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An Attempt to Detect Transient Crustal Deformation from Ocean Bottom Pressure Gauge Data Using Principal Component Analysis

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Ocean Bottom Pressure gauges (OBPs) are devices installed on the seafloor to continuously measure ocean bottom pressure. They are expected to detect vertical seafloor crustal deformation caused by transient tectonic events. However, OBP data contain pressure changes originating from various sources other than tectonic events, such as ocean tides, non-tidal fluctuations due to meteorological and oceanic variations, and instrumental drift. We need to remove these non-tectonic components to identify the pressure changes related to vertical crustal deformation. However, the timescale of non-tidal fluctuations (ocean noise) is similar to that of transient tectonic signals, such as slow slip events (SSEs), which makes it difficult to separate these components.

Otsuka et al. (2023) applied principal component analysis (PCA) to seafloor pressure data obtained by an OBP array to detect transient events, assuming that pressure changes due to transient events cause temporal fluctuations in the PCA results. To verify the performance of this method, they applied PCA to synthetic data and confirmed that the method can detect temporal changes in the composition of principal components (PCs). In the present study, we apply this method to OBP data obtained before the 2011 Tohoku earthquake, which includes transient events resulting from aseismic slip, as reported by Ito et al. (2013), to verify whether we can identify the event through temporal changes in the PCs decomposed from the OBP data. We performed PCA on de-tided OBP data covering about four months before the Tohoku earthquake using a short sliding time window, to examine temporal variations in the PCs.

Changes in the PCs were evaluated using the normalized inner product (NIP) of the eigenvector of each PC (Otsuka et al., 2023), which measures the difference in the direction of the vector. We expect the NIPs to be stable if the OBP data do not contain any transient events, whereas evident changes in the NIPs of more than one PC would occur when transient pressure variations are included in the data. In the present study, the NIPs of PC1 (the most significant component) and PC2 (the second most significant component) remained stable over time, whereas the NIPs of PC3 and PC4 began to decrease as the moving window (60-day length) approached late January 2011 and remained low for about 40 days. Based on a comprehensive analysis of seismic and geodetic data, including the same OBP data, Ito et al. (2013) reported that an SSE lasted for about 40 days

from late January 2011. The NIP changes detected in the present study may correspond to pressure changes due to this transient event.