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Abnormal rise of surface temperature in association with thunderstorm downdrafts

A. K. BANERJEE, K. K. SHARMA and A. B. CHOWDHURY

Regional Meteorological Centre, Nagpur

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ABSTRACT. In association with downdrafts from thunderclouds, an abrupt and abnormal rise in surface temperature of the order of 5 to 6°C was recorded at Nagpur and Visakhapatnam on two different days during summer season and with this abrupt rise, the surface temperature touched once again the day's maximum temperature at these two places recorded earlier in the afternoon. These two cases are described in this paper and a plausible explanation for the abrupt rise in temperature is also presented.

1. Introduction

Downdrafts from a thunderstorm generally produce cooling at the surface on reaching the ground. The extent of cooling, however, varies from case to case depending upon the mass of raindrops evaporated in the downdraft. But, very rarely, warming occurs with downdrafts reaching the ground level. In their extensive study on the dynamics of thunderstorms, Mull and Rao (1950) have cited instances of rise in surface temperature associated with thunderstorms and also reproduced self-recording charts to depict a few typical cases of this category. Similar instances of rise in surface temperature associated with the passage of a few Nor'westers over Dum Dum have also been reported by Padmanabhamurty and Chaudhury (1967). In the present study two cases of abnormal rise of surface temperature (of the order of 5 to 6°C) and corresponding fall of surface humidity of the order of 20 to 40 per cent in association with downdrafts from thunder-clouds have been presented. A plausible explanation for the rise of temperature and fall in humidity has also been offered.

2. Description of the cases

In association with the passage of a thundercloud, an abnormal rise of surface temperature was recorded at 2345 IST on 6 May 1962 at Nagpur and 1755 IST on 27 March 1961 at Visakhapatnam. The changes in other meteorological elements at the time of this warming in the two cases are indicated in Table 1. The traces of the thermographs (dry and wet), hygrographs, anemographs and barographs for the two cases are shown in Figs. 1(a), 1(b), 1(c) and 1(d) respectively. The traces of the self-recording instruments for Case II (*i.e.*, for Visakhapatnam) shown in the above figures are reproduced from those which appeared in this journal (*Indian J. Met. Geophys.*, 1961, **12**, 3, p. 504).

It is interesting to know that in both the cases the dry bulb temperatures shot up rapidly and touched the days' maximum for the places concerned again. At Nagpur, this happened towards midnight. The surface temperature and humidity, however, reverted back approximately to their earlier values rather quickly, being about 10 minutes in the case of Visakhapatnam and about 30 minutes in case of Nagpur when the squally winds nearly subsided. It is important to note that no rain occurred on both the occasions and also no thunder was heard. Of course, 3 to 4 oktas *Cb* were reported with lightning on both the occasions near about the time of the rise of temperature.

3. Synoptic situations

The synoptic situation on 6 May 1962 (for the case of warming at Nagpur, *i.e.*, Case 1) was quite favourable for convective developments in the vicinity of Nagpur. Flow pattern at 850-mb level in the morning for this case is shown in Fig. 2. A discontinuity between dry and relatively moist air lay close to Nagpur on this level.

Radarscope observations indicate that a few *Cb* cells developed 30-40 km away from Nagpur towards west (*see* Fig. 3) at 1630 GMT. At about 1800 GMT, a well marked *Cb* cell was located about 15 km away from Nagpur towards west and Nagpur reported 4 oktas *Cb* with lightning at this hour. This cell later moved away eastwards and degenerated. It is believed that during its movement eastwards, it came very close to Nagpur at 1815 GMT and from downdrafts released from this thunder cloud, Nagpur experienced squally winds from WNW/W'ly direction with a

TABLE 1

Changes in meteorological elements at Nagpur and Visakhapatnam at the time of rise of surface temperature

Station	Date	Time (IST)	Rise in D.B. (°C)	Fall in W.B. (°C)	Fall in R.H. (per cent)	Fall in surface pressure (mb)	Squall: Squall direction	Squall: Peak speed (kmph)	Clouds	Weather
Nagpur	6 May 1962	2345	6·5	0·5	22	0·5	WNW	50	4/8 *Cb*	Lightning, no rain or thunder
Visakha-patnam	27 Mar 1961	1755	5·3	1·8	42	1·0 (approx.)	SSW	72	3/8 *Cb* 4/8 *St*	Do.

D.B. — Dry Bulb W.B. — Wet Bulb R.H. — Relative Humidity

maximum speed of 50 kmph and simultaneously conspicuous rise in surface temperature also.

For the other case, *i.e.*, for Visakhapatnam also, both the upper and lower level conditions were favourable for convective developments (streamlines charts not produced) as in Case I.

4. Probable cause of warming

Before offering an explanation for the rise in surface temperature in the two cases under study, it is necessary to establish that this rise occurred entirely due to a downdraft from a thundercloud. With this objective, other cases of rise in surface temperatures at Nagpur were examined. It was observed that in fair weather on many occasions the surface temperatures at Nagpur rose by 1 to 3° C in association with abrupt and marked changes in direction of surface winds (and sometimes in speed also) particularly after sunset lasting for very brief periods (less than 15 minutes). Since in the present cases, the warming was of considerably higher magnitude (5 to 6°C), it is unlikely that these cases of warming were merely due to changes of surface winds alone. Further, in these cases, the warming was associated with the passage of a *Cb* cell very close to the stations and was accompanied by squally winds of the order of 50 to 70 kmph. Thus, it is quite possible that the rise of surface temperature in the present cases was due only to downdrafts from thunder-clouds.

While discussing the cause of downdraft from dry thunderstorm over USA, Krumm (1954) indicated that these dry thunderstorms developed in air which containsd much less amount of moisture than the normal and that the bases of the thunder-clouds were very high, nearly 3 km (10,000 ft) a.g.l. Nearly moist adiabatic lapse rate was maintained in the downdrafts from these thunderstorms roughly upto 1·5 km (5000 to 6000 ft) below the cloud base and thereafter the downdrafts followed almost a dry adiabatic lapse rate.

The soundings near about the rise of surface temperatures in the two cases are shown in Figs. 4(a) and 4(b). The tephigram shown in Fig. 4(a) is the mean of the two soundings at Nagpur taken at 1200 and 2300 GMT of 6 May 1962. In this tephigram, the dry bulb (29°C) and dew point (17·5°C) temperatures recorded in the 1800 GMT surface observation of Nagpur have been utilised for the surface level. The dry bulb and dew point temperatures in the two soundings (1200 and 2300 GMT) did not differ by more than 3°C at any level from 900 to 500 mb. Thus, the mean sounding shown in Fig. 4(a) can be taken to represent the approximate atmospheric conditions at Nagpur near about the time when the rise of temperature took place. The sounding for Visakhapatnam (Fig. 4b) at 1200 GMT on 27 March 1961 was very near to the time of occurrence of the phenomenon (at 1215 GMT) at that place.

It is seen from the dew point curves in Figs. 4(a) and 4(b) that the moisture present in the air was quite less in both the cases. The condensation level, as calculated from TT and T_dT_d values at 900 mb (representative of the conditions of the surface layers), approximately works out as 730 mb in both the cases and this was roughly near about the reported height of the base of *Cb* cloud in both cases at about the time of warming. As mentioned earlier, there was no rain at the ground at the time of this warming on both occasions and further that the surface pressure did not rise at this time but on the contrary it fell (*see* Fig. 1d). Fujita (1959) has pointed out

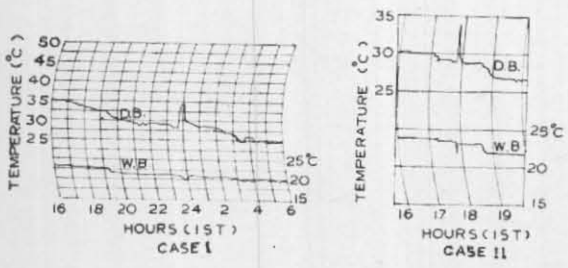

Fig. 1(a). Dry and wet thermograph trace for Case I (Nagpur on 6/7 May 1962) and Case II (Visakhapatnam on 27 March 1961)

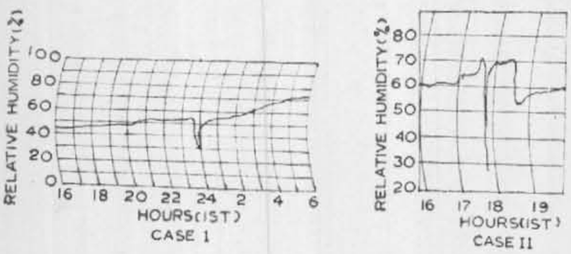

Fig. 1(b). Hygrograph traces for Cases I and II

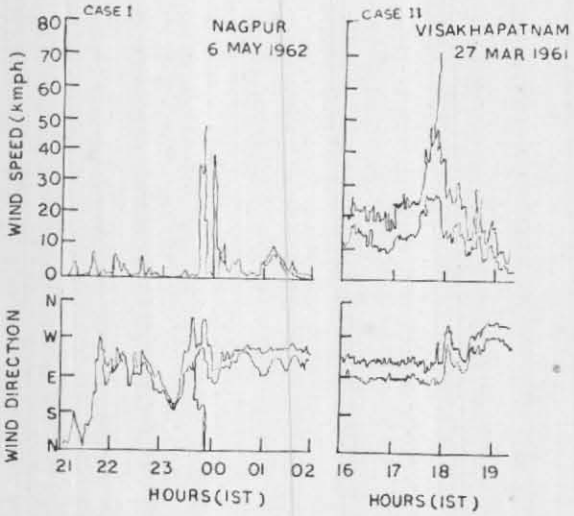

Fig. 1(c). Anemograph traces for Cases I and II

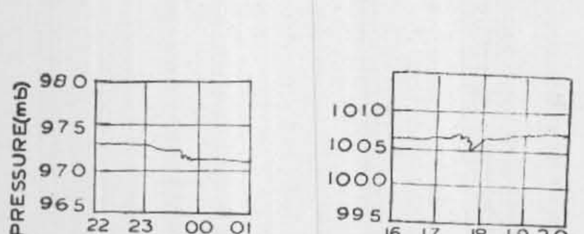

Fig. 1(d). Barograph traces for Cases I and II

that the rise in surface pressures, associated with convective storms, manifesting as pressure domes etc, is dependent upon the mass of raindrops evaporated inside the downdraft beneath the cloud base. In these cases, since there was no rain at the surface in association with the phenomena, the mass of raindrops evaporated in the sub-cloud layer was perhaps very small and hence no rise in pressure was experienced in association with the downdrafts. It is, therefore, reasonable to expect that all the raindrops evaporated when the downdrafts descended to a small distance of about 1 km (about 3000 ft) below the cloud level in these cases. Krumm (*loc. cit.*) assumed that complete evaporation of raindrops in the downdraft took place when it descended through a height of about 1·5 to 2 km (5000 to 6000 ft) below the cloud base in cases of dry thunderstorms over the plateau area in U.S.A. Of course, the downdrafts from these dry thunderstorms produced cooling (but not appreciable) at the ground unlike in present cases when the surface temperature rose considerably. Thus, the assumption in the present cases that all the raindrops evaporated within a distance of only about 1 km below the cloud base, is reasonably justified.

Thus, taking the height of the base of *Cb* cloud at 730 mb in the present cases and assuming that complete evaporation of raindrops in the downdraft was over when it descended through a distance of only 1 km below the base of the cloud, a plausible reason for the rise in surface temperature and fall in humidity in the present cases is suggested below.

Due to evaporation from falling rains cooling occurred in the air just below the cloud base and due to sinking of this cooled air, a downdraft was initiated. The probable path followed by the downdraft from the cloud base up to the ground level is shown in Figs. 4(a) and 4(b) by ABCD. The downdraft followed a moist adiabatic path in the initial stages on being released from the cloud base from the point A. But in later stages when the mass of the raindrops available for evaporation and for keeping up the saturated conditions, became less and less, the path followed by the sinking mass also started deviating from the moist adiabatic path. Under these circumstances, the sinking mass reached the point B (nearly 1 km below the cloud base). At B the saturation conditions nearly ended as there was little raindrops left in the downdraft for evaporation. Consequently, the subsequent path from B to D followed by downdraft was almost dry adiabatic. The net downward acceleration that the sinking mass gathered on reaching the point C was sufficient

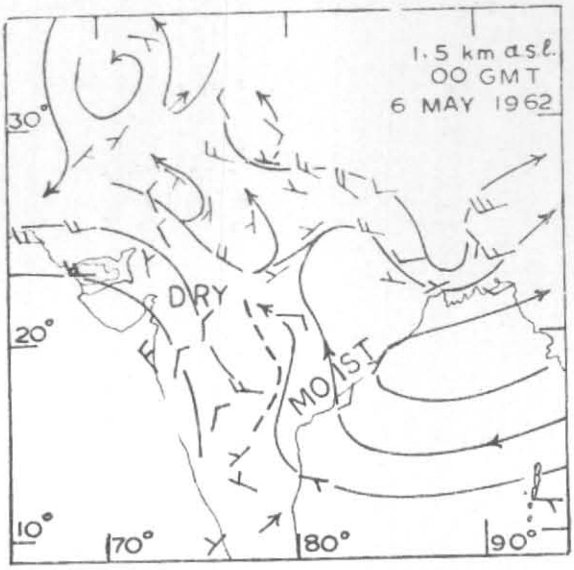

Fig. 2. Flow pattern at 1·5 km a.s.l. on 6 May 1962 at 00 GMT

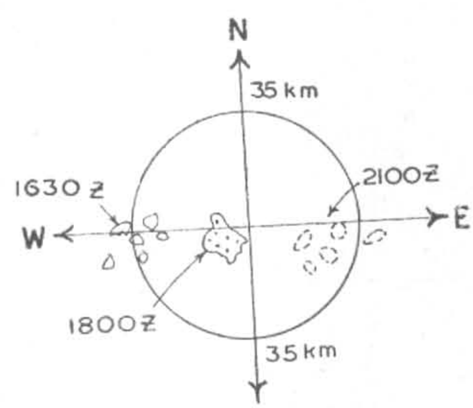

Fig. 3. Chief radar echoes around Nagpur at 1630, 1800 and 2100 GMT on 6 May 1962

to overcome the upward retarding buoyancy forces that it experienced during its subsequent motion from the point C up to the ground level. This is also borne out by the fact that the area ABCQ in Figs. 4(a) and 4(b) is greater than the area PCD. Consequently this sinking mass emerged out as a warm downdraft at the ground breaking through the ground inversion which was at the formative stage at that time in both the cases (Figs. 4a and 4b). Although there was maximum cooling in this sinking mass near B but due to the absence of evaporation, cooling in later stages, it emerged out as a warm mass of air at the ground and assumed a higher surface temperature for sometime represented by the point D in Figs. 4(a) and 4(b). That the downdraft was very dry when it reached the ground level, is also evident from the fact that nearly 90 to 95 per cent of the fall in relative humidity at ground level could be accounted for by the rise of surface temperature alone in both the cases.

To account for the extent of fall in relative humidity in the two cases, the property of θ_w (wet bulb potential temperature) that it remains

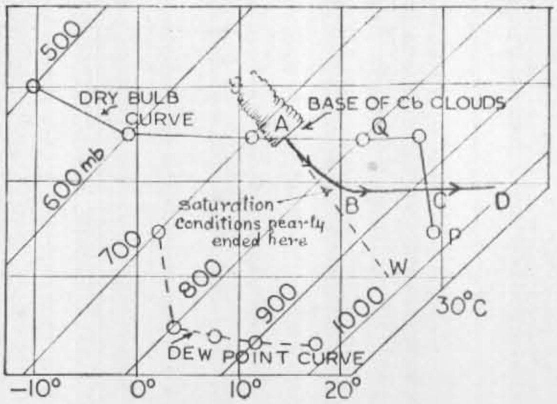

Fig. 4 (a). Approximate sounding at 1800 GMT for Case I (average of 1200 and 2300 GMT soundings of Nagpur on 6 May 1962)

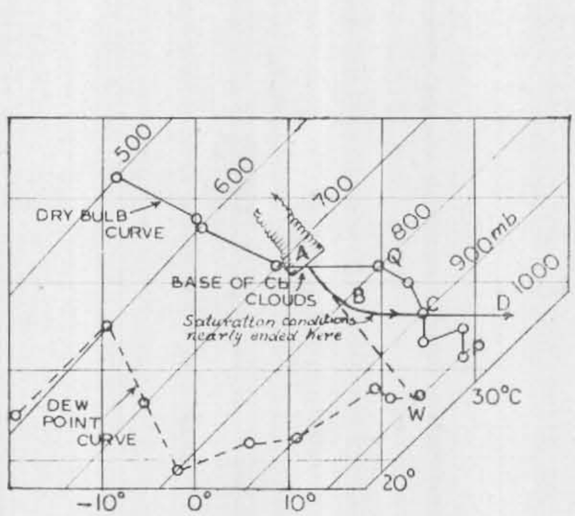

Fig. 4 (b). Sounding at 1200 GMT for Case II (1200 GMT sounding of Visakhapatnam on 27 March 1961)

conservative with respect to evaporation from falling rain has been utilised. During its saturation stage, the dry and wet bulb temperatures in the sinking mass were nearly the same. Taking the dry bulb temperature near the cloud base *i.e.*, at the point A, as also the wet bulb temperature of the sinking mass, θ_w for the sinking mass works out approximately as 24°C (corresponding to the point W in Figs. 4a and 4b) for Case I and 23°C for Case II. So when the sinking mass reached the ground level, its dry and wet bulb temperatures were 35° and 24°C respectively in Case I and 34° and 23°C respectively in Case II. The corresponding relative humidity values in the sinking mass at the ground level as calculated from the above values of dry and wet bulb temperatures, would be nearly 36 per cent in both cases. But in Case I, the prevailing relative humidity just before the rise in temperature was 52 per cent and in Case II 70 per cent (*see* Fig. 1b). Thus the expected fall in relative humidity would be theoretically 16 per cent in Case I and 34 per cent in Case II. The recorded fall in relative humidity was nearly 22 per cent in Case I and 42 per cent in Case II and these were more or less of the same order as the theoretical values. Thus although, the sinking mass had nealry the same value of relative humidity (about 36 per cent) when it reached the ground level in both the cases the fall in Case II was nearly double of that in Case I because of the difference in the actual relative humidity values that prevailed prior to the occurrence of the phenomenal rise of surface temperature in the two cases.

Thus, with the assumption that (*i*) the base of the *Cb* cloud was very high (at about 730 mb) and (*ii*) all the raindrops in the downdraft evaporated with its descent from the cloud base to a distance of only 1 km, both the abnormal rise in surface temperature and fall in relative humidity in both the cases under study can be explained with a fair degree of satisfaction. Since the trace of the wet element in the thermograph is not reliable, no attempt has been made here to account for the slight fall in wet bulb temperature in the two cases. Instead, an attempt has been made above to account for the fall in relative humidity in the two cases as the hair hygrograph is known to be a very sensitive instrument. It is worthwhile to note that fairly high dry bulb temperatures that existed in the two cases from 900 mb upto the *Cb* cloud base, helped the sinking mass to gather sufficient acceleration to overcome the retarding upward buoyancy forces and to reach the ground as a warm downdraft.

5. Conclusion

From the above study, it appears that downdraft from thunder-cloud can reach the ground level in the form of warm gusty winds under favourable conditions when the cloud base is high enough and the moisture present in the atmosphere is comparatively less.

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