19 Probing the Deep Rheology of Tibet: Constraints from 2008 $M_w$ 7.9 Wenchuan, China Earthquake

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19.1 Introduction

The 2008 $M_w$ 7.9 earthquake occurred at Wenchuan of Sichuan Province, China, and studies of the earthquake and its postseismic relaxation give us an opportunity to examine the rheology of east Tibet. The surface motion after a large earthquake is a response to the redistribution of stresses induced by the earthquake and can be used to probe the viscous strength of the upper lithosphere. Various processes can contribute to the postseismic deformation, such as aseismic afterslip, aftershock related deformation, viscoelastic relaxation in the lower crust/upper mantle, and poroelastic rebound. In this study, we consider the viscous relaxation due to the coseismic stress redistribution that would primarily affect the middle- to far-field surface deformation.

Figure 2.38: Wenchuan postseismic deformation from GPS. The arrows show horizontal motions, and colored circles are the vertical displacement (the scale is shown above). The inset shows the topographic contrasts between Tibet and the Sichuan basin (SB).

Figure 2.39: The slant range displacement along the profile in Figure 2.38. The mean SRD is the average of the dots representing extracted data from InSAR pair 2008/07/21-2009/09/08. The predicted model shows agreement with InSAR and GPS (projected to line of sight).

19.2 Method and Data

We apply an analytical solution (Pollitz, 1992) to calculate postseismic deformation due to viscoelastic relaxation of a layered spherical Earth, and include the effects of gravity and medium compressibility. Each layer can be represented with elastic or viscoelastic (Maxwell and Burgers) properties. In this study, the density, bulk modulus, and rigidity of each layer are based on the CRUST 2.0 model (http://igppweb.ucsd.edu/~gabi/crust2.html). The Wenchuan earthquake fault geometry is based on Shen et al., 2009, based on geodetic inversion of coseismic deformation. Our simplified fault geometry is composed of five segments with different slip rates, extends to a depth of 20 km, and runs along the 285 km Longmenshan fault zone oriented 229° (Figure 2.38).

Thirty one cGPS stations are deployed in eastern Tibet in the hanging wall of the Longmenshan fault zone. To obtain the first-year postseismic deformation, we fit the cGPS time series in terms of a linear least square fit with the assumption of zero displacement right after the main shock (Figure 2.39). We used more than 30 ALOS PALSAR L band (23.6 cm wavelength) data sets from May 2008 to October 2010 to measure the postseismic deformation. The ALOS PALSAR data from six paths (471-476) and seven frames (590-640) cover most of the Wenchuan postseismic deformation. All PALSAR data are processed using the software ROI PAC 3.0, and the 90 m SRTM DEM is used to correct the phase due to topography.
19.3 Results

All cGPS time series data show transient displacements in the horizontal and vertical components. The 1.5-year observations (Figure 2.38) show southeastward displacement in the SW and northeastward displacement in the NE Longmenshan. Most of the interferograms have strong topographic and ionospheric correlated noise and low coherence in the mountains. The mean slant range displacement (SRD) of one 2.5-year interferogram of track 474 (Figure 2.39) shows postseismic deformation comparable with the cGPS measurements.

The best fitting forward model suggests that a Burgers body based lower crust with a steady-state viscosity of $10^{19}$ Pa s and a transient viscosity of $4 \times 10^{18}$ Pa s, with a 20 km elastic upper crust, can represent the rheology of Longmenshan. Figures 2.39 and 2.40 show the predicted viscoelastic relaxation and the comparison with the InSAR and cGPS data, respectively. Figure 2.40b shows the temporal fitting of 4 out of 31 cGPS stations representing far-field, middle-field, and near-field deformation, respectively. The prediction is generally of the same scale as the data and better fits the middle- to far-field data. The poor fit to the near field might be because of the lateral heterogeneity in the boundary of the plateau and the basin, which is not considered in our 1D model. Neither afterslip nor poroelastic deformation, either of which could control the near-field postseismic deformation, are considered here.

Future work will focus on a reliable 3D rheological structure of eastern Tibet and the consideration of other processes such as afterslip and poroelastic deformation. Additional ENVISAT InSAR data will be considered in order to obtain the deformation in time series following the Wenchuan mainshock.

19.4 Acknowledgements

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19.5 References
