Fluctuations in the Position of the ITCZ in the Atlantic and Pacific Oceans

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1. Introduction

There has recently been renewed interest in the intertropical convergence zone (ITCZ), both theoretically (Bates, 1970; Holton et al., 1971; Charney, 1968) and observationally (Hubert et al., 1969; Bjerkes et al., 1969; Godshall, 1968).

It is the purpose of this note to present some additional results, based on satellite observations, concerning the spatial and temporal variations of the ITCZ as well as other prominent cloudy zones over the tropical oceans, primarily the Atlantic and Pacific. Emphasis is being placed on these regions since they are least affected by continental influences.
a. Data

The source of data for this investigation is the digitized brightness values obtained from the ESSA series of satellites for the period February 1967 through February 1970 and June, July and August 1970. Over the oceans the brightness is essentially a measure of the cloudiness, and the regions of maximum brightness represent (in the mean) low or middle level convergence. The data were utilized in the form of mean monthly brightness values mapped on a 5° latitude by 5° longitude grid. The data sample is an extension of the 13-month sample reported on by Taylor and Winston (1968), who describe the preparation of the charts as well as corrections to the data necessary to improve their compatibility from one period to another. Unfortunately, the necessary corrections have not yet been devised for the entire sample, making comparisons of absolute brightness values and the intensity of observed features for different months uncertain. However, the data are considered reliable with respect to relative spatial differences of mapped features, such that maxima and minima can be readily distinguished. The quasi-zonal axes of maximum brightness in the tropics for the Atlantic (50W–10E) and Pacific (80W–140E) regions were determined from these maps. The latitudinal position of maximum brightness at 5° longitude intervals was tabulated for each month of the 40-month sample. These positions make up the set of data on which the subsequent analysis is based.

b. Mean annual position of maximum brightness axes

The axes connecting the mean latitudes of maximum brightness based on at least 30 observations at each 5° longitude are shown in Fig. 1. North of the equator, across both the Atlantic and Pacific Oceans, there is a zonally oriented maximum which essentially indicates the mean annual location of the ITCZ. It should be pointed out that despite the extension of the axis in the North Pacific Ocean to 140E, there are months when there is no discernible cloud maximum west of about 155E.

In addition, there is an axis of maximum brightness in the South Pacific extending southeastward from New Guinea. As will be shown later, the western terminus of this cloudy zone appears to be anchored over New Guinea and the islands just to the southeast, but shows considerable time and space variability at its eastern portions. There is reason to believe that this axis represents convergence of essentially Southern Hemisphere air particularly east of about 160E, i.e., it is an intratropical convergence zone. This is indicated by examination of ATS cloud motions (Gruber et al., 1971) as well as by mean gradient wind analysis (Atkinson and Sadler, 1970).

Occasionally a zonally oriented cloud zone is observed in the eastern South Pacific at about 5S between 90 and 135W. This feature was first described by Kornfield et al. (1967). It is not shown in Fig. 1 because it appeared rather infrequently with variable longitudinal extent. For example, it was well developed between about 90 and 140W in March and April 1967, but was found between about 105 and 135W in May 1967 and between 90 and 115W in March and April 1968. It is a feature that has no long-term persistence, but it does recur occasionally in the March-May period, and its long-term variations may have some significance as a feature of the tropical circulation.

2. Seasonal and interannual positions

In order to gain a greater appreciation for seasonal and inter-annual variations of the ITCZ\(^1\) and the South Pacific convergence zone, time-longitude sections of the latitude of the axis of maximum brightness were prepared for the Atlantic Ocean, the North Pacific Ocean, and the South Pacific Ocean. Each will be discussed in turn.

a. Atlantic Ocean

The results for the Atlantic Ocean (Fig. 2) clearly show an annual oscillation of the latitude of the ITCZ. It generally has its southernmost position during the late winter to early spring and its northernmost position during late summer to early fall.

\(^1\)The axis of maximum brightness in the Atlantic and North Pacific Oceans will be used interchangeably with the term ITCZ.
Examination of some of the details of the section reveals an interesting year-to-year variability. For example, during the period February–May 1969, the axis of maximum brightness was found fairly consistently at about 5N at most longitudes, whereas during the same months for 1967 and March–May 1968, the axis of maximum brightness was generally further south particularly in the western portion of the section. In some instances it was on the equator or south of the equator.²

It is worth noting that the ITCZ was farther south in the west and central Atlantic during July and August 1968 than during 1967 and 1969, while the most northward position in the western Atlantic during the three years occurred during September and October 1969.

Interestingly, a review of tropical weather systems in the Atlantic by Frank (1970) indicated that August 1968 had significantly fewer depressions than the same month for 1967 and 1969. Examination of the large-scale circulation by Frank revealed that the 700-mb flow over the subtropical Atlantic was characterized by negative height anomalies paralleled by a southward extension of the westerlies. This is in contrast to normal heights in 1969 and above normal heights in 1967. According to Simpson et al. (1969), the circulation pattern in 1968 inhibited tropical cyclogenesis. The positions of the ITCZ, presented above, are consistent with this circulation pattern and illustrates the influence that the higher latitude circulation has on the location of the ITCZ as well as on tropical weather systems.

b. North Pacific Ocean

The North Pacific (Fig. 3) shows a somewhat more complicated pattern than the Atlantic, with considerably more longitudinal variation for a given month. There is also considerable east-west variation in the amplitude and frequency of the time variation. This is best illustrated by examination of Fig. 4 which shows the time variation alone at individual meridians representative of the eastern (100W), central (140W), and western (160E) parts of the Pacific. The time variation along 20W, representative of the Atlantic, is also shown for comparison. In the western and eastern Pacific, the semi-annual as well as the annual frequency appears to be represented although the amplitude in the western Pacific is generally greater than in the eastern Pacific. The situation in the central Pacific is quite different, however. From May 1967 through December 1968 there is hardly any time variation at all, the axis of maximum brightness being found consistently at about 10N.

c. South Pacific

The South Pacific (Fig. 5) shows the greatest variability of all, both spatially and temporally. Over most of the longitudes covered by this section one observes
relatively high-frequency oscillations of quite dramatic amplitude, particularly in the eastern portions. West of about 160E the amplitude of the oscillation decreases markedly. This is a reflection of the tendency of the brightness maximum to remain in the vicinity of the islands located there, as mentioned previously. An interesting feature of the oscillation is shown in Fig. 6 which compares the time history of the latitude of the ITCZ in the North Pacific with the latitude of the convergence zone in the South Pacific at 160E. Here we find that in addition to higher frequency oscillations the southern convergence zone tends to be out of phase with the ITCZ, so that on the average both move equatorward and poleward at the same time.

3. Concluding remarks

The preceding analysis has illuminated some of the characteristics of the ITCZ over the Atlantic and Pacific Oceans. One of the more intriguing characteristics was the tendency for the ITCZ to remain north of the equator in both oceans, regardless of the season. It is interesting to note that if the ITCZ marks the upward branch of the Hadley circulation, there is essentially no inter-hemispherical seasonal shift of that portion of the circulation in the Atlantic and Pacific Oceans. This suggests that the Indian Ocean region, as well as the land masses of South America, Africa, and Indonesia, contribute significantly to the zonally averaged meridional wind statistics that show such a migration (Oort and Rasmussen, 1970). Support for this idea is also given by Winston (1971) and Hubert et al. (1969) who have shown that there is a seasonal shift of brightness across the equator in those regions. What is not clear, however, is the relative importance of the land masses themselves in producing the observed cloudiness. This is also true for the Indian Ocean region, where the configuration of the land
masses have a significant influence on the brightness distribution.

Questions concerning the causes of the year-to-year and month-to-month variations are probably best studied by an analysis of wind data, information on which is sorely lacking over the bulk of the oceans. On the other hand, questions concerning the intensity of the ITCZ and the southern convergence line are probably best studied from satellite infrared observations. Continued study of data from both geostationary and polar orbiting satellites should prove to be invaluable in providing answers to some of these questions.

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REFERENCES


