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Strong winds at Allahabad and their forewarnings

K. L. SINHA

Regional Meteorological Centre, New Delhi

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ABSTRACT. A study of the strong surface winds that occur at Allahabad (Bamrauli Aerodrome) has been made. Records of the wind velocity of 20 mph or more during the period 1941-45 have been analysed. The strong winds have been classified into three groups, (1) Strong gusty winds, as experienced in the summer, or those in monsoon, not connected with monsoon depressions, (2) strong winds, accompanying the depressions and (3) squally winds, associated with dust and thunderstorms. General characteristics of the different types of the strong winds and the associated synoptic situations are discussed. Some local indications at the station and at a few neighbouring stations which have been found useful for the issue of short-time warnings for the squally winds that are associated with the severe duststorms and thunderstorms of the summer months are also discussed.

1. Introduction

The usefulness of the knowledge of frequencies of strong winds, their seasonal variations and the directions from which they blow most frequently at aerodromes needs no emphasis for flying purposes. Not only pilots are interested in these phenomena but ground engineers at aerodromes also will find such information useful. Also, a knowledge of synoptic situations and the local indications associated with such strong winds will ultimately lead to methods of forecasting of such phenomena at aerodromes. An analysis of available observational data of strong winds at Allahabad (Bamrauli Aerodrome) during the years 1941-1945 is attempted in this paper from the above points of view.

2. Situation of the Aerodrome

The aerodrome of Allahabad is located at Bamrauli, which is about 5 miles from the nearest part of the Allahabad city. Its position is : Latitude 25° 27′N and longitude 81° 44′E and its altitude is 319 feet above sea level. The situation of the aerodrome is shown in Fig. 1. It is surrounded in the north by the river Ganges, in the south by the Jumna and in the east partly by the Ganges and partly by the Jumna. The Himalayas in the north is at a distance of about 150 miles and the hillocks of the Vindhya range in the south are at a distance of about 30 miles.

3. General features of winds at Allahabad

The general features of the surface winds at Allahabad are shown in the chart under Fig. 2. They are generally light to moderate. Directions are usually from west to northwest from January to April. During May, the winds show a tendency for easterly direction till about noon and then they change to northwest to north later during the day. Winds are mostly easterly in June and they alternate between easterly and westerly directions in July, August and September. From October to December they are again from west to northwest direction.

4. Winds exceeding 20 mph

Records of winds in which the maximum velocity was 20 mph or more have been collected from the anemograms of Allahabad for the five years 1941-1945. They are grouped according to velocity and direction and are given in Table 1. They are also shown graphically in Figs. 3 to 6.

The months of November and December are conspicuous by the absence of winds of 20 mph or more. In January, the frequency is very small, say once a year on the average, and the maximum velocity does not reach 50 mph. In February, the frequency increases to about twice a year. The maximum velocity is generally below 40 mph. In March, the frequency suddenly rises to 7 per year and although in most of the cases, the maximum wind velocity is below 40 mph, it may occasionally rise to 50 mph or more.

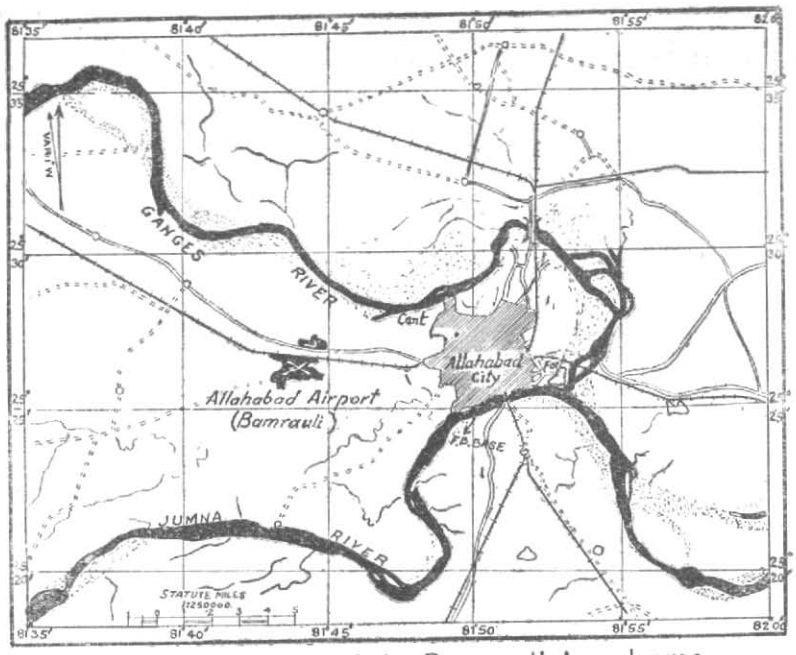

Fig. 1. Situation of the Bamrauli Aerodrome

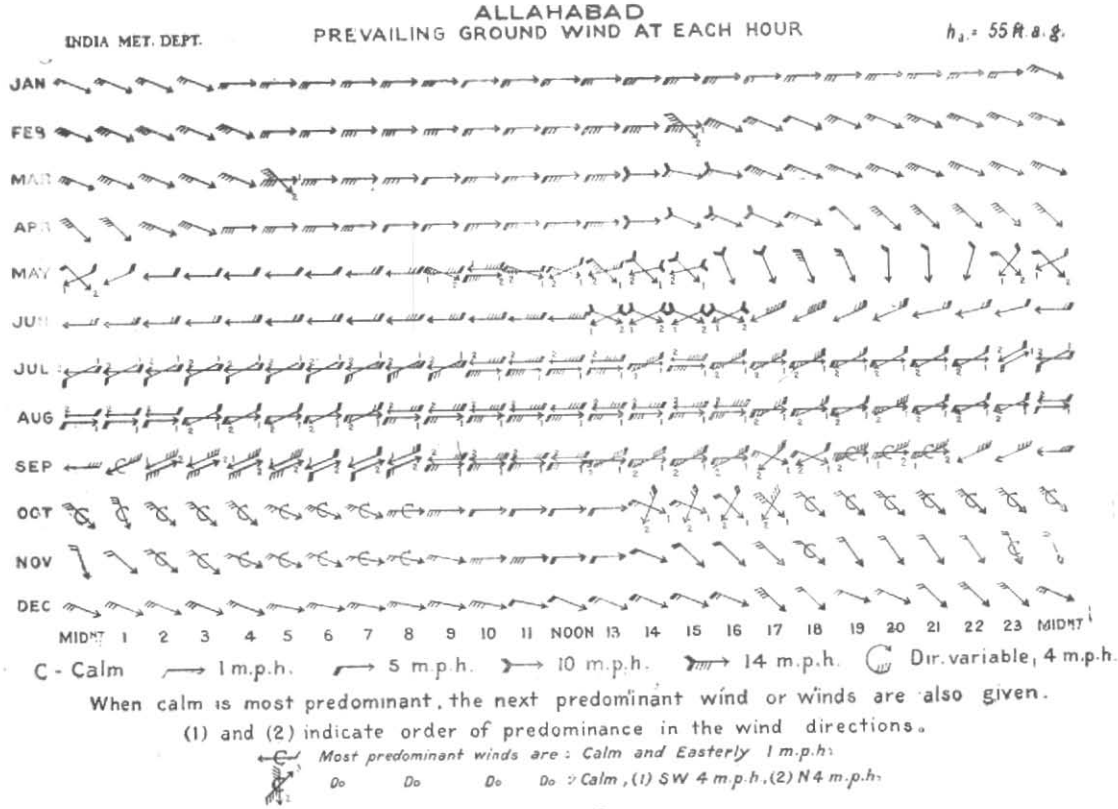

Fig. 2

TABLE 1

Number of days of wind velocity of 20 mph and above at Allahabad during 1941-45

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Highest wind velocity (mph)							JANUARY										
20 to 29	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
30 to 39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	2
40 to 49	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
50 and above	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2	1	4
							FEBRUARY										
20 to 29	—	—	—	—	—	1	—	—	—	—	—	—	1	—	1	—	3
30 to 39	—	1	—	1	1	—	—	—	—	—	—	1	—	2	2	—	8
40 to 49	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50 and above	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	1	—	1	1	1	—	—	—	—	—	1	1	2	3	—	11
							MARCH										
20 to 29	—	—	—	—	—	—	—	—	—	1	1	—	—	—	1	—	3
30 to 39	1	—	—	—	—	—	—	1	—	—	—	—	3	8	14	1	28
40 to 49	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	3
50 and above	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Total	1	—	—	—	—	—	—	1	—	1	1	—	5	8	15	3	35
							APRIL										
20 to 29	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	2
30 to 39	—	—	—	—	—	—	—	—	—	1	1	—	2	3	16	1	24
40 to 49	—	—	—	—	—	—	—	—	—	—	2	1	—	3	3	—	9
50 and above	1	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	3
Total	1	—	—	—	—	—	—	—	—	1	3	1	3	6	22	1	38
							MAY										
20 to 29	—	1	1	—	—	—	—	—	—	—	—	—	—	1	3	—	6
30 to 39	—	—	2	—	—	—	—	—	—	1	1	—	—	8	18	1	31
40 to 49	—	—	—	—	—	—	—	—	—	—	—	—	1	2	5	1	9
50 and above	—	1	—	—	—	—	—	—	—	—	—	—	—	—	3	—	4
Total	—	2	3	—	—	—	—	—	—	1	1	—	1	11	29	2	50
							JUNE										
20 to 29	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	2
30 to 39	1	—	1	1	—	1	1	—	1	—	4	—	3	4	6	6	29
40 to 49	—	2	—	—	—	—	—	—	—	—	2	—	3	1	1	1	10
50 and above	—	—	1	—	—	—	—	—	—	—	—	—	2	—	4	—	7
Total	1	2	2	1	—	1	1	1	1	—	6	—	8	5	12	7	48

TABLE 1 *(contd)*

Number of days of wind velocity of 20 mph and above at Allahabad during 1941-45

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Highest wind velocity (mph)																	
								JULY									
20 to 29	—	—	—	—	1	—	—	—	—	—	2	—	—	—	1	—	4
30 to 39	—	—	4	2	1	—	2	1	3	—	—	—	1	3	2	1	20
40 to 49	—	—	—	—	2	—	—	—	—	—	1	—	—	—	—	—	3
50 and above	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	2
Total	—	—	4	2	4	—	3	1	3	—	3	—	1	4	3	1	29
								AUGUST									
20 to 29	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
30 to 39	—	—	3	—	1	1	—	—	—	—	1	—	—	2	1	—	9
40 to 49	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	3
50 and above	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
Total	—	1	3	1	2	2	1	—	—	—	1	—	—	2	1	—	14
								SEPTEMBER									
20 to 29	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
30 to 39	—	—	2	1	—	—	1	—	—	—	—	—	—	—	2	2	8
40 to 49	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50 and above	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	2	1	—	—	2	—	—	—	—	—	—	—	2	2	9
								OCTOBER									
20 to 29	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
30 to 39	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
40 to 49	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50 and above	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
Total	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	2

NOVEMBER AND DECEMBER—*Nil*

								YEAR									
20 to 29	—	1	1	—	2	1	2	1	—	1	3	—	1	1	9	—	23
30 to 39	2	1	12	5	3	2	4	2	5	2	7	1	9	30	63	12	160
40 to 49	—	3	—	1	3	—	—	—	—	—	6	—	5	6	9	5	38
50 and above	1	1	1	—	—	1	1	—	1	—	—	—	4	1	8	—	19
Total	3	6	14	6	8	4	7	3	6	3	16	1	19	38	89	17	240

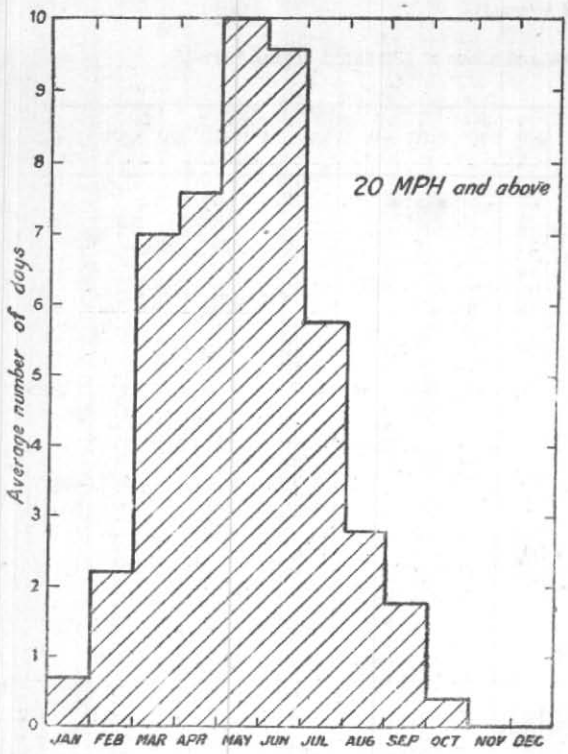

Fig. 3. Average number of days of wind velocity of 20 mph and above

From April upto June, there is further increase in the number of occasions and also in the strength of the winds. In May and June, the frequency is ten days in each month. On 2 to 3 occasions, the maximum wind velocity goes above 40 mph. From July the frequency decreases, but in this month also, the winds may go above 40 mph once a year on the average. The frequency decreases to 3 in August and to 2 in September. In September, the maximum wind velocity does not generally rise even to 40 mph. Winds of 20 mph or more occur only very occasionally in October.

These winds are mostly from a north westerly direction during the months January to June, whatever be the velocity. During July to September, the winds are both from westerly and easterly directions.

Taking the year as a whole, the most frequent group of wind velocity and the associated wind direction is 30-39 mph with northwesterly direction. Such cases occur on about 12 days on the average in a year.

5. Classification of the strong winds

Winds of 20 mph or more that are recorded at Allahabad may be classified as follows—

(*i*) Strong gusty winds during summer and monsoon months, not associated with depressions,

(*ii*) Strong winds associated with depression and

(*iii*) Strong winds associated with dust-storms and thunderstorms.

The average number of the days of winds of 20 mph or more under the three groups, is given in Table 2.

The strong gusty winds in the first group, are observed from February and they continue their predominance in the summer months. The effect of the depressions, on the other hand, comes into prominence during the peak monsoon months. The effect of thunderstorm is noticeable practically during the whole year excepting the last two or three months.

6. Some characteristics of the strong winds

(*i*) *Strong gusty winds of summer and monsoon season*

(*a*) *Summer season*—The gusty hot winds of summer are one of the chief features at Allahabad. They are popularly known as *Loo*. They blow from westerly to a northwesterly direction. They do not generally go up beyond 35/40 mph in gust. These winds are mainly confined from about forenoon till about sunset. In fact, these are the winds of the hot times of the day during the hot months of the year.

These gusty winds occur for two to five successive days and sometimes they may continue for a week at a time. As for examples, gusty winds occurred from 23 to 25 March and from 10 to 16 April 1941. Such winds were also observed from 6 to 10 May 1942 and again from 17th to 24th in the same month.

TABLE 2

Distribution of days of winds of 20 mph or more under different groups

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(*i*) Strong gusty winds in Summer and Monsoon	—	1·4	6·0	5·4	5·8	4·6	1·4	1·0	0·2	—	—	—
(*ii* Winds associated with depressions	—	—	—	—	0·2	0·2	2·0	0·6	0·2	0·2	—	—
(*iii*) Winds associated with dust or thunderstorms	0·8	0·8	1·0	2·2	4·0	4·8	2·4	1·2	1·4	0·2	—	—
Average number of days of winds 20 mph or more	0·8	2·2	7·0	7·6	10·0	9·6	5·8	2·8	1·8	0·4	—	—

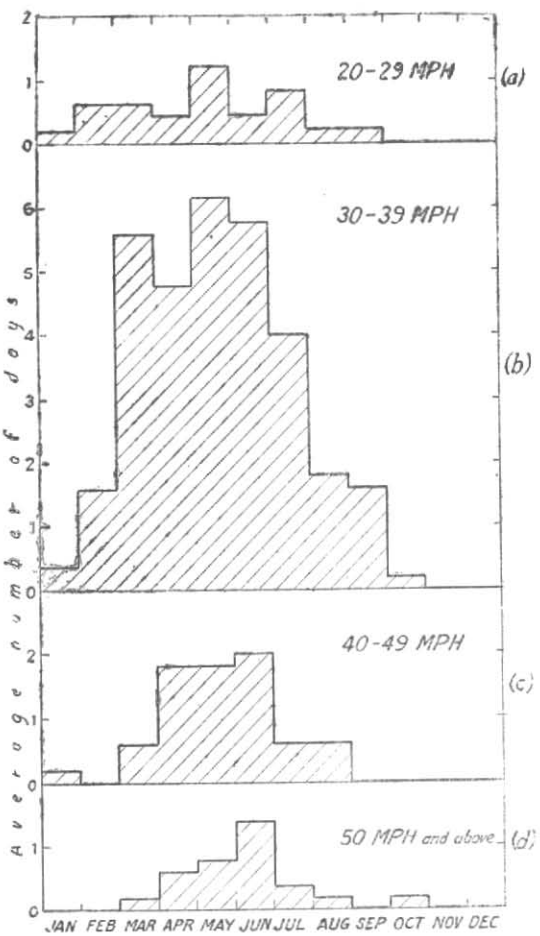

Fig. 4. Average number of days of strong winds classified according to velocity

(*b*) *Monsoon season*—Strong gusty winds, not connected with depression, observed during the monsoon season are from a westerly direction. The wind velocity in a gust is generally below 35 mph. The frequency of such winds is, however, small as compared to those in the summer. They are generally associated with the break in the monsoon.

The gusty winds of the summer have the maximum velocity in the afternoon, while monsoon winds are often observed to have the maximum effect in the early part of the day. Whereas the maximum effect of the gusty winds of the summer type exemplified before was observed in the afternoon in all those cases, that in the case of the gusty winds of the monsoon type on 25 July 1941 and also on two or three continuous days was noticed between 0800 and 1030 IST.

(*ii*) *Strong winds associated with depressions*

Strong gusty winds, associated with depressions, are mostly from easterly direction. The wind velocity in gust is generally below 40 mph. Thus the order of the wind velocity associated with depressions is the same as that of the strong gusty winds of the summer. The strong winds are observed both during the day and the night, unlike the gusty winds of the summer that are observed during the day time only. If the rate of the movement of the depression is slow and the centre is near the station, the associated strong winds may continue to blow both during the day and the night for a day or two. An example of a

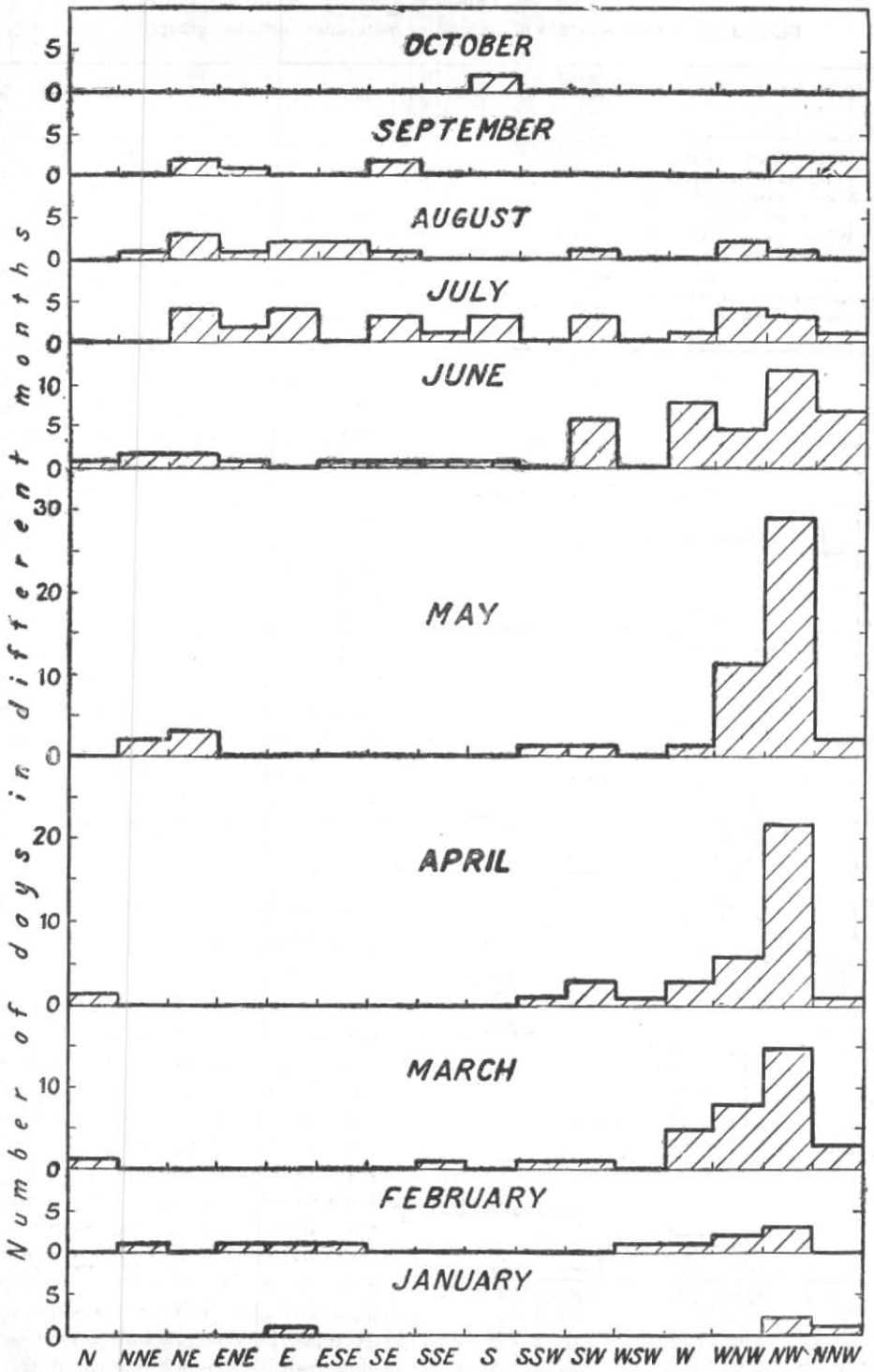

Fig. 5. Direction of winds of velocity 20 mph and above (Number of days during 1941-45)

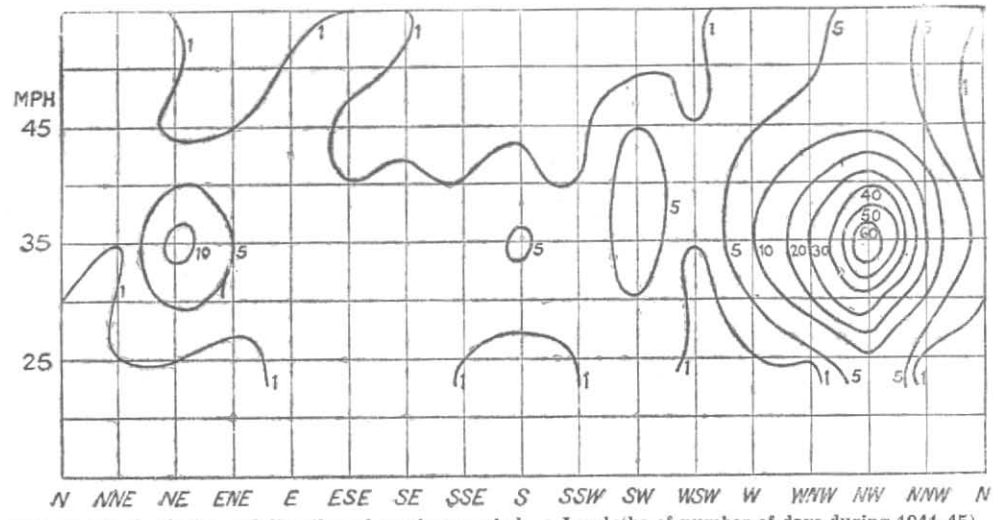

Fig. 6. Wind velocity and direction of maximum winds (Isopleths of number of days during 1941-45)

depression producing strong winds at Allahabad is given under 7(*ii*).

(*iii*) *Strong winds associated with duststorms and thunderstorms*

The severe winds that constitute a great danger are the squalls associated with duststorms and certain thunderstorms. The wind velocity in gust on occasions rises to more than 50 mph. The anemogram of Allahabad for 8 May 1943 shows that the wind velocity in connection with a dust and thunderstorm on that day rose to 70 mph (A severe thundersquall of 100 mph was experienced at the station on 21 March 1950).

The frequency of the duststorm, thunderstorm etc. that occur at Allahabad at different times of the year is available on page 4 of the 'Aviation Climatological Tables' published by the India Meteorological Department. The severe thunderstorms occur at the station usually during the period from the end of March to the beginning of June. In most of these cases, thunderstorms are preceded by duststorms. As is expected of the thermal instability phenomena, these dust and thunderstorms of the hot weather period mostly occur in the late afternoon or evening and early part of the night. The duststorm passes away in about half an hour and the thunderstorm in about an hour or two. The most prominent squally winds thus associated with duststorms and thunderstorms take place generally towards summer evenings and they are of short durations.

7. **Forecasting of the strong winds at Allahabad**

(*i*) *Strong gusty winds of summer and monsoon seasons*

(*a*) *Summer*—Although strong gusty winds are more pronounced in the summer, they are noticeable even in February. Strong gusty winds are produced when a 'Low' from southwest or west moves to the east or northeast of the station, and they blow on successive days if a quasi-stationary 'Low' appears in the neighbourhood of the sub-montane regions of Bihar. Strong gusty winds continue till a western disturbance or its secondary approaches the station from the west or southwest, when the winds weaken and may even change to easterly direction. When the disturbance passes east of the station, the winds change to west to northwest and freshen and then remain strong and gusty till another disturbance appears. Fig. 7, depicting the morning weather chart of 21 March 1945, gives an illustration of strong gusty winds at Allahabad, associated with the appearance of 'Low' over the sub-montane regions of Bihar. Allahabad had surface winds gusting to 36 mph in the afternoon of that day and 37 mph in the afternoon of the next day.

The midnight or the morning pilot balloon data of the station also provide a simple method of forecasting these winds during the day. The upper wind within the height of 1 km are enough for the purpose. If the wind speed in the first one or two reported levels of the pilot balloon observations is four or better five Beaufort number and more, strong gusty winds follow in the day time. As surface heating is an essential mechanism in the production of these winds, factors affecting surface heating should also be taken into account while forecasting.

Table 3 below gives the early morning pilot balloon data of Allahabad upto 1·5 km for some days on which strong gusty winds followed during the day.

(*b*) *Monsoon season*—During the monsoon as Allahabad is ordinarily in the monsoon trough of low pressure, where pressure gradient is not much, the surface winds at Allahabad, under this usual condition, do not become strong. When the axis of the trough of low pressure moves upwards towards the Himalayas, Allahabad comes under greater pressure gradient and strong gusty winds begin to blow over the station from a westerly direction. These strong gusty winds may, therefore, be anti cipated from the upward shift of the axis of the monsoon trough of low pressure towards the Himalayas. The weather chart of 25 July 1941 is reproduced in Fig. 8 to show that when the axis of the monsoon trough had shifted upwards, the result was that strong gusty winds blew over Allahabad. Gusty winds of 33 mph blew over the station on the afternoon of 25 July 1941.

Fig. 7. Weather chart at 0300 IST on 21 March 1945. Low over Bihar causing strong winds at Allahabad

TABLE 3

Morning pilot balloon data of Allahabad and the gusty winds that followed

Date	Time of ascent (IST)	Reported upper winds								Maximum wind velocity in gusts during the day (mph)
		·2 km		·5 km		1·0 km		1·5 km		
		dd	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	
11-3-41 ..	06	31	22	32	48	32	62	29	53	35
11-4-41 ..	06	30	26	32	44	32	49	31	50	40
26-4-41 ..	05	28	25	30	32	30	29	29	38	41
4-5-41 ..	06	26	40	23	65	23	45	28	38	37
19-4-42 ..	06	28	29	32	45	32	51	31	66	35
17-5-42 ..	05	32	22	33	23	32	29	31	31	34
18-5-42 ..	05	29	43	28	57	30	55	29	46	31
19-5-42 ..	05	—	—	29	44	28	32	—	—	35
21-5-42 ..	06	27	36	29	44	30	57	31	61	36
18-4-43 ..	06	31	30	32	20	32	20	31	30	32
27-4-43 ..	06	28	20	29	30	31	25	33	40	42

dd=Direction in tens of degrees *vv*=Velocity in km per hour

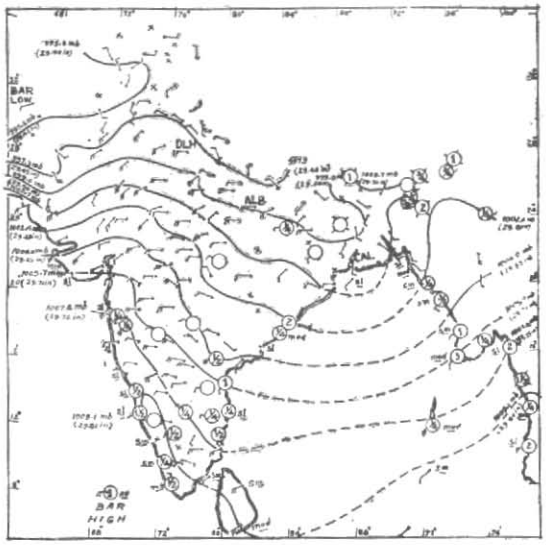

Fig. 8. Weather chart at 0800 IST on 25 July 1941. Upward shift of the axis of the monsoon trough

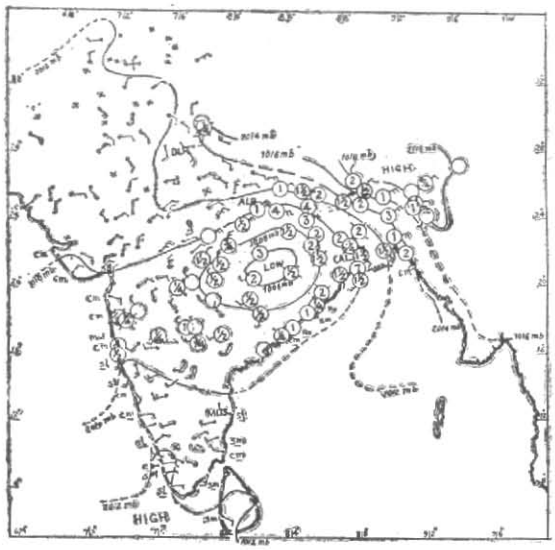

Fig. 9. Weather chart at 0800 IST on 21 October 1945 Depression causing unusually strong gusty winds at Allahabad on 20-21st night

(ii) Strong winds associated with depressions

In this connection, it is mainly necessary to confine attention to the monsoon depressions at peak monsoon period. Only a very few of the cyclonic storms of the post-monsoon period from the Indian Seas approach Allahabad as depressions in the month of October. Their effect on Allahabad winds is more or less similar to that produced by the monsoon depressions. The anticipated winds may be estimated by the usual methods from the pressure gradient in the isobaric chart, from the expected deepening of the depressions and movement of its centre towards the station, and also from the upper winds strength of the station and the neighbouring stations.

As an example of a depression, causing strong winds at Allahabad, the 0800 IST weather chart of 21 October 1945 is reproduced in Fig. 9. A cyclonic storm from the Bay of Bengal crossed the coast near Cocanada on 18 October and recurving through Hyderabad (Dn) lay as a depression over the northeast Central Provinces about 100 miles to the northeast of Raipur at 0800 IST on the 21st. This depression caused abnormally strong gusty winds at Allahabad on the 20-21st night. The winds in gust were 35/40 mph and once rose upto 50 mph in association with a thunderstorm.

(iii) Strong winds associated with duststorms and thunderstorms

(a) Duststorms and thunderstorms in non-monsoon period—The duststorms and thunderstorms in the non-monsoon period are mainly due to the influence of western disturbances or rather mostly their secondaries. These disturbances begin to affect the station from the end of December or beginning of January till the beginning of the monsoon. When the primary or secondary 'Low' is farther west or southwest of the station, the weather effect is observed there. This low has sometimes the appearance of a tongue of low pressure. (Due to the superimposed effect of this low on the Deccan low, the latter may look protruded like a tongue of low pressure). As this low or tongue of low moves eastwards towards Allahabad, the region of weather also moves eastwards and affects the station.

In the hot weather period till the monsoon is established, due to the combined influence of the western disturbances, which help to bring in the moisture over the area, and instability that is created due to strong surface heating at that time, duststorms and thunderstorms with high winds generally result from the western disturbances of that time. In the other non-monsoon months,

these disturbances may cause sometimes only rain and sometimes thunderstorms with or without appreciable winds. In such cases, however, the nature of weather will generally be apparent from what has already happened to the west or southwest of the station and may thus be utilized as the helping guide.

Before an active disturbance overtakes the station, there is significant change in the wind direction of the station. The usual northwesterly winds give place to easterly winds one or two days (sometimes more) before the weather actually occurs. This is a simple and useful symptom in anticipating weather at the station fairly long time ahead. This clue, however, does not work well in the month of May when dry easterlies may be over the station for a number of days without giving rise to dust and thunderstorms.

Line of discontinuity—The position of line of wind discontinuity at the surface or mostly in the upper air is helpful for making a forecast. When the line of discontinuity between the southeasterly or southerly current with the winds from the other direction passes through or near the station, dust and thunderstorm is likely to occur at the station. The upper air charts of the morning of 18 April 1945 (Fig. 10) will show how the lines of the discontinuity at different levels were passing near Allahabad on that day. The discontinuity gave rise to a dust and thunderstorm at Allahabad later on that day.

Near about the month of May, however, the line of wind discontinuity at the surface and in upper air is observed to be present near Allahabad for days together without giving dust or thunderstorm. This is due to the fact that both the easterly and westerly currents at that time are dry on most of such occasions. Whenever there is little moisture added to them, dust and thunderstorms result. Due to strong surface heating, there exists so much instability in the air currents that incursion of moisture from the sea areas upto a height of ·3 or ·4 km is capable of producing dust and thunderstorms at the station at that time.

Triple Point—Sometimes in summer, a triple point is formed near the station by three converging air currents—one from northwesterly direction, one from the southerly direction and another from easterly direction. This marks out a quite favourable situation for the occurrence of dust and thunderstorm at the station. As for example, a triple point, as can be seen from the upper air charts (Fig. 11) was formed near Allahabad on 27 April 1945. This gave rise to a thunderstorm with high winds on the evening of that day.

Tephigram—As the radiosonde ascent at the station is taken only once in the evening and most of the effective dust and thunderstorms also occur at that time, tephigram data of Allahabad had only limited applications.

(*b*) *Dust and thunderstorms of monsoon period*

During the monsoon period, Allahabad is sometimes in the sweep of the Bay current and sometimes of the Arabian Sea current. When the meeting line of the two currents oscillates through Allahabad or establishes itself near it, most of the weather, including thunderstorm, occurs at the station during this time.

There may also be a thunderstorm at the station when the line of the discontinuity is away from the station. Cumuliform clouds may develop at places, due to instability, in the Bay or in the Arabian Sea current away from the line of the discontinuity. These move with the currents, develop further and give thunderstorms at places. To forecast such thunderstorms at the station, it is useful to watch the cloud development and weather to the east of the station, say, Gaya, Banaras, for the thunderstorms originating in the Bay current, and watch similar developments towards the southwest or west of the station for the thunderstorms, originating in the Arabian Sea current.

Thunderstorms during the monsoon are not generally severe, so far as the surface winds are concerned. When the monsoon is feeble or there is a break in the monsoon, the land is exposed to more heating just as in the summer, causing an increase in the

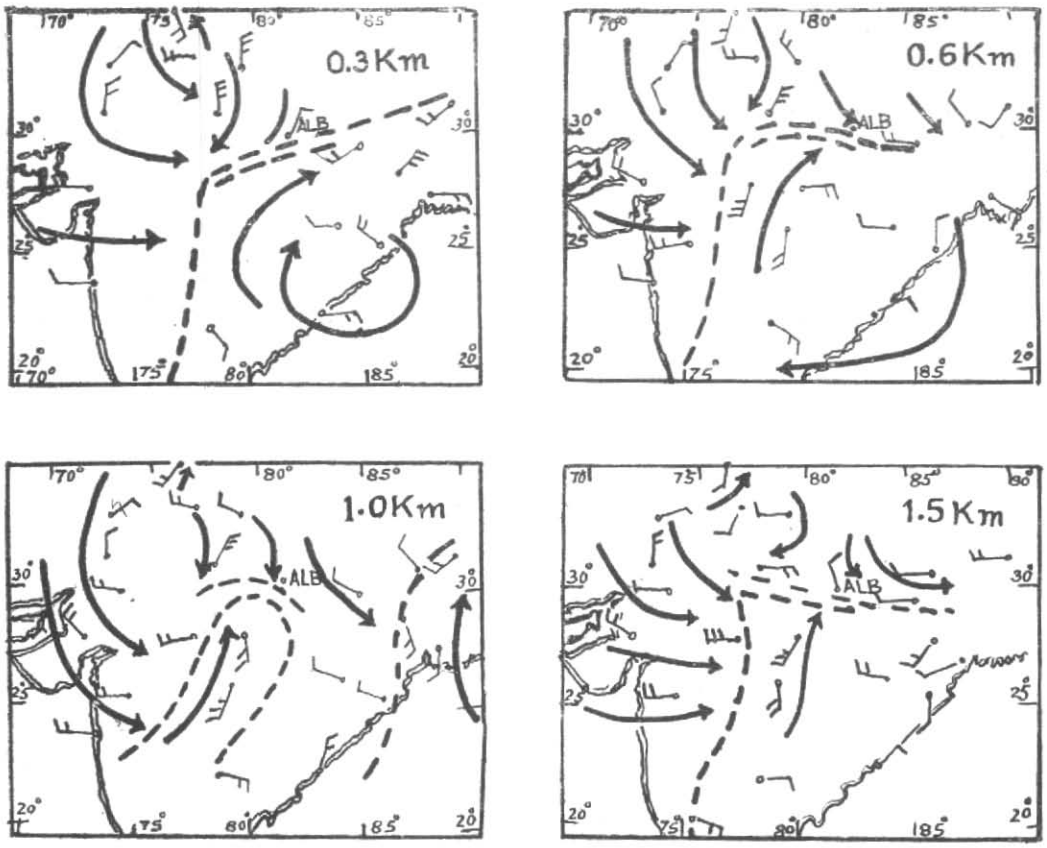

Fig. 10. Upper air discontinuity near Allahabad on 18 April 1945—shown by ═══.

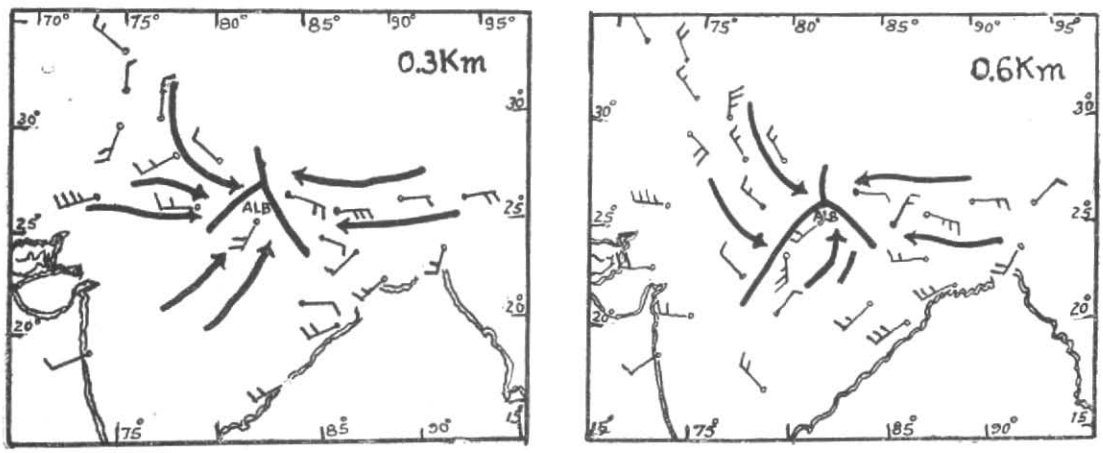

Fig. 11. Three air masses converging near Allahabad on 27 April 1945 (Partitioned by thick lines)

thermal instability. Dust and thunderstorms of severity may then be expected with the fresh incursion of the monsoon.

8. **Some other considerations for short-time warnings of severe dust and thunderstorms of the summer months**

Most of the dust and thunderstorms, as has been stated, occur at this station during the period from end March to June before the monsoon is established. Because of their severity, they invite special attention and short-time warnings also prove very useful.

Most of these storms originate to the west or northwest of the station. When they approach the station from the west, the winds are generally from an easterly direction and the winds pass through other directions to westerly or northwesterly direction as the disturbance moves towards east of the station. The winds from the easterly direction are usually light but may freshen temporarily as the disturbance is quite near the station. Severity of the winds is, however, mostly experienced when the winds change to some northwesterly direction. The effect of these storms on clouding is often so much localised that little or no cloud might be observed till the disturbance is close to the station.

Some points that may be usefully employed for issuing short warnings for these disturbances are indicated in the following paragraphs.

(*i*) *Utilisation of electrical activity of thunderstorm*

In the absence of facilities of radio location of a thunderstorm due to its electrical activities, some use can be made of the lightning effect of the thunderstorm for short-time warnings. The lightning effect of the thunderstorm has, of course, restricted applicability in warnings, as it can only be employed in the case of storms that affect the station in the evening or night. As the thunderstorm approaches the station some time after sunset, it can be detected an hour or so before the storm is over the station. Lightning gives the only visual indication of the coming storm, because the sky over head may be clear. It is, however, to be noted that lightning in any direction does not culminate into a thunderstorm at the station. As the severe thunderstorms of the hot weather period generally come from the west to the northwest direction lightning from that direction can only be reliably taken as the beacon light of the storm that would soon be affecting the station. When the lightning is observed on the eastern side, it can be taken that the thunderstorm has developed on the eastern side and will affect the places east of the station and not the station itself.

(*ii*) *Previous weather at Cawnpore*

The approach of the severe duststorms and thunderstorms of the hot weather period, whether they affect the station after sunset or before it, can often be located earlier from their effect at Cawnpore. It is a common experience at the station that if a deterioration report for a dust and thunderstorm is received from Cawnpore during this period, dust and thunderstorm is likely to occur at Allahabad. These dust and thunderstorms occur at Cawnpore two to three hours before they reach Allahabad. This provides a quite useful criterion for issue of warnings a few hours in advance.

This connection in the occurrence of dust and thunderstorms at Cawnpore and later at Allahabad should, however, be used with some restriction. Those dust and thunderstorms that are recorded at Cawnpore in the afternoon and evening will affect Allahabad and others will not. The reason is perhaps that afternoon or evening dust and thunderstorms have more energy and the afternoon instability conditions prevailing along and near the track are favourable for their survival upto a larger distance. The dust and thunderstorms of the other times, reported from Cawnpore, are mostly the remnants of the disturbances coming from further west; or if they have originated near Cawnpore, they possess less energy. Also instability along and near that track at that time may not be as much as it is in the afternoon or evening and thus conditions are not so favourable for survival of these disturbances to large distance. So they dissipate before they reach Allahabad.

A few examples given in Table 4 will show how the occurrence of such dust and

TABLE 4

Dust and thunderstorm at Cawnpore and subsequent weather at Allahabad on that day

	Dust and thunderstorms at Cawnpore			Weather at Allahabad on that day		
	Date	Phenomena	Time (IST)	Phenomena	Time (IST)	Remarks
Occurring in the afternoon or evening	8-4-43	Thunderstorm	2045	Duststorm followed by thunderstorm	2230	Wind velocity rose upto 49 mph
	12-4-43	Do.	1800	Do.	2005	Wind velocity rose upto 51 mph
	22-4-43	Do.	Afternoon (time not given)	Duststorm	1527	Wind velocity rose upto 50 mph
	29-5-43	Duststorm	1635	Do.	1750	Wind velocity rose upto 44 mph
	25-6-43	Do.	Afternoon	Dust and thunderstorm	1926	Wind velocity rose upto 51 mph
Occurring at other times	9-9-43	Thunderstorm	0530	—	—	No dust or thunderstorm at Allahabad
	23-4-43	Do.	1100	—	—	Do.
	5-5-43	Dust and thunderstorm	0500	—	—	Do.
	9-6-43	Thunderstorm	0130	—	—	Do.

thunderstorms at Cawnpore in the afternoon and evening can be taken as good indication for later occurrence of dust and thunderstorm at Allahabad, whereas those occurring at Cawnpore at other times have little effect at Allahabad.

(iii) Previous Weather at Gwalior

It is observed on a number of occasions that there are preoccurrences of dust and thunderstorms at Gwalior before their occurrence at Allahabad. Because of the location of Gwalior at a greater distance from this station than Cawnpore, the indications at Gwalior give a large interval of time before the dust and thunderstorm occurs at Allahabad. Often the dust and thunderstorm takes six or seven hours to occur at Allahabad after it had occurred at Gwalior.

One or two examples may be added here to show the utility of the observations of dust and thunderstorms at Gwalior for issuing warnings of the same for Allahabad. On 18 April 1945, Gwalior reported thunderstorm with high winds at 1630 IST. Later on, at 2300 IST there was dust and thunderstorm at Allahabad. Similarly a thunderstorm was reported from Gwalior at 1600 IST on 27 April 1945. This was followed by a thunderstorm with high winds at Allahabad at about 1900 IST on that day. To cite an interesting example, the dust and thunderstorm of 5 May 1947 might also be mentioned. Gwalior reported dust and thunderstorm at 1515 IST on that day. Sky over Allahabad was practically cloudless. Sky continued to be so till the evening and sometime thereafter. Then suddenly clouds closed in and dust and thunderstorm followed at the station at about 2100 IST.

9. Conclusion

If the analysis regarding the nature of the winds that may be expected at Allahabad at different times of the year is kept in view and careful watch is maintained on the meteorological situations that produce such winds and also the various appliances including the different local indications are taken note of, it is observed from experience that a good deal of success can be achieved in the issue of warnings for the strong winds at Allahabad.

10. Acknowledgement

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