*Mausam*, (1991), **42**, 2, 155-160

551.557.2 : 551.511.13

# Upper air circulation and thermal anomalies over India and neighbourhood *vis-a-vis* Indian summer monsoon activity

M. RAJEEVAN

*Meteorological Centre, Ahmedabad*

(*Received 6 December 1989*)

**सार** — भारत और उसके पड़ोसी देशों के ऊपर लिए गए 20 वर्षों के उपरितन पवन आंकड़ों के द्वारा भारत में सूखे और बाढ़ से संबंधित त्रीविमीय परिसंचरण एवं तापीय विसंगतियों की जांच की गयी। विश्लेषण के द्वारा ज्ञात हुआ कि इन वर्षों में भारत में सूखा (बाढ़) पश्चिमोत्तर भारत के ऊपरी क्षोभ मंडल में 200 एवं 500 हेक्टोपास्कल के बीच होने वाले चक्रवात (प्रतिचक्रवात) परिसंचरण विसंगतियों तथा ठंडा (गर्म) तापीय विसंगतियों के कारण था। सूखा (बाढ़) के वर्षों में ऊपरी क्षोभमंडलीय पश्चिमाभिमुख (पूर्वीय) पवन विसंगतियों मई और जून माह में निम्न अक्षांश में पायी गयी हैं। सूख के वर्षों में माह जून के दौरान तिब्बतीय प्रतिचक्रवात अपने सामान्य स्थिति से पूरब की ओर हट गया है। पश्चिमोत्तर भारत में पवन का अनुरेखांशीय अवयव 200 हेक्टोपास्कल तथा भारतीय ग्रीष्मकालीन मानसून वर्षा के बीच परस्पर गुणांक — 0.72 पाया गया जो सार्थक है।

ABSTRACT. The three dimensional circulation and thermal anomaly features associated with droughts and floods over India are examined using 20 years of upper wind data over India and neighbourhood. The analysis reveals that years of droughts (floods) in India are associated with cyclonic (anticyclonic) circulation anomalies and cold (warm) thermal anomalies in the troposphere between 500 hPa and 200 hPa over northwestern India. In drought years (flood years) upper tropospheric westerly (easterly) anomalies are observed in the lower latitudes in the months of May and June. Tibetan anticyclone is shifted to east of its normal position in drought years during the month of June. The correlation coefficient between the meridional component of the wind at 200 hPa over northwestern India and the summer monsoon rainfall is found to be — 0.72 which is significant.

**Key words** — Floods and droughts, monsoon, upper air circulation, variability.

## 1. Introduction

The interannual variation of Indian summer monsoon rainfall has a profound influence on socio-economic activities in India. Many parts of India receive 75-90% of annual rainfall during the summer months of June to September. The interannual variability of the monsoon is related to interaction between the land, the oceans and the atmosphere.

The purpose of the present paper is to examine the three dimensional circulation and thermal anomaly features over India and neighbourhood associated with the extremes of Indian summer monsoon rainfall.

All India summer monsoon rainfall has been estimated by weighting each station rainfall by the area of the district in which the station is located. Hilly regions of India with high spatial variability of rainfall and sparse raingauge network are not included in the averaging. For more details refer to Shukla and Mooley (1987).

In the present paper a deficient (drought) year is defined as the year in which the normalized deviate (deviation from normal/standard deviation) of all India summer monsoon rainfall is less than — 0.7 and excess (flood) year as the year in which the normalized deviate is more than 0.7. Therefore, during the period 1961-1980 there were six drought years (1965, 1966, 1968, 1972, 1974 and 1979) and six flood years (1961 1964, 1970, 1973, 1975 and 1978). Due to lack of sufficient data the features of the year 1961 are not studied.

In section 2 data used and method adopted are described. In section 3 results are discussed and in final section 4 conclusions are drawn.

## 2. Data and method of study

Data used for the computation of circulation and thermal anomalies are the monthly mean vector winds at 850, 500 and 200 hPa surfaces derived from the magnetic tape of Rawinsonde data supplied by Roy. L. Jenne, Data support section, National Center for Atmospheric Research, U.S.A. These data were quality controlled and digitized by National Center for Atmospheric Research. The major source of data in this tape were monthly reports provided by WMO stations and that were published in the "*Monthly Climatic Data for the World*". Thermal patterns are studied by calculating vector wind shear between 200, 500 and 850 hPa surfaces using thermal wind relationships and not with actual temperature data at this surfaces.

The stations considered along with the years of data prior to 1980 are shown in Fig. 1.

Circulation anomalies at 850 hPa, 500 hPa and 200 hPa surfaces and thermal anomalies of the upper tropospheric layer (200 hPa-500 hPa), middle tropospheric layer (500 hPa-850 hPa) and the whole tropospheric layer (200 hPa-850 hPa) were calculated monthwise from April to June with respect to 5 flood years, *i.e.*, 1964, 1970, 1973, 1975 and 1978 and 6 drought years *i.e.*, 1965, 1966, 1968, 1972, 1974 and 1979. The 20 years mean is subtracted (vectorially) from the calculated mean wind of the particular month and thus the anomaly is calculated. In addition composite anomalies in respect of the 5 flood years and 6 drought years also were calculated and salient features were looked into.

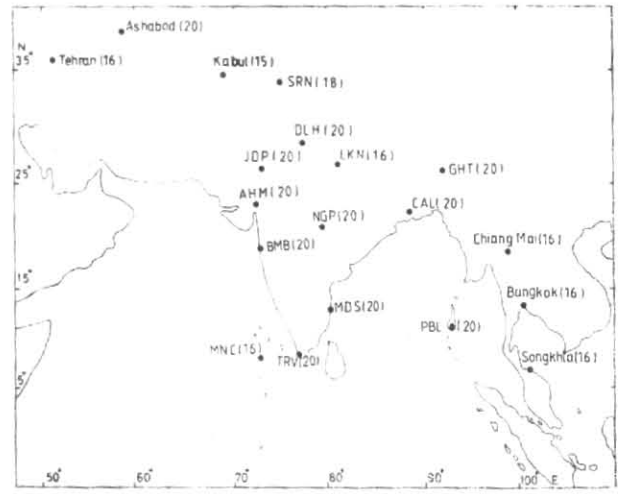
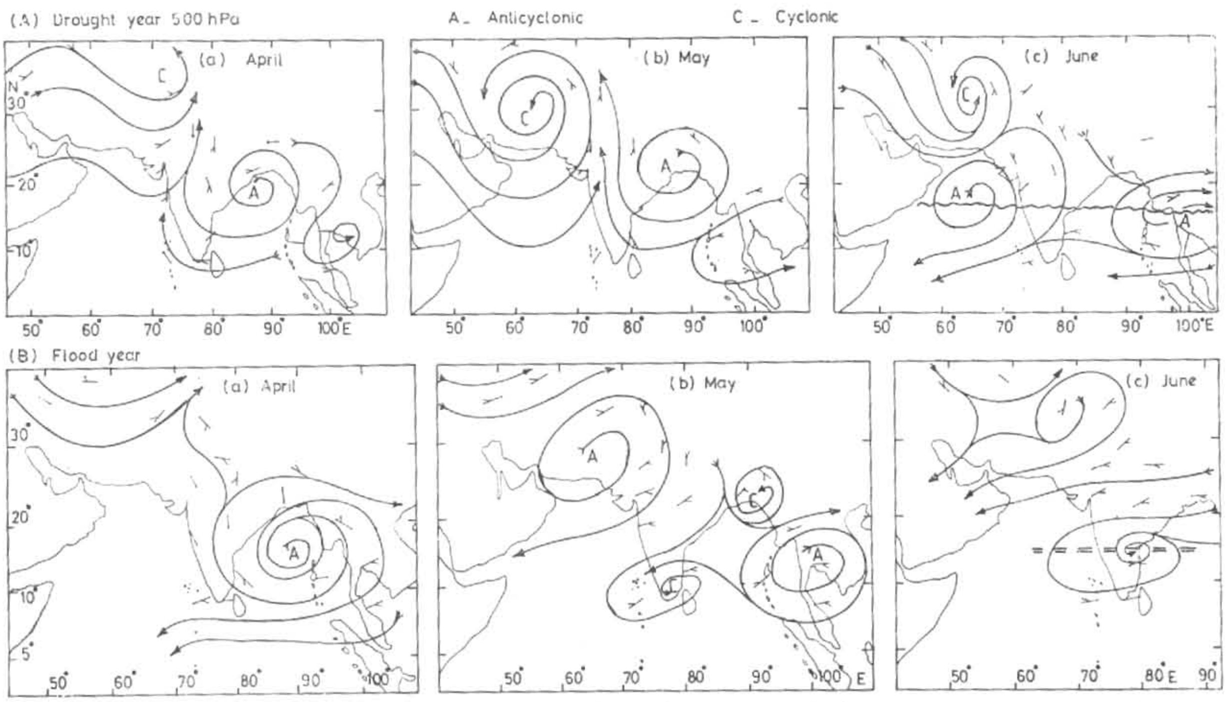



Fig. 1. Stations considered for the study along with the number of years of data used (shown in bracket)

### 3. Results and discussion

#### 3.1. *Circulation anomalies*

Composite anomalies at 850 hPa in respect of drought years and flood years were very small.

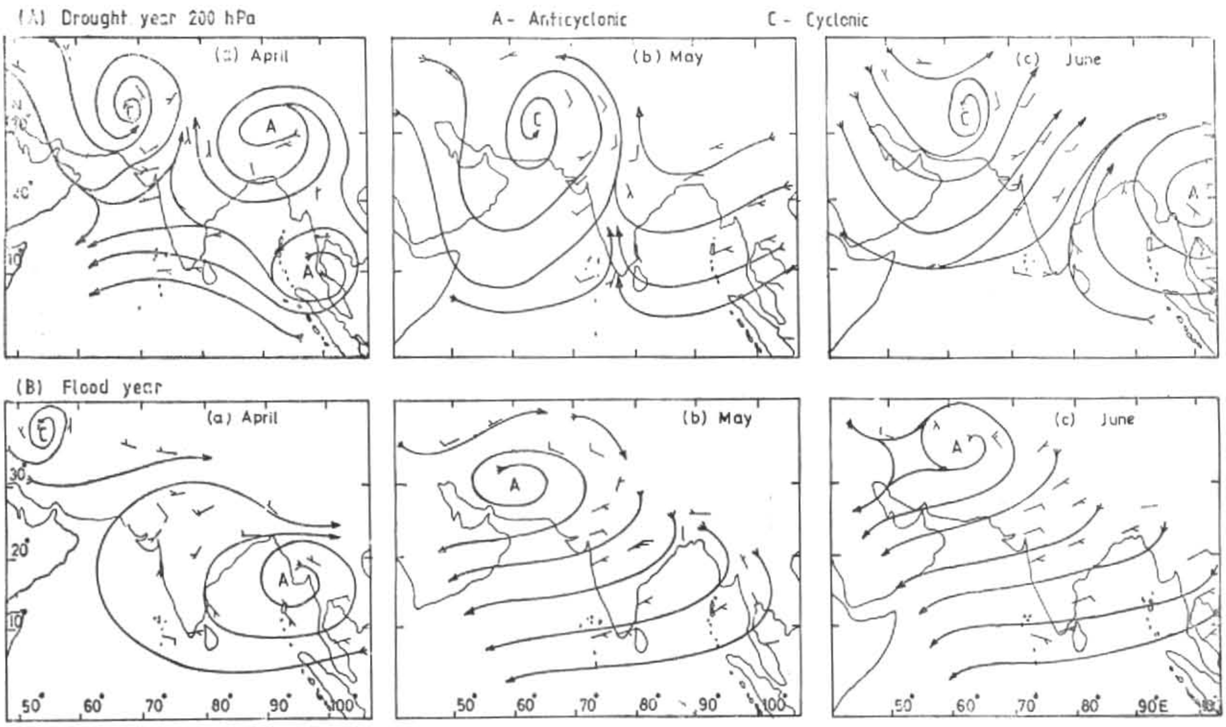



Figs. 2 (A&B). (A) Composite circulation anomalies at 500 hPa for the month of (a) April (b) May and (c) June in respect of drought year & (B) for flood year

Fig 2 (A) shows the composite circulation anomalies at 500 hPa during the months April, May and June in drought years and Fig. 2(B) shows that of flood years.

Fig. 3(A) shows the composite anomaly pattern at 200 hPa during the months of April to June in drought years and Fig. 3(B) shows that of flood years.

Thus it was observed that in drought years during the month of April an anomalous cyclonic circulation developed over northwestern India at middle and upper surfaces, amplitude being larger at upper surface. This anomaly persisted during the months of May and June and was well marked in the later month. The shift of the anticyclonic circulation to east of Burma also was noticed




Figs. 3 (A & B). (A) Composite circulation anomalies at 200 hPa for the month of (a) April (b) May and (c) June in respect of drought years & (B) for flood years

On the other hand in flood years during the month of May an anomalous anticyclonic circulation developed over northwestern India and it persisted in the month of June also.

The position of the anticylone in the drought years in the month of June is to east of its normal position during an active monsoon over India. Such an eastward shift of the divergent circulation was noticed by Keshavamurty *et al.* (1980), Kanamitsu and Krishnamurti (1978) and Krishnamurti *et al.* (1989). Such shift was attributed to the *El Nino* related warm SST anomaly of the central Pacific Ocean and equatorial eastern Indian Ocean. Two of the drought years considered in this study are also *El Nino* years, *i.e.*, 1965 and 1972.

During drought years the equatorial side of the cyclonic circulation which occupies a larger part of India, presumably brings cold dry air from west and north west which may suppress organized convective activity. The westerly anomalies were seen extended up to 8° N in the composite chart of May and June. The westerly anomalies in the lower latitudes were noticed by Joseph (1978) in association with the southward intrusion of westerlies and by Arkin (1982) in the 200 hPa composite wind field corresponding to *El Nino* epochs.

### 3.2. *Thermal anomalies*

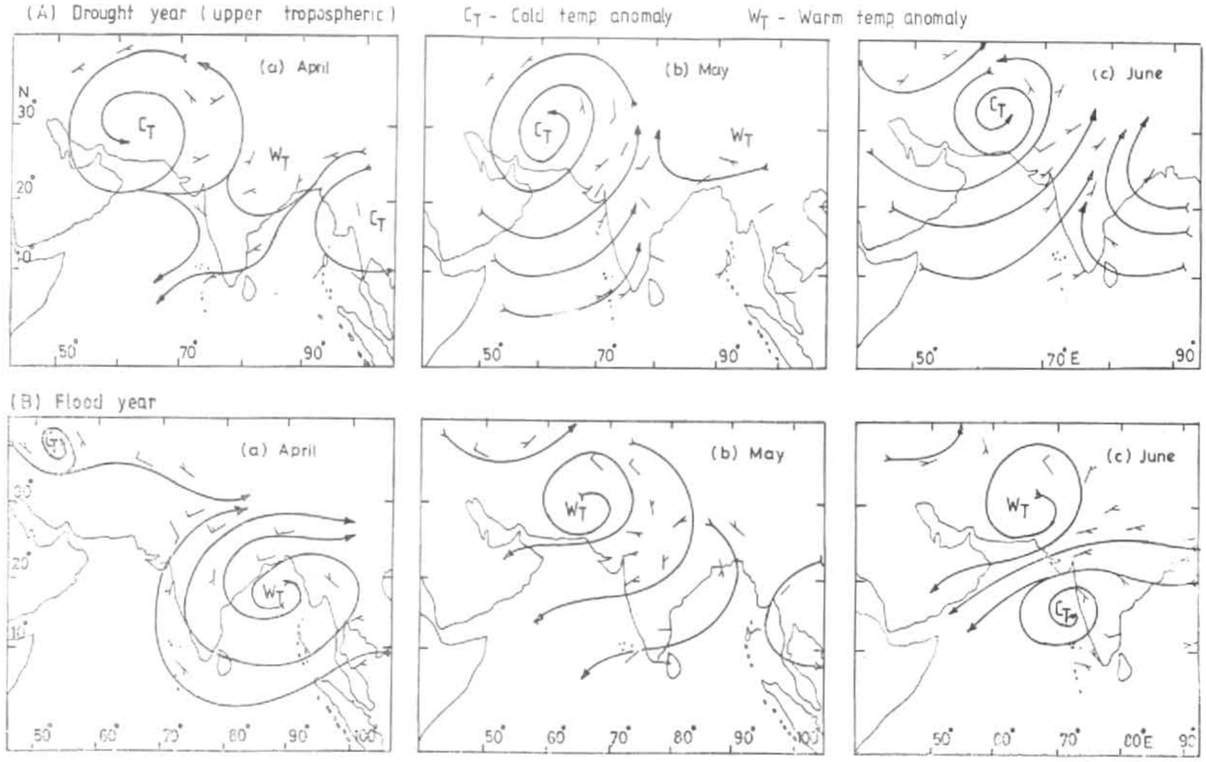
Fig. 4(A) shows the composite anomaly pattern of vector wind shear between 200 hPa and 500 hPa during the months April to June in drought years and Fig. 4(B) shows that of flood years.

In drought years by the month of April cold anomaly was observed over Afghanistan and neighbourhood and by the month of May this cold anomaly extended southeastward and covered a larger area. of summer monsoon. It persisted in the month of June also. On the other hand in flood years during the month of May and June the upper troposphere was warmer. Second and third part of Fig. 4 (B) shows that in flood years warm anomaly persisted over northwestern India during the months of May and June.

In order to see the yearly variation of the thermal pattern over northwestern India, meridional components of the wind shear anomaly between 200 and 500 hPa of Delhi, Jodhpur and Ahmedabad during the months of May were calculated and averaged stationwise for each year 1963-1980, and are shown as the dashed line in Fig. 5. The continuous line shows the averaged meridional component of the wind shear anomaly between 200 hPa and 850 hPa during the month of May. A large positive value of the meridional component means the northwestern India is colder and reverse is true for negative values.

From the Fig. 5, it can be seen that in all drought years the whole troposphere was colder over northwestern India during the month of May. The amplitude of the anomaly was large in 1966, 1972 and 1979. Similarly in all flood years the whole troposphere was warmer. Its amplitude was very small in two flood years 1970 and 1975. In fact in 1975 the upper troposphere was colder and only the middle troposphere was warmer.

This thermal pattern associated with the large scale droughts and floods was reported earlier by Verma (1982). He found that years when cold conditions in the upper troposphere over northwestern India in May persisted through the subsequent monsoon months also the years when summer monsoon rainfall was poor.




Figs. 4 (A & B). (A) Composite upper tropospheric thermal anomalies for the month of (a) April (b) May and (c) June in respect of drought years & (B) for flood years

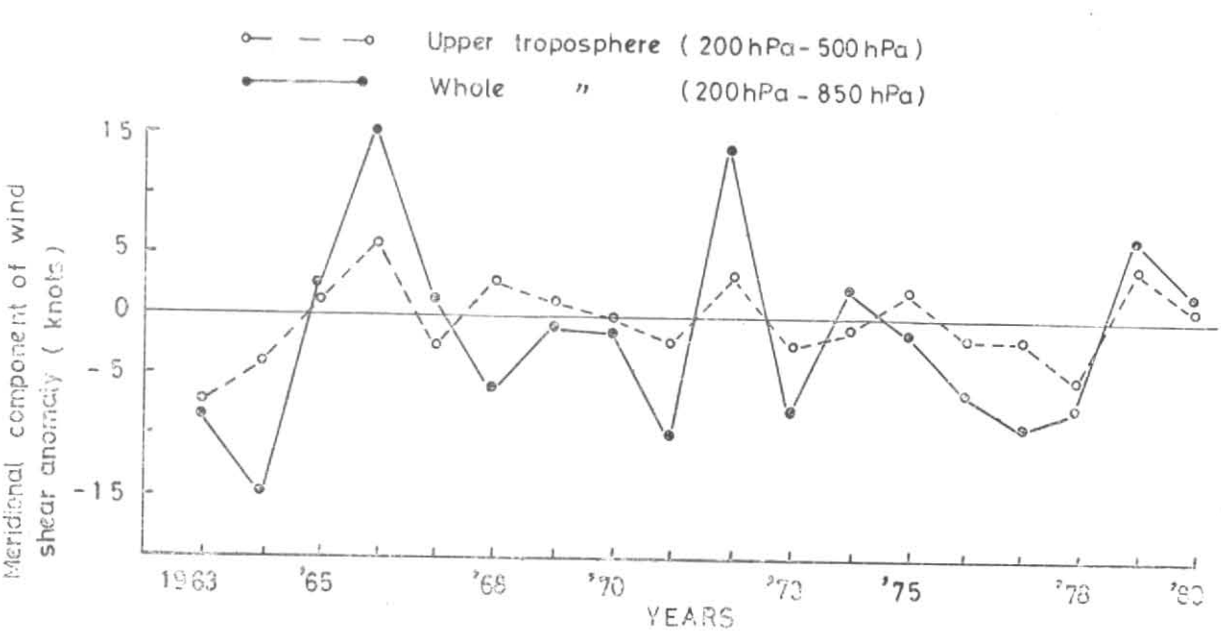



Fig. 5. Time series of meridional index of thermal anomaly of upper troposphere (200 - 500 hPa)and meridional index of thermal anomaly of the whole troposphere (200 - 850 hPa) for the period 1963-1980

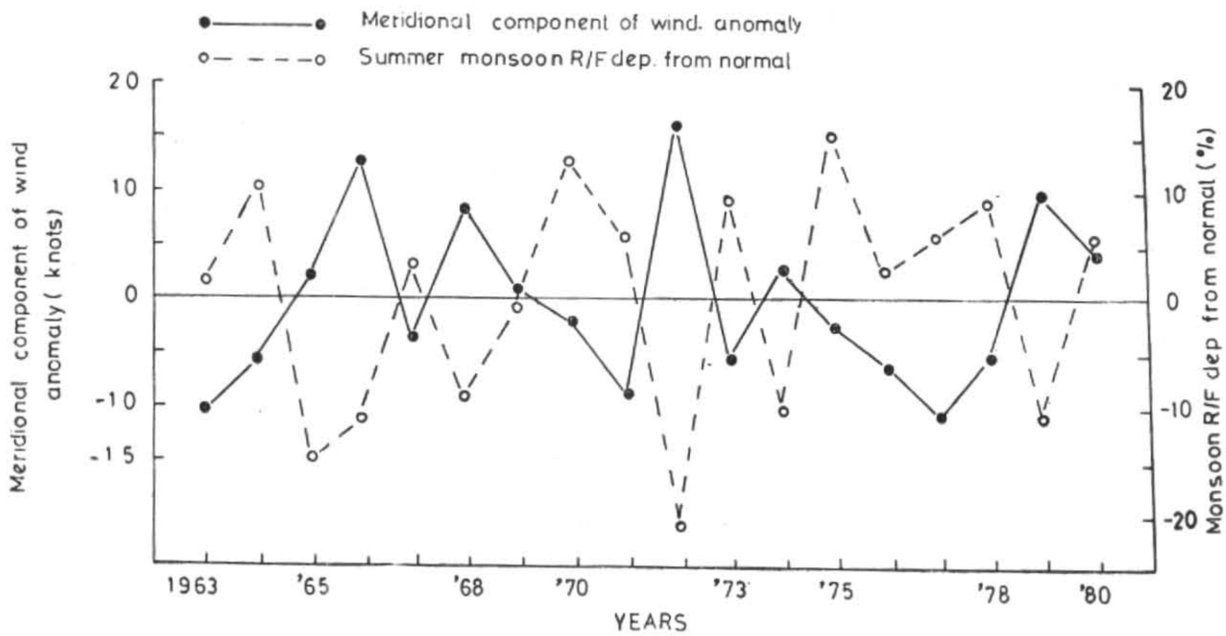



Fig. 6. Time series of meridional component of wind anomaly and summer monsoon rainfall departure from normal for the period 1963-1980

These thermal patterns found in pre-monsoon and early monsoon months may be associated with southward intrusion of sub-tropical trough/ridge system. Such penetration of westerlies to south of Himalayas can occur when the Tibetan anticyclone is shifted to southeastward or eastward during early monsoon months. Note that in third part of Fig. 3(A), anomalous anticyclons was shifted to east of Burma, far to east of its normal position.

Fig. 6 shows the yearly values of the meridional component of the 200 hPa anomaly in the month of May averaged for the stations Ahmedabad, Jodhpur, Delhi and Srinagar. The dashed line shows the monsoon rainfall departure from normal from Shukla and Mooley (1987). It can be seen that in drought years the meridional component was positive and in flood years it was negative. The correlation between the meridional index and Indian summer monsoon rainfall time series was found to be — 0.72, which is significant.

#### 4. Conclusions

From the present study following conclusions can be drawn:

(*i*) In drought years it was observed that an anomalous cyclonic circulation developed over northwestern India at middle (500 hPa) and upper (200 hPa) levels during the month of April. It subsequently persisted and extended to larger area in the later months. Upper tropospheric westerly anomalies were observed in the month of May and June which indicated a weaker easterly jet. It was also observed in drought years that Tibetan anticyclone was shifted to east of its normal position during the month of June.

(*ii*) In flood years an anomalous anticyclonic circulation was observed over northwestern India at middle and upper levels during the months of May and June. Upper tropospheric easterly anomalies were observed over Peninsular India during the months of May and June which indicated a stronger easterly jet.

(*iii*) It was observed that meridional component of upper tropospheric anomalies during the month of May over northwest India was positive (southerly) in drought years and negative (northerly) in flood years. The correlation between the meridional index and Indian summer monsoon rainfall time series is signifiant.

(*iv*) In drought years during the month of April it was observed that the whole troposphere over northwestern India was colder. This cold anomaly persisted in the later months. On the other hand in flood years the whole troposphere was warmer in this region. The amplitude of this anomaly was large in drought years 1966, 1972 and flood years 1973 and 1978. However, the amplitude of this anomaly was weak in 1975.

(*v*) Circulation and thermal anomalies at lower level (850 hPa) were generally weak.

*Acknowledgements*

The author is grateful to Prof. R.N. Keshavamurty, Physical Research Laboratory, Ahmedabad for his guidance and help during the course of the study. Sarvashri S. V. Kasture and V. Krishnakumar of P.R.L. offered help in computation. The author is also thankful to the anonymous referee for his valuable comments.

**References**

Arkin, P.A., 1982, *Mon. Weath. Rev.*, **110**, pp. 1393-1416.

Joseph, P.V., 1978, *Indian J. Met. Hydrol. Geophys.*, **29**, pp. 412-418.

Kanamitsu, M. and Krishnamurti, T.N., 1978, *Mon. Weath. Rev.*, **106**, pp. 331-347.

Keshavamurty, R.N., Satyan, V., Dash, S.K. and Sinha, H.S.S., 1980, *Proc. Indian Acad. Sci.*, **89**, pp. 209-214.

Krishnamurti, T.N., Bedi, H.S. and Subramaniam, M., 1989, *J. Climate*, **2**, pp. 321-340.

Shukla, J. and Mooley, D.A., 1987, *Mon. Weath. Rev.*, **115**, p. 695.

Verma, R.K., 1982, *Mausam*, **33**, 1, pp. 35-44.