Seismic observations of the 2021 Uttarakhand landslide/debris flow and flood events

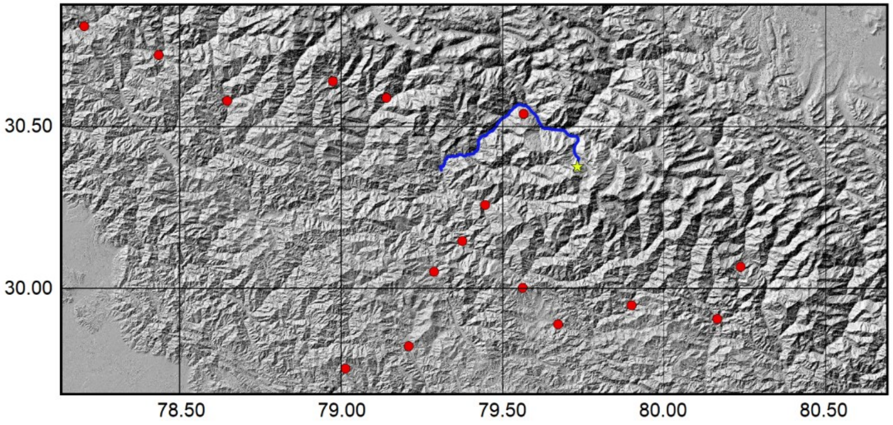
Marco Pilz[1], Fabrice Cotton[1,2], Kristen Cook[1], Michael Dietze[1], Niels Hovius[1,2], Rajesh Rekapalli[3], Venkatesh Vempati[3], Ravi Prakash Singh[3], N. Purnachandra Rao[3], D. Srinagesh[3], V. M. Tiwari[3]

(1) Helmholtz Center Potsdam GFZ German Research Center for Geosciences, Telegrafenberg, 14476 Potsdam, Germany
(2) University of Potsdam, Institute for Geosciences, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany
(3) CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad, 500007, India

GFZ Helmholtz Centre Potsdam

HELMHOLTZ

Regional seismic network

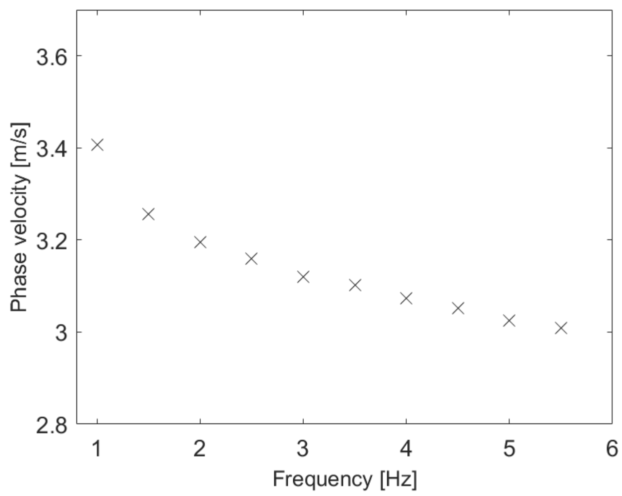


The tracking method consists of three main steps:
(1) determining a regional Rayleigh wave phase velocity model of the area
(2) mapping an envelope of a frequency-dependent cross-correlation function to a probability density as a function of time shift
(3) back-projecting the time series of temporal probability density into space using the predefined velocity model of step (1).

Regional Rayleigh wave phase velocity model

Vertical seismic noise time series of all stations before 7 February, 04:40 UTC were used to compute cross-correlations between each station pair.

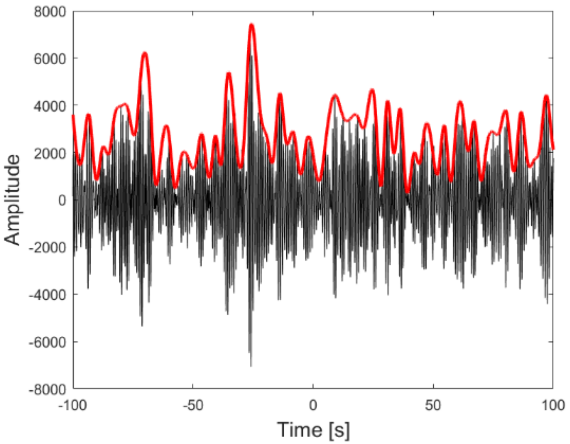
From the continuous data streams, time series were filtered by applying a narrow-band Gaussian filter with a standard deviation of 0.25 Hz for frequencies ranging from 0.5 to 5.5 Hz with an increment of 0.5 Hz.
From the stacked cross-correlations, the frequency-dependent propagation delay, i.e. the dispersion curve, between each station pair was estimated by picking the maximum on the Green's functions envelope, computed through a spline interpolation.



Event location and tracking analysis

Each seismic trace was split into 5-min (between 04:45 UTC and 05:10 UTC) or 10-min segments (after 05:10 UTC), each with 50% overlap.

Normalized cross-correlation of the individual segments in the time series were calculated followed by computing envelopes for every station pair for time lags ranging from –*D*/2 to +*D*/2 with D being the interstation distance.

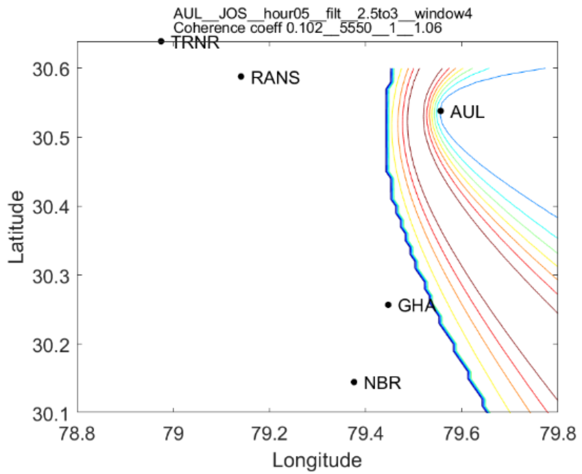


Event location and tracking analysis

The frequency-dependent travel time difference of seismic energy travelling from any source to stations *i* and *j* is represented by the lag time of the envelope of the cross correlation function for the station pair *ij*.

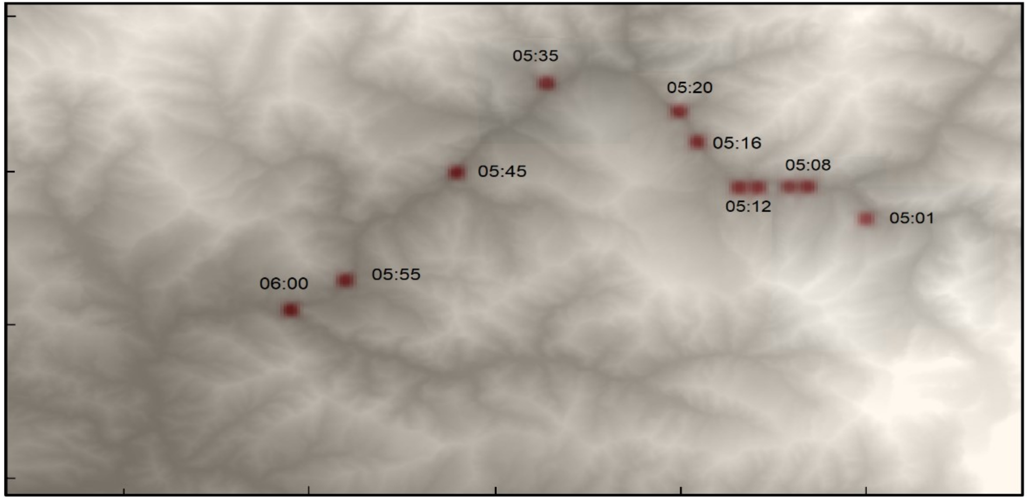
Brightness function $$B_{ij} = \mathrm{EnvCCF}_{ij}\left[\frac{d_i - d_j}{v(f)_{ij}}\right] * W_{ij}$$

Mapping the brightness function to space



Event location and tracking analysis

The source location for each time segment is estimated to be the one where the stacked back-projected amplitude (i.e. the brightness) for all station pairs and frequency values is maximized.



The flood can be tracked precisely during the down-valley movement.