorporate a realistic tsunami model for this case as the model assumptions the available shallow water codes (GeoClaw) would be violated.

Finally, we note also that this project also triggered discussions for potential future improvements of the BingClaw code. Specifically, the interest for including bed shear stress as an output from BingClaw was requested. This may be a potential improvement of future versions of the code.

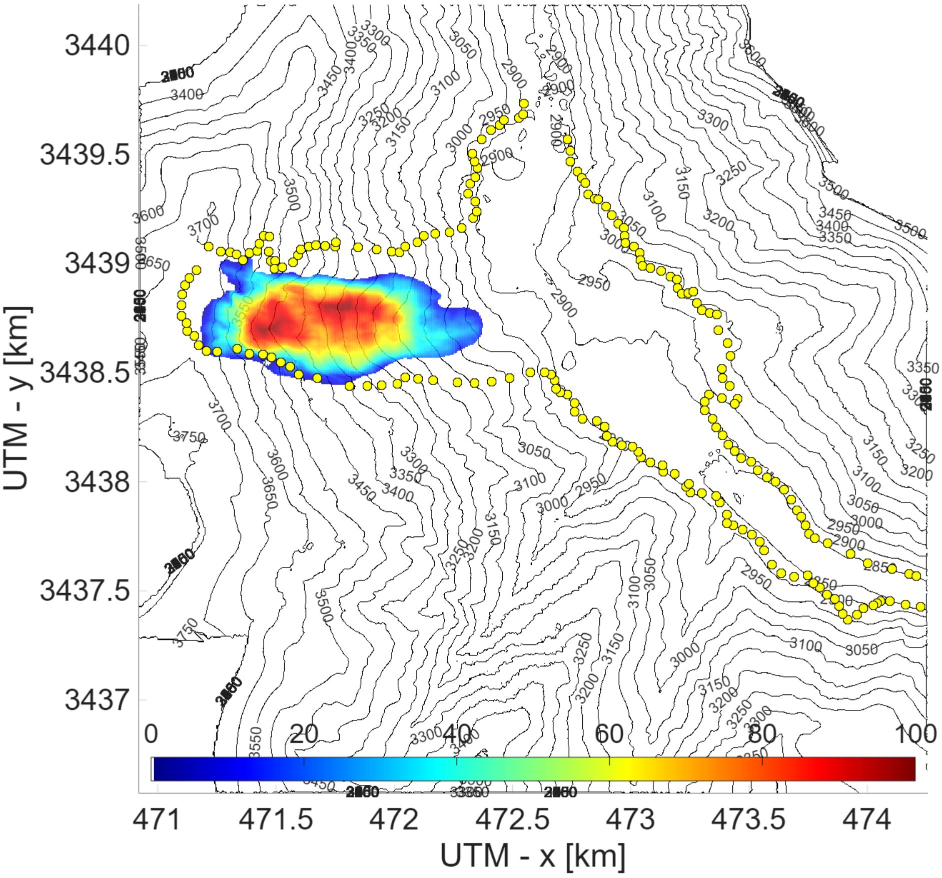

Figure 1: Initial landslide volume configuration based on pre-and post topography used as input to BingClaw. The yellow markers show the outline of the landslide footprint.

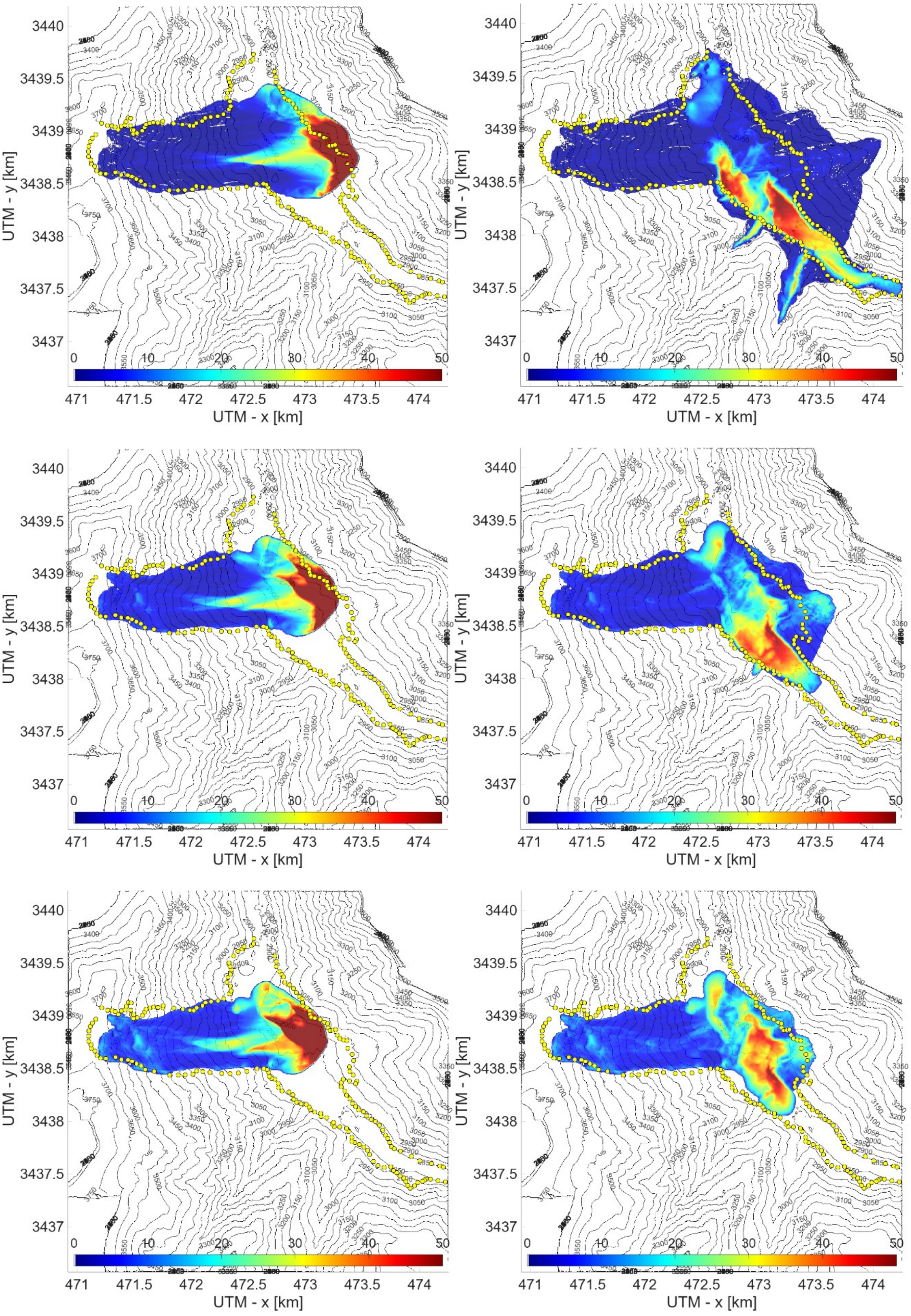

Figure 2: Snapshots of simulations outputs from BingClaw at different output times and for different values of the material yield strength. The yellow markers show the outline of the landslide footprint. Upper left, τ_y=30kPa, t=30s. Upper right, τ_y=30kPa, t=90s, at this point the landslide has hit the boundary and the simulation is terminated while the material is still in motion. Mid left, τ_y=100kPa, t=30s. Mid right, τ_y=100kPa, t=150s, at this stage the landslide has come to rest. Lower left, τ_y=150kPa, t=30s. Lower right, τ_y=150kPa, t=150s, at this stage the landslide has come to rest.

Table 1: Landslide parameters used for the simulations.

Parameter	**Values**			
Slide density (kg/m^3)	1800			
Yield Strength (kPa)	30	50	100	150
Friction Drag	0.01			
Pressure Drag	0.01			
Added Mass coefficient	0			
Dynamic consistency μ	1000			
Herschel Bulkley parameter n	0.5			
Volume (m^3)	23 Mm^3			

References

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