

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

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Supplementary file

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This file contains

- Data and Methods section
- Figures S1, S2, S3 and S4
- Tables S1 and S2

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Data and Methods

Seismic data were processed using SeisComP in offline playback mode (GFZ and gempa GmbH, 2008). Continuous waveforms were bandpass filtered between 0.7 and 8 Hz, and P-wave arrivals were identified using STA/LTA-based detection and refined with the Akaike Information Criterion (AIC). Phase picks were manually reviewed to remove spurious detections and ensure consistent phase assignments. The mass-movement source was located using the probabilistic NonLinLoc locator (Lomax et al., 2000, 2014) and the local 1-D velocity model of Pandey et al. (1995), without assigning a magnitude. The M_L 2.5 event detected approximately 17 min before the mass movement was characterized using both P- and S-wave phases.

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Waveform coherence was evaluated using vertical-component recordings from 23 seismic stations. Cross-correlation was performed on 1–10 Hz filtered waveforms for all available

station pairs using moving time windows, with the maximum correlation coefficient used to quantify waveform similarity and its temporal evolution. Waveforms from globally distributed stations available through the EarthScope, IPGP, and GEOFON data centers, including the G, GE, and II networks, were also examined to assess teleseismic detectability.

Flood propagation was constrained using independently documented arrival times from CCTV footage, hydrological observations from the Department of Hydrology and Meteorology (DHM), Nepal, and published national and international reports. Water-level observations were used to constrain flood-passage timing and magnitude at selected locations. Trishuli River channel geometry and coordinates were extracted from Google Earth, and elevation data were obtained from the Copernicus GLO-90 Digital Elevation Model (ESA, 2021). These datasets were integrated to construct the longitudinal river profile and estimate downstream flood-propagation velocity.

We located the mass movement event using a waveform coherence-based back-projection approach applied to response-corrected vertical-component seismic data. For each candidate source location on an approximately 1 km grid, the station waveforms were shifted according to the source to station travel times using a propagation velocity of 3.4 km/s, and the absolute mean stack was used to quantify waveform coherence. The analysis was performed in the 0.01–0.05 Hz frequency band using a 180 s receiver window and stations within 2° of each candidate source. Six stations provided the preferred solution, with a maximum coherence of 0.969 at 28.2604°N, 85.5057°E. Sensitivity tests using different propagation velocities and station subsets showed that the preferred location was

50 reasonably stable, although the location uncertainty is larger than that implied by the formal
grid spacing.

We estimated the mass movement volume from the maximum low frequency vertical
displacement amplitude at each station, corrected for source distance, and converted the
median amplitude to volume using the empirical scaling relationship of Karasözen and
55 West (2024).

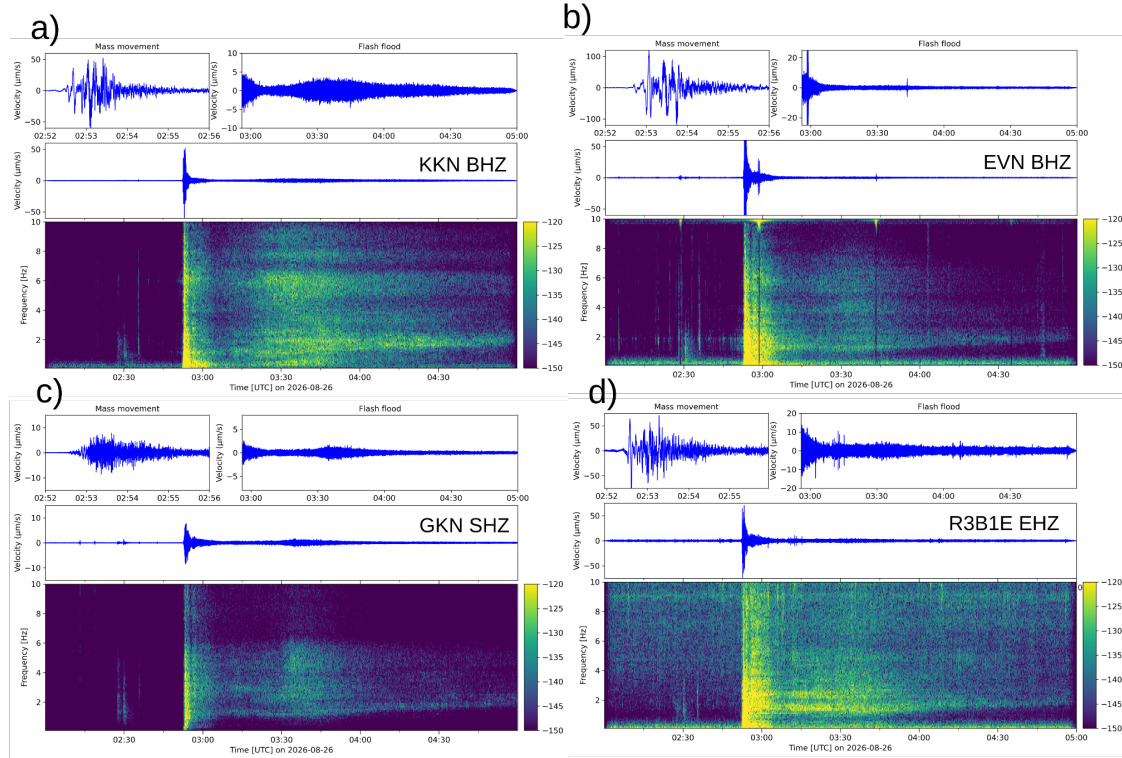


Figure S1. Seismic signatures of the mass-movement event and subsequent flash flood. Seismic recordings from four stations: (a) KKN, (b) EVN, (c) GKN, and (d) R3B1E. For each station, the bottom panel shows the spectrogram in the 1–10 Hz frequency range, while the middle panel shows the corresponding bandpass-filtered waveform. The upper panels show zoomed waveforms corresponding to the mass-movement event (left) and the subsequent flash-flood signal (right). All waveforms are bandpass filtered between 1 and 10 Hz.

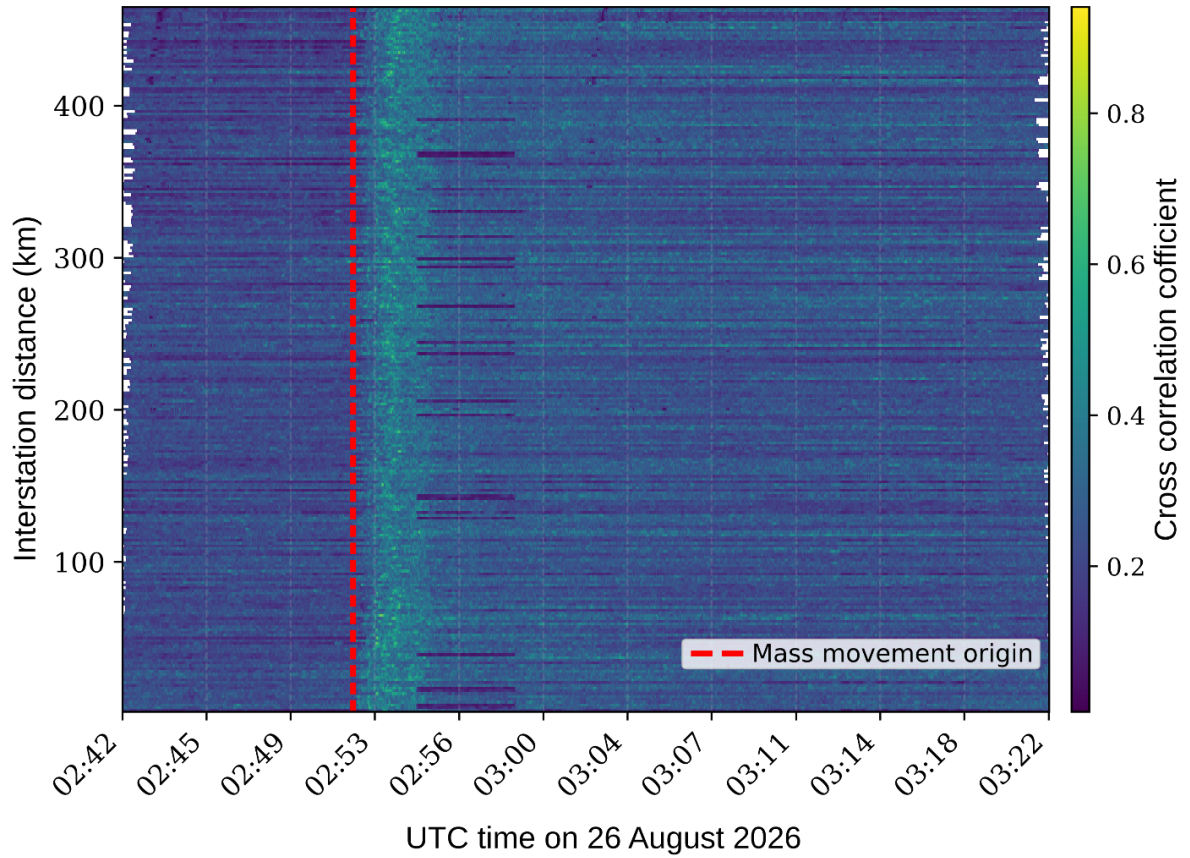


Figure S2. Temporal evolution of the cross-correlation coefficient (cc) between all station pairs during the 10 min preceding and 30 min following the 26 August 2026 mass-movement event. Each row represents a station pair positioned according to its true interstation distance, while color intensity indicates the magnitude of the waveform cross-correlation coefficient. The cross-correlation coefficient was computed after the station waveforms were shifted. The vertical dashed line marks the mass-movement origin time at 02:52:16 UTC.

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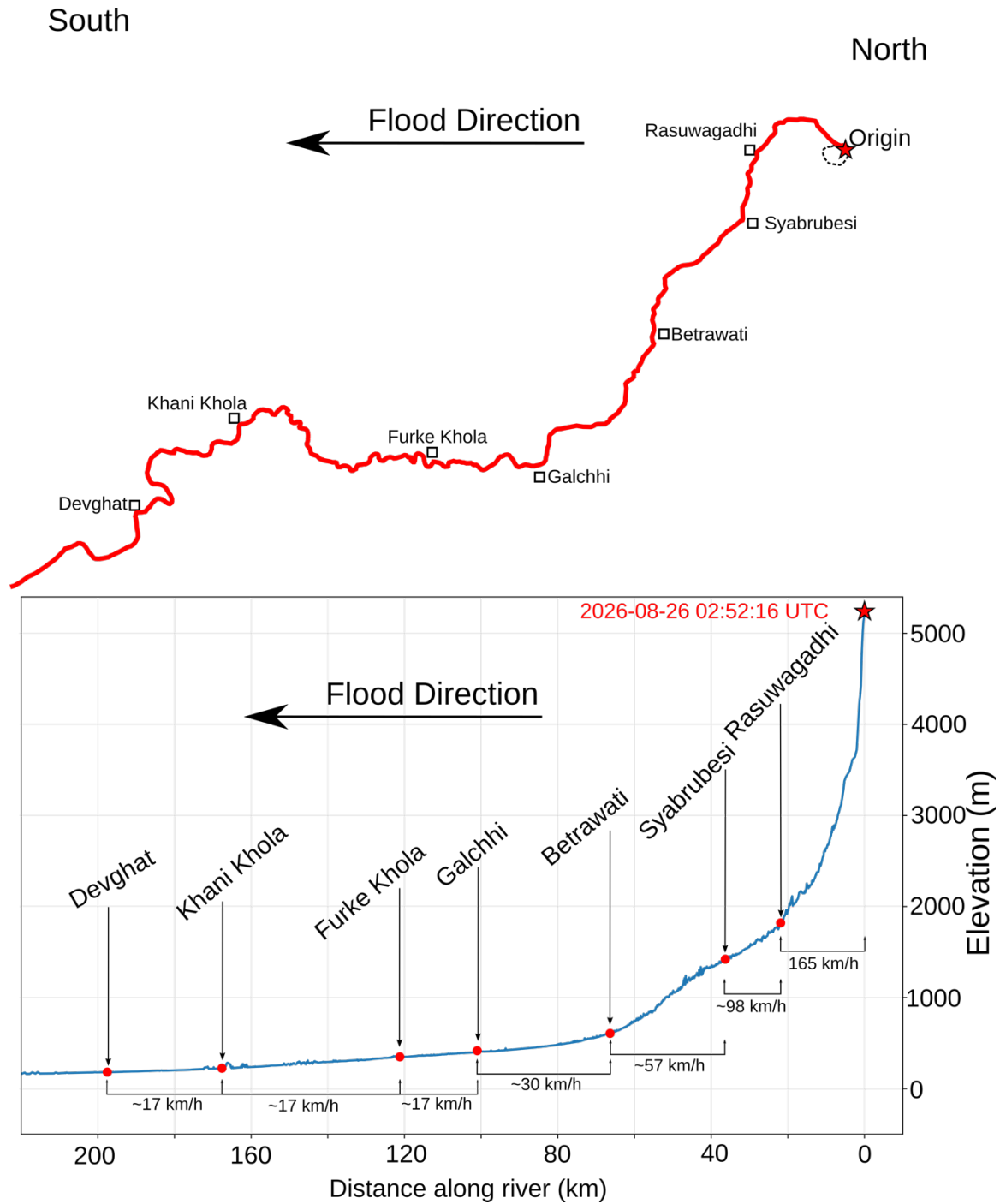
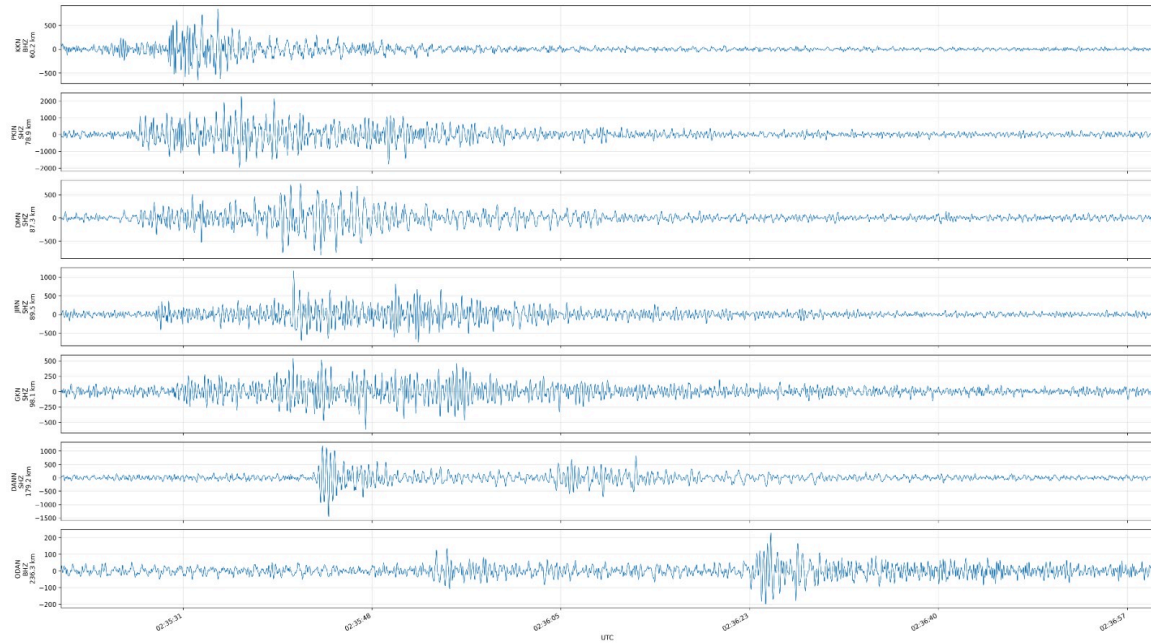


Figure S3. Elevation profile along the Trishuli River showing the observed average flash-flood wave speed and the locations where flood wave arrival times were identified. The inset map shows the corresponding measurement locations along the river (the increase in topography is due to inaccuracy of the DEM). Average flash-flood wave speeds are in km/h and were estimated from the arrival-time differences between successive locations, with a maximum estimated average speed of ~165 km/h in the northernmost section. Source: European Space Agency (2024), Copernicus Global Digital Elevation Model DHM.



85 Fig. S4: Recorded waveforms of the M_L 2.5 seismic event, band-pass filtered between 0.7 and 8 Hz. The station name, channel name, and event distance are written in Y axis, while the x-axis shows time in UTC on 26 August 2026.

Network	Station name	Latitude °N	Longitude °E	Elevation m
AM	R023E	28.234	83.417	1320
AM	R02C2	27.622	85.32	1429
AM	R038D	28.369	83.052	1429
AM	R0BD5	28.18	83.604	785
AM	R0F23	28.045	84.072	516
AM	R2C6D	28.198	84.736	1885
AM	R3B1E	27.829	85.573	856
AM	R43A3	27.973	83.12	971
AM	R51F6	27.649	84.13	189
AM	R5A68	27.685	86.725	2867
AM	RA5AB	28.00	84.623	1121
AM	RB628	28.405	83.386	1088
AM	RC951	27.937	83.673	754

AM	RCCCC	28.036	82.871	668
AM	RD14A	27.676	83.452	156
AM	RD7E6	28.333	83.608	1770
AM	RE2F2	27.577	84.486	170
AM	RE497	27.667	85.299	1314
AM	RF015	27.658	85.25	1443
AM	RF542	28.703	80.572	109
AM	S8618	28.198	84.389	747
IO	EVN	27.959	86.812	5010
NK	BAYN	29.474	81.201	3050
NK	BHMN	28.656	81.714	2280
NK	DANN	28.348	83.765	2500
NK	DMN	27.608	85.106	2225
NK	GHAN	29.177	80.627	2450
NK	GKN	28.003	84.637	1478
NK	JIRN	27.657	86.19	3064
NK	KKN	27.80	85.279	2042
NK	ODAN	26.863	87.394	2045
NK	PKIN	27.577	85.397	2300
NK	PUSN	28.875	81.271	1520
XZ	RKZ01	29.25	88.87	3853
XZ	ZB	31.09	87.61	4608
XZ	NMA	31.78	87.23	4564
NP	DARC	29.699	80.544	1409
XZ	ZHF	28.36	86.94	4303
XZ	PYZ	30.05	83.46	4623
XZ	ARZ	29.31	87.06	4438
XZ	ZBA	29.68	84.16	4608

90 Table S1: Coordinates of stations used for locating the main event.

Network	Station	Channel	Arrival Time UTC
AM	R3B1E	EHZ	02:52:26
NK	KKN	BHZ	02:52:27
NK	PKIN	SHZ	02:52:32
NK	DMN	SHZ	02:52:32
NK	JIRN	SHZ	02:52:34
NK	GKN	SHZ	02:52:34
AM	RA5AB	SHZ	02:52:34
AM	S8618	EHZ	02:52:38
IO	EVN	BHZ	02:52:41
AM	R5A68	EHZ	02:52:42
XZ	ZHF	HHZ	02:52:40
AM	R0F23	EHZ	02:52:45
NK	DANN	SHZ	02:52:49
AM	RC951	EHZ	02:52:51
AM	R023E	SHZ	02:52:54
NK	ODAN	BHZ	02:52:58
AM	R43A3	EHZ	02:52:58
AM	RCCCC	EHZ	02:53:01
XZ	PYZ	SHZ	02:53:06

Table S2: P-wave arrival times for the mass-movement event at the stations used.

95 **References**

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