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Structure of the intertropical convergence zone over the GATE area

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ABSTRACT

The meridional structure of wind, temperature, and moisture of the intertropical convergence zone (ITCZ) over the GATE observational area is presented. The structure is obtained by compositing rawinsonde observations with respect to the surface wind confluence line. The most important characteristic of the structure is the absence of any significant temperature maximum at any level in the central core of the ITCZ. This absence indicates that condensational heating and, hence, CISK is only a secondary mechanism in the development and maintenance of the GATE ITCZ. The primary mechanism may be either barotropic instability or pressure energy flux from temperate latitudes.

1. Introduction

The structure of the intertropical convergence zone has been described within the past few years by Godbole & Ghosh (1975) and also by Estoque (1975). Both articles present meridional cross-sections of wind, temperature, and moisture which have been constructed by composite analysis of aerological data. The structure which has been presented by Estoque (1975) pertains to the ITCZ over the central regions of the tropical North Atlantic and the North Pacific Oceans. On the other hand, Godbole & Ghosh (1975) presented a corresponding structure over the Indian Ocean. The broad picture which emerges from these two articles shows that the ITCZ is cold-cored near the 700 mb level, somewhat like the temperature structure of the classical easterly wave. The cold core is also a region of maximum moisture content and, presumably, of upward motions. This region is not located directly over the line of surface wind confluence. In the case of the Indian Ocean ITCZ, the region is located a few hundred kilometers south of the confluence line. On the other hand, the corresponding region in the Central Atlantic ITCZ is located north of the surface confluence line. With regard to the temperature distribution in the upper troposphere, the Central Atlantic ITCZ appears to be warm-cored. Due to lack of data, it is not possible to ascertain whether there is also a warm core in the Indian Ocean and the Pacific Ocean ITCZ.

The wind, temperature, and moisture fields which have been described in the preceding paragraph are based on the analysis of a relatively limited amount of data. Hence, these fields may not be entirely reliable. It is, therefore, desirable to do further studies of the ITCZ with the aid of more extensive data. We have done this by analyzing selected data from GATE observations. This paper describes the results of the analysis.

2. Data and method of analysis

The data which have been analyzed consist of rawinsonde observations (Phase II) for cases during which the ITCZ was characterized by a strong confluence of the surface wind. A typical example of such a case is depicted in Figs. 1 to 3, which show the synoptic flow patterns at three different levels in the atmosphere (surface, 500 mb and 200 mb). Fig. 4 shows the corresponding satellite cloud distribution. The rawinsonde observations for all selected cases were composited with respect to their distance south or north of the

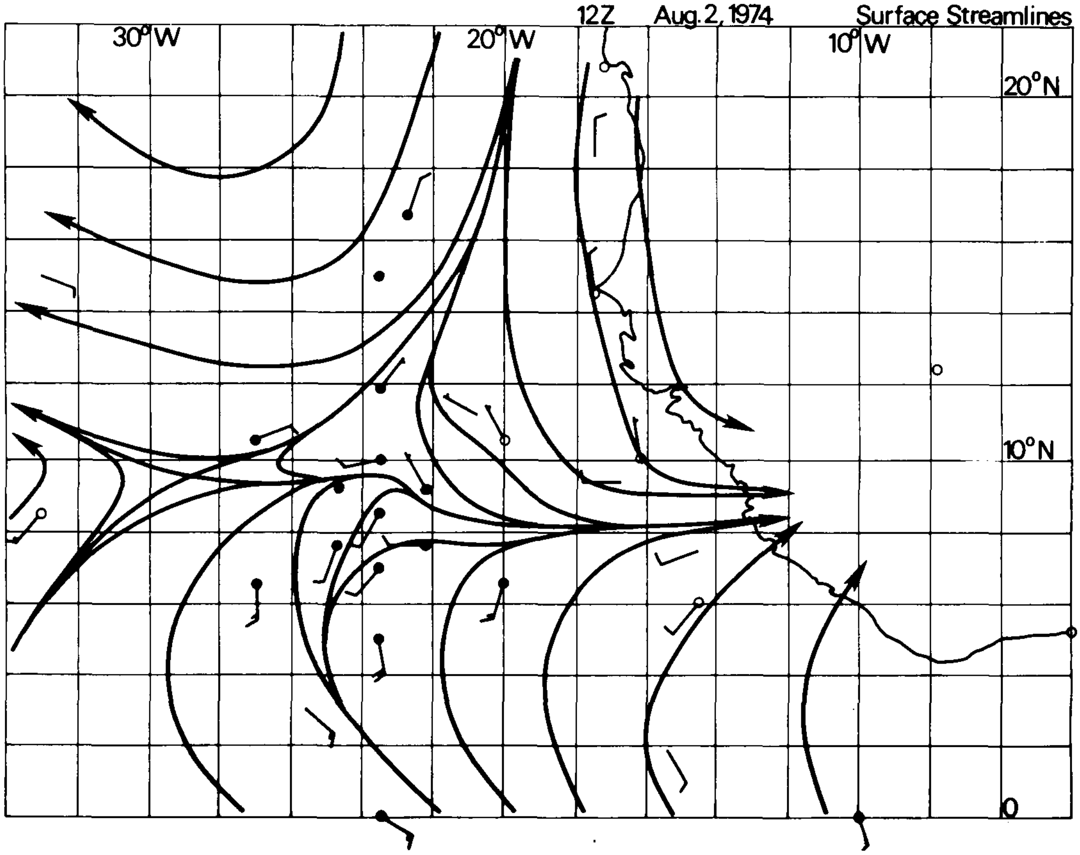

Fig. 1. Surface streamlines for 1200Z, August 2, 1974.

surface confluence line. A total number of 25 cases were composited. Only stations which were located between the meridians, 20° W and 28° W, were used.

3. Results

The results of the compositing are summarized in Figs. 5 and 6. Fig. 5 is a meridional cross-section of the wind and the anomalies of temperature and mixing ratio. The anomalies are based on Jordan's (1958) mean tropical sounding. Fig. 6 gives the corresponding distribution of cloudiness and rainfall. The former is obtained from the satellite cloud pictures while the latter is based on surface observations. In Fig. 5 the location of the line of confluence at the surface (for convenience, defined in this study as the ITCZ axis) is indicated by zero. It may be seen that the low-level confluence region is relatively shallow, being limited only to the region from the surface to the 800 mb level. Above this level, the winds become predominantly parallel and easterly. It may be noted that the axis of maximum confluence slopes northward with height in the lowest levels. Looking next at the moisture field, one notes that there is maximum water vapor content in the layers near the surface at the axis of confluence. This maximum is presumably due to the fact that the surface air picks up moisture continuously from the underlying warm ocean as it converges towards the axis from both southern and northern regions. The location of the moisture maximum shifts southward with height; at the 700 mb level, it occurs about 100 km to the south of the corresponding surface location. It is interesting to note that both cloudiness and precipitation (Fig. 6) have their maximum at about the same location as

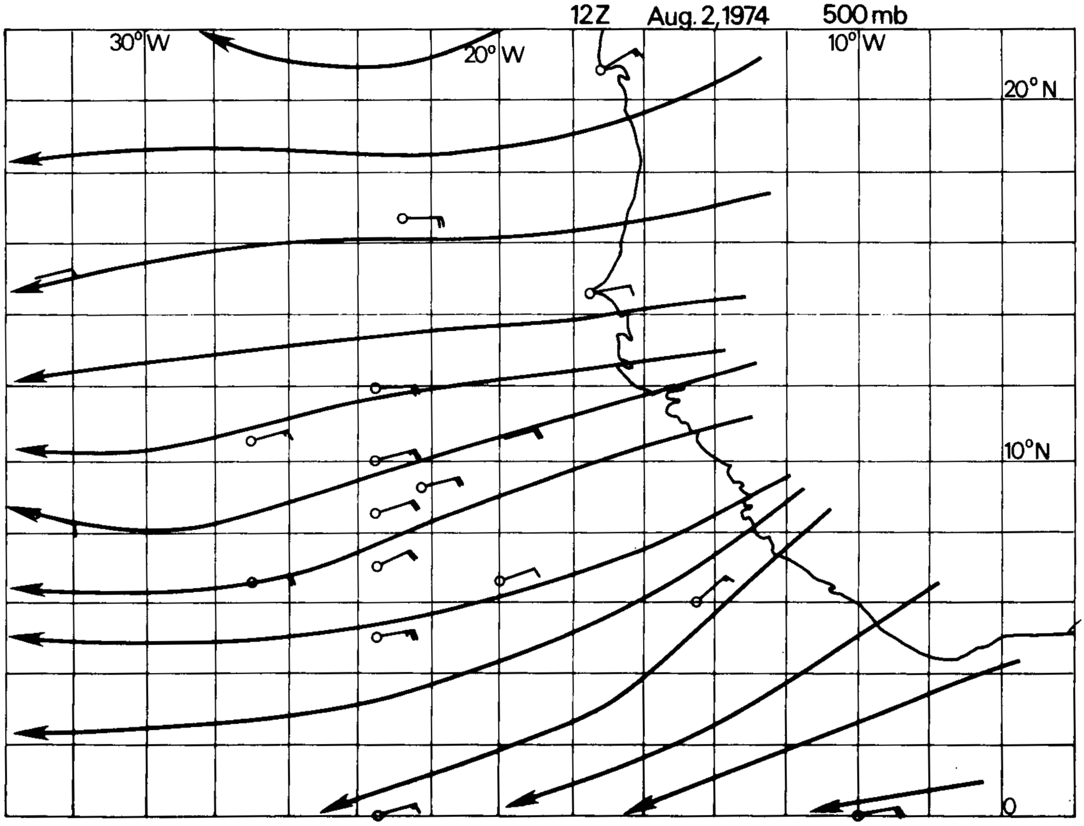

Fig. 2. Streamlines at 500 mb for 1200Z, August 2, 1974.

the 700 mb moisture maximum. Another moisture maximum at the 700 mb level occurs about 800 km north of the ITCZ axis; this feature is not, in any way, related to ITCZ activity. Between these two maxima, one notes a region of pronounced minimum. The moisture pattern which consists of two maxima separated by a moisture minimum is supported by the appearance of the parallel east–west cloud bands shown by the satellite picture in Fig. 4.

Next, we look at the temperature distribution. Broadly speaking, the distribution is characterized by a general decrease in temperature from north to south in the lower half of the troposphere. There is a strong low-level temperature inversion at a distance of about 600 km north of the ITCZ axis. At about the same distance to the south, another inversion is indicated; this inversion is much weaker and is located at a higher elevation. As expected, the inversion appears to be weak or non-existent in the vicinity of the ITCZ axis.

The most interesting aspect of the temperature field is the lack of any pronounced warm air over the general region of maximum rainfall in the ITCZ. While there is an indication of a weak temperature maximum near the 500 mb level, its magnitude (less than 1 ° C) is small and comparable to the customary error in temperature observations. Certainly, this magnitude is small compared to the warming which is generally observed in such tropical disturbances as tropical cyclones and easterly waves. The absence of a significant maximum in temperature for the ITCZ is rather surprising in view of the fact that a large amount of condensation heating is indicated by the rainfall distribution.

The structure described above may be compared in somewhat greater detail, with the corresponding

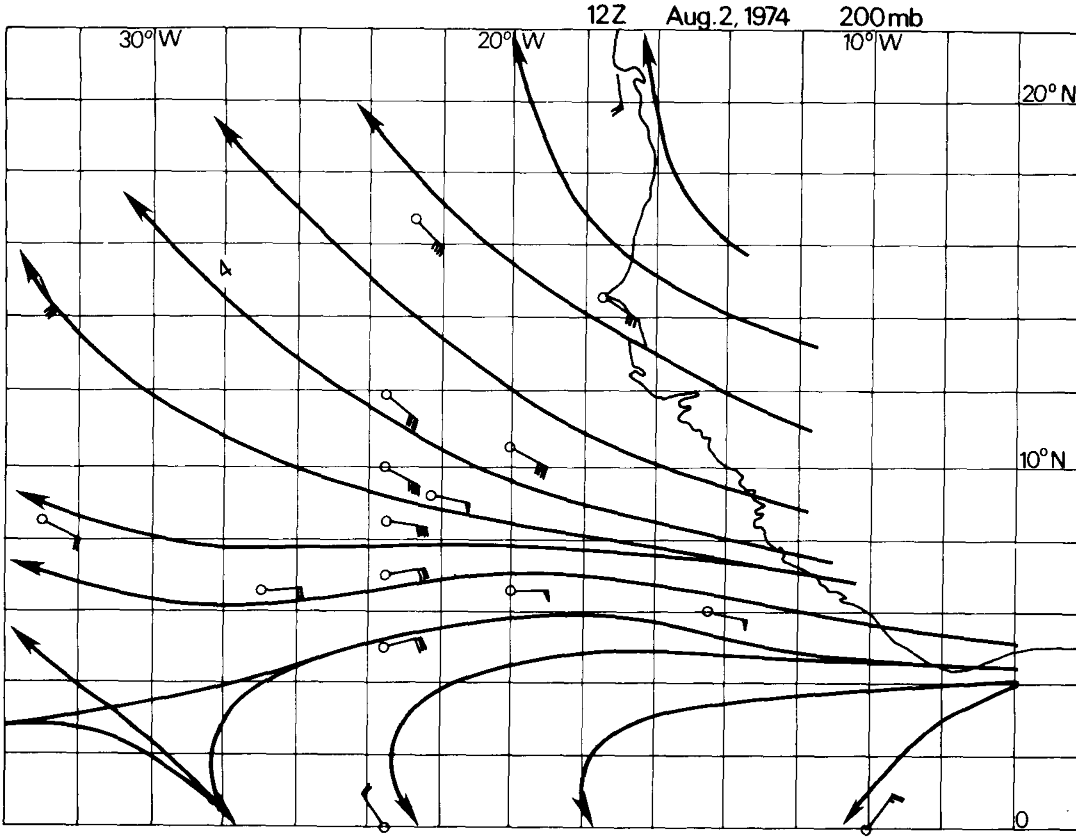

Fig. 3. Streamlines at 200 mb for 1200Z, August 2, 1974.

ITCZ structure over the Central Atlantic as shown in Fig. 7. The cross-section in this figure is the same as that presented by Estoque (1975), except for the fact that the analysis has been extended to include a small region south of the ITCZ axis. In making the comparison, one must remember that the Atlantic cross-section is based on data obtained earlier in the year (February). Therefore, differences in the structure may be due to seasonal as well as geographical variations. An important difference between the two structures may be seen in the wind field. At low levels, the GATE ITCZ is characterized by a strong confluence; this feature is associated with the surface monsoonal flow induced by the African Continent. On the other hand, the Atlantic ITCZ is characterized by a very weak confluence between the Southeast and the Northeast Trades. At upper levels, the wind field in the GATE ITCZ is characterized by easterlies. These easterlies are extensions of the African middle and upper tropospheric jets. In contrast, the upper level flow in the Central Atlantic ITCZ is dominated by westerlies; this flow is the equatorward extension of the temperate latitude westerlies. These large differences between the wind structure in the two regions appear to indicate that the occurrence of the ITCZ is not very sensitive to the characteristics of the basic flow patterns. Another important difference between the two structures may be seen in the temperature field. The Central Atlantic ITCZ shows a distinct cold core structure near the 700 mb level; however, at the surface and at the 300 mb level, the ITCZ, appears to be warm-cored. The GATE ITCZ, on the other hand, is not characterized by any significant temperature maximum or minimum. The only apparent similarity between the two structures lies in the occurrence of a moisture maximum over the

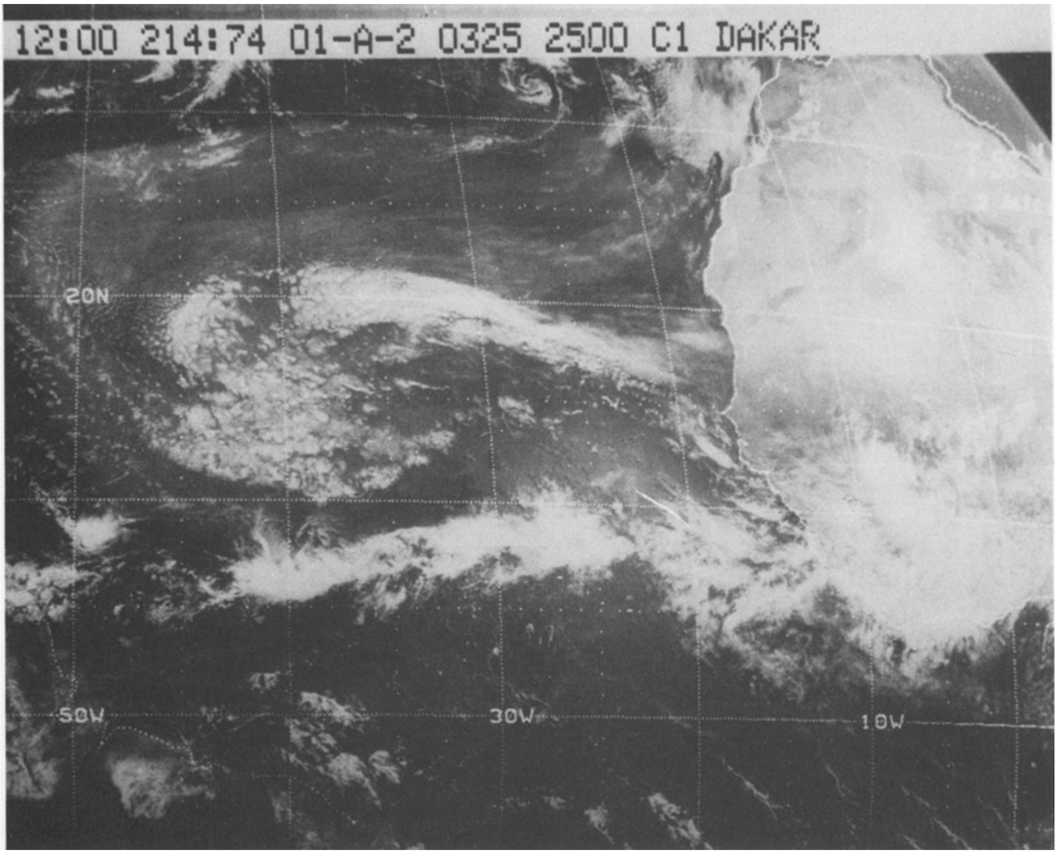

Fig. 4. Satellite cloud picture for 1200Z, August 2, 1974.

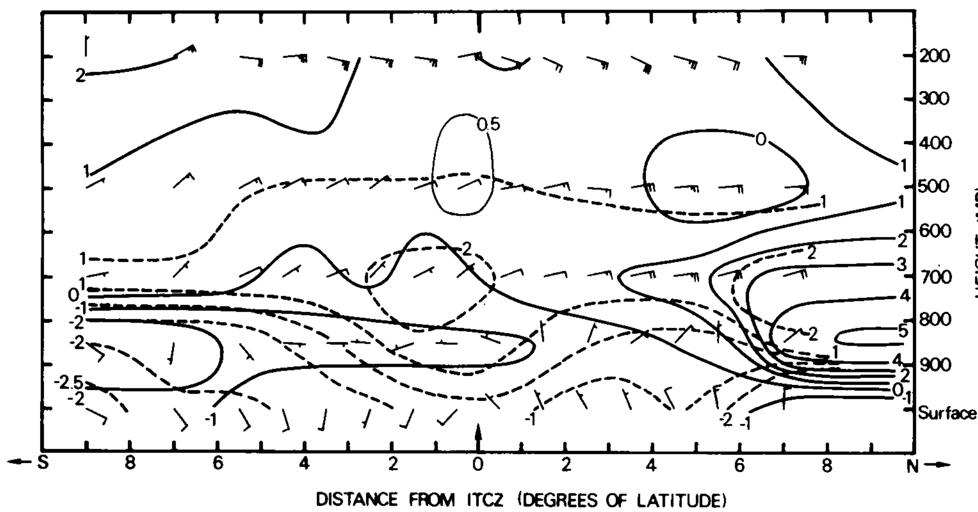

Fig. 5. Meridional structure of the GATE ITCZ showing the wind, temperature, and moisture distributions. Temperature (° C), in full lines and mixing ratio (g/kg), in dashed lines, are deviations from Jordan's (1958) mean sounding. Wind is plotted in conventional form (full barb = 10 knots).

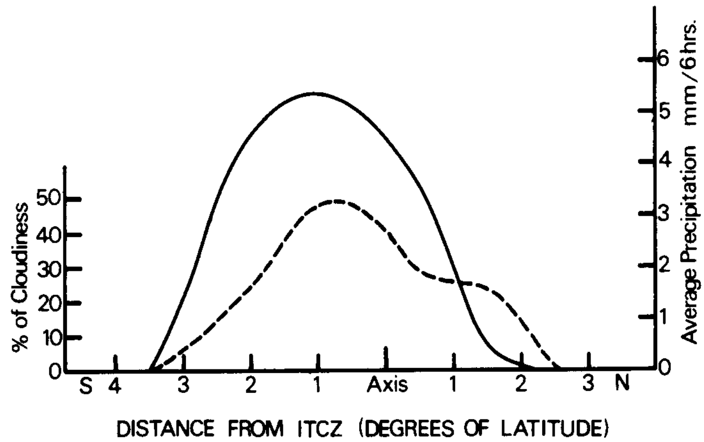

Fig. 6. Meridional distribution of rainfall (mm/6 hours) and cloudiness (percent of sky covered with convective clouds). Precipitation, full line; cloudiness, dashed line.

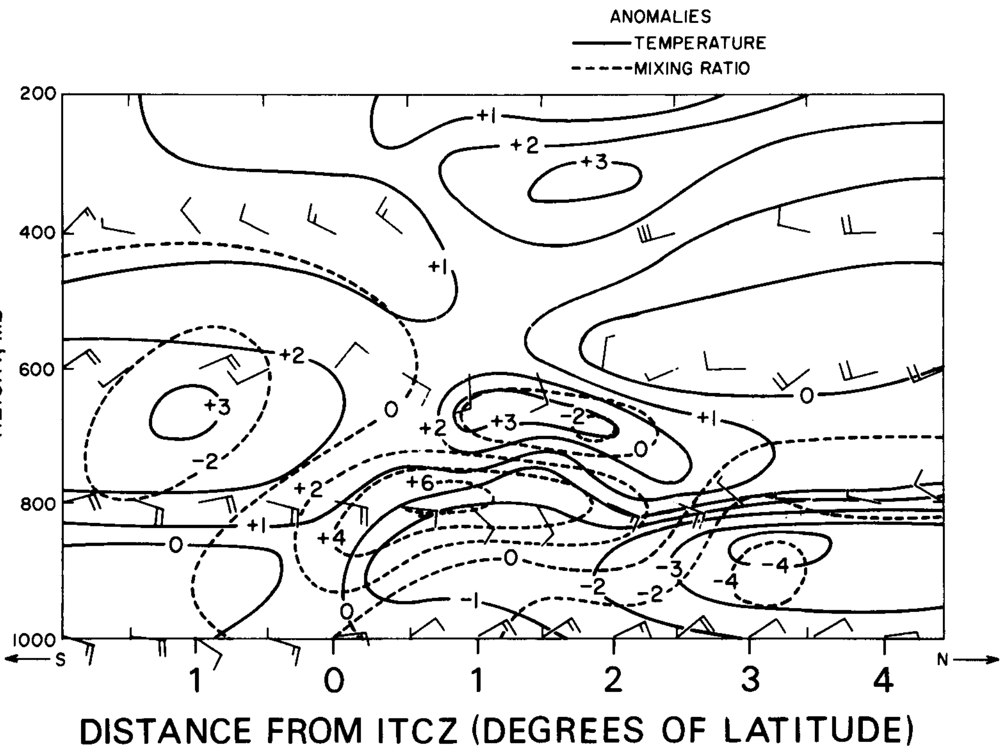

Fig. 7. Meridional structure of the Central Atlantic ITCZ showing the wind, temperature, and moisture distributions. Temperature (° C), in full lines and mixing ratio (g/kg), are deviations from Jordan's (1958) mean sounding. Wind is plotted in conventional form (full barb = 10 knots).

general region above the location of the surface wind confluence. In summary, one notes large differences in the wind and temperature structures between the Central Atlantic and the GATE ITCZ. These differences may indicate corresponding differences in the physical mechanisms for their development and maintenance. In particular, the temperature structure of the Central Atlantic ITCZ indicates that the conversion of available potential to kinetic energy is an important mechanism; for the GATE ITCZ this mechanism appears to be of secondary importance.

4. Concluding remarks

In this paper we have presented a composite structure of the active, zonally oriented ITCZ over the GATE observational area. The main features of the structure are as follows:

(1) Strong wind confluence in the lowest layers of the troposphere.
(2) Maximum rainfall and cloudiness south of the confluence line in the surface wind.
(3) A distinct water vapor minimum north of the confluence line.
(4) Absence of significant temperature maxima or minima.

The patterns of rainfall, cloudiness, and water vapor indicate the existence of a vertical circulation whose ascending motions are located about 100 km south of the surface confluence line and primary compensating downward motions about 300 km north of the line. The lack of any pronounced temperature maximum at upper levels over the region of maximum rainfall is puzzling. It suggests that condensational heating and the conversion of available potential to kinetic energy are not primary physical processes for the ITCZ over the GATE area. As a corollary, this implies that CISK is only a secondary mechanism. Therefore, an alternative mechanism, such as barotropic instability or pressure energy flux from temperate latitudes appears to be necessary for explaining the GATE ITCZ.

5. Acknowledgement

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СТРУКТУРА ВНУТРИТРОПИЧЕСКОЙ ЗОНЫ КОНВЕРГЕНЦИИ НАД ОБЛАСТЬЮ АТЭП

Представлена меридиональная структура полей ветра, температуры и влажности во внутритропической зоне конвергенции (ВЗК) над областью наблюдений АТЭП. Эта структура получена сопоставлением данных радиозондов с линией сходимости ветра. Наиболее важной характеристикой структуры является отсутствие какого-либо существенного максимума температуры на всех уровнях в центральном ядре ВЗК. Это отсутствие указывает на то, что конденсационный нагрев и, следовательно, КИСК являются лишь вторичными механизмами в развитии и поддержании ВЗК АТЭП. Основным механизмом может быть либо баротропная неустойчивость, либо поток энергии от умеренных широт.