Implications of Precise Tremor Event Location for the Mechanism of Deep Nonvolcanic Tremor

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Nonvolcanic tremor has been observed in southwest Japan and Cascadia to coincide temporally with large slow slip events on the plate interface downdip of the seismogenic zone. However, the exact relationship between tremor and aseismic slip remains uncertain, largely due to difficulty constraining the source depth of tremor. Here, we locate low-frequency tremor events that occur as part of deep nonvolcanic tremor sequences in the western Shikoku region of the Nankai trough subduction zone in southwest Japan. These tremor events, designated as low-frequency earthquakes in the seismic catalog, are energetic portions of tremor where phase arrival times can be estimated at several stations. We use a combination of double-difference tomography and waveform cross-correlation to determine precise hypocenters and high-resolution velocity structure in this area. In total, we relocate 6713 events occurring between June 2002 and June 2005, including 1180 low-frequency events, using waveforms from 112 seismic stations operated by NIED, JMA, University of Tokyo, and Kochi University. P- and S-wave arrival times are provided by JMA.

Despite low signal to noise ratios and sometimes-indistinct arrivals for recordings of the tremor events, the waveform similarity is high enough that they can be successfully relocated. Starting with only a rough estimate of the P- or S-wave arrival time, we are able to obtain very precise differential travel time measurements by cross-correlating similar waveforms from two events at a given station. Among the tremor events, S-wave correlations are particularly successful, due to the greater amplitude, and thus greater signal to noise ratio, of the S-wave recordings compared with those of P-waves. We also obtain successful correlations between some tremor events and normal earthquakes, thereby helping to locate the tremor events relative to the regular intraslab seismicity. The larger S-wave amplitudes and the ability to correlate the tremor events with normal seismicity suggest that they represent shear failure.

We find that the tremor events locate along a distinct plane at 35-40 km depth, which we interpret as the plate interface. This plane is 5-8 km above, and dips approximately parallel to, the seismicity within the subducting Philippine Sea slab. While it's unclear what portion of tremor these events compose, the locations and earthquake-like signals of the tremor events suggest that they result from shear slip on the plate interface during otherwise aseismic transients. High pore fluid pressure in the immediate vicinity of tremor, as implied by our estimates of seismic P- and S-wave speeds, may promote this transient mode of failure. If our interpretation is correct, nonvolcanic tremor events could provide a new means of detecting and precisely monitoring slow slip at depth.