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Long range forecast of the onset of the monsoon

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सार — 75° पू० देशांतर के साथ-साथ 8° उत्तर से 55° उत्तर अक्षांश तक 200 मि०बार स्तर के लिय क्रास सैक्शन चार्ट का, भूमध्य रेखा से 55° उत्तर अक्षांश तथा 20° से 100° पूर्व तक 850 से 100 मि० बार के लिये सभी मानक स्तरों हेतु दो परस्पर विरोधी वर्षों (1971-72) के अप्रैल और मई मास के मासिक औसत स्थिर दाब चार्टों का अध्ययन किया गया। 1971 में दक्षिण-पश्चिम मानसून देश क अधिकांश भागों में नियत सामान्य तिथि से 7 से 10 दिन पहले ही आ गया था, जबकि 1972 में मानसून 10 से 15 दिन विलम्ब से आया था। उपरोक्त अध्ययन से पता चलता है कि दक्षिणी प्राय:द्वीप तथा उत्तर-पश्चिमी भारत के अतिरिक्त समूचे देश में मानसून के आरंभ के पूर्वानुमान के लिये 200 मि०बार पर मानसून-पूर्व के महीनों के कुछ उच्च वायु प्राचल बहुत उपयोगी है। ये प्राचल हैं :-(1) 30° से 35° उत्तर अक्षांश के पास 60° से 100° पूर्व देशान्तर रेखाओं के बीच के क्षेत्र के ऊपर क्षेत्रीय पछुआ पवनों के क्षैतिज की प्रकृति व परिमाण, (2) उत्तर-पूर्वी भारत के ऊपर 85° पूर्व देशान्तर के पास द्रोणी की उपस्थिति अथवा अनुपस्थिति, (3) पाकिस्तान तथा पड़ोसी क्षेत्रों के ऊपर पवन विसंगति प्रारुप, (4) 30° से 40° उत्तर अक्षांश तथा 80° से 100° पूर्व देशान्तर वाले क्षेत्रों के ऊपरी पवन के तापक्रम का सामान्य से विचलन।

यह आलेख 1975 से 1979 तक मानसून के पूर्वानुमान में उपरोक्त प्राचलों की उपयोगिता की पुष्टि के परिणाम तथा 1957 से 1974 तक की अवधि के लिये विसंगति प्रारूप प्रस्तुत करता है, ऐसा देखा गया है कि ये प्राचल बिहार, उड़ीसा तथा मध्य प्रदेश पर मानसून की शुरुआत के संबंध में विश्वसनीय संकेत देते है। गुजरात, उत्तरी प्राय:द्वीप तथा पूर्वी उत्तर प्रदेश में मानसून की शुरुआत के संबंध में भी कुछ संकेत प्राप्त किए जा सकते हैं।

ABSTRACT. A study of the cross-section charts along longitude 75 deg. E from latitude 8 deg. to 55 deg. N for the 200 mb level and the monthly mean constant pressure charts for all standard levels from 850 to 100 mb for the area, equator to Lat. 55 deg. N and Long. 20 deg. to 100 deg. E for the months of April and May for two contrasting years, 1971 when the southwest monsoon advanced 7 to 10 days ahead of the normal date over most parts of the country and 1972, when the advance of the monsoon was delayed by 10 to 15 days, shows that a few upper air parameters of pre-monsoon months at 200 mb are useful for forecasting the onset of the monsoon over the country outside south Peninsula and northwest India. These parameters are (*i*) the nature and magnitude of the horizontal shear of the zonal westerlies near Lat. 30 deg. to 35 deg. N, over the longitudinal belt 60 deg. to 100 deg. E, (*ii*) the presence or absence of a trough near Long. 85 deg. E over northeast India, (*iii*) wind anomaly pattern over Pakistan and neighbourhood and (*iv*) the departure from normal of upper air temperature over the area Lat. 30 deg. to 40 deg. N and Long. 80 deg. to 100 deg. E. The paper also presents the results of verification of the utility of the above parameters in forecasting the onset of the monsoon for the years, 1975 to 1979 and the anomaly pattern for the period, 1957 to 1974 as well. It has been found that the parameters provide reliable indication regarding the onset of monsoon over Bihar, Orissa and Madhya Pradesh. Some indication can also be drawn for monsoon onset over Gujarat, north Peninsula and east Uttar Pradesh.

1. Introduction

A number of investigators (Ananthakrishnan 1970, Dao *et al.* 1957, De La Mothe and Wright 1969, Koteswaram 1958 and 1960, Murakami 1958, Rai Sircar and Patel 1962, Ramamurthi and Keshavamurthi 1964, Ramaswamy 1965, Sutcliffe and Bannon 1954, Yeh *et al.* 1959, Yin 1949 and Staff members, Academica Sinica, Peking 1957) have studied the association of general circulation features with the onset of monsoon rains over India. The studies can be broadly classified into two categories. In the first category, the onset of the monsoon has been related with the features of mid-latitude westerlies like the changes in the position and intensity of the sub-tropical jet stream and the variations in the mean 500 mb trough and ridge positions over Europe and Asia. In the second category the arrival of monsoon in India has been studied in relation to the northward progression of the sub-tropical ridge line in the upper troposphere and the appearance and strengthening of the upper tropospheric easterlies. Most of these studies deal with the changes taking place at or about the time of onset of the monsoon and do not have much prognostic value. The studies made by Rai Sircar and Patel (1961) and Sutcliffe and Bannon (1954) have some forecast value, but applications of their findings to subsequent years by

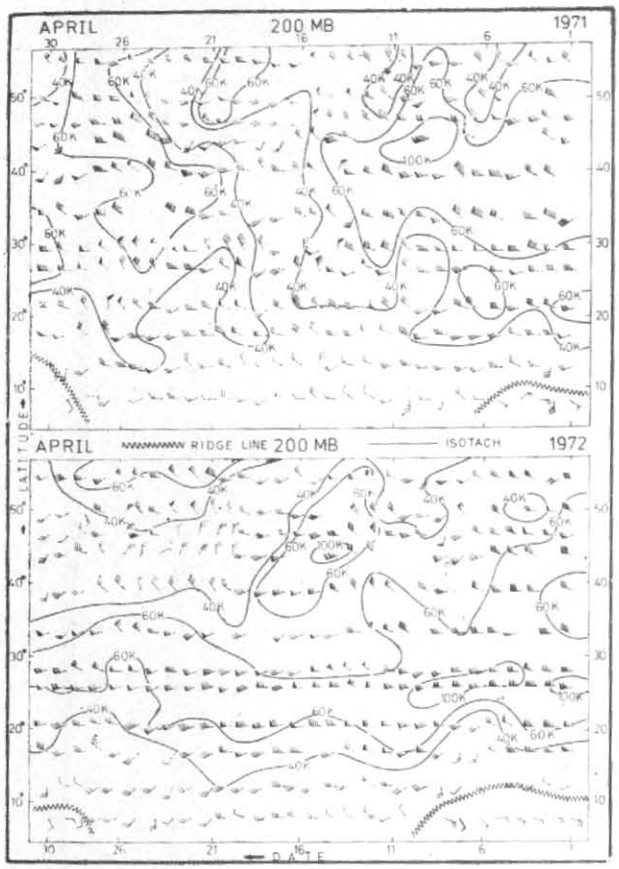

Fig. 1. Cross-section charts along Long. 75° E (200 mb, April 1971 and 1972)

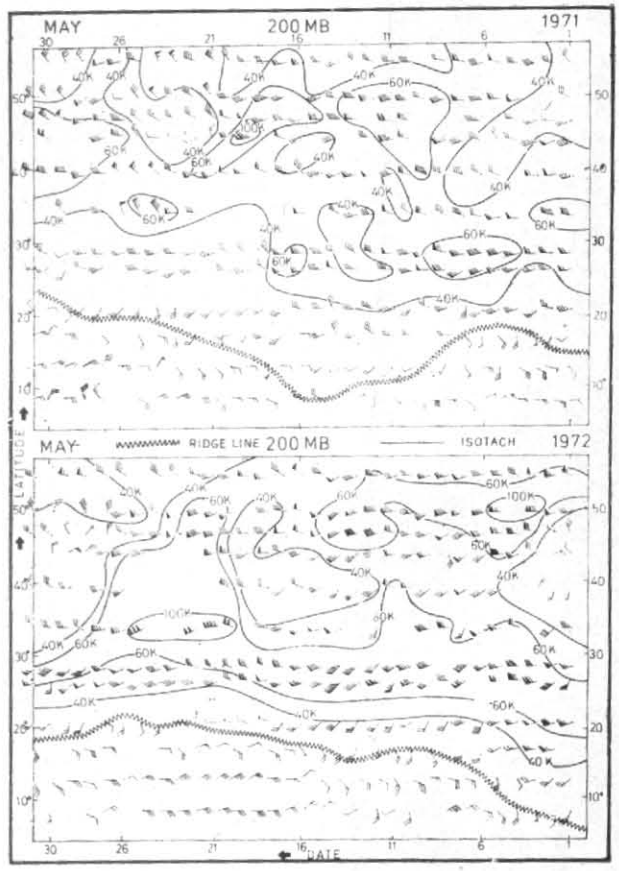

Fig. 2. Cross-section charts along Long. 75° E (200 mb, May 1971 and 1972)

Ramamurthi (1967) and Ananthakrishnan and Ramakrishna (1965) did not yield satisfactory results.

The authors have made a detailed study of the upper air conditions prevailing over India and neighbourhood in the months of April, May and June in two contrasting years, 1971, early onset of monsoon and 1972, late onset of monsoon over most parts of the country with a view to identify contrasting features in the two years which may serve as predictors for onset of monsoon over India. The predictors, thus identified, have been tested for the 5-year period 1975-1979.

2. Significant day to day features in two contrasting years

In 1971, the advance of the monsoon over the different parts of the country was about a week to 10 days ahead of the normal date, whereas in 1972, though the monsoon advanced into northwest India (comprising of Rajasthan, Punjab, Himachal Pradesh and Jammu & Kashmir) near about the normal date, its advance into the Peninsula (south of Lat. 20 deg. N) and northeast India (comprising of Orissa, Bihar, West Bengal, Assam and adjoining northeastern States) was delayed by 10 to 15 days and over the rest of the country by about a week. In this study, the monsoon is considered to be early or late when the actual date of onset differs by more than 5 days from the normal date. It is considered to be normal, if it arrives within 5 days of the normal date.

To study the different circulation features, the cross-section charts along Long. 75 deg. E from Lat. 8 deg. to 55 deg. N were prepared for 200 mb level for the months of April, May and June for two contrasting years, 1971 and 1972. In this study, 200 mb level was chosen, as the axis of the sub-tropical westerly jet stream is close to this level. The charts for April and May of 1971 and 1972 are given (Figs. 1 and 2). In the figures, sub-tropical ridge line is indicated by scurvy line, while isotachs of 40, 60 and 100 knots are indicated by solid lines. An examination of the charts reveals the following interesting features.

2.1. *Winter westerlies*

The position, intensity and other characteristics of the sub-tropical jet stream were different in the two years. The salient features are given below :

(*i*) The sub-tropical jet stream was very pronounced over Indian in April and the first half of

May in 1972 (late onset), while it was found to be north of the Himalayas in the corresponding period of 1971 (early onset).

(*ii*) In both years, the strength of the westerlies over India showed a decreasing trend during the second half of May. Earlier, there were periods of strong and weak winds in both years, without any gradual decrease or increase in strength.

(*iii*) In 1971, the southwest monsoon set over Kerala on 27 May while in 1972 it advanced temporarily over the south Peninsula towards the end of the second week of May, but retreated later and revived over Kerala only on 18 June. However, sudden weakening of the upper tropospheric westerlies over India and/or sudden strengthening of the westerlies to the north could not be noticed in either of the two years at about the time of onset of the monsoon over Kerala.

2.2. *Northward progress of the sub-tropical ridge*

In 1971, the ridge appeared over the extreme southern tip of the country on 20 April and moved rapidly northwards to Lat. 17 deg. N by 3 May. After 8 May, the axis of the ridge slowly drifted southwards reaching Lat. 8 deg. N on 15 May. Thereafter, it started moving northwards and reached Lat. 20 deg. N by 25 May. The ridge occupied the northernmost position of about Lat. 28 deg. N from 5 June onwards.

In 1972, the ridge appeared near Lat. 8 deg. N on 28 April and shifted northwards to about Lat. 15 deg. N by 9 May. The ridge line slowly crept northwards reaching Lat. 20 deg. N on 20 May. In June, it was oscillating between Lat. 18 deg. and 25 deg. N.

Although the ridge moved near Lat. 13 deg. N earlier in 1971 (30 April) than in 1972 (6 May), the easterlies continued to be steady from 6 May in 1972, whereas they were so in 1971, only from 18 May. While the monsoon made a steady advance over the Peninsula in 1971, it was a temporary advance followed by a recession and revival in 1972. On the other hand, the sub-tropical ridge line which started moving northwards had a southerly swing followed by a northerly shift in 1971 and a steady advance northwards in 1972. The northward progress of the sub-tropical ridge line does not seem to be correlated with the onset of the monsoon over Peninsular India.

The signficant feature brought out by the time section charts is the prevalence of stronger westerlies near about Lat. 25 deg. N to 28 deg. N with weaker winds in the latitudinal belt Lat. 35 deg. to 40 deg. N in 1972 (late onset) in contrast to the prevalence of stronger westerlies in the latitudinal belt 35 deg. to 40 deg. N and weaker westerlies near about Lat. 25 deg. to 30 deg. N in 1971 (early onset of monsoon). The nature of the horizontal shear of the zonal westerlies at 200 mb near Lat. 30 deg. N in the pre-monsoon months appears to be a good predictor of the time of onset of ensuing monsoon. Large cyclonic shear indicates late monsoon while anticyclonic shear indicates early monsoon.

3. Mean monthly features in the two contrasting years

Monthly mean upper air charts for the two contrasting years, 1971 and 1972, over the area, equator to Lat. 55 deg. N and Long. 20 deg. to 100 deg. E were studied in detail. The daily values of the contour heights, temperatures and winds for all standard isobaric surfaces from 850 to 100 mb for stations in Tibet and China were compiled, from the *Daily Weather Reports of Japan* for the relevant months and the monthly means worked out. The data for the rest of the area were extracted from the *Climatic Data of the World*. The charts for all standard isobaric levels were prepared and analysed for April and May of 1971 and 1972. The upper air charts for 200 mb for the month of April alone for a restricted area are given in Figs. 3 and 4. On comparing the charts of 1971 with the corresponding charts (months and levels) for 1972, the following points are noticed :

(*i*) To the east of Long. 60 deg. E, westerlies to the north of Lat. 30-35 deg. N were stronger in 1971 (early onset) than the winds to the south of Lat. 30-35 deg. N, while in 1972 (late onset), the westerlies were stronger to the south of Lat. 30-35 deg. N than to its north. The difference in the strength of the winds in the two latitudinal belts was about 15 to 25 kt. The horizontal shear of the zonal westerlies near Lat. 30-35 deg. N is anticyclonic in 1971 (early onset) and cyclonic in 1972 (late onset).

(*ii*) In 1971 (early onset), there was a trough over India near Long. 85 deg. E which was absent in 1972 (late onset). Consequently, upper winds between Long. 70 deg. and 85 deg. E over north India were northwesterlies in 1971 (early onset), while they were southwesterlies in 1972 (late onset).

(*iii*) The above features were quite pronounced in the charts for the levels 300 to 100 mb but were also perceptible at 500 and 700 mb.

(*iv*) The features were similar in the charts of April and May.

(*v*) North of Lat. 20 deg. N, upper air temperatures from 300 to 100 mb were higher in 1971 than in 1972. The difference was marked at 200 and 150 mb over the area Lat. 30 deg. to 40 deg. N and Long. 80 deg. to 100 deg. E where it was about 5 deg. to 7 deg. C.

The study of the cross-section as well as monthly mean upper air charts indicates that the following parameters of April 200 mb charts would serve as predictors for assessing the time of onset of the ensuing monsoon. (*i*) nature of the horizontal shear of zonal westerlies in the latitudinal belt 30 deg. to 35 deg. N Long. 60 deg. to 100 deg. E anticyclonic shear indicating early onset and cyclonic shear late onset, (*ii*) presence or absence of a trough near Long. 85 deg.

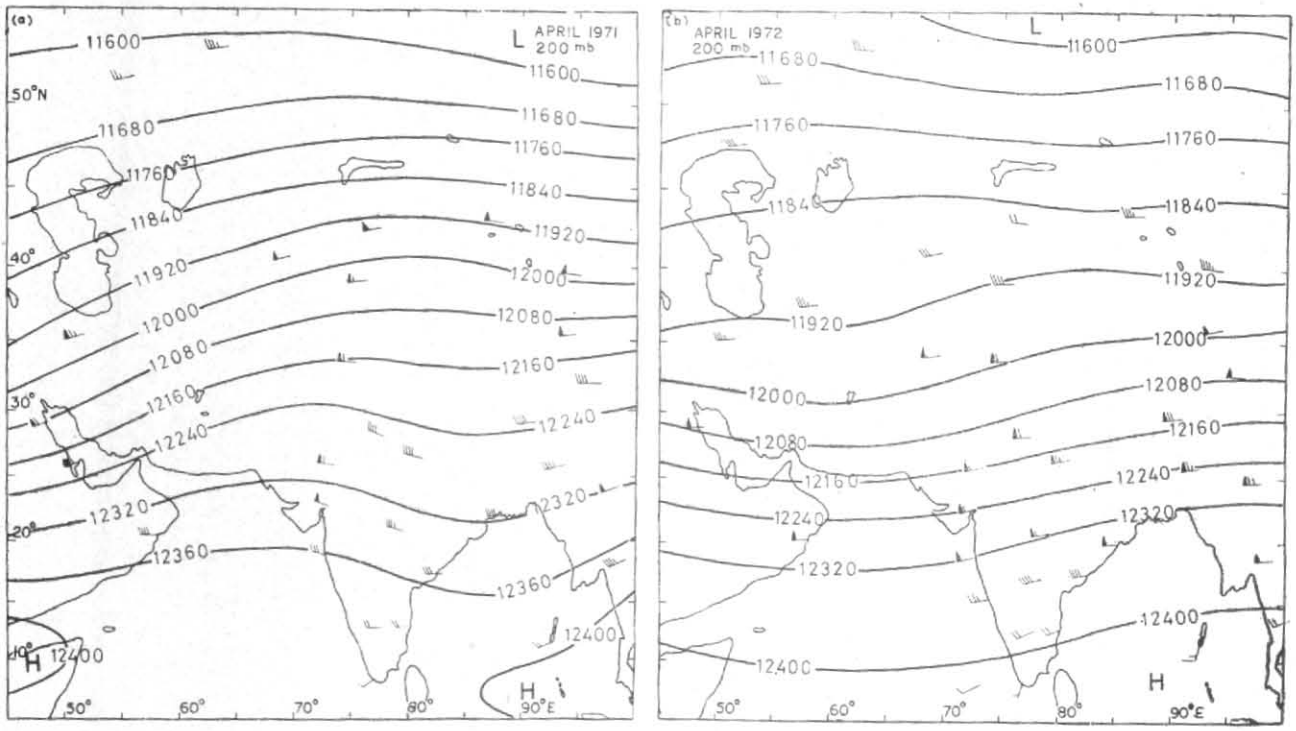

Fig. 3. Winds and contours (200 mb, April 1971 and 1972) (Contours in gpm)

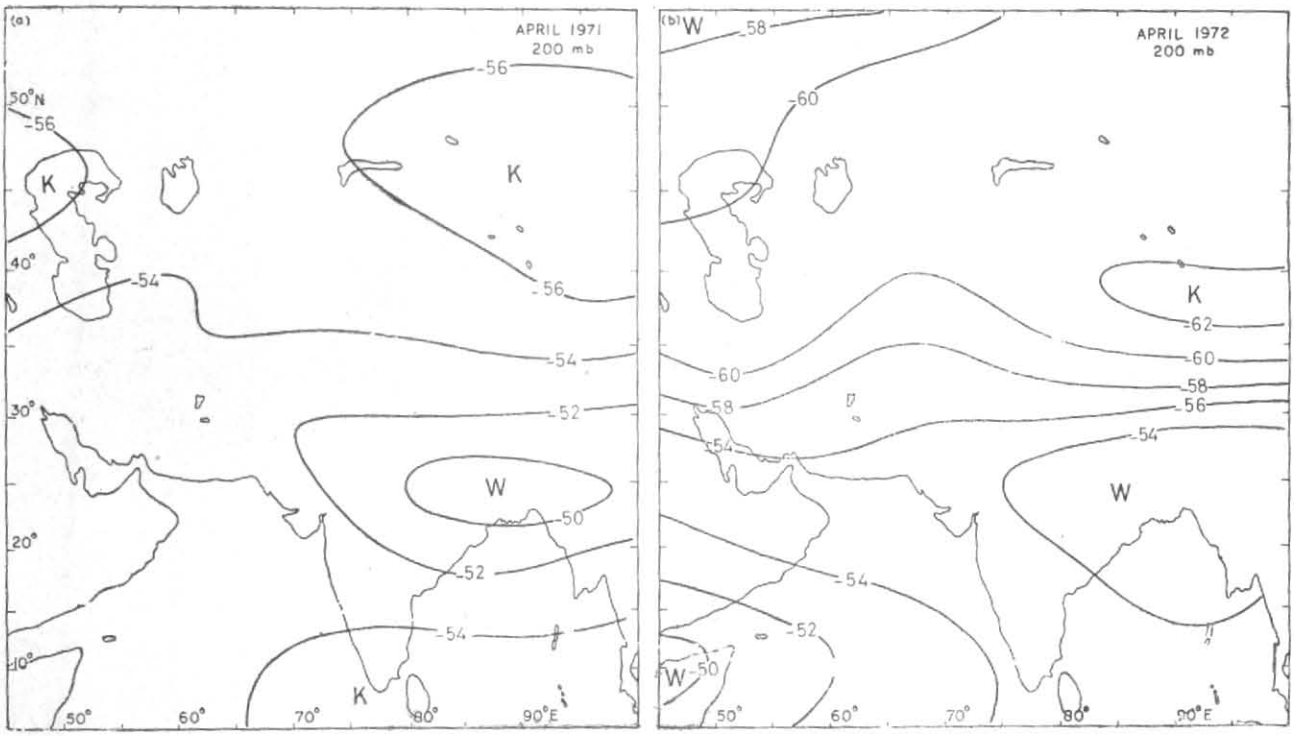

Fig. 4. Isotherms 200 mb, April 1971 and 1972 (Isotherms in °C)

E over north India, the former indicating early onset and the latter late onset and (*iii*) departure of the upper air temperatures over the area Lat. 30 deg.-40 deg. N, Long. 80 deg.-100 deg. E from normal-above normal temperatures indicating an early onset and below normal temperatures late onset.

With the onset of the monsoon, the sub-tropical westerly jet stream over India dissipates and winds to the north of India strengthen, the cyclonic shear becoming anticyclonic, the meridional flow in the upper troposphere changes from southerlies in winter to northerlies in the monsoon months and upper tropospheric temperatures increase over Tibet and neighbourhood. The implication of the present study and the parameters given in the preceding paragraph is that the "setting in" of the summer conditions in April itself would indicate an early onset, while the prevalence or intensification of the winter conditions would indicate a later onset of the monsoon.

4. Verification of the utility of the parameters for monsoon onset prediction

4.1. *For the period* 1958 *to* 1974

It may be worthwhile to assess the utility of the above parameters by applying the same to the data of a few more years. Unfortunately, the monthly mean data for stations in Tibet and China have to be worked out from daily values. The climate data of the world were also not readily available to the authors who had to restrict the examination to the Indian region. Over India, the C and F type radiosondes have been replaced by the audio-modulated type during the last decade and the earlier data are not readily comparable with the data since seventies. Hence the authors had to confine the examination to the wind field over the Indian region.

The anomaly pattern reveals more details compared to the actual flow pattern. The wind anomaly patterns for 200 mb for the month of April for the two contrasting years, 1971 and 1972 are shown in Fig. 5. The anomaly chart for 1971 (early onset) shows anticyclonic flow over Pakistan and neighbourhood, while the corresponding chart for 1972 (late onset) shows anticyclonic flow over Pakistan and (late onset) shows southerly flow over the area, associated with a trough to the west. Similar patterns are also noticed at 500, 300, 150 and 100 mb levels (figures not reproduced). The patterns are more pronounced in the higher levels. However, since the number of observations decreases with height, 200 mb seemed to be the optimum level for the examination. The anomaly patterns at 200 mb levels for the year 1956 to 1970, 1973 and 1974 have been prepared. Table 1 gives the significant features of the anomaly pattern and the times of onset of the monsoon over the different parts of the country.

It may be seen that a trough or cyclonic circulation lay over Pakistan and/or adjoining northwest India in the anomaly patterns or the years, 1957 to 1960, 1965, 1966, 1969, 1973 and 1974. In all these

TABLE 1

Year	Onset of monsoon	Significant features in the anomaly chart
1957	Delay of about 2 weeks over most parts of the country outside south Peninsula where normal.	Cyclonic circulation over northwest India.
1958	Delay of about 2 weeks.	Cyclonic circulation over north Arabian Sea and neighbourhood.
1959	Delay of 10 to 15 days outside south Peninsula and northwest India where normal.	Cyclonic circulation over Pakistan or further west.
1960	Delay of about a week over northeast India, Madhya Pradesh and Uttar Pradesh; early by about 2 weeks over south Peninsula.	Cyclonic circulation over northwest India and Pakistan.
1961	Early	Pattern not definite due to lack of data.
1962	Early by a fortnight as a feeble current.	Light northerly winds over western parts of country, suggesting anticyclonic circulation over Pakistan.
1963	Normal	Cyclonic circulation over Bihar and adjoining east Uttar Pradesh and north west Madhya Pradesh.
1964	Normal	Anticyclonic circulation over north Arabian Sea and neighbourhood.
1965	Delay of 10 to 15 days over most parts of north and central India.	Cyclonic circulation over northern parts of Pakistan and Afganistan.
1966	Delay of 2 weeks in Gujarat State, central parts of the country and adjoining northwest India.	Cyclonic circulation over Pakistan.
1967	Normal	Pattern not definite due to lack of data.
1968	Normal outside Peninsula and Assam where delayed by about a week.	Cyclonic circulation over Gangetic West Bengal and adjoining north Bay of Bengal.
1969	Delay of 2 weeks over Madhya Pradesh, Uttar Pradesh and adjoining north west India, early by about 5 days over Peninsula and northeast India.	Cyclonic circulation over Punjab and adjoining Pakistan.
1970	Normal outside Peninsula where early by about 5 days.	Mainly easterly flow over northwest India.
1973	Delay of about 10 to 15 days in Uttar Pradesh and a week in Assam and most parts of northwest India.	Cyclonic circulation over Gujarat State and adjoining Pakistan.
1974	Delay of 10 to 15 days over north Peninsula, central parts of country and northwest India, though early by about 5 days over extreme south Peninsula.	Trough over northwest India and Pakistan.

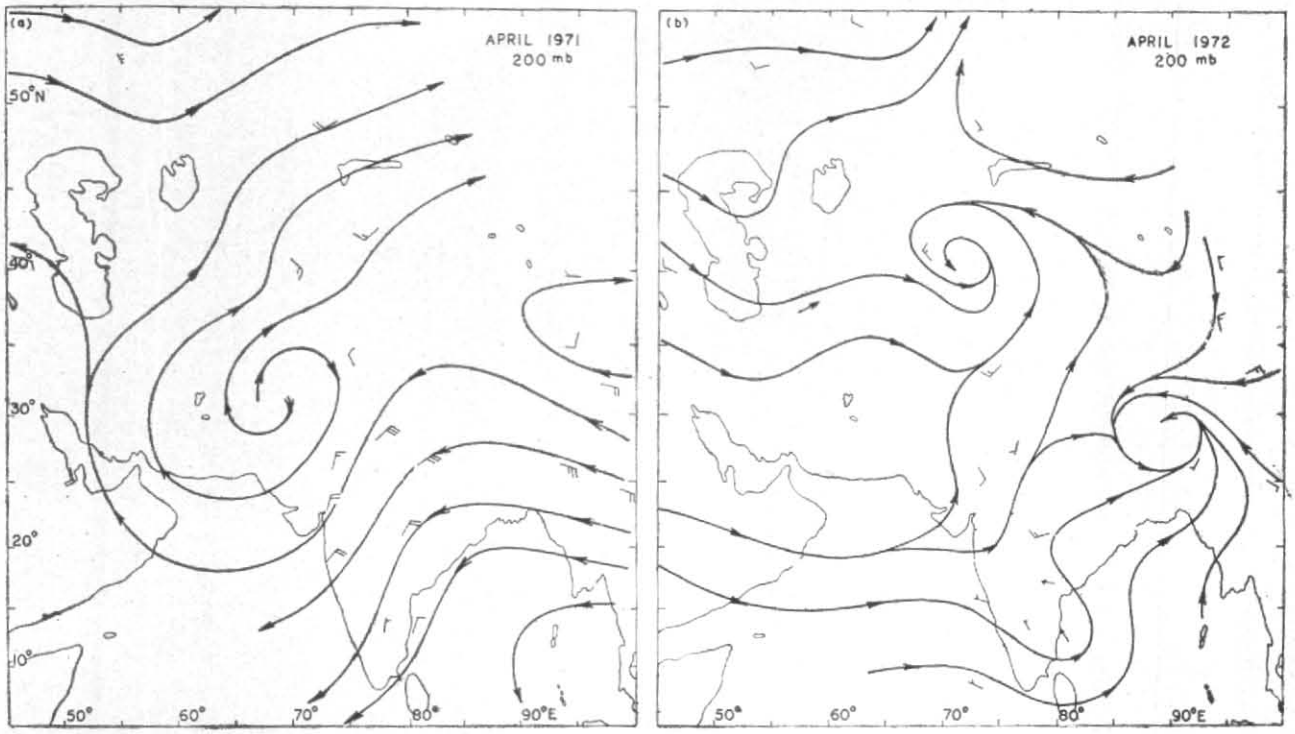

Fig. 5. Wind anomaly charts 200 mb, (a) April 1971 and (b) April 1972)

TABLE 2

Year	Mean wind speed (kt) 35-40° N (a)	25-30° N (b)	Difference (kt) (a)−(b)	Trough near Long. 85° E	Mean temp. 30-40° N, 80-100° E (°C)	Flow over Pakistan in anomaly chart	Onset of monsoon Early	Normal	Late
1975	50	75	—25	Absent	—56	Trough/ Cyclonic	—	Uttar Pradesh, Assam	North Peninsula, Gujarat Madhya Pradesh, Bihar, West Bengal, Orissa by 7 to 10 days.
1976	50	65	—15	Absent	—56	Trough/ Cyclonic	Maharashtra, Gujarat, west Madhya Pradesh by 1 to 2 weeks	West Bengal, Assam, Andhra Pradesh	Orissa, Bihar, east Madhya Pradesh, Uttar Pradesh by 2 weeks.
1977	45	70	—25	Absent	—56	Trough	—	West Uttar Pradesh, Assam	North Peninsula, Gujarat, Madhya Pradesh, East Uttar Pradesh, Bihar, West Bengal, Orissa by 7 to 10 days.
1978	55	65	—10	Absent	—56	Cyclonic	—	North Peninsula, Gujarat, west Uttar Pradesh, Assam	Madhya Pradesh, Orissa, West Bengal, Bihar, east Uttar Pradesh by 7 to 10 days.
1979	65	55	10	Absent	—55	Anti-cyclonic	—	—	Most parts of the country by 10 days.

years, the monsoon was delayed over most parts of central and north India. The anomaly chart for the year 1962 shows northerly winds over the western parts of India, suggesting anticyclone to the west of the country. The monsoon was early this year by a fortnight. Due to lack of sufficient observations, the patterns for the years 1961 and 1967 were not definite. In the other four years, neither an anticyclonic circulation nor a cyclonic circulation lay over Pakistan and monsoon was normal over most parts of the country.

The wind anomaly pattern seems to be a good parameter for forecasting the onset of the monsoon over the country outside the south Peninsula (south of Lat. 15 deg. N) and the northwest India.

4.2. *For the period* 1975 *to* 1979

Monthly mean 200 mb charts were specially prepared for April for the years 1975 to 1979, from the daily data received on tele-type and all the parameters given earlier as predictors for onset of the monsoon tested with reference to the onset of the monsoon over the country outside the south Peninsula and northwest India. Table 2 shows the features observed in each of the above years and also the regions where the monsoon was early, normal or late. The effect of each of the parameters on the onset over different parts of the country are examined in detail and the results are discussed below :

(*i*) *Nature and magnitude of the horizontal shear of the zonal westerlies near Lat.* 30 *deg.*-35 *deg. N*

During the years, 1975 and 1977, the horizontal shears near Lat. 30 deg. to 35 deg. N were cyclonic, winds in the latitudinal belt, 35 deg. to 40 deg. N being weaker than the winds in the belt 25 deg. to 30 deg. N by 25 knots. The shear was cyclonic in 1976 also, but the value was smaller (difference in the speeds in the two latitudinal belts being 15 knots). In 1978 and 1979, the shear was small the difference in the windspeeds in the two latitudinal belts being 10 knots or less.

The monsoon was delayed in all the five years in Bihar, Orissa and east Madhya Pradesh. Hence, it appears that a large value of the anticyclonic shear as in 1971 (winds at 35 deg.-40 deg. N being stronger by 15 to 25 kt than the winds at 20 deg.-25 deg. N) is required in the pre-monsoon months for this area to get an early monsoon.

North Peninsula, Gujarat State and West Madhya Pradesh get a late monsoon, when the horizontal shear is cyclonic and large as in 1975 and 1977, but a normal or early monsoon if the shear is anticyclonic or is cyclonic but of small value.

This predictor does not appear to be of much utility for forecasting the times of onset of monsoon over Uttar Pradesh, Assam and West Bengal. Large anticyclonic shear as in 1971 has not occurred in any of these years. Hence, it has not been possible to verify whether large anticyclonic shear would lead to early onset.

(*ii*) *Presence or absence of trough over north India near Long.* 80 *deg. to* 85 *deg. E*

The trough was absent in all the five years. The monsoon was delayed in Bihar, Orissa and east Madhya Pradesh during all the five years, in West Bengal, west Madhya Pradesh and east Uttar Pradesh in four years and in north Peninsula and Gujarat in three years. Since the trough was not present in any of these years, it could not be verified that the presence of the trough would lead to an early onset of the monsoon.

(*iii*) *Flow pattern over Pakistan and neighbourhood in the anomaly chart*

Trough or cyclonic circulation prevailed over Pakistan and neighbourhood in the anomaly chart from 1975 to 1978 and in all the years, monsoon was delayed in Bihar, Orissa and east Madhya Pradesh and in three years in West Bengal, west Madhya Pradesh and east Uttar Pradesh. Anomaly pattern showed anticyclonic flow over Pakistan and neighbourhood in 1979, but the monsoon was delayed over most parts of the country. This parameter has completely failed this year. The verification for the earlier years, 1958 to 1973 has already been discussed (under 4.1).

(*iv*) *Upper air temperatures over the area, Lat.* 30 *deg. to* 40 *deg. N, Long.* 80 *deg. to* 100 *deg. E*

The upper air temperatures over Tibet and neighbourhood were slightly below normal in all the five years. The monsoon was delayed in Bihar, Orissa and east Madhya Pradesh in all the five years, in West Bengal, west Madhya Pradesh and east Uttar Pradesh in four years and in north Peninsula and Gujarat in three years. Since the upper air temperatures were not above normal over Tibet and neighbourhood in any of the years, it has not been possible to verify the conclusions regarding the onset in years of above normal upper air temperatures.

The reliability of the various parameters for forecasting the onset of the monsoon in decreasing order seems to be the nature and magnitude or the horizontal shear of the zonal westerlies near Lat. 30 deg. to 35 deg. N, the presence or absence of the trough over north India near Long. 80 deg. to 85 deg. E, mean upper air temperature over Tibet and the anomaly pattern over Pakistan and neighbourhood. The predictive value is highest in Bihar, Orissa and Madhya Pradesh, while none of the parameters seem to have any predictive value in forecasting the onset of the monsoon in south Peninsula, Assam, west Uttar Pradesh and northwest India.

Except for the anomaly pattern (which has been verified for 20 years) verification has been done for the other parameters over a period of five years only, monsoon being late in most parts of the country during this five-year period. Hence, the conclusions are only tentative. However, the study indicates good potentialities of the parameters for forecasting the onset of the monsoon over Bihar, Orissa and Madhya Pradesh.

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