"The Equatorial Front"

Text of two lectures given by C. E. Palmer, University of California, at the Central Meteorological Observatory, Tokyo, Japan on the 5th and 12th February, 1949.

The Equatorial Front

The subject upon which I am going to speak, the equatorial front, is one in which Japanese meteorologists have taken great interest; that is partly the reason why I chose it as the subject of discussion. Other names are used for the system -- sometimes we hear it spoken of as the intertropical convergence zone; some, for example, the Norwegian meteorologists, call it the intertropical front. The different names reflect different ideas concerning both the atmospheric circulation in the neighborhood of the equator and the perturbations that affect it, and at least a brief historical account of those ideas is necessary to a complete understanding of the problems I shall discuss. The first description of the equatorial front was given by two English meteorologists, Brooks and Braby, (3) in a paper, "The Clash of the Trades in the Pacific," published by the Royal Meteorological Society in its Quarterly Journal soon after the First World War. From surface wind data for various stations in the South Pacific, together with a few North Pacific observations, the authors calculated and plotted the mean surface air transport in the equatorial west Pacific. I wish to emphasize that their study was almost completely a statistical one. They found that a line could be drawn near the equator on the map for the southern hemisphere summer, the mean transport being roughly northeasterly north of the line and southeasterly

on surface observations and upon observations of pilot balloons. Since radiosonde data have become more plentiful in equatorial regions, less emplasis has been placed on airmass difference and upon fronts. As far as we can tell from these observations the atmosphere more closely approaches autobarotropy near the equator than in any other region. The so called air masses in the tropics so closely resemble one another that even if surfaces of discontinuity existed between them (which may be doubted) there could be no concentration of solenoids in the frontal zone, and consequently no marked acceleration of circulation that could be attributed to a redistribution of mass. We must, in fact, look for some source of energy otner than the initial mass distribution to account for the development of the circulation of typhoons. It cannot be emphasized too strongly that by 1940 many tropical meteorologists were convinced that except in the immediate neighborhood of typhoons the atmospheric variables, pressure, temperature and density, upon whose gradients in space and time we base our major analytic techniques in high latitudes, reveal only weak gradients between 15° north and 15° south of the equator, and that, therefore, the frontal techniques of high latitudes are only doubtfully applicable to tropical analysis.

It cannot be doubted that Deppermann, and others who followed him, found "fronts" on synoptic maps for the tropical western Pacific. Aircraft observations made during and after

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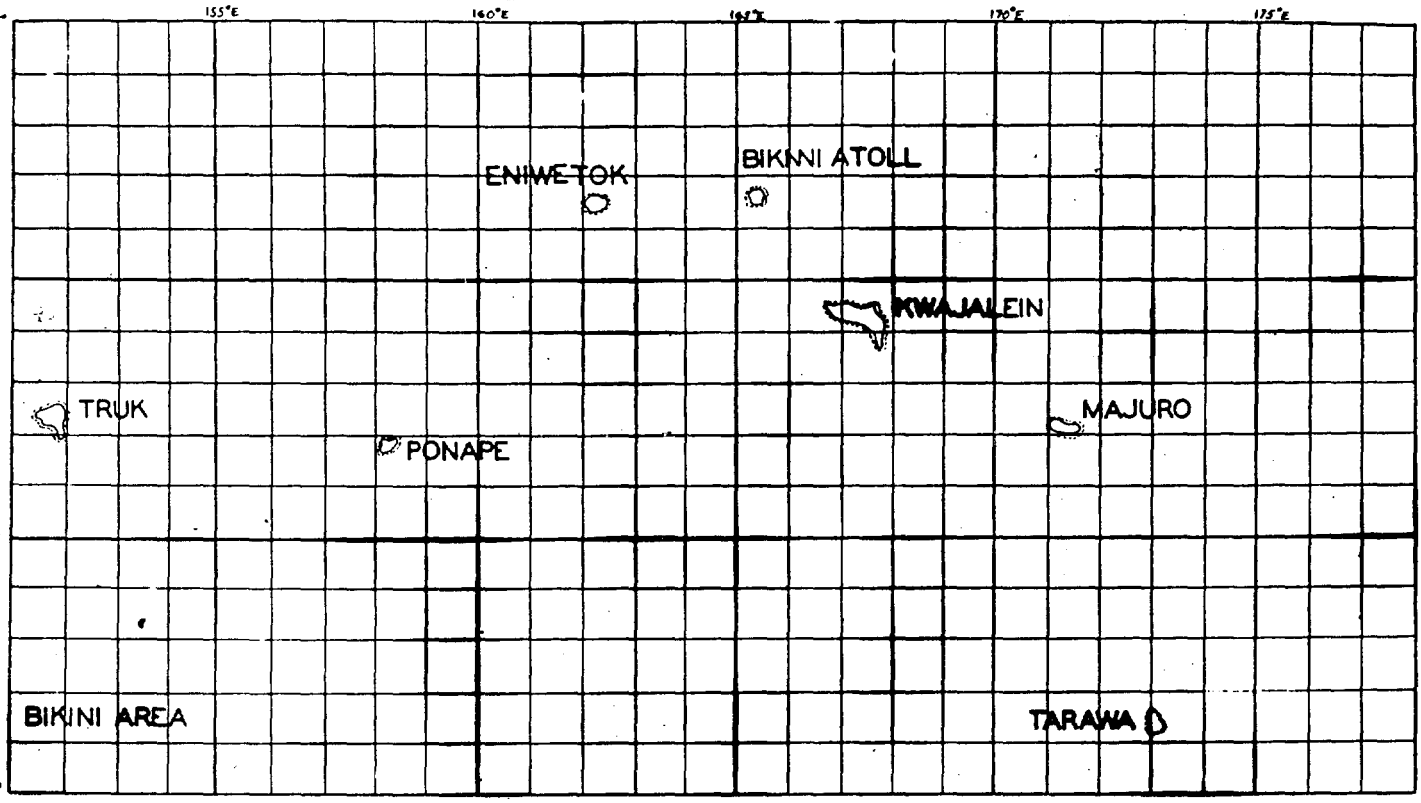
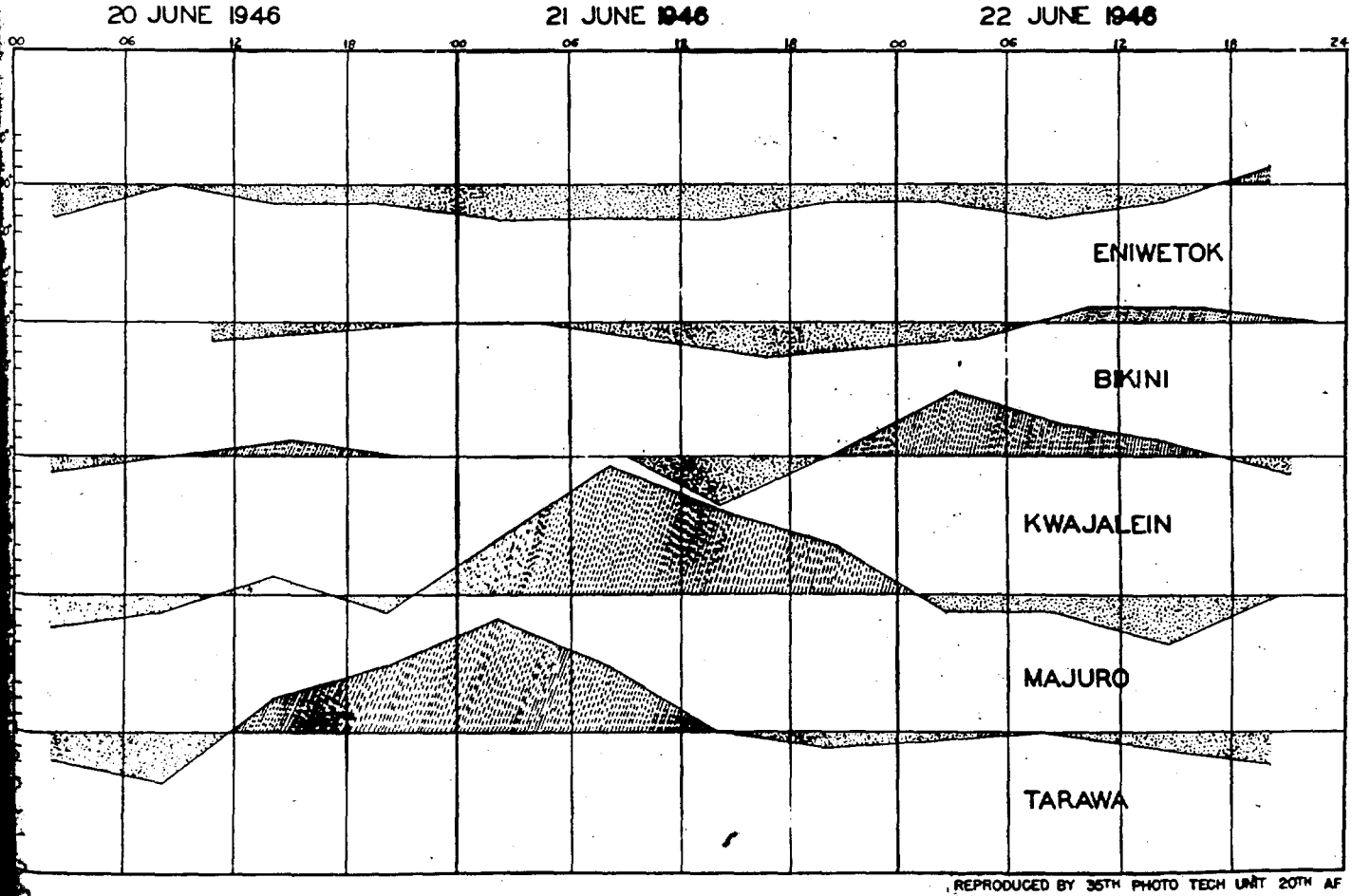
confirmed its position. During the forecast period in-flight reports might further confirm the analysis. Next day, with no obvious variation in the surface analysis, the in-flight reports could show the complete absence of the equatorial front both in the weather and wind fields. This has been the experience time and time again of forecasters in the North and the South Pacific, and has given rise to complicated theories of intensity change, with little dynamic or synoptic backing.

We cannot leave this topic without reference to the work done in the Philippine Islands by Father Deppermann. In a long series of papers he has devoted himself to investigating the relation between the equatorial front and the origin of typhoons. It was thought, and still is by many meteorologists, that typhoons originate or are generated on the equatorial front in the same way as extra-tropical cyclones are generated as waves on the polar front. Using the classical methods of the Bergen school, the group of meteorologists of whom Depperman is the most distinguished representative identified "air-masses" in the neighborhood of the equator, discovered triple points where three fronts met, and where typhoons were supposed to originate, and finally discovered well-marked fronts even in the central portions of the mature typhoon. Great significance was attributed to small differences in temperature, to the supposed source regions of the air masses and to the slope of the fronts. It should be emphasized that a large part of this work was based





VARIATION WITH WIND DIRECTION WITH TIME AT 2000 FT. AT EACH STATION

Fig. 7

behind and in front of the positive axis.

d) Instable vortex (Stage 3). Suddenly (the details are as yet obscure, because the change is so rapid) the tangent point is replaced by two singular points, one negative, lying to the east, the other a neutral point which moves ahead of and relative to it. Westerly winds make their appearance for the first time in an obvious circulation about the negative point, while the asymptote of convergence extends well ahead of the disturbance joining up with that of the previous vortex of the series, if there is one. It is now possible to draw a continuous "equatorial front" from one vortex to another in a series such as exists between 150° E and the China coast when the typhoon season is well advanced. However, it may be difficult to detect a closed pressure center about the negative point; though one will undoubtedly exist, the depression of the barometer in that central region may be so slight in comparison with the surroundings that it would require very accurate and dense pressure observations, and the careful drawing of isobars at half-millibar intervals to delineate it. The chances are that at an early stage in the deepening process the whole vortical disturbance will be mistaken for an easterly wave. We regard the vortex as unstable so long as it deepens, with increasing development of kinetic energy in the lower layers. The deepening may be very slow so that the vortex may pass from the longitude of Guam to beyond the Philippines as a simple weak, but slowly developing depression. On the other hand the deepening may be very rapid

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indeed, the circulation attaining typhoon intensity in a matter of 24-36 hours, from the time of first appearance of the singular points (which marks the inception of the definitive vortex.)

e) Stable vortex. Sooner or later the vortex reaches a stage where it deepens no more and moves without much change of intensity for long distances. Stable vortices seem to be of every degree of intensity from feeble circulations barely detectable as such in the pressure field up to the most destructive typhoons. All stable vortices seem subject to the same vicissitudes; they may move westward for long distances, or may recurve into higher latitudes. They appear to be much weakened by prolonged passage over land. So long as they are on the westward track they move uniformly at a speed between 10 and 15 knots (this also is the speed range of the stable waves) but near, at and after recurvature the speed of movement may be erratic. In other words the known characteristics of typhoons (except for intensity) seem to apply to stable vortices in general. Indeed a typhoon is simply a vortex that has attained sufficient intensity to be of practical interest to man.

It will be obvious to you that I have merely described the appearance of typical streamline maps at low levels in one small area in the central Pacific and that for only a short period in 1946. Nevertheless even this limited information throws a flood of light on many problems that beset us in the days when we relied on inadequate surface pressure maps. First, we can give up the

attempt to explain equatorial weather by means of concepts developed from the study of the weather in Northwest Europe -- in other words, by frontal and air mass concepts -- and treat equatorial research as a department of Meteorology with problems of its own, requiring special observations and methods of solution. Of these methods the analysis of the velocity field stands out as the most useful at the present time, because it has been the most neglected. We must, of course, consider also the relation of the wind field to the fields of pressure, of temperature, and of composition (weather). The researches I have described, in fact, raise more problems than they solve, which is a promising sign for the future.

Secondly, the "fronts" of the equatorial regions, now receive an unequivocal kinematic definition -- they are asymptotes of convergence in the streamline field. In the early stages of wave development, they are absent or weak. They develop in intensity as the wave becomes unstable and are most marked when the definitive vortex is formed. In other words the equatorial front, or fronts, considered as synoptic entities do not <u>precede</u> the formation. The influence of this principle on forecasting is obvious. Thirdly, the "equatorial front" in the sense I have described, is continuous only where one has a continuous series of vortices such as occurs westward from Guam during the wet season. Elsewhere it appears and disappears with the varying history of the equatorial waves, in a manner entirely familiar to equatorial forecasters.

Fourthly, the problem of typhoon formation takes on a new aspect. During the wet season vortices are forming in an almost continuous series westward from the Marshalls and Carolines. Only a few of these become intense enough to be called tropical depressions, storms or typhoons. The problem of typhoon formation is now seen to be the problem of intensification. Some vortices intensify greatly, others remain weak, difficult to detect in the pressure field. The ideal method of investigating the causes of typhoon formation would be to classify the vortices of a long series of maps into two classes -- the class of those that remain weak and the class of those that deepen rapidly and pass a certain arbitrary intensity. Then the wind, temperature, pressure, and composition fields of two classes ought to be compared closely to discover what features are common to all members of the typhoon-depression class and absent from the weak-vortex class. Work along these lines is already in progress.

Fifth, typhoon tracks of the North Pacific take on a new significance. We have so far not failed to trace back every typhoon studied to either a wave or a weak vortex passing previously across the Bikini-Tarawa-Wake axis. The heterogeneous typhoon tracks on published maps, if extrapolated eastward, all pass through this narrow "throat". It follows that we ought to improve typhoon forecasting greatly by developing the observational network in that area to a high degree.

I expect you would like to have heard something about the

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