Water mass variation in the Japan Sea from satellite gravimetry: Comparison with seasonal movements of GNSS stations

*Suguru Doto[1], Kosuke Heki[1]

1. Department of Natural History Sciences, Graduate School of Science, Hokkaido University

Fifteen years have passed since the gravity satellite GRACE (Gravity Recovery and Climate Experiment) was launched by NASA/DLR in 2002. Most of the past researches focused on the land area, but it is gradually becoming possible to discuss the time-variable gravity in the ocean. The Red Sea is located between the Arabian Peninsula and Africa. Wahr et al. (2014) studied seasonal gravity changes there by combining the seasonal gravity change from GRACE with satellite altimetry and various in-situ data, and found that the seasonal ocean mass changes are driven by wind stress exerted near the strait connecting the Red Sea with the Indian Ocean. We also analyzed seasonal changes around the world oceans using GRACE data 2002-2016, and found significant seasonal variability in the Arctic Sea, Hudson Bay, Arafura Sea, Japan Sea, etc. Here, we focus on the Japan Sea.

To analyze the gravity changes, we used of the Stokes' coefficients with degrees and orders complete to 60 from the Level-2 RL-5 data released by CSR, University of Texas, and applied the de-striping filter and the Gaussian filter with average radius of 300km. In our previous report (Doto & Heki, Geod. Soc. Japan, Fall Meeting, 2016), we analyzed data from GSM files, in which the oceanic and atmospheric mass changes are supposed to be removed using various geophysical models. In the present study, however, we added back the values in GAD files to recover the originally observed gravity changes in the ocean. In the GSM files, the gravity maximum occurred in November and the minimum occurred in June in the Japan Sea, and the peak-to-peak amplitude was ~10 cm in equivalent water depth. In the GSM + GAD files, however, the maximum and the minimum moved to October and February, respectively, and the amplitude decreased to ~4 cm (Fig.1). This means that the non-tidal mass change model used to make the GAD files is wrong at least in the Japan Sea.

We compared the GRACE data with the average seasonal variation of the sea surface height using the tide gauge data at the Tobishima and Okushiri (both in Japan Sea) observatories. The tide gauge showed the amplitude ~5 times as large as the GRACE data with maximum in August and September. This result suggests that the sea surface height changes mainly reflect thermal expansion of warm water above the thermocline rather than the real change of the amount of sea water.

Seasonal gravity changes also occur above the land area of Northeast Japan, and its maximum (February to March) suggest that it comes from snowpack in winter. GNSS stations in NE Japan often show clear seasonal movements, and a large part of them comes from the seasonal load, i.e. snow on land and sea water in the Japan Sea. We try to validate the GRACE results by comparing them with the GNSS data on land.

Figure 1: Gravity deviation in October compared with February, converted to equivalent water depth from the GRACE data. We can see the positive deviation in the Japan Sea.

Keywords: GRACE, Water mass variation, Japan Sea, Crustal deformation, GNSS