

Statistical structure of the meteorological parameters over the Bay of Bengal during Monsoon-77 experiment

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(Received 20 November 1979)

ABSTRACT. During Monsoon-77 experiment four USSR research vessels collected six hourly RS and RW data, over the Bay of Bengal in August 1977 in a stationary polygon position. This study presents certain statistical characteristics of the meteorological parameters observed during the period.

1. Introduction

One of the important aspects of Monsoon-77 experiment objectives was to understand the space-time structure of meteorological parameters over the Indian seas, particularly over the Bay of Bengal as it was the first experiment of the kind over there. In the present paper an attempt has been made to study the time variations of sea level pressure and geopotential, temperature, relative humidity, specific humidity and wind at various atmospheric pressure levels recorded by research ships in a stationary polygon position over the Bay of Bengal during this experiment. The results of this study may be of interest not only from observational point of view over data sparse region but may provide considerable information towards the study of monsoon circulation, numerical modelling of the atmospheric processes and air-sea interaction over the Bay of Bengal.

2. Data used

For the purpose of present study we have used the radiosonde and rawin wind data collected by four USSR research vessels *Okeao*, *Academician Shirshov*, *Priboy* and *Shokalasky* in the Bay of Bengal during August 1977. These vessels remained nearly stationary at locations 15.2 N, 89.2 E; 17.2 N, 90.9 E; 19.1 N, 88.9 E and 17.3 N, 87.9 E respectively from 12 August to 19 August 1977 and took six hourly aerological observations. Thus we had 32 observations, to study the statistical characteristic of meteorological parameters. The number of observations, though a longest series of its kind so far, may not be sufficient to give statistically stable results. In a subsequent study authors propose to verify

the inferences of this study after analysing Monex-79 data of the same region.

3. Method used

The computations of mean, standard deviation, coefficient of variation, skewness, kurtosis and their standard errors of sea level pressure, geopotential, temperature, relative humidity, specific humidity and wind have been made at 50 mb intervals from surface to 100 mb level, for individual ships as well as average over the polygon, using following formulae (Gandin and Kagan 1976) :

$$\text{Mean } (\bar{x}) = \sum_{i=1}^N x_i / N$$

$$\text{Standard deviation } (\sigma) = \sqrt{\sum_{i=1}^N (x_i - \bar{x})^2 / (N - 1)}$$

$$\text{Coefficient of variation (CV)} = \sigma / \bar{x}$$

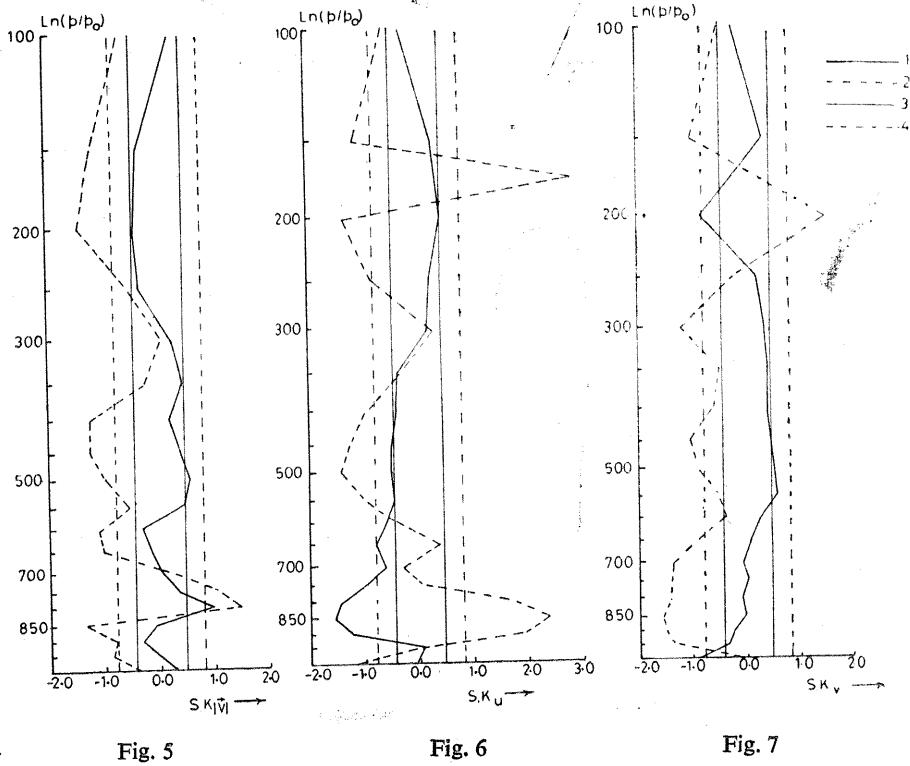
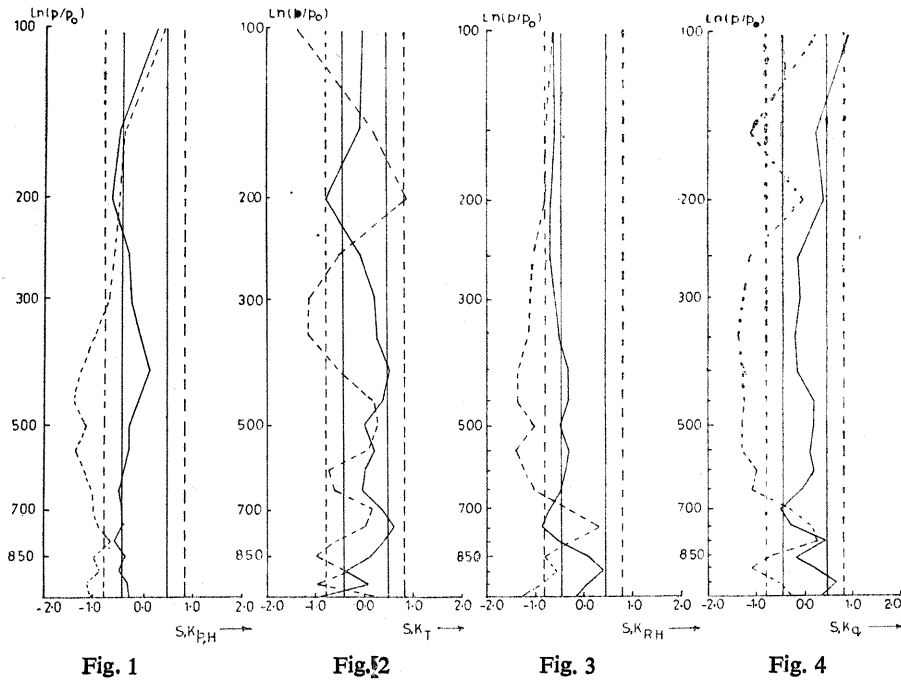
$$\text{Skewness } (s) = \sum_{i=1}^N (x_i - \bar{x})^3 / N^3$$

$$\text{Kurtosis } (k) = \sum_{i=1}^N (x_i - \bar{x})^4 / N^4 - 3$$

$$\text{Standard error of } s (\sigma_s) = \sqrt{6(N-1)/(N+1)(N+3)}$$

$$\text{Standard error of } k (\sigma_k) = \sqrt{24N(N-2)(N-3)/(N-1)^2(N+3)(N+5)}$$

where N is the number of observations and x is the variable parameter.



Vertical profiles of skewness and kurtosis, (1) Skewness (2) Kurtosis, (3) Standard error of skewness and (4) standard error of kurtosis (P_0 surface pressure)

Fig. 1. Sea surface pressure/geopotential ($S, K_{p,H}$); Fig. 2. Temperature (S, K_t); Fig. 3. Relative humidity (S, K_{RH}); Fig. 4. Specific humidity (S, K_q); Fig. 5. Wind magnitude ($S, K_{|v|}$); Fig. 6. Zonal component of wind (S, K_u); Fig. 7. Meridional component of wind (S, K_v)

TABLE 1

Ship : Average over the polygon

Level (mb)	p/H			t° C			RH(%)			q (gm/kg)			V /m/s		
	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)
Sur- face	1004 mb	2.60 mb	<1	301.14	0.55	<1	87	2.14	2	15.309	0.451	3	9.5	1.10	12
950	0.49 km	0.02 km	5	297.2	0.49	<1	89	2.57	3	12.946	0.504	4	11.9	1.24	10
900	0.97	0.02	2	294.4	0.57	<1	87	3.02	3	11.300	0.484	4	11.8	0.98	8
850	1.46	0.02	2	291.8	0.60	<1	85	4.31	5	9.898	0.583	6	10.9	0.98	9
800	1.98	0.02	1	289.2	0.71	<1	83	6.59	8	8.681	0.692	8	10.4	1.03	10
750	2.53	0.02	1	286.5	0.88	<1	81	8.56		7.620	0.681	9	9.4	1.21	13
700	3.11	0.02	1	283.7	0.96	<1	78	10.30	13	6.550	0.725	11	8.5	1.66	19
650	3.72	0.02	1	280.6	1.02	<1	74	10.74	14	5.488	0.711	13	8.0	1.53	19
600	4.38	0.02	1	277.1	1.06	<1	74	11.91	16	4.716	0.729	15	7.5	1.79	24
550	5.08	0.02	<1	273.1	0.90	<1	76	12.65	17	3.983	0.683	17	7.3	2.10	29
500	5.85	0.02	<1	269.0	0.98	<1	77	13.33	17	3.214	0.649	20	6.9	2.36	34
450	6.67	0.02	<1	264.5	0.97	<1	74	15.47	21	2.476	0.611	25	6.5	2.64	41
400	7.58	0.02	<1	259.6	0.95	<1	70	17.10	24	1.772	0.590	29	6.3	2.83	45
350	8.58	0.02	<1	253.4	1.19	<1	68	16.82	24	1.180	0.375	32	7.8	2.02	26
300	9.70	0.02	<1	245.6	1.36	1	67	14.47	21	0.672	0.203	30	10.7	1.68	16
250	10.99	0.02	<1	236.0	1.20	1	66	11.79	18	0.308	0.078	25	15.5	3.42	22
200	12.49	0.02	<1	223.9	1.11	1	63	10.83	17	0.098	0.021	21	20.9	5.09	24
150	14.32	0.02	<1	200.3	1.20	1	61	9.12	15	0.020	0.000	15	28.7	6.62	23
100	16.70	0.03	<1	192.1	1.74	1	61	8.37	14	0.003	0.000	14	34.9	6.83	20

4. Results and discussion

Table 1 gives the values of mean, standard deviation, CV (%) of meteorological parameters at various pressure levels for the polygon (space average). Figs. 1-7 show the vertical profiles of skewness and kurtosis of pressure, geopotential, temperature, relative humidity, specific humidity, wind speed and its zonal and meridional components.

The steadiness of the measurements of the meteorological parameters at different levels as well as their space and time variation can well be explained by the values of σ and CV, as it is known the lower values of these correspond to high steadiness, space homogeneity and time stationarity. The values of skewness and kurtosis tell us the pattern of distribution followed by meteorological parameters as compared to normal distribution and their standard errors enables to infer the extent up to which they follow the normal law of distribution. The characteristics of individual meteorological parameters are discussed below.

4.1. Pressure/geopotential (P/H)

It can be seen from Table 1 that the variability of the sea level pressure and geopotential at various levels is very small with values of σ and CV constant with height.

It may be seen from Fig. 1 that the absolute values of skewness does not exceed 3σ at all the layers in the atmosphere and absolute value of kurtosis is always less than $5\sigma_k$. These facts imply that the sea level pressure and geopotential follow the normal law of distribution with a good degree of approximation.

4.2. Temperature (t)

Table 1 reveals that variability of air temperature at various levels is very small. There appears to be some decrease in the temperature steadiness with height, which is in agreement with the facts observed by previous workers Khanesbkaya (1968) and Sigelneskei *et al.* (1976). The steadiness of temperature over this tropical belt is comparatively higher than in any other latitudinal belt (Sigelneskei *et al.* 1976); the values of σ and CV do not exceed 2 and 1 per cent respectively.

Fig. 2 shows that the fluctuations in the values of skewness and kurtosis lie within their critical limits of normal distribution (*i.e.*, $\pm 3\sigma_s$ and $\pm 5\sigma_k$), at all the levels in the vertical.

4.3. Relative humidity (RH)

Variability of the relative humidity (RH) of the air at various atmospheric levels fluctuates in the limit of 2 to 18 per cent (standard deviation) whereas CV lies in the range of 2 to 24

per cent as can be seen from the Table 1. It may be inferred from the values of σ and CV that steadiness of relative humidity decreases rapidly from surface to a minimum at about 400 to 350 mb and after that steadiness increases slowly.

It can be seen from Fig. 3 that RH follows the normal law of distribution.

4. 4. Specific humidity (q)

It can be seen from the vertical distribution of CV values (Table 1) that the variability of specific humidity is small in the planetary boundary layer (up to 1.5 to 2.0 km) above which the CV fluctuates from 8 to 32 per cent. This is due to the fact that over the sea within planetary boundary layer, the atmosphere is well mixed and the moisture content is almost constant, moreover, the top of the planetary boundary layer also coincides with the lifting condensation level. Above this layer the atmosphere may either be clear or be covered with clouds which gives rise to fluctuation in variability. It is also seen that values of standard deviation decreases very rapidly above 500 mb level, this may not be considered as the criteria of steadiness as the parameter q itself has very low values at those levels.

As in the case of other parameters specific humidity also follows the normal law of distribution (Fig. 4).

4.5. Wind

Standard deviation of magnitude of the wind $|V|$ lies in the range 1 to 7 ms^{-1} , while coefficient of variation is between 8 and 45 per cent (Table 1) with maxima at 400 mb level over the polygon. Same characteristic has been observed for individual ships. From mentioned values it can be inferred that the steadiness of the wind is less as compared to the other meteorological parameters discussed earlier. It is also seen from the table that the steadiness of the wind is higher in the lower and the upper troposphere than in the middle troposphere. This is due to the well known fact that during undisturbed southwest monsoon period over Bay of Bengal (no depression over the Bay), southwesterlies prevail in the lower and steady easterlies in the upper troposphere.

The values of skewness and kurtosis of $|V|$ lies within the specified criteria for normal law of distribution (Fig. 5). It may be interesting to examine the distribution of zonal (u) and meridional (v) components of wind. It may be seen

from Figs. 6 and 7 that although the skewness and kurtosis values, for u and v at all the levels, lies in the range of $\pm 3\sigma_s$ and $\pm 5\sigma_k$ respectively. These results agree with the findings of Gandin and Anapolaskaya (1958).

5. Conclusions

The following conclusions may be drawn from the above statistical analysis.

- (i) The variability of sea level pressure, geopotential and temperature is very small compared to other meteorological parameters over the Bay of Bengal.
- (ii) The variability of relative humidity, specific humidity and steadiness of wind in the tropical atmosphere over the Bay of Bengal varies considerably with height.
- (iii) The relative humidity and wind speed at 400 mb level are least steady as compared at the other levels. This is due to the fact that 400 mb level is the transition zone for these parameters over the Bay of Bengal and, therefore, may be considered as more significant level.
- (iv) Practically skewness and kurtosis of all the parameters do not exceed $\pm 3\sigma_s$ and $\pm 5\sigma_k$ limits respectively and, therefore, they follow the law of normal distribution.

Since the considered series are not very large and it is not possible to get a long series over this oceanic region, the above conclusions can be verified with a series of experiments. We propose to verify the results using Monex-79 data in a later stage.

Acknowledgements

We wish to express our sincere thanks to Dr P. K. Das, Director General of Meteorology and Prof. M. P. Singh, Head, Centre for Atmospheric Sciences, Indian Institute of Technology, New Delhi for their kind encouragement.

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