Sonoma Technology, Inc.

5510 Skylane Blvd., Suite 101
Santa Rosa, CA 95403-1030
707 / 527-9372
Fax 707 / 527- 9398

MEMORANDUM

STI Ref. No. 90213

TO: Paul Roberts/STI
Mike Koerber/LADCO
Steve Hanna/Sigma
Walt Lyons/ASTER
Ralph Morris/SAI
Shao-Hang Chu/EPA

FROM: Tim Dye TSD

DATE: February 26, 1993

SUBJECT: Determination of aloft background ozone concentrations at high altitudes from aircraft and ozonesonde data for the LMOS episodes 1 and 2

The ROM model has predicted aloft background ozone concentrations above about 1900 m msl to be 40-50 ppb, which is substantially lower than ozone concentrations measured by the aircraft instruments and by the ozonesondes. This memo summarizes the range of ozone concentrations measured above 1700 m msl during the June 25-28 and July 16-18, 1991 episodes. In addition, we reviewed aircraft data collected during the 1990 LMOS and during the Sulfate Regional Experiment (SURE) to establish whether or not the background ozone concentrations measured at high altitudes during the 1991 episodes were consistent with previous studies. All altitudes in this memorandum are reported as msl and can be converted to agl by subtracting about 200 m.

One problem that we encountered was that during both the 1990 and the 1991 LMOS, the aircraft did not fly high enough to reach clean background ozone concentrations, typically expected to be about 40 ppb. The highest spirals were made by the boundary aircraft up to 1800 m msl. At that altitude, the aircraft were typically above the synoptic subsidence inversion, but may not have always been in the air associated with clean background ozone concentrations.

We used the aircraft data collected in the upper portions of each spiral and the ozonesonde data to estimate the background ozone concentrations at high altitudes for the June 25-28 and July 16-18 episodes. During these episodes, the ozone concentrations above 1700 m msl were between 50 and 80 ppb. This range is consistent with aloft ozone concentrations measured during previous studies (e.g., 40 to 90 ppb above 1700 m msl). Results from the reviews of the individual data sets are presented below.

1991 LMOS Aircraft Data

Ozone concentrations above 1700 m msl were measured during spirals by only three aircraft: NAWC boundary, NAWC Chicago box, and Wisconsin DNR. These aircraft typically spiraled to altitudes above the synoptic subsidence inversion. Two typical examples, see Figures 1 and 2, show that the ozone concentrations decrease from 90 ppb in the mixed layer to about 70 ppb above the synoptic inversion. We are interpreting these lower concentrations above the synoptic inversion as the background concentration of ozone. In general, ozone concentrations above the synoptic inversion ranged from 50 to 80 ppb.

LMOS Ozonesonde Data

Ozonesondes were launched from the mid-lake boat during the June 25-28 and July 16-18 episodes. The ozonesondes measured ozone concentrations from the surface to about 4000 m msl (the exact altitude coverage varied from launch to launch). During the data validation process, we discovered that the ozonesonde measurements were consistently lower than measurements from other instruments. These comparisons showed that the concentrations measured by the ozonesonde had a bias of 24 ppb when compared to surface and aloft measurements made by other instruments. To remove the bias, the ozonesonde data were increased by 24 ppb.

The bias was determined from 15 data pairs, most of which had concentrations greater than 70 ppb. Thus, no comparisons were available at concentrations less than 70 ppb. When we corrected the ozonesonde data for the bias, we assumed that the bias existed for all concentrations and therefore we have increased all concentrations by 24 ppb. The results from the audit of the ozonesonde system suggested that the bias did not exist at lower concentrations (i.e., less than 70 ppb). At concentrations below 70 ppb, the ozonesonde was only several ppb lower than the reference instrument. When the ozonesonde was subjected to air with an ozone concentration of 180 ppb, its measurement was 17 ppb lower than the reference instrument, which suggests that the bias probably existed only at higher concentrations.

We examined the average ozone concentrations above 2500 m msl with and without the correction for the bias. Table 1 summarizes the aloft ozone concentrations. If we assume that the bias in the ozonesonde data does not exist at lower concentrations, then the background ozone concentration still ranged from 50 to 65 ppb. However if the correction for the bias was appropriate at lower concentrations then aloft background concentrations ranged from about 75 to 90 ppb. In either case, the ozone concentrations are still higher than those predicted by ROM.

Aircraft Data from the 1990 LMOS and the Sulfate Regional Experiment

We reviewed two other aloft data sets to determine whether or not the higher concentrations measured during the 1991 episodes were consistent with

previous studies. During the 1990 LMOS, the Wisconsin DNR aircraft measured ozone concentrations from near surface to 1650 m msl. The average ozone concentration at 1650 m msl was 65 ppb. Individual concentrations measured at the highest altitude of each spiral ranged from 40 to 90 ppb. This observation is consistent with the aloft ozone concentrations measured during the 1991 LMOS.

In the summer of 1977 and 1978, two instrumented aircraft were flown in the Ohio River Valley as part of the Sulfate Regional Experiment (SURE). Ozone and other pollutants were measured during spirals made between near surface and 3000 m msl. The aircraft data summaries (Blumenthal et al., 1981 and Keifer et al., 1981) showed that ozone concentrations above 2000 m msl varied from 40 ppb to as high as 90 ppb. This study confirms that aloft ozone concentrations can be significantly higher than 40 ppb, as were observed during the 1991 LMOS.

Conclusions

Our review of the ozone concentrations measured at high altitudes indicated that:

- Aloft ozone concentrations above 1600 m msl varied from 40 to 90 ppb.
- Ozone concentrations measured above the synoptic subsidence inversion during the June and July 1991 episodes were high, but were consistent with measurements made during previous studies.
- ROM underpredicts background ozone concentrations above about 1900 m msl by at least 10 to 30 ppb when compared to aircraft and ozonesonde data.
- The variation in background ozone concentrations at high altitudes may largely depend upon where the air originated and the transport time. Transport from the Mississippi River Valley will likely have higher ozone concentrations than transport from the Midwest (e.g., Nebraska, Kansas). In addition, convective mixing in the upwind regions may distribute ozone over a deep layer (surface to 3000 m), which is then transported into the LMOS region.

Table 1. Altitudes of the Synoptic Inversion and Largest Gradient of Ozone Concentrations for Each Day During Episodes 1 and 2. The synoptic inversion was determined using the rawinsonde data from the Zion 2-mile, Mid-lake Boat, and Rockford sites. The altitude ranges displayed correspond to the variation of the base of the synoptic inversion throughout the day. The altitude ranges of the ozone gradient represent the variation of the midpoint in the vertical gradient. Ozonesonde data are shown for the approximate ozone concentrations below and above the gradient. The lowest ozone concentrations between 2000 and 4000 m msl are listed with and without the 24 ppb bias.

Day	Inversion Altitude (m msl)	Altitude of Ozone Gradient (m msl)	Ozone Concentration[c] Below Gradient (ppb)	Ozone Concentration[c] Above Gradient (ppb)	Lowest Ozone Concentration between 2000-4000 m msl Corrected (ppb)	Lowest Ozone Concentration between 2000-4000 m msl Uncorrected (ppb)
6/25/91	2400 - 2600	2000 - 2500	100	80	85	60
6/26/91	1700 - 1900	No Ozonesonde data	-	-	-	-
6/27/91	1600 - 1900	900 - 1250	120	80	85	60
6/28/91	1700 - 2100	1000 - 1500	120	95	90	65
7/16/91	1500 - 1900	1700 - 1900	130	80	75	50
7/17/91[a]	800 - 1400	800 - 1100	130	90	85	60
7/18/91	1500 - 1600[b]	500 - 1200	140	80	85	60

a. Synoptic inversion was weak and often non-existent due to strong convective mixing from a thunderstorm.

b. Temperature lapse rates were subadiabatic (stable) for most of the day. The synoptic inversion, when present, was weak (1-2°C).

c. Ozone concentrations were corrected for the 24 ppb bias.

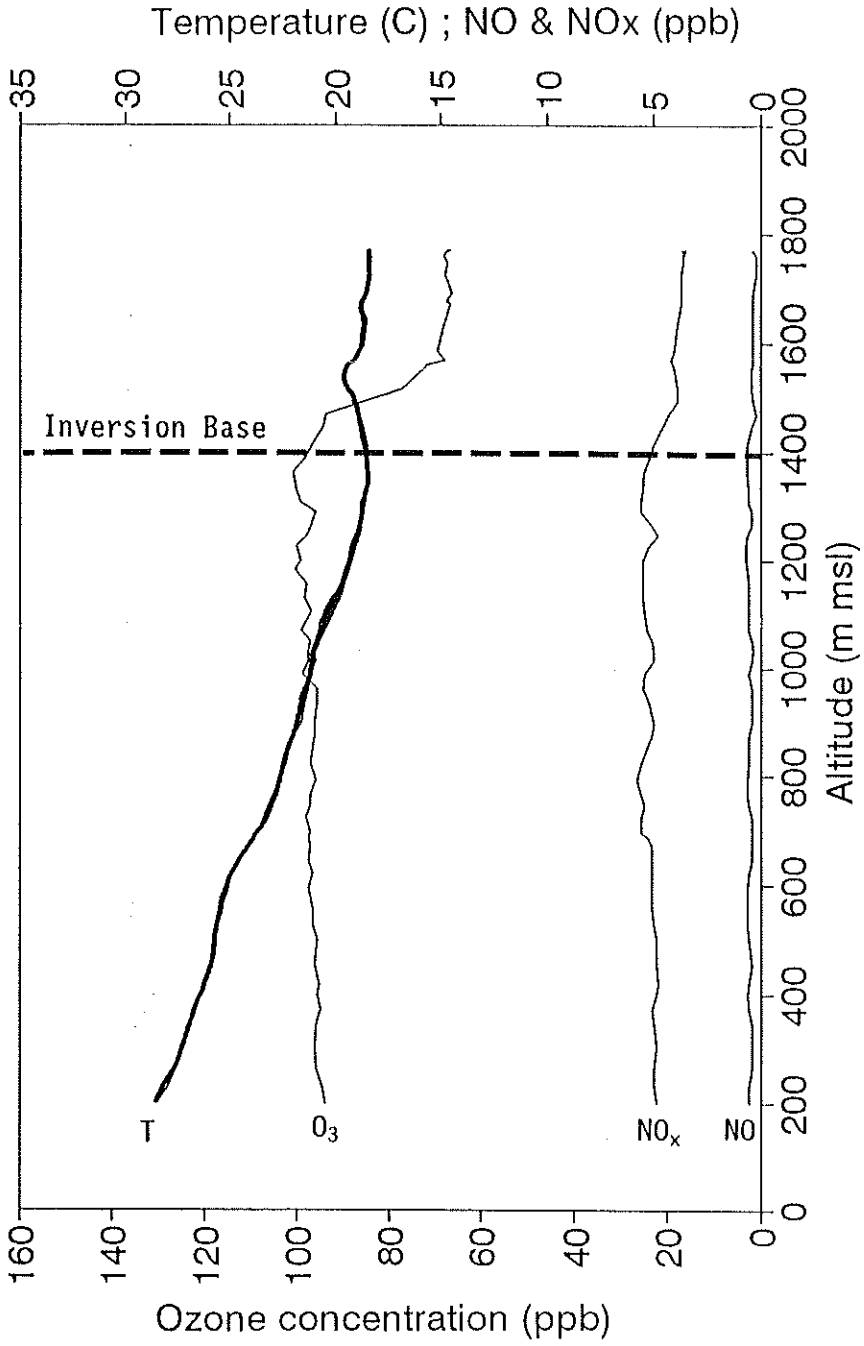

Figure 1. Profile of temperature, O_3, NO, and NO_x data collected by the Boundary Aircraft at 1700 CDT during the spiral over the Beloit Airport on July 16, 1991.

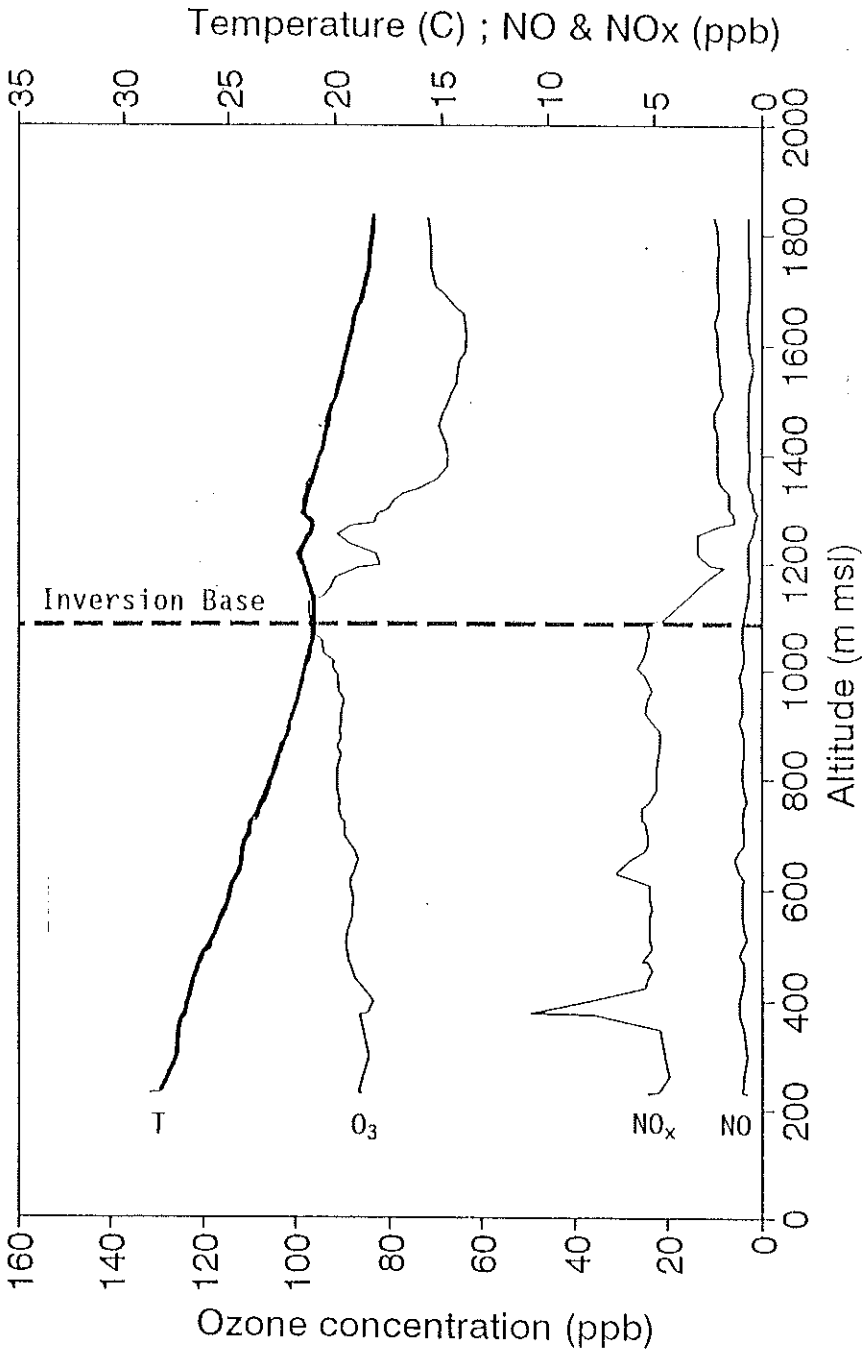

Figure 2. Profile of temperature, O_3, NO, and NO_x data collected by the Boundary Aircraft at 1200 CDT during the spiral over the Streator Airport on July 18, 1991.