

## A study of active monsoon over India using satellite radiation data

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**ABSTRACT.** Tiros VII radiation data in the 8-12 micron channel for the period 5-8 July 1963 has been analysed. This was a period of good monsoon activity in the Peninsula and central India. The I.R. analysis is compared with surface synoptic and upper air charts. The results indicate that the general height of tops of monsoon clouds is about 7-8 km and these clouds presumably do not extend much into the upper tropospheric easterlies. However, in the areas of localised heavy monsoon activity, the clouds extend at least as high as 12 km. The average size of such thick cloud clusters is of the order of 3 to 5 degrees of Lat./Long. across and in some cases even more.

### 1. Introduction

Some of the satellites in the TIROS series carried a medium resolution infrared radiometer (MRIR) which had five channels. One of the channels (Channel 2) was in the 8-12 micron range. The atmosphere is almost transparent to radiation in this spectral range; and hence this range is called the 'atmospheric window'. The amount of radiation from the earth and its atmosphere which reaches the satellite radiometer in this frequency interval can be converted into the equivalent black body temperature ( $T_{BB}$ ) through Planck's law on the assumption that the earth and its cloud cover emit as a black body (in this frequency range). Though  $T_{BB}$  is not to be interpreted as the actual temperature of the viewed surface, for many purposes it is a good approximation to the actual temperature—particularly when we consider only the relative  $T_{BB}$  distribution over large areas.

The instantaneous field of view of TIROS VII radiometer (called the scan spot) has a diameter of 55 km when viewing vertically downward; with large nadir angles the scan spot becomes elongated and may cover more than ten times this area. The radiation that reaches the satellite at any instant is the value averaged over the scan spot. Hence the satellite measured  $T_{BB}$  values can be meaningful only when a homogeneous overcast layer or perfectly clear sky fills the view of the radiometer. But if the sky is partly covered or if the sky, even though overcast, has clouds with widely varying tops or transparency, the  $T_{BB}$  values cannot be interpreted as pertaining to any particular cloud layer.

### 2. Data used

The basic data for the present study was from TIROS VII and was obtained in the form of computer-produced grid prints of  $T_{BB}$  values, with a square mesh of  $1 \cdot 25^\circ$  longitude interval on a 1:10 m scale Mercator Projection map. The population chart (giving the number of value on which each grid value was based) was also available. The data refer to single open mode (where geographic locating has high accuracy). The floor side and wall side readings are mixed. Only readings with less than  $72^\circ$  zenith angle are used, as beyond this, space contamination makes the  $T_{BB}$  readings unrealistic.

TIROS VII was launched on 19 June 1963 and the data studied refer to 5 to 7 July; by this date, no degradation of the sensors had set in. Channel 2 data has been verified to be quite reliable. The estimated absolute accuracy of Channel 2  $T_{BB}$  values is  $\pm 5^\circ\text{K}$  and the short relative term accuracy  $\pm 2^\circ\text{K}$  (Staff Members, NASA 1964).

Thus while the temperature observations used are coarse in the sense that they are averages over sizable areas, these values are sufficiently reliable. As extreme values are smeared out in the averaging over each scan spot, a relatively high or low value of  $T_{BB}$  when it appears in the grid points, should be given sufficient weightage as it represents the mean value over an area. More than the absolute values, the relative values presented on the chart are significant as truly delineating the variations in the heights of cloud tops.

The analysis of the Channel 2 data over India and the neighbouring areas for 5, 6 and 7 July

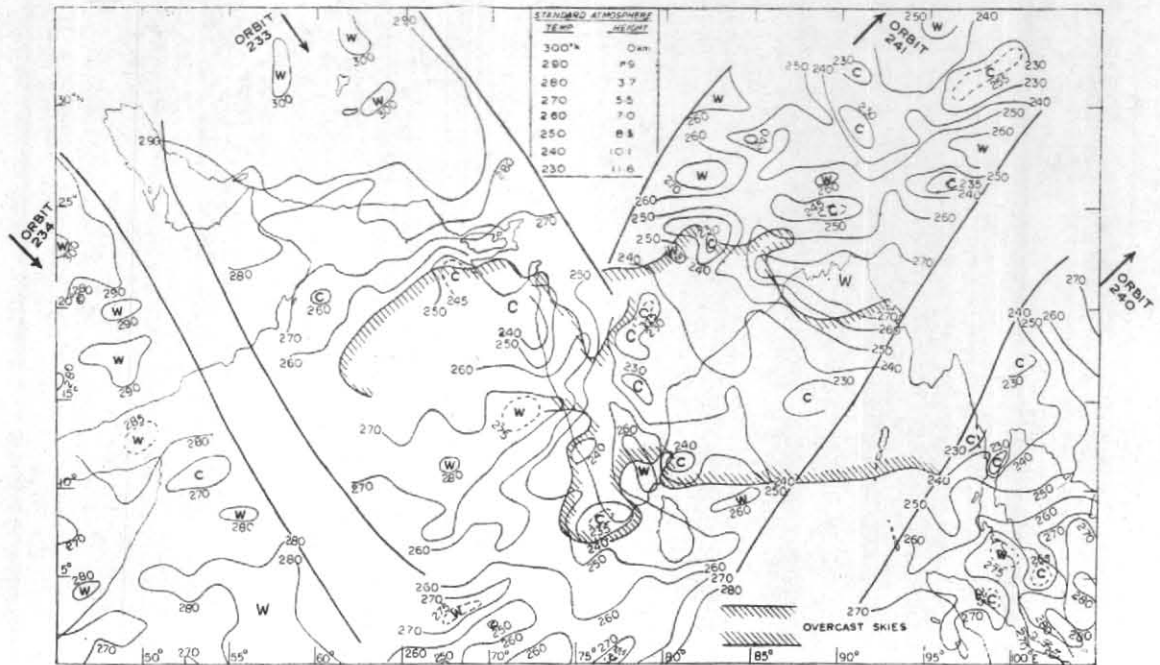


Fig. 1  
Temperature analysis of 5 July 1963

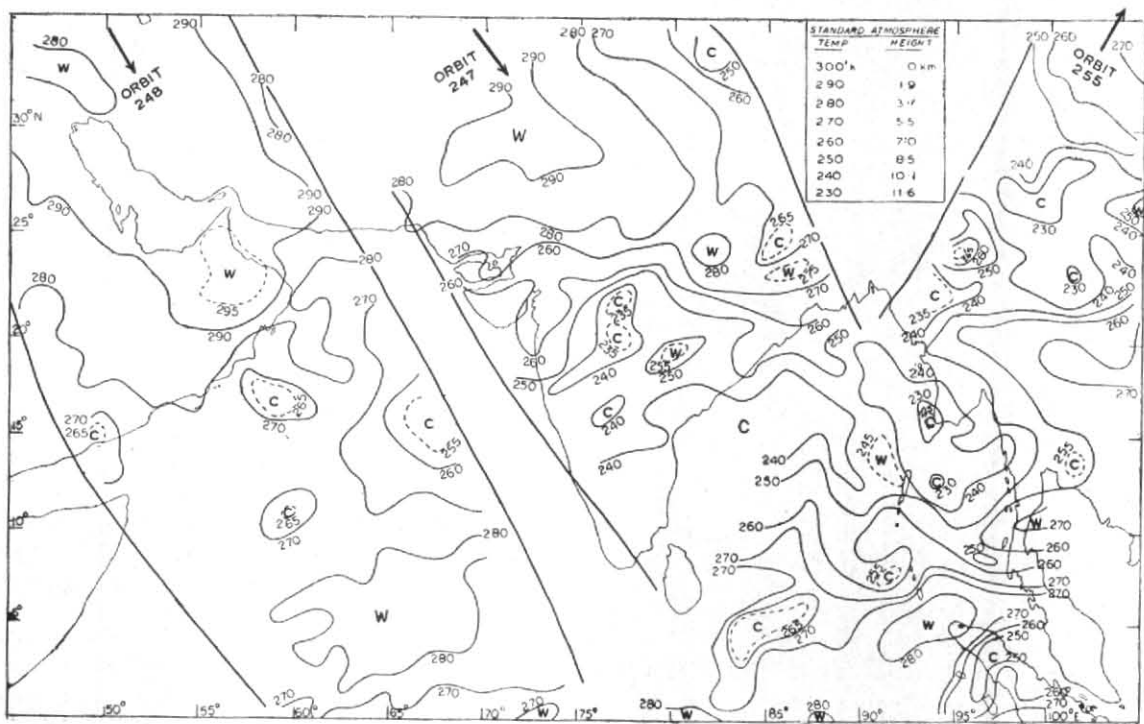


Fig. 2  
Temperature analysis of 6 July 1963  
TIROS VII MRIR Channel 2 (8-12 microns)

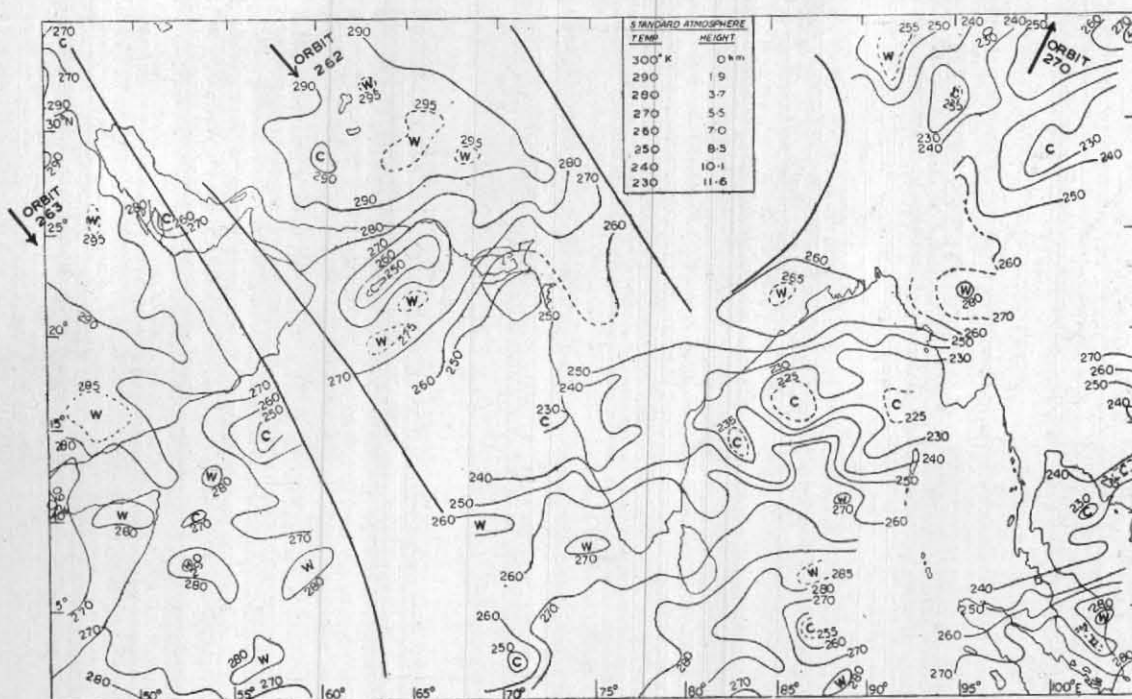


Fig. 3

Temperature analysis of 7 July 1963. TIROS VII MRIR Channel 2 (8-12 microns)

1963 are presented in Figs. 1 to 3. The isopleths were drawn at 5°K intervals. However, in Figs. 1 to 3, 10°K isopleths alone are shown; 5°K lines are shown over some areas only, to bring out the significant features. The heights in the Standard Atmosphere for Asian Tropics (Pisharoty 1959) corresponding to the various temperatures are given in the inset in the diagrams.

### 3. Synoptic situation

The period 5 to 7 July 1963 was one of good monsoon activity over the country south of Lat. 25°N. A depression developed over the head Bay of Bengal and moved towards northwest Madhya Pradesh. It was centred between Calcutta and Saugor Island on 5th (morning), over northeast Madhya Pradesh on 6th and was weakening on 7th. There was also a well-marked low over Gulf of Cambay and the adjoining Gujarat State on the 5th and it weakened the next day.

### 4. Analysis of I.R. data

The main features brought out by the analysis of the I.R. data on 5 to 7 July 1963 (Figs. 1 to 3) are —

(i) There is a cold area running from Arakan coast and north Andaman Sea to the northeast and central Arabian Sea across the northern Peninsula.

(ii) Northern India and West Pakistan are warm areas and there is a steep gradient of tem-

perature between this warm area in the north and the cold area to the south.

(iii) Within the general cold area there are pockets of minimum T<sub>BB</sub> values whose extents are of the order of 3-5° Lat./Long. across or even more in some cases.

Comparing the temperature (T<sub>BB</sub>) analysis with the clouding and weather reported by ground stations, we find thick *As* with present weather rain, or *Cb* with showers and thunderstorms, over the cold areas (particularly the coldest pockets).

The chart for 5 July depicting the clouds and weather at the observatory stations/ships nearest to the times of satellite passes, has been shown as a typical example (Fig. 4). The 24-hr rainfall and past weather charts for 6, 7 and 8 July are also given in Figs. 5 to 7. Orbit boundaries and selected T<sub>BB</sub> isolines from the relevant I.R. data analysis are also superposed on these charts (Figs. 4 to 7). The clouding, weather and rainfall reported over the following areas on 5th were noted—(i) Konkan and south Saurashtra and adjoining Arabian Sea, (ii) Kerala, (iii) northeast Madhya Pradesh, (iv) Andhra Pradesh, (v) central Bay of Bengal and north Andaman Sea, and (vi) north Tamil Nadu coast. Over these areas the I.R. analysis indicated cold pockets.

It is also interesting to see on 5th, the warm area over the head Bay of Bengal where the depression was centred. In the satellite TV pictures

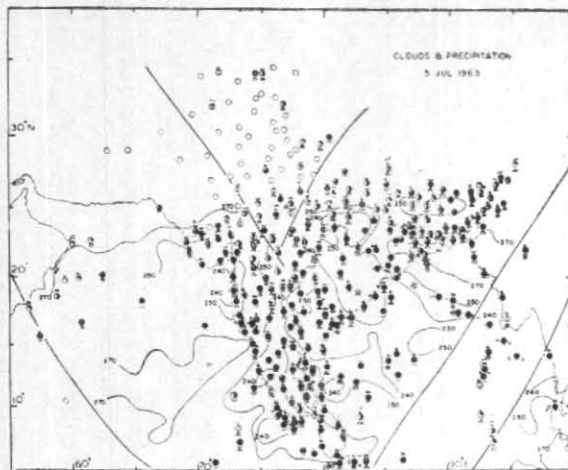


Fig. 4

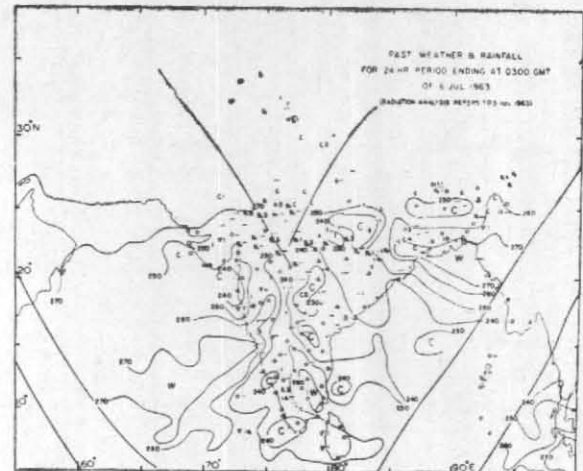


Fig. 5

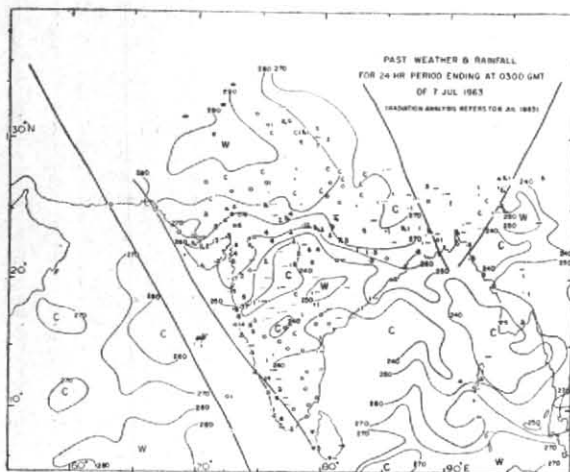


Fig. 6

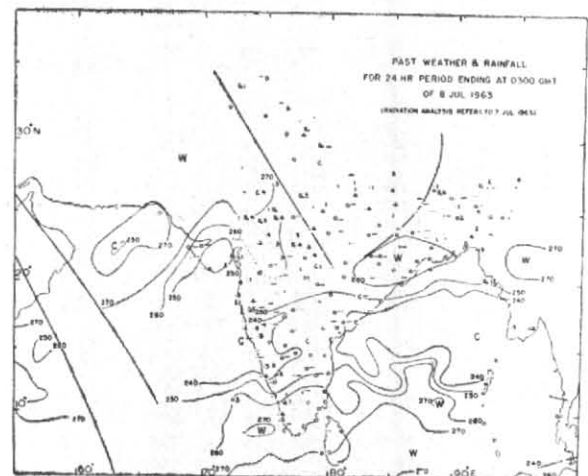


Fig. 7

of monsoon depressions also we generally note the main overcast area to the south of the centre with only some cumuliform bands to the north (Srinivasan, Raman and Ramakrishnan 1971). This feature in the depression field may be noted on the I.R. analysis for 6th also. Another warm area is projecting into Coastal Mysore from the west on 5th and rainfall is considerably less there compared to either north or south.

#### 5. Discussion

Comparing the radiation data with clouding, rainfall and upper winds, the following broad

correspondence are seen—

(i) Over areas where  $T_{BB} > 270^\circ\text{K}$ , there is not much rainfall.

(ii) Over areas of heavy monsoon clouding the  $T_{BB}$  values are about  $250^\circ\text{K}$  or less.

(iii) The coldest pockets have a temperature of  $230^\circ\text{K}$ - $240^\circ\text{K}$ ; over these areas rainfall has been quite heavy or thunderstorm activity pronounced. While it is true that there has been good rainfall over areas where temperatures are low in the I.R. charts presented, the converse—*viz.*, that temperature should be low at every place where the

24-hr rainfall indicated good rains having occurred subsequently—is not true, since clouds have developed after the time of satellite pass at some places and caused rains. Some of the radiosonde ascents in these cold pockets showed deep humid layers with lapse rates almost saturated adiabatic.

(iv) Over the area of low  $T_{BB}$  temperatures, across the Peninsula, the westerlies were found to be strong and quite deep extending upto at least 7 km. The depth of westerlies rapidly decreased over central India where a large gradient of  $T_{BB}$  values may be seen in Figs. 1 to 3. Further north where easterlies prevailed over the entire troposphere, the  $T_{BB}$  values are highest.

The temperature of  $250^{\circ}\text{K}$ - $260^{\circ}\text{K}$  corresponds to 7 to 8 km in the Standard Atmosphere for Asian Tropics and the temperature  $230^{\circ}\text{K}$ - $240^{\circ}\text{K}$  to 10-12 km (Pisharoty 1959). Thus from the radiation data we may infer that (i) generally monsoon clouds extend upto 7 or 8-km level and (ii) in the monsoon field, there are also areas of synoptic scale dimensions where the clouds penetrate much further to 10 to 12 km. The actual cloud tops could have been even higher than these figures deduced from the I.R. data analysis, due to the transparency of the ice clouds to infrared radiation (Fritz and Winston 1962, Fritz and Krishna Rao 1967).

Studies (Ramamurthi 1955, Rao 1955) on clouds over India utilising reports from jet aircraft have shown that over Indian area during the southwest monsoon season, the heights of tops of medium clouds range between 25000 and 30000 ft. This is fairly close to the cloud tops values of about 8 km obtained from I.R. data.\*

Fig. 8 gives the upper winds at 6.0 km, 7.2 km and 9.0 km for 7 July 1963 (1200 GMT) as an example. The  $250^{\circ}\text{K}$   $T_{BB}$  isolines from the I.R. data analysis for the day are also superposed. These isolines enclose the major overcast area, where  $T_{BB}$  is less than  $250^{\circ}\text{K}$ . It will be seen from the figure that over the major overcast area, the winds are westerlies upto 7.2 km. Easterlies come at 9.0 km, the transition from westerlies to easterlies occurring somewhere between 7.2 and 9.0 km. We may not be very much in the wrong if an assumption is made that the transition level is 8.0 km. It would follow, from this, that the

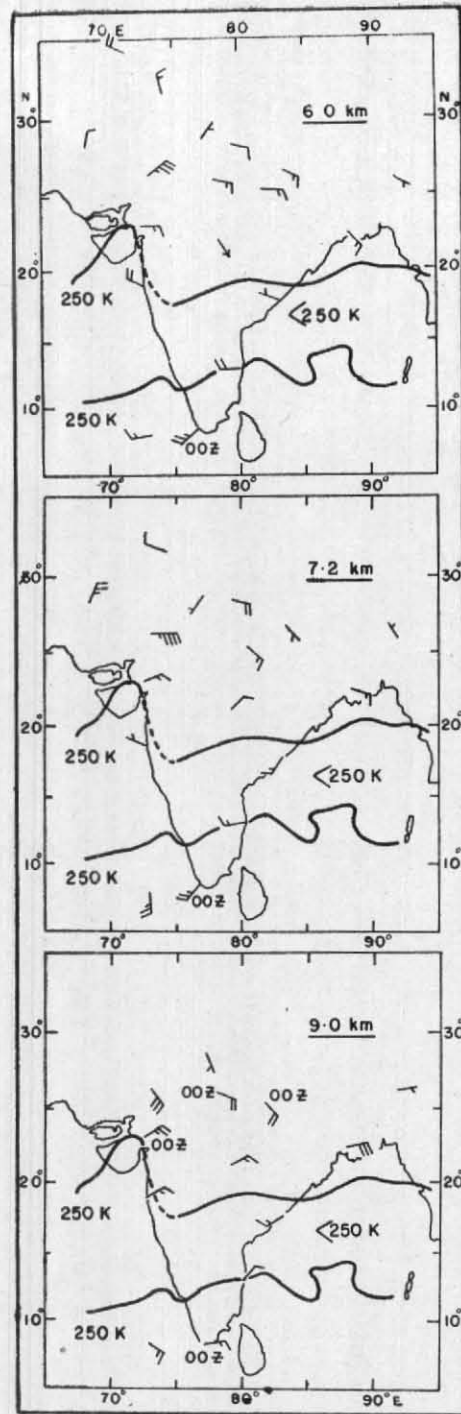


Fig. 8

Upper winds at 6.0, 7.2 & 9.0 km, on 7 July 1963 at 1200 GMT;  $250^{\circ}\text{K}$   $T_{BB}$  isolines from I. R. data are superimposed

\*Very recently Bunker and Chaffee (1968) have given the average and extreme values of the tops and amounts of middle and high clouds off the west coast of India ( $70^{\circ}\text{E}$  to Indian coast between  $12^{\circ}\text{N}$  and  $20^{\circ}\text{N}$ ) during the southwest monsoon as follows—

	Middle clouds	High clouds
Average	4000 m 5 oktas	9300 m 4 oktas
Extreme	8800 m 8 oktas	13400 m 8 oktas

medium clouds whose heights of tops have been estimated from the I.R. analysis as 7 to 8 km, are embedded mainly in the westerlies and if at all they extend higher, they reach only upto the base of the easterlies.

However, in the areas defined by cold pockets in the I.R. analysis, the cloud tops reach much higher. These areas of thicker clouds constitute the synoptic scale 'cloud clusters' whose role in the tropics is being increasingly studied (Oliver and Anderson 1969). These cloud clusters as they appear in the satellite TV pictures are usually interpreted as being composed of *Cb* and *Cb*-generated *As* and thick *Ci*.

#### 6. Conclusions

The following are the main conclusions of the study :

(i) The tops of the clouds in the general monsoon field during active monsoon period, reach about 8km.

(ii) In this monsoon cloud field, there are some pockets of synoptic scale dimensions—3 to 5 degrees across or even more—where cloud development is

much higher, upto 12 km, and the rainfall is quite heavy. These are the 'cloud cluster' which form an important link in the general circulation of the tropics.

(iii) Except probably in the cloud clusters mentioned above, the monsoon clouds are mainly confined to the westerlies; if at all the clouds extend higher they do only upto the base of the upper easterlies.

A co-ordinated investigation utilising satellite data, aerial photographs, radar and specially instrumented aircraft observations are very essential to get a complete picture of the monsoon clouds, which will take us a step further in the attempt to understand the southwest monsoon and the cloud field associated with the monsoon.

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#### DISCUSSION

DR. P. KOTESWARAM remarked that each area of low temperature in the monsoon current could be associated with a synoptic system. He also remarked that he had flown over these areas during this period and found *Ci* even at 45000 ft over a large area. A few low values existing in field of generally high values may bias the readings due to the large scan area. This is the general deficiency with MRIR data with large scan. He suggested that HRIR data should also be studied in conjunction.