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Linkage between north pole winter temperatures and summer monsoon rainfall over India

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An investigation of the possible linkage of the north pole temperatures at 30 mbar (lower stratosphere) for 26 pre-winters (November, 1955-1980), winters (December, 1955-1980; and January, 1956-1981), and springs (March, 1956-1981) with rainfall activity over India for the following 26 summer monsoons (June-September, 1956-1981) has been made. The study suggests an association of the mean warm/cold anomalies in the north pole temperatures at the lower stratosphere during pre-winter, winter and spring with the mean positive/negative percentage departures of rainfall over India during the following summer monsoon. The relationships between anomalies in the north pole temperatures during November and March and the rainfall activity during the following summer monsoons over India are, however, significant and may be responsible for 20 and 10% variabilities in monsoon rainfall. On most of the occasions the wet/dry summer monsoons (percentage departures of rainfall being more than ± 10) in India are preceded by warm/cold anomalies in the north pole winter temperatures at the lower stratosphere during winter. It seems that warm and cold anomalies in the north pole winter temperatures at the lower stratosphere are inter-locked with the oscillations of 500 mbar ridge during the following April over the Indian tropics in some manner which, in turn, influence the rainfall activity over India during the following summer monsoon.

1 Introduction

Understanding of coupling mechanism between the middle atmosphere and the tropospheric events is one of the prime motivations for enhancement of knowledge of the dynamics of the middle atmosphere. Recently McGuirk and Douglas[1] have reported severe weather anomalies over the United States that are associated with the major sudden stratospheric warming (SSW) events. It has also been reported that the stratospheric disturbances are accompanied by tropospheric blocking events between 85 and 95% of the time[2]. The features of interaction between stratosphere and troposphere during SSW events at high latitudes have been discussed at length by several workers[3-7]. Mukherjee *et al.*[8,9] have suggested an association of the phases of the low latitude quasi-biennial oscillation (QBO) with variability of the summer monsoon rainfall over India. Using a short period (6 years) temperature and wind data, they have also made an effort to link inter-annual variability of the stratospheric warming events over high latitudes with the variability of following summer monsoon rainfall over India[10]. The objective of the present study is to examine the anomalies in the north pole temperatures at the lower stratosphere (30 mbar) during pre-winter (November), winter (December and January) and spring (March), and their linkage with the forthcoming summer monsoon rainfall activity (June-September) over India.

2 Data

Since the present investigation deals with the relationship of the lower stratospheric parameters with the tropospheric events, the monthly mean temperatures at only 30 mbar which represents lower stratosphere for the north pole are considered. Mukherjee *et al.*[9] and Labitzke and van Loon[11] also considered the same level (30 mbar) to represent lower stratosphere to find out influence of QBO on Indian summer rainfall and of solar cycle on the stratospheric temperature, respectively. The data considered in the present study consist of 26 north pole temperatures for pre-winter (November, 1955-1980), for winter (December, 1955-1980; and January, 1956-1981) and for spring (March, 1956-1981) and of rainfall over India during the following 26 summer monsoon seasons (June-September, 1956-1981). Analysis of the stratospheric temperatures at the northern hemisphere is being carried out regularly at the Free University of Berlin. The monthly mean 30 mbar temperature data discussed in the paper are exactly for the north pole, thus representing only one single point. They are, however, derived from the daily analysis since 1964. The data related to the period prior to that have been extracted from the monthly analysis. There is no upper air station located exactly over the north pole. The mean temperatures for November and March are considered separately and the mean temperatures for December and January, which represent the temperature field at the north pole during winter are considered together. The deviations of the pre-winter (November), winter (December and January) and spring (March) from their 26-year long-term mean are then derived for each year. The percentage departures of the summer monsoon rainfall (June-September) for entire India (26 years from 1956-1981) are also worked out.

The monthly mean north pole temperatures are obtained from Naujokat[12].

3 Results and discussion

Examination of the north pole temperatures at 30 mbar during winter suggested an existence of a little relationship of warm/cold anomalies in the stratospheric polar temperatures with the rainfall activity over India during the following summer monsoon, the correlation coefficient being +0.18. But, it would be noteworthy to mention here that the positive anomalies in the north pole temperatures were noticed during December and January for 10 winters [i.e. 1958-1959, 1959-1960, 1960-1961, 1965-1966, 1967-1968, 1968-1969, 1969-1970, 1970-1971, 1974-1975, 1976-1977]. The average of these positive anomalies was +6.7°C, while the average of the percentage departures of the rainfall for the following 10 summer monsoons over India (i.e. 1959, 1960, 1961, 1966, 1968, 1969, 1970, 1971, 1975, 1977) was +3.6. The negative anomalies in the north pole temperatures, on the other hand, were noticed during the 16 winters [i.e. 1955-1956, 1956-1957, 1957-1958, 1961-1962, 1962-1963, 1963-1964, 1964-1965, 1966-1967, 1971-1972, 1972-1973, 1973-1974, 1975-1976, 1977-1978, 1978-1979, 1979-1980, 1980-1981]. The average of these negative anomalies for these 16 years was −4.1°C and the average of the percentage departures of rainfall for the following 16 summer monsoons was −0.9. The average of the warm/cold anomalies for November (pre-winter) and March (spring) and the percentage departures of the following summer monsoon rainfall for 26 years are also worked out. Similar type of result as noticed for winter can also be noticed for pre-winter and for spring. But the relationship between the anomalies in the north pole temperature at 30 mbar during November and March with the percentage departures of rainfall during the following summer monsoon is more meaningful. The correlation coefficient worked out for November stratospheric temperatures and the following summer monsoon rainfall is +0.47, and that for March stratospheric temperatures and the following summer monsoon rainfall is +0.33. The average warm anomaly noticed in 13 cases was +2.8°C and the average cold anomaly noticed in another 13 cases was −2.8°C during November, while the respective percentage departures in rainfall were +3.9 and −2.3, respectively. In March, the average warm anomaly was +5.6°C in 13 cases and cold anomaly was −4.6°C in another 13 cases, while the percentage departures of rainfall were, respectively, +2.8 and −1.8.

The rainfall data for the 26 summers are then stratified into two groups—one with rainfall departures more than +10% (wet years) and the other with the rainfall departures less than −10% (dry years). There are 9 such years (1959, 1961, 1965, 1966, 1970, 1972, 1975, 1978 and 1979) when such contrasting rainfall was reported during the span of 26 years considered in this study. The warm/cold anomalies in the north pole temperatures at 30 mbar during the 9 preceding winter years, namely, 1958-1959, 1960-1961, 1964-1965, 1965-1966, 1969-1970, 1971-1972, 1974-1975, 1977-1978 and 1978-1979 are then examined and shown in Table 1. Table 1 shows that out of 5 occasions of wet monsoon years [i.e. 1959(+13.8%), 1961 (+12.4 %), 1970 (+10.6%), 1975(+18.9%) and 1978 (+11.9%)], on 4 occasions good monsoon was preceded by warm anomalies in the north pole winter temperatures at 30 mbar. Only on one occasion (1978) the good rainfall activity was preceded by the cold anomaly, instead of expected warm anomaly, indicating that 80% of the wet monsoon years during 1956-1981 was preceded by warm anomalies in polar lower stratosphere. Scrutiny of the data for the monthly mean north pole temperatures at 30 mbar suggests that the mean north pole temperature during December 1977 was abnormally cold and inconsistent with the trend of the monthly mean temperatures for November 1977 and January 1978. If the mean temperature for December 1977 is worked out from the linear interpolation of the monthly mean temperatures of November 1977 and January 1978, a warm anomaly in the north pole at 30 mbar during winter could be ascertained. The mean north pole winter temperature during 1977-1978 would then show a warm anomaly of +1.8°C in place of the cold anomaly of −2.7°C as shown in Table 1.

Again it can be noticed from Table 1 that out of 4 occasions of dry monsoon years, [i.e. 1965 (−15.0%), 1966 (−11.1%), 1972 (−17.8%) and 1979 (−15.4%)], on 3 occasions weak monsoon activity was preceded

Table 1—Mean warm and cold anomalies in polar temperatures at 30 mbar for winter, location of 500 mbar ridge at 75°E in April and percentage departures of summer monsoon rainfall over India

Winter years (December and January)	Warm (+)/cold(−) anomaly in polar temperatures at 30 mbar during winter (°C)	Location of ridge at 500 mbar along 75°E in April	Summer years	Percentage departures of rainfall over India (June-September)
1958-1959	+ 2.3	16.0°N	1959	+13.8
1960-1961	+ 7.8	15.0°N	1961	+12.4
1964-1965	− 3.7	14.0°N	1965	−15.0
1965-1966	+ 5.3	13.5°N	1966	−11.1
1969-1970	+11.8	15.8°N	1970	+10.6
1971-1972	− 5.7	11.0°N	1972	−17.8
1974-1975	+ 3.3	17.5°N	1975	+18.9
1977-1978	− 2.7	14.0°N	1978	+11.9
1978-1979	− 1.7	12.5°N	1979	−15.4

by cold anomalies in the north pole winter temperatures at 30 mbar. On one occasion the warm anomaly, instead of expected cold anomaly, was noticed in the pole during the winter of 1965-1966. The above result could lead to the conclusion that 75% of the dry monsoon years during 1956-1981 was preceded by cold anomalies in the north pole winter temperature at 30 mbar. It may not be out of context to mention here that the mean temperature for January 1966 was cooler by as much as 4.4°C than the 26-year mean temperature for January, showing a cold anomaly existing in the month of January.

Similar type of analysis has been done for the months of November and March. During November, 80% of occasions (4 out of 5 years) of warm anomalies was associated with more than 10% of excess rainfall and 75% of occasions (3 out of 4 years) of cold anomalies was associated with more than 10% of deficient rainfall during the following summer monsoons. But the relationship of warm/cold anomalies during March with the rainfall activity during the following summer monsoon is not, however, encouraging.

Shukla and Mooley[13], on the basis of their analysis of 46 years' data, have made an attempt to correlate the location of the 500 mbar ridge at 75°E over tropics during April with the following summer monsoon rainfall activities over India. In order to examine the position of the ridge at 500 mbar at 75°E during April preceding the 9 occasions of contrasting monsoon rainfall (wet and dry years), the anomalies in the winter polar temperatures at 30 mbar and the locations of the ridge at 500 mbar at 75°E for these 9 years are also shown in Table 1. During these 9 occasions, the ridge position has oscillated between 11°N and 17.5°N. On 5 occasions of excess rainfall (wet years), i.e. in 1959, 1961, 1970, 1975 and 1978, the ridge oscillated between 14.0°N and 17.5°N. But on 4 occasions of deficient rainfall (dry years), i.e. in 1965, 1966, 1972 and 1979, it oscillated between 11°N and 14°N. The above feature suggests an association between north/southward shift of the ridge at 500 mbar at 75°E during April and the following wet/dry summer monsoon years. Since warm/cold anomalies in the winter polar temperatures at 30 mbar were mostly linked with the excess/deficient rainfall in the following summer monsoon years, it may not be farfetched to conceive that the weakening/strengthening of the grip of the stratospheric polar vortex during the winter would be conducive to the northward/southward shift of the ridge at 500 mbar over Indian tropics during the following April, which, in turn, could influence the performance of the following summer monsoon (June-September) over India. Wallace and Chang[14] have shown a teleconnection of the southern oscillation with intensity of the stratospheric polar vortex. They have put forward an impressive evidence envisaging the linkage between 'high/dry' winters and winters with strong polar vortex, and between 'low/wet' winters with weak polar vortex. It has been hinted[10,15] that the early breaking of the stratospheric polar vortex could be helpful to the better performance of the following summer monsoon over India. Significant weather anomalies over the United States were reported in association with the January and February SSW events[1]. A teleconnection of inter-annual variability in the tropical wind field at 200 mbar with the southern oscillation has also been suggested[16]. Two plots of warm/cold anomalies in the north pole at 30 mbar during pre-winter and spring for the block 1955-1980 and 1956-1981, respectively, and the percentage departures of rainfall during the following summer monsoon over India have also been included (Figs 1 and 2). The

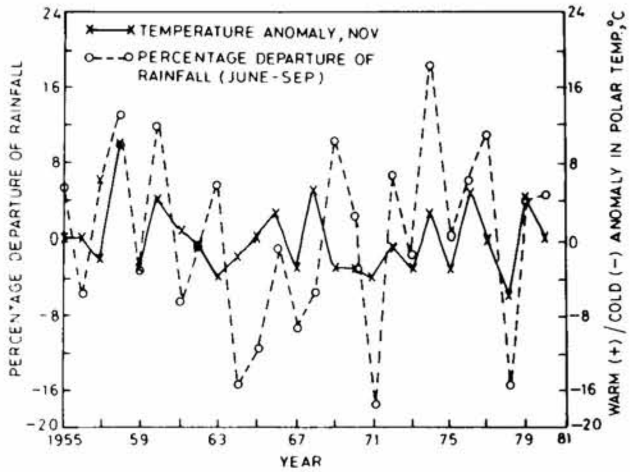

Fig. 1—Warm/cold anomalies in the north pole temperatures at 30 mbar during pre-winter (November) and departures of rainfall during the following summer monsoon (June-September) over India

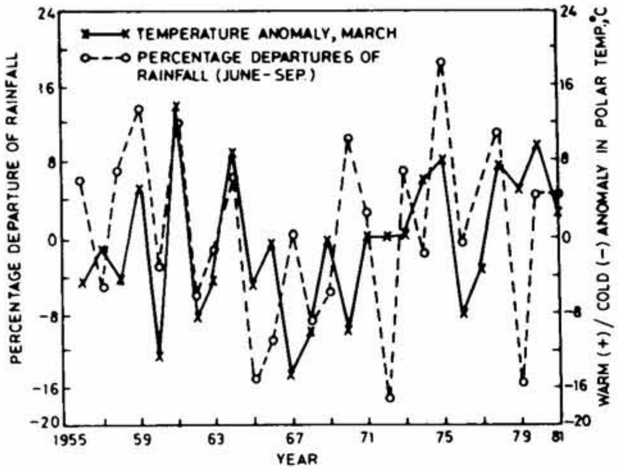

Fig. 2—Same as Fig. 1 but for March

values of correlation coefficients are, respectively, +0.47 (significant at less than 5% level) in November and +0.33 (significant at less than 10% level) in March. The above feature suggests that about 20 and 10% variabilities in the summer monsoon rainfall over India could be attributed to the warm/cold anomalies at 30 mbar north pole temperatures during the preceding November and March, respectively.

4 Conclusion

Summer monsoon rainfall affecting Indian subcontinent and the other Asian region is the product of the global and local anomaly in the circulation features. Moreover, if there is, at all, any influence of the middle atmospheric parameters on the rainfall activity, it could not be expected to be a spectacular one. It has been shown earlier[8,9] that about 15% of rainfall variability could be linked with phases of the low-latitude QBO in the zonal wind. Besides, the present investigation has suggested that about 20 and 10% variabilities in the rainfall during the following summer monsoon could be associated with the anomalies in the north pole temperatures at 30 mbar during the preceding November and March. Also the anomalies in the 30 mbar north pole temperatures during the preceding winter (December and January) may be considered as an indicator of excess/deficient rainfall activity noticed during the following summer monsoon over India. The results of the earlier study[9] and the present study have indicated that the dynamical parameters of the lower stratosphere of the tropics as well as of the north pole may have some bearing towards judging the performance of the rainfall activities over India. With the availability of more stratospheric data, the linkage between the middle atmospheric parameters and the monsoon rainfall would become further clear.

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