Response to RC3

This study addresses an important and specialized type of landslide—large failures in clay-rich rocks that transition into flow-like movements. The authors present a depth-averaged SPH model with a novel rheology capable of simulating slow-moving landslides (velocities on the order of m/day) and conduct detailed back-analyses of two well-documented events at Brienz/Brinzauls, which exhibited emplacement velocities differing by five orders of magnitude. The topic is highly relevant, and the manuscript is well-structured and clearly written. I recommend minor revisions before publication in NHESS.

Specific Comments:

1. The Lgl Rutsch event was simulated using 4,000 SPH particles. Could the authors clarify the rationale for this choice and discuss whether the results are sensitive to particle resolution?

This is a fair point, which we should have justified better. 4,000 particles was selected to trade-off simulation resolution and model runtime, which we wanted to keep low as we use a calibration methodology that requires hundreds to thousands of model runs. We updated section 3.1 to read:

We back-analysed the lgl Rutsch and Insel case histories in order to derive model parameters that can be used for forecasting events that have similar types. For lgl Rutsch, we used the new semi-implicit runout model (Equations (7) and (8), as well as the failure geometry shown on Figure 2. We used timesteps of 720 seconds, 4000 particles, a topographic resolution of 10 m, and performed a probabilistic calibration (described below) in order to calibrate the friction angle and viscous parameter (Equation (5)). ***We used a numerical resolution of 4,000 particles as the results are relatively insensitive to this choice (Aaron, 2023), and it keeps model runtimes low.*** *As part of this calibration, we compared measured and simulated velocities for the event (Figure 3). The latter velocities were obtained by calculating the velocity of the simulated front as it moves over the slope, as this provides the closest simulated quantity to the velocities estimated from eye witness accounts.*

2. The adopted SPH model is depth-averaged, which simplifies the real 3D dynamics. Please discuss how this assumption might influence the model's predictive accuracy, particularly for flow transitions and velocity distributions.

Thanks for this comment, we have updated Section 3 to read (new text in bold):

In the present work we use the numerical model 'Orin-3D' as the computational framework with which to analyse the lgl Rutsch and Insel failures. Orin-3D is a GPU accelerated, depth-averaged Lagrangian model that solves the equations of motion using a parallel implementation of the smooth particle hydrodynamics (SPH) numerical method (Aaron, *2023). **The use of a depth-averaged model is justified in the present cases due to the fact that both case histories have a much greater planar extent compared to their thickness, and the topography is relatively regular. However, we note that our model cannot resolve the vertical velocity distribution of the flow, and instead computes a depth-averaged velocity.** Orin-3D provides an over two orders of magnitude increase in computational efficiency, compared to a widely used equivalent fluid model (Aaron, 2023).*

3. Table 1 reports best-fit friction angles of 23°–28° for different stages. However, field and experimental studies (e.g., rock avalanches, earthflows) typically suggest much higher friction coefficients. Note that the reviewer is mainly working on fast-moving geophysical flows (e.g., Kong et al., JGR, 2023, 10.1029/2022JF006870). Are these smaller values physically justified for clay-rich rocks?

This is a great point. For the upper range (28°), this value is close to that expected for the dynamic friction coefficient of flowing fragments of rock (Heim; Hsu). For the clay rich rocks, our value is within the range determined for other studies ***(Ranalli et al., 2010; Skempton et al., 1997)*** We updated the text as follows:

In section 5.2:

*Our lgl Rutsch simulation results, which are verified by the eye witness accounts, suggest that this landslide experienced significant viscous resistance during its emplacement, which lead to its low velocities and three-year emplacement duration (Figure 3). We infer that the source of the viscous resistance experienced by this landslide is the clay-rich Allgäu Schists which are present in the source zone (Figure 2). Our back-analysis results further imply that these units can experience relatively low dynamic friction angles (~23°), **although these are consistent with some other reported values (Ranalli et al., 2010; Skempton et al., 1997).***

In section 5.3:

*Our analysis clearly demonstrates that, compared to many other large volume catastrophic rock slope failures which transitioned into rock avalanches (e.g. Aaron, 2017; Aaron & McDougall, 2019), the Insel event exhibited low mobility**, consistent with that expected for a dry granular flow of rock fragments (e.g Heim, 1932).** This is demonstrated by its high H/L value (0.6), the observed limited runout beyond the toe of the slope (Figure 10), and best-fit Voellmy resistance parameters that are much more resistive than typical for rock avalanches (Aaron & McDougall, 2019). Previously, the relative low mobility of some events had been explained with reference to disintegration into a series of small volume failures over a long time (e.g. Eberhardt et al., 2004). However, our analysis of available monitoring data, as well as our simulation results, support an interpretation of the Insel event whereby the majority of the mass failed during an ~2 minute period starting at approximately 23:37 (local* *time). Our results further suggest that, if multiple failures happened, they were not separated substantially in time and featured significant dynamic interaction, which is necessary to reproduce the observed deposit distribution. This interpretation is consistent with the seismic data, as it shows a pronounced spike at this time, the georadar, which shows downslope decorrelation at this time, as well as the simulation results, which show a better fit to observed deposit lithologies if the event is simulated as a single slope failure. We therefore interpret the thin mantling of blocks of Vallatscha dolomite on the deposit (Figure 4) as the result of dynamic interaction and overriding of the upslope Vallatscha unit onto the downslope Allgäu unit.*

4. For the Insel event (Section 4.2), were the same SPH parameters (fitted to Lgl Rutsch) applied? If so, this seems inconsistent given the five-order magnitude velocity difference between the two events. Please clarify whether material or rheological differences explain this discrepancy.

For this event we use a different, non-viscous rheology, with different rheological parameters. This results in the substantial difference in the simulated velocities of the two events, which are consistent with observations.