# Investigation of sea surface height detection by Global Navigation Satellite System Reflectometry (GNSS-R)

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In recent years, the possibility of detecting ocean parameters such as sea surface height (SSH), ocean wind from the Global Navigation Satellite System reflectometry (GNSS-R) was shown. The Cyclone GNSS (CYGNSS) mission aiming to contribute to the forecast of extreme weather phenomena by observing the sea surface wind in the cyclone is in progress operating eight small satellites and ocean wind speed products are being delivered. In GNSS-R, it is theoretically possible to measure the SSH from the ellipsoid by measuring the delay of the reflected wave and the direct wave. The investigation of SSH detection using TDS-1 which was developed and operated mainly by Surrey Satellite Technology Ltd (SSTL) in the UK has been reported. Even in our group, SSH detection was performed using TDS-1 data observed near Japan and the detected ones was compared with the mean SSH constructed by the altimeter observations. It was confirmed that the SSH can be detected with an error of about 1m at observation with good conditions (antenna gain is 7.5 dBi or more). Regarding CYGNSS, SSH is not calculated as an official product and it is limited to detectability study. In this report, we used CYGNSS data to investigate SSH detection from GNSS-R like TDS-1.

The CYGNSS data used for the present study is a full resolution Delayed Doppler Map (DDM) provided as special data through the GNSS Reflectometry for Ocean Waves, Tides and Height (GROWTH) project, which is a member of NASA CYGNSS External Science Member. The size of DDM is 20 (Doppler) ×128 (Delay) bin. On the other hand, the size of the normal DDM is 11 (Doppler) ×17 (Delay) bin in the Level 1 ver 2.1 data provided by NASA's The Physical Oceanography Distributed Active Archive Center (PO.DAAC). Thus, the data are compressed to 1/2 in the doppler direction and 1/8 in the delay one. Since the resolution in the delay direction affects the range measurement, it is expected that the detection resolution by the full DDM will be improved over the usual L1 data. The data provided was data acquired mainly in the East China Sea and acquired for the purpose of demonstrating the possibility of detecting the SSH related to the large tide amplitude.

Since the provided full resolution data are those in which only a part of data on DDM is stored, L1 ver 2.1 data at the same time were collected and the positions of the transmitting GNSS satellite and the receiving CYGNSS, the position of the reflection point and the delay information of the reflection point corresponding to the full DDM were extracted to calculate the SSH. A random variation of about 6m in standard deviation was confirmed in the delay information of the reflection point, so we with calculated weighed average with the 1/e scale of 75 km after excluding the abnormal values. Based on the above information, the SSH along the reflection point was calculated and compared with the mean SSH data calculated based on the altimeter data. A large spatial error that can be approximated by a linear equation of the distance was confirmed for the difference between the two SSHs, and therefore the relative SSH was evaluated by subtracting the approximate expression. The RMS error along the 4 passes of the observation on April 18, 2018 was about 0.8 m to 1.5 m, which was almost the same accuracy as TDS-1.

In the present study, the possibility of SSH detection as a spatial relative altitude was suggested. However since the large spatial error remains, whether the SSH variation in the East China Sea with O (1 m) can be detected will be a subject for further study. In particular, since corrections to the ionosphere and the

 

troposphere delays have not been made at the stage of this study, it is considered necessary to estimate their influences from model data.

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