

Integrated Space Geodetic Study of the 2019 Typhoon Hagibis: Signatures in Troposphere, Lithosphere, and Ionosphere

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Strong typhoons hit the Japanese Islands repeatedly in 2019 autumn. Here we study one of these typhoons (2019 #19 Hagibis, 915 hPa, 86 casualties) that made landfall in central Japan on Oct.12 during the Rugby World Cup tournament, using three different space geodetic approaches to study multiple spheres, i.e. tropospheric water vapor, ionospheric electron content, and lithospheric deformation due to stormwater load. The first approach is the recovery of Precipitable Water Vapor (PWV) using the zenith wet delays (ZWD) estimated by the dense GNSS array in Japan GEONET (GNSS Earth Observation Network). Because atmospheric water vapor concentrates in relatively low altitudes, high humidity is often difficult to recognize in ZWDs when the surface altitude is high. To overcome the difficulty, we reconstructed ZWDs, converted to sea-level values, by spatially integrating the tropospheric delay gradient (azimuthal asymmetry of water vapor) vectors. We also calculated convergence of such delay gradients, equivalent to water vapor concentration (WVC) index proposed by Shoji (2013). We found that extreme rainfall occurs where both reconstructed ZWD and the WVC index are high. Next, we studied vertical crustal movements associated with the water load brought by the typhoon, using the two solutions of the GEONET station coordinates, one from the official F3 solution and the other from the UNR data base. After applying a network filter to remove common mode errors, we confirmed subsidence down to ~2 cm in multiple regions where severe flood occurred, e.g. in Izu-Peninsula, Coastal region of Fukushima, and Nagano (see attached figure). Such subsidence was observed to recover with a time constant of 1-2 days reflecting rapid drain of rainwater to ocean due to large topographic slope and proximity to the sea. We could not identify, however, crustal uplift due to the low atmospheric pressure at the center of the typhoon. At last, we look for ionospheric disturbances possibly excited by the typhoon Hagibis as changes in the ionospheric total electron content (TEC) measured using Quasi-Zenith Satellite System (QZSS) tracked by the GEONET stations. Geostationary satellite (PRN07) of QZSS enables us to monitor ionosphere above the Japanese Islands continuously and are useful in detecting ionospheric disturbances above Japan.

In the attached figure, we show subsidence of GNSS stations in Japan on 2019 Oct. 12 due to stormwater load (right) and vertical coordinate time series of selected stations (left). They are all based on the F3 solution of the GEONET GNSS stations after removal of common mode errors.

Keywords: Typhoon Hagibis, GNSS, water vapor, crustal deformation, surface load, ionospheric disturbance

