DIRECTION OF MOVEMENT OF TROPICAL CYCLONIC STORMS

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THE movement of a cyclonic storm is of great importance for a forecaster, and to the general public as those who experience the effects of the weather. It is well known that the direction of movement of an extra-tropical cyclone is determined by the cirrus or 6 km. winds in the warm sector or the sector containing the maritime air. Many attempts have been made to find out if similar general rules are likely in the case of tropical disturbances. A systematic attempt was made to study tropical weather and several useful deductions derived.* Taking all salient facts into consideration, it is suggested that a useful rule would be: that *the movement of a tropical cyclonic storm is determined by the higher level air motion corresponding to the sector containing the "energy source" air mass.*

It has been stated that the general sweep of 4, 6 and 8 km. winds gives an approximate direction of motion of the tropical cyclonic storm (p. 46). It has been pointed out (pp. 34-43 and pp. 87-92) that both in the case of monsoon depressions and tropical cyclonic storms, one has to consider the advent of three air masses. Due to various factors and the regions of travel, these air masses cannot be distinguished by the differences of temperature alone. Some characteristics, like the diurnal variation of temperature, content of moisture and degree of inherent instability (latent instability?) have been pointed out as the distinguishing characteristics of the different air masses. The three air masses that go to form the tropical depressions are:

(1) *Equatorial Maritime Air*—which has crossed the equator as a "pulse", from the south to the northern hemisphere and from the north for the southern hemisphere. It has large moisture content and can be made easily unstable and give rise to thunderstorms.

(2) *Transitional Air* (containing mixture of tropical maritime and tropical continental air in varying proportions corresponding to the season and region of the country)—reaching the depression in Indian lattitudes from the far-east, the ultimate origin being the Pacific high.

(3) *Continental Air* (mostly tropical with an occasional slight mixture of Polar continental) reaching Indian area from a north-westerly or westerly direction. The air is dry and is hotter in summer and colder in winter on the surface than the other air masses.

Without the existence of the three air masses, the formation of a monsoon depression or a tropical cyclonic storm is not possible, only a low pressure wave, which travels faster across the country than the depression, results.

In the extra-tropical depressions there are only two air masses involved: one maritime (tropical) and the other continental (tropical or polar in varying proportions depending on the season and locality).

The tropical cyclonic storm recurves towards an easterly direction if it reaches a sufficiently northerly latitude in the northern hemisphere and a southerly latitude in the southern hemisphere. It has been pointed out (p. 100 A and Addendum to p. 47) that it is possible to locate on an extended chart an extra-tropical cyclone or disturbance under whose influence the tropical cyclonic storm apparently recurved.

It is also well known that a tropical cyclonic storm after recurvature and entering the temperate lattitudes has the character of an extra-tropical depression (after Bjerknes). The upper air wind at about 6 km. in the lattitudes nearer the equator (in the regions where the depressions form and in the seasons when they form) are easterly and in the latitudes further away westerly.

The tropical cyclonic storm, as a tropical cyclonic storm, fills up soon after the supply of the fresh equatorial maritime air is cut off, due to the formation of a fully formed tropical depression on the other side of the equator. Thereafter the resulting low may be influenced by a passing extra-tropical disturbance and may recurve towards the east.

All the above facts can be integrated into a single unified picture, under the folloing hypotheses:

(1) So long as the movement of the tropical cyclonic storm is some westerly direction, the cyclonic storm has all the three sectors.

(2) When the equatorial maritime air is cut off, the tropical cyclonic storm as envisaged till that time assumes a different character; it may fill up completely or under the influence of an extra-tropical disturbance may recurve towards an easterly direction and hence the recurved cyclonic storm has only two air masses (one maritime and the other continental). This, however, does not prevent its redevelopment into a cyclonic storm with three sectors if a fresh supply of equatorial maritime air reaches the depression, when the depression would once again have a westerly movement.

In this connection pp. 116-17 of the book referred to may be seen. The Calicut cyclone is being looked into with collaboration of Mr. P. R. Pisharothy. The cyclone moved eastwards from the S.E. Arabian Sea into the Bay of Bengal, moved in a north-westerly direction and later again recurved in an easterly direction. The speed of motion and the short life pointed to the fact that in the initial and final stages, the depression was influenced by western disturbances. As mentioned there, a secondary of a western disturbance can be destructive and show a good circulation. The several types of cyclonic storms mentioned by Deppermann* and others can also be simplified if they are divided into groups which were secondaries of extra-tropical disturbances and those that formed with all the three

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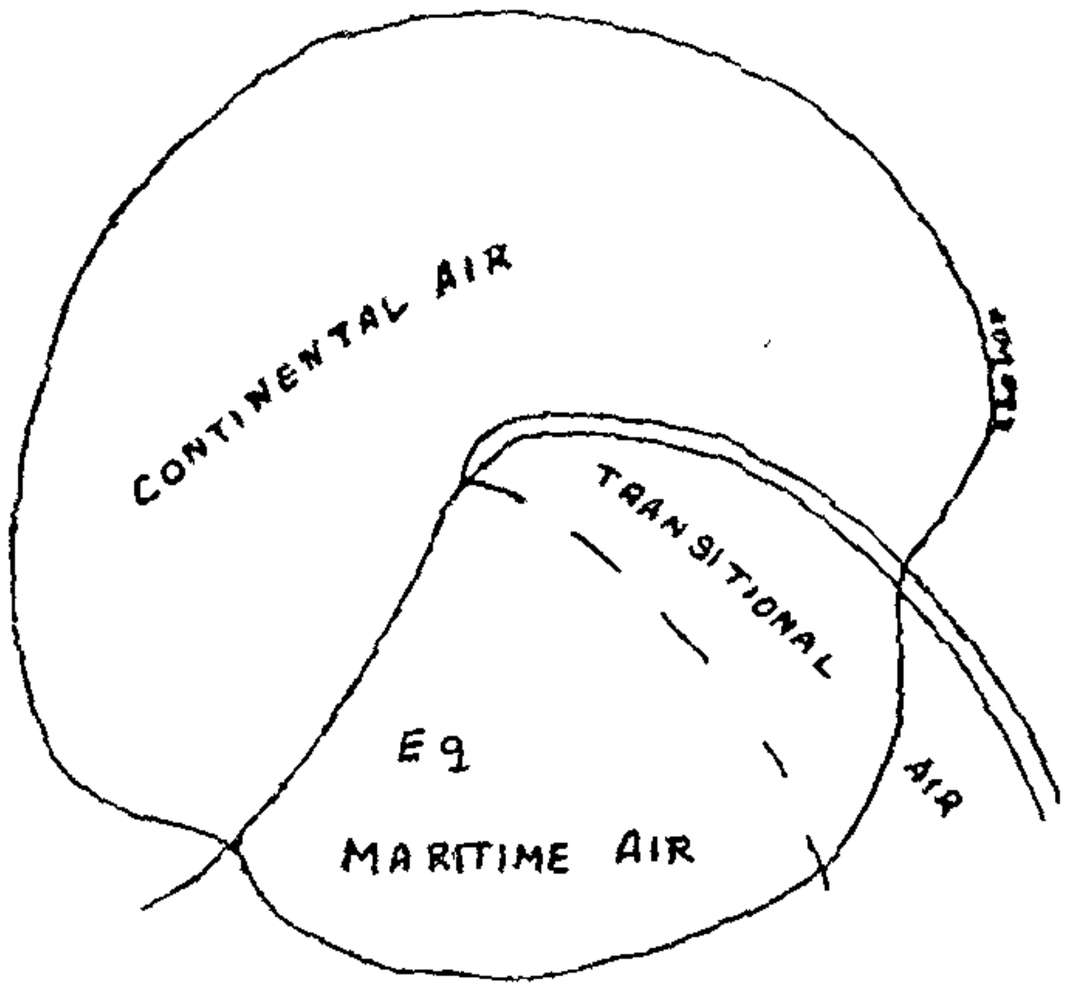
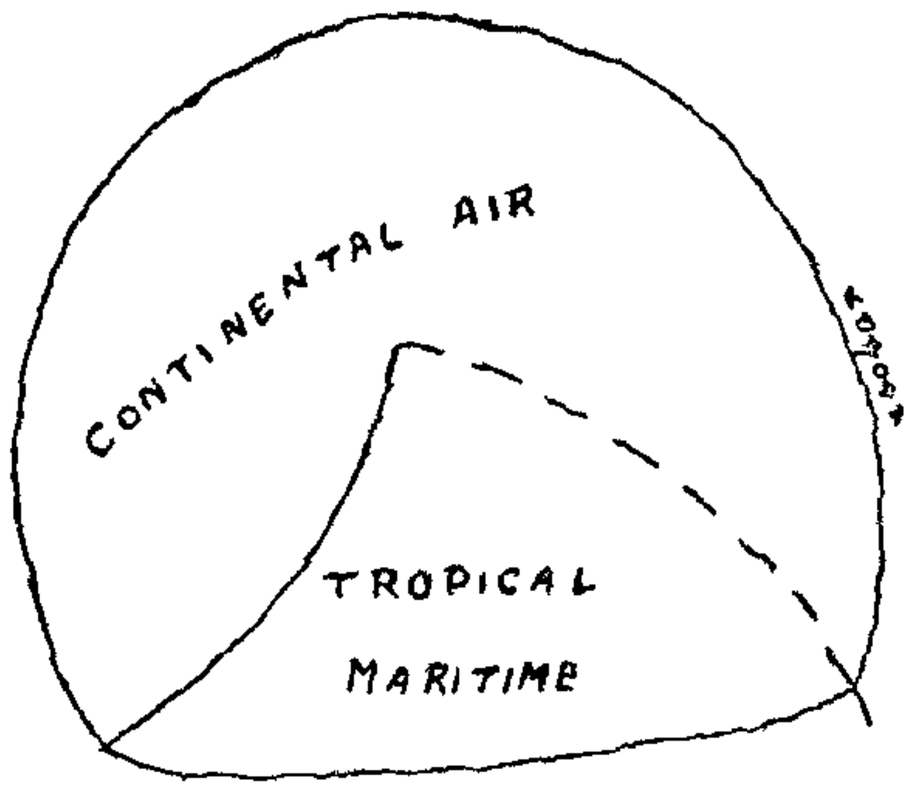
sectors and moved into China Seas. Then the same simplification as made by the author in the book and this note results.

It has been pointed also that the "source" of energy of a tropical cyclonic storm is the equatorial maritime air and the "sink" is the continental dry air or tropical continental air, and that the role of the far-eastern air is to delay the cycle of operations till sufficient vorticity is developed (the earth's rotational effect being smaller in equatorial latitudes, the time required to develop vorticity would necessarily be greater). In the extra-tropical depression the "source" of energy is the tropical maritime air.

In the regions where depressions form near the equator and in the seasons, the easterly and westerly winds at levels from 4 to 8 kms. are well known, and for India were worked out by H. C. Banerjee and K. R. Ramanathan.† The hypothesis and the available diagrams all



1. Tropical Cyclonic Storms (Northern Hemisphere)



2. Recurved Cyclone or Extratropical Depression

show that the direction of movement of the tropical cyclonic storms is determined by the upper air in the equatorial maritime air so long as there are three air masses and by the tropical maritime air when there are only two air masses. To conclude, it follows that the air mass which acts as the energy "source" for the depression seems to control the direction of motion of the depression. The result can be generalised, as a suggestion, that even for a low pressure wave the upper air motion at about 6 kms. in the "source" air mass must determine its direction of motion in addition to all other factors that may be responsible for its movement. When a pulse moves from south of the equator to the north carrying fresh monsoon air often one finds that the surface air is northerly. But the upper air at higher levels give a west south-westerly or even southerly direction, which permits the flow of air under suitable conditions. Further work is in progress.

*Deppermann, "Are there warm sectors in Philippine Typhoons: Bureau of Printing", Manila, 1937.

†*Sc. Notes Ind. Met. Dept.* **13**, p. 21.

APPLICABILITY OF THE PLACZEK'S THEORY OF RAMAN SCATTERING AT HIGH TEMPERATURES

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THE polarisability $\alpha(q)$ of a molecule may be expanded as a series

$$\alpha(q) = \alpha_0 + \sum_j \left(\frac{\partial \alpha}{\partial q_j}\right)_0 q_j + \tfrac{1}{2} \sum_j \left(\frac{\partial^2 \alpha}{\partial q_j \partial q_k}\right)_0 q_j q_k + \ldots, \quad (1)$$

where the suffix 0 refers to the equilibrium configuration. q_j, q_k, etc., are the various normal co-ordinates of the molecule and a particular set of values of q_j, q_k, etc., define a configuration q of the molecule.

The first term α_0 which is independent of the nuclear vibrations is responsible for Rayleigh scattering, while the term in $\left(\frac{\partial \alpha}{\partial q_j}\right)_0$ gives rise to Raman effect. The aggregate intensities of the Stokes and the anti-Stokes Raman lines according to the Placzek's theory of Raman scattering are given by (2) and (3) respectively.

$$I_{(\nu-\nu_j)} = \frac{64\pi^4}{3c^3} (\nu-\nu_j)^4 \{4A^2_{1j} - 7B_1{}^2\} \frac{1}{1-e^{-\frac{h\nu_j}{KT}}} \quad (2)$$

$$I_{(\nu+\nu_j)} = \frac{64\pi^4}{3c^3} (\nu+\nu_j)^4 \{4A^2_{1j} - 7B_{1j}\} \frac{1}{e^{\frac{h\nu_j}{KT}} - 1} \quad (3)$$

where A_{1j} and B_{1j} are the invariants of the symmetric tensor $\left(\frac{\partial \alpha}{\partial q_j}\right)_0$. The ratio of the intensity of the Stokes Raman line to that of