

A study of changes in the pattern of cloud distribution associated with movement of depressions during the southwest monsoon season using satellite pictures

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ABSTRACT. Charts of mean cloudiness and variability for the periods of movement of depressions during the southwest monsoon season of 1966 are presented. Similar charts have also been prepared for the periods when there were no depressions. A comparative study of the cloud patterns over the Indian Seas during periods of activity and periods when there no depressions was made. It is found that the cloud cover in the equatorial region undergoes considerable change during the monsoon season irrespective of the activity associated with the formation and movement of depressions.

1. Introduction

One of the most interesting phenomena of Indian weather is the formation and movement of monsoon depressions. Before the advent of weather satellites the distribution of clouds over the sea associated with these monsoon depressions were studied only with reference to synoptic charts, which are obviously limited in their scope on account of unrepresentative and limited data from ships.

A more meaningful climatology of the cloud cover of the sky in the Indian Ocean areas can therefore be based upon the information fed by satellites only. A study by Srinivasan (1968) discussed the general details of cloud distribution during the earlier monsoon period of 1964. But so far as the authors are aware, no such study on the influence of depressions on the cloud coverage in the equatorial regions or otherwise has been made so far.

In the earlier literature the depressions in the Bay of Bengal were often associated with the increased weather activities in the region apparently far away from their depression field. Malurkar (1958) for example speaks of the steady continuous rain along the west coast of India when a cyclonic depression is situated at the northwest angle of the Bay of Bengal. He also speaks of the 'pulses' which after crossing the equator bring fresh equatorial air and strengthen the monsoon there, or feed into tropical cyclonic depressions or storms. According to him, such air carried by the so-called pulses can easily become unstable and thunderstorms can occur all along its path.

Whether depression or cyclonic storm causes such increased weather activity in the equatorial region or they are a result of such increased weather activity is an open question. In fact this question was engaging the attention of workers who have been studying the tropical cyclones over Indian

Ocean and West Pacific for long. Herbert Riehl (1951) refers to this problem in the following terms 'Writers, however, disagree on the usefulness of cross-equator analysis for short term hurricane forecasting. Some, for example, state that West Pacific and Indian Ocean typhoons form following an intensification of flow across the equator. Others maintain that such an increase occurs after and in consequence of typhoon development. This writer has seen instances of the second type of situation but would not maintain that this is always the case. Experimental analysis across the equator is obviously useful'. Even if it can be established that there is a very good association between the existence of a depression and such increased weather activity, it would be a gain to an understanding of the situation; and it is not merely of academic interest, but also of practical value in issuing fleet forecast and sea bulletins etc. With this end in view, the present study was taken up.

Assuming that there is an increased weather activity in the equatorial region which is specifically associated with the existence of a depression, if we consider a period centred or nearly centred within the period of the existence of the depression, it stands to reason to say that there should be maximum weather activity in the said period in the region concerned. As pointed out by Napier Shaw (1942) the weather activity is best reflected in the cloud cover of the sky. The method of locating the existence of disturbances in the equatorial atmosphere by cloud distributions as recorded by satellites has recently been shown to be very fruitful by J. S. Sawyer (1970) in his paper on 'Large scale disturbance of the equatorial atmosphere'. Therefore, if we compute mean cloudiness in a particular grid during the whole period centred in the mid-period of the life-time of depression, then the mean cloudiness

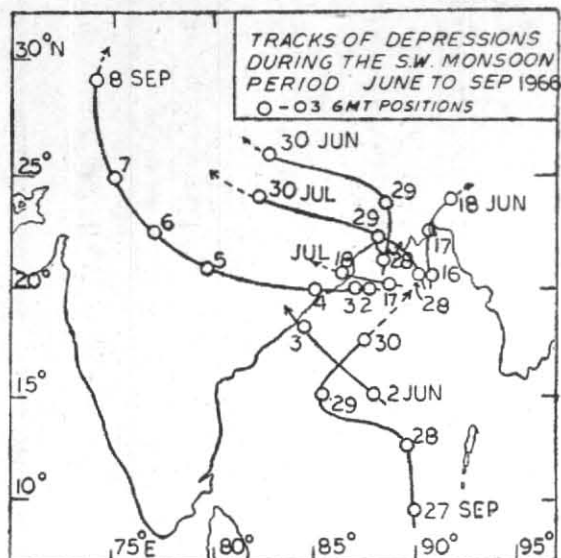


Fig. 1

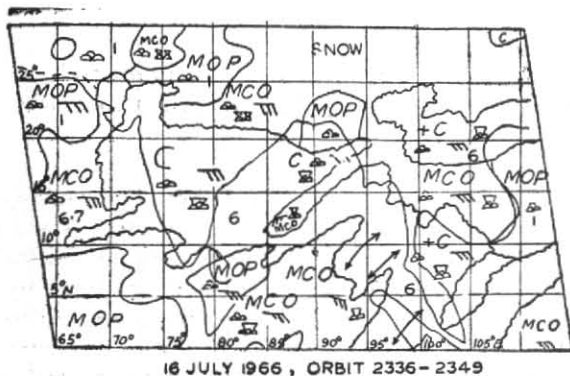


Fig. 2

A typical neph analysis chart for India and neighbouring areas

along with the variation of cloudiness should throw light on the association of depression with the weather activity in that grid.

It is easily seen that the values of mean cloudiness and its variation can be combined in four ways.

(1) The mean is small and the variation is relatively more: In this case apparently the depression has no effect on the cloudiness in that grid.

(2) Mean is small and the variation is large: It is found that during monsoon season when depressions form, the mean cloudiness is generally 50 per cent or more; as such the question of mean cloudiness being small does not arise.

(3) The mean is large and variation is small: in this case apparently the depression has no effect on the cloudiness in the grid.

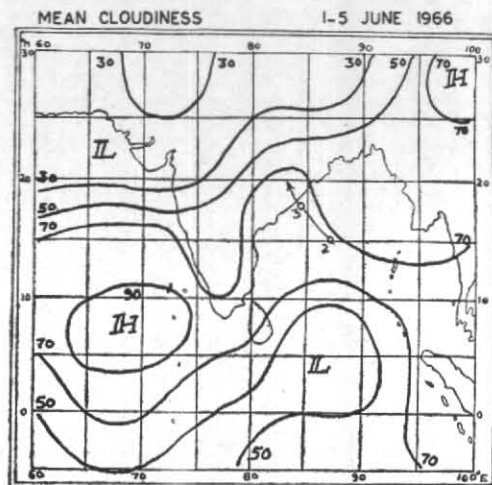


Fig. 3

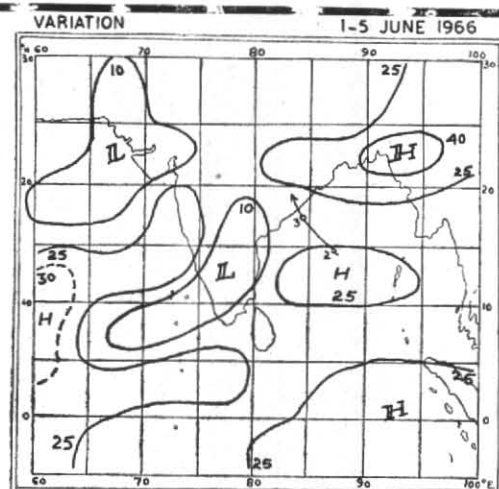


Fig. 4

Track of the depression and the isopleths of mean cloudiness and its variation

(4) The mean is fairly large and the variation is large: In this case the depression can be said to have effect on the cloudiness in the grid.

2. Technique adopted in the study

In the present study the monsoon period of the year 1966 was taken for discussing the influence of monsoon depressions in the Bay of Bengal on the cross equatorial activity or *vice versa*. The year 1966 was taken because the neph analysis charts for the whole season were available for this year only. The neph analysis charts were obtained through the kind courtesy of U.S. Department of Commerce for the period June-September 1966. These neph analysis charts are the cloud pictures covering the entire globe prepared from the observations of ESSA I and TIROS 9 on each day.

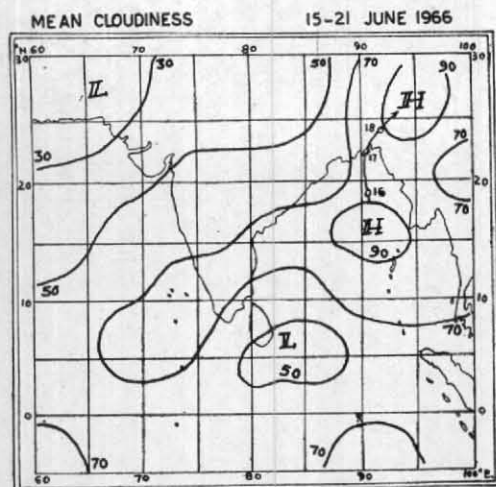


Fig. 5

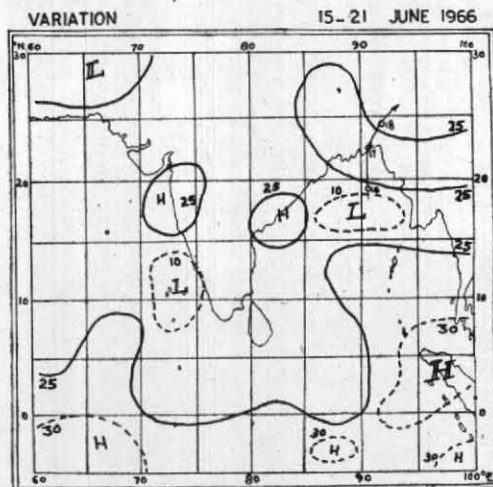


Fig. 6

Track of the depression and the isopleths of mean cloudiness and its variation

Fig. 1 gives the tracks of the depressions during the SW monsoon period June to September 1966. Fig. 2 gives a typical neph analysis chart; in such a chart the cloud cover of the sky in different parts of the world is classified as :

- (1) Open (O)
- (2) Mostly open (MOP)
- (3) Mostly covered (MCO)
- (4) Covered (C)
- (5) C+covered with *Cb* clouds.

The most representative cloud amount for each 5-deg square grid is determined as a numerical value assigned in accordance with the following scheme :

Neph analysis symbol	Approx. cloud cover
Open (O)	10 per cent
Mostly open (MOP)	30 ..
Mostly covered (MCO)	60 ..
Covered C or C+	100 ..

This is the scheme followed by Sadler (1965) also. For the purpose of our study, an area between Lat. 05°S and 30°N and Long. 60°E and 100°E has been divided into 5 degree square grids totalling 56 in number. The mean cloud cover of the sky and the variation in each grid during the period of disturbance has been worked out. The period here means the duration from a day or two prior to the formation of the depression to a day or two after the weakening of the depression. The mean cloud cover has been worked out by assigning the numerical value

of the cloud cover for each day and for each grid in accordance with the scheme pointed out earlier.

3. Discussion

Case 1 — Fig. 3 gives the track of the depression during the period 2 to 4 June 1966. It also gives the isopleths of mean cloud cover during the period June 1 to 5. Fig. 4 gives the isopleths of the variation in cloud cover of the sky in the same period. The isopleths give the percentage of the sky covered. The same holds good for the subsequent figures also.

It is easily seen that the mean cloudiness is lowest in Rajasthan and West Pakistan and highest in the Arabian Sea adjoining Laccadive area. As regards variation, it is lowest in the Indian Peninsula, south coastal portion of the Arabian Sea, north Arabian Sea and adjoining land areas of India and Pakistan. It is highest over East Pakistan, central Bay of Bengal and Indian Ocean to the east of Long. 80°E between Lat. 05°S and 05°N.

Case 2 — Fig. 5 gives the track of the depression and the isopleths of mean cloudiness for the period 15-21 June 1966. Fig. 6 gives the isopleths of variation in the same period.

It is seen that the mean cloudiness is lowest in West Pakistan and adjoining areas; and highest in east central Bay of Bengal with intermediate values in other regions; as regards variation it is lowest over northwest Pakistan and Bay of

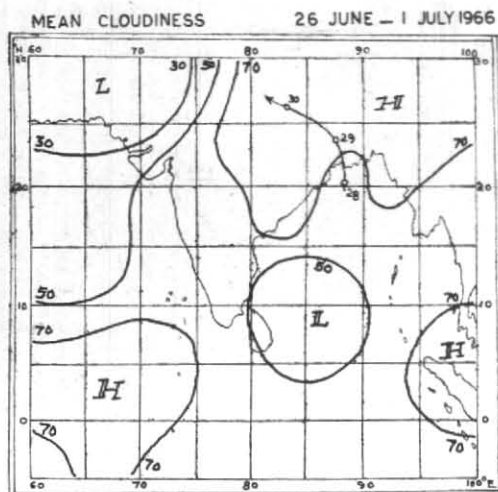


Fig. 7

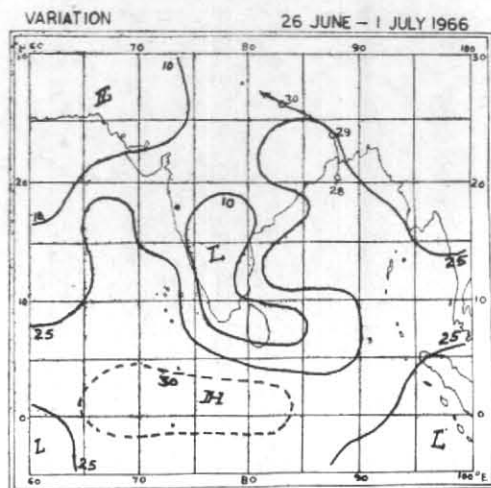


Fig. 8

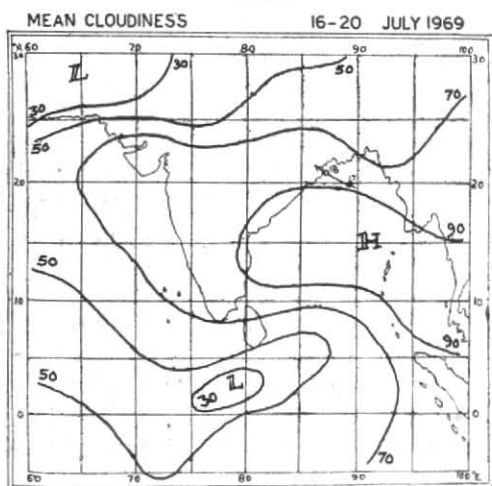


Fig. 9

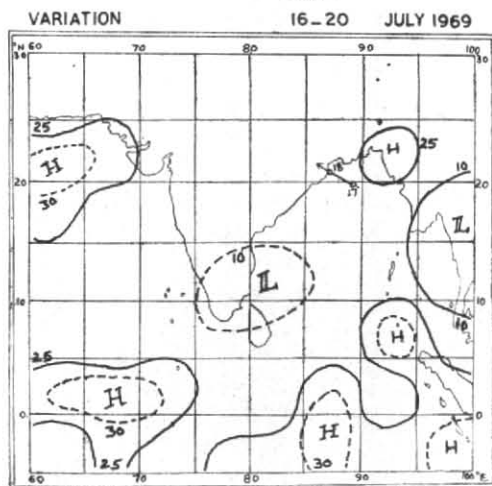


Fig. 10

Tracks of depressions and the isopleths of mean cloudiness and their variations

Benga just north of Lat. 15°N . Maximum variation occurs in the equatorial region.

Case 3—Fig. 7 gives the track of the depression and isopleths of mean cloudiness for the period 26 June to 1 July. Fig. 8 gives the isopleths of variations in the same period. It is seen that the lowest cloudiness is in West Pakistan and adjoining west Rajasthan; and lower amount of cloudiness is in southwest Bay and neighbourhood. The highest amount lies in Madhya Pradesh adjoining Uttar Pradesh, West Bengal, Assam and equatorial regions to the east of Long. 95°E and to the west Long. 70°E with intermediate values lying in between them. As regards variation, the lowest variation is over northeast Arabian sea and adjoining land masses of West Pakistan and Kutch and also over Peninsula and the highest over equatorial regions between Long. 65°E and 82°E .

Case 4—Fig. 9 gives the isopleths of mean cloudiness together with the track of the depression for the period 16 to 20 July. It can be seen that the lowest amount of cloudiness occurs in the equatorial region between Lat. 01°N and 4°N and Long. 75°E and 81°E and in West Pakistan and Rajasthan. The highest amount occurs in the central Bay of Bengal and adjoining Andaman Sea,

As regards variation it is lowest in the extreme southern Peninsula and adjoining Ceylon and Bay and also over Burma and adjoining areas. Highest variation occurs in (1) cells in the equatorial region between Long. 64°E and 72°E , between 85°E and 90°E and also between 95°E and 100°E and (2) west central and northwest Arabian Sea.

Case 5—Fig. 11 gives the isopleths of mean cloudiness together with the track of the depression for the period 2 to 10 September. It is seen

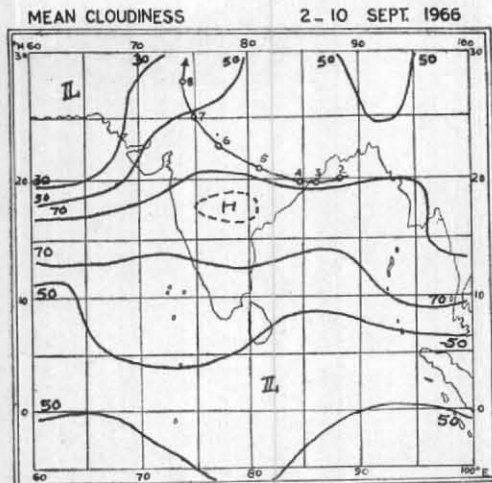


Fig. 11

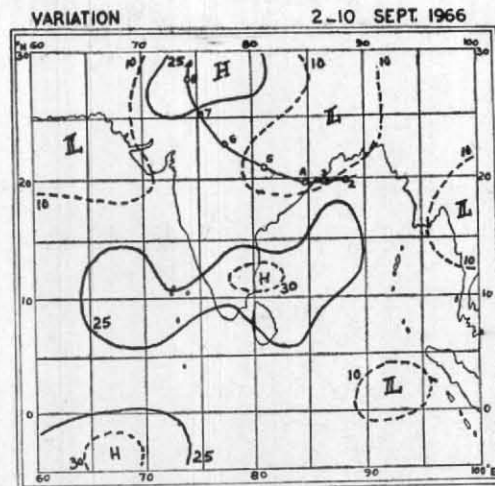


Fig. 12

Track of the depression and isopleths of mean cloudiness and their variations

that the lowest amount of mean cloudiness lies over equatorial region and in north of West Pakistan and neighbourhood and highest amount lies over central Peninsula.

As regards variation Fig. 12 gives the isopleths. The variation is lowest just north of equator between 90°E and 95°E and north Arabian Sea and adjoining West Pakistan and Kutch and also in Madhya Pradesh, Uttar Pradesh, Nepal, Bihar, West Bengal and East Pakistan. The highest variation lies inland close to the Madras coast.

Due to the nonavailability of data discussion of one case of depression—28 to 30 July and another case 27 to 30 September could not be made. The study was therefore necessarily confined to the remaining cases.

To sum up, the foregoing analysis has brought out the following characteristics regarding the cloudiness during spells of monsoon depressions in 1966.

1. The lowest cloud amount occurs in West Pakistan and adjoining Rajasthan. Except in the case of September depression (Case No. 5) the equatorial region as a rule have a fairly large amount of clouds.

2. The highest amount of mean cloudiness occurs in east central Bay of Bengal, Madhya Pradesh and adjoining areas of Uttar Pradesh, West Bengal and Assam, central Bay of Bengal and over central Peninsula.

3. Equatorial regions have intermediate values of clouding—roughly of the order of about 60 per cent of the sky covered.

4. The variation is lowest generally in northwest Pakistan and adjoining Rajasthan and other areas.

5. The variation is highest generally in equatorial region.

It would therefore appear that the formation and existence of monsoon depressions can be associated with the increased weather activity in the equatorial regions as reflected in the fairly large variation together with the large amount of mean cloudiness in the equatorial region. But this may be purely accidental.

Therefore to make sure that this is not merely accidental it was proposed to investigate the cloudiness pattern in non-depression periods also and the following 5-periods were chosen.

- (1A) 6 to 10 June
- (2A) 10 to 13 July
- (3A) 5 to 9 August
- (4A) 11 to 15 August
- (5A) 20 to 24 September

The periods were so chosen as to represent the various phases of monsoon like the period of advancement, withdrawal, strong activity and weak activity.

Case 1A—On 6 June, 1966 the northern limit of monsoon air upto 500 mb runs approximately from Mangalore to Madras and then to Chittagong and Jalpaiguri; on 10 June the northern limit of monsoon runs from Vengurla to Ongole. The monsoon conditions were normal during the period.

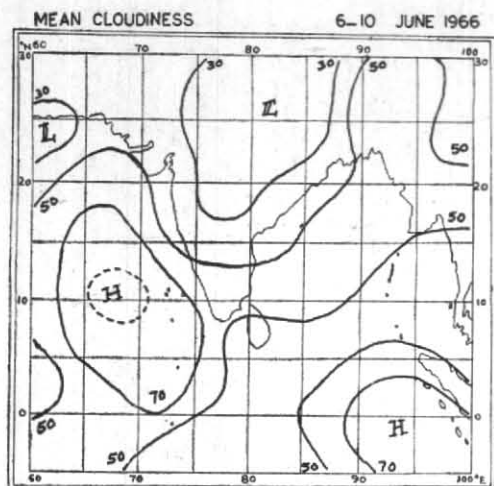


Fig. 13

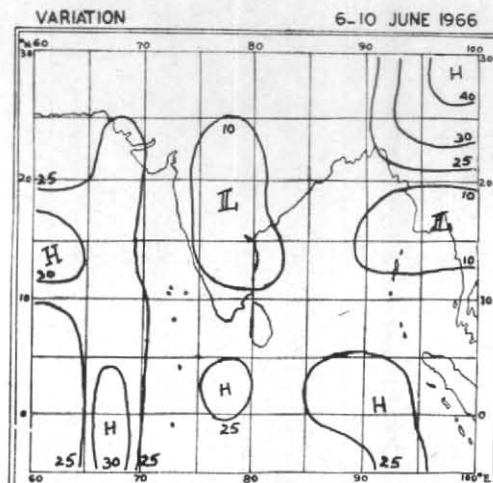


Fig. 14

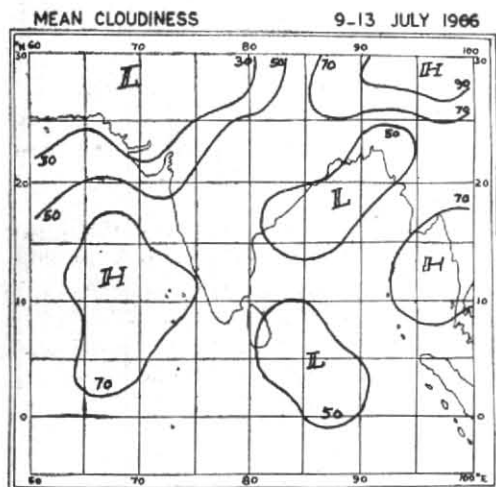


Fig. 15

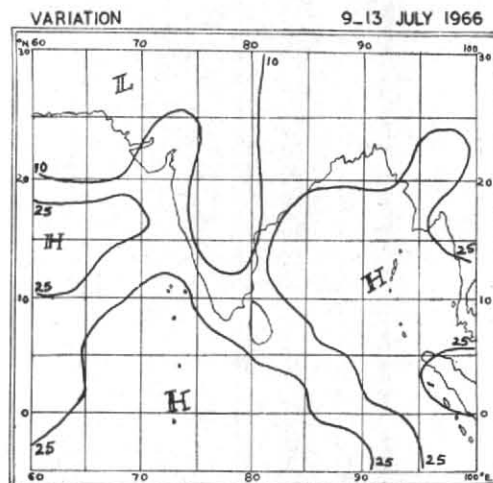


Fig. 16

Isopleth of mean cloudiness and its variation

Fig. 13 gives the isopleths of mean cloudiness. It can be seen that the lowest amount of cloudiness occurs in the north Gujarat State, Uttar Pradesh, Madhya Pradesh, Bihar and adjoining area and Gulf of Oman.

The highest amount of cloudiness occurs in the southeast Arabian Sea and regions south of equator to the east of 88°E.

As regards variation Fig. 14 gives the isopleths of variation. It is found it is lowest over Peninsula and east central Bay. It is highest (a) in three cells across equator and (b) in the East Pakistan, adjoining Burma, Assam and West Bengal.

Case 2A—The period under consideration is 9 to 13 July, when the monsoon conditions were generally normal. Fig 15 gives the isopleths of mean cloudiness during this period. It can be seen that it is lowest in the north Bay and adjoining East Pakistan, Burma and west Central Bay and also across the equator between 80° E and 85°E. It is higher over Laccadives and adjoining east central and southeast Arabian Sea; north Andaman and adjoining Burma with intermediate values elsewhere.

Fig. 16 gives the isopleths of variation. The variation is lowest over India and highest everywhere south of latitude 20° N outside India.

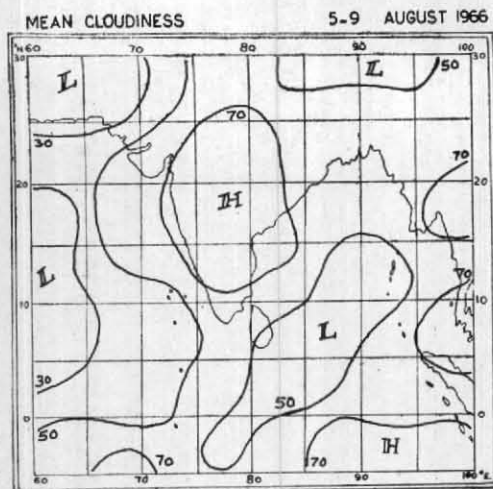


Fig. 17

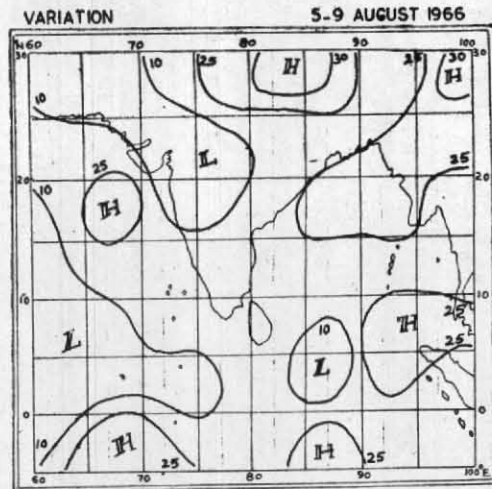


Fig. 18

Isopleth of mean cloudiness and its variation

Case 3A — During this period (August 5 to 9) active monsoon conditions existed in east Uttar Pradesh, Vidarbha and Madhya Pradesh. Fig 17 gives the isopleths of mean cloudiness. It is lowest in (1) central and southwest Bay of Bengal, (2) West Pakistan and adjoining areas and (3) area between Lat. 5° N and 20° N to the west of Long. 65° E. It is highest over Peninsular India and Madhya Pradesh.

Fig. 18 gives the isopleths of variation during the same period. It is lowest over Maharashtra, Gujarat, Rajasthan and adjoining northwest Pakistan and (2) west central Bay, southwest Arabian Sea and adjoining equatorial region north of equator. It is highest with 2 cells south of equator and extreme northeast Assam and Nepal.

Case 4A — In this period (11 to 15 August) active monsoon conditions existed over Uttar Pradesh and West Bengal and east Madhya Pradesh and Punjab. Fig. 19 gives the isopleths of mean cloudiness during this period. It is lowest (1) in West Pakistan (2) Laccadives area and adjoining southeast Arabian Sea, and highest in (a) equatorial region to the south of equator, (b) equatorial region to the north of equator to the east of 90°E and (c) Assam and adjoining Burma.

Fig. 20 gives the isopleths of variation during the period. It is lowest in (1) west central and adjoining southwest Bay, (2) east Arabian Sea and (3) Extreme southeast equatorial region to the south of equator. It is highest over equatorial region to the west of Long. 80° E.

Case 5A — In the period 20 to 24 September monsoon was withdrawing from East Pakistan, Gujarat State, west Uttar Pradesh and west Madhya Pradesh.

Fig. 21 gives the isopleths of mean cloudiness during this period. It is lowest (1) over West Pakistan and adjoining Konkan and Gujarat State, (2) in area bounded by Lat. 15° N and equator to the west of Long. 60° E. It is highest over West Bengal and adjoining Bihar, East Pakistan and adjoining Burma.

Fig. 22 gives the isopleths of variation during this period. It is lowest over central Arabian Sea, Madras coast and adjoining Bay, north Gujarat region adjoining West Pakistan and Afghanistan. The variation is highest over Andaman Sea and also north equatorial region to the east of Long. 70° E.

From the foregoing analysis it is seen that (1) The lowest clouding occurs in West Pakistan and adjoining areas as is to be expected (2) The highest amount has no preferred region and occurs at places depending upon activity of the monsoon; (3) Equatorial region has as usual the intermediate values of cloudiness; (4) The lowest variation has no preferred region; and (5) Equatorial region generally exhibits large variations.

Thus it is seen that there is a large variation in the cloud cover in the equatorial region together with large mean values of cloudiness irrespective of the formation of depression in the Bay of Bengal.

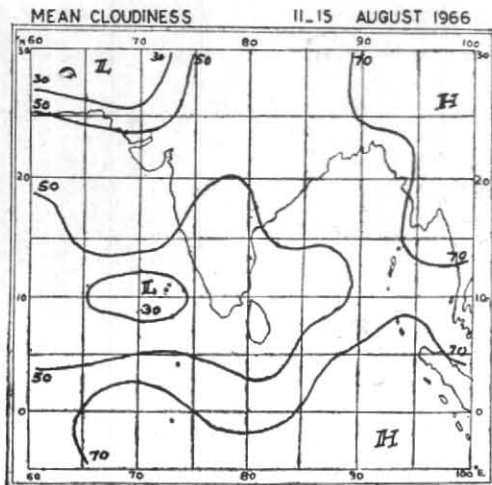


Fig. 19

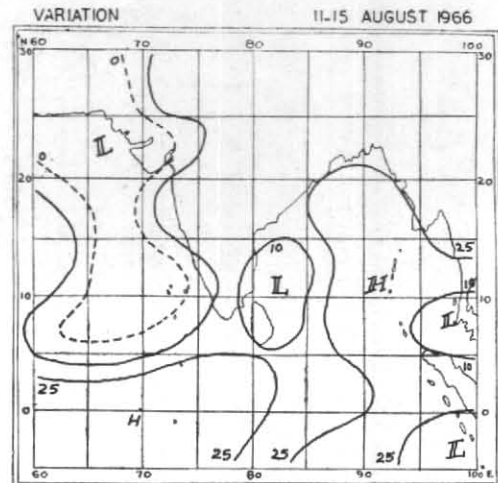


Fig. 20

Isopleth of mean cloudiness and its variation

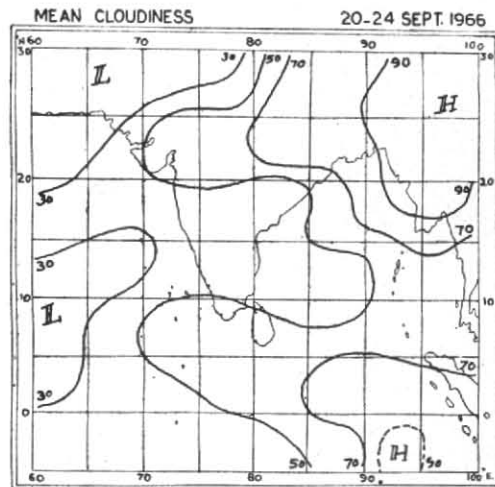


Fig. 21

Isopleth of mean cloudiness

4. Conclusion

The fact that there is large variation in the cloud cover in the equatorial region irrespective of the formation of a depression in Bay of Bengal in higher latitudes seems to imply a poor association between equatorial activity and movement or formation of depressions. That is to say, no inference of forecasting value can conceivably be drawn regarding the formation or the movement of depressions by analysing the cross-equatorial activity.

The authors are aware of the inherent limitation of a study of this type. It may be said, for instance, that the cloud cover in a region during the particular period of the pass of the satellite over the region considered, may not be representative of the cloud cover of the entire day which is likely to undergo diurnal variation. It may also be said that only one year's data was used in this present study and this conclusion may require modification. But it is felt that the approach presented in this paper is in the right direction because the conclusion in the earlier literature before satellite

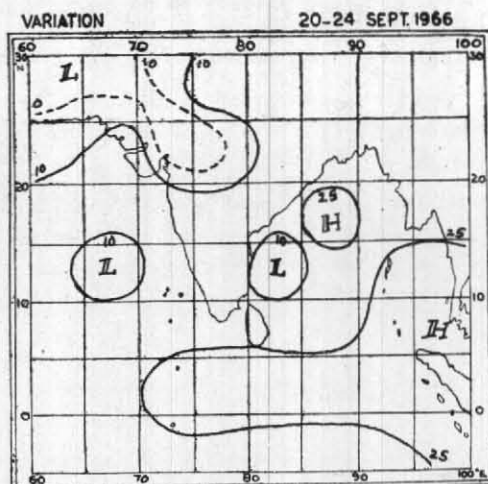


Fig. 22

Isopleths of variation of mean cloudiness

cloud pictures were available, relating to cross-equatorial activity and depressions in the Bay of Bengal were naturally handicapped by paucity of data over wide areas. Satellite pictures precisely fill this gap as cloud cover is the most representative index of weather activity in a particular place. With the increasing availability of satellite

data it is proposed to study this problem in greater depth.

Acknowledgement

We are grateful to Shri M. Rama Rao, Director, Regional Meteorological Centre, Bombay for valuable suggestion and encouragement in this study.

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DISCUSSION

(Presented by G. S. Ganesan)

SHRI J. SHUKLA remarked that if the aim is to find cloudiness in relation to a depression for the purpose of composing, the grid of averaging must be made moving along with the centre of the depression.

SHRI H. S. BEDI : How did you work out deviations within the depression period ?

SHRI G.S. GANESAN : In the usual way, by finding the variance and its square root for the period under consideration.

SHRI BEDI : You have mentioned about the school of thought according to which there is activity over equatorial region at the time of formation of a depression in the Bay. Could you elucidate ?

SHRI GANESAN : The school of thought, I referred to, associated the increased weather activity in the equatorial region with existence or strengthening of a depression in the Bay, *e.g.*, Malurkar's hypothesis of pulses moving northwards and feeding the Bay depressions.

DR. C. RAMASWAMY : From the few studies that I have made, I find it difficult to draw any reliable conclusion about active or weak monsoon conditions in the north Bay of Bengal in relation to cloudiness on either side of the equator. More of such cases have to be studied.

DR. K.R. SAHA : Did you find any kind of organisation in cloud distribution in the equatorial Indian Ocean ?

SHRI GANESAN : Except for what has been given in the summary of results, we could detect no other patterns.

SHRI P. JAGANNATHAN : What is the mean and variation of cloudiness associated with the different stages of the depression ?

SHRI GANESAN : The cloudiness for each grid was worked out for the entire period of the depression. The aim was to see if increased weather activity could be detected in regions apparently far from the depression.