Dear Editor and Reviewer,

Thank you very much for your careful evaluation of our manuscript entitled "Selection of onset of acceleration points and failure time prediction of landslides based on ground-based radar" (Manuscript ID: egusphere-2026-4006). We sincerely appreciate the constructive comments and suggestions, which have helped us improve the scientific clarity, methodological rigor, and presentation of the manuscript. We have carefully considered each comment and revised the manuscript accordingly. Detailed point-by-point responses are provided below.

Comment 1: I have read this manuscript twice, on July 20 and July 30, 2026.

The selection of the onset of acceleration (OOA) point is a critical issue in landslide time prediction. This study proposes to identify OOA points using the standard deviation of displacement (DSD) values of pixels within the deformation zone. I acknowledge that this approach has certain practical value. However, in my assessment, this represents only a minor technical improvement and does not meet the standards of innovation required for publication in NHESS. After two careful readings, I am inclined to recommend rejection, or alternatively, major revision and resubmission. The manuscript suffers from several significant issues, which I outline below:

Response: We sincerely thank the reviewer for the careful reading of our manuscript and for raising important concerns regarding the novelty and scientific contribution of this study. We appreciate the reviewer's recognition that the selection of the onset of acceleration (OOA) point is a critical issue in landslide failure-time prediction.

We would like to clarify that the contribution of this study is not limited to introducing a new empirical criterion for selecting the OOA point. The central motivation of this work is to address an important challenge in applying inverse velocity-based prediction methods to ground-based radar (GBR) monitoring data: the reliability of failure-time prediction is highly dependent on whether the identified OOA point corresponds to the actual transition into the acceleration stage. Although the inverse velocity method has been widely applied in landslide prediction, the determination of the OOA point remains a key uncertainty source because different OOA selection strategies may lead to substantially different prediction results. Therefore, this study focuses on improving the reliability of OOA determination by extracting additional deformation evolution information from GBR observations.

The main scientific contribution of this study is the introduction of a deformation standard deviation-based framework that utilizes the statistical evolution characteristics of radar-observed deformation fields. Unlike conventional approaches that directly select an acceleration point from displacement or velocity evolution, the proposed method investigates whether the collective deformation behavior within the monitored landslide area can provide a more reliable indication of acceleration onset. By integrating the proposed DSD-OOA identification method with the modified inverse velocity model, this study establishes a complete framework from radar deformation-field characterization to landslide failure-time prediction. The results from three landslide cases demonstrate that the proposed approach can improve the stability and accuracy of failure-time prediction compared with the commonly used MA-OOA-based method.

We acknowledge that the applicability of any OOA identification approach depends on the deformation characteristics and monitoring conditions. Therefore, following the reviewer’s suggestion, we have further clarified the methodological contribution, applicability conditions, and limitations of the proposed approach in the revised manuscript.

We sincerely appreciate the reviewer’s comments, which have helped us better articulate the scientific significance and scope of this work.

Comment 2: Insufficient comparison with state-of-the-art OOA identification methods

In recent years, numerous advanced methods for automatic OOA identification have been developed, including approaches based on BIC (Bayesian Information Criterion) change point detection, CUSUM (cumulative sum) algorithms, and Kalman filtering. The authors' comparison is limited to the MA-OOA-INV method, which is now more than ten years old (Carla et al., 2017). This is far from sufficient to demonstrate the superiority of the proposed DSD-OOA method. The authors must include comparisons with contemporary methods. The following recent contributions are particularly relevant:

Urgilez Vinueza et al. (2021): A new methodology to detect changes in displacement rates of slow-moving landslides using InSAR time series (EGU General Assembly)

A new data-driven approach for dynamic landslide life expectancy prediction based on kinematic features (Acta Geotechnica, 2025)

Acceleration stage detection and dynamic model selection for real-time landslide time-of-failure predictions (using Bayesian theory)

Wang, J.Z. et al. (2023): A framework for identifying the onset of landslide acceleration based on the exponential moving average (EMA) (Journal of Mountain Science)

Response: We sincerely thank the reviewer for this valuable comment. We agree that several advanced time-series change detection and acceleration identification approaches, including BIC-based change-point detection, CUSUM algorithms, Kalman filtering, and data-driven methods, have provided important contributions to landslide deformation analysis.

However, we would like to clarify that the objective and data characteristics of our study are different from those of these methods. Most existing OOA identification approaches are primarily developed for one-dimensional displacement or velocity time series, where acceleration initiation is determined based on temporal variations of a single monitoring point or an aggregated deformation curve. In contrast, the motivation of this study is to address the specific characteristics of ground-based radar (GBR) monitoring, which provides high-resolution spatial deformation observations over an entire landslide area rather than isolated monitoring points. In GBR observations, hundreds or thousands of pixels within the deformation zone simultaneously record heterogeneous deformation responses. As illustrated in this manuscript, each pixel forms an individual cumulative deformation trajectory, and the evolution from stable creep to accelerated deformation is accompanied not only by changes in the average displacement rate but also by increasing spatial divergence among pixels. Therefore, the proposed DSD-OOA method does not aim to replace general time-series change-point detection algorithms; instead, it introduces a spatial-statistical perspective for identifying OOA points from area-based radar deformation observations.

Specifically, the proposed method characterizes the deformation evolution by calculating the temporal variation of displacement standard deviation (DSD) among pixels within the detected deformation area. The DSD-time curve integrates the collective deformation behavior of the entire landslide area and reflects the transition from relatively uniform creep deformation to accelerated deformation with increasing spatial heterogeneity. This spatial information cannot be directly obtained from conventional single-point velocity-based methods. Regarding the comparison with MA-OOA, we selected this method because it is one of the most representative and widely applied OOA identification approaches in inverse velocity analysis. Carlà et al. (2017) determined the OOA point through the intersection of short-term and long-term moving-average velocity curves, and this approach has been widely adopted in landslide forecasting studies. The purpose of this comparison was therefore not to claim that DSD-OOA universally outperforms all existing change-point detection algorithms, but to demonstrate that for GBR-based spatial deformation monitoring, incorporating spatial dispersion characteristics can provide a more suitable OOA input for inverse velocity prediction.

Following the reviewer's suggestion, we have revised the manuscript to further discuss recent OOA identification and change-point detection approaches, clarify the differences between temporal point-based methods and spatial radar-based approaches, and better position the contribution of the proposed DSD-OOA method.

Comment 3: The OOA identification procedure remains overly simplistic and subjective

The method for determining when DSD reaches "greater fluctuation" (Line 133) lacks a quantitative threshold. This is a critical weakness. For example, in Figure 4, the authors fit the DSD–time curve using two simple straight lines. This approach is not rigorously justified and remains semi-quantitative, as it is subject to subjective choices in the placement of the fitting segments. In fact, if one zooms in on different portions of the curve, the linear fitting equations—and consequently the identified OOA point—could shift. I suggest that the authors consider more robust techniques, such as morphological analysis or other image/curve processing methods, to address this issue objectively.

Response: We sincerely thank the reviewer for identifying this important issue. We agree that the original description of the DSD-OOA identification procedure was insufficiently detailed and could give the impression that the two fitting intervals were selected visually. In particular, the expression "greater fluctuation" was intended only to describe the increasing spatial dispersion of pixel-level displacement values during accelerated deformation, rather than to serve as a qualitative threshold for determining the OOA point.

To avoid this ambiguity, we have revised Section 2.2 by replacing “greater fluctuation” with a more precise description of the progressively increasing spatial dispersion within the deformation zone. We have also clarified the two-segment fitting procedure and introduced a consistent breakpoint-search rule for all three cases. Specifically, each observation time that leaves at least five consecutive DSD observations on both sides is considered a candidate breakpoint. A continuous two-segment linear model is then fitted for each candidate. Only candidates for which the post-break slope is positive and greater than the pre-break slope are retained, reflecting the expected transition from relatively stable deformation to a more rapidly increasing DSD trend. The candidate producing the minimum total residual sum of squares is selected as the DSD-OOA point. The same procedure and minimum segment-length requirement were applied to all cases without case-specific adjustment of the fitting intervals. Requiring at least five observations on each side ensures that each fitted trend is supported by multiple measurements and reduces the influence of isolated short-term fluctuations. Consequently, the identified breakpoint is determined by the complete candidate search and fitting error rather than by the visual scale of Figure 4 or by manually positioning the two fitting segments.

We appreciate the reviewer’s suggestion regarding morphological analysis and other curve-processing techniques. These approaches may provide useful alternatives in future studies. In the present study, however, we retained the two-segment linear formulation because it provides a direct and physically interpretable representation of the transition in the DSD growth rate, while the revised breakpoint-search procedure makes its implementation objective and reproducible. In addition, the identified DSD breakpoint is treated as a candidate OOA and is subsequently evaluated using the inverse-velocity trend. A transient increase in DSD that does not produce a sustained, approximately linear decrease in inverse velocity is regarded as a false positive, as illustrated by the first candidate point in Case 3. This subsequent consistency check further reduces the possibility that a short-duration disturbance is incorrectly interpreted as the onset of sustained acceleration.

Accordingly, we have revised the description in Section 2.2 to clarify that the DSD-OOA point is determined using a consistent continuous two-segment fitting and breakpoint-search procedure rather than subjective visual selection. We thank the referee for this comment, which has substantially improved the clarity and reproducibility of the proposed method.

Comment 4: Case studies lack diversity and do not demonstrate general applicability

All three case studies are from open-pit mines in northwestern China, with similar lithologies and triggering mechanisms (construction vibrations). This raises a serious concern: can the proposed DSD-OOA method be applied to other types of landslides, such as slow-moving creeping landslides or rainfall-induced landslides? The authors must include a dedicated discussion on the applicability boundaries and limitations of their method, clearly specifying the conditions under which DSD-OOA is expected to perform well and where it may fail.

Response: We sincerely thank the reviewer for raising this important concern regarding the applicability and limitations of the proposed DSD-OOA method. We agree that the diversity of landslide types and triggering mechanisms is an important consideration when evaluating the general applicability of an early-warning approach. We acknowledge that the three cases investigated in this study are all from open-pit mine slopes monitored by ground-based radar, and therefore they mainly represent engineering slopes with relatively high-resolution area deformation observations. The objective of this study is not to claim that the proposed DSD-OOA method is universally applicable to all landslide types, but rather to investigate an OOA identification strategy that exploits the unique spatial deformation information provided by ground-based radar observations.

The applicability of the DSD-OOA method is fundamentally related to its underlying assumption: the transition from stable deformation to accelerated failure is accompanied by increasing spatial heterogeneity within the monitored deformation zone. For landslides where acceleration involves progressive deformation localization, differential movement between different regions, or expansion of the unstable area, the spatial dispersion of pixel-level deformation is expected to increase, and the DSD-OOA method can provide an effective indicator of acceleration onset. However, we agree that the method has limitations. For slow-moving creeping landslides characterized by long-term quasi-uniform deformation, the increase in spatial heterogeneity may be weak, making the DSD evolution less sensitive to acceleration onset. Similarly, for rainfall-induced landslides dominated by abrupt local failures or highly transient deformation responses, short-term DSD increases may not necessarily indicate a sustained acceleration stage. In addition, the reliability of the method depends on the quality and spatial coverage of radar deformation measurements; insufficient coherent pixels or severe observation noise may reduce the robustness of DSD estimation.

Following the reviewer's suggestion, we have added a dedicated discussion in Section 4.2 to clarify the applicability conditions and limitations of the proposed method. We have emphasized that DSD-OOA is particularly suitable for GBR-monitored landslides where the deformation evolution exhibits observable spatial heterogeneity, while its performance for other landslide types requires further validation using more diverse monitoring datasets.

We appreciate the reviewer's comment, which has helped us better define the scope and limitations of the proposed method.

Comment 5: The complexity of landslide deformation is not adequately addressed

Landslide deformation is inherently complex. Many slow-moving creeping landslides exhibit step-like displacement curves, where a single episode of rapid deformation does not necessarily indicate imminent failure. In such cases, the OOA is not a fixed value. I suggest that the authors consider this as a direction for future research—for example, by employing machine learning techniques to predict OOA points probabilistically rather than deterministically, thereby accounting for the uncertainty and variability inherent in landslide deformation processes.

Response: We sincerely thank the reviewer for this important and constructive comment. We agree that landslide deformation may exhibit highly complex and episodic behavior, particularly for slow-moving creeping landslides characterized by step-like displacement curves. In such cases, a short-term acceleration episode may be followed by stabilization or deceleration and therefore does not necessarily indicate imminent failure. We also agree that representing the entire deformation process using a single fixed and deterministic OOA point may be insufficient under such conditions. We would like to clarify that the proposed method does not automatically regard every increase in DSD or velocity as a valid onset of sustained acceleration. Instead, the breakpoint detected from the DSD curve is treated as a candidate OOA point and is subsequently evaluated according to the evolution of the inverse-velocity series. This issue is illustrated by Case 3, in which the first candidate DSD-OOA point was followed by only a brief increase in velocity and subsequent stabilization. The corresponding inverse-velocity series showed strong nonlinear behavior, with an R^2 value of only 0.169, and this candidate was therefore identified as a false positive. In contrast, the subsequent candidate was followed by sustained acceleration and a clear linear decrease in inverse velocity, with an R^2 value of 0.983, and was retained as the valid OOA point. Thus, the current framework allows candidate OOA points to be rejected and dynamically updated rather than assuming that the first acceleration episode necessarily represents the onset of imminent failure.

Nevertheless, we acknowledge that the current method remains deterministic because it ultimately provides a single confirmed OOA point at each stage of the rolling analysis. It does not explicitly quantify the uncertainty associated with multiple possible acceleration transitions. Following the reviewer's suggestion, we have added a dedicated discussion of this limitation. We now explicitly state that for landslides exhibiting repeated step-like or episodic deformation, an identified DSD breakpoint should be interpreted as a candidate transition rather than a unique and permanent OOA point. We have also expanded the future research discussion to include probabilistic OOA identification. Machine-learning or Bayesian sequential approaches could estimate a time-varying probability distribution for the occurrence of acceleration onset and update this distribution as new radar observations become available. Such approaches could jointly consider DSD evolution, velocity persistence, the spatial extent of deformation, and relevant environmental factors, while providing confidence or credible intervals for candidate OOA times. This development would help distinguish transient acceleration episodes from sustained pre-failure acceleration and more appropriately represent the uncertainty inherent in complex landslide deformation processes.

We sincerely appreciate this comment, which has helped us more clearly define the interpretation, limitations, and future development of the proposed DSD-OOA method.

Comment 6: Overall Recommendation

In summary, while the DSD-OOA concept has some intuitive appeal and practical potential, the current manuscript does not present a sufficiently rigorous, well-validated, or broadly applicable method. The lack of comparison with state-of-the-art methods, the subjective nature of the OOA identification, the limited case study diversity, and the oversimplified treatment of complex deformation behavior collectively undermine the contribution. I recommend rejection, or at minimum, major revision with a clear plan to address the above concerns before any resubmission.

Response: We sincerely thank the reviewer for the comprehensive evaluation of our manuscript and for identifying the key issues related to methodological rigor, applicability, and scientific contribution. We greatly appreciate the reviewer's constructive comments, which have provided valuable guidance for improving both the presentation and the positioning of this work.

We acknowledge that the original manuscript did not sufficiently clarify the methodological scope and applicability boundaries of the proposed DSD-OOA method. In the revised manuscript, we have carefully addressed the concerns raised by the reviewer and strengthened the explanation of the scientific contribution from several aspects.

First, regarding the novelty and comparison with existing approaches, we have clarified that the primary contribution of this study is not to develop a general-purpose time-series change detection algorithm, but to introduce a spatial-statistical strategy for identifying acceleration onset from ground-based radar (GBR) deformation fields. Unlike point-based deformation monitoring approaches, GBR provides dense spatial observations over the entire deformation zone. The proposed DSD-OOA method exploits the spatial heterogeneity evolution among radar pixels as an additional indicator of acceleration onset, complementing existing temporal displacement- or velocity-based approaches.

Second, regarding the subjectivity of OOA identification, we have revised the methodology description by clarifying the breakpoint determination procedure. The DSD-OOA point is now identified through a consistent two-segment fitting strategy with a predefined breakpoint-search rule applied to all cases, rather than through subjective selection of fitting intervals. The revised manuscript also clarifies that candidate acceleration points require subsequent inverse-velocity consistency evaluation to distinguish sustained acceleration from transient deformation fluctuations.

Third, regarding case-study diversity and general applicability, we agree that the current validation mainly focuses on ground-based radar-monitored open-pit mine slopes. We have therefore revised the Discussion section to explicitly define the applicability conditions and limitations of the proposed method. The method is expected to be most suitable for landslides where acceleration is accompanied by increasing spatial deformation heterogeneity that can be captured by radar observations. We have also clarified that further validation using more diverse landslide types, including slow-moving creeping landslides and rainfall-dominated landslides, is required in future studies.

Fourth, regarding the complexity and uncertainty of landslide deformation processes, we have expanded the discussion on transient acceleration events and non-unique OOA behavior. The revised manuscript emphasizes that DSD-OOA provides candidate acceleration onset points rather than assuming every deformation increase represents imminent failure. Future development toward probabilistic OOA identification using machine-learning or Bayesian sequential approaches has also been discussed to better quantify uncertainty associated with complex deformation evolution.

Through these revisions, we have aimed to improve the methodological rigor, clarify the scope of the proposed approach, and provide a more balanced discussion of its advantages and limitations. We sincerely appreciate the reviewer's insightful comments, which have significantly improved the quality and scientific clarity of this manuscript.

Once again, thank you very much for your comments and suggestions.