Letters To The Editor

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MONSOON DEPRESSIONS IN THE BAY OF BENGAL

In view of the uncertainties regarding the mechanism of monsoon depressions in the Bay of Bengal, a study of the wind field was made along the following lines.

1. The strength of the monsoon current was measured by the poleward transport of angular momentum from the wind data at Minicoy (8°N 73°E). The poleward transfer of angular momentum[1] is proportional to

$$\int_0^z \oint_0^x (\rho V^x V^y)\, dx\, dz$$

where V_x, V_y refer to the easterly and northerly components of wind and, dx denotes an element of the latitude circle. For measurements over a particular station, this becomes equivalent to determining $[\rho V_x V_y]$ at a chosen level. In the present work, V_x and V_y were determined from the daily morning pilot balloon data for the monsoon months of July, August and September. For density, a standard value corresponding to saturated air at 850 mb and 59°F was selected. Small variations from this arbitrarily chosen mean are possible; but fluctuations in the flow of angular momentum are primarily determined by variations in $(V_x V_y)$.

From an examination of three years data, an increase in the negative flux of angular momentum was often found to be closely associated with the formation of a depression in the head Bay. The relationship is shown in Figs. 1 and 2 for two typical months and the values obtained for a number of depressions are shown in Table 1. It will be seen from the table that, except on three occasions, conditions became favourable for the formation of a depression whenever the flux of angular momentum exceeded 6×10^2 C. G. S. units. From the data examined it was found that there were in all 34 synoptic situations when the flux of angular momentum exceeded the above value, and in 22 cases the increase could be attributed to either unsettled conditions or the formation of a depression. There were, in addition, four cases where the increase could have been due to a land depression or the passage of a low pressure wave. In the remaining eight cases, the increase was not associated with any depression.

It is not claimed that the above assessment is perfectly objective. In the present work, a depression was assumed to have formed when streamlines at 1·5 km showed a closed cyclonic circulation. Similarly, conditions were taken as unsettled when the monsoon trough line extended south into the Bay and winds near Calcutta were backing to a southeasterly or easterly direction.

The data compiled so far showed no conclusive evidence of a time lag between the formation of the depression and the ‘ peak ’ in the flux of angular momentum. This, however, is being examined in greater detail with data from a larger number of years.

2. The region between Gangetic West Bengal and the Orissa coast was divided into a series of triangles (cf. Fig. 3), such that the apex of each triangle was a pilot balloon station. Then, from the wind data at 5000 ft the vertical component of vorticity within each triangle was computed. We have

$$\zeta = \lim_{A \to 0} \frac{\int_L \mathbf{V}\, ds}{A}$$

or for a triangle,

$$\zeta = \frac{\Sigma\, \mathbf{V} \cos\theta\, ds}{\text{Area of triangle}}$$

where, ζ is the vertical component of vorticity, ds represents the length of each side of the triangle and θ is the angle between the wind vector and the side of a triangle.

The vorticity was computed for the periods when conditions in the Bay were normal, unsettled and after the depression had formed. The values obtained are shown in Table 2 and it will be seen that, but for a

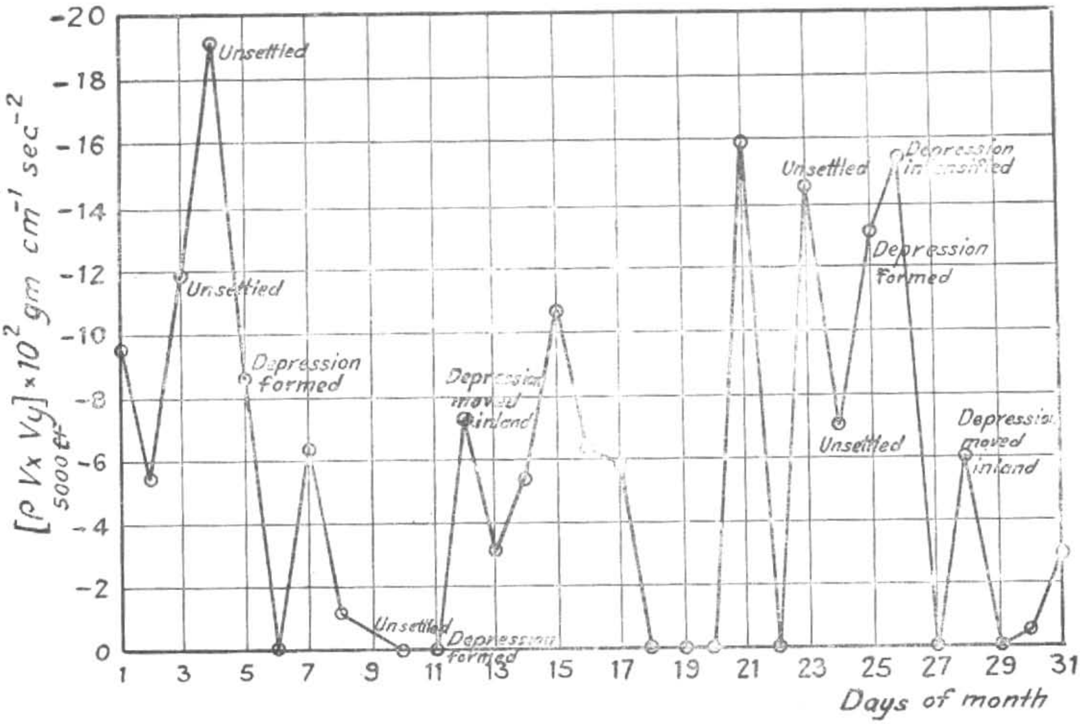

Fig. 1. Values of negative flux of angular momentum Minicoy (July 1950)

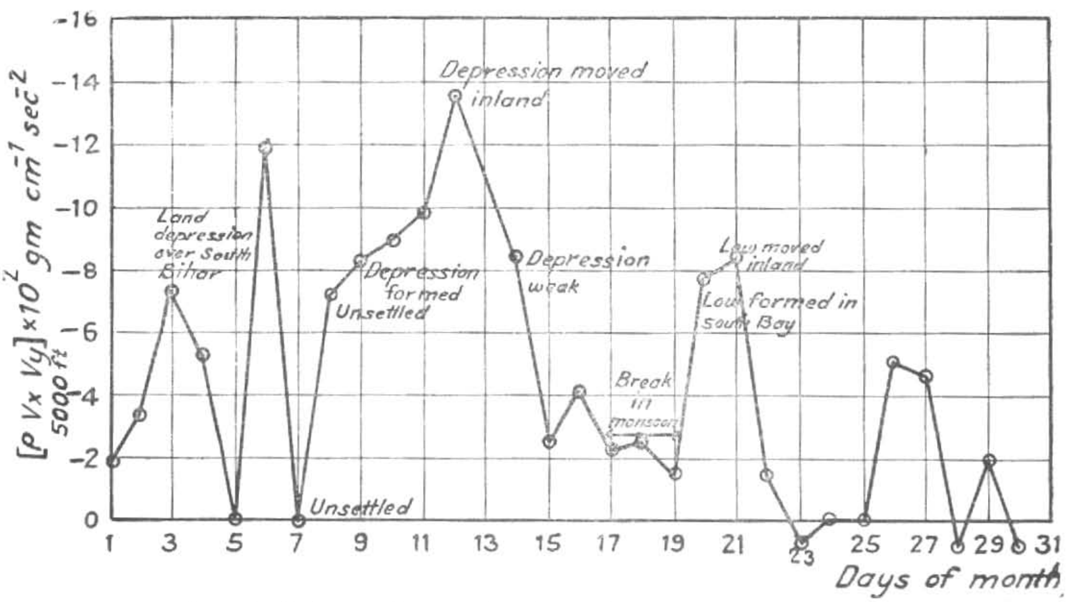

Fig. 2. Values of negative flux of angular momentum Minicoy (August 1950)

TABLE 1

	Date	Condition in Bay	$(\zeta V_x V_y)$ 5000′ $\times 10^2$ gm cm^{-1} sec^{-2}
1	4-7-50	Unsettled	—19·2
	5-7-50	Depression formed	—8·6
2	10-7-50	Unsettled	0
	11-7-50	Shallow depression formed	0
	12-7-50	Depression moved inland	—7·3
3	24-7-50	Unsettled	—6·9
	25-7-50	Shallow depression formed	—13·1
	26-7-50	Depression intensified into cyclone	—15·3
4	7-8-50	Unsettled	0
	9-8-50	Shallow depression formed	—7·3
	15-8-50	Depression unimportant	—2·5
5	7-9-50	Unsettled	—5·2
	9-9-50	Depression formed	—7·5
	12-9-50	Depression became unimportant	0
6	5-7-48	Unsettled	—8·3
	7-7-48	Shallow depression formed	—10·6
7	18-7-48	Unsettled	—8·5
	19-7-48	Depression formed in northwest Bay	—11·8
8	11-8-48	Unsettled	—11·2
	12-8-48	Depression formed	—8·8
	14-8-48	Depression concentrated into a cyclone	—
	16-8-48	Storm weakened into a depression	—16·0
	18-8-48	Diffuse low over southeast of Uttar Pradesh	—10·6
9	20-8-48	Unsettled	—9·8
	22-8-48	Shallow depression formed	—
10	17-9-48	Unsettled	—1·3
	19-9-48	Depression formed	—1·7
11	24-9-48	Unsettled	—3·1
	26-9-48	Depression formed	—1·7
12	10-7-47	Unsettled ..	—6·4
	11-7-47	Depression formed	—3·4
	12-7-47	Depression intensified into cyclone	—7·8
13	16-8-47	Unsettled	—
	19-8-47	Depression formed	—10·0
14	18-9-47	Unsettled	—7·6
	25-9-47	Depression formed	—7·3

TABLE 2

	Situation	Mean Vorticity $\times 10^{-5}$ sec^{-1}	Conditions in Bay
1	18-6-47 19-6-47	—0·2	Normal
	23-6-47 25-6-47	—1·0	Unsettled
	26-6-47 27-6-47	—1·6	Depression formed
2	5-6-50 6-6-50	—0·5	Normal
	7-6-50 8-6-50 9-6-50	+1·3	Unsettled
	10-6-50	—13·2	Depression formed
3	26-7-49 27-7-49	—1·3	Normal
	30-7-49	—4·0	Unsettled
	1-8-49	—1·6	Depression formed
4	4-9-49 5-9-49	—3·0	Normal
	7-9-49	—10·5	Unsettled
	8-9-49	—4·4	Depression formed
5	16-9-49 17-9-49	+0·6	Normal
	20-9-49	—2·6	Depression formed
6	24-7-48 25-7-48	—1·9	Normal
	26-7-48	+0·3	Unsettled
	27-7-48	—4·4	Depression formed
7	8-8-48 9-8-48	—1·5	Normal
	10-8-48 11-8-48	+1·2	Unsettled
	12-8-48 14-8-48	—2·7	Depression formed
8	29-6-46 30-6-46	—3·1	Normal
	1-7-46 2-7-46	—1·5	Unsettled
	3-7-46	—6·9	Depression formed

Coriolis parameter for 20°N $= 4·99 \times 10^{-5} sec^{-1}$

few individual cases, the vorticity seldom exceeded the coriolis parameter (λ) for 20°N. Solberg's criterion for dynamic instability, *i.e.*, $\zeta > \lambda$ was, therefore, not generally exceeded before the depression was formed. This confirms a similar result obtained by Sawyer[2] for extra-tropical depressions.

3. Using the same set of triangles as in Fig. 3 the convergence was evaluated using a method due to Sheppard[3]. The convergence within the triangle is given by

$$\nabla_2 \mathbf{V} = \frac{V_a}{h_a} + \frac{V_b}{h_b} + \frac{V_c}{h_c}$$

where, h_a, h_b, and h_c represent the perpendiculars from each apex to the opposite side, and V_a, V_b and V_c are the components of the wind along the perpendiculars.

The convergence pattern could only be evaluated for a few well marked depressions because the available data were often unreliable. Sometimes, the relevant 'pibal' data were also not available; in such cases approximations were made on the basis of the streamline chart. Such approximations undoubtedly impose a limitation, but could hardly be avoided.

The convergence patterns for 5000 ft are shown for a typical case in Figs. 4 and 5.

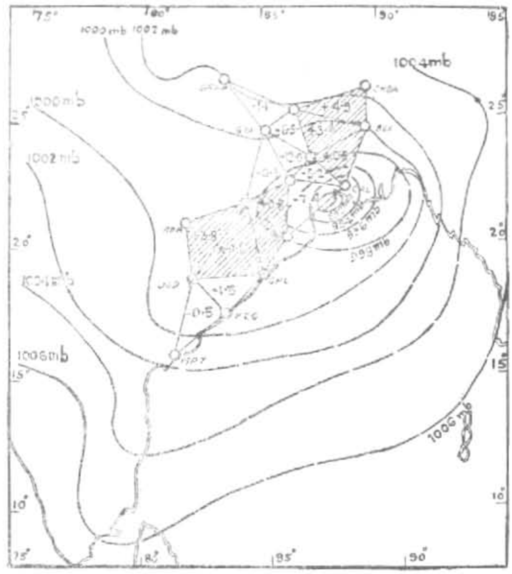

Fig. 4. Observed convergence at 5000 ft (10^{-5} sec^{-1}) 10 June 1950

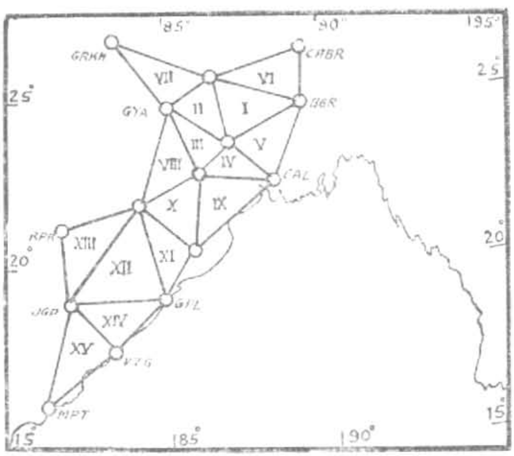

Fig. 3. Convergence Triangles

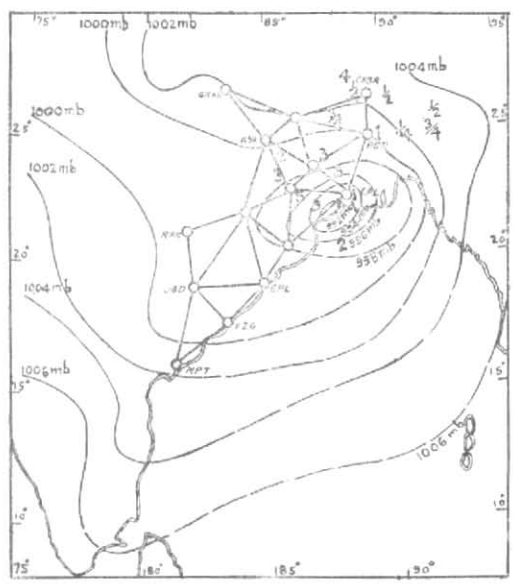

Fig. 5. Convergence at 0700 IST on 10 June 1950 Rainfall recorded on the morning of 11 June 1950

They show, as expected, a rough association between areas of convergence and precipitation in the subsequent 24 hours. It has, however, to be emphasized that such zones of convergence only represent areas of large scale ascent at the rate of 5 to 10 cm sec^{-1}; they do not indicate short period violent upcurrents that may also be present.

The present investigations along the above lines are in progress and details will be presented in a subsequent paper. A considerable amount of assistance in the present work was received from Messrs Chakravarti and Madnani to whom grateful acknowledgement is made.

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Poona
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