Mausam, (1984), 35, 4, 525-530

551.573 : 551.553.21(540)

April evaporation in relation to subsequent monsoon rainfall in India

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(*Received 25 March 1982*)

सार — देश में अनुवर्ती मानसून वर्षा के व्यवहार के संबंध में प्रतिवर्ष 1965 से 1975 की अवधि के मार्च से मई के महीनों के मासिक माध्य वाष्पन चार्टों की जांच की गई है। अप्रैल के चार्ट सामान्यतया दो क्षेत्र दर्शाते हैं। पहला उच्च वाष्पन पट्टी का प्रारंभिक क्षेत्र और दूसरा द्वितीयक क्षेत्र। यह उन वर्षों के लिए हैं, जब देश में अनुवर्ती मानसून वर्ष सामान्य हो। उच्च वाष्पन का प्रारंभिक क्षेत्र गुजरात से महाराष्ट्र होता हुआ आंध्रप्रदेश और निकटवर्ती कर्नाटक तक फैला हुआ है। यह सामान्य और कमी वाले वर्षों, दोनों ही में पाया जाता है। अधिकांश कमी वाले वर्षों अर्थात् 1965, 1968 एवं 1972 में इसके प्रारूप में खासा परिवर्तन हुआ है। द्वितीय क्षेत्र जो कि राजस्थान से मध्यप्रदेश तक फैला है, अपनी सामान्य जगह से हट गया है। मार्च और मई के महीनों में वाष्पन के प्रारूप में कोई परिवर्तन नहीं पाया गया। यद्यपि अप्रैल 1970 में द्वितीयक क्षेत्र हट गया था फिर भी यह वर्ष मानसून की दृष्टि से अच्छा वर्ष रहा और इस वर्ष से उच्च वाष्पन पट्टी के कुल क्षेत्र मे भी कोई कमी नहीं आई। इससे लगता है कि द्वितीयक क्षेत्र पश्चिम की ओर खिसक गया है और वहां उसने प्रारंभिक क्षेत्र के साथ मिलकर उच्च वाष्पन पट्टी का एक बड़ा क्षेत्र विकसित कर लिया है।

अतः देश मे अनुवर्ती मानसून वर्षा की प्रागुक्ति मे अप्रैल मास के माध्य वाष्पन चार्ट का उपयोग किया जा सकता है।

ABSTRACT. Monthly mean evaporation charts for the months March to May are examined year by year for the period 1965 to 1975 in relation to the behaviour of the subsequent monsoon rainfall in the country. April charts, in general, show two regions, one primary and other one secondary region of high evaporation belt in the years where the subsequent monsoon rainfall is normal over the country. The primary region of high evaporation extends from Gujarat to Andhra Pradesh through Maharashtra and adjoining Karnataka. It is found for both normal and deficient years. In most of the deficient years, *viz.*, 1965, 1968 and 1972, the pattern changes substantially; the secondary region which extends from Rajasthan to Madhya Pradesh disappears from its normal position. No such change in the evaporation pattern is found in the months of March and May. Though secondary region disappears in April 1970 which was a good monsoon year yet there is no shrinking in total area coverage of high evaporation belt. It appears that secondary region has shifted towards west and forms a bigger region of high evaporation belt in combination with the primary one.

April mean evaporation chart may, therefore, serve as a tool for predicting the behaviour of the subsequent monsoon rainfall in the country.

1. Introduction

The agricultural production and Indian economy are so intimately linked with the southwest monsoon that long-range forecasting of this rainfall in space and time is, perhaps, the most fundamental problem of Indian meteorology.

Attempts have been made to relate the distribution of rainfall of Indian southwest monsoon with antecedent upper air factors near the scene of activity for the purpose of long-range forecasting. A synoptic-cum-statistical approach has been made (Banerjee *et al.* 1978) to forecast overall distribution of monsoon rainfall over India. Authors have found a significant correlation of monsoon rainfall with the latitudinal position of the subtropical ridge at 500 mb in the mean upper air circulation of the month of April. By studying the global circulations features at 50 mb mean January circulation, the large scale rainfall deficiency in the subsequent monsoon months has been indicated (Thapliyal 1979). He has tried to forecast severe drought conditions due to large scale monsoon failure about 5 months prior to the start of the monsoon over India. Recently, Joseph *et al.* (1981) have found that the upper tropospheric winds over India in the month of May are significantly correlated with the monsoon rainfall in India. Based on this, they have derived a meridional wind index by using the 200 mb meridional winds over Bombay, Calcutta, Madras and Nagpur for forecasting monsoon rainfall over India.

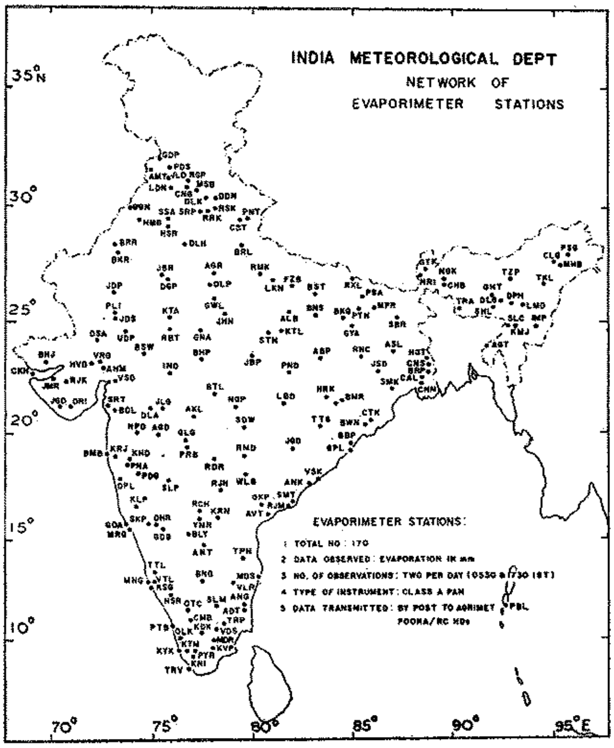

Fig. 1. Location of evaporation stations

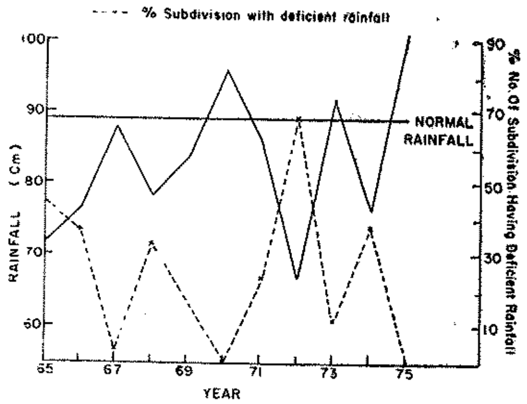

Fig. 2. Area weighted rainfall (cm) & percentage number of sub-divisions having deficient rainfall of India

Atmospheric processes and resultant weather phenomena are dependent on large scale circulation which is induced by incoming solar radiation reaching the earth. Sen *et al.* (1978) have shown that in April, high radiation area extends from Rajasthan to Tamil Nadu through Deccan Plateau in the years when subsequent monsoon rain is normal over the country and in deficient years, *viz.*, 1965, 1966 and 1972, the radiation pattern changes substantially with a tongue of low radiation over the Peninsula and central parts of India.

As potential evaporation is directly dependent on net radiation and aerodynamic term which can be expressed by Penman's (1948) equation as :

$$E = \frac{\Delta R_n + \gamma E_a}{\Delta + \gamma}$$

where, R_n = Net radiation,

E_a = Aerodynamic term,

Δ = Slope of the saturation vapour pressure and temperature curve at the mean air temperature,

γ = Psychrometric constant.

Any change in the aerodynamic and radiation patterns over India will cause subsequent change in the evaporation pattern.

This led the authors to analyse year to year variation of evaporation in the summer months, *viz.*, March to May and to see whether this can give any indication about the behaviour of the subsequent monsoon rainfall.

2. Methodology

A long series of monthly evaporation (in mm) values are available for about 110 stations distributed over India and these data have been utilised for the present study. The locations of these stations are shown in Fig. 1. The mean daily evaporation values for each of the months, March to May for these stations have been plotted and analysed year by year for the period 1965 to 1975. Yearwise distribution of area weighted rainfall and percentage number of sub-divisions having deficient rainfall are shown in Fig. 2. The mean value (normal) of area weighted rainfall derived by Parthasarathy and Mooley (1978) for the 105-year period, 1866 to 1970, is 88.75 cm which is also indicated in Fig. 2. The normal evaporation charts for these months have been taken from the publication on *"Evaporation data of observatories in India"* issued by India Meteorological Department. The pattern of evaporation in the monthly charts (March to May) for each year from 1965 to 1975 is examined in relation to the behaviour of the subsequent monsoon rainfall distribution in the sub-divisions of India. For this purpose, in describing weekly rainfall distribution, the departmental convention categorises rainfall in each sub-division as normal (departure between + 19% & —19%), deficient (departure from normal between —20% & —59%), scanty (departure of —60% or less) and excess (departure of + 20% and above).

3. Results and discussion

Year to year analysis of evaportion charts for the month of April shows considerable variation in evaporation pattern with the distribution of subsequent monsoon rainfall (June to September) over the sub-divisions of India. However, no distinction can be made in year to year variation in evaporation pattern for the months of March and May with the distribution of subsequent monsoon rainfall over the country. The mean daily normal evaporation pattern for the month of April which is averaged over the years 1959 to 1975 is shown in Fig. 3. It is found that the high evaporation ($\geqslant$ 10 mm is taken as a high value) belts are confined in two regions. One region comprises of Gujarat, Maharashtra, parts of Karnataka and Andhra Pradesh. This region will be called primary region of high evaporation belt as it is observed in all years. A secondary region comprises of parts of Rajasthan, Madhya Pradesh and Uttar Pradesh. This region will be called secondary region as it undergoes radical changes from year to year.

The line of high evaporation belt runs from Rajkot to Anantapur through Aurangabad in the primary region. In case of secondary region, the line of high evaporation belt runs mostly from Ganganagar to Satna through Agra. In general, the year when the April evaporation pattern is normal or area of high evaporation belt expands, the subsequent rainfall in the monsoon season is also observed to be normal or in excess in about 90 per cent of the sub-division. But in most of those years when the region of high evaporation belt shrinks and only one region of high evaporation belt forms, the subsequent monsoon rainfall is found to be deficient in more than 30 per cent of the sub-divisions in the country. Abnormalities of evaporation pattern in relation to subsequent monsoon rainfall are observed in two deficient years, *viz.*, 1966 and 1974 and in one normal year, *viz.*, 1967. April evaporation patterns and axes of high evaporation belts in three typical years, *viz.*, 1970 & 1975 and 1973 when the rainfall is normal or in excess in most of the sub-divisions are shown in Figs. 4, 5 and 6 respectively. In all these years, evaporation patterns conform the normal pattern except in the year of 1970 in which only one region of high evaporation belt is observed instead of two distinct regions. It appears that secondary region shifts towards west and forms a bigger region of high evaporation belt. Sen *et al.* (1978) have also found a shifting of 540 isoline of radiation towards west from its normal position in the year 1970. The total area coverage of high evaporation belt is found almost same in 1970 to that of normal year. Evaporation patterns of 1973 and 1975 conform the normal pattern except with 3 and 4 cores of high evaporation belts respectively and maxima reaching 16 mm instead of 14 mm in the normal pattern. In these two years the axis of the high evaporation belt runs almost in the same region as the normal region.

Evaporation patterns of deficient years, *viz.*, 1965, 1968 and 1972 are presented in Figs. 7, 8 and 9 respectively. It is interesting to note that in the years where monsoon rainfall is highly deficient over the country, the evaporation pattern in April is considerably different. The region of high evaporation belt

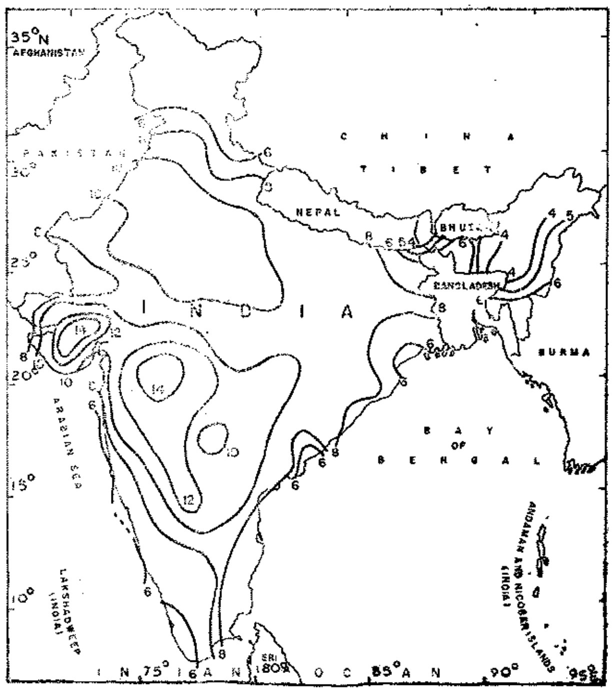

Fig. 3. Mean daily normal evaporation (mm) pattern for the month of April 1959-75

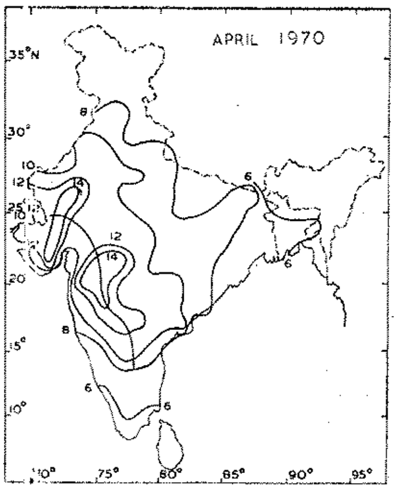

Fig. 4. Mean daily evaporation pattern of April 1970

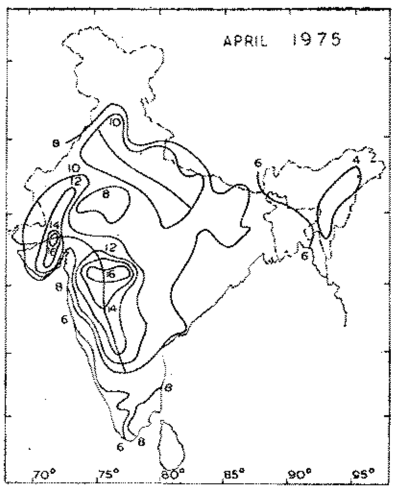

Fig. 5. Mean daily evaporation pattern of April 1975

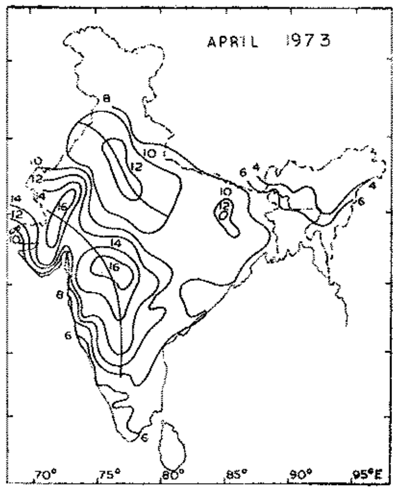

Fig. 6. Mean daily evaporation pattern of April 1973

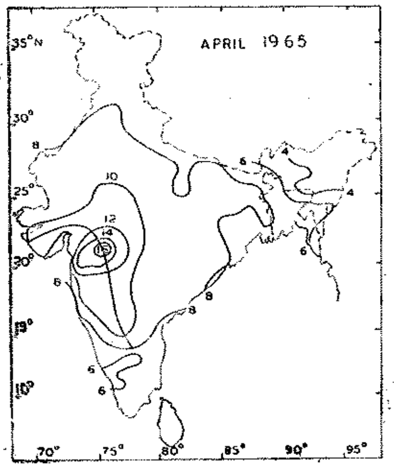

Fig. 7. Mean daily evaporation pattern of April 1965

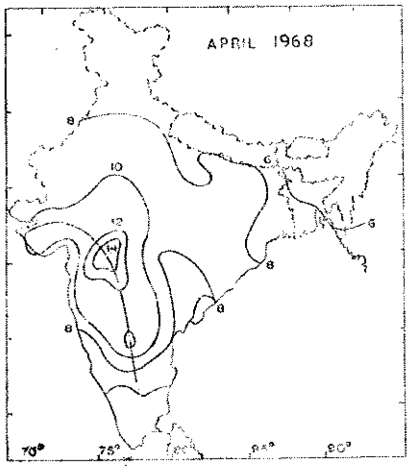

Fig. 8. Mean daily evaporation pattern in April 1968

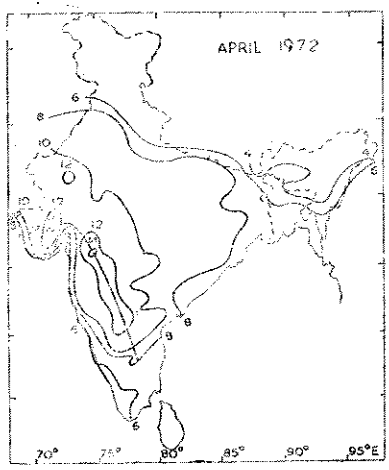

Fig. 9. Mean daily evaporation pattern in April 1972

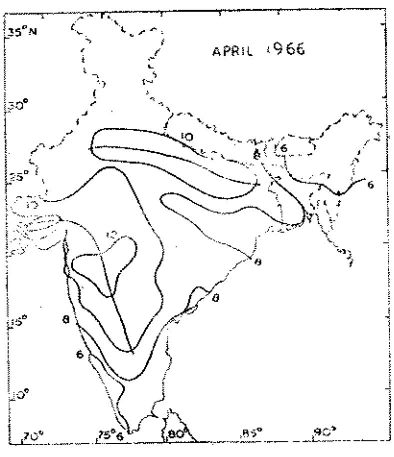

Fig. 10. Mean daily evaporation pattern in April 1966

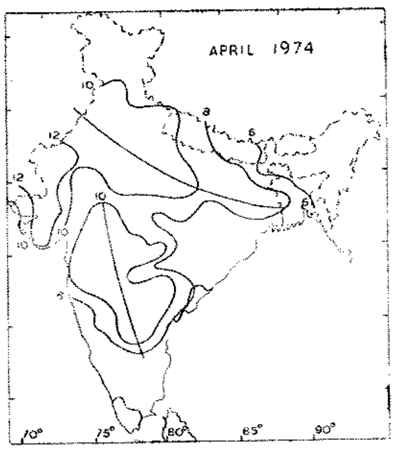

Fig. 11. Mean daily evaporation pattern in April 1974

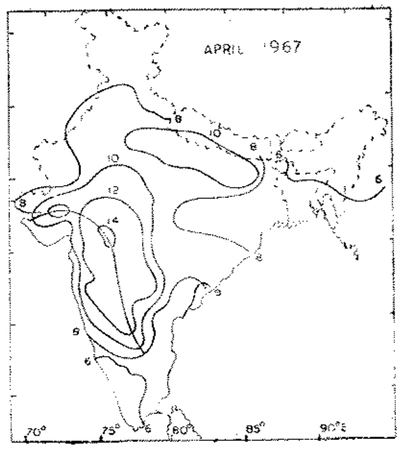

Fig. 12. Mean daily evaporation pattern in April 1967

shrinks markedly and secondary region disappears in all the cases. It is also observed that evaporation over the whole country reduces considerably in the years where the monsoon rainfall is highly deficient. This can be related with the change in radiation balance in the central part of India. Sen *et al.* (1978) have also found in April a tongue of low radiation over central parts of India. But axis of high evaporation belt in the primary region is observed in the same position.

Out of all these years, April evaporation pattern of three years, *viz.*, 1966 & 1974 and 1967 which are deficient years and normal year respectively has shown deviation from the one region (primary) and two regions (both primary and secondary) of high evaporation belts respectively. Evaporation pattern of 1966 (Fig. 10) has shown a smaller and narrow secondary region of high evaporation belt. This region extends from 75 deg. E to 87.5 deg. E through parts of east Rajasthan, NE Uttar Pradesh and Bihar with a width of 2.0 deg. in the N-S direction. The axis of high evaporation belt of secondary region lies from Sikar to Sabour through Lucknow. Evaporation pattern of 1974 (Fig. 11) shows a normal pattern with slight change in the position of the axis of primary region. The axis of primary region runs from Ujjain to Anantapur through Jalgaon. The secondary region is found almost in the same position to that of normal position. Deviation of evaporation pattern is also found in 1967 (Fig. 12) when the rainfall is normal or excess in 97% of the sub-divisions of the country. Though primary region appears in the normal position yet secondary region is found much away to the SE from its normal position with shrinking in area coverage. The axis of secondary high evaporation belt runs from Mathura to Bhagalpur through Lucknow with a width of 15 deg. in the N-S direction. The deviation of evaporation pattern of these three years indicates that aerodynamic term might have played significant role towards April evaporation rate in these years and effect of this term should be taken into account separately for further critical analysis.

April evaporation pattern may, therefore, be used as a clue for forecasting of subsequent monsoon rainfall. Thus it may be possible to predict drought condition in the months of June-September. Importance of this findings is that these results are based on observations from 110 stations. Installation of U.S.A. class A pan evaporimeter is much cheaper. Further, increase of evaporation measurement network will provide additional data which will be more useful to predict subsequent monsoon rainfall in the country.

4. Conclusions

The study has revealed that disappearance or change in position of secondary high evaporation belt in April from its normal position plays an important role in relation to the subsequent monsoon rainfall over the country. The regions of high evaporaton belts in April generally lie more or less in nomal positions and total area coverage is found almost same with that of normal area coverage, *viz.*, in 1967, 1970, 1973 and 1975 and in these years normal or excess rainfall is realised in about 90 per cent of the sub-divisions in the country. But in deficient years, though axis of high evaporation belt runs almost in the same position in primary region, the secondary region of high evaporation belt disappears, *viz.*, in 1965, 1968 and 1972. In some years, the appearance of secondary region in the deficient years, *viz.*, in 1966 and 1974 and shrinking in the area coverage and shifting from its normal position of secondary region in the normal year, *viz.*, 1967, indicate that the effect of aerodynamic term may be studied separately for further critical analysis. In general, the disappearance of secondary region of high evaporation belt from its normal position or shrinking in total area coverage of high evaporation belts may be taken as a tool for forecasting deficient rainfall of subsequent monsoon months over the country.

Acknowledgements

The authors are thankful to Shri H. M. Chaudhury, D.D.G. (C&G) for giving constant encouragement and full facilities for carrying out the work. They are also thankful to Dr. D. A. Mooley and Shri A. K. Banerjee for going through the manuscript and giving valuable suggestions. Thanks are also due to the staff members, Data Collection Unit, Agrimet for assisting the work and to Shri Y.G.H. Khan for typing the paper.

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