Asymmetric features of near-surface wind fields in typhoons revealed by the JMA mesoscale analysis data

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Recently the relationships between azimuthal wavenumber-one inner-core structures of tropical cyclones (TCs), and environmental vertical wind shear, have been increasingly investigated with numerical simulations at high resolution and theoretical considerations. However, due to the lack of detailed observations, which are usually obtained through a special field observational program, the results have not been endorsed by observational studies in a systematic manner. A viable alternative for detailed observations is analytical gridded data produced with a relatively high resolution by using a state-of-the-art data assimilation technique, such as the mesoscale analysis (hereafter referred to as "meso-analysis") data operationally produced at the Japan Meteorological Agency (JMA).

Over the years, researchers have developed parametric wind models to depict the surface winds within a TC. Parametric models have shown utility in creating wind fields as input to models such as the wave model, storm surge model, statistical-parametric model to predict TC wind radii, and pressure–wind model to relate the minimum central pressure to maximum surface winds in TCs. In most of such studies storm motion is assumed to be the only contributor to the near-surface wind asymmetry in TCs. Furthermore, most of previous theoretical studies on the wind distribution in the TC boundary layer have focused on the effect of TC translation on the wind distribution. Based on results from a real data simulation of Typhoon Chaba (2004), however, Ueno (2008) suggested that vertical wind shear could play a dominant role in determining the wind structure in the TC boundary layer insofar as the shear is significantly large. In the simulation low-level inflow tends to occur in the downshear-left quadrant, in accordance with the preferred location of rainfall maximum, and the strongest tangential wind is about 90° of azimuth downstream of the maximum inflow. A better knowledge of the role of vertical wind shear in determining the near-surface wind asymmetry would help to significantly improve parametric wind models.

The purpose of the present study is to document, in an extensive manner using the meso-analysis data, the influence of environmental vertical wind shear on the wavenumber-one asymmetries of near-surface wind components in the TC inner-core region. As a first step to quantify the shear contribution to the near-surface wind asymmetry in real TCs, here in the present study we analyze the wind fields at about 20 m height (the lowest analysis level) obtained from the JMA operational meso-analysis, putting emphasis on the azimuthal location of wind maximum and its relevance to shear and storm motion. For the purpose a total of 190 cases from 35 typhoons observed during 2004–2007 seasons are examined. Figure 1 shows the directional relationship between shear and tangential wind maximum. The azimuth of tangential wind maximum is found by performing the first-order Fourier decomposition of earth-relative wind field with respect to the surface center. In the figure both the shear direction and azimuth of tangential wind maximum are defined relative to the direction of storm motion. The storm motion vector is calculated from the JMA best-track position fixes. As expected, and in accordance with various earlier observational studies, the wind maxima are found predominantly to the right of TC motion. Interestingly, however, a small fraction (17 %) of the total cases exhibit a left-of-motion maximum and it occurs only in cases in which the shear direction is nearly equal to the storm heading. This result is in qualitative agreement with expectations from the simplified formulae derived in Ueno and Kunii (2009), which predict the tangential wind maximum in storm-relative coordinates to the left of TC center facing in the direction of enhanced eyewall convection.

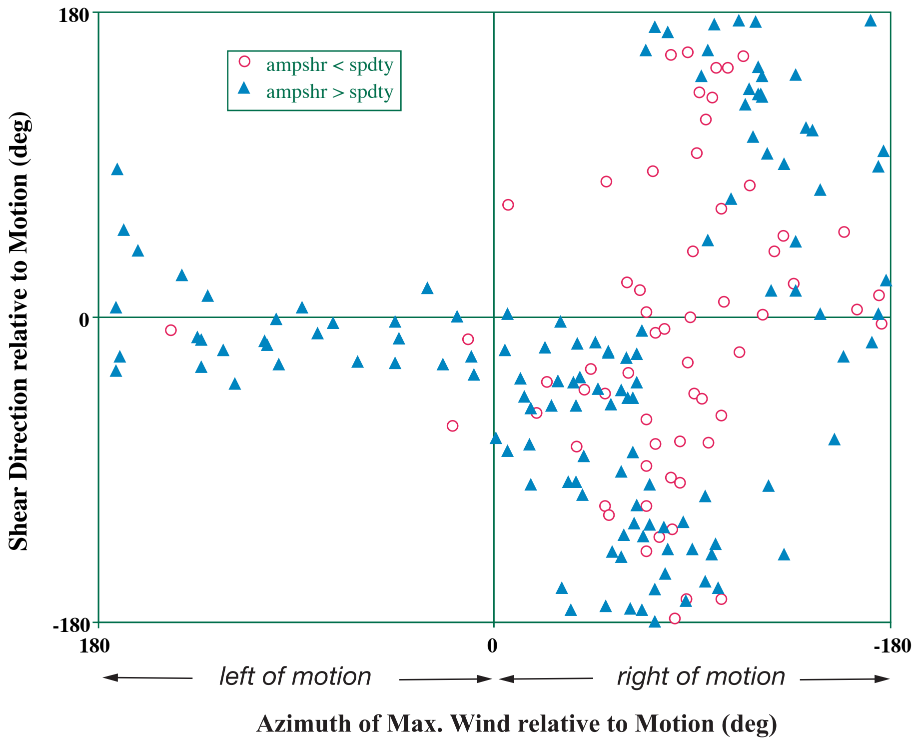

Figure 1: Directional relationship between vertical wind shear and tangential wind maximum. Vertical axis denotes the direction (in degree) of shear relative to that of storm motion vector with positive (negative) values for the shear to the left (right) of the motion, while horizontal one represents the azimuthal direction (in degree) of tangential wind maximum relative to storm heading. The sampled cases are stratified into two groups according to whether the shear magnitude is greater than storm translation speed (closed triangles) or not (open circles).

References

Ueno, M., 2008: Effects of ambient vertical wind shear on the inner-core asymmetries and vertical tilt of a simulated tropical cyclone. *J. Meteor. Soc. Japan*. **86**, 531-555.