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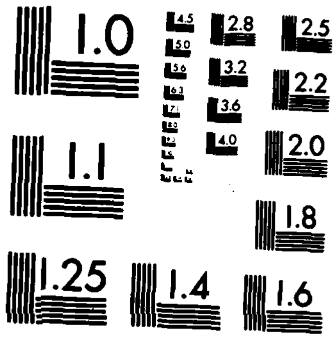
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VOLUME I

# MEAN UPPER TROPOSPHERIC FLOW OVER THE GLOBAL TROPICS

BY


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JANUARY 1984




AIR WEATHER SERVICE (MAC)
Scott AFB, Illinois 62225

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Upper air climatology over the tropics is a powerful forecast tool. This technical report consists of mean monthly 200- and 300-mb wind charts for the global tropics. Volume I is a brief discussion on how the charts were developed, the significant climatological features, and their use. Volume II contains the maps. In day-to-day use the forecaster must identify the location of key synoptic features and adjust the forecast to these features. This requires an understanding of these features, their persistence, and their relative effect on sensible weather.

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# MEAN UPPER TROPOSPHERIC FLOW OVER THE GLOBAL TROPICS

## Chapter 1

## INTRODUCTION

1.1 Background. The Mean Upper Tropospheric Circulation Over the Global Tropics charts were developed by James C. Sadler of the University of Hawaii. The period of record is 1960-1973, and consist of 175,000 observations per month. Data were drawn from PIREPs and RAWINs. These charts were originally published by the University of Hawaii on smaller scale maps (Sadler, 1975). Those wishing an in-depth discussion of these data should consult the original publication. The fact that Sadler's work is frequently referenced by other writers lends credence to the validity of his analysis.

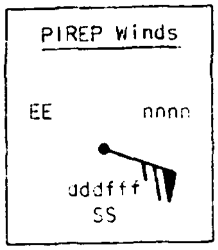
1.2 Upper Air Climatology. The value of upper-air climatology is that it establishes a norm with which to compare day-to-day deviations. In data sparse areas it provides the basic analysis that is adjusted to fit the limited data. It also explains regional weather regimes.

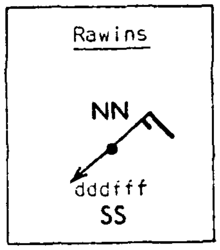
Chapter 2

DATA PLOT

2.1 Data Plot. Fewer than 10 aircraft observations for a 5-degree square were not plotted and plots containing fewer than 25 observations are indicated by a dashed wind staff and barbs.

2.2 Plotting Model. Figure 1 is the plotting schematic.




| | | |
|---|---|---|
| EE | - | percentage of winds with an east component |
| nnnn | - | number of observations |
| ddd | - | mean resultant wind direction |
| fff | - | mean resultant wind speed in knots (flag = 50 knots, long barb = 10 knots, short barb = 5 knots) |
| SS | - | steadiness of winds in percent |
| NN | - | number of years of record |

Figure 1. Plotting Schematic.

# Chapter 3

# ANALYSIS

3.1 Methodology. Aircraft observations for all levels were analyzed first to make maximum use of the PIREP data base. The excellent data base permitted a definitive analysis over most of the Pacific Ocean, the North Atlantic Ocean, Africa, the Middle East, and portions of the Indian Ocean. The mean monthly composite analyses were then used as underlays to control the analyses of the streamline and isotach patterns for the 200-, 250-, and 300-mb charts over oceans and other regions of sparse RAWIN observations. Time continuity was maintained by underlaying analyses of adjacent months.

## Chapter 4

## TERMINOLOGY

4.1 Troughs and Ridges. The upper tropospheric flow patterns can be rather complex, particularly during summer. Therefore, discussion will be aided if major circulation features are identified and labeled. The complex Northern Hemisphere systems of August are shown in figure 2. When only a single ridge exists in a hemisphere or portions of a hemisphere, it is referred to as the subtropical ridge. When a double ridge system exists, the lower latitude ridge is designated the subequatorial ridge, and the higher latitude ridge is designated the subtropical ridge. NOTE: The subequatorial ridge of the western and central North Pacific becomes the subtropical ridge across the United States and the North Atlantic. The subtropical ridge of the eastern North Pacific, northern South America, and the north Atlantic becomes the subtropical ridge over Africa, Asia, and the North Pacific. The trough between the subequatorial and subtropical ridge is referred to as the Tropical Upper Tropospheric Trough (TUTT). Similar troughs exist during summer in the Southern Hemisphere, eastern North Pacific, Central America, and the Gulf of Mexico.

Figure 2. The location of troughs, ridges, and major currents at 200 mb during August

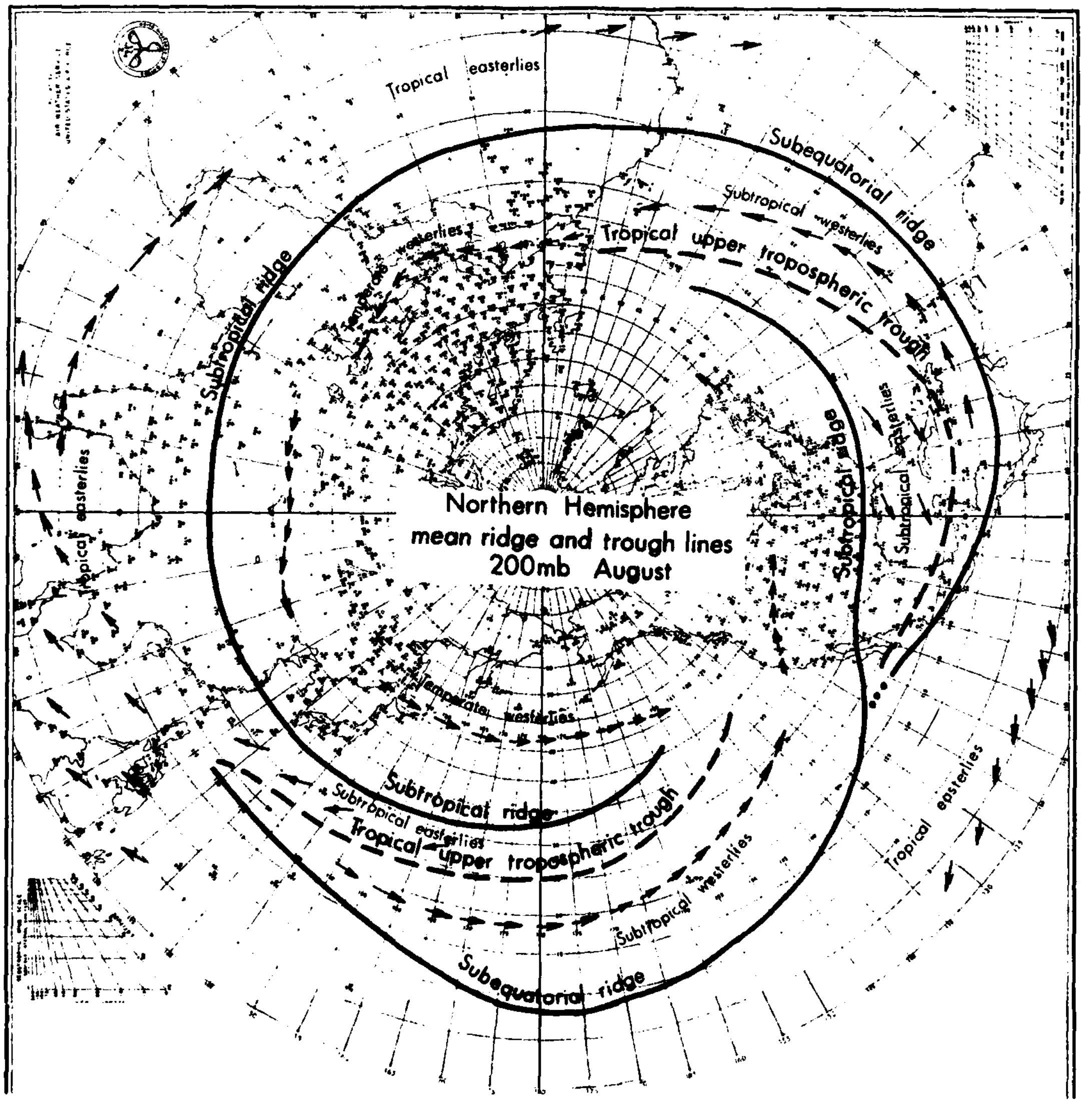



Figure 2. The Location of Troughs, Ridges, and Major Currents at 200 Mb During August.

A near-equatorial system which needs defining results from the development and existence of a primary system in one hemisphere without a counterpart in the opposite hemisphere. The evolution of a near-equatorial system in the eastern Pacific is depicted in figure 3 by sketches of the changing 200-mb features from January to August. In January [figure 3(a)], westerly flow covers the equatorial region east of 170W in the absence of a ridge system in either hemisphere. In May, a ridge forms over the eastern North Pacific between 10N and 15N, and by June [figure 3(b)], it extends westward to near 140W. Easterly winds are established south of the ridge line. No counterpart ridge forms in the Southern Hemisphere and westerlies exist from the equator southward. A counterclockwise turning wind system is therefore established between the westerlies of the Southern Hemisphere and the easterly flow south of the ridge line. The ridge continues to strengthen and move northward, and by August (figure 3(c)), mean easterly flow is established across the North Pacific south of the ridge line. A similar system forms in the Atlantic by late May when the Northern Hemisphere ridge begins to extend westward from Africa. Also by late May the South American anticyclone of the Southern Hemisphere summer disappears and westerlies extend northward to the equator. By July the Northern Hemisphere subequatorial ridge is well established across the Atlantic, northern South America, and the eastern Pacific and near equatorial counterclockwise turning wind system is continuous from the central Pacific to the central Atlantic. The axis of the system, lying very near the equator, can move back and forth across the equator and also slopes with height across the equator. For example, during July and September, the average 200-mb position is just north of the equator and at 300 mb just south of the equator. During August, when the Northern Hemisphere northeasterlies are strongest in the eastern Pacific and eastern Atlantic, the average axis at 200 mb is "pushed" south of the equator in the Atlantic and extreme eastern Pacific but remains north of the equator over South America and the eastern Pacific between 140W and 160W. The sense of rotation is cyclonic when the system axis is north of the equator and anticyclonic when south of the equator.

4.2 Major Currents:

a. Westerlies. The westerly currents of temperate latitudes persist throughout the year and will be referred to as the temperate westerlies.

The westerly currents of tropical latitudes which are distinct from the temperature westerlies will be referred to as the subtropical westerlies. These currents normally exist equatorward of the tropical upper-tropospheric troughs and are therefore a seasonal feature.

The westerly currents of the equatorial region are usually equatorward extensions of the temperate westerlies or of the subtropical westerlies. However, distinct equatorial westerlies are observed over the eastern Pacific from October to April and over the central Atlantic from October to January.

b. Easterlies. The easterly currents between the tropical upper-tropospheric troughts and the subtropical ridges will be referred to as subtropical easterlies. The easterly currents of the tropical and equatorial region between the subtropical ridges of the two hemispheres will be referred to as the tropical easterlies.

Figure 2 shows the major currents of August in the Northern Hemisphere. The spiral configuration of the ridge systems is also present in the wind streams. The subtropical westerlies become a branch of the temperate westerlies and the subtropical easterlies merge into the tropical easterlies.

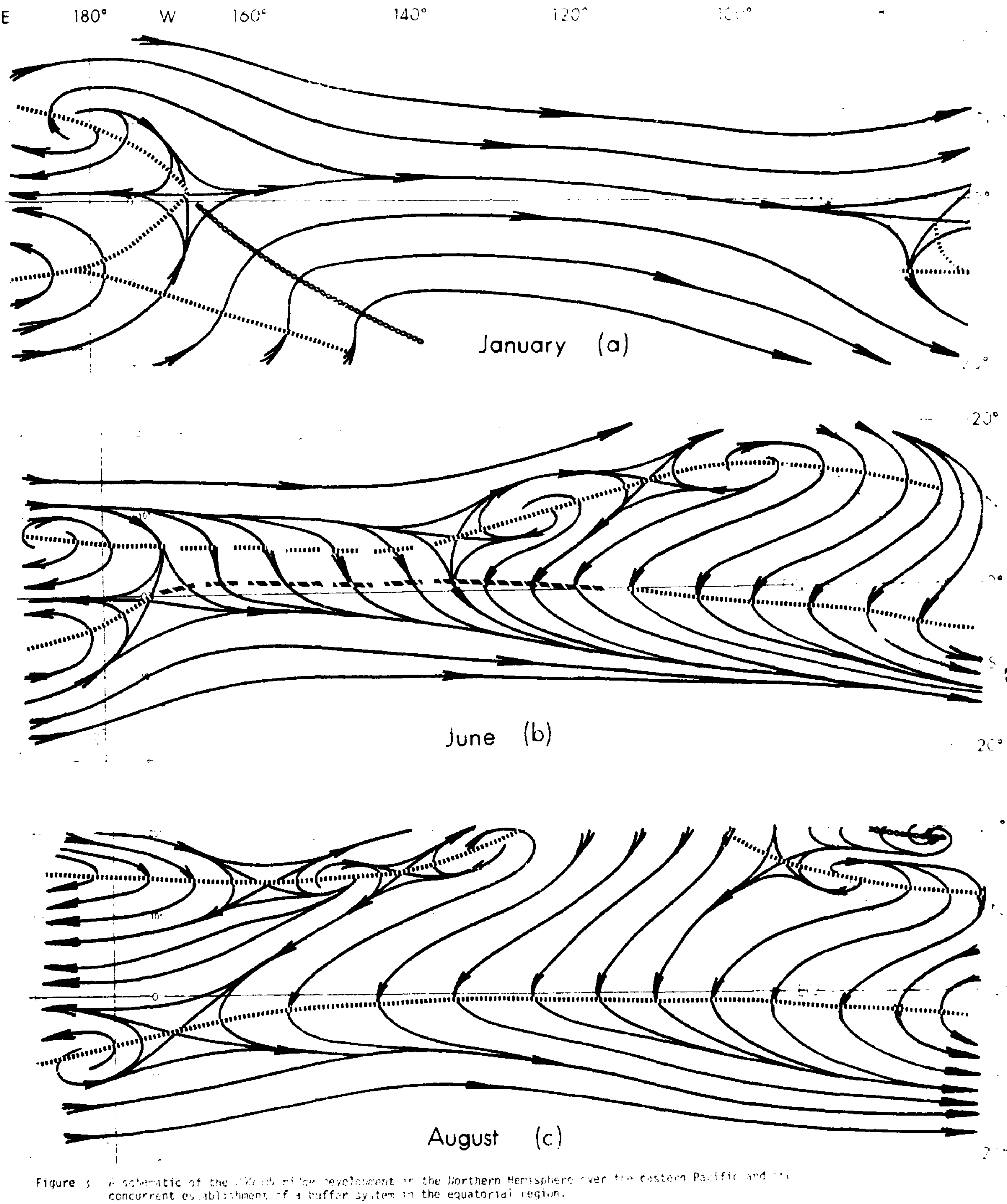



Figure 3. A Schematic of the 200-Mb Ridge Development in the Northern Hemisphere Over the Eastern Pacific and the Concurrent Establishment of a Buffer System in the Equatorial Region.

## Chapter 5

## DISCUSSION

This discussion focuses only on the very gross features of the upper tropospheric circulation in terms of their (1) position and intensity change with time; (2) asymmetries with respect to latitude; (3) asymmetries with respect to longitude, and (4) associations with convective energy sources.

### 5.1 General Features:

a. Tropical Upper Tropospheric Trough (TUTT). Tropical upper tropospheric troughs are a summer feature over the oceans. They are best developed in the North Pacific and in the North Atlantic, Caribbean, and Gulf of Mexico. In the Southern Hemisphere the most pronounced TUTT is in the east central Pacific with weaker ones east of Australia, South America and perhaps Africa. TUTTs can be defined in terms of either the speed field or the direction field. When defined as a distinct minimum speed zone separating the temperature and subtropical westerlies, the North Pacific TUTT lasts from May through November and the North Atlantic TUTT from June through October. When defined as a well-marked trough oriented more or less east-west, TUTT lasts from June-October in the North Pacific and from July-September in the North Atlantic. The North Pacific TUTT is best developed and farthest north in August. In the North Atlantic there is little distinction in intensity or position between July and August. The dense RAWIN network in French Polynesia and observations from the recently established station at Easter Island fix the duration of the TUTT in the east central South Pacific as November through April; it is best developed in January and February.

b. Maximum and Minimum Speeds in Relation to Continents. In the Northern Hemisphere temperate zone, minimum wind speeds are observed over the eastern oceans and west sides of continents and maximum winds are observed east of continents. The opposite is observed in the Southern Hemisphere with maximum winds over eastern oceans and the west coasts of South America and Africa, and minimum speeds over the east coasts. In the Australian region, the maximum axis has a large longitudinal extent and speeds are only slightly greater on the west coast than on the east coast.

The patterns of intense thermal gradients of the Northern Hemisphere winter are determined mostly by the distribution of land masses in high- and mid-latitudes. However, it would appear from these analyses that cross-equatorial outflow from the summer hemisphere plays a significant role in determining position and intensity of the maximum westerlies of the winter hemisphere. This is particularly noticeable in the Southern Hemisphere where there is little land between 30S and 70S and the maximum westerlies are observed on the "wrong" side of continents. In August, the longitudes of the maximum westerlies closely correspond to the longitudes of the maximum cross-equatorial flow. In February, correspondence between the cross-equatorial flow and the longitudes of maximum westerlies in the Northern Hemisphere is also quite good but less striking. Significant flow from the winter to the summer hemisphere occurs in the eastern Pacific between 150W and 110W during the Northern Hemisphere winter. Northwesterlies originate in the near-equatorial region where the maximum convective cloudiness (or heat source) is found north of the equator in the winter hemisphere. The northwesterlies, which are quite strong over the eastern South Pacific, may be responsible for the unseasonably strong and equatorward-displaced westerlies over western South America.

c. Rainfall and Upper Tropospheric Circulation. Features of the rainfall climatology of many tropical and equatorial regions can be explained by either the lower tropospheric mean circulation or the majority of current synoptic models which involve convection being <u>initiated</u> by convergence associated with lower tropospheric features.

The upper tropospheric data base is becoming sufficiently detailed in some areas to suggest that many of the clues to rainfall "anomalies," "mysteries," "singularities," etc., lie in the upper tropospheric circulation and an increasing number of synoptic models depend on divergence in the upper tropospheric to <u>initiate</u> tropical convective systems.

Cited are three examples of "anomalous" rainfall regimes which probably result from a mean large scale feature of the upper troposphere. The Hawaiian Islands have a winter maximum rainfall regime which is usually attributed to frontal systems and cutoff lows in the upper troposphere. However, in April there is a peak in rainfall and in the frequency of occurrence of heavy rains, neither of which can be attributed to an increase in frontal systems nor cutoff upper tropospheric lows. The monthly analyses and the cross section at 150W show a major change in the upper tropospheric flow. The maximum speed axis in the westerlies moves southward through the Islands from March to April and speeds at the axis are greatest in April.

The Caribbean has a summer maximum rainfall regime within which there are early May and late September and October peaks separated by a relative minimum in midsummer. The late summer peak is usually attributed to the occurrence of tropical cyclones. This may be partially true but of course cannot account for the May maximum nor for the midsummer minimum. The upper tropospheric analyses and the cross section at 60W show that (as in the Hawaiian region) the maximum axis of a westerly current migrates southward into the Caribbean in May and then decays in June when the TUTT forms between the double ridges.

Another region for intriguing speculation is Northeast Brazil where the midsummer rainfall is much below expectations and the maximum is observed in the late summer and early fall, March-May. The lower tropospheric mean flow offers no obvious reasons for this "anomaly." However, the upper tropospheric circulation changes appreciably between mid and late summer. During December-February the Northern Hemisphere westerlies and outflow from intense convection over central and western Brazil, between them create a system across Northeast Brazil. This anchored strong cyclonic, convergent flow aloft must be compensated in the lower levels by sinking divergent flow which in turn inhibits precipitation. Perhaps then, the intensity of the summer rains of central and western Brazil in part control the variability of rainfall over Northeast Brazil. The system position and intensity also depends on the intensity and direction of the Northern Hemisphere westerlies.

d. Application in Day-to-Day Analysis. There is a serious deficit in the literature on how to use synoptic climatology in day-to-day forecasting. In the tropics, the mean features are normally found daily. They may be displaced or distorted, but they are there. This is comforting in that the tropics is a relative data sparse area. The challenge is to fit these mean features with the limited data available at any one time. The next step is to relate these features to synoptic scale sensible weather and in turn local weather. In the previous section, examples of mean synoptic scale events were cited. These features are not static. There is day-to-day movement and daily variation in the weather. Through judicious application, these charts are a valuable forecast tool for any tropical location, continental or maritime.

An understanding of the synoptic scale controls is important. One particular feature is the geographically locked anticyclone over the Himalaya massif during the summer. During the summer, the Sahara, North Africa, is under the influence of its strong subsidence capping convective attempts. If this suppressive flow was to shift north or south, it would allow precipitation to occur over the Sahara. In the winter, the massif represents a major heat source to the atmosphere.

The satellite has dramatically shown the weather associated with the Tropical Upper Tropospheric Trough. The trough axis represents an axis of convergence and the downwind side an area of divergence. It is through the use of satellite pictures that one can fix the location of the TUTT by the clear axis.

These mean charts are a valuable tool not only in analysis of daily charts, but also provide a point of departure in sensible weather forecasting. If a trough or ridge is displaced from the norm, the associated weather will be proportionally shifted.

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Sadler, James C., 1975, The Upper Tropospheric Circulation Over the Global Tropics, University of Hawaii, UHMET 75-05.

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