Epicenter of large subduction-zone earthquakes is often used as a reference point for finite-fault 
versions and back-projection mapping. However, these earthquakes generally lack regional seismic stations in the offshore direction leading to diverse epicenter estimates. Here we use the differential timing between the water phase reflected from the air-water interface and the depth phase reflected from the water-crust interface to locate a master earthquake using the well-known ocean bathymetry. After calibrating teleseismic arrays (30° to 90°) at short periods for timing and amplitude with respect to the master event, we are able to study the beginning 4 sec of teleseismic body waves of the great 2011 Tohoku-Oki earthquake, which began with a thrust event (Mw = 4.9) located at 38.19N, 142.68E at a depth of about 21 km.

The 2008 master earthquake

The 2008 master earthquake inverted by global CMT, the beginning of the great Mw = 9.0 Tohoku-Oki earthquake by Zhao et al. (2011).

The 2011 Tohoku-Oki earthquake

Figure 5. Sensitivity test on epicenter locations using composite finite-fault versions of GPS and teleseismic P-waveform data. Map view of slip models are played in black and red waveforms, respectively. The 2011 Tohoku-Oki earthquake has a mechanism with strike/dip/rake of 200°/18°/90° at a depth of 21 km.

Discussion

Locating the 2011 Tohoku-Oki earthquake

Discussion

Figure 4. Focal mechanism and relocation for the beginning of the main rupture. (A) Comparison of waveforms at 0.2-2.0 Hz for the mainshock's black and the master earthquake's red for a sample of 5 teleseismic stations. All seisograms are aligned with IASPEI91 predictions using the refined location for the master event and NEIC location for the mainshock. Since beginning of the mainshock has the magnitude 0.4 smaller than the master event, all black traces are multiplied by 2.5 to display accurately. Black and red vectors denote arrival times of the mainshock and master event, respectively. (B) Comparison of data for the first 2.5 sec from these two earthquakes aligned with IASPEI91 predictions. The seisograms are normalized to the maximum amplitudes. The epicenter of mainshock is refined location. Waveforms from the master earthquake and the mainshock match very well, which confirms the accuracy of refined location. (C) The first 4 sec of 82 recorded seismograms are displayed in black and red waveforms, respectively. The number after the name is the azimuth, the lower numbers indicate the distance in km and initial timing in seconds followed by two numbers indicating time shift and the CC. Each seisgram has been corrected by the AAFs from the master event. A maximum shift of 1.0 sec is allowed and the solution with strike/dip/rake at 191°/123°/90° is obtained. (D) Relative travel time residuals of the mainshock with respect to the master event is shown as black dots. Red dots denote residuals correctly with respect to the new location given as the red star in Figure 1.