The structure of the inter-tropical convergence zone and equatorial westerlies during MONEX-1973

By R. V. GODBOLE, *Indian Institute of Tropical Meteorology, Poona, India, and*
S. K. GHOSH, *India Meteorological Department, New Delhi, India*

(Manuscript received October 26, 1973; revised version August 2, 1974)

ABSTRACT

Aerological data obtained during the meridional cruises undertaken by the USSR ships along 55° E and 65° E from May 23 to May 28 during MONEX-1973 are analysed. The Inter Tropical Convergence Zone is located near 10° N with an equatorward inclination with height. A broad zone of westerlies—equatorial westerlies—which exists to the south of the Inter Tropical Convergence Zone is found to extend even to the south of the equator. Computations of water vapour flux indicate that there is a significant convergence of moisture flux just south of the Inter Tropical Convergence Zone, whereas to the immediate north of it, there is a weak divergence of moisture flux.

Introduction

An expedition, MONEX-1973, over the Arabian Sea and the north Indian Ocean was undertaken jointly by India and USSR during May to July 1973 to study the Indian summer monsoon. Four ships of the USSR Hydrometeorological Service participated in the expedition. These were Ocean (the Flagship), Priliv, Shokalskiy and Voeikov. As part of the expedition, Shokalskiy and Voeikov cruised along 55° E from 15° N to 3° S. Ocean and Priliv cruised along 65° E from 20° N to the equator. These two sections were covered between May 23 and May 28, 1973. The present study deals with the identification and structure of the Inter Tropical Convergence Zone (ITCZ) and the equatorial westerlies, as based on the data obtained during the cruises along these sections.

Each of the four ships took RS/RW observations at 00, 06, 12 and 18 GMT daily (radio wind observations over the above oceanic regions are available for the first time). Vertical cross sections of winds along 55° E and 65° E are presented in Figs. 1 and 2 respectively. Similar cross sections of zonal and meridional components of winds, and of temperature and specific humidity are presented respectively in Figs. 3*a*, 3*b*, 4*a*, 4*b*, 5 and 6. Dew point depressions have also been analysed along with zonal wind component (Figs. 3*a* and 4*a*).

For the above analyses, the observations obtained during the ships' cruises are obviously not for the same synophic time. Therefore, while constructing the vertical time sections, it has been tacitly assumed that the atmosphere remains quasi-stationary in the meridional direction during the period of observations. The assumption may be justified because the purpose of the present study is to examine the gross features of the weather phenomena such as the ITCZ and the equatorial westerlies which are of a global scale in nature. In the last section of the paper, we have presented the satellite photographs in support of this assumption.

Disussion

The vertical cross sections of winds along 55° E (Fig. 1) shows a zone of convergence between westerlies and easterlies from the surface up to 300 mb. This is the Inter Tropical Convergence Zone (ITCZ) because it has, to its north, the northern hemispheric trades (easterlies) and, to its south, the westerlies extending to the southern hemisphere (Burlutsky et al.,

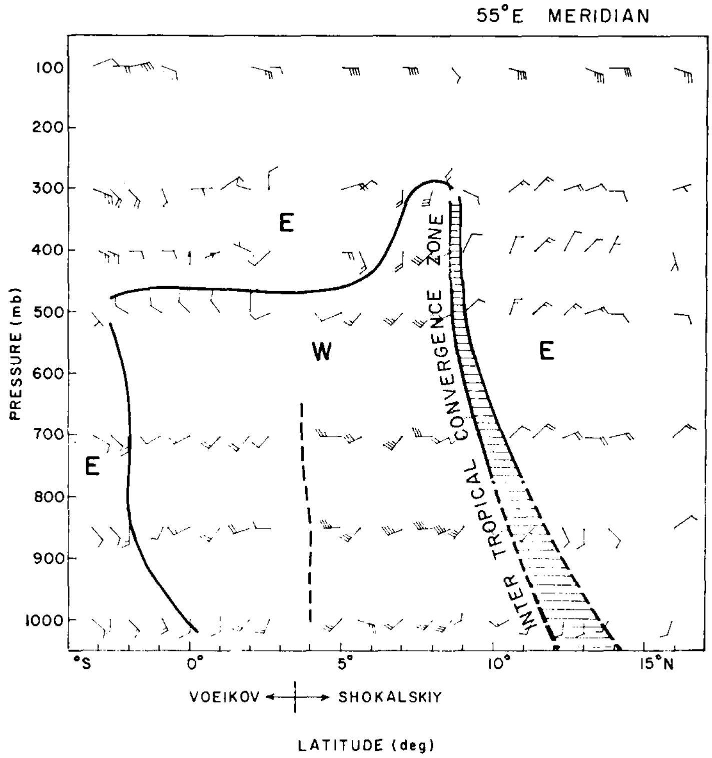

Fig. 1. Vertical cross section of winds along 55° E longitude.

1973; Sanderson, 1973). The ITCZ has an equatorward inclination with height. It is located near 12°30′ N at the surface and 8°30′ N at 300 mb with the mean position near 10° N. The width of the zone is about 2° latitude near the surface and decreases gradually with height. Above 700 mb it narrows down to less than half a degree of latitude (Fig. 1).

There is an indication of another trough in the southern hemisphere which extends from surface to 500 mb and has a poleward inclination with height with the mean position of about 2° S. The existence of such a through has been reported earlier by Fletcher (1945) and subsequently by others (Flohn, 1960; Koteswaram, 1960; Raman, 1965; Ghosh & Godbole, 1973*a*). It is seen from the figure that westerlies are confined in between the southern hemispheric trough and the ITCZ. It is, therefore, appropriate to call these as equatorial westerlies as is found in the current literature. The depth of these westerlies is a little above 500 mb but increases up to 300 mb near the ITCZ.

Within the equatorial westerlies, there is a region north of about 4° N of strong winds at all levels with the maximum strength confined in the layer between 850 and 700 mb.

The cross section along 65° E (Fig. 2) shows similar features as in Fig. 1, except that the ITCZ has more equatorward inclination with height and the westerlies have greater depth than those of Fig. 1.

The cross section of zonal and meridional components of wind (Figs. 3 and 4) give quantitatively the strength of the winds. Along 55° E, westerlies to the south of the ITCZ have a maximum speed of more than 15 m sec^{-1} (Fig. 3*a*) whereas along 65° E, the maximum speed of the westerlies is between 10 and 15 m sec^{-1} (Fig. 4*a*). Easterlies to the north of the ITCZ, however, are stronger along 65° E than along 55° E. Again, southerlies to the south of the ITCZ are stronger and have greater vertical depth along 55° E than along 65° E. Thus, in general, winds are stronger along 55° E than along 65° E.

Analyses of dew point depression (Figs. 3*a* and 4*a*) indicate that the westerlies to the

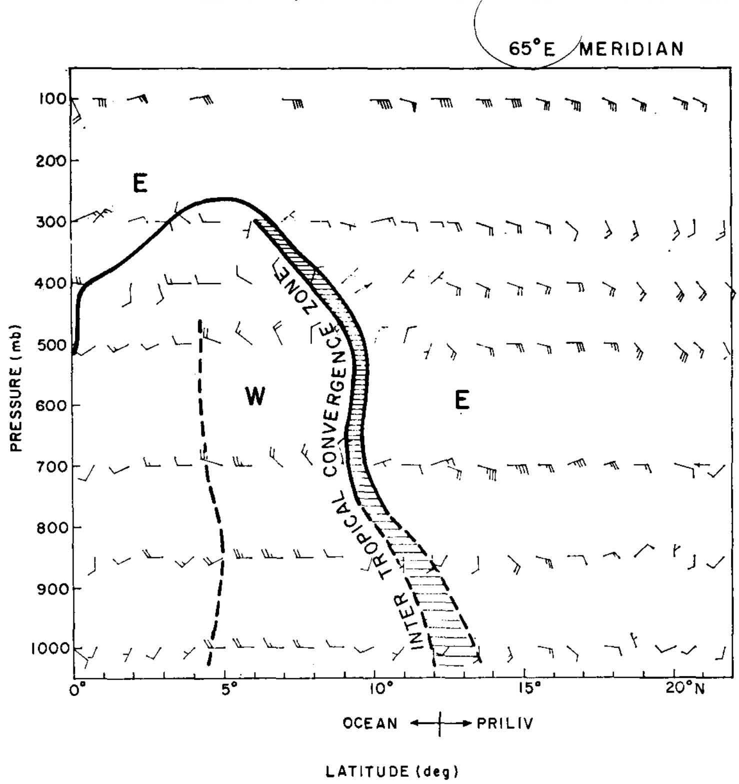

Fig. 2. Vertical cross section of winds along 65° E longitude.

south of the ITCZ are moist (relative humidity greater than 80% in the core) and easterlies to the north of it are dry (relative humidity about 50% in the core). A similar feature is observed across the southern hemispheric trough (Fig. 3*a*). Here, westerlies to the north of the trough are dry and easterlies to its south are moist. It follows, therefore, that within the belt of equatorial westerlies, the air is moist to the north and dry to the south. This seems to suggest that the moisture in the north of the equatorial westerlies does not come from the southern hemisphere, at least not directly from across the southern hemispheric trough. Rather its source lies in the equatorial westerlies in the northern hemisphere being due to either evaporation from the ocean or advection from west of 55° E or both.

Above 300 mb, the easterlies are relatively moist (Figs. 3*a* and 4*a*) because these are tropical maritime easterlies (Ghosh & Godbole, 1973*a*).

Figs. 5 and 6 show the vertical distribution of both temperature and specific humidity from surface up to 500 mb along 55° E and 65° E respectively. From both the figures it is apparent that the mean latitude of 10° N (9° N in Fig. 5 and 11° N in Fig. 6) divides the moisture field into two regimes—moist to the south of this latitude and dry to its north. It is also seen that the maximum specific humidity occurs near 10° N (i.e. mean position of the ITCZ). Again, the temperature distribution indicates that the air to the north of 10° N (i.e. region of easterlies) is warmer than that to its south (i.e. region of westerlies). The patterns thus corroborate the existence of the ITCZ near 10° N.

An additional feature revealed by the cross section along 55° E (Fig. 5) is that there is a secondary maximum in the specific humidity field at a mean location of the southern hemispheric trough. In between the two moist regimes (i.e. between the ITCZ and the southern hemispheric trough), relatively dry air prevails giving rise to a dip in the moisture field at about 2° N. Also, north of 15° N, the air is dry along both 55° E (Fig. 5) and 65° E (Fig. 6).

From the foregoing it becomes evident that

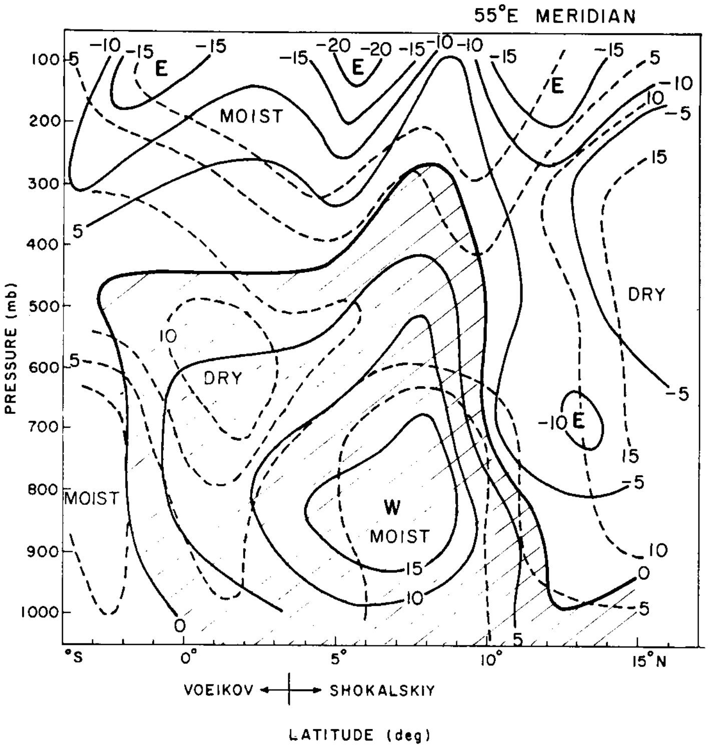

Fig. 3a. Vertical distribution of zonal component of wind (m sec^{-1}) (——), and dew point depression (°C) (····) along 55° E longitude.

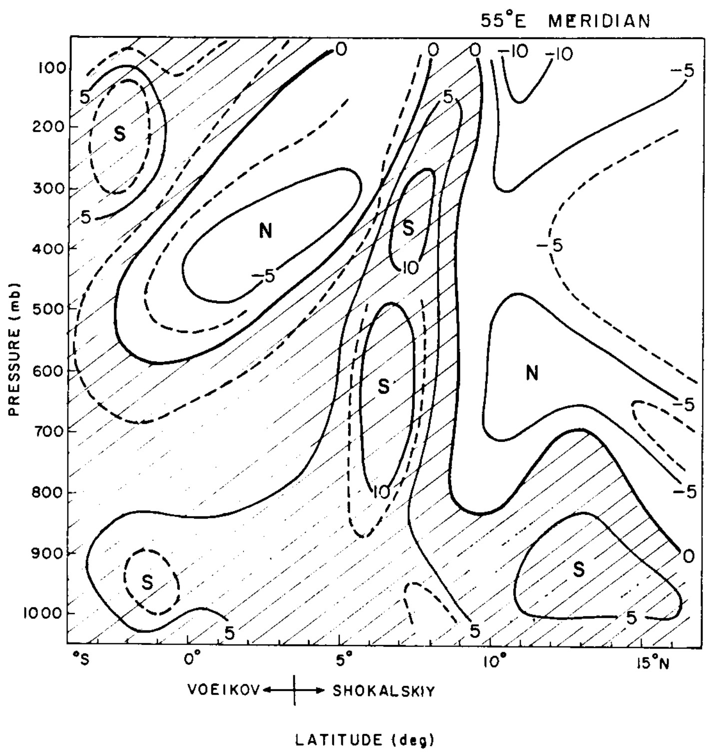

Fig. 3b. Vertica distribution of meridional component of wind (m sec^{-1}) along 55° E longitude.

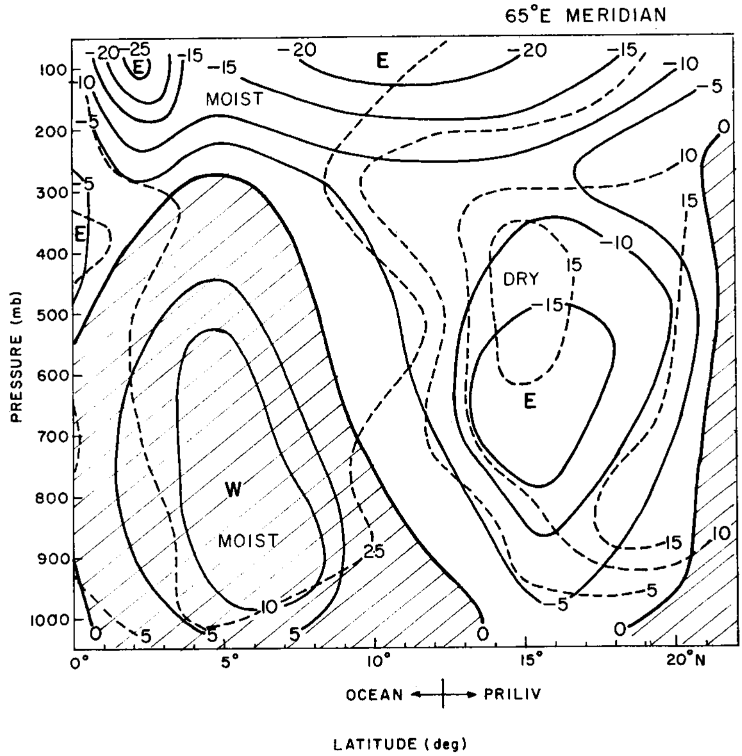

Fig. 4a. Vertical distribution of zonal component of wind (m sec^{-1}) (——), and dew point depression (°C) (····) along 65° E longitude.

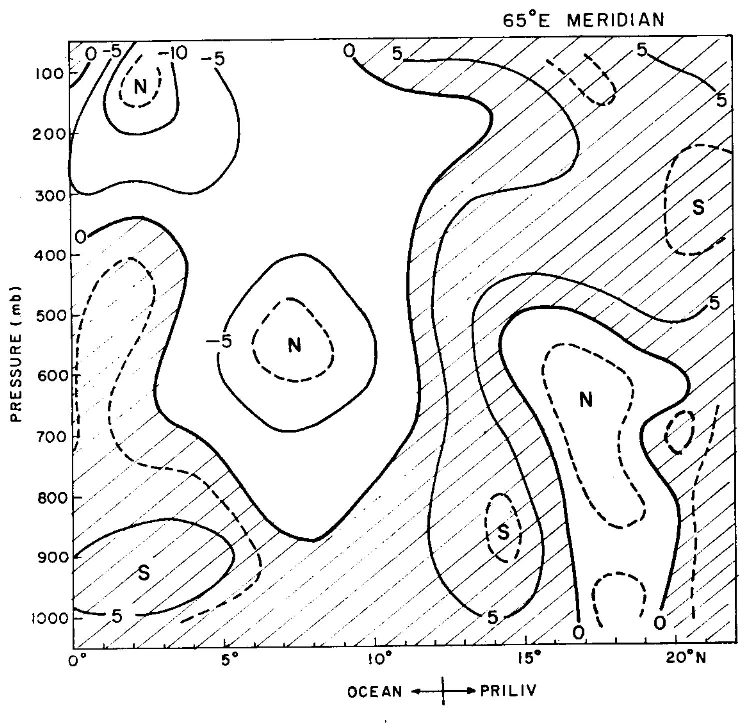

Fig. 4b. Vertical distribution of meridional component of wind (m sec^{-1}) along 65° E longitude.

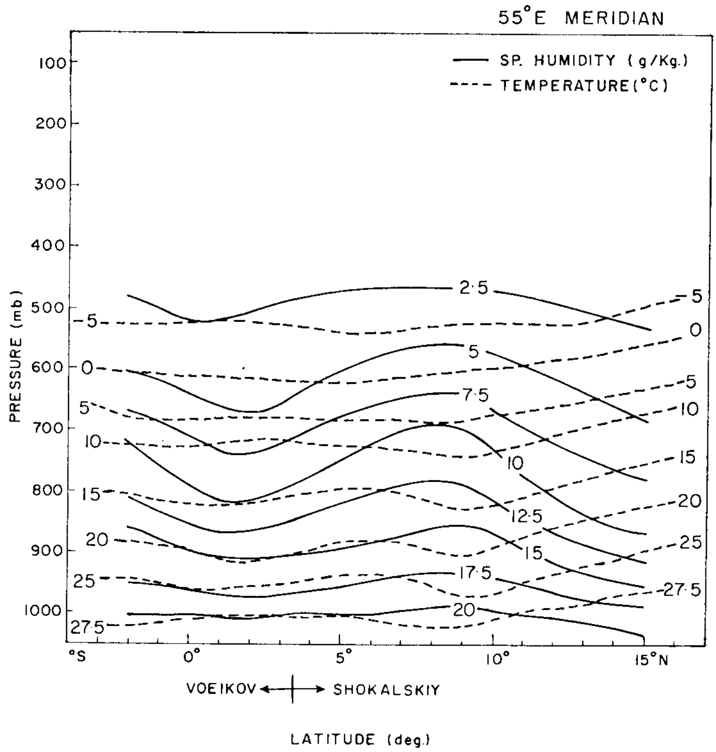

Fig. 5. Vertical distribution of specific humidity (g/kg) (——), and temperature (°C) (····) along 55° E longitude.

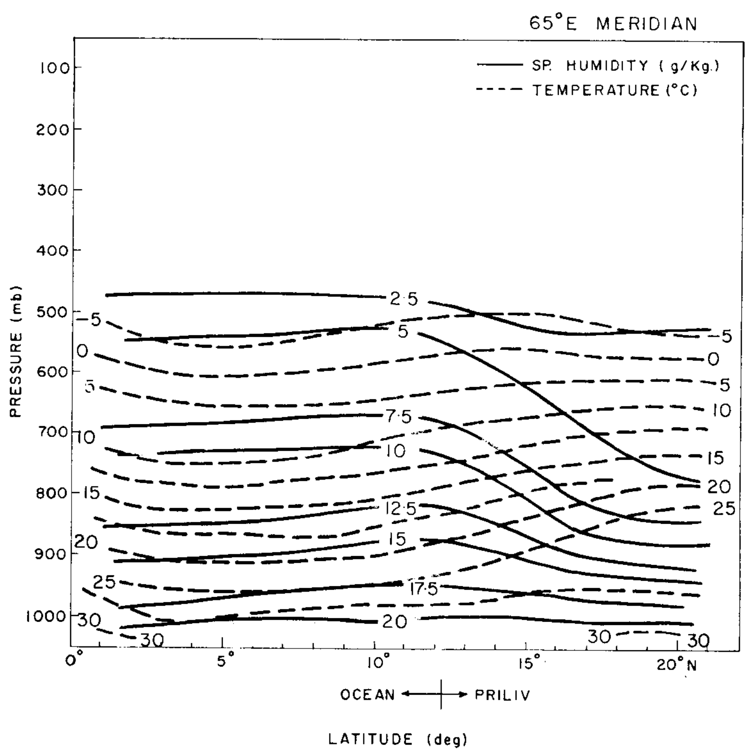

Fig. 6. Vertical distribution of specific humidity (g/kg) (——), and temperature (°C) (····) along 65° E longitude.

Table 1. *Flux of water vapour across the lateral boundaries of the region considered*

The flux into the region is considered positive. Units: 10^{10} metric tons per day

	Northern boundary at		
	15° N	10° N	5° N
Western boundary (55° E)	4.7	4.8	1.9
Southern boundary (equator)	1.5	1.5	1.5
Eastern boundary (65° E)	−2.0	−3.1	−1.3
Northern boundary (15° N/10° N/5° N)	−1.3	−0.2	−1.9
Net flux (convergence)	2.9	3.0	0.2

no large scale trans-equatorial flux of moisture can take place at least up to as far west as 55° E. In the first place, the flow pattern (Figs. 3 and 4) does not favour a large transport across the equator. Secondly, even the existing weak southerly component of the wind would be ineffective in transporting moisture across the equator since the air over the equatorial belt is dry (Fig. 5). The results support the earlier finding based on the I.I.O.E. data by Pisharoty (1965).

Budget of water vapour

In order to examine the probable source of the high moisture content in the equatorial westerlies, transport of water vapour from surface up to 500 mb across the boundaries of the region between the two meridians 55° E and 65° E and equator and 15° N has been computed by using the well-known expression,

$$\text{Transport of water vapour} = \frac{1}{g}\int\int_{ps} qV_n\,dp\,ds$$

where s represents a segment of latitude/longitude and the other symbols have their usual meaning.

The values of the mean transport of water vapour across the four vertical walls of the region under consideration are shown in Table 1. The values are expressed in units of 10^{10} metric tons per day and are of the same order of magnitude as those obtained by Pisharoty (1965) and Saha (1970). It is seen that for the whole box from equator to 15° N, there is a convergence of moisture flux into the region, the import being predominantly from the western wall. For the region from equator to 10° N, the amount of convergence of the water vapour flux is slightly higher (or practically the same) than that for the region from equator to 15° N. This means that the convergence of the moisture flux associated with the ITCZ is limited only to its south. Again, for the region from equator to 5° N, the amount of convergence of the water vapour flux is negligibly small as compared with that for the region from equator to 15° N or from equator to 10° N which further suggests that the area of convergence of the moisture flux due to the ITCZ is confined to a narrow band immediately to the south of the ITCZ.

The above results are schematically shown in Fig. 7 for every 5° latitude interval. The slight amount of divergence of the moisture flux obtained north of the ITCZ should be reflected in less clouding over the region. In other words, while delineating the ITCZ on a satellite cloud photograph, the ITCZ should represent the northern boundary of the cloud cluster.

Conclusions

The study brings out the following:

(i) The existence of the ITCZ from surface up to 300 mb. It has equatorward inclination with

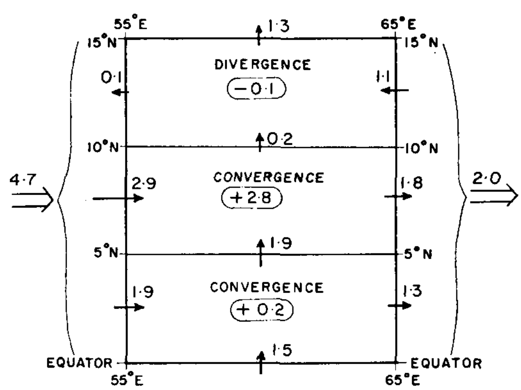

Fig. 7. Fluxes of moisture across the vertical walls of the region from equator to 15° N and from 55° E to 65° E. The values are expressed in units of 10^{10} metric tons per day.

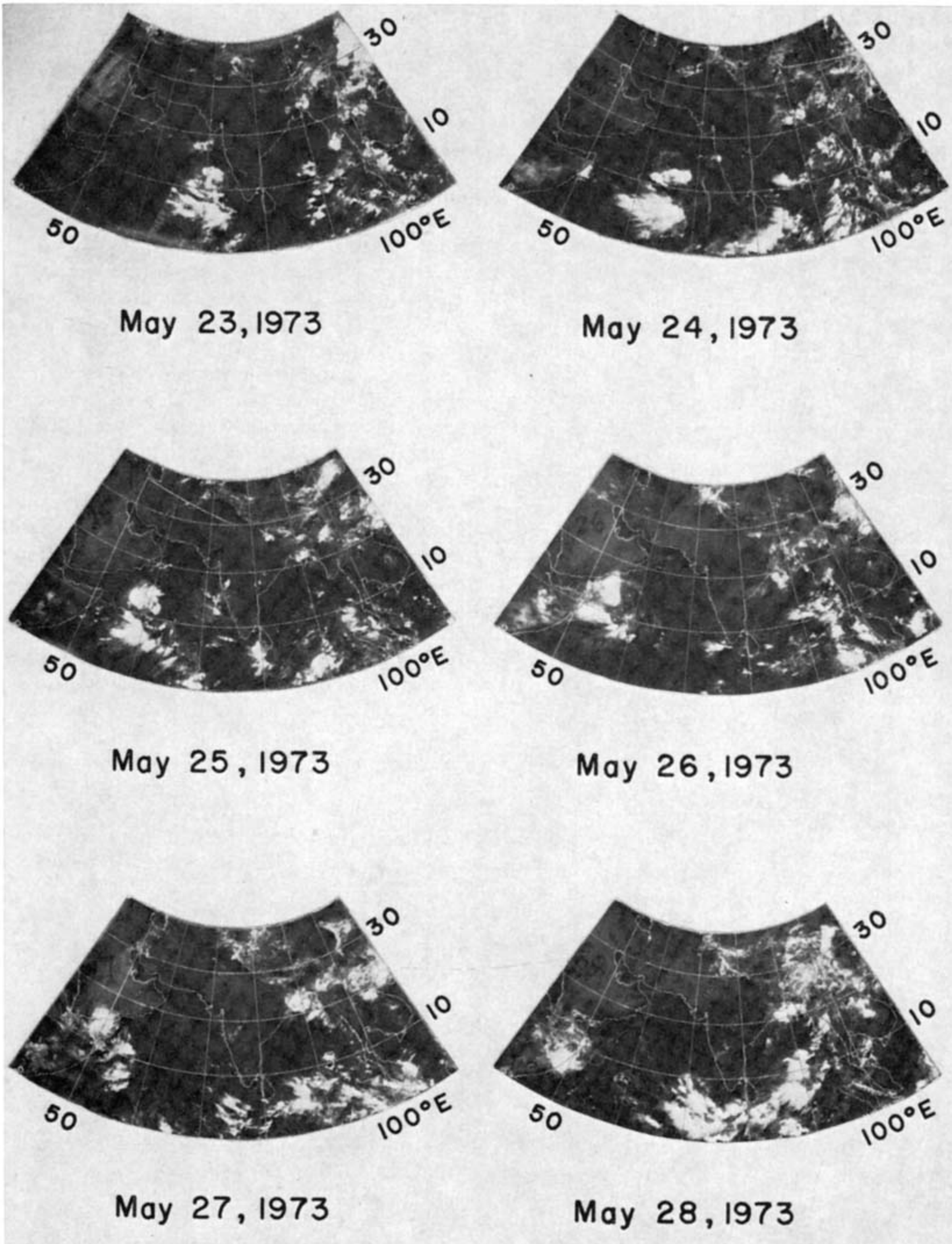

Fig. 8. Satellite-visible pictures for the period from May 23 to May 28, 1973.

height with its mean position near 10° N. It is diffused near the surface and sharp aloft.

(ii) The existence of a trough in the southern hemisphere from surface up to 500 mb having poleward inclination with height at a mean position near 2° S.

(iii) A broad band of westerlies, called the equatorial westerlies is found between the ITCZ and the trough in the southern hemisphere.

(iv) Easterlies to the north of the ITCZ are dry and warm whereas westerlies to its south are moist and cold.

(v) The air over the equatorial belt is dry. As such, large transport of moisture from southern hemisphere across the equator into the Arabian Sea is ruled out, at least up to as far west as 55° E.

(vi) Computations indicate significant convergence of water vapour flux to the south of the ITCZ.

The above findings are subject to the assumption that the ships' observations represent the characteristics of the atmosphere as stationary phenomena during the period of observations. The following rationale was adopted in justifying the use of vertical cross sections of ships' observations to illustrate the above comments.

We have examined soundings for a period of one week. These have been used to construct meridional sections such as those illustrated in Figs. 3, 4, 5, and 6. An inherent assumption of a quasi-steady state in the meridional direction is thus implicit in this work. We justify the use of this assumption from an examination of satellite photographs for this period. The visible pictures (one per day) taken from the Environmental Satellite Imagery (NOAA, 1973) are shown in Fig. 8. It may be noted from these drawings that an active portion of the ITCZ (bright clouds) is present near 10° N. Although there is an indication of zonal propagation of disturbance activity around 10° N, since there is no large meridional shift of the ITCZ clouds, the above-stated assumption may be valid for this period.

Acknowledgements

The authors express their thanks to Dr N. I. Lisogurskiy, the project leader of MONEX-1973 for his encouragement and for extending all the facilities during the course of this study. Thanks are also due to Dr R. F. Burlutsky and Dr S. O. Krichak of the Hydrometeorological Center of the USSR for many fruitful discussions. The authors also wish to place on record their thanks to the Director-General of Observatories, India Meteorological Department and the Director, Indian Institute of Tropical Meteorology for deputing them to participate in MONEX-1973.

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СТРУКТУРА ВНУТРИТРОПИЧЕСКОЙ ЗОНЫ КОНВЕРГЕНЦИИ И ЭКВАТОРИАЛЬНЫЕ ЗАПАДНЫЕ ВЕТРЫ ВО ВРЕМЯ МОНЭКС-73

Анализируются аэрологические данные, полученные во время меридиональных разрезов, предпринятых судами СССР вдоль 55° в. д. и 65° в. д. с 23 по 28 мая 1973 г. Внутритропическая зона конвергенции расположена вблизи 10° с. ш. и с высотой наклонена к экватору. Найдено, что широкая зона экваториальных западных ветров, которая существует к югу от внутритропической зоны конвергенции, простирается к югу от экватора. Вычисления потока водяного пара указывают на значительную конвергенцию потока влаги непосредственно к югу от внутритропической зоны конвергенции, тогда как непосредственно к северу от нее имеет место слабая дивергенция потока влаги.