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Role of Pressure Tendencies in Forecasting Rainfall

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ABSTRACT. Change of pressure at a place is a direct result of convergence with associated vertical transport of air and advection of air at that place. Pressure changes due to advection alone would be large and could not account for the pressure tendencies ordinarily noticed. If the pressure changes of order ordinarily noticed are due to convergence, then a direct confirmation of the same may be obtained by a study of pressure tendencies in the field of monsoon depression, the rainfall in which is supposed to be due mostly to convergence. This aspect has been studied *vis-a-vis* short duration pressure tendencies.

1. Introduction

The changes in the field of motion above a point determine the changes in the pressure there. This is represented by the tendency equation (Priestley 1947)—

$$\left(\frac{\partial p}{\partial t}\right)_r = -g \int_r^{\infty} \text{div}\,(\rho V)\,dr \qquad (1)$$

where r is the radial distance of the point from the centre of the earth, V is the velocity vector, and p, ρ and g have usual significance. According to Bjerknes (1945) the pressure changes at a point h above ground is brought about by—

(*a*) Horizontal divergence above h,

(*b*) Vertical air transport through the level h,

(*c*) Horizontal advection above level h,

and arrived at the equation for pressure changes—

$$\left(\frac{\partial p}{\partial t}\right)_h = \int_h^{\infty} g\,\rho\,\text{div}_2\,(\text{v})dz + (g\rho v_z)_h - g\int_h^{\infty}\left(v_x\frac{\partial \rho}{\partial x} + v_y\frac{\partial \rho}{\partial y}\right)dz \qquad (2)$$

Lewis (1945) showed that as far as the pressure change on the ground is concerned, the advection term is exactly equal and opposite to the contribution to pressure changes due to isobaric—isosteric solenoid term in the horizontal divergence of the gradient wind. Matthewman (1946) also arrived at a similar conclusion. Lewis explained that the pressure fall over ground associated with warm air advection was in effect due to convergence in the lower levels resulting in upward currents and divergence aloft.

Priestley (1947) came to the conclusion that the small changes in the pressure at a place are caused by the small deviation of the wind flow from the gradient flow pattern. Apparently, therefore, horizontal divergence has the highest contribution to make towards the pressure tendencies at a place. Mull and Rao (1949) discussed the distribution of rainfall in Indian tropical storms and arrived at the conclusion that the zones of heavy rainfall are also zones of convergence. Das (1952) who also considered the ascents of air mass due to convergence arrived at the same conclusion. The present investigation was, therefore, undertaken to see if tendencies of change of sea level pressure bear any relation to the rainfall distribution over an area.

2. Procedure

Large scale convergence (or divergence) is a short period process and rarely extends beyond a period of 8 to 10 hours. Pressure tendencies of 24 hours duration are, therefore, of dubious value and those for shorter periods will, therefore, be considered. In

TABLE 1

Pressure tendency at hours I and II with or without rain

	Fall in hours I and II			Fall in hour I and rise in hour II			Rise in hour I and fall in hour II			Rise in hours I and II		
	No.	With rain	With no rain	No.	With rain	With no rain	No.	With rain	With no rain	No.	With rain	With no rain
Dhubri	3	—	3	1	1	—	5	—	5	1	—	1
Calcutta	4	3	1	2	2	—	1	—	1	1	1 (1)	—
Asansol	4	4 (1)	—	3	3	—	1	—	1	1	1	—
Jalpaiguri	3	2	1	1	—	1	3	1	2	2	2 (1)	—
Balasore	3	3 (1)	—	1	1	—	1	1	—	1	1	—
Cuttack	3	3 (2)	—	2	1	1	4	1	3	—	—	—
Gopalpur	2	2	—	1	1	—	1	—	1	—	—	—
Sambalpur	5	4	1	1	1	—	—	—	—	2	1	1
Jamshedpur	2	1	1	1	1	—	1	1	—	—	—	
Ranchi	4	4 (1)	—	—	—	—	2	2	—	—	—	—
Hazaribagh	6	5	1	1	1	—	2	1	1	1	—	1
Daltongunj	3	1	2	1	1	—	2	2	—	2	1	1
Dharbhanga	2	1	1	5	4 (1)	—		1	2	—	—	—
Gaya	6	4	2	2	1	1	4	2	2	—	—	—
Gorakhpur	2	—	2	1	1	—	6	1	5	1	—	1
Varanasi	2	1	1	2	1	1	7	2	5	1	—	1
Allahabad	2	1	1	2	1	1	7	2	5	—	—	—
Satna	—	—	—	1	1 (1)	—	8	1	7	1	—	1
Pendra	3	2	1	1	1 (1)	—	2	2	—	—	—	—
Raipur	5	5 (1)	—	—	—	—	3	2	1	—	—	—
Jabalpur	4	2	2	—	—	—	5	1	4	—	—	—
Total	68	48 (6)	20	29	23 (3)	5	68	23	45	14	7 (2)	7

Figures in bracket indicate rain 2″ or more in 24 hours this investigation pressure tendencies for 0830 IST (hereafter referred to as hour I) and that for 1730 IST (referred to as hour II) have been evaluated for 21 selected stations for periods when a depression in the Bay was likely to form during the months June to September for the years 1953 and 1954. 15-hour pressure tendency for hour I was calculated by subtracting algebraically pressure departure from normal at hour II of previous day from the same for hour I of date. Similarly 9-hour pressure tendencies for hour II of date have been computed by subtracting the pressure departure of hour I of date from the same for hour II of date. The number of days when rainfall was recorded during the 24 hours following hour I have also been collected and the results have been tabulated station-wise in Table 1. While tabulating rainfall, amount less than one cent has been neglected. Also on the days when any station recorded rainfall of 5 cents or more within the period between hour II of previous day and hour I of date, the tendencies have not been computed for these days since stabilizing processes, *viz.*, cooling due to rain, thunderstorms etc will have contributed largely to pressure rise. Monsoon depressions for the months June to September for the years 1953-54 have been selected for the purpose of investigation, since before the formation of depression the wind flow around the seasonal trough is easterly or westerly over the plains of Bengal, Bihar and Uttar Pradesh. These situations have been selected with the intention of avoiding cases where the streamlines would indicate strong north-south flow which is capable of contributing very large values to the changes in pressure as has been shown by Priestley (1947). It was, however, not possible to avoid completely all cases where north-south flow was indicated through a considerable level. As the investigation was intended to find a qualitative rather than quantitative relationship between rainfall and associated pressure tendencies, it was considered desirable not to sacrifice continuity by selecting only those cases where the upper air flow was strictly east-west.

While selecting stations care was taken that all Indian areas around the Bay were considered, so that local effects, if any, could be brought out. With this end in view, stations were selected from coastal areas, Chota Nagpur and sub-Himalayan Bengal and Assam and Bihar, as well as the plains of Uttar Pradesh, Bihar and east Madhya Pradesh. The results are tabulated in Table 1. It will be noted that the pressure tendencies at hours I and II have been grouped together in four separate categories according to the tendencies at hours I and II, *i.e.*, (*i*) where fall was recorded at both the hours I and II, (*ii*) where fall was recorded at hour I and rise at hour II, (*iii*) where rise was recorded at hour I and fall at hour II, and (*iv*) where rise was indicated at both the hours I and II.

There were few cases where the rise in hour I was indicated to be of the order of 0·1 or 0·2 mb in 15 hours. These cases have been grouped along with cases where fall in the pressure tendencies at hour I were indicated, for, it may be argued that the presence of slight convergence was offset by the nocturnal cooling in the lower layers. There were seven such cases (only one with rain) which were included in columns 1 or 2 of Table 1. In the table, figures in paranthesis indicate occasions when rainfall was 2 inches or more during 24 hours following hour I.

3. Discussion

(*i*) An examintion of Table 1 reveals that amongst the occasions when fall in tendency at hour I was indicated, rain occurred in over 70 per cent occasions; most of the heavy falls that occurred were associated with such situations only.

(*ii*) Rain occurred in about a third of the occasions when rising pressure tendencies were indicated. Of special mention amongst such cases are the stations of Chota Nagpur plateau. Regarding these stations, it is noticed that in 50 to 75 per cent of situations where the pressure tendency indicated rise, rainfall occurred. It is, however, not possible to prove conclusively that this is due to orography without calculating in detail the convergence at different heights for each of these stations; an investigation which is not possible with available radiosonde observational network.

(*iii*) Rising tendency at hour I followed by similar tendency at hour II at some of the coastal stations and at Jalpaiguri resulted in rain in about 50 per cent cases. Superficially, it would appear, therefore, that pressure tendencies cannot present any index of precipitation distribution. It was, however, noticed from the synoptic situation that so far as the coastal stations were concerned, the advection term in the tendency equation made large positive contribution towards the pressure changes with a burst of fresh monsoon current. Similar tendencies are also noticed whenever the Arabian Sea branch makes first advances over coastal Malabar. Calcutta recorded 2 inches of rain in subsequent 24 hours ending on 16 June 1953. Over Jalpaiguri, it was noticed that tropical easterlies from sub-Himalayan regions were occasionally invading the area—here too, therefore, the contribution of the advection term was probably the deciding factor.

(*iv*) Detailed description of few selected synoptic situations is given below along with charts showing the tendencies at hours I and II. Rainfall during 24 hours following hour I is also plotted in inches within brackets on the chart showing pressure tendency at hour II.

Figs. 1, 2, 3 and 4 indicate 15-hour pressure tendency at hour I of 23 September 1953, 9-hour pressure tendency at hour II on 23 September 1953, 15-hour pressure tendency at hour I of 26 September 1953 and 9-hour pressure tendency at hour II of 26 September 1953 respectively. The synoptic situation may be described as follows—

A low pressure wave moved into the east central and adjoining Bay on the morning of 21 September 1953 and concentrated into a depression centred within a degree of Lat. 16°N, and Long. 91°E on the 23rd morning. It intensified into a deep depression on the same evening centred near Lat. 16½°N and Long. 91°E. The deep depression moved initially in a west-northwesterly direction and then took a westerly course and intensified into a cyclonic storm on the 26th morning, centred about 40 miles southwest of Sandheads. Marked fall in 15-hour pressure tendency at hour I (Fig. 3) of 26 September 1953 may be noticed over east Uttar Pradesh followed by heavy rise in hour II of same day. The cyclonic storm weakened into a deep depression by the 26th evening and was centred near Saugar Island, crossed the coast near Contai in the night and weakened. It was centred near Chaibasa on the 27th morning. Moving further rapidly in northwesterly direction, it was centred near Allahabad on 28th morning and thereafter lay as a diffuse low on 29th. It caused locally heavy to very heavy rain in Gangetic West Bengal and Chota Nagpur.

Figs. 5 and 6 indicate 15-hour pressure tendency at hour I of 1 August 1953 and 9-hour pressure tendency at hour II of 1 August 1953 respectively. The synoptic situation associated with the present case was as follows—

Unsettled conditions in northwest Bay of Bengal gave rise to a depression on the morning of 1 August 1953 with centre near Lat. 21°N and Long. 81°E. The depression intensified into a cyclonic storm on the morning of 2 August 1953, centred about 100 miles south of Calcutta. A perusal of Fig. 6 will indicate amply that the depression indicated intensification since the immediate pressure fall was nearly 4 mb in 9 hours. Another notable fact was that the pressure tendency at hour II showed marked

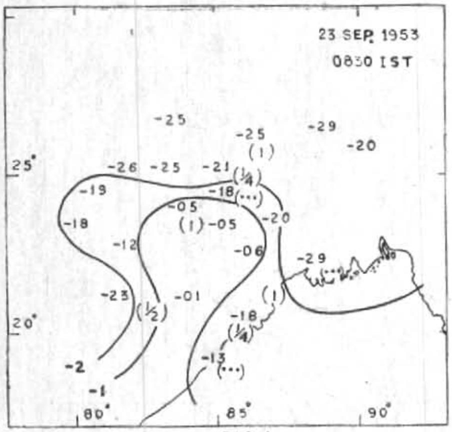

FIG. 1

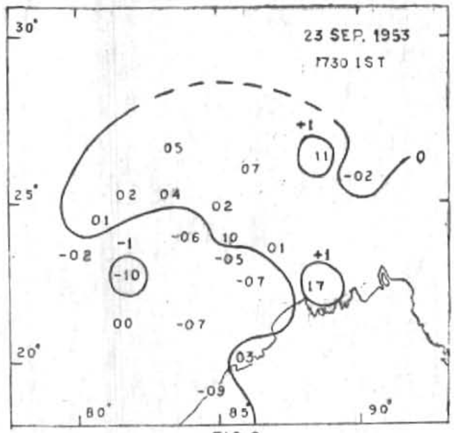

FIG. 2

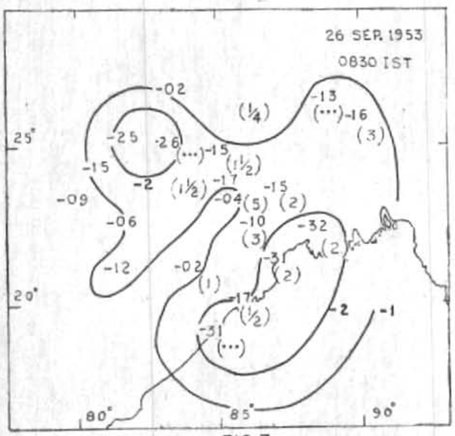

FIG. 3

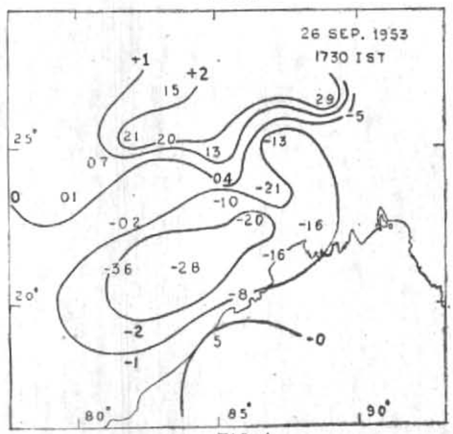

FIG. 4

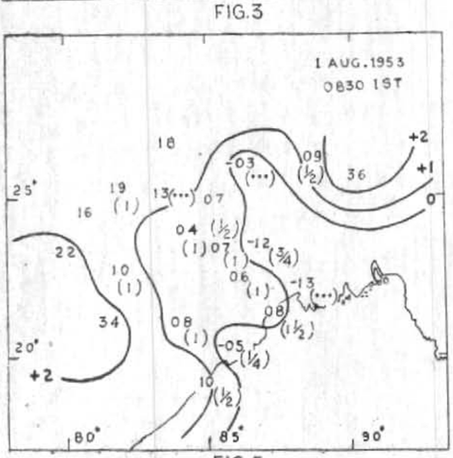

FIG. 5

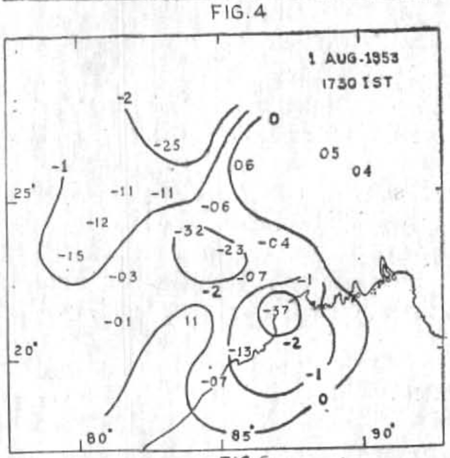

FIG. 6

15 HOURS PRESSURE TENDENCY IN MB (TENTHS) AT 0830 IST ON 23 SEP, 26 SEP AND 1 AUG 1953 AND RAINFALL DURING NEXT 24 HOURS

9 HOURS PRESSURE TENDENCY IN MB (TENTHS)

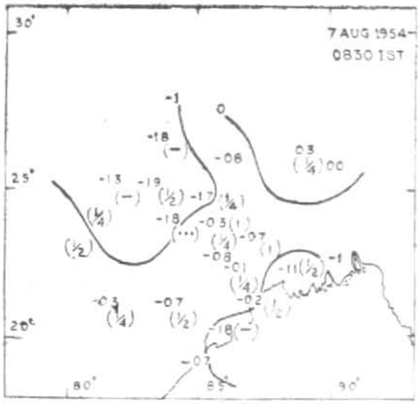

FIG 7

15 HOURS PRESSURE TENDENCY IN MB (TENTHS) AT 0830 IST ON 7 AUG 1954 AND RAINFALL DURING NEXT 24 HOURS

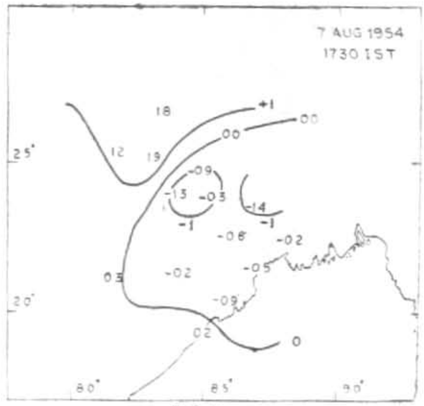

FIG. 8

9 HOURS PRESSURE TENDENCY IN MB (TENTHS)

fall over east Uttar Pradesh and neighbourhood. It is also significant that while the depression was intensifying, more rain occurred in Chota Nagpur and neighbourhood than in the immediate vicinity of the depression, *i.e.*, coastal Orissa and Bengal, probably due to orographic effect.

Figs. 7 and 8 correspond to the 15-hour pressure tendency at hour I and 9-hour pressure tendency at hour II on 7 August 1954. A study of the synoptic situation reveals that a shallow depression formed over northwest Bay centred about 80 miles southeast of Puri on the morning of 7th. Moving in the northerly direction it was centred about 50 miles southeast of Cuttack; it moved further northwestwards and passed inland by the same evening. The fall in pressure tendencies over Orissa coast though indicated slight intensification of the depression between hours I and II, it was not of the order of fall noticed in Fig. 6. More rainfall over Chota Nagpur where the fall in pressure tendency at hour II was more than in the vicinity of the depression, again confirms that the orography plays a significant part so far as the rainfall over Chota Nagpur was concerned.

4. Conclusions

From the above mentioned descriptions the following conclusions can be made—

(*i*) Whenever the 15-hour tendencies indicate fall for hour I (0830 IST), in two out of three occasions, rain may be expected.

(*ii*) During advent of monsoon or when cold advection occurs, frontal lift rather than convergence causes precipitations associated with rising tendency.

(*iii*) Small areas of fall surrounded by areas of rising tendency are regions of intense convergence and consequently cause precipitation in most cases.

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