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Huge crustal displacements just above the source region of the Tohoku earthquake observed by GPS/acoustic survey

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The 2011 off the Pacific coast of Tohoku earthquake brought devastating damage to Tohoku region especially due to unexperienced large tsunami. Such a large tsunami must be originated in large vertical deformation of seafloor and hence significant horizontal displacement should be accompanied. Actually the largest co-seismic displacement observed on land exceeds 5 meters in horizontal, which suggests much larger displacement on seafloor close to the source region. On April 11, just a month after the earthquake, we have conducted GPS/acoustic survey to measure the positions seafloor benchmarks, GJT3 and GJT4, installed just on the source region. GJT4 is located roughly the middle between the Tohoku shoreline and the trench axis while GJT3 is located in much more trench side. Since the survey is urgent using chartered ship and operation is limited in daytime to avoid crush with numerous driftage originated in the tsunami destruction, total ship time to assigned to GPS/acoustic survey was 4 hours at GJT3 and 3 hours at GJT4. Although our basic survey style is ”stationary”, keeping a surface buoy at the center of seafloor transponder array, we conducted moving survey because we have to reconfigure the exact shape of the transponder array to assess its distortion due to strong ground motion generated by the earthquake and succedent possible local landslide other than regional crustal deformation. It found that 3 out of 5 transponders in GJT4 were not responded or lost after the earthquake, while all 6 transponders were survived in GJT3. Stationary survey is no longer make sense in GJT4 because the total number of transponder is less than 3. Therefore we concentrated on a single transponder as a target and made moving survey quickly so as not to change the sound speed with a path as even as possible. Then the final horizontal accuracy in positioning reached to less than 1 m, while the vertical accuracy is limited to 2 m. The final solution of the co-seismic displacement is 15 m in horizontal (ESE) and 3.5 m in vertical (UP). For GJT3, we made 3 hours of moving survey and an hour of stationary survey. Comparing relative difference in traveltime residual to each transponder before and after the earthquake, we can evaluate relative motion among transponders exited by strong ground motion of the earthquake at least in ”line of sight” direction. Roughly 30 cm of relative motion can be detected. These small change in the relative position indicates no local landslide occurred beneath GJT3. From the stationary survey compared past survey before the earthquake, we obtained 31 m (ESE) horizontal displacement. While 5 m (UP) vertical displacement from moving survey. For GJT4, no information of relative motion can be obtained due to the lost of 3 transponders. The reason of the lost of the is questionable. GJT4 installed fairly flat seafloor. One possibility is just a lifetime of internal battery. Investigation using ROV is desired. The huge eastward displacement and uplift at GJT3 indicates large slip on the fault is extended to up-dip close to the trench.

Keywords: seafloor geodesy, GPS/acoustic, crustal deformation, Tohoku earthquake