framework of the Euler equations. It is planned to make a detailed presentation of the results in a CFD journal.

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A possible relationship between the wind in the atmospheric boundary layer over north Indian Ocean and the summer monsoon rainfall over India

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The relationship between the power of wind in the atmospheric boundary layer over the north Indian Ocean and the summer monsoon rainfall over India has been studied utilizing marine meteorological data for the north Indian Ocean and all-India rainfall for the period 1972–91. Monthly mean fields of wind, air temperature and sea surface temperature have been determined, and the power of wind in the atmospheric boundary layer has been computed on a grid mesh of 5° over the area bounded by 50°E to 100°E, north of the equator. Correlation coefficients were computed between seasonal (June–September) area-weighted rainfall over India and the winds in atmospheric boundary layers over the Arabian Sea and the Bay of Bengal during the month of May. Significant correlations have been found between (i) June–September rainfall over India and the wind over the Arabian Sea area bounded by the equator and 10°N during May, and (ii) June–September rainfall over India and the wind over the north Indian Ocean between the equator to 10°N and 50°E–100°E. We find that the wind in the boundary layer over the equatorial regions of the north Indian Ocean (equator to 10°N) during May could be a useful predictor for the summer monsoon rainfall.

THE quantum of rains falling over India during the summer monsoon from June to September is important for India's economy. It is thus natural that the prediction of summer monsoon rainfall should draw the attention of many meteorologists.

Pioneering efforts in this direction have been made by Blanford[1] and Walker[2]. Recently, Singh[3] and Singh and Joshi[4] have shown that the initial state of the north Indian Ocean before the commencement of summer monsoon season plays an important role in the performance of the ensuing monsoon.

This communication reports the relationship between the wind strength in the atmospheric boundary layer over the north Indian Ocean during May and all-India rainfall for the subsequent monsoon. The mechanical stirring of the ocean is dependent on the wind in the lower atmosphere. By mechanical stirring, the centre of gravity of the upper ocean is raised as the warmer surface waters are forced to subsurface layers, enhancing the heat storage capacity of the ocean. The heat storage capacity of the ocean has a major influence on climate.

The power of the wind, P (W m^{-2}), has been computed at each grid point by

$$P = \rho_a C_D [(U^2 + V^2)^{1/2}]^3, \tag{1}$$

where ρ_a = 1.18 kg m^{-3} is air density, C_D is the exchange coefficient for momentum, U and V are the eastward and northward components of the wind velocity in m S^{-1}. For this study C_D is considered to be a function of wind speed, $(U^2 + V^2)^{1/2}$, and of the difference between air and sea temperatures, $T_a - T_s$. It is given by[5]

$$C_D = 0.934\times 10^{-3} + 0.788\times 10^{-4}(U^2+V^2)^{1/2} + 0.868\times 10^{-4}(T_a - T_s) - 0.616\times 10^{-6}(U^2+V^2) - 0.120\times 10^{-5}(T_a - T_s)^2 - 0.214\times 10^{-5} \times (U^2+V^2)^{1/2}\ (T_a - T_s). \tag{2}$$

Table 1. Correlation coefficients between *P* for May over the north Indian Ocean and all-India area-weighted rainfall for June–September

Oceanic area	Latitudinal belt for which *P* was considered	Correlation coefficient between *P* for May and all-India area-weighted rainfall for June–September
Arabian Sea	Equator to 10°N	0.59**
	10°N to 20°N	0.36
Bay of Bengal	Equator to 10°N	0.42
	10°N–20°N	0.02
North Indian Ocean	Equator to 10°N, 50°E–100°E	0.51*

*Significant at 5% level.
**Significant at 1% level.

All marine meteorological observations of the north Indian Ocean for the period 1972–91 that were available at the National Data Centre, Pune, have been used. The data were collected by ships of opportunity. The Indian summer monsoon rainfall data, published periodically in *Mausam*, were used to compute the correlation coefficient between *P* and area-weighted all-India rainfall for June–September.

The computed values of the correlation coefficients between *P* for May over different regions of the north Indian Ocean and all-India rainfall of June–September are shown in Table 1. This table shows that there is good correlation between the wind in the lower atmosphere over 0°N–10°N and in the subsequent summer monsoon rainfall. The highest correlation coefficient (0.59) which is significant at 1% level, is observed over the southern Arabian Sea and the Indian summer monsoon rainfall. There is a substantial decrease in correlation coefficients when we consider the northern areas of the Arabian Sea. Similarly, over the Bay of Bengal the correlation coefficient decreases from south to north. In fact, *P* over the northern areas (10°N–20°N) of the Bay of Bengal is uncorrelated with monsoon rainfall over India. If we consider the north Indian ocean regions of 0°N–10°N, 50°E–100°E, the correlations coefficient is 0.51, which is significant at 5% level. We thus draw the following conclusions:

i) The wind over the Arabian Sea, during May, appears to have more influence on the subsequent monsoon rainfall over India compared to the wind over the Bay of Bengal.
ii) The winds over the southern areas of the Arabian Sea and the Bay of Bengal have higher correlations with the monsoon rainfall compared to those of northern areas.

The computed values of *P* and the all-India area-weighted rainfall departures from normal for the period 1972–91 are shown in Table 2. The *P* values for the northern parts of the Bay of Bengal have been omitted due to low correlation.

Table 2. Interannual variability of wind power over the north Indian Ocean during May and all-India area-weighted rainfall departures from normal for June–September

Year	*P* for May over southern (0°–10°N) areas of the Arabian Sea (10^{-1} W m^{-2})	*P* for May over northern (10°–20°N) areas of the Arabian Sea (10^{-1} W m^{-2})	*P* for May over southern (0°–10°N) areas of the Bay of Bengal (10^{-1} W m^{-2})	All-India rainfall departure from normal for June–September (%)
1972	1.1	1.8	2.9	−23.4
1973	2.6	2.6	3.1	7.5
1974	1.8	3.0	2.8	−12.0
1975	2.8	2.7	3.4	15.0
1975	1.8	2.2	5.1	2.4
1977	3.3	1.3	3.9	4.0
1978	6.0	2.8	7.4	9.2
1979	1.5	1.7	5.9	−18.9
1980	2.1	1.3	2.4	3.9
1981	5.9	2.1	4.3	−0.2
1982	0.3	0.3	0.8	−14.5
1983	—	1.6	2.0	12.9
1984	3.0	1.7	2.8	−4.3
1985	3.0	2.0	3.0	−7.0
1986	2.2	1.8	—	−12.0
1987	1.6	1.1	0.3	−19.4
1988	3.5	2.2	6.0	19.3
1989	4.0	3.4	7.0	1.0
1990	6.2	5.8	7.7	7.0
1991	3.0	—	1.3	−7.0

— Insufficient marine data.

Corresponding to the significant correlation coefficients 0.59 and 0.51, the linear regression equations are:

$$Y = -15.199 + 42.978 X_1 ,$$

$$Y = -12.084 + 29.354 X_2 ,$$

where Y is the all-India area-weighted percentage rainfall departure from normal for June–September, X_1 is the average power of wind (W m^{-2}) during May in the atmospheric boundary layer over the Arabian Sea between the equator and 10°N, X_2 is the average power of wind (W m^{-2}) during May in the atmospheric boundary layer over the north Indian Ocean between the equator to 10°N, 50°E–100°E.

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