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Interaction of southern hemispheric equatorial trough with the southwest monsoon circulation during severe drought years

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सार — वर्तमान अध्ययन ने भारत में दक्षिणी गोलार्धीय में विषुवतीय द्रोणी (एसएचईटी) की सघनता और दक्षिण-पश्चिम मानसून की सक्रियता के मध्य विपरीत सम्बन्ध को और अधिक पुष्ट कर दिया है। इस प्रकार, एसएचईटी के क्षेत्र में साप्ताहिक माध्य मेघमयता का निरन्तर मानीटरन, दक्षिण-पश्चिम मानसून के दौरान भारत में वर्षा की शुष्क और आर्द्र बौछारों के पूर्वाभास में एक उपयोगी उपकरण के रूप में कार्य कर सकता है।

ABSTRACT. The present study has further confirmed the inverse relationship between the intensity of the southern hemispheric equatorial trough (SHET) and the activity of the southwest monsoon over India. Continuous monitoring of weekly mean cloudiness in the zone of SHET may, therefore, serve as an useful tool in foreshadowing dry and wet spells of rainfall over India during the southwest monsoon.

1. Introduction

Saha (1971) using APT pictures demonstrated the occurrence of two separate cloud bands in the Indian Ocean one in each hemisphere. These east-west oriented cloud bands are the visual manifestation of the existence of double equatorial troughs in the Indian Ocean. Satellite observed cloudiness data has been extensively used by Prasad (1981, 1982), Prasad *et al.* (1983, 1988) in the study of the equatorial troughs during the southwest monsoon season. These studies have clearly demonstrated an important role of the interaction of these troughs in the development of the southwest monsoon and its different phases. Out of these two troughs, *i. e.*, the northern hemispheric equatorial trough (NHET) and the southern hemispheric equatorial trough (SHET), the latter is found to play a dominant role in monsoon dynamics : intense convection in the zone or SHET results in weak monsoon conditions over India. When the SHET is weak and close to equator and allowing large cross-equatorial flow to the north of the equator, the monsoon is active. SHET serves to regulate the air flow from the southern hemisphere and thereby leads to the development of different phases of southwest monsoon. This paper examines the role of SHET during the southwest monsoon season of 1987 which was a severe drought year. This aspect of the southwest monsoon circulation is further discussed for the severe drought years of 1965, 1966, 1972 and 1979 and also for the normal to excess monsoon rainfall years of 1983 and 1988.

2. Data used and method of analysis

Estimates of daily percentage cloud cover have been obtained for every 5° Lat. and 5° Long. blocks covering the area of the Indian Ocean bounded by latitudes 20° S and 30°N and longitudes 60° E and 100° E. In obtaining the cloud cover data the blocks having less than 20 per cent cloudiness have been counted as cloud free. This daily cloud cover data has been used to obtain the weekly mean cloud cover (WMCC) data. WMCC data was obtained only for those weeks in which the cloud pictures were available for five days or more in a week. INSAT visible cloud imagery of 6 GMT has been used. Equatorial troughs as the zone of maximum cloudiness have been shown by dashed lines in the WMCC data. In the month of June the cloudiness has been estimated up to 20°N only.

3. Southwest monsoon 1987

In the year 1987 the southwest monsoon set in over Kerala on 2 June and covered the entire country by 27 July. Monsoon began to withdraw from west Rajasthan, Jammu & Kashmir and Punjab from 14 September. The monsoon withdrew from other parts of northwest India and even from some parts of Peninsula by 24 September. The monsoon withdrew from northwest India in a rapid manner. During this year the monsoon prevailed over several parts of northwest India for about 45 days only. The seasonal rainfall distribution from 1 June to 30 September is shown in Fig. 1.

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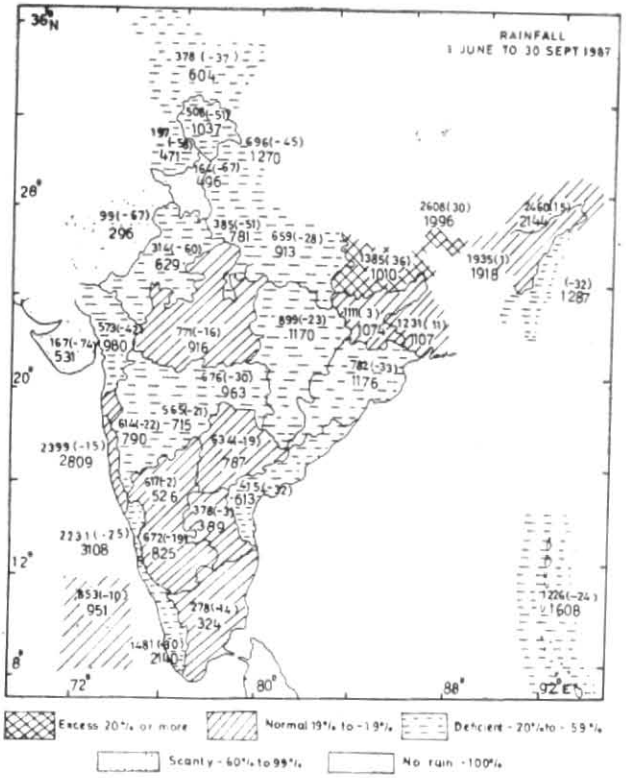

Fig. 1. Rainfall for the period 1 June to 30 September 1987

4. Weekly mean location of equatorial troughs and the activity of southwest monsoon

Fig. 2 (a-h) shows the weekly mean location of NHET and SHET from the week ending on 3 June up to the week ending on 28 July. The monsoon had already set in over Kerala on 2 June. The data on the location and intensity of NHET and SHET during different phases of southwest monsoon are summarized in Table 1.

From the table it follows that the SHET remained active during delayed onset of monsoon over central and northwest India, its poor performance in the month of July and its rapid withdrawal from northwest and central parts of India. On the contrary, the active phases of the southwest monsoon occurred when the SHET was weak.

5. Role of SHET during other severe drought years

Starting from the year 1965 when the satellite observed global cloud cover data started becoming available, severe drought conditions prevailed over India in 1965, 1966, 1972, 1979 and 1987. Cloudiness data for the years 1966-1970 have been studied by Saha (1971), 1966-1973 by Yasunari (1979, 1980). The data for the year 1965 has large amounts of missing data and hence, not used in the study of the southwest monsoon by Yasunari (1980). The data for the years 1973-1977 have been used by Sikka and Gadgil (1980), and for the years 1973, 1974, 1979, 1983 and 1984 by Prasad *et al.* (1983, 1988). The data presented by Saha (1971) on the frequency of the occurrence of double cloud bands in the Indian Ocean for the period July 1966 to September 1970 (Table 2) shows that the double cloud bands one in each hemisphere were seen on 23 days in July and

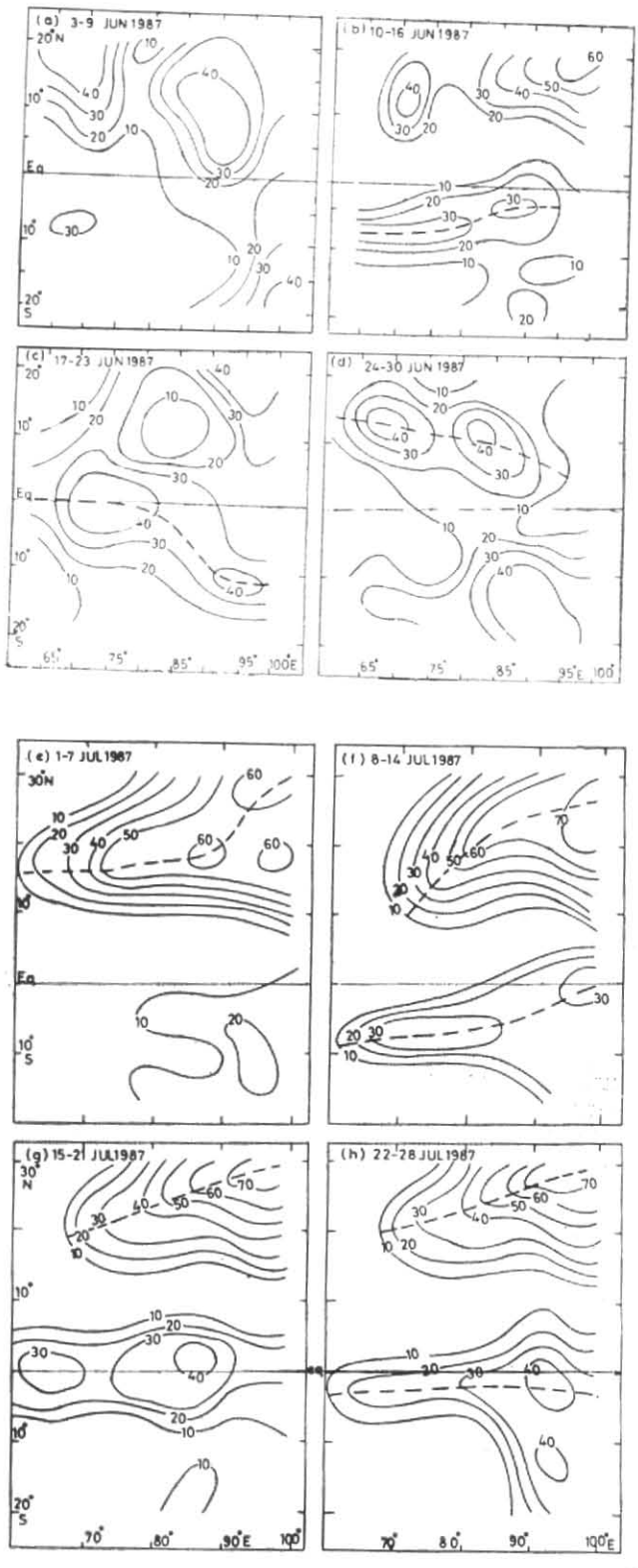

Fig. 2 (a-h). Weekly mean cloud distribution and location of equatorial troughs

TABLE 1

Location and intensity of equatorial troughs and southwest monsoon activity over India during 1987

Period		Location and intensity of		Remarks on monsoon activity
From	To	SHET	NHET	
(1)	(2)	(3)	(4)	(5)
3 Jun 1987	9 Jun 1987	Inactive	Active between 5° and 15° N with embedded convective clusters one each in Bay of Bengal and Arabian Sea	A deep depression formed in the Central Bay of Bengalon on 2 June, intensified in to a cyclonic storm and moved into Bangladesh by 6 June. Almost simultaneously a well marked low pressure area formed over central Arabian Sea. A low pressure area formed over NW Bay on 9 June. The monsoon advanced over Tamil Nadu, Karnataka, Goa, Konkan, Assam, Sub-Himalayan West Bengal and parts of Gangetic West Bengal
10 June 1987	7 Jul 1987	Active around 5°S from 10th to 16th June and moved close to equator by 23rd. Thereafter, the SHET was inactive till the end of the period	Active which showed northward movement and reached the location 18°N, 60°E to 30° N, 90° E by the end of the period	The low pressure area which formed over NW Bay on 9 June crossed Orissa coast on 11 June and became unimportant on 13 June. Monsoon advanced over Orissa and Bihar. The advance of monsoon was close to normal over these parts of India. Thereafter there was lull for about 10 days in advance of monsoon to Gujarat and along Gangetic valley. Monsoon advanced to Bihar plains on 25 June nearly two weeks behind the normal date. This surge was rather weak. No active monsoon disturbance formed. The monsoon activity remained weak for about a month. A few week systems which developed in the lower and middle troposphere were responsible for the advance of monsoon to Maharashtra, Vidarbha, Gujarat and M.P. by the first week of July
8 Jul 1987	4 Aug 1987	Active between equator and 10°S from 8 to 14 July and close to equator from 15 to 28 August. It weakened during the week ending on 4 Aug 1987	Active NHET mainly confined to the east of 80°E and north of 20°N	Development of a low pressure area/cyclonic circulation resulted into advance of monsoon over U.P. and Rajasthan during 5-15 July. This was followed by a lull for about two weeks. Monsoon advanced over Delhi, Punjab and other parts of India during the period 24-28 July in association of a weak upper air circulation. Weak cyclogenesis during July, the peak month of monsoon activity was responsible for delayed onset (for about a month) over Delhi, Haryana, plains of west U.P. and parts of Rajasthan and a large deficit in seasonal rainfall
5 Aug 1987	1 Sep 1987	Undeveloped	NHET developed in Bay of Bengal around 5°N in the week ending on 11 Aug 1987. It showed northward movement up to 20° N in the week ending on 1 Sep 1987	The following disturbances formed during this period : (*i*) A low pressure area over Bihar Plateau which moved over U.P. (7-8 August) (*ii*) A low pressure area off north Andhra Pradesh which was short lived (14-15 August) (*iii*) A low pressure area emerged in east central Bay as remnants of a typhoon Betty which dissipated over Rajasthan (19-25 August). (*iv*) A depression over Bangladesh which weakened over west U.P. (26-31 August). These disturbances resulted into the revival of monsoon activity

TABLE 1 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
2 Sep 1987	29 Sep 1987	Active SHET between equator and 10° S	NHET mainly confined to the east of 80°E and north of 20°N	The following disturbances formed during this period : (*i*) A low pressure area over NW Bay which became unimportant over NE M.P. (4-8 September) (*ii*) A depression over Bihar Plateau which moved westward across M.P. (10-19 September) (*iii*) A low pressure area formed over NW Bay. It moved over Bihar Plateau and persisted there with irregular track (22-30 September) Monsoon withdraw from northwest India and even some parts of Peninsular India by 24 September. It withdrew rapidly from those areas of the country where the rainfall was scanty

TABLE 2

Number of occurrence of double cloud bands in equatorial Indian Ocean during July 1966 through September 1970
(*After* Saha 1971)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1966	a	a	a	a	a	a	23	15	12	12	8	15
1967	4	6	4	4	3	3	3	6	4	2	0	3
1968	4	4	8	5	3	7	5	8	12	9	14	14
1969	3	3	1	0	6	4	6	7	7	2	3	1
1970	5	11	0	2	3	11	4	4	5	—	—	—

a — APT picture not available.

15 days in August in the year 1966. The frequency of double cloud bands ranged from 3 to 6 days in July and 4 to 8 days in August for the good monsoon years of 1967-1970. Yasunari (1980) reported that the period of the northward propagation of the cloudiness which was 30 to 40 days in other years became as large as 60 days in the drought year of 1972. The data presented in this paper on the occurrence of the equatorial troughs during the year 1987 depicts the features as noted by Saha (1971) and Yasunari (1980) for the drought years of 1966 and 1972 respectively. Prasad *et al.* (1988) have shown that the SHET remained active during the 'break' in monsoon in the month of July 1979 and the second spell of the increased activity of SHET in that year began in the second half of August and continued till the end of the season. Southwest monsoon did not revive after the second half of August.

An examination of the seasonal rainfall distribution over India during the severe drought years of 1965, 1966, 1972, 1979 and 1987 (Fig. 3) shows that the deficient or scanty rainfall are recorded over central and northwest India, where rainfall occurs during the periods of active monsoon trough. Thus the failure of the rainfall over these areas is attributed to the absence or weak monsoon trough in the peak months of summer monsoon, *i. e.*, July and August. It may be concluded here that severe drought conditions over India result due to the development of an active SHET which leads to considerable decrease in cross-equatorial flow and thereby weakening of the monsoon circulation.

6. Northward movement of the maximum cloud zone (MCZ)

Northward propagation of MCZ as reported by Sikka and Gadgil (1980) and Yasunari (1979) is also seen in 1987 and 1988 (Fig. 4). While the first MCZ in the year 1987 took 4-5 weeks to move from close to equator to the northernmost latitude belt, the second MCZ took 8 weeks. For the first 4 weeks of the 8-week period, the MCZ remained confined close to equator. In contrast to this, in a good monsoon year like 1983 SHET remained undeveloped after the onset of the monsoon (Prased *et al.* 1988). However, in another good monsoon year, *i. e.*, 1988, there were as many as five spells of increased cloudiness (SIC) in the zone of SHET (Fig. 4). Except for the last SIC which began in the week

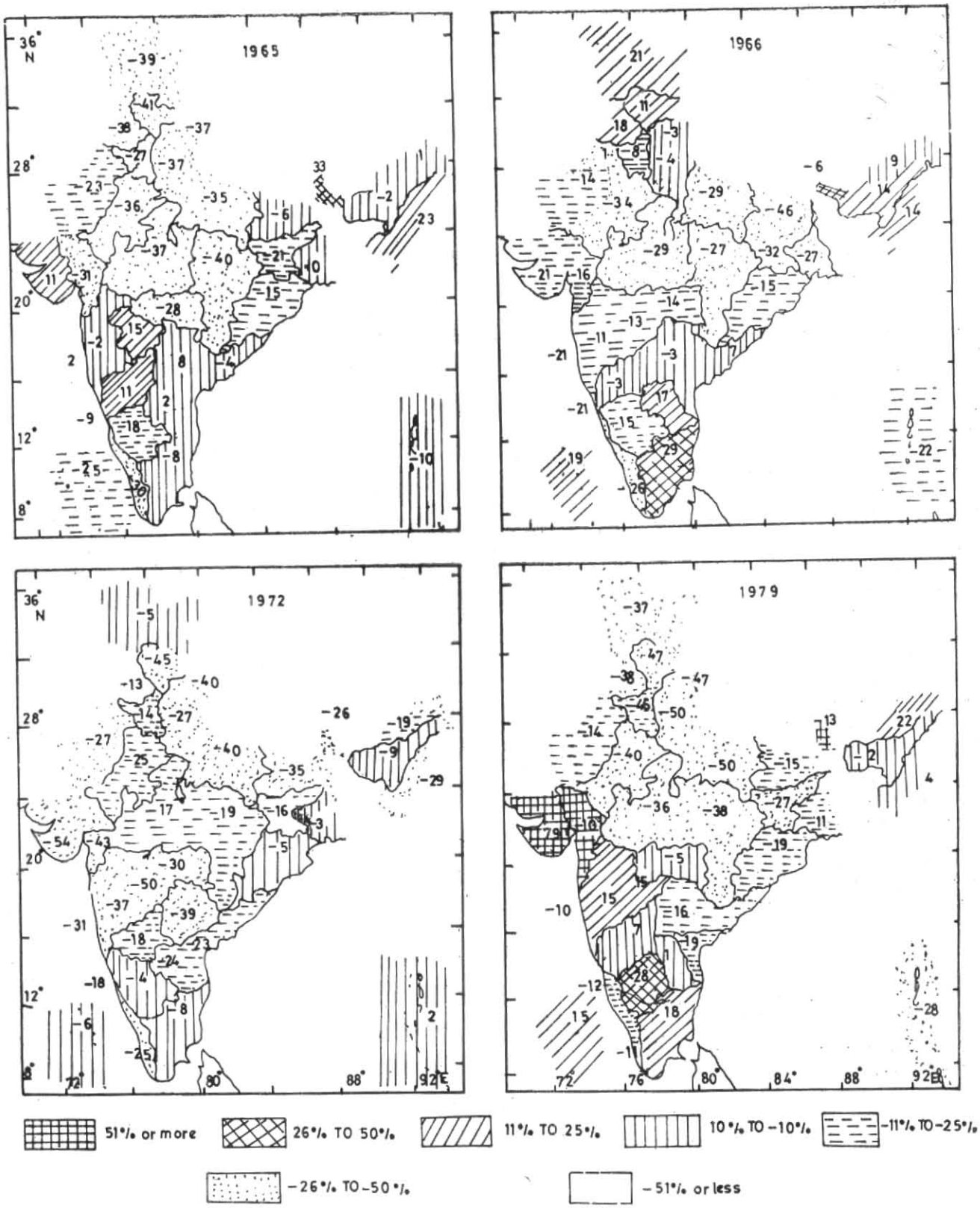

Fig. 3. Rainfall for the period 1 June to 30 September 1965, 1966, 1972 and 1979

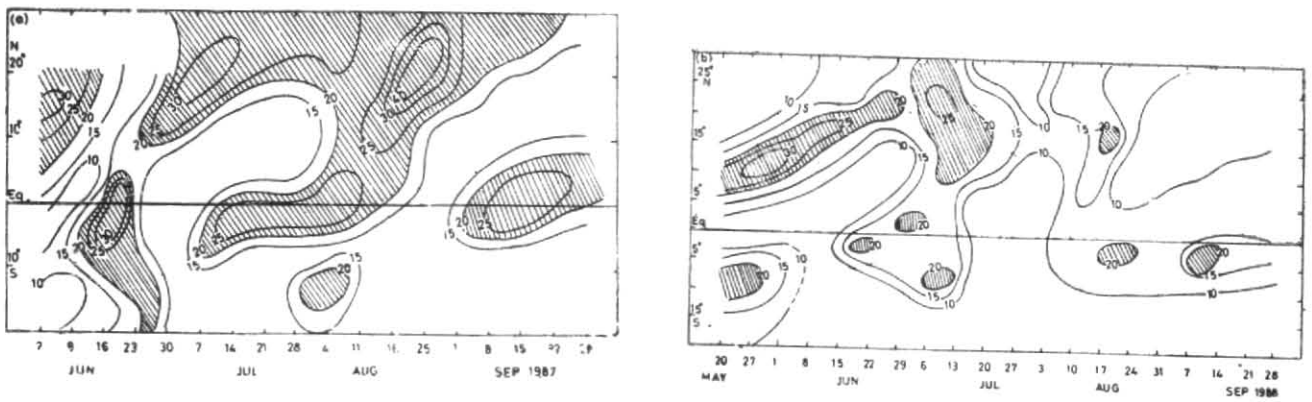

Fig. 4. Time-latitude cross-section of weekly mean cloudiness averaged over the longitudes of 60° and 100°E : (a) 1987 and (b)1988

ending on 14 September, all other SICs did not persist for more than a week. The first two SICs showed northward movement with time. The last three SICs did not show any movement to the north with time. For the season as a whole 1988 was a good monsoon year with weak monsoon conditions prevailing for short periods during mid-June to early July, mid-August and early September. This interference occurred due to occasional development of SHET though for short durations. The other aspect noted here is the large variation in the period of the northward movement of the MCZ. This aspect has been dealt in detail by De and Vaidya (1987) and De *et al.* (1988). This limits the use of the low frequency mode as a reliable tool in medium range forecasting of summer rainfall over India.

7. Air-sea interaction

Presence of an active equatorial trough has been shown to be associated with the existence of large areas of warm waters at the equatorial ocean surfaces (Saha 1971). Similar conclusions have been drawn by Manabe *et al.* (1970) and Pike (1971) who conducted numerical experiments on the interaction between ocean and atmosphere on the formation of inter-tropical convergence zone, its location and itensity, In this respect the availability of the sea surface temperature distribution from the equatorial regions of Indian Ocean may prove helpful in monitoring the SHET. This may give a longer lead time in foreshadowing the dry and wet spells of rainfall over India.

8. Conclusions

(*i*) Development of different phases of southwest monsoon depends on the intensity of SHET.

(*ii*) The period of northward movement of MCZ varies from year to year and also within the season itself.

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