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Meridional wind index for long range forecasting of Indian summer monsoon rainfall

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ABSTRACT. The monthly mean meridional wind in the upper troposphere over India in May is found to be significantly correlated with the monsoon rainfall over the whole of India during the following 1 June to 30 September. An index for the meridional wind useful for long range forecasting of Indian summer monsoon rainfall has been derived.

1. During the sixties and seventies, there were large year to year variations of the summer monsoon (June to September) rainfall over India. Large scale failure of monsoon rains occurred during many years in these two decades. In this paper the period 1964 to 1978 has been studied. During this period year to year variation of the monsoon rainfall was large as may be seen from Fig. 3 and monthly mean upper tropospheric wind data were available for most of the Indian RS/RW stations (For the period prior to 1964 wind data were not available for many stations).

2. Joseph (1978) showed that southerly meridional winds occurred over northwest Indian stations during June, July and August, in the upper tropospheric levels like 150 mb, during years of large scale monsoon failure; in May of such years southerly meridional winds over Indian RS/RW stations at 150 mb level were stronger than in other years. In this paper this persistence of upper tropospheric southerlies in association with monsoon failure has been made use of and a method for the long range forecasting of southwest monsoon rainfall (1 June to 30 September) for the whole of India has been derived.

3. The monsoon rainfall index '*R*' for the rainfall of the whole of India for the period 1 June to 30 September is the mean rainfall of the whole of India (in centimetre) obtained from the area-weighted rainfall of all the meteorological subdivisions of the country by Parthasarathy and Mooley (1978). To represent the meridional flow over India several indices of meridional wind (V_m) were tried. V_m for a particular level, say 200 mb, is the average monthly mean meridional wind (in metre per second) at that level of a chosen number of RS/RW stations.

4. Meridional wind index V_m, as an average of Bombay, Calcutta, Delhi, Madras and Nagpur was tried first. For the period 1964 to 1978 the linear correlation coefficient between V_m and R for V_m at various levels and for various months are given in Table 1. It may be seen that the highest correlation in May is at the 200 mb level. The correlation coefficients for May at 300 mb, 200 mb and 150 mb levels are all significant at 1 per cent level. Combining 300 mb, 200 mb and 150 mb gives a slightly higher correlation as may be seen from Table 1. At the 200 mb level the correlation is very small in April and June. This analysis has shown that the meridional wind of May particularly at 200 mb level can be used as a tool for long range forecasting of monsoon rainfall.

5. Correlation coefficients between R and the monthly mean meridional wind V at individual

TABLE 1

Correlation coefficient between V_m* and R
(Data of period 1964 to 1978 used)

Month	V_m at pressure level	Correlation coefficient** between V_m and R
May	300 mb	—0.770
May	200 mb	—0.827
May	150 mb	—0.810
May	Mean of 300 200 and 150 mb	—0.838
April	200 mb	—0.165
June	200 mb	—0.322

*V_m is mean of Bombay, Calcutta, Delhi, Madras and Nagpur.

**Correlation coefficient for levels of significance 1% and 5% relevant to this case are — 0.641 and — 0.514 respectively.

stations for May at 200 mb level were worked out to find out the areas in and around India where the meridional wind is significantly correlated with Indian monsoon rainfall. The correlation coefficients are shown for chosen stations in Fig. 2 (The stations whose data have been used in this study are marked in Fig. 1). Isolines of the correlation coefficient are marked in the figure at intervals of 0.2 northwest India is an area of significant negative correlation. Almost equally strong positive correlation is found around Kuwait. There is another positive area over Burma and neighbourhood and a negative area further east (Negative correlation means southerly meridional winds are stronger during years of poor monsoon or northerly meridional winds weaker, as southerly meridional wind is taken as positive). This cellular structure of the correlation coefficient is interesting and will be discussed in section 8 with reference to the 200 mb stream line charts of May for two contrasting monsoons.

6. Different combinations of Indian stations with high negative correlation were then tried as meridional wind indices (V_m) and their correlation with R worked out using data of the period 1964 to 1978. The results are presented in Table 2. From Table 2 it is seen that combination of stations Bombay, Delhi, Madras, Nagpur and Srinagar for 200 mb May for deriving V_m gives he highest correlation between V_m and R for the period 1964 to 1978 and so meridional wind index with this combination may be used as a tool for long range forecasting of Indian monsoon rainfall.

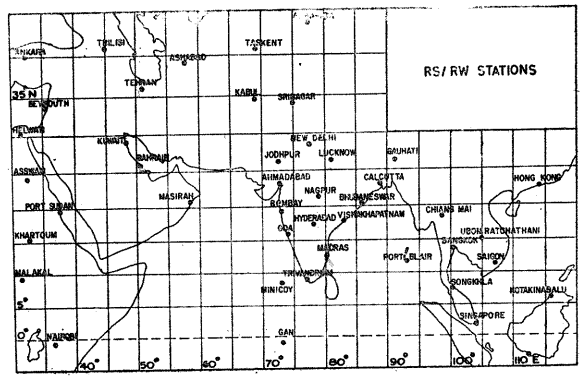

Fig. 1

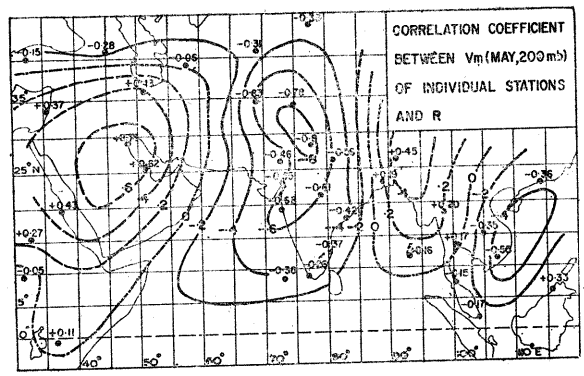

Fig. 2

TABLE 2

Correlation coefficient between V_m and R
(Data for the period 1964-1978 used)

V_m as mean of May 200 mb meridional wind of	Correlation coefficient between V_m and R
Bombay, Delhi and Nagpur	—0.826
Bombay, Delhi, Madras and Nagpur	—0.841
Bombay, Delhi, Nagpur and Srinagar	—0.879
Bombay, Delhi, Madras, Nagpur and Srinagar.	—0.891

7. Using the meridional wind index V_m as the mean monthly meridional wind of Bombay, Delhi, Madras, Nagpur and Srinagar for May 200 mb, a linear regression equation has been derived between V_m (in metre per second) and R (in cm) as : $R = 92.55 - 3.15\ V_m$.

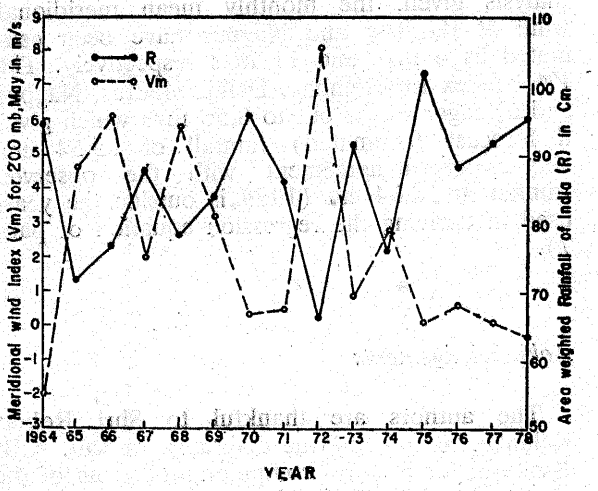

Fig. 3

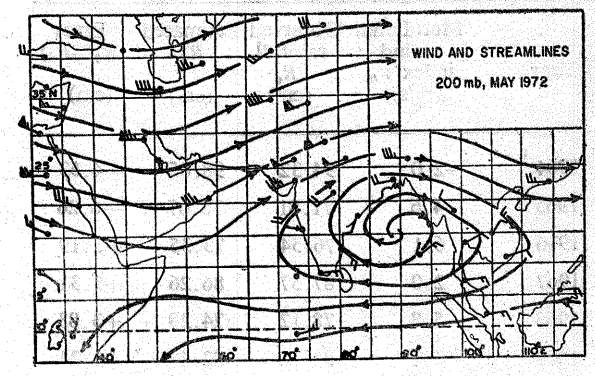

Fig. 4

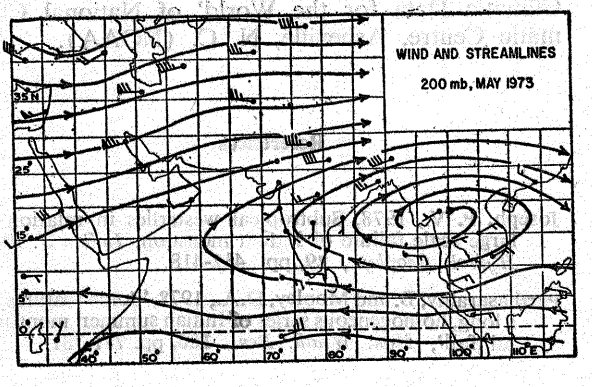

Fig. 5

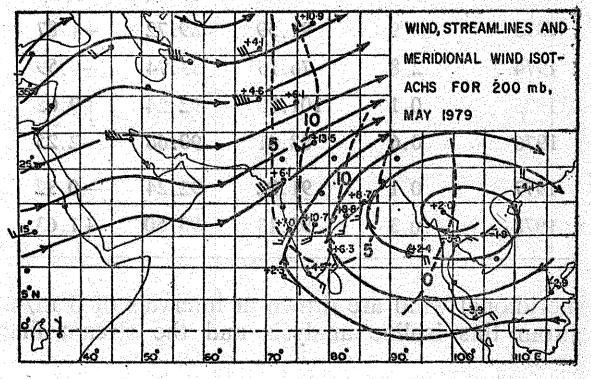

Fig. 6

The year to year variation of R and V_m are as shown in Fig. 3. Table 3 gives the values of observed rainfall of each year (R_0), the meridional wind index (V_m) and the rainfall estimated (R_e) using the regression equation. The error (R_0—R_e) is given in the last column. It is seen that the maximum error was in 1975 of + 9.65 cm. The standard error in rainfall during the period 1964 to 1978 is 4.40 cm. The mean value (normal) of R_0 derived by Parthasarathy and Mooley (1978) for the 105 year period 1866 to 1970 is 88.75 cm.

8. Figs. 4 and 5 give the monthly mean winds and the stream-line analysis for 200 mb level for May of 1972 and 1973. There was large scale monsoon failure over India in 1972 leading to severe drought; in 1973 monsoon was good with more than normal rainfall in many areas. It may be seen from the figures that the westerly wind flow in May 1973 was more zonal and the anticyclone over south Asia very much elongated in the east-west direction. In 1972 the sub-tropical westerly belt had marked meridional motions south and north. A prominent trough in the westerlies may be seen intruding into the Arabian Sea. The anticyclone is compressed in the east-west direction. The flow patterns explain the high negative correlation over northwest India and the high positive correlation around Kuwait and over the Arabian peninsula. This gives confirmation to the findings of Joseph (1978) that the equatorward intrusion of upper-tropospheric subtropical westerlies into areas immediately west of India which has persistence of many months, is the major cause of large scale failure of Indian monsoon.

9. During the year 1979 there was a major monsoon failure over India. Using the subdivisional rainfall averages published in *'Weekly Weather Report'* of India Meteorological Department, the area weighted mean rainfall of India for 1979 monsoon season has been worked out as 68.64 centimetres. Available 200 mb monthly mean winds are shown in Fig. 6. The meridional winds (in m/s) are marked for the stations in and around India and isolines for

TABLE 3

Observed and estimated monsoon rainfall during 1964-1978

Year	Meridional wind index V_m (m/s)	Observed rainfall R_0 (cm)	Estimated $R_e^{\rightarrow}$ (cm)	Error $(R_0—R_e)$ (cm)
1964	—2.0	94.32	98.85	—4.53
1965	4.6	71.81	78.07	—6.26
1966	6.1	76.54	73.35	+3.19
1967	2.0	87.57	86.26	+1.31
1968	5.8	78.12	74.29	+3.83
1969	3.2	83.72	82.48	+1.24
1970	0.3	95.56	91.61	+3.95
1971	0.5	86.02	90.98	—4.96
1972	8.1	66.29	67.05	—0.76
1973	0.9	91.59	89.72	+1.87
1974	2.8	76.15	83.74	—7.59
1975	0.1	101.89	92.24	+9.65
1976	0.6	88.41	90.66	—2.25
1977	0.1	91.92	92.24	—0.32
1978	—0.3	95.13	93.50	+1.63

meridional wind are drawn at intervals of 5 m/s. From this isoline analysis and the stream line analysis given, the monthly mean meridional wind at Bombay and Nagpur have been estimated as 6 m/s and 11 m/s respectively. The V^m index for Bombay, Delhi, Madras, Nagpur and Srinagar works out to 8.58 m/s which gives a forecast (estimated) rainfall of 65.54 cm, very closely in agreement with the observed rainfall of 68.64 cm (1979 is outside the years used in deriving the regression equation of para 7).

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