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Role of southern hemispheric equatorial trough in medium range forecasting

ONKARI PRASAD*, A. A. RAMA SASTRY, A. K. HANSDA and U. S. DE

Meteorological Office, Pune

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सार — वर्तमान शोधपत्र में भारतीय ग्रीष्मकालीन मानसून के दौरान दक्षिण गोलार्द्ध-भूमध्यरेखीय द्रोणी के ऊपर मेघाच्छन्नता में विविधता का परीक्षण दिया गया है तथा इसमें भारतीय प्रायद्वीप पर मानसून सक्रियता के पूर्वाभास में इसकी महत्ता दर्शाई गई है।

मध्यावधि पूर्वानुमान के लिए प्राग्वक्ता के रूप में लगभग पिछले चालीस दिवसीय बहुलक और उसकी क्षमताओं और सीमाओं का भी अध्ययन किया गया है। यह दिखाया गया है कि भारतीय प्रायद्वीप के निश्चित भागों में, ग्रीष्मकालीन मानसून ऋतु के दौरान दक्षिण गोलार्द्ध-भूमध्यरेखीय द्रोणी मेघाच्छन्नता का निरन्तर प्रबोधन (मॉनीटरन) से वर्षा का मध्यावधि पूर्वानुमान लगाने के लिए उपयोगी मार्गदर्शन मिल सकता है।

ABSTRACT. The present investigation examines the variations in the cloudiness over the southern hemispheric equatorial trough during the Indian summer monsoon *vis-a-vis* its importance in foreshadowing the monsoon activity over the Indian sub-continent.

The near forty-day mode and its potentialities and limitations as a predictor for medium range forecasting are also examined. It has been shown that a continuous monitoring of the SHET cloudiness during the summer monsoon season could be a useful guide for medium range forecasting of rainfall over certain parts of the Indian sub-continent.

1. Introduction

Medium range weather forecasting, covering a period of 3 to 10 days, has received the attention of scientists during the last three decades. This is mainly because of its use in agricultural operations and water management. Medium range forecasting of rainfall has now assumed special significance in India in view of the development of various crop varieties with considerably reduced crop duration. The yield from such crops, to a great extent, depends on the occurrence of rains at appropriate phases of the plant growth. Planned irrigation scheduling is possible only if medium range forecasts of dry and wet spells are available in time.

The evolution of monsoon circulation, particularly the slowly moving ones, help to indicate the areas of activity as well as the trend in weather over different parts. The evolution of such circulation patterns has been studied by Pant (1981, 1983) using Monsoon-77 and Monex-79 data over the Indian sub-continent. He has shown the role of oscillation of the 700 mb trough and the corresponding changes in the meridional flow pattern in the development of different phases of summer monsoon. The formation of a trough in the south Bay of Bengal has been noted by him as an important feature of a weak monsoon circulation. This trough persists for about a week. The increased rainfall over the southern Peninsula during a weak phase of summer monsoon is attributed to the formation/movement of low pressure systems in this trough zone.

Studies of satellite observed cloudiness by Yasunari (1981) and Sikka and Gadgil (1980) have shown a near 40-day cycle during summer monsoon season over the Indian sub-continent. A maximum cloud zone which develops near the equator moves to 30°N at the rate of about 1° Lat. per day. However, the period of this low-frequency oscillation has been found to vary from 30 to 50 days becoming as long as 60 days in a drought year like 1972. A periodicity of 15-day has been reported by Krishnamurti and Bhalme (1976). Phase-locking between these two modes and monsoon activity over India has been reported by Krishnamurti *et al.* (1985) using FGGE data. This interesting feature of summer monsoon circulation needs further investigation using data for a number of years covering different types of monsoon activity. 15 and 40-day periodicities were sought to explain the active/break cycle in summer monsoon. But, the climatology of break situations as presented by Ramamurti (1969) does not show any clear cut periodicity in the occurrence of 'break' in summer monsoon.

In an earlier study of the satellite observed cloud distribution over the Indian Ocean during the southwest monsoon season, Prasad *et al.* (1983) have shown that

*Present address : Meteorological Office, New Delhi.

there exists an inverse relationship between the cloudiness in the southern hemispheric equatorial trough (SHET) zone (equator to 10° S, over Indian Ocean) and the rainfall activity over central India. Earlier investigations by Prasad (1982) have confirmed the important role of SHET in the southwest monsoon activity over India. Intense convection in the zone of SHET results in weak monsoon conditions over India. When the SHET is close to equator and weak and allowing large cross-equatorial flow of air to the north of equator, the summer monsoon is active. SHET serves to regulate the air flow from the southern hemisphere. Changes in the intensity of SHET may lead to the development of different phases of the summer monsoon. This aspect of the summer monsoon curculation appears to be promising for development of medium range rainfall forecasts in India. One of the aims of the present investigation is to examine the significance of this relationship.

Above mentioned results have often been used in recent years to explain the variability in summer monsoon rainfall. This paper examines the scope of utilising the role of (*i*) inter connection between SHET and the summer monsoon activity and (*ii*) near 40-day mode in cloudiness for medium range forecasting of summer monsoon rainfall over India. The cloud and rainfall data for three characteristic summer monsoon seasons namely (1) a drought year (1979), (2) a year of normal to excess rainfall (1983) and (3) a year of near normal rainfall (1984) have been studied. As per the practice in the India Meteorological Department, rainfall is considered to be normal when its departure is ± 19 per cent of the normal, it is considered excess when departure is + 20 per cent or more; when the departure ranges between—20% &—59% rainfall is considered as deficient and rainfall less than—60% of the normal is referred to as scanty. During a drought year a large number of meteorological subdivisions receive scanty or deficient rainfall.

2. Data used and method of analysis

Estimates of the daily percentage cloud cover have been obtained for 5° Lat. and 5° Long. blocks covering the areas bounded by Longs. 40° E and 100° E and Lats. 20° S and 30° N. In obtaining the cloud cover data, the blocks having cloudiness less than 20 per cent have been counted as cloud free. These data have been used to obtain the weekly mean cloud cover. Weekly mean cloudiness was obtained for those weeks only where daily data was available for more than five days. Visible cloud imagery alone has been used for obtaining cloud cover data. Environmental cloud imagery published by NOAA were utilised for the years 1979 and 1983 for this purpose. With the availability of INSAT-1B cloud imagery, 06 GMT full disc visible pictures have been used for the year 1984. Weekly cloud cover data over the region under consideration has been analysed. The time-longitude cross-section of weekly mean cloudiness has been prepared for three latitude belts, *viz.*, (*i*) 10° S to equator, (*ii*) equator to 15°N and (*iii*) 15°N to 30°N. Weekly rainfall departures for the following belts over the Indian sub-continent : (*i*) from the southernmost part of India to 10° N, (*ii*) 10°N to 15°N, (*iii*) 15°N to 20°N, (*iv*) 20°N to 25° N and (*v*) 25°N to 30°N, were taken from the data set utilised by Rama Sastry *et al.* (1986). Areal coverage

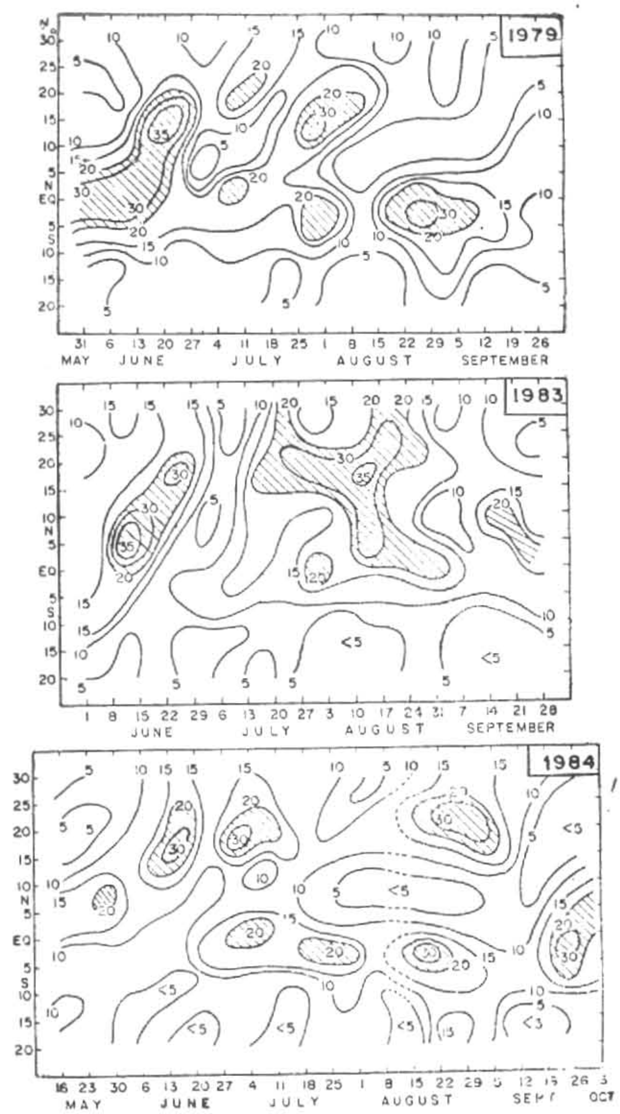

Fig. 1. Weekly mean cloudiness, in per cent, in different latitude belts over the region bounded by longitudes 40° E and 100° E

of weekly mean cloudiness in the latitude belt, equator to 10°S, is plotted against the weekly departure of rainfall in each of the 5° Lat. belts over India.

3. Discussion

3.1. *Weekly mean cloudiness*

Fig. 1 shows the weekly mean cloudiness (WMC) in 5° latitude belts. WMC ranges from zero to 40 per cent. Accordingly, we have taken 20 per cent as the dividing line between a spell of increased cloudiness (SIC) (cloudiness 20 per cent or more, hatched area) and a spell of decreased cloudiness (SDC) (cloudiness less than 20 per cent). Cloudiness is described below in terms of spells of increased cloudiness (SICs) and spells of decreased cloudiness (SDCs). SDCs are described only to the north of 10° S as the cloudiness is generally less than 20 per cent to the south of this latitude. Similarly SDCs are described to the north of equator only after the first SIC has already reached the belt 15°-20°N, or further north.

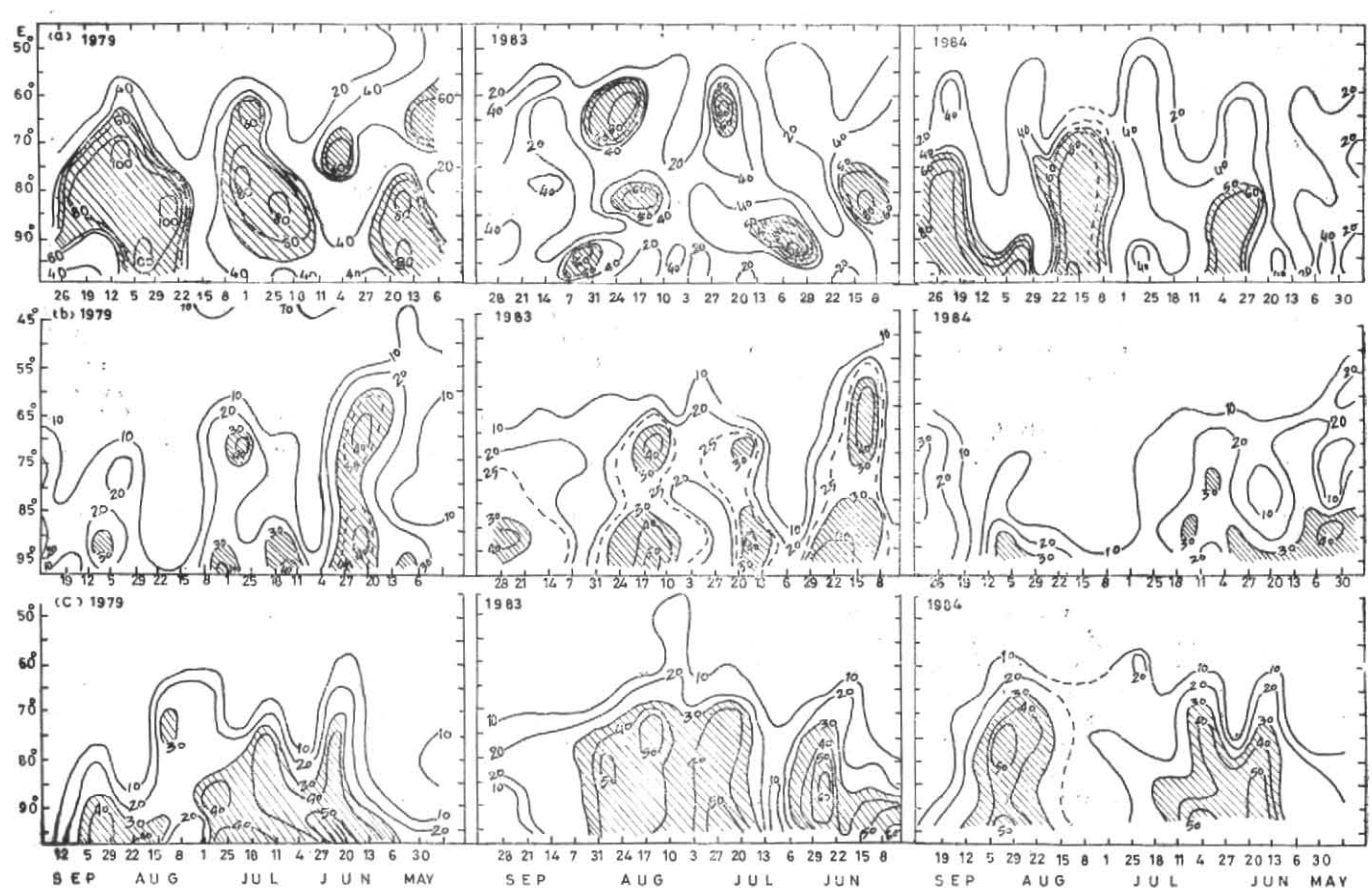

Fig. 3. Time-longitude cross-section of the weekly mean cloudiness, in per cent, in the latitude belts : (a) equator to 10°S, (b) equator to 15°N and (c) 15°-20°N

Two northernmost belts, *i.e.*, 20°-25°N and 25°-30°N have also shown a general inverse relationship between cloudiness in the zone of SHET and rainfall in these belts. However, there are periods when this relationship does not hold good, *e.g.*, from the week ending 22 August to week ending 19 September 1984 in the belts, 20°-25°N, from the week ending 8 August to week ending 22 August 1979 in the belt, 25°-30°N. Large positive rainfall departures as seen in the year 1983 in the belts up to 20°N are not prominently seen in the two northernmost belts. Some more details of cloud distribution are discussed in the following sections.

3.3. *Time longitude cross-section of weekly mean cloudiness*

Fig. 3 shows the time longitude cross-section of weekly mean cloudiness in the latitude belts, equator-10° S [Fig. 3(a)], equator-15°N [(Fig. 3 (b)] and 15°-20°N [Fig. 3(c)]. Weekly mean cloudiness is found to vary from zero to 100 per cent in the belt equator-10°S. In order to demarcate the SICs, spells having cloudiness 50 per cent or more have been hatched in Fig. 3(a). Similarly, spells having cloudiness 30 per cent or more have been hatched in Figs. 3(b) and 3(c) as the cloudiness in the belts equator to 15°N and 15°-20°N have varied from zero to 60 per cent.

In the year 1979, the belt equator-10°S, witnessed three SICs of duration three weeks or more. In all the three SICs the longitude strips to the west of 70°E were almost cloud-free and the increase in cloudiness was confined to the east of 70° E only. Increase in cloudiness is seen to spread from the easternmost longitude strip towards west. In the year 1983, the SICs did not persist for three or four weeks as was the case in 1979. In this year the SICs were generally confined to the east of 75°E. However, three SICs also occurred in the longitude strips between 55° and 70°E. In the year 1984, there were three SICs after 20 June. These were confined to the east of 75°E only. The year witnessed two intervening SDCs also. Westward propagation of cloudiness on the time scale of weeks is not clearly seen in this year.

The latitude belt equator-15°N witnessed SIC of duration 1-2 weeks during the year 1979. They were confined to the east of 85°E. However, one such spell first commenced in the longitude strip between 65°E and 75°E in the week ending on 13 June and, thereafter, in the next week it was seen from 60°E to 100°E. Two isolated SICs lasting for one week each also occurred in the longitude strips 70°-75°E and 75°-80°E in the weeks ending 25 July and 29 August respectively. SICs in the year 1983 in this belt occurred more or less in the same fashion as in 1979. The first such spell was more marked in the strips between 60°E and 75°E. Two such isolated spells occurred in the strips 70°-75°E and 75°-80°E and other spells remained confined to the east of 85°E only. The year 1984 showed altogether a different picture in the sense that there was no prominent SIC in this latitude belt west of 90°E. Two SICs of duration 3 weeks or more remained confined to the east of 90°E only.

In the belt, between 15° & 20°N during the year 1979 there were two SICs commencing in the weeks ending on 27 June and 25 July respectively. Both these spells showed westward propagation. In 1983 also there were two SICs commencing in the weeks ending 8 June and 27 July. However, unlike 1979, the general cloudiness in the belt 15°-20°N, was high in the year 1983. Interestingly as per the inverse relationship, the overall cloudiness in SHET was very much suppressed in this year. In 1984, features similar to the year 1979 were seen with propagation of SICs westward. However, the activity continued in September also which was not so during 1979.

Cloudiness in the remaining two northern belts, *i.e.*, 20°-25°N and 25°-30°N, in the years studied showed features similar to those observed in the belts, 15°-20° N, but the pattern was considerably influenced by the *in situ* development of synoptic scale systems along the monsoon trough and their westward movement with time. The year 1983, showed a distinct feature of alternate spells of increased and decreased cloudiness from the equator to all the northern belts except in the belt 15°-20°N, where abnormally high cloudiness prevailed from the week ending on 20 July till the end of the season. The duration of the SDCs is around two weeks only. During an year of weak or undeveloped SHET the period of the oscillation in cloudiness (SIC & SDC) reduces to nearly bi-weekly mode.

4. Conclusion

(*i*) The near forty-day mode appears to have year to year variability on period mainly due to the spasmodic northward progression. During the onset phase it is seen somewhat clearly and regularly.

(*ii*) After the initial onset a spell of increased cloudiness, SIC, may occur (a) either north of the equator and propagate northward with variable speed and duration or (b) south of the equator and propagate northward with variable extent and speed, (c) the northward extent of the propagation and the time required for reaching the maximum northern limit for the SICs is uncertain. The above factors limit the use of the forty-day mode as a tool for MRF.

(*iii*) There appears to be a significant westward propagation of SICs in the latitude belt 15° to 30°N and to some extent between equator and 10°S also. This factor causes interference with the northward propagating mode which depends upon the phase of these two disturbances.

(*iv*) The inverse relationship between cloudiness in SHET and rainfall in the belts 10°-15°N and 15°-20°N over the Indian sub-continent appears promising in foreshadowing the rain spells with a lead time of 2 to 3 days. However, for the belts north of 20°N the contribution of synoptic scale systems developing north of 15°N becomes equally important.

(*v*) The SICs in SHET are mainly confined to zones east of 70°E to 75°E. It will, therefore, suffice if cloud distribution in this belt is considered from 60°E to 100°E only.

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