Strain release by "rapid" aseismic slip at the Izu-Bonin trench

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Abstract
No great earthquakes have been historically documented at the Izu-Bonin Trench, where subduction is believed to be taken up largely by aseismic slip, although the detail of the slip process has been poorly known. We deployed an array of ocean bottom pressure gauges and a broadband ocean bottom seismometer with a differential pressure gauge inward of the northern Bonin Trench for a year from May 2015 (Fig.1). The array recorded pressure changes associated with the sudden uplift/subsidence of the seafloor caused by the nearby Mw6.0 thrust earthquake (01/Sep/2015), and the consequent generation and propagation of sea surface disturbance (tsunami) (Fig.1). The records were inverted for the slip distribution of the mainshock (Fig.1). The inversion result was consistent with the seismic moment of the reported CMT solution, indicating that the mainshock was an ordinary event, not a tsunami earthquake. The records in a longer time window, however, showed the co-occurrence of aseismic slip with a characteristic time on the order of 5000 s (Fig.2). The similar aseismic slip recurred 3.5 days after the mainshock which was abruptly accelerated upon the occurrence of a small aftershock (Fig.3). Both of the aseismic events occurred mainly on the deeper extensions of the coseismic slip. The total seismic moment of the mainshock and two aseismic events was more than an order of magnitude larger than that of the mainshock, while the resultant stress drop was similar to that of the mainshock (~1 MPa). "Rapid" aseismic slip (a characteristic time of ~5000 s with a relatively low stress drop of ~1 MPa) may be a phenomenon that bridges the gap between geodetic SSEs (slow slip events) (a few days or longer in duration with stress drops of 0.01 to 0.1 MPa) and seismic earthquakes (a few minutes or shorter in duration with stress drops of 1 to 10 MPa). This new mode of slip may play a significant role at the Izu-Bonin Trench and possibly in other Mariana-type trenches.

Figure captions:
Figure 1. Top right: Source region and reported focal mechanisms of the Mw6.0 earthquake of 01/Sep/2015 near the Izu-Bonin trench and the location of the APG (Absolute pressure gauge) array. The slip distribution at the source is the result of the tsunami waveform inversion from the APG data. **Bottom right:** Cross-section across the trench showing the seismologically estimated plate boundary with the presumed hypocenter and mechanism of the Mw6.0 earthquake on it. The site distribution of the array is also shown. **Left:** Lowpass-filtered, tide-removed pressure record at station B10 showing the seafloor uplift and the consequent tsunami due to the Mw6.0 mainshock. The observed and synthetic traces are shown in black and red, respectively. The M5.6 foreshock which took place 1 min before the mainshock is not taken into account in the synthetic calculation.

Figure 2. Lowpass-filtered, tide-removed pressure records at eight stations of the APG array over a time window of 80000 s including the 01/Sep/2015 earthquake in the middle. The records show co-seismic and post-seismic vertical displacements of the seafloor, based on which the co-seismic slip and post-seismic slip along the plate boundary are estimated, including the characteristic time of the post-seismic slip. The resultant model curves of seafloor displacement are compared with the observed

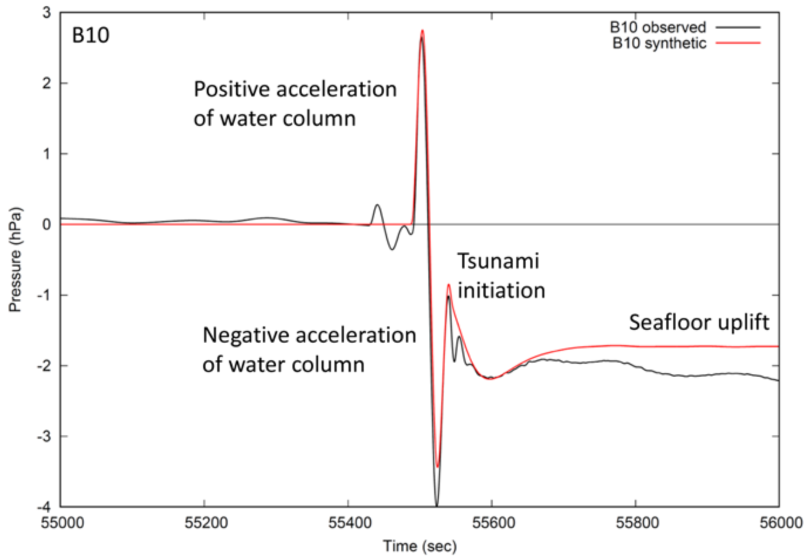
records.

Figure 3. Tide-removed pressure records at eight stations of the APG array over a time window of 80000 s including the 05/Sep/2015 small aftershock in the middle. The records show aseismic uplifts of the seafloor which are apparently accelerated upon the occurrence of the small aftershock. The aseismic slip along the plate boundary is estimated and the resultant model curves of seafloor displacement with the characteristic times different before and after the small aftershock are compared with the observed records.

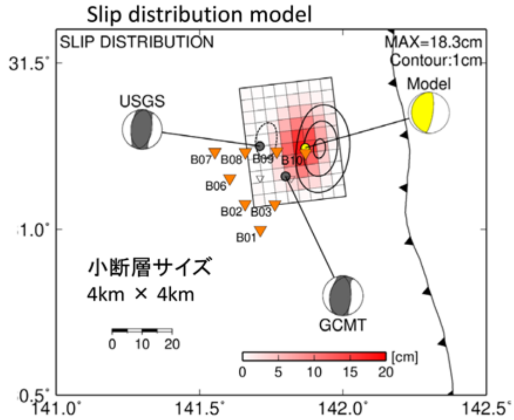
Keywords: Ocean bottom seismology, Tsunami, Aseismic slip, Ocean bottom pressure observation

Figure 1

Comparison of observed and synthetic pressure records at B10



Slip distribution model



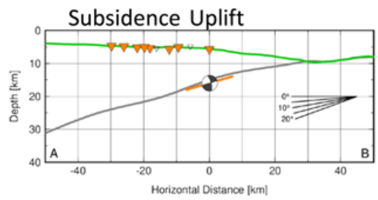
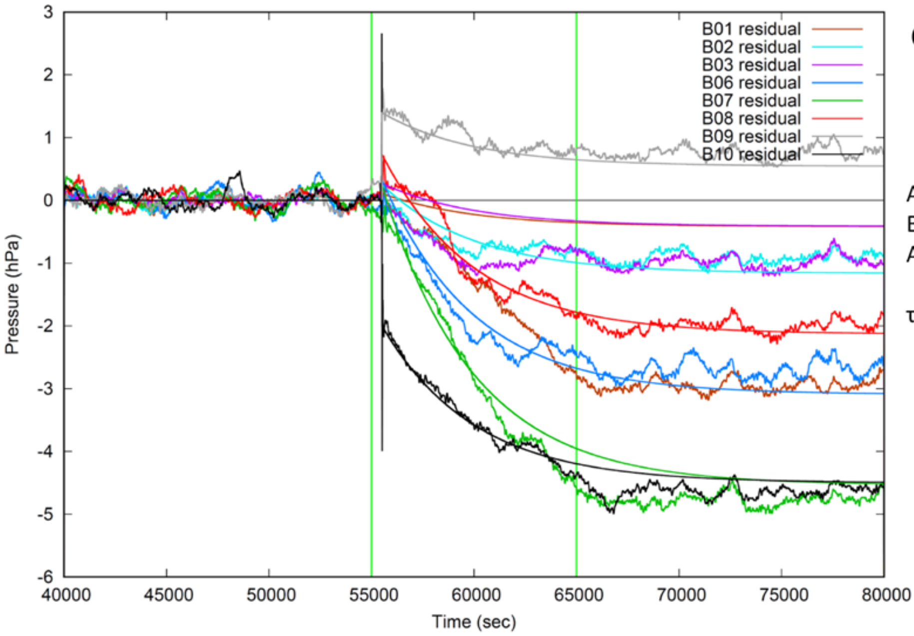


Figure 2

Seafloor uplift due to post-seismic slip



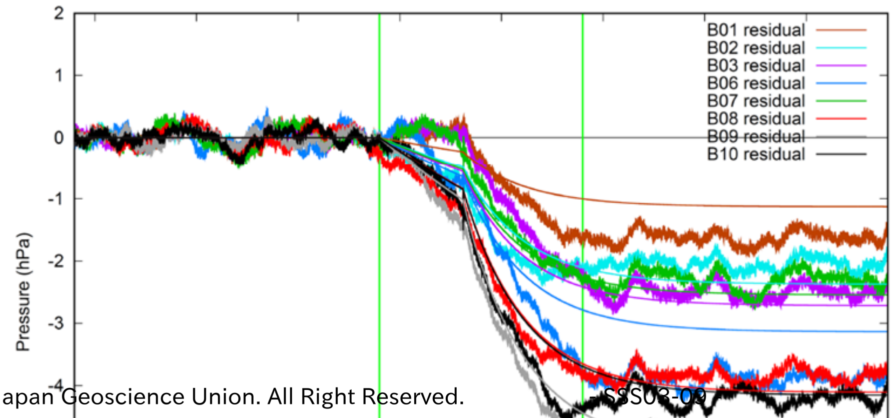
Curve fitting by

$$f(t) = A + B(1 - e^{-\frac{t}{\tau}})$$

A: Coseismic seafloor displacement
B: Post-seismic seafloor displacement
A+B: Resultant seafloor displacement
= Baseline offset
τ: Time constant of aseismic slip
Here, τ = 4500 s.

Figure 3

Seafloor uplift due to aftershock-associated aseismic slip



Pre-aftershock stage

$$f(t) = A\left(1 - e^{-t/\tau1}\right)$$

$0 \le t \le t1$

Post-aftershock stage

$$f(t) = A\left(1 - e^{-t1/\tau1-(t-t1)/\tau2}\right)$$

$t1 \le t$

t1=4100 s: Aftershock origin time

Here, τ1 = 18000 s, τ2 = 3000 s,