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Coseismic and interseismic displacements at a subduction zone - a parameter study using finite-element modelling

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Tide-gauge and geodetic measurements of coseismic and interseismic displacements in the forearc of subduction zones showed that the coastal region undergoes uplift during the interseismic phase and subsidence during the coseismic phase, while opposite vertical movements are observed in the neighbouring regions (e.g., Savage & Thatcher 1992; Hyndman & Wang 1995). Horizontal displacements during the interseismic phase are typically directed landward, whereas the forearc moves seaward during the earthquake (e.g., Klotz et al. 1999). Here we use two-dimensional finite-element modelling to evaluate how the friction coefficient along the plate interface, the length and the position of the downdip end of the locked zone affect the coseismic and interseismic displacements. Our model consists of a deformable, rheologically stratified upper plate and an undeformable oceanic plate, which rotates at a prescribed angular velocity (cf. Cailleau & Oncken, 2008). The frictional plate interface is divided – from the trench to the base of the continental lithosphere – into a seismogenic zone, a transition zone and a landward free slip zone. During an initial phase, the seismogenic zone is locked, which leads to the accumulation of elastic strain in the forearc. During the subsequent coseismic phase, the strain is released and causes sudden slip of several meters on the plate interface. During the next interseismic phase, the seismogenic zone is locked again. Our model results show patterns of vertical and horizontal displacements that are in general agreement with geodetically observed patterns. A sensitivity analysis reveals that the magnitude of the vertical displacements is strongly influenced by the friction coefficients of the seismogenic zone and the transition zone. The location of the zones of maximum interseismic uplift and coseismic subsidence in the coastal regions depends on the length and position of the locked zone. Preliminary results from three-dimensional models show that the lateral extent of the rupture zone also affects the direction of the coseismic surface displacements, as recorded by GPS stations during the 2011 Japan earthquake (Ozawa et al. 2011).

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