A New Method to Estimate Circulations in Tropical Cyclones from Single-Doppler Radar Observations

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Doppler weather radars are a powerful tool for investigating and forecasting the inner-core structure and intensity in tropical cyclones (TCs). In particular, the Doppler velocity captured by the azimuthal surveillance in the radars can provide quantitative information on the maximum wind speed and vortex structure in the TCs. On the other hand, the Doppler velocity from a single radar has no information on the wind component normal to the radar beam. Therefore, closure assumptions are needed to estimate the circulations of the TCs from single-Doppler radar observations. The Ground-Based Velocity Track Display (GBVTD; Lee et al. 1999) technique used to estimate the TC-circulations adopts the closure assumption of no asymmetric radial winds in the TC vortex. According to the retrieval formulations in the GBVTD, the retrieval results can have large errors of axisymmetric components in TCs with significant asymmetric structure due to the aliasing of the neglected asymmetric radial winds into the axisymmetric tangential wind from the closure assumption.

The present study proposes a new closure assumption introducing asymmetric radial winds to improve the axisymmetric-circulations estimation in TCs with asymmetric structure. Our new method with the closure can consider the asymmetric radial winds by using streamfunction based on the Helmholtz decomposition of horizontal winds. As with the GBVTD, the new method retrieves TC circulations based on the Fourier decomposition of winds in the azimuthal direction and the least-square fit of the Doppler velocity from the single radar observation.

Accuracy in the new method is assessed with analytical vortices and a TC vortex simulated by a full-physics model simulation. The retrieval of the axisymmetric tangential wind in the analytical vortices (full-physics-simulated vortex) with asymmetric winds has a relative error of less than 2% (10%) near the radius of maximum wind speed. The new method and GBVTD are applied to the tangential wind estimation in a real typhoon with a counter-clockwise rotating elliptical eyewall. The GBVTD-estimated axisymmetric tangential winds have periodical fluctuations with an amplitude of about 10 m s^{-1} near the eyewall. The fluctuation period of the axisymmetric winds is approximately synchronized with the rotating period of the elliptical eyewall, suggesting possible errors due to the closure assumption in the GBVTD. The axisymmetric tangential winds estimated from the new method do not exhibit synchronized fluctuations with the elliptical eyewall rotation. We find that the new method can reduce the errors of the axisymmetric circulation in the GBVTD.

Reference: Lee, W., Jou, B. J., Chang, P., and Deng, S. 1999: Tropical cyclone kinematic structure retrieved from single-Doppler radar observations. Part I: Interpretation of Doppler velocity patterns and the GBVTD technique. *Monthly Weather Review*, **127**, 2419-2439.

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