

A study of 6-day mean satellite-derived brightness patterns in relation to upper air circulation features during the 1967 southwest monsoon season

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ABSTRACT. Six-day mean brightness patterns as derived by ESSA-5 photography for the 1967 southwest monsoon season are examined in relation to mean upper air circulation features for the same period. Their association at the time of onset, advance and withdrawal of monsoon has been studied.

1. Introduction

The Medium Range Forecasting Unit at the Institute of Tropical Meteorology is engaged in studying relationships between large scale flow patterns and weather, and the development of suitable techniques for forecasting weather about 5-7 days in advance. During the last decade a large amount of cloudiness and longwave radiation data have been collected over whole of the globe through satellite observations. These data are of particular importance for tropical regions consisting of large data sparse oceanic areas, which are the major sources of tropical weather systems. A number of studies made by utilising these data have shown that changes in day to day cloudiness in the satellite pictures are associated with changes in large scale circulation systems. However, there are very few studies on the association between cloudiness and synoptic systems of medium range durations (5-7 days).

Rao (1966) has earlier studied the onset of Indian summer monsoon utilising 5-day mean TIROS-IV radiation data. In the present study we have utilised the 6-day mean brightness data of ESSA-5 photography for the SW monsoon period of 1967 to study association between 6-day mean brightness and 700-mb flow patterns during the different stages of the monsoon. The brightness charts were provided by Dr. Winston of National Environmental Satellite Centre and have been prepared on the lines of Taylor and Winston (1968). Brightness values higher than 4 were found to be associated with heavily clouded areas and in the discussion which follows this has been kept in view. 700-mb mean charts for the corresponding 6-day periods were prepared

both for the contour height field and the wind field. A preliminary study showed that the mean wind charts have better relationship with mean cloudiness; hence these were used for this study. Detailed examination of all the 6-day mean sequences covering period from 12 April to 26 September 1967 was made for the purpose of this study. However, only a limited number of typical 6-day sequences representing various stages of the monsoon are presented here.

2. Discussion of typical mean situations

2.1 Onset and advance of the monsoon

The first surge of the monsoon over Ceylon, south Kerala coast and Andaman Sea Islands occurred around 12 May in association with a well marked cyclonic circulation over the Mysore-Kerala coast, and a low pressure area near the Bay Islands. The latter concentrated into a depression on the same day. The depression intensified into a storm, which weakened and become unimportant after crossing the Arakan coast on 18 May. 6-day mean 700-mb flow features together with brightness patterns for 13-18 May are shown in Fig. 1. The brightness maxima over the Bay of Bengal and over the Kerala coast and adjoining areas agree with cyclonic circulations over these areas. No cloud maximum is noticed in association with weak cyclonic circulation over Malaya Peninsula. The axis of minimum brightness running E-W across the northern parts of the country agrees well with the 700-mb ridge axis but runs somewhat to the north of it. Brightness maximum over Himalayas may be associated with snow cover or cloudiness associated with extratropical westerly systems not brought out in the 700 mb chart.

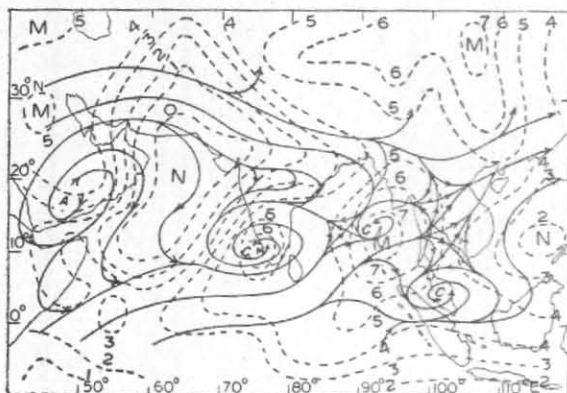


Fig. 1. 13-18 May 1967

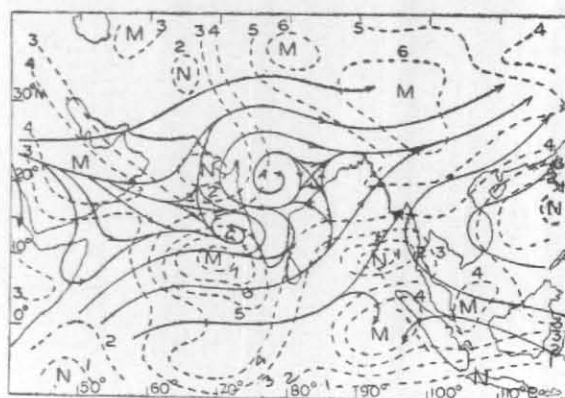


Fig. 2. 11-16 June 1967

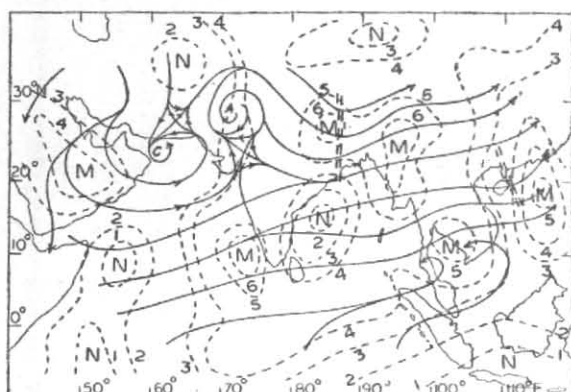


Fig. 3. 11-16 July 1967

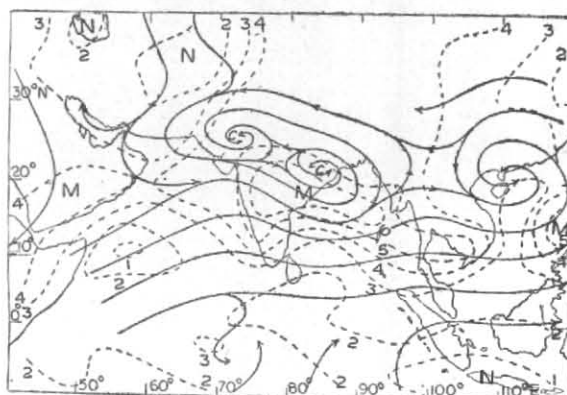


Fig. 4. 29 July-3 August 1967

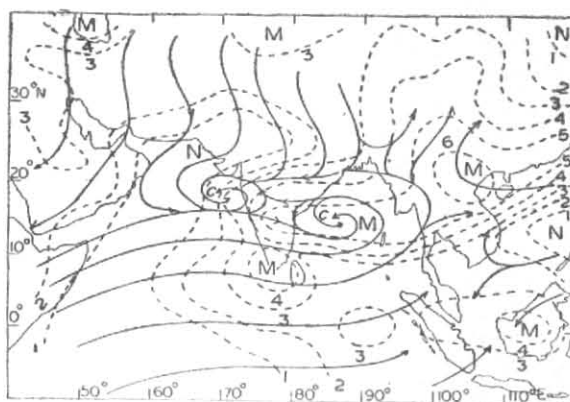


Fig. 5. 21-26 September 1967

Solid lines represent 6-day mean stream lines at 700-mb level and dotted lines 6-day mean brightness in units of 1/10.

With the weakening of the depression on 18 May the monsoon receded temporarily but revived over Kerala coast on 8 June. The cloudiness was also found to decrease with this weakening. Monsoon advanced over whole of the Peninsula

during next 10 days in association with a well marked cyclonic circulation off Mysore coast. Mean brightness and flow patterns for 11-16 June in Fig. 2 show that brightness maximum associated with this cyclonic circulation is centred to its

south and is embedded in the westerly flow.

Further northward advance of the monsoon continued and by 2 July it had advanced over the whole of India. During this phase of advancement the positions of the monsoon trough and the maximum in brightness patterns agreed well.

2.2. Weak monsoon phase

There was no pronounced 'break' in the monsoon during the 1967 season. However, during the second week of July there was a spell of rather weak monsoon activity when the surface monsoon trough lay close to the foot hills. As a result of this there was good amount of rain along the foot hills of Bihar, Bengal and Assam and the adjoining plains and the monsoon was weak over rest of the country except Kerala-Mysore coast between 8 to 15 July. Fig. 3 shows the association between the 700-mb flow and the brightness pattern. Westerlies prevailed over most parts of the country during this period. The maximum brightness over Bihar, Bengal and Assam lay in the zone of the north/south trough in westerlies along 88°E. There is another maximum in brightness off Kerala-Mysore coast which is apparently difficult to explain from the 700-mb stream lines though the speed field (not shown in the diagram) suggested that this maximum lay in the region of cyclonic shears. The minimum in brightness in the central parts of the Bay of Bengal also shows no association with the flow patterns at 700 mb.

2.3. Active monsoon phase

The monsoon strengthened again during the third week of July and was sustained by the formation of a series of low pressure areas and depressions over the north Bay of Bengal and their northwestward passage across the country. During this period of sustained monsoon activity the brightness maximum values were generally 6-7 tenths and the axis of brightness maximum either coincided with or lay somewhat south of the 700-mb trough axis. This is depicted in Fig. 4 which is for the period 29 July to 3 August. During this period two depressions affected the weather over the country and kept the monsoon rather strong with the westerlies in the mean reaching 35-40 kt over the Peninsula.

2.4. Commencement of withdrawal of the monsoon

Around the middle of September the withdrawal of the monsoon commenced from west Rajasthan and the monsoon withdrew from whole of the northwest India and adjoining central parts of the country by 27 September. As the subtropical ridge line took a position around 25°N from Arabia to Bengal, the cloudiness sharply decreased near and to the north of the ridge. The major cloudi-

ness shifted to the central Bay of Bengal where the seasonal trough lay around 15°N. Fig. 5 brings out the above aspects of the withdrawal phase.

3. Meridional variation of mean brightness

Fig. 6 (a,b,c) shows the latitude-time cross sections of 6-day mean brightness along three longitudes 70, 90, and 110°E respectively covering latitudinal width 30° S to 30° N. These cross sections were prepared on the basis of average brightness within 5 degrees on either side of the meridian concerned, e.g., for 70° E the brightness data were averaged for the belt 65-75° E. The following broad features are shown by these cross-sections.

(i) Higher values of brightness along 30°N during April and May in association with the mid-latitude westerlies. This is most pronounced along 110°E.

(ii) Sub-tropical minimum in brightness in the northern hemisphere during April and May which shifts northward with the advance of the brightness maximum associated with the southwest monsoon.

(iii) Equatorial maximum in brightness in April and May which advances northward with the onset of the monsoon and establishes near 20-25°N along 70°E and 90°E in July and August. The section along 110°E shows the advance of the brightness maximum from the 3rd week of May which merges with the maximum in the sub-tropical westerly belt near 25-30°N toward June. There is a secondary maximum in 110°E section near 10-15°N during some periods between June and August.

(iv) Sub-tropical minimum in brightness in the southern hemisphere which oscillates between 15-20°S in April and May and between 20-25°S in June to September.

(v) Periodical increase of cloudiness along 25-30° S in association with the activity in the sub-tropical westerlies.

The section along 70°E shows that over the equatorial region of the northern hemisphere there was increase of brightness from the end of April and the maximum shifted to 10°N during the 2nd week of May with the temporary onset of the monsoon over the Kerala coast. This maximum weakened and there was a period of lull from 18 May to 6 June. In the second week of June brightness again increased in the equatorial region and the maximum gradually shifted northwards till it established near 20°N by the first week of July. This northward shift was associated with the

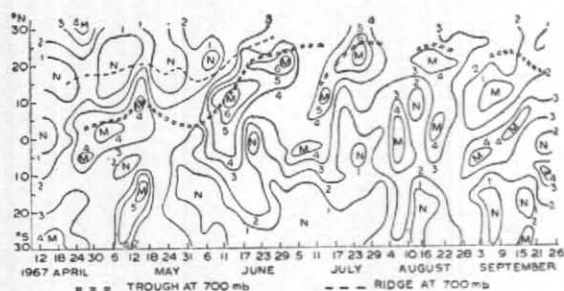


Fig. 6(a). Section along 70°E

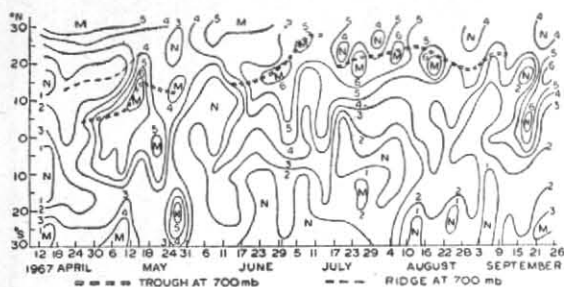


Fig. 6 (b). Section along 90°E

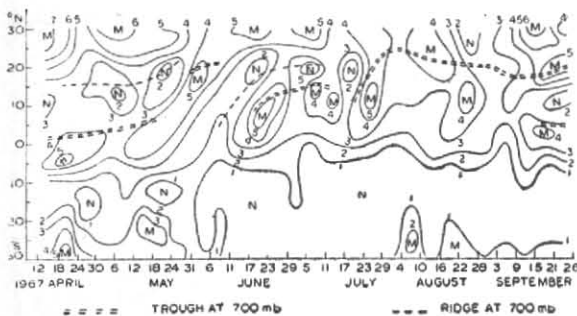


Fig. 6(c). Section along 110°E

Meridional variation of 6-day mean brightness

advance of the southwest monsoon along the west coast of India. There was a brief period of weakening in the maximum in the 2nd week of July which was associated with the weakening of the monsoon. The maximum again intensified in the third week of July and remained along 20°N till the end of August with some oscillations both in its intensity and position. The axis of the brightness maximum either coincided with the stream line trough at 700 mb or had a slightly southwards shift. The axis of the brightness minimum also generally coincided with the position of the sub-tropical ridge.

Srinivasan (1968) has examined the ships' data collection of IIOE period for the years 1963 and 1964 and found three cloud belts characteristic of

the monsoon field (July and August), viz., (i) the prominent cloud maximum in association with the northern hemisphere equatorial trough along 20°N, (ii) a near equatorial cloud maximum near 5-10°N, and (iii) another near equatorial cloud maximum near 5-10°S. The cross-sections presented in this study do not show clearly the two near equatorial cloud maximum belts in the brightness data as a characteristics feature. However, there were one or two spells in which there were two distinct cloud maximum, one near 20°N and the other near 5°S. What is observed in this study is that the equatorial zone has spells of weather activity intercepted with spells of rather quiescent conditions. During these spells too generally the clouds increase from southern hemisphere equatorial region across the equator toward the monsoon trough zone in the northern hemisphere, the equator having about 4 tenths of brightness value.

Along 90°E the brightness was high in the equatorial area at the end of April and showed northward advance and lay near 10-12°N between 13-18 May. It receded southward again in the 3rd week of May. Low values of brightness prevailed in the equatorial zone between 24 May and 6 June. Regular northward advance of brightness occurred in the 2nd week of June and by the 2nd week of July, it reached its northernmost position of 25°N. Subsequently it shifted to 20°N and remained near 30°N with some oscillations till the end of August.

In this belt also the prominent maximum in brightness is the one associated with the monsoon trough. The double maximum in brightness does not seem to be characteristic feature in this section too. This section also shows spells of increased brightness in the equatorial zone and the spells observed were between 30 April-24 May, 11 June-5 July, 11-17 July, 10-22 August and 9-21 September.

In the section along 110°E the equatorial maximum in brightness moved north of the equator in the third week of May, lay along 20°N by the beginning of June and merged with the maximum along 30°N by the third week of June. This maximum oscillated between 25-30°N till the third week of August. However during June to August there were spells when a secondary maximum existed between 10-15°N. Along this section the belt 25-30°N is influenced by weak frontal lows over China and these features together with the seasonal position of surface trough produce the maximum in brightness along this belt. The secondary maximum at 10-15°N is linked with periodic activation of the 700-mb trough under the

influence of tropical disturbances some of which intensify into typhoons. By the beginning and middle of September the subtropical minimum becomes more prominent and separates the southwards migrated equatorial trough maximum along $5-10^{\circ}\text{N}$ and the maximum in the frontal zone at the northern end of the section. The characteristic feature of this section in contrast to that of 70°E and 90°E is that throughout the peak activity of the monsoon from the middle of June to the end of August the brightness values were generally between 1-2 units in the equatorial zone and another maximum in the southern hemisphere equatorial belt did not exist on any occasion. Besides the subtropical minimum in the southern hemisphere was very much pronounced and oscillated within 2-3 degrees of 15°S and a very broad belt between 5°S to 30°S was generally having brightness value of less than one unit.

4. Association between brightness and rainfall

Attempt was also made to verify whether any association existed between the brightness over an area and the average rainfall over the same area for the corresponding period. For this purpose three five-degree latitude-longitude squares were selected, *i.e.*, (i) between $20-25^{\circ}\text{N}$ and $80-85^{\circ}\text{E}$, (ii) between $20-25^{\circ}\text{N}$ and $75-80^{\circ}\text{E}$ and (iii) $25-30^{\circ}\text{N}$ and $75-80^{\circ}\text{E}$. The average brightness for each of these squares was worked out for each 6-day period from April to September. The average rainfall for the corresponding 6-day period in each of these squares was also worked out based on the daily rainfall records of all the meteorological observatories. Fig. 7 shows the time-sections of areal average brightness as well as areal average rainfall. It is seen that the brightness commenced increasing in all these squares during the period 31 May to 5 June. This increase continued till about the end of June and the beginning of July. The rainfall started increasing from the 2nd week of June. Thus there was initially a lag of about two weeks in the commencement of increase in brightness and the onset of rainfall. However, there was practically very little rain till the brightness value was below 4 units in all the squares. This probably happens since during the onset phase of the monsoon the rainfall generally occurs in a narrow belt of heavy clouding. After the onset of the monsoon rains there was general agreement in the temporal variation in the brightness and the rainfall, the two curves following generally the same trend. There were, however, a few exceptions to this agreement. For example, in the area covered by the square $25-30^{\circ}\text{N}$ and $75-80^{\circ}\text{E}$ an increase in rainfall between the period 4-9 August was associated with slight decrease in the brightness. Examination of daily rainfall data showed that this

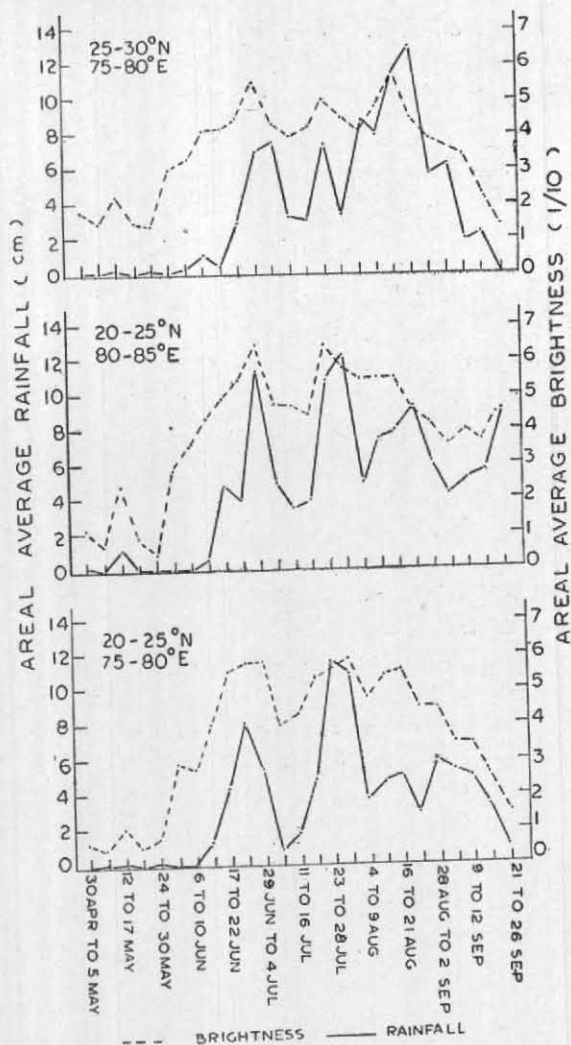


Fig. 7

Relationship between 6-day mean brightness and rainfall

increase was mainly accounted by a few locally very heavy falls. The non-agreement in the trend of the two curves in the area between $20-25^{\circ}\text{N}$ and $80-85^{\circ}\text{E}$ during the period 10-15 August as well as for the area between $20-25^{\circ}\text{N}$ and $75-80^{\circ}\text{E}$ during the period 29 August to 2 September could be explained due to similar local heavy falls. During the withdrawal phase of the monsoon, rainfall occurred even when the brightness was less than 4 units in contrast to the onset phase of the monsoon. This is probably due to the occurrence of isolated convective rain not associated with widespread cloudiness during the withdrawal phase of the monsoon.

5. Conclusion

This study shows the following two aspects—

(i) The large scale cloudiness of the southwest monsoon field over the Indian region is well associated with the large scale circulation features at

700 mb even on five to six days average basis. This association is satisfactorily observed in different phases of the southwest monsoon.

(ii) After the onset of the monsoon rains over India the areal averages of the temporal changes in cloudiness on 5 to 6-day basis over an area covered by five degrees latitude-longitude square occur in general in phase with the temporal changes in the areal averages of the rainfall over the same area.

In the Medium Range Forecasting Project, efforts are being made to forecast the 700-mb flow patterns during the southwest monsoon on 5-day mean basis on statistical and other considerations

(Shukla and Suryanarayana 1968). It is hoped that in due course a satisfactory technique would be evolved for forecasting the flow patterns on this scale of time. Making use of such forecast flow-pattern charts, results such as obtained from the present study may be helpful in practical purposes like assessing the cloudiness or the trends in the areal distribution of rainfall.

Acknowledgement

We are thankful to Dr. Jay S. Winston of the National Environmental Satellite Centre, ESSA, Washington D.C. for supplying us the 6-day mean brightness values used in this study.

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DISCUSSION

(Presented by H. S. Bedi)

PROF. K.R. RAMANATHAN remarked that there was a general displacement of the cloud area from the low pressure trough at 700 mb towards the south or southeast. He suggested incorporating the rainy areas also in the maps.

SHRI P. JAGANNATHAN: Uniformly weighted averagings will exhibit a phase shift. As such one should be cautious in placing the cloud maxima to the south or southeast of the trough.

SHRI H.S. BEDI: Similar type of averaging has been applied to the wind field also. Therefore, the occurrence of cloud maxima to the south of the trough may be taken to be genuine.

DR. G.C. ASNANI: What is the unit block area for averaging?

SHRI BEDI: The unit is 1/16 degree square.

DR. C. RAMASWAMY: Was there any system in the westerlies to account for the 6-day mean cloudiness off Kerala coast?

SHRI BEDI: No system could be detected.

SHRI M. RAMA RAO: Have you separated out the cases of depression and non-depression days?

SHRI BEDI: No. The 6-day averages of clouding was received from ESSA for certain periods for which corresponding mean flow patterns were worked out.

SHRI J. SHUKLA: From the observed cloudings in monsoon season, is it possible to infer whether it is a large scale vertical velocity field or only cumulus convection?

DR. P.R. PISHAROTY: The clouding is spread over a large area about 200,000 sq. miles. It is not of uniform convection but consists of thousands of clusters of individual clouds.