EVALUATION OF APRIL 500 MB RIDGE AND DARWIN PRESSURE TREND AS PREDICTORS FOR INDIAN MONSOON RAINFALL

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1. INTRODUCTION

Banerjee et al (1978) found that the number of Indian subdivisions with monsoon (June through September) rainfall ≥ 81% of the normal is significantly related to the location of the mean April 500 mb ridge along 75°E (hereafter, April ridge). Later, using area-weighted monsoon rainfall series of India based on a fixed network of 306 evenly distributed stations, Mooley et al (1986) showed that the relationship between Indian monsoon rainfall (hereafter, IMR) and the April ridge is positive and highly significant and that the relationship is stable even for 20-year periods. Shukla and Paolino (1983), utilizing Darwin mean sea level pressure as a measure of Southern Oscillation (SO), brought out that the S.O. Trend from DJF to MAM season is inversely and significantly related to IMR. Shukla and Mooley (1986) have recently examined the joint performance of the two predictors. In this paper, the April ridge and the trend in Darwin mean sea level pressure from January to April (hereafter Darwin trend) have been evaluated as predictors, both singly and jointly with and without interaction, for forecasting IMR.

2. DATA UTILIZED

Data for the predictors and the predictand are available for 1939-84. The ridge is fixed on the basis of streamline analysis of mean April 500 mb wind over India. On examination of the relationships between IMR and April ridge for sliding 30-year period, it is observed that the correlation coefficients (CCs) between IMR and April ridge, and between IMR and Darwin trend both attain stability in significance at 1% level during the period 1942-84. In view of this, data for 1942-84 have been utilized for this study.

3. STRENGTH OF PREDICTAND-PREDICTOR RELATIONSHIPS

3.1 IMR - April ridge relationship

Table 1 gives normalized April ridge anomaly in deficient and good monsoon rainfall years which have been defined by normalized rainfall anomaly of ≤ -1.0 and ≥ +1.0 respectively.

Table 1: Normalized April ridge anomaly in deficient and good rainfall years.

Deficient monsoon rainfall year	Ridge anomaly	Good monsoon rainfall year	Ridge anomaly
1951	-1.80	1942	1.10
1965	-0.65	1947	1.35
1966	-0.90	1956	1.10
1968	-1.40	1961	-0.15
1972	-2.15	1970	0.25
1974	-0.90	1975	1.10
1979	-1.40	1983	-0.48
1982	-2.00		
Mean	-1.40		0.61

The ridge anomaly in deficient monsoon is always negative and mostly < -0.90 but in good monsoon it is positive in a majority of the years. The difference between the mean ridge anomaly in deficient and good monsoon years is highly significant.

The ccs between IMR and April ridge for sliding 30-year period attained the highest value of 0.74 and the lowest value of 0.62, showing that the relationship throughout the period 1942-84 is significant at 0.1% level.

3.2 IMR - Darwin trend relationship

Table 2 gives normalized anomaly of Darwin trend in years of deficient and good monsoon rainfall.

Table 2: Normalized Darwin trend anomaly in in years of deficient and good monsoon rainfall.

Deficient monsoon rainfall year	Darwin trend anomaly	Good monsoon rainfall year	Darwin trend anomaly
1951	0.85	1942	-0.92
1965	1.46	1947	-0.69
1966	-0.46	1956	0.38
1968	2.00	1961	-0.81
1972	1.38	1970	-0.92
1974	1.38	1975	-1.30
1979	0.54	1983	-2.08
1982	0.62		
Mean	0.97		-0.91

The Darwin trend, in years of deficient monsoon rainfall is mostly positive exceeding 0.50, and in years of good monsoon rainfall it is mostly negative, less than -0.60. The difference in the mean Darwin trend anomaly for years of deficient and good monsoon rainfall is highly significant.

The CC between IMR and Darwin trend for sliding 30-year periods has varied from -0.51 to -0.65, and the relationship is significant at 1% level or above throughout the period 1942-1984.

CC between April ridge and Darwin trend for sliding 30-year period varied generally between -0.30 and -0.40 and was near 5% level of significance. Contingency table with three clases of the predictors, when tested by Chi-square test suggested quasi-independence. With the limited data it is not possible to have 4 or more classes of the predictors, since for such a contingency table the cell frequencies would be rather too small to apply the Chi-square test. It is, therefore, rather difficult to rule out any interaction between the two predictors.

4. PREPARATION AND EVALUATION OF FORECASTS OF IMR

Regression equations between normalized anomalies of (i) IMR and April ridge, (ii) IMR and Darwin trend, (iii) IMR, April ridge and Darwin trend, (iv) IMR, April ridge and Darwin trend with interaction between the predictors, are obtrained for sliding 30-year periods. The interaction between the predictors is included in the regression equation by the addition of the product term, for example,

$$y = a_1x_1 + a_2x_2 + a_3\, x_1x_2$$

where y, x_1, x_2 are normalized anomalies of IMR, April ridge and Darwin trend and a_1, a_2 and a_3 are regression constants.

Regression equations for fourteen 30-year periods are obtained and each of these has been utilized to obtain forecast for the year immediately preceding and or immediately following the period of regression equations. In this way, forecasts for 26 independent years are obtained.

The measures adopted for comparative evaluation of these forecasts for independent years are root mean square error, cc between observed and forecasts rainfall, variance explained, percentage of years with error numerically less than 0.5 S.D., and performance in deficient/good monsoon rainfall years.

Table 3 gives these measures of evaluation of the forecasts obtained from single predictors and jointly from the two predictors. Table 4 gives the forecast error (i.e. forecast minus observed rainfall) in deficient and good monsoon rainfall years.

Table 3: Measures of evaluation of forecasts for the years 1942-54 & 1972-84 (26 forecasts)

Forecasts from predictor	RMSE mm (% of SD)	CC Forecast & observed rain	Variance explained	% of years with error numerically < 0.5 S.D.
April ridge	51.7(63)	0.77	61.2	61
Darwin trend	61.2(74)	0.64	27.5	50
April ridge & Darwin trend	35.9(44)	0.90	67.2	77
April ridge & Darwin trend with interaction	32.8(40)	0.93	67.9	85

Table 4: Forecast error inyears of deficient and good monsoon rainfall years.

Forecast from Predictors	Error (mm) in deficient monsoon rainfall years					RMSE mm
	1951	1972	1976	1979	1982	
April ridge	13.8	83.7	49.1	18.7	-6.6	44.7
Darwin trend	85.2	164.0	56.1	87.0	96.4	104.1
April ridge & Darwin trend	10.9	63.8	20.2	23.4	2.4	32.1
April ridge & Darwin trend with interaction	2.8	36.3	6.6	23.8	1.0	19.7

Forecast from Predictors	Error (mm) in good monsoon rainfall years				RMSE mm
	1942	1947	1975	1983	
April ridge	-38.8	- 6.8	-40.5	-131.9	71.7
Darwin trend	-55.6	-52.7	-40.7	- 6.2	43.5
April ridge & Darwin trend	-20.2	- 0.8	-11.9	- 54.9	29.9
April ridge & Darwin trend with interaction	-40.1	-19.0	-33.0	- 29.3	31.3

Tables 3 and 4 bring out that (a) as a single predictor, April ridge is much better than Darwin trend, (b) the performance of the two predictors taken together is good, (c) the joint performance with interaction is better than that without interaction except in years of good monsoon. It is also interasting to note that in nearly all the cases of observed deficient (good) monsoon rainfall, the forecast rainfall was more (less) than the observations.

It is not clear why the regression equation with interaction should give a much better forecast for 1983 than that without interaction. The normalized anomalies of the April ridge and Darwin trend for the four years of good monsoon are, 1942 (1.10, -0.92), 1947 (1.38, -0.69), 1975 (1.11, -1.3), 1983 (-0.48, -2.08) respectively. The year 1983 thus differs from the other three years in respect of the ridge anomaly which is of opposite sign and is relatively small and the Darwin trend anomaly which is of the same sign but is unusually large in magnitude.

6. CONCLUDING REMARKS

The regression equations with mean April 500 mb ridge location along 75°E and Darwin mean sea level pressure trend from January to April, as predictors, can be jointly used to make useful operational forecasts of Indian monsoon rainfall. As the Indian economy is closely linked to the monsoon performance, these forecasts can be utilized for suitable planning of the water-dependent activities of the country. Regression equation with interaction between the predictors give on the whole better forecasts except for years of good monsoon rainfall.

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REFERENCES

Banerjee, A. K., P.N. Sen and C.R.V. Raman, 1978: On forecasting of southwest monsoon rainfall over India with mid-tropospheric circulation anomaly of April. Indian J. Met. Hydrol. Geophy., 29, 425-431.

Mooley, D. A., B. Parthasarathy and G. B. Pant, 1986: Relationship between All-India summer monsoon rainfall and location of ridge at 500 mb level along 75°E, J. Clim. and Appl. Met., 25, 633-640.

Shukla, J. and D. A. Mooley, 1986: Empirical prediction of the summer monsoon rainfall over India. Accepted for publication in Monthly Weather Review.

Shukla, J. and D. A. Paolino, 1983: The southern Oscillation and long-range forecasting of the summer monsoon rainfall over India, Mon. Wea. Rev., 111, 1830-1837.