Isolating oceanic contributions to ocean bottom pressure observations by using numerical ocean models to detect transient seafloor displacements

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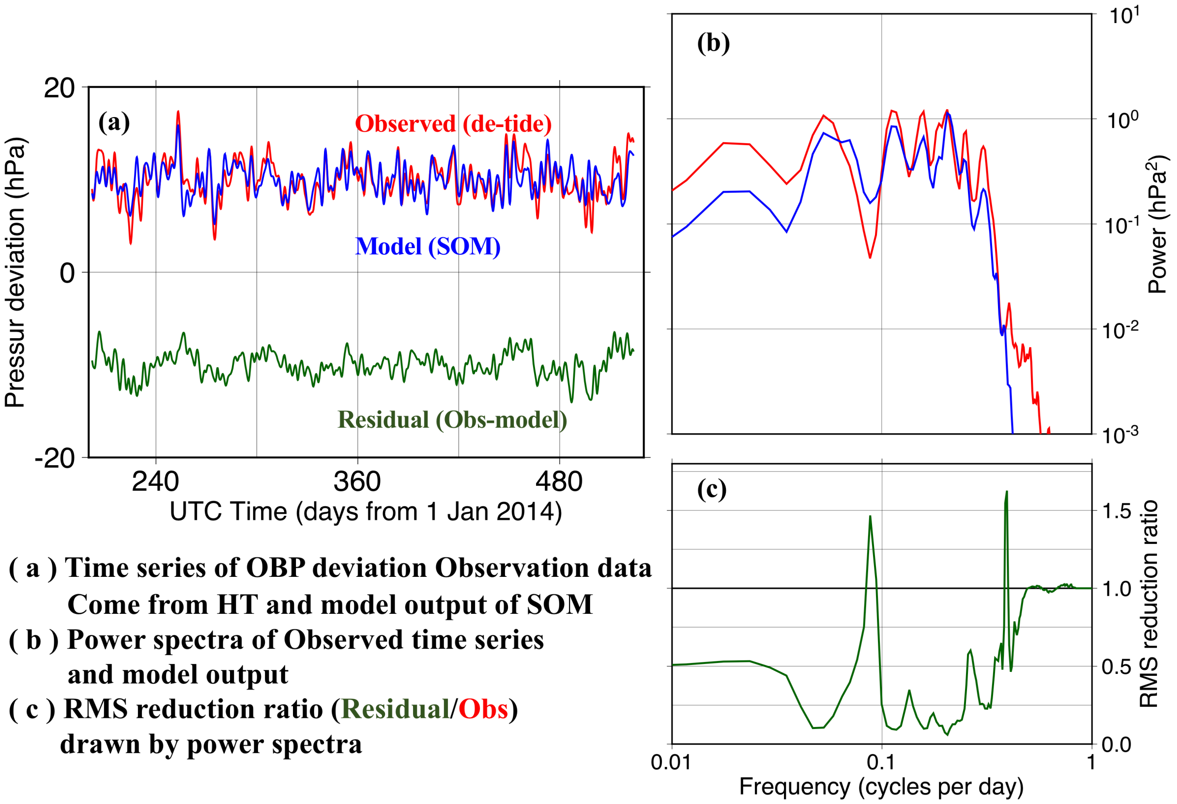
The purposes of Ocean Bottom Pressure (OBP) observations are diverse, mainly physical oceanography and marine geodesy. OBP gauges record phenomena on various temporal variations by long-term continuous and detectability of sub-centimeter changes of water column height just above them. Focusing on seafloor deformations, there are expectations for detecting cm-scale vertical seafloor displacements associated with slow earthquakes because slow earthquake events are highlighted as clues to understand huge earthquakes (Mw8+). 1hPa pressure change is almost equivalent to 1cm seafloor displacement under the hydrostatic condition, so 1hPa pressure decreasing can be interpreted 1cm seafloor uplift. Although OBP gauges have potential to resolve cm-level seafloor displacement, it isn't easy task to detect signals precisely because OBP time-series contain overlying lots of components, so we should isolate some signals as noise. Especially, non-tidal oceanic variation and mechanical drift are definitive contributions to mask earthquake signals from the point of amplitude and temporal scale (days to tens of days).

In this research, We focused on isolating non-tidal oceanic contributions by using several numerical ocean models. Ocean modeling has hardly ever been used to calculate OBP, however comparison has begun with expanding of OBP observation (e.g. Muramoto et al., 2018; Fredrickson et al., 2019). We show the applied models in this research as follows; #1 HYCOM (Cummings et al., 2013), #2 GLORYS (Ferry et al., 2010), #3 JCOPE2M (Miyazawa et al.,2017), #4 ECCO2 (Menemenlis et al., 2011), #5 Single-layer Ocean Model (SOM) (Inazu et al., 2012). Each model except #5 has tens of vertical layers to explain pycnocline. Horizontal resolution of model #1, #2, #3, #4 is 1/12° (about 10 km), though 1/4° is employed for model #4, also output from #3 is available only in Northwest Pacific. Model skills of each models were compared by amplitude after subtracting modeled ocean variations from observed OBP time series. We employed RMS noise level (3 σ) and power spectrum of the observed OBP for evaluating the model skills. We compiled OBP datasets (10~12months) from several subduction zones around Pacific rim (Japan Trench (JT) 19 sites, Nankai Trough (NT) 51sites, Hikurangi Trough (HT) 7sites, Cascadia subduction zone (CSZ) 27sites, Chile trench (CT) 5sites).

We report that there were different characteristics of noise correction ability within 5 models for each region. Especially in HT, we can see the high predictability of SOM driven by wind stress and sea level pressure in short periodic band (shorter than 20 days) than other models driven by wind stress and heat/freshwater flux (e.g. 3 σ comparison; before model correction 6.24cm; after SOM correction 3.57cm; after HYCOM correction 4.65cm). This result implied that OBP variations of HT is significantly affected by sea level pressure, actually HT is located under the effect of low-pressure zone around Antarctica which causes strong synoptic scale atmospheric disturbance. Based on this result, We calculated wind stress and sea level pressure driven OBP variations separately using the SOM framework. After confirming the linearity of wind stress and sea level pressure to OBP variation, we combined multi-layer model output and sea level pressure driven OBP from SOM, then compared with observations. As a result, We got better noise correction ability from all multi-layer models combined with sea level

pressure component in HT (e.g. GLORYS wind 4.88cm; wind + prs 4.02 cm). In addition to the HT case, comparison in NT also showed large contributions of sea level pressure to OBP variations because all models became to be improved by combining sea level pressure component. From this result, We concluded sea level pressure contribution as well as wind stress should be considered in order to predict consistent OBP variations and contribute to detect centimeter-scale vertical seafloor displacements.

Keywords: Crustal deformation, Ocean Bottom Pressure , Numerical Ocean Modeling



(a) Time series of OBP deviation Observation data Come from HT and model output of SOM
(b) Power spectra of Observed time series and model output
(c) RMS reduction ratio (Residual/Obs) drawn by power spectra

