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A preliminary study of cloud clusters in the near-equatorial regions of south Indian Ocean during southwest monsoon season

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ABSTRACT. The occurrence, characteristics and movement of cloud clusters within the latitude belt equator to 15°S over the Indian Ocean during the period 1 May to 31 July 1973 have been studied in this paper, utilizing the daytime visible channel satellite cloud imagery received from NOAA-2 spacecraft. It is found that cloud clusters mainly occur east of latitude 60°E and that their number generally increases from west to east. They have the maximum frequency of occurrence in the latitude belt equator to 5°S. The cloud clusters are predominantly amorphous in shape, indicating that mostly weak low pressure systems occur in this region. Their life period ranges upto 8 days but most of them have a life period of less than 2 days. A majority of those having a life period of 2 days or more show a westward or northwestward movement, with a tendency to recurve northeastward subsequently, as they approach the equator.

1. Introduction

While discussing southwest monsoon circulation, Malurkar (1960) postulated that in the field of trades over a wide stretch of ocean, shallow low pressure areas (which he called monsoon pulses) move in a westward direction and cross over to the other side of the equator to form the fresh monsoon air either to strengthen the monsoon there or to feed a westward moving tropical depression. In the northern summer, monsoon pulses crossing the equator from the southern hemisphere between longitudes 80°E and 90°E would strengthen the monsoon in the Bay of Bengal. Similarly if the monsoon pulses crossed over into the Arabian Sea, they would strengthen the monsoon over the Arabian Sea. Findlater (1969) has shown that the bulk transport of air from southern to northern hemisphere during the northern summer occurs in a relatively narrow belt in the lower troposphere over the western south Indian Ocean. However, the physical processes in operation in this season ove rmost of the south Indian Ocean are still not well understood, mainly because of the absence of any systematic meteorological observations over this region.

The cloud formation in the equatorial regions of tropics is mainly of cluster type. A study of these cloud clusters can throw some light on the atmospheric processes taking place in this region, which in turn influence the southwest monsoon circulation. With this end in view the authors have studied the cloud clusters occurring in the southwest monsoon season over the near equatorial region of the south Indian Ocean, and the results are presented in this paper. Cloud clusters which occurred during the period May to July 1973 over the Indian Ocean between equator and latitude 15°S have been considered in this study. This was the period of Indo-Soviet Monsoon Experiment (ISMEX-73) when special efforts were made to collect more meteorological data from Indian Ocean.

2. Data used and method of analysis

The day time cloud imagery, received from U.S. meteorological satellite NOAA-2 in the visible channel, has been utilized in this study to identify and track the cloud clusters. The authors have found that cloud clusters in this region varied widely in size and shape. In some cases they

TABLE 1

Frequency distribution of different shapes of cloud clusters occurring in the period 1 May to 31 July 1973

Latitude belt	Amorphous	Elongated	Quasi-circular	Vortical	Total
Equator—5°S	170	1	9	0	180
5°—10°S	105	3	6	1	115
10°—15°S	76	1	1	2	80
Total	351	5	16	3	375

occupied an area as large as 10,00,000 square kilometres. Following Barrett (1971) four types of cloud clusters namely (*i*) amorphous, (*ii*) elongated (band type), (*iii*) quasi-circular and (*iv*) vortical were distinguished. Amorphous and elongated nephmasses have been found to be generally related to a non-circulating disturbance. A quasi-circular cloud organisation is related to a weak cyclonic disturbance. Vortical nephmasses invariably indicate a cyclonic disturbance. A minimum area of one-half of a 5-degree latitude square has been chosen for identifying an individual cloud cluster. This minimum area chosen roughly approximates to the area of the smallest synoptic scale disturbances. The frequency distribution of cloud clusters in the three latitude belts, *viz.*, equator to 5°S, 5°S to 10°S, and 10°S to 15°S, which occurred during the months of May, June and July in the year 1973 in south Indian Ocean, has been analysed. The occurrence of the four types of cloud clusters according to their shape has also been studied. Well identified nephmasses which persisted for two days or more have been tracked. These characteristics are described in the following paragraphs.

3. Frequency

The longitude-wise distribution of cloud clusters in the three latitude belts for May, June and July 1973 is shown in Fig. 1. In May a comparable number of clusters occurred in the two belts, *viz.*, equator to 5°S, and 5°S to 10°S. Their number is mush less in the belt 10°S to 15°S. The maximum frequency occurs in the region east of 90°E with a secondary maximum between 80°E and 85°E.

In June an overall increase is noticed in the number of clusters over the area between longitudes 60°E and 90°E. A significant increase is noticed in the occurrence of clusters in the belt 10°S to 15°S west of 75°E. The area of maximum number of clusters is almost the same, *i.e.*, east of 95°E. In June the number of cloud clusters east of longitude 60°E is significantly higher in the belt equator to 5°S as compared to the other two latitude belts. The peak frequency is again east of 95°E though the secondary maximum between 70°E to 75°E is also prominent.

In July the occurrence of cloud clusters is almost wholly confined to the east of 60°E in all the three latitude belts. The belt equator to 5°S records more number of cloud clusters compared to other two belts. The number of clusters has substantially decreased in the belt 10°S to 15°S as compared to May and June. The area lying between longitudes 70°E to 90°E records maximum number of clusters between equator and 10°S.

It is to be noted that within the three latitude belts, the maximum number of clusters occur closest to the equator, *i.e.*, between latitudes 0° and 5°S. This is seen from the last column of Table 1. In this belt, the number of cloud clusters increases from May to June, and again decreases in July. This maximum in the frequency of cloud clusters between equator and latitude 5°S has occurred during the onset phase of southwest monsoon over India. The cloud clusters have the lowest frequency in 10°-15°S belt, but here also they show a similar behaviour. They increase from May to June and then decrease sharply, becoming almost insignificant in July. However, the occurrence of cloud clusters has a different pattern in

the belt 5°-10°S, where the cluster frequency is the highest in May, then decreasing uniformly in June and subsequently increasing in July.

The monthwise distribution of all the cloud clusters in the region equator to 15°S is shown in Fig. 2. The frequency distribution has similar characteristics in all the three months. The cluster frequencies have two maxima around longitudes 72°E and 83°E. Also, the frequencies increase eastwards of 92°E in all the three months, and reach the highest values in May and June around 100°E (the eastern edge of the region considered).

Two points emerge from the foregoing discussions: (*i*) the number of cloud clusters generally increased from west to east in the south Indian Ocean in all the three months and (*ii*) the number of clusters occurring west of 60°E decreased steadily from May to July. The occurrence of cloud clusters over this region became nearly insignificant in July. Miller and Jefferies (1967) have derived the mean monthly surface temperature distribution over the Indian Ocean from the data collected during the International Indian Ocean Expedition (1963-64). Between equator and latitude 10°S, the eastern Indian Ocean is warmer than the western Indian Ocean throughout the year. The sea surface temperature difference widens in the summer season because of the spreading of cold waters eastward due to upwelling along the Somalia coast. Thus the eastern south Indian Ocean becomes distinctly warmer than the western part, hence more favourable for the cloud formation. Considerable reduction in the number of clusters west of 60°E in July as revealed in this study appears to be due to the spreading of cold waters of Somalia current which inhibits cloud development.

4. Shape

The frequency distribution of different shapes of cloud clusters in the three latitude belts is shown in Table 1. It is seen that the cloud clusters over whole of the region are predominantly amorphous in nature. Out of 375 cloud clusters identified, 93·6 per cent were amorphous, 4·3 per cent were quasi-circular, 1·3 per cent were elongated, and 0·8 per cent were vortical type. The dominance of amorphous cloud clusters indicates that weak tropical disturbances are common over whole of this region. This is also supported by the fact that only one well defined vortex occurred during the whole of the period and that too in the very beginning of May. This vortex was observed for 3 days within the region of our study and was moving poleward during the period. Subsequently it moved away southward of the region.

5. Movement of cloud clusters

5.1. During the period 1 May to 31 July 1973, 12 nephmasses which could be tracked for 2 days or more, were identified. The average life of these nephmasses was between 3 and 4 days, while the maximum life period observed was 8 days. The other nephmasses could not be tracked because of (*i*) their short life span, and (*ii*) rapid change in cloud pattern with time. Out of these 12 nephmasses, 7 showed westward movement, 2 moved towards northwest and one each towards northeast, southeast and south. Three of the westward moving nephmasses showed a tendency of recurving eastward in the later part of their life cycle when they approached the equator. Three individual nephmasses out of the 12 mentioned above, persisted for four days or more and are described below.

5.2. *Case I (12 to 19 May 1973)*

On May 12th, a cloud cluster was seen near 5°S, 94°E (Fig. 3). This nephmass occupied an area greater than 5-degree latitude square. On 13th and 14th the nephmass moved westward. On 15th the nephmass had a more spread out appearance along with broken cloudiness; its cumulus cloud lines indicated a possible weak circulation in the low level wind field suggesting the existence of a low pressure area there. On 16th it again showed development, while continuing its westward movement. On 17th it lay near 7°S, 80°E. On this day another nephmass formed *in situ* around 10°S, 95°E. On the next day, the second nephmass moved westward and merged with the first nephmass. On 19th the low pressure area associated with the cloudiness lay near 3°S, 83°E. This conclusion is also supported by the available wind observations. Subsequently the low pressure area weakened and the nephmass got disintegrated on 20th. Moderate cross-equatorial flow is seen to occur in the Bay of Bengal on this day.

5.3. *Case II (30 June to 4 July 1973)*

On 30 June, convective clouds were seen south of 5°S and east of 80°E (Fig. 4). On 1 July these

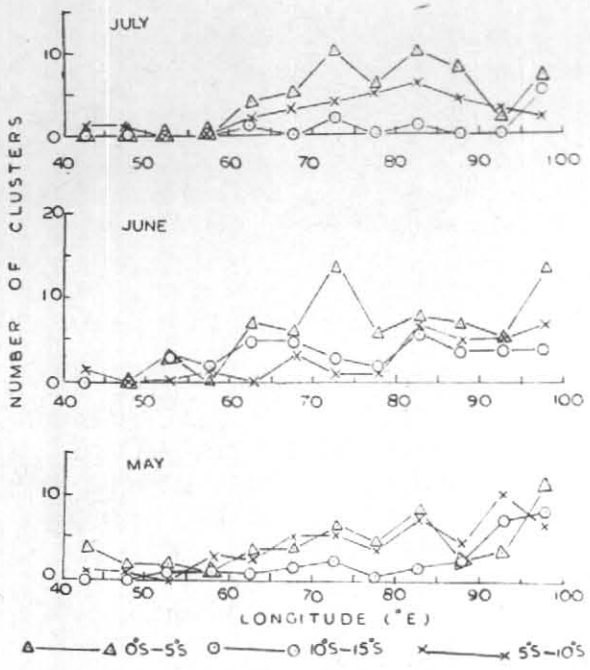

Fig. 1. Distribution of cloud clusters for May, June and July 1973

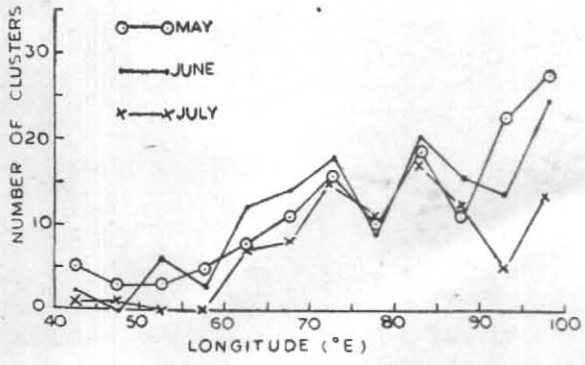

Fig. 2. Monthwise distribution of cloud clusters

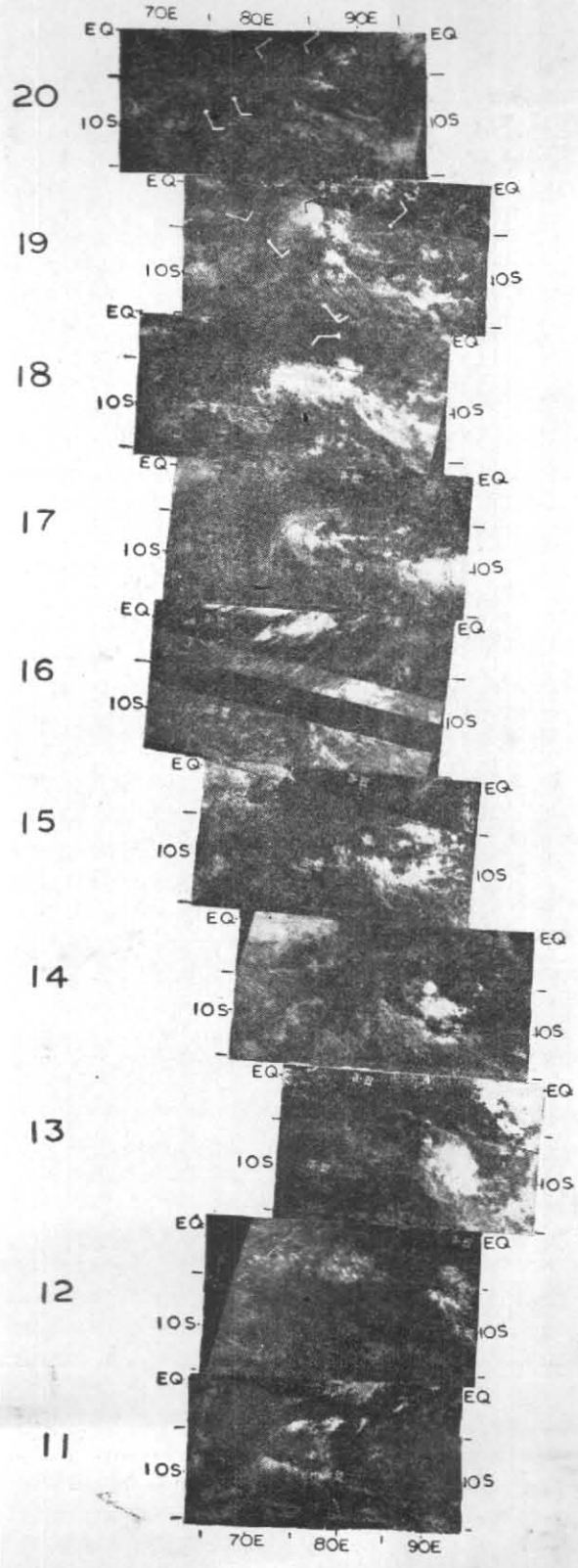

Fig. 3. Successive daily satellite photographs, 11-20 May 1973 (Date of each picture is shown on its left)

clouds formed a cluster near 5°S, 80°E. On 2nd the clusters did not show any significant movement. On 3rd it moved eastward and lay near 5°S, 85°E. On 4th it is seen as cloud cluster near 4°S between 85°E and 90°E. Subsequently, the cluster got disintegrated.

5.4. *Case III (8 to 11 July 1973)*

On 7 July, convective clouds were seen around 7°S between longitudes 82°E and 70°E (Fig. 5). On 8 July the clouds formed a nephmass nearly circular in shape with its centre at 4°S, 72°E. By 9th the nephmass moved eastward and was located around 4°S, 77°E. The nephmass increased in size also. On 10th the nephmass appeared more elongated, with its major portion lying between 5°S to 10°S and 70°E to 80°E. On 11th the nephmass was seen as a band of clouds extending from 80°E to 90°E near latitude 5°S. The cloudiness disappeared on 12 July 1973.

5.5. There are three possible explanations of predominantly westward movement of the nephmasses. One is that they may be associated with the formation of shallow low pressure areas as postulated by Malurkar (1958). The second possibility is that they may be associated with the waves in the easterlies. The third possibility is that these nephmasses are simply advected westward by the mean flow. The correct interpretation can only be obtained if adequate meteorological data are available from this region. However the authors have found that the inverted 'V' cloud pattern, associated with waves in easterlies (Frank 1968), was not observed in any of the cloud clusters in this study. Further, the clouds showed both weakening and development during their life periods. They were thus not simply advected by the mean flow. It may, therefore, be concluded that these cloudiness are associated with the formation of weak low level circulations and/or weak low pressure areas south of equator. Wind observations wherever available provide considerable evidence in the favour of this conclusion. These low pressure areas initially move towards west and weaken as they come close to equator. The movement of nephmasses initially westwards and then towards northeast in the eastern south Indian Ocean also supports the existence of South Equatorial Trough (SET) or a southern hemispherical near equatorial trough. If the existence of SET is more firmly established, then these shallow low pressure areas south of equator may be compared with the monsoon depression moving along the monsoon trough but with much less intensity.

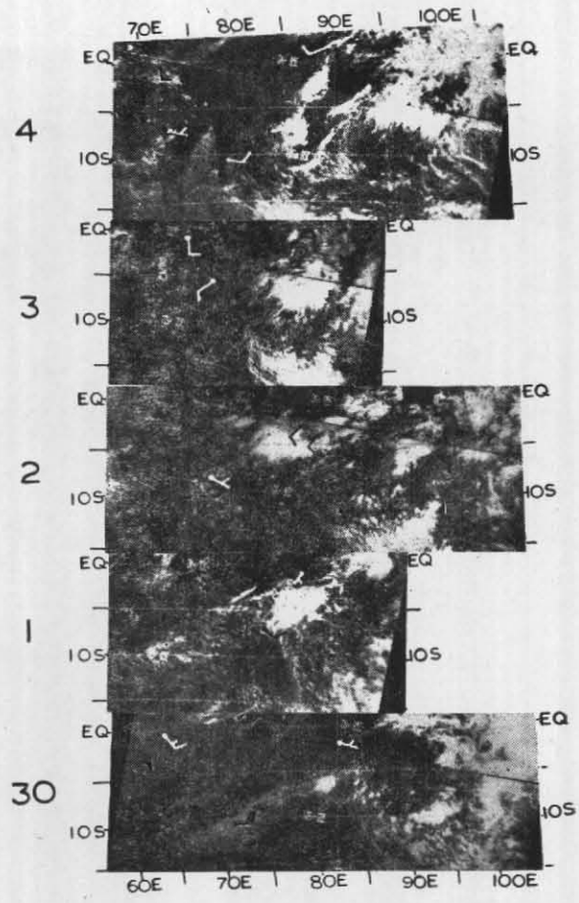

Fig. 4. Successive daily satellite photographs, 30 June to 4 July 1973 (Date of each picture is shown on its left)

5.6. It may be seen that most of the cloud clusters identified in this study had a life period of less than 2 days. It is possible that many clusters with life periods of less than 1 day, which did not occur at the time of satellite picture, would have been missed altogether. In order to track such nephmasses satisfactorily, more frequent satellite cloud pictures are needed. It is hoped that in the coming years nearly continuous cloud imagery over the Indian Ocean will be available from the projected geosynchronous meteorological satellites. Such cloud imagery, together with surface and upper air observations over the ocean which will be available during the Monsoon Experiment (MONEX) 1979, can improve our understanding of the dynamics of the southwest monsoon considerably.

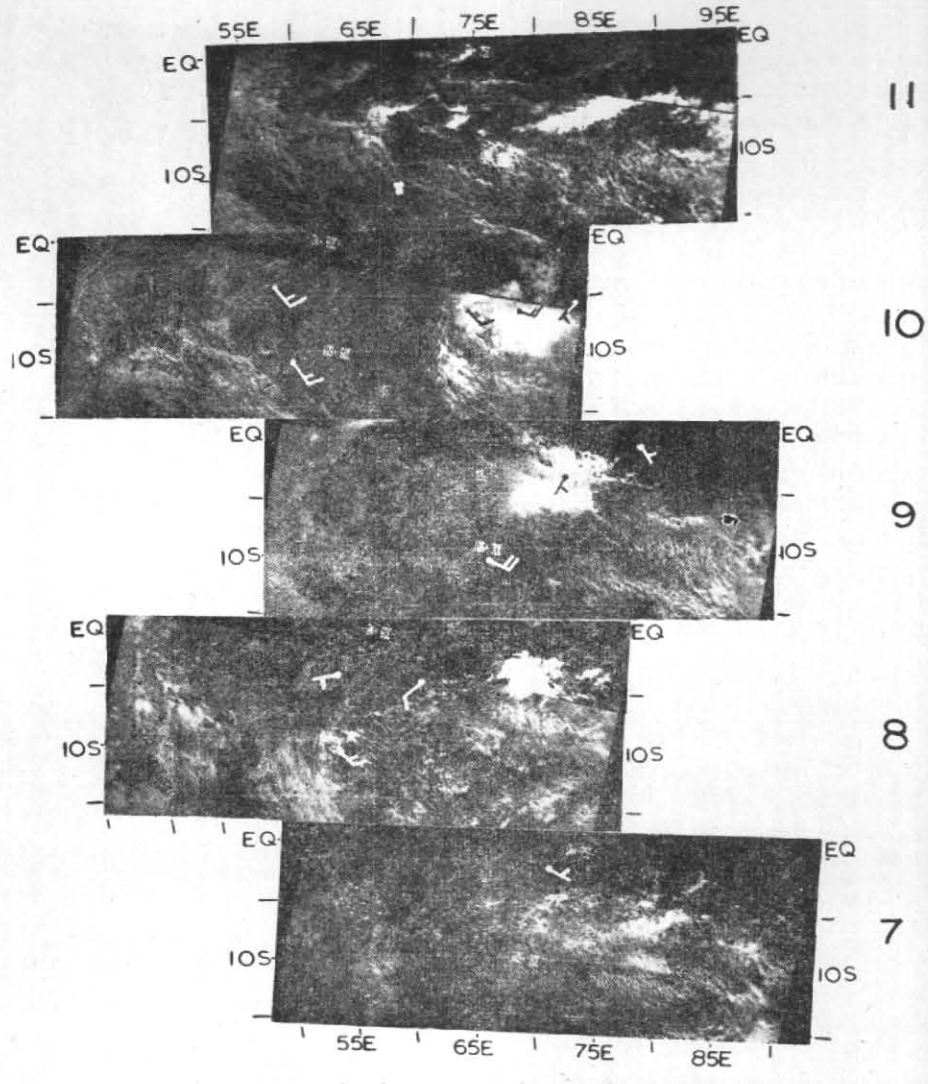

Fig. 5. Successive daily satellite photographs, 7-11 July 1973
(Date of each picture is shown on its right)

6. Conclusions

(*i*) During May to July, the period of onset and establishment of southwest monsoon over India, the number of cloud clusters increases from west to east in the south Indian Ocean. The maximum cloud clusters occur in the belt 0°-5°S in the eastern south Indian Ocean. The western south Indian Ocean is relatively cloud free.

(*ii*) The cloud clusters are predominantly amorphous in shape, indicating that mostly weak tropical systems develop south of the equator in the eastern south Indian Ocean in this season. A majority of them move towards west or northwest and subsequently show a tendency to recurve northeastwards at low latitudes.

(*iii*) Most of the cloud clusters have a life period of less than 2 days, possibly one day or less.

(*iv*) While the bulk of transport of southern hemispheric air occurs in the lower levels of troposphere over the extreme western part of south Indian Ocean, a part of the total transport of southern hemispheric air may also occur in association with the westward moving weak low pressure systems in the near equatorial region, the rest of the Indian Ocean.

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DISCUSSION

(Paper presented by D .K. Mishra)

G. C. ASNANI : (1) It is significant that cloud clusters move roughly along the south-equatorial trough, suggesting that there are easterly waves along this trough.

(2) It is noteworthy that cloud clusters have a tendency to dissolve when they approach the equator. This is consistent with the idea given by Pisharoty and Asnani (1964) that air approaching the equator in the lower levels has a tendency to subside.

J. FINDLATER : This is an important paper on forecasting rain at the coast of eastern Africa where clusters approaching the coast often disappear very quickly.

AUTHOR : Thanks.

K.R. SAHA : To see what happens to cloud clusters when they approach the equator from either hemisphere, it is suggested that the area of study may be extended to cover that between 10°N and 10°S.

AUTHOR : Thanks. We propose to cover this area in the next part of our study.