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Statistical relations between winter monsoon rainfall and the preceding summer monsoon

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सार — भारत जून से सितम्बर तक में कई स्टेशनों पर सतह प्राचलों तथा ग्रीष्म मानसून (दक्षिण-पश्चिम) के महीनों के 7 मानक समदाब स्तरों पर माध्य मासिक पवन सदिशों की जांच की गई है । इसका उद्देश्य भारतीय प्रायद्वीप के उपखंडों, तमिलनाडु, केरल, तटीय आंध्र प्रदेश और रायल सीमा की उत्तर-पूर्वी मानसून वर्षा के लिये प्राग्वक्ताओं का चयन करना था । इस अध्ययन में 33 वर्षों (1951-83) की अवधि के आंकड़ों का उपयोग किया गया । इन उपखंडों के लिये विश्वसनीय प्राग्वक्ताओं के चयन के लिये एक क्रम में अनेक छानबीन किये गये । यह दर्शाया गया है कि अगस्त-सितम्बर की त्रिवेन्द्रम की 150 मि.बार. आंचलिक माध्यपवन तमिलनाडु की अनुवर्ती उत्तरपूर्वी मानसून वर्षा के लिये सन्तोषप्रद पूर्वानुमान देने में सक्षम है । बहु प्राग्वक्ताओं के प्रयोग में आने वाले अवरोधों की चर्चा की गई है ।

ABSTRACT. The mean monthly wind vectors at 7 standard isobaric levels and surface parameters of several stations of the summer (southwest) monsoon months of June to September over India have been examined. The objective was to select predictors for the northeast monsoon rainfall of the Indian Peninsular subdivisions of Tamilnadu, Kerala, coastal Andhra Pradesh and Rayalaseema. The data for a 33-year period (1951-83) were used in this study. A sequence of screening tests were employed to select reliable predictors for these subdivisions. It has been shown that the August-September 150 mb zonal mean wind of Trivandrum is capable of giving satisfactory forecasts for the following northeast monsoon rainfall of Tamilnadu. The constraints in using multiple predictors have been discussed.

1. Introduction

Even though the southwest monsoon (June-September) is the major rainfall season for India, the post monsoon or northeast monsoon of October-December is equally important for the southern Peninsula. This is so for the meteorological subdivisions of Tamilnadu, Kerala, coastal Andhra Pradesh and Rayalaseema. Table 1 provides the rainfall normals, annual and NE monsoon, with the latter expressed as the percentage of the former for these subdivisions (India Met. Dep. 1962). For Tamilnadu the NE monsoon season is the major rainy season. Although the SW monsoon is the major contributor for coastal Andhra and Rayalaseema, the NE monsoon accounts for a fairly substantial part (one third) of annual rainfall. The NE monsoon rainfall is only 19% of the annual rainfall for Kerala. But, the amount of rainfall is large and in south Kerala this figure increases to about 28%. The coefficient of variation of NE monsoon rainfall of the above regions varies between 30 and 50 per cent. The high values of variation reveal the importance and necessity of long range forecasting for the above subdivisions.

The importance of foreshadowing seasonal rainfall for a subdivision, or for a region with several subdivisions is well known. Das (1968,1986, 1987) has given an account of long range prediction of SW monsoon rainfall over India, and the usefulness of the coefficient of variation. Studies on long range prediction of SW monsoon rainfall have been attempted by several workers. Jagannathan and Khandekar (1962), Banerjee *et al.* (1978), Joseph *et al.* (1981) and Raj *et al.* (1985) used the middle and upper tropospheric meteorological parameters of the pre-monsoon season to foreshadow the rainfall of the subsequent SW monsoon season.

Some attempts have also been made in respect of NE monsoon rainfall. Doraiswami Iyer (1941) evolved a regression equation to forecast NE monsoon rainfall of Tamilnadu. The equation was based on South American pressure during June to August and Bangalore and Agra upperwinds of September and yielded a multiple correlation coefficient (CC) of 0.59 explaining 34.8% of the variation. Studying the relation between NE monsoon and simultaneous weather events elsewhere, Ramaswamy (1972) attributed poor NE monsoon rainfall over Tamilnadu to the southward shift of the westerly jet stream over India. Rao (1963) claimed an association between the weather over the European region and the Indian NE monsoon.

In this paper we will try to identify antecedent meteorological parameters which provide an indication of the following NE monsoon. Several parameters of the SW monsoon season will be tested to pick up suitable predictors. Those that show promise will be utilized to form a final set of forecast equations. Lorenz (1956) gives a detailed account of screening procedures for possible predictors.

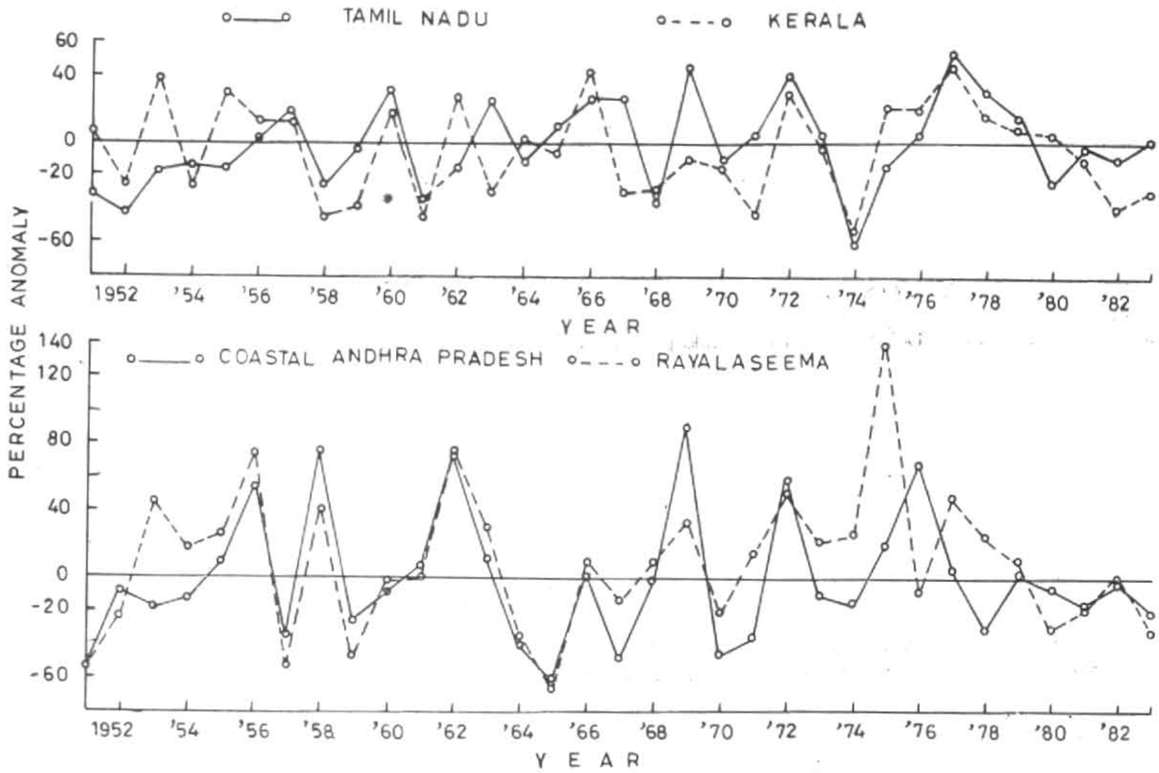


Fig. 1. Northeast monsoon rainfall of Tamilnadu, Kerala, coastal Andhra Pradesh and Rayalaseema for the period 1951-1983 as percentage anomalies

TABLE 1

NE monsoon rainfall for SE Peninsula

Sub-division	Annual normal rainfall (cm)	Seasonal normal rainfall		Std. dev. of seasonal rainfall (cm)	Coeff. of variation (%)
		Oct-Dec (cm)	Percentage of annual		
Tamil Nadu	101	48	47	13	27
Kerala	297	55	19	16	29
Coastal Andhra Pradesh	101	33	33	15	46
Rayalaseema	68	23	32	10	44

2. Data

The selected period represents the 33 years from 1951 to 1983. In this, the 25-year period 1951-75 has been taken as the developmental period, and the 8-year period 1976-83 as the test period. For the period of study, the mean monthly winds for the SW monsoon months of June-September for the seven standard isobaric levels of 850, 700, 500, 300, 200, 150 and 100 mb for the 9 stations : Bombay, Calcutta, Delhi, Jodhpur, Madras, Minicoy, Nagpur, Trivandrum and Visakhapatnam have been extracted from the U.S. Dep. of Commerce publication '*Monthly Climatic Data for the World*'. They yielded 252 wind vectors as possible predictors. The mean values of pressure, vapour pressure and temperature at the surface for the above months for four stations: Madras, Pamban, Trivandrum and Visakhapatnam have been extracted. They gave rise to another 48 predictors. The rainfall figures of Tamilnadu, Kerala, coastal Andhra and Rayalaseema for the NE monsoon were collected from the '*Weekly Weather Reports*' of the India Met. Dep. as percentage departures from normals and the data have been shown in

Fig. 1. From the normal rainfall figures of Table 1, the actual rainfall for each subdivision for each year was computed.

3. Analysis of rainfall

The standard deviation and the coefficient of variation were computed for each subdivision for the developmental period. These are shown in Table 1. It is seen that coastal Andhra and Rayalaseema have approximately the same coefficient of variation of 45%; similarly Tamilnadu and Kerala have a coefficient of variation of 30%.

For Tamilnadu and Kerala 1977 was the year that received the maximum NE monsoon rainfall; the rainfall excess was 55% and 47% respectively. The year of maximum deficiency was the same for both the regions; namely, in 1974 the rainfall deficiencies were 61% and 52% respectively. For coastal Andhra, 1961 and 1951 were the years of highest and lowest rainfall but in Rayalaseema they were 1967 and 1975.

4. Screening of predictors

As mentioned we have chosen 252 wind vectors and 48 other parameters as possible predictors for winter monsoon rainfall over four subdivisions. If each wind vector is resolved into its meridional and zonal component, we have 552 possible predictors for each subdivision. We have to select a few reliable predictors for prediction. To screen off the unwanted predictors, the correlation approach was used. Let r denote the CC between a possible predictor and the predictand, based on the developmental period 1951-75. The statistical significance of r was tested by the t-test and a predictor was rejected if the corresponding r was not significant at the 5% level.

With 504 zonal or meridional components of upper winds, a total of 2016 CCs were computed. Out of the 2016 CCs only 85 amounting to 4.2% turned out to be significant at 5% level. The remaining 95.8% were rejected. It is possible that a predictor rejected for one subdivision may have been accepted for another. Among the 85 tentatively selected predictors, Tamilnadu, Kerala, coastal Andhra and Rayalaseema accounted for 15, 20, 19 and 31 respectively. The 100 mb winds accounted for roughly 36% of the predictors and the remaining 64% were spread equally among the remaining six pressure levels. The percentage of predictors selected from the months of June, July, August and September were 23, 32, 14 and 31 respectively.

The other 48 predictors mentioned earlier provided 192 CCs. Out of them only 6 met the stipulated conditions. However, the standard deviations of the predictors were found to be very small. They were 0.7 mb and 0.3°C for surface pressure and temperature respectively; consequently they were discarded.

During the SW monsoon strong southwesterly winds prevail over the Indian Peninsula in the lower troposphere and strong easterlies occur in the upper troposphere. The CCs obtained from successive levels for a station should, thus, be reasonably consistent with one another, and if they are not, they could be spurious and fit for rejection. Among a set of several inter correlated predictors, it is adequate to choose only one or two which correspond to high CCs and are based on bigger samples. This eliminated 27 out of the 85 initially selected, thus leaving only 58 predictors.

5. Forecast equations and final choice of predictors

A single predictor regression equation based on the development sample was derived for each of the 58 predictors for appropriate predictands. The equations were tested in the test sample by means of the following procedure. The India Met. Dep. classifies the seasonal rainfall of a subdivision as large defect, moderate defect, slight defect, normal, slight excess, modetrate excess or large excess if the percentage anomaly of the rainfall lies in the intervals (— 100, — 51), (— 50, — 26), (— 25, — 11), (— 10,10), (11, 25) (26, 50) and (51, ∞) respectively. This procedure was followed to classify the actual and forecast rainfall. The forecast was taken as correct if the observed class coincided with the forecast class or one of its adjacent classes. Otherwise the forecast was considered to be wrong. Predictors that gave 60% or more correct forecasts were accepted and others were rejected. This final screening procedure led to the acceptance of 16 predictors; the break up was 4 each for each of the four subdivisions considered.

The 16 predictors yielded the same number of forecast equations for which the standard errors of the developmental and test samples were also computed. The details are given in Table 2. The regression equation was of the form $y=Ax+B$ where x is the meridional/zonal wind measured in m/s and y is the rainfall of the subdivision expressed as a percentage of the normal.

6. Best predictors for NE monsoon rainfall of Tamilnadu

For Tamilnadu for which the NE monsoon is the major source of rain, the zonal 150 mb winds for August and September over Trivandrum appeared to show promise. The respective CCs with the Tamilnadu rainfall were 0.61 and 0.65. But, the mean zonal 150 mb winds for August and September over Trivandrum yielded a much higher CC of 0. 77 explaining 59.3% of the variation. Fig. 2(a) gives the variation of this predictor with the predictand for the extended period 1957-87. The regression equation was formed by using the available 18 years data during 1957-75 and was tested over the extended 12-year test period of 1976-87. The performance of the equation both in developmental and test periods is shown in Fig. 2(b). The predictor has given 11 correct forecasts during 1976-87, the only wrong forecast was in 1978. The defects in rainfall for the years 1980, '84 and '86 and the excess for 1977 and '87 were predicted satisfactorily. The skill scores based on the forecast contingency table was 0. 76. During 1980-86 the 150 mb zonal easterlies over Trivandrum during Aug-Sep were stronger than normal and have shown less dispersion. This feature corresponds well with the over all below normal and less dispersive performance of NE monsoon over Tamilnadu during the same period.

This predictor (x) thus gives a good indication of the ensuing NE monsoon over Tamilnadu. The standard deviation of the predictor is 2.8 m/s. The regression equation is $y=7.5x+317.3$. Here y denotes the Oct-Dec

TABLE 2

Predictors for northeast monsoon rainfall over south Peninsula

Predictor	Size of samples		Correlation coefficient (× 100)	Percentage variance explained	Percentage of no. of correct forecasts	Regression coefficients		Standard errors	
	m	*n*				A	B	SE	SE_1
				Tamilnadu					
Jodhpur Sep 100 mb ME	10	6	64*	41.0	67	8.7	87.5	25	27
Nagpur Sep 100 mb ZO	12	5	69*	47.6	80	5.4	184.8	21	25
Trivandrum Aug 150 mb ZO	18	8	61**	37.2	71	5.6	279.6	22	19
Trivandrum Sep 150 mb ZO	18	8	65**	42.3	88	3.7	197.7	24	25
Trivandrum Aug-Sep 150 mb ZO	17	12	77**	59.3	92	7.5	317.3	18	18
				Kerala					
Jodhpur Jun 200 mb ME	13	7	66*	43.6	71	7.8	88.0	20	24
Madras Jul 150 mb ME	14	6	—59*	34.8	67	—10.0	24.9	25	15
Nagpur Jul 700 mb ZO	15	8	—53*	28.1	75	—7.6	128.4	23	24
Trivandrum Sep 200 mb ZO	19	8	46*	21.2	75	3.8	166.7	26	22
				Coastal Andhra Pradesh					
Bombay Aug 300 mb ME	19	7	55*	30.3	86	26.7	141.2	38	31
Calcutta Jun 200 mb ME	14	6	65*	42.3	83	16.1	96.1	32	19
Delhi Jun 500 mb ZO	25	8	48*	23.0	63	11.5	55.4	36	34
Trivandrum Sep 100 mb ME	14	7	—57*	32.5	71	—11.5	101.2	36	25
				Rayalaseema					
Bombay Jul 850 mb ME	18	7	—62**	38.4	71	—19.1	163.5	34	34
Calcutta Jun 200 mb ZO	14	6	—64*	41.0	67	—9.6	663.5	32	34
Delhi Jun 150 mb ZO	20	8	—48*	23.0	63	—4.3	129.6	37	24
Nagpur Sep 700 mb ME	17	8	56*	31.4	63	20.0	151.3	36	34

ME/ZO—Zonal/Meridional wind *m*, *n*—Sizes of developmental/test samples

SE, SE_1—Standard errors (expressed in percentage of normal rainfall) based on developmental/test samples

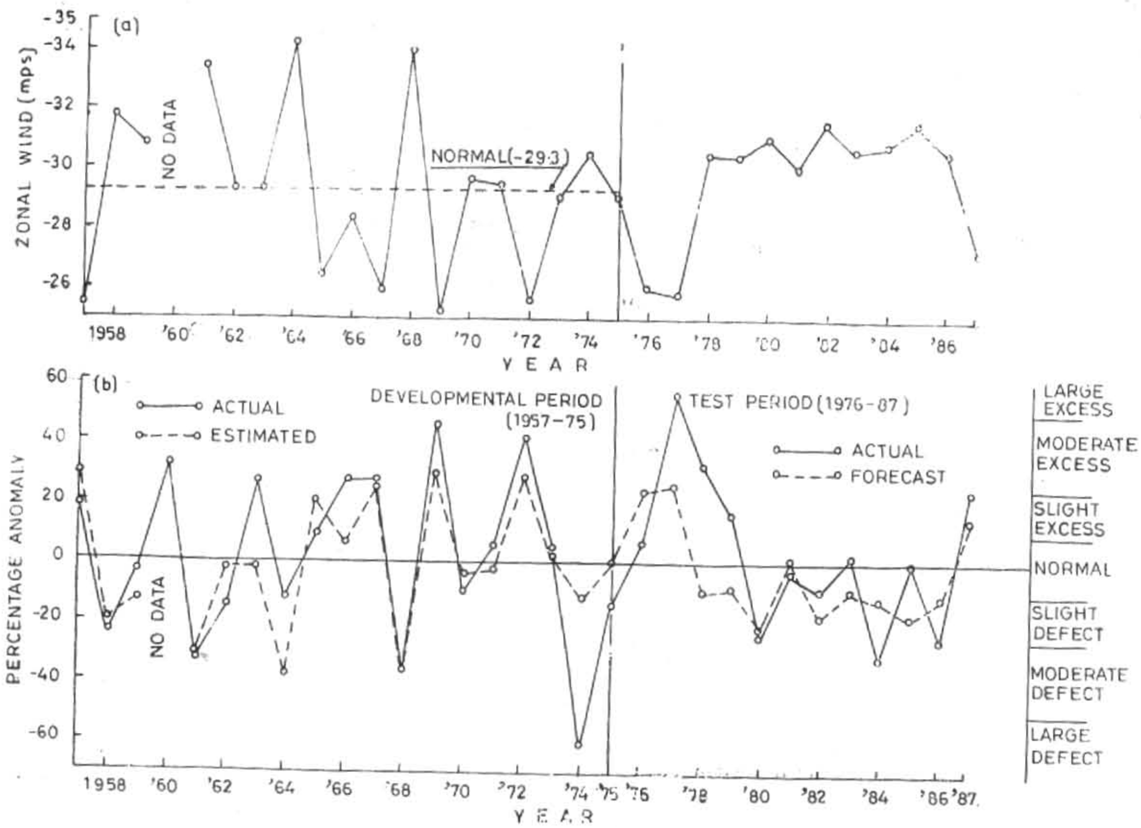
**—Significant at 1% level, *—Significant at 5% level

rainfall of Tamilnadu expressed as percentage of normal. The standard error of the forecast value is 8.5 and 8. 9 cm for the developmental and test periods. Consequently an error of about 18% should be expected in the forecast percentage of rainfall.

During the SW monsoon, the tropical easterly jet stream is observed over the Peninsula with the strongest winds occurring at 150 mb. It is evident that weakening of 150 mb easterlies is suggestive of a disintegration of easterly jet stream over the extreme southern Peninsula in the later part of the SW monsoon. This is favourable for a good subsequent NE monsoon over Tamilnadu. While, continuation of strong easterlies suggesting stronger persistence of the jet is unfavourable.

7. Reliability of the predictors and scope for further improvement

Even though most of the spurious predictors have been weeded out by the several screening procedures, it is improbable that each and every predictor listed in Table 2 is genuine or that all that were discarded



Figs. 2(a & b). Inter annual variation of easterly component of Aug-Sep 150 mb winds over Trivandrum during 1957-87 and (b) Actual and estimated/forecast of rainfall of NE monsoon of Tamilnadu as percentage anomalies

were spurious. As the screening tests have involved the test data also, reliability of the final set of predictors in the test sample has been assured to a fair extent. If other things are equal it is advisable to prefer predictors whose choice is based on bigger test samples. As upper air data are more readily available in the lower levels of the atmosphere predictors from lower levels should be preferred.

So far we have considered single predictor regression equations only. The possibility of forming multiple regression equations by clubbing 2 or 3 predictors was also examined. The major difficulty encountered in such a step was non-availability of data for some years for almost every predictor. Thus, when two or more predictors were clubbed the size of the test sample was considerably diminished. It may be pointed out that the predictors listed in Table 2 alone need not be the best set of predictors for a set of multiple regression equations. It is also the inter CCs between the predictors and not just the actual CCs between the predictors and predictands, which are important in such equations. Predictors that were discarded for single predictor equations may still be useful in multiple predictor equations.

In the long run some predictors may lose their value or may even change the direction of the relationship. A watch will have to be kept on their future behaviour to discard those that outlive their utility. The possible predictors which have been tested represent fairly well the wind distribution at all important standard levels over India during the SW monsoon. As seen earlier our limited effort in finding predictors from the surface did not bear fruit. Jagannathan and Khandekar (1962) have utilised contour heights and temperatures of upper air for forecasting SW monsoon rainfall of India. The discontinuities in heights and temperatures resulting from change of radiosonde instruments which took place in India in the late sixties (Raj *et al.* 1987) and the resulting heterogenity in a large volume of upper air data precluded a similar effort for NE monsoon rainfall. We have examined the data of the SW monsoon season only. A possible relation between parameters of the preceding pre-monsoon and the winter seasons with NE monsoon rainfall cannot be ruled out. It may be possible to pick up a few more predictors of NE monsoon rainfall by making a similar study for the winter and pre-monsoon season.

8. Summary

The important results of the study may be summarized as follows :

(*i*) The monthly mean winds, especially of the middle and upper tropospheres of certain stations of India during the southwest monsoon provide some pre-indication of the ensuing north east monsoon rainfall of the southern Indian Peninsula. The single predictor equations developed performed reasonably well in the test period.

(*ii*) It may be possible to obtain marginally better results by resorting to multiple regression equations.

(*iii*) The 150 mb Aug-Sep mean zonal wind of Trivandrum is capable of providing satisfactory forecasts for the rainfall of Tamilnadu for the subsequent northeast monsoon season of Oct-Dec.

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