Detection of sea surface height and wave height using Global Navigation Satellite System Reflectometry (GNSS-R)

*Osamu Isoguchi[1], Taku Izumiyama[2], Kaoru Ichikawa[3], Yukihito Kitazawa[2]

1. Remote Sensing Technology Center, 2. IHI Corporation, 3. Kyushu University

In recent years, the possibility of detecting ocean parameters such as sea surface height (SSH), ocean wind, wave height, 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. In this report, we conducted the waveform analysis of the reflected wave, and examined the detection of SSH and significant wave height (SWH) which are not standard detected parameters in CYGNSS.
TechDemoSat-1 (TDS-1) data developed and operated mainly by UK Surrey Satellite Technology Ltd (SSTL) was used for the SSH detection. Delay Doppler Maps (DDM) of Level 1b was used for analysis. A method based on a theoretical model (Brown Model) used in waveform analysis of a nadir altimeter was applied. SSH along the specular points was calculated based on delay calculated by waveform analysis, transmitting and receiving satellite positions and specular points. The calculated SSH profile was able to detect the SSH change relatively well with a high antenna gain value of 7.5 dBi or more. On the other hand, it was greatly scattered at where the antenna gain decreases. The standard deviation of the residuals was 2.63 m. As a result of comparison after performing weighted averaging with the 1/e scale of 75 km, the standard deviation of the residual is 0.83 m.
It was found that by processing the GNSS-R signal, it is possible to detect SSH with error of about 1 m at observation with good condition. The accuracy of 1 m is not sufficient for detecting the dynamic topography (O˜10 cm) related to ocean current, but by repeated observation it is applicable to phenomena with large fluctuations such as mean SSH, tides of the Yellow Sea and East China Sea. In addition, noise-like detection error is improved by raising the range resolution (bandwidth) and SNR, so it can be said that this is a promising result for detection in the order of 10 cm for future GNSS .
For detection of SWH, CYGNSS L1 ver2.0 data was used. We examined data for three days from 25th December to 27th December 2017 which was relatively high sea state condition. We investigated the relationship between the SWH from the coastal wave model (CWM) by the Japan Meteorological Agency (JMA) and the leading edge slope (LES) of the reflected waveform and scaled SNR of the received signal. LES is stored in CYGNSS L1 data that is defined as the slope of the 3 delay ×5 Doppler bin box in the DDM.
In each observation profile, SSNR and LES tend to decrease as SWH increases. Comparisons were made on the data of the reflection points where the antenna gain is 12 dBi or more. The comparison number was about 20,000 points. Both parameters showed a general pattern decreasing with increasing SWH. On the other hand, especially in SSNR, relationships are clear in individual observations, but the variability is large from observation to observation, and the relationship is unclear as a whole. Here, the model function is calculated by specifying the LES by the relational expression using the power of SWH. SWH was then estimated from the LES using the calculated model function and compared with SWH of CWM. As a result, the bias was almost zero, but the RMS error was as large as 1.45 m.
It was confirmed that LES and SSNR were related to SWH, and the possibility of SWH detection using GNSS-R was shown. Although good correspondence was obtained for individual observations, variations are large for a large amount of cases, and when one model function is applied, at present it is not possible to meet the needs for SWH observation. One possible reason is that the radiometric characteristics are changed depending on each GPS satellite and observation time. It is expected that SWH can be estimated

more accurately if the correction of radiometric characteristics progresses due to the accumulation of data in the future.

Keywords: GNSS-R, Sea surface height, Wave height