Geophysical Research Abstracts
Vol. 18, EGU2016-2512, 2016
EGU General Assembly 2016
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Necessity of using heterogeneous ellipsoidal Earth model with terrain to calculate co-seismic effect

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Co-seismic deformation and stress changes, which reflect the elasticity of the earth, are very important in the earthquake dynamics, and also to other issues, such as the evaluation of the seismic risk, fracture process and triggering of earthquake. Lots of scholars have researched the dislocation theory and co-seismic deformation and obtained the half-space homogeneous model, half-space stratified model, spherical stratified model, and so on. Especially, models of Okada (1992) and Wang (2003, 2006) are widely applied in the research of calculating co-seismic and post-seismic effects. However, since both semi-infinite space model and layered model do not take the role of the earth curvature or heterogeneity or topography into consideration, there are large errors in calculating the co-seismic displacement of a great earthquake in its impacted area. Meanwhile, the computational methods of calculating the co-seismic strain and stress are different between spherical model and plane model.

Here, we adopted the finite element method which could well deal with the complex characteristics (such as anisotropy, discontinuities) of rock and different conditions. We use the mash adaptive technique to automatically encrypt the mesh at the fault and adopt the equivalent volume force replace the dislocation source, which can avoid the difficulty in handling discontinuity surface with conventional (Zhang et al., 2015). We constructed an earth model that included earth's layered structure and curvature, the upper boundary was set as a free surface and the core-mantle boundary was set under buoyancy forces. Firstly, based on the precision requirement, we take a testing model——a strike-slip fault (the length of fault is 500km and the width is 50km, and the slippage is 10m) for example. Because of the curvature of the Earth, some errors certainly occur in plane coordinates just as previous studies (Dong et al., 2014; Sun et al., 2012). However, we also found that: 1) the co-seismic displacement and strain are no longer symmetric with different latitudes in plane model while always theoretically symmetrical in spherical model. 2) The errors of co-seismic strain will be increased when using corresponding formulas in plane coordinate. When we set the strike-slip fault along the equator, the maximum relative error can reach to several tens of thousand times in high latitude while 30 times near the fault. 3) The style of strain changes are eight petals while the errors are four petals, and apparent distortion at high latitudes. Furthermore, the influence of the earth's ellipticity and heterogeneity and terrain were calculated respectively. Especially the effect of terrain, which induced huge differences, should not be overlooked during the co-seismic calculations. Finally, taking all those affecting factors into account, we calculated the co-seismic effect of the 2008 Wenchuan earthquake and its adjacent area and faults using the heterogeneous ellipsoidal Earth model with terrain.