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# Long-term acceleration of aseismic slip prior to the 2011 M9 Tohoku-oki earthquake: Constraints from repeating earthquakes

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A very long-duration deformation transient that spanned the period 1996-2011, prior to the M9 Tohoku-oki earthquake, was reported from continuous GPS observations in northern Honshu, Japan (Mavrommatis et al., 2014; Yokota and Koketsu, 2015). The transient was interpreted as accelerating aseismic slip on the Japan Trench megathrust, i.e. a decadal-scale transient slip event. Here we use independent observations of small repeating earthquakes that occurred on the megathrust to test for the GPS-inferred accelerating slip and improve its spatial resolution.

We test whether sequences of repeating earthquakes exhibit a statistically significant monotonic trend in recurrence interval by applying the nonparametric Mann-Kendall test. Offshore northern Tohoku, all sequences that pass the test exhibit decelerating recurrence, consistent with decaying afterslip following the 1994 M7.7 Sanriku earthquake. On the other hand, offshore south-central Tohoku, all sequences that pass the test exhibit accelerating recurrence, consistent with long-term accelerating creep prior to the 2011 9 earthquake. Using a physical model of repeating earthquake recurrence, we produce time histories of cumulative slip on the plate interface. After correcting for afterslip following several M$\sim$7 earthquakes in the period 2003-2011, we find that all but one sequence exhibit statistically significant slip accelerations. Offshore south-central Tohoku, the estimated slip acceleration is on average 2.9 mm/yr$^2$, consistent with the range of 2.6-4.0 mm/yr$^2$ estimated from independent GPS data (Mavrommatis et al., 2014).

From a joint inversion of GPS and seismicity data, we infer that a substantial portion of the plate interface experienced accelerating creep in the 15 years prior to the M9 Tohoku-oki earthquake. The large slip area of the Tohoku-oki earthquake appears to be partly bounded by accelerating creep, implying that most of the rupture area of the Tohoku-oki earthquake was either locked or creeping at a constant rate during this time period.