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Constraint on the seismic cycle of the 2011, Mw 9 Tohoku-Oki earthquake region (East Honshu, Japan) from coastal uplift and active deformation

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The strain accumulating between M9-class earthquakes is a major component of the active deformation and seismic cycle at plate boundary zones. Recent geodetic and seismotectonic work constrained the ∼500-km-long 2011 Tohoku megathrust rupture and related slip distribution. Field investigations along coastal regions of northeast Honshu indicate late Quaternary uplift reflecting seismic coupling on a segmented Japan subduction zone.The tectonic process shows 0.2 and 0.4 mm/yr uplift rate of Quaternary marine terraces in northern Tohoku, and 0.1 – 0.2 mm/yr along the Sanriku and southern Tohoku coastline. Holocene benches and notches reveal ∼1.1 mm/yr uplift rate in northern Tohoku which denotes clear upheaval acceleration during late Quaternary. Previous work assessed the palaeotsunami record in the last 7 kyr on the Sanriku and Sendai coastline and constrained the 500 – 800 years recurrence interval of palaeoearthquakes.

The correlation between the short-term geodetic results and long-term (late Pleistocene-Holocene) geologic data is decisive for understanding the tectonic process and related earthquake cycle on the subducting Pacific slab. While up to 1.2 m of coseismic subsidence was recorded after the 2011 earthquake by leveling and GPS data, postseismic GPS measurements (from 15 selected coastal stations covering northeast Honshu) display up to 30 cm uplift over the following 2.5 years. The coseismic subsidence is compared to the GPS measurements at each station. Extrapolating the logarithmic decay of postseismic uplift, it suggests a total accommodation of an average 0.55 m coastal subsidence within 500 to 700 years. The millennial active deformation from terrace uplift and recurrence of M9-class earthquakes illustrate the relationship between subsidence and uplift in northeast Honshu.

An inversion of the co-, post- and long-term slip distribution models how the successive coastal subsidence during M9-class earthquakes is concealed by the interseismic uplift due to deep (> 50 km) slab deformation. The consistent long-term uplift with postseismic deformation compared with the coseismic subsidence in coastal Honshu and Tohoku region provides a better understanding of the seismic cycle associated with an M9-class subduction zone earthquake.