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The Cooch Behar - Assam Tornado of 19 April 1963

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ABSTRACT. The physical, meteorological and kinematical aspects of a severe tornado that occurred in Cooch Behar-Assam area on 19 April 1963 are studied in the present paper with the aid of available survey reports and meteorological data. It is estimated that the pressure defect inside the tornado war about 100 millibars, the strength of the updraft was 165 knots, and the tangential velocity of rotation was 184 knots. The vortex motion inside the tornado is discussed.

1. Estimates of pressure defect and wind velocity

(*a*) *Pressure defect at centre of the tornado*—The severe and destructive tornado of 19 April 1963 (described in the preceding paper) moved over a wide river bed (confluence of two rivers, R. Torsa and R. Kaljani) from where it picked up a huge volume of water including mud from a portion of the river where water was about 1 metre deep. Suction of a layer of water a little over a metre deep from a river bed indicates a tremendous pressure defect at the centre of the tornado. The normal atmospheric pressure of about 1000 mb at m.s.l. can raise water to a height of about 10 metres in a water barometer and at this rate suction of the layer of water 1 metre deep in the present case would seem to indicate a pressure drop of about 100 mb inside the tornado.

(*b*) *Rotational velocity*—Assuming cyclostrophic motion in which the centrifugal force of rotation is roughly balanced by the pressure gradient inside, we may obtain a measure of the wind velocity by employing the relationship—

$$\partial p/\partial r = \rho V^2/r$$

where $\partial p/\partial r$ is the pressure gradient inside the tornado, r the radius of the funnel, ρ the air density, and V the wind velocity. If we assume a pressure difference of 100 mb between the centre and the periphery of the tornado funnel and take $\rho = 1{\cdot}2\times 10^{-3}$ gm/cc, we obtain $V \sim 92$ m/s or 184 knots.

(*c*) *Strength of updraft*—Very strong updraft which could support hailstones measuring nearly 14 cm in diameter must be inferred inside the tornado. If we assume that hailstones were spherical and that they fell out of the cloud when they could not be supported by the updrafts any longer (Wichmann 1951) we may obtain a rough measure of the magnitude of the updraft. The relevant expression is—

$$w = [2dDg/(3\rho k)]^{1/2}$$

where,

w = updraft velocity,

d, D = diameter and density of hailstone respectively,

g = acceleration due to gravity,

ρ = air density,

and k = coefficient of aerodynamic resistance.

If we take d = 14 cm, $D = 0{\cdot}9$ gm/cc, g = 980 cm/sec/sec, $\rho = 1{\cdot}2\times 10^{-3}$ gm/cc and $k = 0{\cdot}1$ (for a spherical body at high Reynolds numbers), we obtain $w \sim 82{\cdot}5$ m/s or 165 knots.

2. Meteorological conditions

Meteorological conditions favourable for occurrence of tornadoes have been described by Showalter and Fulks (1943), Harrison and Orendorff (1941), Fawbush, Miller and Starrett (1951), Fulks (1951), Gilman (1954), the U.S. Weather Bureau (1956), and others. The relevant synoptic charts in the case of the tornado under study showed that there was low-level moisture feed, veering of wind with height indicating marked warm air advection in the lower troposphere, and dry cold air aloft. The atmosphere was vertically very unstable. Table 1 gives the values of the level of free convection and lifted index over Gauhati, a town about 100 km to the east of the affected area (the only RS/RW station in the vicinity) at 00 and 12 GMT during the period from 16 to 20 April 1963. Figs. 1 (a) and 1(b) give vertical time-sections over Calcutta and Gauhati and show vertical distribution of moisture and wind during the period 16 to 20 April. Figures reveal high moisture content in the lower levels over both the places and two wind maxima over Gauhati, one about 60 knots at 3·6 km asl and the other about 80 knots at about 12·0 km asl. Fig. 2 gives the relative longitudinal positions of the two wind maxima in the latitude band 25°—27°N on 18 and 19 April 1963. It may be seen that there is some kind of superimposition of the two maxima over north Bengal area on the day of the tornado. There was thunderstorm activity and a marked rise in barometric pressure over the sub-Himalayan West Bengal and upper

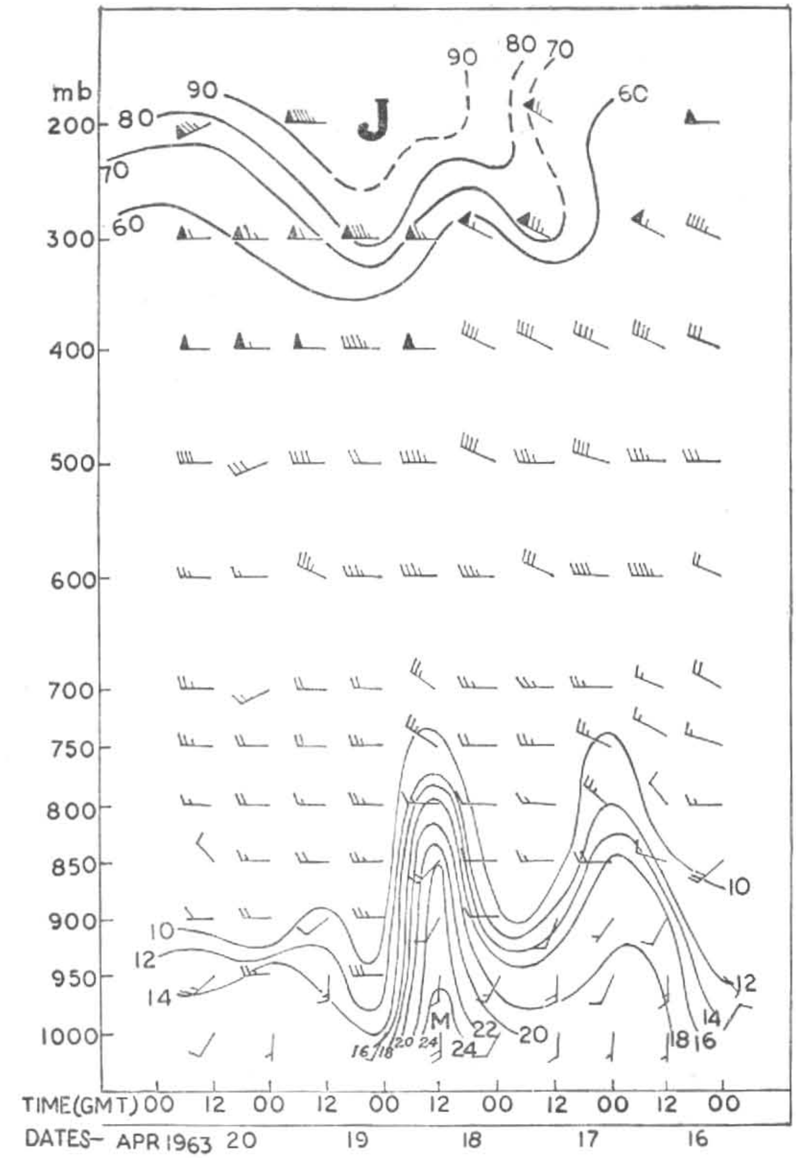

Fig. 1 (a). Vertical time-section showing moisture and wind maxima over Calcutta during period from 16 to 20 April 1963

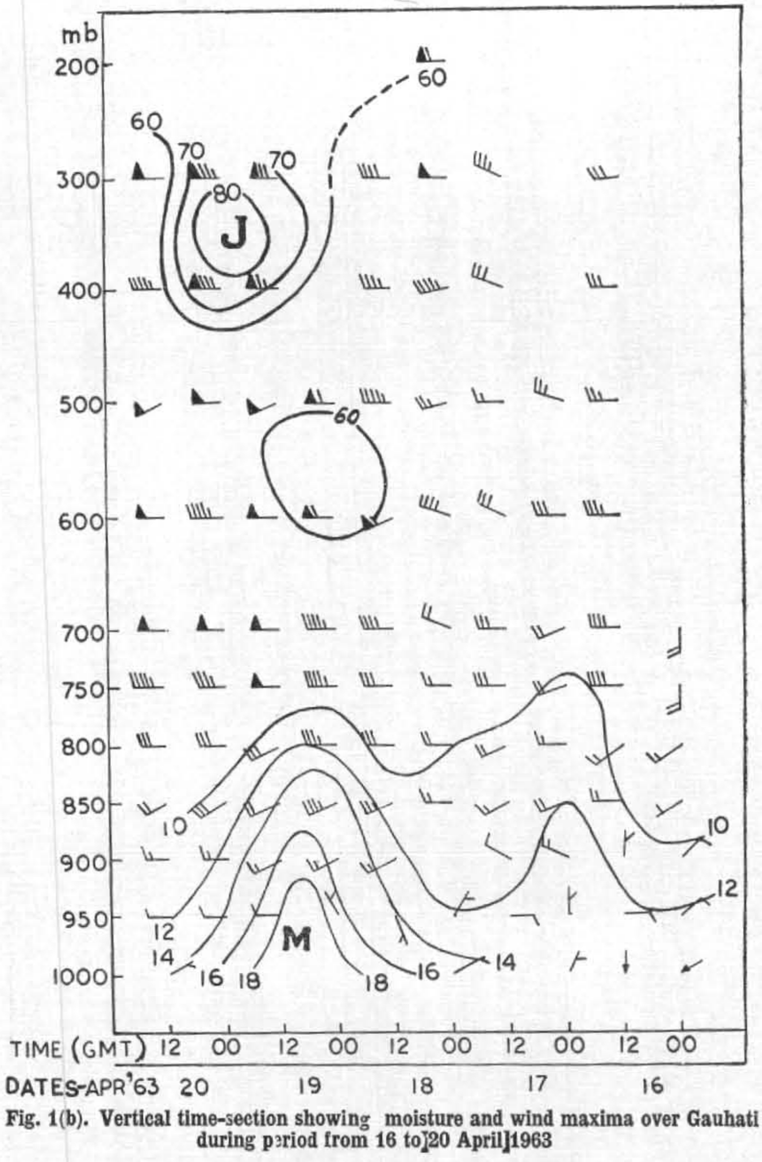

Fig. 1(b). Vertical time-section showing moisture and wind maxima over Gauhati during period from 16 to 20 April 1963

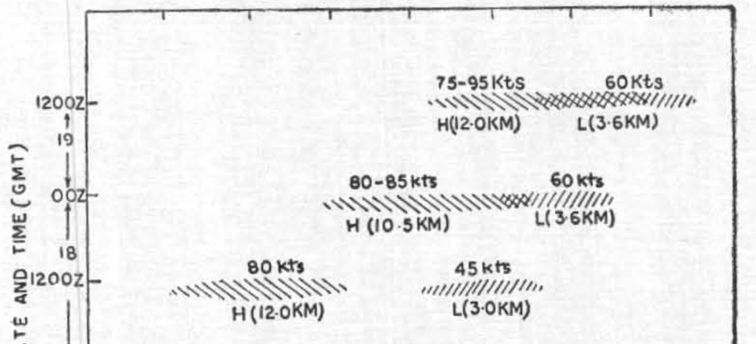

Fig. 2. Relative longitudinal positions of lower and upper wind maxima in the latitude band 25° — 27°N on 18 and 19 April 1963

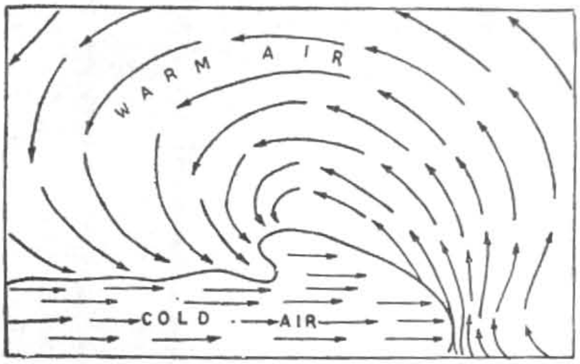

Fig. 3. Formation of a Mother-vortex

TABLE 1

Values of Level of Free Convection (LFC) and Lifted Index (LI) over Gauhati during the period 16 to 20 April 1963

Date (April 1963)	Hour (GMT)	Gauhati LFC (mb)	Gauhati LI (°C)
16	0000	745	—
	1200	780	—2·5
17	0000	695	2·5
	1200	760	0
18	0000	785	0·5
	1200	755	—4·5
19	0000	805	—8·5
	1200	810	—8·0
20	0000	750	—2·5

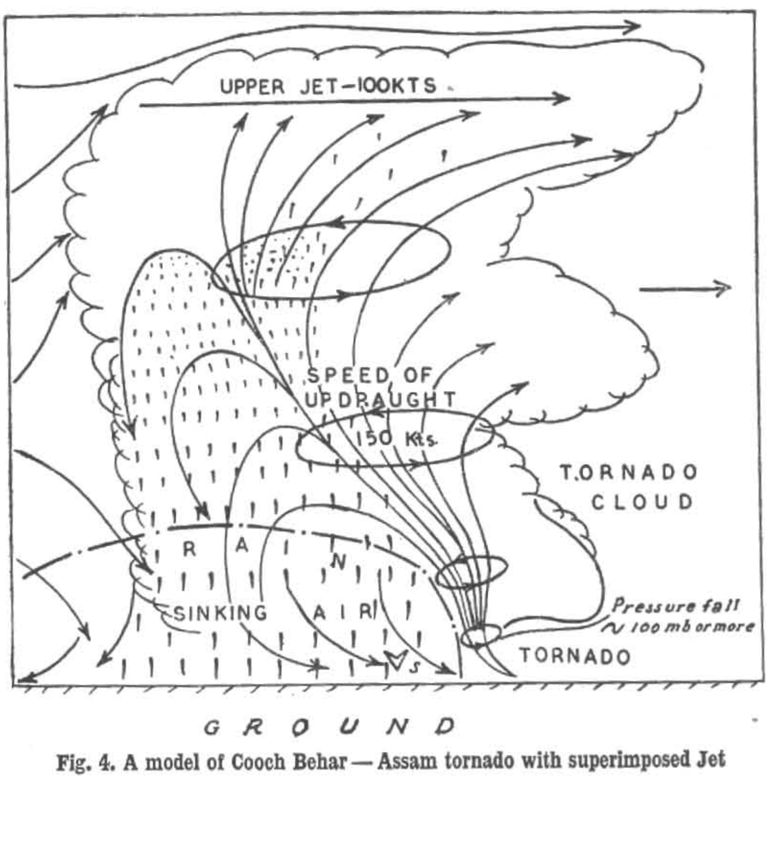

Fig. 4. A model of Cooch Behar — Assam tornado with superimposed Jet

Assam. It is plausible that the latter indicated flow of cold air from thunderstorm downdraught near the surface.

3. The Tornado Vortex

Available data would suggest that the tornado had an intense vortex with a core of extraordinarily strong spiralling winds and an outer region of comparatively lighter winds. To a close degree of approximation, such a vortex would resemble a combined Rankine vortex whose velocity distribution is given by the relations —

$V=c_1 r$, where $0<r<R_0$ (inner core)

$V=c_2 r^{-1}$, where $R_0<r<R_f$ (outer region)

where, V is the horizontal component of the tangential velocity of rotation, r the radial distance from the centre of the tornado, R_0 the radius of the inner core, R_f an assumed radius of the outer region at which the velocity drops to a value found in the environment and c_1, c_2 are constants.

It is well known that most tornadoes form in a field of low pressure (Brooks 1951). Das (1933) following an idea originally given by Wegener (1917) suggested a model for the formation of an initial tornado vortex called a "Mother Vortex" during the movement of a thundersquall and held that such a model would apply realistically to conditions that prevail in the Bengal region during the premonsoon summer season.

The mechanism of formation of a "Mother Vortex" in accordance with the above ideas is shown in Fig. 3. After formation of the initial vortex, its further concentration into a mature tornado would seem to require rapid vertical stretching of the atmosphere and consequent horizontal contraction of the column by nearly an order of magnitude. The initial tornado vortex may have a diameter of a few kilometres but this has to concentrate to a diameter of 100-200 metres to become a mature tornado.

The association of high level wind shear with severe convective storms has been referred to in the work of Wichmann (1951), Fawbush and Miller (1953), U. S. Weather Bureau (1956), Ramaswamy (1956), Newton and Newton (1959), Newton (1960), Cunningham (1960), Dessens (1960), Fujita and Byers (1960), Browning and Ludlam (1962), Das (1962), and Stankewitz (1964), although what exact role it plays in the life of the storm has not yet been clearly assessed. Perhaps, the divergence associated with high-level wind shear may be an important factor in causing a marked reduction of pressure inside the vortex column. The effect may commence aloft and gradually descend through the column as more and more air diverges out of the column. The pressure and dew-point surfaces would then lower below the cloud base to form the characteristic funnel. In a recent work on the distribution of hail-swath areas in U.S.A., Frisby (1964) gives a diagram in which the main hail-swath areas are seen to lie along and to the southern side of the axis of the westerly jet stream. This is what should perhaps normally be expected considering the fact that the southern side of the axis represents an area of divergence and anticyclonic vorticity and as such should experience increased convectional activity. A model of a mature tornado incorporating the jet stream is presented in Fig. 4. A somewhat similar model was given by Fulks (1962).

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