Inner-core wind field in a concentric eyewall replacement of Typhoon Trami (2018): A quantitative analysis based on the Himawari-8 satellite

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Strong tropical cyclones (TCs) often have concentric eyewalls (CEs), and experience eyewall replacement cycles (ERCs). Formation of the CE structure leads to increase in the storm size. The CE storm can drastically change the maximum wind and the radius of maximum wind speed within 24 h during an ERC. Dynamics of the CE formation and ERC are important for understanding and prediction of the intensity and size changes in the TCs. Inner-core wind field in the TCs is essential for understanding of the CE-formation and ERC dynamics. However, it is difficult to estimate the inner-core wind field associated with the CE formation and ERC because the strong TCs mostly move over open oceans with less instruments. Recently, a geostationary satellite of Himawari-8 was launched by the Japan Meteorological Agency. The satellite has a target observation for typhoons with high frequency (temporal interval of 2.5 min). Time series of imageries in the high-frequency observation allow us to trace each cloud. The present study conducts a quantitative analysis of the inner-core wind field in a typhoon with clear CE structure, based on the temporally high-resolution imageries in the target observation.

The present study focuses on Typhoon Trami (2018), which had a clear CE structure near the mature stage. After the secondary eyewall formation, the original inner eyewall in Trami gradually decayed. Evolution of the inner core is similar to an ERC event. We used data of brightness temperature (Tb) captured by an infrared band (Band 13) in the target observation of the Himawari-8. The quantitatively estimation of the wind field is based on a spectral analysis of time series for the Tb in azimuthal directions, which is similar to that in conventional estimation of zonal propagation speeds of tropical waves. At a certain radius from the typhoon center, the Tb on the physical space of azimuthal angle and time is transformed to the spectral space of wavenumber and frequency. Tangential wind speed at the cloud top is estimated as a function of radius based on the azimuthal phase speeds in wavenumbers and frequencies with high spectra in the Tb.

After formation of the CE structure, the maximum (~50 m s^{-1}) of the tangential wind speed is estimated in the inner edge (~30-km radius) of the eyewall cloud. Vertical component of relative vorticity derived by the estimated tangential wind has typical monopole structure with the vorticity peak at the center. During the decay of the inner eyewall, the maximum of the tangential wind speed rapidly decreased (~30 m s^{-1}), and the location of the maximum wind speed expanded to a radius of 100 km from the center. Moreover, the satellite-derived wind field is validated by dropsonde observations in a special field campaign. The tangential wind speed based on the satellite had difference of about 5 m s^{-1} with the dropsondes. In spite of the relatively small difference, the maximum wind speed of 50 m s^{-1} based on the satellite was quite similar to that in the dropsondes (~50 m s^{-1}) before the ERC.

The results suggest that the high-frequency observation in the Himawari-8 is available to quantitatively estimate the inner-core wind field associated with the CE structure. Moreover, the estimated wind field and its time series might be helpful for understanding of the CE-formation and ERC dynamics.

Keywords: Typhoon, Meteorological satellite