Revision letter: response to Reviewer #1

egusphere-2025-4531
Bayesian data selection to quantify the value of data for landslide runout calibration

January 26, 2026

We would like to thank Reviewer #1 for their valuable comments and suggestions, which improved the quality of the manuscript substantially. We present herein our responses to the comments of Reviewer #1.

Italicized line, figure, section numbers refer **to the revised manuscript**.

The changes in the revised manuscript with respect to the original manuscript can be traced in the `diff.pdf` file. Note that the line numbers in this file deviate from the pure manuscript PDF due to the tracked changes displayed.

Legend

> Shows original reviewer comment

Response Contains direct response and explanations.

Resulting changes in manuscript Summarizes resulting changes in the paper.

Contains a direct quote of new or modified manuscript content with significant changes with respect to the original manuscript.

1 Comments of Reviewer #1

1.1 Comment 1.364

> Figure 11a: What is the reason for the shape of the KL div curve? Why is there a plateau between 300 and 500 steps and then an increase again?
>
> I suppose figure 11 shows number of time steps used (a) and time steps (b) but that's a guess since x-axis labels are missing. If that is so the start of the plateau corresponds to about 200 steps. It would be interesting to see that length also in figure 10. In figure 10 the three uppermost curves (1000, 1100, 1200 steps) look very similar. In figure 11a, however, the KL divergence is still increasing significantly in that range. Why is that?

Response

Thanks for the comment.

To address this comment, we recomputed the KL divergence between the posterior and prior distributions of the turbulent friction coefficient ξ using datasets with finer spacing in the number of velocity time steps. Previously, we calibrated posteriors using 100 velocity time series datasets, each containing progressively more time steps with larger increments between successive datasets. We now use 1000 datasets with smaller increments in time step count between successive datasets, eliminating interpolation artifacts. The analysis confirms three distinct phases observed in the original figure: (1) a sharp rise as the mass accelerates, (2) a plateau where KL divergence remains relatively constant, and (3) a subsequent increase until saturation.

However, we identified an artifact in Figure 11(a) (*Figure 12(a)* in the revised manuscript): the emulator was trained on velocity time series data only up to the initial 1334 time steps, the maximum length available consistently across all training simulations. Although calibration used nominally higher number of time steps, observational data was effectively truncated to 1334 steps to match the emulator output dimensionality. This truncation was inadvertently overlooked during plotting. We have now corrected Figure 11(a) (reproduced here as fig. 1) to show KL divergence only up to 1334 time steps, accurately reflecting the actual calibration range.

- **Regarding the shape of KL divergence curve:**

  To understand the behavior of the KL divergence curve, we examine the coefficient of variation (COV) of the posterior distribution of ξ versus the number of time steps, plotted in fig. 3, as a complementary measure of uncertainty. The COV drops sharply in the observation window corresponding to when the sliding mass accelerates and attains maximum velocity, then slowly decreases toward saturation. This indicates the broader trend that as velocity time series length increases, information gain diminishes, suggesting diminishing returns. While the rate of decrease in COV becomes modestly steeper beyond $\sim$ 500 time steps, this change is not as pronounced as depicted in the KL divergence plot. This contrast arises from the logarithmic nature of KL divergence, which is more sensitive to small relative changes. When the COV is plotted on a logarithmic scale (fig. 4), its trend closely mirrors that of the KL divergence. This comparison indicates that the increase in KL divergence after $\sim$ 500 time steps is more moderate than it seems.

  Nevertheless, there is an observable rise in KL divergence values after a plateau (approximately between 300 to 500 time steps). We hypothesize that this behavior reflects friction regime transitions described by Hergarten [2024]. During the initial acceleration phase with high velocity, velocity-dependent turbulent friction may dominate, causing a sharp rise in KL divergence for ξ. The plateau likely marks a transition zone where dynamics are relatively stable. As the mass decelerates and velocity decreases, Coulomb friction may become dominant, producing a second, more gradual increase. To explore this hypothesis, we compared KL divergence change with number of time steps for both μ and ξ (see fig. 5). In the initial turbulent-friction dominated phase, ξ increases sharply compared to μ. This pattern reverses in the later Coulomb friction dominated phase where μ rises more steeply than ξ, with both parameters showing minimal change during the transition zone. This behavior is consistent with the regime-switching explanation.

- **Regarding Figure 11 (*Figure 12* in the revised manuscript):** As per your suggestion in comment 399, we have updated the axis label to explicitly denote the number of time steps used for calibration, improving clarity of the temporal scope.
- **Regarding Figure 10 (*Figure 11* in the revised manuscript):**

  Following your suggestion, we added the posterior distribution calibrated using the initial 200 velocity time steps. We found that the posterior distribution of ξ based on these 200 time steps exhibits a trend of posterior contraction similar to that observed in the original figure. The revised figure is reproduced here for your convenience (fig. 2).
- **Regarding the three uppermost curves:**

  As shown in fig. 3, the coefficient of variation for the posterior distributions corresponding to the three uppermost curves (1000, 1100, 1200 time steps) in fig. 2 varies minimally, reflecting limited additional contraction. However, because KL divergence operates on a log scale, these small variations are amplified fig. 1, creating the appearance of significant increase despite minimal changes in the posterior distributions.

Resulting changes in manuscript

The x-axis label in *Figure 12a* (Figure 11a in the original manuscript) has been updated to indicate the number of time steps. Additionally, KL divergence values beyond 1334 time steps have been removed from this figure to accurately reflect the actual calibration range. An additional posterior distribution (200 time steps) has been added to *Figure 11* (Figure 10 in the original manuscript).

2 Figures changed in the manuscript

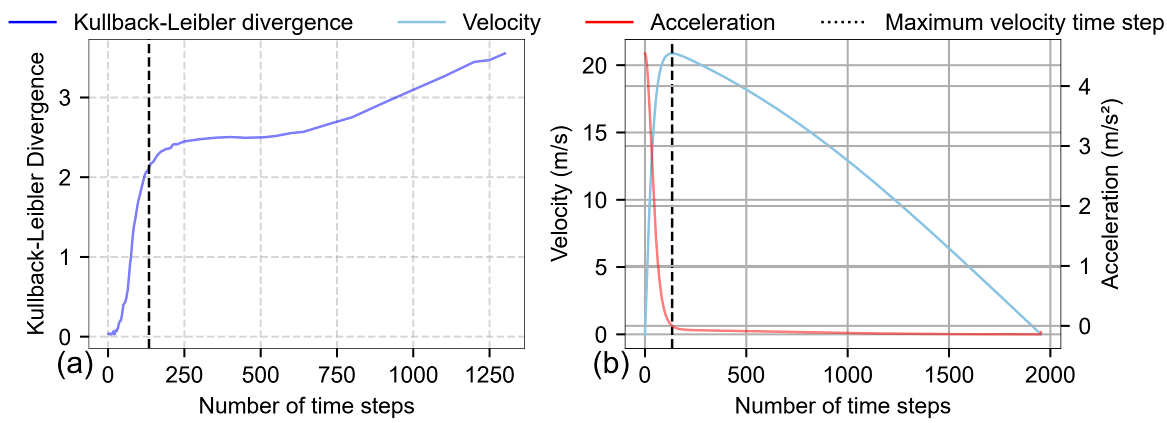

Figure 1: (a) Variation of Kullback-Leibler divergence of the posterior and prior distributions of turbulent friction coefficient ξ with number of velocity time steps. (b) Variation of velocity and acceleration with number of time steps.

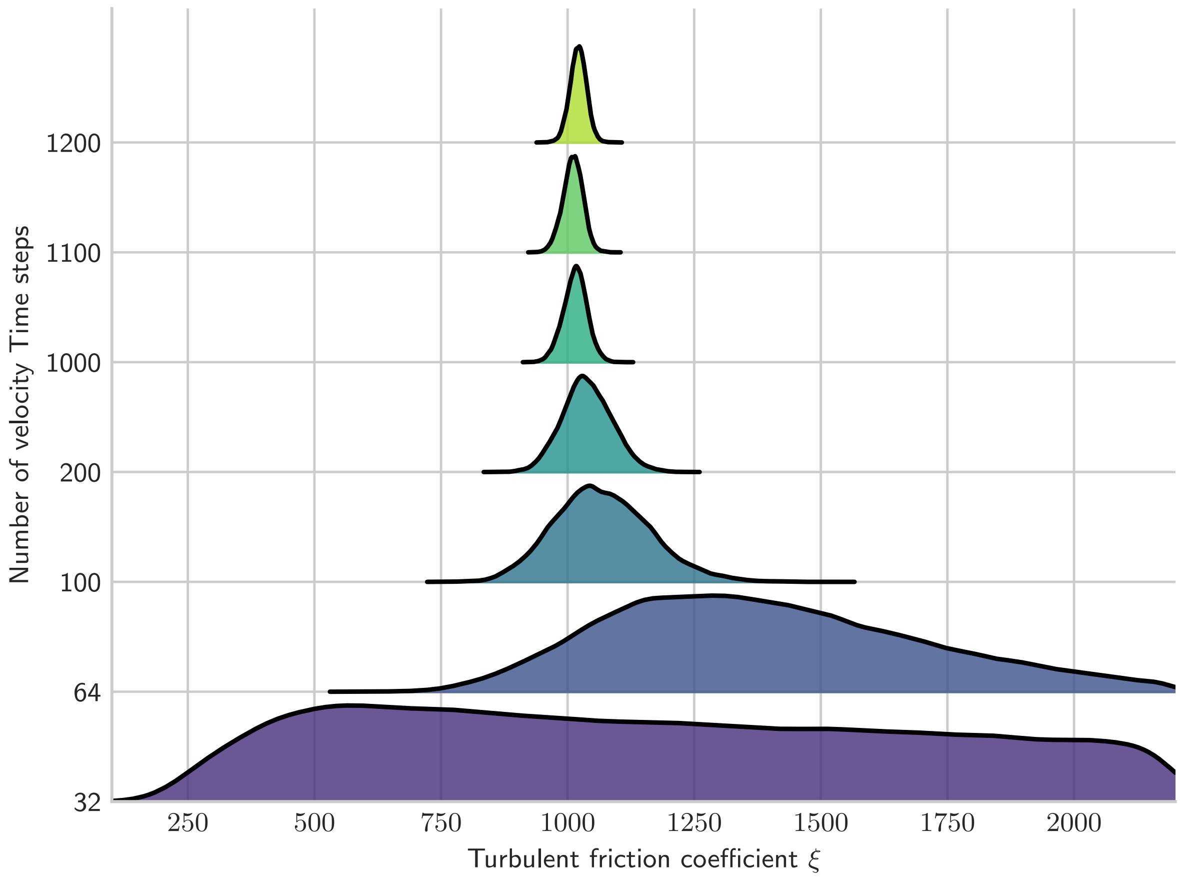

Figure 2: Posterior distributions of turbulent friction coefficient ξ calibrated with a varying number of velocity time steps. The rate of information gain is more profound in the initial time steps than the later.

3 Additional figures for explanation

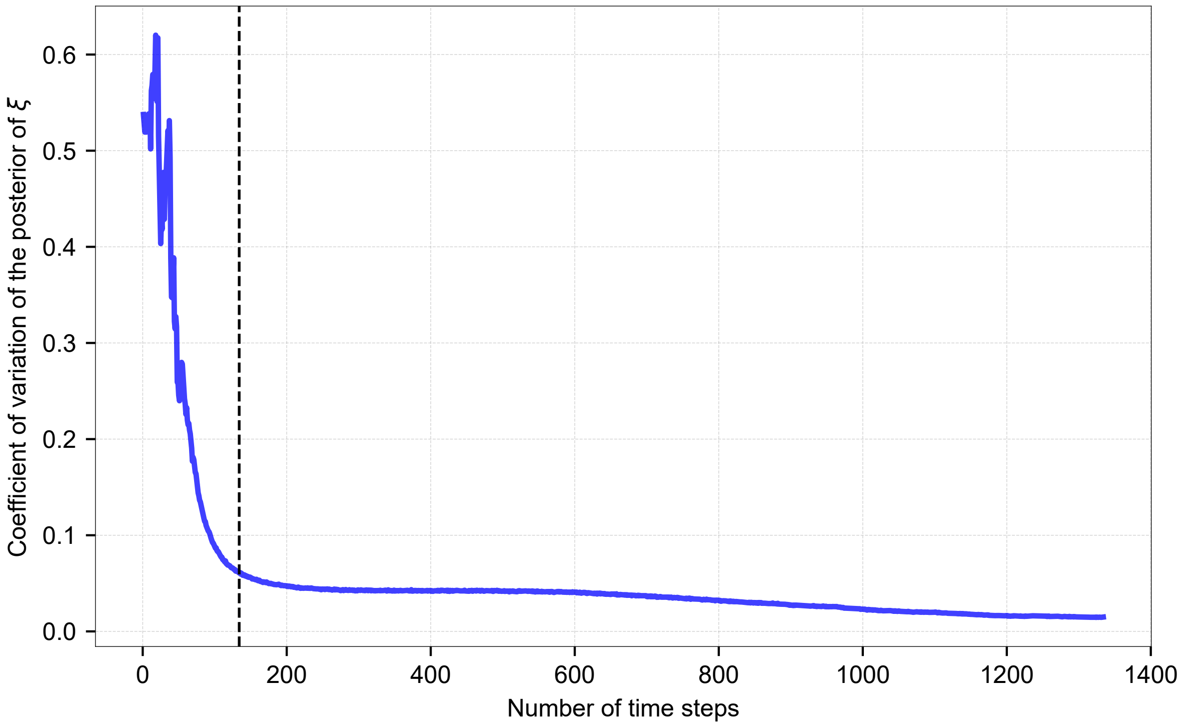

Figure 3: Coefficient of variation (COV) of the posterior distribution of ξ as a function of the number of velocity time steps used for calibration. The COV decreases sharply during the phase when the sliding mass reaches maximum velocity, then plateaus, indicating diminishing posterior contraction as additional observations are assimilated.

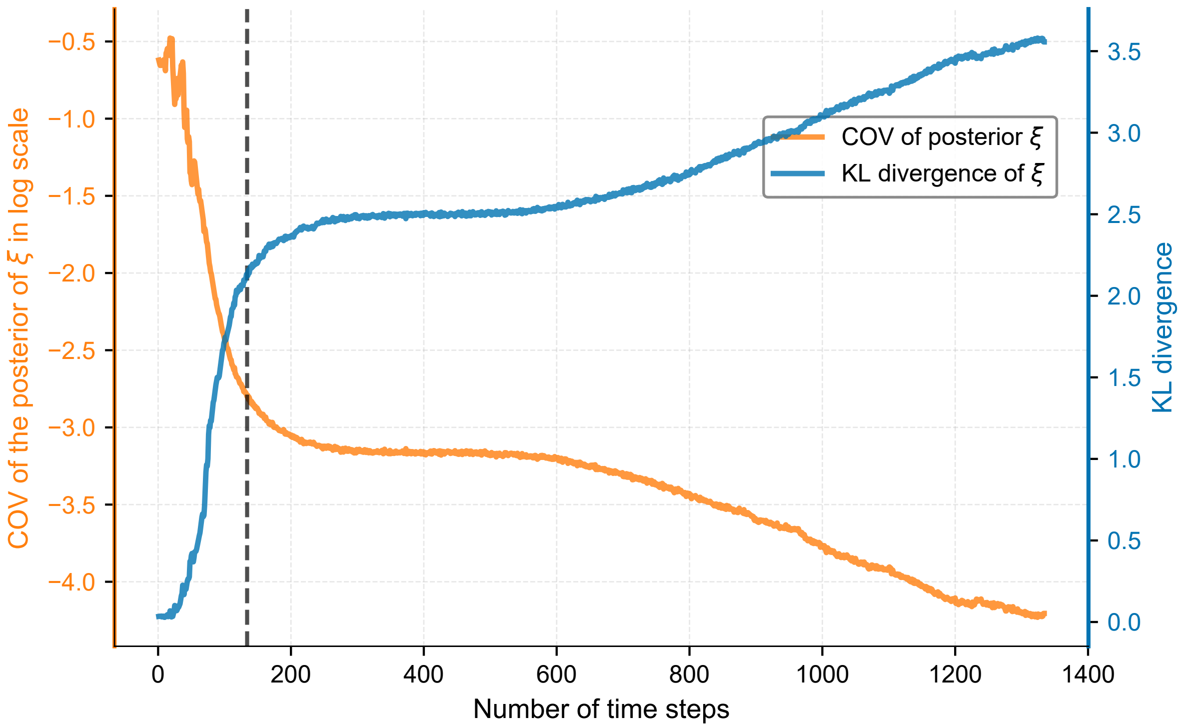

Figure 4: Coefficient of variation (COV) and KL divergence of the posterior distribution of ξ as a function of the number of velocity time steps used for calibration. When COV is plotted on a log scale, the variations are amplified similarly to the KL divergence curve, demonstrating the log-scale amplification effect.

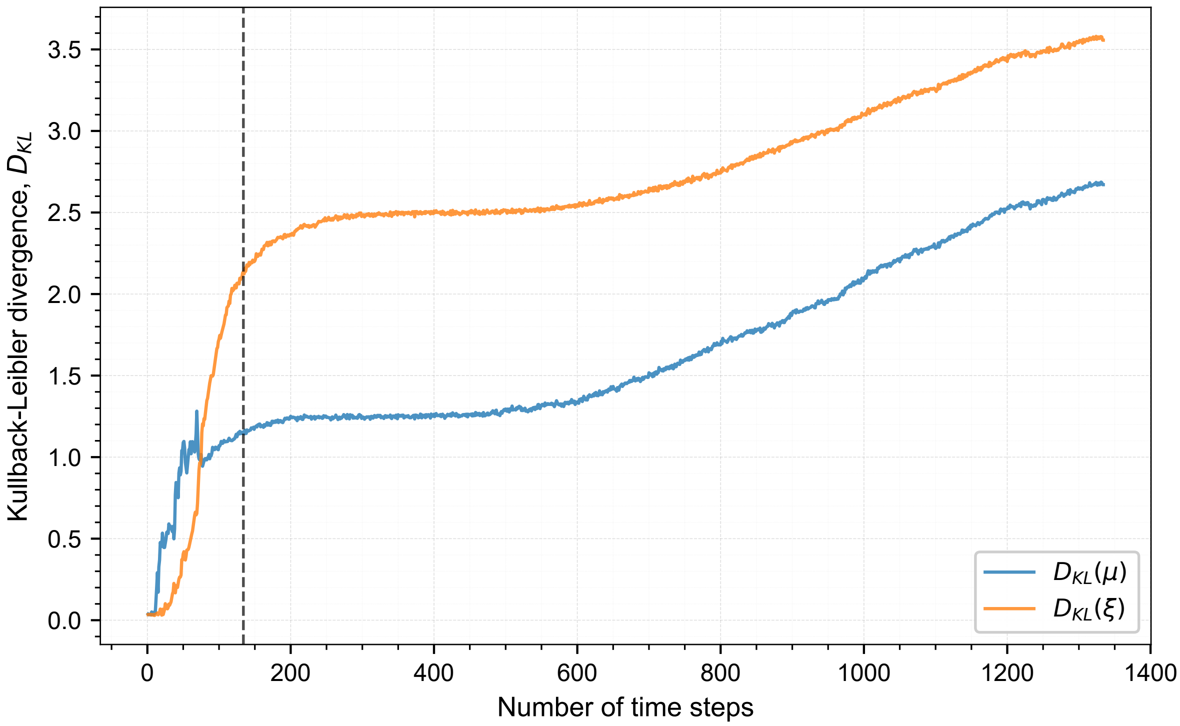

Figure 5: KL divergence between posterior and prior distributions of μ and ξ calibrated with varying number of velocity time steps.

References

S. Hergarten. Scaling between volume and runout of rock avalanches explained by a modified voellmy rheology. *Earth Surface Dynamics*, 12(1):219–229, 2024. doi: 10.5194/esurf-12-219-2024. URL `https://esurf.copernicus.org/articles/12/219/2024/`.