RELATIONSHIPS OF SOUTHERN-OSCILLATION AND OTHER LARGE-SCALE FEATURES WITH BAY OF BENGAL CYCLONES DURING THE POST-MONSOON SEASON

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ABSTRACT

Relationships of three Southern Oscillations and a few other large-scale atmospheric indices, like Stratospheric Quasi-Biennial Oscillation, Northern Hemispheric surface air temperature, 50 hPa subtropical ridge position, Indian monsoon rainfall, with the movement and formation of the tropical cyclones over the Bay of Bengal during the post-monsoon season are examined. In general, these relationships are not very satisfactory. However, there is some indication that the low phase of the Southern Oscillation is associated with lower mean latitude of the tracks of cyclones.

1. INTRODUCTION

The tropical cyclones are perhaps the most important features of the weather over India and the neighbouring countries during the post–monsoon season (October through December). The passage of these weather systems over the land is associated with very heavy rains and strong winds, which cause considerable loss of life and property, particularly in the coastal areas. These systems are classified over the Indian region as depression, cyclonic storms and severe cyclonic storms depending on their intensity. Rao (1981) presented several climatological features, such as the frequency and variability, areas of formation and dissipation, the frequency of storms striking different parts of the Indian coast, skewness and kurtosis of monthly, seasonal and annual frequency distributions and mean tracks of these disturbances over the Bay of Bengal and the Arabian Sea. He noted that over the Indian seas, even though the maximum number of cyclonic disturbances develop during the summer monsoon season, a higher percentage of them intensifies into the cyclonic storms during the post–monsoon season. Mooley (1980) and Mooley and Mohile (1983) have studied some further aspects of the Bay cyclones like the trend, efficiency in developing into severe storms, the waiting time between two severe storms, and the fitness of the Poisson distribution to the frequency distribution. Subbaramayya and Mohan Rao (1984) found the quasi–periodicities of 2.1 and 3 years in the frequency of the post–monsoon cyclonic storms in the Bay of Bengal. They linked these periodicities to the Stratospheric Quasi–Biennial Oscillation (Q.B.O.) and the Southern–Oscillation (SO) and suggested for exploring the relationship between the SO and the Bay cyclones.

The Southern Oscillation/El Nino phenomena are recognized as the most important short-term climatic fluctuations of the global tropics. The Indian summer monsoon is involved in these fluctuations. A lower index of the SO and warm equatorial east Pacific Sea Surface Temperature (SST) (El Nino events) is associated with poor monsoon rainfall (Rasmusson and Carpenter, 1982). The indices of Southern-Oscillation show highly significant correlation with concurrent monsoon rainfall but show relatively poorer predictive value. Results of several studies indicate that the correlations between the monsoon rainfall indices and the SO indices are higher when the SO indices lag the monsoon rainfall than the vice versa. It thus appears worthwhile to explore the relationships of the SO with the weather events which take place after the monsoon season. There are two more reasons in support of such investigation. Firstly, several indices of the SO show maximum interannual variability for the period from October through January and maximum autocorrelations for the period from July through February (Wright, 1985). Secondly, the warming of the east equatorial Pacific or its detection is occasionally delayed enough to prevent any lead time for prediction of monsoon rainfall. On such occasions, sufficient lead time for prediction of frequency and track of post-monsoon tropical cyclones may still be available.

Several studies have related the variations in the large-scale atmospheric flow features with the number of tropical cyclones in various oceanic basins. For example, Ding and Reiter (1961) observed a decrease in hurricane activity in the Caribbean in the presence of abnormally strong low-level easterlies in the North Atlantic region south of 20°N. The Southern Oscillation/El Nino (ENSO) phenomenon is found to be associated with the tropical cyclone activity (frequency, typical locations and tracks) over the Atlantic, South Pacific and Northwest Pacific regions. The Atlantic hurricane activity is only 40% as much during periods of moderate and strong El Nino as compared with non-El Nino periods (Gray, 1984). Over other basins the location and tracks rather than frequency may be more influenced. For example, El Nino years are associated with (1) a larger number of Northeast Pacific tropical cyclones tracking further westward than average and (2) further eastward formation of tropical cyclones over the South Pacific (Gray, 1986). Chan (1985), Aoki (1985) and Koichi Kurihara (1986, Personal communication) have studied the influence of ENSO on the tropical cyclone activity over the Northwest Pacific. Chan (1985) found that the tropical cyclone activity over the Northwest Pacific, particularly the western and central part (up to 150°E longitude), decreased in the El Nino year as compared to the previous year. He further noted that the low Southern Oscillation phases are associated with above-normal tropical cyclone activity in the eastern part (east of 150°E) of the Northwest Pacific. The fluctuations in the cyclone activity over the Pacific and Atlantic basins and their association with the ENSO may be explained in terms of the changes in the horizontal and vertical circulations in the atmosphere, particularly the position and intensity of the Walker Circulation.

II. DATA

Although the data of the cyclonic storms and several other parameters are available from the last quarter of the previous or the beginning of the present century, the present study utilizes the data of only the past 30 to 50 years. The basic source of data of cyclonic storms crossing the three coasts of India (see Fig. 1) has been the India Meteorological Department publication (1979) "Tracks of storms and depressions over the Bay of Bengal and the Arabian Sea (1877—1970)" and other official publications of the India Meteorological Department (see Mooley and Mohile, 1983). The frequency of depressions and storms forming in the Bay of Bengal has been obtained for the period 1935—1969 from Rao (1981). The data of Tahiti–Darwin pressure have been obtained from Parker (1983) for the period 1935—1980, and those for equatorial Pacific SST and rainfall index from Wright (1984) for the period 1950—1980. Wright's SST index is the average of SST over a homogeneous core area over which the Southern Oscillation signal shows dominant and in phase variation. The longitudinal extent of this area is 180°W to 90°W and somewhat varying latitudinal width is confined between 10°S to 6°N. This rainfall index is derived from seven stations lying close to the equator within the sector 160°E—150°W. Other data considered are: (1) Northern-Hemispheric surface air temperature (Jones et al., 1982), (2) 50 hPa subtropical ridge position over the West Pacific (Zhang Yan, Personal Communication), and (3) 30 hPa stratospheric winds (K. E. Trenberth, Personal Communication).

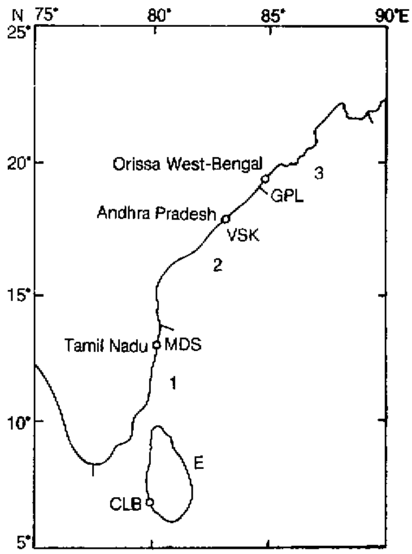

Fig. 1. The three sections of the east coast shown separated by the slashes normal to the coast line.

III. RESULTS

The correlation coefficients of three SO indices, viz. (1) Tahiti–Darwin sea level pressure difference, (2) Wright's SST and (3) Rainfall indices in the concurrent and 2 antecedent 3 month seasons, with the frequency of the tropical cyclones crossing the three sectors of the east coast and the entire east coast are given in Table 1. In general the correlation coefficients are small, particularly for the cyclones crossing the entire east coast. The correlations for pre-monsoon season (March-April-May) are smaller. The correlations are generally higher and reverse in sign for the cyclones crossing the Andhra Pradesh and Orissa–West Bengal coasts. These correlations suggest that the Southern–Oscillation influences the latitude of the tracks of the cyclones, rather than the total frequency crossing the east coast. The lower SO index or higher equatorial Pacific SST/Rainfall is associated with the increase in cyclone frequency crossing a lower latitudinal sector, i.e. Andhra Pradesh. This result is converse of what is found by Gray (1984) for Atlantic hurricanes. He found that there is more severe suppression of the frequency of hurricanes in the West Atlantic equatorward of 20°N latitude during the El Nino years. It may be noted that the frequency of storms in the two basins, viz. the West Atlantic and the Bay of Bengal is independent (correlation $= -0.02$, $N=31$).

Table 1. Correlation Coefficients between Wright's Equatorial Pacific SST (SST), Line Island Rainfall (RN) and Parker's Tahiti-Darwin Southern Oscillation Index (TD) and the Tropical Cyclones Crossing Tamil Nadu (TN), Andhra Pradesh (AP), Orissa and West Bengal (OWB), and the Entire East Coast of India (E. Coast)

	Season	TN	AP	OWB	E. Coast
	MAM**	0.08	−0.05	−0.05	0.02
SST	JJA	0.01	0.25	−0.19	0.06
	SON	0.04	0.29	−0.15	0.12
	MAM	−0.05	0.14	−0.24	−0.07
RN	JJA	−0.10	0.25	−0.42*	−0.12
	SON	0.00	0.24	−0.30	0.00
	MAM	−0.15	−0.24	0.08	−0.20
TD	JJA	0.00	−0.22	0.18	−0.04
	SON	−0.13	−0.24	0.25	−0.09

* Significant at 5% level.

** MAM–March-April-May, JJA–June-July-August, SON–September-October-November. The Data considered are for 31 years, 1950–1980.

In order to examine higher lags between the Southern Oscillation indices and the cyclone frequency, correlations with higher lags between the Wright's Line Island rainfall index and the frequencies of tropical cyclones crossing the east coast are computed. The correlation for the SO index corresponding to the winter (December–January–February) of the concurrent year is 0.28 and those for the indices corresponding to the seasons DJF, MAM, JJA and SON of the previous year are −0.24, −0.23, 0.29 and 0.26 respectively. Thus limited skill in forecasting the tropical cyclone frequencies can be achieved even 21 months in advance.

Frequency of cyclones crossing various coasts is also examined with respect to various phases of Q.B.O., viz. (1) when seasonal 30 hPa winds are from the west, (2) when seasonal 30 hPa winds are from east, (3) when winds are increasing in west component, (4) when winds are decreasing in west component, (5) when the westerly winds are increasing and (6) when the easterly winds are increasing, as done by Gray (1984). No significant association in these various phases of the Q.B.O. and the cyclonic activity over this region is found. Likewise no significant association is found between four other large-scale atmospheric indices, viz. (1) Northern-Hemispheric surface air temperature in January; (2) Indian summer monsoon rainfall; (3) latitudinal position of the 50 hPa subtropical ridge over the West Pacific in September; and (4) western most longitude of the 50 hPa ridge over the West Pacific in September and the tropical cyclone activity. For example, the correlation coefficients between these parameters and the tropical cyclones crossing the Andhra Pradesh coast are respectively −0.07, −0.14, −0.11 and 0.09 on a sample of 31 years (1950—1980).

We note that the average number of tropical cyclones crossing the east coast is only 1.17 as compared to 5.9 in the West Atlantic. These events may encompass only a few days. Hence the large-scale parameters averaged over a month or a season may not show significant association with the events taking place over a few days. Further more, the examination of the time series of cyclones crossing the Orissa-West Bengal coast revealed that the cyclones crossed this coast only during 7 (1967—1973) of the 31 years. This kind of situation may again arise due to the small frequency of cyclonic storms forming over this basin. Therefore the series of frequencies of depressions and storms (Rao, 1981) with an average of 4.1 were also related with all these large-scale parameters. The correlation coefficients of this new series of cyclonic disturbances with (1) Northern Hemispheric surface air temperature, (2) Monsoon rainfall, (3) Tahiti-Darwin pressure for June-July-August are found to be respectively 0.01, 0.01 and —0.27 when the past 35 years (1935—1969) of data are used. These again show poor correlation between large-scale atmospheric parameters and the number of Bay of Bengal disturbances. It is likely that the number of cyclone days may show better relationship with these parameters but the data for the cyclone days are not readily available for investigation.

IV. *CONCLUSIONS AND DISCUSSION*

From the above results we can state that the global-scale atmospheric/oceanic parameters show small influence on the frequency of tropical cyclones over the Bay of Bengal. However the SO appears to influence the mean latitude of the tracks of the cyclones. The low phases of SO are associated with the increase in frequency of cyclones in the lower latitudes (Andhra Pradesh) and the decrease in the higher latitudes (Orissa-West Bengal).

It may be noted that Gray (1984) found no significant association between the large-scale atmospheric/oceanic parameters, viz. the El Nino and the stratospheric Q.B.O. and the cyclonic activity over the North Indian Ocean and other storm basins where the storms form in the monsoon trough zones. Our findings thus confirm Gray's results. Nicholls (1984), however, found some predictive relationship between the SO indices and the tropical cyclone activity over the North Australian region, perhaps because this region lies near the core of the SO. Results of Chan (1985) and Kurihara (1986) regarding the Northwest Pacific have already been noted. As far as India is concerned, it lies on the wrong side (towards west) of the SO region, as the influences of the anomalous convection on the atmosphere associated with the SO is downstream (towards east) of its source region and these influences had to travel round the globe before they could affect the weather over India. The possibility of influence of local atmospheric/oceanic parameters (sea level pressure, SST) on the Bay cyclone activity is not ruled out even though Gray (1984) is skeptical about it. The condition of the atmospheric environment (background climatology) and the antecedent factors conducive to large-scale cyclonic activity over the Bay of Bengal may be different from those over the other basins. In future studies, efforts shall be directed towards understanding of these conditions.

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