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The 500 hPa sub-tropical anticyclone during April and May 1988 and the weather over India

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सार — अप्रैल में 500 एच पी ए पर उपोष्ण कटक में सिनॉप्टिक पैमाने पर पर्याप्त उतार चढ़ाव रहा है। अप्रैल 1988 में इसमें भूमध्य रेखा की ओर स्थायी दक्षिणवर्ती विस्थापन देखा गया। मई 1988 में इतर कटिबंधीय चलने वाली उत्तर-पश्चिमी शुष्क हवाओं के प्रतिचक्रवाती प्रतिवर्तन से उत्तरी अक्षांओं में एक नया उपोष्ण प्रतिचक्रवात बना दक्षिण की ओर बढ़ने पर उत्तरी हवाओं ने बड़े पैमाने पर उपोष्ण कटक (एस.टी.आर.) के दक्षिण में शुष्क दौर प्रारंभ किया। यह घटना भूमध्यरेखीय मौसम क्षेत्र और एस. टी. आर. की सामान्य उत्तराभिमुखी प्रगति के विपरीत है। इसलिये माध्य अप्रैल 500 एच पी ए कटक भारत के ऊपर दक्षिण-पश्चिम मानसून वर्षा के दीर्घ अवधि पूर्वानुमान के लिये तर्कसंगत प्राचल उपलब्ध नहीं कराता है।

ABSTRACT. The sub-tropical ridge at 500 hPa in April has a considerable synoptic scale fluctuation. In April 1988, it showed a steady southward displacement to the equator. In May 1988, a fresh sub-tropical anticyclone formed in northern latitudes by the anticyclonic recurving of the dry northwesterlies of extra-tropical origin. By extending southward the northerlies ushered a dry spell extensively to the south of the sub-tropical ridge (STR). This was an event contrary to the normal northward progress of equatorial weather belt and the STR. Thus the mean April 500 hPa ridge does not provide a logical parameter for long range forecasting of the southwest (SW) monsoon rainfall over India.

Key words — 500 hPa ridge, Indian weather, Mean April, May position, Monsoon rainfall.

1. Introduction

The position of 500 hPa sub-tropical anticyclone (STA) during April, particularly the 500 hPa mean April sub-tropical ridge (STR) has gained prominence with the work of Banerjee *et al.* (1978) in which they associated its position along 75°E, with the subsequent monsoon rainfall (June to September) over India. According to them the years, when the STR at 500 hPa in April is poleward of the normal position (14.25°N), have a good monsoon rainfall distribution while the years, when this ridge is equatorward of the normal position have poor monsoon rainfall. They developed a regression equation with using data for a period of 21 years (1950-1970). Using this equation they computed the total rainfall for the earlier eleven years (1939-1949) and the later five years (1971-1975) and found that the average deviation of these, from the actual values was 6 per cent. This was quite an encouraging finding with some explicit scientific reasoning compared to the previous techniques in ues (Jagannathan 1974). Later, it has been used in India Met. Dep. as an important input parameter in the DST (Dynamic Stochastic Transfer) model to forecast the SW monsoon rainfall about a month ahead of the season, for the peninsular and northwest India (Thapliyal 1982). Several other scientists working on the problem of long-range forecasting of SW monsoon rainfall have also confirmed its efficacy (Mooley *et al.* 1986).

Now, the sub-tropical anticyclone is an important feature of the general circulation with tropical easterlies to its south and extra-tropical westerlies to its north. Its position and displacement to north and south is controlled by tropical and extra-tropical circulations both on synoptic as well as seasonal scale (Ranjit Singh 1987, 1988). With this background, an attempt is made to study its behaviour during April and May 1988. Some new results obtained are presented in this study.

2. Data used

Weekly mean and anomaly wind charts (with week ending on Wednesday), for different levels (850, 700, 500, 300 & 200 hPa) prepared in the Office of the DDGM (WF) Pune were studied. Of these the 500 hPa charts were found the most representative. The results obtained were further scrutinized with the help of daily charts.

3. The mean weekly circulation at 500 hPa during April 1988

The mean wind charts of 500 hPa for the weeks ending on 5, 12, 19 and 26 April 1988 are shown in Fig. 1. In the first week ending on 5 April the Arabian Sea STA extends over the Bay of Bengal and the STR intersects Long. 75°E along 17.25°N. In the week ending on 12 April, it is the Bay of Bengal STA cell which extends over the Arabian Sea and the STR intersects the Long. 75°E along 15°N. In the third week ending on 19 April, two STA cells are observed one each over the Bay of Bengal and the Arabian Sea with STR intersecting Long. 75°E along 15.5°N. An equatorial eastwest trough with axis along 10°N and embedded cyclonic circulations off Kerala and Tamil Nadu coasts lies to the south of STA. In the fourth week ending on 26 April, the mid-latitude westerlies extend southward and the STA cell is displaced equatorward over the Arabian Sea.

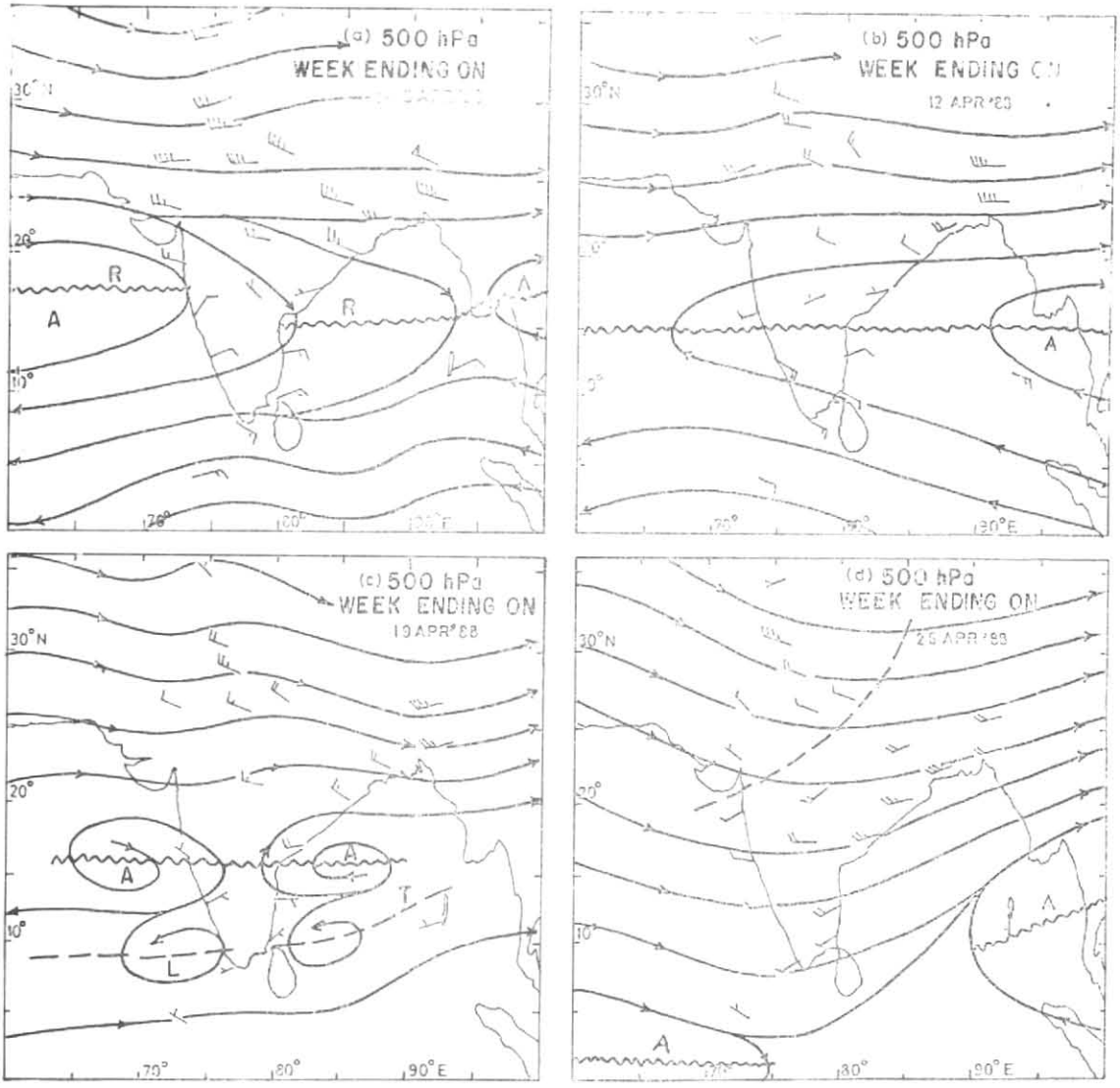

Fig. 1. Weekly mean charts for April 1988

The STR intersects the Long. 75°E approximately along 1°N. Thus the STA, though a very steady feature of the general circulation, has a very high synoptic variability with respect to its shape and position of STR. In April 1988, it showed a persistent equatorward displacement.

4. The mean weekly circulation at 500 hPa during May 1988

The study was continued for May 1988 as well (Fig. 2). The STA begins to move northward over the Arabian Sea. The mean STR for the week ending on 3 May intersects the Long. 75°E along 11°N. The extra-tropical westerlies extend equatorward covering the entire Bay of Bengal. In the week ending on 10 May, strong mid-latitude northwesterlies appear over north India and they extend up to Port Blair in the Bay of Bengal. A STA cell appears suddenly in the northern latitudes of the Arabian Sea, with STR intersecting Long. 75°E along 22°N. A pair of equatorial trough and ridge is located to its south. The equatorial trough appears to have formed between the STA of last week and the new STA in the northerly latitude of this week. The formation mechanism of the northerly cell will be discussed on a synoptic scale in the next section. In the next two weeks ending on 17 and 24 May, the northern cell is displaced southward with STR meeting Long. 75°E along 21°N and 17°N respectively. With the disappearance of southern cell, this becomes the main STA with equatorial trough to its south. The equatorial trough begins its seasonal northward propagation in the week ending on 31 May. With this the STA also shows a northward movement meeting the Long. 75°E along 25°N. The monsoon advances northward along Kerala and Karnataka coast with effect from 2 June.

5. Synoptic scale development of a 500 hPa sub-tropical anticyclone

In sections 3 and 4 we have seen that the north and southward displacement of the STR at 500 hPa about its normal position is basically a synoptic feature modified by the (*i*) equatorward extension of extra-tropical westerlies, when the STR is displaced southward,

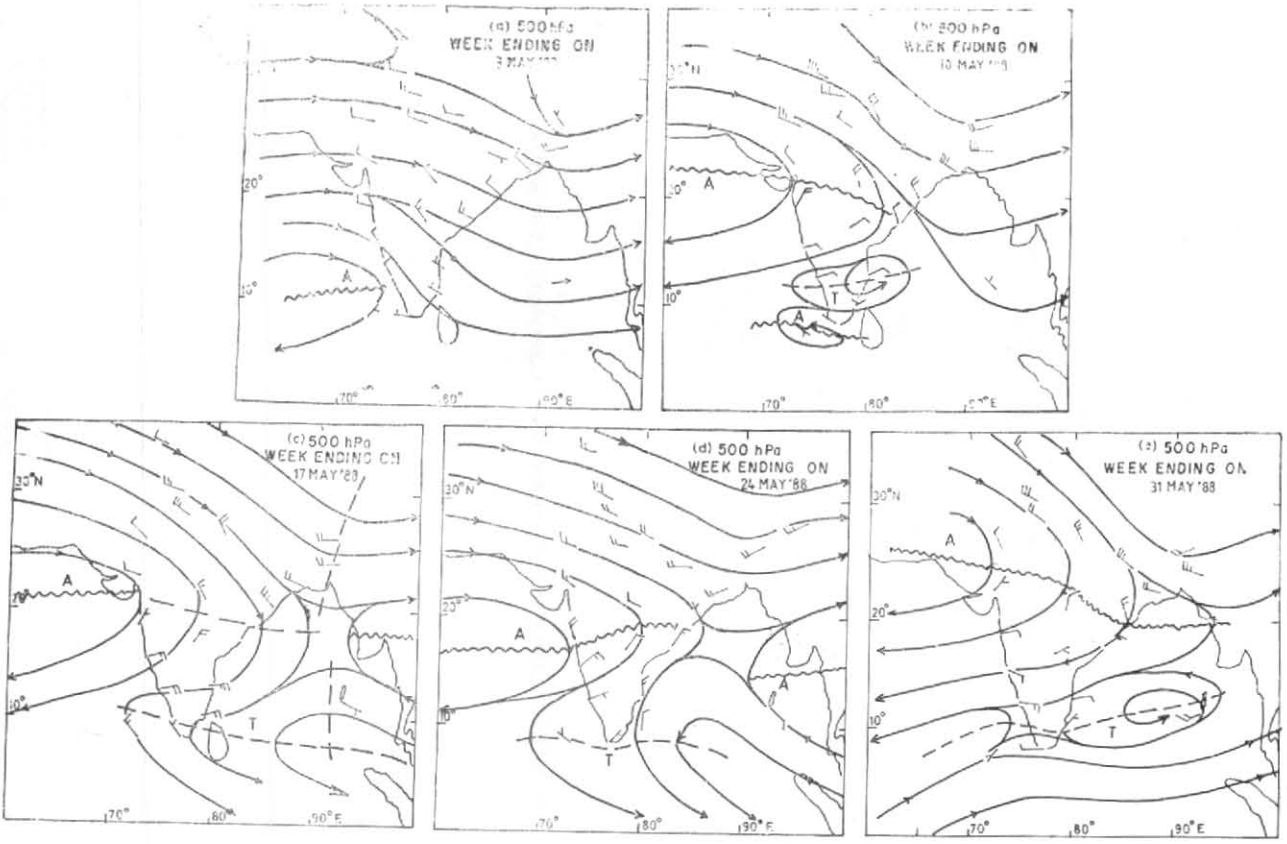

Fig. 2. Weekly mean charts for May 1988

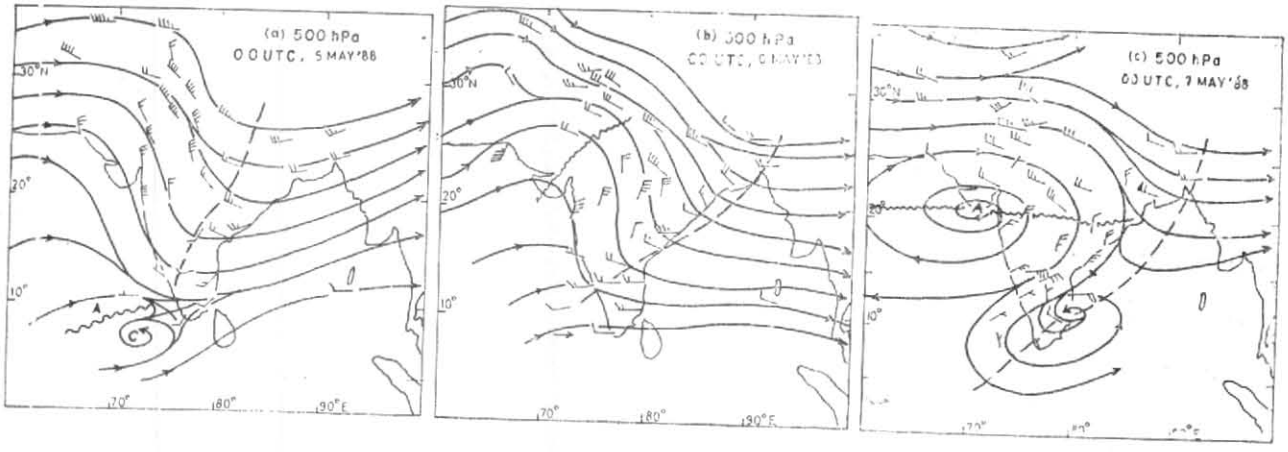

Fig. 3. Development of sub-tropical anticyclone from the northerlies

(*ii*) equatorial convection and its northward propagation, when the STA is displaced northward alongwith the Hadley cell circulation. In this section the development of a STA from the recurving of extra-tropical westerlies is discussed.

In Fig. 3 on 00 UTC of 5 May, STA cell in the Arabian Sea is located off Kerala coast with a cyclonic circulation to its south. We get the first indication for veering of the winds over Gujarat and development of an anticyclonic cell on 12 UTC of 5 May. A full STA cell forms over the Arabian Sea, on 00 UTC of 7 May with STR intersecting Long. 75°E along 21°N. A cyclonic circulation is observed to it south off Tamil Nadu coast. The formation of a STA in the northerly latitudes following this mechanism brings the extra-tropical dry winds which by their equatorward extension cause a temporary clearing of the weather over the region swept by them. This effect is reverse to the effect of northerly displacement of the STA by the northward propagation of the equatorial trough when a weather belt moves northward. Thus the efficacy of 500 hPa STR parameter for long-range forecasting can be questioned on two accounts, (*i*) it has a great synoptic variability, (*ii*) its northerly position gives no guarantee

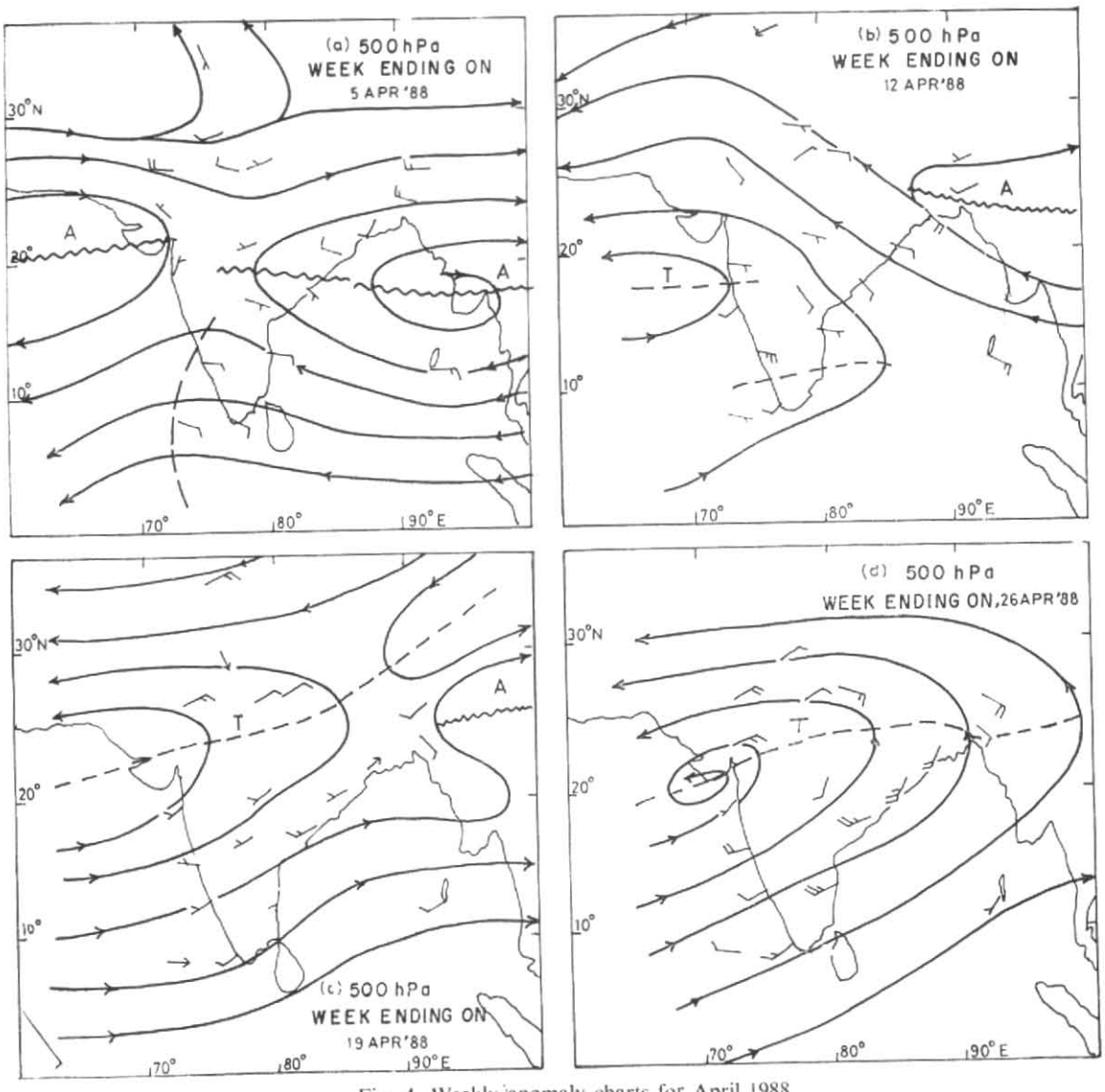

Fig. 4. Weekly anomaly charts for April 1988

that the equatorial trough has propagated northward. It is very likely that STA might have formed from the anticyclonic recurving of extra-tropical northwesterlies; in which case the equatorial trough is displaced southward by the northerly dry current.

In 1988, this happened on two occasions : (1) SW monsoon was advanced into the Bay islands on 10 May. However, as can be seen even from the mean weekly 500 hPa chart of 10 May, the dry northwesterly current advanced southward around the STA, up to the latitude of Port Blair. As a result it stopped raining over Port Blair the same day (10 May). (2) Similarly SW monsoon was advanced along Kerala coast on 26 May. However, dry northwesterlies extended southward and rains stopped along Kerala coast the same day (26 May). The monsoon current began its actual northward progress in the Bay of Bengal on 17 May and in the Arabian Sea along the Kerala coast on 2 June.

6. South-north-oscillation in April and May 1988

While discussing the general circulation and the south-north-oscillation over Indian region during MONEX-1979, it was shown by this author that westerlies in the lower troposphere and easterlies in the middle and upper troposphere made up the circulation over equatorial zone and this advances northward between May and July and remains as the main monsoon circulation over India. Embedded in this circulation, a sequence of east-west trough and ridge pairs propagate from the equator to the Tibetan Plateau at 500 hPa and this forms a south-north-oscillation (SNO) of 36-42 day period (Ranjit Singh 1987). The northward propagation of such east-west troughs and ridges were demonstrated by Alexander *et al.* 1978 on the wind anomaly charts of 850, 700 and 500 hPa and Krishnamurti and Subramanayan (1982) at 850 hPa. In Figs. 4 & 5 we present the weekly wind anomaly charts of 500 hPa level for April and May 1988 and compare them with the corresponding weekly rainfall charts (Fig. 6); only normal ($+19\%$ to -19%) and excess (20% or more) rainfall is shown on the rainfall charts. An east-west equatorial trough is observed to form in the week

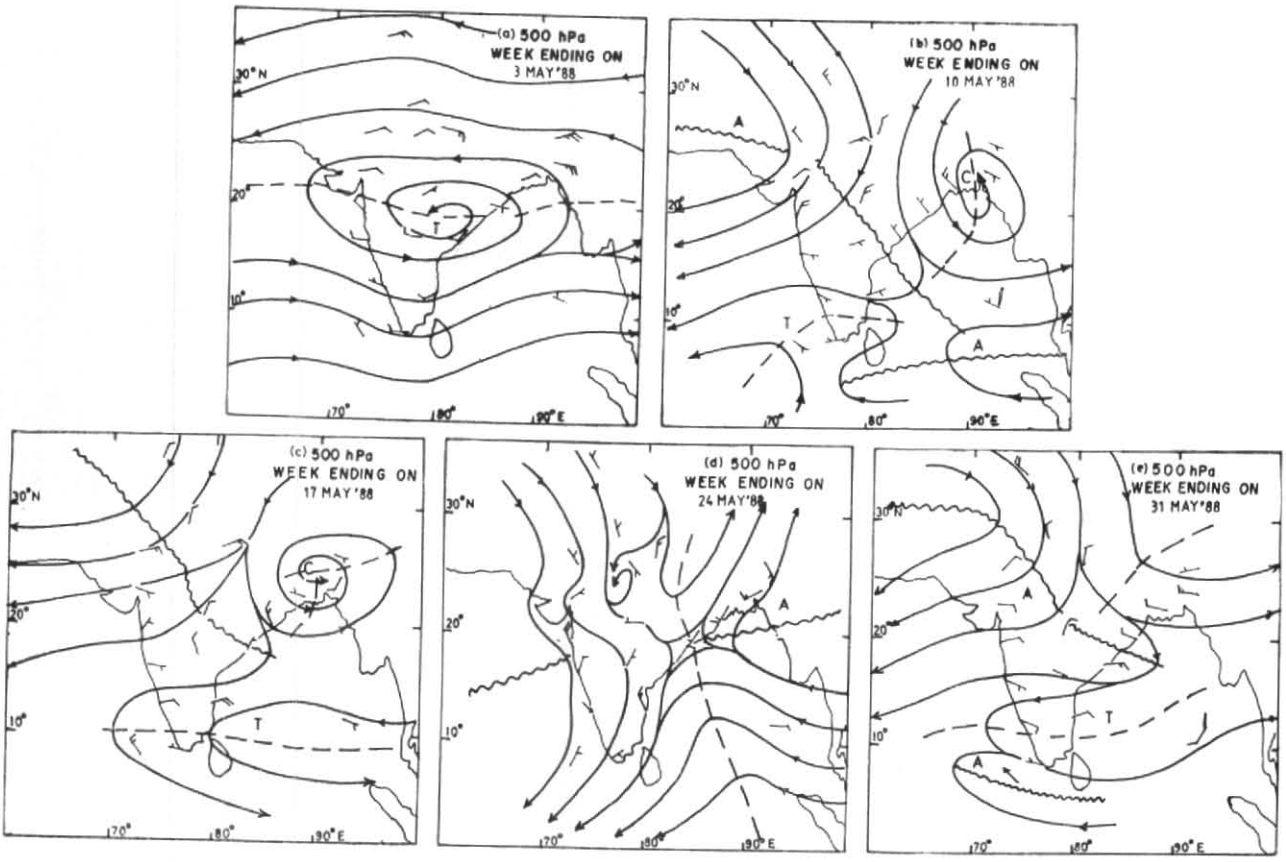

Fig. 5. Weekly anomaly charts for May 1988

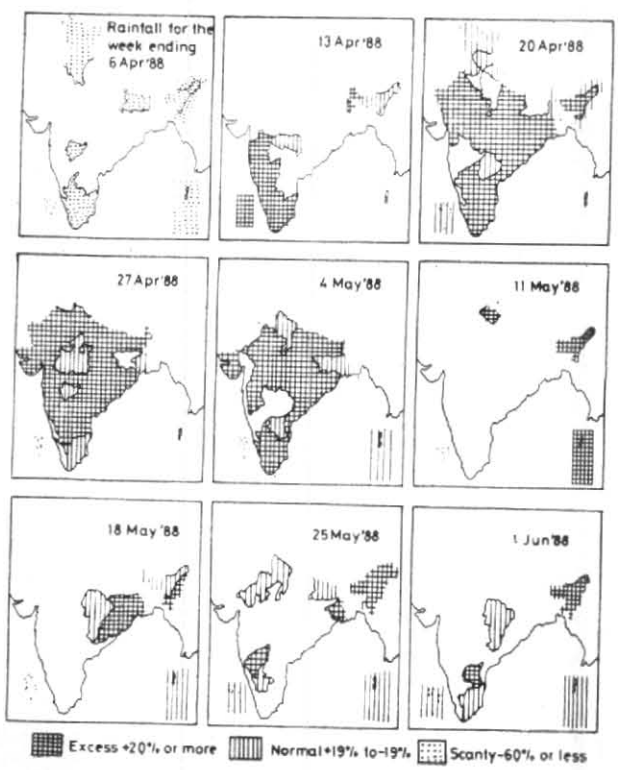

Fig. 6. Weekly rainfall charts

ending on 12 April and propagate northward in the next two weeks. It is displaced southward in the week ending on 3 May. In the week ending on 10 May, this trough appears to have been driven away northeastward. A sub-tropical anticyclone forms over northwest India by the recurving of dry northwesterlies and its ridge extends from northwest to southeast up to the latitude of Port Blair. On the weekly rainfall charts also, the rainfall belt is seen to extend northward between week ending on 13 April and week ending on 27 April. This is slightly displaced southward in the week ending on 4 May. Then dry weather sweeps over India, except the northeast sub-division of Assam & Meghalaya, in the week ending on 11 May. The new east-west equatorial trough begins to organise subsequently and begins it northward progress in the week ending on 31 May. Thus the SNO could be identified in the wind anomaly, cloud and rainfall fields in April and May 1988.

7. Discussion and conclusion

In April 1988, the 500 hPa STR was found to have consistently moved equatorward from its weekly mean position of 17.5°N in the first week to 1°N in the 4th week. This coincided with good rain over India. In May a new STA developed from the anticyclonic recurving of the extra-tropical westerlies with STR along 22.5°N. This STR also showed a southward displacement with dry extra-tropical winds sweeping

around, which led to dry spell over most of the country. The April event occurred from the northward propagation of and equatorial trough in wind anomaly and cloud field which resulted in the weakening of the main STA cells over India. On the mean weekly charts we saw the merging of extra-tropical and the equatorial westerlies and hence the extreme southward displacement of the STR to 1°N. In May we saw southward extension of the extra-tropical dry current by recurving around the STA.

In Table 1 of Gowariker *et al.* (1989), the position of the April 500 hPa ridge after 1975, has been reported unfavourable in 1977, 1978, 1980, 1983, 1984, 1985 and 1988. However, the rainfall has been normal or above normal in all these years. It has been reported favourable in 1987. However, India witnessed one of the worst droughts in this year. Therefore, this parameter has not given a correct long-range forecast in 8 years out of 13 years.

In normal coniditions the STA cells intensify under the subsiding motions of the Hadley cell when the equatorial convections intensifies, and are steadily displaced northward with the northward propagation of the equatorial trough. Only this aspect appears to have been considered while developing it as an LRF parameter, hence, the deficiency of the parameter to give a correct long-range forecast in all these years.

The 500 hPa level, which divides the atmospheric mass into two nearly equal halves is generally considered to be the level of non-divergence and is the lowest atmospheric level for which data is available over the Tibetan Plateau (average height 4.5 km). The heating of Tibetan Plateau during summer forms an important driving mechanism for the monsoon circulation over India. During SW monsoon the equatorial trough and ridge pairs are observed to propagate from equator to Tibetan Plateau forming the SNO at 500 hPa. During April and May 1988 again, the northward propagation of the equatorial troughs in the wind anomalies give the best results at 500 hPa level when compared with cloud and rainfall belts. During October and November also, the interaction between the tropical and extra-tropical weather systems are identified more clearly at 500 hPa level (Ranjit Singh 1990). The 500 hPa level is, therefore, the most appropriate level for use in the synoptic, medium and intraseasonal range forecasts. It appears to lose or have a limited validity in the long-range forecast of SW monsoon rainfall (covering 4 months) made during May.

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