Indian J. Met. Geophys. (1974), 25, 2, 223-227

551.510.534 : 551.513.2 (547.1)

Ozone concentration studies near the ground at Poona Part II : Short term fluctuations

C. R. SREEDHARAN and V. S. TIWARI

Meteorological Office, Poona

(*Received 20 September 1972*)

ABSTRACT. The paper discusses short term fluctuations, superimposed on the diurnal variation of surface ozone recorded at Poona during 1969-1970, in association with thunderstorms and the breakdown of temperature inversions near the ground.

While there is a net production of ozone during electrical discharges in a thundercloud, the surface ozone recorder at Poona often registered a decrease in surface ozone concentration. This decrease coincided with updrafts generated during the formation and movement of a thunderstorm. Similar sharp increases in ozone were observed with downdrafts. In cases of lightning without the appearance of thunderstorm over the station, an increase in ozone density was observed immediately after the first lightning discharge.

Apart from the fluctuations associated with thunderstorms in summer, sharp fluctuations in ozone density were also noticed during certain winter mornings. Rapid falls in ozone occur with the formation of a stable layer near the ground at night and sudden upward surge with the breakdown of the inversion layer in the morning. The changes in ozone are, however, much more pronounced than those in temperature and wind and this striking correlation between surface ozone, surface air temperature and wind shows that ozone provides a unique tool for the study of low level temperature inversions, their establishment and destruction.

1. Introduction

The distribution of ozone in the free troposphere in the tropics is fairly uniform with height due to the presence of strong horizontal winds and vertical mixing, and the troposphere serves as a well mixed secondary reservoir for ground ozone (Junge 1962). Near the ground, ozone is destroyed due to direct contact with organic material and aerosols. When there is strong turbulence, there is a high equilibrium density of ozone near the surface, because the ozone destroyed at the ground is rapidly replenished from above. When the regime of thermal turbulence changes to one of stable stratifications, only a small concentrations of ozone is found at the surface as the replenishment becomes weak. Apart from the regular variations of ozone near the earth's surface (Tiwari and Sreedharan 1973) short period fluctuations superimposed on the regular variations were noticed in the records of surface ozone density at Poona. These sudden changes are associated with thunderstorms and the formation and breakdown of temperature inversions. These are discussed in the present paper.

2. Method of measurement

The Brewer electrochemical bubbler sensor (Sreedharan and Tiwari 1971) was used for the continuous recording of surface ozone concentration. Measurements were made with the sensor exposed at 0, 15 and 35 m above ground and records were made on an electrical chart recorder. Temperature and wind speed and direction at the levels of the sensors were also recorded simultaneously.

3. Ozone changes associated with thunderstorms

Continuous records of surface ozone were made from October 1969 to September 1970, during which ozone changes associated with fourteen thunderstorms were recorded and analysed. Thunderstorms mostly occur at Poona in the premonsoon hot season (April, May and June) and the post monsoon season (September, October and November) and these are triggered by local heating and generally occur in the afternoons.

During all the four thunderstorms studied during the post monsoon season decreases in ozone amount were observed, associated with updrafts, followed by rapid increases during downdrafts. Fig. 1 shows the records on 13 November 1969, when a thunderstorm passed over the station. The records showed (*a*) a decrease in ozone concentration, from 40 to 2 μ gm^{-3} at 1730 hr, before the commencement of the downdraft, with

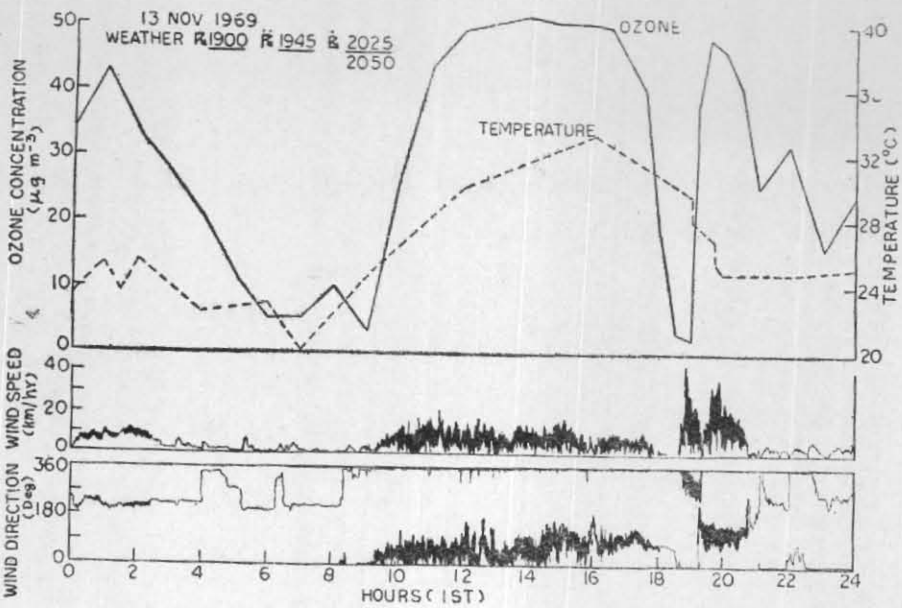

Fig. 1

Ozone, temperature and wind changes associated with thunderstorms

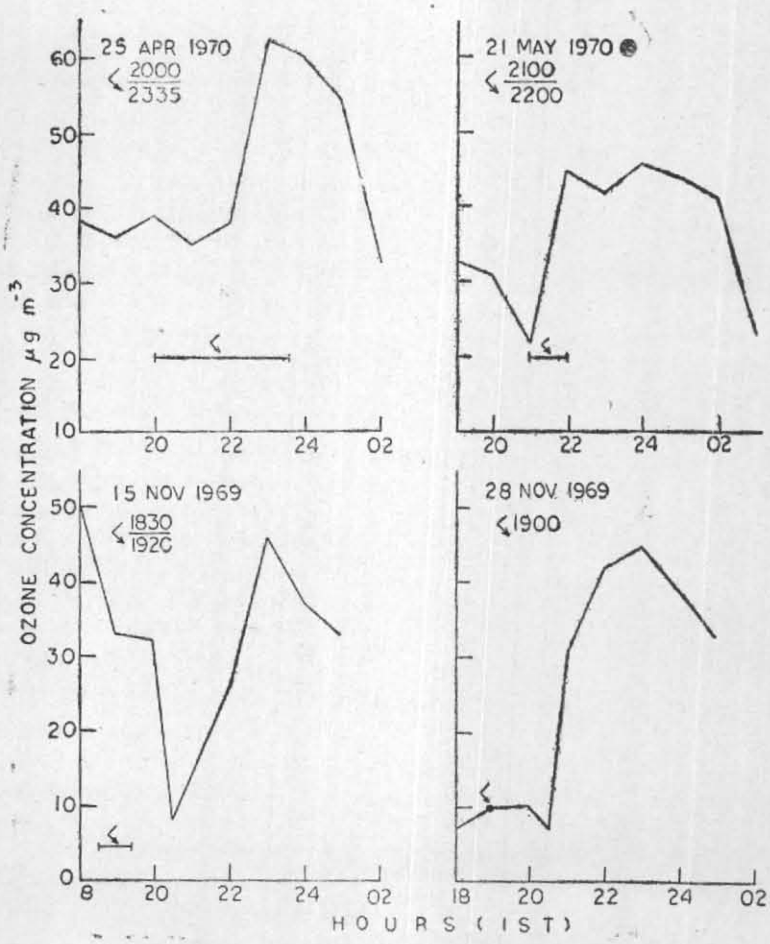

Fig. 2

Ozone increase due to lightning

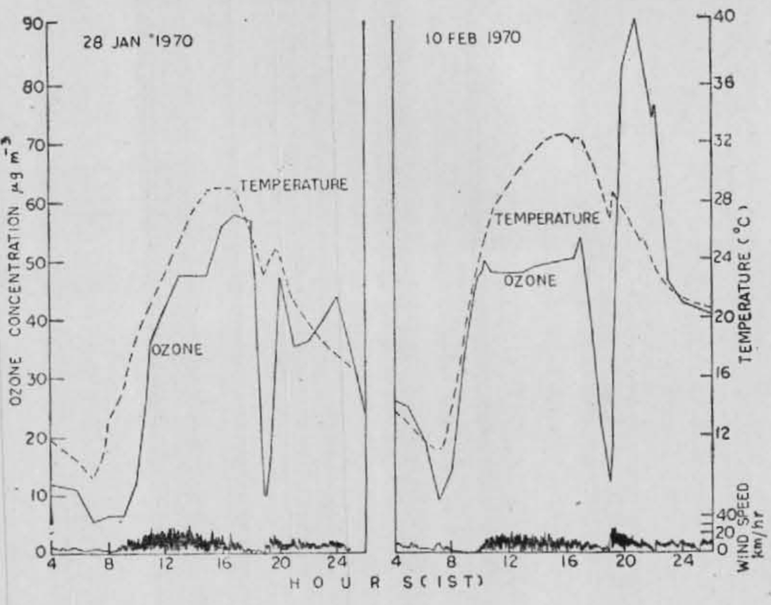

Fig. 3

Sharp ozone changes associated with subsidence during winter

a simultaneous decrease in wind speed from 6 km ph to zero, (*b*) a sharp rise in ozone at about 1900 hr from 2 to 39 μ gm^{-3} in 10 minutes, with the commencement of the downdraft and a simultaneous fall of temperature by 4°C and (*c*) a return to normalcy after 3 hours.

Ozone increases were recorded before the occurrence of thunder during eight of the pre-monsoon season thunderstorms studied and a decrease during three. But in all these cases the observed variations of ozone, temperature and wind can be explained, if the location of the ozone sensor with respect to the updraft and downdraft regions of thunderstorm are taken into account.

Dobson (1949) and Vassy (1965, 1969) have reported that ozone is produced during electrical discharges in a thundercloud. Measurements made by Dobson *et al.* indicated a two-fold increase in ozone concentration in a thunderstorm. Vassy reported from a statistical survey that the ozone amount increases by about three to ten times its clear air value during a thunderstorm. Surface ozone records at Poona were examined to see if these earlier observations hold good over Poona. Thunderstorms with and without lightning were analysed separately. In cases of lightning without the appearance of a storm overhead, an increase in ozone concentration was invariably noticed preceding the first lightning discharge (Fig. 2) which supports the views of Dobson and Vassy.

4. Ozone fluctuations on cold clear nights

Two cases of sudden ozone concentration increase during clear winter nights with definite changes in temperature and wind, are shown in Fig. 3. The surface ozone concentration and temperature decrease simultaneously and then a sudden increase occurs in both. In contrast to thunderstorms which occur on hot afternoons, the change in temperature is in the same sense as the ozone change. A reasonable explanation appears to be that the sharp radiational cooling after sunset causes a steep decrease of temperature near the ground and the formation of a stable layer near the ground results in a decrease in ozone. Katabatic winds flowing down the sides of the bowl in which Poona lies, bring down air from above and a sudden rise in temperature and ozone is observed. Rapid cooling and ozone decrease are accompanied by a decrease in wind speed and the increase by a sudden gust.

During the monsoon season also, a few cases of large increases in ozone density with a corresponding change in the temperature profile were observed. These were recorded by both ozone sensors 15 m and 35 m above ground. An example of this is shown in Fig. 4.

A close examination of the ground ozone, temperature and wind records show that ozone fluctuations occur even without changes either in temperature or wind and the converse is also often true.

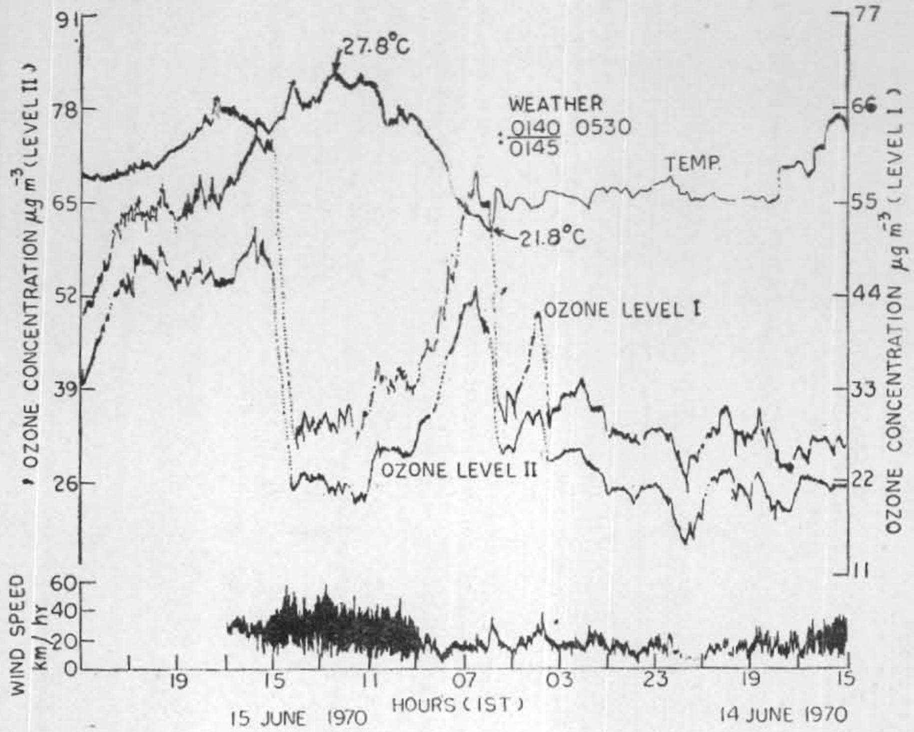

Fig. 4

Rapid ozone fluctuations during monsoon season

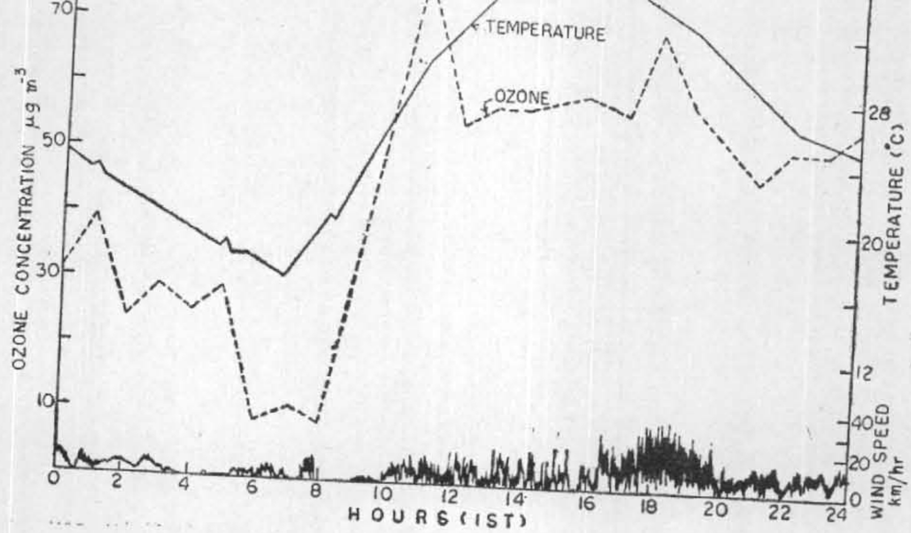

Fig. 5

Ozone and temperature variation on 16 March 1970

Since ozone changes are far more pronounced than corresponding temperature changes during the ascent or descent of air, it would appear that ozone is a better indicator of turbulence or vertical transport than wind or temperature.

5. Ozone changes associated with temperature inversions

Kroening and Ney (1962) and Galbally (1968) measured the ozone concentration near the ground at night across a temperature inversion layer using tethered balloons and found that, with the formation of a temperature inversion, the ozone concentration below the inversion level shows a sharp decrease, while above the inversion, the ozone concentration increased slowly and remained constant. Next morning, with the breaking up of the inversion, a sudden increase in ozone concentration below the inversion level and a decrease above were noticed.

During winter, temperature inversions often occur near the ground over Poona. Associated sharp increases in the surface ozone were observed as a result of the breaking up of these thermally stratified layers near the ground. An example is shown in Fig. 5, where records of surface ozone, temperature and wind speed for 16 March 1970 are reproduced.

The surface ozone reaches a minimum between 0600 and 0800 hr, while the temperature attains a minimum at 0645 hr and begins to increase afterwards. At 0800 hr the temperature shows a sharp fall and the ozone a sudden increase. The sudden cooling and the sharp increase in ozone is due to the breaking up of the inversion level, thereby bringing down cold ozone rich air from above. At times two discontinuities were observed in the temperature curve with associated increases in ozone. This obviously arises from the breaking up of a double inversion layer. On other occasions sudden increases in ozone were recorded without any corresponding temperature fall indicating the break up of a thermally stable layer without a temperature inversion.

6. Conclusions

Continuous records of surface ozone temperature and wind made at Poona have shown the distinct possibility of using ozone as a tracer for the detection of vertical air currents, particularly up and down drafts associated with thunderstorms. A preliminary analysis of the ozone changes associated with thunderstorms suggests the production of ozone in thunder clouds even before the lightning discharge starts. Evidence has also come to light of vertical currents associated with sudden radiational cooling. In general ozone promises to be a better indicator of turbulence and of vertical transport than wind or temperature.

REFERENCES

Dobson, G. M. B., Brewer, A. W. and Gwilong, B. N.	1956	*Proc. Roy. Soc.*, **A 185$_1$** pp. 144-175.
Galbally, I.	1968	*Nature*, **218**, pp. 456-457.
Jung, C. E.	1962	*Tellus*, **14**, pp. 363-377.
Kroening, J. L. and Ney, E. P.	1962	*J. Geophys. Res.*, **67**, pp. 1867-1875.
Sreedharan, C. R. and Tiwari, V. S.	1971	*J. Phys., E. Sci. Inst.*, **4**, pp. 995-997.
Tiwari, V. S. and Sreedharan, C. R.	1973	*Indian J. Met. Geophys.*, **24**, pp. 353-362.
Vassy, A.	1965	*Atmospheric Ozone*, Adv. Geophys., **11**, Acad. Press, pp. 116-118.
	1969	*Ann. de. Geophys.*, **25**, pp. 153-155.