

Tsangbu Ri slope failure triggers massive flash flood across the Himalaya and shakes the globe – the seismic observations

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Abstract On 26 August 2026, a massive slope failure in the Himalaya caused a destructive flash-flood all along the Trishuli River. Here we report the first complete set of related seismic observations from Nepal and China. Using first-arrivals of high-frequency waveforms, we localize the main mass-movement and a nearby M_L 2.5 seismic event shortly preceding it. The flash-flood increased seismic signal levels, persisting for hours. We also report global seismic detections of the main event. We conclude that a regional seismic monitoring network coupled with a signal detection and classification system would provide an early warning tool for future high-risk events.

Résumé Le 26 août 2026, un glissement de terrain majeur dans l'Himalaya a provoqué une crue éclair dévastatrice tout au long de la rivière Trishuli. Nous présentons ici le premier jeu de données complet d'observations sismiques au Népal et en Chine liées à cet événement. À l'aide des premières arrivées des ondes à haute fréquence, nous localisons le glissement principal ainsi qu'un événement sismique de magnitude 2,5 survenu à proximité peu avant le glissement. La crue soudaine a entraîné une augmentation des niveaux de bruit sismique, qui a persisté pendant plusieurs heures. Nous présentons les détections sismiques de l'événement principal à travers le monde. En conclusion, nous estimons qu'un réseau régional de surveillance sismique, associé à un système de détection et de classification des signaux, constituerait un outil d'alerte précoce pour de futurs événements à haut risque.

Resumen El 26 de agosto de 2026, un enorme deslizamiento de ladera en el Himalaya provocó una inundación repentina y destructiva a lo largo de todo el río Trishuli. En este trabajo presentamos por primera vez un conjunto completo de observaciones sísmicas procedentes de Nepal y China relacionadas con este evento. A partir de la lectura de los tiempos de llegada de las primeras fases de registros sísmicos de alta frecuencia, localizamos el movimiento de masas principal, así como un evento sísmico cercano de magnitud $M_{2.5}$ que lo precedió. La riada incrementó de forma notable el nivel de ruido sísmico durante varias horas. Adicionalmente, presentamos las detecciones sísmicas del evento principal a escala mundial. A modo de conclusión, argumentamos que el mantenimiento de una red regional de monitoreo sísmica, combinada con un sistema de detección y clasificación de señales, proporcionaría una herramienta de alerta temprana para futuros eventos de alto riesgo.

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सारांश सन् २०२६ अगस्त २६ मा नेपाल र तिब्बतको सिमानामा भएको पहिरो तथा बाढीले नेपालमा धेरै मानिसको ज्यान लियो भने ठुलो भौतिक क्षति गर्यो । यस अध्ययनमा नेपाल र चीनका भूकम्पीय तरङ्गहरूबाट प्राप्त जानकारीको आधारमा उक्त पहिरोको बारेमा पहिलो विस्तृत भूकम्पीय नतिजाहरू प्रस्तुत गरिएको छ । सेस्मोमिटरले नापेको तरङ्गहरूको अध्ययनबाट उक्त पहिरो भएको समय, भएको स्थान तथा ठुलो पहिरो जानु केही समय अगाडि नजिकै भएको २.५ म्याग्नेच्युडको भूकम्पीय घटनाको पनि केन्द्रविन्दु पत्ता लगाइएको छ । साथै, भूकम्पीय तरङ्गहरूबाट पत्ता लगाएको केन्द्रविन्दु उपग्रहबाट पहिचान गरिएको पहिरोको स्थानभन्दा करिब ४ किलोमिटर मात्र फरक देखिएको छ । आकस्मिक रूपमा आएको बाढीका कारण उत्तरदेखि दक्षिणसम्म नै जमिनको कम्पन उल्लेखनीय रूपमा बढेको र त्यो मात्राको कम्पन केही घण्टासम्म कायम रहेको पाइएको छ । नेपालमा भएको उक्त पहिरो संसारका धेरै ठाउँहरूमा रहेका भूकम्पमापक यन्त्रहरूले समेत रेकर्ड गरेका छन् । यी जानकारीहरूले भविष्यमा जान सक्ने यहि प्रकृतिका घटनाहरूको लागि राष्ट्रिय तथा स्थानीय रूपमा पुर्व सुचना प्रणालीको विकास गर्न आवश्यक रहेको देखाउँछ ।

Non-technical summary The catastrophe that occurred in the Himalaya on 26 August 2026 was widely reported in the media. Preliminary information shows that an entire mountain flank with a glacier on top collapsed. This then triggered a flash-flood, devastating the Trishuli River across Nepal. Here we show how these events are recorded by seismometers in terms of ground vibrations. The analyses allow us to locate the main event, a small seismic event just before that, and to characterize the flash-flood. Seismic stations all around the world detected the vibrations. This is the first complete seismic dataset and first-order analysis of the events. We establish that seismology could play a more important role in detection and early warning of such events.

1 Introduction

The Himalaya is the world's currently most active continental collision zone. While at depth tectonic earthquakes are frequent, the steep topographic, glaciated relief at high altitudes is conducive to potentially hazardous landslides (e.g., [Lavé et al., 2023](#)). All these processes shape topography and the river network that has been transporting sediments for millions of years, and today provides a critical source of both electricity and fresh water for nearly two billion people across Asia (e.g., [Immerzeel et al., 2010](#)). While the individual natural hazards inherent to elements of this geological system are high on a global scale, they are not independent of each other. Chains of causally linked hazardous processes in which one event triggers or amplifies subsequent hazards, so-called “cascading” events, are harder to anticipate, and present a higher risk to local populations.

On 26 August 2026, a sudden rock and glacier / ice collapse occurred on the northern flank of the 6,781 m high Tsangbu Ri mountain, near Langtang Lirung (7,234 m) (Figs. 1 & 2). This mass-movement generated a catastrophic flash-flood and debris flow that propagated over 200 km from the high Himalaya into the fore-land basin (Fig 3). It first reached the Lhende Khola valley along the Nepal-China border, then fully re-entered Nepal and followed the Trishuli River valley. According to satellite images, there was no glacial lake at the origin of this event, so the sequence of events differs from glacial lake outburst floods (GLOFs). The flash flood seems to have been exceptionally high and fast-moving due to the large amount of initial and entrained rocks, debris, ice, and water. The consequences of the event were severe and truly shocking: as of 21 September 2026, the flash flood had resulted in 1,451 reported deaths, 5,745 missing persons, including 636 foreign nationals, 10,365 injured people, and 13,784 rescues ([NDRRMA, 2026](#)). The preliminary economic loss in

Nepal has been estimated at approximately USD 2.69 billion ([NDRRMA, 2026](#)). Chinese authorities reported 16 deaths in Gyirong County and 546 missing as of August 30, 2026 ([Zhang, 2026](#)) and many still missing. The flood caused extensive damage to critical infrastructure, including 120 Nepal Telecom towers and seven hydropower projects with a combined capacity of approximately 480 MW. These impacts highlight the substantial societal and economic consequences of rapid high-altitude mass movements transitioning into large downstream floods.

Given the catastrophic impacts of the 26 August 2026 event in Nepal, it is vital to better understand how these types of events evolve and what triggers them, so we can prepare better and provide warning for the next inevitable event. In particular, we need to understand whether and how such cascading events are related to changes in the climate system, the evolution of glaciers with time, tectonic forcing, and other factors. These relationships require further investigation in future studies (e.g., [Maurer et al., 2019](#)).

Seismic observations offer a powerful way of monitoring and recognizing such cascading geohazards in extreme landscapes and situations (e.g., [Burtin et al., 2009](#); [Maurer et al., 2020](#); [Svennevig et al., 2024](#); [Shugar et al., 2026](#)). Nepal's national seismological network has continuously monitored earthquake activity since 1994 ([Adhikari et al., 2021, 2023](#)), but can also capture signals generated by environmental and cryospheric processes, including landslides, rockfalls, glacier collapses, and other mass-movements (e.g., [Burtin et al., 2009](#); [Cook et al., 2018](#)). Seismic recordings provide precise temporal information on the onset and evolution of mass-movements, facilitate source localization, and allow characterization of frequency-dependent seismic radiation and signal directionality, as well as the quantified evolution of forces associated with mass-movement and landslide force-histories ([Ekström and Stark, 2013](#)). Such seismic observations, when telemetered and analysed in real-time, are particularly valuable during catastrophic events when conventional monitoring systems may be damaged or destroyed, as occurred during the 26 August 2026 event ([Department of Hydrology and Me-](#)

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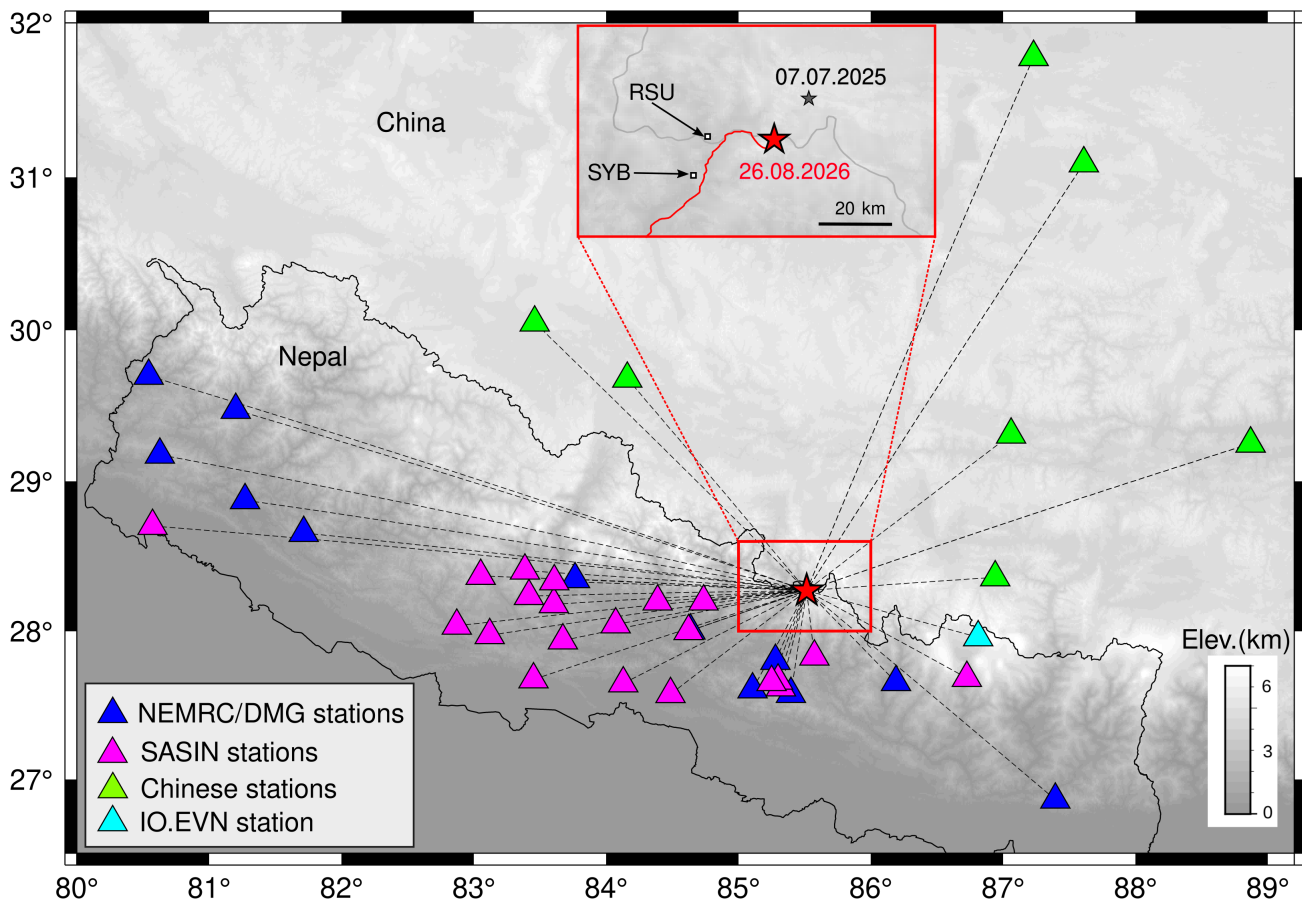


Figure 1 Study area centered on Nepal (border in black) and the network of seismic stations (triangles). The location of the mass-movement as located by this study using seismic waveforms, is marked by a red star (28.298°N, 85.566°E). Great-circle paths between each seismic station and the mass-movement location are shown in dashed lines. The inset provides a magnified view of the event's source area. The small black star in the inset indicates the location of the GLOF (Glacial Lake Outburst Flood) that occurred on 7 July 2025. The red line shows the path of the flood along the Lhende Khola and Trishuli Rivers. Abbreviations: RSU – Rasuwagadhi at the Nepal–China (Gyirong) border, SYB – Syabrubesi, NEMRC – National Earthquake Monitoring and Research Centre, SASIN – Seismology at School in Nepal.

teorology (DHM), 2026).

Here, we provide the first complete dataset of local seismic observations of the 26 August 2026 mass movement and subsequent flash flood in Nepal, constraining their timing, location, seismic signature, detectability, and relationship with preceding seismicity. We combine seismic, hydrological, and geomorphic observations to characterize flood propagation and establish a benchmark for identifying similar events and developing rapid seismic detection approaches in remote Himalayan regions.

2 Data and Methods

We have integrated seismic, hydrological, topographic, and field observational datasets to characterize and constrain the source of the mass-movement and subsequent flash-flood / debris flow event that occurred on 26 August 2026 (Fig. 1). Continuous seismic waveform data were acquired from three networks: the National Earthquake Monitoring and Research Center (NEMRC) at the Department of Mines and Geology (DMG), the Nepal

School Seismology Network (NSSN) of the Seismology at School in Nepal program (SASIN, Subedi et al., 2020, 2024), and selected seismic stations in China. The combined network comprises broadband three-component, short-period, and low-cost Raspberry Shake seismometers distributed at source-to-station distances of approximately 60–300 km and across a range of azimuths, providing relatively dense spatial coverage for event detection and source localization (Table S1). In total, waveform data from 45 stations were examined, of which 19 stations with high-quality recordings were selected for event location (Fig. 1; Table S2).

Seismic events were detected using SeisComp with bandpass-filtered waveforms and automated P-wave picking. Picks were reviewed manually, and events were located with NonLinLoc using a local 1-D velocity model (Pandey et al., 1995). Three nearby seismic events were identified and located during the 15 days preceding the mass movement. Among these, an M_L 2.5 event occurred 17 min 4 s before the mass movement and was located less than 10 km southeast of the inferred source, making it the closest event in both

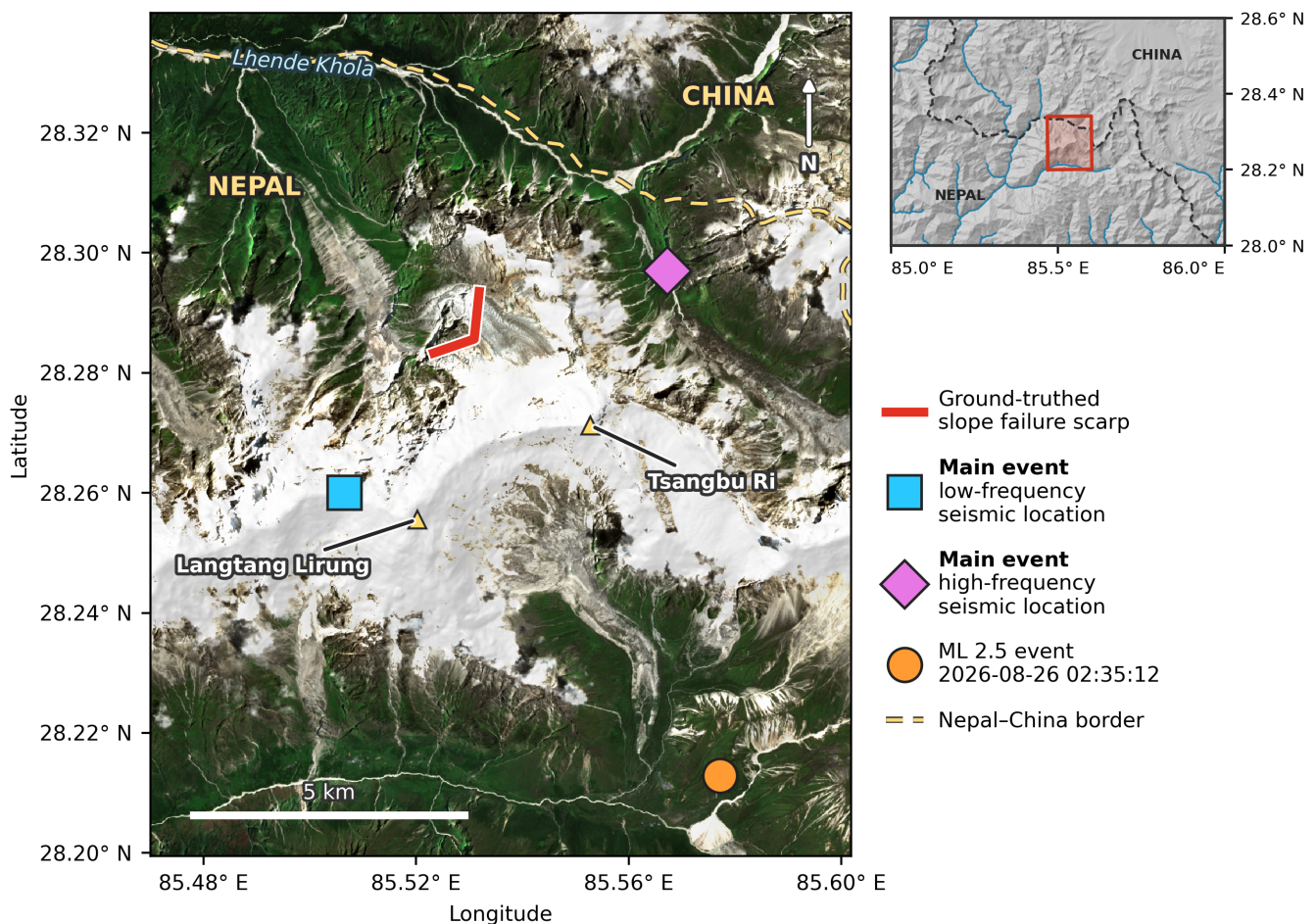


Figure 2 Location of events determined from seismic waveforms in this study. The mass-movement event is located very close to the scarp seen in post-event satellite images (red line). The low-frequency waveform coherence location and high-frequency location of the mass-movement event are shown by the square and rhombus, respectively. About 17 minutes earlier, an M_L 2.5 seismic event occurred to the SE (orange circle). Contains modified Copernicus Sentinel data 2026; produced using Copernicus WorldDEM-30 © DLR e.V. 2010-2014 and © Airbus Defence and Space GmbH 2014-2018 provided under COPERNICUS by the European Union and ESA; all rights reserved. Boundary: geoBoundaries / Open Data Nepal (2019), CC BY 4.0.

time and space. We therefore investigated this event in greater detail using both P and S wave phases, while also assessing network-wide waveform coherence and teleseismic detectability. Flood propagation was estimated by integrating seismic, hydrological, CCTV, geomorphic, and river-channel observations. Further details of the data and methods are provided in the Supplementary Information.

3 Results and Discussion

3.1 Event locations

Using the seismic waveforms recorded across the regional network, we constrained the origin time and source location of the 26 August 2026 mass-movement event. Our relocation workflow using high frequency first-arrivals yielded an origin time of 02:52:16 UTC on 26 August 2026, and a robust source location of 28.298°N,

85.566°E, which is within 5 km of the ground-truthed mass-movement scarp identified from post-event satellite images (Figs. 1, 2), showing the value of seismic recordings even with sub-optimal station coverage. The uncertainties associated to time-picks are approximately 1.0 and 0.4 km in latitude and longitude, respectively; however, considering all sources of uncertainty, a location uncertainty of ca. 5 km is more realistic (Fig. 2). The location solution has an average travel-time residual of 0.8 s, an azimuthal gap of 133°, with the closest station 63 km away.

The location and origin of the event are particularly important to assess whether the mass-movement was initiated by an earthquake or by processes associated with rock or glacier instability and/or other mass-movement activity. Early discussions were initially prompted by the United States Geological Survey (USGS) reporting a M4.4 earthquake in the region,

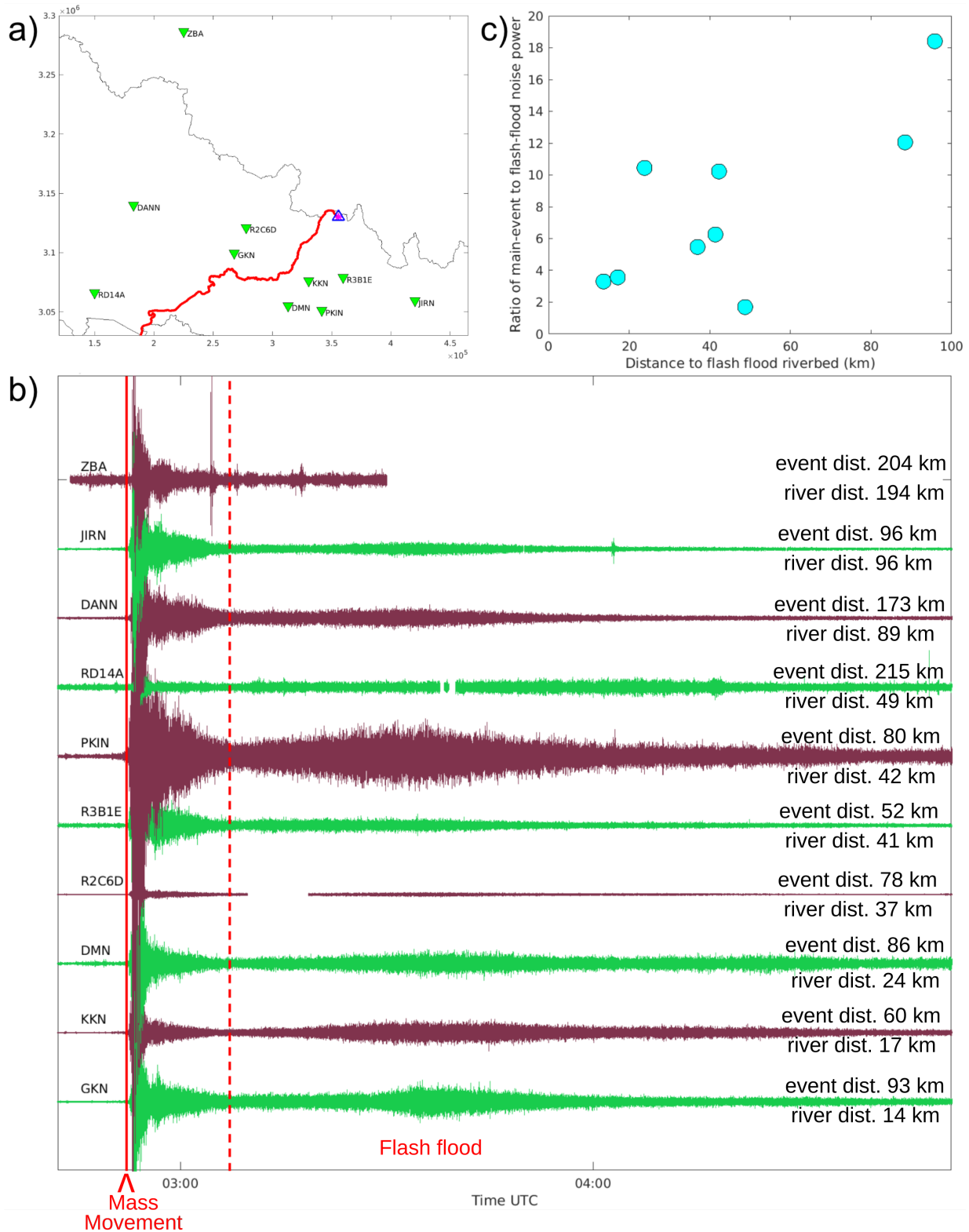


Figure 3 Overview of seismic observations characteristic of the evolution of ground motion following the events. (a) Map of 10 selected seismic stations with clean signals suitable for analysis during the time window of interest. Coordinates are in UTM. (b) Vertical-component band-pass filtered (0.7–8 Hz) waveforms from the selected stations, showing ground-motion amplitudes from 10 min before the onset of the event (red line) to 2 h after. The red dashed line is 15 minutes after the event origin. Seismograms are sorted along the y-axis by increasing the minimum distance to the Trishuli River. (c) Noise power (amplitude squared) ratio between the first 15 minutes and the subsequent 105 minutes as a function of the minimum distance of the station from the Trishuli River's bed. The analysis for the station ZBA is not shown as the recording was rather short.

which was subsequently reclassified as a M5.2 landslide (<https://earthquake.usgs.gov/earthquakes/eventpage/us7000tbwb/executive>). To further investigate the possibility of earthquake triggering or seismic precursors to the landslide, we systematically searched the seismic waveforms for events occurring before the rock-ice avalanche. Among the three seismic events located in the vicinity, an M_L 2.5 event was located less than 10 km southeast of the mass-movement source seen in satellite images (Figs. 2, S4). Its focal depth was estimated at approximately 9 km beneath Langtang Lirung, although this depth is poorly constrained. In addition, template-matching analysis detected more than 60 smaller events during the preceding two weeks, including several events in the preceding hours with waveforms similar to that of the M_L 2.5 event, with detailed analysis to be presented in a separate study. Given the uncertainties in their locations and source characteristics, a tectonic origin cannot be formally excluded. However, their close spatial association with the mass-movement source and their repeated occurrence over the preceding days make a tectonic origin less likely and may instead point to near-surface slide-quakes associated with gravitational mass movement. The temporal proximity and spatial relationship of this seismic event warrant consideration when evaluating potential triggering or precursory mechanisms; however, temporal and spatial coincidence alone does not establish a causal relationship at this stage. The arrival times and associated phase information for the mass-movement are provided in the Supplementary Material (Table S1).

We independently verified the mass movement source using waveform-coherence back projection of long-period vertical-component seismic data (e.g., Karasözen and West, 2024). The preferred solution is located at 28.2604°N, 85.5057°E (Fig. 2). Details of the waveform processing, grid search, and coherence calculation are provided in the Supplementary file Text in Data and Methods section. A second, smaller mass movement signal was also identified at approximately 05:59 UTC, although its location is less well constrained than that of the main event. To estimate the landslide volume from the long-period seismic records, we adopted the empirical seismic amplitude – landslide volume calibration for Alaska from Karasözen and West (2024). This suggests a volume on the order of 10^2 million m^3 for the main event, which, based on satellite imaging, means primarily rocks with smaller portion of ice. This volume estimate is consistent with an independent inversion of the broadband seismic records using LSSforce, which produced a run-out trajectory that closely follows the observed path of the landslide. However, this estimate is highly uncertain because the empirical calibration is based on substantially smaller landslides from a different region, so more robust volume estimates are needed as part of future studies. We estimated an order-of-magnitude lower volume (10^1 million m^3) for the secondary landslide at 05:59 UTC.

3.2 Landslide and flash-flood characterization

To track the cascading evolution of the event and subsequent downstream processes, vertical-component waveforms (0.7–8 Hz) were analyzed across ten different regional seismic stations with the cleanest records (Fig 3). The onset of the main mass-movement event is characterized by a distinct, sharp, and high-amplitude impulse recorded at around 02:52 UTC, which is clearly observed across all stations and decreasing in amplitude over several minutes. Near-source stations, such as PKIN (80 km from the event), captured exceptionally high-amplitude ground motion during the first 15 minutes of the event (indicated between the solid and dashed red lines on Fig 3). This first phase carries most of the kinetic energy of the slope failure and the initial valley-floor impact, caused by the highly turbulent flash-flood and debris flow moving downstream along the Lhende Khola (part of the valley in Tibet, China) and then the uppermost part of the Trishuli River channel in Nepal (red path in Fig 3a). The subsequent part of the seismic signal is a gradual increase of amplitudes into a consistent, long-duration, tremor-like seismic coda that lasts for more than 2 hours (Fig 3b), due to the continued propagation of the flash-flood all across Nepal down the Trishuli River.

To characterize the seismic signature of the flash-flood following the main event, the ratio of noise power (i.e., the sum of the squared vertical ground motion amplitudes) between the first 15 minutes and the subsequent time window until 2 hours was computed, and compared with the nearest distance from the river bed (Fig 3c). These observations reveal that stations situated closer to the active river channel recorded highly pronounced and prolonged tremors caused by the flash-flood. This validates that the seismic energy observed after the initial 15 minutes of the event was mostly driven by the downstream progression of the debris flow.

In terms of frequencies, the initial mass-movement phase is characterized by a high-amplitude, broadband impulsive signal, with spectrograms showing an instantaneous burst of vertical energy across the 1–10 Hz frequency range, consistent with a massive, short-duration kinetic impact (Fig. S1). In contrast, the subsequent flash-flood phase exhibits a sustained, long-duration seismic energy envelope rather than an impulsive burst (Figs. 3b, S1). In addition, the cross-correlation results show high waveform coherence among the recorded seismic signals, with correlation coefficients reaching up to 0.8 for the mass-movement event (Fig. S2), demonstrating the potential of waveform similarity for identifying regional signals generated by the mass-movements.

The spectral signature of the seismic signal related to the river flood includes several harmonics and progressive increase of the dominant frequency. These features have been often observed at seismic stations located near the river bed (e.g., Díaz et al., 2014), but must be considered as exceptional for stations located at several tens of kilometers. The higher amplitudes are ob-

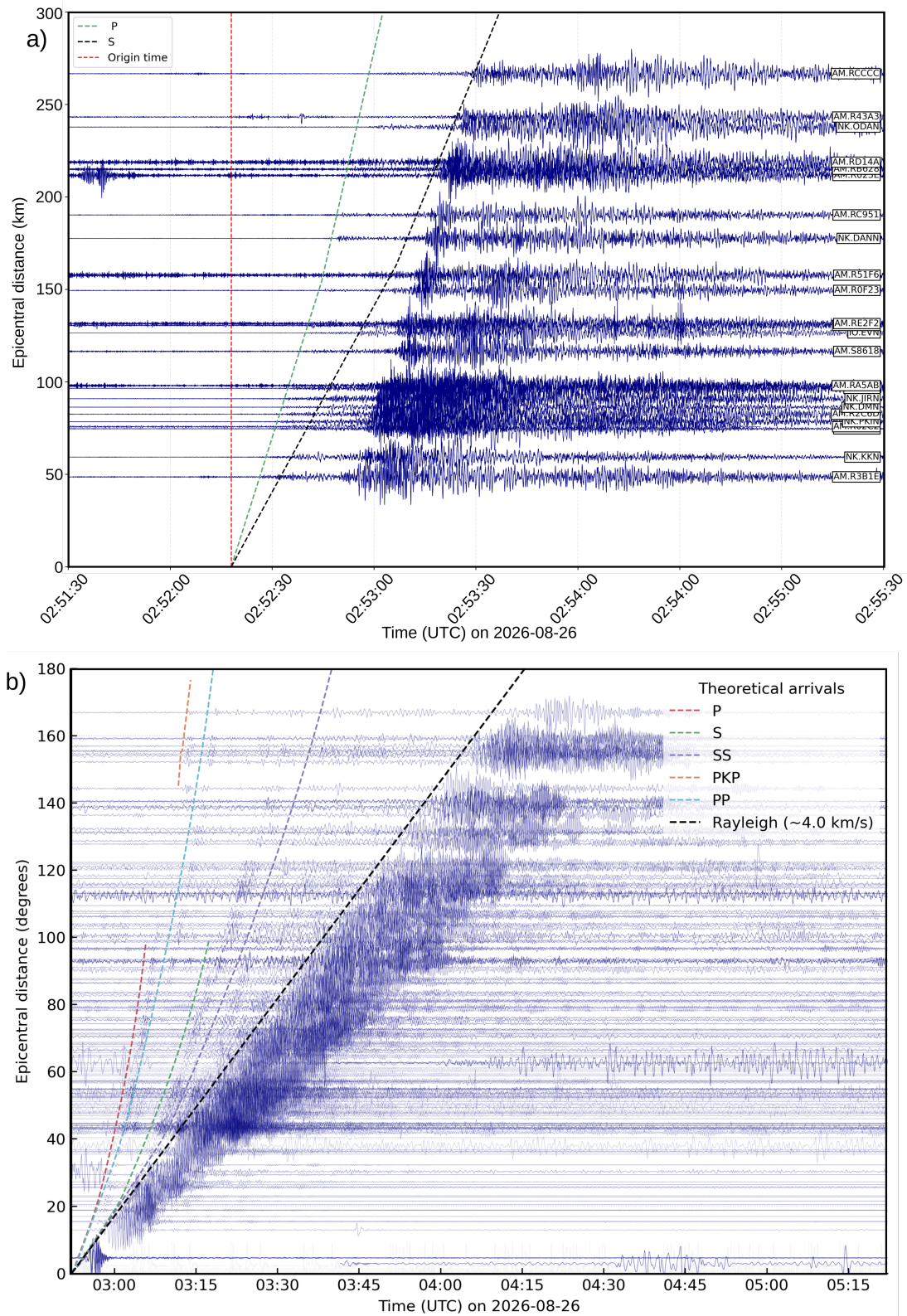


Figure 4 Seismic record sections of the mass-movement event. (a) Vertical-component seismic record section from local and regional broadband stations, showing the seismic signals associated with the mass-movement. Waveforms are band-pass filtered between 0.7–8 Hz. Station names are indicated alongside each waveform. The theoretical P-wave arrival times calculated using the IASP91 velocity model are shown by black dashed lines, while the red dashed line indicates the origin time of the glacier collapse. (b) Vertical-component seismic record section from broadband stations distributed around the globe. Waveforms from G, GE, and II networks were retrieved from the EarthScope data archive. The theoretical arrival times of the P, S, PKP, PP, and SS phases calculated using the IASP91 velocity model, and Rayleigh waves of 4 km/s are indicated by dashed lines. Waveforms are bandpass-filtered between 15 and 70 s.

served at stations relatively close to the river, confirming that their origin is related to the flood.

3.3 Regional and global detection

To evaluate the seismic footprint of the mass-movement, we compiled not only local but also regional and global seismograms (Fig 4). At the regional scale (Fig 4a), high-frequency vertical-component waveforms (0.7–8 Hz) exhibit clear, distance-dependent delays across stations located 50–250 km from the source. The arrivals are compared with theoretical IASP91 model's P- and S- wave travel times (dashed lines), with consistent time differences between the first and second arrivals across stations. The later arriving, though larger amplitude wave packages (Fig 4a) represent the prolonged, progressive slope failure and falling masses, and not an instantaneous tectonic rupture. The seismic arrivals of the mass-movement are dominated by high-amplitude signals associated with the subsequent flash-flood.

The mass-movement event was not only detected regionally, but also around the globe, with amplitudes larger than those of the 2025 Tracy Arm landslide in Alaska (e.g., [Shugar et al., 2026](#); [Huang et al., 2026](#)). At teleseismic distances (Fig 4b), long-period seismic energy (15–70 s) is detected at stations around the entire world. These signals closely follow the theoretical teleseismic travel-time curves, with Rayleigh-wave propagation at 4.0 km/s, which is slightly higher than the Rayleigh-wave speed (3.7 km/s) generated by the 2015 Gorkha earthquake ([Tulasi Ram et al., 2017](#)), but comparable to the 4.1 km/s generated by the 2011 Tohoku earthquake ([Hung and Rau, 2013](#)) and the 2004 Sumatra earthquake ([Singh et al., 2005](#)). The global detectability of the event indicates that the movement involved sufficiently large-scale mass displacement and momentum transfer to generate long-period seismic waves detectable worldwide, extending its seismic footprint far beyond its local geomorphic source region.

For the first time, the origin time of the mass-movement event was precisely constrained from seismic observations, providing a reference time for tracking the subsequent propagation of the flash-flood. Combined with independently observed flood arrival times at the China–Nepal border and along the Trishuli River, this allowed us to estimate the flood propagation velocity over different segments along the river (Fig. S3). The longitudinal elevation profile shows a pronounced topographic control on the downstream flow, with a 3000 m elevation drop over the first 25 km and a peak propagation velocity of about 163 km/h on that segment, followed by a progressive decrease to 33 km/h as the river gradient becomes gentler downstream. This quantitative velocity pattern provides an independent framework for interpreting the spatiotemporal evolution of the seismic signals, with the rapid, high-velocity surge in the steep headwater region corresponding to the high-amplitude energy recorded at near-source stations and the slower downstream propagation associated with the prolonged seismic tremor observed across the regional network.

Detailed on-site analysis of the northern slope of Tsangbu Ri is essential, in order to characterize the local conditions in terms of ice thickness, temperature fluctuations, rock condition (level of fracturing, permeability, weathering, etc.) and other factors that exceed the frame of this contribution. While this contribution provides the first set of complete seismic dataset related to the Tsangbu Ri – Trishuli cascading events, multiple further seismic and interdisciplinary analyses become possible. The present seismic dataset is made available for community use (see the Data and code availability section).

4 Conclusions

The 26 August 2026 event was a high-mountain slope failure that cascaded into a highly destructive flash-flood. Seismic records allowed detecting the main mass-movement event, as well as a local seismic event (magnitude 2.5) in the immediate vicinity shortly before. The long duration of persistent high-noise on seismic stations indicates that the flash-flood lasted for hours as it swept down the Trishuli River valley.

Mass-movements and flash-flood events are not rare in the geological record. Future events will certainly happen, therefore regional monitoring networks are warranted. Water level gauges on rivers are certainly useful for small amplitude and slow floods, but not suitable for catastrophic events. Based on the observed seismic signature of the mass-movement and the flash-flood, we assert that a seismic network spanning the Himalaya is an important and desirable monitoring. Such a network has a strong potential to evolve into a valuable early warning system, not only for regional earthquakes but also for landslides and flash floods.

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Data and code availability

A subset of the seismic waveform data used in this study is openly available on Zenodo in MiniSEED format, including recordings from the NEMRC and SASIN networks (Adhikari and Subedi, 2026).

Competing interests

Shiba Subedi and György Hetényi are handling editors at Seismica and have fully withdrawn themselves from the peer-review and publication process.

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