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Unusual pressure fluctuations associated with thunderstorms

G. C. ASNANI

Meteorological Office, Poona

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1. Introduction

On occasions of important weather phenomena, the barograph trace is disturbed from its normal smooth curve and quite a few interesting patterns result. Amongst these, thunderstorm 'hump' and 'nose' are well known. However, in accounting for these phenomena, meteorologists have been faced with certain unusual pressure curves which do not fit in with the current theoretical explanation of thunderstorm 'high'. Pressure dip associated with some squalls has created a good deal of interest in the subject and any reasoning accounting for thunderstorm 'high' has failed to explain this pressure dip. Mull and Rao (1950) have examined the explanations given by Levine (1942), Buell (1943) and Schaffer (1947) and have shown their inadequacy to explain the pressure dip which still remains an open problem.

The author has closely scrutinised the autographic records of about 18 years (1935—1952) at Begumpet (Latitude 17° 26′N, Longitude 78°27′E) and feels that a new approach to the problem of pressure dip is necessary. It is found that when we collect a large number of unusual pressure patterns, the pressure dips fall into the following few clear categories —

(*i*) During the development of a thunderstorm cloud,

(*ii*) During certain hailstorms and

(*iii*) After a thunderstorm at the station or in its neighbourhood.

Pressure dips of the last type generally showed a rise of wind speed when the pressure was falling and a fall of wind speed when the pressure was recovering from its low value, thus giving an appearance of a squall accompanied by a pressure dip. It was also found that this phenomenon sometimes reversed its time-sequence, *i.e.*, a pressure rise (accompanied by a fall in wind speed) was followed by a pressure fall (accompanied by a rise in wind speed) giving the appearance of a pressure hump accompanied by a wind—calm. Without being categorical on the issue, it appears plausible to visualise that the apparent alternation between the potential (pressure) and the kinetic (wind speed) energy may be due to some oscillatory motion started after the stabilising effect of a thundershower.

It is not the purpose of this paper to claim any justification for the above kind of classification. At this moment, it is proposed only to present a number of unusual pressure patterns along with other relevant records which appear to contribute towards better understanding of observational facts related to thunderstorm pressures.

2. Autographic records

The autographic charts relate to Nizamiah Observatory, Begumpet (Hyderabad—India). The Negretti and Zambra microbarograph was located inside the room on the ground floor where barometer was kept. Its working was satisfactory.

The Dines pressure tube anemograph was located on the top of the Observatory building. The vane was 29 ft above the roof of the building and was 58 ft above ground. The exposure was good. A few remarks are, however, necessary regarding the working of this

instrument. From the illustrated cases, it will be noticed that the velocity pen was frequently touching the base line suggesting that the float was too heavy. Hence the recorded velocity will always be lower than the actual. For exact quantitative evaluation, the velocity record is somewhat defective; however, the record is quite useful for qualitative analysis in respect of increase or decrease of wind velocity. The direction record is quite good.

The working of Casella type self-recording raingauge at about two minutes' walking distance from the barometer room was generally satisfactory, but a hyetogram was changed only when some rain had been recorded.

A general defect in the records is that check-time marks were not given. In their absence, inter-comparison of autographic records over short intervals of time like 5 to 10 minutes may have no meaning since one chart may be 'fast' and the other 'slow' by a few minutes. To overcome this difficulty, though only partially, the fastness or the slowness of a chart was examined from the observer's entries of 'setting' and 'removal' times generally available on the autographic records.

3. Perturbation pressures

The dot curve shown on barograms gives the normal daily pressure curve for that month at Begumpet. Difference between the actual and the normal pressure curve at a moment is called the "perturbation pressure". In fact, we are here concerned with variations of perturbation pressure only. In the following paragraphs, unless stated otherwise, perturbation pressure is, for brevity, referred to as pressure. However, this does not cause any confusion because in the particular situations under scrutiny, variations of perturbation pressure are large compared to variations of pressure due to diurnal cycle.

4. Some unusual curves

Nineteen interesting pressure curves are listed below in chronological order. Ten of the cases are illustrated by diagrams (Figs. 1–10). For each example given below, significant weather reported by the following seven observatories at and near Begumpet is also mentioned—Aurangabad, Parbhani, Nizamabad, Gulbarga, Begumpet, Raichur and Hanamkonda.

Case 1: 31 March–1 April 1935

(*i*) At 1920 IST—Pressure passed through a maximum and wind speed through a minimum.

(*ii*) At 1935 IST—Pressure passed through a minimum and wind speed through a maximum.

(*iii*) At 2015 IST—Pressure was rising and wind speed was also rising.

(*iv*) At 2140 IST—Pressure passed through a maximum and wind speed through a minimum.

(*v*) Between 2140 and 2210 IST—Pressure fell rapidly by 0.06 inch and surface wind rose rapidly from 0 to 25 mph.

(*vi*) Hyderabad (Begumpet) recorded no rain during 24 hours ending at 0800 IST on 1 April 1935, but during the same period, out of the seven observatories at and near Begumpet, Gulbarga reported thunderstorm and Raichur duststorm.

Case 2: 10–11 February 1936 (Fig. 1)

(*i*) A thunderstorm accompanied by *hail* occurred over the station at about 1715 IST. A cup-type pressure curve was traced.

(*ii*) Between 1930 and 1945 IST—Pressure steadily decreased and wind speed steadily increased.

(*iii*) Between 1945 and 2015 IST—Pressure was either steady or increasing, but the wind speed was generally decreasing.

(*iv*) Between 0030 and 0037 IST —Pressure fell rapidly through 0·04 inch and wind speed rose rapidly from 0 to 21 mph.

(*v*) Between 0037 and 0107 IST—Pressure increased and wind speed decreased.

(*vi*) Between 0107 and 0115 IST—Pressure fell rapidly through 0·06 inch and wind speed increased rapidly from 0 to 27 mph.

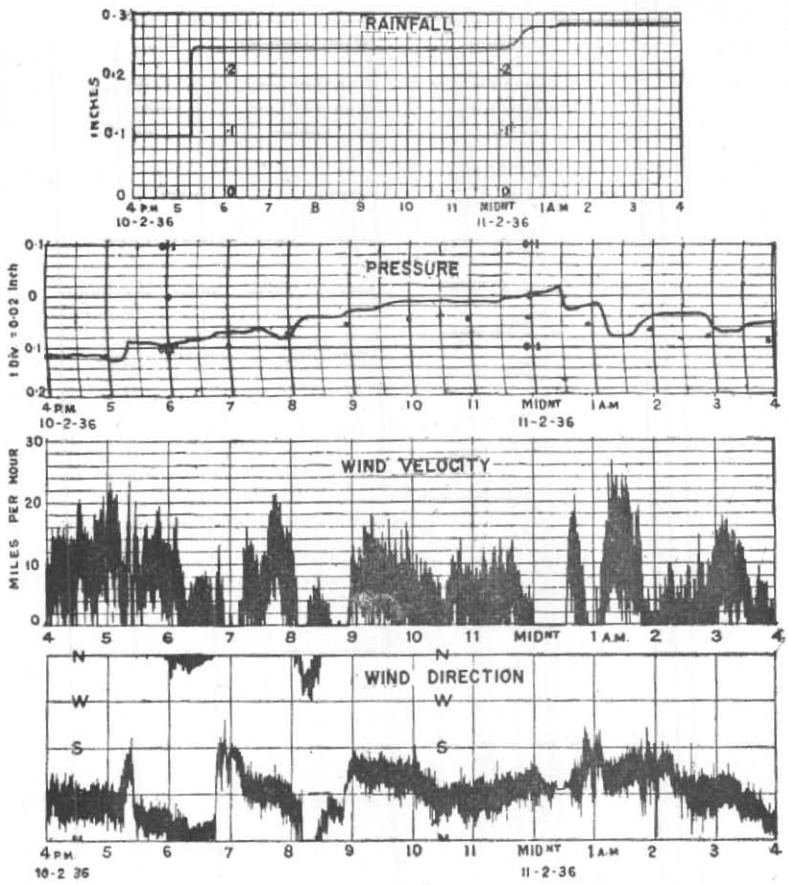


Fig. 1

(*vii*) Between 0115 and 0140 IST—Pressure continued near its lowest value and wind remained relatively strong and gusty.

(*viii*) Between 0140 and 0200 IST—Pressure increased and wind speed decreased.

(*ix*) After 0200 IST also, there is marked coincidence between pressure maxima and wind *minima* and *vice versa*.

(*x*) There were two light showers between midnight and 0130 IST.

(*xi*) During 24 hrs ending at 0800 IST on 11 February 1936, Aurangabad reported hail and Parbhani, Gulbarga and Hanamkonda each reported thunderstorm.

Case 3 : 11–12 February 1936

(*i*) The station experienced a 40-mph squall at 2230 IST, but the perturbation pressure was by no means maximum at 2230 IST; it was showing a rising tendency at that moment. Even when the wind started dying down, the pressure continued to rise.

(*ii*) Between 2215 and 0115 IST—The station experienced moderate rain.

(*iii*) Between 0230 and 0240 IST—There was a rapid fall of pressure accompanied by a rapid increase of wind speed.

(*iv*) Between 0245 and 0250 IST—There was a rapid rise of pressure accompanied by a rapid fall of wind speed. Thus the pressure minimum at 0240 IST was accompanied by a significant wind maximum.

TABLE 1

Wind direction (Time by anemograph clock)		Pressure (Time by barograph clock)	
2132 IST	ENE	2130 IST	Maximum
2141 „	SE	2140 „	Minimum
2152 „	E	2150 „	Maximum
2202 „	SE	2200 „	Minimum
2210 „	E	2207 „	Maximum
2220 „	SSE	2215 „	Minimum
2230 „	E	2227 „	Maximum
2240 „	SE	2235 „	Minimum
2245 „	E	2240 „	Maximum
2250 „	ESE	2247 „	Minimum
2255 „	E	2253 „	Maximum
2305 „	SE	2300 „	Minimum

(*v*) There was also a shower between 0215 and 0235 IST.

(*vi*) During 24 hrs ending at 0800 IST on 12 February 1936, thunderstorms were reported by Aurangabad, Gulbarga, Hyderabad and Hanamkonda.

Case 4 : 4–5 May 1936

(*i*) A thundershower occurred in the afternoon between 1500 and 1610 IST.

(*ii*) The first squall commenced at 1453 IST from ESE (time by anemograph clock). The anemograph clock was fast by 10 minutes in 24 hrs and the barograph clock was fast by 5 minutes in 24 hrs; thus the anemograph clock was ahead of the barograph clock by 5 minutes in 24 hrs. Between 1400 and 1600 IST the anemograph clock was, therefore, ahead of the barograph clock by about one minute only. This squall ended at 1530 IST. During this period, there was a light rise of pressure but was not quite significant.

TABLE 2

Wind direction (Time by anemograph clock)		Wind speed (Time by anemograph clock)		Pressure (Time by barograph clock)	
(IST)		(IST)		(IST)	
0022	SSW	0022	Calm	0025	Minimum
0032	NNE	0032	Maximum (37 mph)	0032	Maximum
0036	S	0038	Calm	0038	Minimum
0045	NE	0044	Maximum (30 mph)	0045	Maximum
0052	SE	0052	Calm	0052	Minimum
0100	NE	0100	Maximum (15 mph)	0102	Maximum
0107	SE	0107	Minimum	0109	Minimum
0112	E	0113	Maximum (14 mph)	0113	Maximum
0116	SE	0116	Indifferent	0116	Indifferent
0120	E	0120	Indifferent	0120	Indifferent

(*iii*) Between 1535 and 1543 IST—Wind speed was low, being a relative calm between two squalls; wind direction changed through nearly 180 degrees from SW to NE and pressure rose rapidly by 0·05 inch. It was raining over the station.

(*iv*) At 1645 IST—Pressure passed through a maximum and wind velocity through a minimum.

(*v*) Between 2130 and 2305 IST—Wind direction performed a few clear oscillations between NE and S. Simultaneously, pressure also experienced marked oscillations. The wind speed also exhibited similar oscillations, but these are less marked. The wind at its maximum appears to be blowing from southeast and at its minimum from east. Between wind direction and pressure, the following association (Table 1) is observed.

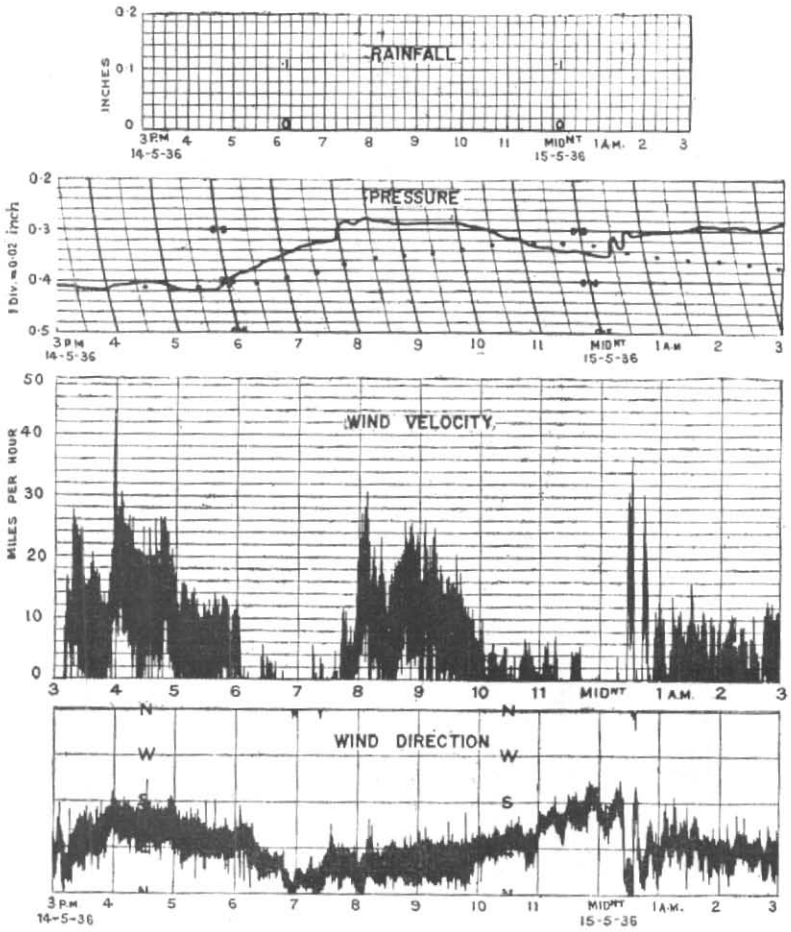


Fig. 2

During this period, anemograph clock was 2-3 minutes ahead of the barograph clock. Applying this correction, we find that pressure maxima almost coincide with easterly swing of the wind, *i.e.*, with wind minima. Similarly pressure minima nearly coincide with wind maxima from southeasterly direction.

Case 5 : 14–15 May 1936 (Fig. 2)

(*i*) Begumpet experienced a 44-mph squall at about 1600 IST and another weaker squall at about 2000 IST.

(*ii*) Between 2300 and 0300 IST—The wind direction manifested apparent oscillations, the most pronounced being between midnight and 0100 IST.

(*iii*) The anemograph clock was fast by 7 minutes in 24 hrs and the barograph clock fast by 10 minutes in 24 hrs; thus the barograph clock was ahead of the anemograph clock by 3 minutes in 24 hrs. Hence between 2300 and 0100 IST, the barograph clock was 1–2 minutes ahead of the anemograph clock.

(*iv*) The following association (Table 2) is observed between different elements during the oscillations.

Applying the time correction, we find that pressure maximum appears to coincide with

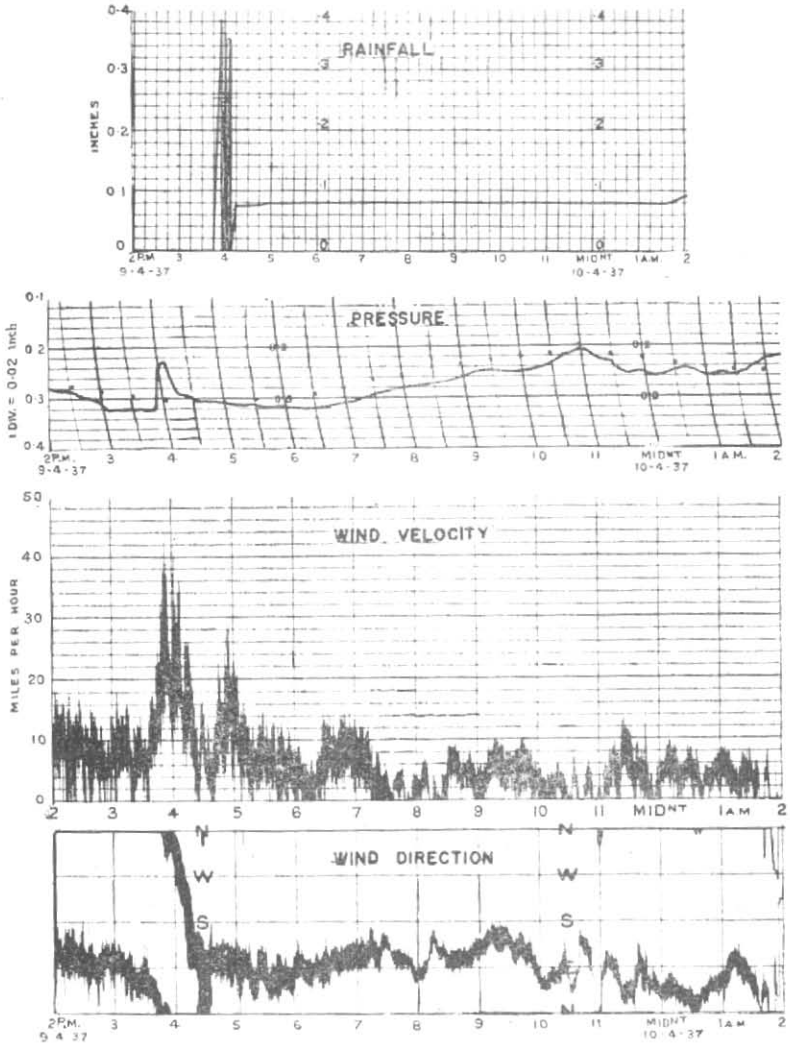


Fig. 3

wind maximum; similarly pressure minima appear to coincide with wind minima.

(*v*) During the 24 hrs ending at 0800 IST on 15 May 1936, Hyderabad had no measurable amount of rain while Aurangabad and Hanamkonda reported thunderstorms, Aurangabad recording 0·4 inch rain.

Case 6 : 9–10 April 1937 (Fig. 3)

(*i*) Anemograph clock was fast by 8 minutes in 24 hrs; barograph clock was fast by 6 minutes in 24 hrs. Therefore, comparatively the anemograph clock was ahead of the barograph clock by only 2 minutes in 24 hours.

(*ii*) Between 1545 and 1615 IST—The wind speed fluctuated rapidly touching the following peaks.

1553 IST	46 mph	from NNW
1602 ,,	44 ,,	,, NW
1607 ,,	36 ,,	,, WSW
1613 ,,	26 ,,	,, SSE

Between 1553 and 1607 IST, pressure

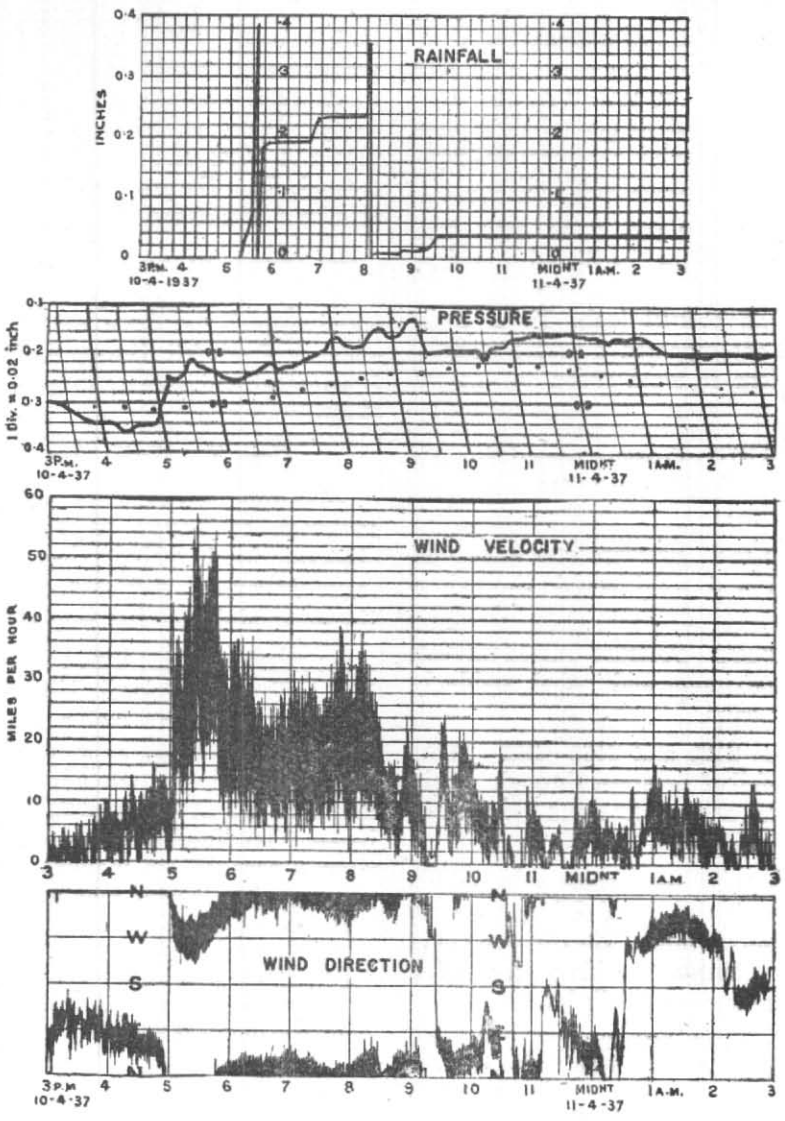


Fig. 4

steadily and rapidly increased by 0·09 inch and between 1607 and 1615 IST pressure steadily and rapidly decreased by 0·06 inch, irrespective of fluctuations in wind speed. A heavy shower accompanied by hail starting at 1545 IST and ending at 1615 IST suggests that the pressure nose was associated with the central regions of precipitation. Shift of wind direction during the interval also supports the inference.

Case 7 : 10–11 April 1937 (Fig. 4)

(*i*) The anemograph clock was fast by 9 minutes in 24 hours and the barograph clock was fast by 6 minutes in 24 hours. Thus the anemograph clock was gaining time over the barograph clock at the rate of 3 minutes in 24 hours. Hence between 1600 and 2400 IST, the anemograph clock was 1 to 2 minutes ahead of the barograph clock.

(*ii*) Before the onset of squall at 1700 IST, the perturbation pressure was markedly negative. Also there was a pressure minimum between 1615 and 1630 IST. With the arrival of the squall, negative perturbation pressure was wiped out and a considerable positive perturbation pressure was built up.

(*iii*) Between 1930 and 2130 IST—The perturbation pressure oscillated round a mean value of about +0·08 inch with an amplitude of about 0·01 inch. These oscillations were accompanied by quite interesting variations in wind speed as shown below—

(*a*) At 2000 IST—Pressure passed through a maximum and wind speed through a minimum.

(*b*) At 2045 IST—Pressure passed through a maximum and wind speed through a minimum.

(*c*) At 2120 IST—Pressure passed through a marked maximum and wind suddenly became dead calm.

(*d*) Between 2125 and 2135 IST—There was a rapid fall of pressure through nearly 0·07 inch and an equally rapid rise of wind speed from 0 to 25 mph.

(*iv*) At 2230 IST—Pressure experienced a dip and it was accompanied by a singular wind maximum (24 mph). The rise and fall of wind so consistently coincide with the fall and rise of pressure respectively.

(*v*) There were intermittent showers between 1700 and 2200 IST.

Case 8 : 17–18 April 1940

(*i*) The anemograph clock was fast by 8 minutes in 24 hours and the barograph clock by 7 minutes in 24 hours. Therefore, between 0600 and 0800 IST on 18 April 1940, the anemograph clock was only one minute ahead of the barograph clock.

(*ii*) Begumpet experienced a squall at 1745 IST and gusty wind during the night.

(*iii*) The barograph traced a significant dip early in the morning between 0645 and 0720 IST. It is very interesting to note that between 0645 and 0710 IST when the pressure was steadily and rapidly falling, the wind speed was also steadily and rapidly rising. Again with rise of pressure between 0715 and 0722 IST the wind rapidly decreased. Thus the pressure dip was accompanied by a prominent wind maximum.

(*iv*) During 24 hours ending at 0800 IST on 18 April 1940, although Begumpet experienced a squall, yet there was no measurable amount of rainfall. During the same period, Nizamabad and Gulbarga reported thunderstorms.

Case 9 : 25–26 April 1940

(*i*) During the 24 hours ending at 0800 IST on 26 April 1940, out of seven reporting observatories in Hyderabad State, five (Aurangabad, Nizamabad, Raichur and Hanamkonda) reported thunderstorms.

(*ii*) Early in the morning between 0330 and 0700 IST on 26 April 1940, clear large-period waves are visible on the barograph trace. During the same period, wind velocity also exhibited clear oscillations giving wind minima at about 0445 and 0545 IST. It will be seen that simultaneously the pressure was passing through its maxima at these moments. Similarly wind maxima also coincide with pressure minima.

(*iii*) During the period these oscillations were being performed, there was a shower that started at 0440 IST and continued till about 0700 IST.

Case 10 : 23–24 April 1941 (Fig. 5)

(*i*) There was a good shower between 1700 and 1745 IST.

(*ii*) Between 1643 and 1705 IST, pressure rose by 0·07 inch; between 1705 and 1708 IST it rose by another 0·08 inch. The total rise of 0·15 inch (a little over 5 mb) is remarkable. Between 1708 and 1710 IST, pressure suddenly dropped by 0·05 inch.

During the above period, 1643 to 1710 IST, there were large fluctuations in wind speed

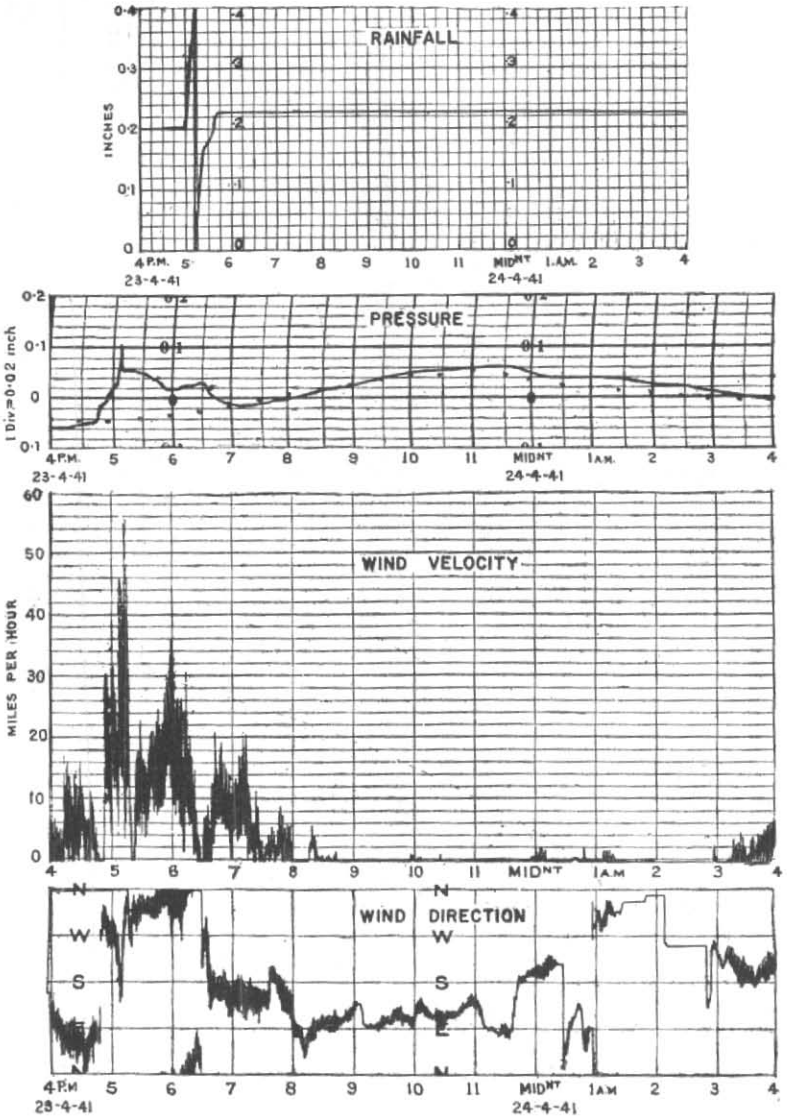


Fig. 5

and wind direction, but the pressure shows a consistent rise without corresponding fluctuations.

(*iii*) Between 1720 and 1800 IST, pressure gradually decreased and wind speed gradually increased.

(*iv*) At 1800 IST pressure passed through a minimum and wind speed through a maximum (36 mph). Between 1800 and 1830 IST, pressure rose gradually and wind speed fell gradually. At 1830 IST, pressure passed through a maximum and wind speed through a minimum. Between 1830 and 1840 IST, pressure decreased and wind speed increased.

Case 11 : 28–29 April 1942 (Fig. 6)

(*i*) The anemograph clock was fast by 11 minutes in 24 hours and barograph clock by 7 minutes in 24 hours. Thus the anemograph

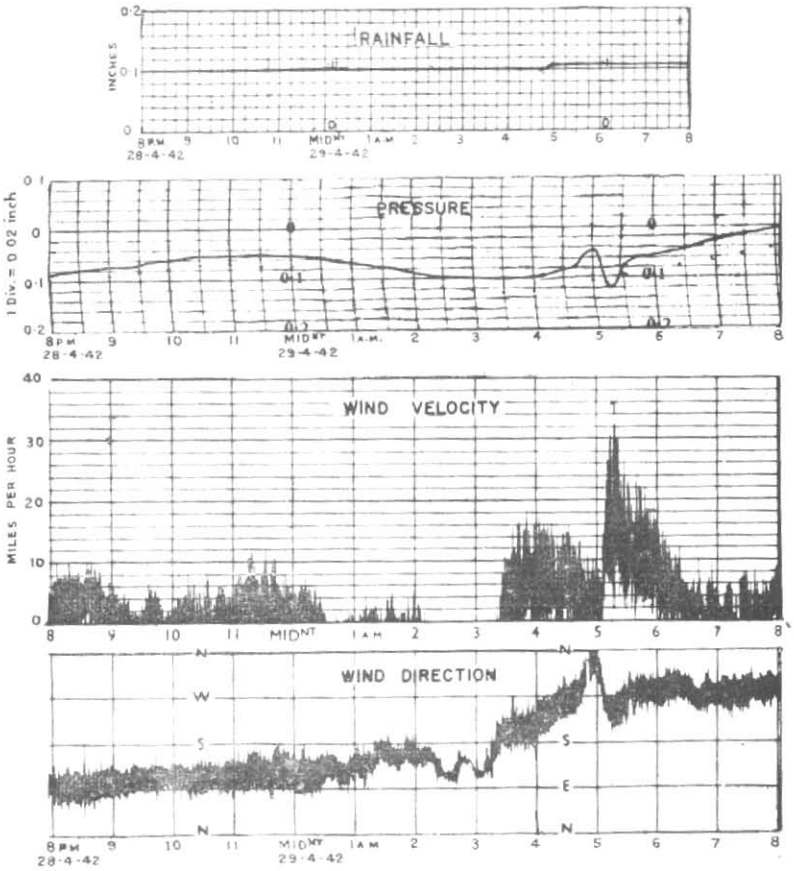


Fig. 6

clock, being faster than the barograph clock by 4 minutes in 24 hours, was ahead of the barograph clock by about 3 minutes between 0400 and 0600 IST on the 29th morning.

(*ii*) Wind activity started at 0320 IST. Perturbation pressure started rising after 0400 IST reaching a maximum at 0500 IST; simultaneously the wind showed a general tendency to decrease during that period.

(*iii*) During 0505 and 0515 IST—There was a sudden and marked fall of pressure through 0·07 inch. In the same short interval, wind speed shot up from 6 to 36 mph giving a clear wind squall.

(*iv*) Between 0515 and 0530 IST—There was a steep rise of pressure accompanied by a steep fall in wind speed.

(*v*) Between 0530 and 0600 IST—There was a gradual rise of pressure accompanied by general decrease in wind speed.

(*vi*) There were a few drops of rain at about 0450 IST on 29 April.

(*vii*) During the 24 hours ending at 0800 IST on 29 April 1942, Nizamabad reported thunderstorm.

Case 12 : 29–30 April 1942

(*i*) There was a shower in the afternoon on 29 April 1942.

(*ii*) During the night that followed, there were some oscillations on the pressure curve, the most pronounced being a significant pressure hump at 0110 IST. It is interesting to see that this pressure maximum was

acccompanied by equally prominent wind minimum which decreased from 14 mph to dead calm and again rose to 22 mph.

Case 13 : 5–6 May 1942

(*i*) There was a heavy shower between 1645 and 1700 IST followed by lighter rain later. Between 1630 and 1730 IST, squally winds (peak speed 55 mph) swept over the station.

(*ii*) Between 1750 and 1840 IST—The wind first rose to 35 mph at 1755 IST, suddenly became weak, again strengthened at 1810 and reached 39 mph at 1825 IST and soon dropped back becoming dead calm at 1840 IST. During this interval, the pressure went on rising almost unmindful of wind fluctuations.

(*iii*) After 1840 IST, we see the alternation between potential energy in the form of pressure and kinetic energy in the form of wind—

(*a*) Between 1840 and 1915 IST—Pressure decreased, wind increased.

(*b*) At 1930 IST—Pressure passed through a relatively unimportant maximum and wind passed through a relatively unimportant minimum.

(*c*) At 2000 IST—Pressure passed through a significant maximum and wind through an equally significant minimum.

Case 14 : 4–5 June 1942

(*i*) At 0025 IST on 5 June, pressure passed through a maximum and the wind through a minimum.

(*ii*) Between 0025 and 0045 IST —Pressure decreased and wind speed generally increased although the rise was more pronounced in the beginning.

(*iii*) Between 0050 and 0055 IST—Pressure registered a steep rise and wind speed rapidly fell. Thus the significant pressure dip between 0030 and 0100 IST is a clear case of alternation of pressure and wind energy.

(*iv*) Between 0055 and 0200 IST—The pressure showed oscillating tendency, the wind direction also manifested the same tendency although the wind speed was irregular. But it may be noted that the general prevailing wind itself was strong so that superimposition of small oscillating component will not become apparent on the velocity record.

(*v*) During the progress of these oscillations, the station experienced a light shower between 0200 and 0215 IST.

(*vi*) During the 24 hours ending at 0800 IST on 5 June 1942, Gulbarga and Raichur reported thunderstorms.

Case 15 : 22–23 April 1943 (Fig. 7)

This is an example probably unique in one of its features. There was thunder, rain and *hail* over the station between 1600 and 1625 IST giving a 60-mph squall. But it is surprising that within a short interval of 10 minutes from 1605 to 1615 IST pressure jumped up by 0·04 inch, dipped back through an equal amount and again jumped up by the same amount. This rapid rise, fall and again rise of pressure during the course of a thundershower accompanied by hail will always remain a very rare phenomenon.

Case 16 : 30 April–1 May 1943

(*i*) There was a thundershower in the afternoon between 1615 and 1645 IST. Late in the evening and early in the night, pressure curve showed marked oscillations.

(*ii*) At 1940 IST—Pressure passed through a marked maximum and wind speed through a minimum.

(*iii*) At 2040 IST—Pressure passed through a marked minimum and wind through a maximum. Between 2040 and 2100 IST, pressure steadily rose and wind speed markedly decreased.

Case 17 : 20–21 March 1944 (Fig. 8)

(*i*) Comparatively large negative perturbation pressure was created between 1600

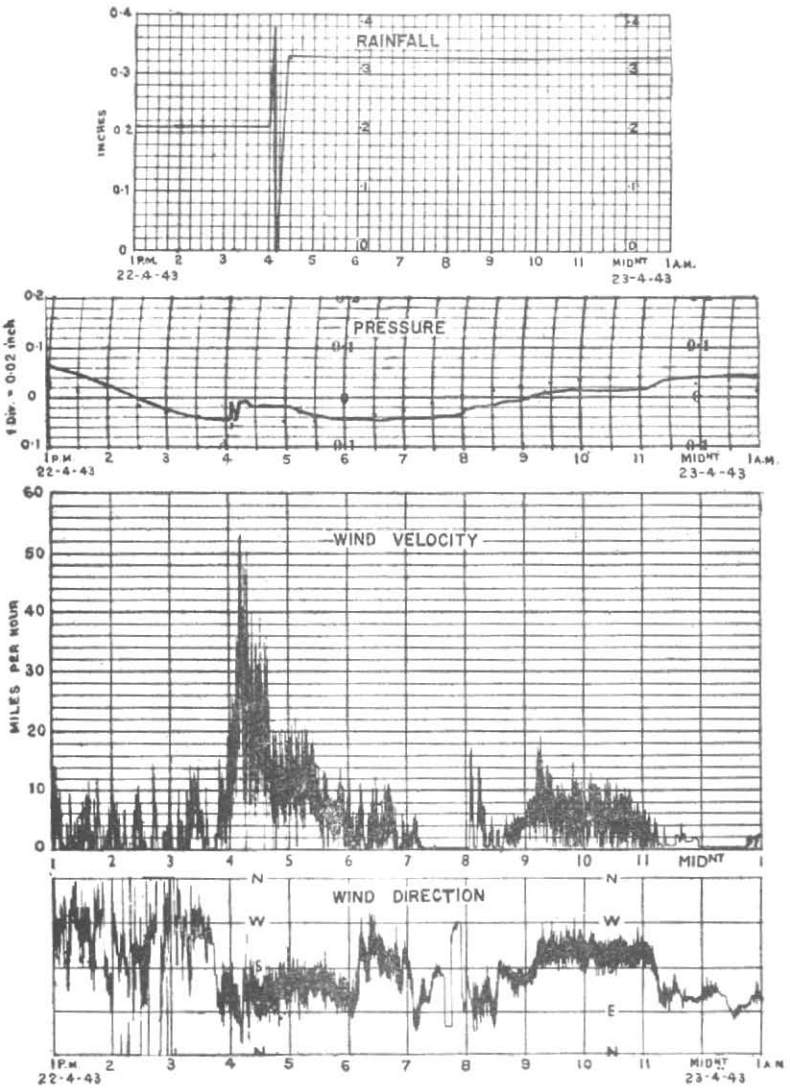


Fig. 7

and 1730 IST. It was almost completely wiped out at 1730 IST with the approach of a squall. There was no measurable amount of rain for this squall.

(*ii*) There was a sharp shower between 2120 and 2130 IST. Another shower started at 2245 IST and lasted till midnight but it was very light.

(*iii*) There was a marked pressure nose at 2125 IST accompanied by a wind minimum. Between 2125 and 2135 IST there was a steep fall of pressure through 0·06 inch accompanied by a sharp rise of wind speed from 4 to 28 mph. Between 2135 and 2200 IST, pressure gradually increased and wind speed generally decreased. Thus a marked pressure nose at 2125 IST is found to be accompanied by a lull in wind speed and a marked pressure dip at 2135 IST is accompanied by a wind maximum that looks like a squall.

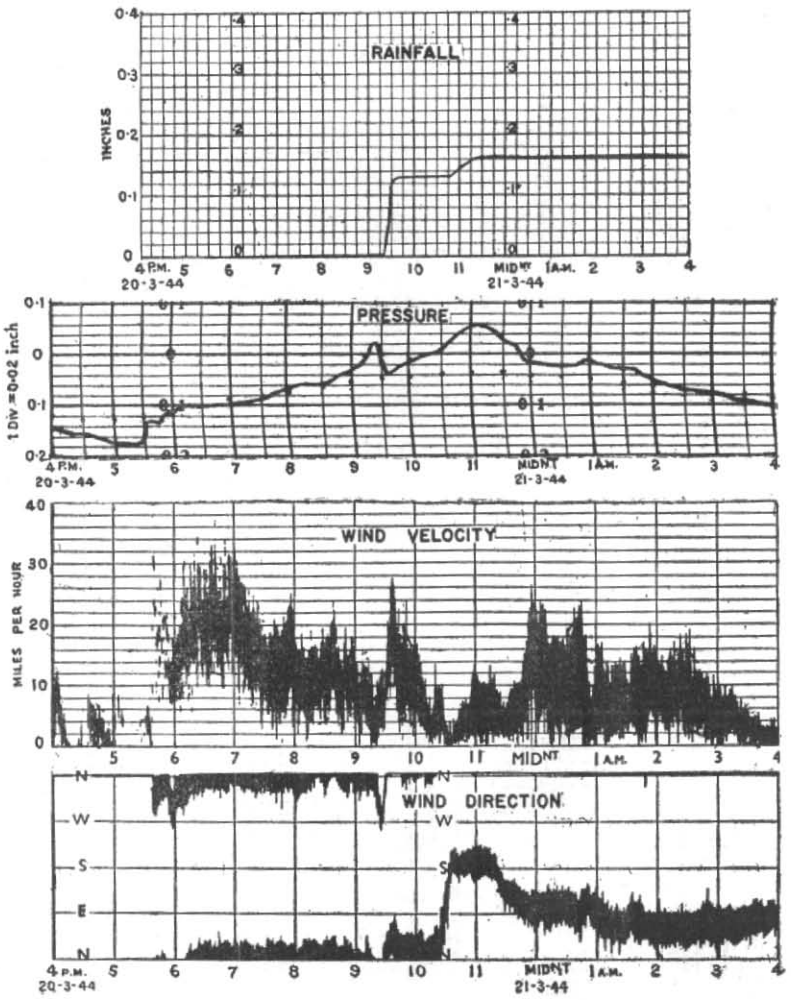


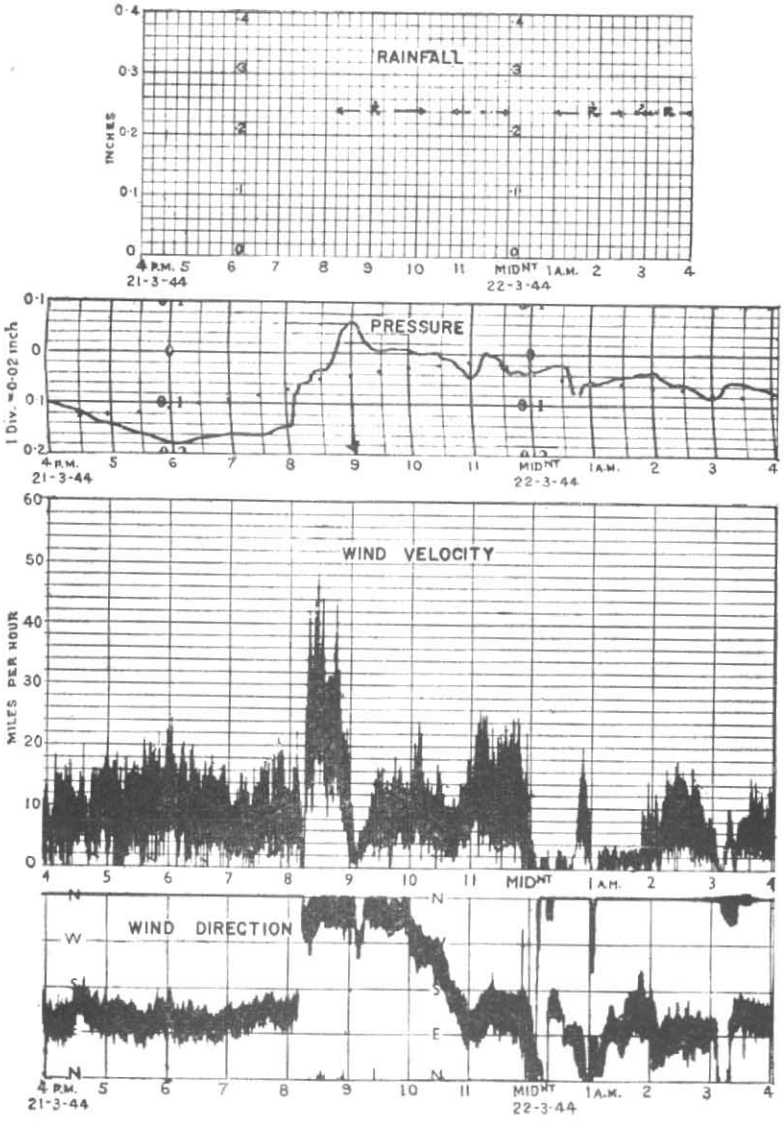
Fig. 8

Case 18 : 21–22 March 1944 (Fig. 9)

(*i*) We rarely come across a case like this when in association with a thunderstorm, pressure rises by as much as 0·20 inch (nearly 7 mb). There was a considerable negative perturbation pressure (about—0·08 inch) between 1800 and 2000 IST, but all that was wiped out rapidly between 2005 and 2010 IST with the approach of a squall.

(*ii*) The barograph clock was running correctly but the anemograph clock was fast by 10 minutes in 24 hrs. Thus between 2000 and 0100 IST, the anemograph clock was 4—6 minutes ahead of the barograph clock. Keeping this in view, the timings are referred to in respect of the barograph clock.

(*iii*) At 2022 IST, the highest speed of 53 mph was recorded ; subsequently the wind speed generally decreased till 2035 IST. Again the wind increased between 2035 and 2040 IST reaching 45 mph, decreased later and within 20 minutes dropped down to almost calm. During all these fluctuations of wind, the pressure did not show any


RAINFALL
INCHES
0·4
0·3
0·2
0·1
0
4 P.M. 5 6 7 8 9 10 11 MIDNT 1 A.M. 2 3 4
21-3-44
22-3-44
PRESSURE
1 Div. = 0·02 inch
0·1
0
0·1
0·2
4 P.M. 5 6 7 8 9 10 11 MIDNT 1 A.M. 2 3 4
21-3-44
22-3-44
WIND VELOCITY
MILES PER HOUR
60
50
40
30
20
10
0
4 5 6 7 8 9 10 11 MIDNT 1 A.M. 2 3 4
WIND DIRECTION
N
W
S
E
N
4 P.M. 5 6 7 8 9 10 11 MIDNT 1 A.M. 2 3 4
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22-3-44

Fig. 9

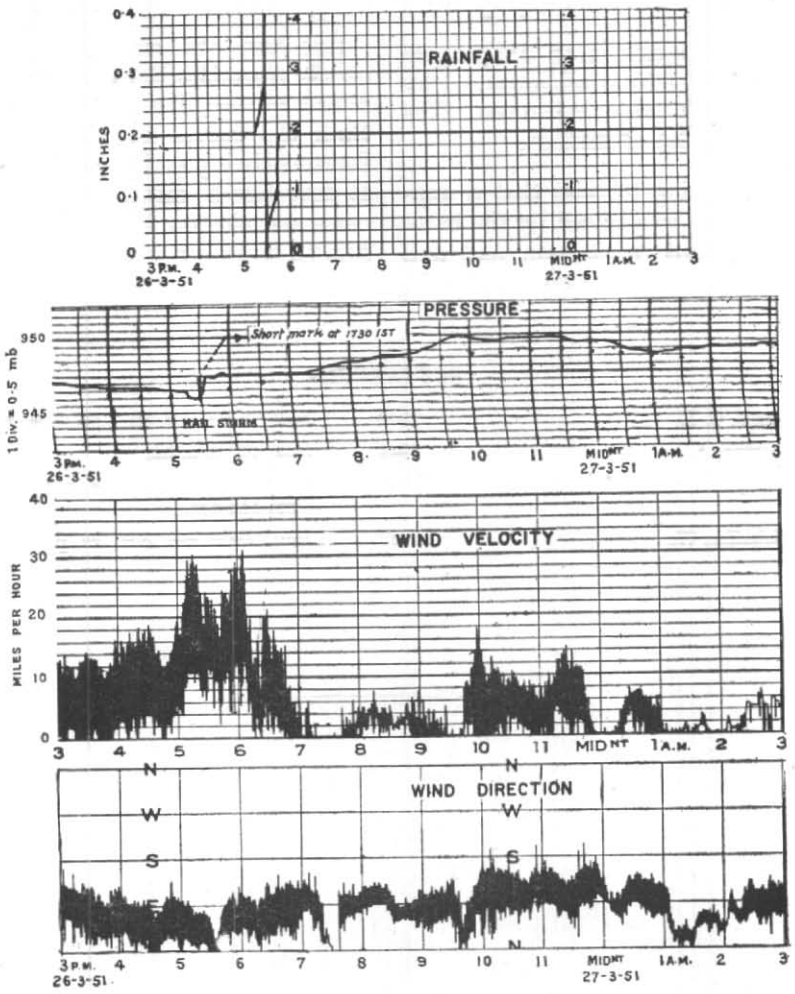

Fig. 10

tendency to decrease but went on rising step by step. Rather it is surprising that between 2040 and 2100 IST when wind was rapidly decreasing, the pressure was still rapidly rising. Between 2040 and 0100 IST, we find some alternation of pressure and wind energy, the most pronounced being at 0045 IST when pressure dip obviously coincides with a marked wind maximum, wind rising from dead calm to 20 mph and again dropping down to calm.

(*iv*) Unfortunately, the self-recording raingauge did not work on this occasion; we give below the observer's relevant entries for the two days, 21 and 22 March 1944—

21-3-1944	R $\frac{0530}{0600}$	R $\frac{0815}{0820}$	R $\frac{2015}{2210}$	$\frac{2245}{2400}$
22-3-1944	R $\frac{0100}{0230}$	$\frac{0245}{0300}$	R $\frac{0300}{0400}$	$\frac{0450}{0515}$

Rainfall—

0900 to 1800 IST of 21 March 1944 — Nil
1800 IST of 21 March to 0900 IST of 22 March 1944 — 1·81 inches.

Case 19 : *26–27 March 1951* (Fig. 10)

(*i*) Between 1715 and 1745 IST, there was a severe thunderstorm accompanied by rain and unusually large hailstones. The hailstorm caused a lot of damage.

(*ii*) It is interesting to note that a cup-type pressure curve was traced by the barograph and also that when rain and *hail* were falling between 1715 and 1730 IST, the pressure was not rising but falling.

(*iii*) Also the cup-type pressure curve closely resembles the cup-type curve on 10 February 1936, illustrated in Case 2 (Fig. 1). Both the curves have one more common feature of being on the occasion of a hailstorm. It may also be mentioned that in these two cases and also on 22 April 1943 (Case 15, Fig. 7), hailstorm was accompanied by a fall of pressure.

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