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On the 30-40 day oscillations in southwest monsoon : A satellite study

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सार – इस शोधपत्र में 1986 और 1987 की दक्षिण-पश्चिम मानसून ऋतुओं के दौरान निम्न बारंबारता दोलनों का तुलनात्मक अध्ययन प्रस्तुत किया गया है। इन दोलनों के अध्ययन के लिए प्रयुक्त किया गया प्राचल आंशिक मेघ आवरण है जो 2.5° अक्षांश/दशांतर के प्रत्येक क्षेत्र के ऊपर (अवसीमा) तापमान से ठंडा है। इसमें इसके अन्तर्गत इनसैट-1 बी अवरक्त आंकड़ों का प्रयोग किया गया है और अरब सागर, बंगाल की खाड़ी और हिन्द महासागर के कुछ भाग शामिल है।

समय-अक्षांश अनुभाग मेघ उच्चिष्ठ के उत्तर की ओर नियमित गतिशील होने का संकेत देते हैं जो कि 30–40 दिनों की अवधि के साथ लगभग 30° उ० तक जाता है, भूमध्य रेखीय हिन्द महासागर से आरम्भ होता है। प्रावस्था गति लगभग 0.9 अक्षांश/दिवस है। ये आंकड़ अनुलोम फोरियर रूपान्तर विधि द्वारा मानावलीय विश्लेषण के विषय थे। इसकी गणना प्रत्येक क्षेत्र के लिए चौड़ाई में 5° अक्षांश और लम्बाई में 10° देशांतर के लिए की गई है। परिणामों से पता चलता है कि यह प्रक्रिया 25° उ० अक्षांश तक देखी जा सकती है जिसके बाद यह नष्ट हो जाती है। यह अवधि 1987 में, जो कि सूखा वर्ष है, 20° और 25° उत्तर के मध्य 60 दिनों के लिए बन गई थी।

संवहन के साथ अल्पस्थायी प्रणालियों को 10 दिनों से भी कम अवधि के साथ 5° उ० के पश्चिम की ओर बढ़ते हुए देखा गया है। 1987 के मानसून की अपेक्षाकृत कमजोर गतिविधि का कारण, संभवत: समय रूप में अपेक्षाकृत कम मेघाच्छन्नता का होना और अल्पस्थायी विक्षोभ की गतिविधि का दमन होना और उनके अपेक्षाकृत छोटे क्षेत्रीय पैमाने पर होना है।

ABSTRACT. A comparative study of the low frequency oscillations during the southwest monsoon seasons of 1986 and 1987 is presented in this paper. The parameter used to study these oscillations is the fractional cloud cover, colder than a threshold temperature over each area of 2.5° Lat./Long. covering Arabian Sea, Bay of Bengal and part of Indian Ocean, using INSAT-1B IR data.

The time-latitude sections indicate a regular northward movement of the cloud maxima starting from equatorial Indian Ocean to about 30° N with a period of 30-40 days. The phase speed is about 0.9° Lat./day. This data was subjected to the spectral analysis by DFT method. This was computed for each area of 5° Lat. in width and 10° Long. in length. The results indicate that this mode can be seen up to 25° N latitude beyond which it gets obliterated. The period is enhanced to 60 days between 20°& 25° N in 1987, which is a drought year.

Transient systems with the associated convection are seen to be moving westwards north of 5° N with a periodicity of less than 10 days. Comparatively poorer activity of monsoon of 1987 is possibly due to overall less cloudiness and the suppression of transient disturbances activity and their smaller zonal scale.

1. Introduction

The importance of low frequency oscillations in the summer monsoon circulation over and around India was emphasized by Yasunari (1979). By analysing the fluctuations in the cloudiness obtained by NOAA satellite values, for the year 1973 (which is a normal monsoon year) he detected two major modes with periodicities around 40 days and around 15 days. His subsequent studies revealed an interesting northward propagation of 30-50 day perturbations which originate in the equatorial Indian Ocean and dissipate near the foothills of Tibetan plateau (Yasunari 1980, 1981). The meridional propagation of these low frequency modes is related to the phase changes between active and break monsoon. Ever since their discovery (Murakami 1976), these low frequency modes have been studied by many scientists. Krishnamurti and Subramanyam (1982) presented a mapping of 30-50 day filtered wind fields at 850 mb over an extensive region during the period 2 May to 28 July 1979. They found a steady northward propagation of anomalies of troughs and ridges from the equator to about 30° N; with a meridional phase speed of 0.75° latitude/day. Other interesting studies of these oscillations were carried out using wind and geopotential fields (Murakami 1985, Yasunari 1985, Ahlquist 1985). By analysing the weekly rainfall departures for Indian sub-divisions for monsoon seasons for five years, De and Vaidya (1987) observed that the 30-50 day oscillation not only shows considerable variation from year to year, but the northward propagation of this mode also appears to be irregular. They further concluded that large part of the intra-seasonal oscillations in the rainfall is explained due to the synoptic scale disturbances, while the low frequency mode explains only 10% of the observed variance in rainfall. Iyengar (1987) performed statistical analysis of weekly rainfall over 8 stations in the southern

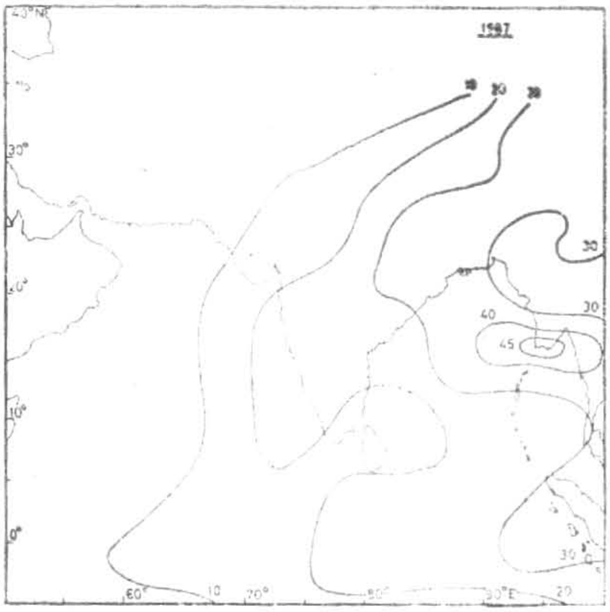


Fig. 1. Mean cloudiness (fractional) for the monsoon season of 1987 expressed as percentages

India. He found a prominent 40-day periodicity in the rainfall of Mangalore which is located on the west coast and which receives its maximum rainfall during the southwest monsoon season.

Using GMS infrared data Murakami (1983) found a systematic northward progression of highly convective cloud bands with a period of 30 to 40 days, across Indo-China and Bay of Bengal region during the monsoon season of 1979. He further calculated that the regions of strong and weak monsoon westerlies at 850 mb level are highly coincident with the enhanced and suppressed convective regions. Sikka and Gadgil (1980) also investigated the northward propagation of this mode in terms of the cloudiness changes. Murakami *et al.* (1984) investigated these low frequency oscillations during the summer 1979 using the FGGE level III B data. They showed that v' spectrum at 850 mb over the monsoon region shows peaks with period shorter than ten days while the u' spectrum at the same level indicates a pronounced 40-50 day peak over monsoon region, where u' and v' are the intra-seasonal transient variations in the wind components as defined by them. They conclude that these transient systems in and around the monsoon trough move westward and contribute to the intensification of the convective activity and monsoonal zonal flow and as a result of the interaction between the transient systems and the monsoon trough, the 40-50 day mode becomes prominent near 15° N. During break monsoon conditions, the activities of the transient systems and associated convection are below normal. From their study, it appears that the transient disturbances play an active role in determining the performance of the monsoon.

Since the fluctuations in the cloudiness are one of the most important measures of those in the monsoon rainfall, cloudiness data from the meteorological satellites can provide immediate and invaluable information on the large scale monsoon circulation system. While all the earlier studies of these low frequency oscillations over Indian monsoon region were carried out with twice daily cloudiness values of the polar orbitting satellites, in the present study we used the data of INSAT-1B, which is more frequent and yields a better sampling for daily values.

Although the long period (40 days) oscillations are present in any monsoon season, the question arises whether there is any change in the periodicity in a bad monsoon year and if so, at what latitude it can be seen ? Is there any variation of this mode with latitude ? If so, up to what latitude this mode is seen ? What role, if any, the transient disturbances play in the monsoon activity ? These are some of the questions we examined in the present study.

2. Data

The Indian National Satellite (INSAT-1B) is a three-axis stabilized satellite and has its principal sensor Very High Resolution Radiometer (VHRR). The VHRR is capable of producing an infrared (IR) and visible full disc earth image every thirty minutes. The IR sensor has a linear resolving power of about 11 km at nadir and can discriminate temperature differences of 1 K or less, while the resolution of the visible sensor is 2.75 km. During normal operations, the ingests are processed every three hours.

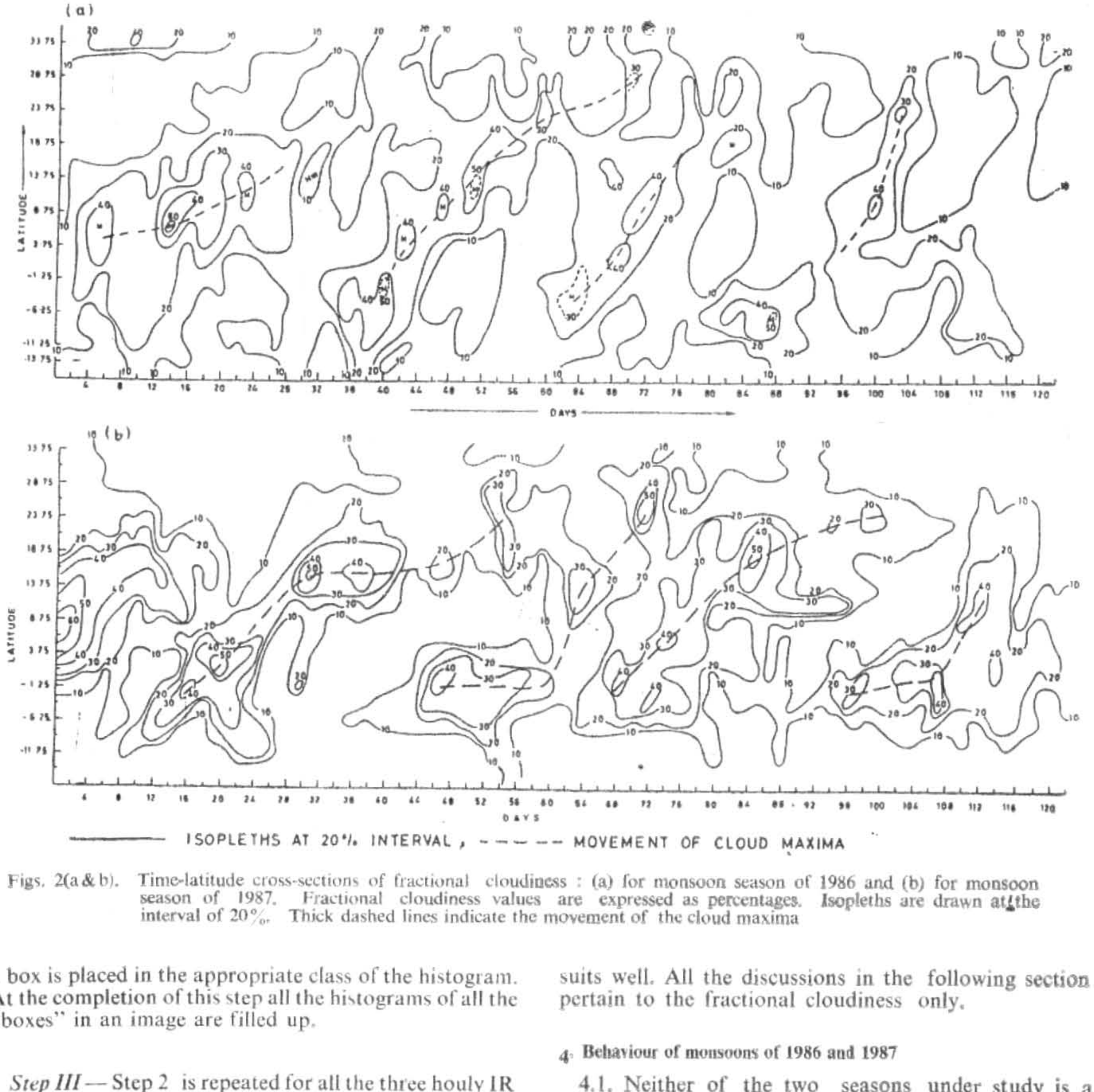
In the present study, we used the three hourly IR digital data for the monsoon period of 1986 and 1987. The cloudiness is expressed as a fractional area covered by clouds colder than a given threshold temperature (called fractional cloud cover) over every 2.5° Lat./Long. sub-area, while the area chosen for the study extends from 50° E to 100° E and 35° N to 20° S. The daily values of this fractional cloud cover for the monsoon season are used. The missing values are interpolated from those of the previous day and the following day. There are only two such cases in September 1986.

3. Method

As indicated above, the area of analysis (area extending from 50° E to 100° E and 35° N to 20° S) was divided into smaller areas, hereafter called "boxes" of 2.5°×2.5° Lat./Long. and are serially numbered starting from the 1st row. All three hourly IR images of the day (8/day) are used for the study. The calculation of the fractional cloud cover is carried out in the following steps :

Step I — A sixteen-class histogram is defined in each box. There are 12 classes of 5 K interval between 270 and 210 K and two classes at 10 K interval between the temperatures 210–190 K. Two more classes with temperatures > 270 K and < 190 K complete the 16 classes of the histogram.

Step II — The grey shade value of each pixel (picture element of size 11 km × 11 km) is read and is converted to the corresponding temperature according to a lookup table. Depending on its position each pixel is assigned a "box" number, which is more or less constant as the INSAT is a three-axis stabilized satellite. Normally serveral hundred pixels lie in a box. All the pixels which are outside the area of analysis and missing lines, if any, are eliminated by the software from entering into the processing. Based on the temperature value each pixel in



Figs. 2(a & b). Time-latitude cross-sections of fractional cloudiness : (a) for monsoon season of 1986 and (b) for monsoon season of 1987. Fractional cloudiness values are expressed as percentages. Isopleths are drawn at the interval of 20%. Thick dashed lines indicate the movement of the cloud maxima

a box is placed in the appropriate class of the histogram. At the completion of this step all the histograms of all the "boxes" in an image are filled up.

Step III — Step 2 is repeated for all the three houly IR data images of the day. Then the daily total of all the frequencies in each class are made, using the data of all 8 images of the day.

Step IV — After having obtained the daily totals, the fractional cloud cover for each box is calculated by :

$$\frac{\text{Sum of all the pixels colder than a chosen threshold temperature}}{\text{Total number of pixels in a box}}$$

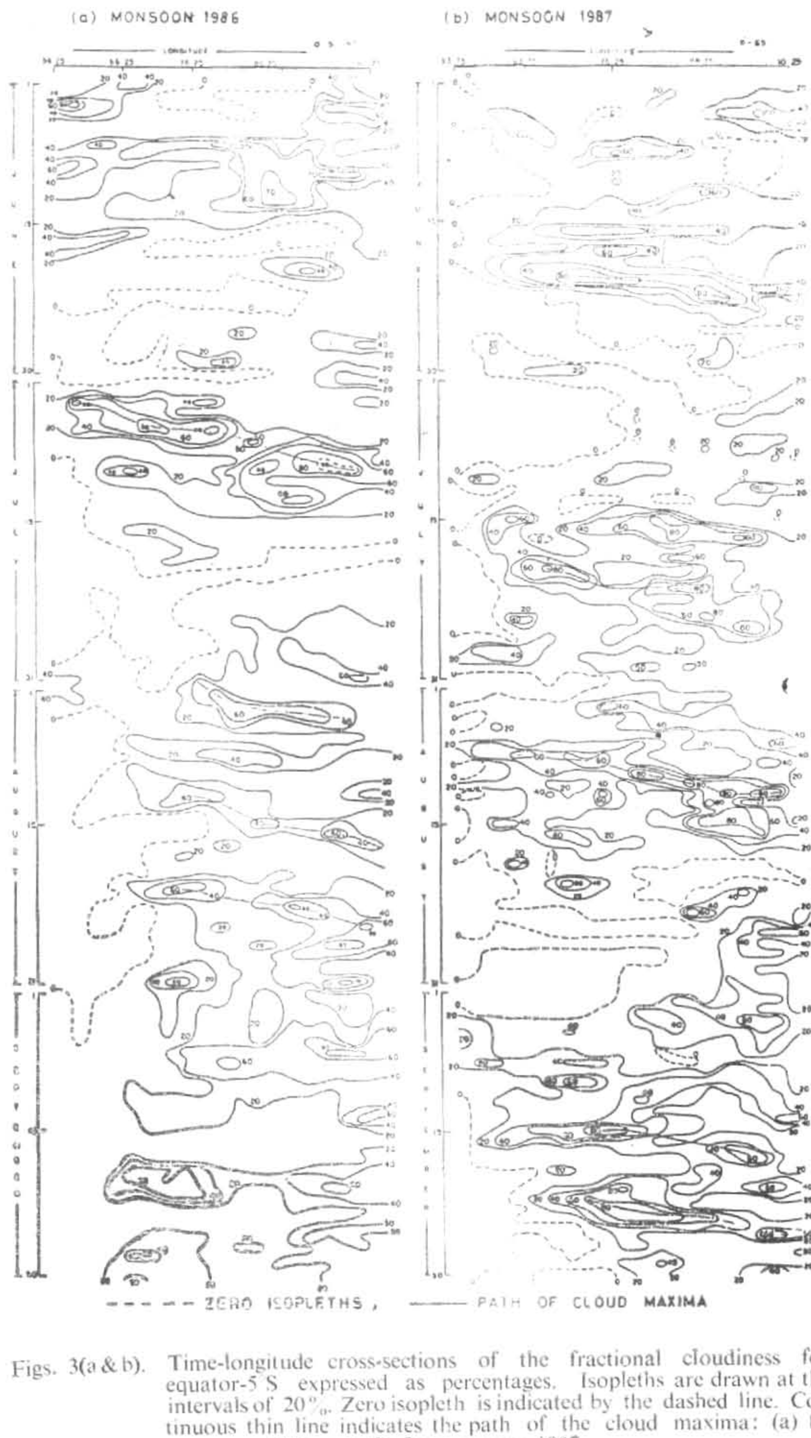
The threshold temperature in this case is chosen to be 260 K, as this represents most of the convective clouds (top > 8 km) in this season. Therefore, it does not represent the total cloudiness. Since our aim is to study the fluctuations in the convective activity associated with the low frequency oscillations, this temperature threshold suits well. All the discussions in the following section pertain to the fractional cloudiness only.

4. Behaviour of monsoons of 1986 and 1987

4.1. Neither of the two seasons under study is a normal monsoon. During 1986 monsoon, 21 sub-divisions of the country received normal ($+19\%$ to -19%) or excess ($+20\%$ or more) rainfall and 14 sub-divisions received deficient (-20% to -59%) rainfall, while in 1987 monsoon, only 14 sub-divisions received normal or excess and 21 subdivisions received deficient rainfall. Thus 1986 monsoon is better than that of 1987.

4.2. *Advance of the monsoon*

During 1986, monsoon onset over Kerala was delayed by about five days, but was around normal dates over central and south interior Karnataka. Its further advance over the rest of the Peninsula and Gujarat was delayed by four to seven days, as the Arabian Sea branch was stalled between 4 June and 13 June. Due to the delay of the Bay branch, the onset of monsoon over Assam and adjacent States was late by about 10 days. Its advance over Orissa



Figs. 3(a & b). Time-longitude cross-sections of the fractional cloudiness for equator-5°S expressed as percentages. Isopleths are drawn at the intervals of 20%. Zero isopleth is indicated by the dashed line. Continuous thin line indicates the path of the cloud maxima: (a) for monsoon 1986 and (b) for monsoon 1987

West Bengal & Sikkim, Bihar and Madhya Pradesh was delayed by about 4 to 7 days, while it was around normal dates over U. P., north India except west Rajasthan.

In 1987, the onset of summer monsoon over Kerala was around normal date and its northward progress till 17 June was satisfactory. Later, both the branches stalled and as a result over most of the northern States the onset was delayed. It covered the whole country by 27 July as against the normal date of 15 July. Particularly, the onset was delayed inordinately over northwest India, northern parts of Madhya Pradesh and parts of Gujarat. Though in neither of these two years either monsoon onset or its performance is normal, monsoon of 1987 is worse of the two, leading to an unprecedented drought over the large parts of the country. We shall try to search the reasons for these differences.

5. Results and discussion

5.1. In Fig. 1 the mean cloudiness (fractional) for the monsoon season of 1987 is given. Similar map for 1986 is also prepared (not shown as the mean features are not much different). Using the daily values, average of the fractional cloudiness for all the 122 days of the monsoon season for each box of 2.5° Lat./Long. is calculated and expressed as percentages. Isopleths are drawn at the interval of 10%. It shows a maximum of cloudiness over east central Bay off Burma coast. Over the northwest India, parts of central India and western India, the cloudiness is very less. There is no cloudiness over Arabian Sea west of 65°E. Over Tamilnadu and adjoining Bay areas also the cloudiness is very less. Though the patterns are similar in 1986 and 1987, the values are slightly higher in 1986. Considerable differences may be seen if these patterns were compared with that of a normal monsoon year.

5.2. In Figs. 2(a) and 2(b) the time-latitude cross-sections of the fractional cloudiness are presented.

The latitudinal average of fractional cloudiness values over all longitudes are calculated for each day and the time-latitude section is prepared to study the fluctuations along a meridional plane. Original values of fractional cloudiness are used to prepare the cross-section.

The striking difference between the years 1986 and 1987 is that there is no significant cloudiness north of 25° N in the year 1987.

Remarkable northward movement of cloudiness maxima which is indicated by dashed line can be seen from about 5° S to 30°N with a period of around 30-40 days. It is also seen that, when one of the maxima in its northward journey reaches the highest latitude belt, another spell starts from south. Thus, the meridional fluctuations of the cloudiness appear as a repetitive northward shift of cloudiness from Indian Ocean to Tibetan plateau. Similar movements were also observed by Sikka and Gadgil (1980), Yasunari (1979). The average northward phase speed is calculated to be 0.9° Lat./day, which is almost the same value as obtained by Murakami (1976) and nearer to the value as obtained by Krishnamurti and Subramanyam (1982).

During the whole monsoon season, there are 4 spells, which move northwards. In the year 1987, only one such spell starting from the 2nd week of August (day 68), has gone to the northernmost latitude. The other spells dissipated somewhat south of this position. This has resulted in the less cloudiness, in the mean, north of 25°N during the year 1987. It is interesting to note that a cloud maximum appears around 2 June at about the latitude of Trivandrum in 1987, and around 4 June in 1986 (extreme right hand side of the diagrams) which coincide with the onset of the monsoon over Kerala, in the respective years.

5.3. *Zonal structure of cloudiness fluctuations*

In this section, we present the nature of temporal fluctuations in the zonal cross-section.

5.3.1. *Time-longitude section of cloudiness*

In this analysis, time-longitude sections of each 5° latitude zone were prepared between the latitudes of 5° S and 30°N. The aim of this analysis is to find eastward or westward moving disturbances with their associated convective activity responsible for the fluctuations of the monsoonal current. From this analysis, it should be possible to trace the transient disturbances, found by Murakami (1984), with their associated convective activity, as the westward moving cloud maxima. Though such cross-sections are prepared for each 5° latitude belts between 5° S and 30° N, we present here in Figs. 3(a & b) and 4(a&b), the time-longitudinal cross-sections for 5° S-equator and 10°-15°N for the years 1986 and 1987 as typical cases.

In the diagrams the longitudes are plotted as abscissa increasing from west to east and the time in days is represented on the ordinate increasing southwards. The fractional cloudiness is plotted in percentages and the isopleths are drawn at the interval of 20% and the positions of maxima are located. The positions of maxima on different days are joined by a thin line which indicates the direction of movement of the maxima. Dashed lines indicate the zero isopleth.

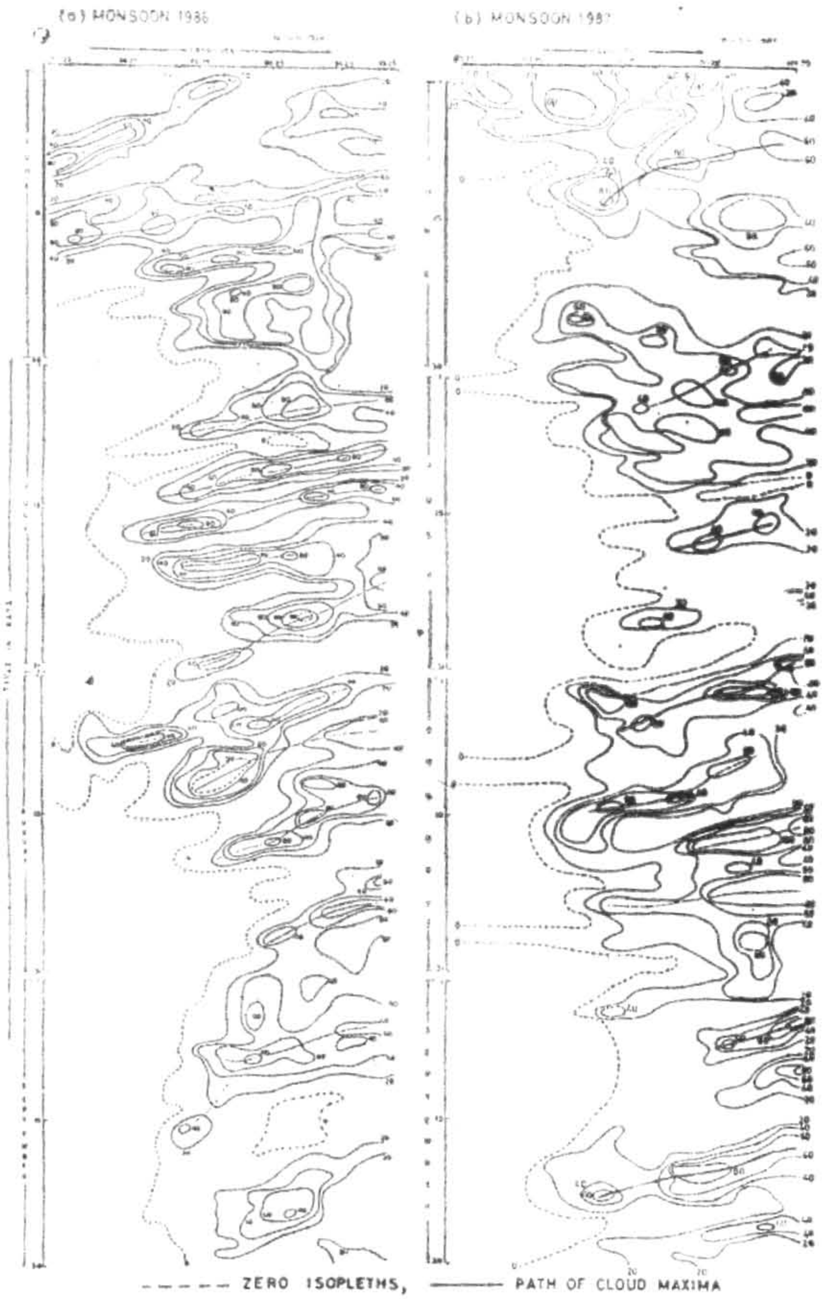
5.3.1.1. *Cross-section of 5° S-Equator*

Fig. 3(a) is for the year 1986 and Fig. 3(b) is for the year 1987.

In the zonal cross-section, predominant west to east movement of cloudiness is seen. Cloudiness maxima start from about 60° E longitude and move towards east. Since the domain of the analysis terminates at 100° E, the area of their dissipation, which may be further eastwards cannot be traced. Those disturbances, which persist up to the end of the domain, are considered as major and those which dissipate within the domain are considered as minor. The major disturbances seem to have occurred roughly once in 35 days in 1986 while they occurred in around 50 days in 1987. These disturbances progressed about 5° longitude/day.

5.3.1.2. *Cross-sections of 10°-15° N*

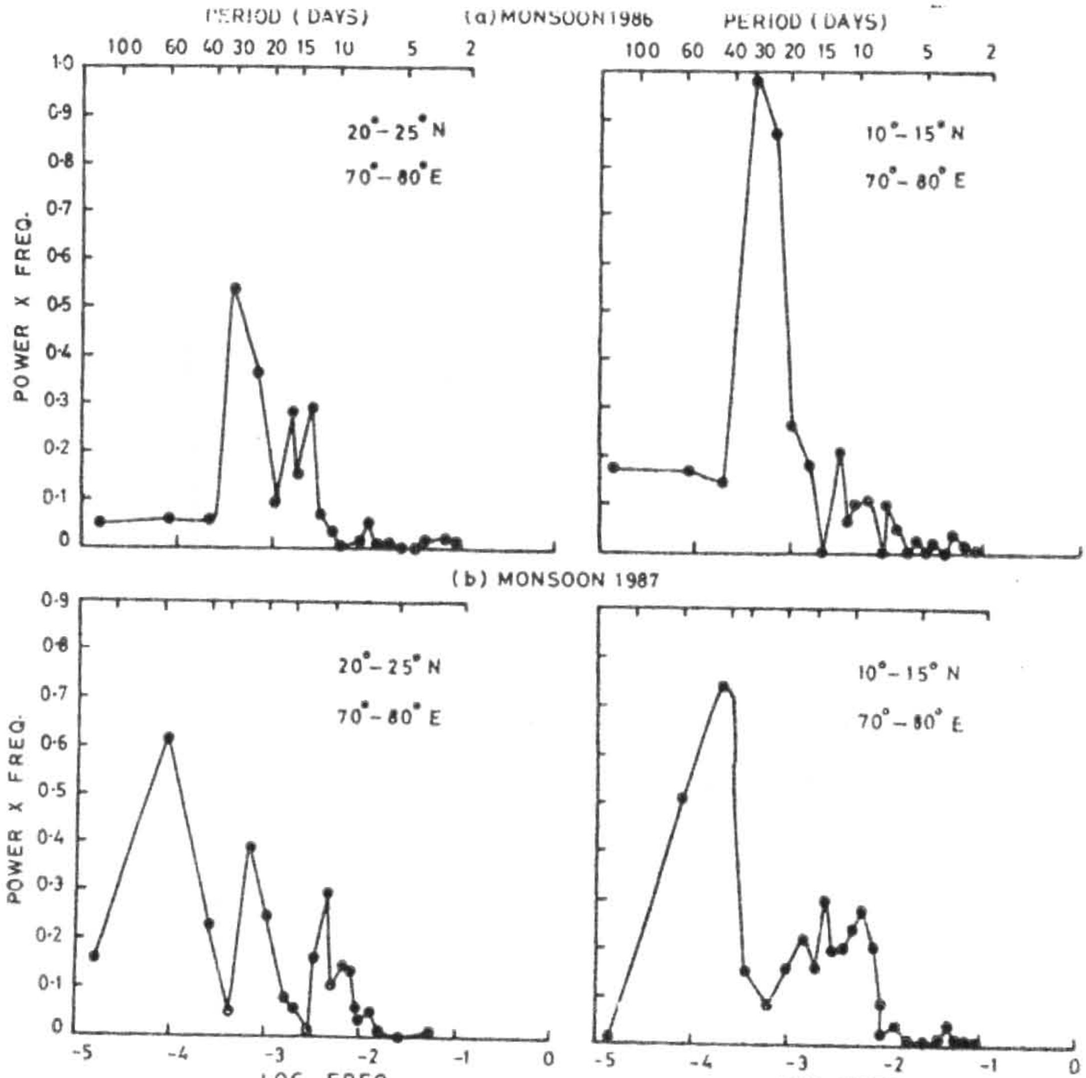
The time-longitude cross-section between 10° & 15°N is presented in Figs. 4(a) and 4(b). The patterns for other latitude belts (north of 5° N) are similar.



Figs. 4 (a & b). Same as Fig. 3 except for the latitude belt 10°-15°N

In this cross-section, the westward moving cloud systems are dominant. The cloud maxima are seen to be moving within the domain of broad scale cloudiness extending roughly up to 60° E. Comparison of the cross-sections for the year 1986 and 1987 indicate that (*i*) there are less number of westward moving disturbances in 1987 than in 1986, (*ii*) the month of July 1987, in particular, is comparatively cloudless over many longitudes compared to July 1986, as indicated by the zero isopleth in the former case and (*iii*) the westward extensions of the cloudiness, in general, are smaller in 1987 than in 1986.

These cloud maxima moved at a phase speed of 4°-5° Long./day with zonal scale of 20°-40° in 1986 and 12°-30° longitudes in 1987. The average period with which these disturbances occurred is 9.6 days. The cloud maxima are tracked from their first appearence in the domain till their dissipation. The extent of its travel in terms of longitude and the period in days that it took to travel that distance is noted for each cloud maxima. The speed of each cluster is calculated from this data and the average of all these speeds is found. The distance travelled by a cluster before dissipation is taken as the zonal scale. The number of disturbances in each monsoon season is noted and the period of occurrence is found from the total number of disturbances in a monsoon season of 122 days. This period is comparable to the period of 10 days obtained by Murakami (1984) for the transient disturbances.



Figs. 5(a & b). Spectral analysis of the fractional cloudiness for the longitude belt of 70°-80°E : (a) for monsoon season of 1986 and (b) for monsoon of 1987

It is, therefore, possible that the maxima of convective activity are associated with the westward moving transient disturbances.

It is further seen that majority of the disturbances moved farther westwards in 1986, while it is not so in 1987. In fact many of them dissipated in 1987 east of 85° E. Moreover, in the first two months, the number of transient disturbances in the year 1987 is less in number than in 1986. As the activity of the monsoon depends on the interaction of the transient disturbances with the monsoon flow (Murakami 1984), the differences in the number of disturbances and the zonal scale of these disturbances may explain the differences in the overall activity of the monsoon during these two years, the activity being poorer in 1987 than in 1986.

The activity of the monsoon during July is crucial in the context of its overall performance in a given year. This is borne out from the fact that over most of the meteorological sub-divisions the July rainfall, being the highest, contributes maximum to the seasonal totals. Over a very small number of sub-divisions August rainfall is highest, but only marginally. Murakami *et al.* (1984) have also shown that substantial northward moisture transport occurs in the month of July which contributes to the rainfall over northern India. During the other months of the monsoon season the transport is much less.

Therefore, failure of monsoon during July may result in below normal rainfall for the season over many northern States. This is what seems to have happened during 1987. Comparatively less activity of the monsoon in the year 1987 can be seen from these two cross-sections from the month of July (day 31 to day 61), where general cloudiness is not only less in July 1987, but the activity of the transient disturbances also is much suppressed. These observations, thus, indicate that the interaction of the westward moving synoptic scale transient systems play an important role in keeping up the activity of the monsoon.

5.4. *Spectral analysis*

In the earlier sections, the characteristics of the temporal fluctuations of cloudiness, in the zonal and meridional cross-sections, were presented. The periodicities of these fluctuations are roughly estimated.

To determine the predominant periodicities, spectral analysis by direct Fourier transform method is applied to to the fractional cloudiness data, and the results are presented in this section. The aim of this analysis is to examine (*i*) the latitudinal extent of this 30-40 days mode and (*ii*) the differences, if any, in the periodicities of these modes in the year 1987 which is a very bad monsoon year as compared to 1986. Spectral analysis has been performed on the data of both the years.

The time period of each data set is 122 days (June-September). Power spectra were calculated for each block of width of 5° latitude × 10° longitude in length. The results are presented in Fig. 5. The upper part of the figure pertains to the latitudinal belts 20° - 25° N and 10°-15°N for the year 1986 and the lower portion pertains to the same latitudinal belts for the year 1987. On the ordinate power × frequency is represented while log frequency is represented on the abscissa. The advantages of this type of representation were discussed by Zangvil (1977).

Examination of the spectral analysis for all the blocks indicate the same periodicity of 30-40 days in the year 1986 while the periodicity is enhanced in the year 1987 in the 20°- 25° N latitudinal belt. This mode can be seen up to 25° N and north of this belt it gets obliterated.

As seen from Fig. 5 for the latitudinal belt 10° - 15° N two modes are prominent, one near about 30 days in 1986 and the other between 10 & 15 days. During the monsoon season of 1987, the first mode has a periodicity of 40 days while the periodicity of the second mode remains the same. Thus, the 30-day mode periodicity shows interannual variation (De and Vaidya 1987). Another mode, though less prominent, is also seen around 8 days.

In the 20°- 25° N latitudinal belt striking difference is seen in both the years. While in the year 1986, the primary mode has a periodicity of 30-40 days, it is enhanced to 60 days in the year 1987. Similar enhanced periodicity of 60 days was found by Yasunari (1980) for the year 1972 when the cloudiness data (for a block of 10°- 20° N and 70°-100° E) was subjected to spectral analysis. But in this case, we could find this enhanced primary mode between latitudinal belt of 20°-25° N only. It is noteworthy that this region is subjected to severe drought during 1987.

6. Conclusions

(*i*) The fractional cloudiness shows a periodicity of 30-40 days in both the years 1986 and 1987 up to the latitude of 20° N. This mode gets obliterated north of 25° N in both these years. The periodicity of this mode in the latitudinal belt 10°- 15° N seems to vary in small range, whether the monsoon is normal or below normal. But the real differences of the mode can be seen north of this belt which distinguishes a below normal monsoon year from a normal monsoon year. In a bad monsoon year the periodicity of this mode is enhanced.

(*ii*) The transient disturbances, which move westward, north of 5° N, play an important role in keeping up the activity of the monsoon. It can tentatively be said that the frequency of occurrence of these disturbances plays an important role in the sustenance of the active monsoon conditions.

(*iii*) These patterns for a normal monsoon year are also to be studied to confirm the above conclusions.

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