A106

Three-Dimensional Upper Crustal Seismic Velocity Model for Central Nepal from Local Earthquake Tomography

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Introduction

In 2015, an Mw 7.8 earthquake struck the Gorkha region of central Nepal. Several major aftershocks followed this event including an Mw 7.3 near the eastern edge of the mainshock rupture. The Gorkha earthquake is widely considered as to be a repeat of the similar sized 1833 earthquake. During both the 2015 and 1833 events, only the down-dip portion of Main Himalayan Thrust (MHT) ruptured.

Physical heterogeneity may influence the earthquake rupture. Previous studies have suggested the considerable lateral variation of seismic wave speed in central Nepal (1,2). In this study, we present three-dimensional Vp and Vp/Vs models of the upper crust in the source region of the Gorkha earthquake using local earthquake tomography.

Data and Method

We used data of the Gorkha earthquake sequence recorded by a temporary aftershock monitoring network. This network consists of 42 broadband and short-period stations (Fig. 1) and has continuous records of 11 months from June 2015 to April 2016. To make ray coverage as uniform as possible, we selected ~2100 events from an automatic catalog (3) based on their location and recording stations. We then manually picked the arrivals and discarded events with less than 15 P- and 10 S-arrivals. In our final dataset, we had ~ 1,700 events with 39,000 P- and 27,000 S- onsets. Epicenters of these events cover the entire aftershocks zone and represent characteristics of the aftershock sequence.

We used P- and S-wave arrivals times for a simultaneous inversion of the 3D velocity and hypocenters by applying an iterative damped least-squares algorithm (4). Travel times along the ray paths in 3D models were computed using the psuedo-bending technique. Damping parameters were selected empirically based on the trade-off between data misfits and model variances. We followed the gradational inversion approach starting with estimation of a 1D velocity model, followed by a coarse 3D model and finally a fine 3D model. The orientation of the 3D grid was chosen parallel to the strike of major discontinuities in the area (Fig. 1). In both the coarse and fine 3D inversions, depth grid point were at 0, 5, 10, 15, 20 and 25 km.

Resolution Assessment

We assess the resolution of our obtained models through a checkerboard resolution test (CRT) and the full resolution matrix. For the CRT, we design a synthetic velocity model having alternating fast and slow values with a magnitude of 10% relative to the 1D model. We then calculated synthetic travel times using the same source–receiver configuration of our real data. We added Gaussian noise to the calculated travel times and finally inverted to see how well the CRT model is recovered.

By using full resolution matrix of our final inversion, we calculated the spread function (SF) (5) and computed smearing contours where the resolution is 70% of the diagonal element for each node. By combining SF and smearing contours, we empirically set threshold SF values that define well resolved, fairly resolved, and badly resolved areas.

Result of these resolution assessment show that velocity inversion is robust in the central part of the area to the depth of 20 km.

Results and Discussion

Results of our velocity model show three main features. One of the prominent features is a zone of low Vp and low Vs in the southern part of the area at shallow depth (<10 km). This zone is spatially well-correlated with sedimentary rocks of the sub-Himalaya. Since our inversion technique linearly interpolates velocities between nodes, the northern boundary of this low velocity zone cannot be represented exactly in our result.

In the central-northern part of the area, at depths to 10 km, a zone of remarkably low Vp/Vs ratio (<1.65) is found. Such low Vp/Vs ratio at shallow crustal depth is also reported by previous studies in another segment of the Himalaya (6). This anomalous low ratio may represent bodies of felsic (quartz-rich) rocks as mapped at the surface.

The Gorkha earthquake unilaterally ruptured the down-dip segment of the MHT with co-seismic slip concentrated east of the hypocenter. Our results from the velocity inversion at 10 km depth show the area of large (>4 m) co-seismic slip generally coincides with the region of high Vp (Fig. 2). This high velocity zone may represent an asperity on the fault which possibly controlled the rupture of the mainshock.

Summary

Recordings of numerous aftershocks by the dense local network provide a useful dataset to study the detail velocity structure in the source zone of the 2015 Gorkha earthquake. Our results provide a detailed velocity structure of the upper crustal part which is consistent with surface geology and previous geophysical studies of the region.

Acknowledgements

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References

(1) Bai et. al., 2019, Sci Adv. 5, eaav0723 (2) Wei and Zhao, 2016, Phys. Earth and Planet. Int. 253, 58-63 (3) Yamada et. al., 2019 Bull. Seismol. Soc. Am. 110, 26–37 (4) Thurber and Eberhart-Phillips, 1999, Comput. Geosci., 25, 809–818 (5) Michelini and McEvilly, 1991, Bull. Seismol. Soc. Am. 81, 524–552 (6) Monsalve et. al., 2008, J. Geophys. Res. 113 (7) Wei et. al., 2018, Tectonophysics, 722, 447–461.

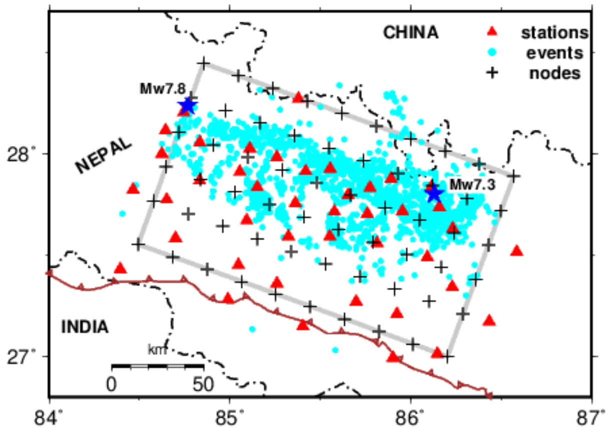

Figure 1: Distribution of events and stations used in this study.

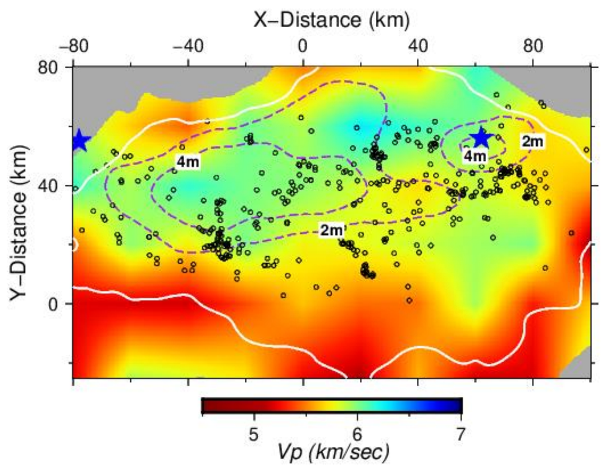

Figure 2: Map view of P-wave velocity at 10 km depth. Purple dashed lines show the co-seismic slip distributions of the mainshock and largest aftershock (7). Open circles represent the aftershock distribution at 9 to 11 km depth. The white line encloses well resolved area.