Mausam, (1980), **31**, 3, 403-408

551.576.2(967)

The large-scale cloud patterns over the Indian ocean during June 1967

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(*Received* 23 *August* 1977)

ABSTRACT. The satellite cloud imagery over Indian Ocean for the month of June 1967 showed extensive cloud bands, thousands of kilometres in length, originating in south Indian Ocean. These cloud bands were aligned along the southeasterly trades, and curved sharply near the axis of southern hemispheric equatorial trough between Lat. 3 deg. S and 10 deg. S. The small scale cloud features, aligned to the low level wind field, showed prominently this turning across the axis of the trough and the equator-crossing of the deflected southwesterly current. There were indications of trade wind inversion in the southeasterlies in the form of cellular cloud patterns. The deuected southwesterly current and convective cloud clusters whose activity was maximum in the sea area north of the equator.

1. Introduction

The satellite picture composites of the Indian Ocean for June 1967 showed an interesting feature in large-scale cloud organisation. Extensive cloud bands were seen originating in the south Indian Ocean, extending thousands of kilometres towards northwest upto Africa coast and then curving sharply towards Indian Peninsula. In this note the authors have attempted to discuss the characteristics of these extensive cloud bands, and the associated features in wind field and the activity of southwest monsoon over the country.

2. Data set

For this study the cloud imagery received from TV camera on-board the U.S. weather satellite ESSA-5 in the form of computer-processed digitized picture composites in mercator projection were utilized. The satellite pictures for the month of June were examined for identifying some singular characteristics in the organisation and behaviour of large scale cloud systems which occurred over the Indian Ocean on both sides of the equator.

During the monsoon season of 1967, the southwest monsoon had advanced over the whole of the Arabian Sea, the Peninsula, central and northeast India and the Bay of Bengal by 19 June. Consequently the cloud systems in the Indian Ocean and the Indian seas during the second half of June were examined in detail. An attempt was made to compare the interpretations derived from satellite pictures with inferences based on synoptic data. This posed a formidable problem because very scanty conventional data are available over the Indian Ocean. The results of these investigations are described below.

3. Large scale cloud features observed in satellite pictures

3.1. During the first week of June 1967, cloud systems in the ocean area north of latitude 20 deg. S and in the Arabian Sea were mostly amorphous type convective cloud clusters. They showed restricted convection and cellular pattern between 20 deg. S and 10 deg. S, and had more intense convection with embedded cumulonimbi north of 10 deg. S. The cloud clusters started organising into elongated, band-like structure on 5 June in the south Arabian Sea south of 10 deg. N, west of 70 deg. E.

3.2. The band structure organised further and on 6th and 7th the cloud clusters north of the equator intensified, while getting aligned in west-east direction, and more of dense convective clusters appeared in the southern hemisphere to form a broken band. On 8 June the cloud band extended from Somalia Coast of Africa to Kerala coast and beyond upto southwest Bay of Bengal, without a break; its extension over Kerala coast marked the revival of

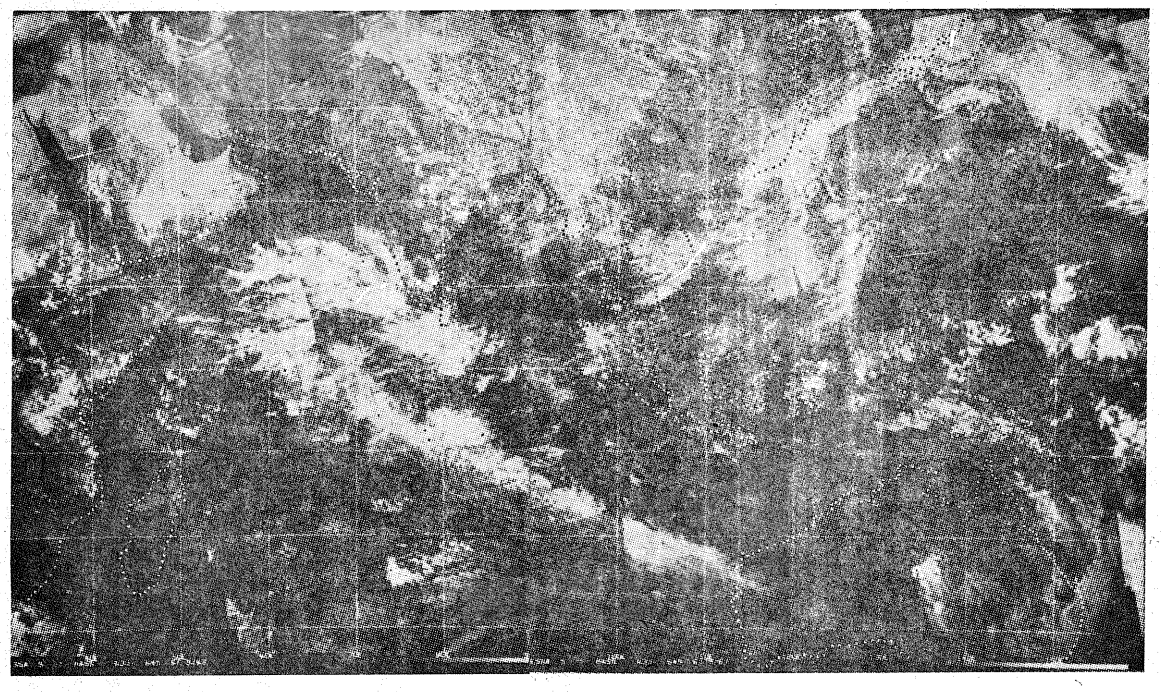

Fig. 1. ESSA-5 visible channel Digitized Composite TV picture of 9 June 1967 showing continuous band of clouds extending from southeast Indian Ocean upto east Africa coast and then to southwest Bay of Bengal

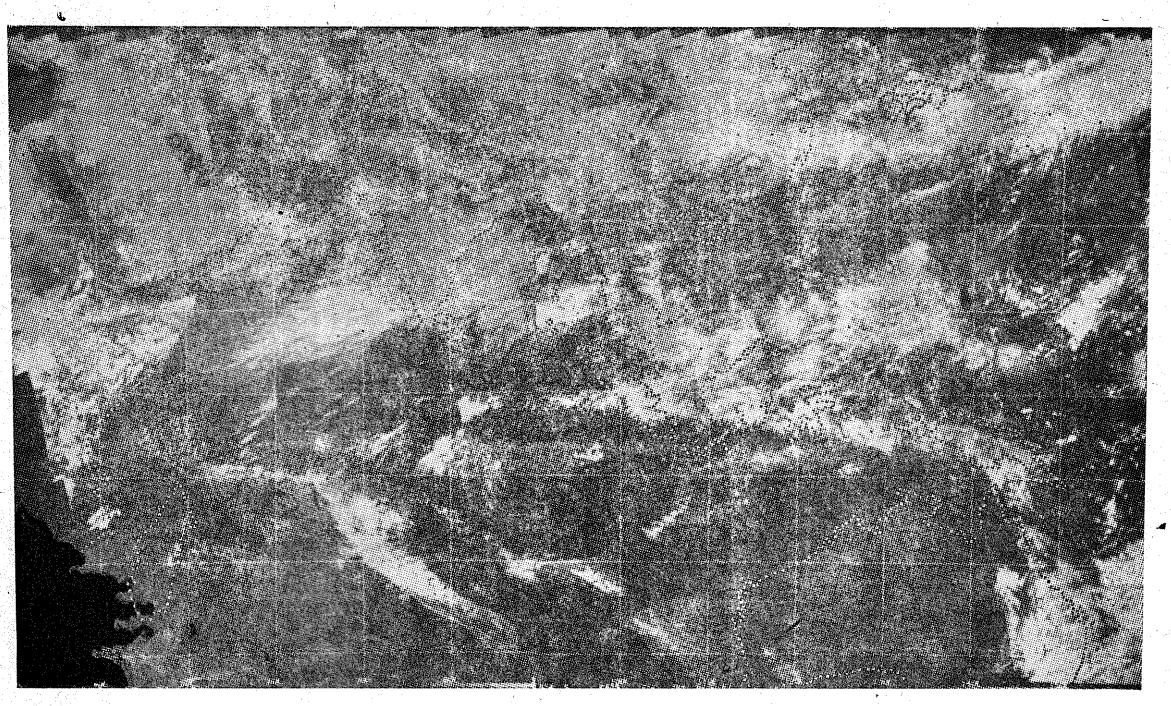

Fig. 2. ESSA-5 visible channel Digitized Composite TV picture of 20 June 1967 showing a broad band of extensive dense overcast clouds from east Africa coast upto the northwest Pacific Ocean

Fig. 3. ESSA-5 visible channel Digitized Composite TV picture of 23 June 1967 showing continuous cloud band in the south Indian Ocean turning eastward off Africa coast and further extending upto northwest Pacific Ocean

monsoon activity over Kerala. Also a continuous band developed south of the equator. This features was most prominent on the 9th (Fig. 1), when a massive band of 3 deg.-4 deg. width extended from 25 deg. S 116 deg. E to 5 deg. N 61 deg. E, broadly aligned from SE to NW. Further, it turned and extended towards east and southeast upto 2 deg. N 83 deg. E. The band north of the equator extended upto latitude 17 deg. N in the Arabian Sea and was associated with more intense deep layer convection and had existed for the previous 3 days with small changes in overall shape. This cloud organisation dissipated after 13 June. However, deep convective cloud clusters persisted in south Arabian Sea, over the Peninsula, and in the central Bay of Bengal.

3.3. The convective clusters in the Arabian Sea south of 20 deg.N progressively formed into a broad band aligned in SW-NE direction from 17 June onwards. The satellite picture of 20 June (Fig. 2) shows an extensive, dense overcast cloud mass in the form of a broad band extending from 2.5 deg. N, 62.5 deg. E northeastward across the Arabian Sea and the Peninsula into the Bay of Bengal. Further east, cloud clusters aligned into a broad band between 10 deg. N and 5 deg. S, and extended into northwest Pacific Ocean. Over land the overcast clouds extended upto about 23 deg. N and broken clouds were seen further northward. On this day the monsoon had advanced upto Lat. 23 deg. N in northeast Arabian Sea and its northern limit ran through Dwarka, Deesa, Hoshangabad, Ambikapur and Patna. In association with this extensive cloud feature, active monsoon conditions occurred over coastal Mysore, Konkan and Saurashtra. Also widespread or fairly widespread rainfall occurred over the rest of the Peninsula. However, it is significant to note that even under such active monsoon conditions the overcast monsoon cloudiness was confined to the northern hemisphere north of Lat. 5 deg. N. It is significant that the region around the equator south of about 5 deg. N was markedly cloud free over the whole of the Indian Ocean. In the southern hemisphere, there were generally narrow cumulus lines in southwest Indian Ocean west of Long. 65 deg. E and scattered convective or multilayer clouds further east. The multilayered cloud band from 29 deg.S 87 deg. E, to 12 deg. S 70 deg. E had resulted from an extratropical system. There was an indication of cloudmasses in southern hemisphere aligning into small broken bands.

3.4. Subsequently, the cloud organisation south of the equator developed into a continuous band. On 23 June the band reached its peak

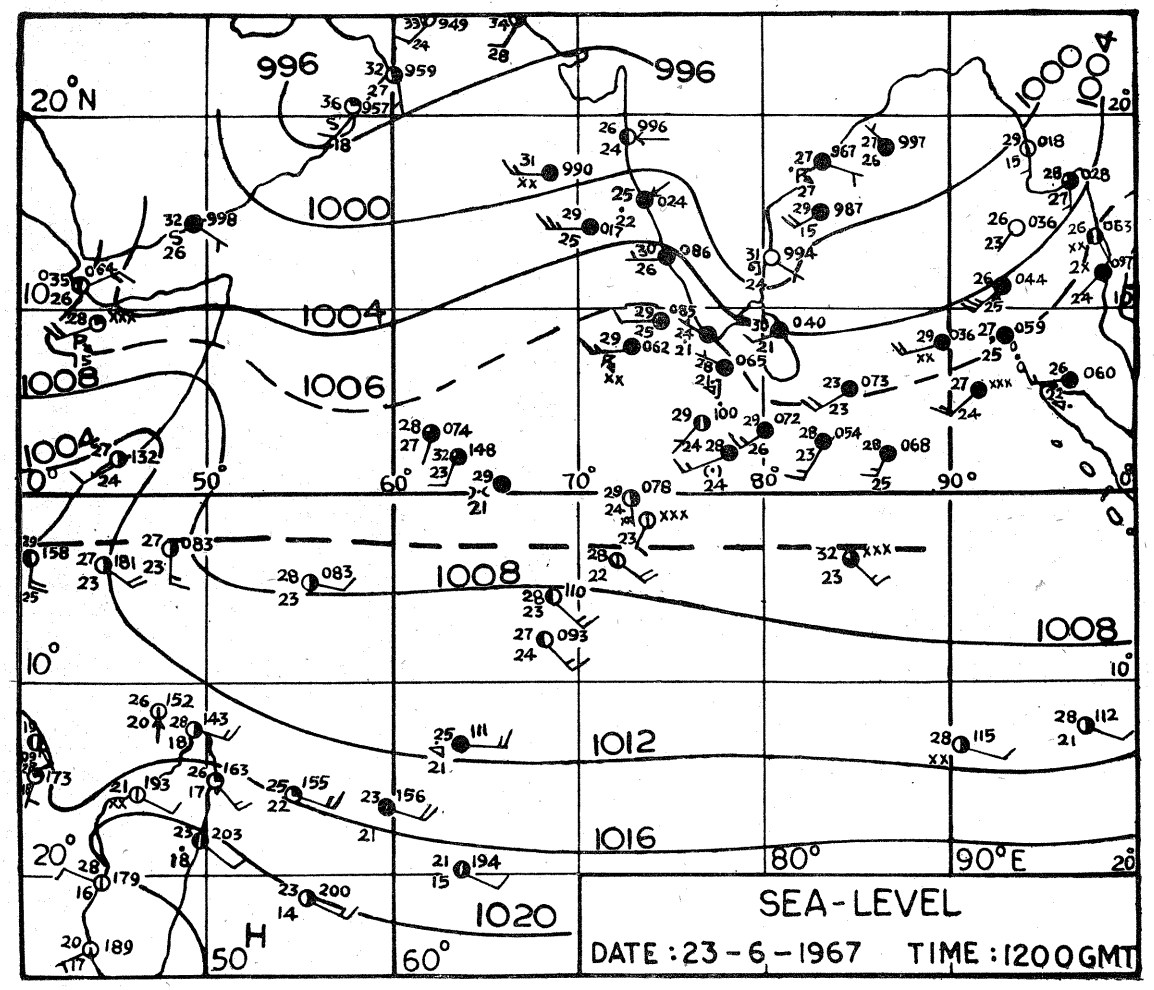

Fig. 4. Mean Sea level chart of 23 June 1967 at 1200 GMT showing the position of the Southern Hemispheric Equatorial Trough along latitude 3°S between Longitudes 40°E and 90°E

intensity. It was aligned ESE-WNW south of Lat. 5 deg. S and thence it turned to ENE upto Bay of Bengal (Fig. 3). South of 10 deg. S, the band consisted of mainly cumulus lines, cellular clouds and multilayer clouds in frontal band associated with a southern hemispheric mid-latitude cyclone. The multilayer clouds were mainly seen around 20 deg. S 70 deg. E and around 20 deg. S 93 deg. E. The band to the north of 10 deg. S consisted of dense convective clouds or multilayer clouds, more so to the north of equator where *Cb, Ns* and *As* clouds dominated. The cloud clusters north of 5 deg. S and east of 80 deg. E were broadly aligned in two convective bands in southwest-northeast direction close to each other. The cloud system thus extended practically unbroken from Long. 50 deg. E to 125 deg. E north of equator. Further east, a broken band of convective cloud clusters corresponding to intertropical confluence existed. The orientation of these large scale cloud bands indicates the cross equatorial flow which was most significant around Long. 50 deg. E and between 80 deg. E and 100 deg. E. Also, the axis of the southern hemispheric equatorial trough (SHET), as indicated by the turning in the direction of the cloud features lies at 3 deg.—5 deg. S between Long. 50 deg. E and 90 deg. E. The 1200 GMT surface chart of 23 June 1967 (Fig. 4) shows the position of SHET along latitude 3 deg. S from 40 deg. E. to 90 deg. E at sea level. This agrees with the axis of SHET inferred from the cloud organization in Fig. 3. No upper air observations could

be available over the equatorial Indian Ocean to support this agreement with surface data. In association with the formation of the cloud band over the Arabian Sea, low level westerlies strengthened appriciably over the Peninsula south of 15 deg. N. On 23 June, the westerlies at 850 mb level had a maximum wind speed of 50 kt along Lat. 10 deg. N. This development caused fairly widespread rainfall over the west coast. The band disintegrated rapidly after 23 June.

3.5. From 26 June onward till the end of the month the ocean area had mainly amorphous cloud clusters and convective cloud lines north of 10 deg. S and narrow cloud lines with relatively less cloud cover to the south.

3.6. On the whole, clouds south of 10 deg. S either had cellular patterns or cumulus lines, or were multilayered. They were less dense and had less areal coverage compared to convective cloud clusters north of 10 deg. S. The most intense convective clusters were generally seen to the north of equator only. A comparison of daily satellite pictures shows that these clusters developed and dissipated within a broad belt, which corresponds to the monsoon trough, without showing any significant or systematic movement. The belt was broad in the Indian Ocean, covering from about 30 deg. N to 10 deg. S around 100 deg. E, and narrowed down to about 5 deg.—15 deg. latitude in width in the northwest Pacific Ocean.

4. Organisation of cumulus lines

4.1. Convective cloud lines form over the oceans when a mass of cold air moves rapidly over a warm underlying sea surface, and become aligned in the direction of wind in the cloud layer (Anderson & Veltishchev, 1973). This situation prevails in southeast trades in southern tropics during the northern summer. Gaby (1967) has observed over the Atlantic and eastern Pacific Oceans between Lat. 10 deg. N and 10 deg. S that very long and very narrow cloud lines are most often parallel to the surface wind. The following characteristics were seen in the narrow cumulus lines observed over the Indian Ocean during June 1967.

4.2. In the south Indian Ocean south of about 10 deg. S the cloud lines had their orientation varying between the directions of 120 deg. and 160 deg., having an average of 135 deg. during the month. Further equatorward the cloud lines turned from SE-NW to SW-NE. The axis of turning was nearly parallel to the latitude lines. It varied between 3 deg. S and 10 deg. S and had an average of 7 deg. S for the whole month. The turning in the cumulus lines was seen within the longitude range of 42 deg. E to 90 deg. E. North of this axis of turning, the cumulus lines were generally oriented from southwest to northeast; their directions could not be inferred precisely because of development of *Cb* clouds in the south-westerly flow. The orientation of cloud lines thus clearly reflected the turning of southeast trades between 3 deg. S and 10 deg. S and the equator crossing of these deflected trades as a southwesterly current at the cumulus level which may be taken at about 850 mb. These features are easily recognised in the satellite pictures presented here (Figs. 1 - 3).

5. Discussions

5.1. The existence of an east-west oriented trough in the southern hemisphere during the southwest monsoon season over south Asia has been reported by several workers (Fletcher 1945; Flohn 1960; Koteswaram 1960; etc). On the basis of data collected during the Indo-Soviet Monsoon Experiment (1973), Godbole and Ghosh (1975), and Ghosh and Pant have concluded that the Southern Hemispheric Equatorial trough (SHET) exists between 46 deg. E. and 60 deg. E from surface to 500 mb, having a poleward inclination with height and a mean position near 2 deg. S at sea level. They also observed the existence of low level temperature inversion around 800 mb to the south of the trough, while no inversion existed to its north, so that the air was moist through deep layer in the equatorial westerlies. These findings are supported by the study of satellite data presented above, except that SHET was seen in June '67 over a much larger ocean area, *i.e.* from 42 deg. E to 90 deg. E. The position of the axis of SHET at Lat. 7 deg. S at 850 mb in June 1967 would appear to be slightly south of that observed by Godhole *et al.* at 2 deg. S at sea level and tilting poleward with height; this difference may be due to limited period of data in both the cases. The observation of cumulus lines or cellular patterns south of 10 deg. S while convective clouds with embedded *Cb* further north, was due to the existence of low level inversion to the south of the trough. Unfortunately no upper air observations are available for this period in the area of our interest to support this inference.

5.2. The cloud pictures did not show any preferred region of deep convective activity over the equator in the west Indian Ocean. This is at variance with conclusion of Pant (1976) on the basis of ISMEX-73 data that the region between 56 deg. E. and 65 deg. E has less convective activity characterised by large scale sinking air in mid-tropospheric levels.

6. Conclusions

(1) The colud organisations clearly showed cross-equatorial flow over the Indian Ocean between Long. 42 deg. E and 90 deg. E.

(2) The turning of southeasterly trades appeared to take place around 7 deg. S, the axis of southern hemispheric equatorial trough. South of the axis there was inhibited growth of clouds, characteristic of trade wind inversion. North of

the axis there were large convective cloud clusters with embedded *Cb,* indicating that inversion did not exist in the deflected southwesterly flow.

(3) Convective cloud clusters north of 10 deg. S developed *in-situ* and did not show any systematic movement.

References

Anderson, R. K. and Veltishchev, N.F., 1973, The use of satellite pictures in weather analysis and forecasting (WMO Tech. Note 124).

Fletcher, R. D., 1945, The General Circulation of the tropical and equatorial atmosphere, *J. Met.*, **2**, pp. 167-174.

Flohn, N., 1960, Monsoon Winds and General Circulation, *Monsoons of the World,* India Met. Dep., New Delhi, pp. 66-74.

Gaby, D. C., 1967, *Mon. Weath. Rev.*, **95**, 4, pp. 203-208.

Ghosh, S. K., and Pant, M. C., — *Indian J. Met. Hydrol. & Geophys.* (Under publication).

Godbole, R. V., and Ghosh, S. K., 1975, *Tellus*, **27**, 2, pp. 123-132.

Koteswaram, P., 1960, Asian Summer Monsoon and General Circulation over the tropics, *Monsoons of the World,* India Met. Dep., New Delhi, pp. 105-110.

Pant, M.C., 1976, *Indian J. Met. Hydrol. & Geophys.* **27**, 1, pp. 1-8.