Observed and simulated relationship between storm motion, vertical wind shear, and rainfall asymmetries in typhoons

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Recently the influences of vertical wind shear on tropical cyclone (TC) structure has been increasingly investigated. For example, Corbosiero and Molinari (2002, 2003; hereafter CM) provided some observational evidence for the strong linkage between vertical wind shear and convective asymmetries in TCs. In the present study we also examine the relationship between ambient vertical wind shear and rainfall asymmetries for the typhoons which made landfall on mainland Japan in 2004.

In the study, vertical wind shear is defined as the vector difference between the average 200-hPa and the 850-hPa wind within a radius of 500 km from the cyclone center and calculated from the JMA global analysis data. On the other hand, wavenumber-one asymmetries of rainfall are determined by applying the first-order Fourier decomposition routine to the Radar-AMeDAS precipitation data in a coordinate system relative to the storm motion. The Radar-AMeDAS data gives hourly precipitation estimated by ground-based C-band radar, calibrated with the AMeDAS (Automated Meteorological Data Acquisition System) rain gauge data. The resolution of the data is about 2.5 km.

Figure 1 shows the number of cases the first-order asymmetry phase maximum is located, per octant, with respect to vertical wind shear (left) and storm motion (right). The figure suggests that the rainfall rate tends to be enhanced directly downshear with a leftward preference, consistent with CM. It also suggests that maximum precipitation tend to be yielded in front of storm motion, with a preference for the right-front quadrant, again consistent with CM. To definitely determine the relative importance of vertical wind shear and storm motion on the distribution of rainfall in tropical cyclones, the location of the maximum of precipitation is examined for different angles of separation between shear and motion after CM. The result suggests a much stronger correlation between rainfall asymmetry and vertical wind shear than between the former and storm motion though the number of cases for rightward deflection of the motion from the shear are very limited (Ueno 2005).

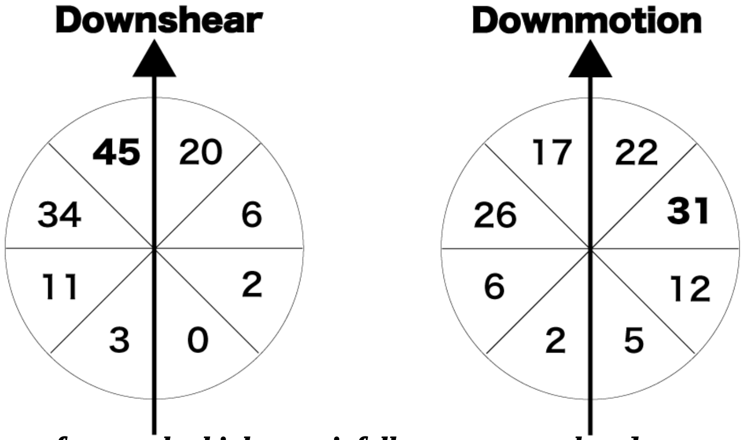

Figure 1: The number of cases the highest rainfall rate was analyzed, per octant, within a radius of 100 km from the storm center, with respect to shear vector (left) and motion one (right). Figures were highlighted in the octant which attained the largest number.

The Radar-AMeDAS data is available only in the midlatitudes in and around Japan, limiting the generality of the foregoing statistics. The relationship between shear and motion, however, can be established irrespective of rainfall data even over tropics. Figure 2 shows that TCs tend to move leftward (rightward) relative to the shear vector in the westerly (easterly) shear zone or in the middle (low) latitudes, suggesting that the above-mentioned statistics should be extended into low latitudes.

Numerical models might be considered as a powerful tool to understand the role of vertical wind shear in governing azimuthal variations of rainfall. Figure 3 shows the relationship between rainfall asymmetry (RA), vertical wind shear (WS) and storm motion (SM) obtained from one of idealized numerical experiments in Ueno (2003), again suggesting a closer relationship between RA and WS.

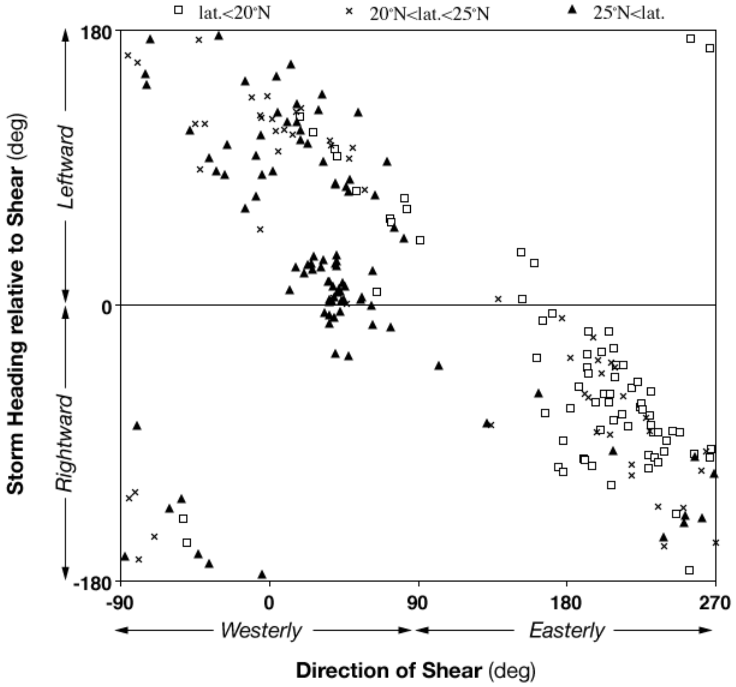

Figure 2: The directional relationship between storm motion and environmental shear (measured counterclockwise from due east).

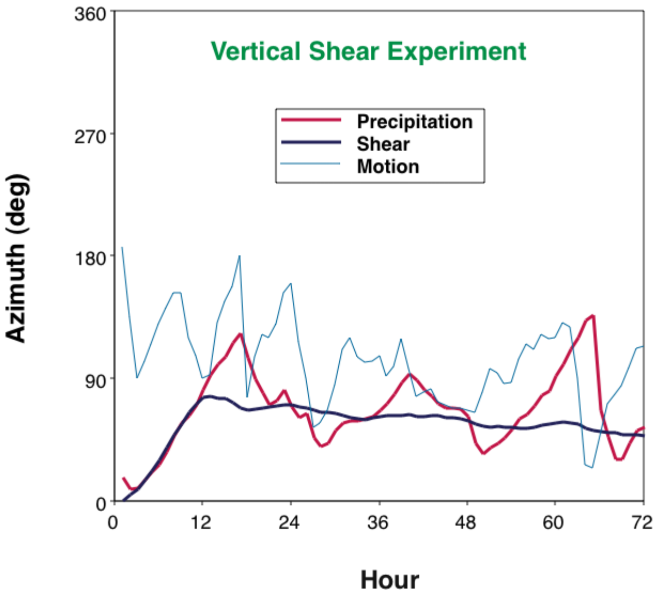

Figure 3: The directional relationship between rainfall asymmetry phase maximum, vertical wind shear and storm motion obtained from an idealized model run to 72 h.