# On the cause of enhanced landward motion of the overriding plate after the Tohoku-Oki earthquake

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During and after the Tohoku-Oki megathrust earthquake, geodetic observations showed that most of the overriding plate above the rupture zone moved oceanward. Enigmatically, the post-seismic motion of the overriding plate at hundreds of km along strike from the rupture zone became faster (in a landward direction) than before the event. Similar observations were made following other recent and large megathrust earthquakes. Previous studies interpreted these changes as the result of increased mechanical coupling along the megathrust interface or transient slab acceleration. However, before invoking additional mechanisms, we need to account for in-plane bending of the overriding plate which is an inherent feature of megathrust earthquakes. The aim of our study is to quantify the contribution of in-plane bending of the overriding plate and determine whether additional mechanisms are needed to understand the observations.

We use velocity-driven 3D mechanical finite element models, in which large megathrust earthquakes are taken to occur periodically on the finite plate interface. The model geometry is similar to that of the Tohoku-Oki and other present-day subduction zones, but does not exactly match any specific subduction zone.

The results show increased co-seismic and post-seismic landward motion at (trench-parallel) distances greater than 450 km from the edge of the rupture zone. Post-seismic velocities are controlled by both viscous relaxation in the mantle wedge and deep afterslip on the shear zone downdip of the brittle megathrust interface. Landward displacement due to postseismic relaxation largely accumulates at exponentially decaying rates until ~6 Maxwell relaxation times after the earthquake. The spatial distribution of the landward displacements is broadly consistent with observations at both the Tohoku-Oki and 2010 Maule the earthquakes. The magnitude of the velocity changes is similar to that of published secular velocity changes associated with the Maule event.

Further model experiments show that patterns of landward motion due to afterslip and to viscous relaxation are insensitive to the locking pattern of the megathrust. The locking distribution does affect the magnitudes of the displacements and velocities. The results show that the increased landward displacement due to postseismic deformation scales directly proportionally to seismic moment.

We conclude that the landward motion results from in-plane horizontal bending of the overriding plate and mantle. This bending is an elastic response to oceanward tractions near the base of the plate around the ruptured asperity, causing extension locally and compression further away along- trench. This elastic in-plate bending consistently contributes to earthquake-associated changes in surface velocities for the biggest megathrust earthquakes, producing landward motion along strike from the rupture zone. Additional mechanisms (e.g., increased mechanical locking or slab acceleration) may not be needed to explain the observations.

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