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Note on probable development of a Transverse Force on a Tropical Cyclone due to its interaction with the Steering Current

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ABSTRACT. The paper discusses the probable development of a transverse force on a tropical cyclone due to its interaction with the steering current. By using a simplified form of the Bernoulli equation, an expression is derived for the cross-current pressure drop and it is concluded that due to this pressure-difference effect alone a cyclone will experience a swerve to the right of its direction of motion in the northern hemisphere. Some limitations of the treatment are pointed out.

The development of a transverse force on a rotating body when moving in a steering current is well-known in fluid dynamics as the Magnus effect and follows directly from the Bernoulli theorem. The cross-current force arises from an asymmetry of tangential velocity between the two sides of the rotating body as it moves downstream. On one side, the tangential velocity of rotation is in phase with the velocity of the steering current whereas on the other it opposes the steering current. The result is an appreciable difference in tangential velocity between the two sides, which causes a difference of static pressure across the current. On the basis of the Magnus effect, Sutton (1949) explains the swerve or deflection of game balls, *e.g.*, a tennis ball when driven forward and also set spinning by an oblique blow of the racket. Lyttleton (1957) in a study of the swerve of cricket balls concludes that a difference of static pressure between the two sides of the ball during its flight through the air would be required to explain the observed swerve. In the present paper it is suggested that a tropical cyclone with its intense vertical circulation while interacting with the steering current may experience a cross-current force which is directed to the right-hand side of the cyclone looking downstream. Jordon (1952) in an observational study of the upper wind circulation around tropical storms, using rawin data, has shown that in the generalised wind pattern much stronger winds prevail on the right-hand side of the cyclone than on the left-hand side looking down the steering current. The same generalised wind pattern was also found by Hughes (1952) by analysing an extensive series of reports of aircraft reconnaissance into large Pacific tropical cyclones. Bernoulli's theorem enables us to compute the cross-current pressure difference between the two sides, arising from this asymmetry of tangential velocity. If p and v denote the magnitudes of the static pressure and the tangential velocity respectively at a point on the periphery of the cyclone at the steering level, it may be shown (*see* Fig. 1) that the value of v will be $(v_s + v_r)$ at A where the tangential velocity of rotation v_r is in phase with the velocity v_s of the steering current and $(v_s - v_r)$ at

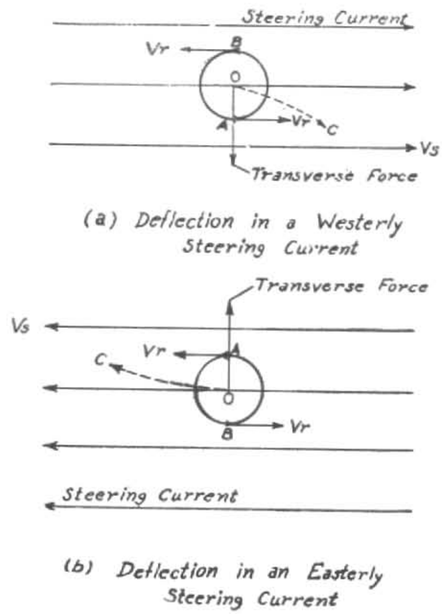

Fig. 1. Sketch showing transverse deflection of a cyclone

B where the two velocities oppose each other. Then according to Bernoulli theorem,

$$p_A + \tfrac{1}{2}\ \rho\ (v_r + v_s)^2 = p_B + \tfrac{1}{2}\ \rho\ (v_r - v_s)^2 \qquad (1)$$

where p_A, p_B are static pressures at A, B respectively and ρ is the air density.

On slight rearrangement, equation (1) yields

$$p_B - p_A = 2\ \rho\ v_r\ v_s \qquad (2)$$

Equation (2) gives a measure of the cross-current pressure drop between B and A and its computed values for a mean $\rho = 1 \cdot 0 \times 10^{-3}$ gm/cc for different combination of the steering current are plotted in Fig. 2. Continual operation of a cross-current pressure force will deflect the cyclone to the right of the direction of motion indicated by the steering currents. This means that cyclones steered in a westerly current will tend to swerve to the south whereas those steered in an easterly current will tend to swerve to the north of the direction of the steering current. This is qualitatively shown by the dotted curve OC in Figs. 1(a) and 1(b).

The following limitations of the treatment should, however, be pointed out. It neglects

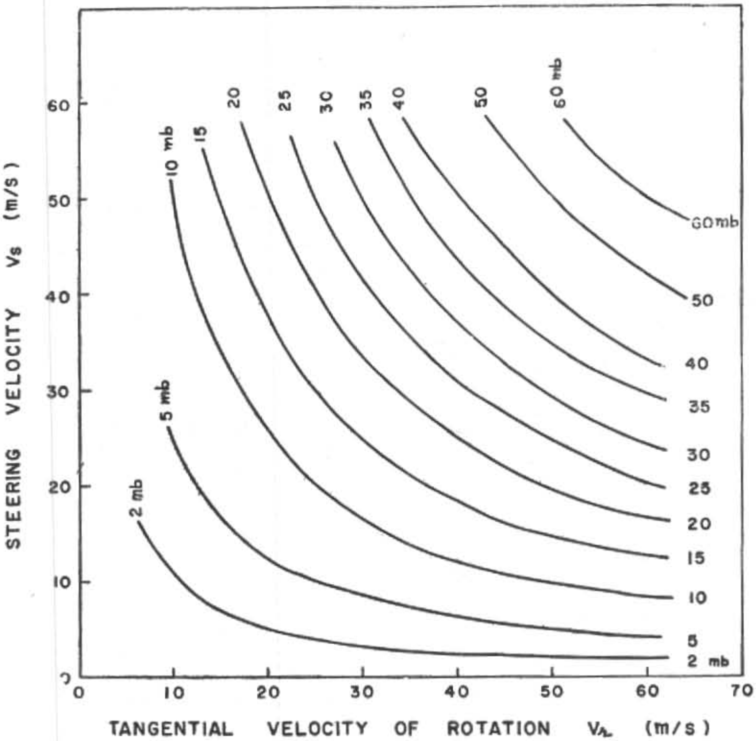

Fig. 2. Magnitude of transverse pressure difference for different velocities of cyclonic rotation and steering current

air friction and is based upon the somewhat unrealistic assumptions that the circulation is uniformly cyclonic up to the steering level and that it is possible to work out a mean air density for the whole atmospheric column covered by the cyclonic circulations. The simplified treatment given in the note may, therefore, yield an over-estimate of the Magnus effect in the case of a tropical cyclone. Further, steering currents are not always easy to delineate in the low latitudes and for this reason alone it may be difficult to evaluate the magnitude of the transverse force in any particular case.

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