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On the formation of the Masulipatam Cyclone of 1949

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ABSTRACT. The formation of the Masulipatam cyclone of 1949 is discussed from the viewpoint of a representative of the non-frontal, non-air mass group of tropical meteorologists and compared with the frontal hypothesis previously presented by Sen and George.

1. Introduction

In a recent article Sen and George (1952) endeavor to show that the Masulipatam cyclone of October 1949 formed as a result of the interaction of three air masses at a so-called triple point and that frontal characteristics were exhibited by the cyclone throughout much or all of its life history. In view of the fact that air mass and frontal techniques are never used in many areas where tropical cyclones form it would appear instructive for a representative of the latter group to discuss the Masulipatam cyclone formation from a different viewpoint. This note can be considered as only a feeble effort in that direction since no maps are presented but instead the charts of Sen and George and those published in the Daily Series Synoptic Weather Maps (U.S. Weather Bureau 1949) will be relied upon for the discussion. An attempt will be made to show that this cyclone formation satisfies a model described by Riehl (1948, 1950).

In general the non-frontal school does not deny the existence of temperature gradients in the tropics or the fact that wind shifts may occur along definite oriented lines or zones. However, they maintain that dynamic and thermodynamic processes in the neighbouring area have more to do with determining the " air mass " characteristics than the source region ascribed to the air. Moreover, in general they hold that such " air mass " boundaries as are found in the tropics fail to behave in the manner of true fronts. For example, it has been noted that tropical fronts appear and disappear over short periods of time and they seldom move with the speed of the wind normal to them. In view of the small density differences between tropical air masses the non-frontal group has not been convinced that redistribution of the air masses as, for example, in the occlusion process, constitutes an important energy transformation. These points will be discussed in more detail in the following paragraphs.

In raising certain objections to the frontal and air mass techniques it has been kept in mind that such models are undoubtedly useful in forecasting or they would not have been retained. However, this does not rule out the possibility that models developed specifically for the tropics may in the future prove even more useful.

2. The Masulipatam Cyclone of October 1949

The low level streamline charts presented by Sen and George (1952) show the northern boundary of the equatorial westerlies (their ITF) had receded over the Indian continent during the four days prior to the storm development in connection with the building of an anticyclonic eddy over northern India. At the time of the cyclone formation, on 22 October in the Andaman Islands area, their ITF extended through the Indian continent near Madras and eastward to the formation area just south of Port Blair. The anticyclonic eddy brought northerly flow over the northern Bay of Bengal. The air masses associated by Sen and George with the cyclone formation were the *Tc* brought from the north by the anticyclonic eddy, the *Em* brought by the westerlies south of the ITF and the *Tm* supplied by the easterlies present in the Tenasserim coastal area of southern Burma. The *Tm* was the warmest and occupied the warm sector according to their description.

The streamline charts mentioned previously show a trough oriented roughly north-south which moved from the vicinity of Allahabad on 18 October to central Burma on 21 October. On this latter date it is drawn from the vicinity of Mandalay to Port Blair. The 500-mb charts in the Daily Series Synoptic Weather Maps (U. S. Weather Bureau 1949) also show clearly the progression of this upper westerly trough across northern India. The surface maps and low level wind data in this publication show evidence of a weak cyclonic vortex passing between Tavoy and Victoria Point between 18 and 19 October.*

3. An interpretation of the cyclone formation

One of the models of tropical cyclone formation described by Riehl (1948) utilizes an interaction between a trough in the middle latitude westerlies and an existing disturbance moving westward in the easterlies or along the equatorial trough. It is suggested that this model is fulfilled on 21 October as the upper trough extended to the area of the Andaman Islands and resulted in the deepening of the weak vortex which passed between Tavoy and Victoria Point two days earlier. Any such interaction results in the spreading of the bad weather area of the initial disturbance but only a small percentage of such systems deepen to cyclone intensity. According to Riehl's model subsequent synoptic events must be such that the upper flow in the vicinity can " organize " the incipient cyclone (Riehl 1950). An eastward progression of the upper trough and the development of anticyclonic northerly flow over the Andaman Island area would constitute a most favourable arrangement since such an upper current must, from the conservation of absolute vorticity principle, be divergent. The upper wind observations (U.S. Weather Bureau Daily Series Synoptic Weather Maps 1949) give strong evidence that just such a sequence took place. The anticyclonic cell over northern India on 21 October sloped eastward with height and at 30,000 ft was centered over the northern Bay of Bengal. Thus, the likelihood of the northerly flow extending to the storm area at the time of the formation was greater at upper levels than near the surface. The flow of the so-called *Tc* air over the Bay of Bengal would from this model be a vital factor in the storm development. However, this is true only since (*a*) it provides an upper divergent flow which favours surface pressure falls and (*b*) since it offers a means of removing the warm ascending air from the storm area ; a necessary condition if the storm is to function as a thermodynamic engine (Riehl 1951).

It will be admitted that the description of the storm formation presented above cannot be fully substantiated by the available data. It is presented, however, as an alternate hypothesis for the cyclone development and an attempt will be made to establish some points in its favor in the following Section.

It is not known to what extent this and other models developed for the Atlantic and Pacific formation areas have been tested for Indian Ocean storms. It is of interest, however, that the mid-summer minimum of tropical cyclones in the Indian Ocean area coincides with the period when the upper westerlies are north of the Himalayas and interactions with disturbances in the Bay of Bengal and Arabian Sea would be infrequent or non-existent.

4. Comparison of the frontal and non-frontal hypotheses

The initial energy source according to the alternate hypothesis was furnished jointly by the small vortex in the equatorial

*Sen and George account for this low level wind shift by moving their ITF about five degrees of latitude southward. The wind normal to the ITF was far from sufficient to account for such a frontal movement trough and the upper westerly trough. The energy source for deepening to cyclone intensity was furnished by the accelerated release of latent heat energy as the disturbance became organized following the " fracture " of the westerly trough and the onset of the upper divergent flow. The process of deepening requires the low level air ascending in the organized convection area to satisfy certain minimum conditions of temperature and moisture (Palmen 1948). However, these conditions are usually satisfied in cyclone formation areas throughout the warmer season.

The initial energy source according to the frontal hypothesis presumably results from a solenoidal circulation created by the sinking of the colder air (*Em*) and the ascent of the warmer air (*Tm*). However, Sen and George suggest that a strengthening of the easterly current following the dissipation of a typhoon in the South China Sea also played a role in the development. However, the easterly flow in the lower few thousand feet at Seno and Vientiane in Indo-China, presumably in the path of *Tm* air, was essentially constant in direction and speed between 18 and 23 October. It is thus suggested that the increase in the easterlies along the Tenasserim coast was a result of deepening of the vortex. A point not discussed by Sen and George was the modification of the *Tm* air as it moved across the highlands of southern Burma. However, assuming that occlusion of this air mass can release an initial energy sum it remains to be shown why the surface pressure falls and the storm takes on " organization ". It should be noted, as pointed out by Riehl (1951), that such an occlusion process would replace the warmer, moister air near the surface with cooler, drier air which would inhibit the convection process and slow down the release of latent heat which in the end must supply the energy of the cyclone. In contrast to middle latitude systems the deepening of the cyclone cannot be attributed to a tilting of the axis toward the vertical because of the small density differences between the air masses in comparison with the large pressure falls which are observed.

The " air masses " about the cyclone are found by the non-frontal analyst after it develops and organizes a low level inflow. However, these " air masses " are thought to have essentially the same low level characteristics except wind direction and speed. These differences will show up as definite lines of streamline convergence and often give configurations similar to middle latitude frontal patterns. These are considered as microstructure and to have secondary importance in the maintenance and movement of the cyclone. The orientation, intensity and location of these lines or zones may change fairly rapidly with time but they often retain their identity as they spiral inward toward the storm center. In this scheme, these show up as the " spiral bands " observed by radar (Wexler 1946-47).

It cannot be denied that even within a tropical cyclone the characteristics of the air, especially at upper levels, vary appreciably with time. However, the dynamic and thermodynamic processes at work in the neighboring area cannot be neglected in assigning a classification to the air mass. For example, Sen and George (1952) present time cross-sections for Calcutta which show clearly a change of " air mass " between 19 and 22 October. But, it cannot be neglected that the Calcutta observations were made in an upper trough on 19 October and in a ridge on 22 October. The non-frontal group would expect the air from any upper anticyclonic cell over land or sea to have the so-called *Tc* characteristics.

Surface fronts drawn within a cyclone should presumably move with the normal component of the surface wind velocity. Thus, fronts near the center should move around the storm several times during its life history and " wind up " to give a pattern similar to the convergence lines noted by the non-frontal group. If, instead, the fronts are moved slower than the wind it would seem that a paradox is introduced since air must move through the "fronts" and, for example, change from *Tm* to *Tc*. It could, of course, be claimed that processes at work within the various sectors of the storm maintain certain "air mass" characteristics within these sectors. However, in such case the frontal and air mass models and techniques borrowed from the middle latitudes clearly cannot be applied to such "fronts" and "air masses".

In conclusion the writer will readily admit that the alternate hypothesis presented above does not offer a complete solution to the cyclone formation problem. However, it is maintained that to the extent to which this model has evolved it is far more consistent with the known physical attributes of the tropical cyclone than is the frontal hypothesis.

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