Spatial-temporal evolution and corresponding mechanism of the far-field post-seismic displacements following the 2011 Mw9.0 Tohoku earthquake

Zhao Qian (qianzhao411@126.com)， **Fu Guangyu**， **Wu Weiwei**

Institute of Earthquake Forecasting, China Earthquake Administration, Beijing 100036, China

2019IUGG
G06p-311

Introduction

Far-field post-seismic measurements can be used to invert the large-scale regional mantle viscosity, and the key point is whether the signal-to-noise ratio (SNR) of data is high enough.

Fortunately, some of the far-field GPS post-seismic measurements in Northeast Asia following the Tohoku earthquake possess high SNR quality, which can provide a unique opportunity on studying the overall mantle viscosity in Northeast Asia.

Moment adjustment of 2011 Tohoku earthquake

The co-seismic displacements of the Tohoku earthquake are derived from 41 GPS stations distributed in Northeastern China, South Korea, and Russian Far East (red arrows in Figure 1 left) . Then, the viscoelastic spherical dislocation theory developed by Tanaka et al. (2006, 2007) is employed, combining with the finite fault slip model of Wei et al. (2012), to simulate the co-seismic displacements of the Tohoku earthquake (blue arrows in Figure 1 left) .

The simulated co-seismic displacements are holistically smaller than the GPS observed ones, and we expect that the post-seismic displacements possess the same feature. So it is necessary to modify the seismic moment of Wei et al. (2012)'s fault slip model first.

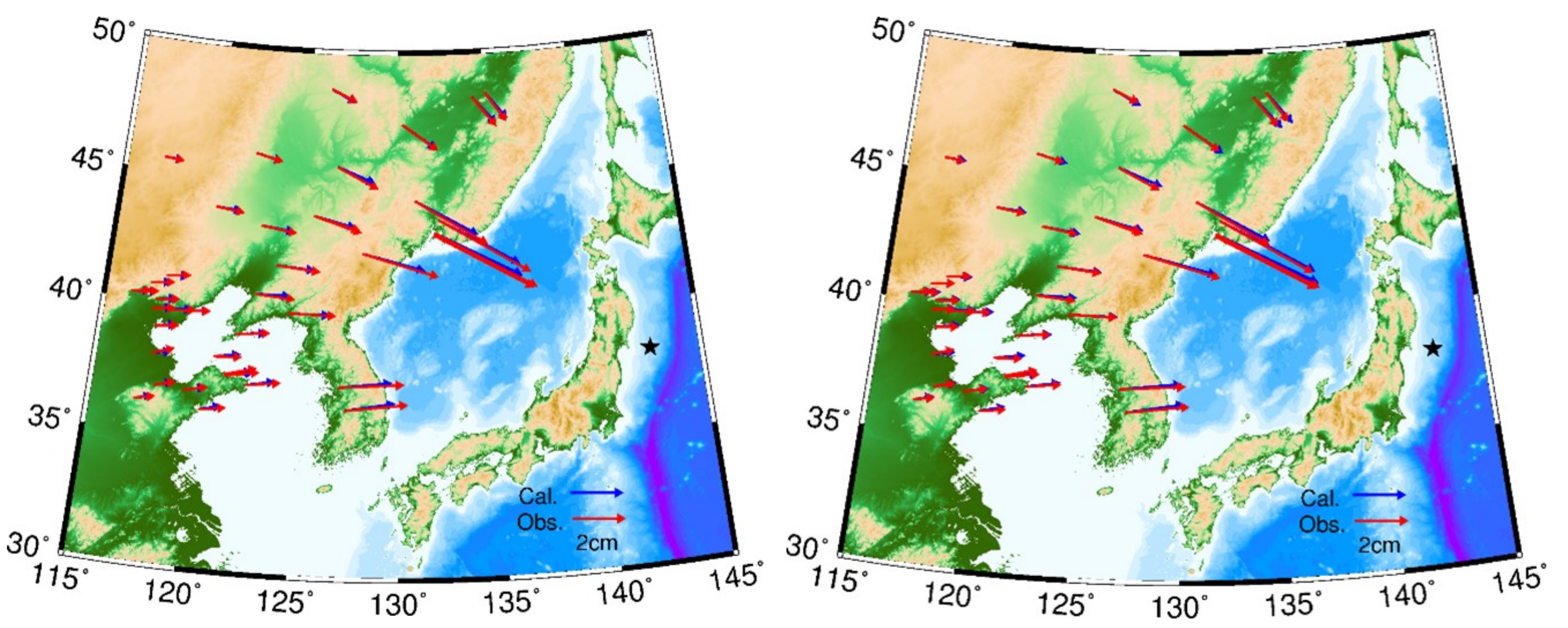

Figure. 1 Far-field horizontal co-seismic displacements of the 2011 Mw 9.0 Tohoku earthquake (left) and with the adjusted fault slip model (right).

The special processes are shown in Fu et al.(2012), the adjusted seismic moment of the Tohoku earthquake is 5.67×10^{22} Nm. Figure 1 (right) shows the horizontal co-seismic displacements from the GPS-derived solutions (red arrows) and the simulated results (blue arrows) by employing the adjusted fault model of the Tohoku earthquake. The consistency between observed and simulated results is improved upon the adjusted situation. We then apply the adjusted fault model to calculating the post-seismic deformations generated by the Tohoku earthquake.

Regional mantle viscosity

Based on (1) 9 GPS stations which are distributed perpendicular to the fault plane of the earthquake and have horizontal post-displacements with high SNR; (2) the viscoelastic spherical dislocation theory; and (3) the adjusted fault model of Wei et al. (2012), we estimate the overall mantle viscosity and the effective lithosphere thickness in the Northeastern Asia area by using the parameter search manner.

We assume that the effects of afterslip in the far-field are gone ~2.5 years later. The far-field post-seismic deformation within 0-2.5 years are jointly caused by both afterslip and the viscoelastic relaxation, while the post-seismic deformation during 2.5-4.5 years are mainly attributed to the viscoelastic relaxation of the earth.

Results

The viscosity is between (0.8-2.0) $\times10^{19}$ Pa·s, and the lithosphere thickness is between 20-50 km. We compute the RMS between the observed and simulated horizontal post-seismic displacements with different viscosities and lithosphere thickness, and the RMS is minimized at a mantle viscosity of 1×10^{19} Pa·s and a lithosphere thickness of 30 km.

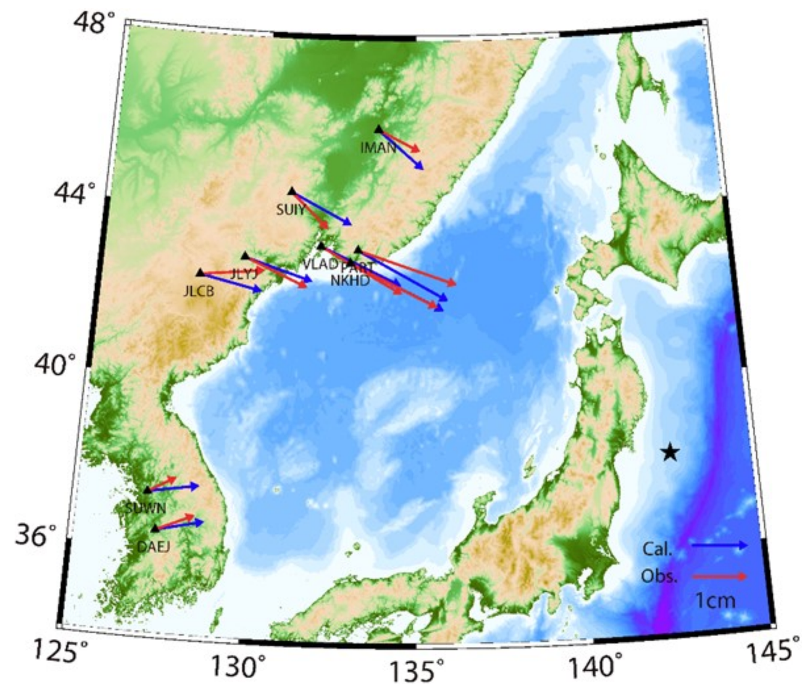

Figure. 2 Comparison between accumulated post-seismic deformations observed from nine far-field GPS stations and modeled from 2.5 to 4.5 years after the Mw9.0 earthquake. The red arrows indicate the GPS results; the blue arrows show the fitted results from the viscoelastic spherical dislocation theory at a viscosity of 1×10^{19} Pa·s

Spatial-temporal evolution characteristics

We recover the post-seismic deformation due to afterslip by comparing the simulations with the observations, separate the two post-seismic deformation effects (afterslip and viscoelastic relaxation).

As a whole, the far-field surface deformations caused by afterslip are greater than those due to viscoelastic relaxation within 0-0.5 years following the earthquake.

During 0-2.5 years following the earthquake, the far-field surface displacements due to afterslip and viscoelastic relaxation were generally equivalent.

The effects of afterslip are almost gone after 2.5 years according to the former assumption, whereas the contributions of viscoelastic relaxation increased with time.

The effect of mantle viscoelastic relaxation in the far-field is significant, and it cannot be neglected in the research of far-field post-seismic deformations, even in the immediately following the Tohoku earthquake.

Figure. 3 Post-seismic displacements from GPS observations (red arrows), and those due to the viscoelastic relaxation effect (blue arrows), and afterslip (purple arrows).