Measuring the behavior of the off-Sanriku trench axis by using direct path ranging

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After the 2011 Tohoku earthquake, the post-seismic deformation has been detected by GNSS-A observations. The displacement rates vary greatly along the trench axis, suggesting that the process of post-seismic deformation is different from region to region. GNSS-A observations require a broad, tectonically stable topography for the placement of the seafloor station array. Therefore, the behavior of the shallowest part of the subduction zone cannot be captured by GNSS-A observations. In this study, we try to measure the behavior of the seafloor near the trench axis by using direct path ranging (DPR) observations across the trench axis. In this presentation, we will report the outline and preliminary analysis results of the observation at the off-Sanriku trench axis, where the existence of slow earthquakes has been shown by seismic and geodetic observations.

In 2019, we installed five instruments, and performed continuous observations for about two years. In this presentation, we will show the analysis results of the baselines between the M4, M6, and M7 instruments, where data were obtained continuously during the entire period. The data consisted of travel time, instrument attitude, water temperature, and water pressure. Travel time and attitude were measured once a day (three measurements at one-minute intervals), and temperature and pressure were sampled by five seconds using external sensors.

The analysis procedure is shown below. Correct the clock drift of the instrument. Calculate the apparent baseline length change by multiplying the travel time by the standard sound speed. For the temperature correction of the sound speed, the average of the temperature at both ends of the baseline was adopted after a median filter was applied to drop the change in short time constants, where the frequency coherency at both ends of the baseline is lower. For the pressure, the average of the pressure at both ends of the baseline was adopted after removing the drift component by function fitting, assuming no long-term trend. For the attitude, we assumed that the acoustic element (3.5m height) moves horizontally with the anchor of the instrument as a hinge due to the attitude change. The apparent distance change is the directional cosine of the horizontal movement to the baseline direction. The final baseline length change is obtained by subtracting the sum of these apparent distance changes from the apparent baseline length change before correction.

Assuming that the baseline length change obtained by the above procedure is constant rate, we performed a linear regression and found that M4-M6 baseline is +0.6 cm/yr, M4-M7 baseline is -1.1 cm/yr, and M6-M7 baseline is -0.7 cm/yr (extension is positive).

Since there remains a long-period variation of approximately 2 cm in each baseline length change, and a similar variation is also apparent in the M6-M7 baseline on the same oceanic plate, there is an uncertainty of approximately 1.5 cm/yr in the baseline length change rate estimated by the current correction. Therefore, the preliminary results suggest that there was no convergence or divergence in velocity over 1.5 cm/yr across the trench axis.

In this analysis, we assumed that there is no long-term trend in pressure, but we cannot deny the effect of long-term oceanic variability. Therefore, an assumption that minimizes the baseline length change on the same plate may be valid. Also, there is still room for optimization of the time width of the median filter for temperature correction. In addition to the three instruments used in this analysis, we also have DPR data (M3) and the indirect path ranging (IPR) data (M5), and we will add these data to the future analysis.

Keywords: Direct path ranging, Seafloor geodesy, 2011 Tohoku Earthquake

