Pilot seafloor borehole tilt observation in the Nankai Trough seismogenic zone: development for future array network observation for slow slip events.

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Monitoring seismogenic zone under the seafloor in the Nankai Trough with seafloor cable observation network has been practical after the development of DONET (Dense Oceanfloor Network for Earthquake and Tsunamis). The seafloor observation sensor for DONET is a broadband seismometer (Guralp CMG3T), a strong motion accelerometer (Metrozet TSA100) to monitor earthquakes and slow earthquakes in broadband and wide dynamic range, as well as pressure sensors to monitor Tsunami and vertical seafloor movement associated with earthquakes. The DONET also has an ability to expand seafloor network for new sensors with its underwater connections, and new sensors has been connected since 2013. Current DONET systems have 96 seafloor sensor connectors and only 51 has been occupied by the original DONET seafloor sensors. Connection of sensors installed in three deep boreholes at IODP Sites C0002, C0010, C0006 drilled in International Ocean Discovery Program, to the DONET further expanded our sensitivity to slower events such as slow slip events of a few weeks period (Araki et al., 2017). Our current effort to expand the ability of the seafloor cabled network DONET is to develop seafloor sensor system that has ability to detect such slow slip events as detected by deep borehole observatories.

The sensor system which we conceived consists of a tiltmeter in shallow (5-20 m deep) borehole to monitor tilt change of the crust, fiber optic strainmeters to monitor seafloor horizontal deformation, as well as a pressure gauge to monitor vertical seafloor movement in long-term. The borehole tiltmeter in shallow seafloor borehole is one of the key sensors and we started a pilot long-term observation since February 2019. The location of the pilot tiltmeter installation is in 1B-S1 site south of DONET 1B node where splay fault is branched from the subducting plate boundary where Tonankai earthquakes occurred in the history. Long-term observation by DONET recorded slow earthquakes near the 1B-S1 site, where our interest is what slow slip associate with slow earthquakes in the splay fault system. In the pilot tilt observation, we drilled 8.6 m deep borehole of 104 mm diameter hole with BMS (seafloor drill by Cellula Robotics) by JAMSTEC R/V Kaimei in November 2018. We installed a Lily tiltmeter from Jewell Instruments in the borehole and packed the borehole by sand to the seafloor. To connect the tiltmeter to DONET to start continuous observation with the borehole tiltmeter, we used a DONET borehole interface which has been used to connect the IODP boreholes to DONET. We continue the observation since February 2019.

The first 1 year pilot observation exhibited the process of the hole and installed tiltmeter gets stable over time. First a half year data showed significant saw tooth trend of tiltmeter record in both x and y components and relatively large long-term drift. After a half year, such trend became much smaller and smooth. As of January 2020, long-term drift of the tiltmeter is ~-1 and ~5 microrad/month for x and y components respectively. The records showed clear and relatively large response in tidal frequencies with peak-to-peak amplitude of ~1 and ~ 2 microradians for x and y components (Figure). The response has good correlation with ocean tide measured by seafloor pressure gauges near the 1B-S1 site. We consider the large tidal response represents surface deformation of sediment layer to ocean tidal pressure loading, but further investigation is needed to clarify the origin of such tidal response, reported also in other seafloor observations (Davis et al, 2017, Araki et al., 2017).

We are planning another tiltmeter installation in deeper (~20 m planned) borehole to establish technique to observe tilt change in the seafloor environment with enough stability to recognize slow slip occurrence at depth. The planned installation also includes use of a laser interferometric long-arm tiltmeter and cementing the instrument at the bottom of the hole to enhance maximum stability.

Keywords: Nankai Trough, seafloor tilt observation, slow slip events