Numerical Simulation of Three Component Velocities from the 25th April, 2015 Nepal Earthquake

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Abstract

The spatio-temporal rupture complexity of Gorkha earthquake was identified by Avouac *et al.* (2015). Recordings of any earthquake are usually available at some scattered locations where instruments have been deployed, and the Gorkha earthquake is no exception. To obtain the actual ground shaking at any location in the Indo-Nepal region, 3D propagation of waves, from the rupture presented by Avouac *et al.* (2015), is carried using a spectral finite element code (SPECFEM3D). Infrastructural facilities should be designed in such a way that the peak residual ground displacements are accommodated easily for post earthquake restoration. Peak ground residual displacements in the Indo-Nepal region can be computed from the velocities for the Gorkha earthquake presented in this work.

Keywords: *Engineering Seismology; Strong ground motion; Numerical simulation*

1. Introduction

The Nepal earthquake of 25th April, 2015 (popularly known as the Gorkha earthquake, named after the district in which rupture started) originated from about 80 km from Katmandu, the capital city of Nepal. Inversions of this earthquake were attempted by various researchers (Galetzka *et al.*, 2015; Avouac *et al.*, 2015; Hayes *et al.*, 2015; Wang *et al.*, 2015; Gradin *et al.*, 2015; Kubo *et al.*, 2016; Yagi & Okuwaki 2015) using high-rate GPS data, ALOS-2 interferometry, teleseismic recordings to explain the rupture process. Most of these studies suggest predominantly unilateral rupture towards east of a fault plane extending approximately 140-160 km in length. Rupture speeds reported were in excess of 3 km/s where assumed shear wave velocities for their shallowest layer (~4 km) is about 3.2 km/s (Avouac *et al.*, 2015; Galetzka *et al.*, 2015). Wang & Fialko (2015) found the maximum slip to be ~ 6 m similar to that reported (~6.5 m) by Galetzka *et al.*, (2015). Pulse-like rupture was observed in a cGPS station by Galetzka *et al.*, (2015). By fitting a Yoffe source time function to that recording they found that the peak slip-rate to be ~1.1 m/s for a ~6 sec pulse width. In this study, we use the rupture model obtained by Avouac *et al.*, (2015) that suggested rupture along the lower portion of locked Main Himalayan Thrust to simulate ground motion at bedrock level for the Indo-Nepal region.

2. Methodology

The ground motion simulation techniques based on numerical solutions to elastodynamic equations in the presence of a shear dislocation could be accurate representation of actual shaking that took place at a particular site of interest as compared to empirical techniques. Here we use one such numerical method based on spectral finite elements (Komatatisch &Tromp, 2002). It becomes particularly important to resort to such computational tools to model basin effects (4-sec resonance resulting in toppling of tall structures like the 60 m Dharahara tower) that were observed by Galetzka *et al.*, (2015) at a GPS station NAST. Although, this study does not include the shallow velocity layers in ground motion simulation, it is a step towards that goal.

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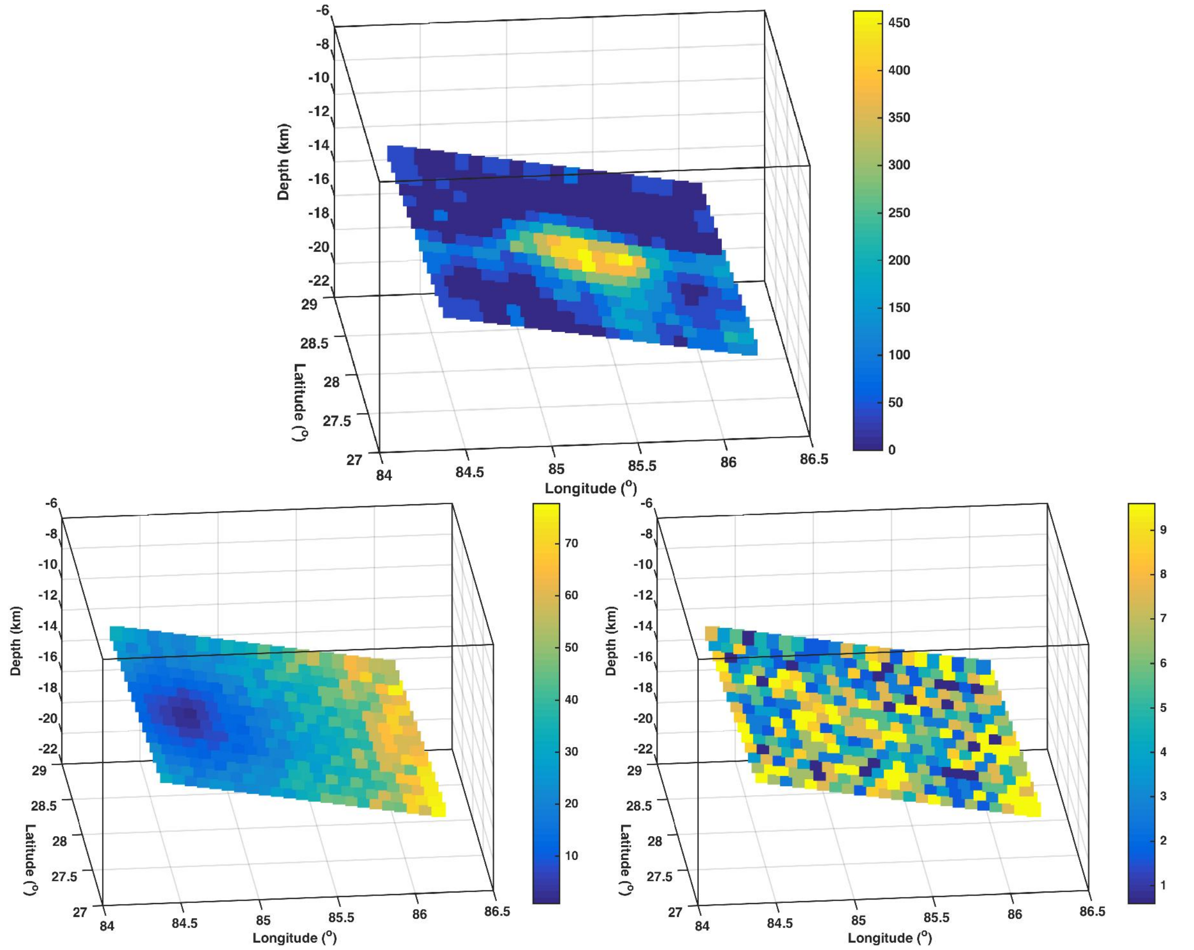

Fig. 1. Rupture process of the 2015 Gorkha earthquake. Slip in cm (top), rupture time in sec (bottom left) and rise time in sec (bottom right) (after Avouac *et al.*, 2015)

The seismic source is applied based on the slip model derived by Avouac *et al.*, (2015) as shown in Fig.1. Each subfault is converted into a point source double couple with origin time given by rupture time and duration taken as rise time. Seismic potency of the double couple source is amplified according to the slip on each patch. The material properties for the earth's crust in the Nepal region is modelled as 1-D layers as shown in Table 1 (Galetzka *et al.*, 2015).

Table 1. Crustal velocity model for the Nepal earthquake (Galetzka *et al.*, 2015).

Thickness (km)	Vp (km/s)	Vs (km/s)	Density (g/cm3)
0-4	5.5	3.2	2.53
4-12	5.85	3.4	2.64
12-16	6.0	3.5	2.69
16-22.5	6.45	3.7	2.83
22.5-32.5	6.65	3.85	2.90
32.5-37.5	7.2	4.15	3.07
37.5-51.5	7.5	4.20	3.17
51.5-	7.9	4.30	3.30

3. Ground motion simulation

Using SPECFEM3D Cartesian package, wave field is simulated in the Indo-Nepal region for latitudes ranging from 25°N to 32.5°N and longitudes ranging from 75.5°E to 85.5°E using elements whose edge length is roughly 1 km. Gauss-Lobatto-Legendre (GLL) quadrature is used for spatial integration with five GLL nodes. Newmark's explicit time integration scheme is used to march forward in time. Snapshots of vertical-component of velocities of free surface are shown in Fig. 2. The computed synthetics are accurate up to frequencies of 0.7 Hz.

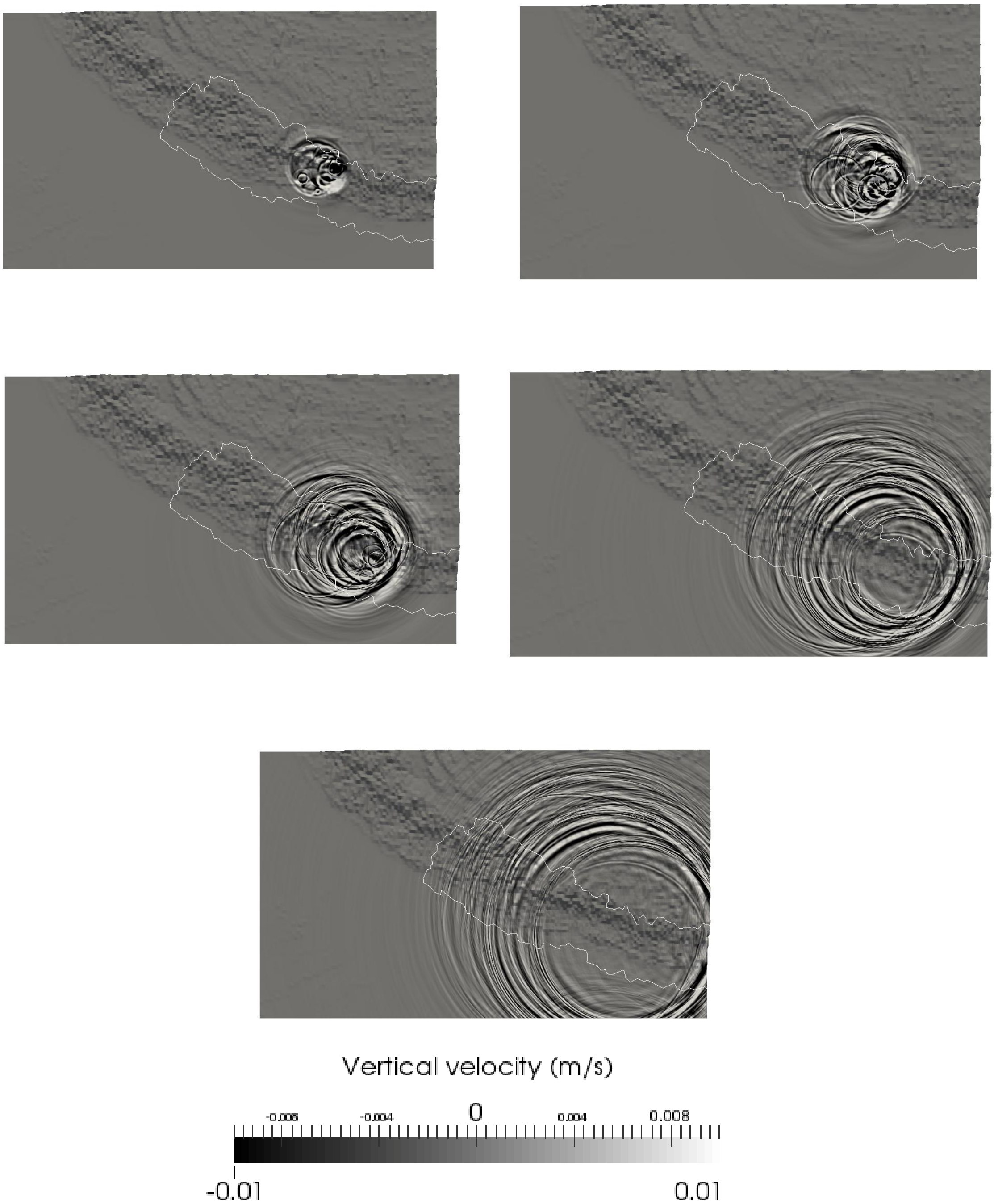

Fig. 2. Vertical component of ground velocities in the Indo-Nepal region. The white boundary on each of the snapshots represents the country Nepal. Snapshots are shown at 20 sec, 30 sec, 40 sec, 60 sec and 80 sec (from top-left going towards right and then downwards). Initial snapshots show the complexity of rupture due to topographical influence.

4. Conclusions

The presence of topographical features of the Himalayas in this work highlight the complexity in surface velocity that could be observed if a good coverage of seismometers were available during this earthquake. Velocities obtained from this ground motion simulation of the Gorkha earthquake for the Indo-Nepal region can be compared with the strong motion recordings close to Nepal in India to see how well the slip model presented in Avouac *et al.,* 2015 explains the observations. The velocities computed in this work can be integrated and maps of peak ground residual displacements can be generated that would reflect the hazards (like landslides, liquefaction and avalanches) induced by this earthquake.

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