2011年東北沖地震の余効変動における粘弾性緩和と深部余効すべりの非線形相互作用

Nonlinear mechanical coupling between viscoelastic relaxation and deep afterslip in the post-seismic deformation of the 2011 Tohoku-oki earthquake

*武藤 潤[1]、Moore James[2]、Barbot Sylvain[2]、飯沼 卓史[3]、太田 雄策[4]、堀内 俊介[3]、岩森 光[3]
*Jun Muto[1], James Daniel Paul Moore[2], Sylvain Barbot[2], Takeshi Iinuma[3], Yusaku Ohta[4], Shunsuke Horicuhi[3], Hikaru Iwamori[3]

1. 東北大学大学院理学研究科地学専攻、2. 南洋理工大学、3. 海洋研究開発機構、4. 東北大学大学院理学研究科地球物理学専攻
1. Department of Earth Sciences, Tohoku University, 2. Earth Observatory of Singapore, Nanyang Technological University, 3. Japan Agency for Marine-Earth Science and Technology, 4. Department of Geophysics, Tohoku University

We conduct a two-dimensional analysis of the post-seismic deformation of the 2011 Tohoku-oki earthquake based on frictional afterslip and power-law viscoelastic relaxation. The simulation is performed using the integral method (Lambert and Barbot, 2016GRL) extended to plane strain (Barbot, Moore, and Lambert, 2017BSSA). The steady-state viscosity is based on the laboratory-derived flow law for dislocation creep and a subduction zone thermal flow model by Horicuhi and Iwamori (2016JGR). Afterslip is governed by the rate-strengthening friction approximation (Barbot et al., 2009JGR). When distributed and localized deformation are coupled the model explains the observed post-seismic deformation fields and its time series in the period from 2011 to 2016 (Tomita et al., 2017Sci. Adv.). Moreover, the model predicts the persistent occurrence of deep afterslip directly downdip of the main rupture regions that controls the post-seismic coastal uplift. The afterslip rate is consistent with previous estimates obtained from kinematic inversion and small repeating earthquakes (e.g., Iinuma et al., 2016Nature Comm; Muto et al., 2016GRL). However, the occurrence of deep afterslip was inconsistent with a recent review of the post-seismic horizontal motion (Wang et al., 2018Geoshpere). They summarized the previously published results on the occurrence of deep afterslip directly downdip of the main rupture region. Then, they pointed out that the deep afterslip is required by models without the subducting slab because the slab reduces the landward (westward) motion of the trench area (Sun and Wang, 2015JGR). However, our model with non-linear rheology and stress-driven afterslip proposes another mechanism for the occurrence of deep afterslip. With the nonlinear constitutive laws employed in the model, most of the stress relaxation occurs during a short period but the process continues at a slower rate for several years (e.g., Masuti et al., 2016Nature). The slow relaxation in the asthenosphere causes a continuous loading onto the plate boundary fault leading to the persistence of the deep afterslip directly downdip of the main rupture. Furthermore, mechanical coupling between viscoelastic relaxation and afterslip (i.e., viscoelastic flow triggered by the occurrence of afterslip and vice versa) changes the afterslip distribution and surface deformation. The effect of the coupling is most pronounced in the forearc region where the mantle wedge becomes weak enough to accommodate the deformation. This indicates that estimates of afterslip made from independent kinematic inversion and viscoelastic forward models may not capture the full complexity of the region.

キーワード：余効変動、東北沖地震、非線形レオロジー、余効すべり

Keywords: post-seismic deformation, Tohoku-oki earthquake, nonlinear rheology, Afterslip