

5. CASE STUDY: DECEMBER 10-11, 1987

NO₂ concentrations on December 10-11, 1987 were higher than during any other SCAQS episode; PM₁₀ concentrations were also high. This episode has been widely studied. This section is similar to Sections 3 and 4 beginning with a description of the meteorology during the December 10-11 episode and continuing with a description of pollutant concentrations at both surface monitoring sites and aloft; including spatial and temporal concentration patterns, vertical profiles of pollutants aloft, and comparisons of pollutant concentrations at the surface and aloft.

5.1 EPISODE METEOROLOGY

The meteorology during the SCAQS has been well-described elsewhere (e.g. Surface winds - Zeldin et al., 1989; Aloft winds - Douglas et al., 1991 and SCAQMD, 1990). The following paragraphs summarize the meteorology during the December 10-11, 1987 episode.

5.1.1 Synoptic Meteorology

The December 10-11 episode was characteristic of the cool season transition from a non-marine air mass to a moist marine layer during weak offshore flow. Offshore pressure gradients produced light winds and weak sea breezes, creating excellent conditions for the build-up of NO₂ and PM₁₀, primarily in the western half of the basin. On December 11, increasing northerly winds in the eastern basin pushed the pollution front westward.

On December 10, a band of high pressure extended from central California eastward across Nevada. A weak surface front was moving into northern California. Surface low pressure off the coast of San Diego helped to produce moderate offshore pressure gradients over southern California. For December 11, surface high pressure was increasing rapidly over northern California, creating a strong pressure gradient field from the southern California coast northward. This caused weak Santa Ana (easterly) winds to develop later in the day in the eastern basin.

5.1.2 Summary of Daily Meteorology

Figures 5-1 and 5-2 show surface streamline analyses prepared by Zeldin et al. (1989) for December 10 and 11, 1987 at 0600, 1100, and 1600 PST. The morning streamlines were similar on both days, while midday and afternoon streamlines showed some differences. The surface winds are described in the following paragraphs.

December 10. In the morning, surface winds were offshore with northerly offshore flow over Orange County. Weak north-easterly flow was apparent over much of the basin between 100 and 600 m agl. Overlying flow at 1000 m agl was northerly. At 1100 PST, north-east flow occurred from the San Gabriel Valley, across eastern Los Angeles County and northern Orange County toward Long Beach. Onshore coastal flow was observed only in southern Orange County. Winds aloft remained northerly. In the afternoon, a typical sea breeze

pattern was evident, but with a convergence zone in the central San Fernando Valley.

December 11. In the morning, surface winds were offshore and similar to the previous day, although offshore flow over Orange County was easterly. Winds aloft were north-westerly. At 1100 PST, a sea breeze flow was more evident than the previous day with south-south-westerly flow across Orange County, and south-westerly flow across western and central Los Angeles County. North-easterly winds were still occurring in the San Bernardino area. Aloft winds continued to be primarily northerly. In the afternoon, north-easterly flow was more evident in the eastern basin which helped to counteract the sea breeze. Northerly flow occurred over much of the San Fernando Valley. South-south-easterly flow continued over Orange County, and westerly flow dominated the central Los Angeles area. A convergence zone was observed in the eastern basin.

5.1.3 Mixing Heights

Figures 5-3 and 5-4 show the mixing heights as determined from surface-based soundings and aircraft spirals for December 10-11 by T.B. Smith (T.B. Smith and Associates). At all sites except Loyola Marymount/Hawthorne, the mixing height was significantly higher during the midday than at other times. Maximum mixing heights reached about 800 m msl at Burbank and Ontario, 600 m msl at El Monte, and 400 m msl at Long Beach and Fullerton. The mixing heights determined from aircraft spirals matched the nearby surface-based meteorological soundings reasonably well.

5.2 DIURNAL POLLUTANT PROFILES AT THE SURFACE

5.2.1 Ozone, NO, and NO₂

On December 10, SoCAB maximum NO₂ concentrations occurred at Anaheim, Long Beach, and La Habra (19 to 21 pphm). On December 11, maximum NO₂ concentrations occurred at Anaheim, Burbank, and Pico Rivera (22-23 pphm).

Figures 5-5 and 5-6 show the diurnal profiles of ozone at the six fall SCAQS surface B-sites. Ozone concentrations at Burbank and Anaheim were the highest, while ozone concentrations at Hawthorne were the lowest. Peak concentrations only exceeded 4 pphm at Burbank. At night, ozone concentrations dropped to zero at all sites.

The diurnal profiles of NO and NO₂ are shown in Figures 5-7 and 5-8 for the same sites. NO concentrations typically peaked in the early morning when traffic emissions were high and mixing heights were low. NO concentrations remained high overnight at all locations. The highest NO concentrations were observed at Hawthorne, Long Beach and Los Angeles. NO₂ concentrations were typically highest during the day, but exhibited a much weaker diurnal profile than NO. NO₂ concentrations were lowest at Rubidoux and relatively similar at the other sites.

5.2.2 Particulate and Gaseous Species

Figures 5-9 to 5-21 show the diurnal profiles of the gaseous and particulate pollutants measured at the six surface sites during the December episode. The plots show PM_{10} and $PM_{2.5}$ mass and species concentrations for the most abundant $PM_{2.5}$ species; and for formic, acetic, and nitric acids. One-hour averages for PAN and NMOC are also provided. Observations from these figures include the following:

- PAN concentrations (Figures 5-9, 5-10) peaked midday at the western basin sites and in the afternoon at the central and eastern basin sites. PAN concentration profiles were broader than the ozone profiles, but the two pollutants peaked at about the same time. The highest PAN concentrations were measured at Burbank, with 11 and 14 ppb on December 10 and 11, respectively.
- PM_{10} and $PM_{2.5}$ mass (Figures 5-11, 5-12) concentrations were much higher and exhibited less diurnal variation during the fall than during the summer. Peak concentrations occurred in the afternoon and at night at most sites. PM_{10} and $PM_{2.5}$ mass concentrations were highest at Anaheim and Rubidoux on December 10, and Burbank and Los Angeles on December 11. $PM_{2.5}$ comprised a more significant portion of the PM_{10} than during the summer.
- Nitric acid concentrations (Figures 5-13, 5-14) were low, typically less than 5 ppb during this episode. The highest concentrations were measured at Burbank in the afternoon (up to 20 ppb).
- $PM_{2.5}$ nitrate ion concentrations (Figures 5-13, 5-14) were highest at Anaheim and Burbank. The lowest nitrate ion concentrations were observed at Hawthorne. The timing of peak nitrate ion concentrations varied.
- Ammonia concentrations (Figures 5-15, 5-16) were as high as 50 ppb at Hawthorne and Rubidoux on the afternoon of December 10. Ammonia concentrations were 5 to 30 ppb at the other locations.
- Ammonium ion concentrations (Figures 5-15, 5-16) were highest at Rubidoux during the night. Ammonium ion concentrations were relatively low at the other locations and exhibited little diurnal variation.
- Organic carbon (OC) concentrations (Figures 5-17, 5-18) reached 25 to 30 $\mu\text{g}/\text{m}^3$ at all the sites. Concentrations were highest overnight or during the early morning.
- Elemental carbon (EC) concentrations (Figures 5-17, 5-18) were about half the OC concentrations. Peak concentrations were about the same at all sites and were somewhat higher overnight and during the early morning.
- SO_2 concentrations (Figures 5-19, 5-20) were highest at Hawthorne and Long Beach, with peak concentrations of about 10 ppb on December 11. SO_2 and sulfate ion concentrations went up and down together.

- Sulfate ion concentrations (Figures 5-19, 5-20) were highest at Hawthorne, Long Beach, and Los Angeles on December 11, with peak concentrations occurring in the midday at Hawthorne, afternoon at Los Angeles, and evening at Long Beach. The lowest concentrations were observed at Rubidoux. Sulfate ions were present mostly in the fine aerosol, which is consistent with emissions and formation mechanisms.
- Acetic acid was more abundant than formic acid (Figure 5-21). The difference was greatest during the midday. Organic acid measurements were only made at Long Beach.
- NMOC concentrations (Figure 5-22) were similar on both days. Concentrations were highest during the 0700 to 0800 PST sampling period. Concentrations were similar across the basin during the different sampling periods, except at Rubidoux, where concentrations were significantly lower.

5.3 VERTICAL POLLUTANT PROFILES

The air quality aircraft flew two flights daily during the fall: early morning and afternoon. On December 10, the morning flight was incomplete. Measurements were described in Section 2 and spiral and orbit locations are shown in Figure 2-10.

Vertical profiles of ozone, b_{scat} , NO, and NO₂ by site, date, and time of day are shown in Figures 5-23 to 5-34. In these plots, the continuous data, which were collected every second (about every 3 meters) during each spiral, were averaged into 30 meter vertical bins. Data are plotted versus altitude in meters above mean sea level (m msl). The following observations may be made:

Morning:

- NO₂ and NO concentrations and b_{scat} levels were greatest near the surface. Ozone concentrations were low at these altitudes, probably because of titration by fresh NO emissions.
- NO concentrations were very high near the surface, up to 500 ppb. NO concentrations decreased sharply with altitude.
- Above about 600 m msl, pollutant concentrations were near background levels. This is in contrast to the summer profiles which showed relatively high pollutant concentrations as high as 1500 m msl.

Afternoon:

- On both days above the mixed layer, pollutant concentrations were near background levels. Again, this is in contrast to the summer profiles which showed relatively high pollutant concentrations as high as 1500 m msl.

- On December 11, ozone concentrations dropped off sharply near the surface at Hawthorne and Fullerton. The formation of the nocturnal boundary layer may have trapped fresh emissions of NO near the surface resulting in a reduction in ozone concentrations.
- NO₂ and NO concentrations and b_{scat} levels were lower while ozone concentrations were higher at PADDR than onshore spiral locations on December 11.
- Ozone and NO₂ concentrations and b_{scat} levels were higher on December 11 than on December 10 at all spiral locations.

5.4 CHARACTERISTICS OF ALOFT INTEGRATED SAMPLES TAKEN DURING ORBITS

Integrated aerosol and gaseous samples were made during constant-altitude orbits using a modified version of the SCAQS sampler. These samples were later analyzed for nitric acid, SO₂, PAN, carbonyls, and particulate sulfur and nitrogen species similar to the surface samples. Orbit locations are shown in Figure 2-10. Samples were collected by the STI aircraft during the SCAQS as described in section 2.2.2. The spatial distribution of these species aloft has not been investigated in much detail in past studies.

We computed the mean values of air quality parameters measured during the orbits and combined these parameters with the results of the filter analyses. Figures 5-35 to 5-41 show the orbit-averages of nitric acid, PAN, ozone, ammonia, SO₂, NO_x, and PM_{2.5} mass, organic and elemental carbon, nitrate ion, sulfate ion, and carbonyl compounds by date, time of day (morning and afternoon), and orbit location. In the morning, all but one of the samples were collected above the mixing height. All the afternoon samples were collected within the mixed layer. Note that orbit samples were only collected at AMTRA and Long Beach. Hydrocarbon samples were collected during spirals at Hawthorne, Fullerton and El Monte. Samples were usually collected at two altitudes, one above 200 m msl and the other below 200 m msl. NMHC samples were collected at sufficiently different locations and altitudes from the carbonyl compound samples that the data were not merged. Observations from these figures include the following:

- Ozone, nitric acid, PAN, OC, and NO_x concentrations were usually higher in the afternoon than in the morning.
- PM_{2.5} mass, OC, and EC concentrations were highest within the mixed layer.
- Elemental carbon, ammonia, sulfate ion, and SO₂ concentrations were low.
- Ammonium and nitrate ion concentrations were highest in the afternoon.
- Carbonyl compound concentrations were generally higher in the afternoon. The C4+ carbonyl compounds comprised a large fraction of the total carbon.

- NMHC concentrations aloft were less than half the NMHC concentrations at the surface. Surprisingly, some morning samples had higher NMHC concentrations than the afternoon samples. The concentrations and compositions of samples collected above and below 200 m msl varied.

5.5 COMPARISON OF SURFACE AND ALOFT POLLUTANTS

Air quality data at the surface are abundant both spatially and temporally in the SoCAB. In contrast, aloft measurements of air quality are rarely available. In this section, we compare the aloft measurements of ozone, NMHC, and $PM_{2.5}$ mass and species made during December 10-11 with surface measurements.

5.5.1 Comparison of Aloft and Surface NO_2 and b_{scat}

We investigated how well the aloft NO_2 concentrations and b_{scat} at the spiral locations compared to the measurements made at nearby surface sites. Figures 5-42 to 5-46 show the surface and aloft measurements made during the December 10-11, 1987 episode. Two values are shown in the figures for the aircraft, the mixed-layer-average (MLA) and the 45-m average. The MLA was computed by averaging the pollutant concentrations over the mixing height (determined by T.B. Smith and Associates) in the afternoon. The 45-m average is the average ozone concentration in the lowest 45 m of the aircraft spiral. Most of the spirals during the fall SCAQS reached altitudes below 30 m agl.

The aircraft NO_2 measurements were in good agreement with the surface measurements at some locations and times and in poor agreement at others. The surface and aloft data from December 10 at Fullerton, Burbank, and Hawthorne and from December 10-11 at Upland/Ontario and El Monte agreed well. The NO_2 measurements from aircraft spirals at PADDR (offshore) did not match the nearby surface-based soundings very well. The PADDR spirals were flown over the ocean and thus, were less influenced by fresh emissions.

The aircraft b_{scat} measurements were in good agreement with the surface measurements at El Monte and at Long Beach/PADDR, even though the latter locations showed poor agreement for NO_2 . Most of the rest of the aircraft measurements were lower than the surface. Many of the b_{scat} profiles showed that b_{scat} decreased rapidly with increasing altitude.

5.5.2 Comparison of Aloft and Surface Particulate and Gaseous Species

Fourteen of the aloft hydrocarbon samples were collected within about one hour of eight surface samples at nearby sites. Some of the aloft samples were collected above the mixed layer, while others were collected within the mixed layer. The composition of the 25 most abundant species in the matched samples correlated very well, $r^2 = 0.63$ to 0.95 ; the correlation was independent of the altitude of the aloft sample. NMHC concentrations at the surface were greater than aloft in most of the matched pairs. Surface and aloft carbonyl compound concentrations were not compared because the aloft acetone data and the Long Beach surface carbonyl data were invalid.

We matched aloft samples collected during 30-minute orbits, with the nearest surface site data collected during four-to six-hour periods. Ammonia, and $PM_{2.5}$ mass, ammonium ion, and sulfate ion concentrations aloft were almost always less than the matched surface concentrations. However, $PM_{2.5}$ elemental carbon and nitric acid concentrations aloft were generally higher than at the surface. $PM_{2.5}$ nitrate ion and organic carbon concentrations were sometimes higher and sometimes lower than matched concentrations at the surface.

5.6 THE PRESENCE AND STRUCTURE OF POLLUTED LAYERS ALOFT

In order to illustrate the structure of pollutant concentrations aloft, we have constructed a 2-dimensional (2-D) plane from the surface to about 1500 m msl along a straight line from the coast to the eastern-basin (see map in Figure 5-47). This line passes near the Hawthorne, El Monte, and Ontario aircraft spiral locations. The PADDR, Burbank, and Fullerton spiral locations do not lie along this line, so we did not use these data in this analysis. We next interpolated and contoured data from spirals along the line to a 2-D plane which illustrates the pollutant structure aloft over the SoCAB. In the figures, the darkened area along the bottom of the figure shows the approximate ground level in the SoCAB.

Figure 5-48 shows ozone, b_{scat} , and NO_2 for the afternoon of December 10, 1987 (data were incomplete for the morning flight). Ozone and NO_2 concentrations were highest over El Monte. In contrast, b_{scat} levels were highest near the surface; levels were similar across the basin. Figures 5-49 through 5-51 show ozone, b_{scat} , and NO_2 for the morning and afternoon of December 11. Ozone concentrations were very low. In the morning, b_{scat} levels were highest near the surface. Similar b_{scat} levels were observed across the basin, with a slight increase in altitude of the b_{scat} layers inland. NO_2 concentrations were 80 to over 100 ppb in a layer between 200 and 500 m msl over all three spiral locations. In the afternoon, ozone and NO_2 concentrations were highest near Hawthorne. The b_{scat} layers were more horizontal than in the morning, but remained highest near the surface and showed a similar magnitude across the basin.

5.7 ALOFT LAYER FORMATION

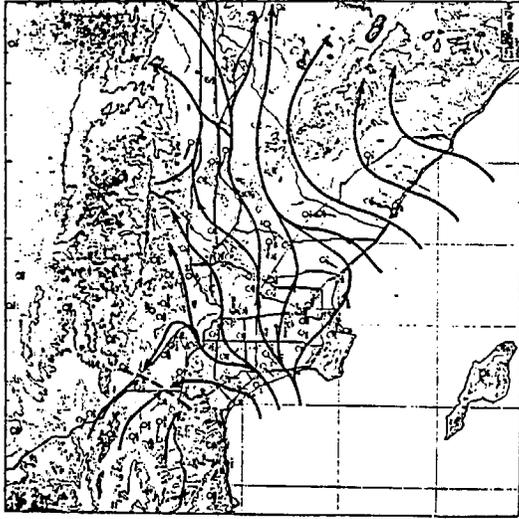
During the fall, the pollutants in the surface layer were present at much higher concentrations than during the summer because of generally lower mixing heights and stagnant wind conditions. Compared to the summer, fewer polluted layers were observed above the surface layer. The fall layers also had lower concentrations than summer layers. These aloft layers of pollutants were formed by some of the same mechanisms as were observed in the summer, including: the injection of pollutants aloft by stationary source emissions, the injection of pollutants aloft by upslope flow in the afternoon, the isolation of polluted material aloft by the nocturnal boundary layer, and the transport of buoyant air parcels from the mixed layer into the inversion layer (convective debris). Two mechanisms observed in the summer SCAQS were not observed during the fall: undercutting of the afternoon mixed layer by the sea breeze and injection aloft at a convergence zone.

Offshore flow and stagnation conditions were evident on each fall intensive day. Pollutants in the mixed layer onshore were sometimes pushed offshore with the land breeze. Figure 5-52 shows backward particle trajectories at 300 m agl beginning at 1500 PST December 11, 1987 and ending at 0000 PST on December 10. The particle trajectories began at PADDR, Long Beach, Los Angeles, Burbank, and Riverside. These trajectories, as well as trajectories using surface and 100 m agl winds, indicated local recirculation of the winds which contributed to the build-up of pollutants within the SoCAB. Pollutants which were carried offshore may become decoupled from the surface by the marine layer and may be pushed onshore the next day, also contributing to pollutant build-up.

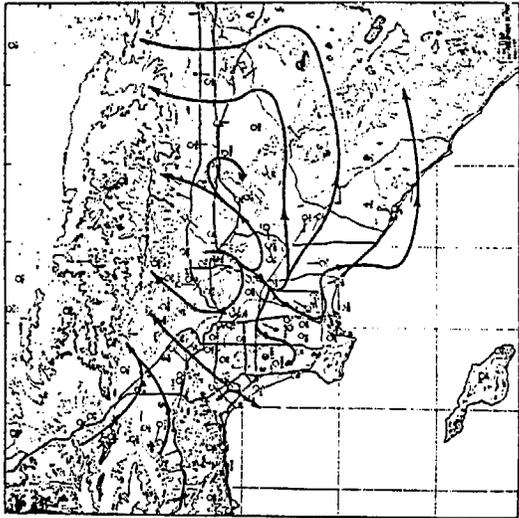
Flow up the mountain slopes due to heating may carry pollutants aloft to form layers above the surface mixing layer. Dispersion of this aloft layer would be dependent on the aloft winds. The December 10-11 lidar data were incomplete and did not show this phenomenon. However, lidar data for December 3 clearly illustrated upslope flow (Roberts and Main, 1992). As in the summer, this layer may or may not affect surface concentrations the next day, depending upon transport and the mixing depth.

Fresh emissions of SO_2 and NO in narrow layers aloft were observed at offshore, western-, and central-basin locations on a few days at fairly low altitudes (300-500 m msl). Concentrations were relatively low (SO_2 less than about 25 ppb and NO typically less than 60 ppb). These layers may indicate the presence of power plant or other stationary source emissions and will probably be entrained into the mixed layer because of their low altitudes. Figure 5-53 shows an example of a layer measured at Fullerton on the afternoon of December 11, 1987 with elevated concentrations of SO_2 , NO_2 , NO , and b_{scat} and depleted ozone concentrations.

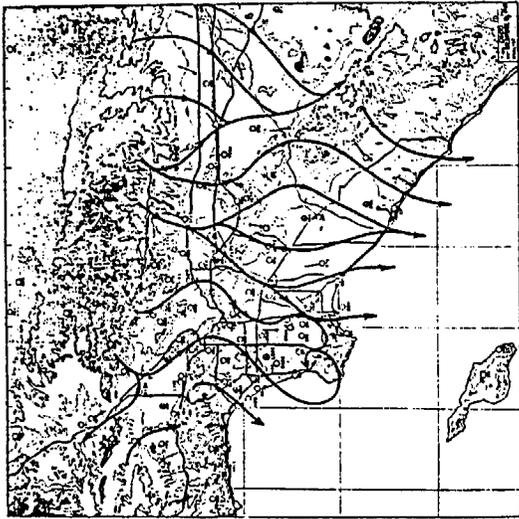
As the wind decreases during the early evening, the surface temperatures in the SoCAB decrease markedly, resulting in the formation of a stable layer close to the ground, the nocturnal boundary layer. The upper portions of the polluted layer are cut off from the surface layer and begin to develop different concentration characteristics than the surface layer. Sources of NO reduce the ozone concentrations in the surface layer while the ozone at the higher altitudes remains relatively unmodified. Evidence of the nocturnal boundary layer was observed in most of the early morning vertical profiles, when the mixing heights were usually less than 50 m agl (see Figures 5-30 and 5-31, for example). These elevated polluted layers are formed at a relatively low altitude and thus, may be incorporated into the mixed layer the next day depending upon transport of the polluted layer.



(a)

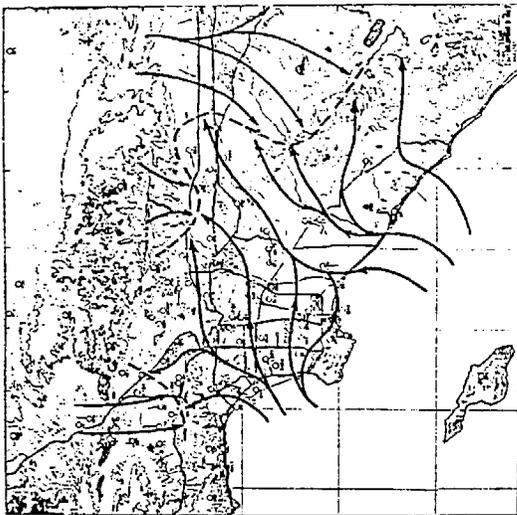


(b)

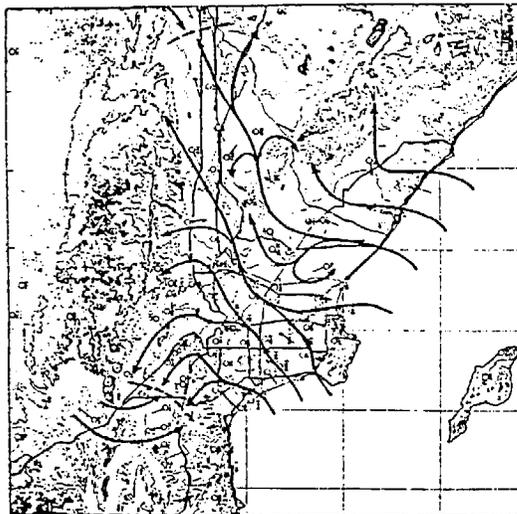


(c)

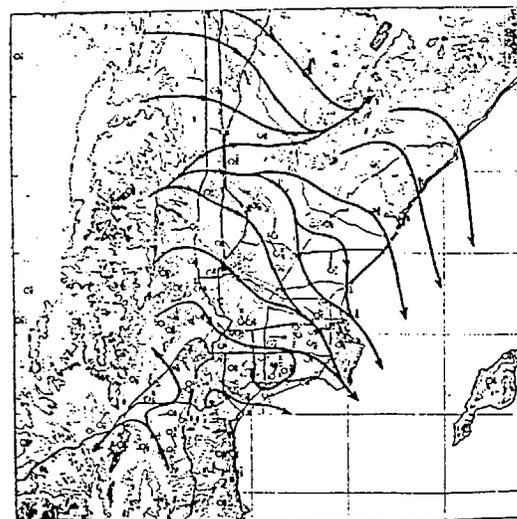
Figure 5-1. Surface Wind Streamline Analyses for December 10, 1987 at (a) 0600 PST, (b) 1100 PST, and (c) 1600 PST (From Zeldin et al., 1989).



(a)

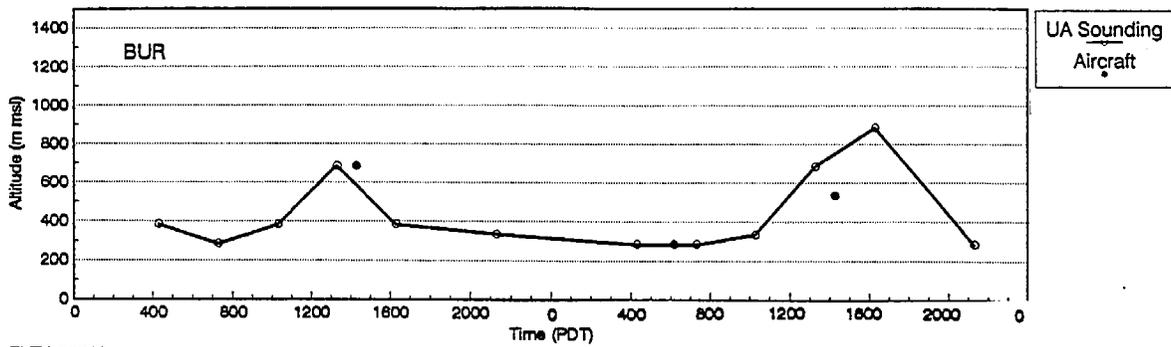


(b)

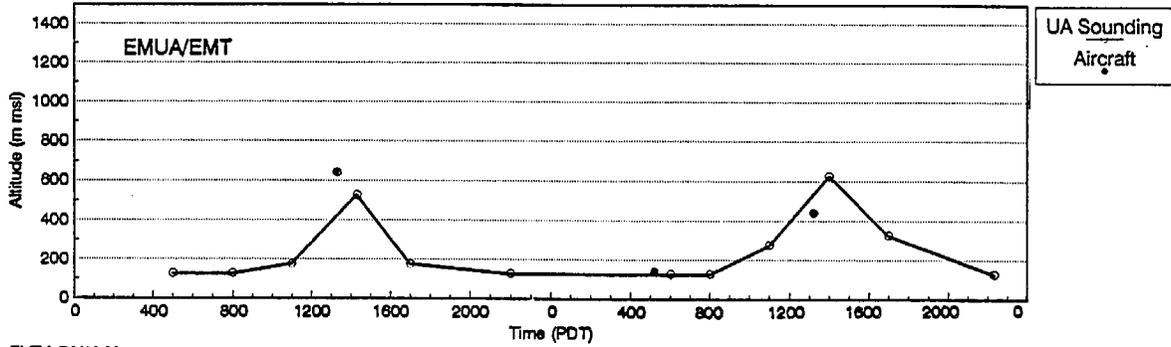


(c)

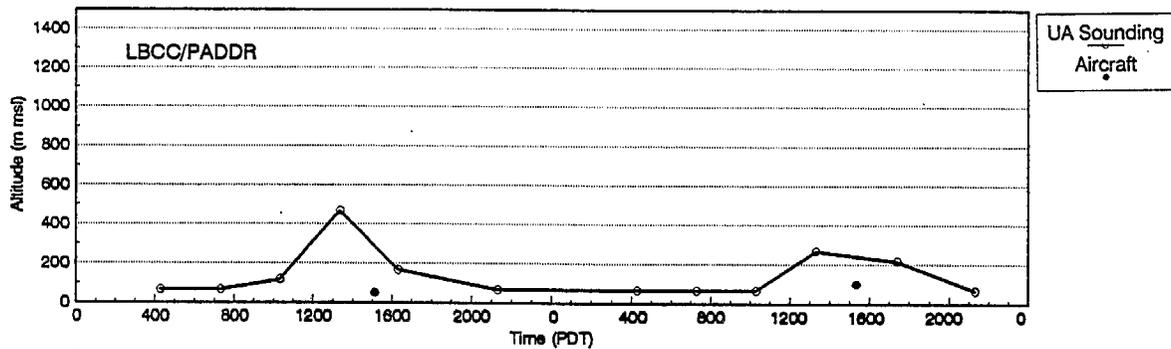
Figure 5-2. Surface Wind Streamline Analyses for December 11, 1987 at (a) 0600 PST, (b) 1100 PST, and (c) 1600 PST (From Zeldin et al., 1989).



ELEV. 236 M

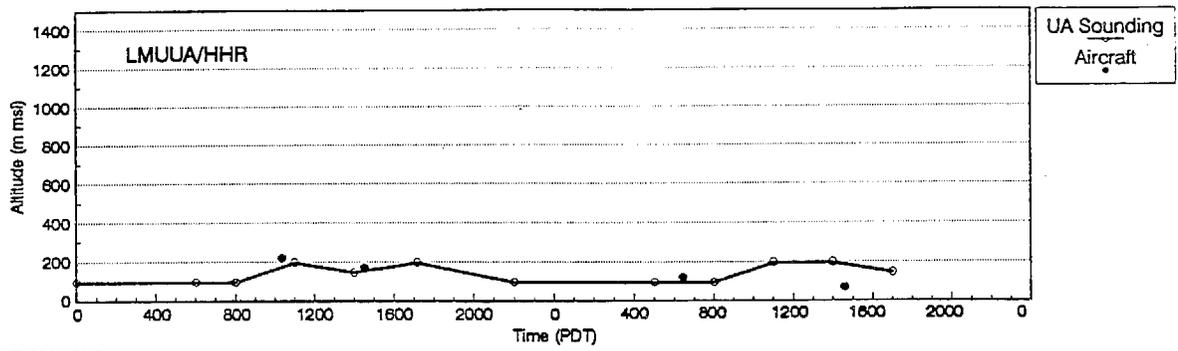


ELEV. 76/60 M

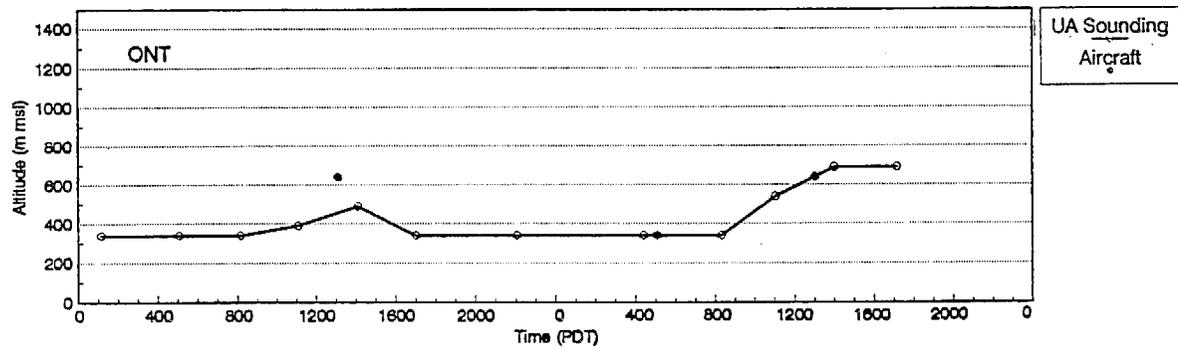


ELEV. 17/0 M

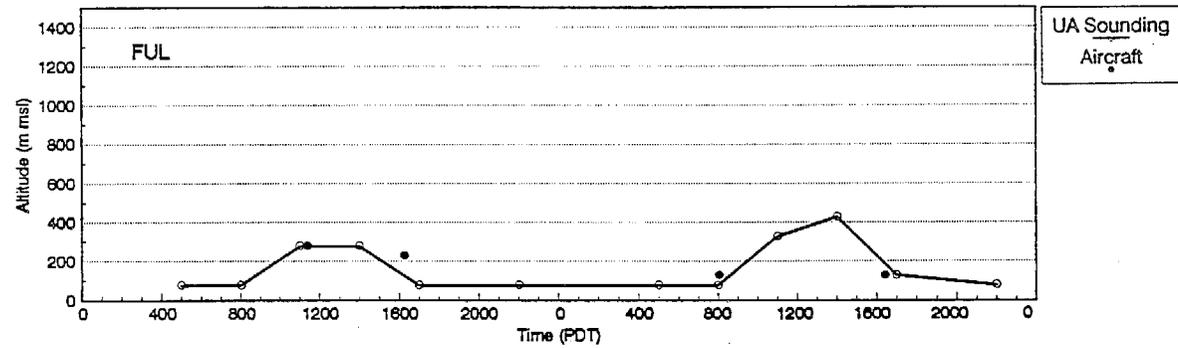
Figure 5-3. Estimated Mixing Heights on December 10-11, 1987 at Burbank, El Monte, and Long Beach Using Rawinsonde Temperature Data and Nearby Aircraft Temperature and Air Quality Data. Elevations are given for the upper air and aircraft measurement locations.



ELEV. 45/19 M



ELEV. 290 M



ELEV. 29 M

Figure 5-4. Estimated Mixing Heights on December 10-11, 1987 at Loyola-Marymount University, Ontario, and Fullerton Using Rawinsonde Temperature Data and Nearby Aircraft Temperature and Air Quality Data. Elevations are given for the upper air and aircraft measurement locations.

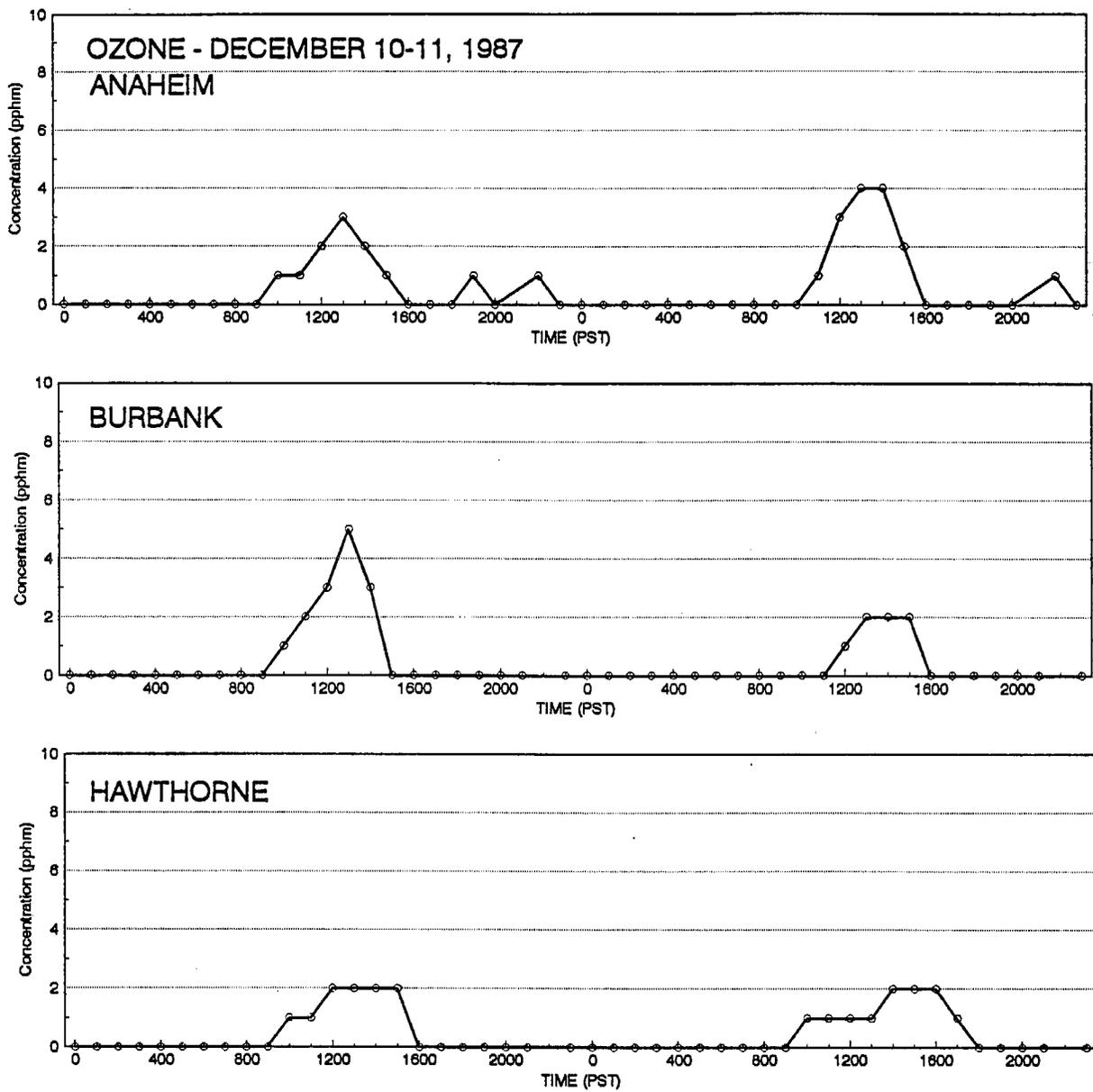
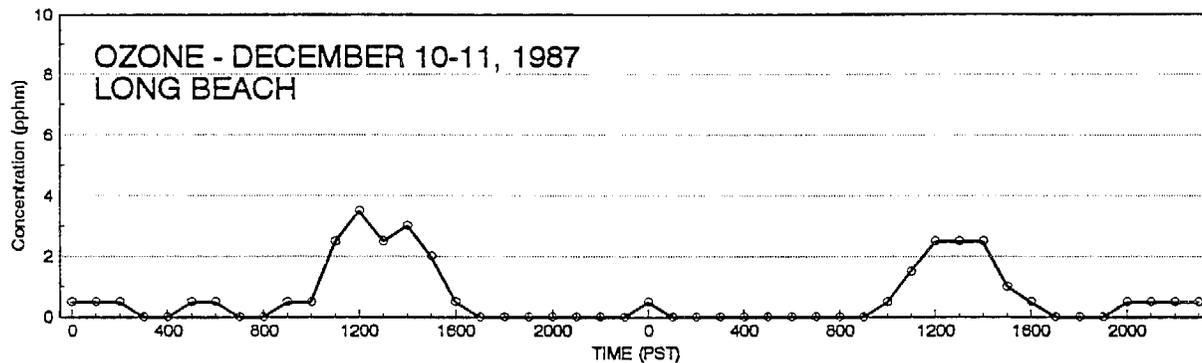


Figure 5-5. Diurnal Ozone Concentrations on December 10-11, 1987 at Anaheim, Burbank, and Hawthorne.



AVERAGE OF GM/ARB

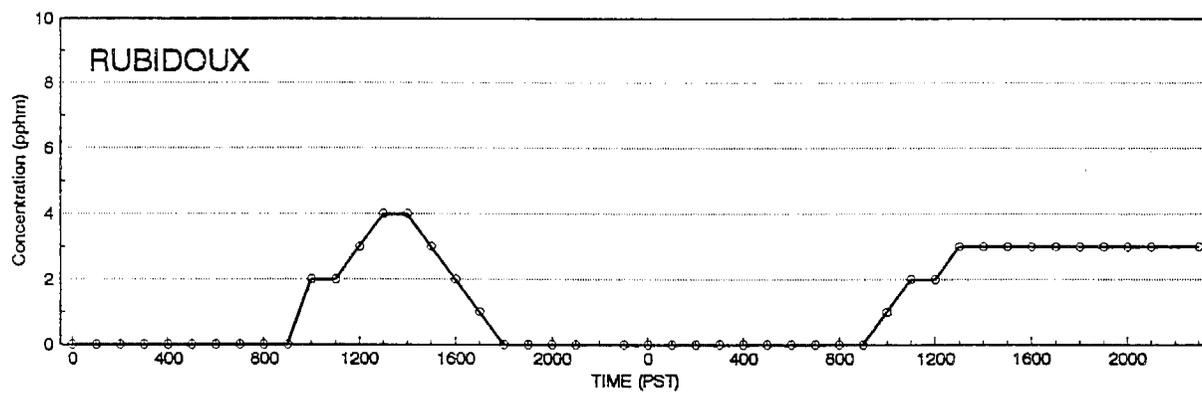
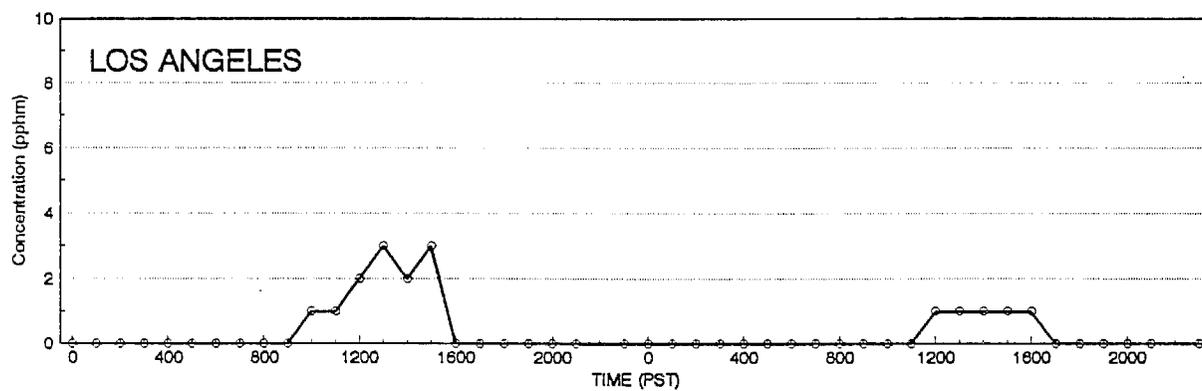


Figure 5-6. Diurnal Ozone Concentrations on December 10-11, 1987 at Long Beach, Los Angeles, and Rubidoux.

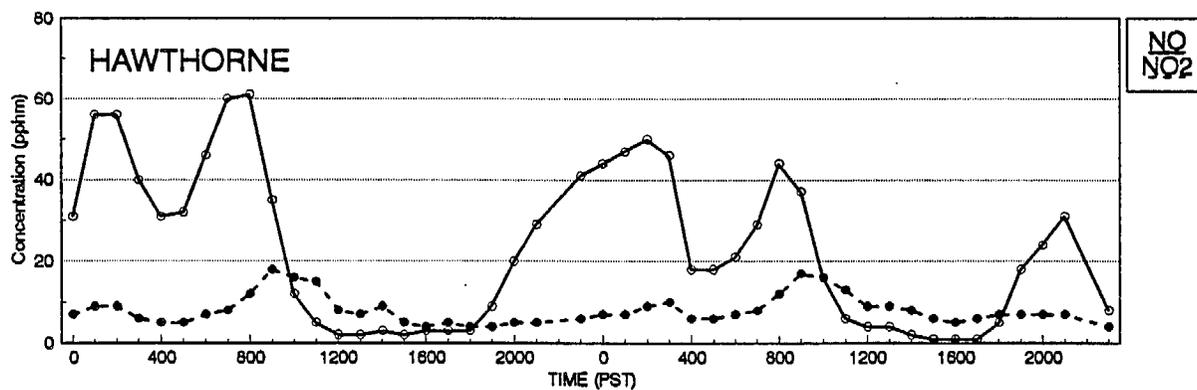
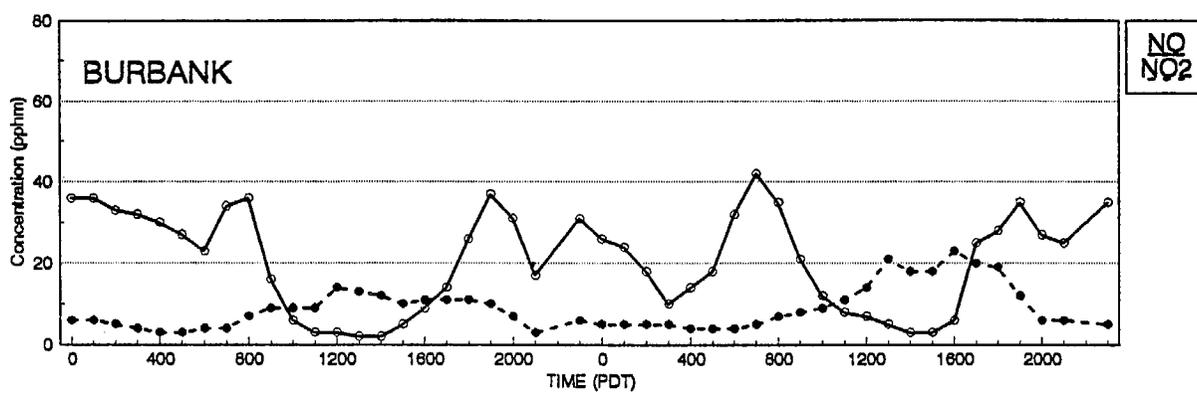
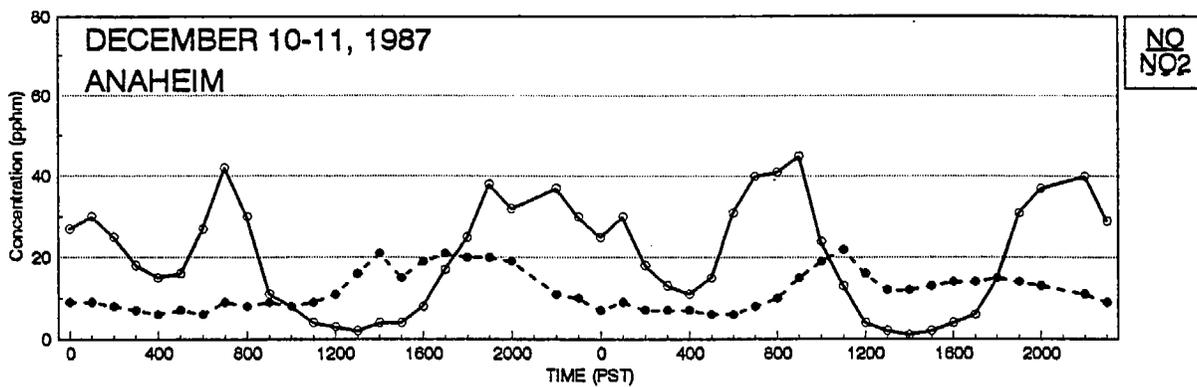


Figure 5-7. Diurnal NO and NO₂ Concentrations on December 10-11, 1987 at Anaheim, Burbank, and Hawthorne.

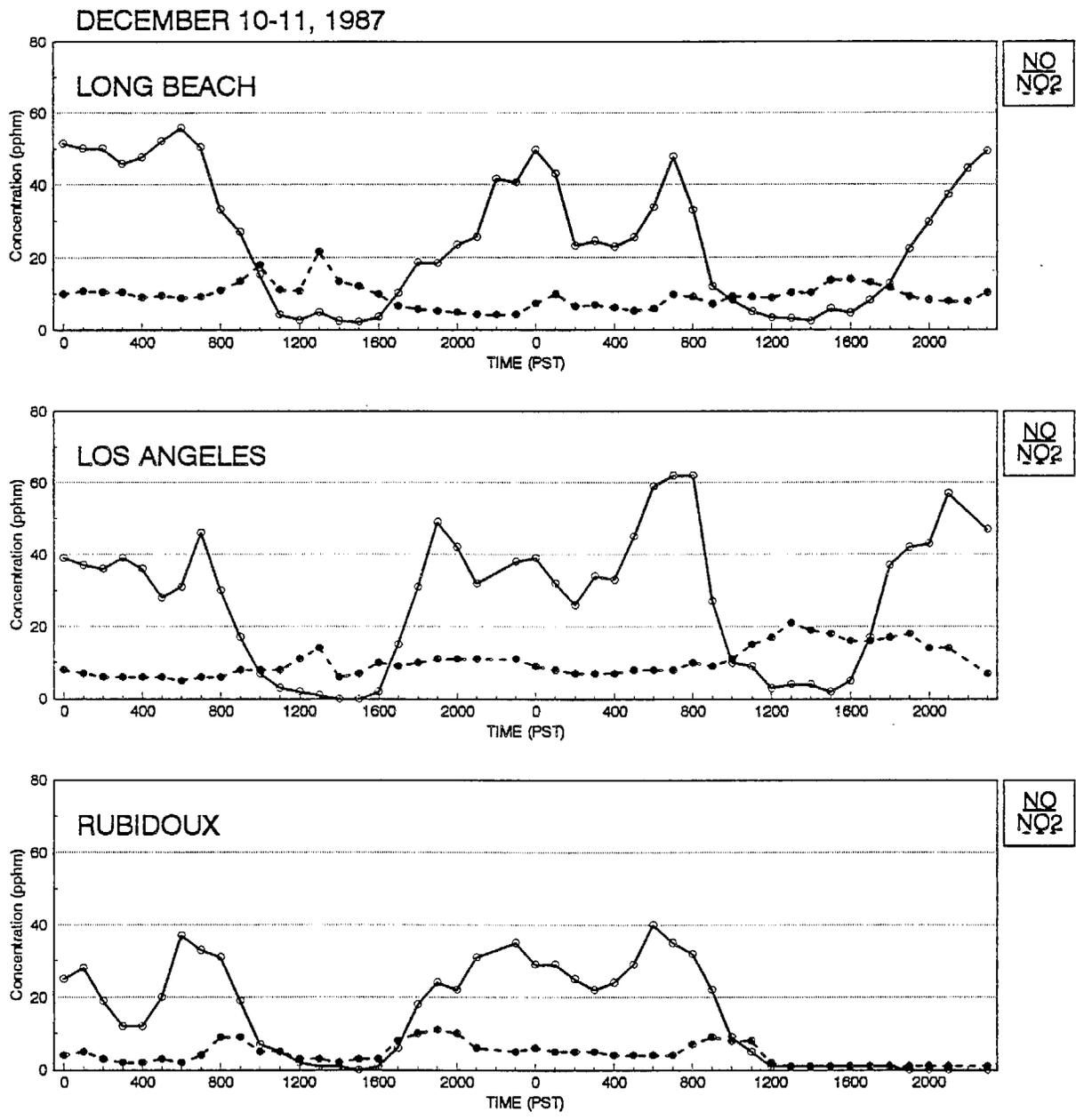


Figure 5-8. Diurnal NO and NO₂ Concentrations on December 10-11, 1987 at Long Beach, Los Angeles, and Rubidoux.

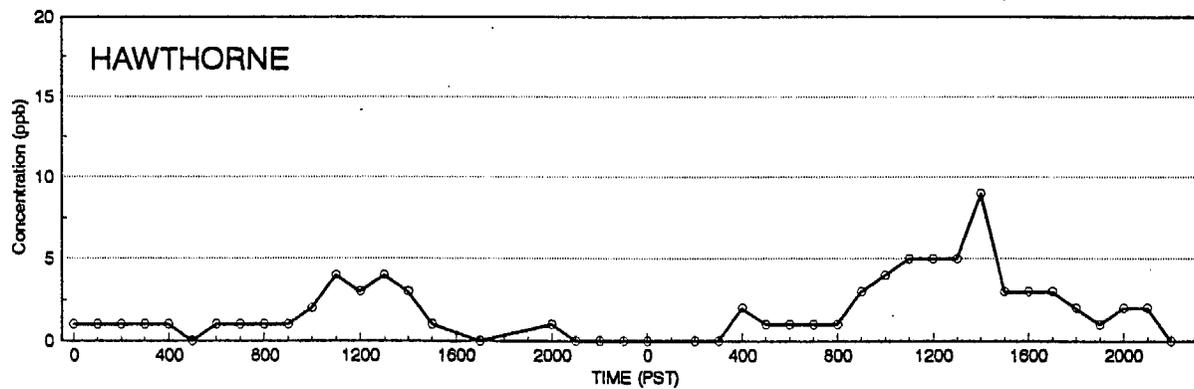
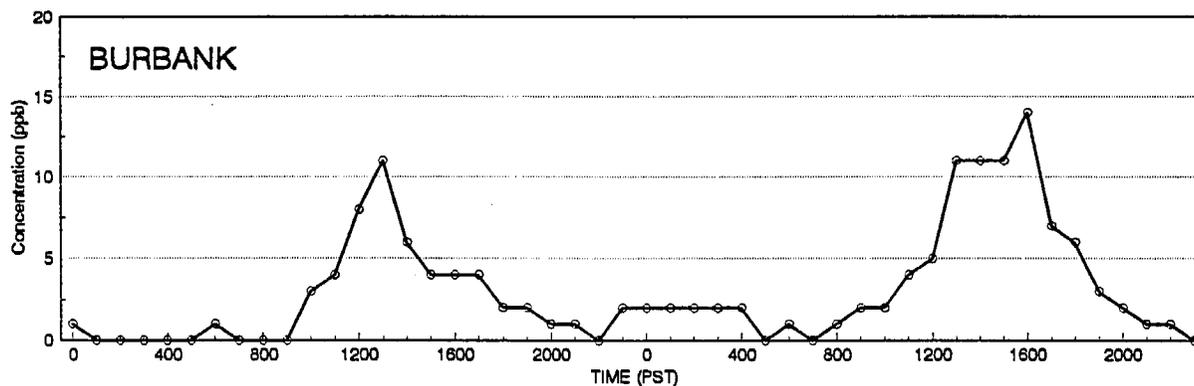
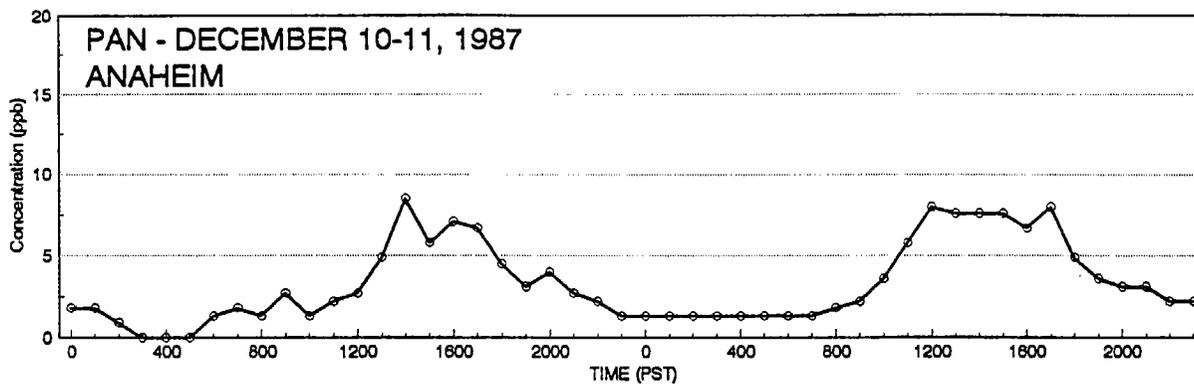


Figure 5-9. Diurnal PAN Concentrations by DGA on December 10-11, 1987 at Anaheim, Burbank, and Hawthorne.

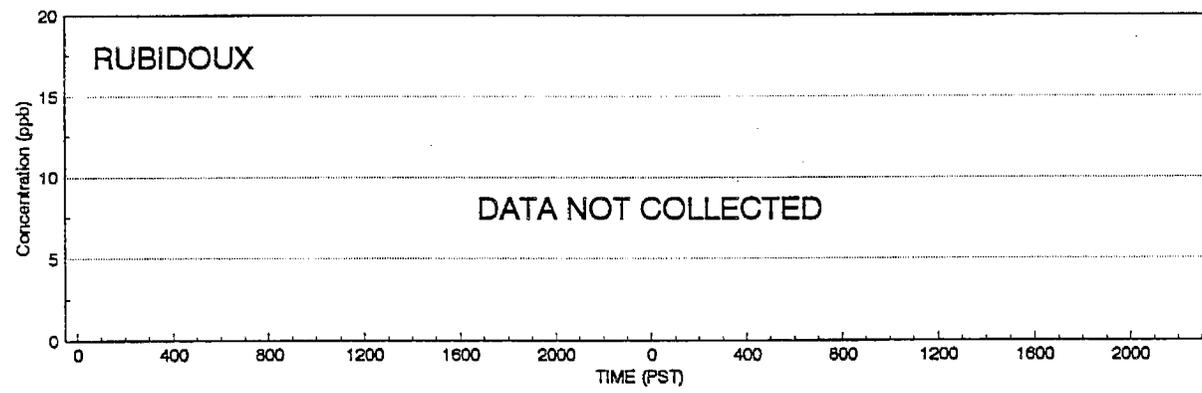
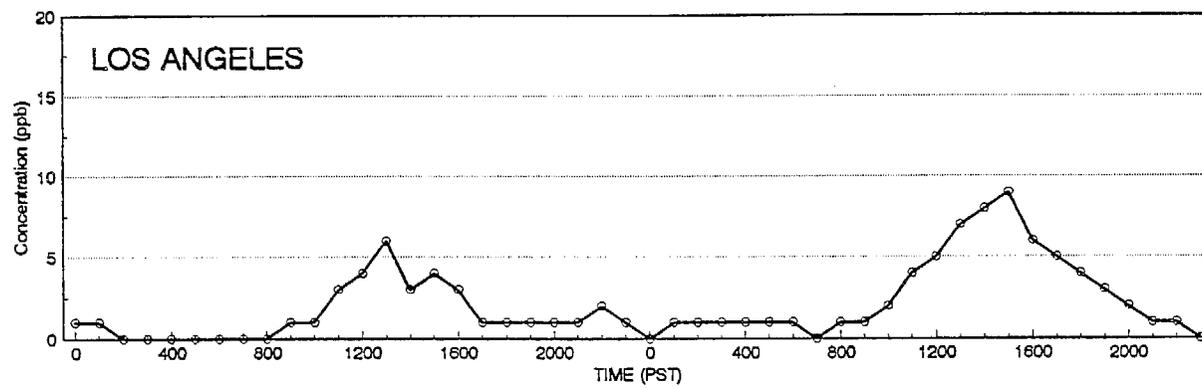
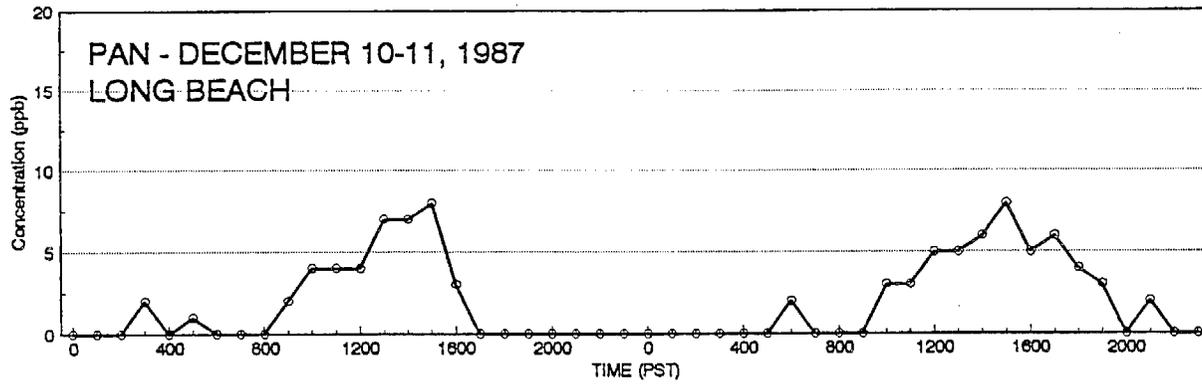


Figure 5-10. Diurnal PAN Concentrations on December 10-11, 1987 at Long Beach, Los Angeles, and Rubidoux.

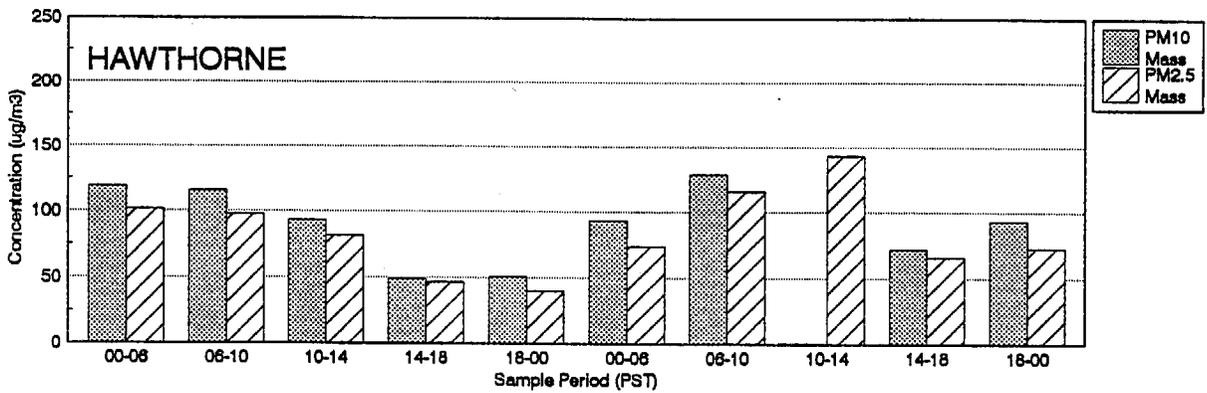
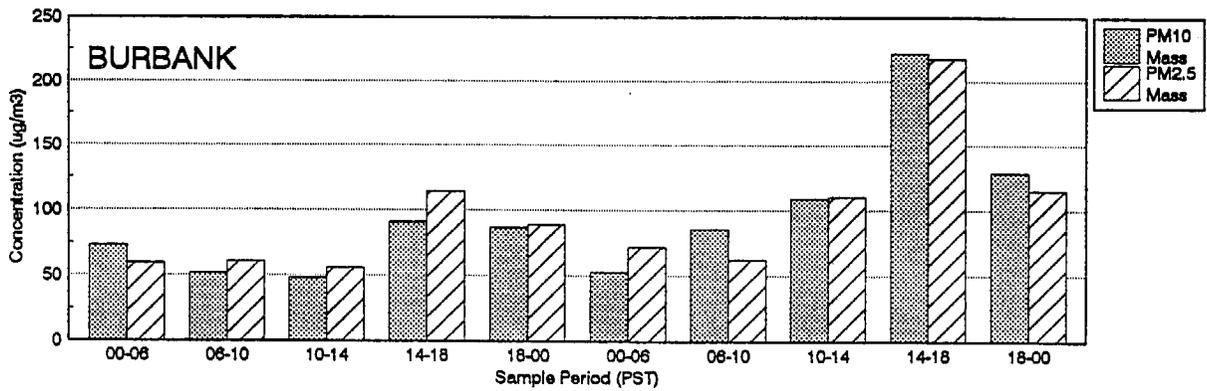
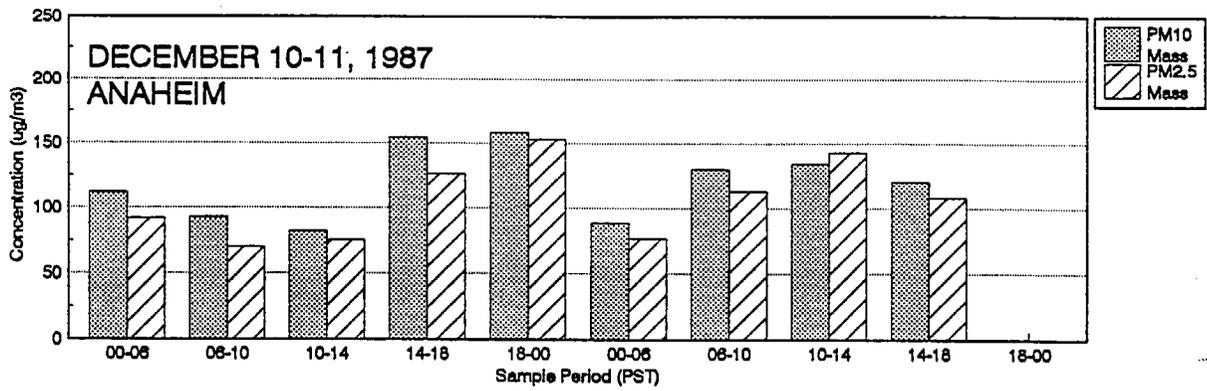


Figure 5-11. PM_{10} and $PM_{2.5}$ Mass Concentrations on December 10-11, 1987 at Anaheim, Burbank, and Hawthorne.

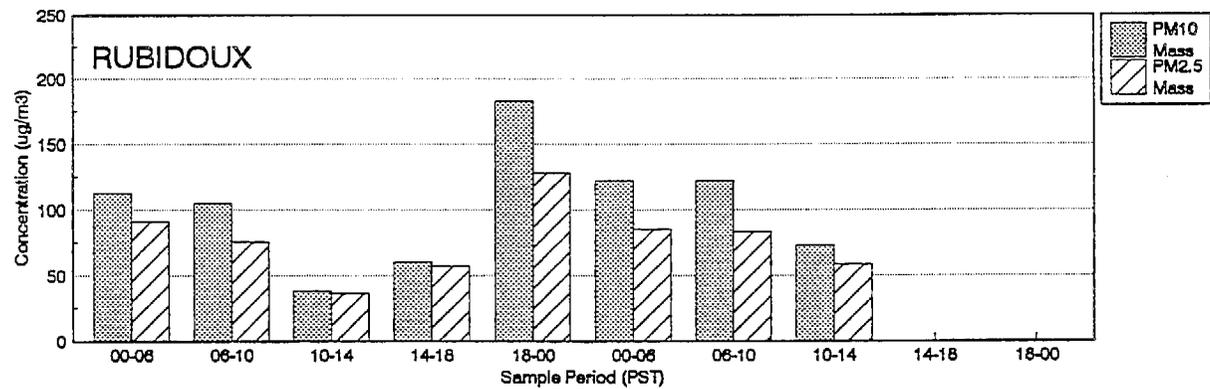
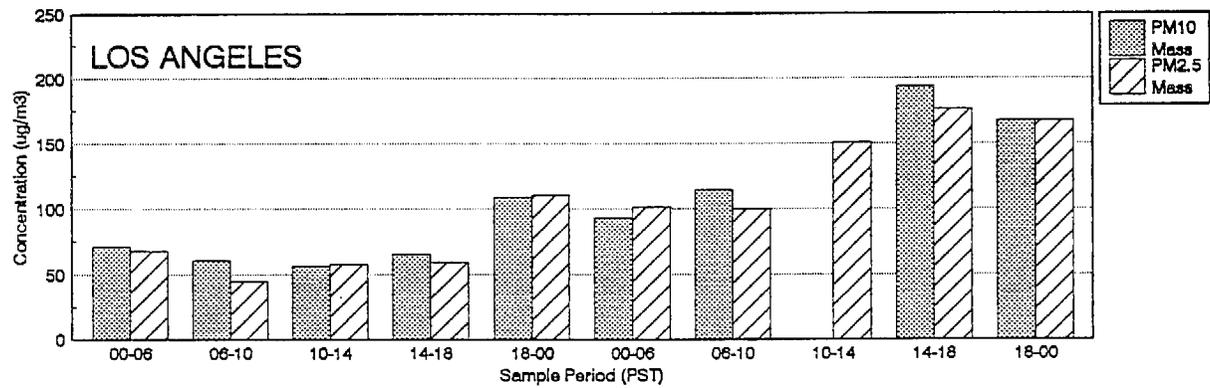
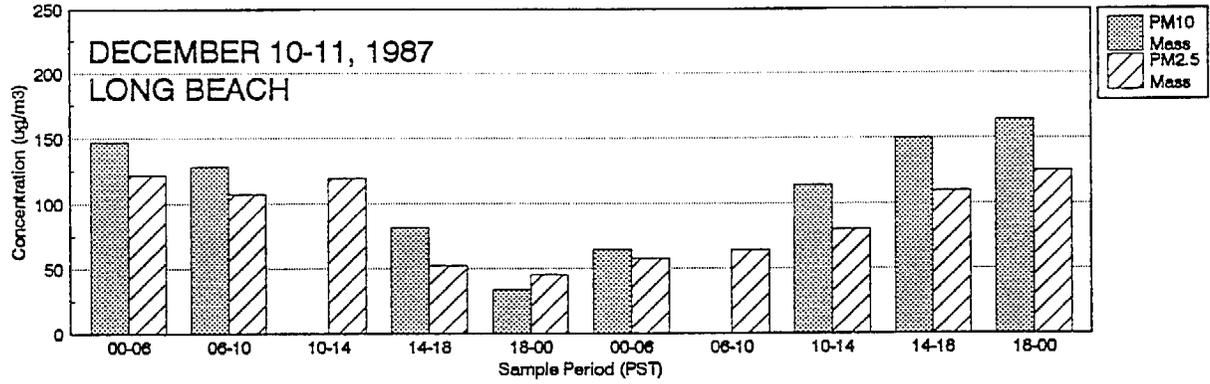


Figure 5-12. PM₁₀ and PM_{2.5} Mass Concentrations on December 10-11, 1987 at Long Beach, Los Angeles, and Rubidoux.

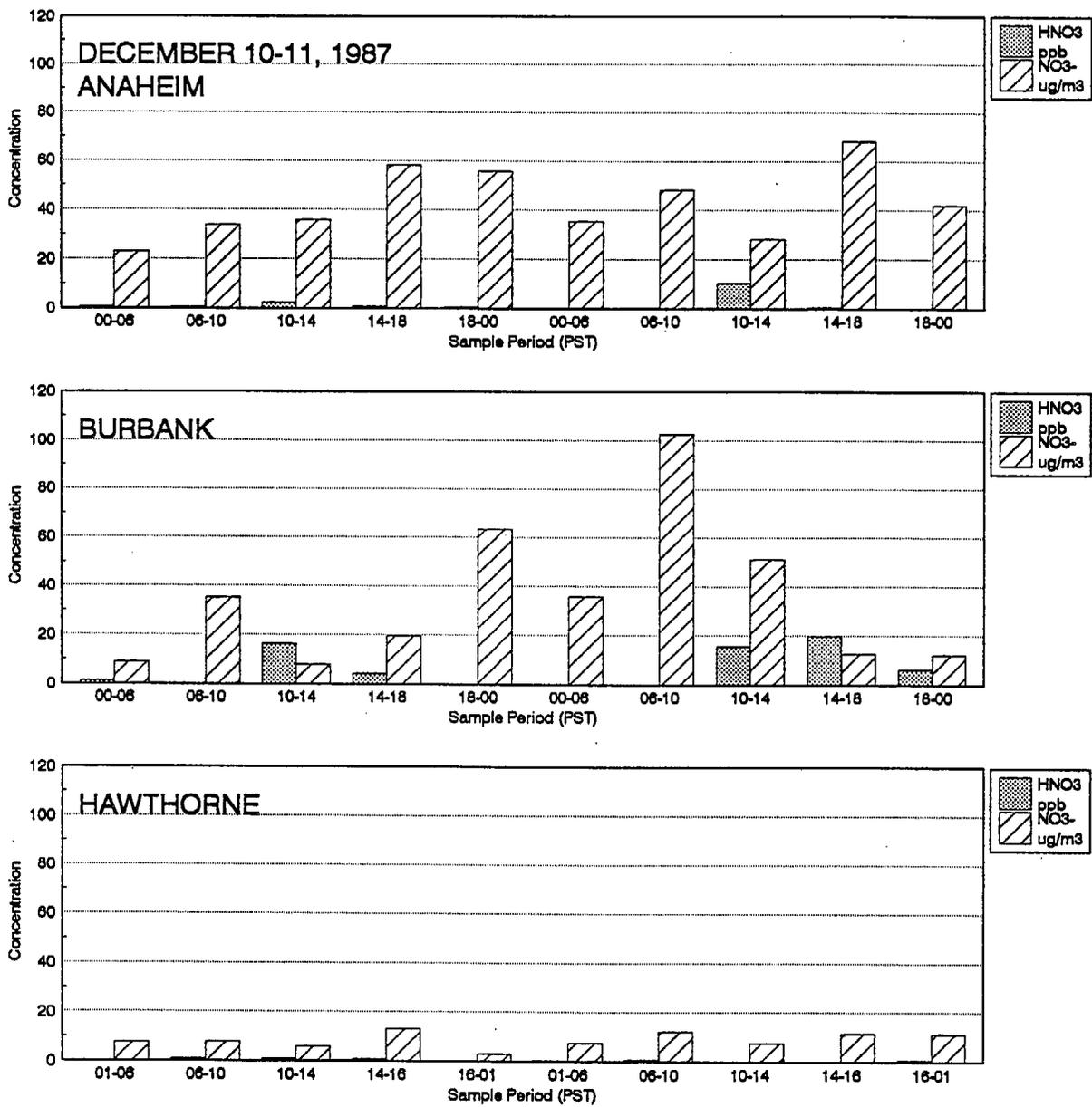


Figure 5-13. Nitric Acid and PM_{2.5} Nitrate Ion Concentrations on December 10-11, 1987 at Anaheim, Burbank, and Hawthorne.

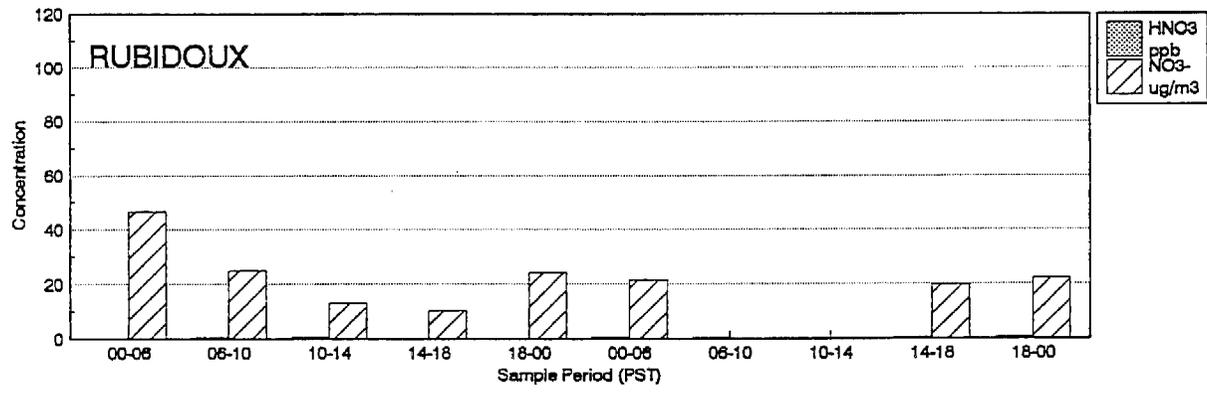
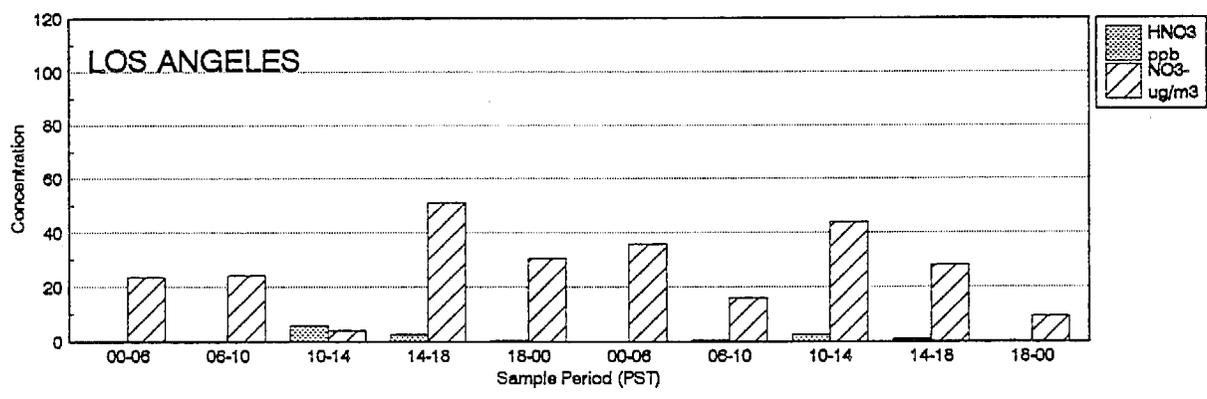
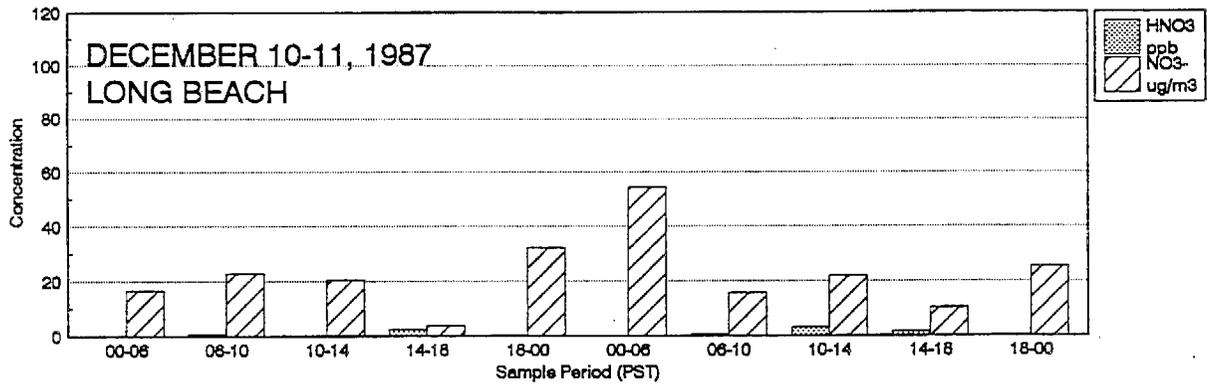


Figure 5-14. Nitric Acid and PM_{2.5} Nitrate Ion Concentrations on December 10-11, 1987 at Long Beach, Los Angeles, and Rubidoux.

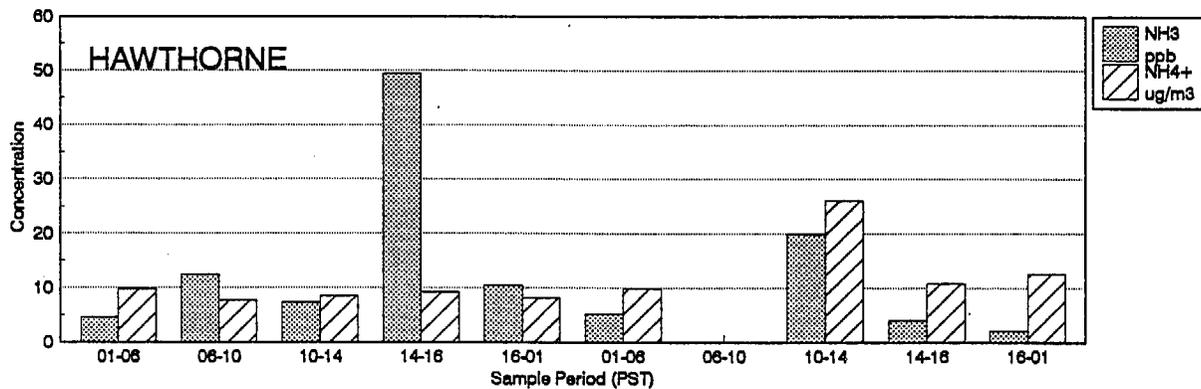
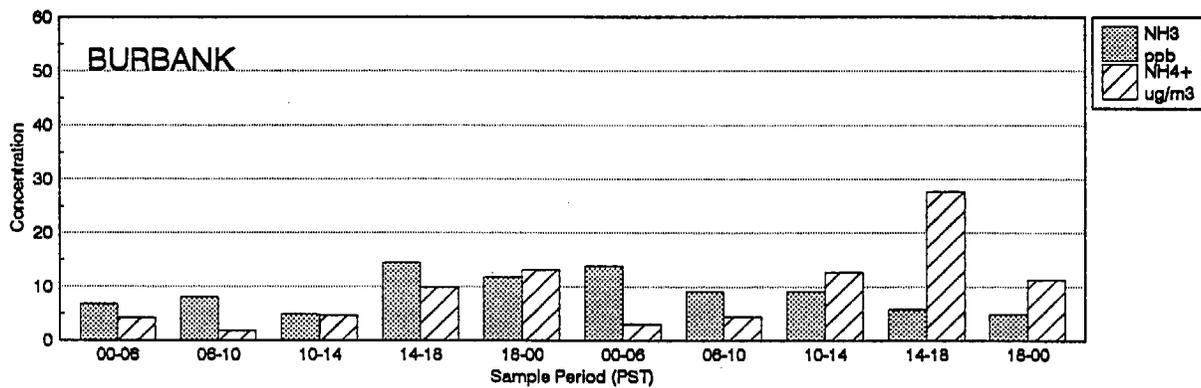
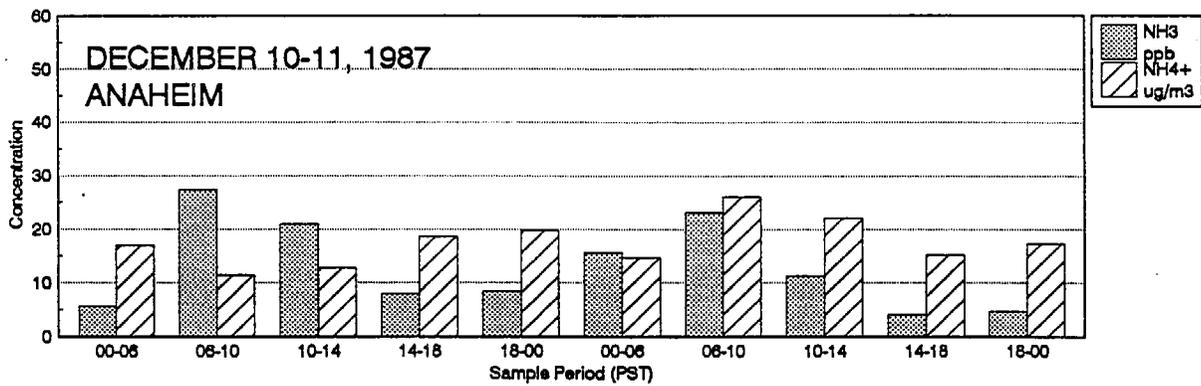


Figure 5-15. Ammonia and PM_{2.5} Ammonium Ion Concentrations on December 10-11, 1987 at Anaheim, Burbank, and Hawthorne.

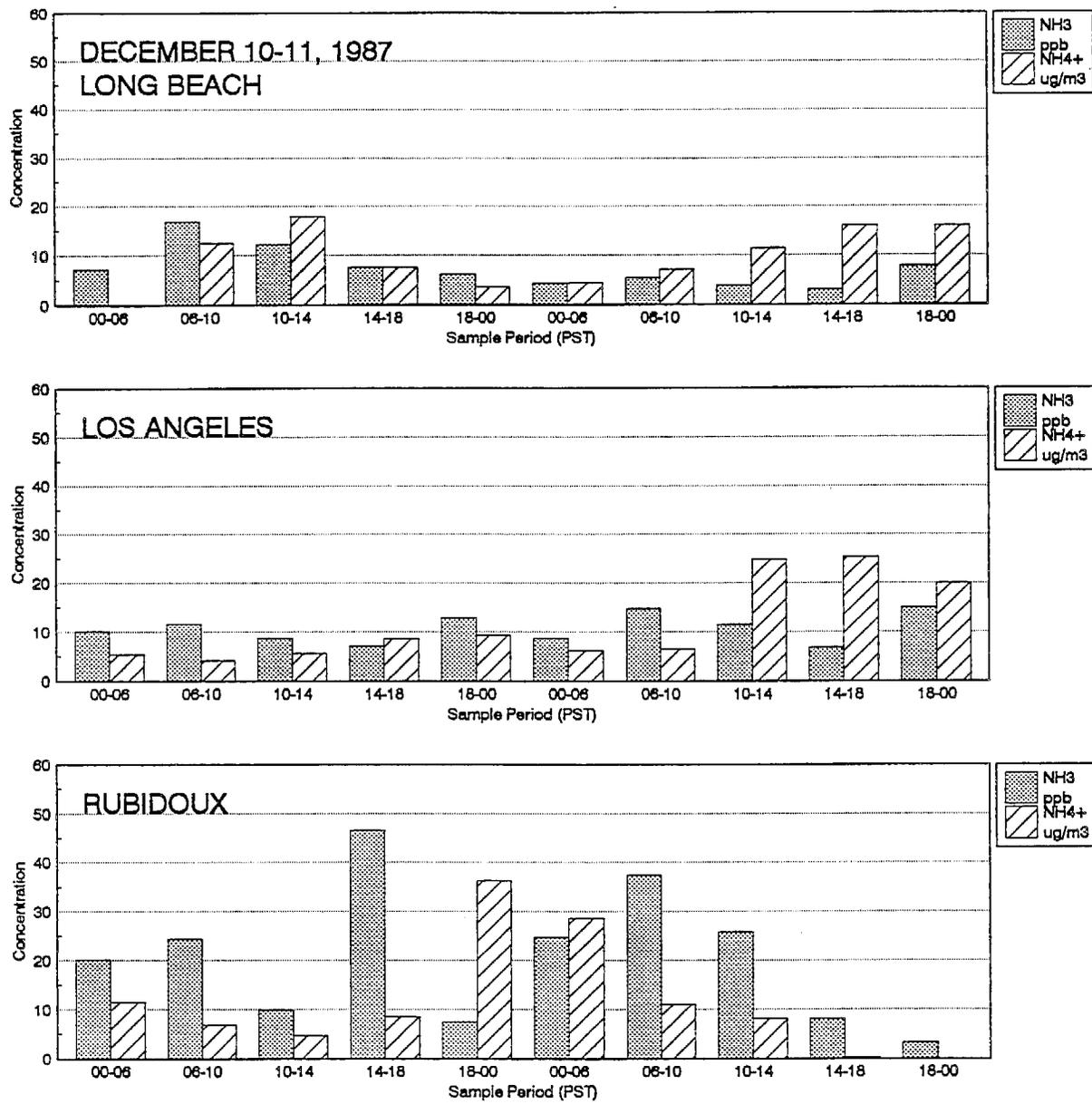


Figure 5-16. Ammonia and PM_{2.5} Ammonium Ion Concentrations on December 10-11, 1987 at Long Beach, Los Angeles, and Rubidoux.

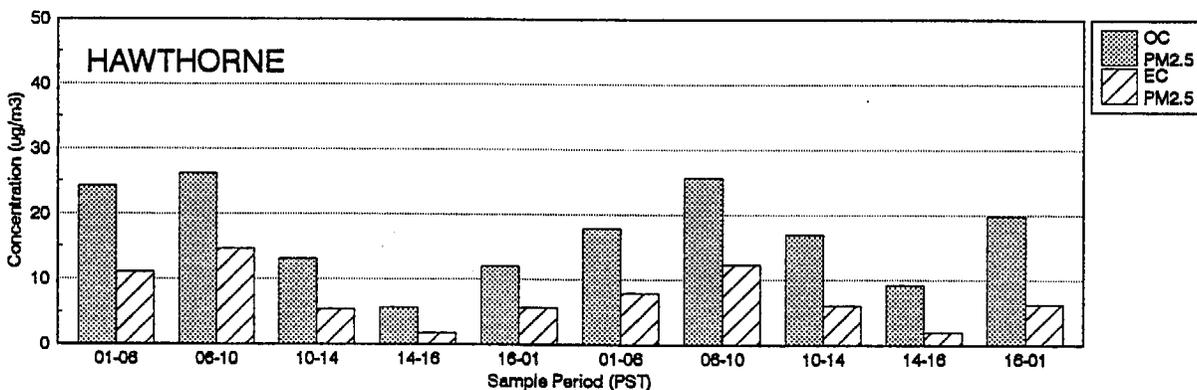
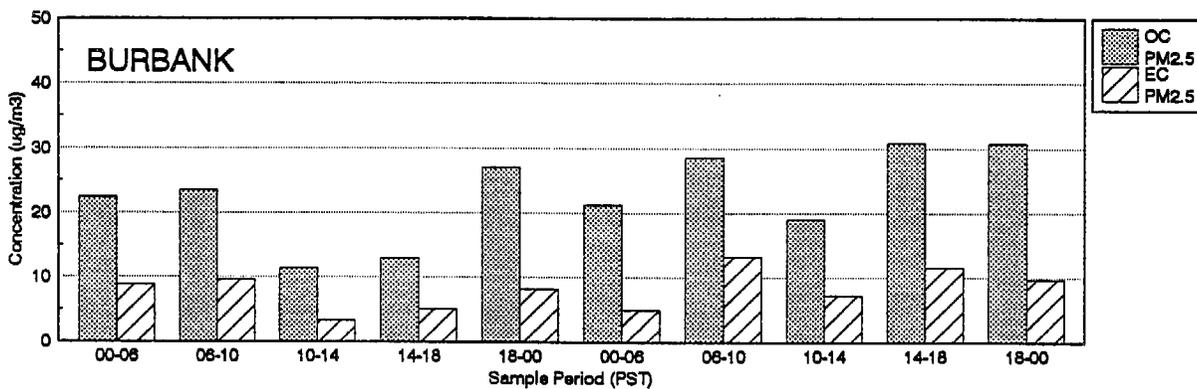
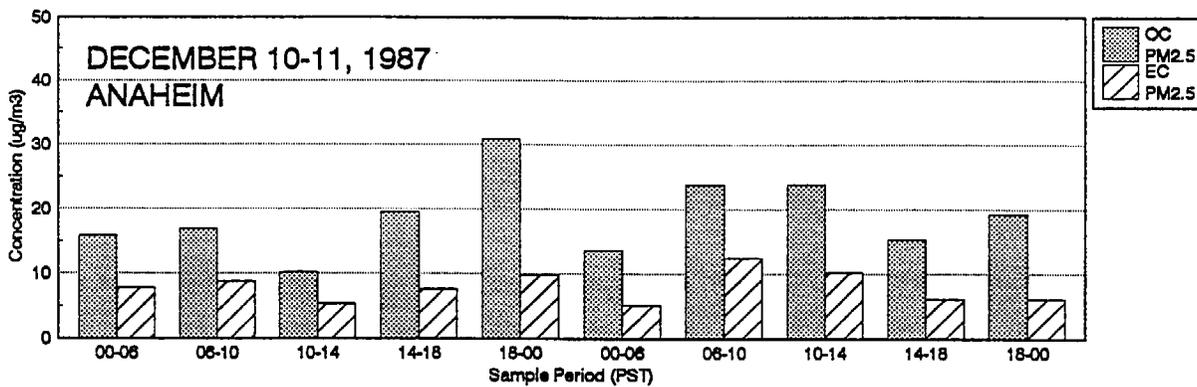


Figure 5-17. PM_{2.5} Organic and Elemental Carbon Concentrations on December 10-11, 1987 at Anaheim, Burbank, and Hawthorne.

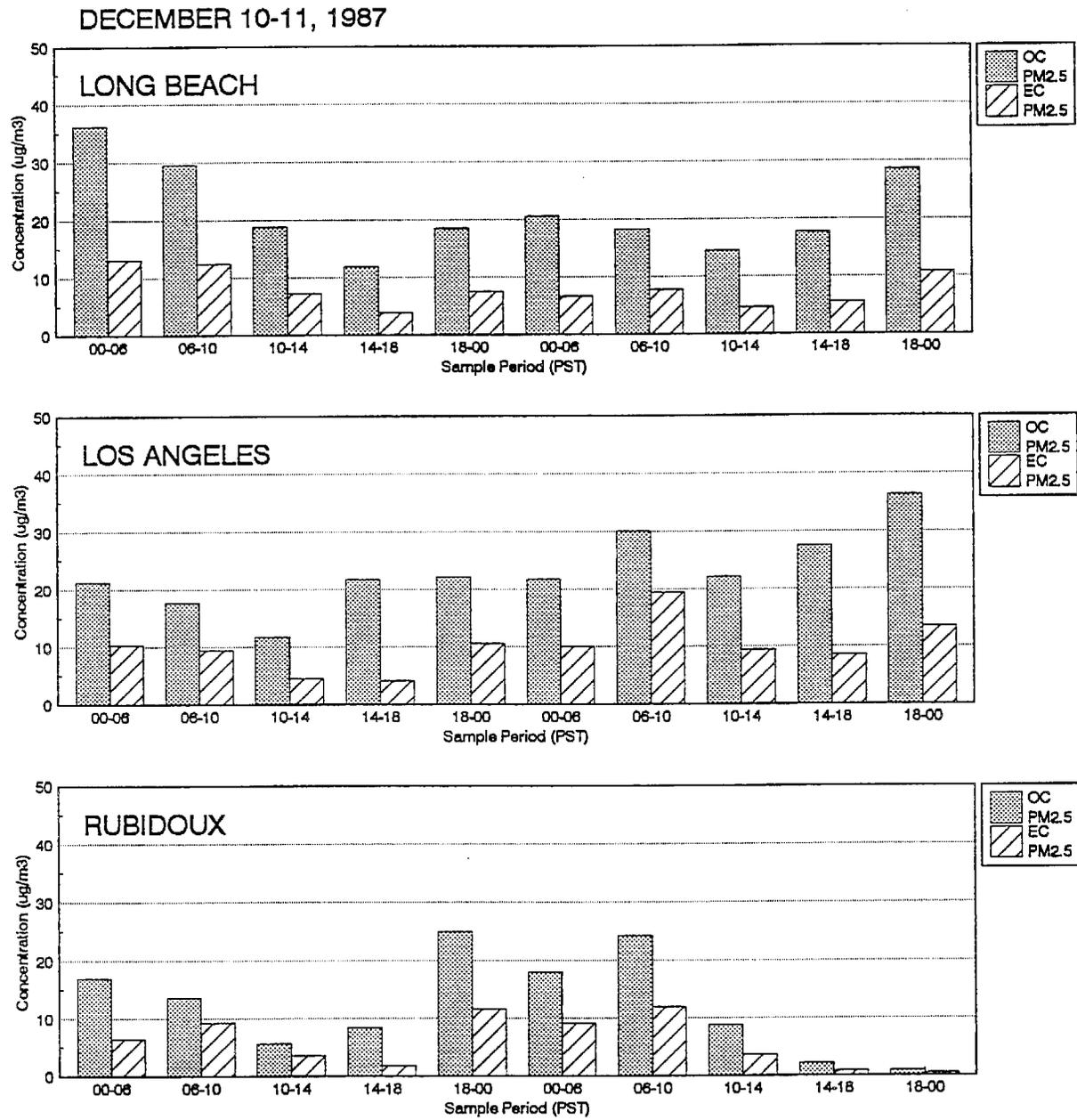


Figure 5-18. PM_{2.5} Organic and Elemental Carbon Concentrations on December 10-11, 1987 at Long Beach, Los Angeles, and Rubidoux.

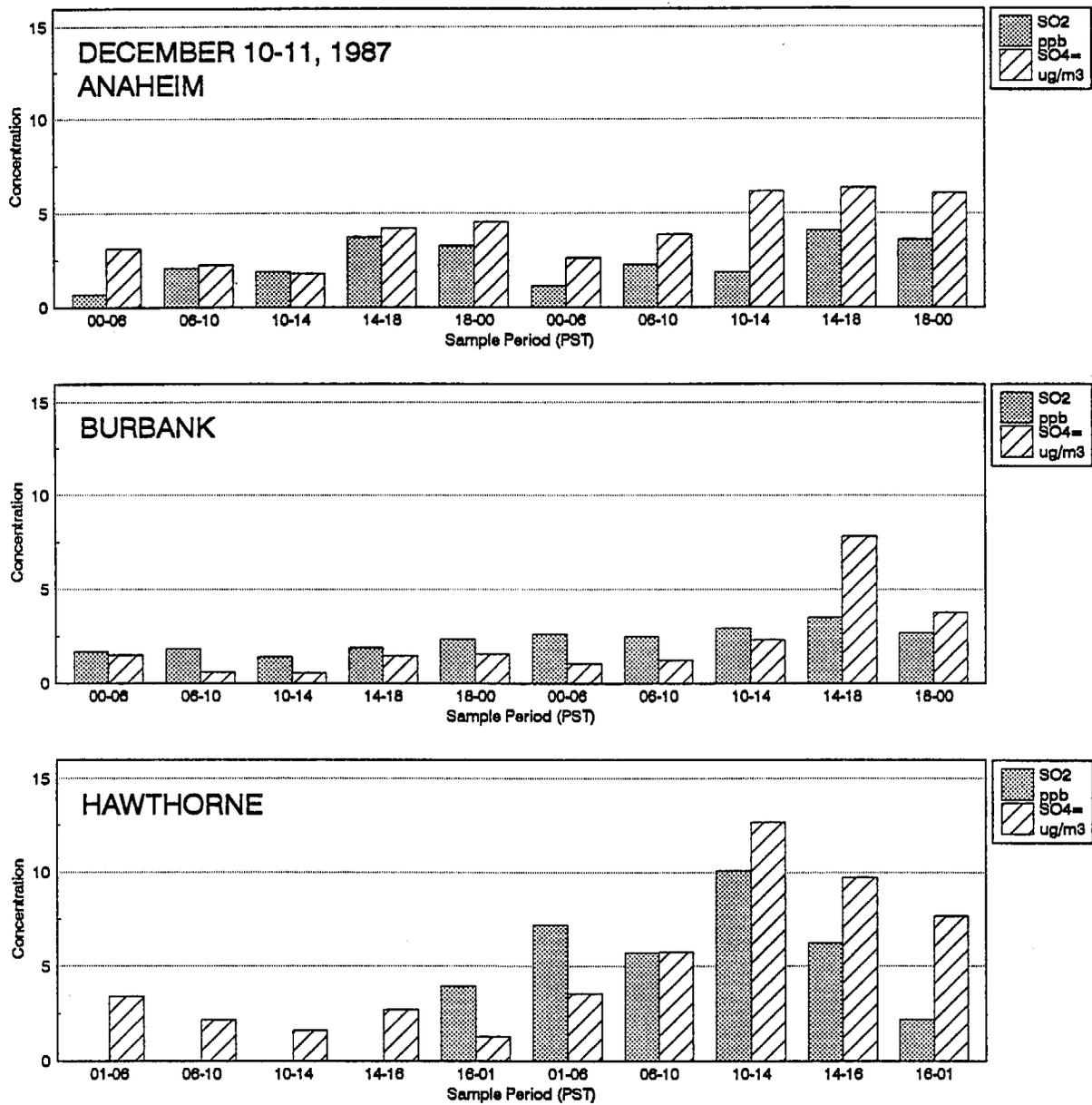


Figure 5-19. SO₂ and PM_{2.5} Sulfate Ion Concentrations on December 10-11, 1987 at Anaheim, Burbank, and Hawthorne.

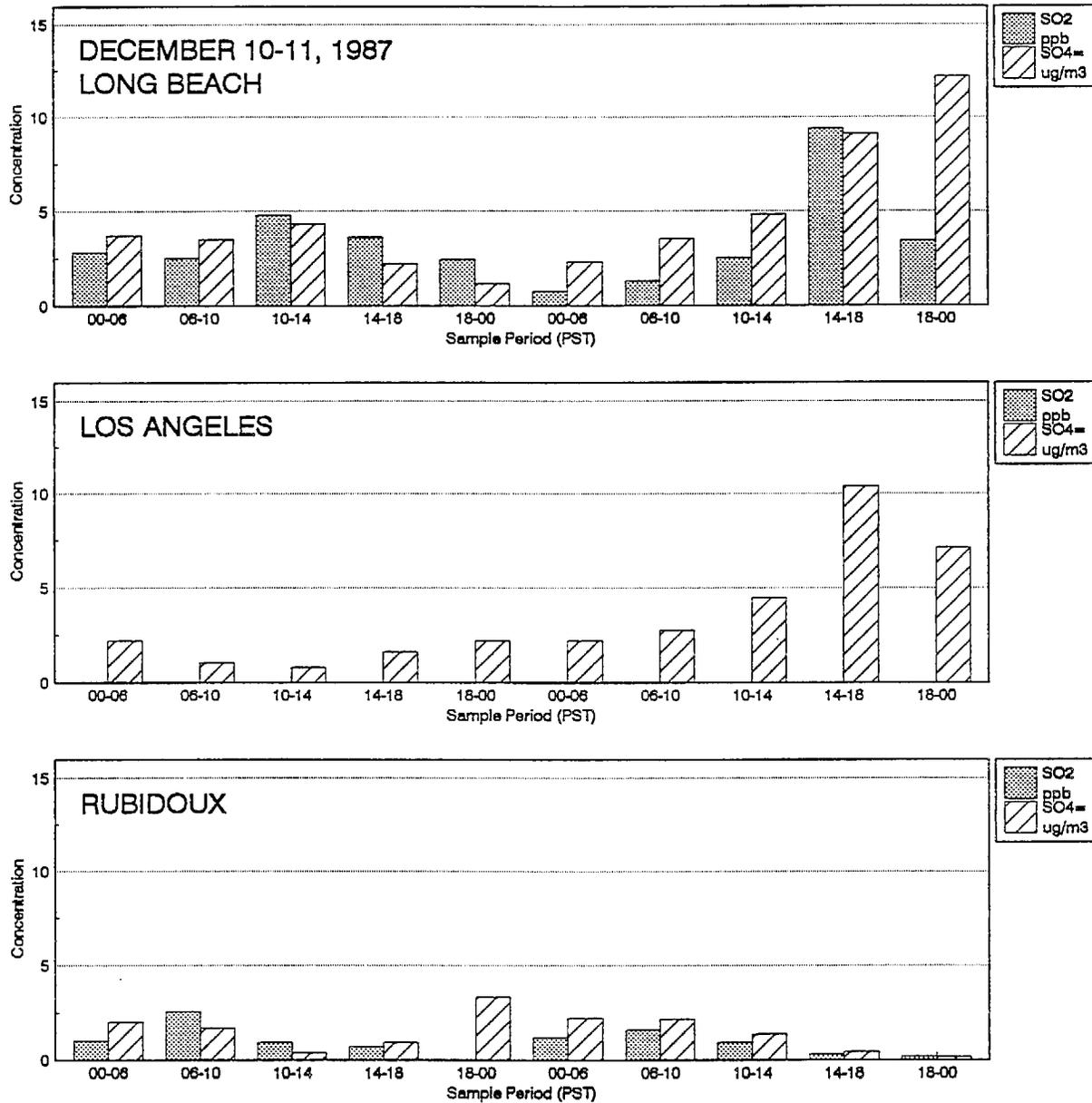


Figure 5-20. SO₂ and PM_{2.5} Sulfate Ion Concentrations on December 10-11, 1987 at Long Beach, Los Angeles, and Rubidoux.

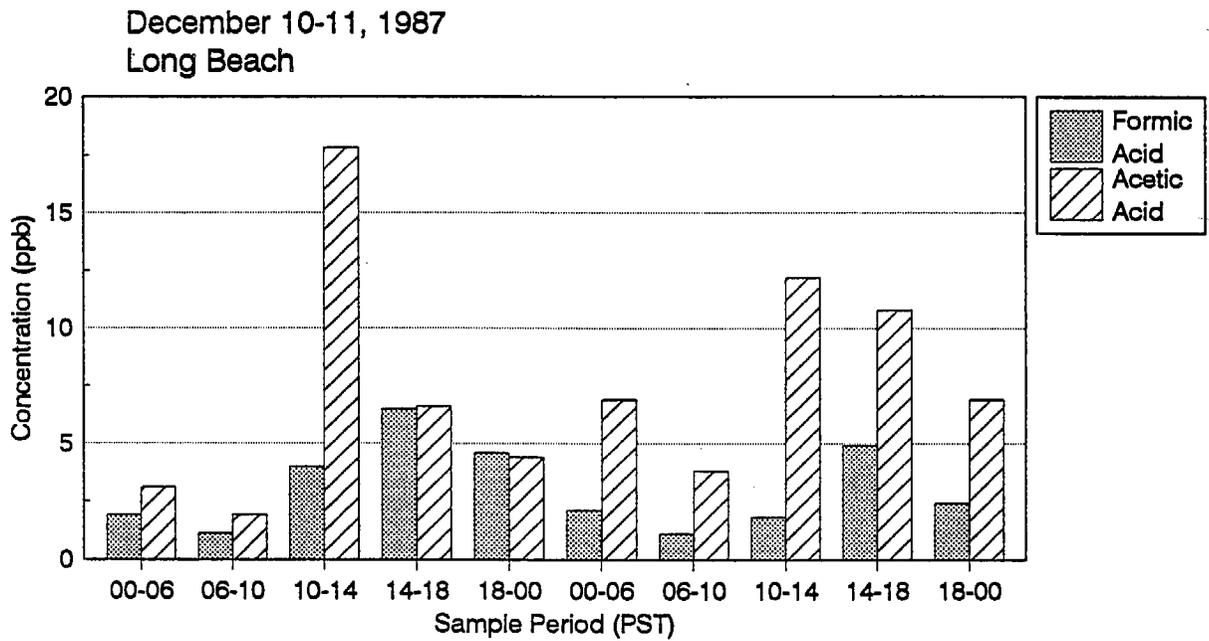


Figure 5-21. Formic and Acetic Acid Concentrations on December 10-11, 1987 at Long Beach.

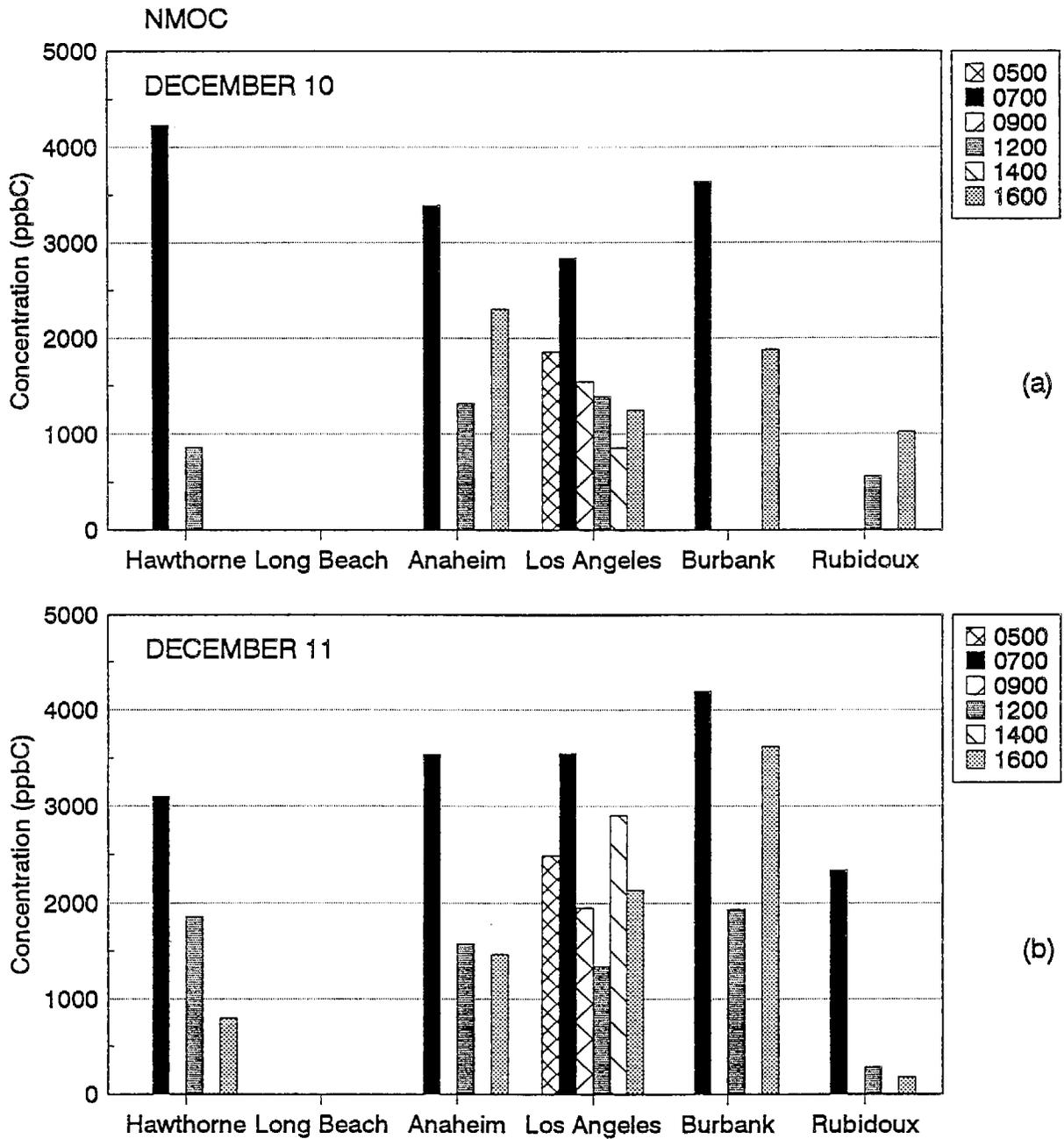


Figure 5-22. Spatial and Temporal Distribution of NMOC Concentrations on (a) December 10 and (b) December 11, 1987. Samples were not taken at all times at all sites and a few samples were invalid (see Section 2.1.3).

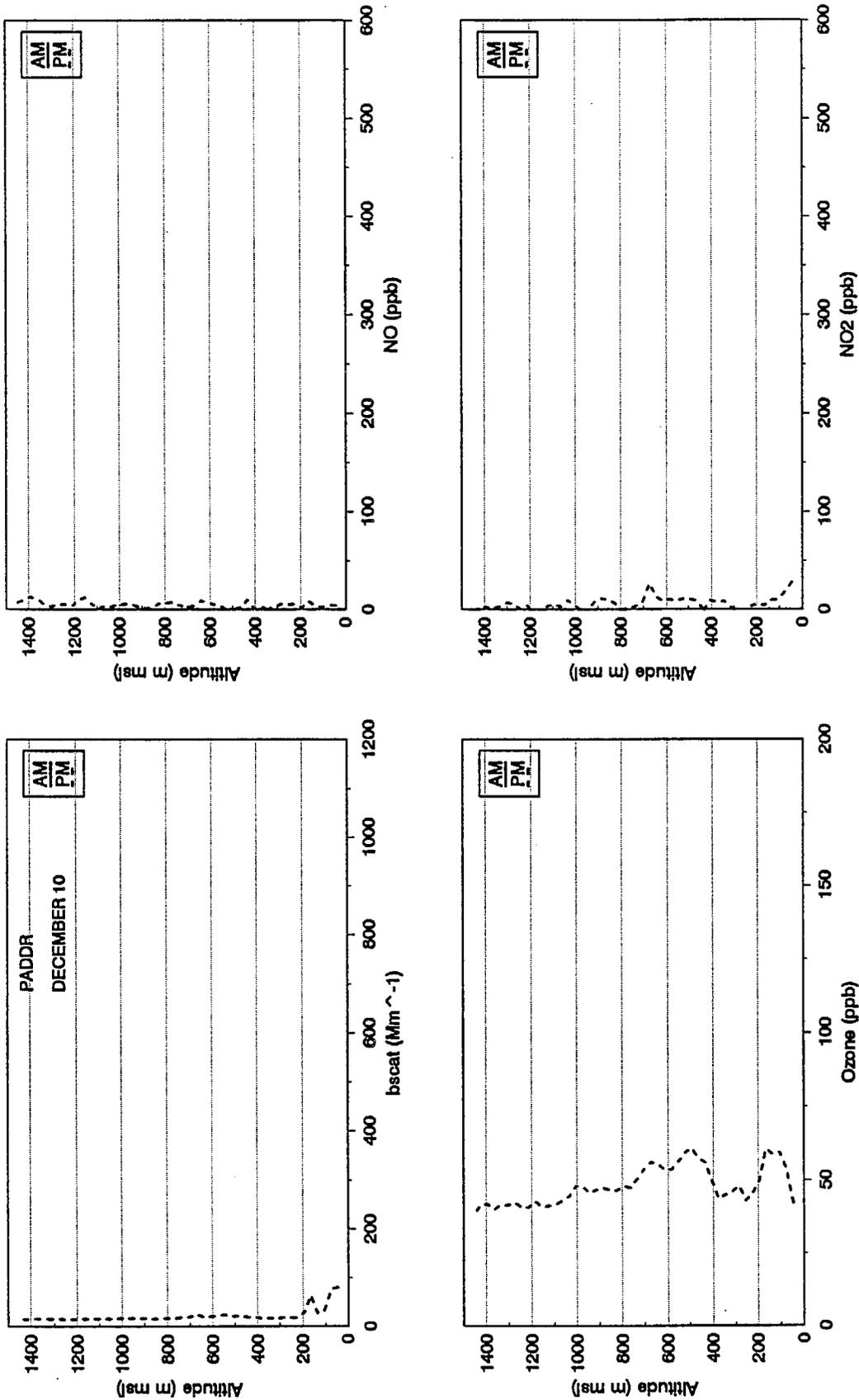


Figure 5-23. Light Scattering (b_{scat}), and Ozone, NO, and NO_x Concentrations for the Afternoon Aircraft Spiral on December 10, 1987 at PADDR. The aircraft did not collect data at PADDR in the morning due to aircraft problems.

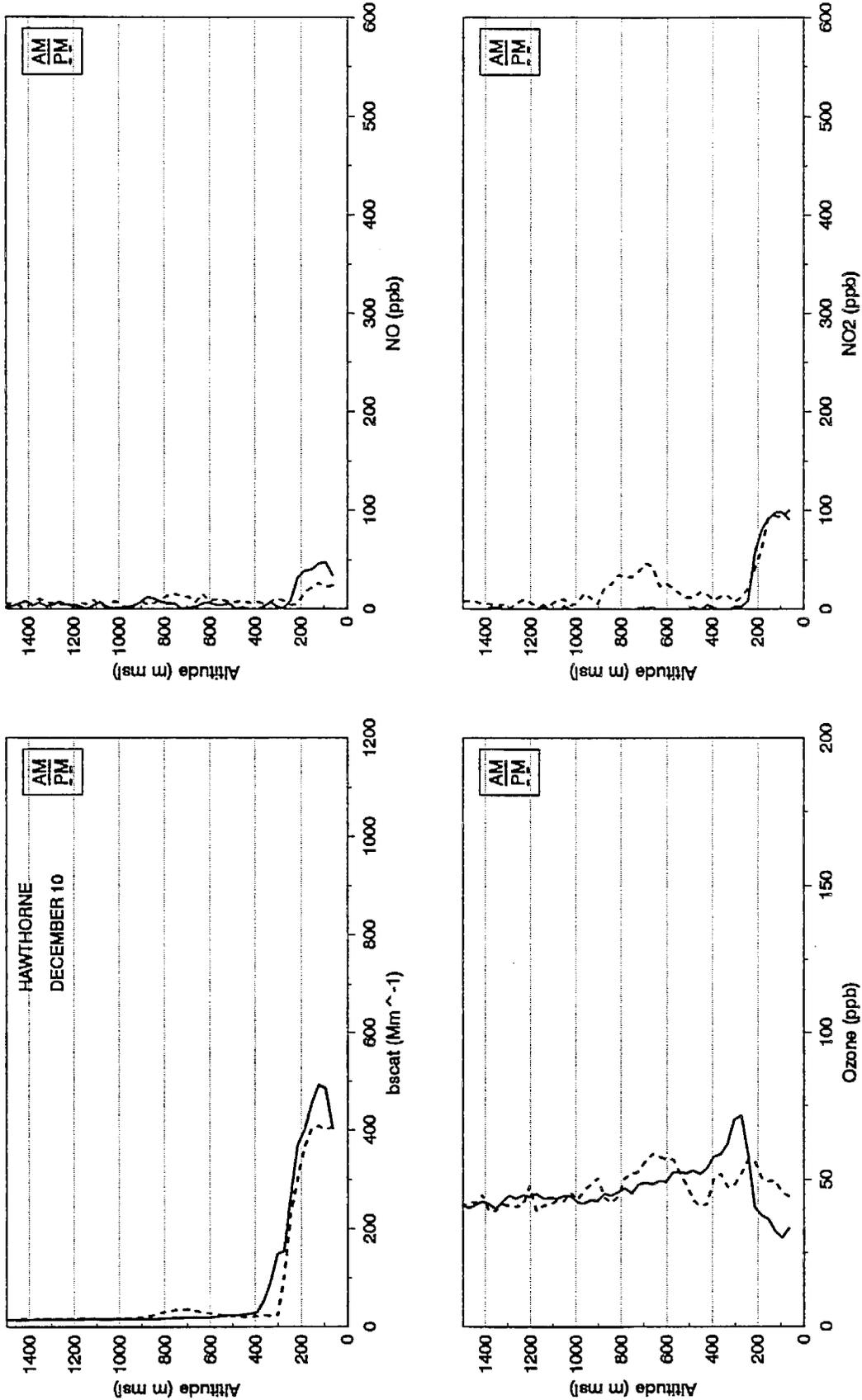


Figure 5-24. Light Scattering (b_{scat}), and Ozone, NO, and NO_x Concentrations for Morning and Afternoon Aircraft Spirals on December 10, 1987 at Hawthorne.

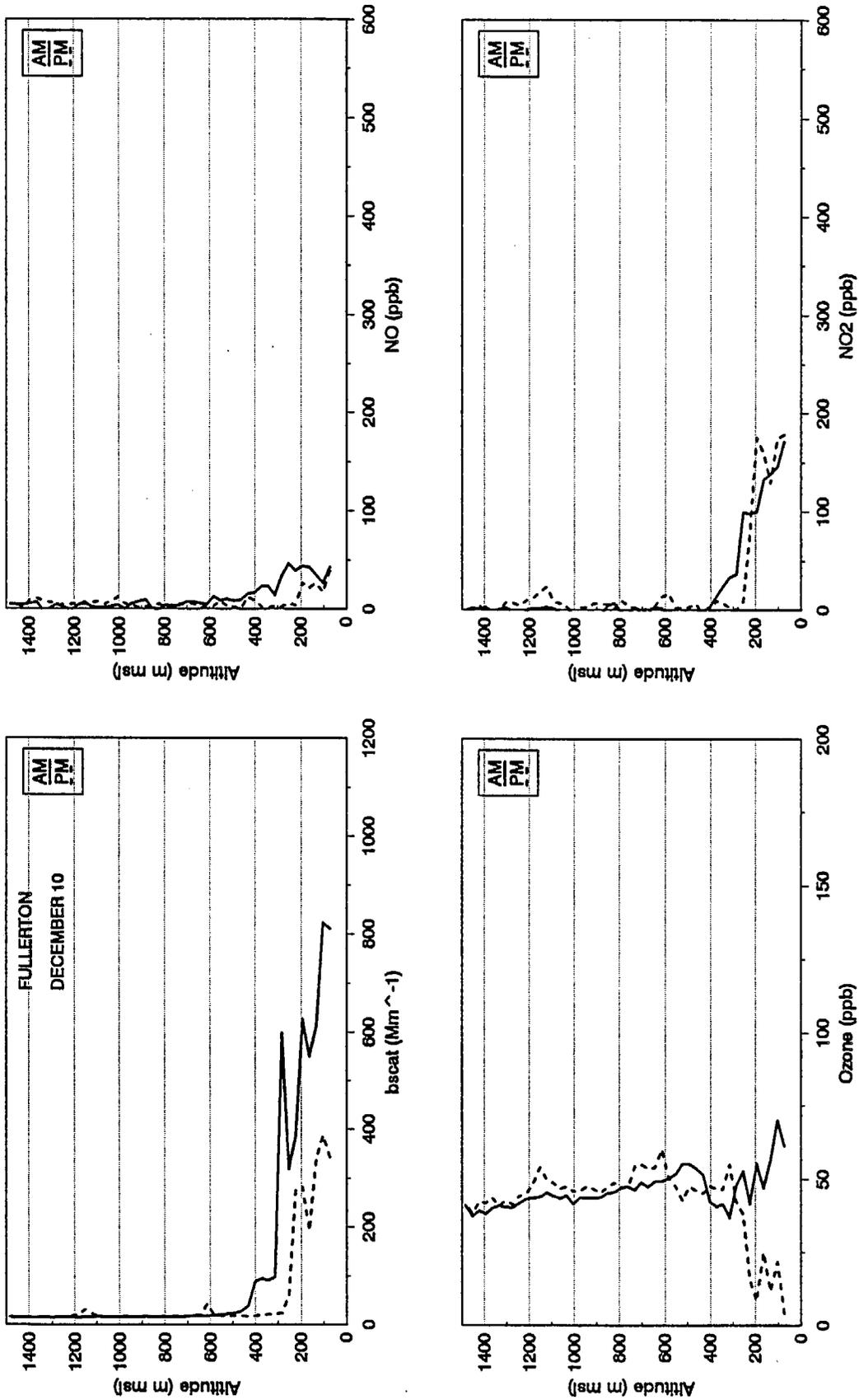


Figure 5-25. Light Scattering (b_{scat}), and Ozone, NO, and NO_x Concentrations for Morning and Afternoon Aircraft Spirals on December 10, 1987 at Fullerton.

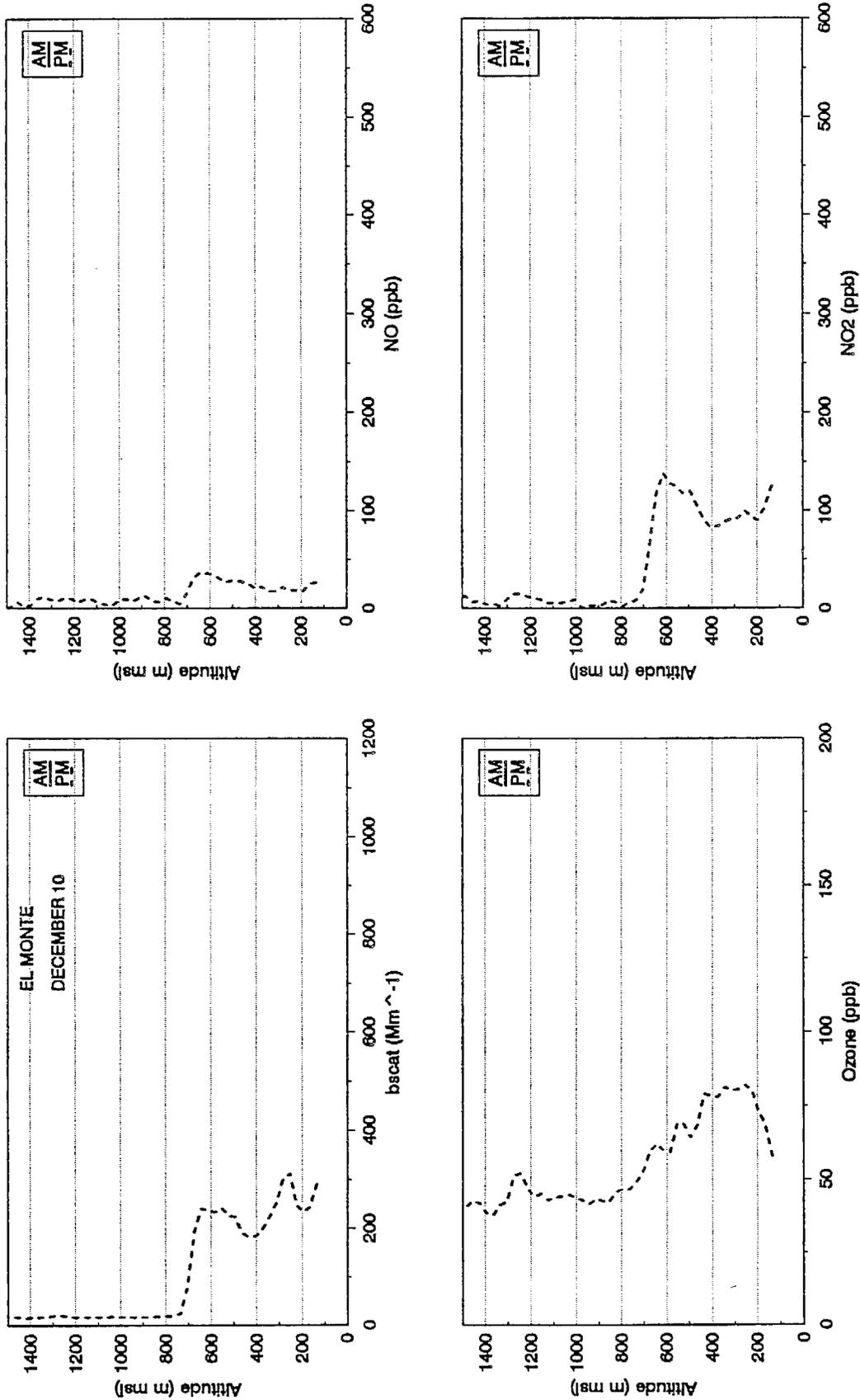


Figure 5-26. Light Scattering (b_{scat}), and Ozone, NO, and NO_x Concentrations for the Afternoon Aircraft Spiral on December 10, 1987 at El Monte. The aircraft did not collect data at El Monte in the morning due to aircraft problems.

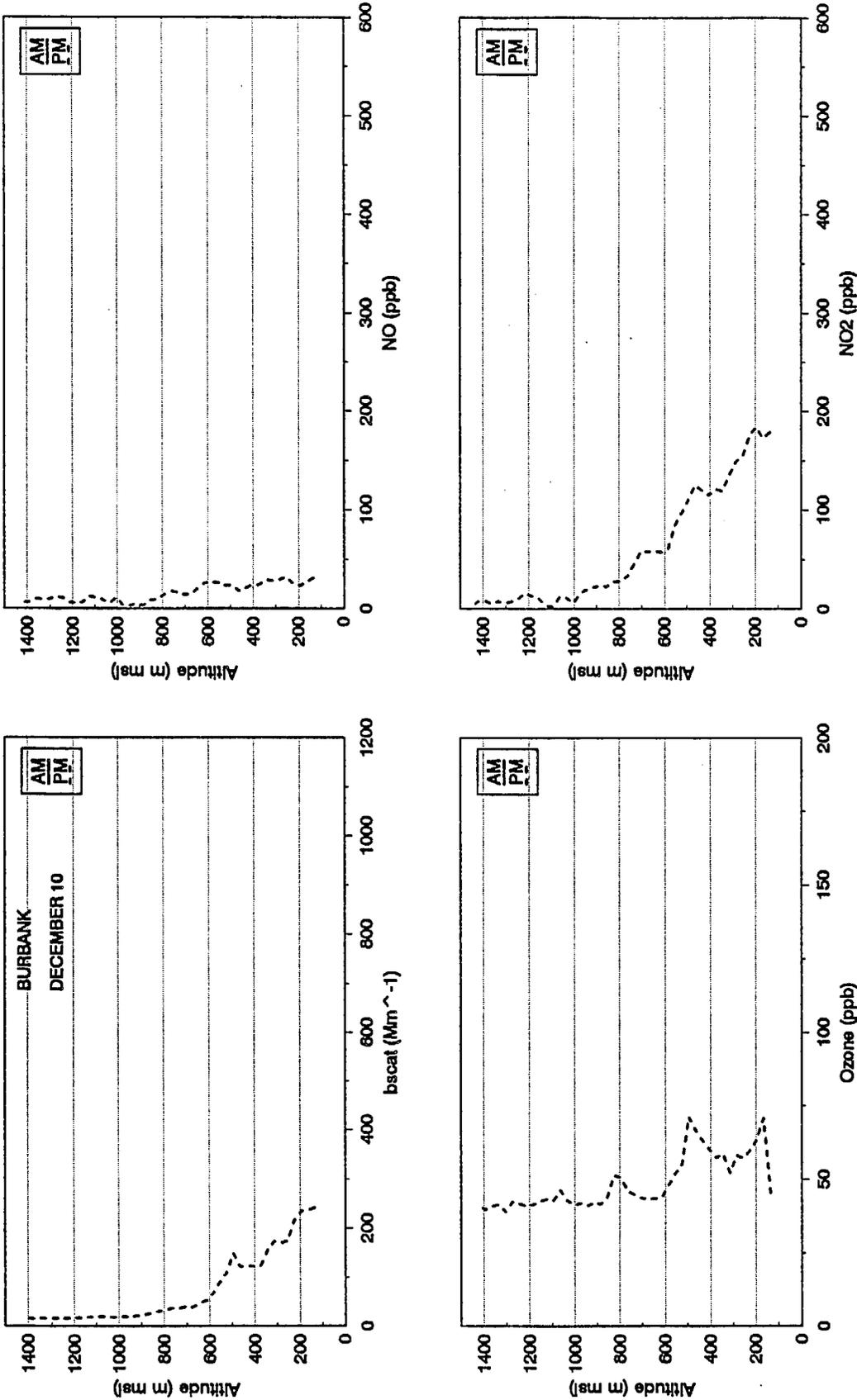


Figure 5-27. Light Scattering (b_{scat}), and Ozone, NO, and NO_x Concentrations for the Afternoon Aircraft Spiral on December 10, 1987 at Burbank. The aircraft did not collect data at Burbank in the morning due to aircraft problems.

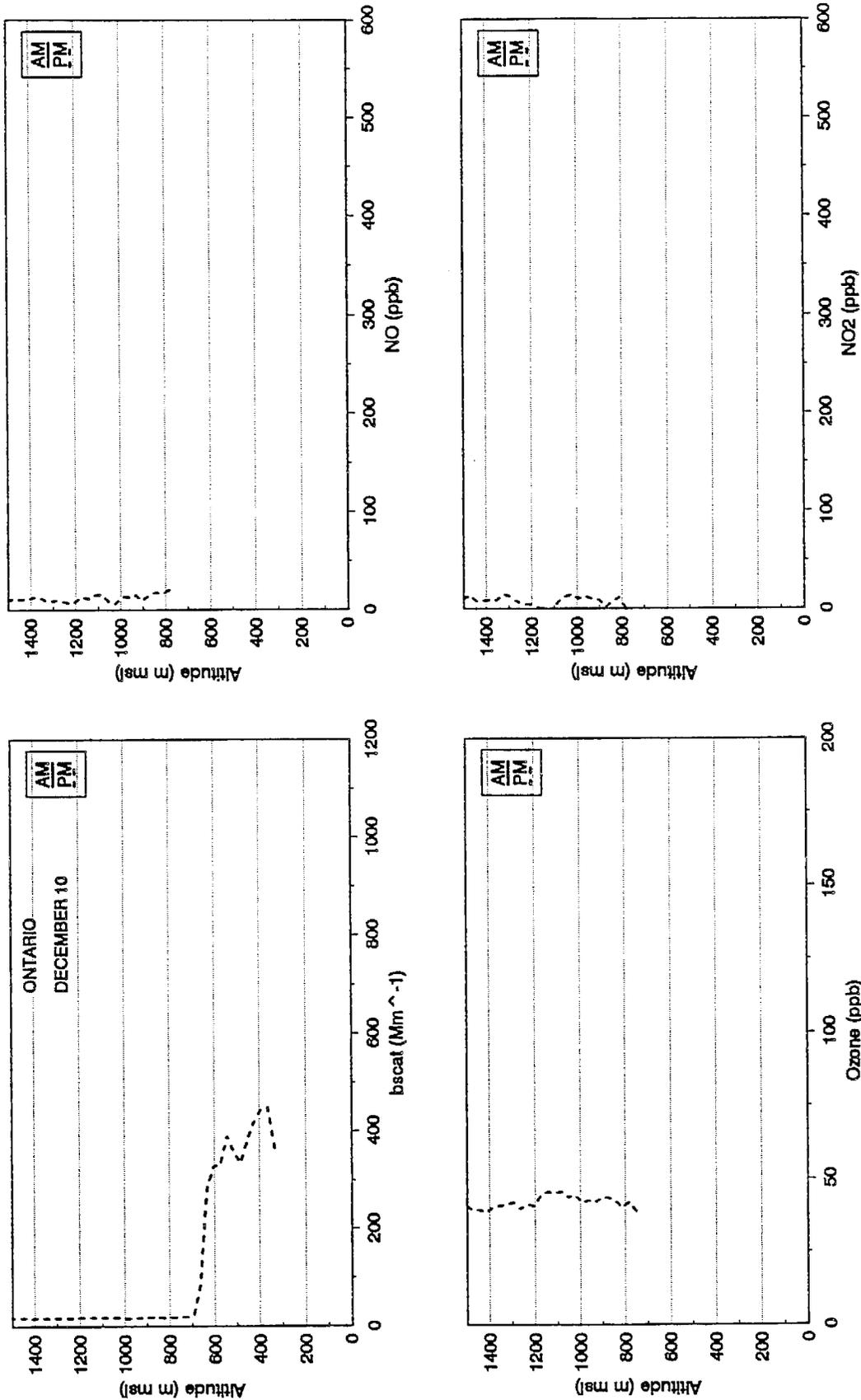


Figure 5-28. Light Scattering (b_{scat}), and Ozone, NO, and NO_x Concentrations for the Afternoon Aircraft Spiral on December 10, 1987 at Ontario. The aircraft did not collect data at Ontario in the morning due to aircraft problems. The ozone, NO, and NO_x data were not collected below about 750 m msl due to instrument problems.

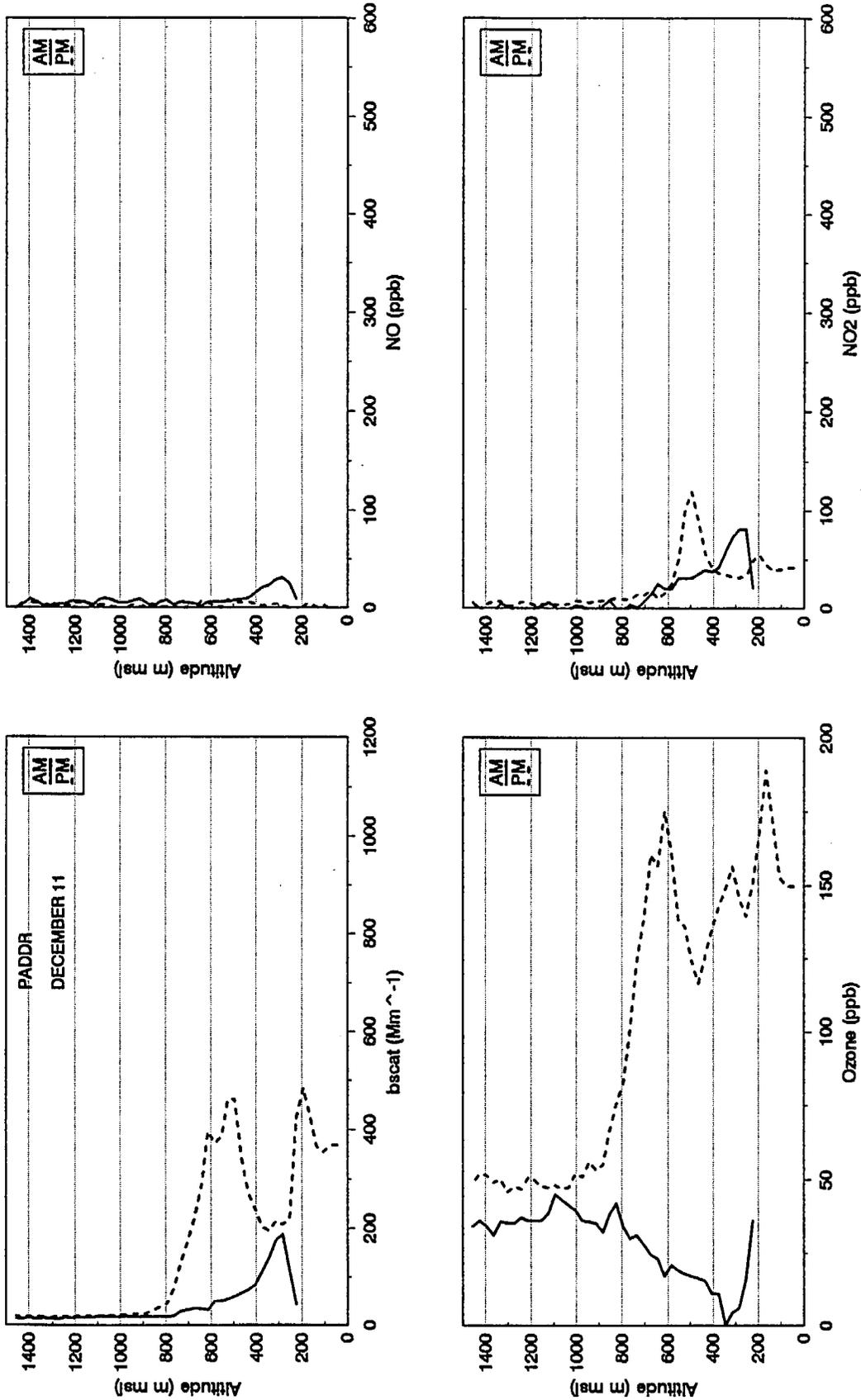


Figure 5-29. Light Scattering (bscat), and Ozone, NO, and NO_x Concentrations for Morning and Afternoon Aircraft Spirals on December 11, 1987 at PADDR.

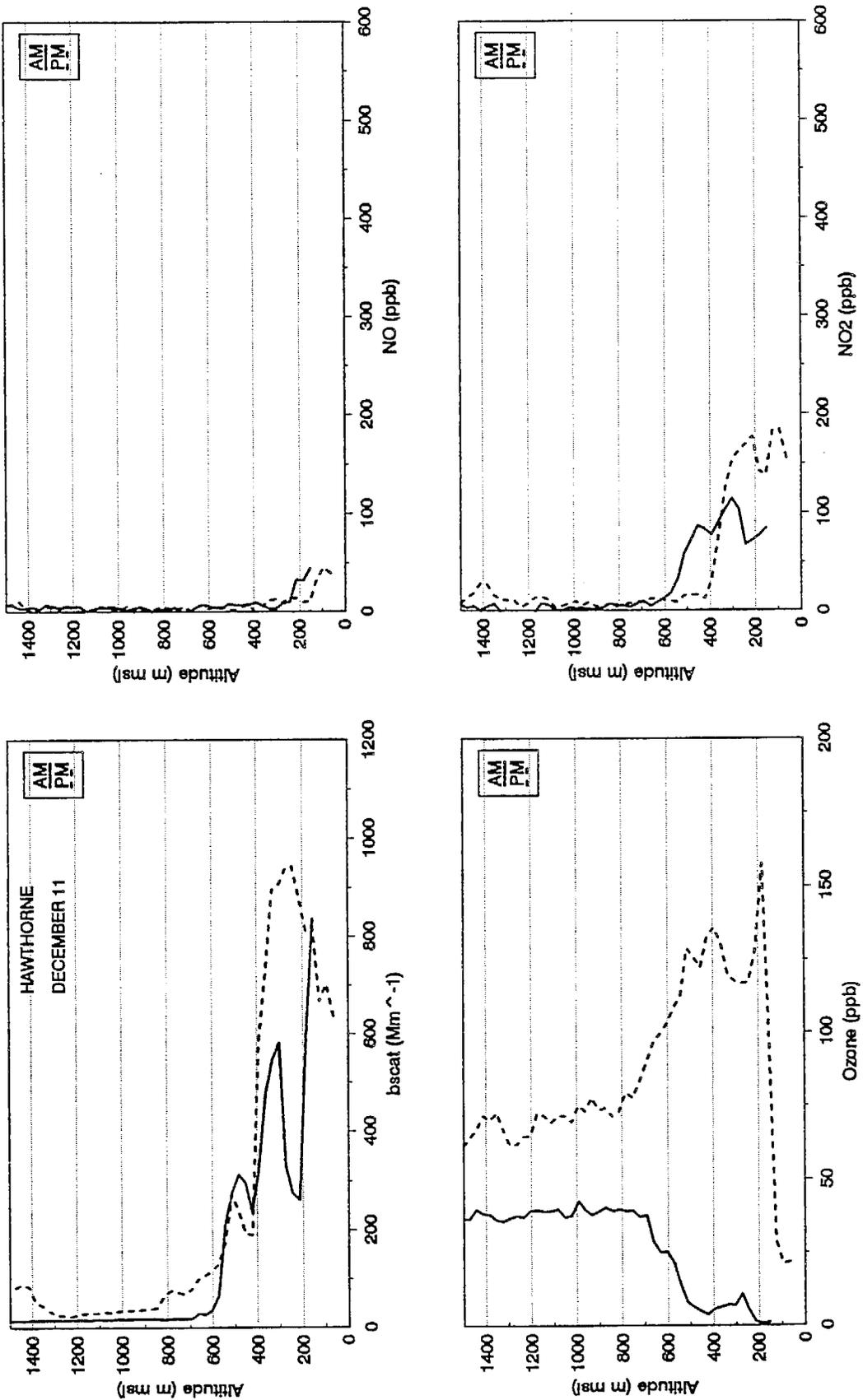


Figure 5-30. Light Scattering (b_{scat}), and Ozone, NO, and NO_x Concentrations for Morning and Afternoon Aircraft Spirals on December 11, 1987 at Hawthorne.

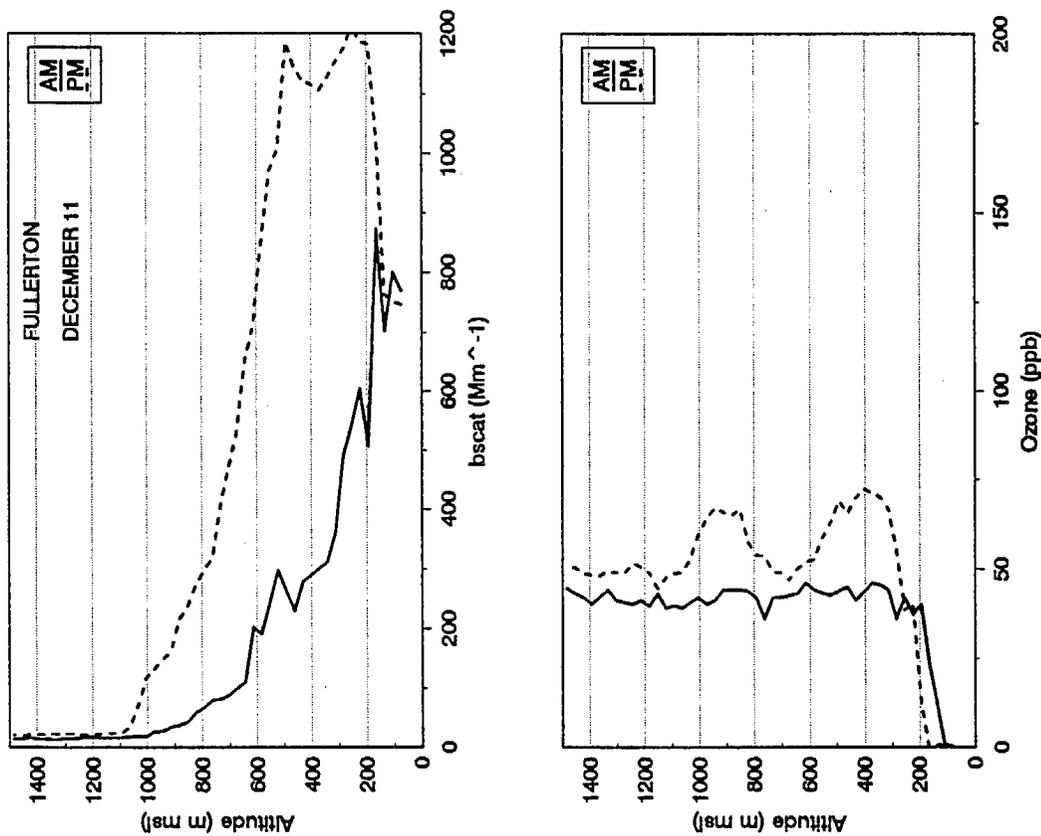
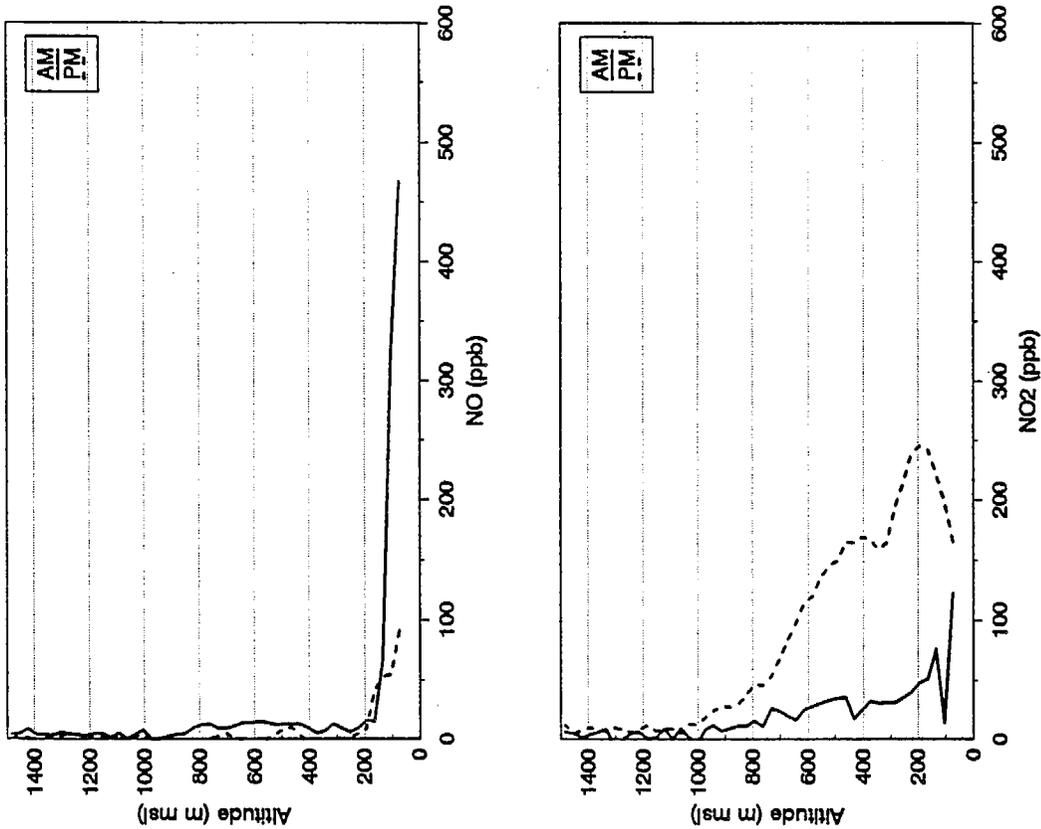


Figure 5-31. Light Scattering (bscaat), and Ozone, NO, and NO_x Concentrations for Morning and Afternoon Aircraft Spirals on December 11, 1987 at Fullerton.

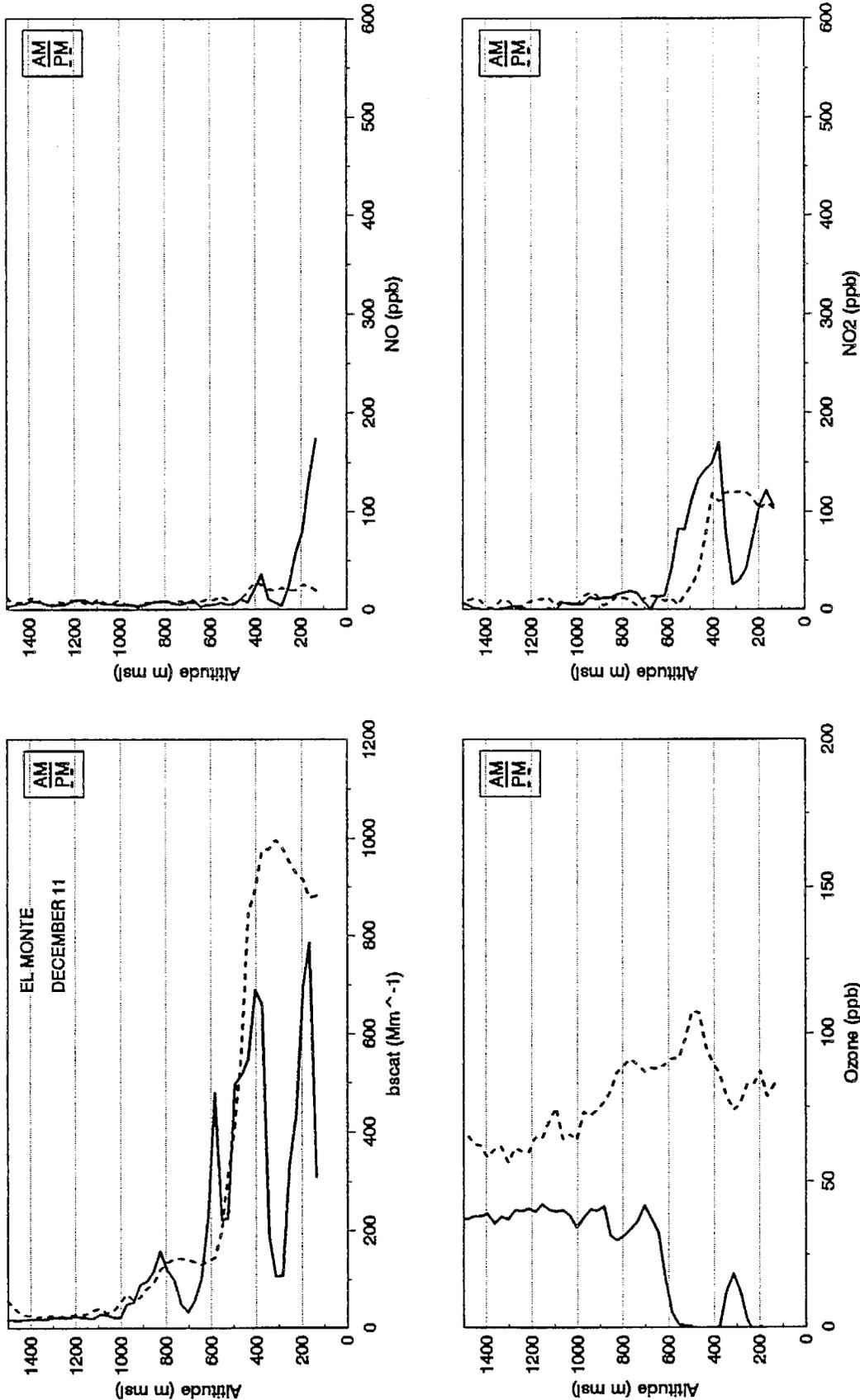


Figure 5-32. Light Scattering (b_{scat}), and Ozone, NO, and NO_x Concentrations for Morning and Afternoon Aircraft Spirals on December 11, 1987 at El Monte.

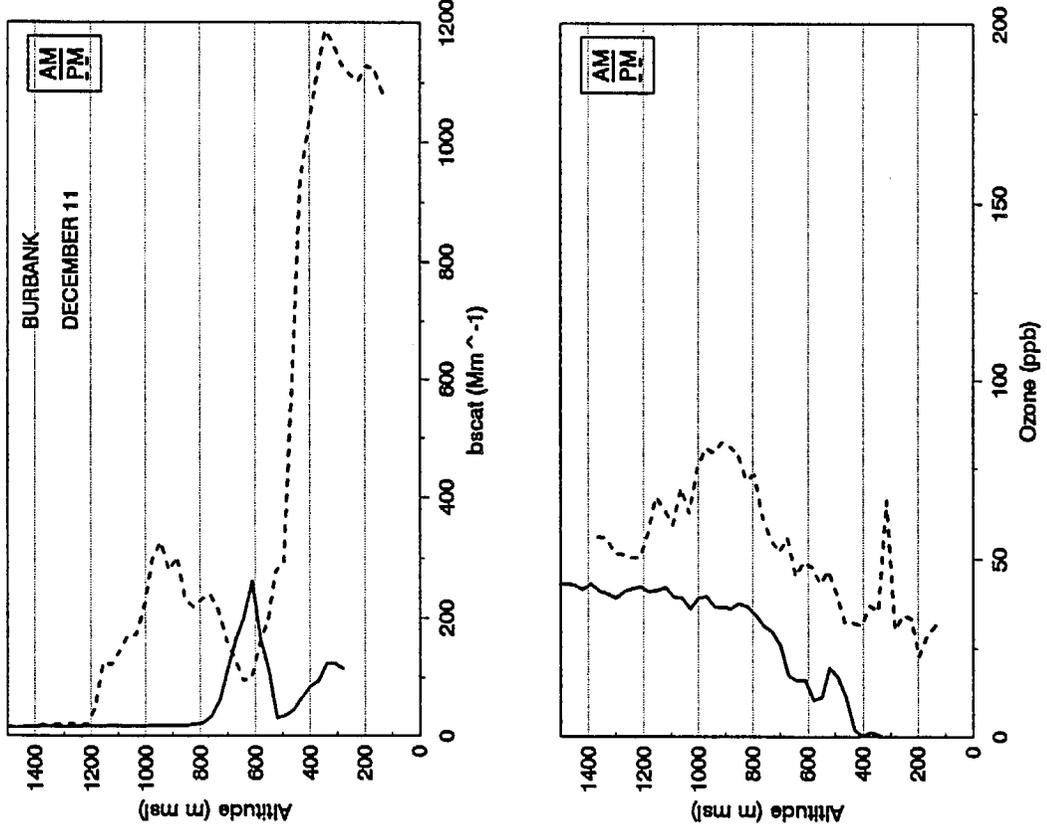
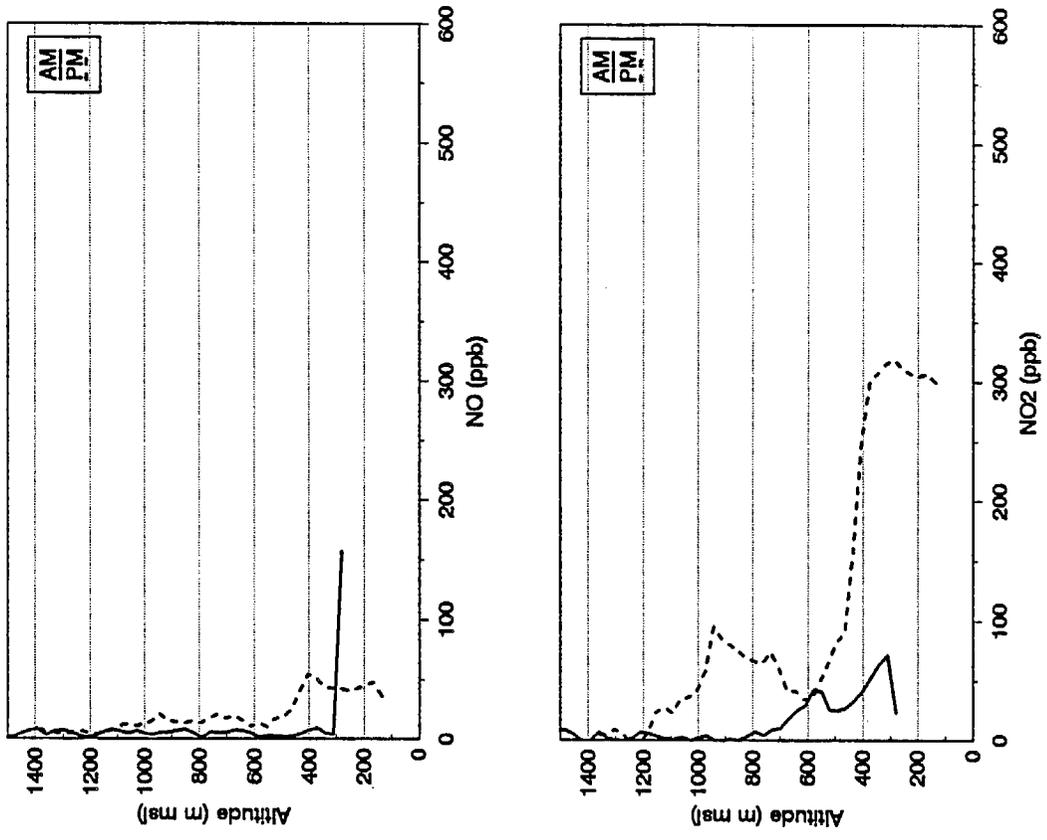


Figure 5-33. Light Scattering (bscat), and Ozone, NO, and NO_x Concentrations for Morning and Afternoon Aircraft Spirals on December 11, 1987 at Burbank.

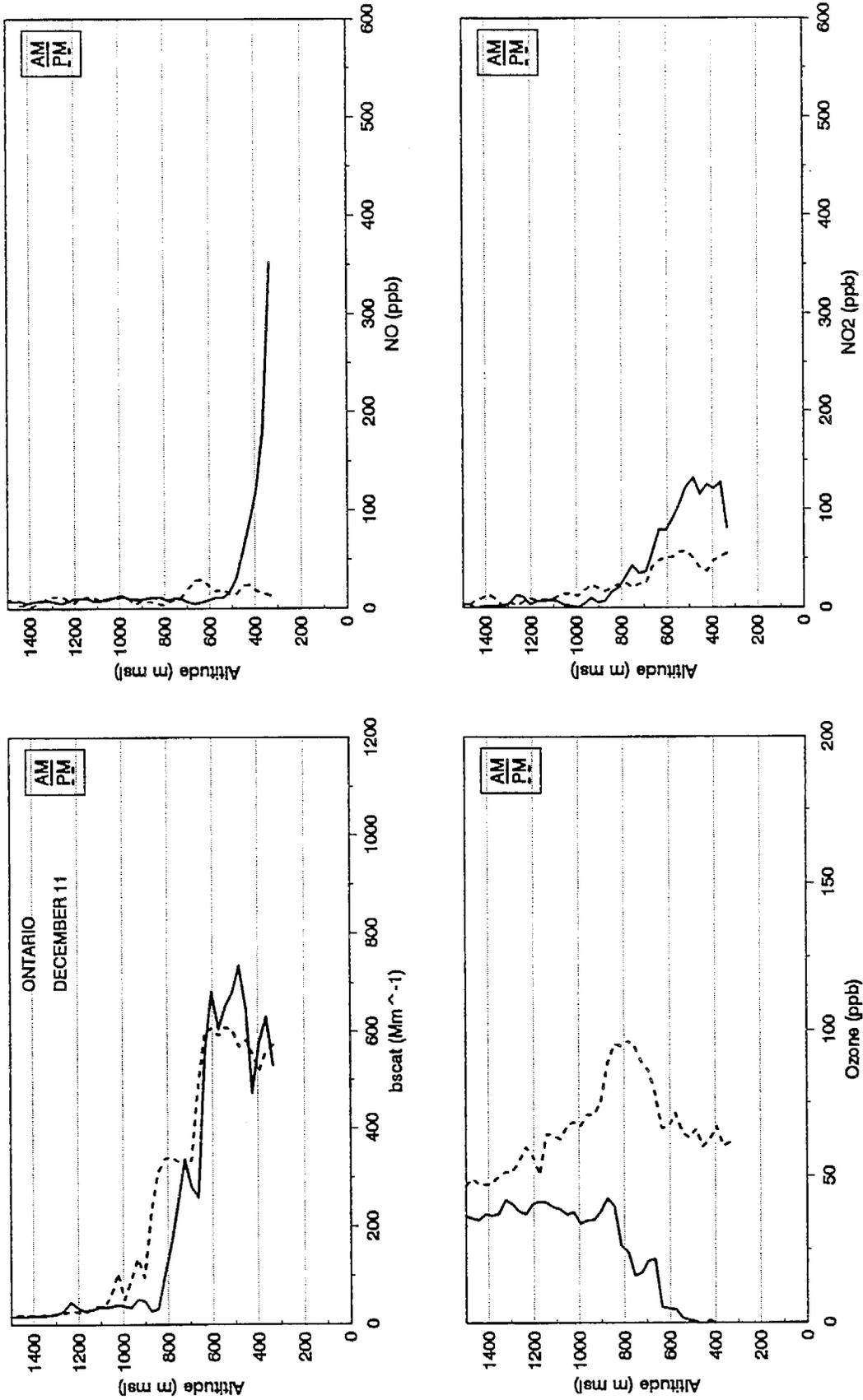
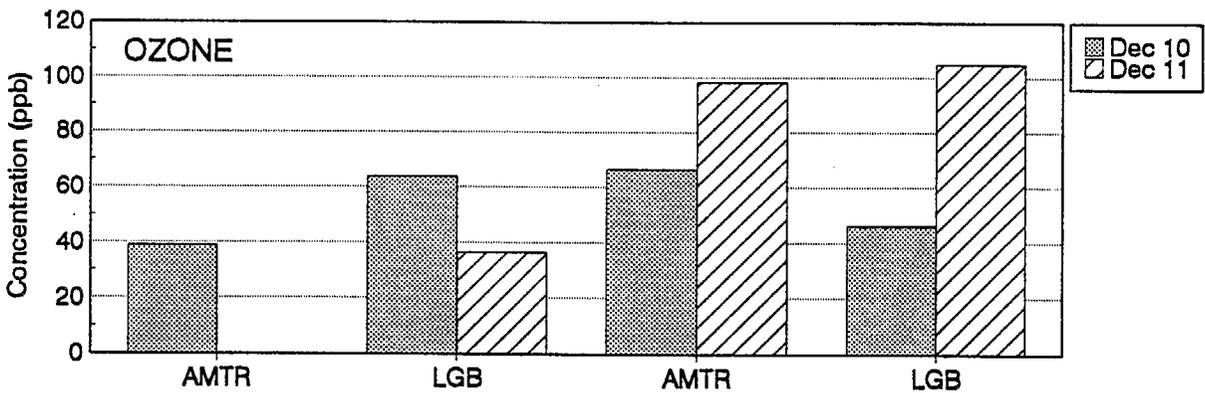
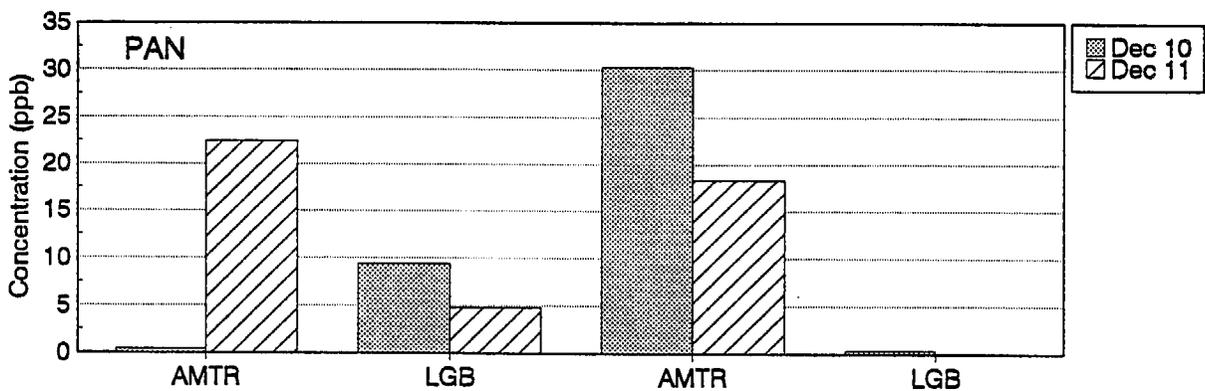
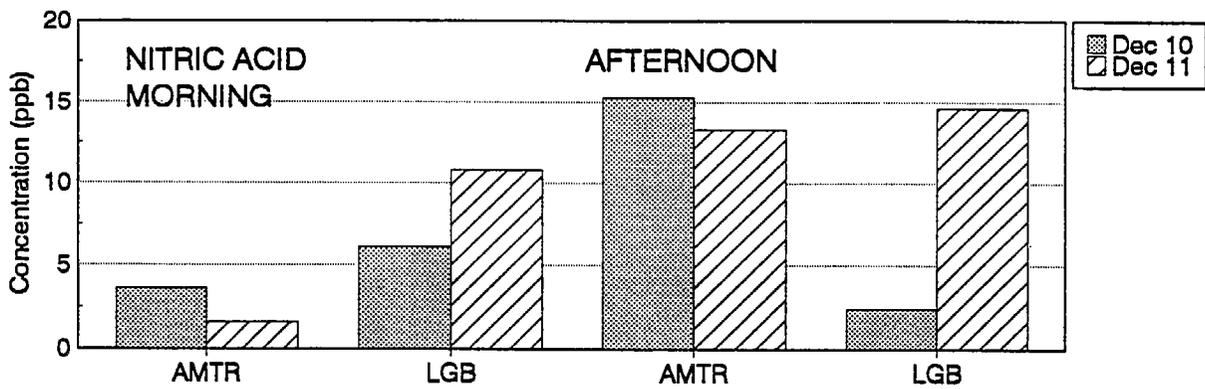
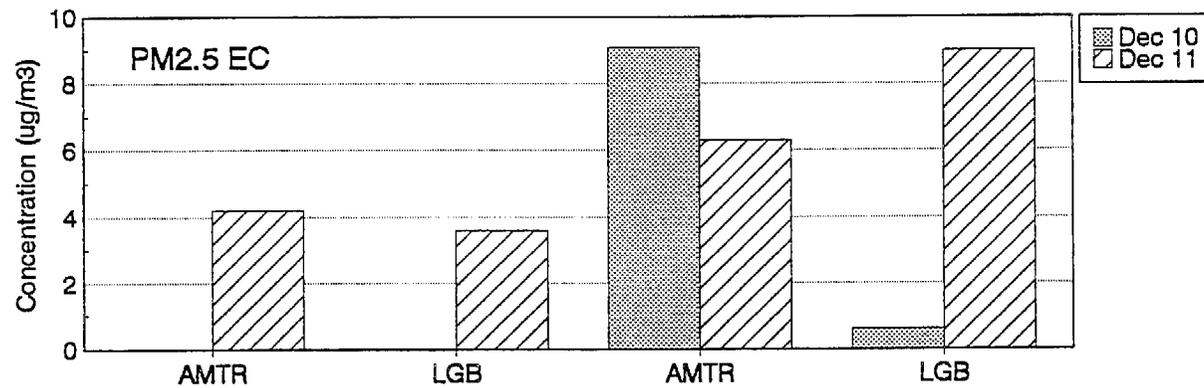
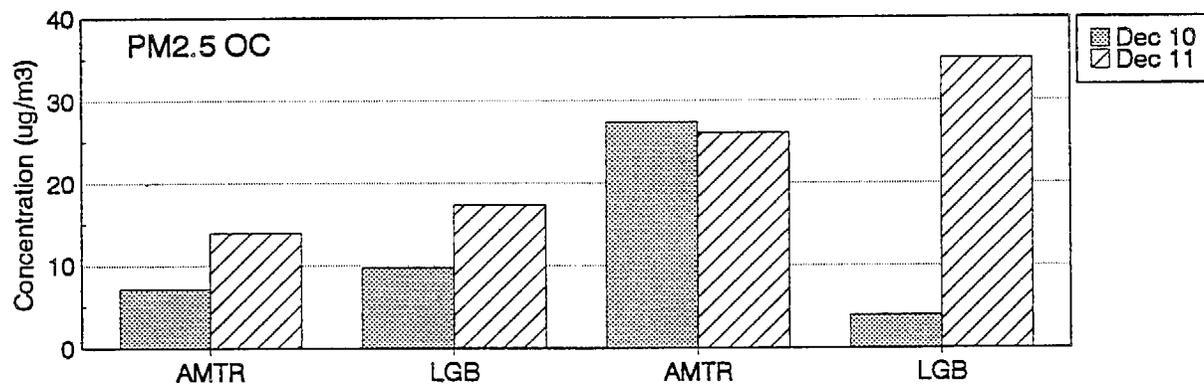
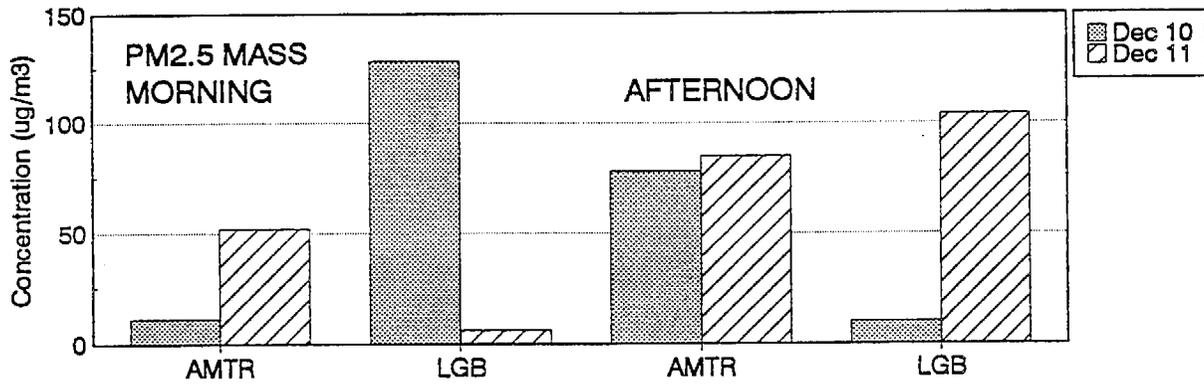


Figure 5-34. Light Scattering (b_{scat}), and Ozone, NO, and NO_x Concentrations for Morning and Afternoon Aircraft Spirals on December 11, 1987 at Ontario.



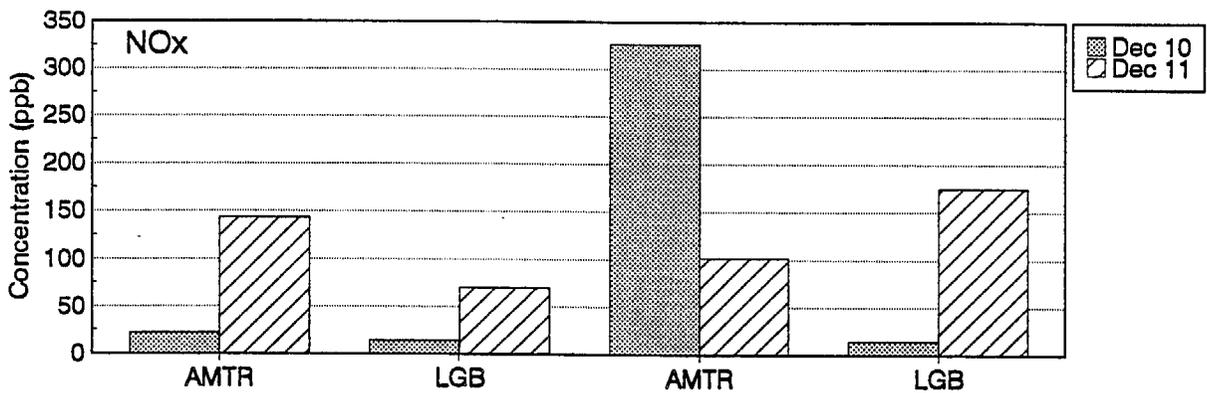
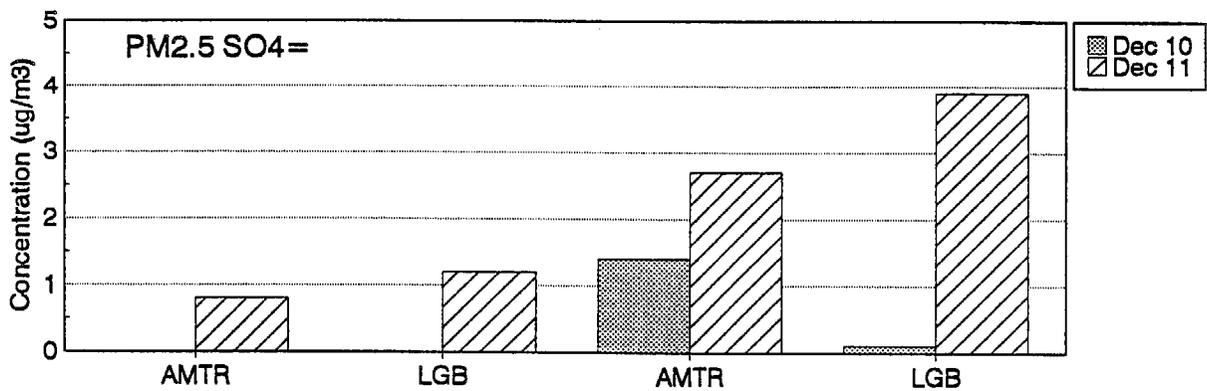
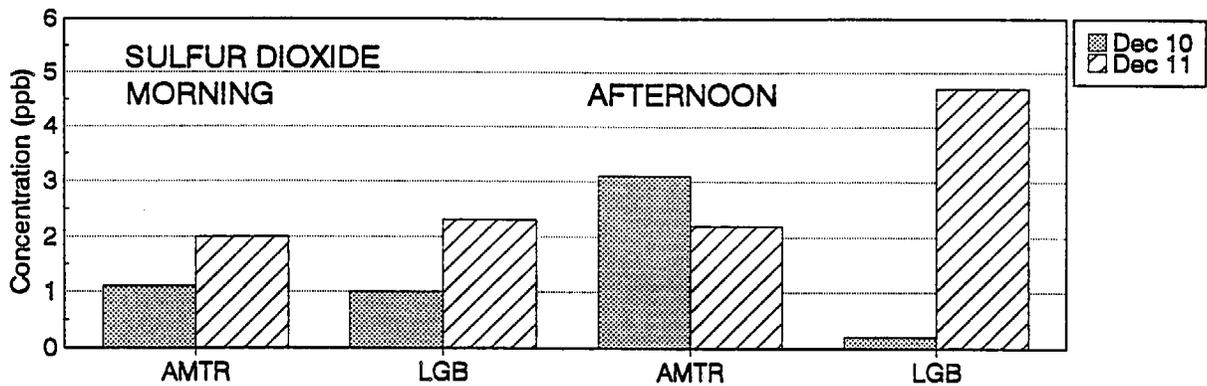
MORNING SAMPLES COLLECTED ABOVE THE MIXED LAYER
 EXCEPT DEC 10 LONG BEACH
 AFTERNOON SAMPLES COLLECTED WITHIN MIXED LAYER

Figure 5-35. Orbit-Averages of Nitric Acid, PAN, and Ozone Measured Aloft on December 10-11 for Each Orbit Location. Morning samples were collected above the mixed layer except the sample collected at Long Beach on December 10. Afternoon samples were collected within the mixed layer.



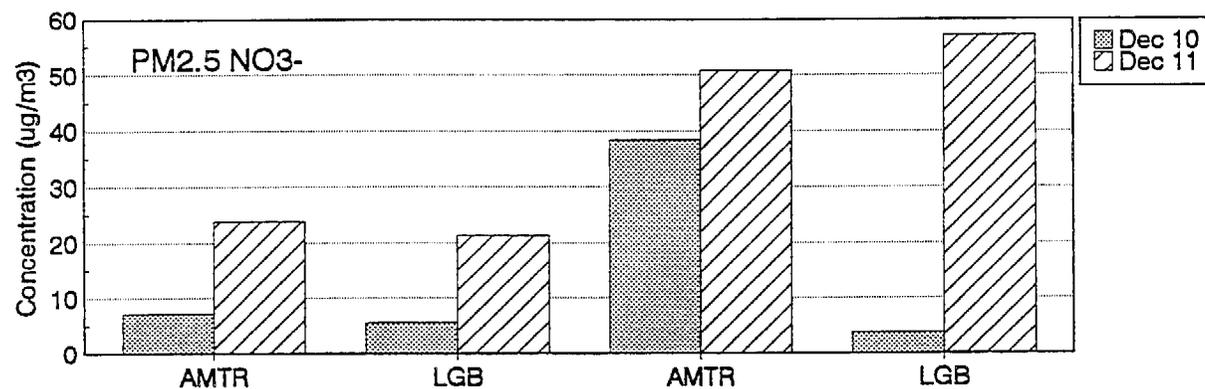
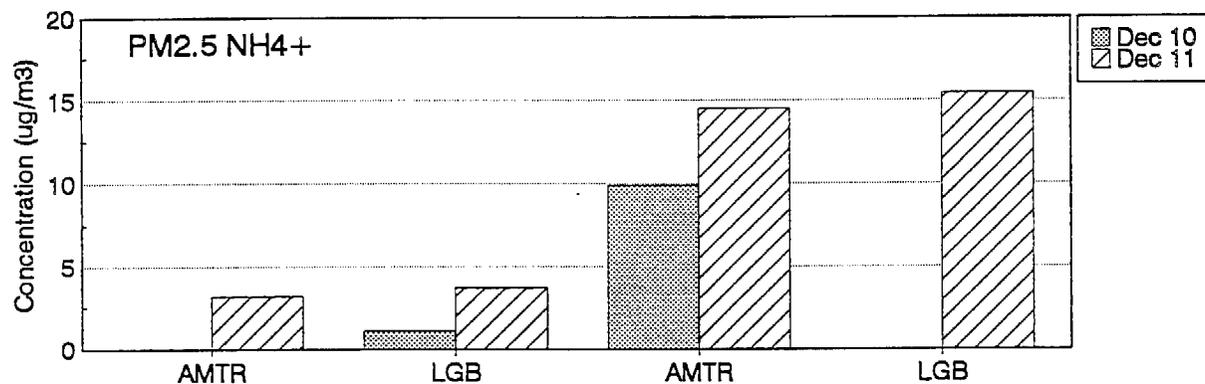
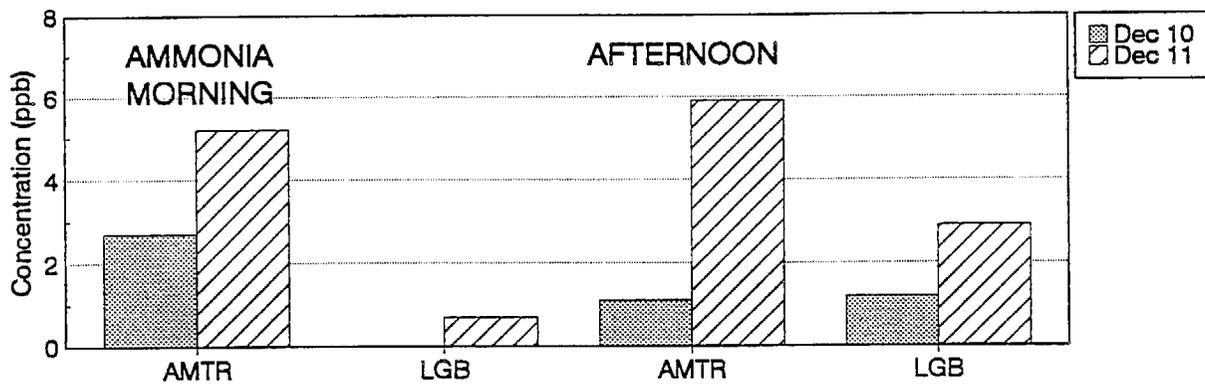
MORNING SAMPLES COLLECTED ABOVE THE MIXED LAYER
 EXCEPT DEC 10 LONG BEACH
 AFTERNOON SAMPLES COLLECTED WITHIN MIXED LAYER

Figure 5-36. Orbit-Averages of PM_{2.5} Mass, Organic Carbon, and Elemental Carbon Measured Aloft on December 10-11 for Each Orbit Location. Morning samples were collected above the mixed layer except the sample collected at Long Beach on December 10. Afternoon samples were collected within the mixed layer.



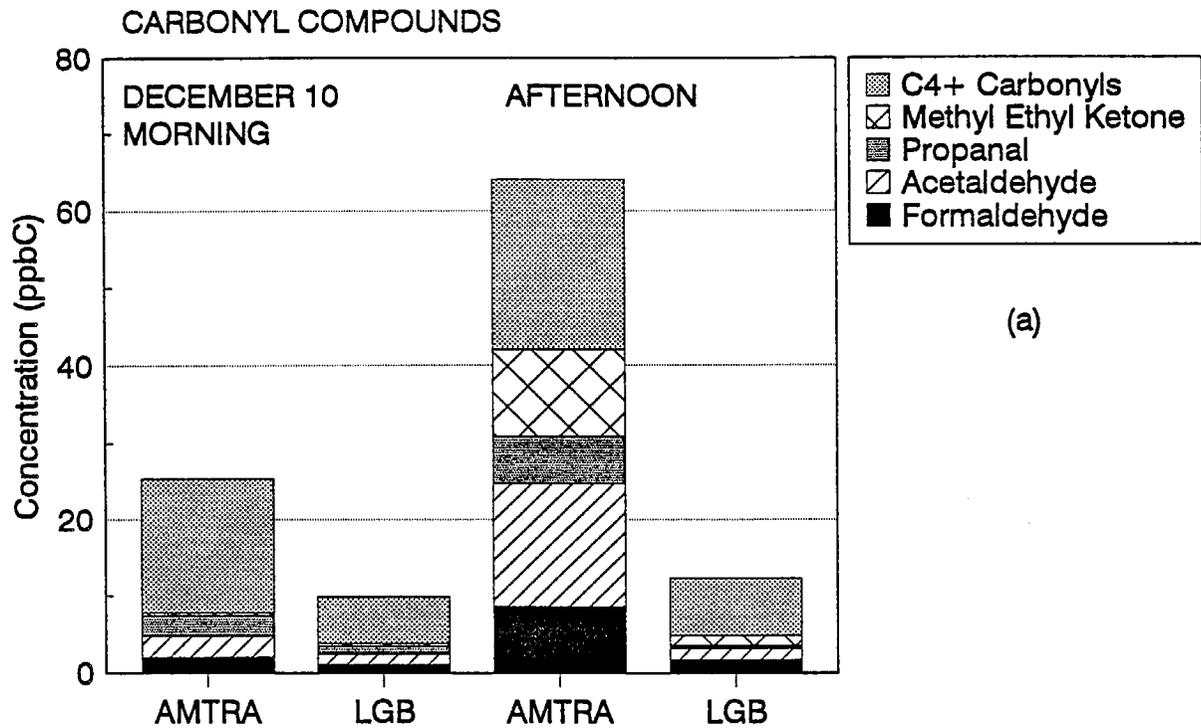
MORNING SAMPLES COLLECTED ABOVE THE MIXED LAYER
 EXCEPT DEC 10 LONG BEACH
 AFTERNOON SAMPLES COLLECTED WITHIN MIXED LAYER

Figure 5-37. Orbit-Averages of SO₂, PM_{2.5} Sulfate Ion, and NO_x Measured Aloft on December 10-11 for Each Orbit Location. Morning samples were collected above the mixed layer except the sample collected at Long Beach on December 10. Afternoon samples were collected within the mixed layer.

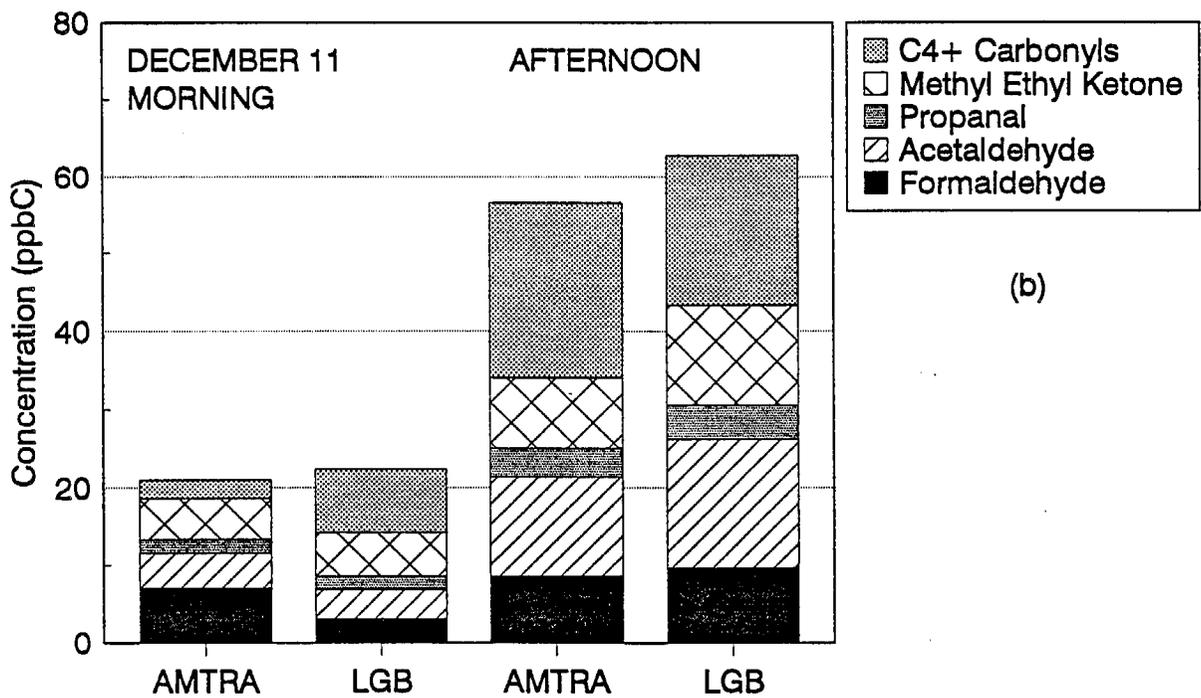


MORNING SAMPLES COLLECTED ABOVE THE MIXED LAYER
 EXCEPT DEC 10 LONG BEACH
 AFTERNOON SAMPLES COLLECTED WITHIN MIXED LAYER

Figure 5-38. Orbit-Averages of Ammonia and PM_{2.5} Ammonium and Nitrate Ions Measured Aloft on December 10-11 for Each Orbit Location. Morning samples were collected above the mixed layer except the sample collected at Long Beach on December 10. Afternoon samples were collected within the mixed layer.



(a)



(b)

Figure 5-39. Orbit-Averages of Carbonyl Compounds Measured Aloft on December 10-11, 1987. Morning samples were collected above the mixed layer except the morning sample collected at AMTRA on December 10. Afternoon samples were collected within the mixed layer. Acetone was invalid in all samples.

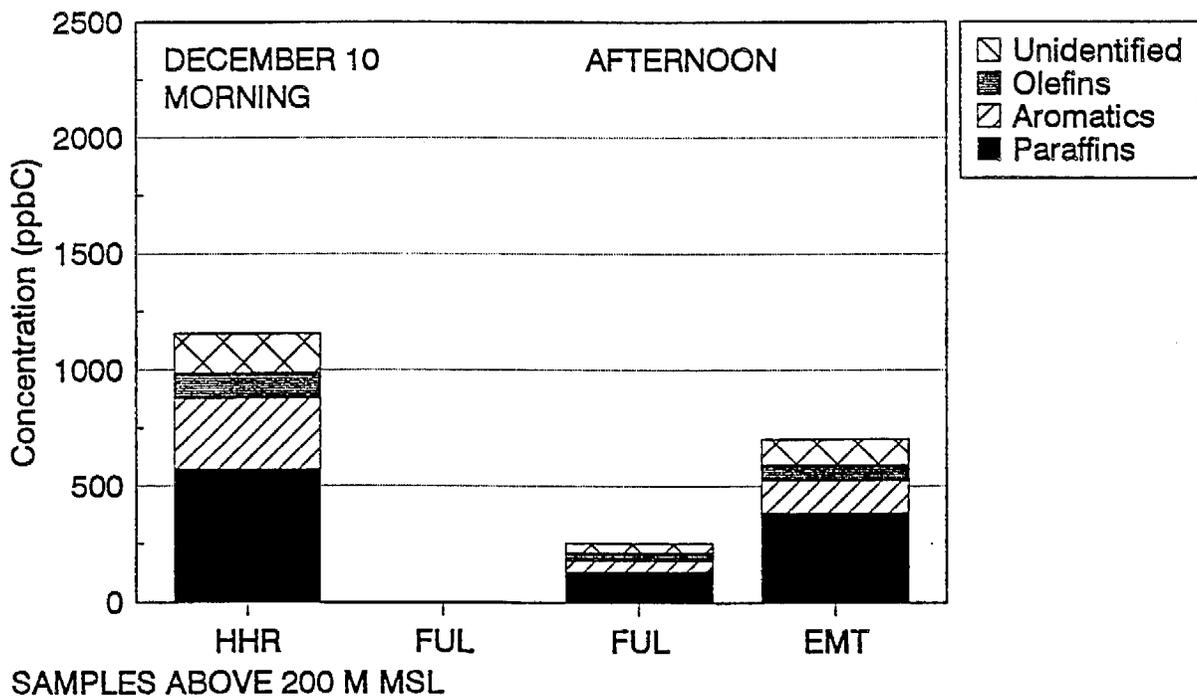
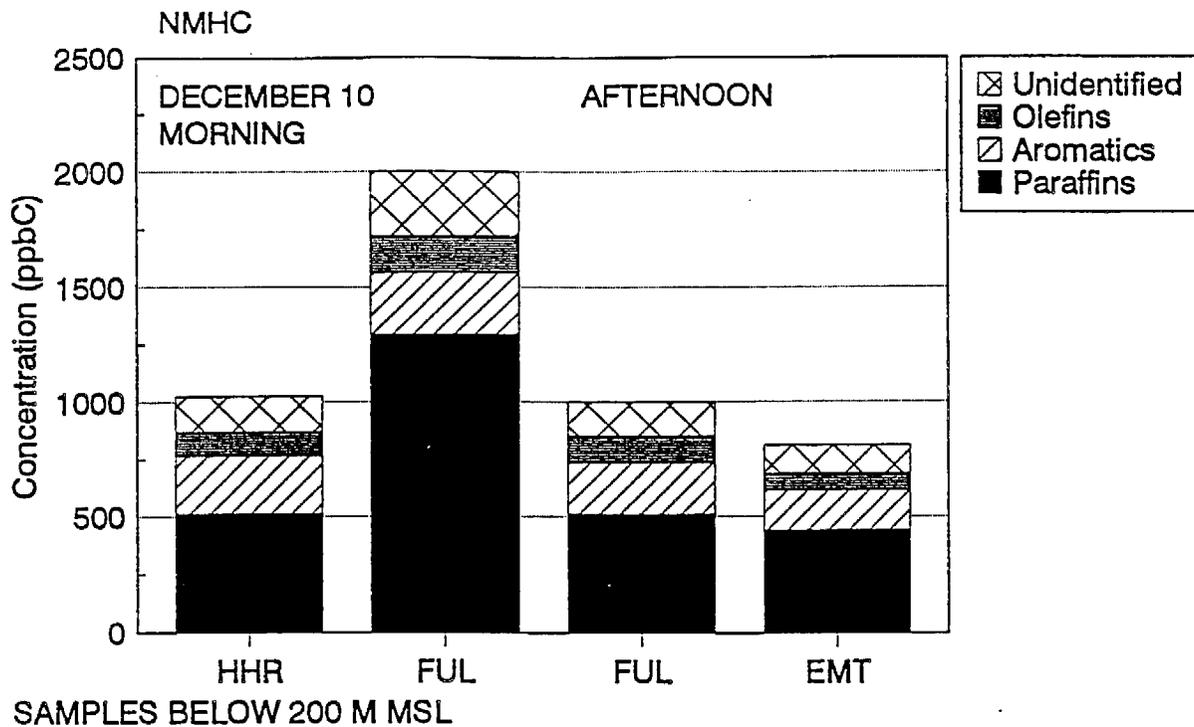


Figure 5-40. Orbit-Averages of NMHC Measured Aloft on December 10: a) Below and b) Above 200 m msl. All the samples collected below 200 m msl were collected within the mixed layer. Of the samples collected above 200 m msl: the Hawthorne sample was collected above the mixed layer, the Fullerton sample was collected within the mixed layer, and the El Monte sample was collected at the top of the mixed layer.

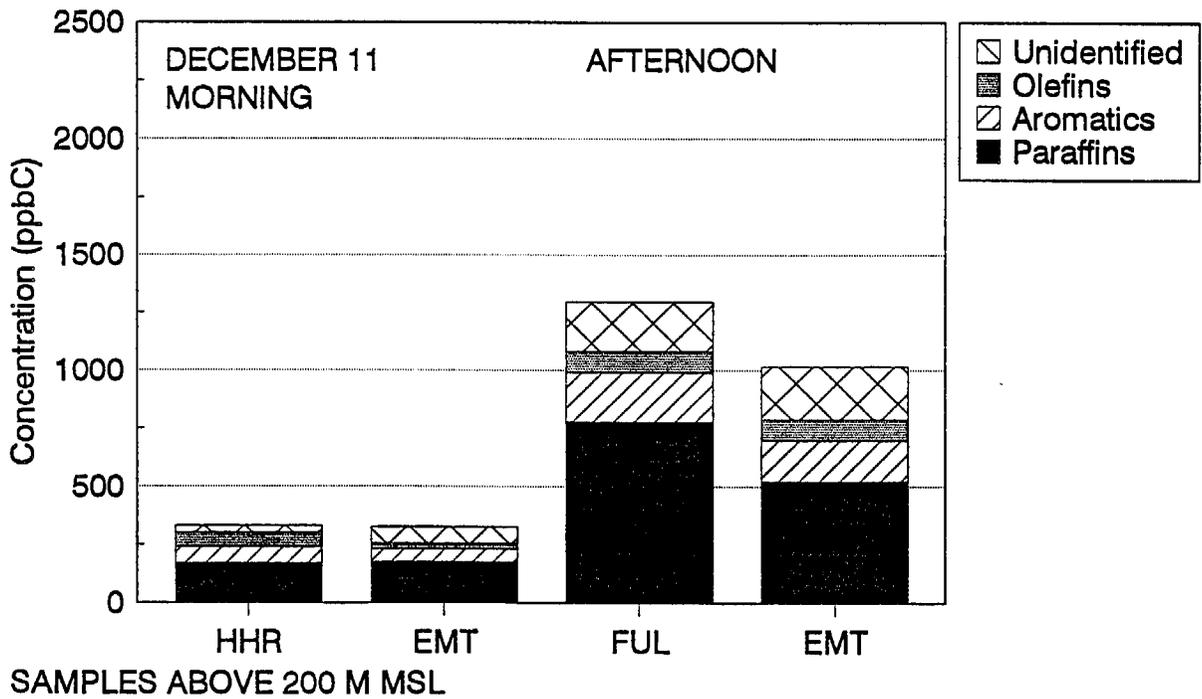
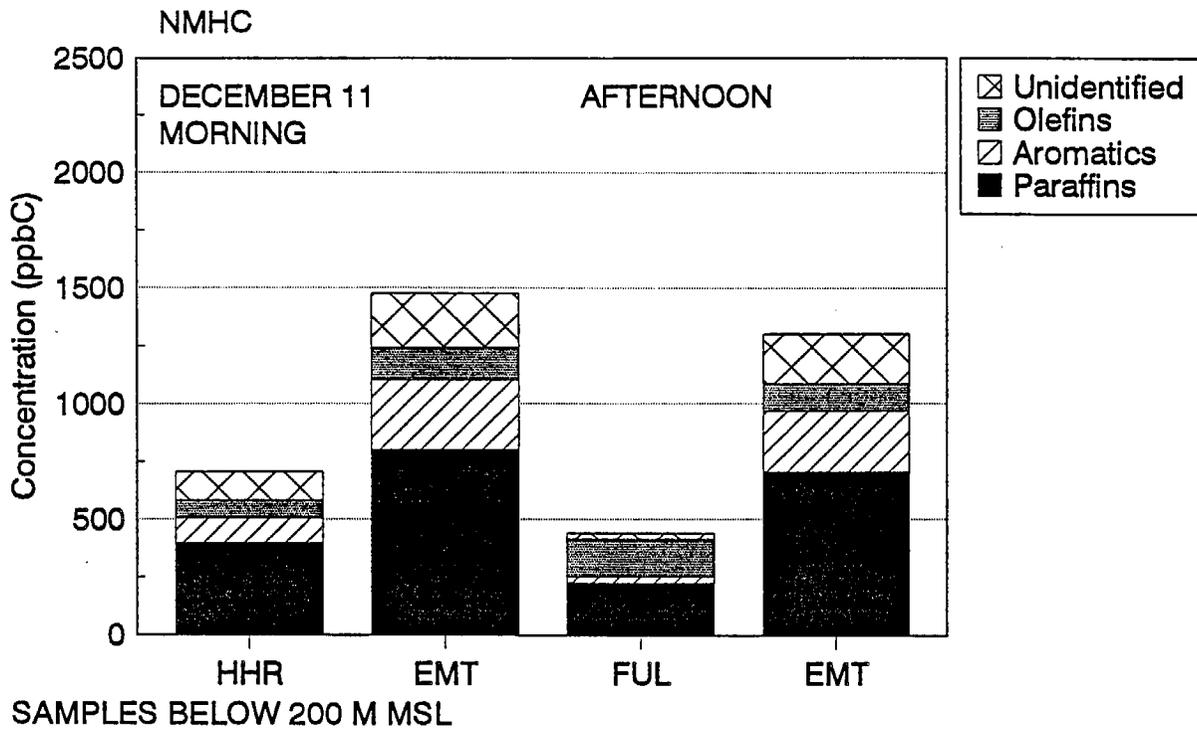
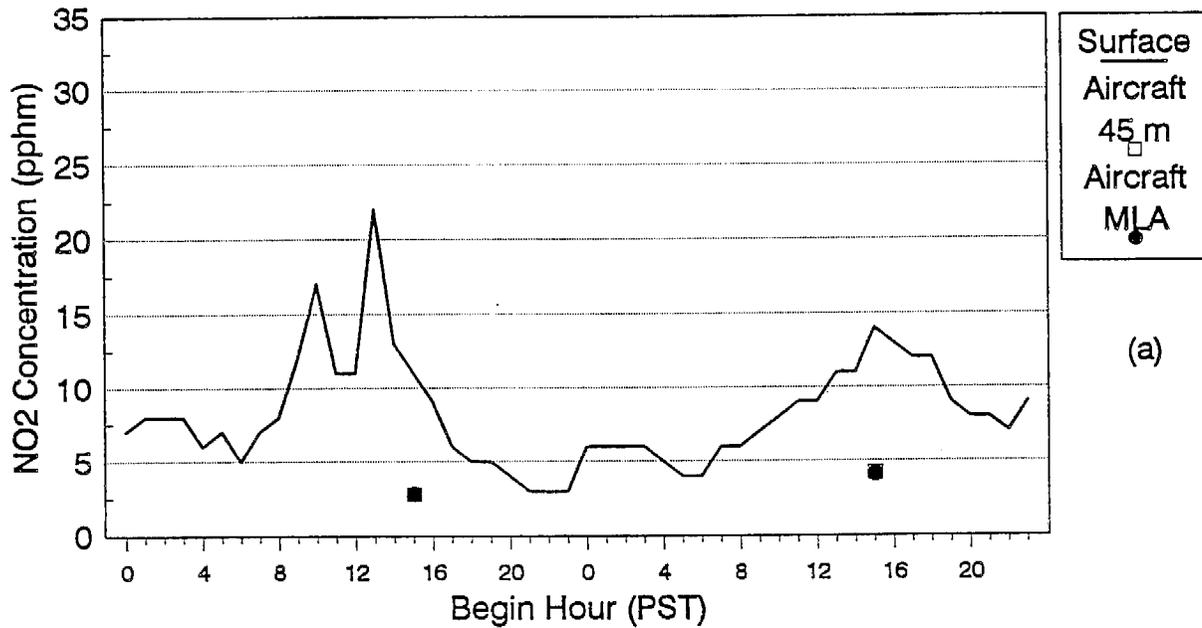


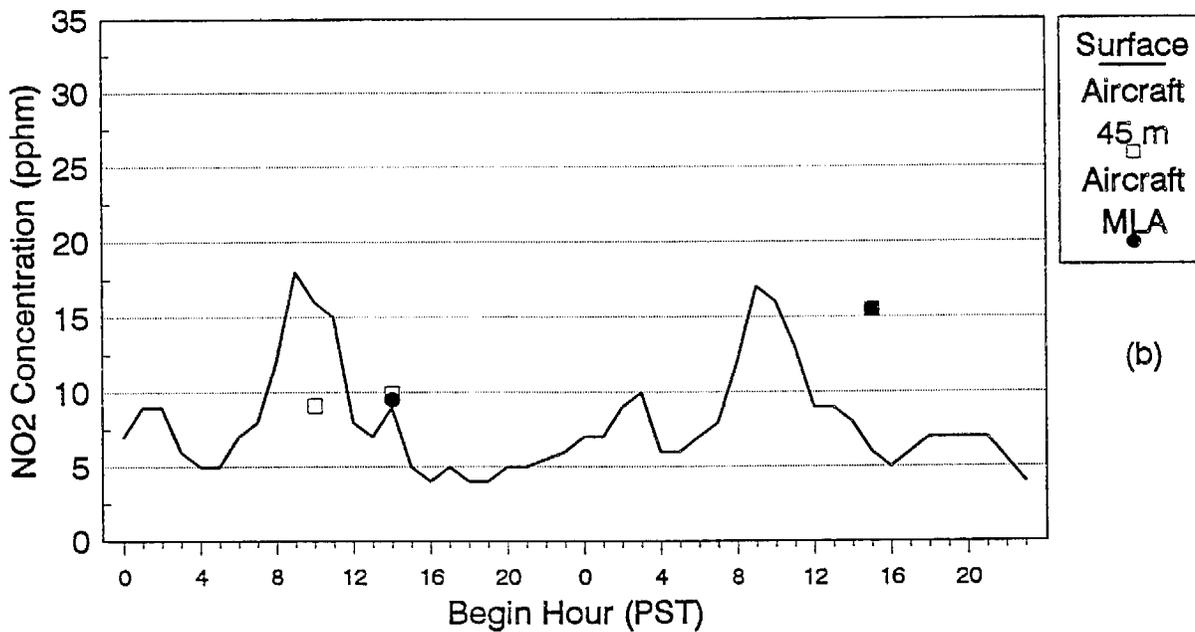
Figure 5-41. Orbit-Averages of NMHC Measured Aloft on December 11: a) Below and b) Above 200 m msl. All samples were collected above the mixed layer except the Fullerton sample collected below 200 m msl.

**Long Beach/PADDR
December 10-11, 1987**



(a)

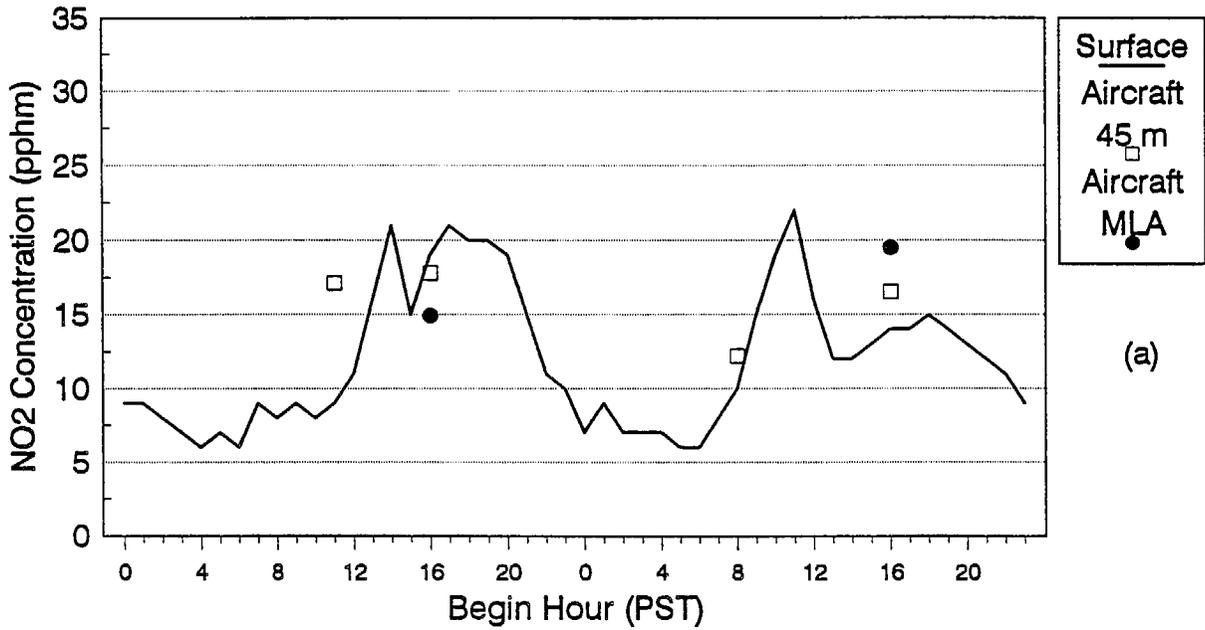
**Hawthorne
December 10-11, 1987**



(b)

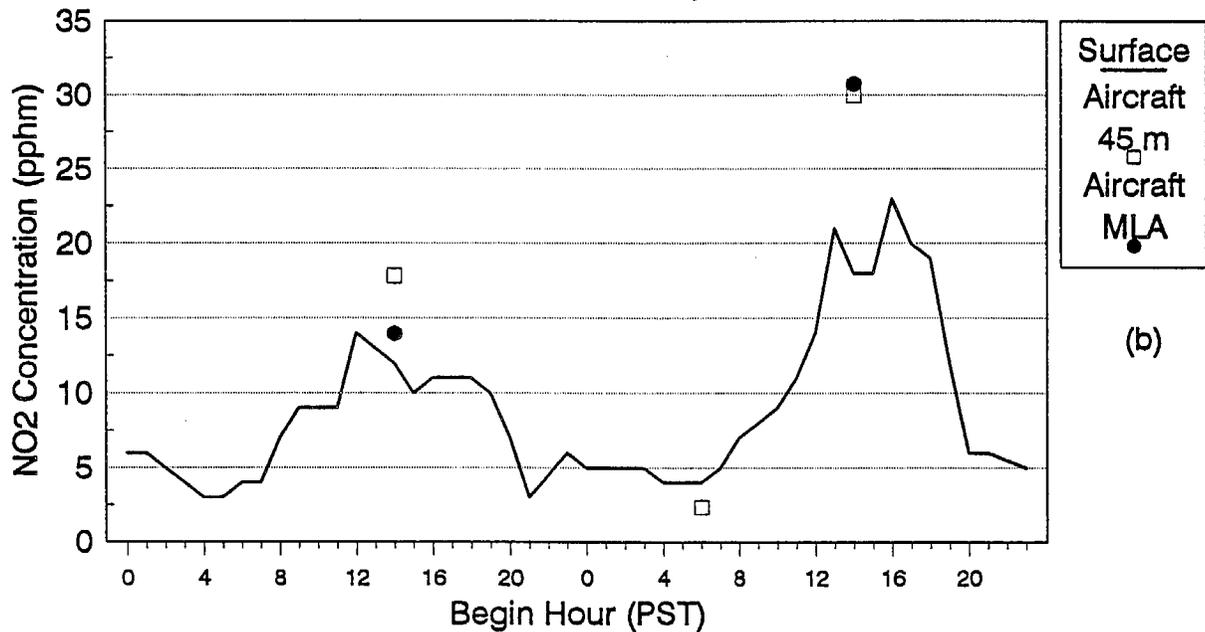
Figure 5-42. Comparison of Surface NO₂ Concentrations With Mixed-Layer-Average (MLA) and the Lowest 45-Meter Average (45 m) NO₂ at (a) PADDR and (b) Hawthorne on December 10-11, 1987. The data compared to the PADDR spiral are from the Long Beach surface monitor.

**Anaheim/Fullerton
December 10-11, 1987**



(a)

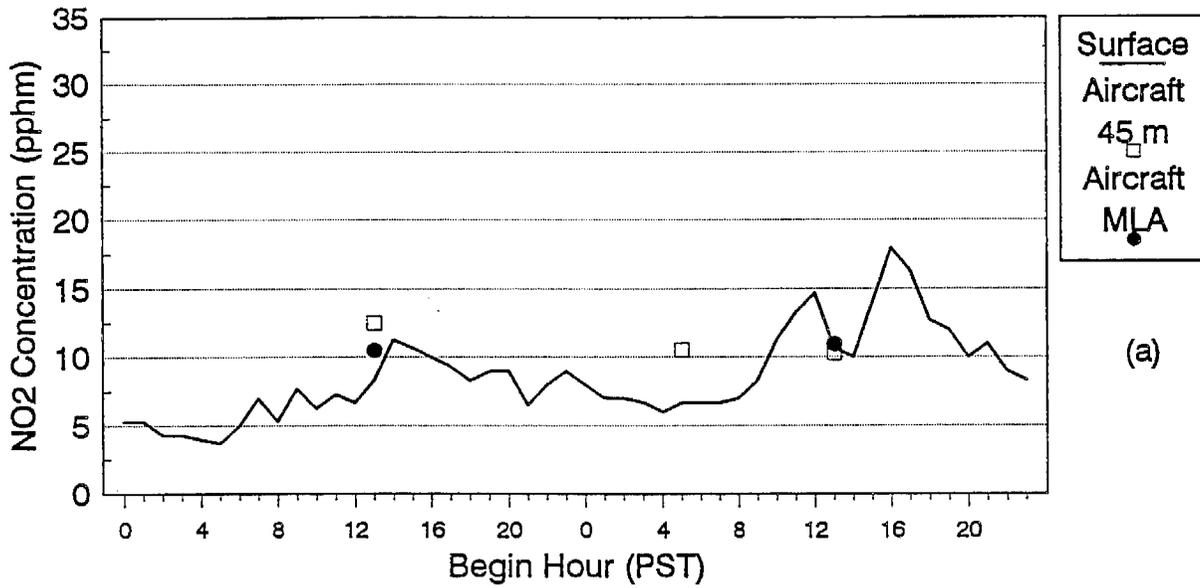
**Burbank
December 10-11, 1987**



(b)

Figure 5-43. Comparison of Surface NO₂ Concentrations With Mixed-Layer-Average (MLA) and the Lowest 45-Meter Average (45 m) NO₂ at (a) Fullerton and (b) Burbank on December 10-11, 1987. The data compared to the Fullerton spiral are from the Anaheim surface monitor.

**3-Site Average/El Monte
December 10-11, 1987**



Pico Rivera, Pasadena, Azusa

**Upland/Ontario
December 10-11, 1987**

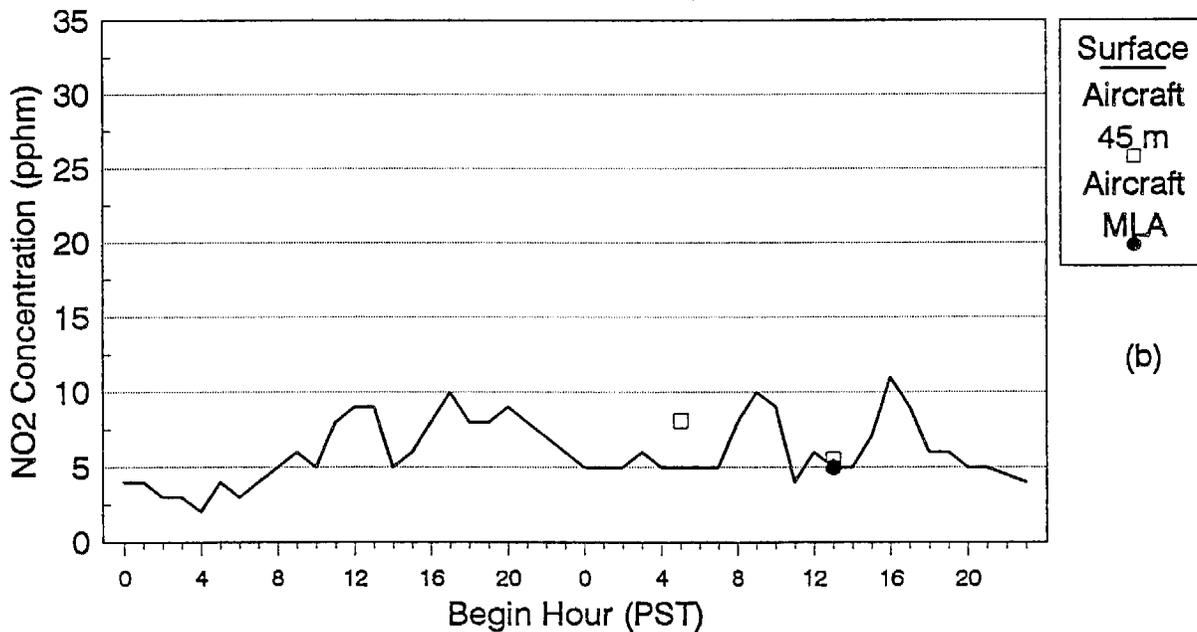
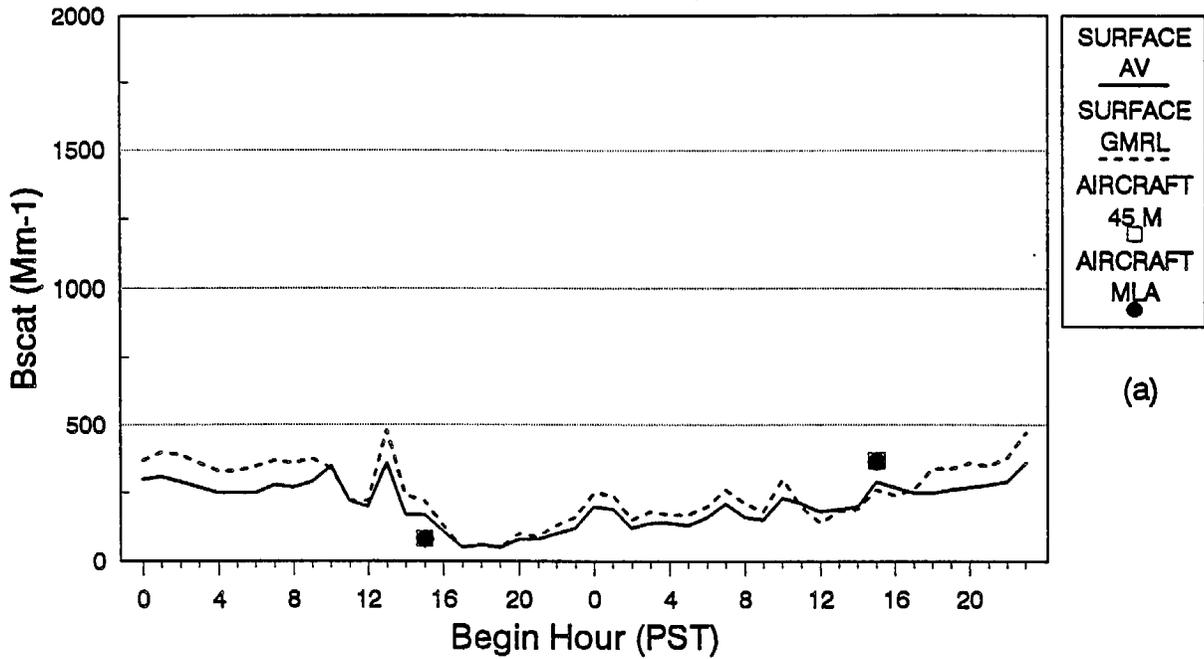


Figure 5-44. Comparison of Surface NO_2 Concentrations With Mixed-Layer-Average (MLA) and the Lowest 45-Meter Average (45 m) NO_2 at (a) El Monte and (b) Ontario on December 10-11, 1987. The data compared to the El Monte spiral are from the average of the Pico Rivera, Pasadena and Azusa surface monitors. The data compared to the Ontario spiral are from the Upland surface monitor.

**LONG BEACH/PADDR
December 10-11, 1987**



**AZUSA/EL MONTE
December 10-11, 1987**

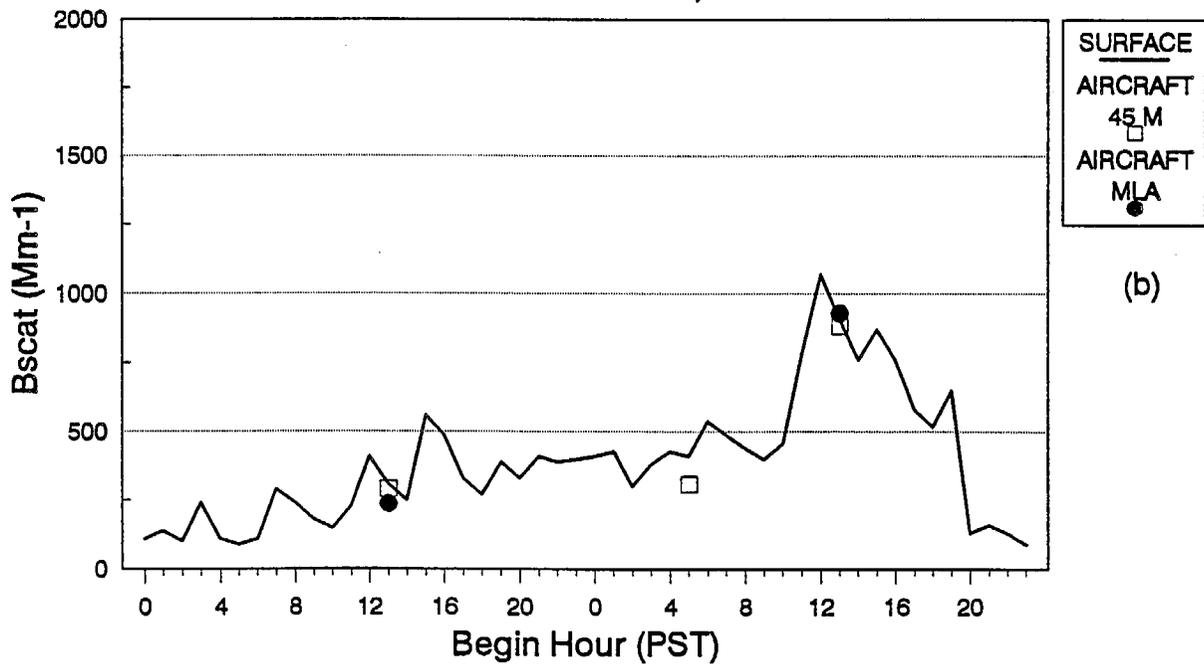


Figure 5-45. Comparison of Surface b_{scat} Concentrations With Mixed-Layer-Average (MLA) and the Lowest 45-Meter Average (45 m) NO_2 at (a) PADDR and (b) El Monte on December 10-11, 1987. The data compared to the PADDR and El Monte spirals are from the Long Beach and Azusa surface monitors, respectively.

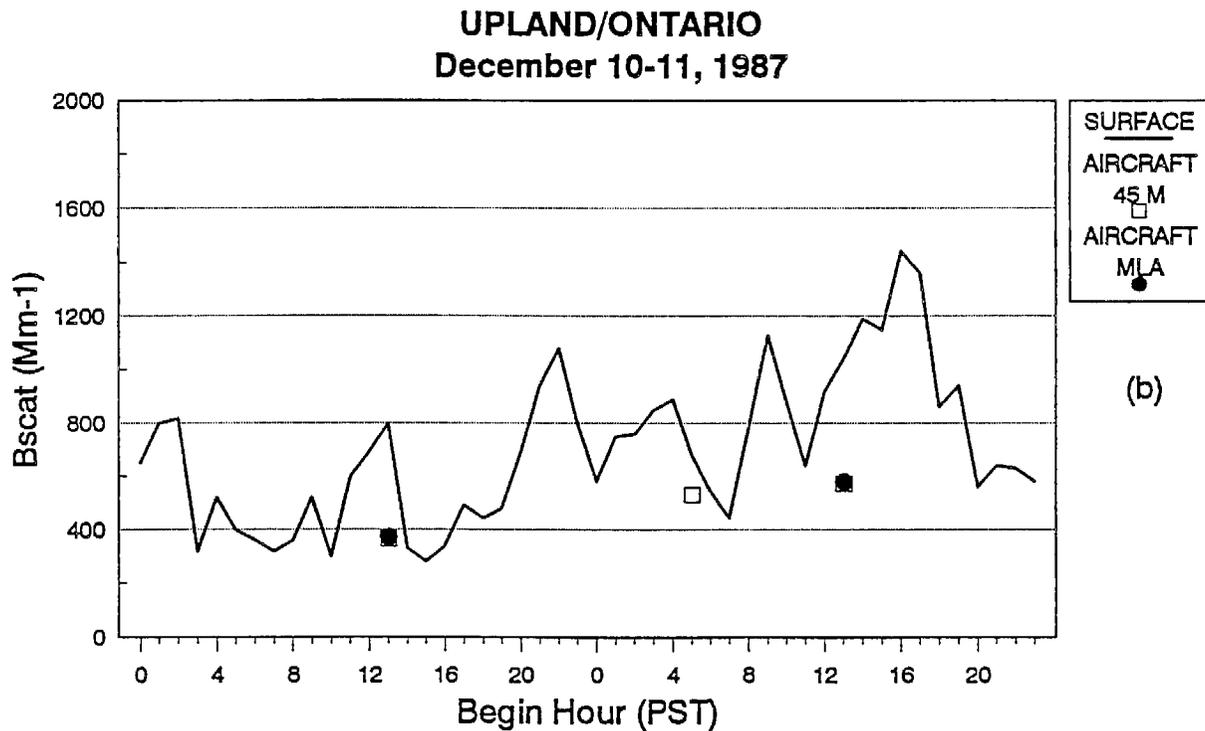
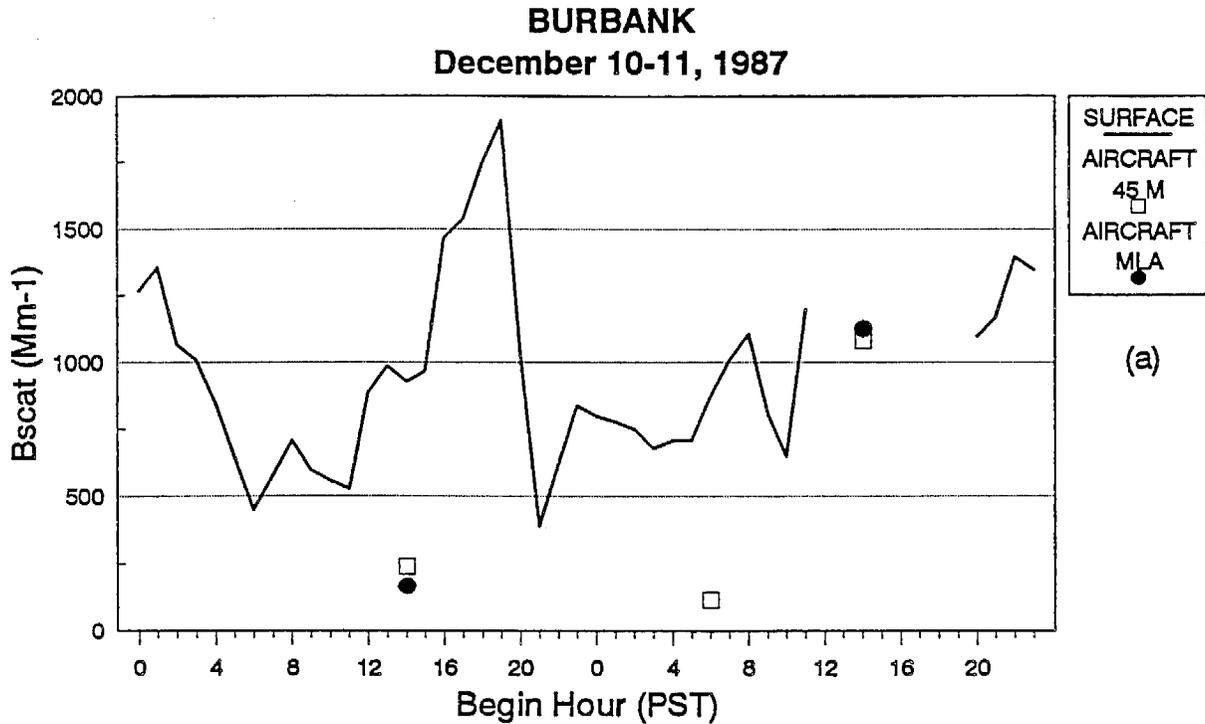


Figure 5-46. Comparison of Surface b_{scat} Concentrations With Mixed-Layer-Average (MLA) and the Lowest 45-Meter Average (45 m) NO_2 at (a) Burbank and (b) Ontario on December 10-11, 1987. The data compared to the Ontario spiral are from the Upland surface monitor.

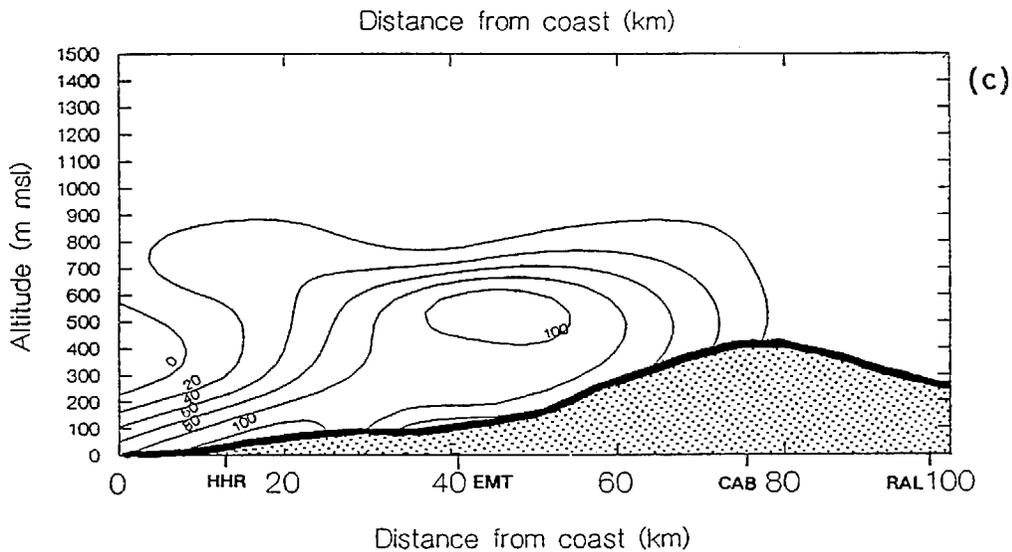
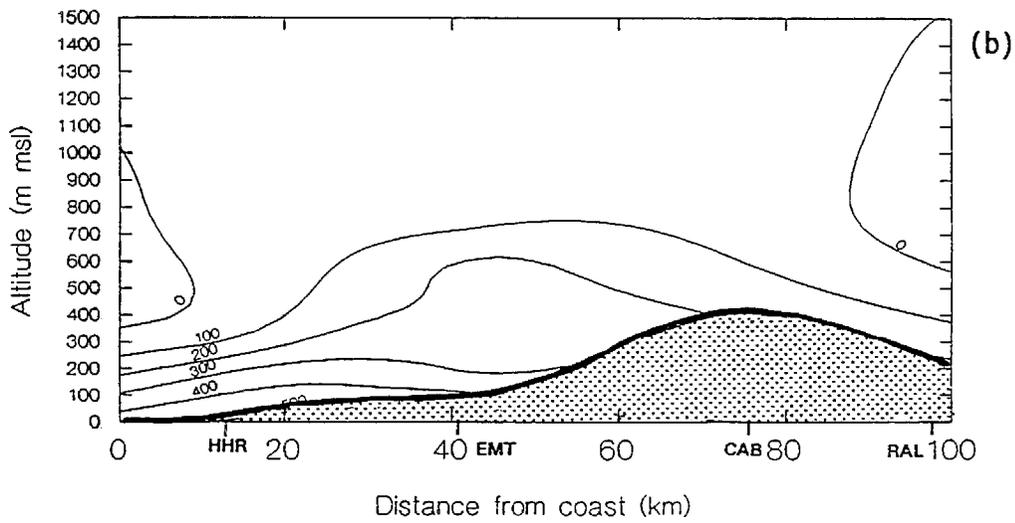
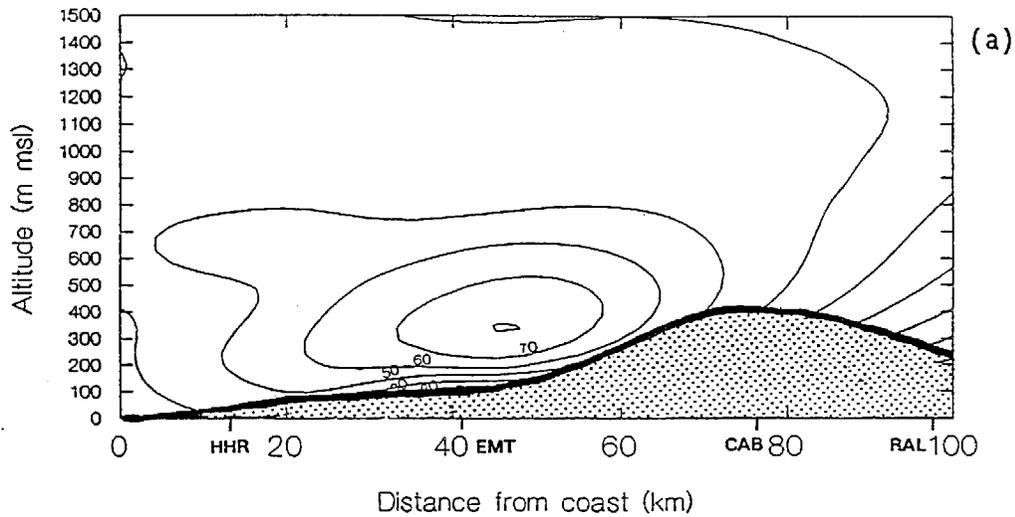


Figure 5-48. (a) Ozone (ppb), (b) b_{scat} (Mm^{-1}), and (c) NO_2 (ppb) Aloft During the Afternoon of December 10, 1987. Contours were generated along a west-to-east plane from the coast near Hawthorne to Ontario using data from aircraft spirals. The shaded area approximately represents the ground.

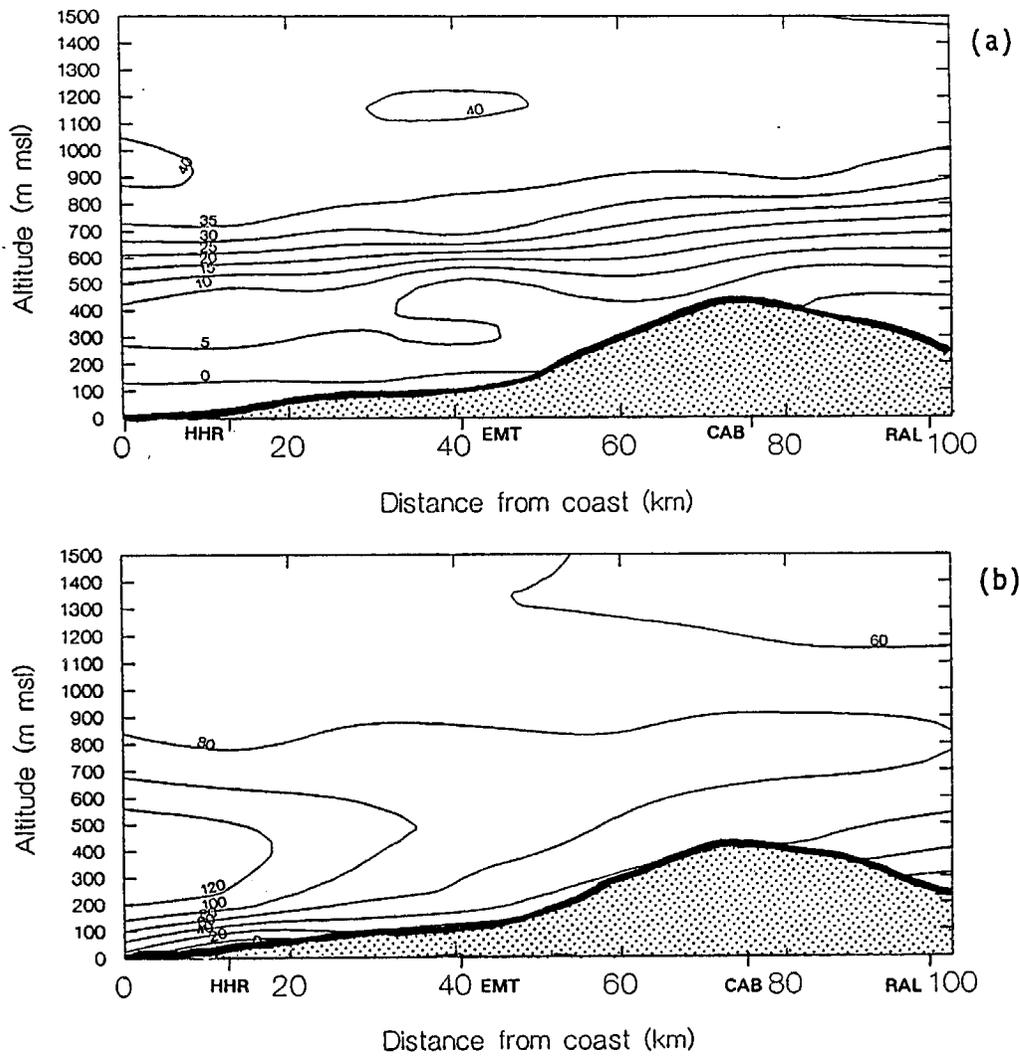


Figure 5-49. Ozone Concentrations (ppb) Aloft During the (a) Morning and (b) Afternoon of December 11, 1987. Ozone contours were generated along a west-to-east plane from the coast near Hawthorne to Ontario using data from aircraft spirals. The shaded area approximately represents the ground.

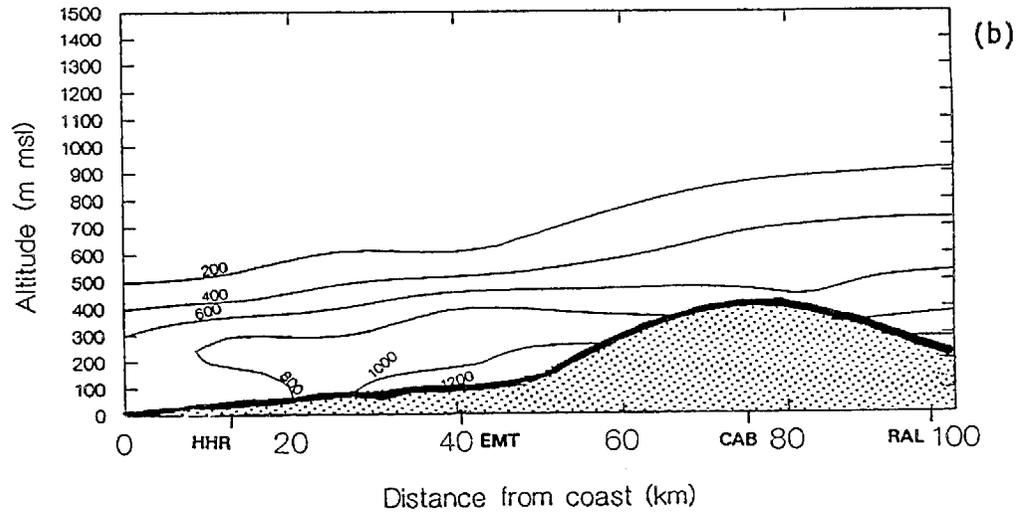
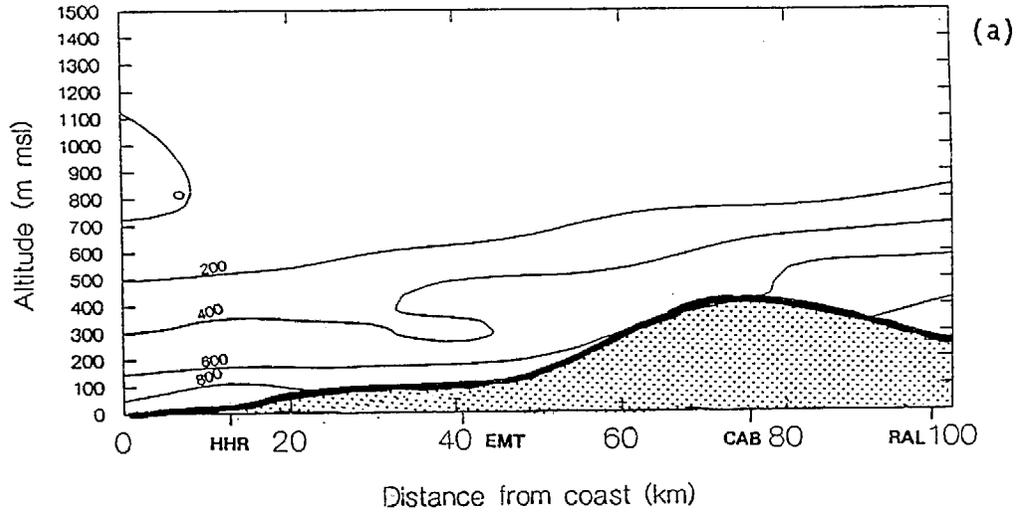


Figure 5-50. Light Scattering ($b_{\text{scat}} - \text{Mm}^{-1}$) Aloft During the (a) Morning and (b) Afternoon of December 11, 1987. Contours were generated along a west-to-east plane from the coast near Hawthorne to Ontario using data from aircraft spirals. The shaded area approximately represents the ground.

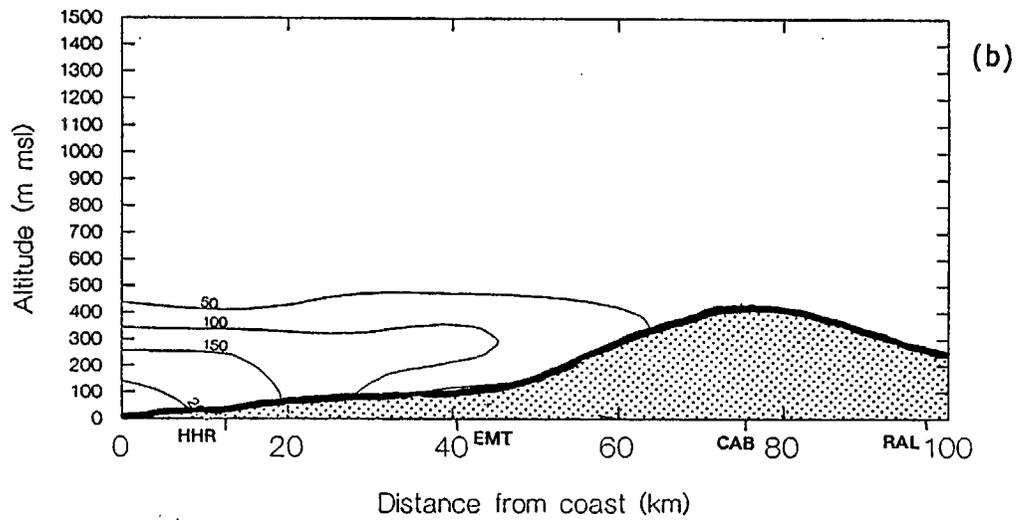
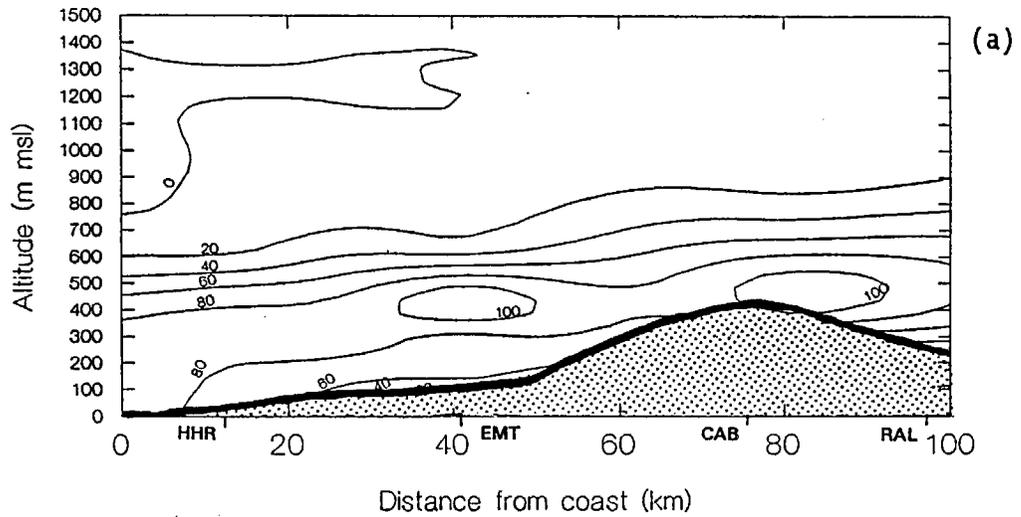
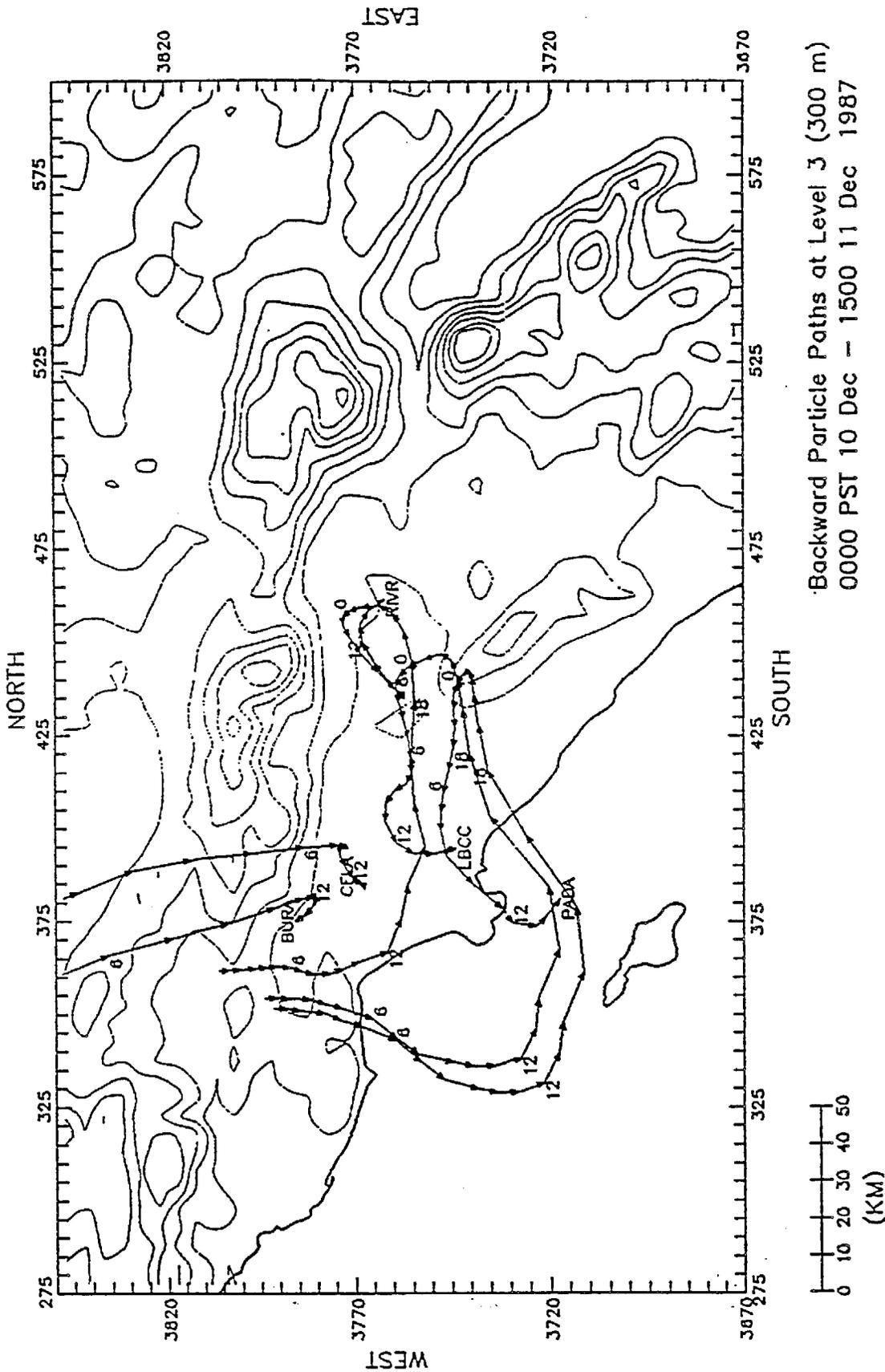


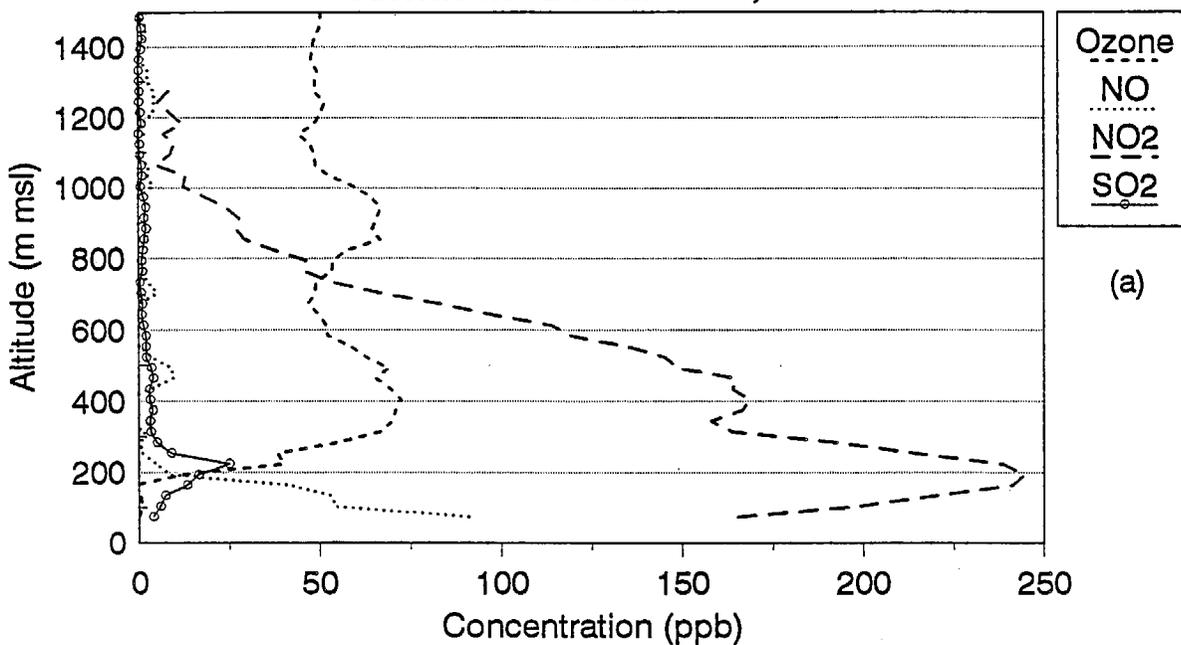
Figure 5-51. NO_2 Concentrations (ppb) Aloft During the (a) Morning and (b) Afternoon of December 11, 1987. Contours were generated along a west-to-east plane from the coast near Hawthorne to Ontario using data from aircraft spirals. The shaded area approximately represents the ground.



Backward Particle Paths at Level 3 (300 m)
 0000 PST 10 Dec - 1500 11 Dec 1987

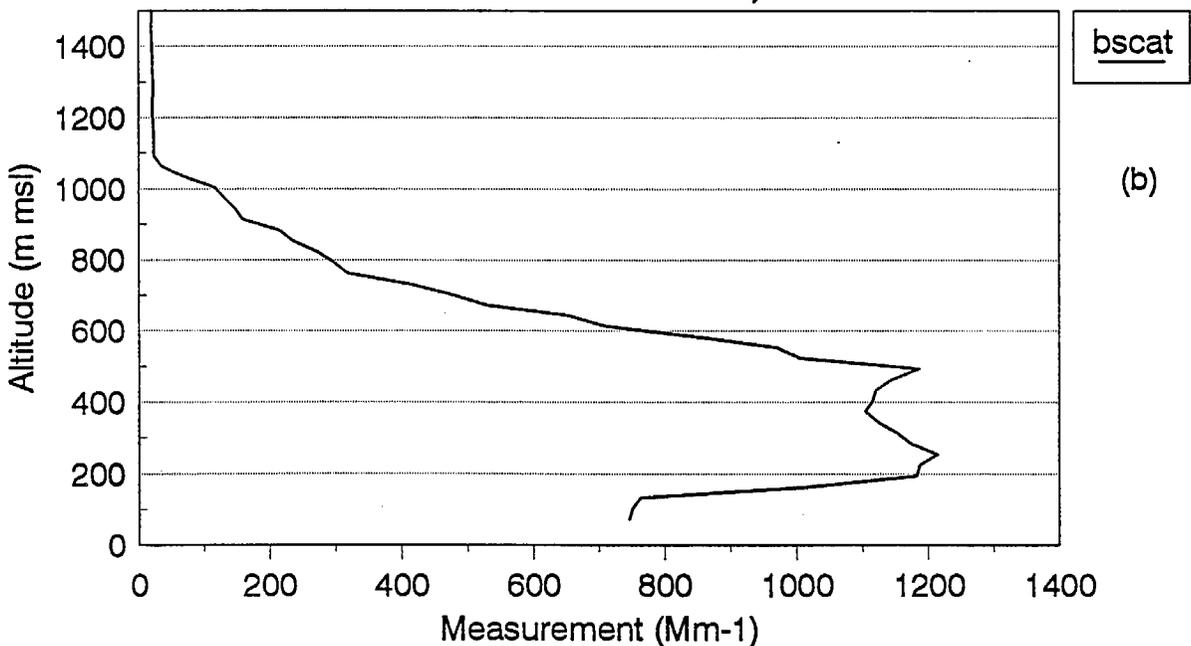
Figure 5-52. Backward Particle Trajectories at 300 m agl Beginning at 1500 PST on December 11, 1987. Trajectories start at Burbank, Los Angeles, Riverside, Long Beach, and PADD and map particle paths to 0000 PST on December 10, 1987.

**Thin Layer of SO₂ at Fullerton
Afternoon - December 11, 1987**



(a)

**b_{scat}
Afternoon - December 11, 1987**



(b)

Figure 5-53. Profiles at Fullerton on the Afternoon of December 11, 1987 for (a) Ozone, NO, NO₂, SO₂, and (b) b_{scat}. The layer of NO₂, SO₂, and b_{scat} centered at about 200 m msl may be due to buoyant point source emissions.

6. CONCLUSIONS AND RECOMMENDATIONS

The SCAQS air quality and meteorological data provide an opportunity to improve the understanding of the spatial and temporal characteristics of pollutants and species distributions at the surface and aloft in the SoCAB, the formation mechanisms of aloft pollutant layers, and the importance of these aloft layers to surface concentrations. These data also provide information needed to refine the conceptual model of pollutant layer formation, transport, and surface impact, and how these phenomena and species distributions are modeled. Many separate data analysis and modeling projects have been performed using the SCAQS data base. Case studies of three specific pollutant episodes were performed to improve our understanding of the evolution and sources of ozone and particulate matter concentrations in the SoCAB by integrating techniques and results from the separate analysis and modeling efforts. This section summarizes our conclusions and recommendations.

6.1 CONCLUSIONS

Characteristics of diurnal profiles of pollutants at the surface and aloft during the June and July summer SCAQS episodes:

- At surface sites, diurnal profiles of primary species such as NO and elemental carbon (EC) were highest during the morning and afternoon rush hours, as expected for pollutants with motor vehicles as the major emissions source; this typically caused ozone concentrations to be zero at night. However, NO and EC concentrations at Anaheim were low all the time and ozone concentrations there were not titrated to zero at night.
- Early morning NO concentrations were often high near the surface and decreased significantly above about 300 m agl; NO concentrations were typically low (less than 5 ppb) from the surface to 1500 m agl during the midday and the afternoon. NO_x concentrations during the midday and the afternoon were highest in the mixed layer (typically 30-50 ppb) and low at higher altitudes.
- Diurnal profiles of ozone, nitric acid, peroxyacetyl nitrate (PAN), organic carbon (OC), and particulate mass were similar, with the highest concentrations during the midday and low concentrations overnight. This is consistent with the conceptual models of transport and chemistry.
- Diurnal profiles of ammonia and PM_{2.5} ammonium ion were also similar to ozone with the highest concentrations during the midday and low concentrations overnight. This is consistent with the conceptual models of transport and chemistry. However, diurnal profiles of PM_{2.5} nitrate concentrations often indicated two peaks, one during the midday and another at night.
- Diurnal profiles of acetic and formic acid at Claremont and Long Beach were also similar to ozone with the highest concentrations during the midday and low concentrations overnight, except formic acid

concentrations were high during the early morning of July 13 at Claremont. In addition, acetic and formic acid concentrations were low at Long Beach on June 24-25. Acetic acid concentrations were typically higher than formic acid concentrations.

- Concentrations of most pollutants aloft were also typically highest during the midday and lowest early in the morning. However, ozone concentrations were often still quite high (up to 200 ppb) above the nocturnal inversion in the early morning. This indicates that there is a significant amount of pollutant carryover from one day to the next. In fact, the thick layer of over 200 ppb ozone which existed over much of the SoCAB on the morning of June 24 (the first day of intensive SCAQS measurements) indicates that modeling of the June 24-25 episode started with dirty conditions. Ozone concentrations on July 13 (the beginning of the July 13-15 episode) were significantly cleaner.

Aloft layers of pollutants during the June and July summer SCAQS episodes:

- High concentrations of ozone and other pollutants often exist in aloft layers covering much of the SoCAB. These layers are usually found at altitudes near the top of the daytime mixed layer (the boundary layer).
- The principal mechanisms which form polluted layers aloft include sea-breeze undercutting of the mixed layer, slope-flows along the mountains and the resulting return flow out over the SoCAB, the formation of the nocturnal surface layer in the lower part of the boundary layer, and the transport of buoyant air parcels from the mixed layer into the inversion layer (convective debris). Injection of pollutants aloft by stationary source emissions and convergence zones was also observed during the SCAQS.
- Aloft layers are generally horizontal in structure and exist at about the same height above sea level (msl) throughout most of the SoCAB. This means that terrain-following procedures, such as those used in meteorological/wind, modeling are not consistent with the observed pollutant structure.
- Ozone concentrations in the midday and afternoon mixed layer are greater than ozone concentrations measured at nearby surface monitors by about 20-30 ppb. We have reviewed aircraft audits and calibrations and found that they were within reasonable bounds ($\pm 5\%$). In addition, these differences did not depend on sampling date, time, or location. We conclude that this difference between surface and aircraft concentrations might be due to ozone deposition at the surface and/or to titration by fresh NO near the surface.
- Midday and afternoon mixed-layer concentrations of most secondary pollutants, including ozone, carbonyls, nitric acid, PAN, and PM_{2.5} OC were typically higher than pollutant concentrations at the surface. In contrast, surface concentrations of species dominated by primary sources, including NMHC, NO, NO_x, EC, and ammonia were higher than concentrations aloft in the mixed-layer. It seems that chemical and

transport processes aloft combine to keep the aloft concentrations of these secondary pollutants high.

- Midday and afternoon surface concentrations of a few other secondary pollutants, including $PM_{2.5}$ mass and sulfate, nitrate, and ammonia ions were typically higher than concentrations aloft in the mixed-layer. This distribution must be strongly influenced by the ammonia distribution (ammonia source and highest concentrations at the surface).

Comparison of model predictions of ozone with ozone measurements aloft:

- Model predictions of ozone in the lower 200 m agl during the morning were often significantly higher than measured concentrations, indicating that these model simulations did not produce enough ozone titration by fresh NO.
- Model predictions of ozone above about 200 m agl were about 50 to over 100 ppb lower than measured concentrations.

Characteristics of NMOC distributions during the June and July summer SCAQS episodes:

- The spatial pattern of average NMOC concentrations showed moderate concentrations (200-400 ppbC) at the surface in the western and southern SoCAB (at Hawthorne, Long Beach, and Anaheim), high concentrations (400-800 ppbC) in the central SoCAB (at Los Angeles and Burbank), and moderate concentrations in the eastern SoCAB during the summer. On average, NMOC concentrations decreased with distance from a high concentration ridge between Los Angeles and Burbank in summer. The spatial pattern of the aloft data in the afternoon was consistent with the surface NMOC patterns.
- Surface NMOC concentrations were highest at 0700-0800 PDT because of a combination of high emission rates from morning traffic and low mixing heights. Concentrations decreased over the day because wind speeds and mixing heights increased during daylight.
- The summer aircraft NMOC data, which were collected between 500 and 800 m msl during orbits, showed NMOC levels that were mostly lower than surface concentrations and NMOC composition that was more aged than surface data. The carbonyl content aloft (about 35 percent of NMOC carbon) was more than twice that in the surface data, indicating the secondary nature of the aloft samples.
- The similarity of NMOC composition throughout the day suggested fresh NMOC emissions were continuously injected into the atmosphere in the SoCAB. While there was evidence of oxidation of the more reactive hydrocarbon species and formation of large amounts of carbonyl compounds, there were significant concentrations of species typical of fresh emissions (Lurmann and Main, 1992).
- The NMOC concentrations had significant day-to-day and seasonal variations, which were undoubtedly controlled by meteorology. In

addition, the NMOC concentrations had significant spatial variation within the SoCAB due to the nonuniformity of emission rates and the effects of transport.

- Fresh emissions had a significant influence on NMOC concentrations everywhere in the SoCAB. This made it extremely difficult to estimate pollutant fluxes and to perform analyses which were designed to evaluate the formation of secondary species along a typical trajectory path. The ideal trajectory path for these analyses would transport pollutants from an upwind emissions area to a downwind receptor area; however, samples collected at most surface locations included significant contributions from local emissions which overwhelmed the secondary species.

Characteristics of particulate matter and carbon, nitrogen, and sulfur species during the June and July summer SCAQS episodes:

- Peak concentrations of pollutants with large secondary contributions, such as $PM_{2.5}$ mass, carbonyl compounds, and organic carbon, occurred at central and eastern SoCAB sites in the afternoon. This is consistent with the conceptual models of transport and chemistry.
- Surface ammonia and ammonium ion concentrations were highest, and nitric acid concentrations were lowest, at Rubidoux in the eastern SoCAB because of upwind sources of ammonia. $PM_{2.5}$ mass and nitrate ion concentrations were also high at Rubidoux. The nitrogen chemistry at Rubidoux was driven by fresh ammonia. In contrast to the surface, aloft ammonia and ammonium ion concentrations were relatively similar across the SoCAB.
- SO_2 and sulfate ion concentrations were generally low throughout the SoCAB, both at the surface and aloft. The sulfur contribution to the particulate mass was small as well.

Characteristics of pollutant concentrations during the December fall SCAQS episode:

- NO_2 concentrations were high (over 50 ppb) in layers within the daytime mixed layer (surface layer); concentrations were typically highest near the surface. The spatial and temporal variation of the pollutant profiles was much greater than in the summer.
- Mechanisms for the formation of aloft pollutant layers in the fall were similar to the summer: injection of stationary source emissions aloft, upslope flow, nocturnal boundary layer formation, and the transport of buoyant air parcels from the mixed layer into the inversion layer (convective debris). Offshore flow and stagnation conditions were observed on all fall SCAQS days, so undercutting by the sea breeze did not contribute to the formation of layers.
- The aloft layers in the fall were generally horizontal in structure and existed at about the same height above sea level (msl) across the SoCAB.

- Fresh emissions were important contributors to the pollutant mix at all surface sampling sites in the SoCAB and within the mixed layer aloft.
- Afternoon mixed-layer concentrations of NO_2 and b_{scat} were similar to surface concentrations.
- Pollutant concentrations were generally highest at Hawthorne and Long Beach during the fall, reflecting the source distributions and the lack of transport. Mixing heights were often lower than during the summer and a strong sea breeze was not observed. These conditions, along with evidence of substantial pollutant carryover, contributed to pollutant build-up in the western and central SoCAB.
- Diurnal profiles of acetic and formic acid at Long Beach included the highest concentrations during the midday and low concentrations overnight. Formic acid concentrations were typically higher than acetic acid concentrations (the reverse of the summer data).
- The fall aircraft hydrocarbon data, which were collected between 30 and 900 m msl during spirals, showed NMHC levels that were mostly lower than surface concentrations and NMHC composition that was more aged than surface data. Sampling and analytical problems prevented a detailed comparison of total carbonyl concentrations at the surface and aloft.
- $\text{PM}_{2.5}$ mass, sulfate ion, and ammonium ion concentrations at all aloft altitudes were usually lower than concentrations at the surface. Organic and elemental carbon concentrations aloft within the mixed layer were equal to or greater than concentrations at the surface, while above the mixed layer, the OC and EC concentrations were lower than at the surface. Nitric acid and PAN concentrations aloft within the mixed layer were greater than the surface concentrations, while nitrate ion concentrations aloft were sometimes higher and sometimes lower than surface concentrations.
- In the fall, surface NMOC concentrations (on average) were similar in the western and central SoCAB and significantly lower in the eastern SoCAB. The highest NMOC concentrations occurred at Burbank in the fall. This is consistent with the conceptual models of transport and chemistry. Spatial trends of hydrocarbons aloft were difficult to assess because the spatial distribution of samples was limited.
- On average, surface NMOC concentrations were highest at 0700-0800 PST because of high emission rates and low mixing heights. Morning NMOC concentrations were about two times higher than in the summer. During the fall, NMOC concentrations declined between 0700 and 1200, as mixing heights and wind speeds increased, and then increased between 1200 and 1600 PST, as mixing heights decreased with the formation of the nocturnal boundary layer.
- Fresh emissions had a significant influence on NMOC concentrations everywhere in the SoCAB, and NMOC concentrations were, in turn, a major component of all carbon species distributions. This made it extremely difficult to estimate pollutant fluxes and to perform analyses which

were designed to evaluate the formation of secondary species along a typical trajectory path. The ideal trajectory path for these analyses would transport pollutants from an upwind emissions area to a downwind receptor area; however, samples collected at most locations included significant contributions from local emissions which overwhelmed the secondary species.

- SO₂ and sulfate ion concentrations were low (typically less than 5 µg/m³) throughout the SoCAB, both at the surface and aloft. The sulfur contribution to particulate mass was also small (usually less than 5%). However, SO₂ and sulfate ion concentrations peaked at about 12 µg/m³ during the afternoon of December 11 at most sites (except Rubidoux); an aloft layer with SO₂ concentrations of up to 25 ppb was also identified on this afternoon.

6.2 RECOMMENDATIONS FOR MODELING IN THE SOCAB:

- The meteorological and photochemical models need to properly represent the formation and transport of aloft polluted layers including the following characteristics:
 - Clean boundary conditions aloft (above about 1500 m on most days).
 - The formation of layers aloft containing high concentrations of ozone, other chemical products, and precursors. Potential formation mechanisms include sea-breeze undercutting of the mixed layer, slope-flows along the mountains and the resulting return flow out over the SoCAB, the formation of the nocturnal surface layer, the injection of pollutants aloft by stationary source emissions and convergence zones, and the transport of buoyant air parcels from the mixed layer into the inversion layer (convective debris).
 - The mixing of many of these aloft polluted layers down to the surface during the midday and afternoon.
 - A pollutant and temperature structure aloft which is more horizontal than terrain-following (i.e. more msl than agl). In addition, the horizontal structure implies that aloft transport is generally horizontal as well.
 - Ozone concentrations in the midday and afternoon mixed layer are greater than ozone concentrations measured at nearby surface monitors by about 20-30 ppb. We conclude that this difference between surface and aircraft concentrations might be due to ozone deposition at the surface and/or to titration by fresh NO_x near the surface. Additional analysis to support this conclusion is needed; if this conclusion is confirmed, then model evaluation procedures need to be revised.

- The meteorological and photochemical models need to properly represent the occurrence and altitudes of clean boundary conditions aloft (above about 1500 m on most days).
- Model simulations should start on mornings with clean conditions aloft and at the surface, and the model simulation should build up the spatial distribution of pollutants, rather than using dirty initial conditions to simulate that build up. Upper air meteorological and air quality data are needed on the starting day to document clean conditions. Many current model simulations started on the day prior to a SCAQS intensive day; maybe they should have been started two days prior to an intensive sampling day. Pollutant concentrations aloft were quite low on the morning of July 13, 1987, so the July 13-15, 1987 episode would be a good episode to model.
- The distribution of pollutants during SCAQS, even on clean days, was not spatially uniform; therefore, initial and boundary conditions should not be spatially uniform. In addition, concentrations at the top of the modeling domain were typically close to background; therefore, top boundary conditions which are significantly above background should not be used.
- Summer SCAQS aloft data show a progression of aloft ozone concentration characteristics over the course of an episode, for example: from clean on the morning of July 13, 1987, to high ozone concentrations over most of the SoCAB (including offshore) that afternoon, to moderate ozone concentrations the next morning, to high ozone concentrations again over most of the SoCAB on the afternoon of July 14, and to moderate concentrations on the next morning. Current model simulations don't seem to show this type of progression of aloft ozone concentration characteristics, but additional evaluation of simulation results should be performed. Model simulations might not properly represent aloft concentration history for a number of reasons, including improper specification of boundary conditions, initial conditions, emissions, winds aloft, and mixing height structure, or due to the starting time of the model simulation.
- It is difficult to adequately evaluate the performance of a meteorological model when all of the meteorological data has been used in the model. Potential approaches for additional work in this area could include:
 - Performing additional particle trajectory studies with the meteorological model, with emphasis on the presence of particles in aloft layers and the history of these particles over a diurnal cycle. Questions to address might include: Are results from such studies similar to field results? Do particles occur in aloft layers, mix down in the afternoon, and are they carried over to aloft layers on the following morning?
 - Performing additional evaluation of the SCAQS inert tracer studies and comparison of aloft tracer data with model simulation results. Questions to address might include: Do aloft tracer results

indicate the formation and transport of aloft pollutant layers in a manner similar to the aloft ozone data? Do model simulations of the tracer releases indicate similar results?

- As part of this project, we compared ozone concentrations measured aloft with ozone concentrations from model simulations using summer data. Because these comparisons were poor, we did not perform comparisons using aloft data for other species, such as NO, NO_x, PAN, or nitric acid, or for the fall data. However, once improved simulation results are available, these additional comparisons should be performed.

7. REFERENCES

- Anderson, J.A., J.C. Koos, and R.G.M. Hammarstrand (1989) *Summary of SCAQS Upper Air Measurements Performed by the STI Aircraft*. Final report prepared for the California Air Resources Board by Sonoma Technology Inc., STI 97010-902-FR, ARB Agreement A6-098-32, April.
- Bastable, H.G., D.P. Rogers, and D.E. Schorran (1990) *Tracers of Opportunity and Pollutant Transport in Southern California*. Atmos. Environ. 24B:137-151.
- Blumenthal, D.L., J.G. Watson, and P.T. Roberts (1987) *Southern California Air Quality Study (SCAQS) Program Plan*. Prepared for the California Air Resources Board by Sonoma Technology Inc. and Desert Research Institute, STI-96030-708-R, ARB Agreement A5-157-32, June.
- Blumenthal, D.L., T.B. Smith, W.H. White, S.L. Marsh, D.S. Ensor, R.B. Husar, P.S. McMurry, S.L. Heisler, and P. Owens (1974) *Three-Dimensional Pollutant Gradient Study - 1972-1973 Program*. Prepared for the California Air Resources Board by Meteorology Research Inc., MRI 74 FR-1262, November.
- Cahill, T.A., R.F. Matsumura, M. Surovick, C. Unger, and K. Wilkenson (1990) *Size-Time-Compositional Analyses of Aerosols During SCAQS*. Final report prepared for the California Air Resources Board by Crocker Nuclear Laboratory, University of California at Davis, ARB Contract No. A7-32-074, March.
- Cassmassi, J.C. and K.R. Durkee (1990) *Comparison of Mixing Height Fields for UAM Application Generated from Limited and Multiple Temperature Sounding Profiles in the South Coast Air Basin*. Presented at the A&WMA Speciality Conference, Tropospheric Ozone and the Environment II: Effects, Modeling and Control, Atlanta, GA, November.
- Cassmassi, J.C., S. Mitsutomi, and M. Shepherd (1990) *Three-Dimensional Wind Fields for Use in the Urban Airshed Model*. Presented at the A&WMA Speciality Conference, Tropospheric Ozone and the Environment II: Effects, Modeling and Control, Atlanta, GA, November.
- Chico, T., S. Mitsutomj, and J.C. Cassmassi (1990) *Assessing Urban Airshed Model Performance in the South Coast Air Basin Using Tracer Gases*. Presented at the A&WMA Speciality Conference, Tropospheric Ozone and the Environment II: Effects, Modeling and Control, Atlanta, GA, November.
- Collins, J.F. and E.M. Fujita (1990) *Southern California Air Quality Study - Quality Assurance Program*. Prepared for the California Air Resources Board by ENSR Consulting and Engineering, ARB Contract No. A6-122-32, June.
- Countess, R.J. (1989) *Southern Air Quality Study SCAQS Sampler Chemistry*. Paper No. 89-140.2 presented at the A&WMA 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30.

- Croes, B. and J.F. Collins (1989) *Data Management for the Southern California Air Quality Study*. Paper No. 89-138.6 presented at the A&WMA 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30.
- Douglas, S.G., R.C. Kessler, C.A. Emery, and J.L. Burt (1991) *Diagnostic Analysis of Wind Observations Collected During the SCAQS*. Report prepared for the California Air Resources Board by Systems Application International, ARB Contract No. A8-32-133, June.
- Drummond, J., H. Schiff, D. Karecki, and G. Mackay (1989) *Measurements of SO_2 , O_3 , PAN, HNO_3 , H_2O_2 , and H_2CO During the SCAQS*. Paper No. 89-139.4 presented at the A&WMA 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30.
- Edinger, J.G. (1963) *Modification of the Marine Layer Over Coastal Southern California*. J. Appl. Met. 2:706-712.
- England, W.G. and S. Marsh (1992) *SCAQS Tracer Study*. Presented at the A&WMA SCAQS Data Analysis Conference, Los Angeles, CA, July 21-23.
- Fitz, D. and J. Zwicker (1988) *Design and Testing of the SCAQS Sampler for the SCAQS Study*. Final report prepared for the California Air Resources Board by AeroVironment Inc., AV-FR-87/649, ARB Contract No. AB-077-32, March.
- Fitz, D., M. Chan, G. Cass, D. Lawson, and L. Ashbaugh (1989) *A Multi-component Size-classifying Aerosol and Gas Sampler for Ambient Air Monitoring*. Paper No. 89-140.1 presented at the A&WMA 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30.
- Fujita, E. (1992) Unpublished data.
- Fujita, E., B.E. Croes, C.L. Bennett, D.R. Lawson, F.W. Lurmann, and H.H. Main (1992) *Comparison of Emission and Ambient Concentration Ratios of CO , NO_x , and NMOG in California's South Coast Air Basin*. J. Air Waste Manage. Assoc. 42:264-276.
- Fung, K. (1989) *Carbonyl Observations During the SCAQS*. Paper No. 89-152.3 presented at the A&WMA 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30.
- Gertler, A.W., D. Lowenthal, J.C. Chow, and J.G. Watson (1992) *Receptor Modeling of SCAQS Volatile Organic Compounds*. Presented at the A&WMA SCAQS Data Analysis Conference, Los Angeles, CA, July 21-23.
- Grosjean, D. (1983) *Distribution of Atmospheric Nitrogenous Pollutants at a Los Angeles Area Smog Receptor Site*. Environ. Sci. Tech. 17:13-17.
- Grosjean, D. (1990) *Formic Acid and Acetic Acid Measurements During the SCAQS*. Atmos. Environ. 24A:2699-2702.

- Harley, R.A., A.G. Russell, G.J. McRae, L.A. McNair, D.A. Winner, M.T. Odman, D. Dabdub, G.R. Cass, and J.H. Seinfeld (1992) *Continued Development of a Photochemical Model and Application to the Southern California Air Quality Study (SCAQS) Intensive Monitoring Periods: Phase I*. Final report to the Coordinating Research Council, February.
- Hegg, D.A. and P.V. Hobbs (1988) *Cloud and Precipitation Scavenging Processes in the South Coast Air Basin*. Final report prepared for the California Air Resources Board by Cloud and Aerosol Research Group, Atmospheric Sciences Department, University of Washington, Seattle, ARB Agreement No. A4-143-32, November.
- Hering, S.V. (1992) *Descriptive Analysis of Los Angeles Aerosols During SCAQS*. Presented at the A&WMA SCAQS Data Analysis Conference, Los Angeles, CA, July 21-23.
- Hering, S.V. (1990a) *SCAQS Sampler Data Plots*. Final report prepared for the California Air Resources Board by Sonoma Technology Inc., ARB Contract No. A8-32-086, August.
- Hering, S.V. (1990b) *Southern California Air Quality Study, Aerosol Data Management*. Final report prepared for California Air Resources Board by Sonoma Technology Inc., STI-90050-1018FR, July.
- Hering, S.V. and D.L. Blumenthal (1989) *Southern California Air Quality Study (SCAQS) Description of Measurement Activities*. Final report prepared for the California Air Resources Board by Sonoma Technology Inc., STI-96030-810-FR, December.
- Hering, S.V. and D.R. Lawson et al. (1988) *Nitric Acid Shootout: Field Comparison of Measurement Methods*. Atmos. Environ. 22:1519-1539.
- Horrell, R.S. (1992) *A Smog Season Examination of the Los Angeles-Glendale Divergence Zone Using SF₆ Tracer*. Presented at the A&WMA SCAQS Data Analysis Conference, Los Angeles, CA, July 21-23.
- Horrell, R.S., M. Deem, P. Wyckoff, F.H. Shair, and N. Crawford (1989) *Ground Release SF₆ Tracer Experiments Used to Characterize Transport and Dispersion of Atmospheric Pollutants During the Southern California Air Quality Study of 1987*. Paper No. 89-138.2 presented at the A&WMA 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30.
- Horrell, R.S., R.S. Halliday, and F.H. Shair (1991) *Analysis of the 1987 Southern California Air Quality Study (SCAQS) Atmospheric Tracer Data*. Final report prepared for the California Air Resources Board, ARB Contract No. A9-32-051, March.
- Huntzicker, J.J. and B.J. Turpin (1991) *Secondary Organic Aerosol in the Los Angeles Basin*. Prepared for the California Air Resources Board by the Oregon Graduate Institute of Science and Technology, ARB Contract No. A8-321-29, June.

- Ingalls, M.N., L.R. Smith, and R.E. Kirksey (1989) *Measurement of On-Road Vehicle Emission Factors in the California South Coast Air Basin, Vol. I: Regulated Emissions*. Final report prepared for the Coordinating Research Council, Inc. by Southern Research Institute, Project SCAQS-1, June.
- John, W., S.M. Wall, J.L. Ondo, W. Winklmayr (1990) *Modes in the Size Distributions of Atmospheric Inorganic Aerosol*. Atmos. Environ. 24A: 2349-2359.
- Lawson, D.R. (1990) *The Southern California Air Quality Study*. J. Air Waste Manage. Assoc. 40:156-165.
- Lawson, D.R. and S.V. Hering (1990) *The Carbonaceous Species Methods Comparison Study - An Overview*. Aerosol Sci. Technol. 12 and accompanying papers in special issue.
- Lehrman, D.E., W. Knuth, N. Alexander, H. Giroux, and L. Lehrman (1988) *Southern California Air Quality Study Meteorological Support Program*. Final report prepared for the California Air Resources Board by Technical & Business Systems, ARB Contract No. A6-097-32, October.
- Lonneman, W.A., R.L. Seila, and W. Ellenson (1989) *Speciated Hydrocarbon and NO_x Comparisons at SCAQS Source and Receptor Sites*. Paper No. 89-152.5 presented at the A&WMA 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30.
- Lurmann, F.W. and H.H. Main (1992) *Analysis of the Ambient VOC Data Collected in the Southern California Air Quality Study*. Final report prepared for the California Air Resources Board by Sonoma Technology Inc., STI-99120-1161-FR, February.
- Main, H.H., P.T. Roberts, J.A. Anderson, and K. Fung (1991) *Pollutant Concentrations Along the Western Boundary of the South Coast Air Basin. Part II: Analysis of June 1990 Data Collected Offshore*. Final report prepared for the South Coast Air Quality Management District by Sonoma Technology Inc., STI-90080-1149-FR, July.
- Main, H.H., F.W. Lurmann, and P.T. Roberts (1990) *Pollutant Concentrations Along the Western Boundary of the South Coast Air Basin Part I: A Review of Existing Data*. Report prepared for the South Coast Air Quality Management District by Sonoma Technology Inc., STI-90080-1016-FR, October.
- McElroy, J.L., D.H. Bundy, C.A. Edmonds, W.H. Hankins, and S.M. Kroth (3) *Operations/Data and Report for the 1987 SCAQS*. U.S. EPA internal report, Las Vegas, NV, September.
- McElroy, J.L. and T.B. Smith (1992) *Creation and Fate of Ozone Layers Aloft in Southern California*. Submitted to Atmos. Environ.

- Richards, L.W., D.F. Bell, and M. Stoelting (1988) *Measurement of Light Transmittance and Path Radiance During the 1987 SCAQS Summer Intensive*. Data volume prepared for UNOCAL Corporation and Western Oil and Gas Association by Sonoma Technology Inc., STI-97050-801-DV, Contract No. 85-8.0.04(3)-04-01-SOT, March.
- Roberts, P.T. and H.H. Main (1992) *Analysis of 3-D Air Quality Data and Carbon, Nitrogen, and Sulfur Species Distributions During the Southern California Air Quality Study*. Draft final report prepared for the Coordinating Research Council by Sonoma Technology Inc., STI-99100-1213-DFR, July.
- SCAQMD (1990) *Draft AQMP 1991 Revision Technical Report V-B Ozone Modeling - Performance Evaluation*, December.
- SCAQMD (1991) *Final AQMP 1991 Revision Technical Report V-B Ozone Modeling - Performance Evaluation*. (Addendum to the Draft Technical Report), July.
- Smith, T.B. (1990) *Mixing Height Analyses*. Final report to Southern California Edison Company, P.O. C2139909.
- Smith, T.B., S.L. Marsh, W.H. White, T.N. Jerskey, R.G. Lamb, P.A. Durbin, and J.P. Killus (1976) *Analysis of the Data from the Three-Dimensional Gradient Study*. Prepared for the California Air Resources Board by Meteorology Research Inc. and Systems Applications Inc., MRI 75 FR-1395 and SAI EF75-84, January.
- Stockburger, L., K.T. Knapp, and T.G. Ellestad (1989) *Overview and Analysis of Hydrocarbon Samples During the Summer Southern California Air Quality Study*. Paper No. 89-139.1 presented at the A&WMA 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30.
- Teuscher, L. (1989) *SCE SCAQS Tracer Study*. Prepared for Southern California Edison by Tracer Technologies, February.
- Turpin, B. and J. Huntzicker (1991) *Secondary Formation of Organic Aerosol in the Los Angeles Basin: A Descriptive Analysis of Organic and Elemental Carbon Concentrations*. Atmos. Environ. 25a:207-215.
- Wakimoto, R.M. and J.L. McElroy (1986) *Lidar Observations of Elevated Pollution Layers Over Los Angeles*. J. Climate Appl. Met. 25:1583-1599.
- Watson J.G., J.C. Chow, D. Lowenthal, and A.W. Gertler (1992) *Diurnal Variability of Source Contributions to PM₁₀ and PM_{2.5}*. Presented at the A&WMA SCAQS Data Analysis Conference, Los Angeles, CA, July 21-23.
- Wheeler, N.J.M. (1992) *Evaluation of Meteorological Inputs for the Urban Airshed Model With the SCAQS Database*. Presented at the A&WMA SCAQS Data Analysis Conference, Los Angeles, CA, July 21-23.

- Wheeler, N.J.M. (1990) *Modeling of Mixing Depths During a Southern California Air Quality Study Ozone Episode*. Presented at the A&WMA Speciality Conference, Tropospheric Ozone and the Environment II: Effects, Modeling and Control, Atlanta, GA, November.
- Wheeler, N.J.M. (1991a) *Urban Airshed Model Sensitivity to Horizontal Transport Paths*. Presented at the A&WMA Speciality Conference, Tropospheric Ozone and the Environment II: Effects, Modeling and Control, Atlanta, GA, November.
- Wheeler, N.J.M. (1991b) *Developing Objective Wind Fields for Photochemical Modeling of a 1987 Southern California Air Quality Study Ozone Episode*. Presented at the A&WMA Speciality Conference, Tropospheric Ozone and the Environment II: Effects, Modeling and Control, Atlanta, GA, November.
- Whiteman, C.D., K.J. Allwine, and J.M. Hubbe (1991) *Winter Meteorology of the Grand Canyon Region*. Prepared for Salt River Project, Phoenix, AZ, Contract No. 16660, by Battelle Pacific Northwest Laboratories, March.
- Williams II, E.L. and D. Grosjean (1990) *Southern California Air Quality Study: Peroxyacetyl Nitrate*. Atmos. Environ. 24A:2369-2377.
- Winer, A.M. and H.W. Biermann (1989) *In-Situ Long Pathlength Differential Optical Absorption Spectroscopy (DOAS) Measurements of Gaseous Species During the 1987 SCAQS Program*. Paper No. 89-139.3 presented at the A&WMA 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30.
- Winer, A.M., H.W. Biermann, T. Dinoff, L. Parker, and M.P. Poe (1989) *Measurements of Nitrous Acid, Nitrate Radicals, Formaldehyde and Nitrogen Dioxide for the Southern California Air Quality Study by Differential Optical Absorption Spectroscopy*. Final report prepared for the California Air Resources Board prepared by the Statewide Air Pollution Research Center, University of California, Riverside, ARB Contract No. A6-146-32, December.
- Wolff, G. T., M.S. Ruthkosky, D.P. Stroup, and P.E. Korsog (1991) *A Characterization of the Principal PM-10 Species in Claremont (Summer) and Long Beach (Fall) During SCAQS*. Atmos. Environ. 25A:2173-2186.
- Zeldin, M.D., L.D. Bregman, and Y. Horie (1989) *A Meteorological and Air Quality Assessment of the Representativeness of the 1987 SCAQS Intensive Days*. Final report prepared for the South Coast Air Quality Management District by InstaWeather, Inc., Contract No. 88-15a, September.

APPENDIX A

SCAQS MEASUREMENT INFORMATION

The following tables contain information regarding SCAQS measurements that were used in this report. Table A-1 provides a list of the A-, B-, and C-site codes, names, locations, elevations, and the meteorological data collected at each site. Table A-2 lists the fall aircraft hydrocarbon and carbonyl samples which were invalidated during our quality control procedures. Invalid fall and summer surface, and summer aircraft hydrocarbon and carbonyl samples are listed by Lurmann and Main (1992).

Table A-1. SCAQS Meteorology Measurement Sites (from Hering and Blumenthal, 1989)

Page 1 of 2

| Code | Type* | Site Name | Latitude | Longitude | Elev. (m msl) | County | WS | WD | T | RH |
|------|-------|------------------------------|------------|-------------|------------------|----------------|----|----|---|----|
| CLAR | A | Claremont College | 34 6' 7" | 117 42' 14" | 364 | Los Angeles | " | " | " | " |
| LBCC | A/U | Long Beach City College | 33 49' 49" | 118 8' 18" | 17 | Los Angeles | " | " | " | " |
| ANAH | B | Anaheim | 33 49' 16" | 117 55' 7" | 41 | Orange | " | " | " | " |
| AZUS | B | Azusa | 34 8' 9" | 117 55' 23" | 90 | Los Angeles | " | " | " | " |
| BURK | B | Burbank | 34 10' 58" | 118 18' 27" | 168 | Los Angeles | " | " | " | " |
| CELA | B+ | Los Angeles-North Main | 34 4' 2" | 118 13' 31" | 87 | Los Angeles | " | " | " | " |
| HAWT | B | Hawthorne | 33 55' 23" | 118 22' 9" | 21 | Los Angeles | " | " | " | " |
| RIVR | B+ | Riverside-Rubidoux | 33 59' 59" | 117 25' 1" | 214 | Riverside | " | " | " | " |
| SNI | B | San Nicolas Island | 33 15' 24" | 119 29' 9" | 122 | Ventura | " | " | " | " |
| ALA | C | Alamitos Generating Station | 33 46' 13" | 118 6' 7" | | Los Angeles | " | " | " | " |
| BANN | C | Banning-Allesandro | 33 55' 40" | 116 52' 25" | 722 | Riverside | " | " | " | " |
| COST | C | Costa Mesa-Placentia | 33 39' 22" | 117 55' 47" | 25 | Orange | " | " | " | " |
| FONT | C | Fontana-Arrow Highway | 34 5' 58" | 117 30' 18" | 381 | San Bernardino | " | " | " | " |
| GLEN | C | Glendora-Laurel | 34 8' 35" | 117 51' 4" | 275 | Los Angeles | " | " | " | " |
| HEME | C | Hemet-State Street | 33 45' 57" | 116 58' 10" | 469 | Riverside | " | " | " | " |
| LAHB | C | La Habra | 33 55' 34" | 117 57' 3" | 82 | Orange | " | " | " | " |
| LGBH | C | North Long Beach | 33 49' 25" | 118 11' 19" | 7 | Los Angeles | " | " | " | " |
| LSAL | C | Los Alamitos-Orangewood | 33 47' 45" | 118 1' 55" | 10 | Orange | " | " | " | " |
| LYNN | C | Lynwood | 33 55' 45" | 118 12' 35" | 27 | Los Angeles | " | " | " | " |
| NEWL | C | Newhall-County Fire Station | 34 23' 15" | 118 32' 1" | 375 | Los Angeles | " | " | " | " |
| NORC | C | Norco-Norconian | 33 55' 14" | 117 34' 17" | 220 | Riverside | " | " | " | " |
| PASA | C | Pasadena-Wilson | 34 8' 1" | 118 7' 37" | 250 | Los Angeles | " | " | " | " |
| PERI | C | Perris | 33 47' 0" | 117 14' 0" | 439 | Riverside | " | " | " | " |
| PICO | C | Pico Rivera | 34 0' 54" | 118 3' 30" | 69 | Los Angeles | " | " | " | " |
| POMA | C | Pomona | 34 4' 1" | 117 45' 3" | 270 | Los Angeles | " | " | " | " |
| RESE | C | Reseda | 34 11' 58" | 118 32' 0" | 226 | Los Angeles | " | " | " | " |
| SIMI | C | Simi Valley-5400 Cochran | 34 16' 39" | 118 41' 5" | 310 | Ventura | " | " | " | " |
| SNBO | C | San Bernardino | 34 6' 26" | 117 16' 24" | 317 | San Bernardino | " | " | " | " |
| TORO | C | El Toro | 33 40' 0" | 117 44' 0" | 117 | Orange | " | " | " | " |
| UPLA | C | Upland ARB | 34 6' 13" | 117 37' 42" | 369 | San Bernardino | " | " | " | " |
| WHIT | C | Whittier | 33 55' 25" | 118 1' 29" | 58 | Los Angeles | " | " | " | " |
| WLSA | C | West Los Angeles-VA Hospital | 34 3' 3" | 118 27' 19" | 91 | Los Angeles | " | " | " | " |
| CA | M | Santa Catalina Island | 33 24' 0" | 118 25' 0" | 482 | Los Angeles | " | " | " | " |
| HF | M | Henninger Flats | 34 12' 2" | 118 4' 43" | 1005 | Los Angeles | " | " | " | " |
| KH | M | Kellogg Hill | 34 4' 48" | 117 49' 19" | 381 | Los Angeles | " | " | " | " |
| PV | M | Palos Verdes-San Pedro Hill | 33 44' 46" | 118 20' 12" | 442 | Los Angeles | " | " | " | " |
| ALHA | S | Alhambra | 34 5' 30" | 118 8' 37" | | Los Angeles | " | " | " | " |
| BARS | S | Barstow | 34 53' 38" | 117 1' 24" | 692 | San Bernardino | " | " | " | " |
| BU23 | S | Buoy 46023-Point Conception | 34 18' 0" | 120 42' 0" | 0 | Pacific Ocean | " | " | " | " |
| BU25 | S | Buoy 46025-Catalina Ridge | 33 42' 0" | 119 6' 0" | 0 | Pacific Ocean | " | " | " | " |
| BUO | S | Beaumont | 33 56' 0" | 116 57' 0" | 792 | Riverside | " | " | " | " |
| CAB | S | Cable Airport - Pomona | 34 07' | 117 41' | 442 | Los Angeles | ? | " | " | " |
| CAJN | S | Cajon Summit | 34 20' 0" | 117 25' 0" | 1219 | San Bernardino | " | " | " | " |
| CASI | S | BLM-Casitas/Los Padres NF | 34 24' 0" | 119 22' 0" | 189 | Ventura | " | " | " | " |
| CHIL | S | BLM-Chilao/Angeles NF | 34 19' 48" | 118 2' 12" | 1661 | Los Angeles | " | " | " | " |
| CHIN | S | Chino | 34 0' 39" | 117 41' 15" | | San Bernardino | " | " | " | " |
| CM36 | S | CIMIS-Blythe | 33 38' 53" | 114 33' 40" | 82 | Riverside | " | " | " | " |
| CM44 | S | CIMIS-U.C. Riverside | 33 57' 54" | 117 20' 8" | 311 | Riverside | " | " | " | " |
| CM50 | S | CIMIS-Thermal | 33 38' 47" | 116 14' 30" | -9 | Riverside | " | " | " | " |
| CM55 | S | CIMIS-Palm Desert | 33 43' 50" | 116 22' 57" | 61 | Riverside | " | " | " | " |
| CM58 | S | CIMIS-Santa Paula | 34 18' 6" | 119 7' 8" | 53 | Ventura | " | " | " | " |
| CM60 | S | CIMIS-Barstow | 34 54' 12" | 117 6' 54" | 664 | San Bernardino | " | " | " | " |
| CM62 | S | CIMIS-Temecula | 33 29' 25" | 117 13' 20" | 433 | Riverside | " | " | " | " |
| CM75 | S | CIMIS-Irvine | 33 41' 19" | 117 43' 14" | 125 | Orange | " | " | " | " |
| COMP | S | Compton Airport | 33 53' 19" | 118 14' 17" | 29 | Los Angeles | " | " | " | " |
| CRES | S | Lake Gregory-Crestline | 34 14' 38" | 117 16' 27" | 1384 | San Bernardino | " | " | " | " |
| DAG | S | Barstow-Daggett Airport | 34 51' 12" | 116 47' 12" | 587 | San Bernardino | " | " | " | " |
| DU | S | Duarte | 34 08' | 117 57' | 220 | Los Angeles | ? | " | " | " |
| ELRI | S | El Rio-Rio Mesa School | 34 15' 15" | 119 8' 36" | 34 | Ventura | " | " | " | " |
| ELSN | S | Elsinore | 33 40' 30" | 117 20' 55" | | Riverside | " | " | " | " |
| EMT | S | El Monte Airport | 34 5' 12" | 118 2' 0" | 90 | Los Angeles | " | " | " | " |

Table A-1. SCAQS Meteorology Measurement Sites (from Hering and Blumenthal, 1989)

| Code | Type* | Site Name | Latitude | Longitude | Elev. (m msl) | County | WS | WD | T | RH |
|------|-------|--|-----------|------------|------------------|----------------|----|----|---|----|
| ESUA | S | El Segundo - SCE Power Plant | 33 55' | 118 25' | 35 | Los Angeles | | | | |
| FUL | S | Fullerton Municipal Airport | 33 52'18" | 117 58'42" | 29 | Orange | | | | |
| HESP | S | Hesperia-17288 Olives | 34 25' 5" | 117 17' 5" | 1000 | San Bernardino | | | | |
| HHR | S | Hawthorne Municipal Airport | 33 55'24" | 118 20' 6" | 19 | Los Angeles | | | | |
| LANC | S | Lancaster | 34 42'44" | 118 8'21" | 709 | Los Angeles | | | | |
| LAX | S | Los Angeles International Airport | 33 56'36" | 118 24'24" | 38 | Los Angeles | | | | |
| LCAN | S | La Canada | 34 12'42" | 118 12'49" | | Los Angeles | | | | |
| LGB | S | Long Beach-Daugherty Field | 33 49' 6" | 118 9' 0" | 17 | Los Angeles | | | | |
| MALJ | S | Malibu | 34 1'59" | 118 41'23" | | Los Angeles | | | | |
| MISS | S | Mission Hills | 34 16'23" | 118 27'55" | | Los Angeles | | | | |
| MWS | S | Mount Wilson | 34 14' 0" | 118 4' 0" | 1741 | Los Angeles | | | | |
| NUC | S | San Clemente Island Airport | 33 1' 0" | 118 35' 0" | 276 | Los Angeles | | | | |
| NZJ | S | Santa Ana-El Toro Airport | 33 40' 0" | 117 43' 0" | 119 | Orange | | | | |
| OJAI | S | Ojai-1768 Maricopa Highway | 34 26'48" | 119 16'13" | 231 | Ventura | | | | |
| OXR | S | Oxnard Airport | 34 12' 6" | 119 12'24" | 13 | Ventura | | | | |
| PLSP | S | Palm Springs-Fire Station | 33 51' 9" | 116 32'25" | 171 | Riverside | | | | |
| PMD | S | Palmdale | 34 38' 0" | 118 5' 0" | 774 | Los Angeles | | | | |
| POC | S | La Verne-Brackett Field | 34 5'30" | 117 46'54" | 308 | Los Angeles | | | | |
| PSP | S | Palm Springs Municipal Airport | 33 49'36" | 116 30'12" | 141 | Riverside | | | | |
| RDLD | S | Redlands-Dearborn | 34 3'36" | 117 9'35" | 520 | San Bernardino | | | | |
| REDO | S | Redondo Beach | 33 50'51" | 118 23' 1" | | Los Angeles | | | | |
| RIAL | S | Rialto | 34 7'33" | 117 24'24" | | San Bernardino | | | | |
| RIV | S | Riverside-March AFB | 33 54' 0" | 117 15' 0" | 467 | Riverside | | | | |
| SBA | S | Santa Barbara Municipal Airport | 34 25'36" | 119 50'24" | 3 | Santa Barbara | | | | |
| SBD | S | San Bernardino-Norton AFB | 34 6' 0" | 117 14' 0" | 352 | San Bernardino | | | | |
| SMO | S | Santa Monica Municipal Airport | 34 1' 0" | 118 27' 6" | 53 | Los Angeles | | | | |
| SNA | S | Santa Ana-John Wayne Airport | 33 40'30" | 117 52' 0" | 16 | Orange | | | | |
| TANB | S | BLM-Tanbark/Angeles NF | 34 12'15" | 117 45'30" | 792 | Los Angeles | | | | |
| TEME | S | BLM-Temescal/Los Padres NF | 34 29' 0" | 118 36' 0" | 323 | Ventura | | | | |
| TOA | S | Torrance Municipal Airport | 33 48'12" | 118 20'18" | 31 | Los Angeles | | | | |
| TRM | S | Thermal Airport | 33 37'36" | 116 9'48" | -36 | Riverside | | | | |
| TRON | S | Trona-Market Street | 35 45'35" | 117 42'25" | 505 | San Bernardino | | | | |
| VCTC | S | Victorville-Civic Drive | 34 30'35" | 117 19'10" | 876 | San Bernardino | | | | |
| VCV | S | Victorville-George AFB | 34 35' 0" | 117 23' 0" | 876 | San Bernardino | | | | |
| VENI | S | Venice Beach | 33 59' 4" | 118 28'13" | | Los Angeles | | | | |
| VENT | S | Ventura-Emma Wood State Beach | 34 17'24" | 119 18'49" | 3 | Ventura | | | | |
| VERN | S | Vernon | 33 59'56" | 118 13' 9" | | Los Angeles | | | | |
| VNY | S | Van Nuys Airport | 34 12'36" | 118 29'24" | 244 | Los Angeles | | | | |
| WALN | S | Walnut | 34 2'57" | 117 50'30" | | Los Angeles | | | | |
| WJF | S | Lancaster-Gen. William J. Fox Airfield | 34 44'30" | 118 13' 6" | 715 | Los Angeles | | | | |
| WSPR | S | BLM-Warm Springs/Angeles NF | 34 35'44" | 118 34'44" | 1225 | Los Angeles | | | | |
| ZUMA | S | Zuma Beach | 34 1'20" | 118 49'37" | | Los Angeles | | | | |
| EMUA | U | El Monte-9528 Telstar | 34 4' 4" | 118 3'39" | 76 | Los Angeles | | | | |
| FUUA | U | Fullerton-SCE Maintenance Yard | 33 52' 0" | 117 56'54" | 30 | Orange | | | | |
| GLUA | U | Glendora-near SCAQMD site 7000591 | 34 8'39" | 117 51' 0" | 277 | Los Angeles | | | | |
| LMUA | U | Loyola Marymount Univ.-Engng Bldg | 33 58'40" | 118 24'48" | 45 | Los Angeles | | | | |
| SFUA | U | Santa Fe Springs-Public Works Yard | 33 56'19" | 118 3'37" | 37 | Los Angeles | | | | |
| YLUA | U | Yorba Linda County Park | 33 56' 1" | 117 46'18" | 88 | Orange | | | | |
| BUR | U/S | Burbank/Glendale/Pasadena Airport | 34 12' 0" | 118 21'30" | 236 | Los Angeles | | | | |
| EDW | U/S | Edwards AFB | 34 54' 0" | 117 52' 0" | 702 | Kern County | | | | |
| MYF | U/S | San Diego-Montgomery Airport | 32 48' 0" | 117 8'24" | 128 | San Diego | | | | |
| NSI | U/S | San Nicolas Island | 33 14' 0" | 119 27' 0" | 14 | Ventura | | | | |
| NTD | U/S | Pt. Mugu Naval Weapons Test Center | 34 7' 0" | 119 7' 0" | 2 | Ventura | | | | |
| ONT | U/S | Ontario International Airport | 34 3'24" | 117 36'12" | 290 | San Bernardino | | | | |
| RAL | U/S | Riverside Municipal Airport | 33 57' 6" | 117 26'42" | 249 | Riverside | | | | |
| VBG | U/S | Vandenberg AFB | 34 43' 0" | 120 34' 0" | 112 | Santa Barbara | | | | |

* "A", "B", and "C" sites are defined in Section 2.3. Other site types are: M=SCAQS surface meteorology sites, S=supplemental meteorology sites, U=upper-air meteorology sites. Those site locations in the study area are shown on Figure 4-1.

Table A-2. Fall Aircraft VOC and Carbonyl Samples in the SCAQS Data Base Which Have Been Flagged

| Spiral or Orbit Location | Date | Time (PST) | Altitude (m msl) | Flight Type | VOC or Carbonyl | Problem |
|--------------------------|--------|------------|------------------|-------------|-----------------|--------------------|
| AMTRA | 871113 | 1359 | 396 | Orbit | Carbonyl | High Pentanal |
| El Monte | 871112 | 525 | 518 | Spiral | VOC | Analytical problem |
| El Monte | 871113 | 528 | 853 | Spiral | VOC | Analytical problem |
| El Monte | 871111 | 538 | 122 | Spiral | VOC | Analytical problem |
| Hawthorne | 871112 | 645 | 427 | Spiral | VOC | Analytical problem |
| Hawthorne | 871211 | 647 | 274 | Spiral | VOC | Analytical problem |
| Fullerton | 871211 | 1649 | 30 | Spiral | VOC | Analytical problem |

APPENDIX B

COMPARISON OF OZONE CONCENTRATIONS FROM MODEL SIMULATIONS AND AIRCRAFT MEASUREMENTS: JUNE 24-25, 1987

Model simulation results were available from the final Air Quality Management Plan (AQMP) UAM runs (SCAQMD, 1990, 1991). Days with both model simulation results and aircraft measurements included June 24-25, 1987 and August 27-28, 1987; in both cases the model simulation started on the previous day.

During each of three flights each day, the air quality aircraft measured ozone concentrations from about 1500 m msl to the surface during vertical spirals. The model predicted average ozone concentrations in six vertical cells centered over a 5 km by 5 km surface grid cell. The size of the six vertical cells varied as a function of mixing height; three cells of equal height below the mixing height and three above. The model simulated the first 1000 m above the surface. For the model predictions, we computed a distance-weighted average over the four horizontal cells nearest the aircraft spiral location; this minimized the effects of any unusual peaks or valleys in the ozone concentration. For the model predictions, we used the hour-averaged ozone concentrations which included the time of the aircraft spiral.

Figures B-1 through B-14 show the comparisons for June 24 and 25, 1987 at seven spiral locations three times per day. The solid line shows 30 m bin averages of the ozone concentrations measured during an aircraft spiral. The dashed line shows the hour-averaged model prediction. We have also included the average of the aircraft data on the same altitude intervals as the model results (the dotted line).

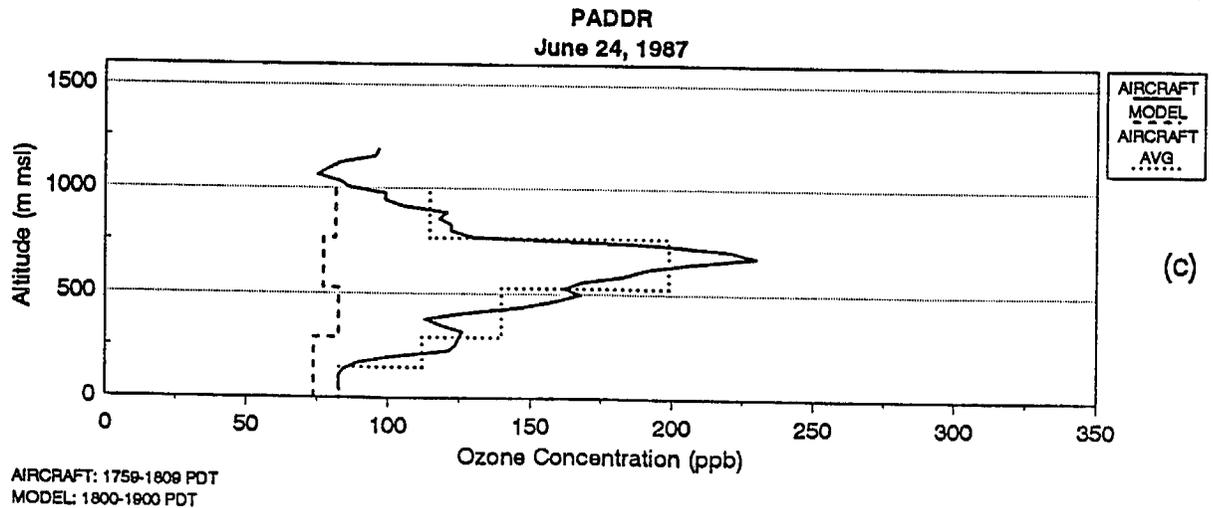
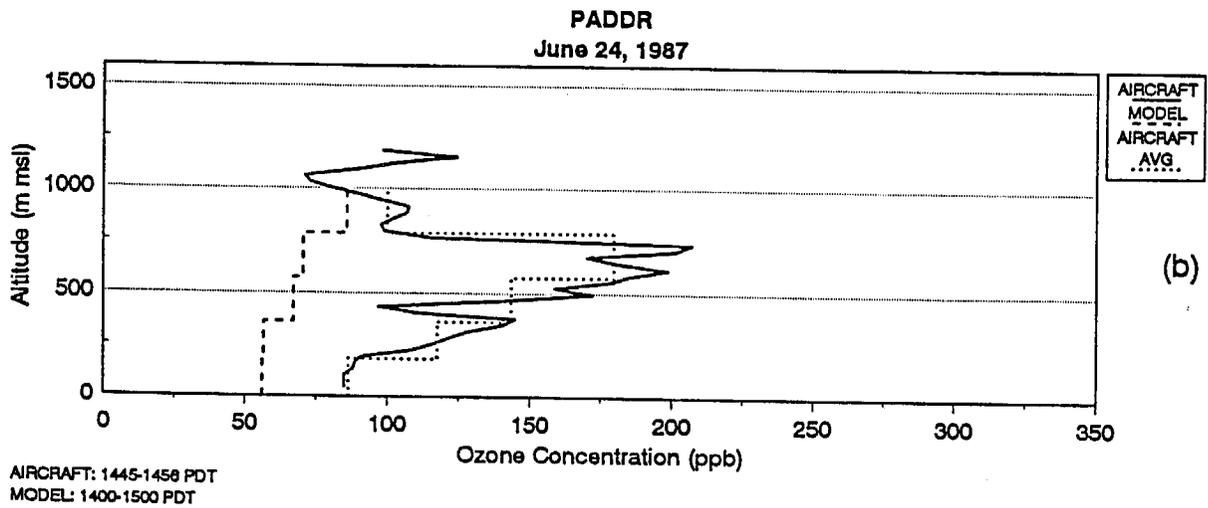
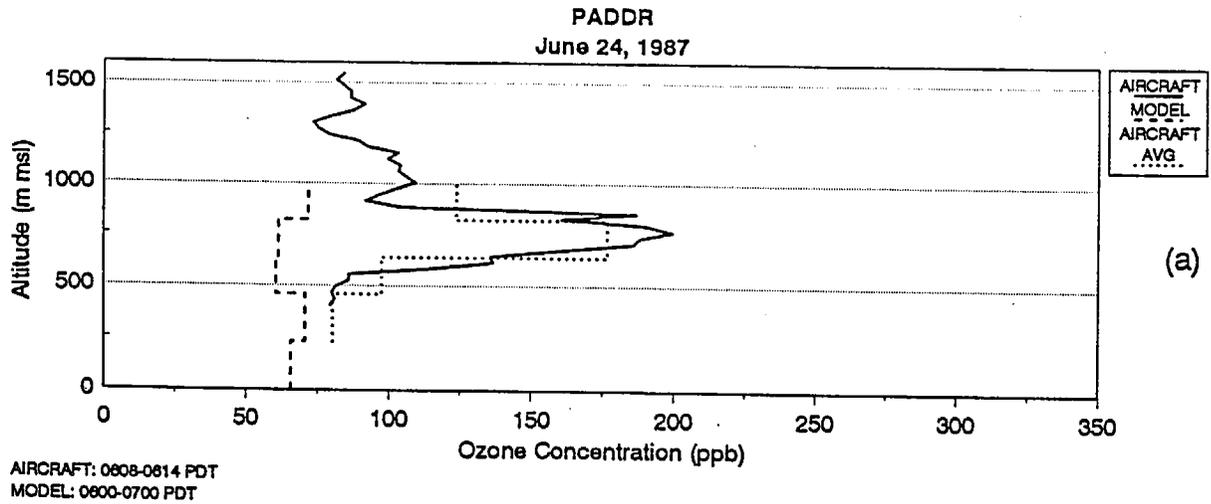
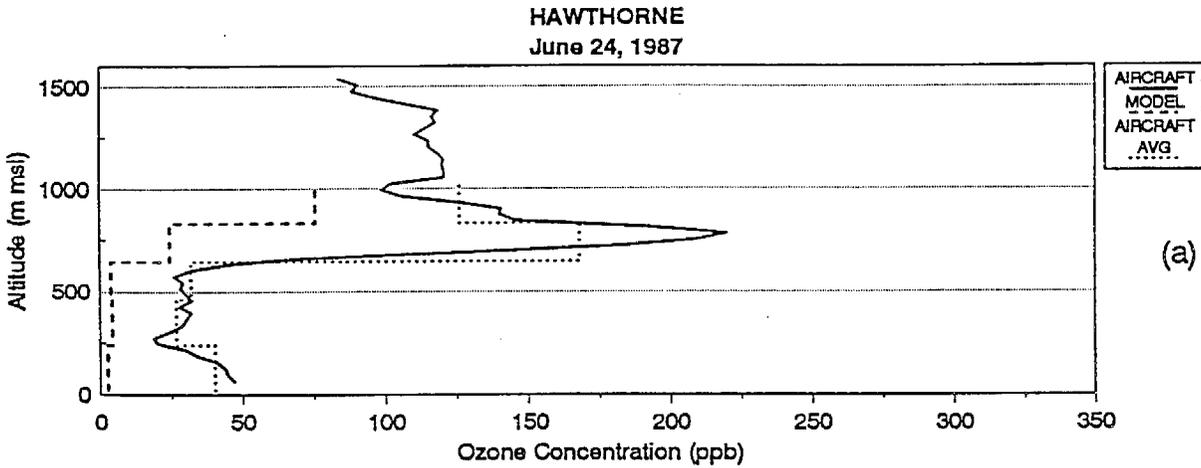
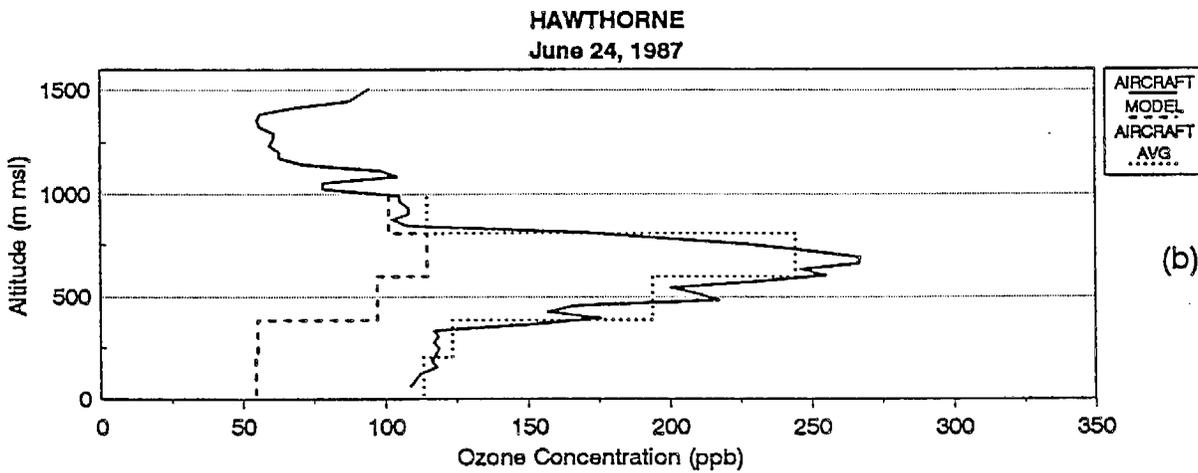


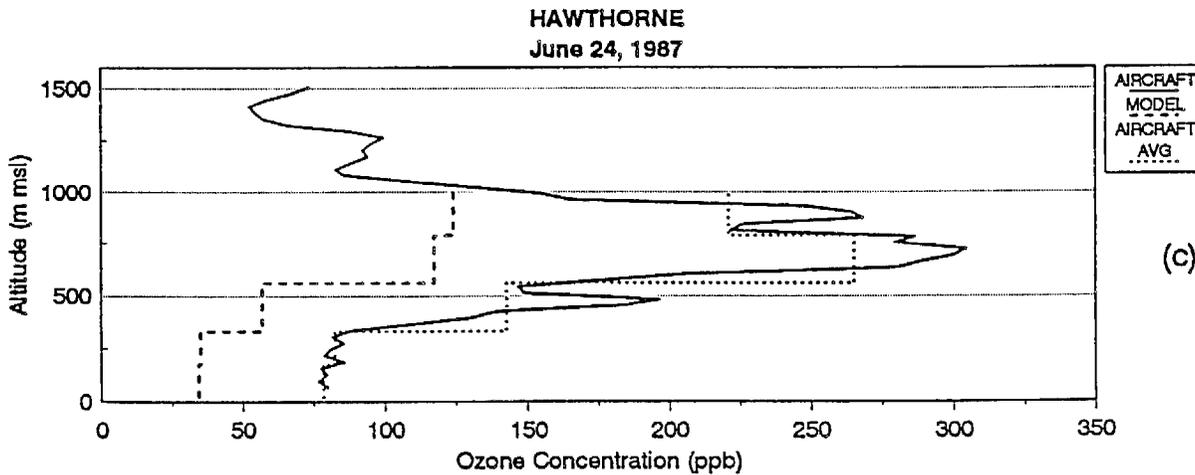
Figure B-1. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at PADDR on June 24, 1987.



AIRCRAFT: 0549-0556 PDT
MODEL: 0500-0800 PDT



AIRCRAFT: 1421-1432 PDT
MODEL: 1400-1500 PDT



AIRCRAFT: 1741-1750 PDT
MODEL: 1700-1800 PDT

Figure B-2. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Hawthorne on June 24, 1987.

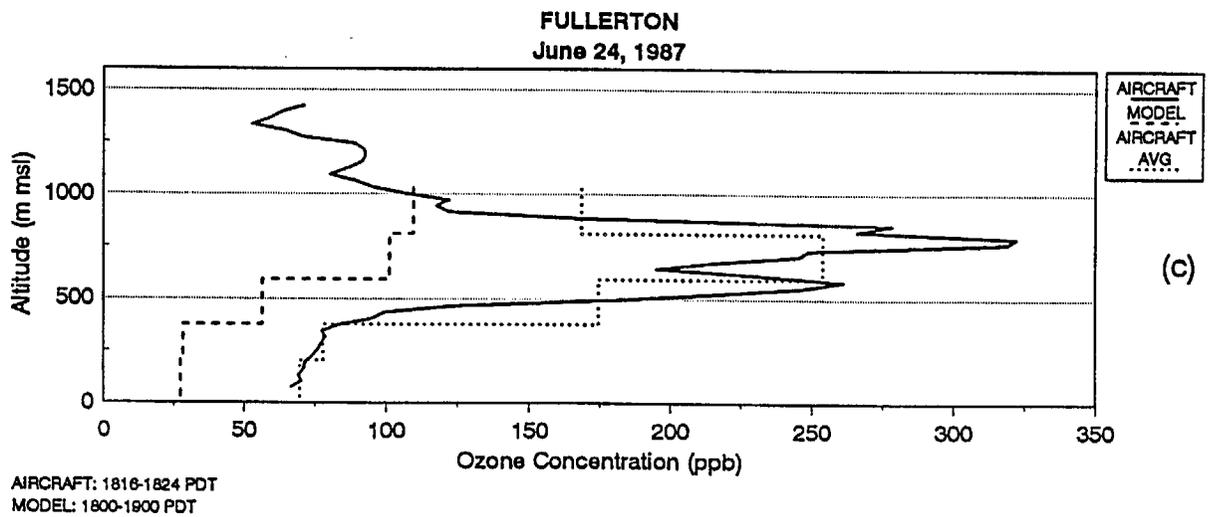
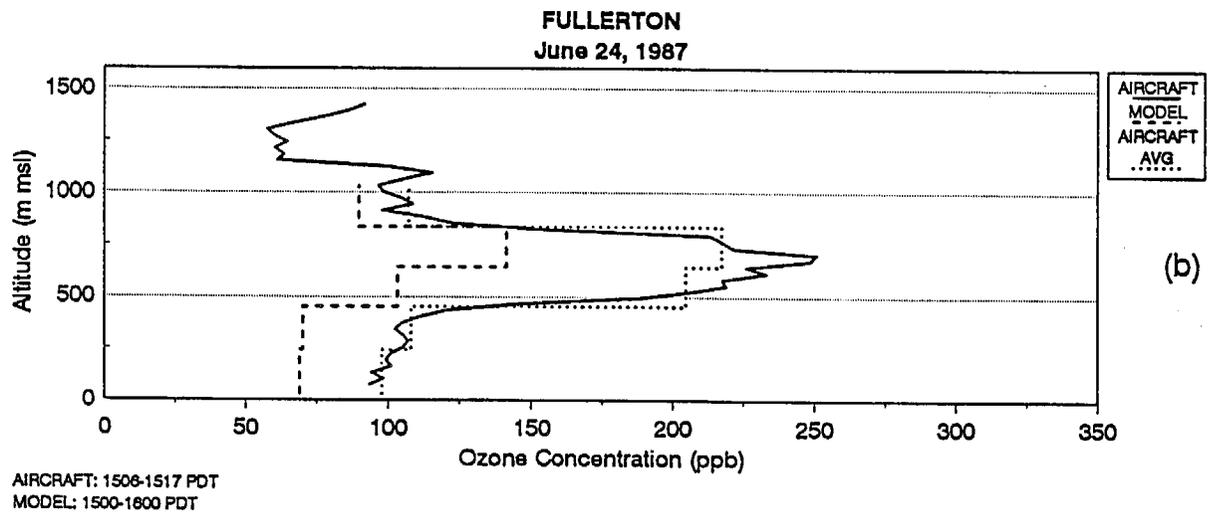
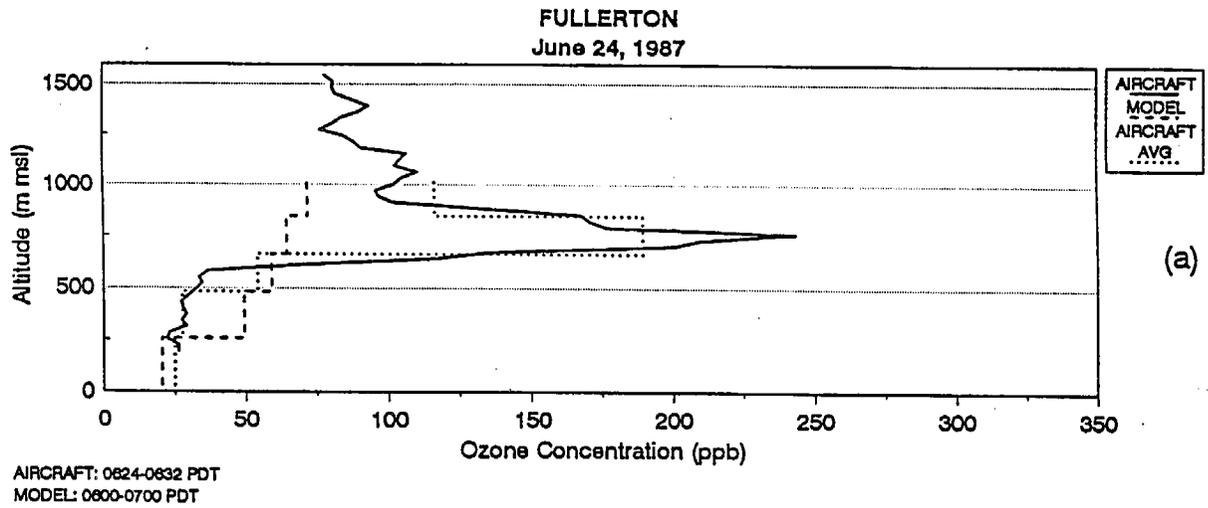
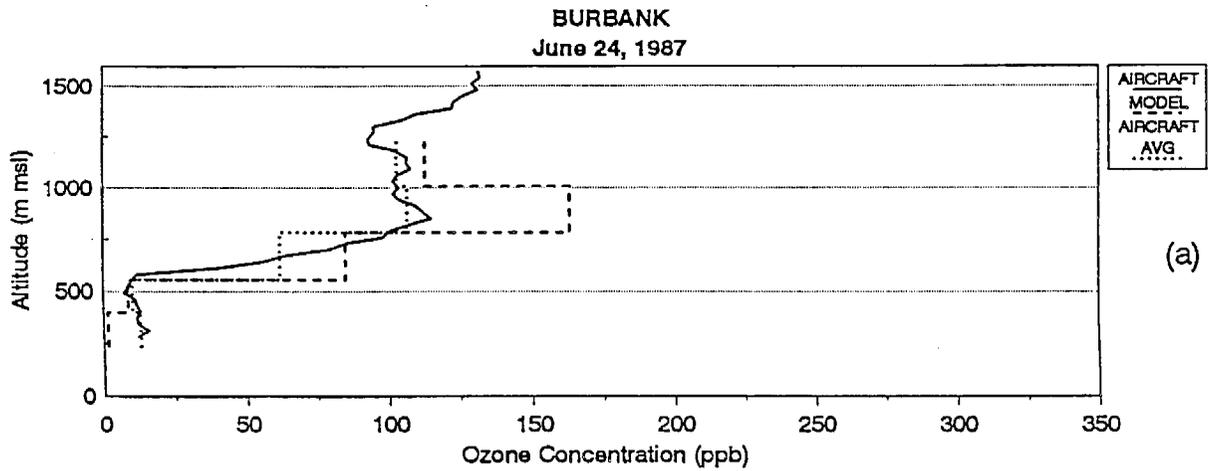
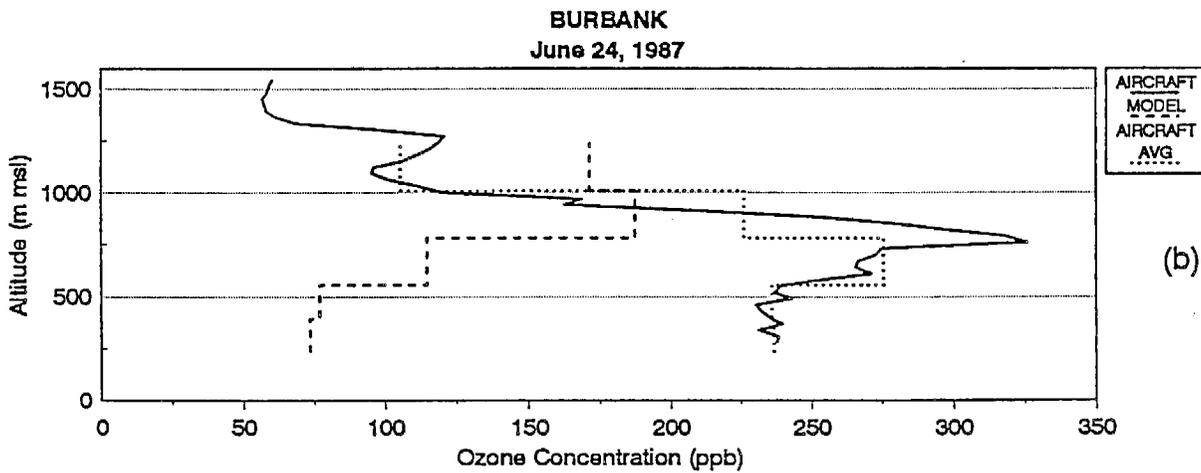


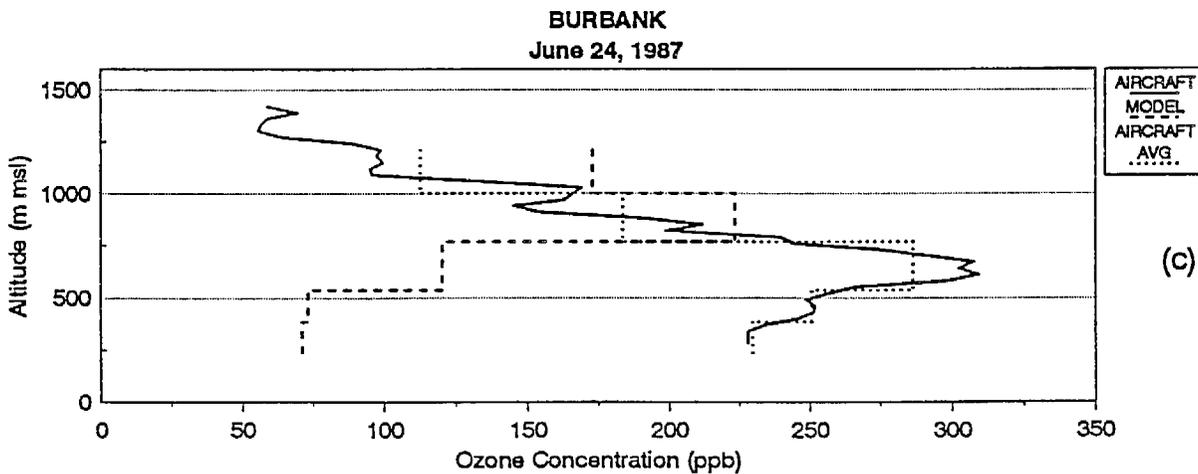
Figure B-3. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Fullerton on June 24, 1987.



AIRCRAFT: 0523-0537 PDT
MODEL: 0500-0600 PDT



AIRCRAFT: 1402-1409 PDT
MODEL: 1400-1500 PDT



AIRCRAFT: 1714-1721 PDT
MODEL: 1700-1800 PDT

Figure B-4. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Burbank on June 24, 1987.

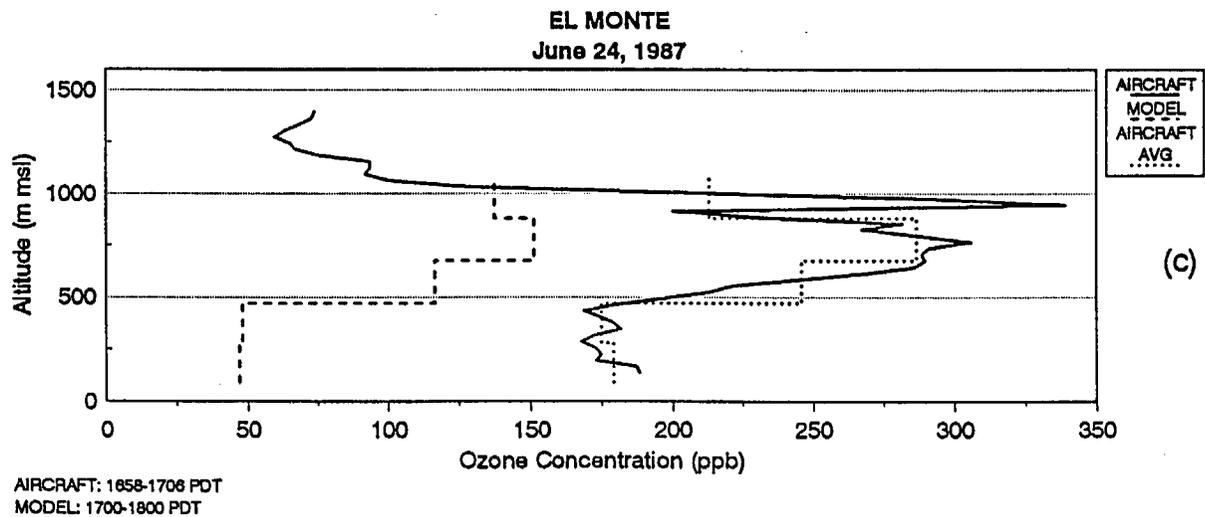
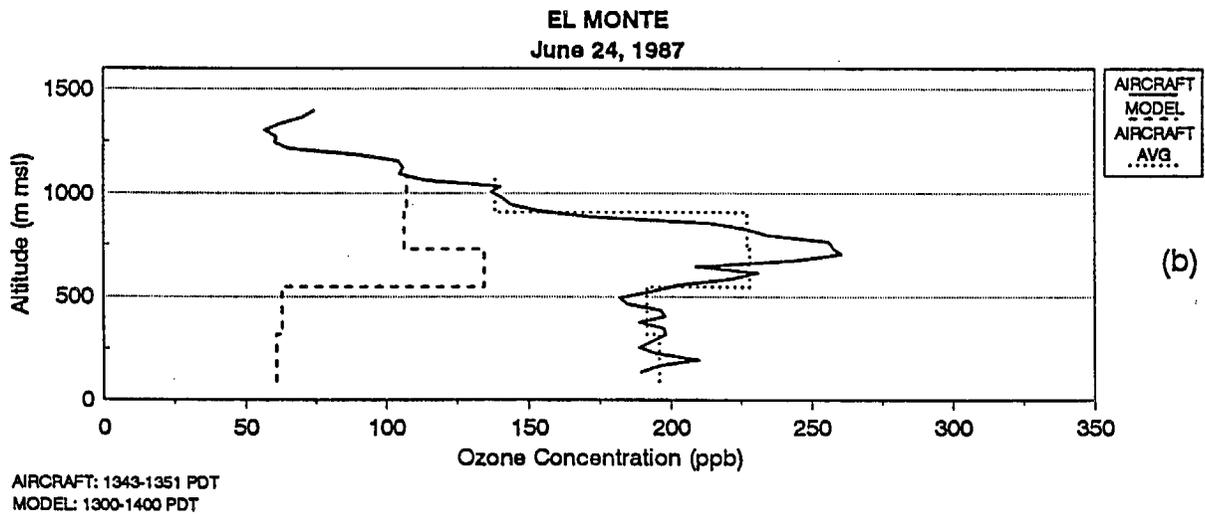
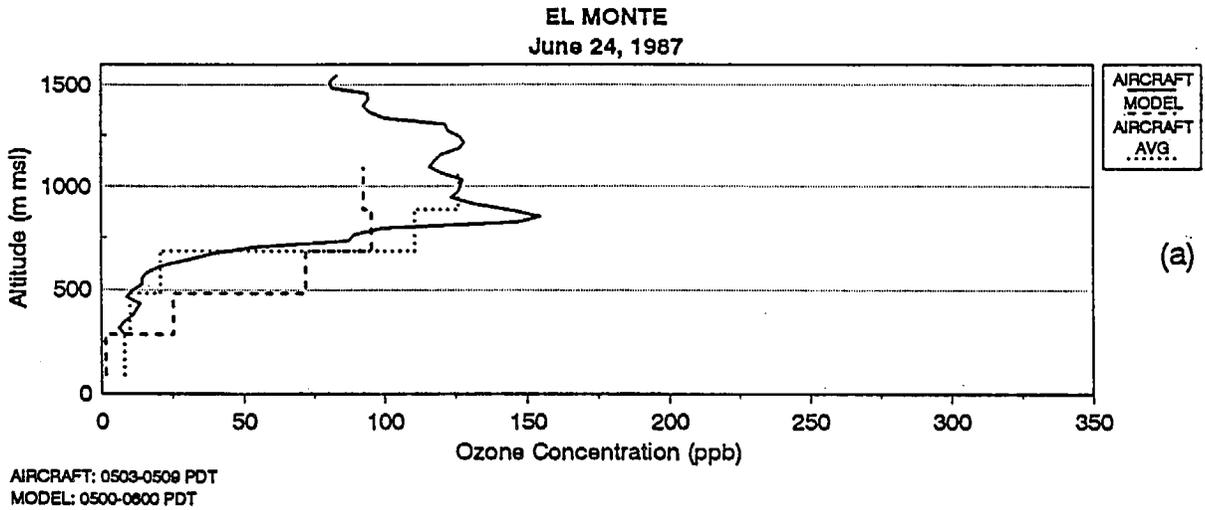


Figure B-5. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at El Monte on June 24, 1987.

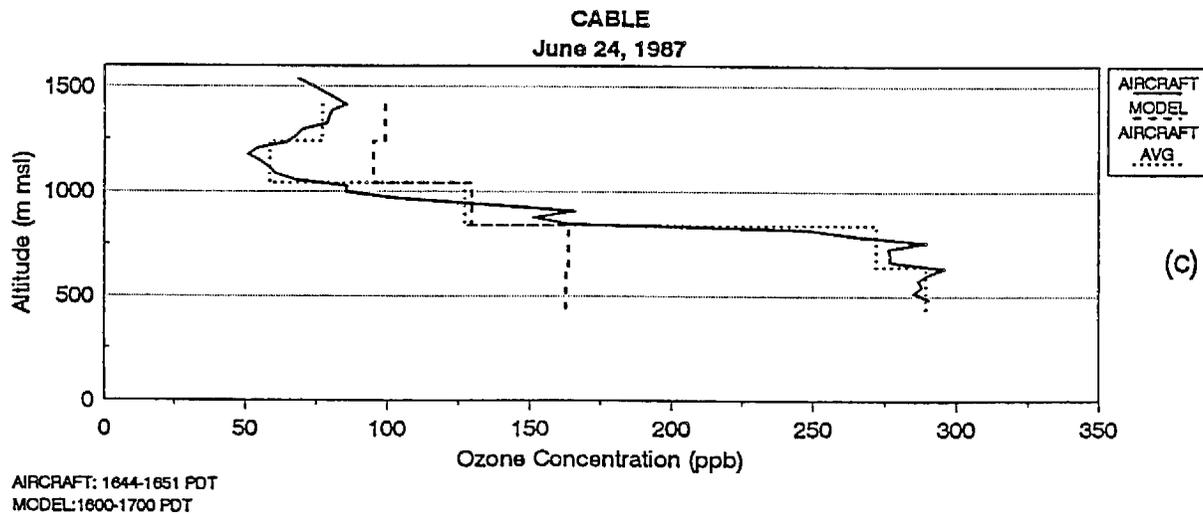
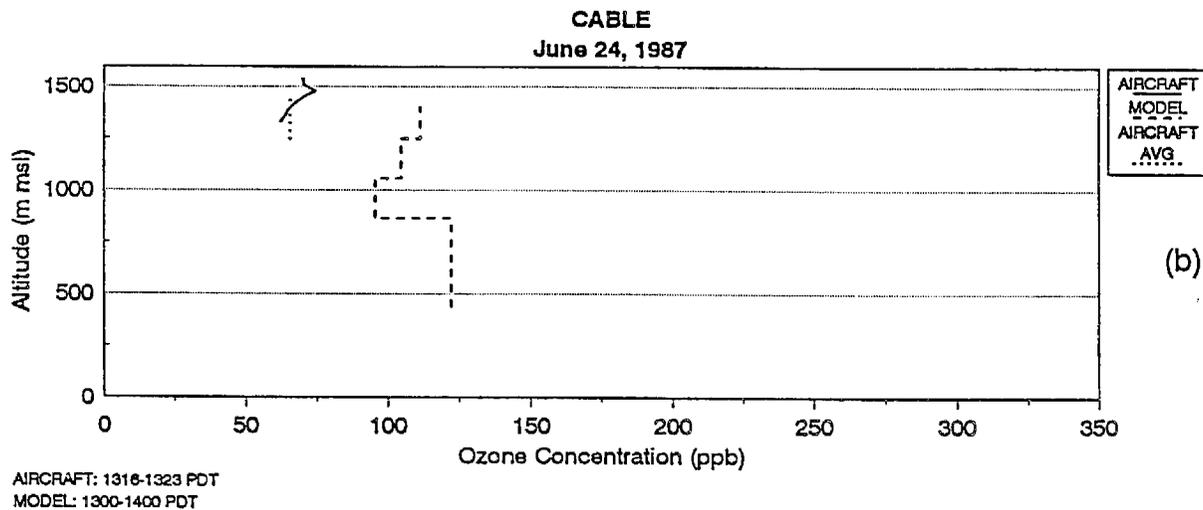
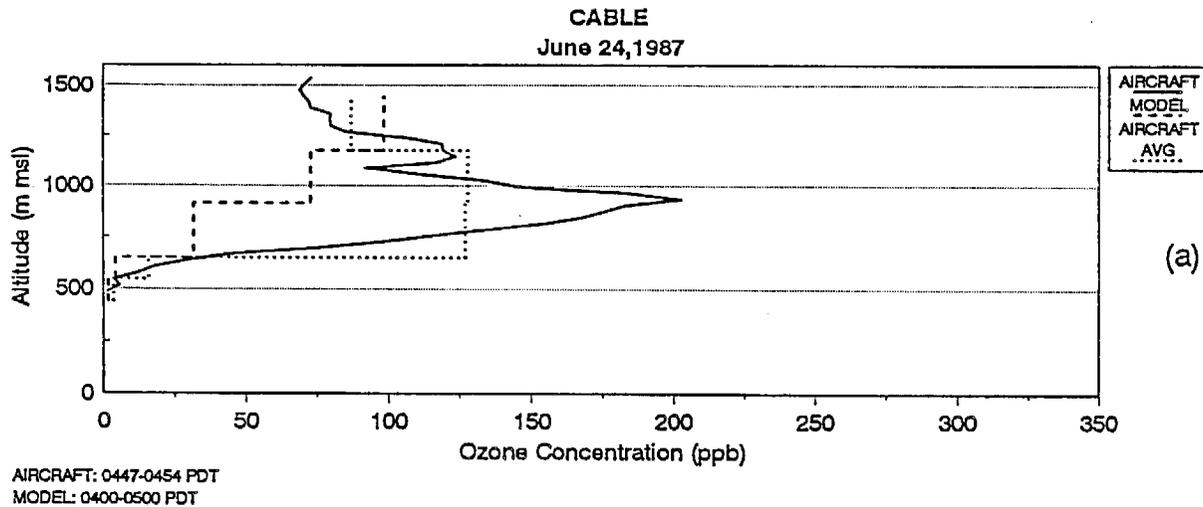


Figure B-6. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Cable on June 24, 1987. Midday, the ozone monitor was inoperable below 1300 m msl.

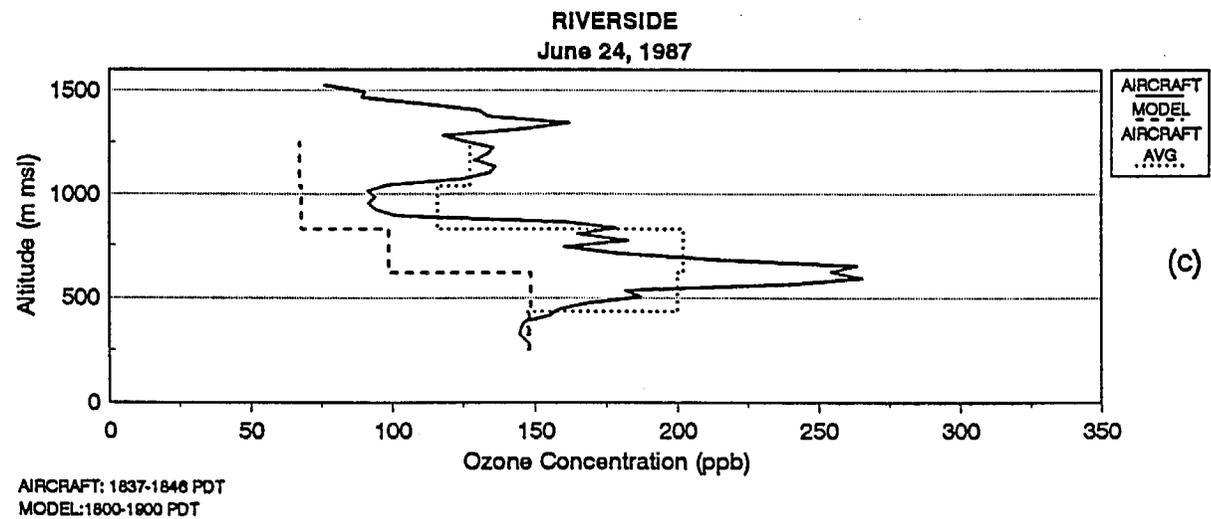
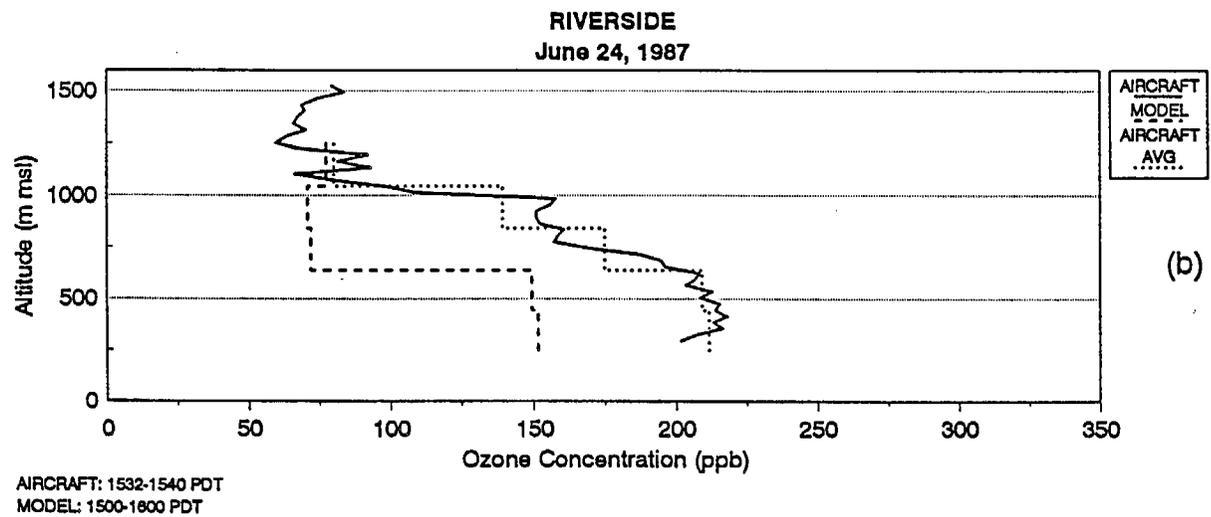
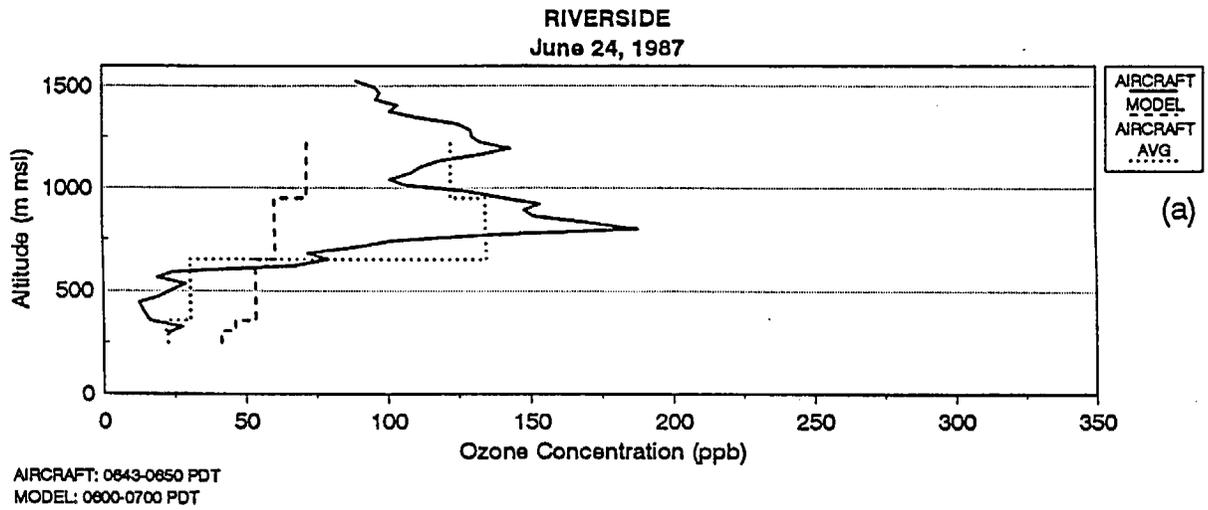
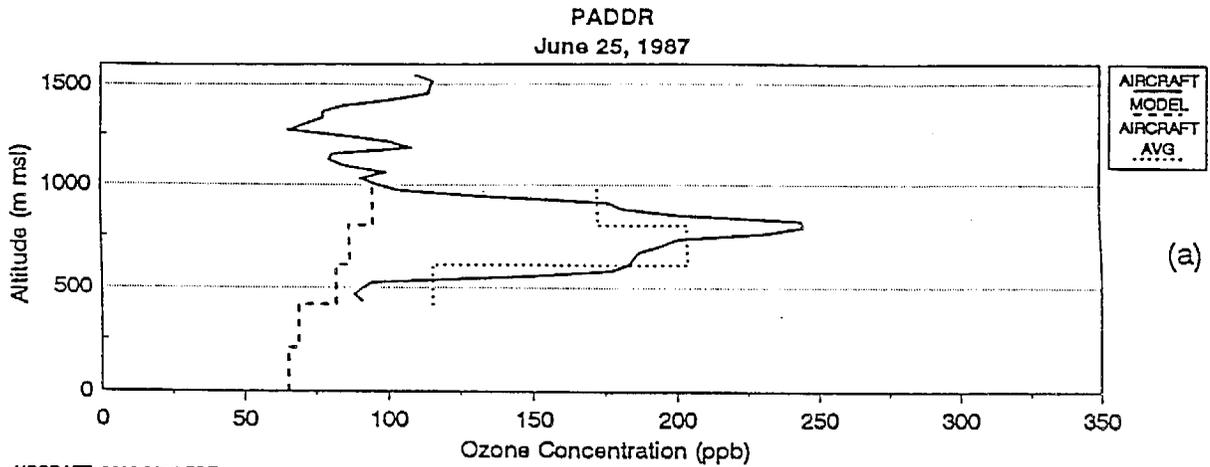
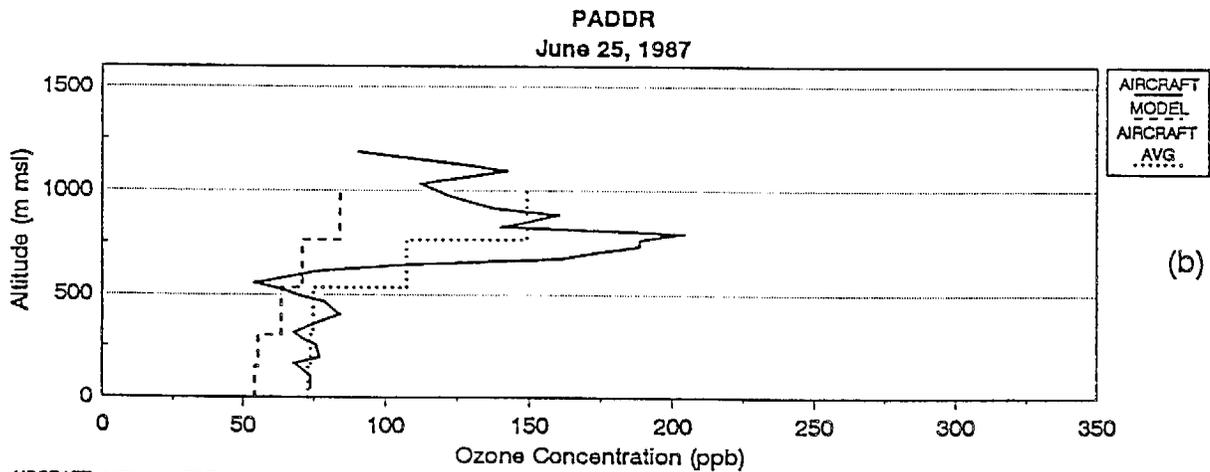


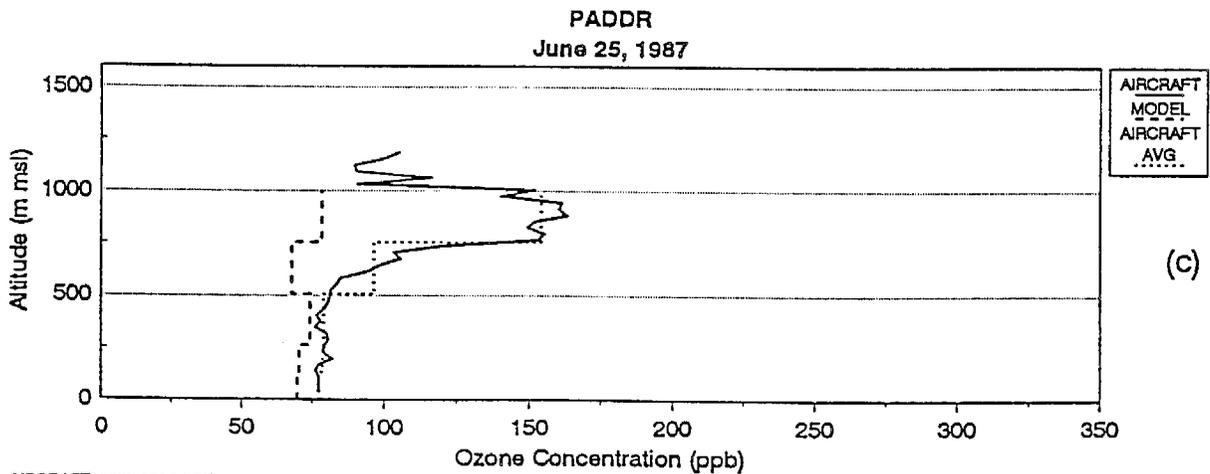
Figure B-7. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Riverside on June 24, 1987.



AIRCRAFT: 0630-0639 PDT
MODEL: 0600-0700 PDT



AIRCRAFT: 1128-1134 PDT
MODEL: 1100-1200 PDT



AIRCRAFT: 1626-1636 PDT
MODEL: 1600-1700 PDT

Figure B-8. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at PADDR on June 25, 1987.

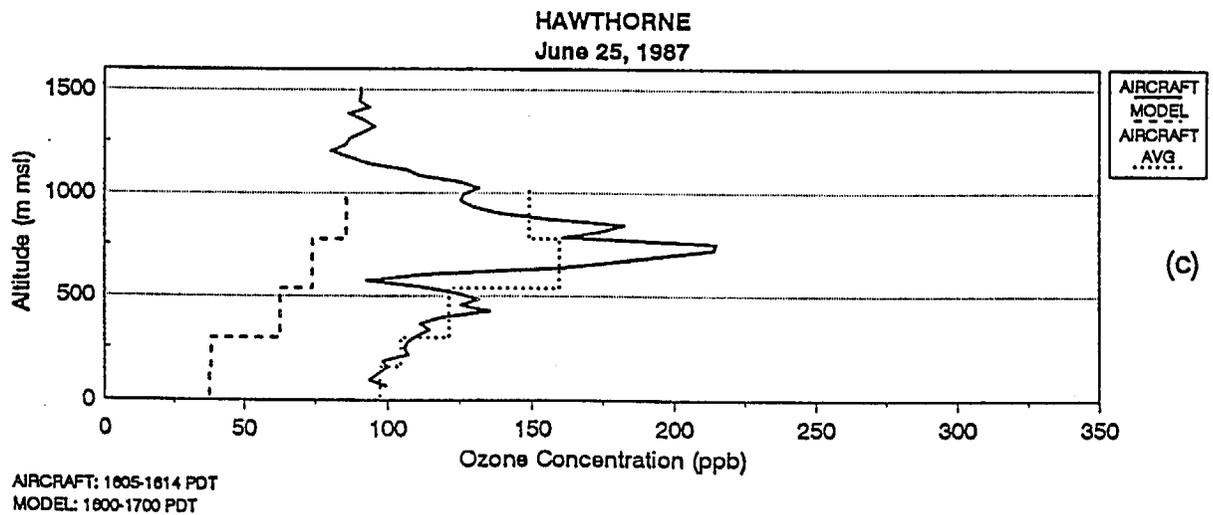
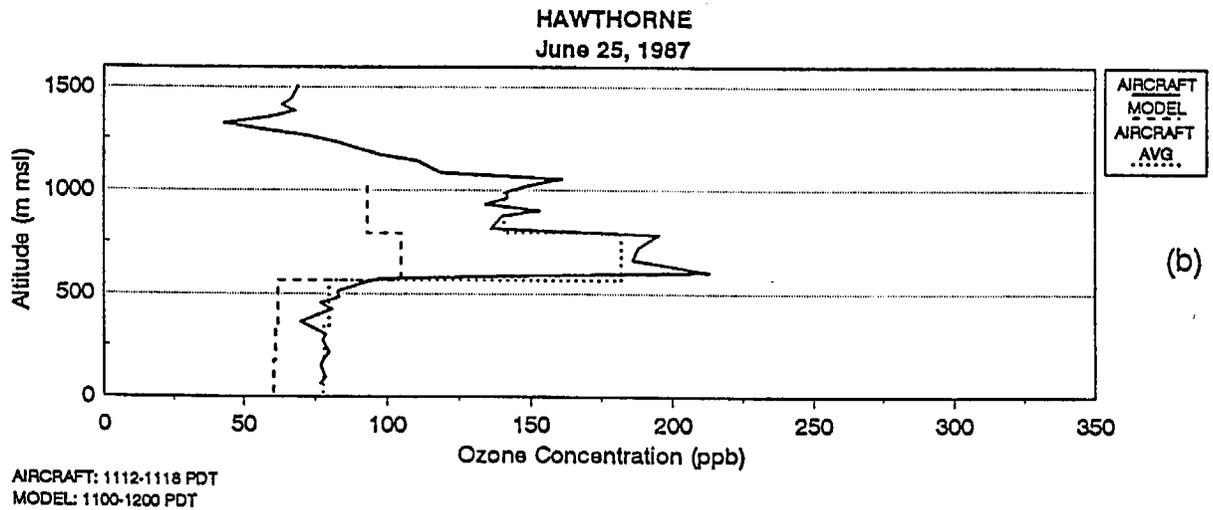
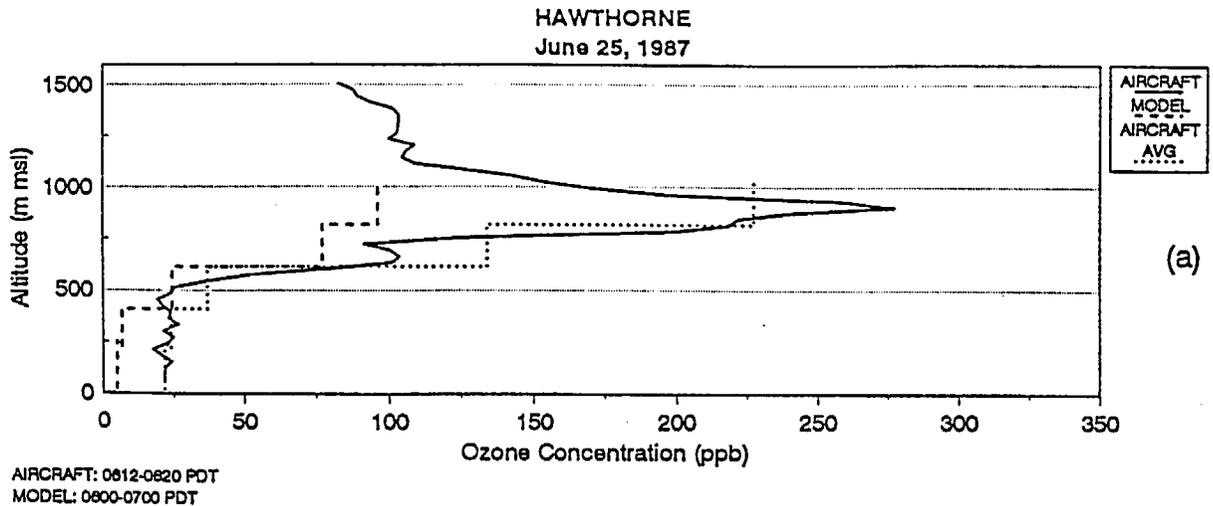
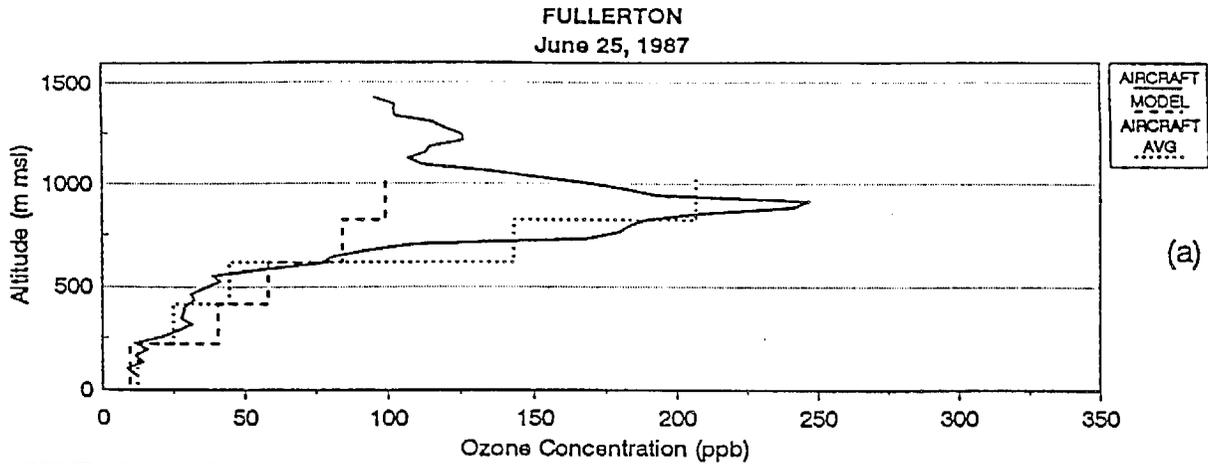
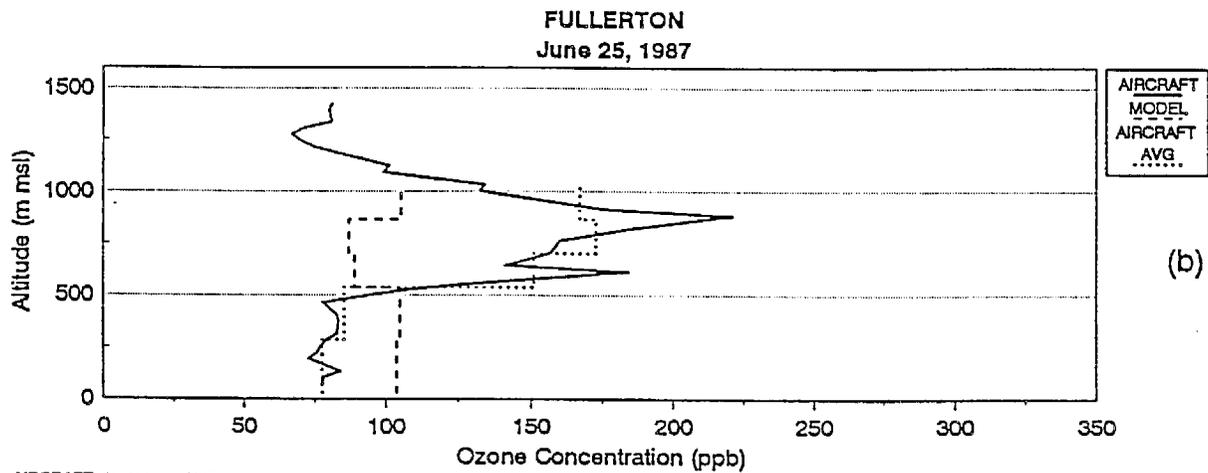


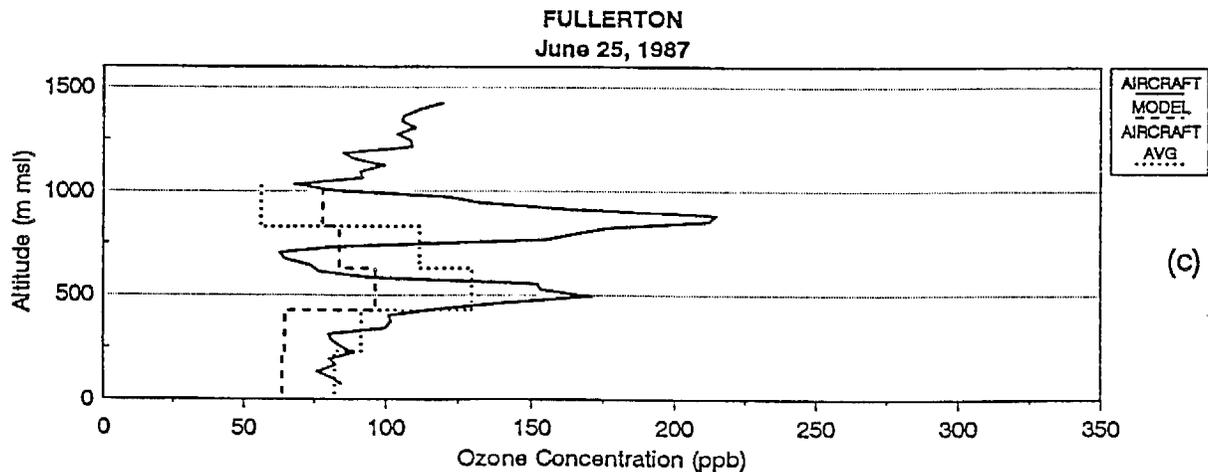
Figure B-9. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Hawthorne on June 25, 1987.



AIRCRAFT: 0652-0658 PDT
MODEL: 0600-0700 PDT

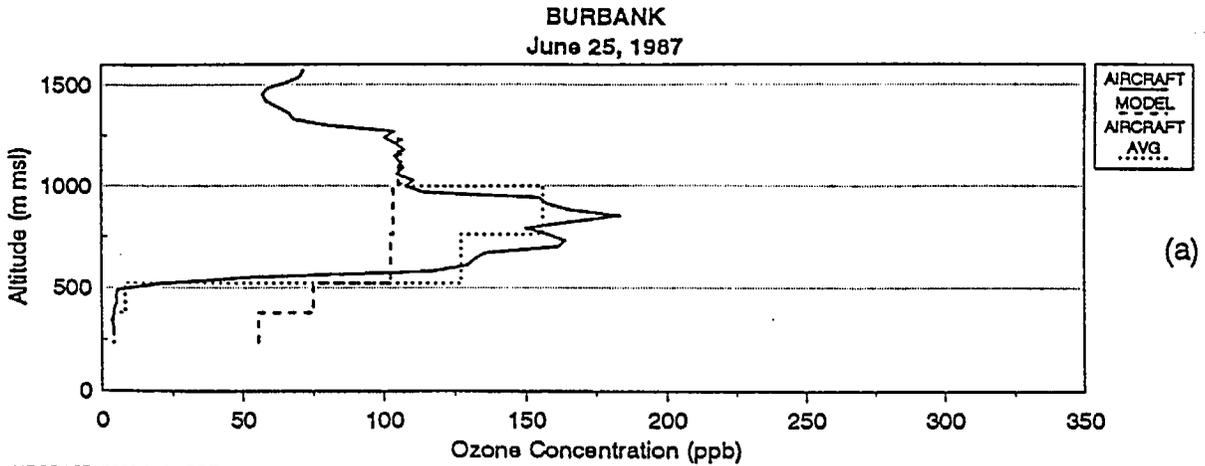


AIRCRAFT: 1143-1150 PDT
MODEL: 1100-1200 PDT

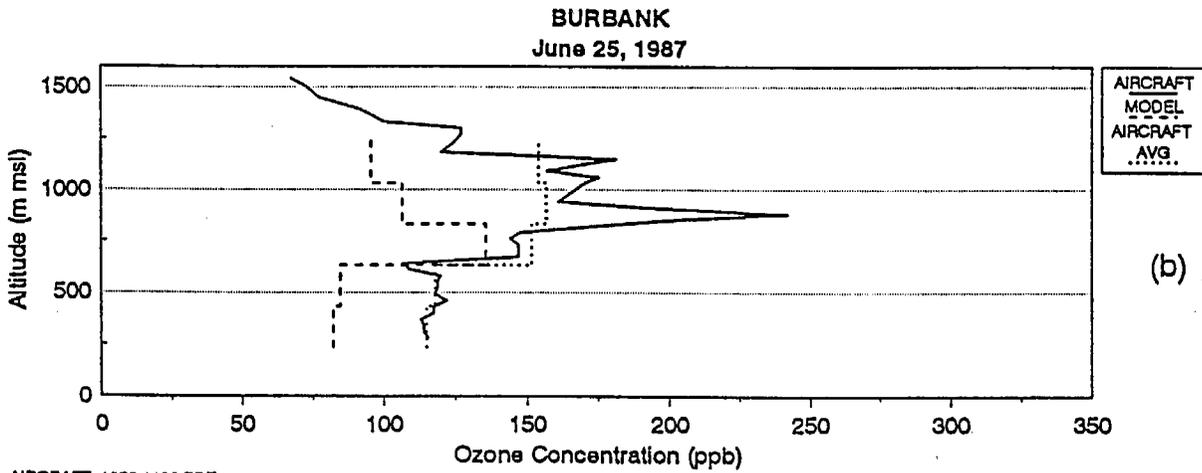


AIRCRAFT: 1645-1654 PDT
MODEL: 1600-1700 PDT

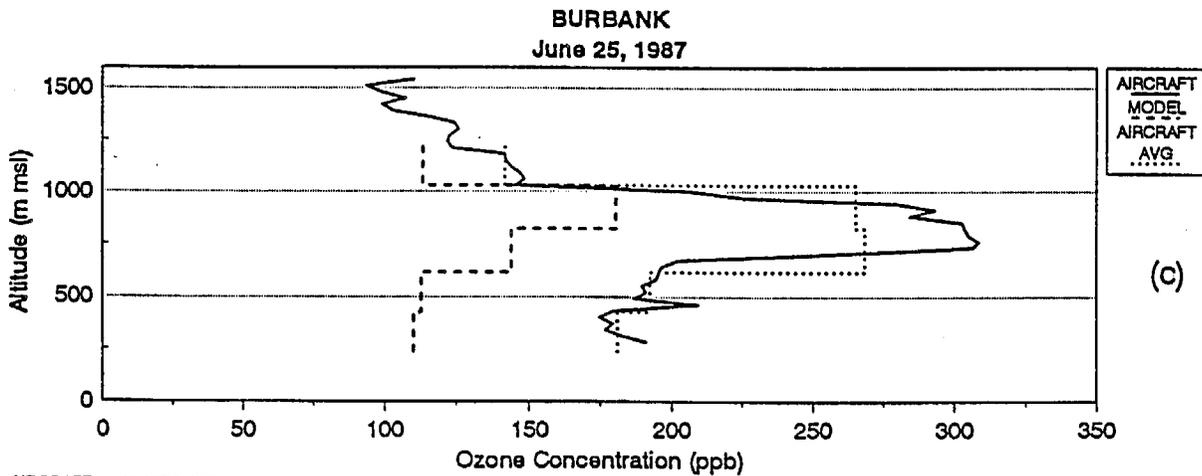
Figure B-10. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Fullerton on June 25, 1987.



AIRCRAFT: 0555-0804 PDT
MODEL: 0800-0700 PDT

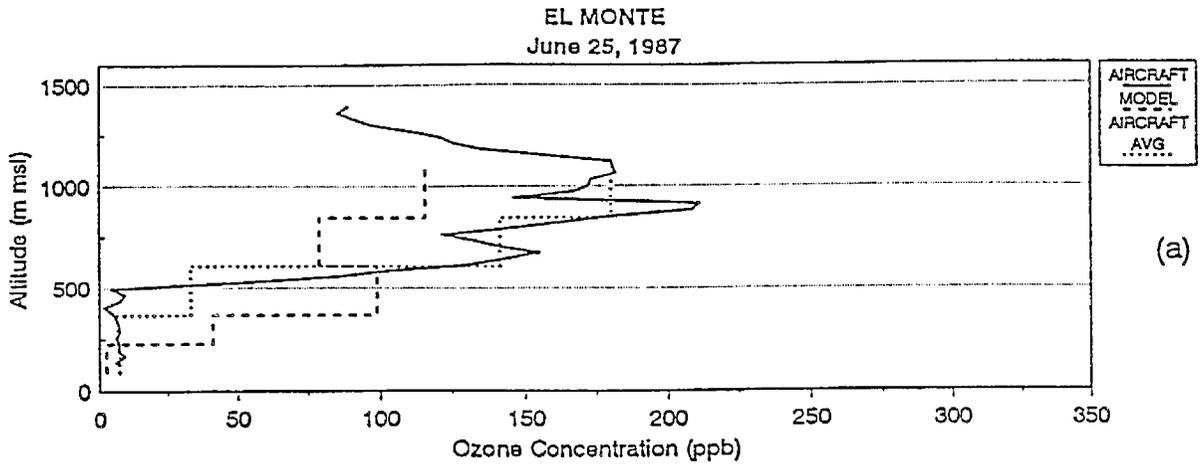


AIRCRAFT: 1058-1103 PDT
MODEL: 1100-1200 PDT

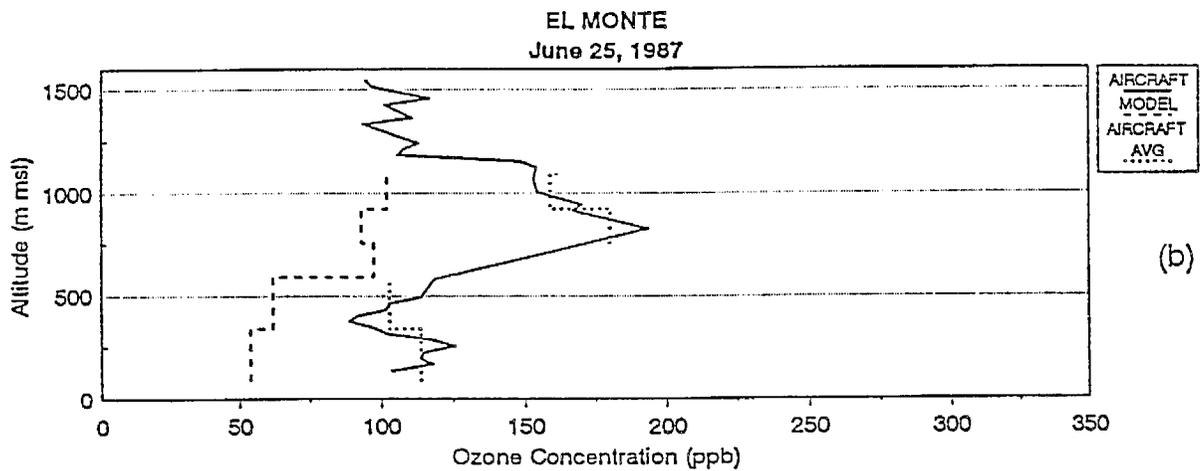


AIRCRAFT: 1546-1554 PDT
MODEL: 1500-1800 PDT

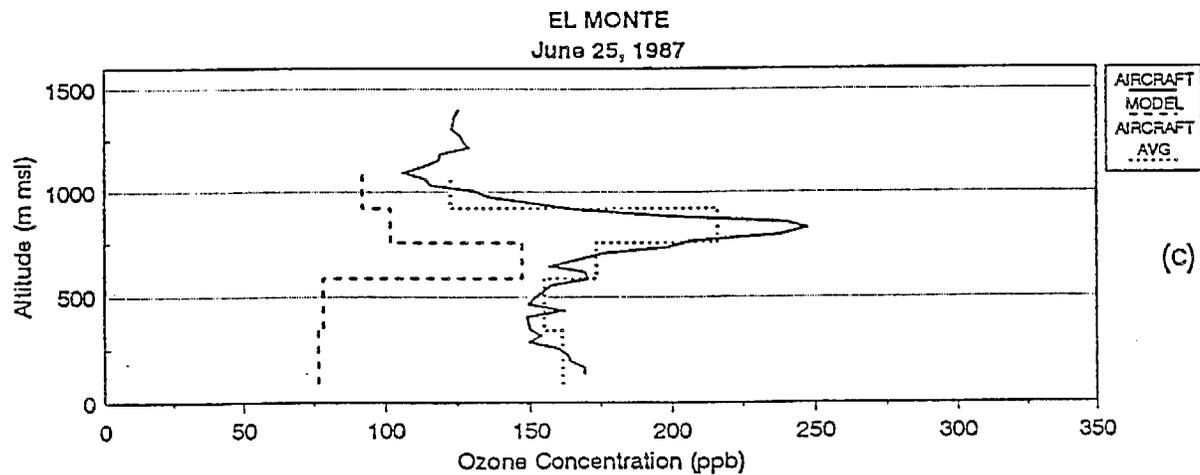
Figure B-11. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Burbank on June 25, 1987.



AIRCRAFT: 0526-0537 PDT
MODEL: 0500-0600 PDT

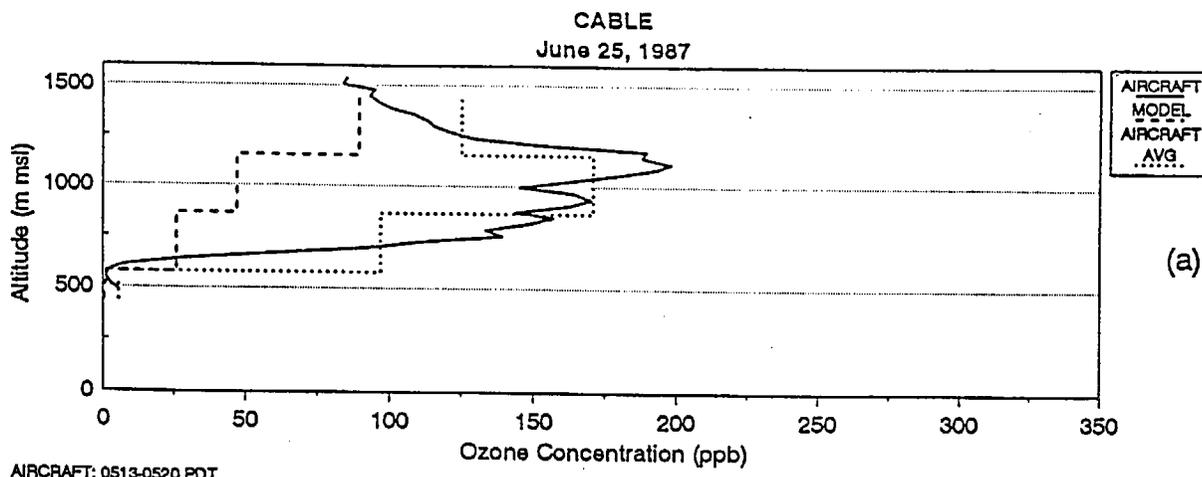


AIRCRAFT: 1041-1049 PDT
MODEL: 1000-1100 PDT

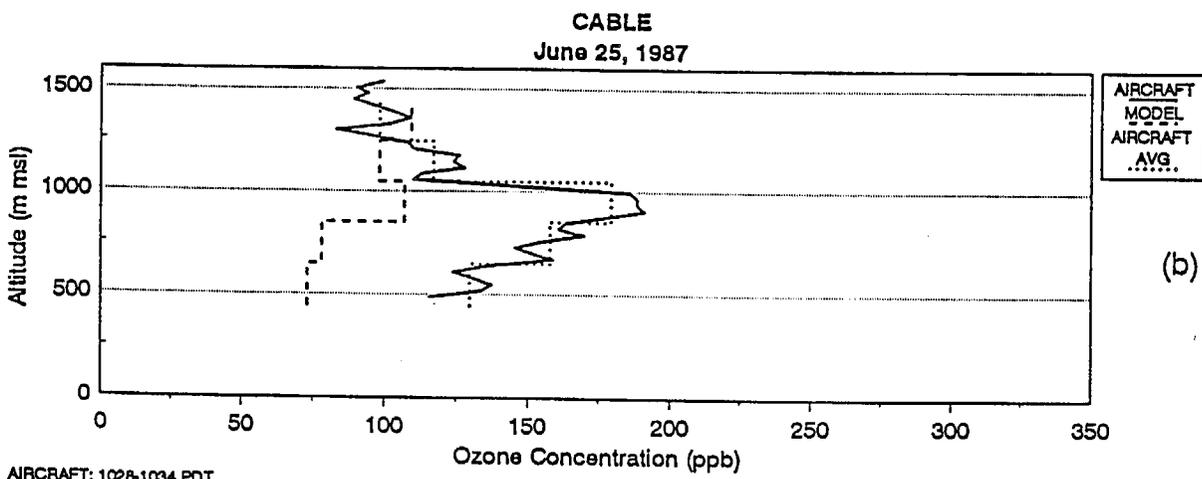


AIRCRAFT: 1528-1537 PDT
MODEL: 1500-1600 PDT

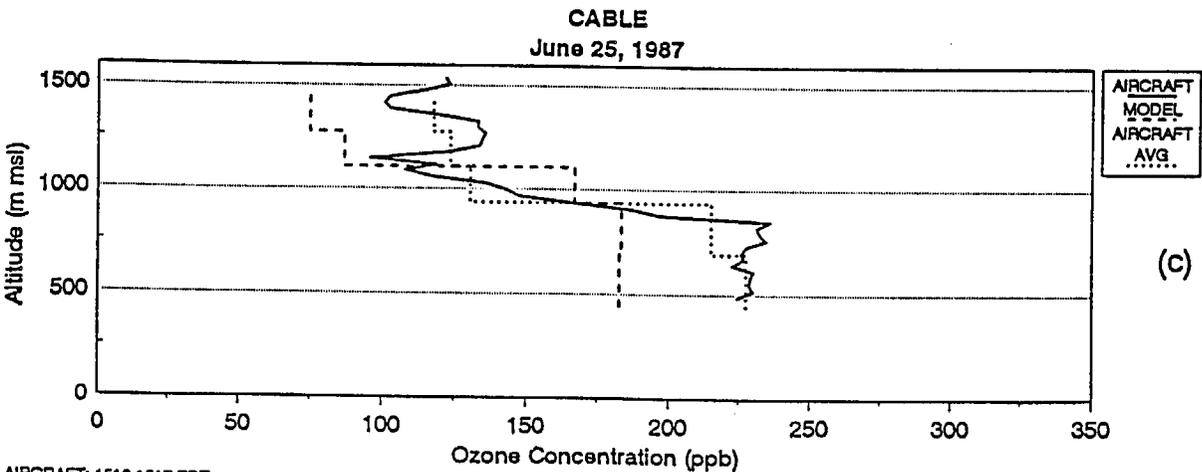
Figure B-12. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at El Monte on June 25, 1987.



AIRCRAFT: 0513-0520 PDT
MODEL: 0500-0600 PDT



AIRCRAFT: 1028-1034 PDT
MODEL: 1000-1100 PDT



AIRCRAFT: 1510-1517 PDT
MODEL: 1500-1600 PDT

Figure B-13. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Cable on June 25, 1987.

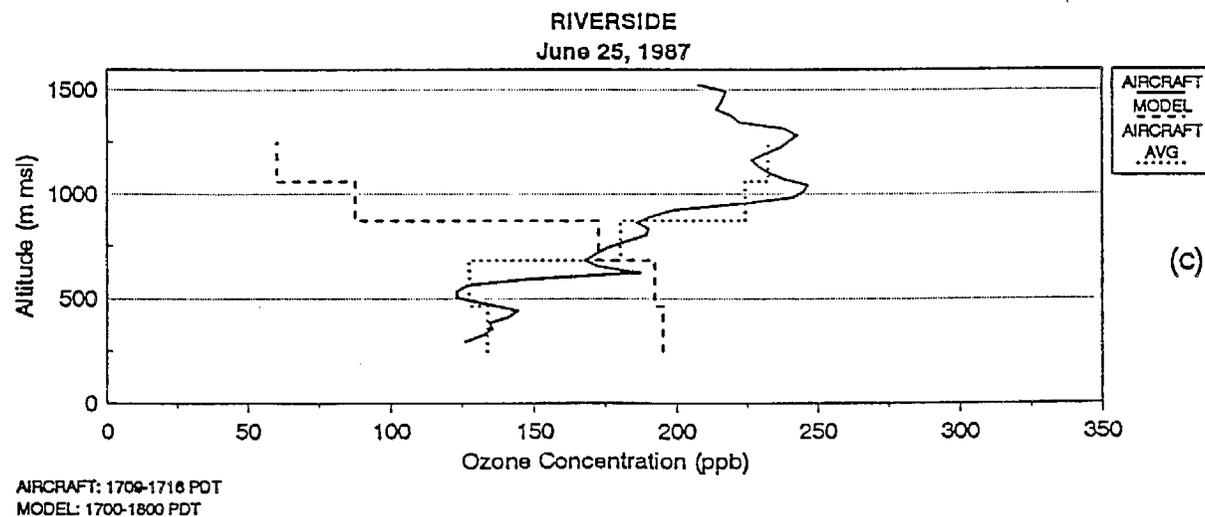
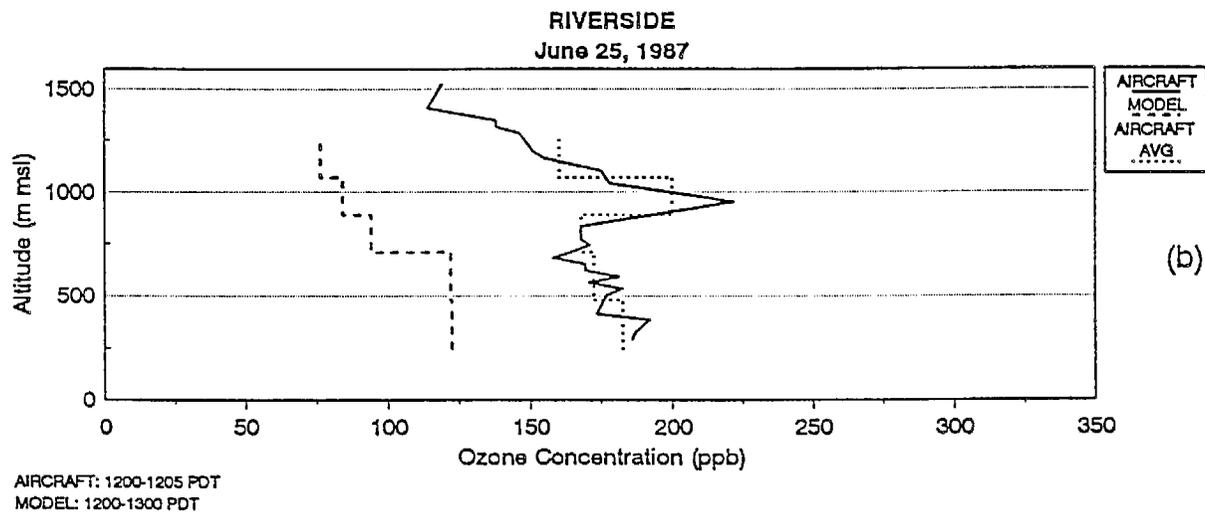
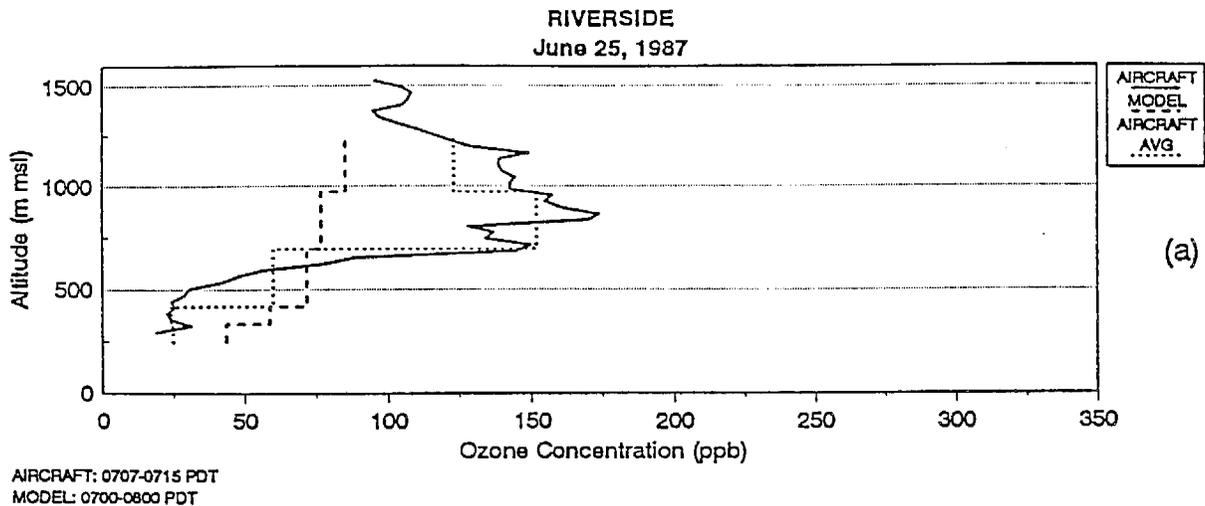


Figure B-14. Vertical Profiles of Ozone Concentration Measured by Aircraft Spiral Compared to the UAM Average for the (a) Morning, (b) Midday, and (c) Afternoon at Riverside on June 25, 1987.



REPORT DOCUMENTATION PAGE

| | | | | |
|--|--|---|---|--|
| 1. AGENCY USE ONLY <i>(Leave Blank)</i> PB94-111606 | | 2. REPORT DATE May 1993 | 3. REPORT TYPE AND DATES COVERED Final Report | |
| 4. TITLE AND SUBTITLE Ozone and Particulate Matter Case Study Analyses for the Southern California Air Quality Study | | | 5. FUNDING NUMBERS Contract Agree. No. A932-050 | |
| 6. AUTHOR(S) Paul T. Roberts Hilary H. Main | | | 8. PERFORMING ORGANIZATION REPORT NUMBER STI-90020-1222-FR | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Sonoma Technology, Inc. 5510 Skylane Blvd., Suite 101 Santa Rosa, CA 95403 | | | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER ARB/R- 93/491 | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) California Air Resources Board Research Division 2020 L Street Sacramento, CA 95814 | | | 11. SUPPLEMENTARY NOTES | |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT Release unlimited. Available from National Technical Information Service. 5285 Port Royal Road Springfield, VA 22161 | | | 12b. DISTRIBUTION CODE | |
| 13. ABSTRACT <i>(Maximum 200 Words)</i> <p>As part of the Southern California Air Quality Study (SCAQS), case study analyses of the surface and aloft air quality data for three SCAQS episodes were undertaken to improve our understanding of the evolution and sources of ozone and particulate matter concentrations in the South Coast Air Basin (SoCAB), the formation mechanisms of aloft pollutant layers, the importance of these aloft layers to surface concentrations, and to recommend how these phenomena and species distributions should be modeled. This report summarizes the data analyses, analysis results, conclusions, and recommendations. The SCAQS episodes selected for analyses were June 24-25, July 13-15, and December 10-11, 1987.</p> <p>High concentrations of ozone and other pollutants often existed in aloft layers covering much of the SoCAB. The layers were generally horizontal in structure.</p> <p>Model predictions of ozone did not agree with aloft ozone measurements. In the lower 200 meters above the ground (m agl) during the morning, ozone predictions were often significantly higher than measured concentrations. Model predictions of ozone above about 200 m agl were about 50 to over 100 ppb lower than measured concentrations.</p> <p>Future meteorological and photochemical model simulations need to properly represent the formation and transport of aloft polluted layers, including the characteristics described in this report. Additional recommendations are made on the use of field data for model inputs and on other ways to evaluate and improve model performance during future programs.</p> | | | | |
| 14. SUBJECT TERMS | | | 15. NUMBER OF PAGES 355 | |
| | | | 16. PRICE CODE 315/\$44.00 | |
| 17. SECURITY CLASSIFICATION OF REPORT Unclassified | 18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified | 19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified | 20. LIMITATION OF ABSTRACT Unlimited | |

