Response to Referee #2 (RC2)

We thank Referee #2 for the positive assessment of our framework and for the constructive suggestions. We acknowledge the concerns regarding the methodological details of rainfall thresholds, the datasets used for validation, uncertainties associated with ECMWF forecasts, and the claims of global transferability. We will carefully revise the manuscript to address these points, strengthen the methodological explanations, and provide a more balanced interpretation of the results and their broader applicability.

> **General comment.** *The manuscript presents an interesting and potentially valuable framework for early warning of rainfall-triggered landslides, particularly by integrating satellite rainfall observations, numerical weather forecasts, susceptibility information, runout modelling, and exposure assessment in a cloud-based environment. The topic is relevant, and the proposed framework has good potential for application in data-scarce regions. The following points should be addressed to improve the clarity and robustness of the manuscript:*

Response: We thank the referee for this encouraging summary. Each point is addressed below.

> **Comment 2.1.** *Clarify the methodology used to derive the rainfall intensity–duration (I–D) threshold. In particular, please provide a clearer justification for the selection of the 10th percentile and briefly discuss how this choice may affect the resulting threshold.*

Response: We agree. As noted in our reply to Referee #1 (Comment 1.4), the revision will describe the methodology section to provide a clearer explanation of the regression procedure used to derive the rainfall intensity–duration thresholds and justify the selection of the 10th percentile. This percentile was selected to obtain a relatively conservative rainfall threshold, intended to capture a large proportion of rainfall conditions associated with observed landslides, thereby reducing the likelihood of missed events. However, we acknowledge that selecting a lower percentile may increase the number of false alarms. We will clarify this trade-off and discuss how the percentile selection influences threshold sensitivity and warning performance.

Planned changes in the revised manuscript:

- Step-by-step description of the threshold derivation, with equations and the number of events per duration.
- Justification of the 10th percentile with reference to the frequentist literature and to sample size.
- A sensitivity analysis showing the thresholds obtained at the 5th, 10th and 20th percentiles and the median, with the POD and FAR of each on the validation set, so that the trade-off between missed events and false alarms is explicit.

> **Comment 2.2.** *Clarify the independence between calibration and validation. Please specify which landslide events were used to derive the threshold and which were used for validation, and discuss whether any overlap exists between these datasets.*

Response: We agree that the manuscript does not adequately document this. We will clarify which landslide records were used for threshold calibration and which were used for validation, and verify whether any temporal overlap exists. Additionally, we plan to incorporate 50 independent landslide events to strengthen the validation. The revised manuscript will clearly document these datasets and their respective roles in the analysis.

> **Comment 2.3.** *Expand the discussion of rainfall uncertainty. Since IMERG and ECMWF products have considerably coarser spatial resolutions than individual rainfall-triggering cells, it would be useful to discuss more explicitly how this scale mismatch and potential precipitation biases may affect threshold exceedance and warning performance.*

Response: We appreciate the reviewer's suggestion regarding rainfall uncertainty. We agree that the spatial resolution and potential biases of satellite-derived rainfall estimates and numerical weather forecasts can affect the identification of rainfall-triggering conditions, particularly in mountainous terrain with strong spatial variability in precipitation. We will expand the discussion to address uncertainties in IMERG and ECMWF products, including spatial

resolution mismatches, precipitation underestimation or overestimation, and their potential influence on threshold exceedance and warning performance. We will also incorporate relevant findings from previous studies to support this discussion.

Planned changes in the revised manuscript:

- A new Discussion subsection on rainfall uncertainty covering points (i)–(iv), with supporting literature.
- A quantitative comparison of IMERG with IMD gauge-based rainfall on the landslide days in our dataset.
- A sensitivity test showing how many warnings change class when rainfall is perturbed by ±10–30 %, as an indication of how robust the warning levels are to rainfall error.

> **Comment 2.4.** *Moderate the claims regarding global transferability. The framework is clearly designed to be transferable to other regions; however, its performance has been demonstrated primarily for the Western Ghats. It would therefore be useful to distinguish between the framework's potential for global transferability and its empirical validation at the global scale.*

Response: We agree; Referee #1 made the same point (Comment 1.7). The revision will distinguish clearly between the framework's technical transferability (configurable thresholds and susceptibility layers) and its demonstrated performance, which is limited to the Western Ghats.

Planned changes in the revised manuscript:

- Claims of global transferability will be made moderate.
- Table 1 will indicate the rainfall data source of each threshold, with a caution that gauge-based thresholds are not directly applicable to satellite rainfall.
- We will add an out-of-region test in at least one additional region with a dated inventory (e.g. Italy, using the ITALICA catalogue; Peruccacci et al., 2023) and state that local recalibration and independent validation are required before operational use elsewhere.

> **Comment 2.5.** *Strengthen the discussion of rainfall threshold approaches. I recommend considering the recent work of Silva et al. (2026), which proposes a combined empirical rainfall-triggered landslide threshold incorporating preparatory and triggering rainfall conditions. This study may provide a useful comparison with the I–D approach adopted here and would strengthen the discussion of alternative threshold formulations. Silva, R. F., Marques, R., & Zêzere, J. L. (2026). A New Approach for Developing Combined Empirical Rainfall-Triggered Landslide Thresholds: Application to São Miguel Island (Azores, Portugal). Water, 18(6), 673. https://doi.org/10.3390/w18060673*

Response: We thank the referee for this relevant reference. The role of preparatory (antecedent) rainfall is especially important in the Western Ghats, where prolonged monsoon rainfall saturates the regolith before a triggering burst. ALERT already extracts rainfall accumulations of up to 72 h, but the current threshold uses only the triggering intensity–duration pair. A combined threshold of the type proposed by Silva et al. (2026) would require only one additional, longer accumulation window from IMERG, so it could be implemented in the existing workflow.

Planned changes in the revised manuscript:

- Silva et al. (2026) will be cited and its combined preparatory–triggering approach compared with the I–D formulation used here, including their respective advantages and data requirements.
- Where our dataset allows, we will test whether adding an antecedent rainfall term (e.g. 7- to 30-day accumulation) improves the discrimination between triggering and non-triggering days. If the dataset is insufficient, this will be identified as a priority for future development of ALERT.

We thank Referee #2 again for these suggestions, which will improve the clarity and robustness of the manuscript.

On behalf of all co-authors,

Ali P. Yunus