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Long-range prediction of monsoon cnset over Kerala

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सार — 33 वर्षों (1961-93) के आंकड़ों के उपयोग से मध्य भारत में, अप्रैल माह के दौरान उष्ण निम्नदाब की प्रबलता के प्रभाव और केरल में मानसून के आरम्भ की तिथि (एम० ओ० डी०) के अंतः वार्षिक परिवर्तन पर शीत ऋतु (दिसम्बर से फरवरी) के यूरेशियन हिम आच्छादन के प्रभाव की जांच की गई।

समय से पूर्व मानसून आने वाले वर्षों में, अप्रैल माह के दौरान, मध्य भारत में समग्र औसत सतही तापमान 3.5 सें० अधिक था। मानसून के आरंभ की तिथि के साथ अप्रैल माह का माध्य सतही तापमान सूचकांक (एम० एस० टी०) और शीत ऋतु (दिसम्बर से फरवरी) का यूरेशियन हिम आच्छादन (डब्ल्यू० एस० सी०) क्रमशः 1% तथा 5% के स्तर पर सार्थक रूप से सहसंबंधित है। निम्न सतही तापमान और हिम आच्छादन की अधिकता से विलंबित मानसून का संकेत मिलता है।

एम० एस० टी० और डब्ल्यू० एस० सी० का स्वतंत्र प्राचलों के रूप में उपयोग करके केरल में मानसून के आरंभ की तिथि का दीर्घावधि पूर्वानुमान जारी करने के लिए एक समाश्रयण समीकरण विकसित किया गया। मूल माध्य वर्ग त्रुटि 4.6 दिन पाई गई। पांच वर्षों के स्वतंत्र आंकड़ों के उपयोग से मॉडल का परीक्षण करने पर यह पाया गया कि मॉडल ठीक कार्य कर रहा है।

एम० ओ० डी० व डब्ल्यू० एस० सी० तथा एम० ओ० डी० व एम० एस० टी० के युगलों के बीच संभाव्यता तालिकाएं विकसित की गईं। इन तालिकाओं का उपयोग मानसून के शीघ्र और विलम्ब से आने के वर्षों का संभाव्यता पूर्वानुमान ज्ञात करने के लिए किया जा सकता है।

ABSTRACT. Using the data of 33 years (1961-1993) the effect of the intensity of heat low over central India during the month of April and winter (December to February) Eurasian snow cover on interannual variation of monsoon date over Kerala were examined.

Composite mean surface temperature over central India during the month of April was higher during early onset years by 3.5° C. April mean surface temperature index (MST) and Winter (December to February) Eurasian snow cover (WSC) are significantly correlated with monsoon onset dates at 1% and 5% significant levels respectively. Lower surface temperature and excessive snow cover indicate a late onset.

A regression equation was developed for long range prediction of onset date over Kerala using MST and WSC as independent variables. The root mean square error (RMSE) of the relationship was found to be 4.6 days. The model was tested using independent data of five years and was found performing well.

Contingency tables were developed between the pairs MOD and WSC and MOD and MST. The tables can be used for probability forecasts of early and late onset years.

Key words — Mean Surface Temperature (MST), Monsoon Onset Date (MOD), Winter Eurasian Snow Cover (WSC), Onset, Contingency table, Model.

1. Introduction

Southwest monsoon sets in Kerala normally on 1 June and its standard deviation is 8 days. Long range prediction of onset date is important in view of its relevance in agricultural planning.

Reddy (1977) proposed as predictor the May 50 hPa zonal wind component over Singapore with westerlies presaging an early and easterlies a late onset date. Kung and Shariff (1982) developed regression methods for forecasting the onset date in Kerala based on April upper air patterns in the India-Australia region and Sea Surface Temperature (SST) around India in the pre-monsoon season.

Joseph and Pillai (1988) made an attempt on long range prediction of monsoon onset date over Kerala using the result of 30-40 day cycle in rainfall. Srivastava and Singh (1993) used eigen vectors of ten parameters for long range prediction of monsoon onset over Kerala. India Meteorological Department uses multiple regression equations for long range predictions of onset (Thapliyal 1993).

In this paper an attempt is made to develop a regression model for long range prediction of onset date using pre-monsoon parameters which have physical linkage with onset process.

The transition to summer involves the development of heat low over Indian subcontinent and is an

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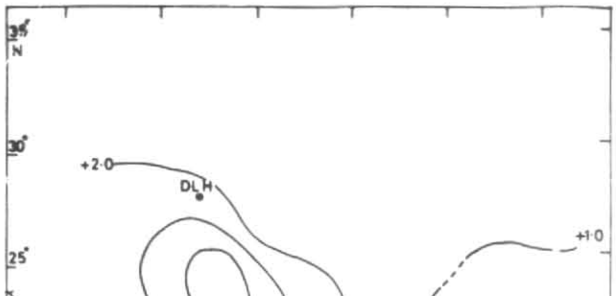

Fig. 1. Difference in April mean surface temperature between early and late onset years (early-late)

important precursor of southwest monsoon. During the month of April, heat low is placed over central parts of India which is the area of maximum heating. Therefore, abnormal surface temperature over central parts of India during April may lead to changes in intensity and position of heat low and in turn can influence the onset process. The transition in the circulation from winter to summer begins in the layers close to sea level and at 100 hPa. It progresses upward in the lower troposphere and downward in the upper troposphere towards 500 hPa (Ananthakrishnan 1977).

Similarly large and persistent excessive snow cover over Eurasia can delay and weaken the spring and summer heating of landmasses that is necessary for the establishment of large scale monsoon flow (Shukla 1987). During the spring and summer seasons following winter with excessive snow cover, most of the solar energy is used for melting the snow or evaporating from the wet soil. Recently, Barnett *et al.* (1989) studied the effect of Eurasian snow cover on Asian summer monsoon using ECMWF numerical model and found significant influence of snow cover on monsoon performance.

This study is, therefore, designed to examine the relationships between mean surface temperature (MST) over central India, winter Eurasian snow cover (WSC) and monsoon onset dates (MOD) and to develop a long-range forecast model using these relationships.

2. Data

The monthly mean surface temperatures were taken from IMD publications and Parthasarathy *et al.* (1990). The monthly mean Eurasian snow cover data were obtained from Climate Analysis Centre, Washington. Monsoon onset dates over Kerala were taken from IMD publications. The period 1961-1993 was considered for this study. However the snow cover data were available from 1967 only.

3. Results and discussion

The composite pattern of mean April surface temperatures during late and early onset years was examined by averaging April mean surface temperatures during late and early onset years. The late onset years were 1967, 1968, 1972, 1979 and 1983, and the early onset years were 1961, 1962, 1965, 1969, 1970, 1974 and 1988. The early (late) onset years were the years in which the monsoon onset date was more (less) than +1.0 (−1.0) standard deviation which is 6.4 days. The difference in April mean surface temperatures between early and late onset years are shown in Fig. 1. It shows that April mean surface temperatures were higher over India especially over central India during early onset years. Over central India the temperatures were higher of the order of 3.5° C, thus highlighting the role of April surface heating on the onset process.

In order to establish the relationships of April mean surface temperature and Eurasian snow cover with monsoon onset dates the following time series were prepared: April mean surface temperature (MST) by averaging the April mean surface temperatures of Indore, Akola and Sagar; winter (December to February) Eurasian snow cover (in sq km) (WSC) and monsoon onset date over Kerala (MOD).

Linear correlation coefficients were calculated between the time series and the results are shown in Table 1.

April mean surface temperature is inversely and significantly (better than 1% level) correlated with monsoon onset dates. That means, lower surface temperature over central India would lead to late onset and vice versa. Eurasian snow cover, also, is significantly (at 5% level) correlated with monsoon onset dates such that excess snow cover during winter indicates a late onset.

TABLE 1

Matrix of correlation coefficients between MOD, MST and WSC (Period : 1967-1993)

	MOD	MST	WSC
MOD	1.000	−0.617	+0.420
MST	—	1.000	−0.318
WSC	—	—	1.000

TABLE 2

Contingency relationship between monsoon onset dates and April surface temperature index (Period : 1961-1993)

	MOD			
	Onset (−)	Onset (N)	Onset (+)	Total
MST(+)	4	4	0	8
MST(N)	4	16	1	21
MST(−)	0	0	4	4
Total	8	20	5	33

TABLE 3

Contingency relationship between monsoon onset dates and Winter Eurasian snow cover (Period : 1967-1993)

	MOD			
	Onset (−)	Onset (N)	Onset (+)	Total
WSC(+)	0	1	3	4
WSC(N)	3	15	1	19
WSC(−)	2	1	1	4
Total	5	17	5	27

Further the consistency of the correlations was tested using sliding window method and the results show that a data length of 21 years is the minimum requirement for establishing stable relationships.

Contingency tables were constructed to study further the relationship between MOD, WSC and MST. Table 2 is the contingency table between MOD and MST and Table 3 is the contingency table between MOD and WSC. Normal years are the years if the parameter is within one standard deviation during that year.

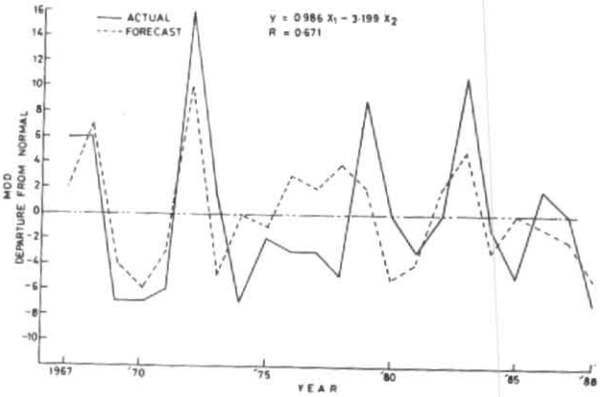

Fig. 2. Actual and model forecast onset dates. Period : 1967-1988

TABLE 4

Predicted and actual onset dates (Period : 1989-1993)

Year	Winter Eurasian snow-cover anomaly (sq Million km) X_1	April surface mean temperature anomaly C X_2	Predicted onset date Y	Actual onset date
1989	−1.000	−0.500	2 June	3 June
1990	−0.800	0.900	28 May	19 May
1991	0.110	0.100	1 June	2 June
1992	−0.799	0.700	29 May	5 June
1993	−0.700	0.866	28 May	27 May

From these contingency tables some useful inferences can be made. For example, the probability for delayed onset, when MST is positive (more than one standard deviation), is zero. When MST is negative, there is cent percent probability that monsoon onset will be late. Similarly, when snow cover is positive, probability of early onset is zero. These tables can be used for probability forecasts of onset dates.

Using these physically and statistically significant relationships a regression equation has been developed for the estimation of monsoon onset date. The equation thus developed using the data for the period 1967-1988 is given below:

$$Y = 0.968\ X_1 - 3.199\ X_2 \qquad (1)$$

where,

Y — departure of onset date from normal.

X_1 — departure of winter snow cover from normal.

X_2 — departure of April mean surface temp. index from normal.

The multiple correlation coefficient was 0.671, thus explaining about 45% of variation. The root mean square error (RMSE) of the estimation is 4.6 days, which is encouraging as the root mean square error of climatological forecasts is 6.2 days.

Fig. 2 shows the actual and estimated onset dates from 1967-1988. It can be seen that the regression model gave fair indication of late onset years 1972, 1979 and 1983 and early onset years, 1969, 1970, 1971 and 1988.

The present model was tested for its use by using independent 5 years' data period 1989-1993. The results are shown in Table 4.

From the Table 4 it can be seen that the model performed well during 1989, 1991 and 1993. However, the model could not indicate the late onset during 1992 and very early onset during 1990. The model, however, indicated that monsoon will be early by about four days during 1990. This anomaly could be attributed to the formation of a cyclonic storm over Bay of Bengal in May. Srivastava and Singh (1993) mentioned the role of storms in May in modulating monsoon onset process in the medium range time scale. However, this aspect is to be studied in detail. The forecast models used by IMD also could not indicate the very early onset during 1990 (Thapliyal 1993).

The present model explains only 45% of variation and therefore it has its own limitations. The model is to be refined by incorporating more physically-based parameters.

4. Conclusions

(*i*) Composite mean surface temperature over central India during the month of April was higher during early onset years by 3.5° C.

(*ii*) April mean surface temperature index (MST) and winter Eurasian snow cover (WSC) are significantly correlated with monsoon onset dates at 1% and 5% level respectively. Lower surface temperature and excessive winter snow cover indicate a late onset.

(*iii*) A regression equation was developed for long range prediction of onset date over Kerala using MST and WSC as independent variables. The relationship explained 45% of variation. The model error (RMSE) is 4.6 days and it is within standard deviation of onset dates and is lower than error of climatological forecasts. The model gave fair indications of early and late onset years.

(*iv*) Contingency tables developed can be used for probability forecasts for early and late onset.

(*v*) The present model was tested using independent data period 1989-1993 and was found to perform well except in 1990 and 1992.

The present model is proposed to be improved by incorporating more physically linked parameters.

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