Detecting short-term slow slip events using six-year records of ocean bottom pressure in Hikurangi subduction zone offshore New Zealand

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Over the last decades, ocean bottom pressure gauges (OBPG) have been widely deployed in the world to measure seafloor crustal deformation due to tectonic events, such as short-term slow slip events (SSE). However, adequate techniques to detect SSE in OBPG data have not been well-established, because some pressure changes due to oceanographic effects can be difficult to distinguish from those due to crustal deformation processes. A common approach to address this is a reference-station method which utilizes pressure records from a reference station outside of the deforming zone under the assumption that the non-tidal components are common-mode over a large region (e.g., Wallace et al., 2016). Fredrickson et al. (2019) recently demonstrated greater coherence in bottom pressure changes observed between sites in similar water depths offshore Cascadia, leading them to suggest a method of placing reference sites at common isobaths to achieve large reductions in oceanographic noise in OBP timeseries. Here, we attempt to develop a new method for the detection of SSE using the reference-station method in conjunction with onshore continuous GNSS and OBP records for data acquired for 6 years between 2014-2019. First, we obtain a continuous time series record calculating the difference between OBPG sites in the combination of all observation sites (hereinafter referred to as a site-pair) using the reference-station method. Next, the ΔAIC method (Nishimura et al., 2013) used in previous studies (e.g. Nishimura et al., 2013) is applied to the obtained differenced time series records (in conjunction with the continuous GNSS records) as a method to detect the seafloor crustal movement caused by SSE. A value of ΔAIC is calculated by subtracting a pair of AICs calculated from fitting with a simple linear trend and fitting with the combination of a linear trend and a step function(Akaike information criterion, Akaike 1974). The average ΔAIC for each day is calculated by averaging the daily ΔAICs for that day obtained from the time series records of all station pairs. We apply DEFNODE (McCaffrey, 1995, 2002) to use relative vertical displacements from the site pairs; we estimate a slip distribution from minimizing the reduced χ^2 value between the observed and model values. We use the average ΔAIC and χ^2 value as the detection thresholds, and classify the date as a Class 1 event if the average ΔAIC and χ^2 are less than -10 and 0.5, respectively. The dates with either threshold below -10 and 0.5 are classified as Class 2 events.

Two Class 1 events are detected twice in 2014 with a duration of less than a month (e.g., about 265-290 days in Julian dates of 2014); the 265-290-day event in 2014 is generally consistent with the duration of SSEs derived from land GNSS and ocean bottom pressure records (Wallace et al., 2016). Meanwhile, two Class 2 events are detected twice with a duration of a few tens of days. Some of the Class 2 events (e.g., 235-255 days and 300-310 days) are events that have not been reported in previous studies. These may be new seafloor crustal movements associated with SSEs that have not been previously identified from the onshore GNSS observation network alone, or they may represent regional oceanographic changes. In the future, we plan to conduct a quantitative evaluation of spatial resolution by means of resolution tests.

Keywords: ocean bottom pressure, seafloor crustal deformation, Slow slip events

