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Tidal Calibration of Borehole Strainmeter Using Green's Functions at the Deployment Depth

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Geological Survey of Japan, AIST deployed 11 Ishii's borehole strainmeters and four Gladwin Tensor Strainmeters (GTSM) for the prediction researches of the Tonankai and Nankai earthquakes. These strainmeters equip four gauges at different azimuths in horizontal plain, and deployed with grout at the bottom of the borehole. The observed strain is different from the strain in the surrounding rocks because of inclusion of host rocks, grout and housing of strainmeter at the deployment depth. We apply in-situ calibration methods for observed strain using calibration matrix determined by response of each gauge to the Earth tides (Gladwin and Hart, 1985; Roeloffs, 2010).

For the in-situ calibration of the borehole strainmeter, amplitudes and phases of M2 and O1 tidal constituents are extracted from the borehole strainmeter data, and then the extracted tidal amplitudes and phases are compared with M2 and O1 constituents of theoretical tidal strain which are estimated by software packages such as GOTIC2 (Matsumoto et al, 2001). In these software packages, amplitudes and phases of theoretical M2 and O1 tidal strain are calculated from the solid Earth tide and oceanic tidal loading. These software packages usually use green's function at surface observation for the surface point load to calculate tidal strain caused by oceanic tidal loading. However, Kamigaichi (1998) showed significant difference between green's function at depth = 0 and that at depth > 0. Kamigaichi also modified the GOTIC2 program to apply the green's function at arbitrary depth to the calculation of theoretical strain caused by the oceanic tidal loading.

We calculated theoretical tidal areal strain at ICU observation site whose distance from the coast is about 150m. We found that the theoretical tidal areal strain calculated by the modified GOTIC2 is about four times of that calculated by the original GOTIC2 at ICU, and the areal strain calculated by the modified GOTIC2 is consistent with the areal strain observed by borehole strainmeter.

We obtain calibration coefficients using one of the calibration methods as follows:
(i) Calibration method #1 "isotropic coupling model" (Gladwin and Hart, 1985; Hart et al., 1996; Roeloffs, 2010) : for four Ishii' s and one GTSM.
(ii) Calibration method #2 "isotropic coupling + shear coupling + vertical coupling" (Roeloffs, 2010): for six Ishii' s and three GTSM.

We observed long-period surface wave produced by the 2010 Chile earthquake (Mw 8.8) by these borehole strainmeters. In order to verify the calibration matrix produced by tidal signals, we apply the calibration matrix for the observed strain of the long-period surface wave. We compare the observed strain wave with no calibration and that after the calibration with the theoretical strain wave. Observed strain waves after the calibration are relatively consistent with theoretical strain waves.

We estimate fault models of two slow slip events (SSE) occurred at March 20-21 and February 7-9, 2009 using both strain data with no calibration and that after the calibration. The fault models of the two SSEs estimated by strain data after the calibration are similar in location and dimension to those estimated by strain data with no calibration. However, the slips of the fault models estimated from strain data after calibration are less than one half of those with no calibration.