Modeling slow-slip events and their triggering by the Kaikoura earthquake along the Hikurangi subduction plate interface

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In the Hikurangi subduction zone, long-term (>1 year) slow-slip events (SSEs) occur at intervals of approximately five years along the deep (>25 km) southern margin, and short-term SSEs (2-4 weeks) occur at intervals of 1-2 years along the shallow (<10 km) northern and central margins. On November 14, 2016, the Mw 7.8 Kaikoura earthquake occurred in the northeastern portion of New Zealand’s South Island. This earthquake triggered a large, shallow SSE and a deep Kapiti SSE in the Hikurangi subduction zone. The dynamic stress changes in the shallow SSE zone were on the order of 100–600 kPa, but the static stress change in this zone was very small (0.2–0.7 kPa) (Wallace et al., 2017). Therefore, dynamic triggering caused the shallow SSE. On the other hand, static stress change in the Kapiti SSE was large (500 kPa), as this zone is very close to the source of the Kaikoura earthquake. The present study models various SSEs along the Hikurangi subduction zone and then considers the stress caused by the Kaikoura earthquake to investigate the mechanisms of triggered SSEs.

We model SSEs along the Hikurangi subduction zone using a rate- and state-dependent friction law with a cutoff velocity to establish an evolution effect. First, we reproduce short- and long-term SSEs by setting the effective stress and critical displacement (Dc) to approximately 1.0 MPa and 0.15 cm, respectively, for shallow, short-term SSEs and to approximately 5.0 MPa and 1.0 cm, respectively, for deep, long-term SSEs. We show that the long-term SSE in southern Hikurangi could have been triggered by static stress increases resulting from the Kaikoura earthquake.

We also try to model shallow SSEs caused by dynamic triggering. For simplicity, we consider only the zone of shallow SSEs, and we simulate cycles of these events. We use large values of Dc and effective stress for the southern section to reproduce the longer recurrence intervals. Then, we give a stress perturbation that is a sine function of time and that propagates from south to north. Just after the perturbation, the slip velocity increases, and then slips continue to occur. In the southern section in particular, a triggered SSE can continue for a long duration, which is consistent with the observations. Our results suggest that the southern section of the shallow SSE zone has a larger fracture energy (i.e., larger Dc and effective stress) than the northern section has.

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