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# An estimate of fluctuating plate subduction velocities caused by tidal modulations and decadal variations in the ocean

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Non-volcanic tremors and slow slip events have been detected in plate subduction zones. The source areas of these events are distributed in the transition zone located below the seismogenic zone, where high-pressure fluids supplied from the dehydration of the subducted slab are decreasing the effective normal stress. Consequently, extremely small external stress disturbances can trigger such events. Actually, variations in the tremor rate synchronized with diurnal and semi-diurnal tides have been observed. In our previous study, a model to predict long-term variations in the tremor rate was constructed by considering modulations of diurnal and semi-diurnal tidal amplitudes in decadal time scales. Tremors and slow slips arise from slips on a plate boundary, so long-term variations in the occurrences of these events generate a fluctuation of a plate subduction velocity. By applying the model to the Nankai area in Japan, it was found that the calculated tremor rate well corresponded to the long-term seismicity. However, in their model, tidal and non-tidal ocean effects were not separated because observed tidal levels were used. Some past studies estimated such non-tidal climatic effects on the seismogenic zone and concluded that the stress changes were insufficient to trigger earthquakes. However, if considering the high sensitivity of the transition zone, smaller stress changes can fluctuate a subduction velocity, which may eventually trigger earthquakes. In this study, employing an ocean model developed by the Japan Meteorological Agency, the effects of non-tidal ocean variations on such a fluctuation of slip rate are estimated for the first time. The result indicates that the non-tidal effects are larger than the tidal effects in some regions. The fluctuation of slip rate computed for a frictional parameter determined by observations of tremors exceeds 1 mm/yr at annual average in decadal scales, and periods with faster rates agree with some variations in seismicity. To quantitatively confirm if such slip variations are sufficient to trigger large earthquakes, incorporating the stress disturbances into numerical simulations of earthquake cycles is necessary.

Keywords: tides, slow slip, tremors, earthquake, seismicity, subduction zone