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A SEARCH FOR SOLAR RELATED CHANGES IN TROPOSPHERIC WEATHER

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The possibility that solar variations associated with the 11-year solar cycle may be the cause of the changes in tropospheric weather and climate has been the subject to scientific investigation for several decades (KING, 1975; PITTOCK, 1978). In the light of recent studies (MOHANAKUMAR, 1985; 1987; VON COSSART, 1985; CHANIN et. al, 1987), it has been established that mesospheric temperature is strongly influenced by the solar activity. Recently (LABITZKE, 1987; LABITZKE and VAN LOON, 1988), it has been shown that marked signals of the 11-year solar cycle emergence into the stratosphere and troposphere when the atmospheric data are stratified according to east or west phase of equatorial quasi-biennial oscillation (QBO) of zonal wind in the lower stratosphere. These findings give a revival of interest on studies about the sun-weather relationship.

Meteorologists are greatly concerned with the changes in tropospheric phenomena. In the present study, an attempt has been made to find solar activity related changes in tropospheric weather, by the modulation of the QBO of zonal wind at 50 mb. Rainfall and surface temperature data for a period of about three solar cycles, 1953 to 1988, from various stations in Indian subcontinent have been utilised in this study. The study is further extended to find a possible teleconnection between the temperature changes in middle atmospheric levels and surface temperature when the data are stratified according to east or west phase of the QBO. The temperature data have been averaged for January and February to represent the winter-time temperature and for July and August to represent the summer-time temperature. Since the southwest monsoon is the major rainfall season for many parts of Indian subcontinent, the total rainfall recorded during June to September, represents the rainfall data. 10.7 cm solar radio flux is chosen as the solar activity parameter.

Equatorial quasi-biennial oscillation of zonal wind (ANDREWS et.al, 1987) at 50 mb in July during the years 1953 to 1988 is shown in Fig.1. The long period average rainfall for India during the monsoon season, June 1 to September 30, is about 85 cm. The amount of rainfall is generally classified as deficient (D): less than 10%, normal (N): ± 10% and excess (E): more than 10%, from the average rainfall and is indicated in Fig.1. High and low solar activity periods, indicated when the solar radio flux for the four months exceeds 600 and is less than 500 respectively are shown in the upper part of Fig.1.

It is evident from Fig.1 that excess rainfall over India is mainly associated with the westerly phases of QBO and when the solar activity is low. Out of 13 excess rainfall recorded during the last 36 years, 10 occurred when QBO was in its westerly phase. Another interesting aspect is that all the above 10 occurrences are reported when the solar activity is low. Only in three cases, excess rainfall is associated with the easterly phase of QBO and this occurred when the solar activity is high. These three excess rainfalls are found prior to 1971 after which no excess rainfall is observed in this phase.

Rainfall is found to be deficient when the QBO was in its easterly phase and the easterly wind speed is less than 10 ms^{-1}. Out of 9 deficient rainfalls recorded, 8 were found to have occurred in the easterly phase and, generally, when the solar activity is low. Only once, deficient rainfall is reported during the westerly phase which occurred when the westerly wind was weak (5 ms^{-1}) and solar activity was normal.

Normal rainfall is also frequent during the westerly phase of QBO. Out of 14 occurrences, 9 were reported in the westerly phase, of which 6 cases occurred when solar activity was high. When the solar activity is low and QBO is in its easterly phase with strong wind speed (above 20 ms^{-1}), the occurrence of normal rainfall is almost certain. There were 4 such cases in which normal rainfall was observed. This type of phenomena occurs once in every 11-year solar cycle.

These results indicate that solar activity exerts some influence on the rainfall pattern through the modulations in the phases of the equatorial stratospheric zonal wind.

Correlation studies between solar activity and surface temperature during winter and summer, after separating the data into easterly and westerly phases of QBO, in three near-equatorial stations, have been carried out and the results are listed in Table 1. The correlation in the westerly phases of QBO is found to be positive and marginally significant, whereas it is negative and statistically insignificant in the easterly phase. During summer, negative and marginally significant correlations are obtained in the westerly phase while positive but insignificant correlations are obtained in the easterly phase except at Calicut. When the data for both the phases are combined, no correlation exists between solar activity and surface temperature.

The study is further extended to find the relationship between temperature at various levels in the middle atmosphere and surface temperature over Trivandrum (8°N), where the meteorological rocket launching station, Thumba is situated. Correlation coefficients were computed between surface temperature and the temperatures at every 5 km levels between 25 and 75 km over Thumba, after separating the data according to the two phases of QBO and also averaging for summer and winter seasons. The computed correlation coefficients plotted against height are shown in Fig. 2. The significance of the correlation coefficients is tested with Students t-test and is indicated in Fig. 2.

In winter, in the westerly phases of QBO, the middle atmospheric temperature shows a better association with the surface temperature. Below 30 km, the correlation is found to be opposite in the two phases of QBO. The correlation values during the westerly phase rapidly decrease with height in the stratosphere and become strongly negative at 40 km. The surface temperature, thus has an out-of-phase variation with the temperature at 40 km altitude. The correlation coefficients increase with height and become positive and highly significant between 60 and 70 km altitude. The middle mesospheric temperature shows a direct relation to the surface temperature in the westerly phase. The correlation decreases towards the upper mesosphere. The correlation profiles in the easterly phase also show similar variations in the middle atmosphere, but never become statistically significant.

Correlation profiles during the summer season show somewhat opposite behaviour to that during winter season. Positive correlations in stratosphere and negative correlations in mesosphere are obtained. Upto 35 km height, the correlation in the two phases are opposite in nature. Positive and marginally significant correlations are seen at 30 and 35 km heights, in the westerly phases of QBO. Correlations are not found to be significant at higher levels in summer season.

Fig. 3 shows the scattergrams of solar radio flux temperature at 60 km and temperature at 40 km with surface temperature when the QBO is its westerly phase during winter. For the period 1971 to 1985, the 10.7 cm solar radio flux has a positive correlation of 0.624 with surface temperature, and the regression line has a positive slope. This indicates that the surface temperature in the westerly phases increases with the solar activity. The surface temperature also shows a positive association with the temperature at 60 km,as evident from the strong positive gradient and high correlation (0.810). On the other hand, the surface temperature indicates an inverse relation with the temperature at 40 km altitude. Thus, the winter-time surface temperature in the westerly phases of QBO increases as the stratospheric temperature at 40 km decreases.

The results obtained from the study between surface temperature and temperatures in the middle atmosphere reveal that the middle mesospheric temperature has a direct, and the upper stratospheric temperature has an inverse association with the surface temperature when the QBO is in its westerly phase and during winter. These results suggest that changes in temperature in mesosphere or stratosphere, for example, due to stratospheric warming or mesospheric cooling, may be reflected in surface temperature.

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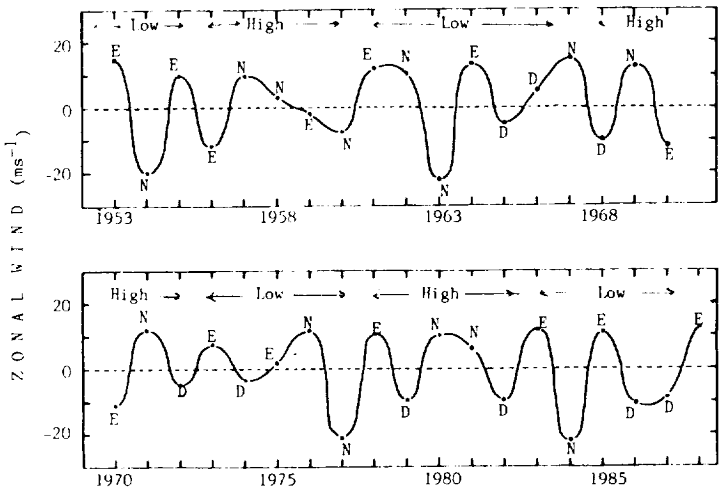

Fig. 1. Equatorial Quasi-biennial Oscillation of zonal wind at 50 mb for July and Southwest Monsoon Rainfall over India (D : Deficient; E : Excess; N : Normal)

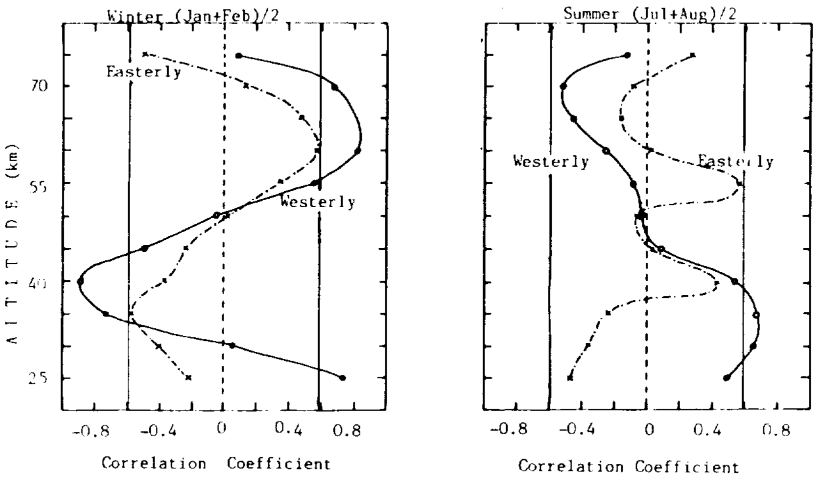

Fig. 2. Vertcal profile of Correlation Coefficient between Surface Temperature and Middle Atmospheric Temperature in Tropics

TABLE 1

CORRELATION COEFFICIENTS BETWEEN SOLAR ACTIVITY AND SURFACE TEMPERATURE

WINTER (JAN + FEB)/2

Station	Westerly Phase n = 19		Easterly Phase n = 15		Combined n = 34	
TRIVANDRUM (8°N)	0.437	(90%)	-0.250	(n.s.)	0.126	(n.s.)
COCHIN (10°N)	0.481	(95%)	-0.309	(n.s.)	0.031	(n.s.)
CALICUT (12°N)	0.614	(98%)	-0.335	(n.s.)	0.213	(n.s.)

SUMMER (JUL + AUG)/2

Station	Westerly Phase n = 19		Easterly Phase n = 15		Combined n = 34	
TRIVANDRUM (8°N)	-0.476	(95%)	0.438	(n.s.)	-0.043	(n.s.)
COCHIN (10°N)	-0.502	(95%)	0.385	(n.s.)	-0.102	(n.s.)
CALICUT (12°N)	-0.389	(90%)	0.640	(99%)	0.196	(n.s.)

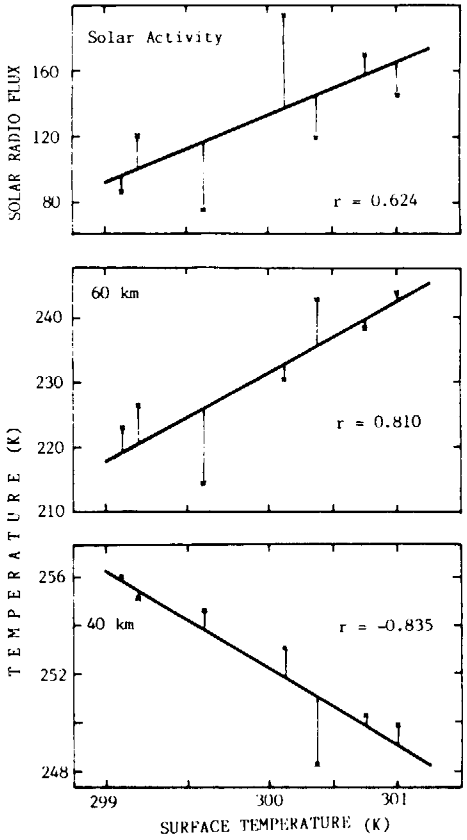

Fig. 3. Scatter diagrams of Surface Temperature with Solar Radio Flux, Temperatures at 60 and 40 km.