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NOTES ON THE EQUATORIAL FRONT.

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This present paper is a preliminary investigation into the phenomena experienced in equatorial regions and it is an endeavour to marshall into some semblance of order the various ideas, theories and facts, which have been gleaned from forecasting association with those areas. It is to be hoped that the contents will be of value as a basis on which we can mould, modify and enlarge with increase in knowledge, data and experience.

When Pan American Airways extended their Operational Air lines of the Pacific to include New Zealand, the onus was on the New Zealand Government Meteorological Office to furnish all weather reports and data necessary in the neighbourhood of the route from Canton to Auckland, via Kingman Reef. (This was later changed to via Suva and Noumea).

The tropical and equatorial regions then became of added interest and importance from both the synoptic and forecasting viewpoint. In order to attain some accuracy in forecasting the winds at flying levels, the weather along the route and the terminal landing conditions, an investigation to endeavour to understand the natural processes in the equatorial region was necessary.

Pan American Airways meteorological organization exchanged their area weather maps among their branches, and in order to obtain other peoples' ideas on the equatorial region, an arrangement was made, whereby the Auckland Branch of the New Zealand Government Meteorological Office received Meteorological data and maps in exchange.

Towards the end of 1939 and early in 1940, reporting stations were very sparse and the instruments and reports were somewhat unreliable. As the P.A.A. service developed, so the meteorological organization advanced, except that now the spread of war has caused a further upset.

At the outset it must be decided what is to be termed the Equatorial Front. It seems most useful to define the Equatorial Front as the zone of convergence between the Northern and Southern Hemisphere trade wind systems, placing the emphasis on the convergence rather than the history of the air masses taking part.

At first sight it appears sufficient to consider it as a boundary between the air masses belonging to the Northern and Southern Hemisphere circulations. As such it would be possible, theoretically, to have drawn it as a continuous boundary from one side of the Pacific to the other. In actual practice, such a division of the Northern and Southern Hemisphere air masses, based purely on origin, does not serve a very useful purpose. Deppermann has pointed out in several of his papers, it is quite a common occurrence for two air masses to flow quietly side by side without any interaction and without sufficient difference in characteristics to make their separate recognition of any synoptic consequence. "The greater wind systems of the atmosphere can be inferred from the pressure distribution by the use of Buys Ballot's Law. On each side of the equator are winds which have an easterly component, the Northeast and Southeast trades, extending from the high Pressure belts nearly to the Equator. They have been conventionally regarded as separated by a belt of calms known as "doldrums", but the doldrums are not clearly marked all round the Equator, or at all times of the year.

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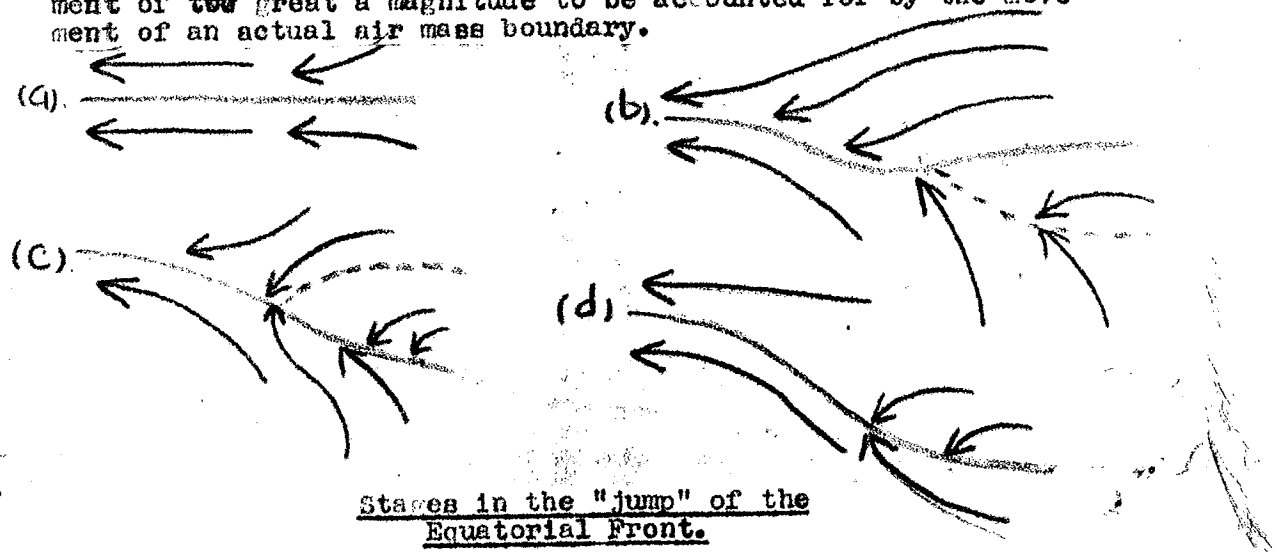
Brooks and Braby (Q.J. Roy. Met. Soc. 47.1921 p.1) have shown that in the Equatorial Pacific the phenomena appeared to be most easily explained by the presence of a sharp surface of discontinuity between the Northeast and Southeast trades, particularly in the region east of longitude 180°. In this region where the Southeast trade meets the Northeast trade, the former rises over the latter, giving heavy rainfall. Beals (monthly weather review 55, 1927 p.215) has shown that the doldrum zone of calms in the Equatorial Pacific is restricted to the shore ends of the tropical belt over that ocean. This same so called doldrum area can fluctuate in width and position, diminishes to vanishing point, giving practically a surface of discontinuity separating the northeast and southeast trades, at times produces extensive vertical convective cloud development and the heaviest rainfall can occur in the zone of light winds." *

In defining the Equatorial front as a zone of convergence between northern and southern hemisphere trade wind systems, it is necessary to remember that, as there is not always convergence between these wind systems, the Equatorial Front will not necessarily be continuous in either time or space.

Being considered as a zone of horizontal convergence in the lower levels, the Equatorial Front is naturally a region where there is a net ascent of air to higher levels (when divergence occurs there is the descent of air). Aloft there is divergence, where the air feeds the antitrade wind systems. It seems probable that this Equatorial convergence zone is associated with a weakening, or more likely, the complete destruction of the trade wind inversion, as was found in the Atlantic from the records of the research ship "Meteor" and described by Von Ficker (inversion of the tradewinds). In such a region, there is a tendency for convective unstable conditions to extend to great heights. Vertical convective activity tends to take place on a larger scale than in the neighbouring regions, where the trade wind inversion is still prominent. Heavy rain squalls are typical of an active portion of the Equatorial Front.

It is found on occasions that the convergence may be concentrated in two more or less distinct zones separated by an undisturbed region of fair weather (can be on other occasions a region of considerable activity and weather), this giving the effect of a double equatorial front. These two zones may vary independently in intensity. The case often arises where a previously active convergence zone loses intensity and ultimately disappears while the other zone is maintained or intensified, giving the appearance of a rapid shift, or jump, in the position of the Equatorial Front. This reappearance of the Equatorial Front in a new position commonly involves a displacement of too great a magnitude to be accounted for by the movement of an actual air mass boundary.



Stages in the "jump" of the Equatorial Front.

This effect of multiple convergence zones similar to that described above for the Equatorial Front may be confused with, or produced by the arrival from higher latitudes of a cold front.

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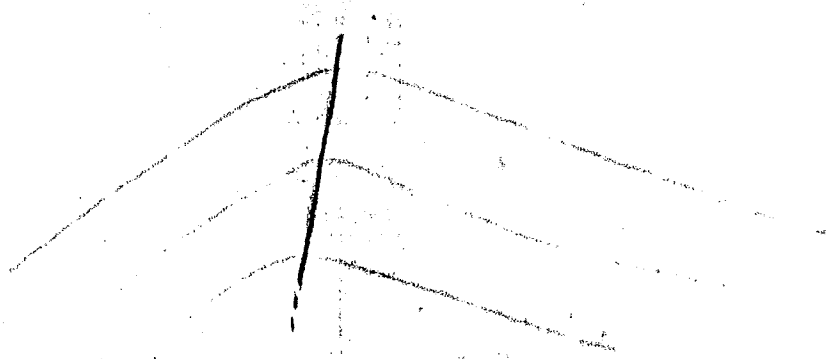
It is common for the cold front lying in the troughs between successive migratory anticyclones of the Southern Hemisphere to be retarded near their Northern extremeties, (Southern extremities in Northern Hemisphere) so that in the equatorial region, they become oriented in a practically East-West direction and move towards the Equator slowly. Complications in the shape of the Equatorial Front may be caused by intrusion of the cold fronts into the equatorial region, or by sinuosities in the stream flow along the Equatorial side of the Northern Hemisphere anticyclones. These sinuosities typically give decreasing and veering (East Southeasterly) winds, followed by a shift to strong gusty Northeasterlies, accompanied by varying degrees of disturbed weather. They have become known as "Northern Hemisphere troughs" and are most conspicuous in the region between latitudes 5° and 25° N.



The name, "Northern Hemisphere Troughs", is due to the P.A.A. Meteorologists working in the Honolulu region. The troughs are usually oriented in a NE-SW direction and usually progress slowly eastwards against the flow of easterly trade winds. They can also take on the East-West orientation similar to that of cold fronts which advance from higher latitudes before an active outburse of cold air. It is considered that they can be accounted for best by Bjerknes perturbations at high levels inducing a fluctuation in the lower level wind system and a disturbance in the weather similar to that of surface front.

Nothing quite similar to these "Northern Hemisphere troughs" or sinuosities have as yet been noted in the Southern Hemisphere, but in the region of Santa Cruz Is. and New Calendonia, there seems to be a tendency for a col to form. Sharpening of this col can be accompanied by bad weather and low ceilings and usually becomes linked to the cold front which moves up from the South.

Petterssen (Weather analysis and Forecasting) has shown that convergence of the trade winds from both hemispheres forms excellent kinematic conditions for frontogenesis to occur in the doldrums, but points out that the temperature difference between the trade winds of winter and summer hemisphere rarely amounts to 1° or 2° C.

Deppermann in "Weather and Clouds of Manila" states that the differences between the trade and the Southwest monsoon are slight and that there is little evidence of much overrunning. He provides an exception, however, when the trade surges back accompanied with wet, rather dark Cumulus or Nimbus clouds, squalls and heavy showers.

From time to time a relatively sharp frontal surface such as this, may be observed in the western half of the Pacific, when a relatively cool air mass intrudes into the Equatorial region, usually, from the winter hemisphere. In these cases, there is usually a discontinuity in wind strength across the front with stronger winds on the side of the intruding air. Often the process is due to the building up of an intense anticyclone, which causes a "Push" of air across the Equator. The trajectories of the air on such occasions have been calculated by Grimes in his "Movement of air across the Equator". The Equatorial Front in these circumstances is often of a rainy type with Nimbus and Altostratus and with Cumulonimbus associated with the squall line. In this example, the position may have been compli-

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cated and confused with the cold front which precedes the outburst of the cold air of the anticyclone.

It is more usual, however, for there to be insufficient density difference between the air masses concerned for a sloping surface to be formed or for appreciable overrunning to take place. Normally the Equatorial Front is simply a rather broad region of doldrums where light and slightly convergent winds produce mildly disturbed weather. Here there is a greater tendency towards scattered cumulus or cumulonimbus development than in the neighbouring regions of true trade winds, where cloud is more predominantly stratocumulus (so called "Trade wind cumulus") limited aloft by the trade wind inversion. In the doldrum region the weakening and possible lifting or complete destruction of the inversion allows freer convection, and scattered showers result.

Varying amounts of Altocumulus (type Cm = 6) and cirrus (typically C_H = 3) may be present, probably originating from the spreading out of the middle portions and tops of occasional Cumulonimbus clouds. This spreading out of the middle and tops of occasional cumulonimbus clouds can take place in front and behind the cloud, or can be more marked in one direction than in the other and the extent of this spreading may cause confision as regards the type of "front" likely to be experienced by the pilot.

The features described in the above paragraph may be responsible for the appearance of the Equatorial Front to take on some of the characteristics of a warm front. In this case the explanation appears to be that the push of air causing the displacement takes place first at high levels (possibly at inversion level) and later near the surface. It also seems to indicate that the vertical convection will not necessarily be maintained and hence the Equatorial Front apparently has warm front characteristics.

The degree of activity of the equatorial convergence zone may vary considerably. In its more intense state convective activity takes place on a large scale - Cumulonimbus, altostratus, altocumulus and cirrus are present in abundance and frequent heavy rain squalls, low ceilings and deep cloud make flying conditions unpleasant and hazardous.

This intensification may take place in a variety of ways. Sometimes it is associated with the narrowing of the belt of doldrums, as may occasionally be caused by the intensification of anticyclones on both sides of the Equatorial zone, resulting in an increase of the pressure gradients and a strengthening of the trade winds with consequent narrowing of the doldrum zone of rather flat pressure distribution. Sometimes the greatest activity is centred on the two outer edges of the doldrum zone. In this case, there is usually a noticeable contrast between the steady, moderate or fresh, trade winds outside and the light variable winds within the doldrum zone. At times this situation develops into one of a single and relatively sharp Equatorial Front by the intensification of the activity along one of these edges, together with a lessening and disappearance of activity at the other edge.

Again, the region of the equatorial front sometimes becomes one of divergence, instead of convergence. Then the activity diminishes and the weather improves. The equatorial Front becomes so diffuse and indistinct that it seems to disappear completely from the region. When this stage is reached and provided there is no appreciable contrast in air masses, there seems little to be gained by marking a continuous front on the synoptic chart.

The Equatorial Front may oscillate in position as the anticyclonic regions on either side vary in intensity, or as depressions orcyclones are formed. Near the Equator, where the coriolis force is negligible, the tendency is for the air to move across the isobars from the higher to the lower pressures. As this pressure increases on one side of the equator, relative to the other, there is a tendency towards a transport of air across to the side of lower pressure, or in other words, an anticyclone appears to exert a "push" on the Equatorial Front.

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* The winds at Ocean Island may provide an excellent example of transport of air across the Equator. It has been found that when the winds back from the light Easterly directions right round to the west and then begin to freshen, there is usually "something brewing" either in Northern or Southern Hemispheres - in the case of the Southern Hemisphere, it seems that cyclone circulation or vorticity has been completed in the flat low pressure area.

Then again, when the winds turn West at Canton Island, squally, changeable and showery weather is generally experienced, rather indicating on occasions, cold fronts which have been pushed across the Equator from the Northern Hemisphere.

Fronts of appreciable intensity are seldom observed during equinoxes and the position of such an equatorial front is ascertained when cyclones form on it, or in the neighbouring region. At equinoctial periods, the temperatures are approximately equal in both hemispheres. The strongest fronts are found in late summer, or late winter, when the temperature difference is a maximum.

In locating the Equatorial Front, great reliance is placed on upper wind reports, which give clues to the regions of convergence and divergence. Unfortunately, however, the pilot baloon network in the Pacific Island region is still very sparse. Very important, also, is the recognition of sky condition. Furtunately, the network of surface observations has been greatly improved in the last year or two, although in some portions, it is still rather open. At present the recognition and location of the Equatorial Front still depends on the ability and experience of the analyst. Until recently, one important type of information has been entirely lacking for the Pacific region, viz., upper air temperature data. With the institution in Fiji of daily aircraft ascents, the observations should prove of great interest in summer, when the Equatorial Front moves Southwards towards Fiji.

I desire to express my appreciation of the encouragement and advice which I received from Mr. J.A. Day, Pan American Meteorologist while he was stationed in Auckland.