Mausam, (1990), **41**, 2, 183-188

551.533.3 : 551.501.777

Interannual variability of monsoon rainfall as estimated from INSAT-1B data

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सार — 1986, 1987 और 1988 वर्षों के दौरान मानसून वर्षा के वार्षिक विभिन्नता के अध्ययन के लिए इनसेट-1 बी आंकड़ों का प्रयोग करते हुए उपग्रह आकलित वर्षा का उपयोग किया है। मानसून महीनों के लिए माध्य मासिक वर्षा के नमूनों और प्रत्येक मानसून महीनों के लिए वर्षा के माध्य से विचलन को प्रस्तुत किया है।

ABSTRACT. Satellite estimated rainfall using INSAT-1B data is utilised to study the annual variations of monsoon rainfall during the years 1986, 1987 and 1988. Patterns of mean monthly rainfall for the monsoon months and the deviations from the mean of rainfall for each monsoon month are presented.

1. Introduction

Monsoon rainfall exhibits variability on many time scales. The prominent among them is the synoptic scale, variability of the period of the order of 5 to 7 days. The second type of variability is due to the low frequency modes, one being the 15-day mode and the other the 40-day mode. The third type of variability is the interannual and longer time scale variability. For short range prediction, the synoptic mode is important. For medium range and long range prediction, the low frequency modes and the longer time scale modes respectively are significant.

The southwest monsoon is a repetitive annual phenomenon, hence the agricultural production depends upon the space time distribution of this monsoon rainfall. The interannual variations of monsoon rainfall sometimes produces calamities like droughts and floods in different parts of the country. The need to forecast such abnormalities is obvious. Before any prediction is attempted, it is necessary to understand the interannual variability of the monsoon.

Past studies were carried out by calculating the areal average using the conventional raingauge data, which varied in number in some years. Over a long time period, some raingauges might cease to operate while new raingauges would be installed at different locations. Their data is taken into consideration for calculating the average rainfall. Averages thus calculated would have suffered some errors as the number of raingauges considered are not same every year. Moreover, in order to study the impact of the variability of monsoon rainfall on the global circulation, the variability of rainfall over land such as Indian subcontinent alone itself will not be sufficient, but its variability over the whole monsoon region is to be studied. Most of the monsoon region is covered by oceans where no conventional methods of rain measurements exist. Over such areas satellite data can advantageously be employed to estimate the precipitation and to study its variability.

In this paper, an attempt has been made to estimate the precipitation from INSAT-1B data over India and adjoining ocean areas during three monsoon seasons, namely, 1986, 1987 and 1988. In section 2, the method of estimation has been briefly described. Section 3 contains the description of mean monthly rainfall and the anomalies of rainfall for the three years studied. Section 4 summarises the results.

2. Data and procedure

3-hourly (8 times/day), full resolution infrared data from INSAT-1B are used in estimating the precipitation. The data for the monsoon months (Jun to Sep) for the years 1986-1988 have been used. The VHRR of INSAT-1B which is located at 74° E, is a two-channel radiometer operating between 0.55μ and 0.75μ in the vis. and 10.5μ -12.5μ in the IR channels. The resolutions in the two channels are 2.75 and 11 km at sub-satellite point, respectively.

The detailed description of the method is given by Rao *et al.* (1989). However, the method adopted is described briefly below :

Estimation of large space and time scale precipitation is carried out using a single parameter linear model (Arkin & Meisner 1987). Rain estimations from satellite data is based on the hypothesis that the brightest (coldest) clouds in vis. (IR) are associated with the highest rainfall.

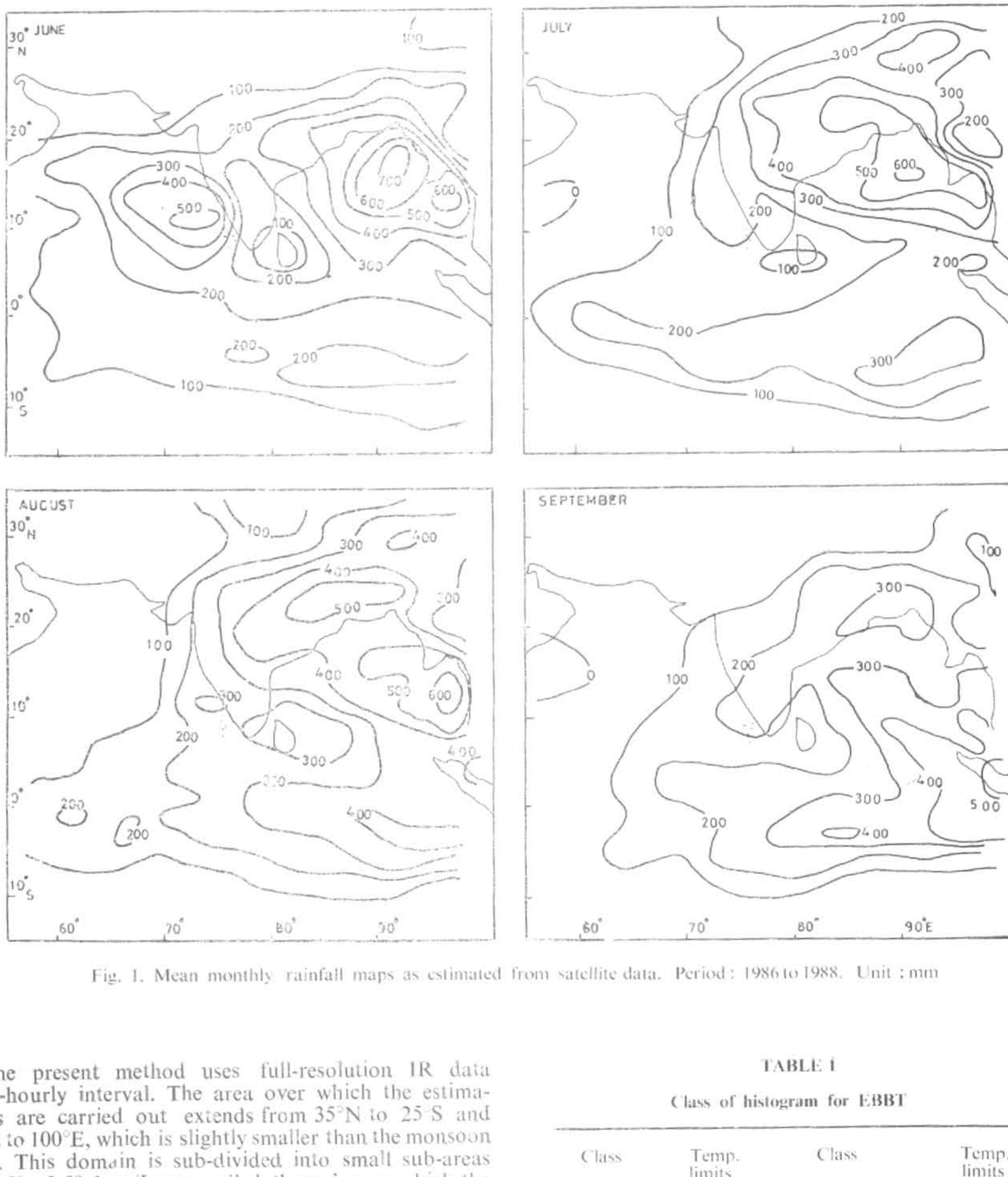

Fig. 1. Mean monthly rainfall maps as estimated from satellite data. Period : 1986 to 1988. Unit : mm

The present method uses full-resolution IR data at 3-hourly interval. The area over which the estimations are carried out extends from 35°N to 25°S and 40°E to 100°E, which is slightly smaller than the monsoon area. This domain is sub-divided into small sub-areas of 2.5°×2.5° Lat./Long., called 'boxes' over which the rain estimation is computed which gives an areal estimation over that box. The computation involves the following steps :

(1) The grey shade value of each pixel in a box is read and is converted into its corresponding temperature by means of a look up table. Then this pixel is placed in a box appropriate to its position and in one of the classes of a pre-defined 16-class histogram (Table 1) by virtue of its temperature. The whole image is scanned and the histogram classes in each box are thus filled.

TABLE 1

Class of histogram for EBBT

Class	Temp. limits (K)	Class	Temp. limits (K)
1	>270	9	231-235
2	266-270	10	226-230
3	261-265	11	221-225
4	256-260	12	216-220
5	251-255	13	211-215
6	246-250	14	201-210
7	241-245	15	191-200
8	236-240	16	≤190

(2) This scanning is carried out for all the 8 images of the day. Then the total number of pixels for the day, in each class of the histogram for each box, is calculated by simple addition.

(3) Such daily totals are prepared for the given period, say a week, fortnight or a month.

(4) Fractional area, in each box, covered by clouds whose cloud top temperatures are colder than a given threshold temperature, is calculated by :

$$F_c = \frac{\text{Sum of pixels colder than a threshold temperature}}{\text{Total number of pixels in a box}}$$

(5) The precipitation index is calculated by :

$$P_I = K \times F_c \times N_c$$

where, K is a constant related to daily rain rate

F_c = Fractional clouding

N_c = Number of days over which the accumulation is carried out.

In the present case the value of K is taken to be 71.2 mm/day and the threshold temperature is taken as 235° K. Monthly precipitation estimates are thus calculated for the months of June, July, August & September for the 3 monsoon seasons of 1986, 1987 and 1988. Using the 3-year values mean monthly precipitation for each month is calculated. Deviation of precipitation in each month from its corresponding mean is also calculated.

3. Results and discussion

3.1. *Mean rainfall for the monsoon months*

Mean precipitation pattern (3-yr mean) for the monsoon months June, July, August & September are shown in Fig. 1.

3.1.1. In the month of June, two maxima of rainfall are seen north of the equator, one in the NE Bay of Bengal (>700 mm) and another in the east central Arabian Sea (> 500 mm) with a minimum in between them lying over Sri Lanka and adjoining S. Peninsula (< 100 mm). The axis of heavy rain extends WNW into central Peninsula from the Bay maximum. Another belt of heavy rain is seen approximately along 5° S roughly coinciding with the mean position of SHET. The orientation of these two belts is such as if both of them have originated from a common source located further eastwards which is beyond the domain considered.

3.1.2. In the month of July, the rainy area has extended further NW-wards to cover almost the whole country as seen from the envelope of 100 mm isopleth. This is in conformity with the progress of the monsoon which covers the country by middle of July. In the month of July, the Bay maximum not only shifted SE-wards but decreased in magnitude also while there is no maximum seen over Arabian Sea. The minimum over Sri Lanka and neighbourhood persisted. The axis of heavy rain belt in the southern hemisphere extended westwards up to 60° E and the maximum also has increased in magnitude (> 300 mm) SW of Sumatra islands.

3.1.3. The pattern in August is more or less akin to that of July except that Bay maximum has shifted further SE-wards towards central Bay. Another maximum of rainfall is seen lying over Gangetic West Bengal, Bihar plateau and east Madhya Pradesh and the axis of the rainbelt is oriented NW-SE. The minimum over Sri Lanka extended eastwards into SW Bay of Bengal. The southern hemisphere maximum remained more or less along the same latitudinal belt, but the maximum in the east Indian Ocean (off Sumatra islands) increased further in magnitude (> 400 mm).

3.1.4. During the month of July and August, in the mean charts, a maximum of rainfall (>400 mm) is seen near the foothills of eastern Himalayas extending into Arunachal Pradesh. This maximum in the mean has the highest contribution from the corresponding months in 1987. Since this was a year of large-scale deficiency in rainfall throughout the country and the foothills received good rainfall as break conditions persisted for a long time.

3.1.5. The pattern for the month of September reflects the withdrawal of the monsoon from the country. The 100 mm isopleth shifted SE-wards in conjunction with the other isopleths. There is a decrease of rainfall in general over the country. The Bay maximum shifted further SE-wards. Maximum rainfall is now located over Indonesia with the axis of heavy rainfall extending NW-wards into the west central Bay. The southern hemisphere maximum rainbelt has shifted slightly NW-wards with increase in magnitude of the maximum (> 400 mm) and is located roughly along 2°-3° S. Minimum rainfall is still located over Sri Lanka.

During all these months except in June, western Arabian Sea remained as a rainless area.

3.2. *Anomalies of rainfall*

Monsoon season of 1987 is characterised by large deficiency of rainfall over most parts of India resulting in unprecedented drought over almost the entire country, while the 1988 monsoon is at the other extreme with normal/above normal rainfall over the entire country. Monsoon season of 1986 falls in between these two extremes. With a view to bringing out this fact, anomalies of rainfall from the 3-yr mean during each month are computed for the three years individually and are discussed below :

3.2.1. In Fig. 2, rainfall anomalies for the year 1986 are presented.

3.2.1.1. The onset of monsoon was delayed by about 4 days over Kerala. Its advance continued more or less in a normal pace except over Gujarat & west Rajasthan. This resulted by and large in normal rainfall over many sub-divisions of the country in this month. The rainfall is marginally excess over east Arabian Sea, east M.P. and adjoining areas and over central Bay. Rainfall is deficient over most of the Indian Ocean.

3.2.1.2. In July, August & September, rainfall is deficient over most parts of the country. The excess rainfall over Rajasthan in July, resulted in unprecedented floods over that region. Rainfall has been excess throughout the season over most parts of Bay of Bengal while over Arabian Sea, it is deficient except in June.

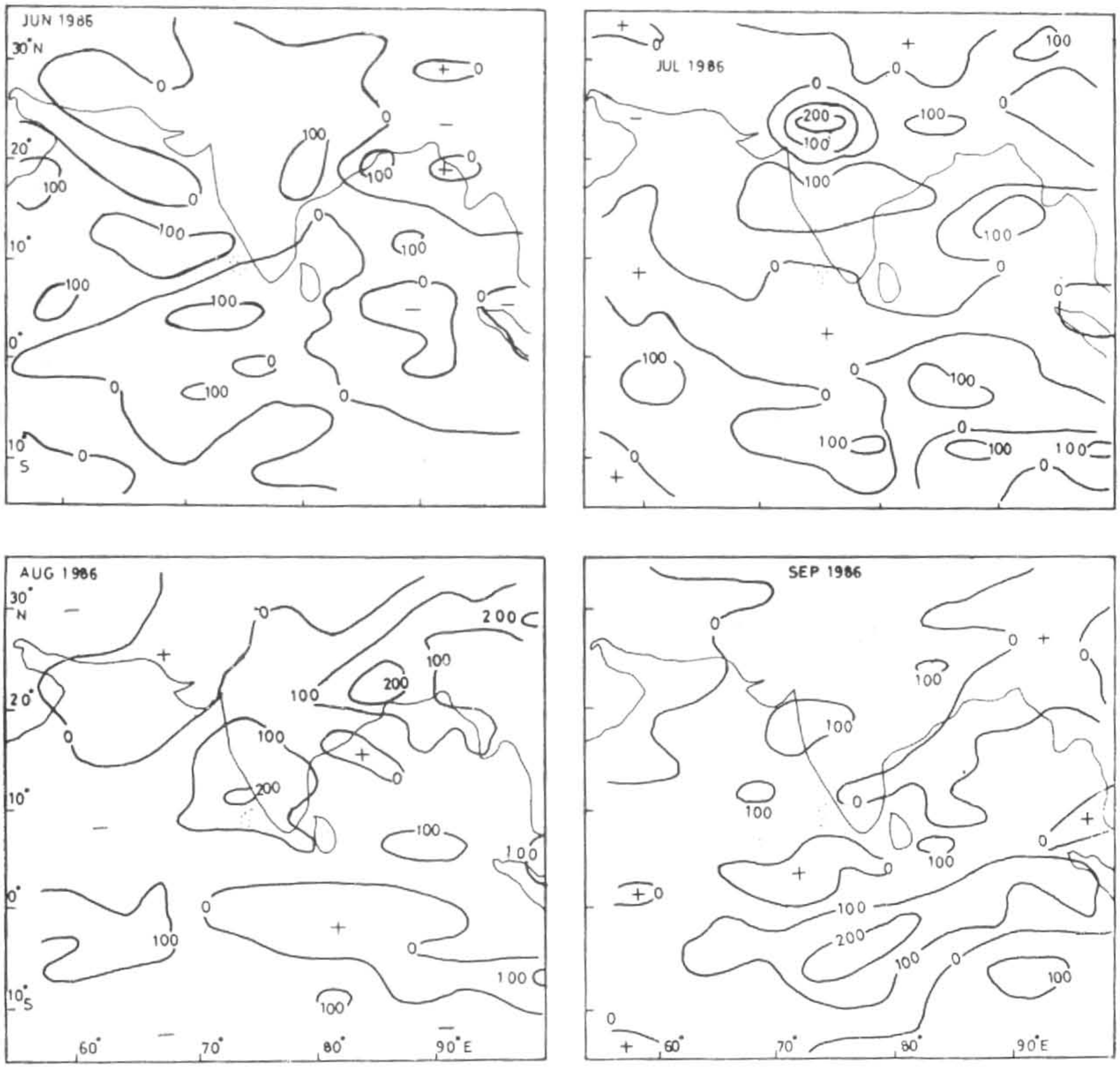

Fig. 2. Deviations from the 3 yr mean of rainfall for the year 1986. Units : mm

Rainfall has been marginally excess over Indian Ocean. south of equator during July and August except in isolated regions where it is deficient. A large belt of negative anomaly extended from Indonesia to 60° E in an E-W direction between equator and 10° S.

3.2.2. Fig. 3 depicts the rainfall anomalies for the monsoon season of 1987.

3.2.2.1. Though the onset of monsoon was quite normal, its northward progress has not been normal. In June there are two pockets of deficient rainfall over north Orissa and adjoining regions of M.P. and parts of east U.P. and the other over S.E. Arabian Sea. In general, the rainfall is deficient over whole of India north of 15° N. It is excess over Bay of Bengal and Indian Ocean.

3.2.2.2. In July there is a belt of negative anomaly over most of the country except over east and north-eastern parts of the country (Orissa, Bihar, W.B. and Assam). This deficient rainbelt extended eastwards up to Burma through central and southern Bay of Bengal. The rainfall is excess over the eastern parts of Indian Ocean. This large scale negative anomaly, in July, is indicative of the unprecedented drought conditions in the country.

3.2.2.3. Though major parts of the country experienced deficient rainfall in August 1987 also, the deficiency is less compared to July 1987. Positive anomaly over the Arabian Sea extending into Rajasthan is an interesting feature. Large parts of Bay of Bengal excessive rainfall during this month, as against deficient rainfall in July, indicating that the Bay branch of the

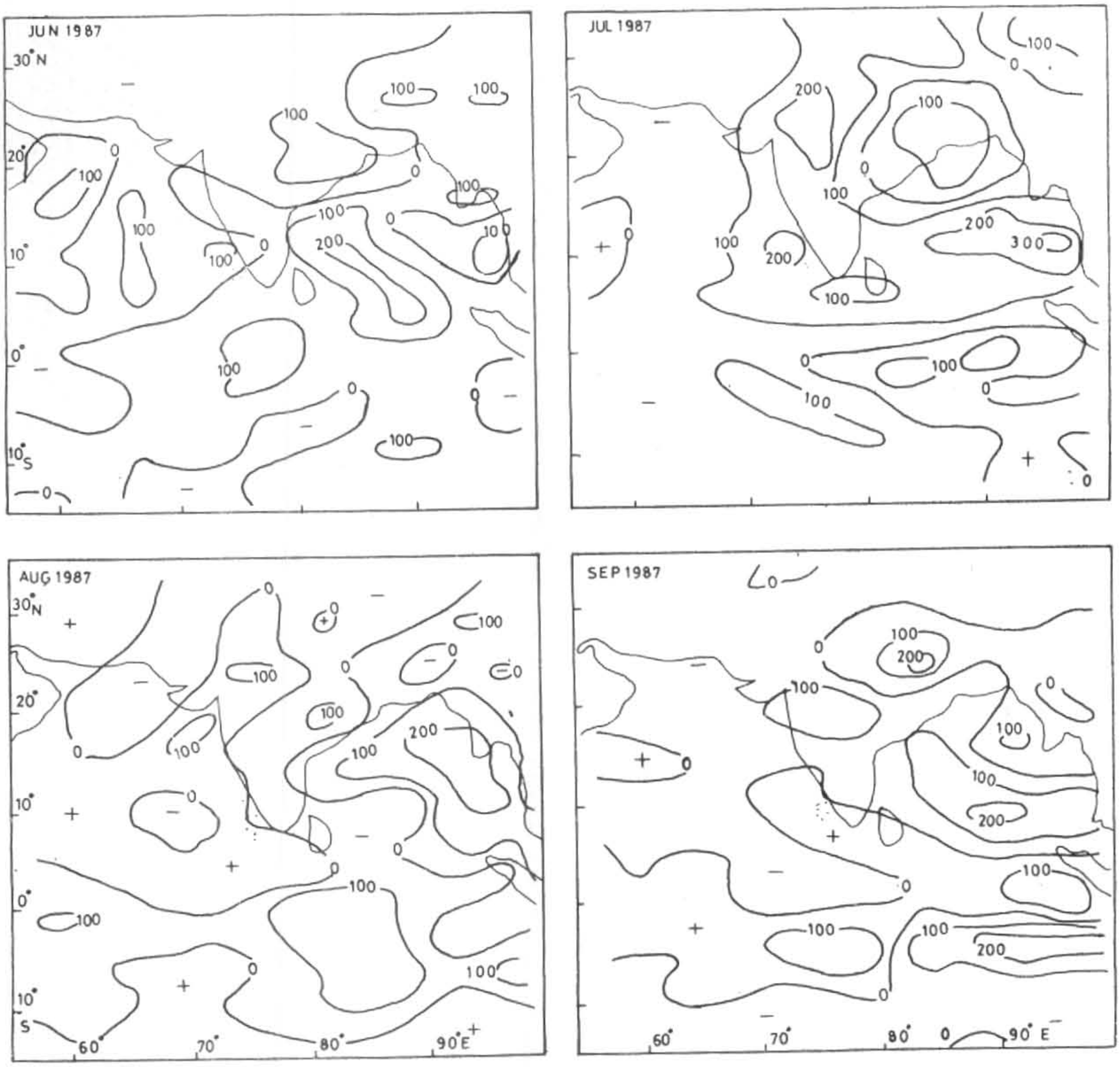

Fig. 3. Same as Fig. 2 except for the year 1987

monsoon is very active and is confined to the oceanic areas only. Indian Ocean between equator and 10° S experienced deficient rainfall.

3.2.2.4. Major portion of the country and Bay of Bengal experienced rainfall deficiency in September also. Positive anomalies are confined to the region north of 25° N. Over the Indian Ocean the rainfall is deficient east of 80° E.

3.2.3. Fig. 4 shows the anomalies of rainfall during 1988. This year is in clear contrast with 1987. Over most of the country including the adjoining oceanic areas, rainfall is more than the 3-year mean, except in June and August where the negative anomalies can be seen over Bay of Bengal. But in July positive anomalies prevailed over large parts of the country and adjoining oceanic areas. This is an year of good monsoon.

4. Summary

4.1. The mean rainfall maps of the monsoon season derived from satellite estimates bring out the following features :

(1) There is a heavy rainfall belt, the axis of which runs from east Arabian Sea to east central Bay of Bengal throughout the season and another belt of heavy rain in the southern hemisphere close to the equator approximately coinciding with SHET. Both the belts seem to have originated from a common source further to the east.

(2) The rainfall pattern shifts SE-ward as the season advances and the maxima in the Bay & Arabian Sea decrease in magnitude while the southern hemisphere rainfall increases.

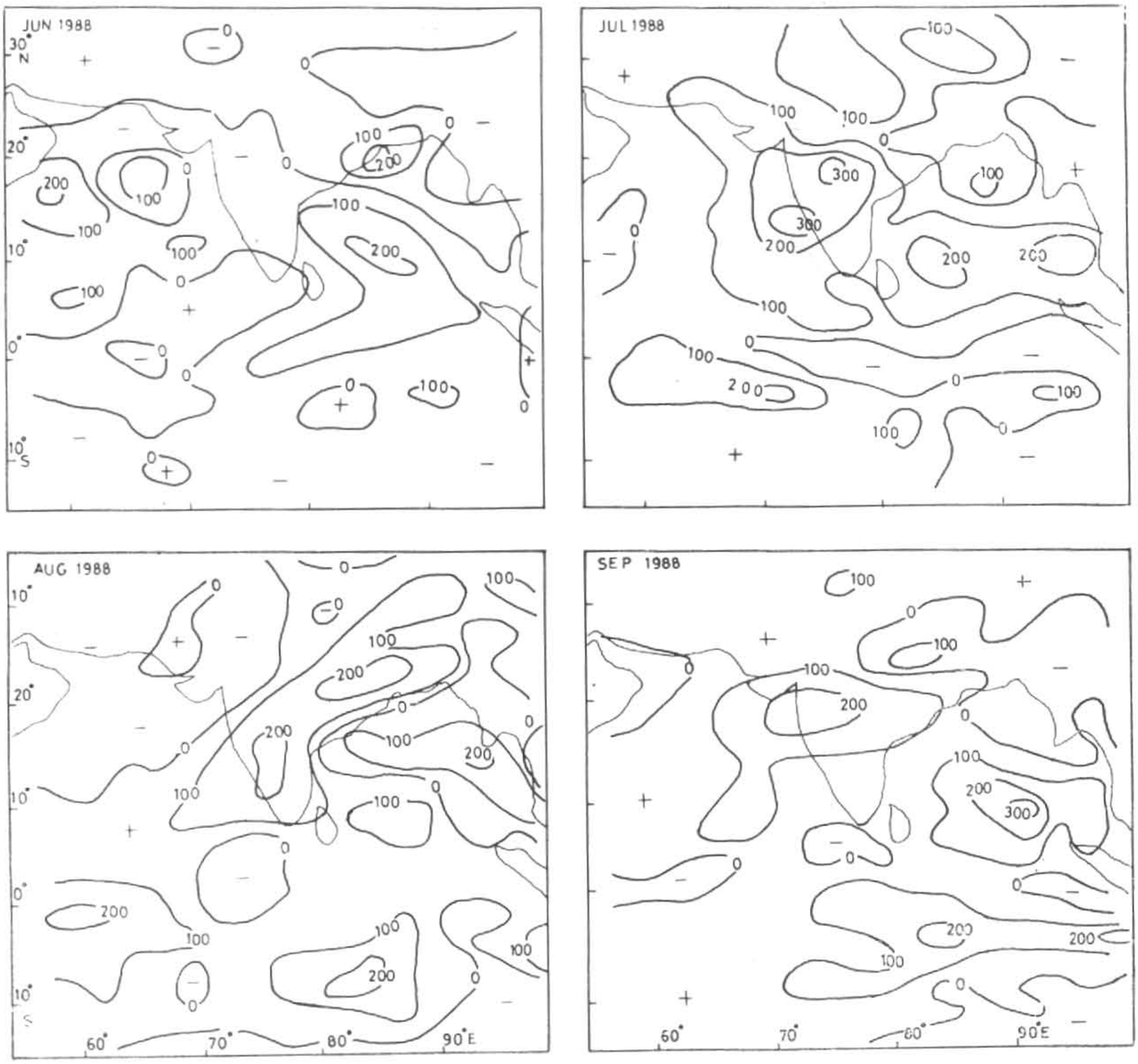

Fig. 4. Same as Fig. 2 except for the year 1988

(3) There is an area of minimum rainfall throughout the season over Sri Lanka and adjoining SE Peninsula.

(4) Western Arabian Sea is a rainless area after the monsoon onset is complete.

4.2. Monthly anomaly patterns in each year bring out large scale deficiencies in rainfall over the country in 1987 and large scale surplus of rainfall during the monsoon of 1988, while monsoon of 1986 is a case in between these two extremes.

Acknowledgements

The authors acknowledge the help received from Dr.V.Rajeshwara Rao in retrieving the data and from Smt. Jasvinder Bawa in typing the manuscript.

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