SOUTHWEST DESERT / LAS VEGAS OZONE TRANSPORT STUDY (SLOTS) (CBE 600709)

FINAL REPORT

Prepared for:

Mr. William Cates
Clark County

Air Quality — Protecting the air we share

Department of Air Quality & Environmental Management
500 South Grand Central Parkway
Las Vegas, NV 89106

Prepared by:

T&B Systems
environmental research associates

David Bush
Robert Baxter
William Knuth
Don Lehrman
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July 15, 2008

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This work was performed for the Clark County Department of Air Quality & Environmental Management under CBE 600709. Messrs. William Cates and John Koswan provided overall project management. A large field program such as SLOTS is successful only when all the participants share the hard work necessary and coordinate their activities. Therefore, we would like to express our gratitude to the DAQEM staff members who participated in planning and operational meetings, and those who contributed to the field monitoring effort. In particular, Mr. Phil Wiker, who participated in daily forecasts; and was instrumental in establishing monitoring sites.

Recognition is due to Ms. Elizabeth Niccum of T&B Systems who assembled all the project-specific measurements and integrated them into a consistent relational database. Many thanks to Ms. Susan Hynek who was central in compiling all the text, figures, and tables from the various authors into a consistent document.

EXECUTIVE SUMMARY

The Clark County Department of Air Quality and Environmental Management (DAQEM) is responsible for preparing state implementation plans (SIPs) for approval by the Clark County Board of Commissioners and to ensure implementation to attain and maintain National Ambient Air Quality Standards (NAAQS). In June 2004, under the Phase I Rule to Implement the 8-hour ozone NAAQS, the U.S. Environmental Protection Agency (EPA) classified specific areas within Clark County as "basic" non-attainment areas for ground-level ozone. Under the "basic" non-attainment classification, Clark County was preparing an attainment demonstration SIP for submittal to the U.S. EPA in June 2007. On December 22, 2006, the United States Court of Appeals (District of Columbia) vacated the Phase I Rule to Implement the 8-hour Ozone NAAQS. In March 2007, the U.S. EPA promulgated the final rule on "Treatment of Data Influenced by Exceptional Events."

These actions require adjustments to air quality planning and regulatory programs for ozone. Accordingly, the DAQEM, rather than submit a SIP to the U.S. EPA in June 2007, is coordinating with the U.S. EPA to receive a "clean data finding" for ozone in accordance with EPA policies. Upon receiving a "clean data finding" for ozone from the U.S. EPA, Clark County will develop and submit to the U.S. EPA a SIP in late 2007 or early 2008 demonstrating maintenance of ozone NAAQS for the foreseeable future. This Maintenance SIP will also include a formal request that Clark County be re-classified from non-attainment to attainment for ozone.

To support development of a Maintenance Plan for ozone, the DAQEM contracted T&B Systems to conduct the Southwest Desert / Las Vegas Ozone Transport Study (SLOTS). The goal of this study was to further study the mechanisms and impact of transport of pollutants into Southern Nevada through enhanced monitoring of ozone air quality and meteorological at key locations during the 2007 ozone season. Objectives include an assessment of both urban and wildfire plume impacts on ozone concentrations, and the development of procedures that will permit Clark County to obtain waivers from regulatory considerations for wildfire events in accordance with the recently promulgated rule on "Treatment of Data Influenced by Exceptional Events."

There were two levels or modes of field measurements in SLOTS: *continuous* and *intensive*. Continuous measurements were ongoing from the start of the field study during the last half of May 2007, and continued until the scheduled end date of August 31, 2007. More extensive measurements were conducted when the meteorological conditions were forecasted to be conducive to producing high ozone levels, hereafter referred to Intensive Operational Periods (IOPs). IOPs focused on the understanding of the three-dimensional structure of key air quality and meteorological features when polluted air masses due to both wildfire and distant urban plumes were directed towards Clark County.

The SLOTS 2007 monitoring program was conducted from mid-May through August, and consisted of the following elements:

- Supplemental surface measurements operating continuously at two key locations in coordination with similar National Park Service ongoing in the Joshua Tree National Monument and Mojave Desert Preserve One site was located upwind within the primary transport corridor between the major population centers in southern California and Clark County. The second site was located in northwestern Clark County where modeling indicated maximum ozone levels.
- Upper air measurements using aircraft, state-of-the-art remote sensing instruments, and balloon-borne instrumentation.

The field measurements underwent a rigorous validation process and assimilated into an integrated relational database consisting of both of both information and data files. The goal was to make the database very usable and accessible by both immediate and future data analysts.

A preliminary analysis of the 2007 ozone season integrating both routine and special SLOTS measurements revealed the following regarding interstate transport:

- Synoptic meteorological patterns occurred during the study that were consistent with the conceptual model developed in past studies, which include the passing of a low pressure trough that initiates southwesterly transport winds from population centers in Southern California into Clark County. HYSPLIT back-trajectories during these conditions showed trajectories from Las Vegas Valley leading to source areas including the Los Angeles Basin, the western Mojave Desert, and the southern San Joaquin Valley. These synoptic patterns typically occurred in June.
- Buildup of ozone concentrations in the above source areas was noted on days preceding the transport event, and was a necessary event for ozone transport.
- "Fenceline monitoring" on the California/Nevada border showed elevated ozone concentrations entering the area from the southwest. The aircraft recorded these during IOPs on June 22, 23 and 24 and July 18 and 19. The SLOTS Mt. Pass site on the California border also showed high ozone concentrations on these days, as well as during two transport-favorable periods when exceedances of the 8-hour standard were reported in Clark County.
- Upper-air measurements at Jean showed steady southwesterly flow throughout the periods leading up to transport events, consistent with the HYSPLIT back-trajectories.
- Well-defined boundaries were noted between regional background ozone concentrations and Southern California urban plumes with higher concentrations, consistent with plume dynamics. This includes an urban plume with 85 ppb ozone identified adjacent to air with regional background ozone concentrations of 40 ppb, though this occurred in a narrowly layered plume which may have been more concentrated.
- Transported urban plume ozone concentrations were typically around approximately 20 ppb above those of the background air in which the plume was imbedded. This is consistent with values seen in previous studies for the DAQEM.
- $PM_{2.5}$ associated with urban ozone plumes are typically very low and not particularly correlated with ozone concentrations.
- SLOTS focused on transport from southern California into Clark County. To fully understand the air quality in Clark County, future field studies should expand the focus to potential pathways from other western states, Mexico and beyond.

What was learned about ozone contributions due to wildfire smoke is summarized as follows:

- The wildfire season in 2007 was limited in terms of fires in the study area. Two fires in California, the White fire and the Zaca fire, provided some opportunity to investigate wildfire contribution to ozone concentrations. Since these fires had only a minor impact of Las Vegas at best, airplane sampling was conducted primarily in California, closer to the fires, rather than in Nevada.
- Because the fires were located close to major urban ozone sources (specifically the western Mojave Desert and the southern San Joaquin Valley), it was difficult to definitively attribute ozone concentrations within fire plumes solely to the wildfire emissions. However, rises in ozone concentration of 10 to 20 ppb were noted within the smoke plumes.

- Persistent differences in measured ozone concentrations between the MOP and the Mt. Pass site during the Zaca fire also hint at a possible 10 to 20 ppb increase in ozone concentration by wildfire smoke, thought the evidence is primarily circumstantial.
- Documentation of smoke impacts within the Las Vegas Valley will be critical evidence for exceptional event justification. A list of currently available resources and recommendations for a documentation protocol were provided.

The MOP site (Modeled Ozone Peak) frequently measured the highest ozone levels in Clark County validating the DAQEM SIP modeling results. This site was installed and operated specifically to investigate the model's performance.

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1. INTRODUCTION

The Clark County Department of Air Quality and Environmental Management (DAQEM) is responsible for preparing state implementation plans (SIPs) for approval by the Clark County Board of Commissioners and to ensure implementation to attain and maintain National Ambient Air Quality Standards (NAAQS). In June 2004, under the Phase I Rule to Implement the 8-hour Ozone NAAQS, the U.S. Environmental Protection Agency (EPA) classified specific areas within Clark County as “basic” non-attainment areas for ground-level ozone (O_3). Under the “basic” non-attainment classification, Clark County was preparing an attainment demonstration SIP for submittal to the U.S. EPA in June 2007. On December 22, 2006, the United States Court of Appeals (District of Columbia) vacated the Phase I Rule to Implement the 8-hour Ozone NAAQS. In March 2007, the U.S. EPA promulgated the final rule on “Treatment of Data Influenced by Exceptional Events.”

These actions require adjustments to air quality planning and regulatory programs for ozone. For example, air quality monitoring data for ozone in Clark County for calendar years 2004 to 2006 demonstrate that Clark County is in attainment with NAAQS for ozone. The DAQEM, rather than submit a SIP to the U.S. EPA in June 2007, is coordinating with the U.S. EPA to receive a “clean data finding” for ozone in accordance with policies articulated in the U.S. EPA memorandum dated May 5, 1995, from John Seitz (Director, OAQPS). Upon receiving a “clean data finding” for ozone from the U.S. EPA, Clark County will develop and submit to the U.S. EPA a SIP in late 2007 or early 2008 demonstrating maintenance of ozone NAAQS for the foreseeable future. This Maintenance SIP will also include a formal request that Clark County be re-classified from non-attainment to attainment for ozone.

To support development of a Maintenance Plan for ozone, the DAQEM contracted T&B Systems to conduct the Southwest Desert / Las Vegas Ozone Transport Study (SLOTS). The goal of this study was to further study the mechanisms and impact of transport of pollutants into Southern Nevada through enhanced monitoring of ozone air quality and meteorological variables (surface and aloft measurements) at key locations during the 2007 ozone season. Objectives included an assessment of both urban and wildfire plume impacts on ozone concentrations, and the development of procedures that will permit Clark County to obtain waivers from regulatory considerations for wildfire events in accordance with the recently promulgated rule on “Treatment of Data Influenced by Exceptional Events.” Specific objectives for this study therefore included the following:

- Promote cooperation and information exchange between federal and state/local agencies in characterizing ozone air pollution during field studies for the 2007 summer season.
- Improve our understanding of the role of pollutant transport into Clark County, particularly emissions from wildfires, and the impact of these pollutants on observed ozone concentrations in Clark County.
- Generate a database to support current and future air quality planning and regulatory programs for ozone, including the development of a Maintenance Plan for ozone, in accordance with the Federal Clean Air Act and U.S. EPA requirements and guidelines.
- Develop standard operating procedures that will permit Clark County to obtain waivers from regulatory considerations for wildfire events in accordance with the recently promulgated rule on “Treatment of Data Influenced by Exceptional Events.”

Several recent studies conducted for the DAQEM, including the Ozone Characterization Study conducted in 2004 (Lehrman, 2006) and the CCROPS study in 2005 (Bush, 2006), produced results demonstrating the mechanism for transporting ozone into Clark County from southern California sources. However, U.S. EPA did an analysis for its Clean Air Interstate Rule or CAIR to identify states that were contributing significantly to nonattainment of PM2.5 and ozone in adjacent states. In the preamble to that rule, U.S. EPA stated that U.S. EPA did an analysis for its Clean Air Interstate Rule or CAIR to identify states that were contributing significantly to nonattainment of PM2.5 and ozone in adjacent states. In the preamble to that rule, U.S. EPA stated that: “In analyzing significant contribution to nonattainment, we determined it was reasonable to exclude the Western U.S., including the States of Washington, Idaho, Oregon, California, Nevada, Utah and Arizona from further analysis due to geography, meteorology, and topography.” The California Air Resources Board’s position on transport, as stated in the State of California Interstate Transport State Implementation Plan (SIP) quoted from same the U.S. EPA: document. However, after reviewing the recent studies in Clark County, removed that wording from their SIP.

Nevertheless, a primary goal of SLOTS was to clearly document the existence and impact of an urban ozone plume originating from the southern California sources. Furthermore, the potential impact of wildfire smoke on ozone concentrations was only serendipitously studied during CCROPS when nearby wildfire occurred. EPA’s resistance to classifying apparent smoke-impacted days as exceptional events demonstrated that further research regarding wildfire impact was needed. Therefore, a second primary goal was to clearly document ozone contributions from a wildfire plume.

1.1 Overview of the Study Design

There were two levels or modes of field measurements in SLOTS: *continuous* and *intensive*. Continuous measurements were ongoing from the start of the field study in the last half of May 2007, and continued until the scheduled end date of August 31, 2007. More extensive measurements were conducted when the meteorological conditions were forecasted to be conducive to high ozone levels being experienced in Clark County. These periods are hereafter referred to as Intensive Operational Periods (IOPs). Each IOP had the potential to last up to four days, and four such IOPs were funded over the study period. IOP measurements comprised the main core of the study in which the three-dimensional air quality and key meteorological features were described.

IOPs were devoted to investigating each of the two types of ozone episode events emphasized above:

Type 1 – Urban transport from California. These IOPs were initiated with the goal of looking for conditions leading to exceedance or near-exceedance levels affecting the greater Las Vegas Valley, not just a rise in Jean. Aircraft were used to investigate ozone flux along the California border, perpendicular to transport winds, with occasional spiral soundings to measure vertical profiles. Flights included a spiral at Jean at the beginning and end of the flight. In general, one morning and one late afternoon/evening flight were conducted each IOP day to provide regular tracking of transport conditions. Rawinsondes were typically released at Primm, but moved if necessary based on incoming data during the IOP. The first rawinsonde was typically released at 0600 PST (transition from nocturnal to daytime conditions, guidance for aircraft flights), with the second released at 1600 PST (coincident with NWS soundings).

Type 2 - Wildfires directly impacting Las Vegas Valley accompanied by poor dispersion conditions, likely leading to exceedance or near-exceedance levels in Clark County. The aircraft conducted a series of transects perpendicular to the plume, systematically moving downwind along the plume axis, starting as near to the source as possible. Rawinsondes were ideally released in the transport path (plume), as close to the Las Vegas Valley as feasible, following the schedule presented above.

A goal of the study was that at least one IOP would be devoted to urban transport and two to wildfire smoke. As the study period progressed, IOP criteria were loosened as follows to increase the chances of IOP conditions:

- Transport from California, including events that only affected Jean air quality
- Fires in the general vicinity that did not specifically impact the Las Vegas valley
- Transport of ozone (smoke or urban) that impacted Clark County, but not necessarily at exceedances levels.

Recognition of the onset and establishment of the conceptual model characteristics in advance was the key to the operational forecasting solution for the SLOTS field measurements operations. National Weather Service (NWS) numerical synoptic-scale models such as the North American Mesoscale model (NAM) and the Global Forecast System model (GFS), coupled with regional NWS Forecast Discussion guidance, provided an experienced T&B Systems weather forecaster with the basis for daily long and medium range operational forecasts. An additional critical factor in the forecasting for the 2007 field project was the presence of smoke from wildfires upwind of the project area and the probable transport characteristics of the fire generated smoke plumes. The T&B Systems forecasters used the current and forecasted NWS Hazard Mapping System (HMS) fire and smoke products, as well as fire advisories issued in the regional Forecast Discussions to determine when and where IOP operations involving smoke measurements were initiated. An operational forecast was prepared by the T&B Systems forecasters each day that included both the short-term and long-term weather and fire smoke outlook.

1.2 Overview of the Field Activities

The SLOTS 2007 field program was conducted from mid-May through August, and consisted of the following elements:

- DAQEM Monitoring – Ozone and meteorology at existing sites operated by Clark County.
- Supplemental Ozone Measurements– Continuous portable ozone monitors operated for the duration of the ozone study. T&B sites were established at two locations. As part of a separately funded project but with similar objectives, the National Park Service (NPS) operated four sites in the Joshua Tree National Monument and the Mojave Preserve.
- Upper Air – Aircraft measurements, rawinsonde measurements, continuous remote sensing of winds at two sites along the transport path from California, and continuous remote sensing of winds, temperature and relative humidity at the North Las Vegas airport

1.3 Content of This Report

This report consists of seven main sections in addition to this introduction. In Section 2, the study design and subsequent CCROPS monitoring network are discussed, including detailed maps of the locations of all of the study-specific measurements. The overall organization of the study is also discussed. Details regarding the monitoring methodologies used during the study are presented in Section 3. Section 4 presents a discussion of the field activities during the SLOTS monitoring conducted in the summer of 2007. A discussion of the quality assurance employed for the study is contained in Section 5. Section 6 discusses the SLOTS database, and presents specifics regarding the structure of the delivered database. Section 7 contains results from initial analyses of the SLOTS data. These analyses address the role that transport of both urban and wildfire smoke plumes on ozone concentrations in Clark County. Finally, recommendations for additional analyses and monitoring are provided in Section 8.

2. SAMPLING NETWORK

Supplemental monitoring locations for SLOTS where chosen based on the SLOTS goals described above, as well as logistics and security. **Table 2-1** lists the SLOTS sites and key site information. **Figure 2-1** is a map of the locations.

Table 2-1. SLOTS Sites and Objectives

Site	Latitude	Longitude	Elevation	Site Goal	Measurements
North Las Vegas Airport, NV	36.215	-115.194	660 m	Upper air meteorology at Las Vegas	Upper-level WS/WD (Radar Profiler, mini-Sodar); T/RH profiles (radiometer); surface WS/WD, T, and RH
Jean, NV	35.7628	-115.3319	855 m	Meteorology and ozone along SW transport path	Upper-level WS/WD (Sodar)
Mountain Pass, CA	35.4837	-115.5222	1495 m	Meteorology and ozone along SW and W transport paths	Ozone; surface WS/WD; Upper-level WS/WD (Sodar)
MOP Site, NV	36.0791	-115.5583	1642 m	Investigation of area of modeled ozone peak (MOP)	Ozone; surface WS/WD
Movable rawinsonde launching site (nominally at Primm, NV)				Upper air meteorology along transport paths	Upper-level WS/WD, T, and RH

2.1 Continuous Measurements

<u>Supplemental Ozone Measurements</u>

Two supplemental surface ozone and meteorological monitoring installations were deployed for the study, one at a site near Mountain Pass, California, and one in the vicinity of the DAQEM modeled ozone peak (MOP site). Ozone and surface meteorology were measured at both sites.

<u>Upper-Air Winds</u>

Two sodars were deployed for the study, one at Jean, Nevada and one at the Mt. Pass site, to measure upper-level winds up to 600 meters. The sites were equipped with cell phone Internet technology, allowing real-time access and polling of data. In addition, the ozone and meteorological measurements at Mt. Pass were also accessible via the system.

Figure 2-1. SLOTS Site Locations

2.2 Intensive Monitoring

During periods when high ozone levels were forecast, more intensive measurements were initiated. The key components of the intensive monitoring periods or IOPs were:

Aircraft Measurements

Ozone, particulate loading, and temperature were measured using a single-engine airplane. A typical flight sampling mission was comprised of measurements at constant levels and spiral ascents and descents which provided vertical profiles. Vertical profiles were made from as near to ground level as safety permitted to approximately 4,000 m-agl.

Two three-hour sampling flights were normally conducted each day of the IOP. Preliminary flight plans were developed prior to takeoff, based on a review of meteorological conditions. The morning flight typically took place approximately 07:00 -11:00 PST. The evening flight took place approximately 15:00 –18:00 PST. An experienced T&B Systems air quality scientist was onboard observing the measurements in real-time. Based on those observations and the winds aloft measurements, the flight plan was modified as necessary in order to best accomplish study goals.

Each aircraft mission concentrated on characterizing the boundary layer air quality and atmospheric stability and consisted of spirals at Jean and other select locations with horizontal traverses between. Flights during both the morning and the afternoon began with a sounding over the North Las Vegas Airport so that changing conditions during the elapsed time of the flight could be identified. Traverses were selected as to best characterize pollutant levels across flux planes, and to define the areal extent of transported plumes.

Rawinsondes

Free ascending balloon-borne measurements of temperature, relative humidity, and winds were made twice daily from select locations depending upon meteorological conditions. Nominally scheduled sounding times were 06 and 16 PST. The early morning sounding documented the vertical structure of the atmosphere during the most stable period over the diurnal cycle. This sounding closely corresponded to the 12 GMT world-wide sounding schedule and suite of synoptic weather charts routinely produced by weather organizations. The afternoon sounding characterized conditions when the atmosphere is generally most unstable, and the mixed layer fully developed. The sounding time corresponds with the 00 GMT world-wide soundings and synoptic analyses products. Soundings extended to at least 500 mb or ~ 5,500 meters. Optimally, data were gathered to 300 mb, which is approximately 10,000 meters.

2.3 Additional T&B Systems Monitoring Support

T&B Systems set up and operated the following DAQEM-owned equipment at a temporary site at the North Las Vegas airport:

- A radar profiler capable of providing wind data from the surface up to 4,000 m agl.
- A mini-Sodar capable of providing high resolution wind data from the surface up to 200 m agl.
- A microwave radiometer capable of providing temperature and relative humidity profiles from the surface to 10 km.

Due to logistical delays associated with establishing the site, the above equipment did not become operational until early July 2007. The equipment was operated through August 30, 2007.

3. MEASUREMENT METHODS

Descriptions of the instrumentation and methods employed in the study specific measurements are provided in this section. The supplemental surface measurements are discussed first and include both ozone and meteorological equipment. Upper-air measurements were made using a variety of methods ranging from remote sensing instruments to balloon-borne, GPS wind finding systems. The air quality measurements include ozone and ozone precursor monitoring equipment.

3.1 Supplemental Ozone Monitoring

All equipment used at the two supplemental ozone-monitoring sites were operated on solar power. Equipment was housed in a 2' x 2' x 6" aluminum box. The following equipment was at each of the sites:

2B Model 202 Ozone Analyzer

The 2B Technologies Model 202 Ozone Monitor™ is designed to enable accurate and precise measurements of ozone ranging from low concentrations (precision of ~1 ppbv) up to 100,000 ppb (0-100 ppm) based on the well established technique of absorption of light at 254 nm. "Absorption spectroscopy" is a chemical analysis technique made possible by the phenomenon that a given molecule absorbs light at selected wavelengths. The wavelengths absorbed are characteristic of each molecule's atomic features. The amount of light radiation absorbed by a substance depends on two factors: the number of molecules in the path of the light, and the characteristics of the molecule (e.g., absorption cross-section). Measurement of changes in the light intensity as it passes through the molecules, and the use of calibration and reference data, enable the determination of the number of molecules encountered.

This method is the same as the DAQEM network monitors used and subject to the same accuracies and uncertainties.

This monitor features low power consumption (12v DC, 0.33 amp, 4.0 Watt) relative to conventional instruments, thus allowing operation with deep cycle batteries and solar panels. Additionally, it does not require a temperature-controlled environment. The sampling system included a ¼" Teflon sampling line with an inlet filter mounted approximately 1.5 meters off of the ground.

Accuracy (performance checks)	±10%
Precision (performance checks)	±10%
Resolution	0.001 ppm
Lower Quantifiable Limit	0.002 ppm

RM Young Model 05305 Wind Monitor

RM Young 05103 Wind Monitor wind speed and direction sensors were used for measuring surface wind conditions. These sensors employ a propeller anemometer. The sensors were mounted on 3-meter high tripods. All sensors were oriented to true north using the GPS walkoff method for orienting wind direction sensors. The monitor and installation at the MOP site are shown in **Figure 3-1**.

Figure 3-1. Surface Tripod Mounting of Wind Sensors, with Ozone Sampling Line – MOP Site

Monitoring quality objectives for the supplemental surface wind measurements are presented in the following table.

Accuracy (instrument specifications)	
Horizontal Wind Speed	±(0.2 m/s + 5% of observed)
Horizontal Wind Direction	±5 degrees
Precision (performance checks)	
Horizontal Wind Speed	±0.1 m/s
Horizontal Wind Direction	±2 degrees
Output Resolution	
Horizontal Wind Speed	0.1 m/s
Horizontal Wind Direction	1.0 deg.
Starting Threshold	1.0 m/s

<u>Campbell Scientific CR10 Data Logger</u>

All data were stored using a Campbell Scientific CR10 data logger as 60-minute averages. Based on the number of measurements and statistics being recorded, the CR10 can operate for a period of up to approximately 4 weeks before it is necessary to download data.

<u>Campbell Scientific CR10 Internal Panel Temperature</u>

The temperature of the ozone analyzer environment was monitored using the integral panel temperature of the Campbell Scientific CR10 data logger.

3.2 Rawinsondes

Balloon-borne rawinsondes were used to profile winds, temperature, and relative humidity from the surface to near the tropopause. Primary components of the system are described below:

<u>Sippican W-9000</u>

The Sippican W-9000 system consists of a SIPPICAN ZEEMET W-9000 GPS based navaid receiver/data system for measuring winds, and SIPPICAN Mark II Microsondes radiosonde packages.

The SIPPICAN ZEEMET W-9000 receiving station interfaces with a personal computer and printer. This is a state-of-the-art wind finding system employing GPS technology. The UHF receiver operates in the 400 MHZ range. SIPPICAN software enables the interface with the SIPPICAN W-9000 receiver and reduces the thermodynamic pressure, temperature and humidity (PTU) and navaid/wind data. During each flight, the technician is able to monitor both raw and reduced data in near real-time. The software also includes graphics and plotting capabilities that allow the technician to review results during and at the end of each flight. Both raw and reduced data were stored on the hard disk in subdirectories identified by the flight name. All data files were copied to both primary and backup diskettes immediately after each flight.

SIPPICAN Mark IIa Microsondes

The SIPPICAN Mark IIa Microsondes are 10 x 19 x 15 cm and weigh 250 grams with a water-activated 18V battery. The radiosonde UHF transmitter sends its modulated signals in the 400 MHZ range. The Microsondes were calibrated at the factory in a computer-controlled environmental chamber. Calibration coefficients are stored in read-only-memory (ROM) within each sonde and are automatically transmitted to the receiver in 1.5 sec intervals. Temperature is measured using a bead thermistor and relative humidity using a carbon hygristor. The SIPPICAN W-9000 is an automatic wind finding system that is based on tracking the sonde using the GPS satellite network. The Microsonde incorporates a low-noise integrated circuit GPS receiver. Winds aloft are calculated from the change in balloon position (determined from navaid) with time. Height is obtained directly from GPS positioning and, unlike older systems, pressure is now a derived parameter, calculated from the hydrostatic equation, using measured height, temperature, and humidity.

Accuracy (instrument specifications)	
Horizontal Wind Speed	± 0.5 ms^{-1}
Horizontal Wind Direction	Unknown
Temperature	± 0.2° C
Relative Humidity	± 2.0%
Output Resolution	
Horizontal Wind Speed	0.1 m/s
Horizontal Wind Direction	1.0°
Temperature	0.1° C
Relative Humidity	1.0%

3.3 Aircraft Sampling

The sampling instrumentation for the aircraft was identical to that which was used during the 2005 SLOTS. Ozone sampling is based on the wet cell KI technique implemented by EN-SCI Corporation for troposphere and stratosphere ozone profiling and implemented in the ECC ozonesonde. The ECC ozonesonde is of a simple design consisting of a rigid mainframe on which is mounted a motor-driven Teflon/glass air sampling pump, a thermistor for measuring pump temperature, an ozone sensing ECC, and an electronics box containing interface circuitry which couple the ozone sensor to the radiosonde.

The ozone-sensing cell is made of two bright platinum electrodes immersed in potassium iodide (KI) solutions of different concentrations contained in separate cathode and anode chambers. The chambers are linked with an ion bridge that, in addition to providing an ion pathway, retards mixing of the cathode and anode electrolytes thereby preserving their concentrations. The electrolytes also contain potassium bromide (KBr) and a buffer whose concentrations in each half-cell are the same. The driving electromotive force for the cell, of approximately 0.13 V, is provided by the difference in potassium iodide concentrations in the two half cells. Sample air is forced through the ECC sensor by means of a non-reactive pump fabricated from TFE Teflon impregnated with glass fibers. The pump is designed to operate without ozone-destroying lubricants. Pumping efficiency for each pump varies from pump to pump and is also dependent on ambient air pressure. The sampling flow rate is calibrated at the factory and checked in the field before launch. The ECC ozone concentration calibration is also determined prior to launch.

When ozone in air enters the sensor, iodine is formed in the cathode half cell according to the relation

$$2KI + O_3 + H_2O \rightarrow 2KOH + I_2 + O_2. \quad (1)$$

The cell converts the iodine to iodide according to

$$I_2 + 2e \rightarrow 2I^- \quad (2)$$

during which time two electrons flow in the cell's external circuit. Measurement of the electron flow (i.e., the cell current), together with the rate at which ozone enters the cell per unit time, enables ozone concentrations in the sampled air to be derived from

$$p_3 = 4.307 \times 10^{-3}(i_m - i_b)T_p t \quad (3)$$

where p_3 is the ozone partial pressure in nanobars, i_m is the measured sensor output current in microamperes, i_b is the sensor background current (i.e., the residual current emanating from the cell in the absence of ozone in the air) in microamperes, T_p is the pump temperature in Kelvins, and t is the time in seconds taken by the sonde gas sampling pump to force 100 ml of air through the sensor.

ECC Ozone

Sensitivity	2-3 ppb by volume ozone in air
Response Time	15 seconds for 67% of change; 60 seconds for 85% of change
Noise	less than 1% of full scale
Estimated Measurement Uncertainty	less than ± 10% of indicated value

For the aircraft sampling system, the sample pump/cell system is housed in a small case with the output signal from the sampler recorded on a Campbell CR1000 data logger. This data logger allows the recording and parsing of a serial data stream from a Global Positioning System receiver as well as recording analog signals of pressure, ambient temperature, detection cell temperature and the calculated values of ozone based on the sampled parameters. Data are sampled and recorded at 2-second intervals. A set of AA batteries provides power and the capability for the entire system to measure ozone continuously for over 8 hours. The sample inlet is through a length of FEP Teflon tubing to a region of the aircraft in free airflow – on the inside portion of the wing in a cabin air vent inlet. The preparation time prior to a flight requires approximately 20 to 30 minutes to install, perform pre-flight check, and assure that the systems are operational. For this study, we used a Cessna 182 based out of the North Las Vegas airport (**Figure 3 -2**). **Figures 3-3** shows the installation of the package in the back seat of the Cessna 182 used for the study, with the sample lines heading out the air vent.

Figure 3-2. Cessna 182 Used for Aircraft Sampling

Figure 3-3. Ozone and $PM_{2.5}$ Sampling Package in Back Seat of Aircraft and Sample Tubing Leading Up to and Out Air Vent on the Cessna 182

In addition to ozone and temperature, $PM_{2.5}$ concentrations were measured using a DustTrak 8520 optical light-scattering instrument.

The Cessna 182 used for SLOTS was equipped with advanced avionics that allowed the displaying of a wide range of information and data, including a number of different meteorological products. In particular, hourly modeled winds could be displayed for flight levels in 3000-ft increments, and the actual wind speed and direction at the current flight altitude could be calculated and displayed, based on GPS and true air speeds and directions. An example of the display is presented in **Figure 3-4**. While the aircraft operators were unclear whether these data were being stored, values were manually recorded by the onboard scientist during the flight.

Figure 3-4. On-board Avionics Display. View shown displays modeled winds for current hour at the 9000-ft level. Arrow in upper right corner indicates current winds at 37 knots from the west-southwest.

3.4 Remote Sensing Measurements of Winds Aloft

AeroVironment (AV) Model 2000 Sodars were used to collect upper-air meteorological data at the Jean and Mt. Pass sites. In addition, a Vaisala 915-MHz radar wind profiler (RWP), a collocated AV Model 4000 mini-Sodar, and a surface-based meteorological system were used to measure the upper-air meteorology data at North Las Vegas Airport. These instruments provide vertically and temporally resolved boundary layer winds, and boundary layer depth (i.e., mixing height) data. In particular, the RWP provides continuous (hourly) wind data with a vertical resolution of 60 to 100 m at heights from about 120 m up to about 3000 m agl. The mini-Sodar fills in data beneath the RWP measurements by providing continuous (hourly or sub-hourly) wind data with 5 m resolution up to about 200 m agl. The exact height coverage at any given time depends on atmospheric conditions. Continuous (hourly or sub-hourly) boundary layer depth can be derived from the RWP and Sodar/mini-Sodar reflectivity data.

Sodar Accuracy (instrument specifications)	ASC 4000 MiniSodar	ASC 2000 Sodar
Horizontal Wind Speed	0.5 m/s	0.5 m/s
Horizontal Wind Direction	±5°	±5°
Maximum Altitude	200 meters	600 meters
Sampling Height Increment	5 meters	20 meters
Minimum Sampling Height	15 meters	40 meters
Transmit Frequency	4500 Hz.	2000 Hz.
Averaging and Reporting Interval	1 to 60 minutes	1 to 60 minutes

3.5 Remote Sensing of Upper-Air Temperature and Relative Humidity

Vertical temperature and relative humidity profiles were obtained using a Radiometrics Model TP/WVP-3000 Profiling Radiometer. The TP/WVP-3000 produces vertical temperature and water vapor profiles from the surface to 10 km in height. The TP/WVP-3000 includes two radio frequency (RF) subsystems in the same cabinet that share the same antenna and antenna pointing system. The temperature profiling (TP) subsystem utilizes sky observations at selected frequencies between 51 and 59 GHz. The water vapor profiling (WVP) subsystem receives at selected frequencies between 22 and 30 GHz. Surface meteorological sensors (Met Sensors) measure air temperature, relative humidity and barometric pressure. To improve the measurement of water vapor and cloud liquid water density profiles, the TP/WVR-3000 also measures cloud base temperature using a zenith-pointed infrared thermometer (IRT). All Profiling Radiometers have been designed for ease of use, accuracy, reliability, portability, and operation on a minimum of power. They only use passive technology, thus they do not emit any detectable radiation. The TP/WVP-3000 is shown in **Figure 3-5**.

Figure 3-5. Radiometrics Profiling Radiometer

4. FIELD PROGRAM

4.1 Supplemental Sites

The SLOTS supplemental surface measurement at Mt. Pass and MOP operated from May 25 through September 4, 2007. Technicians visited the sites weekly to verify that all equipment was operating and to conduct zero/span checks of the 2B ozone analyzers. Data recovery was very good at both sites, with only the following missing data:

- A week of ozone data was lost at both sites from June 6 to June 13 because of incorrectly installed filters in the inlet filter holder.
- Two days of ozone were lost in late June at MOP because of pump failure. Pumps were changed at both sites.

For the surface meteorological measurements at the two sites, no data were missing. However, the wind data collected at these two sites is of limited use, due to siting. It is our opinion that local terrain dominated the measurements rendering the data unrepresentative of regional flows. As demonstrated in **Figure 4-1**, the wind data collected from Mt. Pass in unidirectional, coming from the west-southwest at virtually all hours throughout the study. Similarly, the winds at the MOP site are from just two basic directions, coming exclusively from the southwest during daytime hours and from the north-northwest during the nighttime and dusk hours. With no day-to-day variability, the surface winds from these two sites did not play any role in the analysis effort (Section 7).

Sodars at Jean and Mt. Pass operated from June 1 through August 30, 2007. Due to preamp problems, the failure of all of the diaphragms in the antennas, and frequency shifting problems that required a reworking of the sodar electronics, the sodar components for the Mt. Pass sodar needed at one point to be returned to the manufacturer for repair. Consequently, the Mt. Pass sodar did not start collecting valid data until June 20. Battery problems at the Jean site resulted in power problems and the loss of sodar data at the Jean site for approximately 1 ½ days around July 11. With those exceptions, the sodars collected good data throughout the study period.

Similar to the surface winds at Mt. Pass, the sodar data for Mt. Pass is too unidirectional due to terrain channeling to be of much value for analysis. **Figure 4-2** presents wind roses of the sodar data collected at Jean and Mt. Pass during the three-month study period. Data for the 260-meter level is shown as this level is typically the highest level routinely collected by both sodars, and is representative of transport winds at an altitude where the effect of the surface is at least reduced. Similar to the surface winds at Mt. Pass, the sodar winds show winds almost exclusively coming from a quadrant centered around the west-southwest direction. In retrospect, this monitoring location is clearly influence by higher terrain to the north and south that funnels the winds through the area. This funneling prevents data from this sited from providing routine confirmation of synoptic flows.

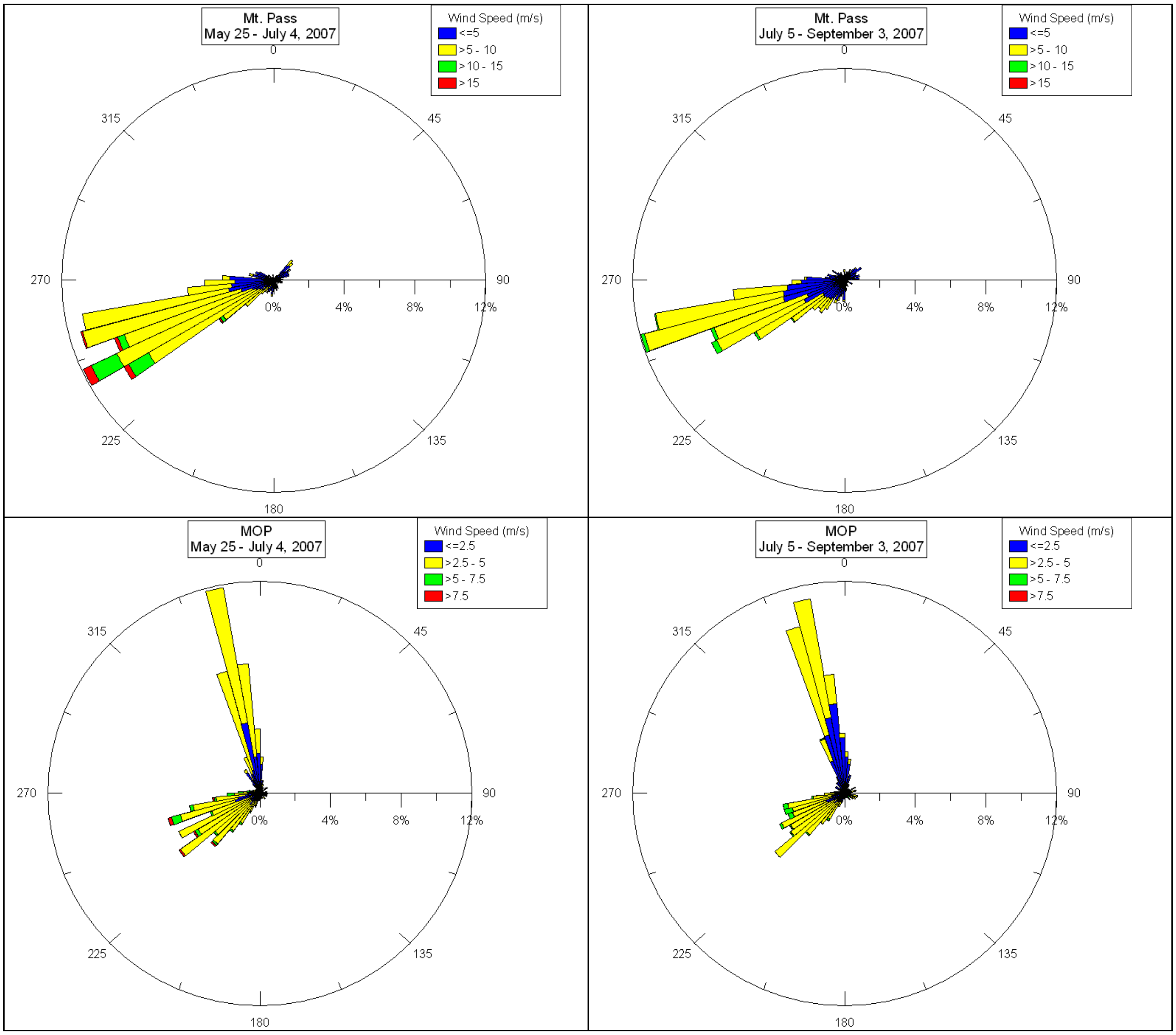

Figure 4-1. Wind Roses for SLOTS Supplemental Sites

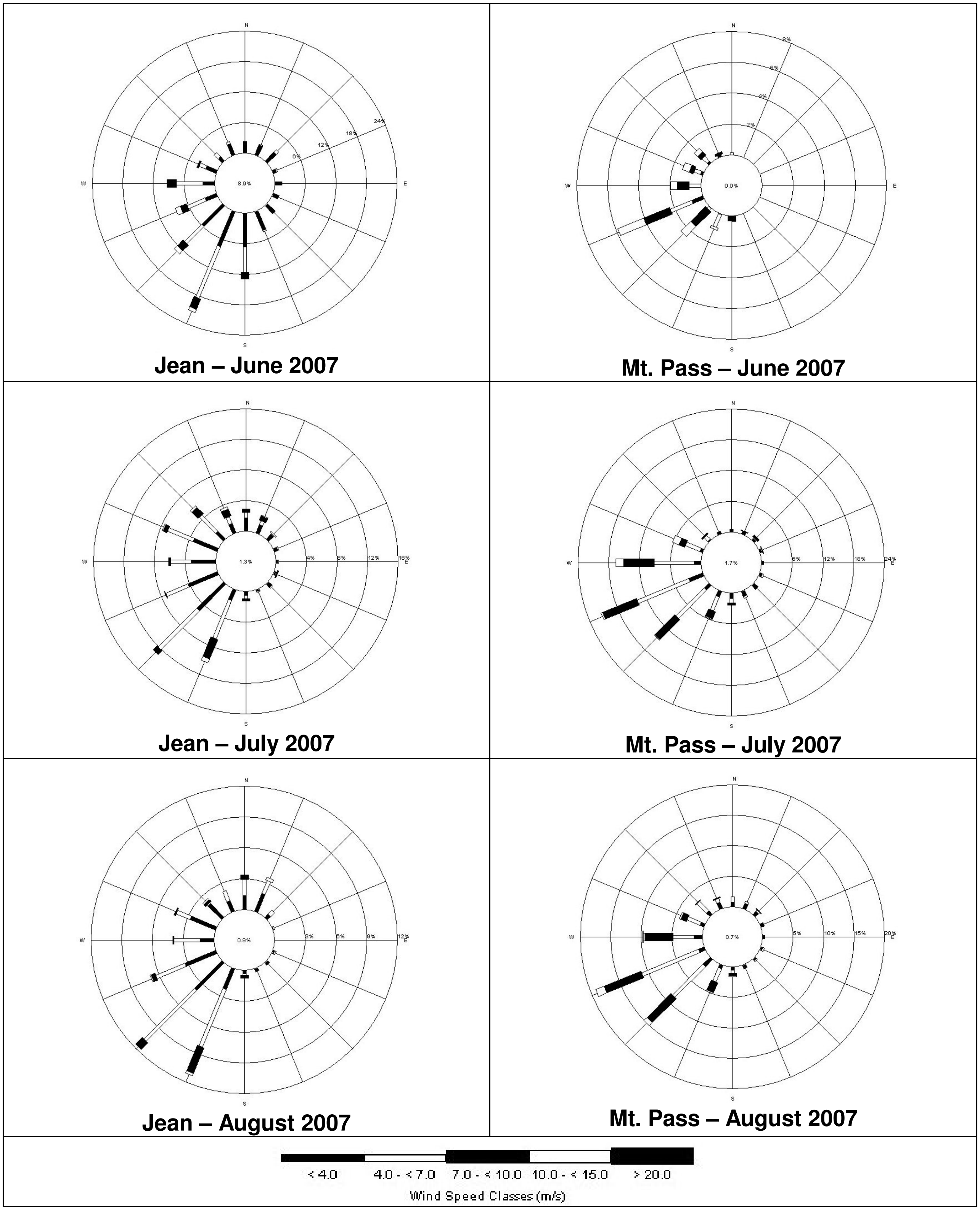

Figure 4-2. 260-meter Winds at Mt. Pass during June 2007

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4.2 Intensive Operation Periods (IOPs)

As stated in Section 2, IOPs were initiated to investigate two distinctly different scenarios: transport of ozone by urban plumes from California to Clark County, and the effect that wildfire plumes have on Clark County ozone concentrations. Since urban transport had been investigated to some extent during the Ozone Characterization Study and the 2005 CROPS study, some preference was given to investigating wildfire smoke. Thus, after a relatively successful urban transport related IOP in mid-June, the decision was made to save resources for the wildfire smoke investigation, anticipating wildfires in July and August.

Table 4-1 lists the IOPs conducted during SLOTS. As it turned out, the 2007 wildfire season was very light. No wildfires occurred in or near the Las Vegas region, and only two fires in California were within a distance of having any potential impact on Clark County, or were out of range for aircraft. Furthermore, as will be discussed in Section 7, conditions for urban transport turned out to occur almost exclusively in June.

Table 4-1. Intensive Operation Periods during SLOTS

Date	Investigative Goal	Comments
June 22-24	Urban transport	IOP providing evidence of interstate transport, though no exceedances noted in Clark County.
June 25-26	Wildfire smoke	Investigation of the White fire near Mojave, CA. Flights into California to investigate, since the fire was not directly impacting Clark County.
July 16-17	Urban transport	Weak transport event which ultimately did not impact Clark County
August 8-9	Wildfire smoke	Investigation of the Zaca fire in Santa Barbara county, CA. Flights into California to investigate, since the fire was not directly impacting Clark County.

While the intention was to target IOPs for periods of exceedance or near exceedance ozone concentrations, it is important to note that IOPs did not occur during several days when ozone exceedances were recorded in Clark County. A detailed summary of ozone conditions during SLOTS is presented in Section 7.1. Several periods of high ozone concentrations stand out, in particular the following:

- June 16 – The decision to call an IOP was based on the balancing of a number of factors, including meteorological forecast, study goals, and available resources. In hindsight, this turned out to be a day with a significant urban transport component. At the time of the decision, however, the meteorological forecast, while meeting many of the conceptual model criteria, did not appear to be entirely favorable for transport. As described above, the meteorological conditions conducive for transport center around a weak upper-level trough that allows for significant southwesterly flow from source areas without significant dispersion. In this case, forecasts showed the trough to be too strong, portending more unstable conditions that would hinder the accumulation of ozone concentrations in the source areas and possibly disperse concentrations over the transport path. This forecast, coupled with a general reluctance to "waste" available resources so early in the study and the expectation that better situations would materialize, resulted in the decision to not call an IOP.

Unfortunately for the study, the meteorological conditions that occurred on June 16 were much more favorable for transport than predicted. An almost identical situation occurred a week later. Based on this recent experience, an IOP was called for June 22 through 24, looking for a repeat of the 16th. While this period in this case turned out to have a slightly stronger than desired trough, the IOP was successful in identifying and tracking a distinct urban plume entering the study area (see Section 7.1.1).

- June 27 – Favorable transport conditions were also forecasted to occur on this day. However, smoke from the White Fire was impacting the area, and it was speculated that it would not be possible to differentiate between impact due to the White Fire and impact due to an urban plume. Thus, the decision to not call an IOP was made. This supposition was confirmed during the analysis of the White Fire IOP (see Section 7.2.1).
- July 28 – This day was forecasted to have stagnant conditions within Clark County with little opportunity for a significant transport component, so no IOP was called. This turned out to be the case.
- August 21 – Higher concentrations on this day were somewhat unexpected as ozone concentrations in the major source areas were low. It is likely that smoke from the Zaca Fire impacted the area (see Section 7.2.2). The Zaca fire had been studied during a previous IOP, and trajectories from the fire were difficult to predict accurately over the distance to Clark County. Thus, an IOP for this day was never considered.

The concentration of actual transport conditions into the first third of the study and the lack of wildfires during the season resulted in some unused assets. Thus, realizing that data regarding the transport and fire impact days mentioned above (including the SLOTS continuous measurement data) could still prove useful in addressing study goals, these assets were used to conduct analyses of these non-IOP days (with the exception of July 28). The reader is referred to the discussions in Section 7.

4.3 Radar Profiler / Mini Sodar

The radar profiler and mini-sodar did not become operational at the North Las Vegas site until July 11 because of delays associated with supplying power to the site. Thus, these data were not available for June when conditions for transport were most ideal. Furthermore, upper air data from this site was of limited usefulness for studying the Zaca fire because of the fire's distance from Las Vegas.

Nevertheless, the systems preformed well and over the course of their operation, with uninterrupted service. As part of the study, performance checks of the systems were conducted using collocated rawinsonde releases. A total of three rawinsonde releases were occurred on August 30 and 31 at the North Las Vegas site. Results of the comparisons for the radar profiler are presented in **Tables 4-2** and **4-3**. Key to interpreting the results are the systematic and RMS (root mean square) differences for the two radar components. EPA audit criteria state that the systematic difference for each component should be within ±1 m/s and the RMS difference should be less than 2 m/s. As the results show, the profiler met these criteria. **Figure 4-3** graphical presents the comparisons, showing the good agreement between the radar profiler and the rawinsondes under a variety of wind conditions.

Though rawinsondes are not typically used for performance checks of sodars, a similar comparison can be made with the Mini-sodar. Results of this comparison are presented in **Table 4-4**. The table presents comparisons for each of the three rawinsonde releases. The first and third comparisons were conducted under very light wind conditions. Consequently, differences between the Mini-sodar and the rawinsonde wind direction are noted, thought wind speed is consistent between the two methods. Using the component criteria describe above for the radar profiler comparison, one sees that under these light wind conditions, the Mini-sodar meets performance criteria for remote wind measurements. The middle comparison was conducted under higher, steady wind conditions. A persistent 25 degree difference is noted between the Mini-sodar and the rawinsonde wind direction, thought once again there is good agreement for wind speed. This difference in wind direction is most likely due to a limitation with this comparison method – namely that the rawinsonde provides a "snapshot", whereas the Mini-sodar generates an hourly average. Mini-sodar data for the previous hour showed wind directions of 280 degrees for all altitudes, identical to the rawinsonde data. Thus, it is very possible that winds from this direction persisted into the 1500 hourly average before shifting higher. In summary, the comparison demonstrates a properly functioning instrument.

Table 4-2. Statistics for Radar Profiler Comparison - Low Mode

NUMBER OF DATA PAIRS

Date	Compo-nent	Virtual Temp	Vector Wind Threshold (m/s) 0	1	2	3	4	5
8 30 7	17	0	17	16	12	3	0	0
8 30 7	9	0	9	9	9	9	9	9
8 30 7	15	0	15	15	7	4	0	0
Total	41	0	41	40	28	16	9	9

STATISTICAL EVALUATION OF DIFFERENCES

Difference	Comp 1	Comp 2	Tvirt	Vector Wind Threshold (m/s) -0- WS	-0- WD	-1- WS	-1- WD	-2- WS	-2- WD	-3- WS	-3- WD	-4- WS	-4- WD	-5- WS	-5- WD
Systematic	0.2	-0.3	-999.0	-0.1	-13	-0.1	-10	-0.2	-10	-0.0	-12	0.3	-21	0.3	-21
RMS	1.7	1.5	-999.0	1.2	45	1.2	40	1.4	34	1.6	23	1.9	27	1.9	27
Minimum	0.0	0.0	-999.0	0.0	1	0.0	1	0.0	-1	0.0	-1	-0.4	-1	-0.4	-1
Maximum	4.5	-4.1	-999.0	-3.2	-146	-3.2	-117	-3.2	-106	-3.2	-45	-3.2	-45	-3.2	-45

Table 4-3. Statistics for Radar Profiler Comparison - High Mode

NUMBER OF DATA PAIRS

Date	Component	Virtual Temp	Vector Wind Threshold (m/s) 0	1	2	3	4	5
8 30 7	17	0	17	17	13	5	3	2
8 30 7	4	0	4	4	4	4	4	4
8 30 7	10	0	10	10	7	5	1	0
Total	31	0	31	31	24	14	8	6

STATISTICAL EVALUATION OF DIFFERENCES

Difference	Comp 1	Comp 2	Tvirt	-0- WS	-0- WD	-1- WS	-1- WD	-2- WS	-2- WD	-3- WS	-3- WD	-4- WS	-4- WD	-5- WS	-5- WD
Systematic	-0.1	-0.0	-999.0	0.0	-1	0.0	-1	0.0	-9	0.4	-2	0.9	2	1.3	5
RMS	0.9	1.3	-999.0	1.0	44	1.0	44	1.0	24	1.1	9	1.4	7	1.6	7
Minimum	0.0	0.1	-999.0	0.0	1	0.0	1	0.0	1	0.1	-2	-0.2	-3	0.3	-4
Maximum	-2.1	-3.6	-999.0	2.8	134	2.8	134	2.8	-81	2.8	-18	2.8	12	2.8	12

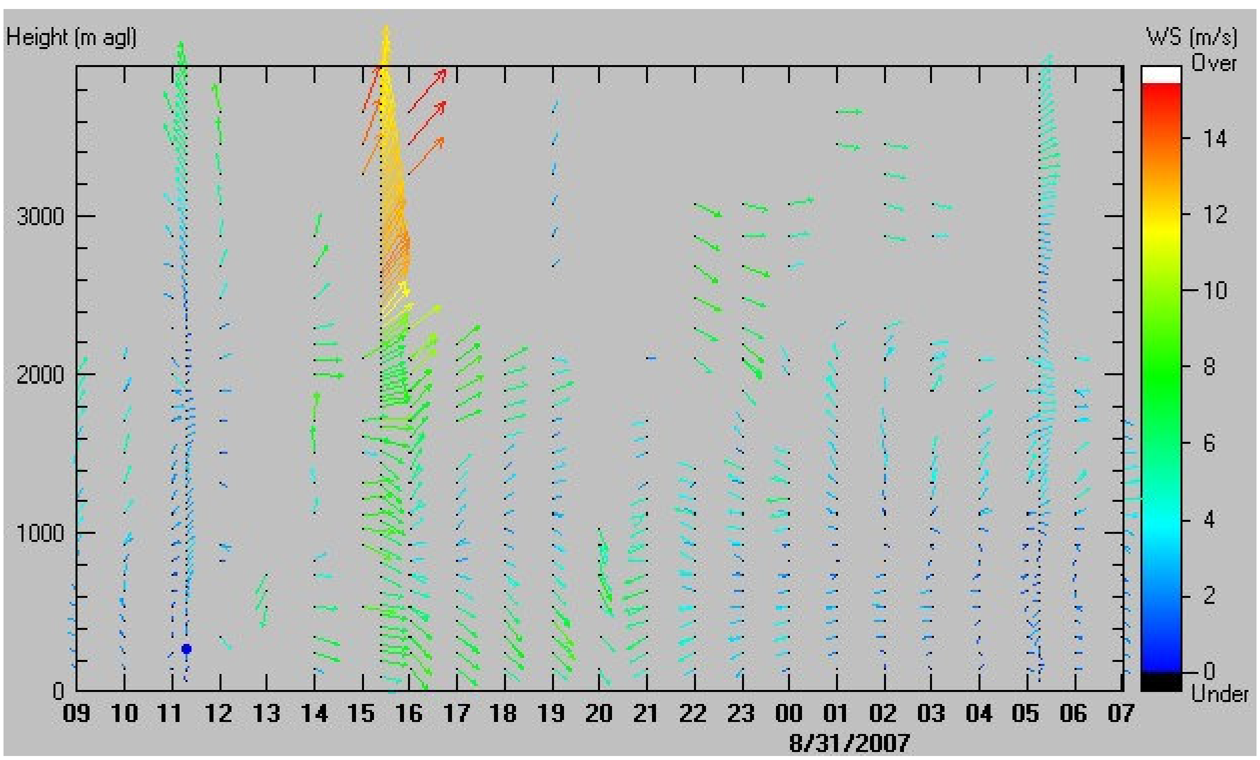

Figure 4-3. Time-height Cross-sections Comparing Radar Profiler with Rawinsondes. Rawinsondes occurred during hours 11, 15, and 05.

Table 4-4. Mini-sodar/rawinsonde Comparison

	8/30/07 1100						8/30/07 1500						8/31/07 0500					
	Mini-sodar		Rawinsonde		Difference		Mini-sodar		Rawinsonde		Difference		Mini-sodar		Rawinsonde		Difference	
HT	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR	SPD	DIR
(meters)	m/s	deg	m/s	deg	m/s	deg	m/s	deg	m/s	deg	m/s	deg	m/s	deg	m/s	deg	m/s	deg
200	99.99	9999					99.99	9999					99.99	9999				
195	99.99	9999					99.99	9999					99.99	9999				
190	99.99	9999					99.99	9999					99.99	9999				
185	99.99	9999					99.99	9999					99.99	9999				
180	99.99	9999					99.99	9999					99.99	9999				
175	99.99	9999					99.99	9999					99.99	9999				
170	99.99	9999					99.99	9999					99.99	9999				
165	99.99	9999					99.99	9999					99.99	9999				
160	99.99	9999					99.99	9999					99.99	9999				
155	99.99	9999					99.99	9999					99.99	9999				
150	99.99	9999					99.99	9999					99.99	9999				
145	99.99	9999					99.99	9999					99.99	9999				
140	3.12	94	1.3	194	1.8	-100	99.99	9999					99.99	9999				
135	2.96	99	1.1	204	1.9	-105	99.99	9999					99.99	9999				
130	2.35	100	1.1	215	1.3	-115	4.96	302	5.4	286	-0.4	16	99.99	9999				
125	2.05	101	1	226	1.1	-125	5.52	301	5.3	286	0.2	15	99.99	9999				
120	1.75	106	0.9	232	0.9	-126	5.36	302	5.3	286	0.1	16	99.99	9999				
115	1.63	107	0.8	235	0.8	-128	5.59	304	5.2	285	0.4	19	99.99	9999				
110	1.26	110	0.7	235	0.6	-125	5.82	302	5.2	285	0.6	17	99.99	9999				
105	1.03	109	0.5	226	0.5	-117	5.76	304	5.2	284	0.6	20	99.99	9999				
100	0.85	105	0.5	209	0.4	-104	5.6	303	5.2	284	0.4	19	99.99	9999				
95	0.72	103	0.6	192	0.1	-89	5.5	304	5.2	283	0.3	21	0.97	231	1.2	205	-0.2	26
90	0.59	114	0.6	178	0.0	-64	5.57	308	5.2	283	0.4	25	0.94	224	1.2	202	-0.3	22
85	0.48	127	0.7	171	-0.2	-44	5.57	307	5.3	282	0.3	25	0.89	234	1.2	199	-0.3	35
80	0.41	110	0.8	161	-0.4	-51	5.63	307	5.4	281	0.2	26	1.06	237	1.3	196	-0.2	41
75	0.44	123	1	157	-0.6	-34	5.53	309	5.4	281	0.1	28	1	242	1.3	193	-0.3	49
70	0.3	129	1.1	154	-0.8	-25	5.49	310	5.5	281	0.0	29	1.07	239	1.4	191	-0.3	48
65	0.35	125	1.2	151	-0.9	-26	5.31	311	5.5	280	-0.2	31	1.11	243	1.5	191	-0.4	52
60	0.39	129	1.2	147	-0.8	-18	5.31	311	5.5	280	-0.2	31	1.29	240	1.5	194	-0.2	46
55	0.29	142	1.1	145	-0.8	-3	5.3	310	5.5	280	-0.2	30	1.15	250	1.6	198	-0.5	52
50	0.34	140	1	146	-0.7	-6	5.29	309	5.4	280	-0.1	29	1.33	249	1.5	204	-0.2	45
45	0.43	140	0.9	149	-0.5	-9	5.21	309	5.4	280	-0.2	29	1.27	262	1.5	211	-0.2	51
40	0.44	124	0.6	156	-0.2	-32	5.07	309	5.2	280	-0.1	29	0.99	273	1.4	216	-0.4	57
35	0.37	128	0.6	160	-0.2	-32	4.87	310	5.2	280	-0.3	30	0.97	279	1.4	220	-0.4	59
30	0.32	157	0.5	173	-0.2	-16	4.83	308	5	280	-0.2	28	1.22	283	1.4	225	-0.2	58
25	0.28	123	0.4	192	-0.1	-69	4.55	309	4.8	281	-0.3	28	1.14	278	1.3	236	-0.2	42
20	0.34	118	0.4	209	-0.1	-91	4.36	307	2.6	281	1.8	26	1.2	291	1.2	241	0.0	50
15	0.84	115	0.4	217	0.4	-102	3.73	305	4.2	282	-0.5	23	1.1	303	1.2	250	-0.1	53
				Average	0.1	-67.5				Average	0.1	24.6				Average	-0.3	46.2
	Sys diff	RMS diff					Sys diff	RMS diff					Sys diff	RMS diff				
Comp 1	0.89	1.51					0.810	1.000					-0.36	0.45				
Comp 2	0.40	0.49					2.000	2.100					0.90	0.93				

4.4 Radiometer

For the reasons stated in Section 4.3, the radiometer did not begin operating until July 11, 2007, but provided continuous, uninterrupted operation thereafter through the end of the study on August 31, 2007.

Figures 4-4 through **4-6** show plots of the three comparisons of the radiometer with the rawinsondes on August 30 and 31. The plots show the general very good agreement in the temperature profiles. These plots do illustrate a fundamental limitation with the radiometer, in that it did not pick up the small elevated-inversions, such as those readily apparent in the rawinsonde profile in Figure 4-5, and to a lesser extent in the other two figures. These inversions are frequently accompanied by noticeable changes in the moisture, show by the dew point temperature, and indicate layering that past experience has shown can play a significant role in trapping ozone.

Regardless, the temperature profiles from the radiometer appear to be comparable to those from other remote sounding equipment. Comparison statistics were calculated for the sounding with the greatest visual differences, the sounding on the morning of August 31. The EPA RASS performance criteria for rawinsonde comparisons require the systematic difference to be within ±1.0°C and the RMS difference less within 1.5°C. For an altitude range comparable to a RASS, the radiometer easily met these criteria for the sounding in question, with a systematic difference of –0.4°C and an RMS difference of 0.9°C.

The comparison profiles also show that the radiometer systematically over reports dew point temperature. The general profile of the dew point temperature is duplicated by the radiometer, though once again some of the finer details are understandably missed.

The response to humidity may be improved in further operations by additional calibrations. For this study, the factory calibration was used, and the instrument performance was verified by conducting a "TIP" calibration, as described in the operator's manual. The more logistically complicated "LN2" calibration, which involves the use of liquid nitrogen, was not conducted, since the North Las Vegas site was only temporary and the radiometer had to be uninstalled after only 50 days of service.

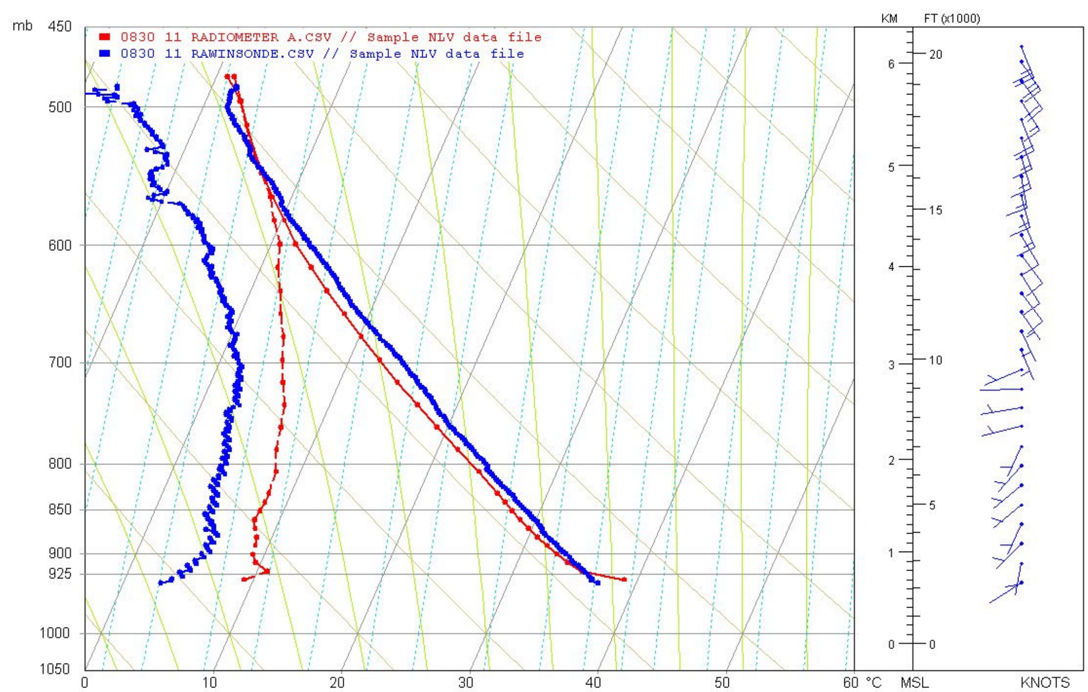

Figure 4-4. Radiometer/Rawinsonde Comparison – August 30, 1100 PST
(Radiometer profile is in red)

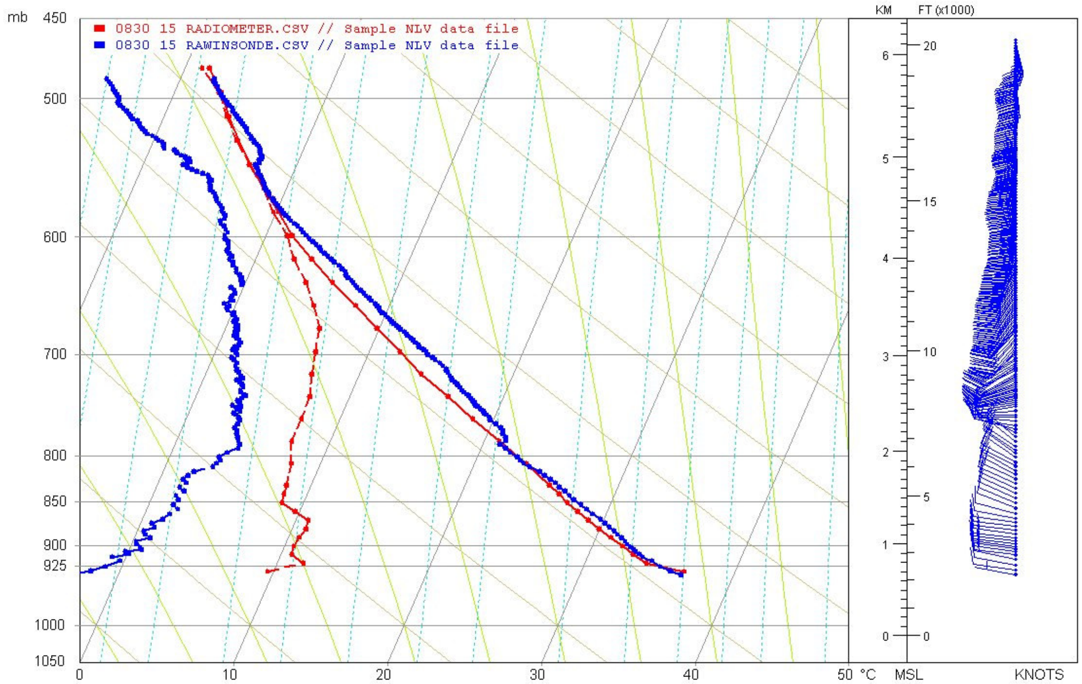

Figure 4-5. Radiometer/Rawinsonde Comparison – August 30, 1500 PST

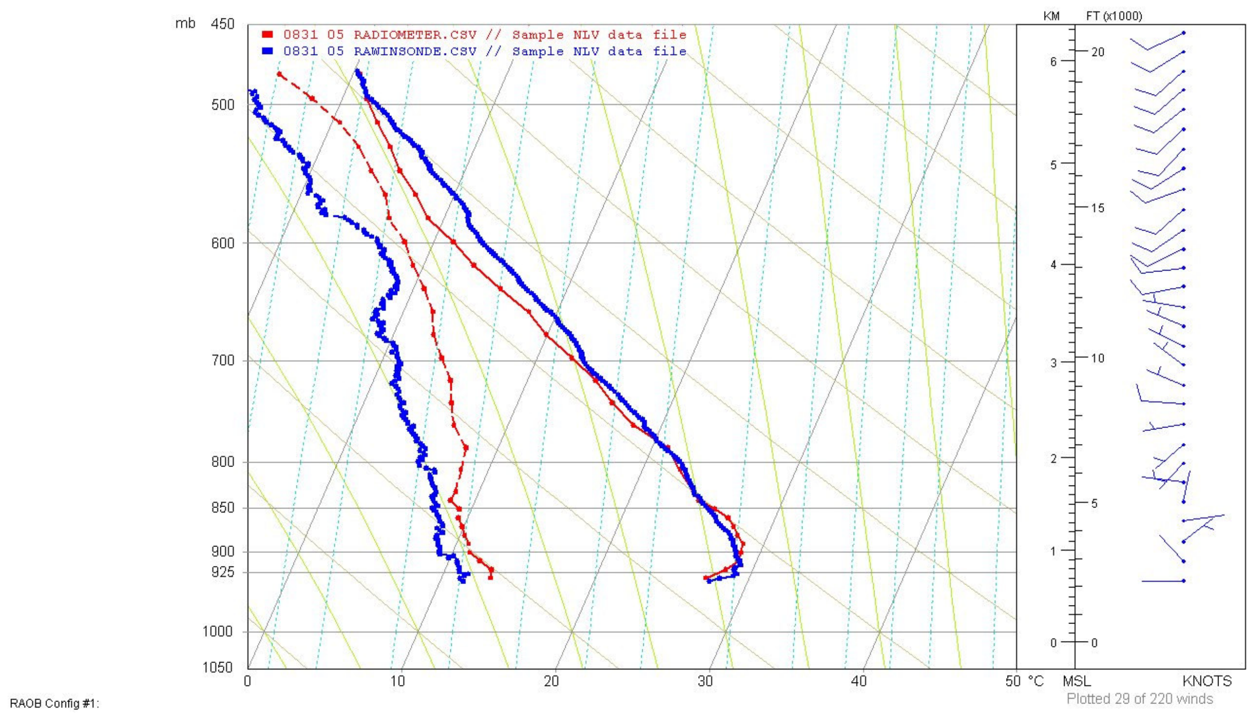

Figure 4-6. Radiometer/Rawinsonde Comparison – August 31, 0500 PST

5. QUALITY ASSURANCE AND DATA VALIDATION

Quality assurance (QA) for SLOTS was achieved through a number of specific efforts, which are summarized below.

5.1 Project Plan

The project plan was created and submitted to the DAQEM in the document "Draft Monitoring and Quality Assurance Plan - Southwest Desert / Las Vegas Ozone Transport Study (SLOTS)" prior to starting the study. In addition, a frequently updated, project-specific web site was created and made accessible through the Internet. The web site contained the following web pages:

- Study Overview - This page presented a brief overview of the study, the study objectives, and study schedule.
- What's New? – This page served as "document control" for the web site, providing a complete history of all modifications to the web site. Anytime the web pages were expanded or modified, a brief summary and the date of the modification were posted.
- Project Status – This page provided information regarding the readiness of participants' monitoring efforts. The page was particularly important during the early stages of the study period for helping to maintain the study schedule.
- Study Forecast – This page provided for the communication of study-specific information regarding forecasted ozone conditions, and served as the alert for IOPs and episode-mode monitoring efforts.
- Monitoring Sites – This page provided a description of the SLOTS measurements and a map of the measurement locations.
- Project Participants – This page provided a list of the SLOTS participants, a summary of each participant's study responsibilities, and contact information for key individuals.
- Planning Documents – This page requested and posted measurement quality assurance documentation. This is discussed in more detail below.
- Preliminary Analysis – This page provided participants with a means to present preliminary analysis of collected data. This in turn provided study management with feedback regarding collected data versus study goals, and the means of refining the monitoring effort, if needed.

5.2 Quality Assurance/Quality Control Documentation

Quality assurance procedures were presented in the Monitoring and Quality Assurance Plan referenced above. As part of the quality assurance program, detailed quality control procedures were implemented to assess and maintain control of the quality of the data collected. All equipment underwent complete checkout and acceptance prior to the start of monitoring. Complete quality control procedures were included in the standard operating procedures (SOPs) for measurements, which were included as an appendix to the Monitoring and Quality Assurance Plan.

Summaries of key elements of the QC program for each measurement are presented below:

Ozone Analyzers and Samplers
The 2B ozone analyzers were routinely checked using a certified transfer standard, following operating procedures consistent with EPA guidelines. This consisted of zero and span checks conducted weekly using a 2B 306 (S/N 2) portable ozone transfer standard certified against T&B Systems primary standard maintained at their office in Valencia, CA following EPA guidelines at the beginning and end of the 2007 summer study.

Aircraft Samplers
QA/QC for the aircraft ozone sampler included a zero and ground-truth check prior to each intensive flight. The DustTrak was subject to zero and flow checks each intensive flight.

Radar Profiler, T/RH Radiometer, miniSodar and Sodar
The status of the instruments was checked daily via remote access of the data. The data were transferred hourly to T&B Systems Internet server using a high-speed cellular Internet modem where they were posted to a web site in real-time. This enabled team members to review the data and use the measurements to assist in IOP forecasting. Daily reviews included a general scan of the data to identify instrument problems.

The calibration method for each of the air quality and meteorological variables is summarized in **Table 5-1.** All ozone analyzers and samplers were calibrated at the beginning and end of the study using a transfer standard certified against T&B Systems primary standard maintained per EPA's guidelines at their office in Valencia, CA.

All meteorological sensors were calibrated at the beginning and end of the study. Wind speed sensors were calibrated using an RM Young constant rpm motor simulating wind speeds at several points across the sensor's operating range. Wind direction sensors were calibrated by checking responses in 30° to 45° increments.

Table 5-1. Calibration Methods for the Monitored Variables

Measurement Variable	Calibration Method
Ozone (O_3)	Multipoint comparison of ozone concentrations with certified ozone transfer standard
Wind Speed	Rotational rate using a selectable speed anemometer drive
Wind Direction	Alignment using true north and linearity with a directional protractor
Temperature	Water bath comparisons to a certified transfer standard
Relative humidity	Collocated comparisons to a certified transfer standard

At the end of the study, a standardized metafile format was generated for submission of collected data. Information from MQOs and SOPs were combined and included in the metafiles. The metafiles contained additional descriptions of QA/QC activities, as well as pictures of all of the monitoring locations. Metafiles for all of the SLOTS measurements are included in the data submission.

5.3 Data Validation

All data collected for SLOTS were validated to Level 1 validation (see Section 6). As part of the validation effort, key personnel were requested to evaluate whether data collected met the stated MQOs. If data clearly did not meet MQOs, they were removed from the database as invalid data. If, however, data missed meeting the primary MQOs in a definable way to the point where the data were still considered useful, secondary MQOs could be assigned to the data in question. This use of secondary MQOs is specifically documented in the metafiles.

6. DATABASE DESIGN

A primary study objective was to produce an adequately documented and validated data set from the field measurements. The overall goal of the data management effort was to create a system that is straightforward and easy for users to obtain data and provide updates.

The raw data was validated to level 1 as described in "The Measurement Process: Precision, Accuracy, and Validity" before being submitted to the database. This included flagging values for instrument downtime and performance tests, applying any adjustments for calibration deviation, investigating extreme values and applying appropriate flags. Flags used for CCROPS are presented in **Table 6-1**.

Included in the database are specifics of the monitoring equipment used in the field study and any additional site information that enhances the overall documentation of the study. In particular, Monitoring Quality Objectives (MQOs) which define the quality of all data submitted as "valid" are included. These MQOs contain the following:

- Accuracy
- Precision
- Lower quantifiable limit
- Resolution
- Completeness

If cases exist where data did not meet the primary MQOs but is still deemed useable and can be defined with a secondary set of MQOs, these additional MQOs and the dates to which they apply were also submitted.

Table 6-1. Data Flags

Flag	Description
V	Valid. Data meets primary MQOs.
S	Valid, but does not meet primary MQOs. Secondary MQOs in effect.
I	Data invalid.
M	Missing. Measurement not taken.

Once the data were validated to level 1, the data were prepared for submittal to the database in a form that clearly defined the time reference, averaging period, parameter names and units. The time reference for the database is local standard time (Pacific Standard Time) and the averaging period reference was standardized to hour beginning (0 – 23). The data were submitted as ASCII comma delimited text files or excel spreadsheet files, with data columns well defined to clarify site identification, parameters, instrumentation, units, and time reference.

A metadata file for each measurable is also included. This metadata file includes all pertinent information regarding the measurement process, including the information described in Section 3.

Preliminary Database Management Design

The data have been merged into an integrated relational Microsoft ACCESS database submitted to the DAQEM as one of the deliverables. The database consists of both information and data files. The goal was to make the database easily usable by both current and future researchers.

The following describes the preliminary design for the database. The database includes an inventory spreadsheet file to help users track and ensure all of the data was submitted and processed in a timely and consistent manner. All data files submitted were examined to verify unique names for all sites, instruments, and parameters so that no orphan or duplicate records exist in any of the tables. A system was also designed for identifying the version and or modification date of all data files.

The main metadata file is a site file that contains all site information as specified above. Data were organized and grouped together by platform, averaging period and data type.

Surface hourly meteorological data have the following flat format:

Surface Hourly Meteorological Data

SITE, DATE, HOUR, WS, WS_QC, WD, WD_QC, TP, TP_QC, and any additional met parameters and QC codes, if collected.

There are three file types for surface air quality with the following formats:

Ozone 8-hr Averaged:

SITE, DATE, HOUR, O3_8HR, O38HR_QC

Hourly Surface Air Quality:

SITE, DATE, HOUR, OZONE, O3_QC, NO, NO_QC, NOx, NOx_QC, NOy, NOy_QC, PAN, PAN_QC and any additional air quality parameters if collected and QC codes.

PARAMETER2, PARAMETER3,..PARAMETERn, notes

Upper-Level Meteorological and Air Quality Data

The rawinsonde, airplane, sodar, radar wind profiler and microwave profilers data measured during episode-mode operations are stored together in a file with the following format:

SITE, DATE, TIME, HEIGHT, PRESSURE, PRESSURE_QC,
O3, O3_QC, WS, WS_QC, WD, WD_QC, TP, TP_QC, RH, RH_QC

The data are formatted into the final database with the following unit configurations and naming conventions:

Parts per million for O_3, NO_x, NO_y
Meters per second for wind speed (as a general rule, metric units will be used)
Degrees Celsius for ambient temperature
Percent for relative humidity
Parts per Billion Carbon for non-methanated hydrocarbon species

SITE = Alpha-numeric site code identifier

DATE = (MM/DD/YY)
HOUR= Nearest whole begin hour (HH) (PST)
TIME, START_TIME or END_TIME = Time stamp of data (HH:MM:SS) (PST)
HEIGHT = Elevation in meters above MSL
QC_CODE (for NMHC-VOC), WS_QC, WD_QC, O3_QC, etc =
“V” (valid), “M” (missing), “I” (invalid), “S” (secondary MQOs)
NOTES = any additional information

The level 1 data files along with the documentation files are available for download on an FTP server.

7. SUMMARY OF THE OBSERVATIONS (DESCRIPTIVE ANALYSIS)

SLOTS was designed to investigate the transport of ozone into Clark County from both urban and wildfire sources. In this section, preliminary analyses of the field measurements are provided which address the following questions:

- What are the synoptic meteorological conditions that can lead to transport of ozone into Clark County
- What physical evidence for transport exists?
- What is the potential impact by transport from the populated regions of California on ozone concentrations in Clark County?
- What is the potential impact of wildfires on ozone concentrations in Clark County?

It is important to note that Intensive Operational Periods or IOPs were devoted to two types of high ozone events:

Type 1 – Urban transport from California. These IOPs were initiated with the goal of looking for conditions leading to exceedance or near-exceedance levels affecting the greater Las Vegas Valley, not just a rise in Jean.

Type 2 - Wildfires with the potential to impact the Las Vegas Valley accompanied by poor dispersion conditions, likely leading to exceedance or near-exceedance levels in Clark County. As it turned out, the major wildfires occurring during the study principally impacted north of Clark County but nevertheless deemed worthy to study as understanding the plume characteristics was a major objective.

This section is divided into three subsections. The first discusses observed ozone transport periods from California. Analysis of transport related IOPs as well as Clark County ozone exceedance days that were potentially impacted by interstate transport are presented. The second section discusses analysis of wildfire smoke related IOPs and potentially impacted exceedance days. The third section presents a preliminary protocol for documenting wildfire smoke impact.

7.1 Transport from California

The basic conceptual model for conditions leading to transport of ozone from southern California to Las Vegas was developed from information gathered in the Clark County Ozone Characterization Study (Lehrman et al., 2006) utilizing synoptic weather maps and other applicable routinely monitored weather data. By examining synoptic weather maps and patterns of various meteorological parameters during known high ozone events during a five-year period (1999 through 2003), subjectively derived synoptic scale regional weather patterns were determined. These concepts were further refined through operational experience during the field operations phase of the 2005 CCROPS program, and again during the summer of 2007 in the SLOTS Project.

Experience gained by the researchers involved in daily forecasting for the 2005 and 2007 field programs, and from the scoping study reported in Lehrman et al. (2006), has shown that the 700 mb constant-pressure surface analysis charts provide the most reliable tool for forecasting the characteristics of the boundary layer over Clark County. The boundary layer over Clark

County during the ozone season typically develops to over 10,000 ft above the surface, which is typically above the 700 mb level. Therefore, the wind charts at 700 mb, in addition to depicting the broad-scale weather patterns over the eastern Pacific and western US, describes the meteorological features that drive interbasin and interstate transport. As a result, the conceptual model for forecasting long-range transport potential focuses on flow patterns and temperature gradients at 700 mb coupled with whatever vertical sounding measurements are available.

Elevated ambient ozone levels in Clark County can be characterized as the result of a combination of regional transport of ozone from upwind source areas and locally produced ozone precursors. It is believed that all high ozone days in Clark County have varying degrees of a transport component. In some cases, transport of ozone from upwind, large urban sources in California is overwhelming. However, the most severe ozone exceedances in Clark County can occur when local emissions are added to an already polluted regional air mass under relatively stagnant conditions. Under these conditions, the elevated regional background ozone probably represents a complex accumulation of ozone transport over a multi-day time scale involving a much larger geographical area.

The requisite synoptic pattern at 700 mb for transport is a large area of stagnant higher pressure located over the interior Southwest, preferably centered just east of the Colorado River. At the same time, a trough of lower pressure should be at or approaching the central or southern California coast so that induced gradient flow at the 700 mb level is south-southwesterly to west-southwesterly throughout the interior southern California and southern Great basin. This flow pattern will provide the trajectory required to transport ozone and precursors from the source areas in the southern third of California to southern Nevada. However, another critical factor needs to be in place in order to provide significant pollution concentrations into the Las Vegas Valley area--a relatively stable structure in the boundary layer between southern Nevada and southern California. If the baroclinic mixing zone associated the west coast trough extends too far inland, vertical mixing will be too strong to maintain the integrity of transported plumes. As a result, too much dilution will take place before the pollution cloud arrives in southern Nevada. Upper air soundings and other available boundary layer measurements are critical in providing the information needed to determine the dilution factor within a transported air mass. In addition, upper air measurements provide an indication of the vertical variation of the wind flow field. Too much directional wind shear with height will tend to smear out the transported pollution plume and too much velocity wind shear will indicate excessive vertical mixing. Both these factors will also affect the dilution factor of the transported pollution cloud. Unfortunately, routine boundary layer measurements are non-existent along the air pathway between the California urban centers and Clark County. An attempt was made during the 2007 field study to obtain additional boundary layer information through aircraft flights and special ground based rawinsonde and continuous profiling measurements, but such information is not normally available for routine air quality use.

Tables 7-1 through 7-3 present peak 8-hour averages for ozone using data provided by the DAQEM for June, July and August 2007, respectively. The two SLOTS ozone sites have also been included for comparison. Looking specifically at the June data, it is immediately apparent that ozone levels are significantly higher during the second half relative to the first. The disparity in ozone concentrations during June is statistically quantified in **Table 7-4** for key sites in the Clark County network. As can be seen, during the second half of the month, peak ozone on the average increased 16 ppb, 17 ppb, and 10 ppb at Paul Meyer, Joe Neal, and Jean, respectively. The peak ozone average for all the sites in the network increased 14 ppb comparing the first half and second half of June. Both July (Table 7-2) and August (Table 7-3) show fewer high ozone days and are more randomly distributed over the period.

Figures 7-1 and **7-2** present 24-hour back-trajectories from Las Vegas for the same 12-day periods, demonstrating fundamental differences in the meteorological conditions between the two periods. As is evident, potential transport trajectories from Southern California source areas, most noticeably the Mojave Desert area north of Los Angeles and the southern San Joaquin Valley, are more prevalent during the latter half of the month corresponding with the higher ozone concentrations.

A discussion about western Mojave Desert flows is helpful in interpreting the air mass trajectories shown on the previous figures. Smith et al. (1997) showed prevailing flows from the southern San Joaquin Valley and the northern SoCAB converging in the western Mojave Desert in the area of Edwards Air Force Base. The air exiting from the SJV has traveled along the length of the valley accumulating pollutants along its path. Air quality in the southern SJV is amongst the worst in California. Smith et al., in the same study, measured ozone levels exiting the SoCAB into the Antelope Valley (specifically Cajon Pass and Soledad Canyon) and into the Mojave Desert. Ozone levels were some of the highest reported in the SoCAB. These polluted air masses after converging in the western Mojave Desert typically transport west into Nevada. Keeping this conceptual model in mind, the streamlines shown in Figures 7-1 and 7-2 generally indicate their origins in the SJV but also include significant if not overwhelming contribution from the SoCAB.

Table 7-1. Peak 8-hour Ozone Averages (ppb) for June 2007. Green values 65 to 75 ppb, orange values 75 to 85 ppb, red values greater than 85 ppb.

June	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SE Valley	67	62	48	53	61	49	48	57	60	44	48	43	54	63	74
E. Craig Road	68	63	54	45	52	44	47	57	63	47	45	45	56	63	69
Apex	69	62	52	51	60	49	48	58	62	47	47	47	58	71	76
Mesquite	51	51	49	42	53	46	44	51	53	44	34	41	52	56	59
Paul Meyer	71	65	52	56	63	55	53	62	68	49	60	52	62	65	83
Walter Johnson					59	53	52	61	70	48	59	53	63	68	82
Palo Verde	68	60	50	53	57	49	46	57	67	41	58	49	57	65	82
Joe Neal	73	64	55	50	54	48	47	59	66	46	52	51	62	74	77
Winterwood	65	61	48	48	59	49	50	59	59	45	48	45	55	62	74
Jean	74	67	55	59	69	57	57	63	70	57	63	56	61	67	85
Orr	58	54	39	38	51	41	41	53	56	36	42	37			
JD Smith	68	62	52	48	59	49	51	59	64	46	50	48	60	65	75
Mt Pass	76	66	64	60	68	50							62	88	90
MOP	75	71	61	60	62	57	51						63	73	96

June	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
SE Valley	84	69	66	64	54	70	64	72	65	72	66	83	74	72	
E. Craig Road	81	76	65	61	48	74	73	63	46	76	60	72	76	61	
Apex	86	73	68	68	57	70	72	64	57	81	65	86	74	78	
Mesquite	77	60	58	59	54	52	58	56	50	58	49	63	56	66	
Paul Meyer	86	79	74	67	53	72	73	74	66	79	71	87	83	69	
Walter Johnson	86	82	75	68	53	78	74	74	66	79	70	86	81	67	
Palo Verde	82	77	70	60	49	69	66	75	63		66	80	75	60	
Joe Neal	81	84	72	66	50	75	75	68	58	77	67	82	82	68	
Winterwood	82	70	71	66	46	66	70	65	56	75	63	79	77	69	
Jean	89	74	76	70	58	69	60	71	62	69	67	84	77	66	
Orr					45	66	70	63	56	71	64	77	79	64	
JD Smith	83	78	69	65	50	73	75	66	53	77	67	80	82	68	
Mt Pass	100	78	85	80	61	73	74	86	74	85	83	98	86	77	59
MOP	94	79	86	82	62	77	78			85	85	100	93	89	65

Table 7-2. Peak 8-hour Ozone Averages (ppb) for July 2007. Green values 65 to 75 ppb, orange values 75 to 85 ppb, red values greater than 85 ppb.

July	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SE Valley	67	51	59	66	64	61	60	55	51	49	50	49	60	61	54
E. Craig Road	68	43	60	64	66	56	55	54	49	52	44	44	61	67	59
Apex	72	54	61	59	62	64	63	56	56	55			61	65	62
Mesquite	57	56	49	53	56	59	57	52	48	44	52	48	45	47	49
Paul Meyer	73	52	65	70	71	73	66	61	59	57	54	56	68	67	63
Walter Johnson	75	52	71	70	78	72	66	62	60	60	54	57	69	69	70
Lone Mountain	71	46	70	68	78	68	60	59	57	56	51	54	66	68	66
Palo Verde	72	49	61	65	74	70	62	59	58	55	51	56	64	67	64
Joe Neal	72	47	69	68	77	68	60	58	58	56	50	52	66	69	67
Winterwood	65	47	56	67	62	59	59	53	51	49	48	45	60	62	53
Jean	66	48	51	60	58	70	59	53	53	52	54	49	60	60	53
Orr	66	43	62	65	65	60	57	51	52	50	47	45	62	60	53
JD Smith	69	48	66	69	68	62	60	55	55	54	49	49	65	66	54
Mt Pass	76	58	67	68	71	69	59	59	51	50	48	51	56	60	52
MOP	78	63	66	71	70	79	68	65	68	65	68	64	72	78	65

July	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SE Valley	51	51	57	48	48	46	50	54	51	54	55	57	62	64	55	52
E. Craig Road	51	47	49	37	42	45	56	55	53	59	51	64	67	66	56	60
Apex	55	53	60	53	53	47	53	56	53	56	53	58	58	64	59	53
Mesquite	47	50	48	44	45	37	41	45	50	49	45	45	50	55	51	51
Paul Meyer	59	53	53	49	51	60	68	65	56	63	65	66	85	77	64	63
Walter Johnson	61	52	54	48	53	61	70	68	55	64	67	70	91	82	66	62
Lone Mountain	56	51	46	43	47	56	68	68	60	62	63	69	86	81	67	60
Palo Verde	55	51	54	46	50	57	69	64	61	62	67	66	89	77	64	59
Joe Neal	58	51	48	45	50	57	67	67	61	65	60	72	81	78	68	63
Winterwood	52	49	56	47	48	43	49	54	47	56	52	59	59	61	48	54
Jean	54	51	50	46	45	54	59	52	49	56	61	61	64	68	58	52
Orr	52	47	46	40	44	49	54	59	53	59	54	61	71	66	55	63
JD Smith	57	52	53	45	49	47	57	60	55	62	57	67	73	70	60	62
Mt Pass	51	60	51	44	52	54	56	53	60	59	63	59	69	67	55	53
MOP	67	65	67	61	65	67	74	63	66	72	79	74	76	77	69	64

Table 7-3. Peak 8-hour Ozone Averages (ppb) for August 2007. Green values 65 to 75 ppb, orange values 75 to 85 ppb, red values greater than 85 ppb.

August	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SE Valley	45	58	77	73	71	58	52	52	48	45	46	44	47		
E. Craig Road	38	59	60	74	61	45	46	52	48	44	49	46	44	46	58
Apex	44	61	71	76	70	55	55	56	52	44	47	45	55	51	60
Mesquite	34	51	60	61	67	48	49	47	48	42	44	45	51	46	52
Paul Meyer	52	71	72	81	73	61	52	58	55	53	54	49			59
Walter Johnson	50	65	69	82	71	62	52	58	54	53	55	50	52	56	59
Lone Mountain	50	62	60	78	64	58	49	57	51	50	52	46	47	53	57
Palo Verde	51	60	61	80	70	62	52	59	52	53	53	48	48	54	58
Joe Neal	48	62	59	79	71			61	54	53	55	50	52	58	62
Winterwood	44	60	72	70	65	51	47	51	49	45	47	43	48	48	55
Jean	49	61	67	74	71	58	48	52	48	45	48	45	47	50	54
Orr	43	63	79	75	64	47	45	56	48	44	48	44	47	47	55
JD Smith	45	63	71	79	67	53	52	58	53	50	53	49	51	53	63
Mt Pass	56	61	65	74	73	58	53	50	51	52	46	46	44	51	61
MOP	54	71	69	86	80	70	61	66	63	62	58	56	55	60	67

August	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SE Valley	62	66	61	61	60	79	78							69	55	71
E. Craig Road	59	65	61	51	56	78	70	64	56	43	49	55	63	64	52	73
Apex	61	66	62	59	64	85	72	61	55	44	46	55	54	57	60	60
Mesquite	54	54	55	57	50	56	67	58	50	45	48	56	57	57	54	58
Paul Meyer	63	64	62	62	62	78	73	63	60	47	53	67	69	76	56	84
Walter Johnson	63	64	62	61	63	78	69	64	61	47	53					87
Lone Mountain	63	62	59	56	60	76	65	61	59	46	51	62	67	71	55	81
Palo Verde	62	61	62	61			68	63	61	45	52	68	65	70	55	84
Joe Neal	68	68	63	58	62	77	70	63	63	46	52	62	68	68	58	77
Winterwood	56	60	56	52	55	77	68	62	53	42	43	52	64	61	49	66
Jean	57	62	55	56	54	79	76	69	57	43	44	62	54	61	55	63
Orr	60	62	56	50	53	76	65	58	54	38	42	55	72	69	44	79
JD Smith	64	66	62	56	58	82	72	65	59	44	49	58	70	68	54	81
Mt Pass	69	65	53	50	65	72	90	74	55	51	48	55	55	56	53	57
MOP	71	75	69	68	70	90	82	72	65	60	53	66	67	80	63	73

Table 7-4. Average Ozone Maximum 8-hour Average (ppb) for Selected Sites

Site	6/2 – 6/13	6/16 – 6/27	Difference
Paul Meyer	58	74	16
Joe Neal	54	71	17
Jean	61	71	10
All sites (averaged)	53	69	14

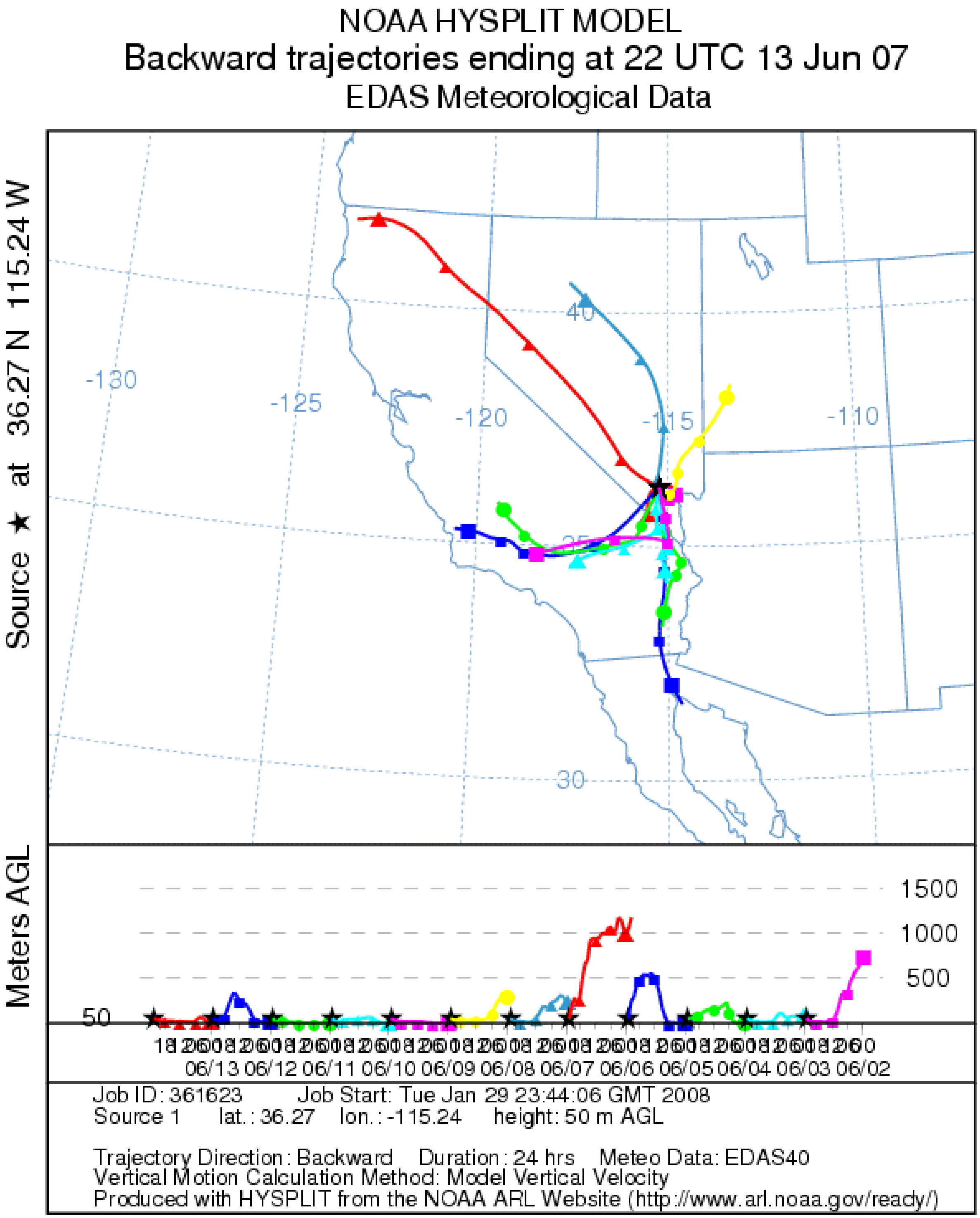

Figure 7-1. Daily 24-hour Back-trajectories – June 2 through 13, 2007

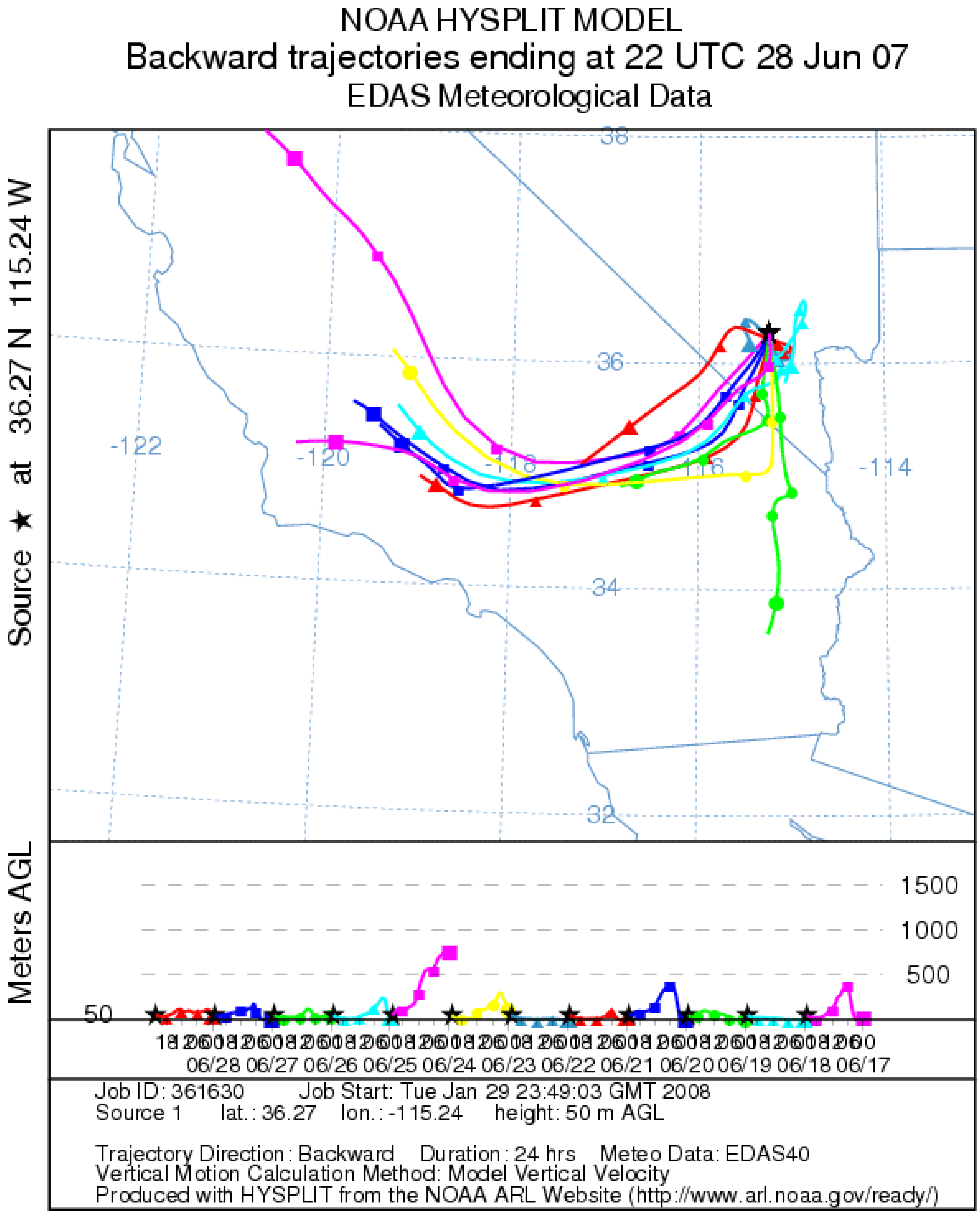

Figure 7-2. Daily 24-hour Back-trajectories – June 16 through 27, 2007

Thus, even a general review of routine data collected during SLOTS points to an apparent role of interstate transport from California on Clark County ozone concentrations. The following sections further discuss transport-related IOPs conducted during SLOTS, as well as non-IOP days during which exceedances of the 8-hour average ozone criteria occurred which likely were significantly affected by transport.

7.1.1 Analysis of IOPs

In this section, the meteorology and air quality affecting ozone levels in Clark County during Intensive Operations Periods (IOP) are examined. During IOPs special measurements of conditions aloft were made: namely aircraft air quality and meteorology sampling; and balloon-borne high-resolution measurements of temperature, humidity, and winds (rawinsondes). IOPs were conducted on June 22-24 and July 16-17.

June 22 – June 24, 2007

Synoptic Description

The synoptic weather patterns affecting the Southwest region of the U.S. during this IOP are presented in the NWS 700 mb constant pressure analyses charts shown in **Figures 7-3** through **7-5** below. A large area of high pressure centered in the southern Plains extended across two thirds of the US from the west coast to the Appalachians on the morning of June 22. Although the high pressure area was quite extensive, pressure gradients were generally weak except around the fringes of the ridge. During the 22nd, a rather strong long wave trough was approaching the northwest coast of the US from the Gulf of Alaska, triggering increasing onshore pressure gradient flow along the entire California coast. At the same time, the broad high pressure ridge to the east was characterized by light and somewhat variable flow over the southern Great Basin with subsidence stability and stagnant conditions prevailing in southern Nevada. The IOP was initiated based on this combination of initial stable conditions that allowed for the accumulation of higher ozone concentrations in the Southern California air basins, followed by transporting winds resulting from the approaching trough.

By the morning of the 23rd, the west coast trough had become stationary just offshore, as its main energy became centered in a deep closed low off the British Columbia coast. During the early morning hours of that day, the eastern ridge actually built back toward the Southern California coast, resulting in very light and somewhat variable flow extending across Southern California and southern Nevada. However, by the afternoon of the 23rd, the west coast trough once again dug southward along the coast resulting in increasing onshore flow across California once again. The west to southwesterly steering flow at 700 mb reached southern Nevada by the afternoon of the 23rd, and persisted there for the next several days.

Figures 7-6 through **7-9** below show four plots of upper-air rawinsonde soundings taken at the North Las Vegas airport profiler site during the 22nd, 23rd and 24th. The profiler was not operational at that time, and no NWS Desert Rock Rawinsondes are available during weekends. Note that winds at and below the 700 mb level were light and somewhat variable generally from the northern quadrant on the 22nd, and the southern quadrant on the 23rd. Stronger southerly to southwesterly flow began to appear by the late afternoon on the 23rd, and was clearly established by the morning of the 24th. Also evident on the soundings was the relatively stable mixing layer on the 22nd and 23rd, with a subsidence cap showing up around the 600 mb (around 13,000 ‘ msl).

It is clear that transport flow from Southern California to southern Nevada was in place by late afternoon on the 23rd, and that the mixing layer was capped by a subsidence stable layer at 600 mb. However, the close proximity of the baroclinic zone of the west coast trough to Southern California induced vigorous mixing which inhibited significant pollution build up. As a result, the air that was eventually transported into southern Nevada did not contain ozone concentrations at the exceedance level.

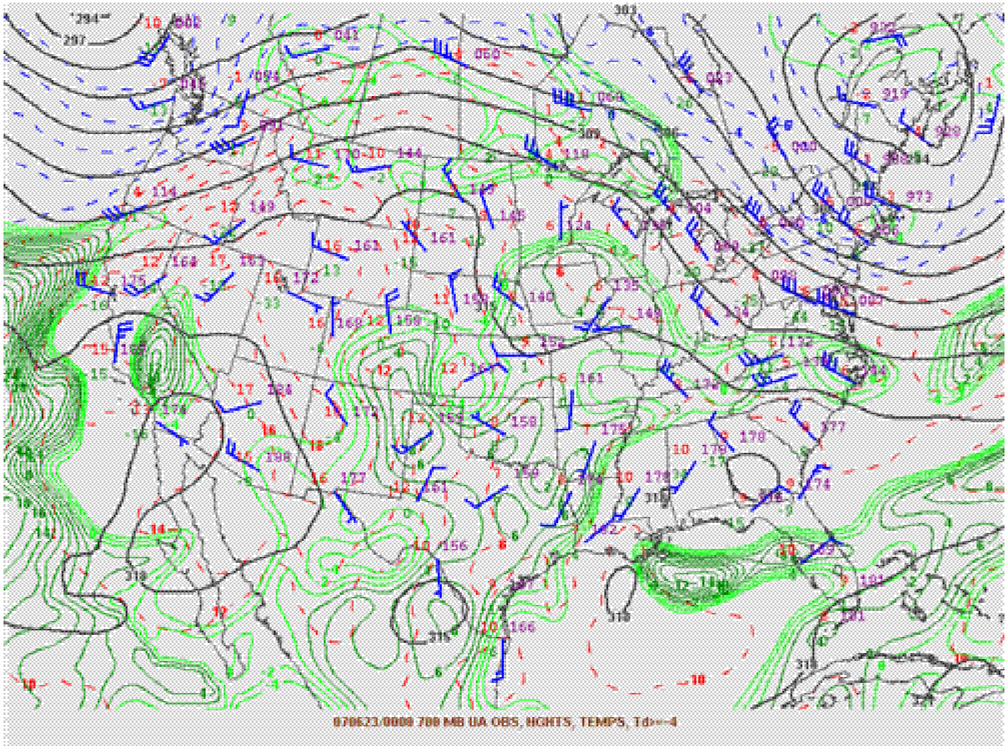

Figure 7-3. 700 mb Analysis for 06/22/07/1600 PST

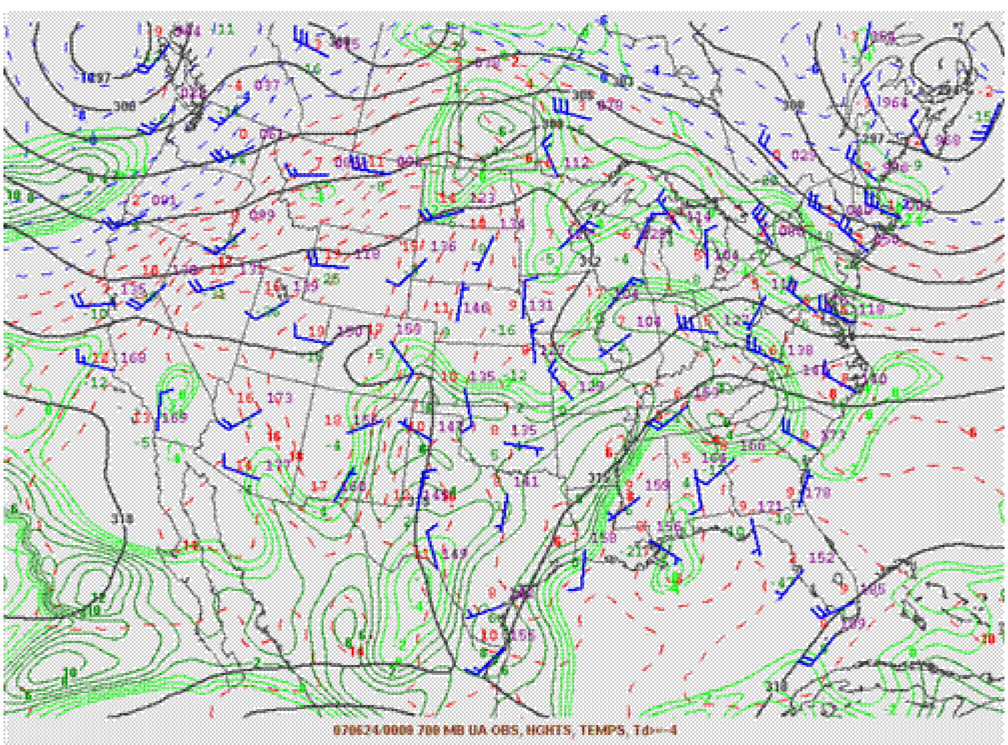

Figure 7-4. 700 mb Analysis for 06/23/07/1600 PST

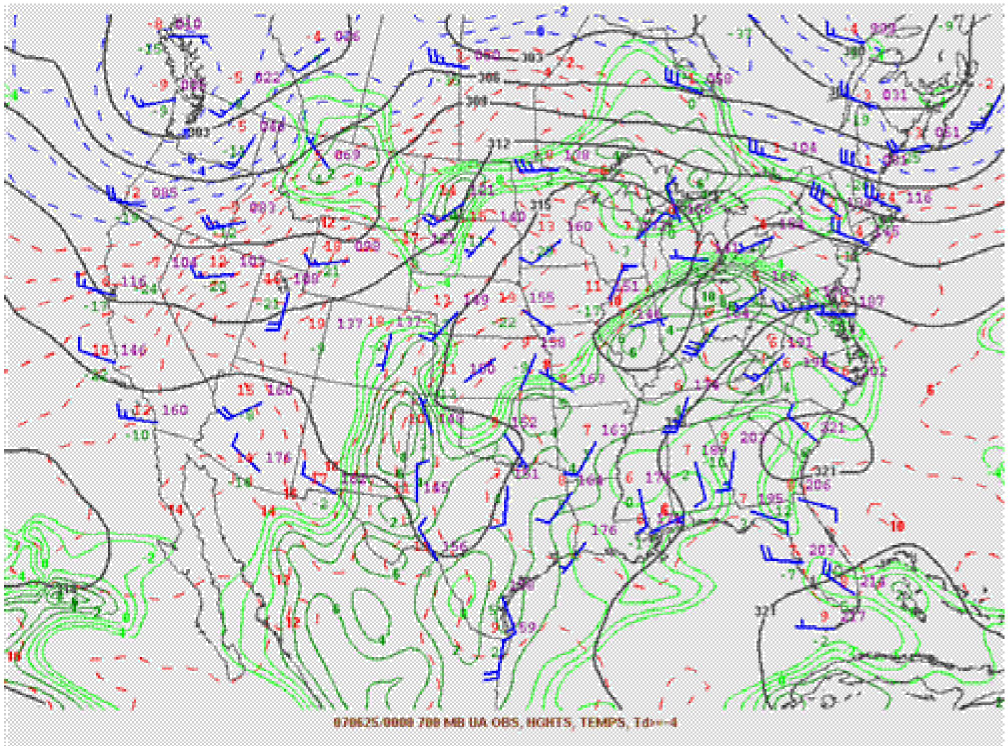

Figure 7-5. 700 mb Analysis for 06/24/07/1600 PST

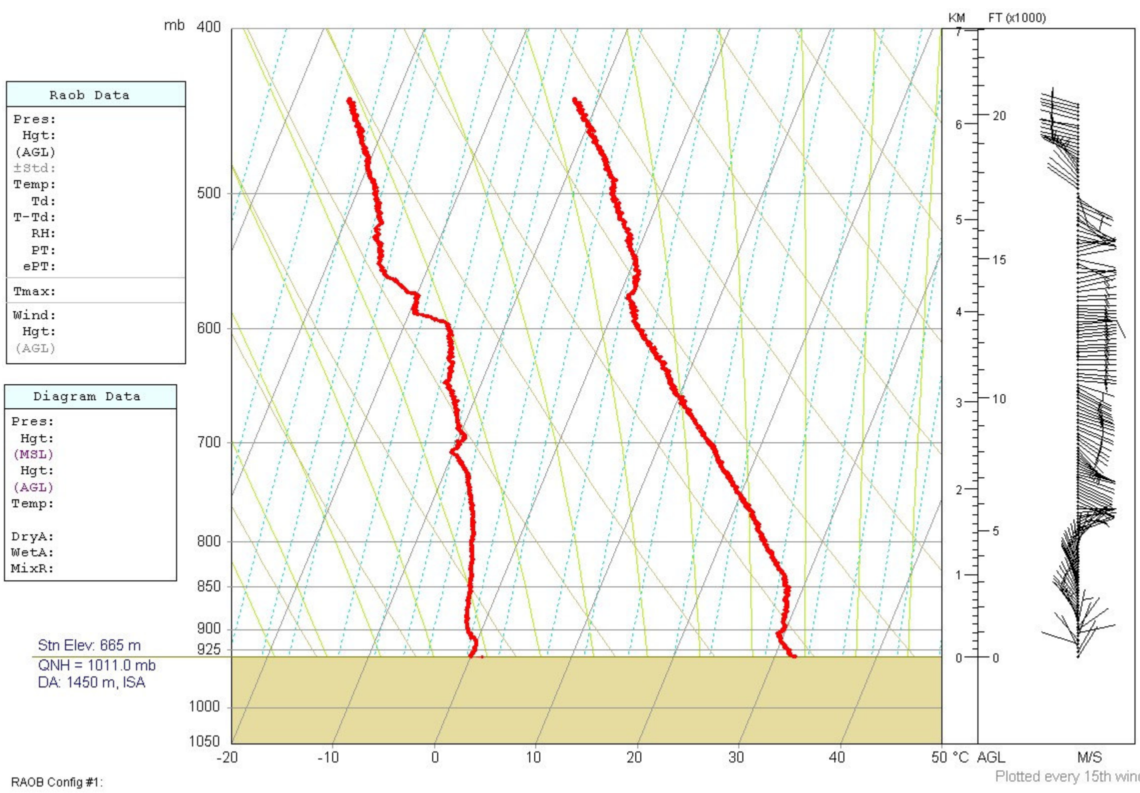

Figure 7-6. North Las Vegas Rawinsonde, 06/22/07/0800 PST

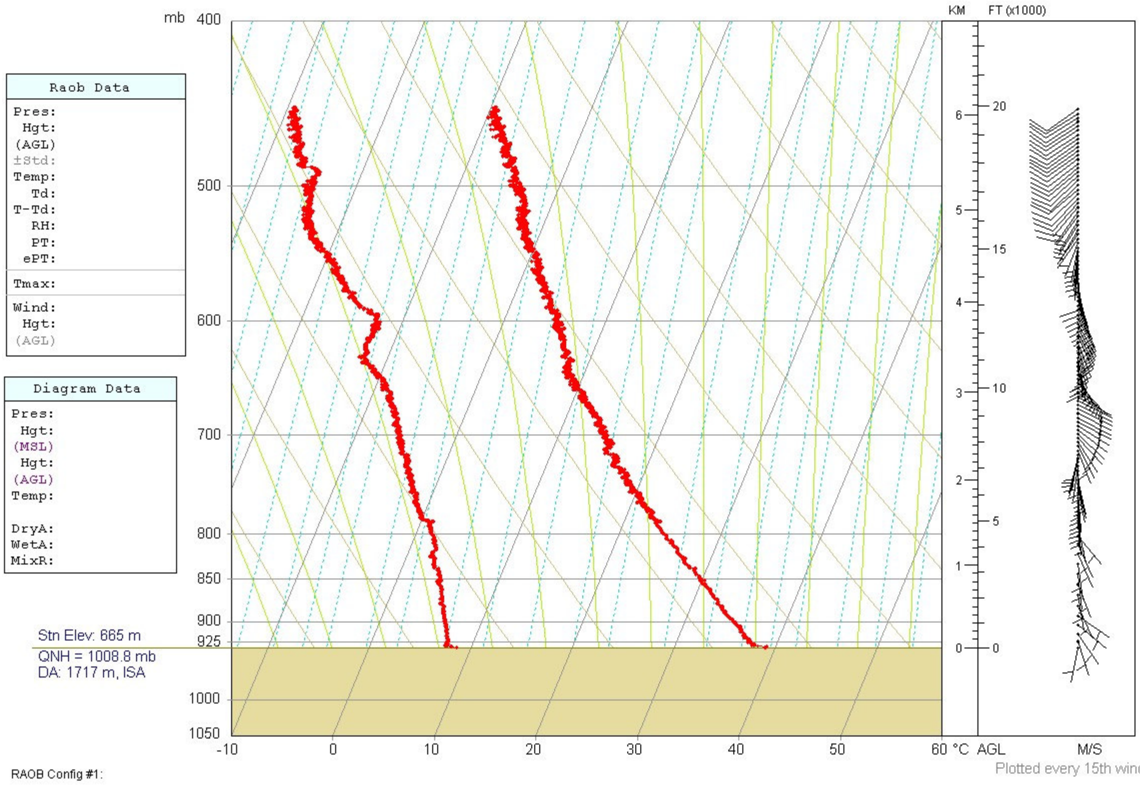

Figure 7-7. North Las Vegas Rawinsonde, 06/23/07/1200 PST

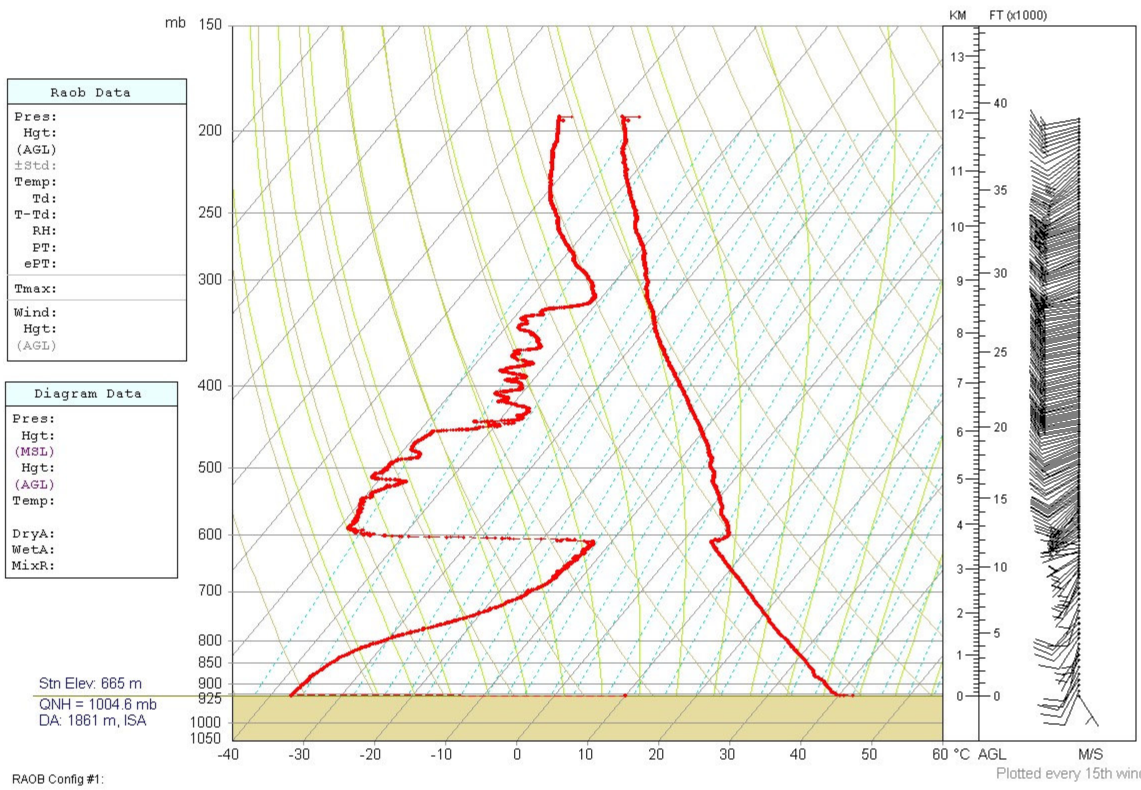

Figure 7-8. North Las Vegas Rawinsonde, 06/23/07/1800 PST

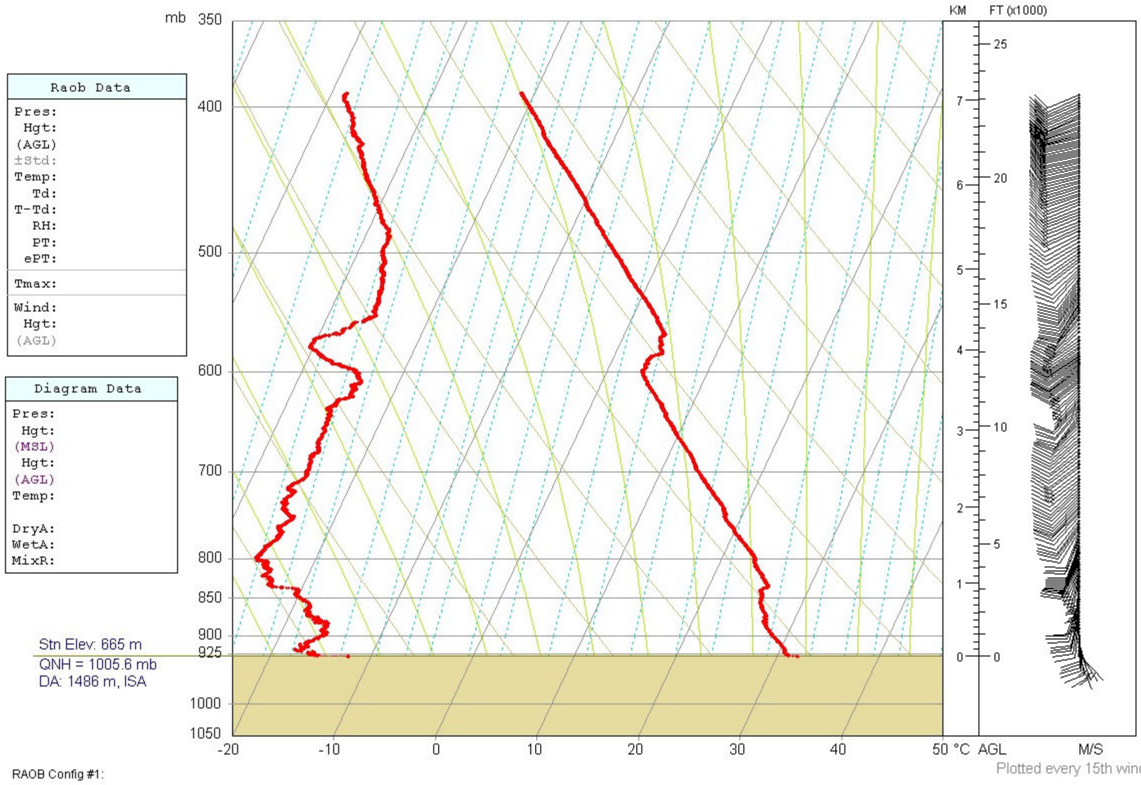

Figure 7-9. North Las Vegas Rawinsonde, 06/24/07/0800 PST

<u>Aircraft Measurements and Summary of Findings</u>

The first flight of the IOP was conducted mid-day on June 22 with the goal of characterizing conditions along the primary pollution transport pathway between Southern California and Las Vegas leading up to a transport event. The flight began with a sounding out of the North Las Vegas airport (NLV), followed by a sounding at Jean. Traverses were then made along the California/Nevada boarder at two levels between the Colorado River area to the south and in the vicinity of Pahrump to the north. The flight ended with second soundings at Jean and NLV. A second flight was conducted in the afternoon/evening. The second flight also began with soundings at North Las Vegas and Jean. Finding little vertical gradient in ozone and PM during the soundings (consistent with findings during the first flight), the decision was made to fly traverses at the 3050 m level. Traverses began by following I-15 from Jean to Baker, California, heading north towards Desert Rock AFB, and finally following US-95 into North Las Vegas. Thus, this flight looked farther west and north than the previous, morning flight.

Figure 7-10 presents a three-dimensional map of the first flight. Shown are color-coded balls, depicting ozone concentrations during the flight, and a corresponding surface "shadow" plotted on the base of the graph to provide perspective. The outline of Clark County is provided as a general reference, though it's boarder with California is hidden by the flight "shadow". Soundings were conducted in the vicinity of the North Las Vegas and Jean airports. Letters are provided to mark the endpoints of the traverses.

Both the June 22 mid-day and evening (**Figure 7-11**) flights show general homogenous conditions throughout the study area. Ozone concentrations are only moderately high and $PM_{2.5}$

concentrations are low. Ozone concentrations were uniform in both the vertical and horizontal planes (**Figures 7-12** and **7-13**, respectively). Winds aloft, as reported by the aircraft GPS navigational system, were 10 to 15 knots from variable directions although primarily westerly. The conditions seemed representative of regional background concentrations prior to a transport event, with no evidence of any definable pollution plumes, aside from the Las Vegas plume along US-95 extending NW from the urban area, observed during the evening flight.

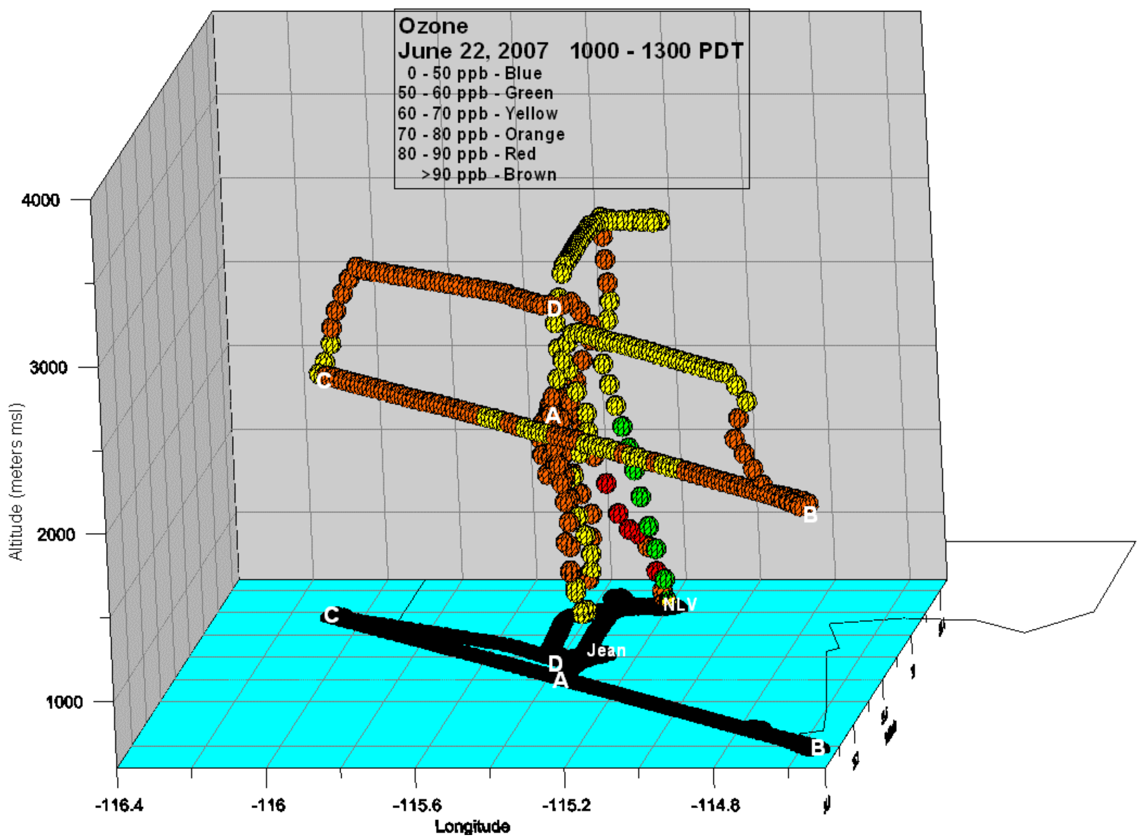

Figure 7-10. June 22 Mid-day Flight

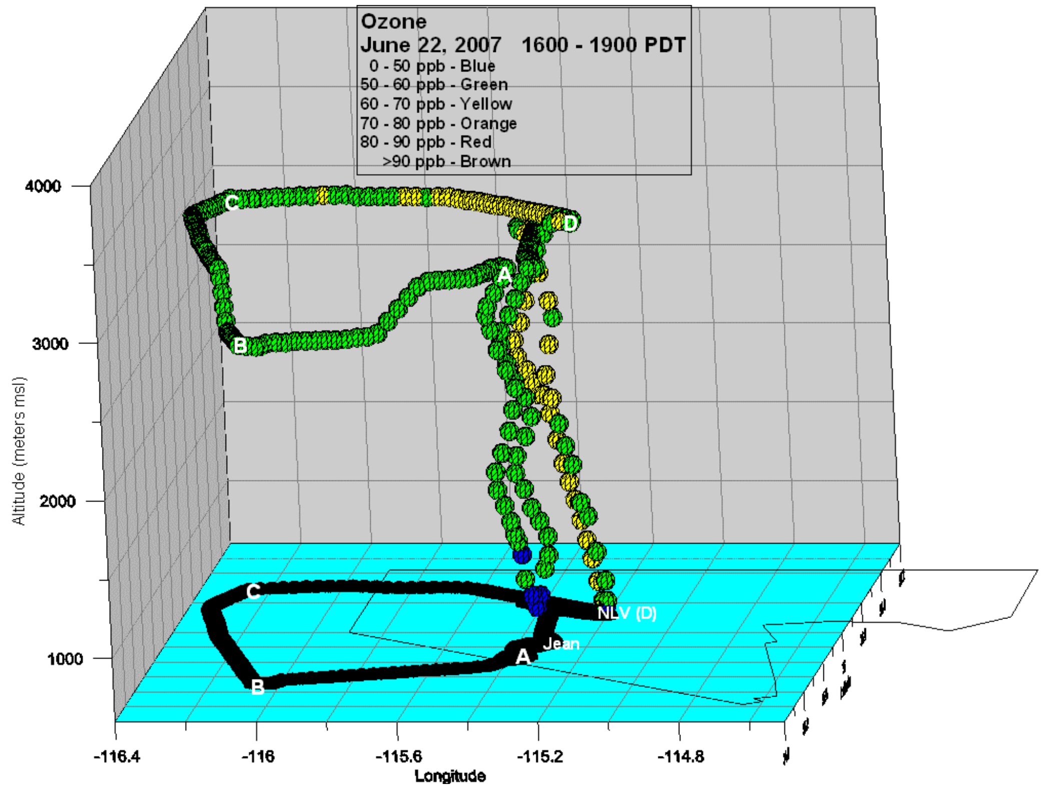

Figure 7-11. June 22 Evening Flight

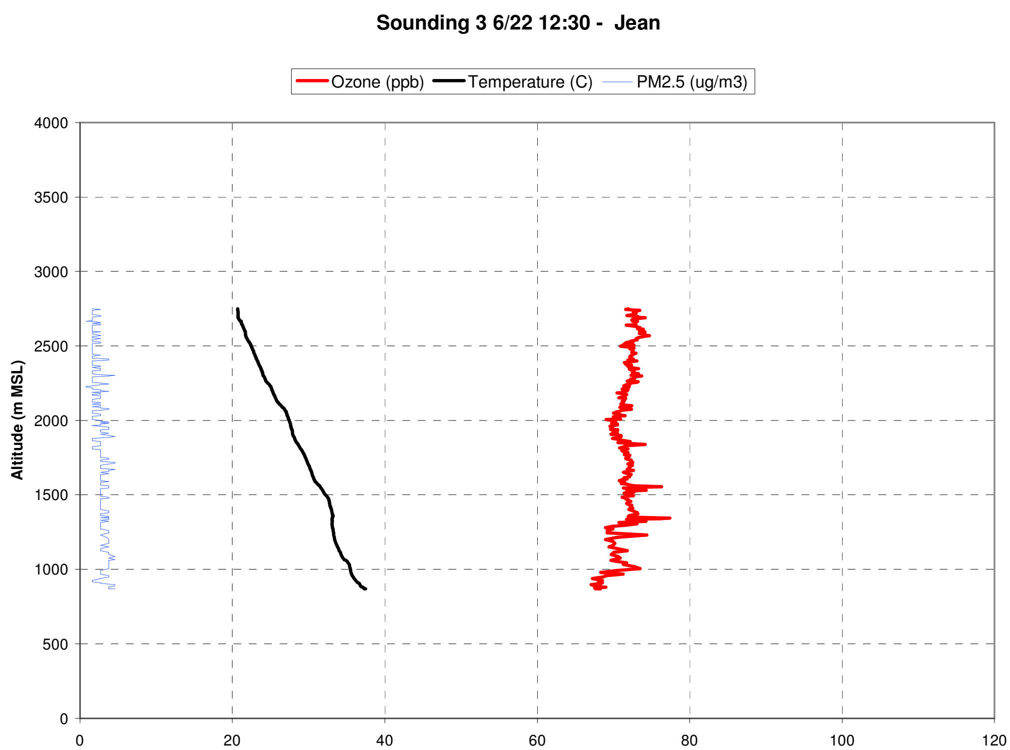

Figure 7-12. Sounding at Jean during June 22 Mid-day Flight

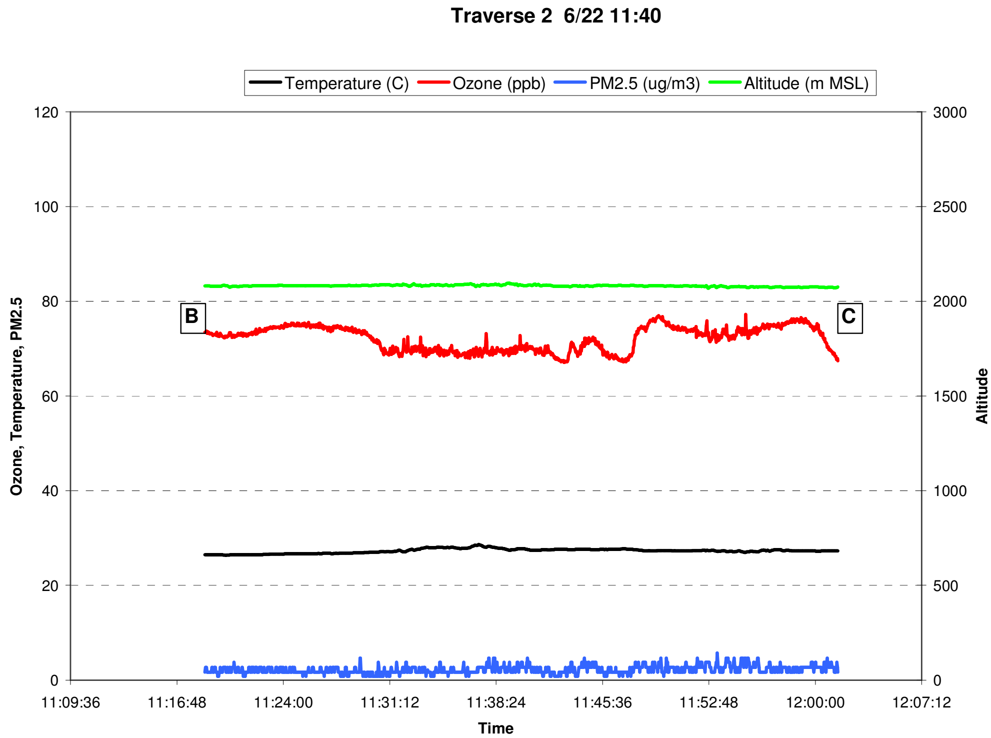

Figure 7-13. Traverse along California/Nevada Border during June 22 Mid-day Flight

In contrast, the June 23 morning flight (**Figure 7-14**) revealed a definite plume of higher ozone concentrations stretching approximately 137 km along the California/Nevada boarder, starting just south of I-15 and extending up to Death Valley Junction. The plume is more easily noted in the plot of the traverse along the California/Nevada boarder, shown in **Figure 7-15**, and represents an increase of approximately 20 ppb over "background" values. The sounding at Jean (**Figure 7-16**) showed very little vertical variability in concentrations from the surface to 3000 m msl. Winds aloft, as reported by the aircraft GPS navigational system, were from the south to southwest at 10 to 15 knots. These conditions, combined with fairly low $PM_{2.5}$ concentrations that were not correlated with ozone concentrations and a lack of any visible smoke, are all consistent with a large, deep urban plume transported from Southern California.

The June 23 evening flight, depicted on **Figure 7-17**, continued to show a distinct plume of higher ozone concentrations noted during the morning flight, stretching approximately 150 km along the California/Nevada boarder, starting just somewhere between I-15 and the Colorado River and extending up to at least Death Valley Junction (**Figure 7-18**). Soundings showed very little vertical variability in concentrations from the surface to 3000 m msl. Winds aloft, as reported by the aircraft GPS navigational system, were steady from the southwest at 15 to 20 knots in all locations. Similar to the morning flight, the flight was characterized by steady, strong southwest winds, high ozone concentrations (about 10 ppb greater than the morning flight, but still showing an increase of 20 ppb at the plume's boundary), relatively low, constant $PM_{2.5}$ concentrations that were not correlated to ozone concentrations, and a lack of visible smoke (again consistent with an urban plume from Southern California) and coincide with an atypical late afternoon, early evening peak in ozone noted at several DAQEM sites, as well as the SLOTS sites.

Hysplit back-trajectories provide further evidence that transport from California occurred on June 23. **Figure 7-19** shows three 24-hour back-trajectories, with winds capable of transport from the southern California deserts present on June 23. In addition, **Figures 7-20** and **7-21** reveal the buildup of ozone concentrations in and around the Los Angeles basin on both June 22 and 23. The highest concentrations are along the western and northwest edge of the basin (San Bernardino). The ozone contour pattern depicts westerly and southwesterly transport of urban air leading to the Las Vegas area.

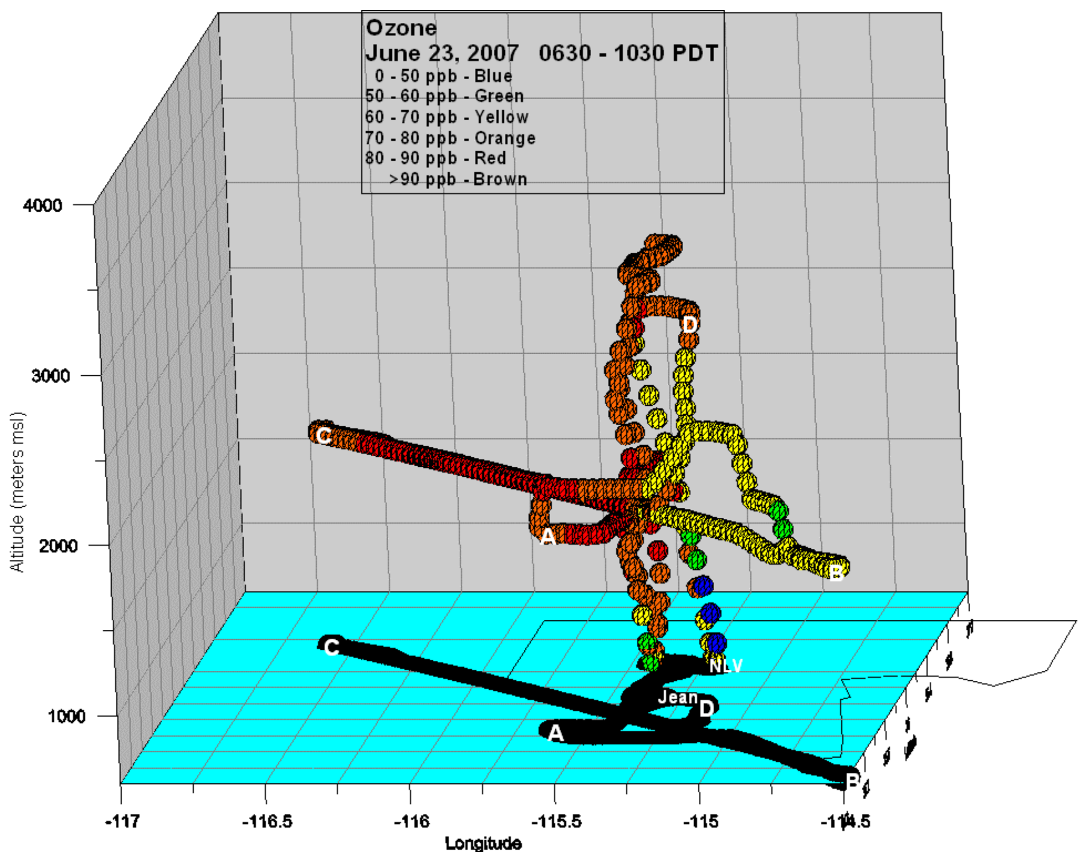

Figure 7-14. June 23 Morning Flight

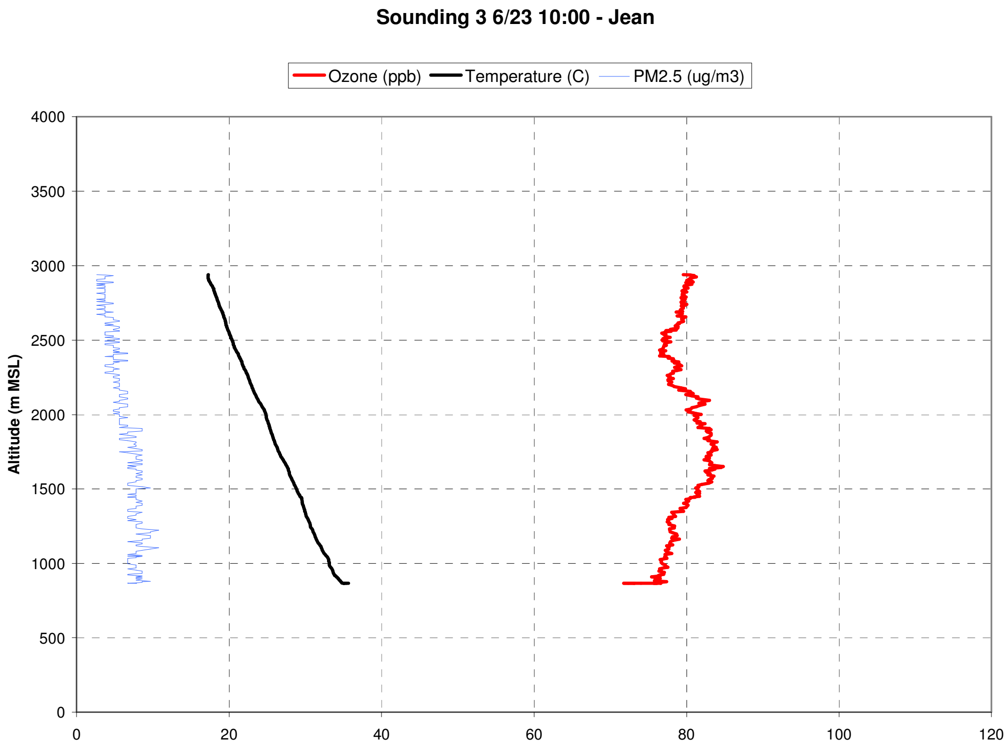

Figure 7-15. Sounding at Jean during June 23 Morning Flight

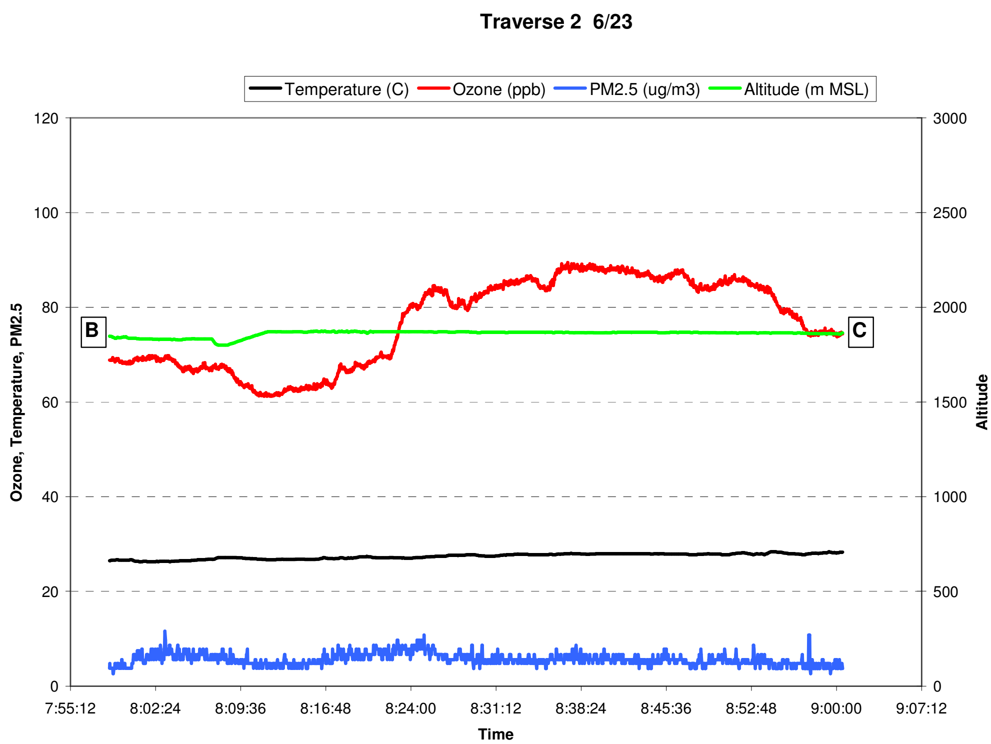

Figure 7-16. Traverse along California/Nevada Border during June 23 Morning Flight

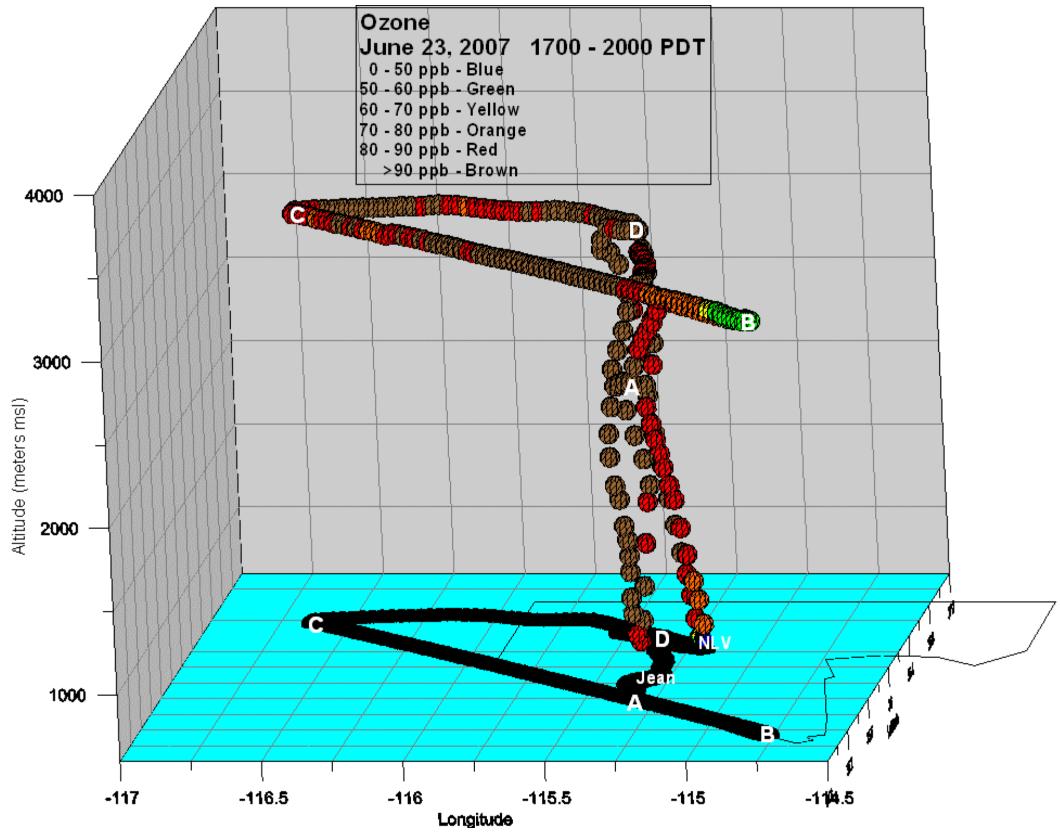

Figure 7-17. June 23 Evening Flight

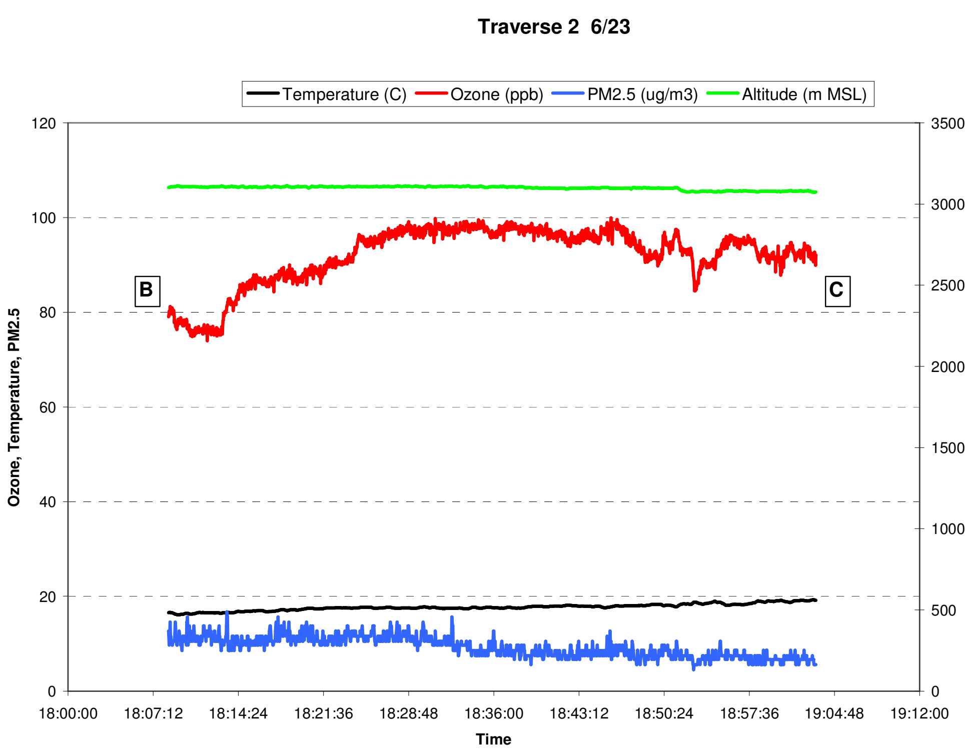

Figure 7-18. Traverse along California/Nevada Border during June 23 Evening Flight

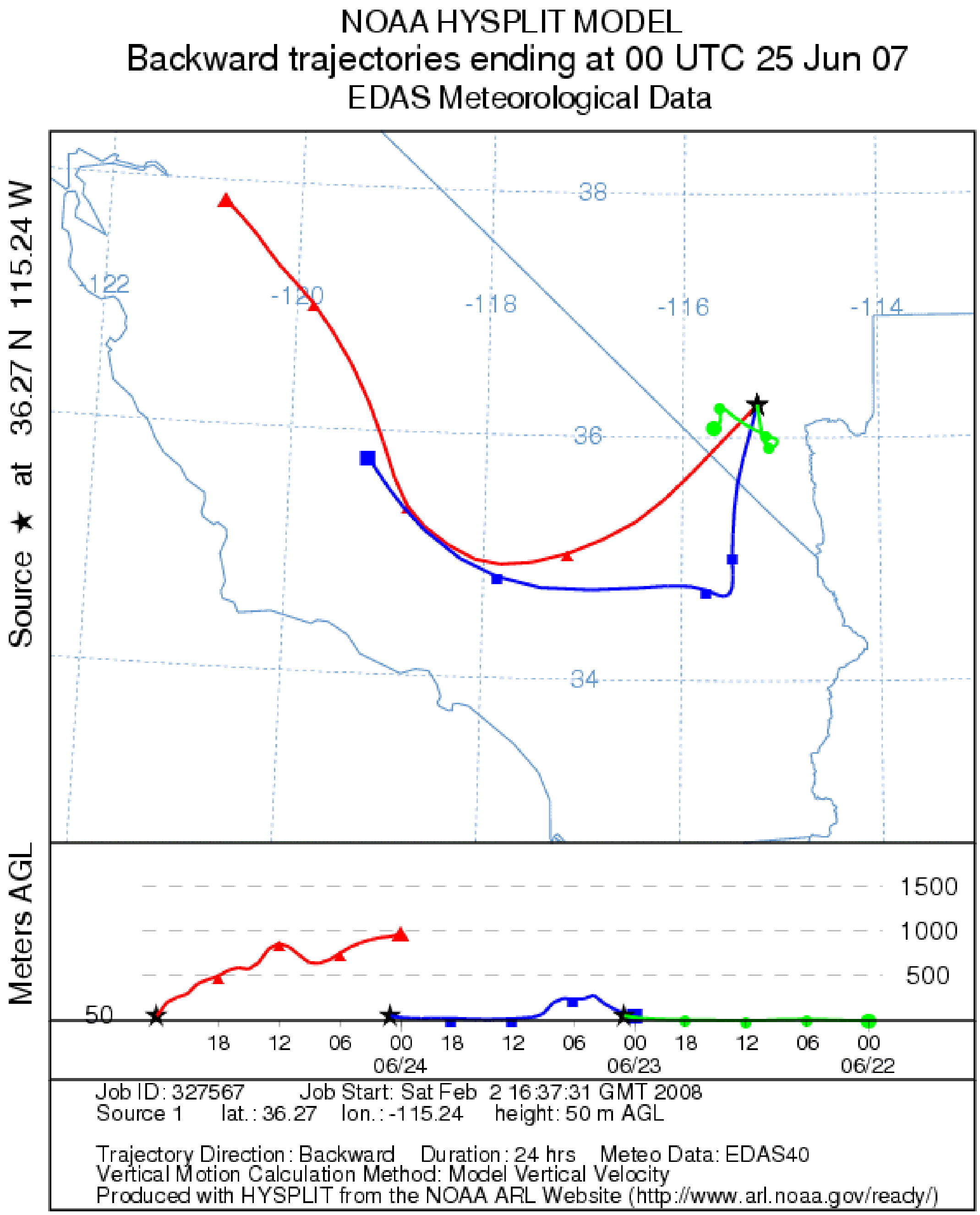

Figure 7-19. Back-trajectories for June 22 through 24

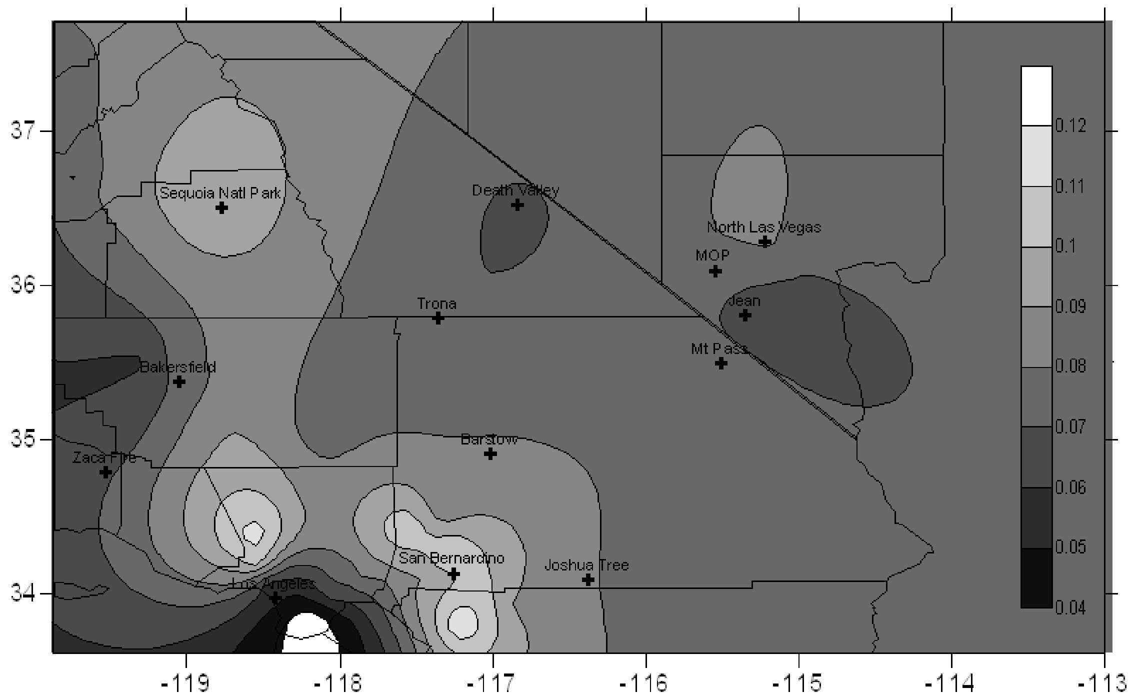

Figure 7-20. Peak Hourly Ozone (ppm) – June 22, 2007

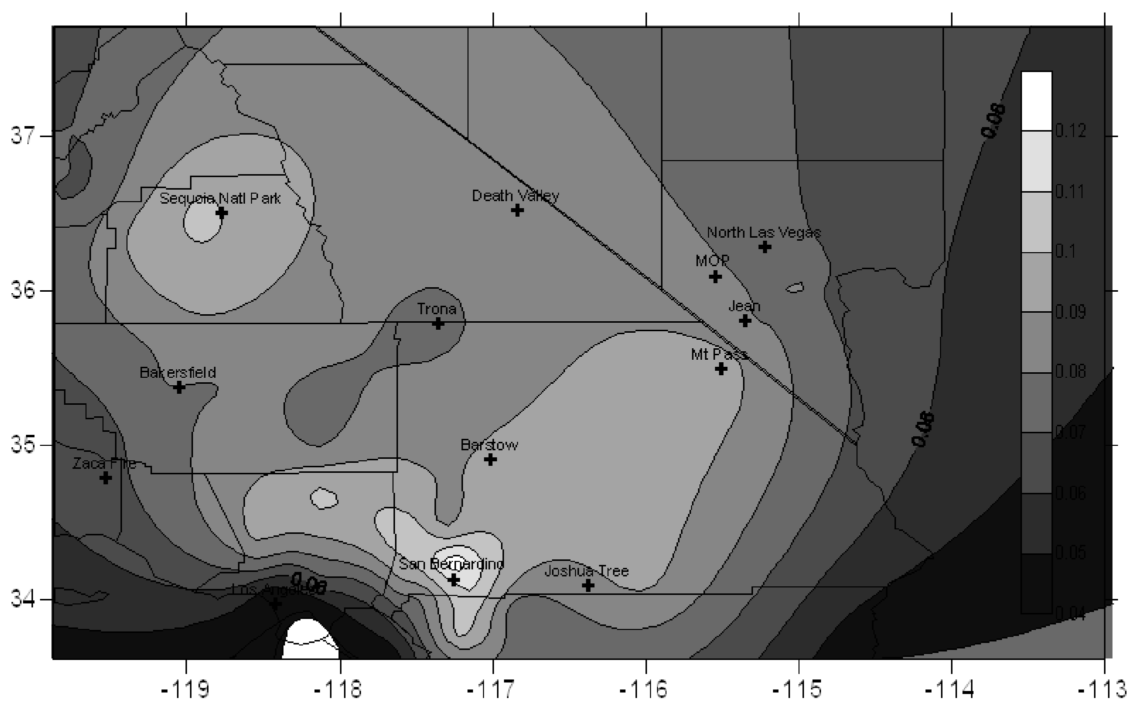

Figure 7-21. Peak Hourly Ozone (ppm) – June 23, 2007

During the June 24 morning flight (**Figure 7-22**), generally good air quality was encountered west and southwest of Las Vegas, with ozone concentrations in the 40 – 50 ppb range and near-zero $PM_{2.5}$ concentrations. This is consistent with what one would expect after the passing of a trough through the area and the good dispersion associated with it. However, conditions change drastically heading to the southeast down the state line from Primm toward the Colorado River, where a visible plume was noted by the airplane crew. In contrast to the basically uniform, low $PM_{2.5}$ values noted the previous day both in and out of the urban plume, $PM_{2.5}$ values in the this plume were somewhat elevated and correlated well with increases in ozone concentrations. The final west/east traverse south of the Las Vegas area showed the plume heading up into the Henderson area, generally staying east of US-95. Ozone concentrations at the DAQEM Henderson (SE Valley) site showed an uncharacteristic morning peak of 63 ppb that was 10 ppb higher than the next highest values (Jean) and 14 to 27 ppb higher than the other sites in the network, demonstrating the impact of the plume on the urban area.

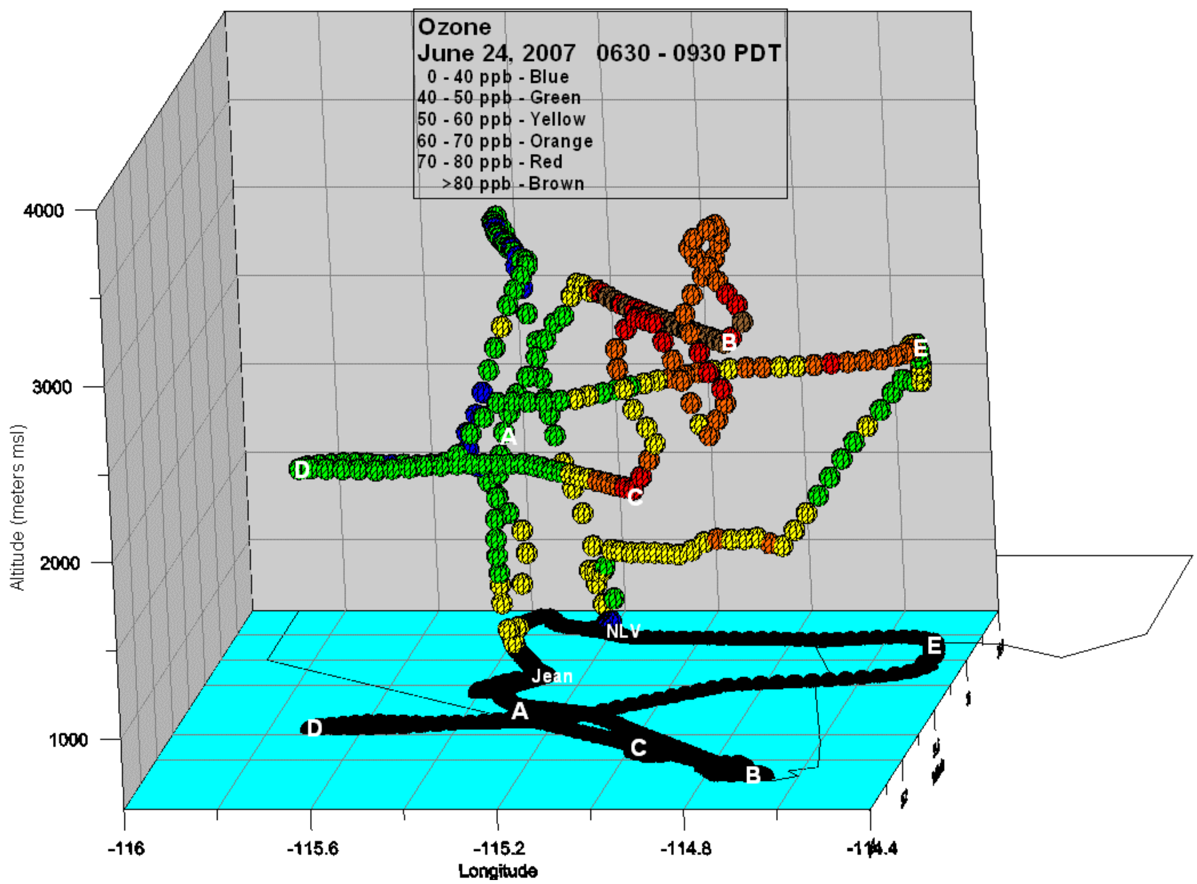

Figure 7-22. June 22 Morning Flight

Figure 7-23 is a re-oriented version of Figure 7-22, viewed from a perspective perpendicular to the California/Nevada boarder in the vicinity of I-15, which more easily shows the vertical structure of the plume. There is a very distinct boundary between the clean air (ozone at 40 ppb, PM at zero) and the more pollution air mass (ozone at 85 ppb, PM at 15 $\mu g/m^3$) essentially south of I-15. This boundary is readily apparent in the constant level traverse depicted in **Figure 7-24**. The layer is fairly narrow in depth (about 1000 ft), centered about 2500 ft agl, and visually identifiable. Our initial interpretation was that the plume was a smoke plume, due primarily to its visual characteristics. However, there were no fires in the area to cause a smoke plume. The White fire reportedly began at about 8:00 AM on June 24, the same time as the flight, so it could not yet have had an influence that far downwind. The NOAA smoke analysis graphics show no smoke plumes in the area on June 23, and shows only what is obviously the White fire on June 24 (**Figure 7-25**), drifting to the north rather then the south of I-15. MODIS satellite photos confirm the White fire smoke trajectory and the lack of any wildfire smoke south of I-15.

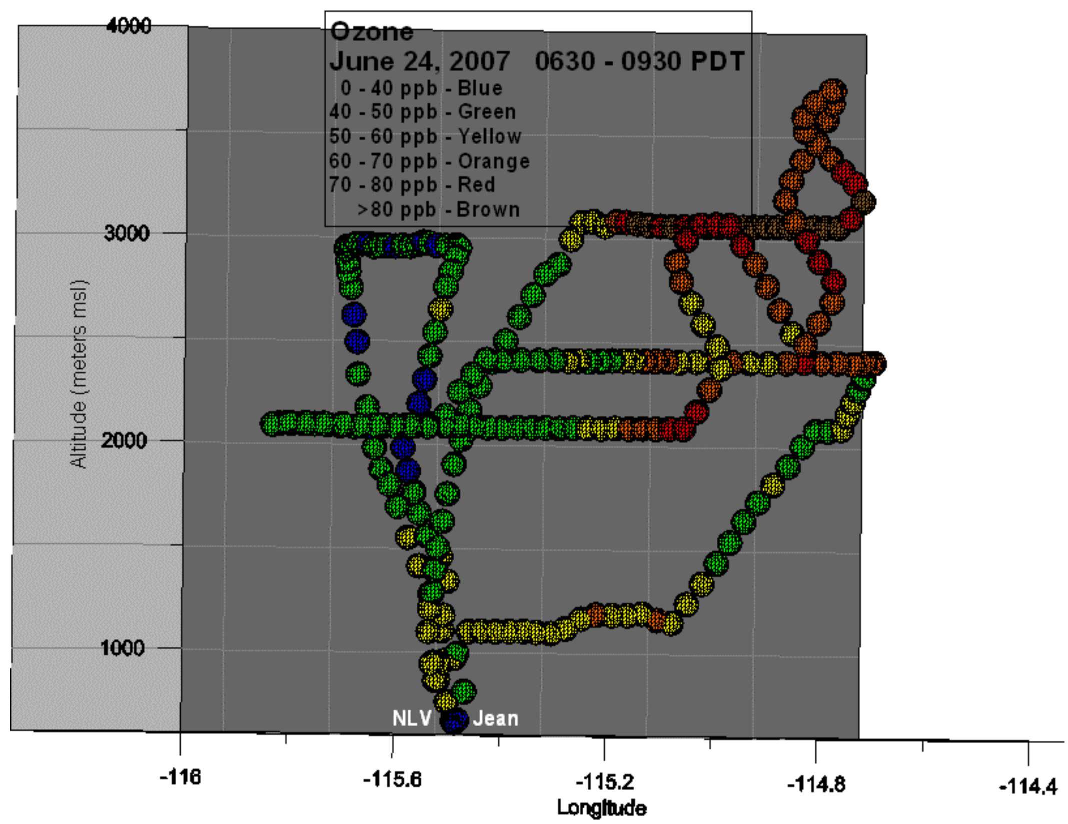

Figure 7-23. View of June 24 Morning Flight Perpendicular to the California/Nevada Border

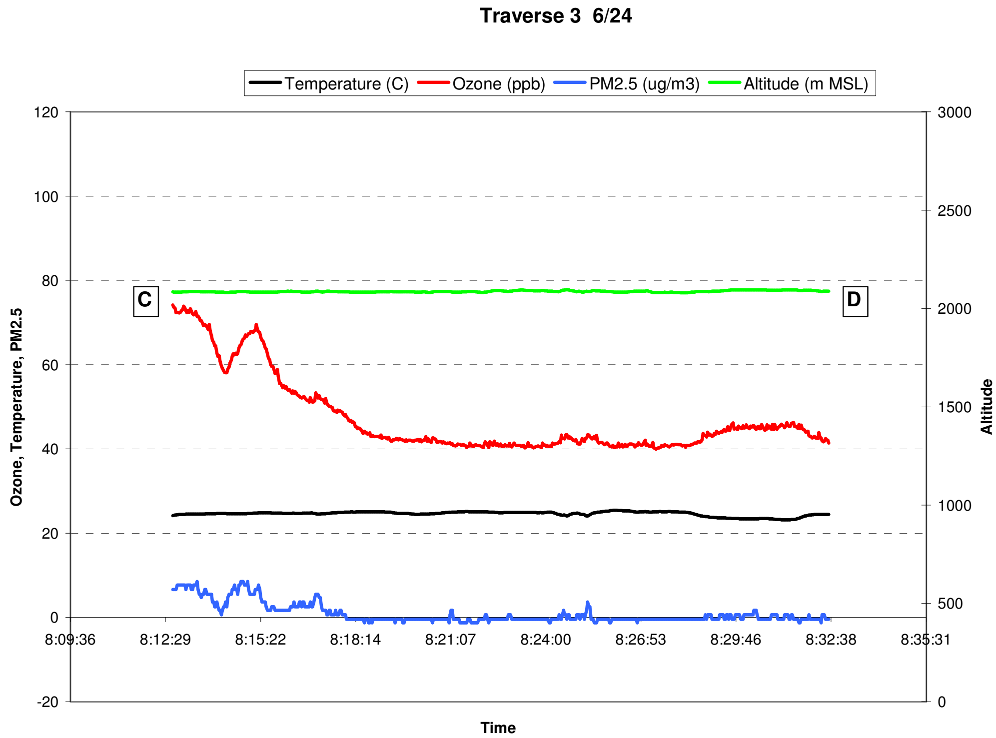

Figure 7-24. Traverse during June 24 Flight

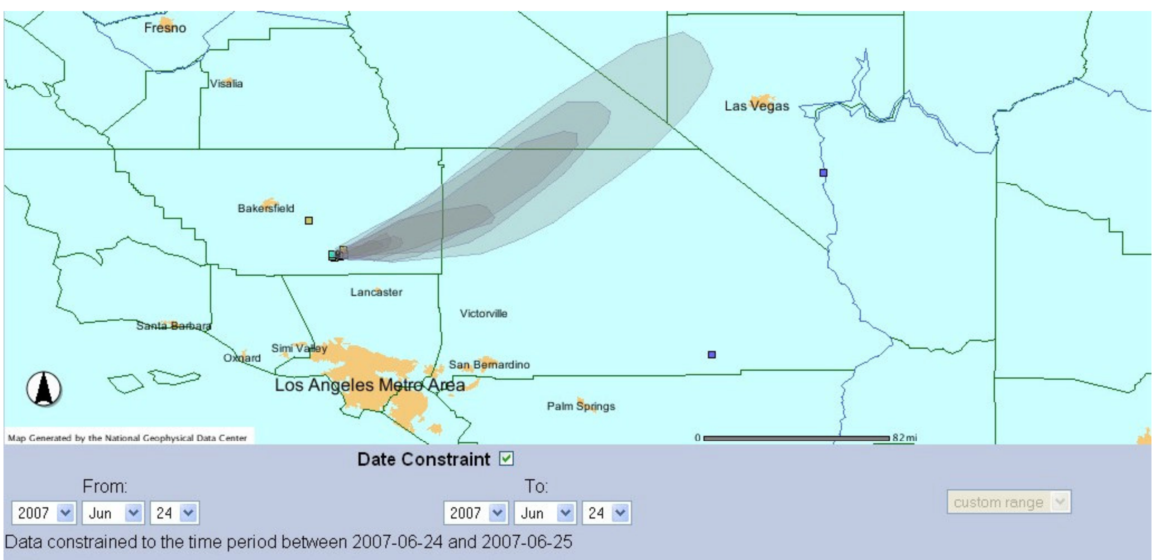

Figure 7-25. Smoke Analysis for June 24

Thus, this plume appears to be an urban plume. Back-trajectories support the possibility of urban air exiting the South Coast air basin through the desert passes affecting regions south of I-15, while the source of the air mass north of I-15 was from the northern Mojave Desert. **Figure 7-26** shows HYSPLIT back trajectories starting where the airplane observed high and low ozone readings during the morning flight of June 24. Ozone concentrations were very high on the previous day (June 23) in the deserts and mountains surrounding San Bernardino (Figure 7-21), consistent with ozone transport along the southern trajectory. More specifically, the positions for the trajectories at hour 00 UTC on June 24 (15 hours before the flight) both fall immediately above existing air quality sites (Mojave for the northern trajectory and Phelan for the southern trajectory, also shown in the figure). During this hour, the average concentrations reported were 62 ppb and 91 ppb for the Mojave and Phelan air quality monitoring sites, respectively. The difference in these values is very consistent with the difference noted by the aircraft (see Figure 7-24).

This example dramatically illustrates the upwind contribution that a transported urban plume can make to the Clark County air quality. However, this particular example contradicted our hypothesis on wildfire smoke markers. As noted above, an observed characteristic of the urban plume that was seen on June 23 was the lack of correlation between ozone and $PM_{2.5.}$ In contrast, an obvious correlation between ozone and $PM_{2.5}$ is noted for the June 24 plume (Figure 7-24). This correlation between ozone and $PM_{2.5}$ was originally considered a means of differentiating between wildfire and urban plumes, but it appears that may not be the case. While this does not negate using the magnitude $PM_{2.5}$ as a marker of wildfire smoke (see Section 7.2), any analysis must take into account the potential for some limited $PM_{2.5}$ to be present in the urban plume.

Another difference between the June 23 and June 24 is the apparent layering of the plume. Figure 7-23 hints at a layer of moderate ozone concentrations from the surface to about 1100 m msl, high ozone concentrations above about 2000 m msl (with maximums near 3000 m msl), separated by a cleaner layer in between. This seems to be consistent with the soundings obtained during the day. Looking back at the rawinsonde sounding taken at North Las Vegas during the flight (Figure 7-9), one sees a slightly elevated temperature inversion at about 1000 m msl, consistent with a capping of a layer, with a more pronounced capping inversion at 3700 m. **Figure 7-27** is the aircraft sounding at Jean with a similar, though slightly higher, elevated inversion, resulting in some moderate trapping of pollutants. **Figure 7-28** plots the sounding made within the identified June 24 plume, and shows a slight inversion at 3400 m msl that provides a cap for the layer of highest concentrations. In contrast, the soundings during June 23 (Figure 7-15) followed the adiabatic lapse rate closely, showing no such layering and a relatively homogeneous, deep mixing layer.

In summary, the June 24 flight provided a quantitative estimate of the contribution of an urban plume. Only tens of miles separate ozone concentrations of 40 ppb and 85 ppb along an upwind plane on the western edge of Clark County. Whether concentrations in these elevated layers impacted surface concentrations is unknown since there were no monitors in the vicinity of the plume, though the morning peak at the SE Valley site hints this is the case. The layering that occurred on June 24 is likely what allowed the plume to be visible from the plane and resulted in the initial thought that the plume might be wildfire smoke, due to visual contrast between layers of different $PM_{2.5}$ concentrations rather than a homogenous air parcel where no such distinctions are possible.

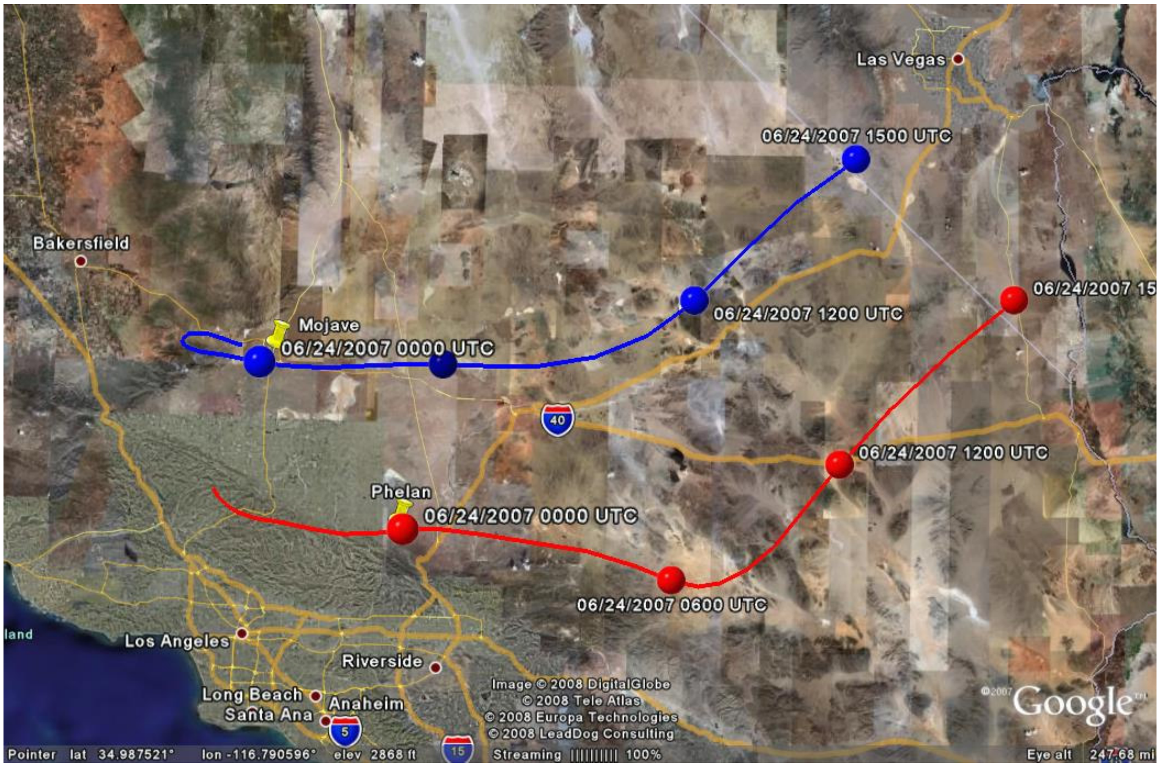

Figure 7-26. Back-trajectories From the Minimum and Maximum Ozone Concentrations Observed on the June 24 Flight

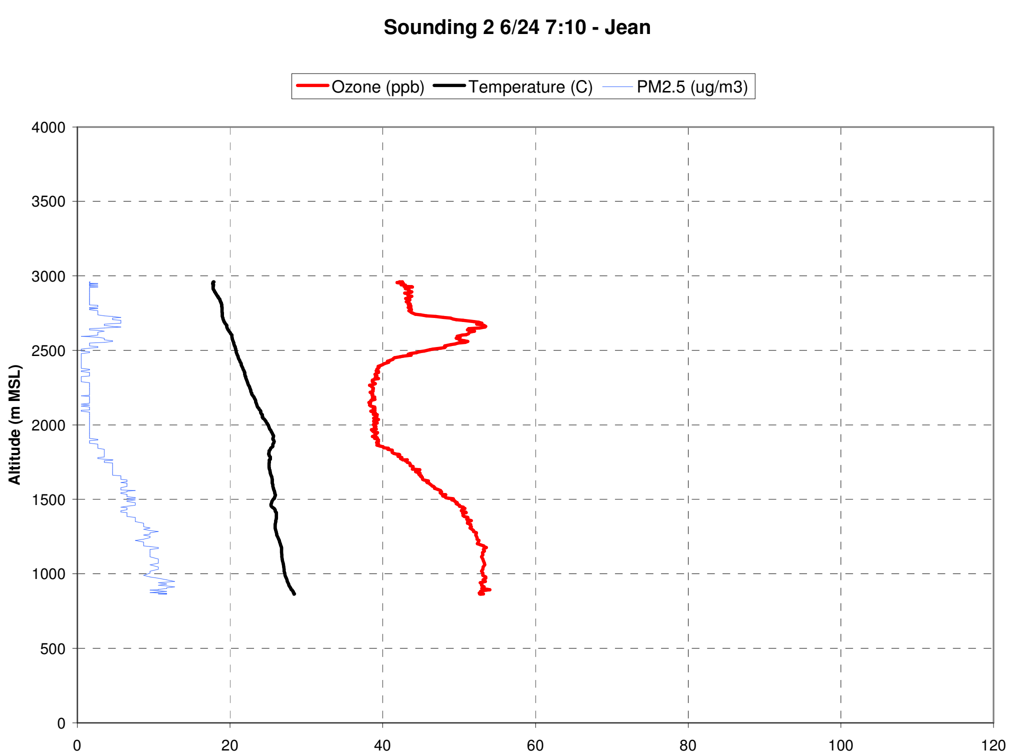

Figure 7-27. Sounding at Jean on Flight of June 24

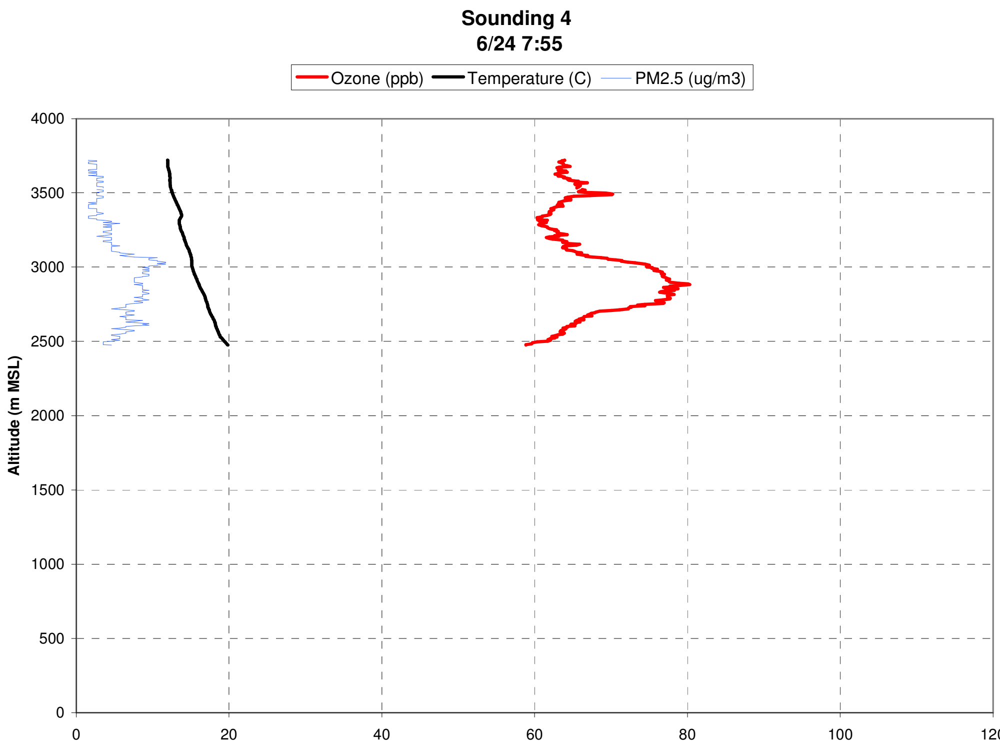

Figure 7-28. Plume Sounding during Flight of June 24

<u>July 16 – July 17, 2007</u>

<u>Synoptic Description</u>

The primary objective of the July 16 -17 IOP was to further characterize the regional dispersion mechanisms that contribute to inter-basin transport of pollutants into southern Nevada from urban sources in California. The IOP was initiated on the basis of forecast conditions that would be similar to those recorded during the June 15 - 17 ozone event discussed reporting Section 7.1.2. Synoptic scale weather patterns were similar to those existing during the identified historical transport events, but the ozone concentrations in the California source areas were not at high enough levels to significantly impact the air quality in southern Nevada.

The synoptic weather patterns affecting the region during the IOP are illustrated in the NWS 700 mb constant pressure analyses charts shown in **Figures 7-29** and **7-30**. As was the case in previous transport events, the Southwest US was under the influence of a broad but relatively flat area of higher pressure that extended from the southern third of California to the southern Great Plains. On July 16th, a strong (for mid-summer) trough was digging down the Pacific coast from the Gulf of Alaska. The advancing trough induced a strong onshore gradient flow in Southern California. The associated southwesterly flow at 700 mb extended into southern Nevada by evening. The Pacific trough continued to deepen on the 17th, increasing the southwesterly flow aloft correspondingly. The deepening trough also brought increasing baroclinic mixing to Southern California thereby contributing to the relatively low pollutant levels there.

Figures 7-31 and **7-32** present two rawinsonde plots from soundings conducted at Primm during IOP operations. Both soundings indicate that southern Nevada was still under the influence of the interior high-pressure area rather than the offshore trough as demonstrated by the strong subsidence inversion seen at around the 600 mb (13,000' msl) level. This stable layer provided a distinct cap to the mixing layer.. The soundings also showed moderately strong south-southwesterly to southwesterly flow throughout the mixing layer on both days.

Synoptic-scale winds on the 16th and 17th were conducive to interbasin transport from southern California to southern Nevada but, due to the advancing trough, regional background ozone concentrations never reached the anticipated levels. Relatively high wind speeds and a deep boundary layer contributed to ozone levels in Clark County being less than anticipated.

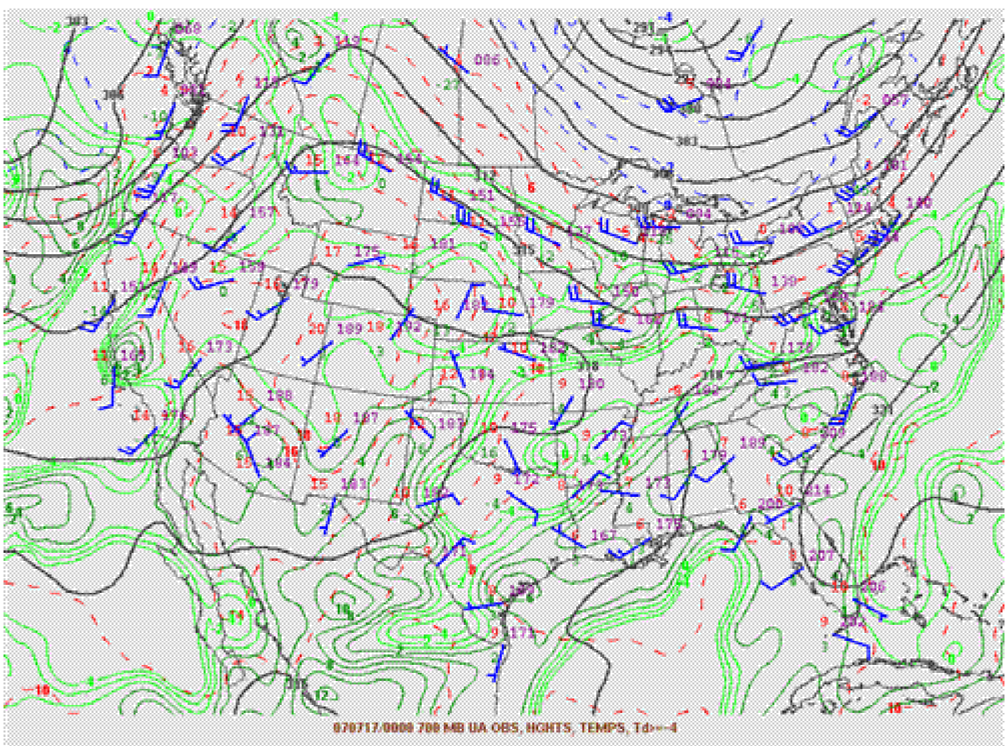

Figure 7-29. 700 mb Analysis for 07/16/07/1600 PST

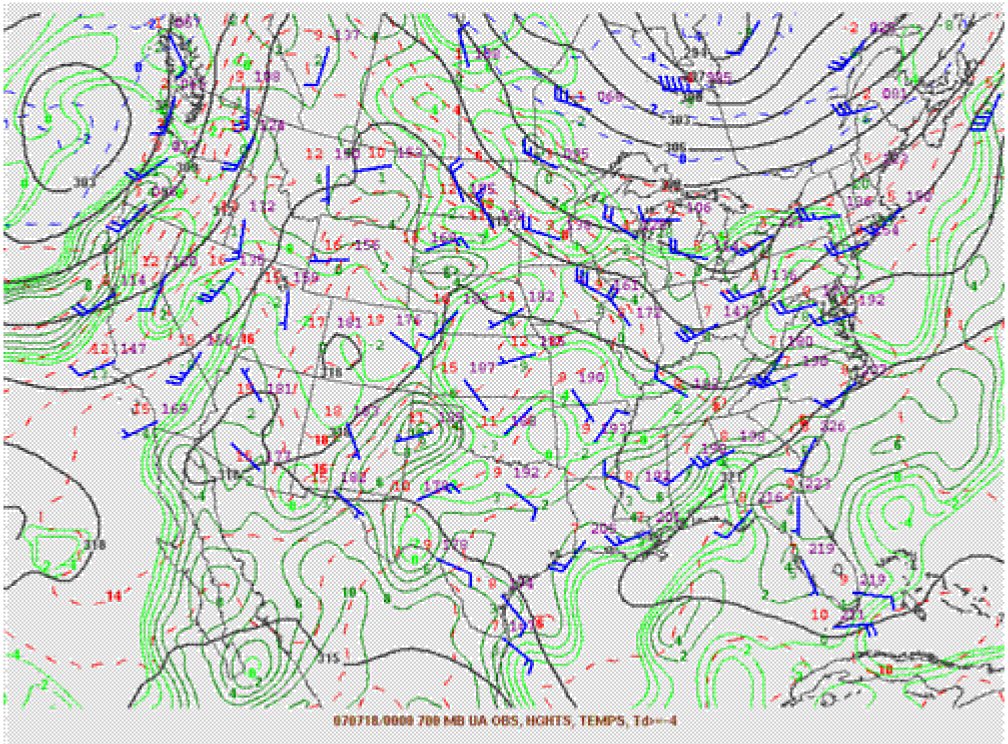

Figure 7-30. 700 mb Analysis for 07/17/07/1600 PST

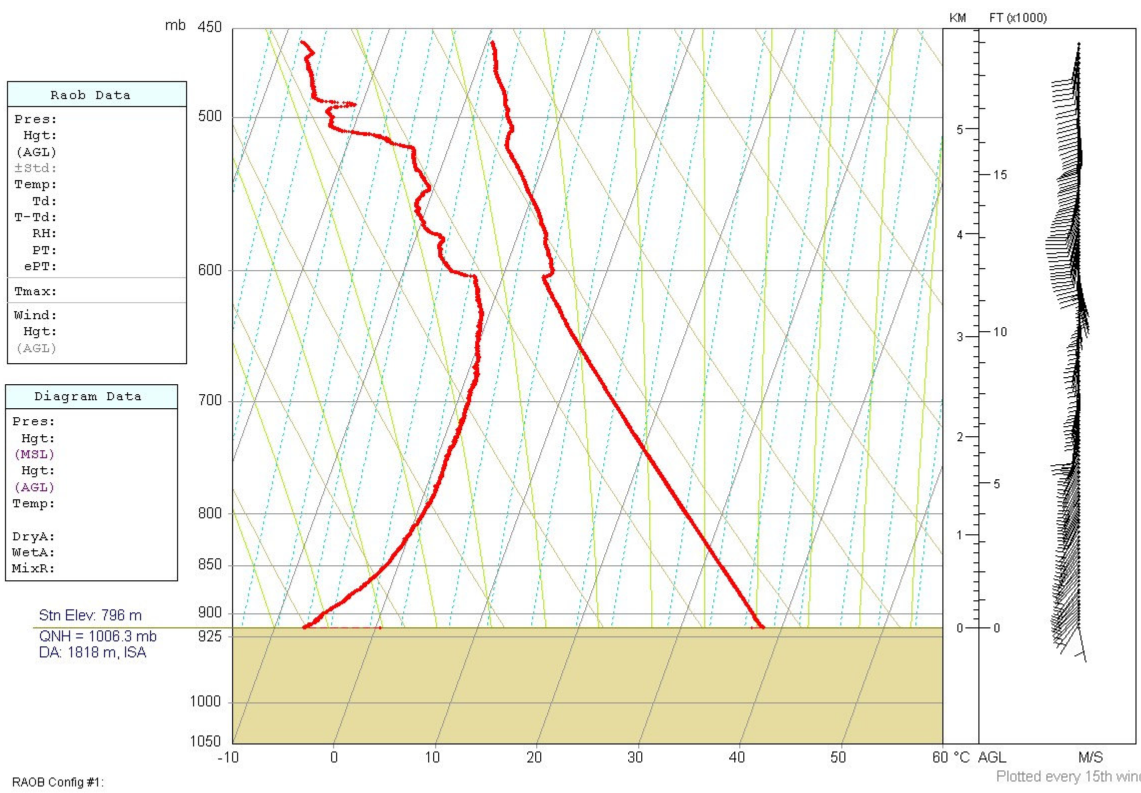

Figure 7-31. Primm NV Rawinsonde, 07/16/07/2000 PST

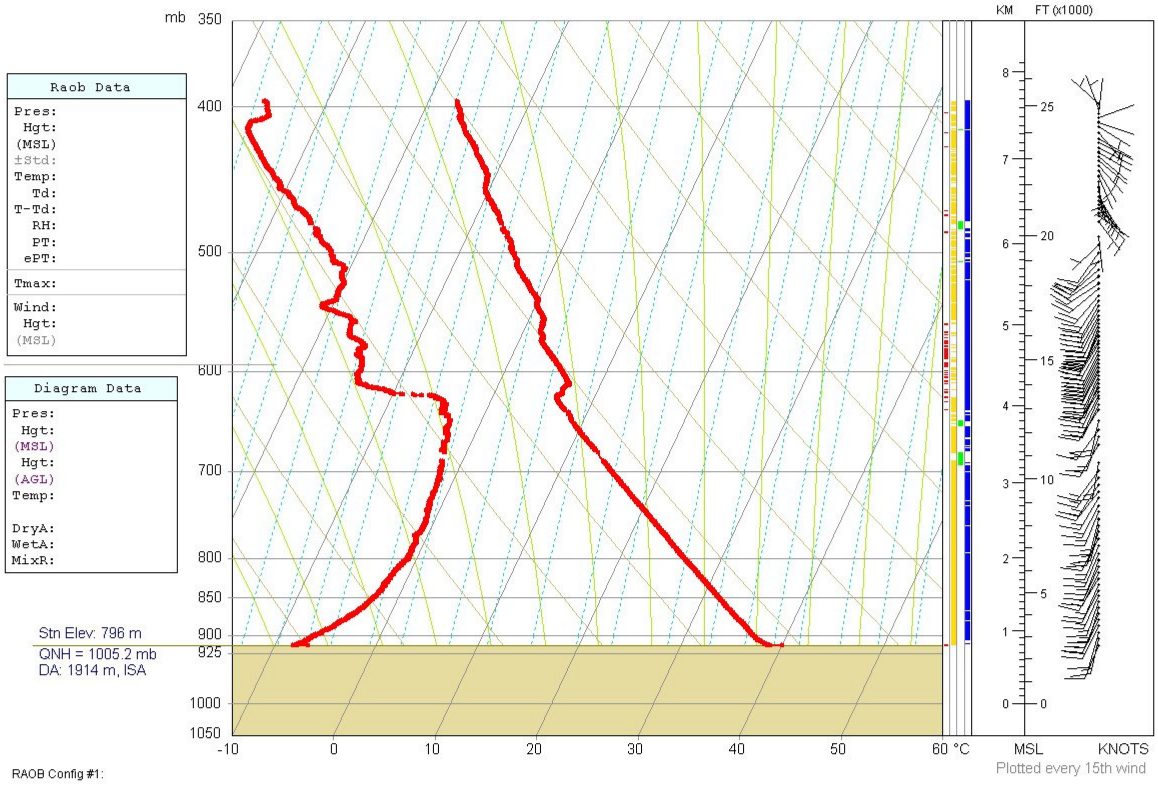

Figure 7-32. Primm NV Rawinsonde, 07/17/07/1800 PST

Aircraft Measurements and Summary of Findings

The July 16 evening flight measured the highest concentrations of ozone along the traverse about 15 miles to the northwest of Pahrump. Due to the late evening timing of the traverse, and since this area of higher ozone was well to the north of Clark County, the flight was redirected back to NLV and not continued along the CA/NV border. Observations of aircraft-calculated winds were more from the south-southwest, which is consistent with any transported plume being north of Clark County. It should be noted that the surface MOP site did show higher concentrations than the Mountain Pass site during this flight, providing additional evidence of a plume further to the north than anticipated. **Figure 7-33** shows the flight path and associated observed concentrations. Concentrations less than 60 ppb are black, 60 – 70 ppb are dark blue and 70 – 80 are in light blue.

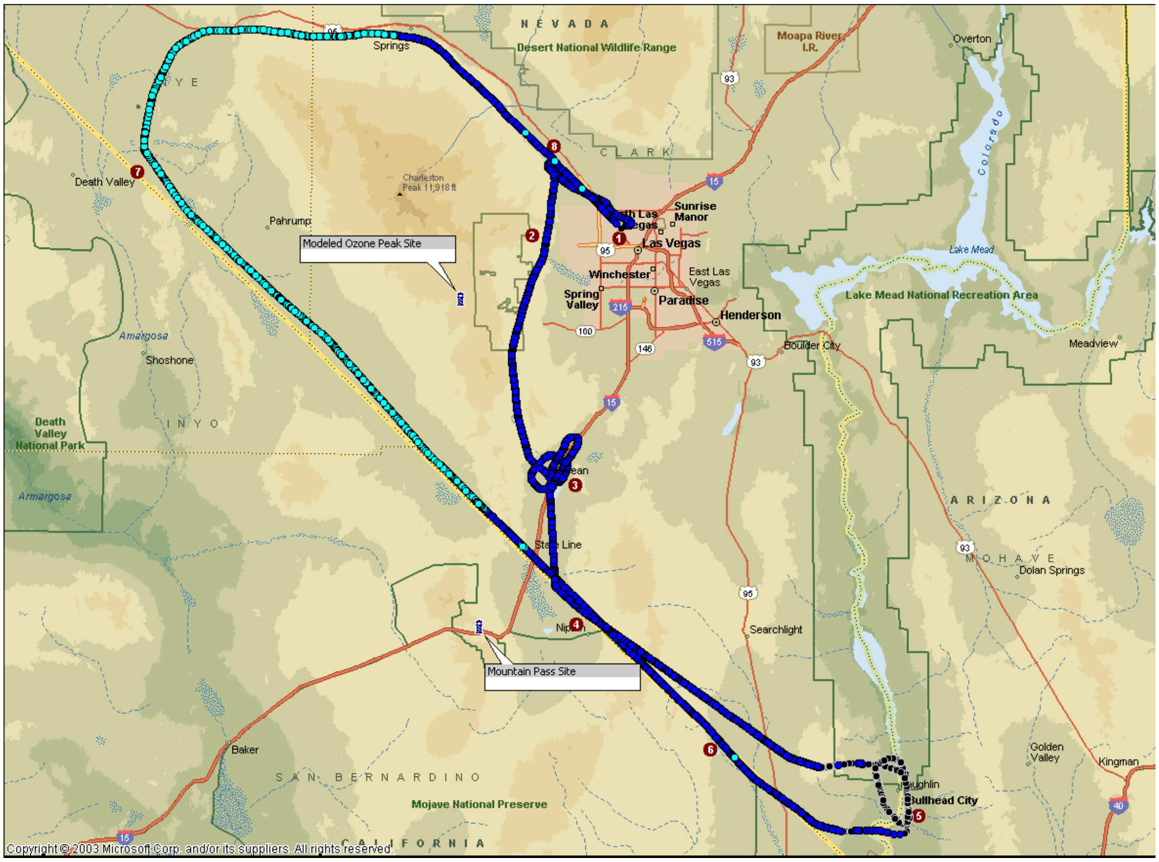

Figure 7-33. Flight Path and Ozone Concentrations Observed from the Aircraft During the Evening of July 16

Figure 7-34 shows the time series plot of ozone, particulate, and temperature for the entire flight. The increase in ozone concentrations as the plane traversed from the southeast to the northwest (toward point 7 on the map) is evident. This shows that any air mass that was transported from southern California was heading well to the west-northwest of Clark County. Ozone concentrations then decreased along the path back to North Las Vegas airport.

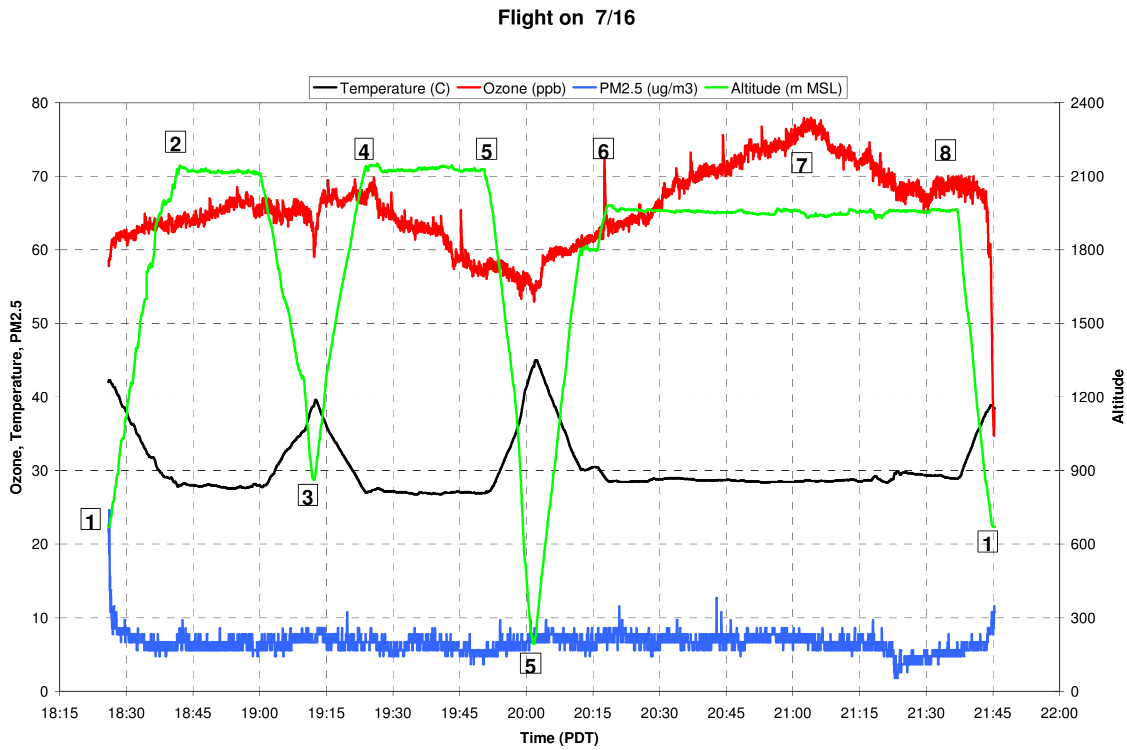

Figure 7-34. Time Series Plot of the Evening Flight on July 16

The July 17 morning flight began with the sounding out of Jean airport and continued with a traverse to the northwest for 25 miles from Jean airport and then a reversal in direction, with a traverse to the southeast at a constant altitude, for a total of 50 miles (ending 25 miles southeast of Jean). The flight then returned to Jean. The plane was parked for a short duration, after which it took off with just the pilot and returned to NLV airport. The highest observed concentrations of ozone were back in the Las Vegas Valley when the plane returned to NLV airport. However, the peak ozone concentrations were still only about 65 ppb. **Figure 7-35** shows the aircraft flight path with concentrations in black being less than 50 ppb, dark blue at 50 to 60 ppb and light blue from 60 to 70 ppb. **Figure 7-36** shows the time series plot from the flight.

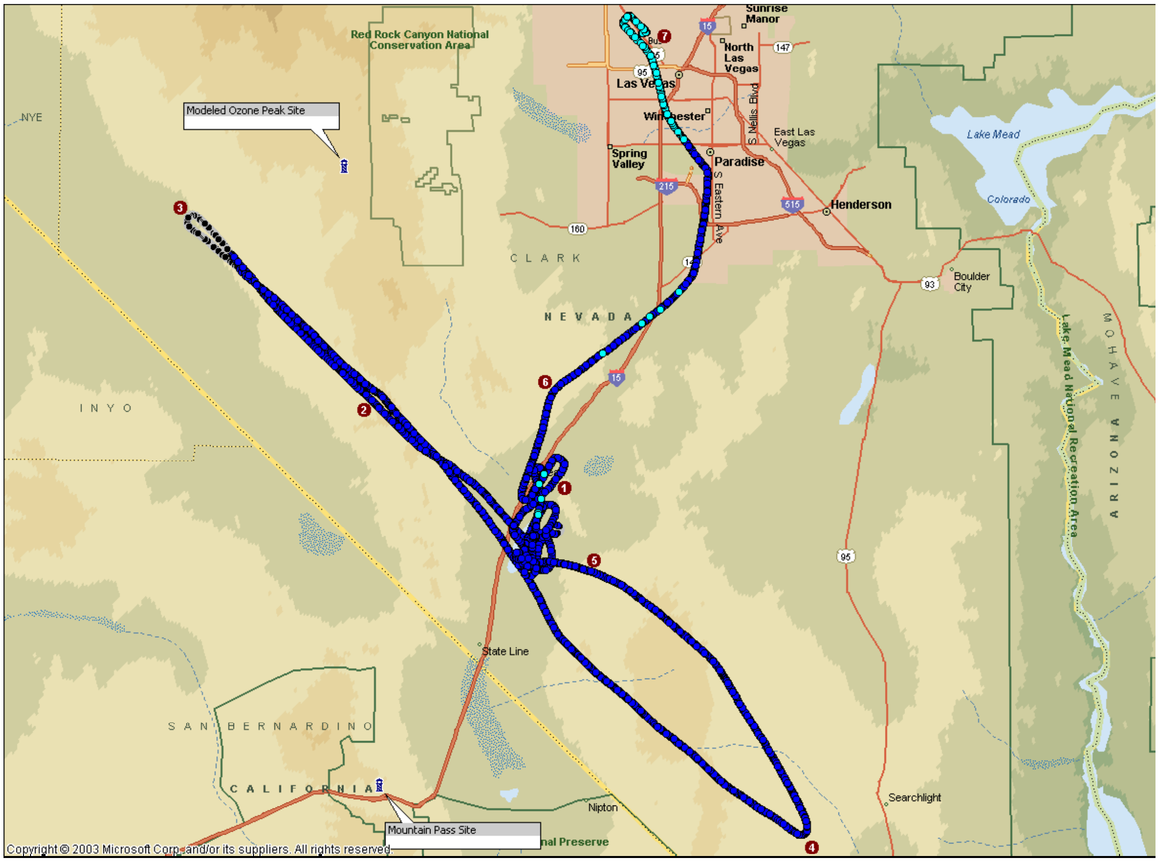

Figure 7-35. Flight Path and Ozone Concentrations Observed from the Aircraft during the Morning of July 17

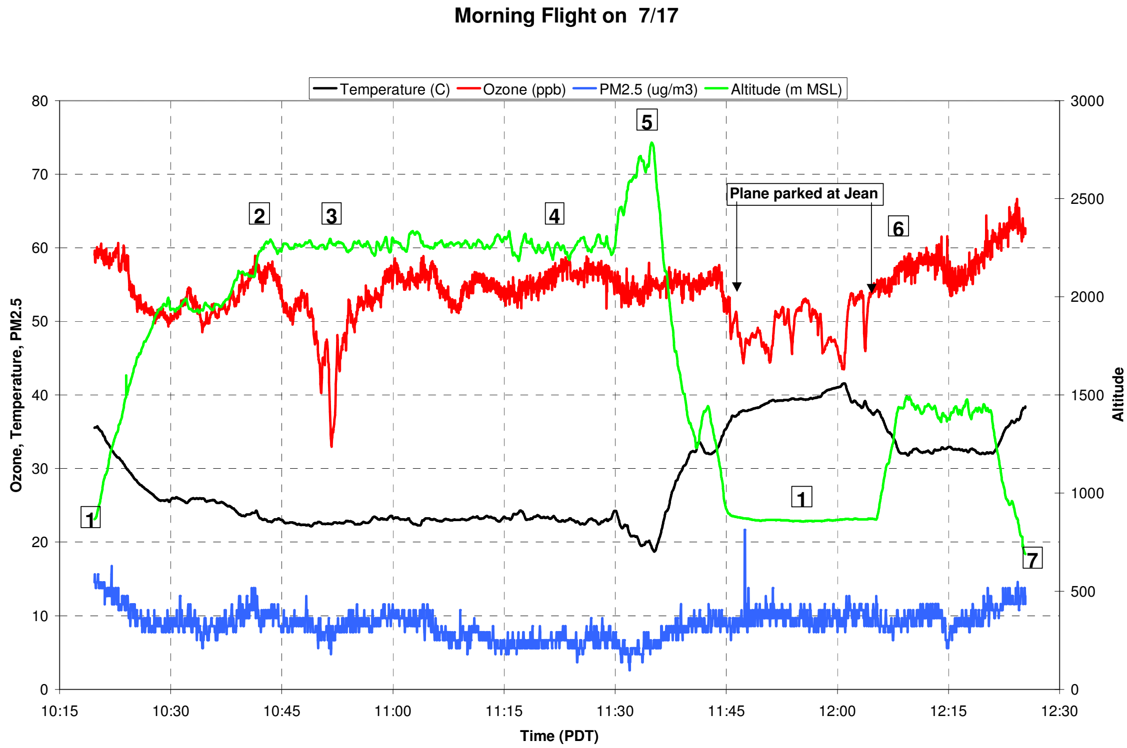

Figure 7-36. Time Series Plot of the Morning Flight on July 17

The July 17 evening flight began with the sounding out of NLV airport and continued with a traverse to Jean and associated sounding. The flight continued to Bullhead City, Arizona with a sounding at the airport. A traverse was then performed along the California/Nevada border heading northwest until a problem developed with the aircraft electrical system. The mission was terminated early in the interest of safety and the aircraft returned to NLV airport. During the final portion of the traverse to the northwest, traces of a possible urban plume from California were noted just prior to the return to NLV. **Figure 7-37** shows the aircraft flight path and ozone concentrations--black being less than 50 ppb, dark blue at 50 to 60 ppb and light blue from 60 to 70 ppb. **Figure 7-38** shows the time series plot of the measurables during this flight.

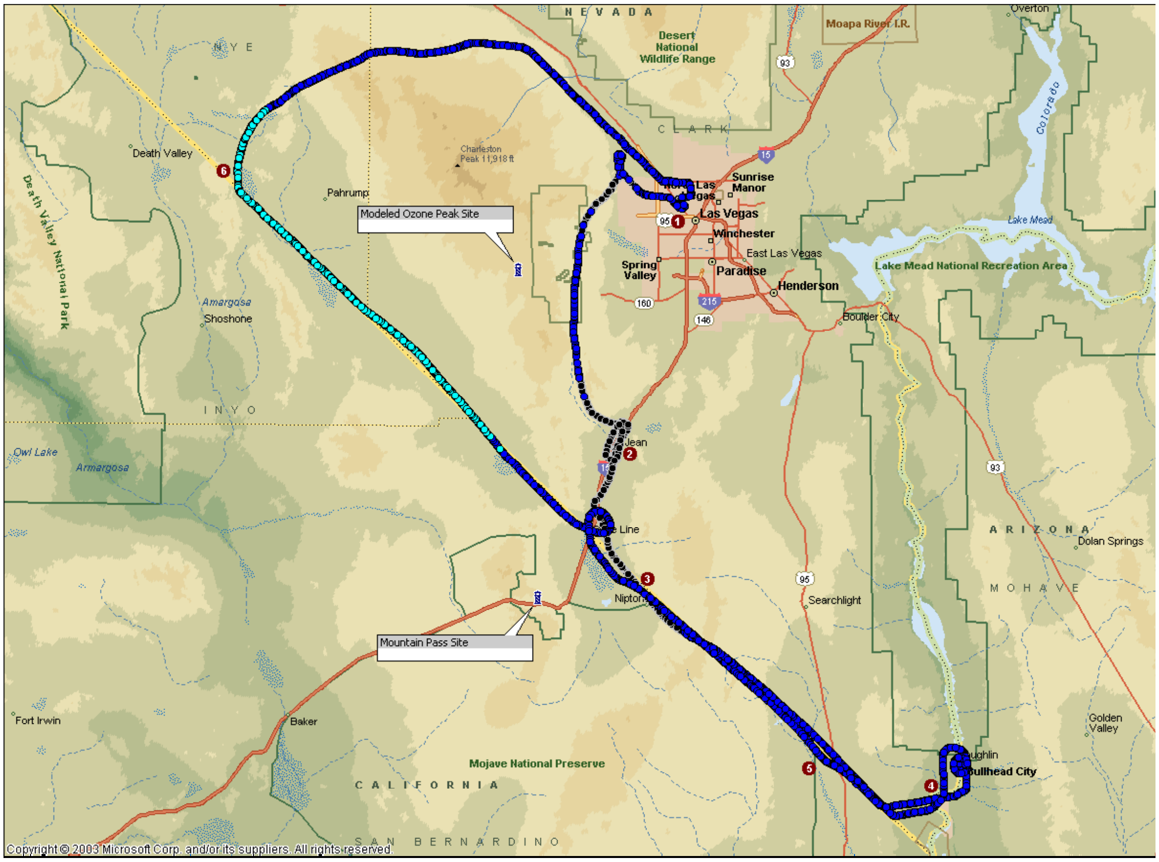

Figure 7-37. Flight Path and Ozone Concentrations Observed from the Aircraft during the Evening of July 17

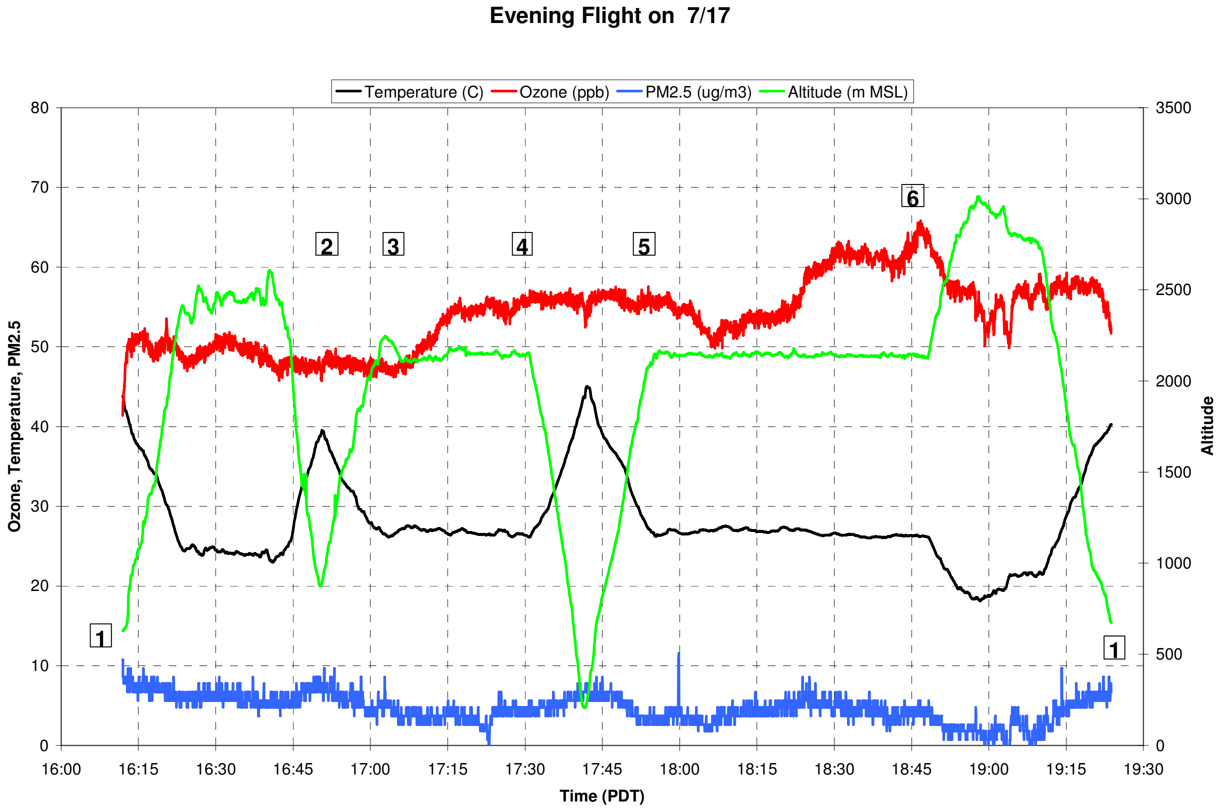

Figure 7-38. Time Series Plot of the Evening Flight on July 17

No aircraft sampling was conducted the morning following this flight. However, winds at the Mountain Pass site did show a turn to a more westerly direction and the ozone concentrations did show a coincident peak increasing almost 30 ppb, providing a sampling of the anticipated Southern California urban plume. This increase, however, was short-lived, and ozone levels in Clark County remained well below the NAAQS. **Figure 7-39** shows the onset of generally favorable back-trajectories on July 16 and 17. However, the peak ozone contour plot for July 16 (**Figure 7-40**) shows clearly the relatively low ozone concentrations in the upwind source areas, resulting in the low concentrations in Clark County.

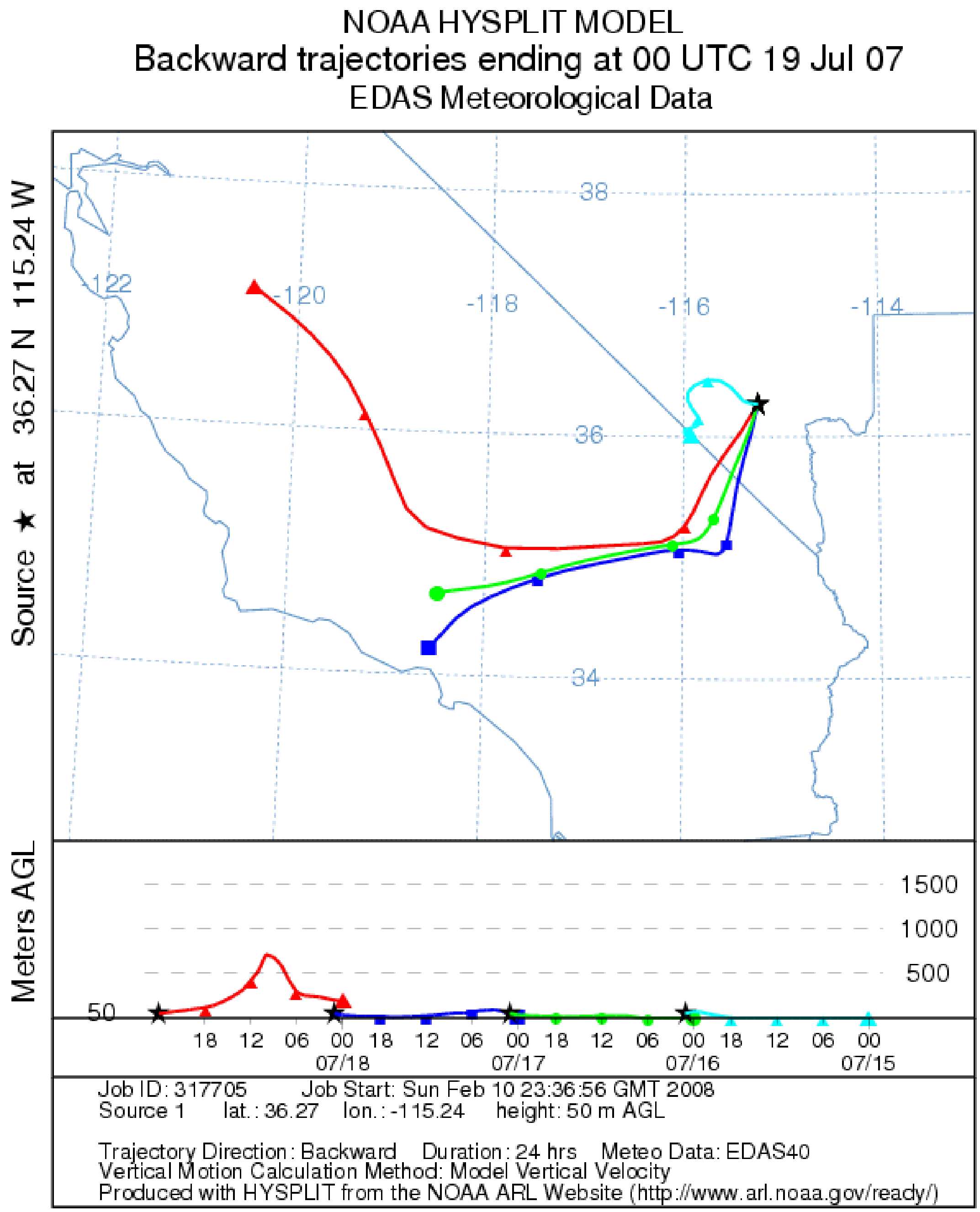

Figure 39. Back-trajectories for July 15 through 18

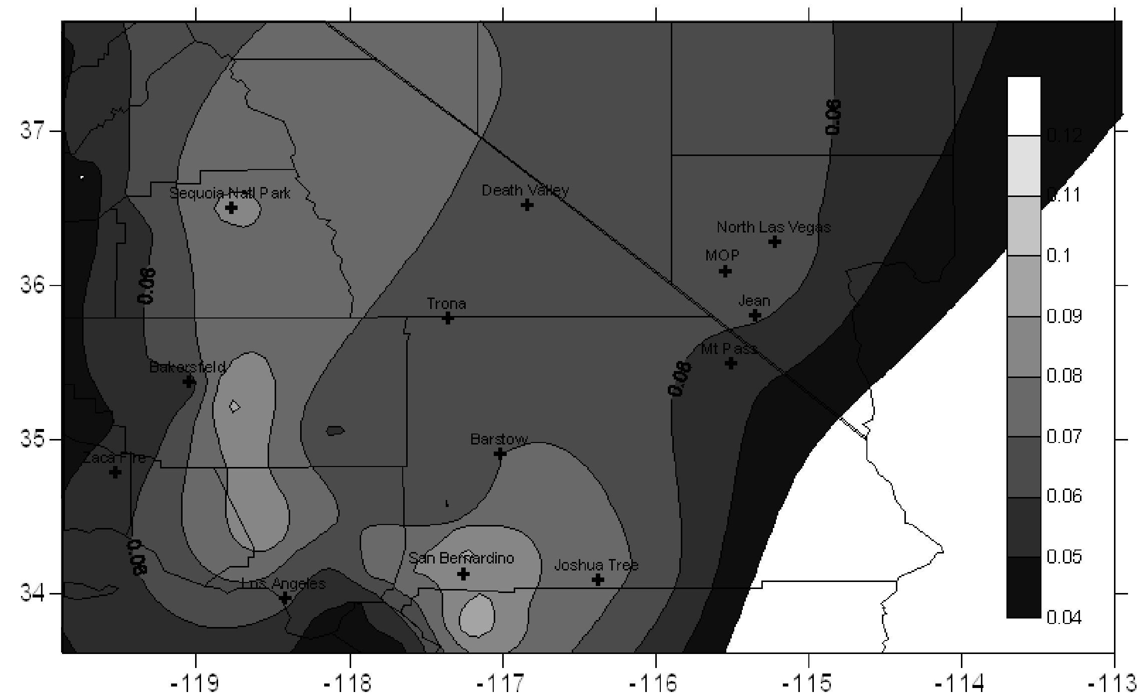

Figure 40. Peak Ozone Averages for July 16

7.1.2 Analysis of 2007 Exceedances

In this section, we examine non-intensive operational periods during the 2007 ozone season when the NAAQS for ozone was exceeded in Clark County during potential transport conditions. These occurred on June 15, June 16, and June 27.

June 15 – June 16, 2007

Synoptic Description

The evolution of the synoptic weather pattern affecting the southwestern U.S. during this period can be seen in the set of NWS 700 mb constant pressure analyses charts presented in Figures **7-41 through 7-44.** A ridge of higher pressure was centered over the southern Great Basin just to the east of southern Nevada on the morning of June 15th. During that day, the ridge flattened and broadened to the south resulting in very light, mostly southerly flow over southern Nevada and southern California. However, by the morning of the 16th, an upper level trough was approaching the Pacific Northwest and tightening the pressure gradient along the west coast. This resulted in an increased southwesterly flow over southern California during the morning and into southern Nevada by the afternoon. Flows aloft developed that supported the afternoon transport of pollutants from southern California into southern Nevada. The Pacific trough quickly advanced eastward during the evening of the 16th, and passed through southern Nevada during the morning of the 17th. As the trough line approached, baroclinic mixing increased during the early hours of the 17th, resulting in better dispersion conditions on June 17th. At the same time, the steering winds aloft changed from southwesterly to west-northwesterly, which effectively ended air mass transport from southern California.

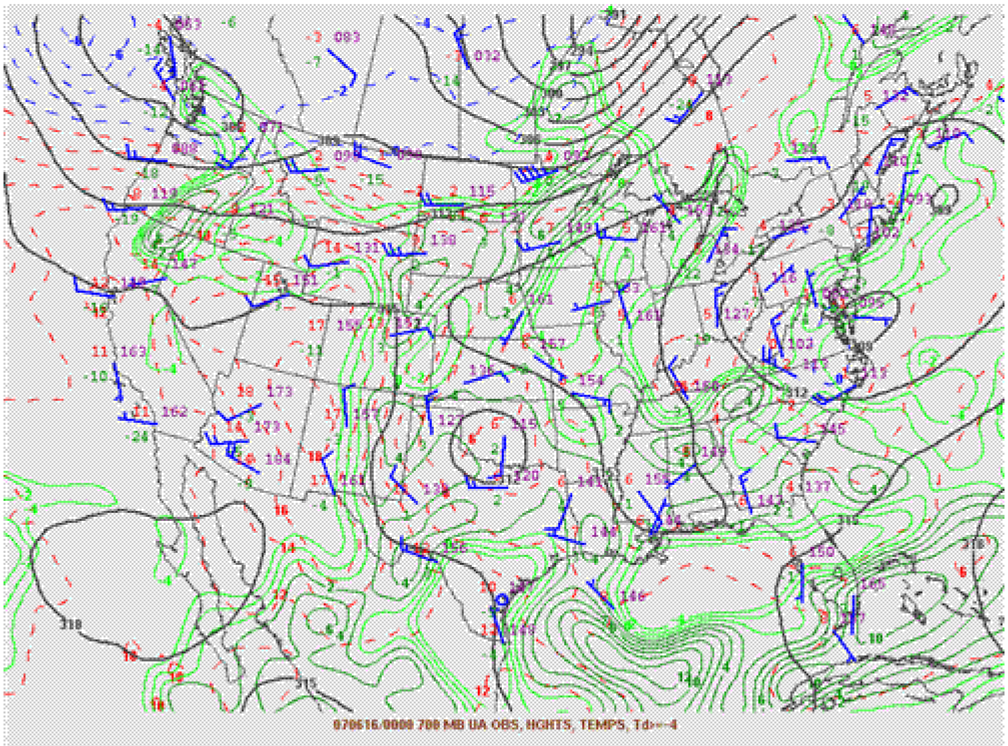

Figure 7-41. 700 mb Analysis for 06/15/07/1600 PST

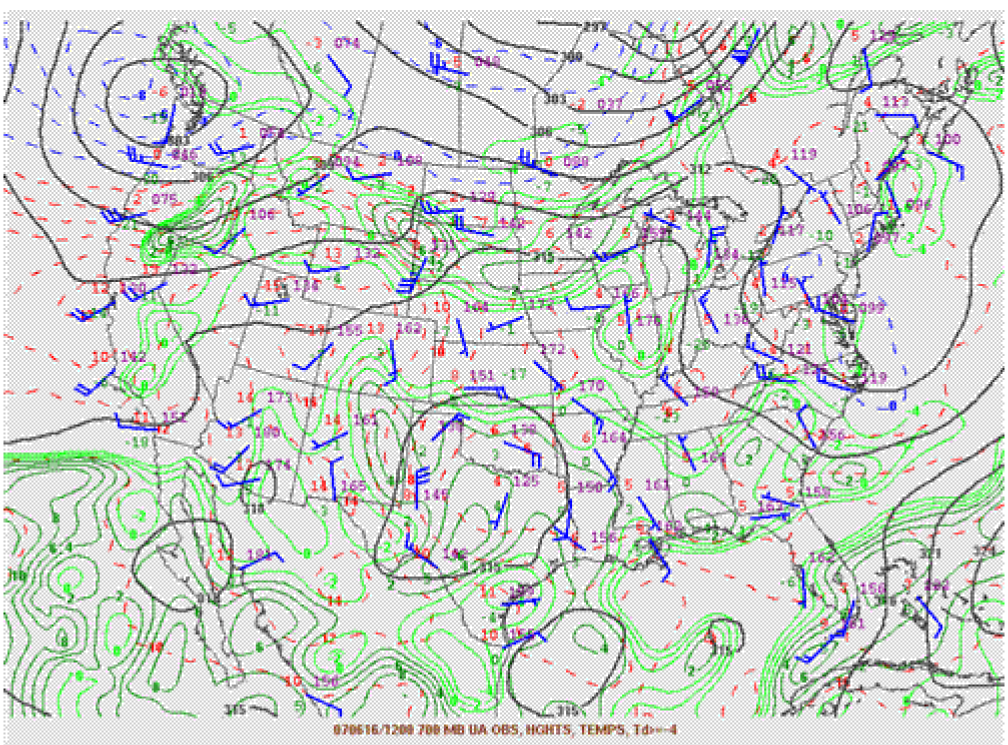

Figure 7-42. 700 mb Analysis for 06/16/07/0400 PST

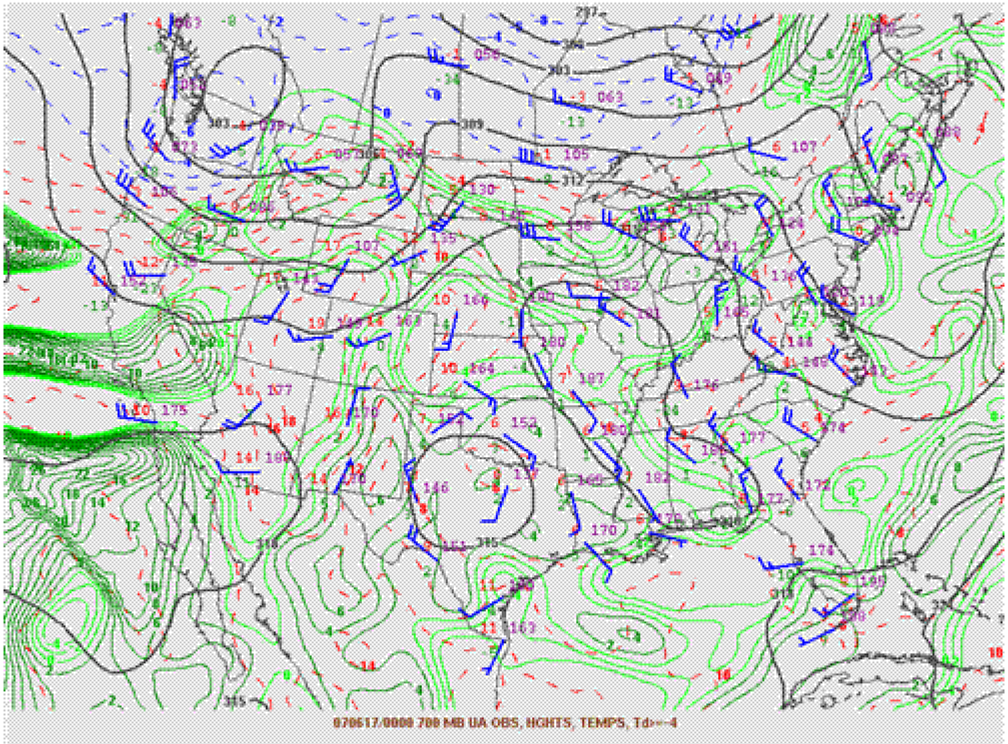

Figure 7-43. 700 mb Analysis for 06/16/07/1600 PST

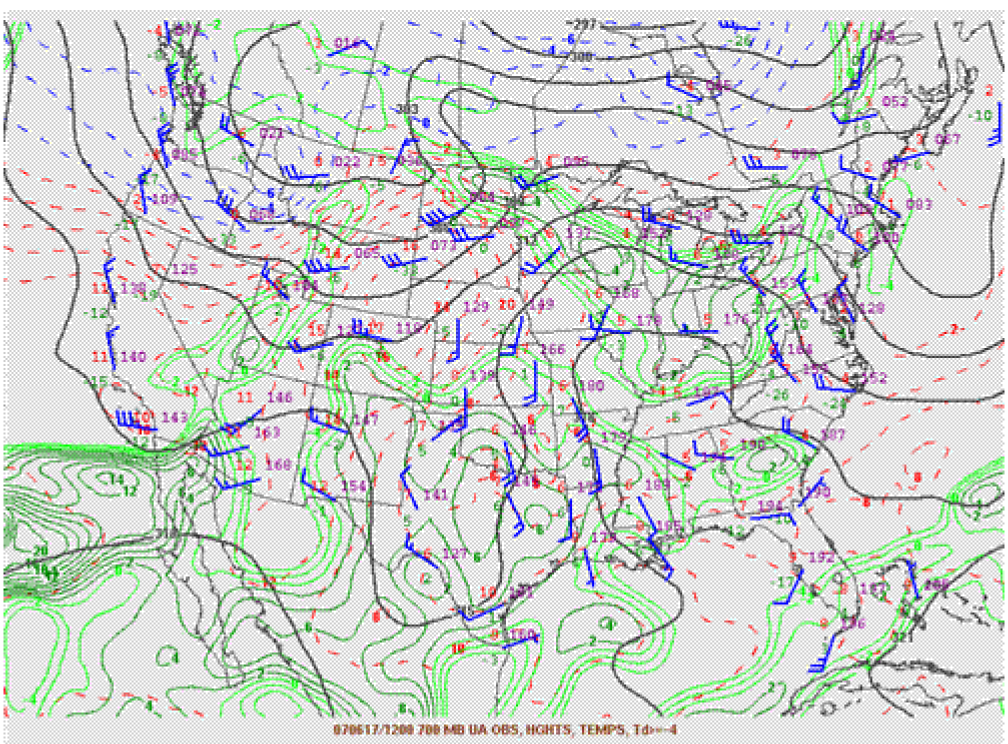

Figure 7-44. 700 mb Analysis for 06/17/07/0400 PST

Unfortunately, no rawinsonde data from the NWS Desert Rock site is available for June 15 – 17. The NLV sodar provides low-level winds but its data does not extend up high enough to couple with the 700 mb flow patterns indicated by the NWS 700 mb analyses presented above. The project radar profiler and radiometer at the North Las Vegas airport were not operational at this time. Thus there is little if any information on the boundary layer structure.

Summary of Findings

Figure 7-45 shows HYSPLIT 24-hour back-trajectories on and around the June 15 and 16. As can be seen, trajectory analyses are consistent with ozone concentrations in Clark County being affected by transport from Southern California. Referring again to **Table 7-5,** relatively low concentrations were recorded in Clark County on June 14 (pink trajectory). Exceedances of the 8-hour ozone standard were experienced at one DAQEM site on the 15th and four sites on the 16th, after the onset of much stronger southwest winds (light blue and green trajectories). Moderately high ozone concentrations persisted into June 17 under similar winds (blue trajectory) before dropping down to lower concentrations after the disappearance of the favorable winds on June 18 (red trajectory). There were no exceedances on either day but Joe Neal was close (84 ppb) on June 17.

Figures 7-46 through 7-48 show hourly peak ozone contours in southern Nevada and the upwind region for June 14, 15, and 16, respectively. During June 14, high concentrations of ozone were produced in the Los Angeles Basin, pushed up against the northeast portion of the basin (San Bernardino area) by the southwesterly flow. This provided the required source of ozone for transport downwind. By June 15, while concentrations in the source area around San Bernardino had dropped off, a large area of moderately high ozone (between 90 and 100 ppb) remained along the trajectory path in a large area encompassing much of the Mojave Desert, providing continued ozone influx resulting in additional exceedances on June 16. The peak ozone was measured at Mt. Pass. Measurements at Mt. Pass are representative of the pathway between the south coast air basin and Clark County. Plumes aloft remain more intact after long distance than at the surface.

Exceedances were recorded at Jean on both June 15 and June 16. **Figure 7-49** shows winds recorded by the sodar at Jean at the 100-meter level. These winds show the persistent southwesterly flow throughout the two days, with no winds recorded from the northeast quadrant in the direction of the Las Vegas Urban area. Thus, it is unlikely that the exceedances at Jean could have been in any way caused by emissions from the Las Vegas Valley. This, combined with the high ozone available in southern California and very favorable transport trajectories, strongly supports the conclusion that, at a minimum, the exceedances at Jean were caused by transport from California, and that ozone concentrations further downwind were also influenced.

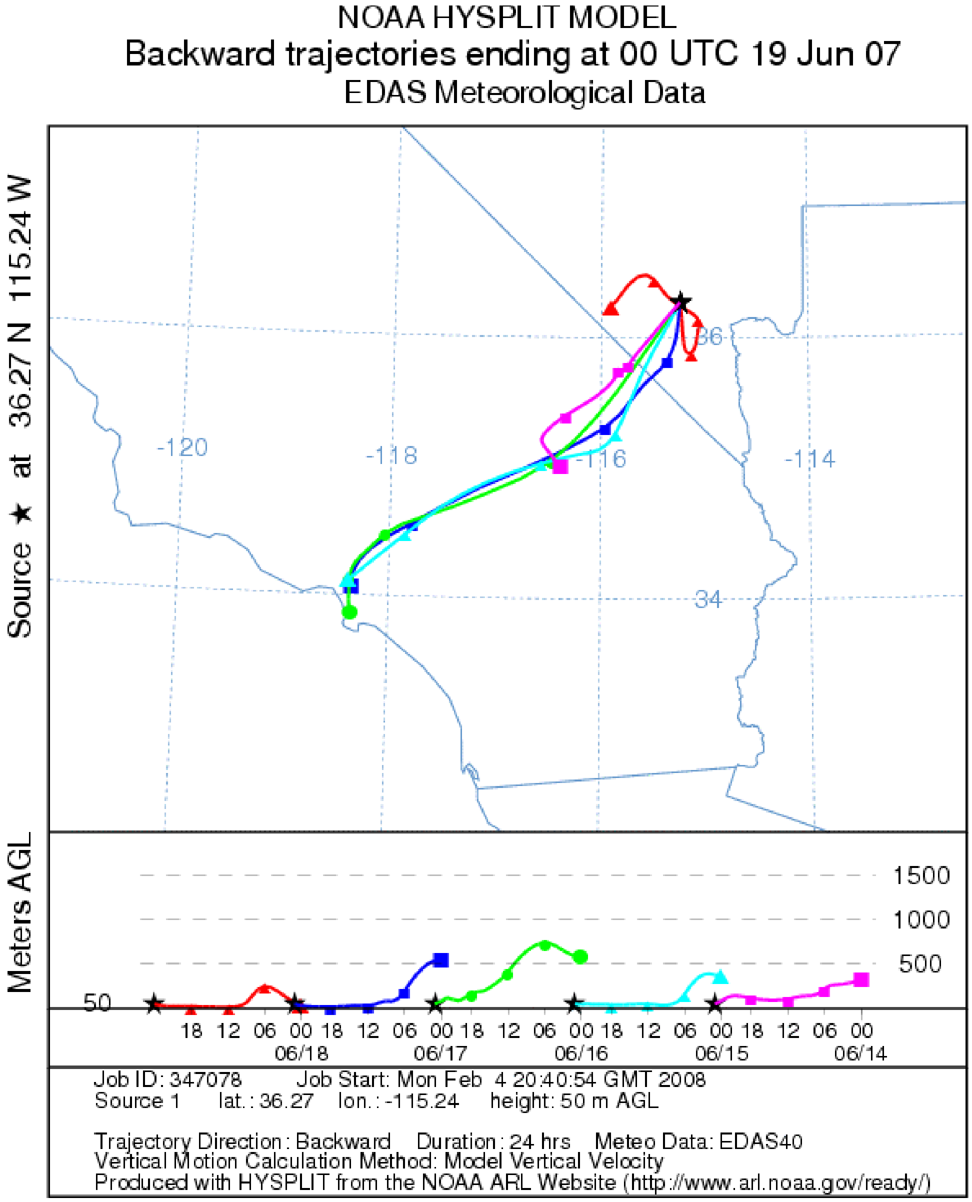

Figure 7-45. Back-trajectories during June 15 – 16 Ozone Exceedances

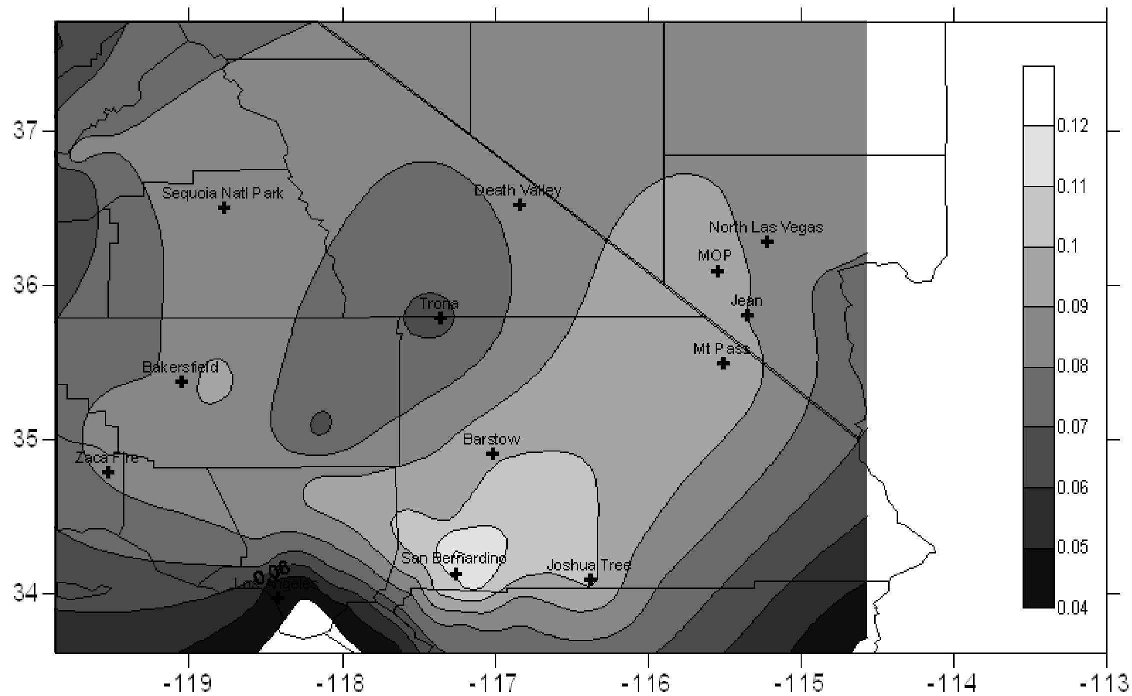

Figure 7-46. Peak Hourly Ozone (ppm) – June 14, 2007

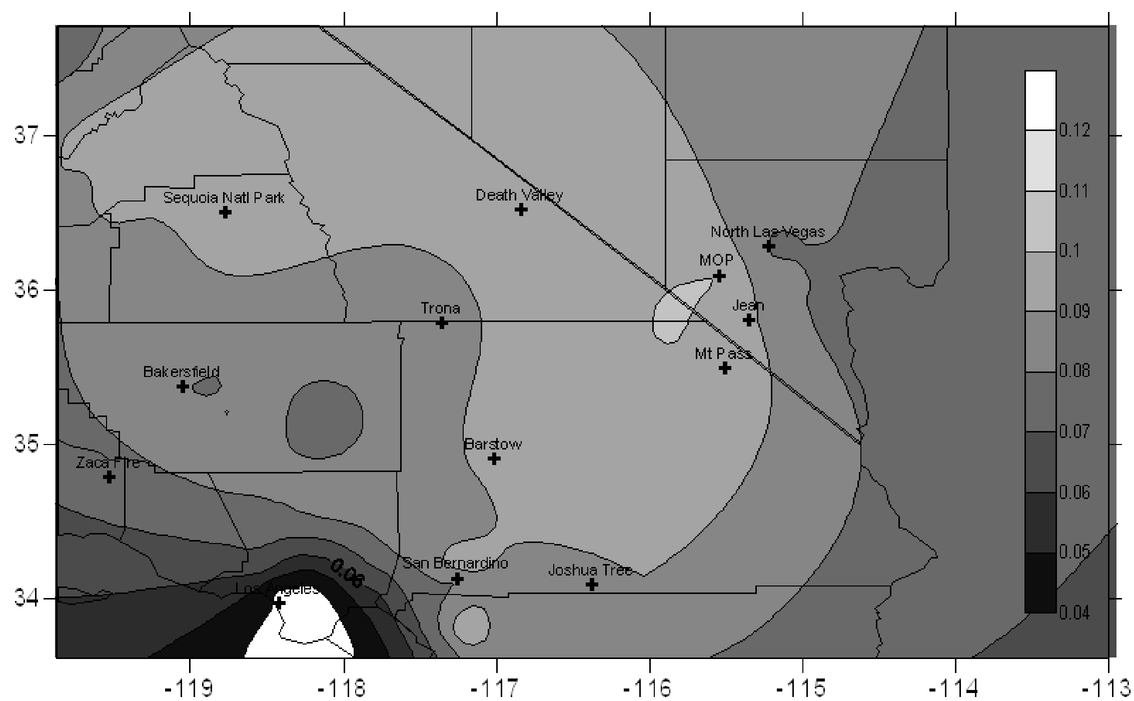

Figure 7-47. Peak Hourly Ozone (ppm) – June 15, 2007

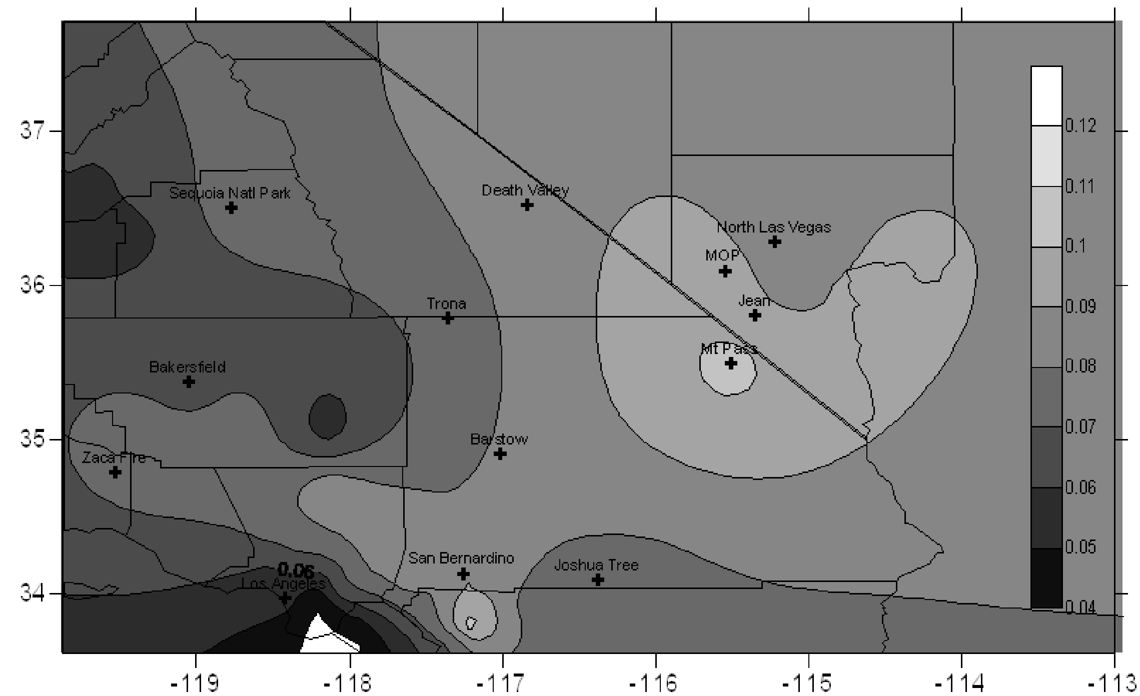

Figure 7-48. Peak Hourly Ozone – June 16, 2007

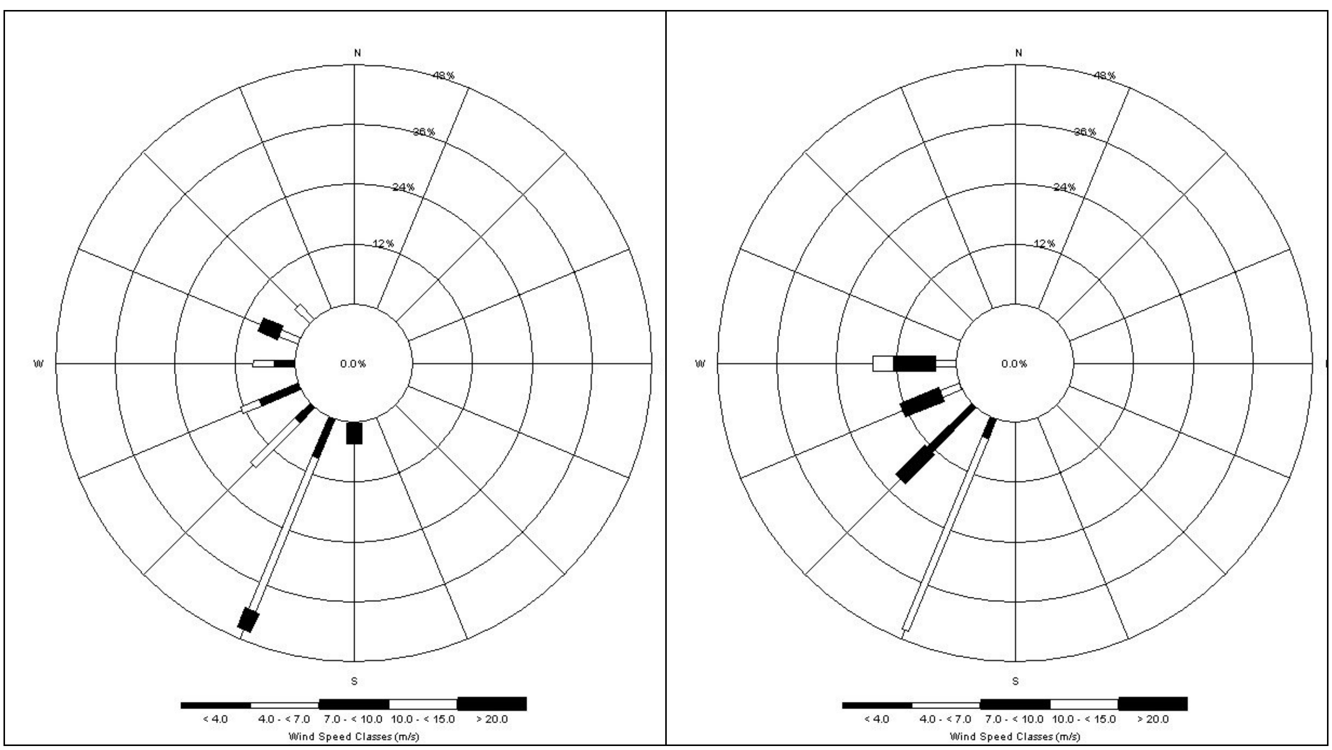

Figure 7-49. 100-meter Winds at Jean – June 15 (left) and June 16 (right)

June 27, 2007

Synoptic Description

The synoptic weather patterns that affected the Southwest US during this exceedance are presented in the NWS 700 mb constant pressure analyses charts shown in **Figures 7-50 through 7-52** below. The southwesterly to south-southwesterly flow pattern that had been established over the region by June 26th continued through the 27th and into the 28th. This steering flow was the result of a persistent quasi-stationary trough that extended from the Pacific Northwest into the northern two-thirds of California in tandem with a flat ridge of higher pressure in the interior Southwest. The interaction between these two synoptic features resulted in a general south-southwesterly flow pattern over Southern California and the southern Great Basin. A stable air mass generally persisted over the region of interest as well. As the gradient flow aloft shifted slightly into a more southerly direction from that noted on the 25th, the air mass entering southern Nevada followed a path that was traceable back to areas in Southern California south of the White fire. By the afternoon of the 28th, the main energy of the trough had consolidated into a strong closed low off British Columbia while its southern extension over the southern half of California broke off as a shortwave trough that then migrated into the Great Basin. As a result, southerly flow ahead of the shortwave trough increased on the 28th, and the air mass became unstable.

Figures 7-53 through 7-55 present three rawinsonde plots from NWS soundings taken at Desert Rock during the 27th and 28th of June, 2007. A subsidence induced stability layer can be seen near 600 mb (13,000' msl) at 0400 PST on the 27th that was capping the mixing layer in the area. Relative stability continued to limit mixing above 700 mb during the afternoon of that day. By the morning of the 28th, the subsidence cap had strengthened and lowered to around 700 mb (10,000' msl), but by the afternoon of that day the stable layer had weakened even though mixing remained somewhat limited. The Desert Rock soundings also show that the wind flow in the mixing layer (below the 700 mb level) had become south-southwesterly to even south-southeasterly on the 27th, and light southerly during the early hours of the 28th. By the afternoon of the 28th, flow between 8,000' msl and 12,000' msl had become light south-southeasterly while wind flow below that level had increased and become southwesterly.

The synoptic features described above indicate that southerly to southwesterly wind flow was taking place in the mixing layer below a subsidence cap during June 27th and 28th, 2007. At times during that period, the flow trajectories indicated that air arriving in southern Nevada came from urban areas in the southern third of California, south of the White fire origin area. Although the mixing layer flow was not always consistently coming directly from Southern California urban sources, there likely was enough volume of flow from those areas to enable at least intermittent transport of pollutants into southern Nevada.

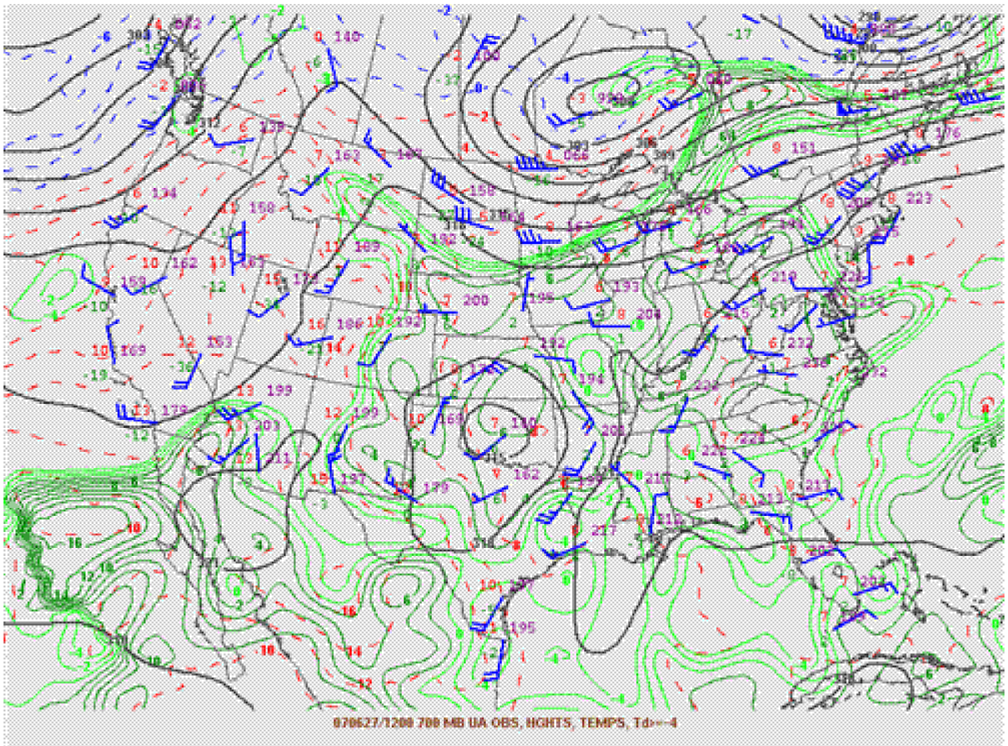

Figure 7-50. 700 mb Analysis for 06/27/07/0400 PST

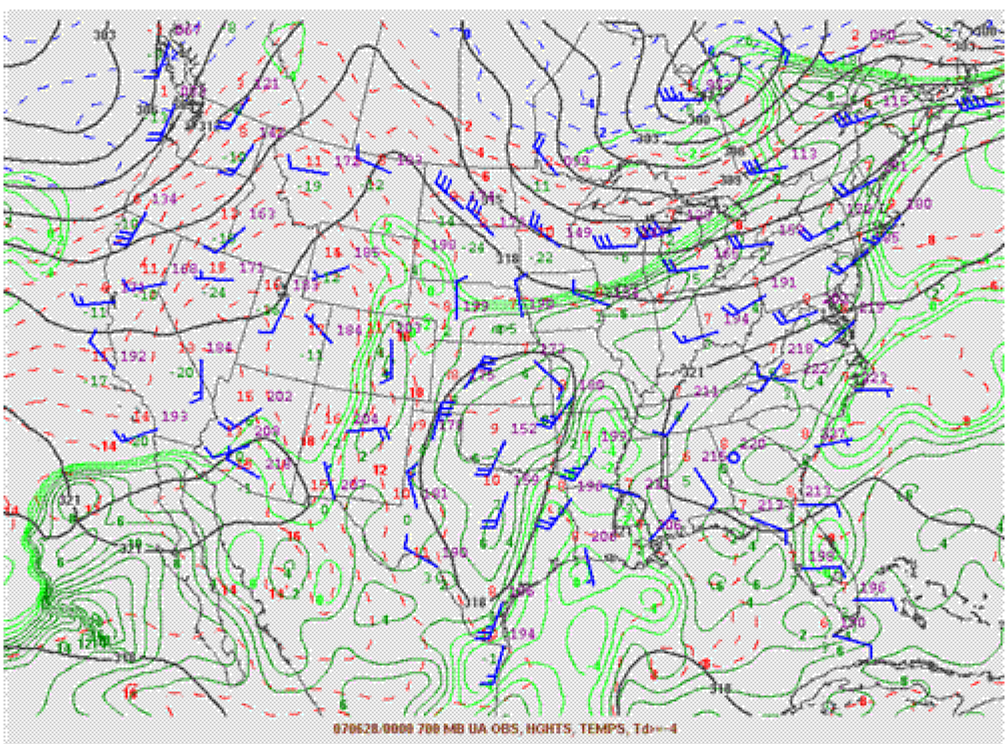

Figure 7-51. 700 mb Analysis for 06/27/07/1600 PST

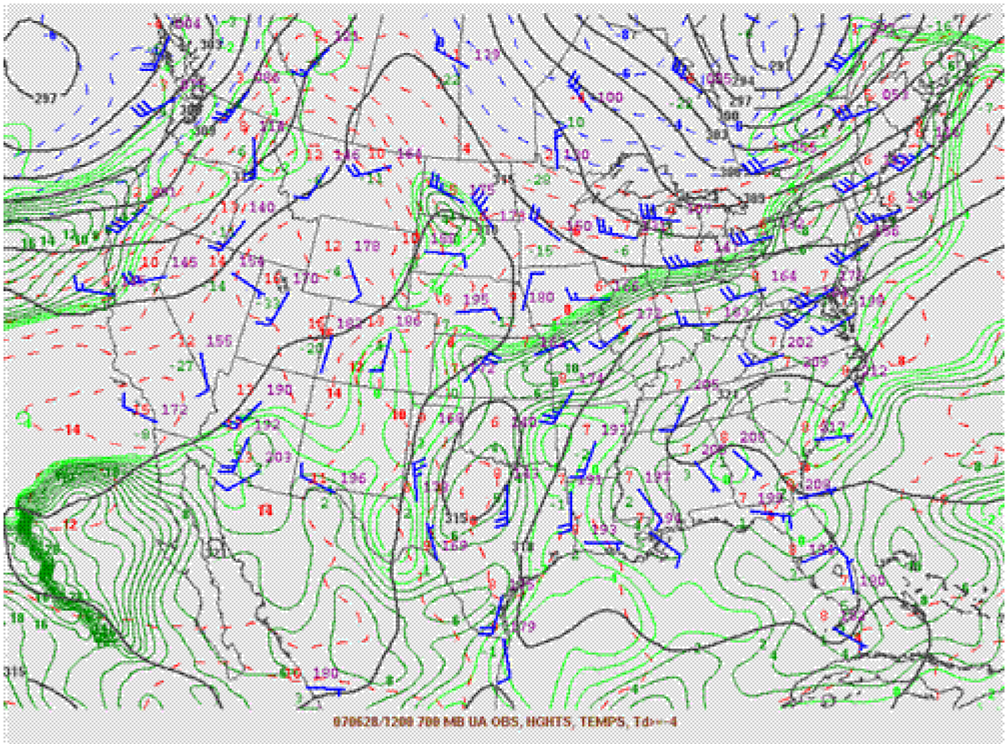

Figure 7-52. 700 mb Analysis for 06/28/07/0400 PST

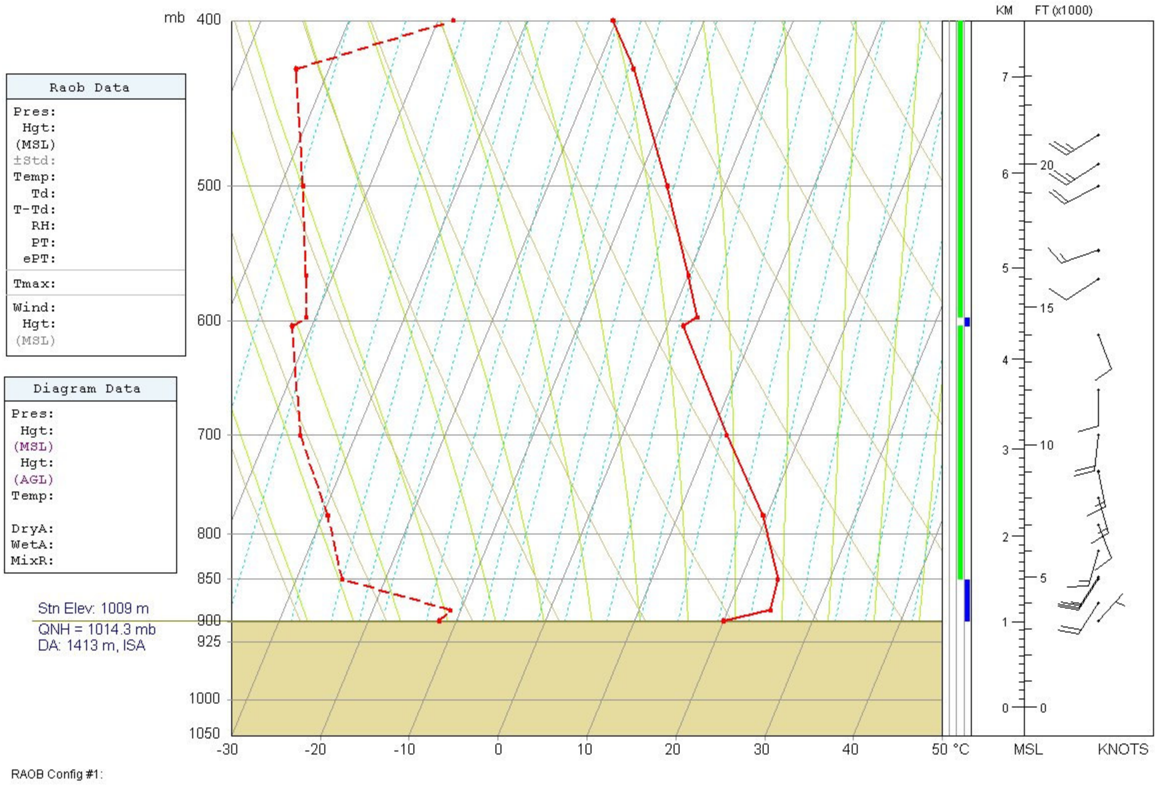

Figure 7-53. Desert Rock Rawinsonde, 06/27/07/0400 PST

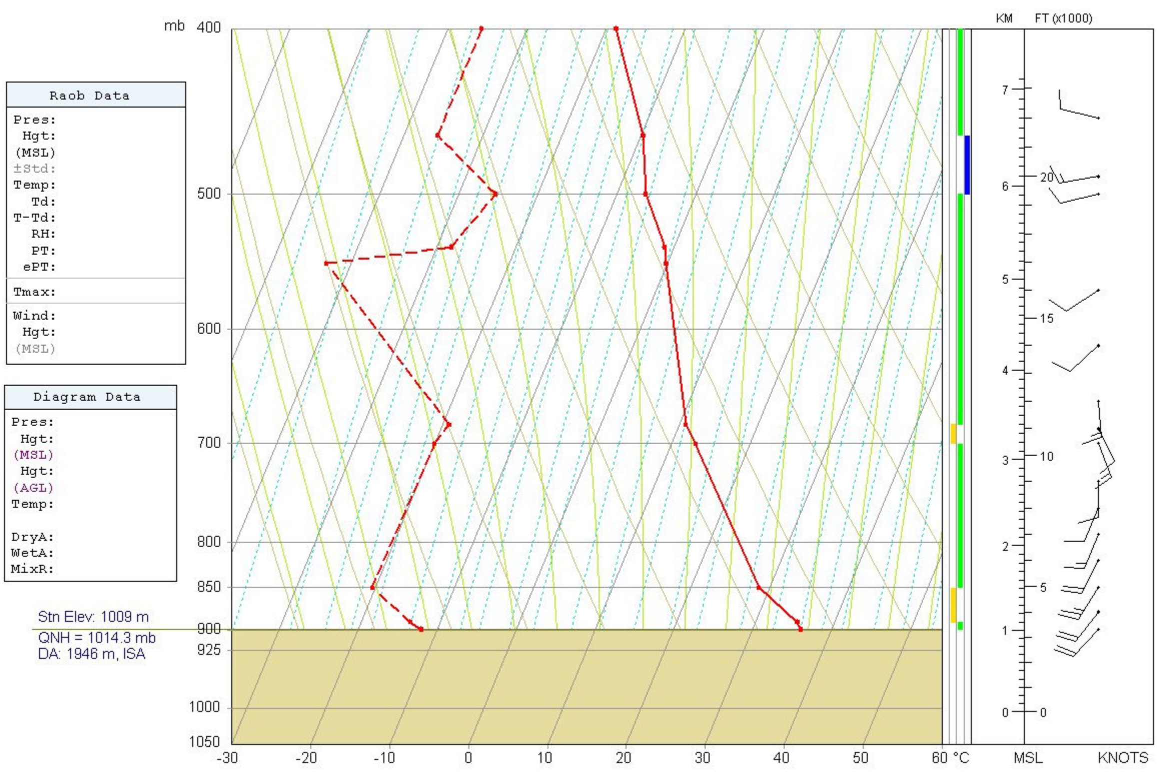

Figure 7-54. Desert Rock Rawinsonde, 06/27/07/1600 PST

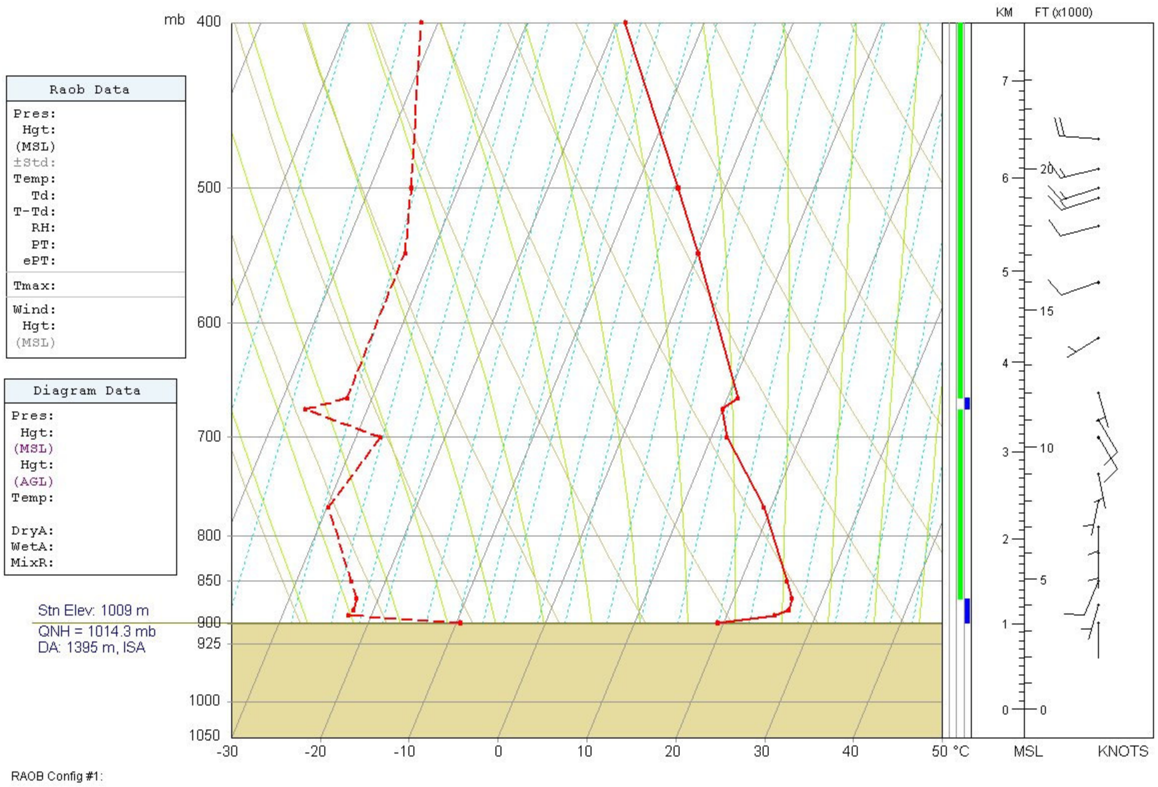

Figure 7-55. Desert Rock Rawinsonde, 06/28/07/0400 PST

Summary of Findings

Figure 7-56 shows back-trajectories surrounding the period of the Jun 27 exceedance. Winds on June 26 were from the southwest, though of insufficient magnitude to support long-range transport. However, by June 27, winds increased in magnitude. Noticeably different from the June 15 and exceedances discussed above, trajectories do not come from the Los Angeles basin, but rather lead back to the southern boundary of the San Joaquin Valley. However, on June 26, the contour plot of peak hourly ozone concentrations **(Figure 7-57)** shows not only the traditional buildup on ozone concentrations in the San Bernardino, but also high ozone concentrations in the southern San Joaquin Valley, providing the necessary ozone source. By June 27 **(Figure 7-58),** ozone concentrations in this region begin to drop, though the trajectory on this day was still favorable, leading to moderately high ozone concentrations in Clark County on June 28. However, by June 28 **(Figure 7-59)**, ozone concentrations had dropped significantly, so that even with persistent transport trajectories concentrations within Clark County had dropped accordingly.

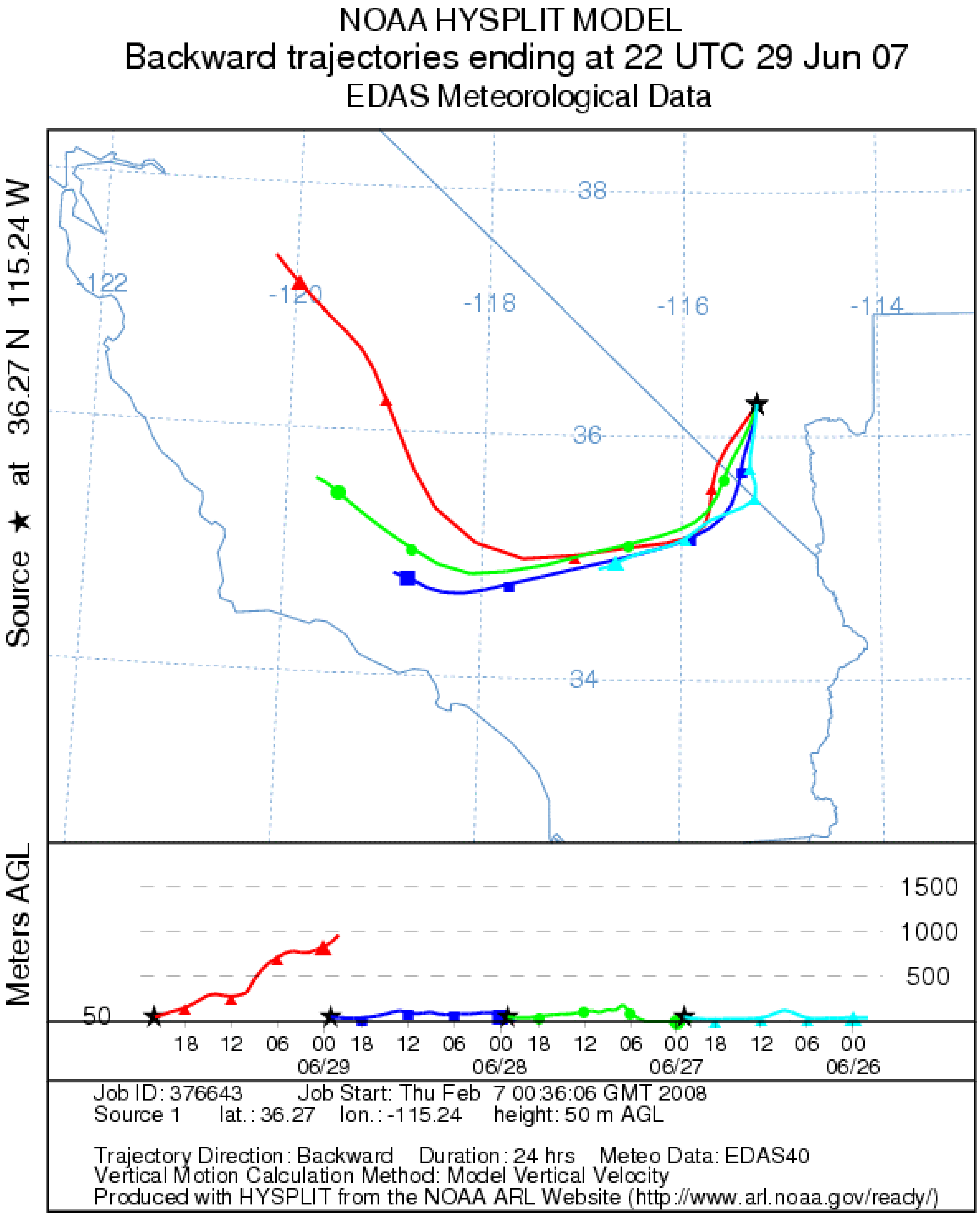

Figure 7-56. Back-trajectories during the June 27 Exceedance Period

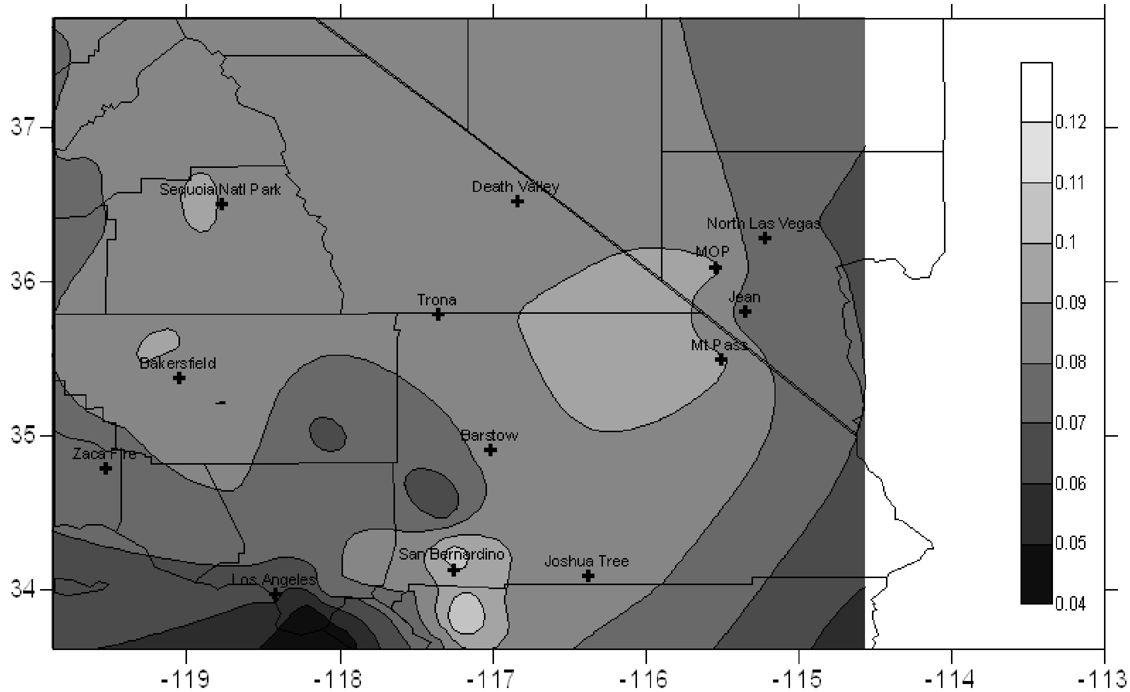

Figure 7-57. Peak Hourly Ozone (ppm) – June 26, 2007

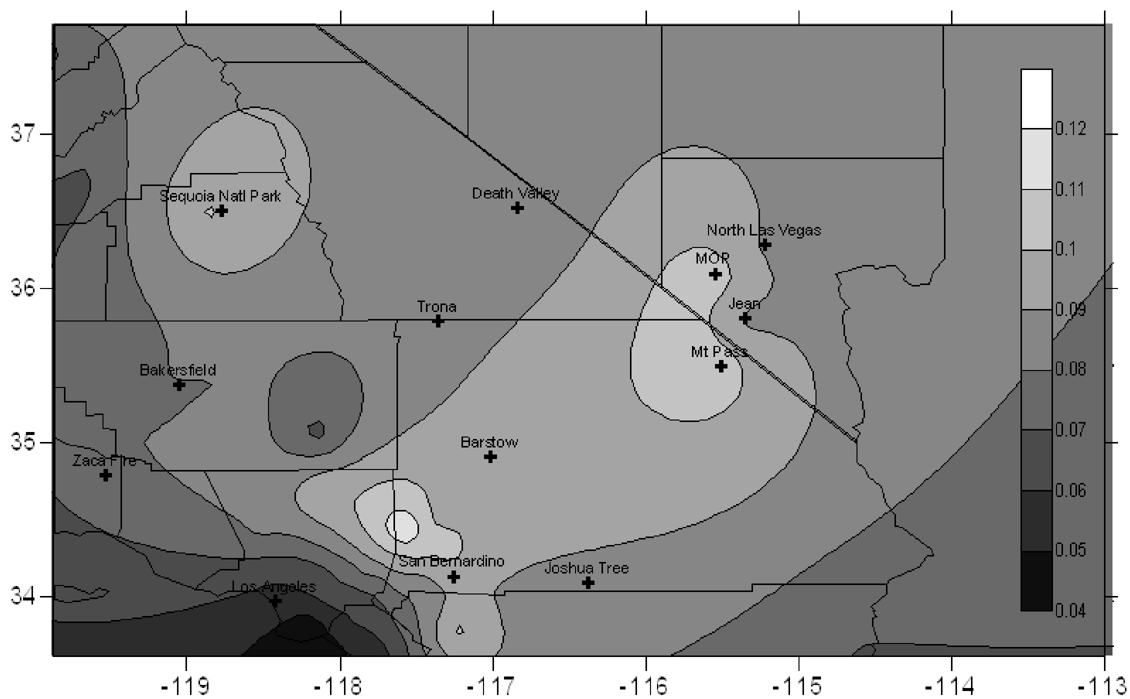

Figure 7-58. Peak Hourly Ozone (ppm) – June 27, 2007

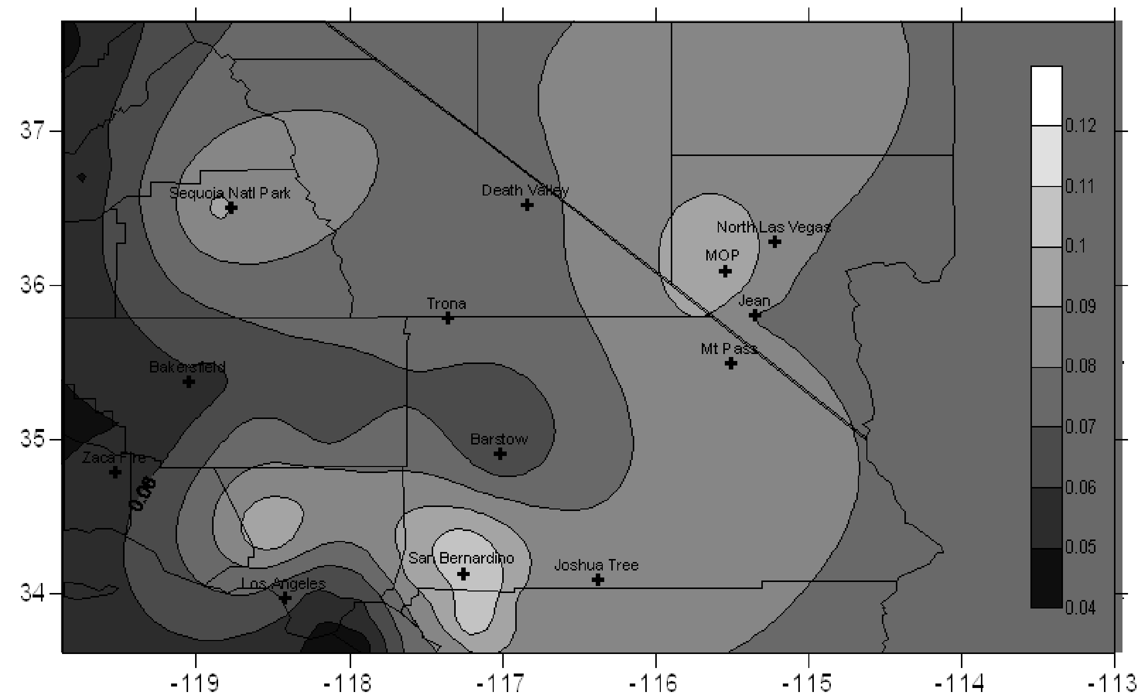

Figure 7-59. Peak Hourly Ozone (ppm) – June 28, 2007

7.1.3 Summary of Transport Scenarios

Prior to summarizing the evidence for transport of ozone from California to Clark County, it is worth looking in more detail at data measured from Jean, which will under almost all conditions be in the transport path from California to Las Vegas. **Figure 7-60** show time-height cross section of winds aloft measured leading up to and during the June 27 Clark County exceedances (Jean had an 8-hour average of 84, just under the criteria). The plot shows consistent southwesterly winds at all levels, typically at around 15 knots, throughout the entire 24-hr period leading to the exceedance. However, the regional background ozone values were elevated based on ambient measurements at Jean, MOP, and Boulder City.

In contrast, **Figure 7-61** presents a similar plot of winds recorded leading up to and including the exceedance reported in Clark County on July 28, an exceedance that occurred under locally stagnant conditions with little opportunity for active same-day transport. Winds on this day are significantly lighter and notably variable, coming from all directions over the course of the day, and even include some vertical variability. **Figures 7-62 through 7-64** show plots for the transport days discussed above (June 15, June 16, and June 23, respectively). West to southwest flow at all levels again show the strong transport conditions existing throughout the 24-hours leading to the exceedance. It is also of interest that on June 23, the IOP day during which exceedance concentrations were not reached, the flow is the weakest, with wind speeds typically in the 5 to 10 knot range, rather than the 10 to 15 knot range on the exceedance days.

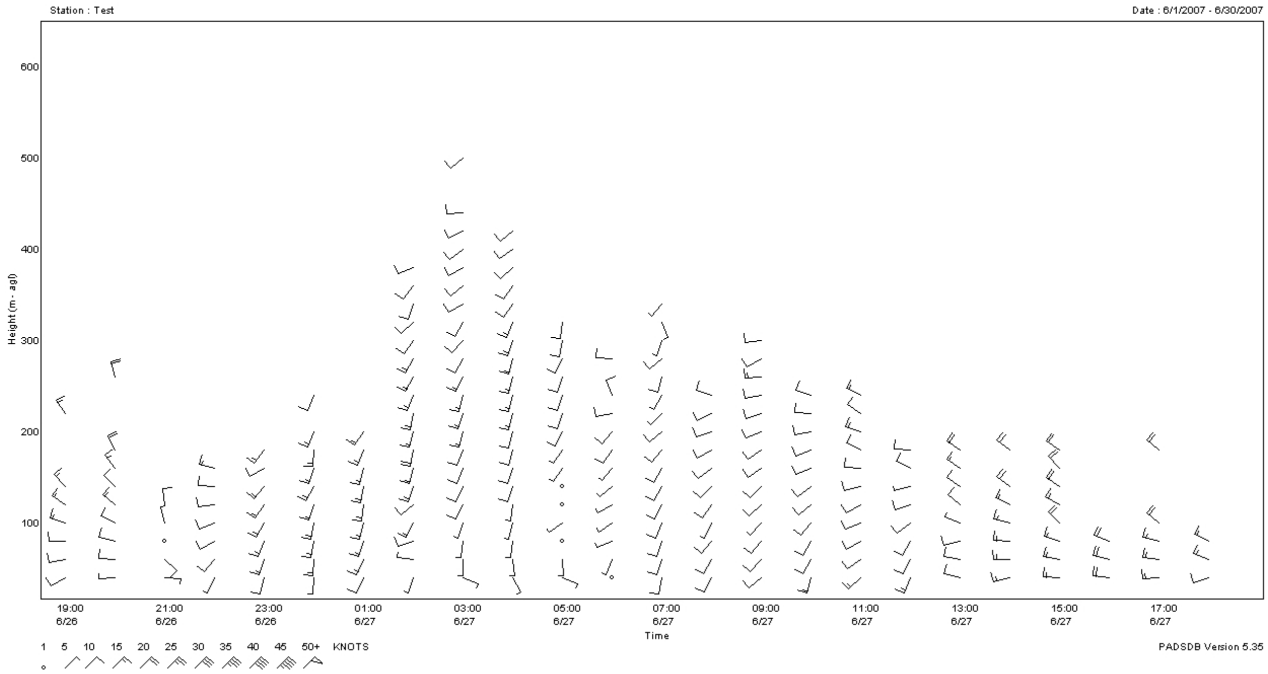

Figure 7-60. Sodar-reported Winds at Jean – Ending June 27, 1800 PST

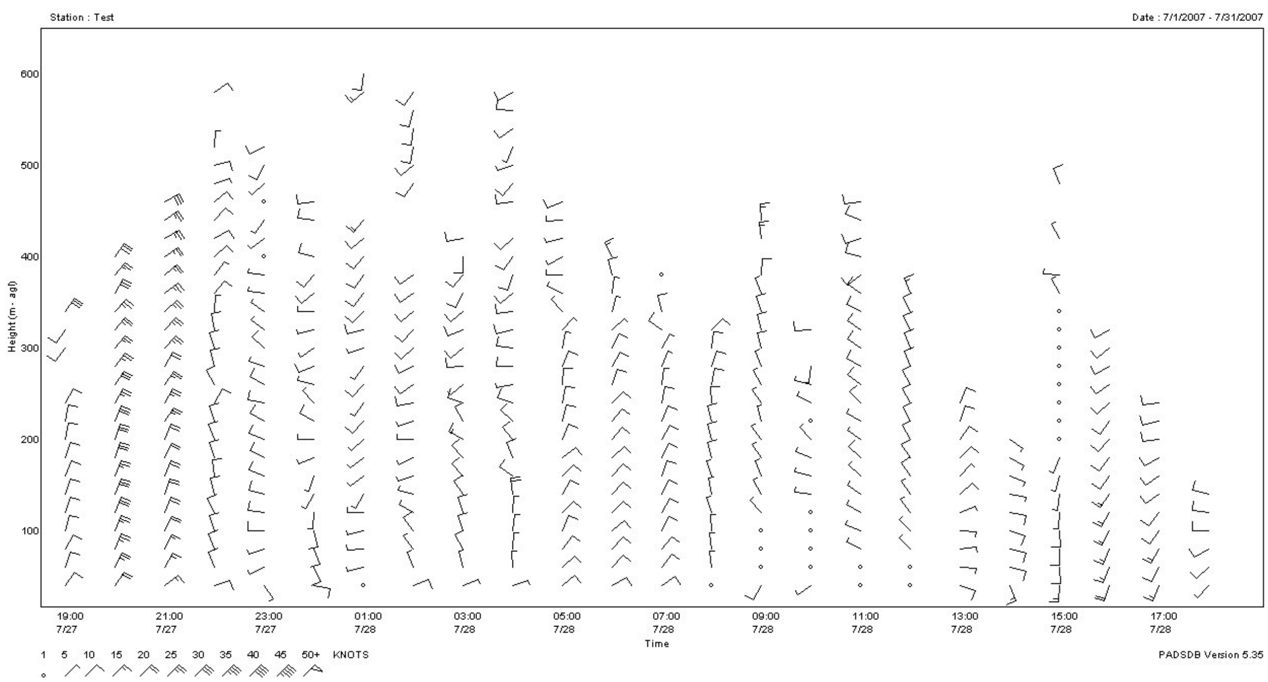

Figure 7-61. Sodar-reported Winds at Jean – Ending July 28, 1800 PST

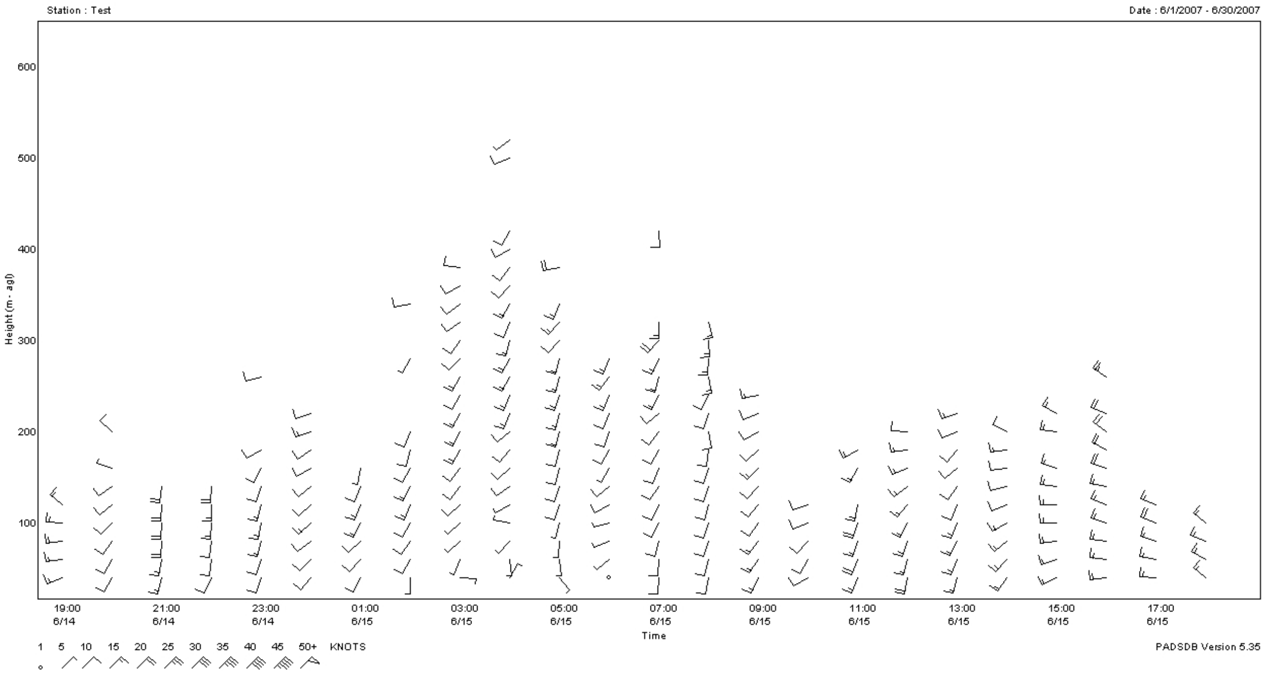

Figure 7-62. Sodar-reported Winds at Jean – Ending June 15, 1800 PST

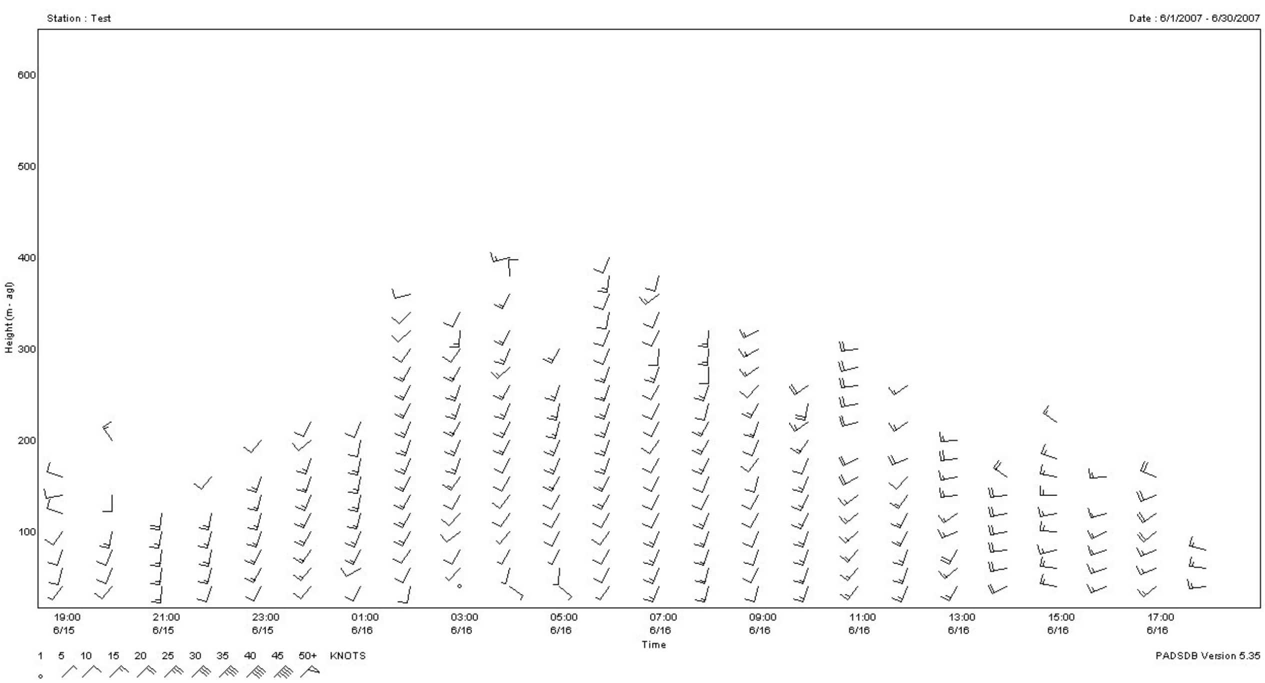

Figure 7-63. Sodar-reported Winds at Jean – Ending June 16, 1800 PST

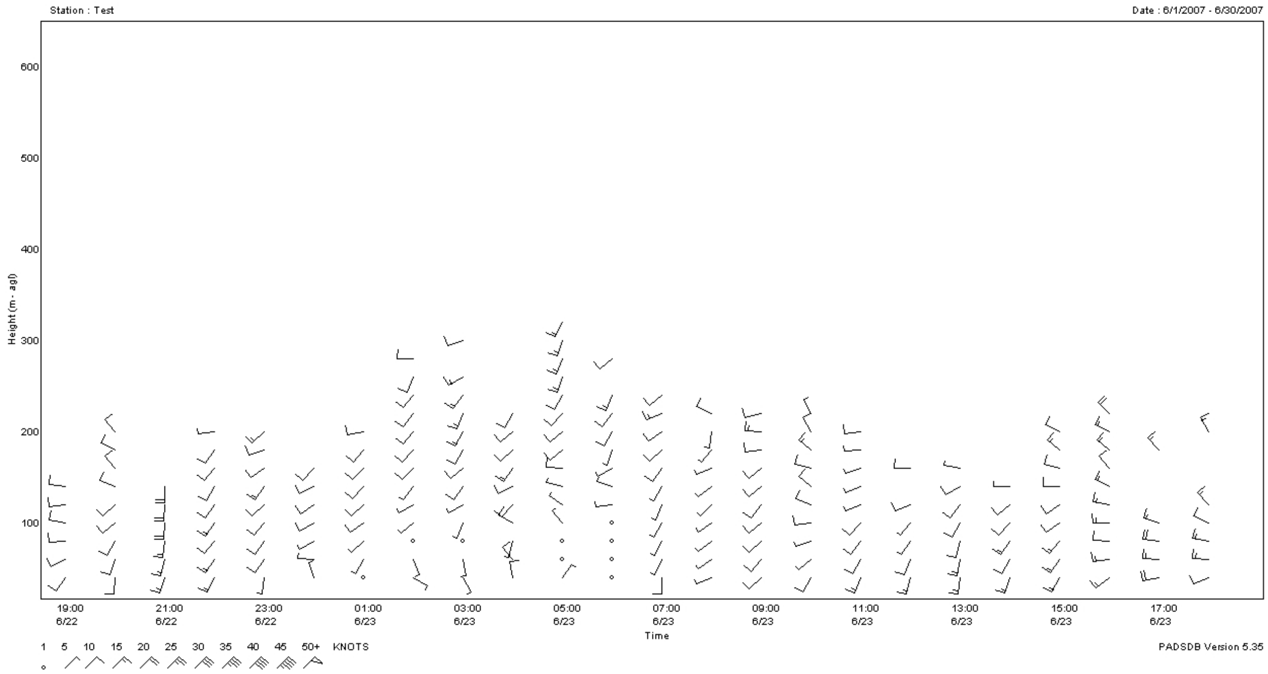

Figure 7-64. Sodar-reported Winds at Jean – Ending June 23, 1800 PST

During SLOTS, the Mt. Pass site also was on the apparent transport pathway. Similar to the Jean sodar data shown above, it is useful to look at difference between direct transport and locally stagnant days, comparing the Mt. Pass ozone concentrations with Clark County monitoring locations experiencing exceedances. **Figure 7-65** compares ozone reading from Mt Pass, MOP, Jean, and Walter Johnson for the latter half of June, when transport conditions were most favorable. Included are the three “transport” exceedance days (June 15, 16 and 27), and the June 22-24 IOP. On all four of these days, the high readings at Jean and Walter Johnson are accompanied by even higher readings at the Mt. Pass site, as expected if it was indeed upwind and along the pathway. In contrast, a similar plot including the July 28 exceedance under locally stagnant conditions **(Figure 7-66)** shows Mt. Pass concentrations significantly lower than Walter Johnson, indicating less impact from transport and more from local sources within the Las Vegas Valley.

Also worth noting in Figures 7-65 and 7-66 is that concentrations at the MOP site are consistently high relative to the other sites, supporting evidence that the modeled ozone peak indeed occurs in this general vicinity (higher elevations in the northwest sector of Clark County). Transport from California and other areas is a likely contributor to the higher readings.

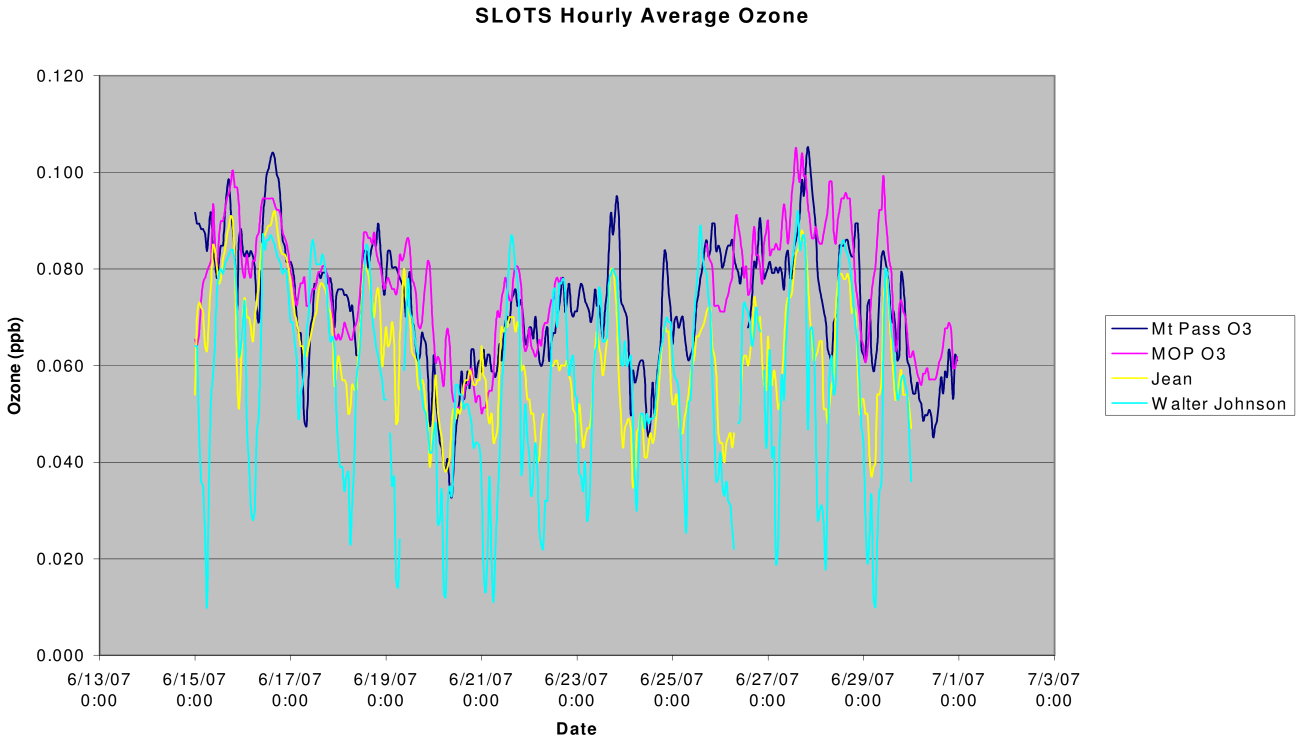

Figure 7-65. Hourly Ozone Averages From Select Sites - June 15 through June 30
All times are PST.

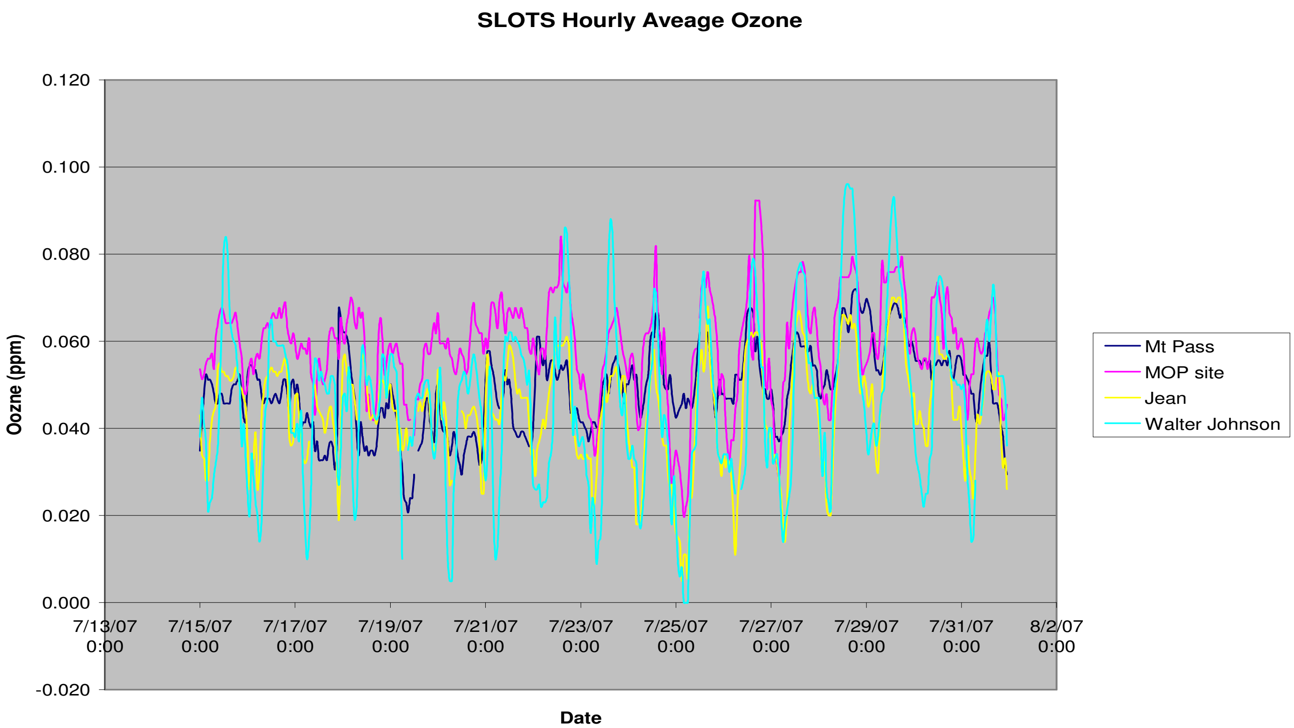

Figure 7-66. Hourly Ozone Averages for Select Sites - July 15 through July 31
All times are PST.

In summary, a large body of evidence points to the likelihood of transport of ozone from California contributing significantly to ozone concentrations in Clark County. This evidence includes:

- Synoptic patterns consistent with the conceptual model developed in past studies, which include the passing of a low pressure trough that initiates southwesterly transport winds from population centers in Southern California into Clark County.
- Airflow back-trajectories from Las Vegas Valley leading to source areas including the Los Angeles Basin and the southern San Joaquin Valley.
- Buildup of ozone concentrations in the above source areas on the day preceding the transport event.
- “Fenceline monitoring” on the California/Nevada border showing elevated ozone concentrations entering the area from the southwest.
- Upper air measurements at Jean showing basically steady southwesterly flow throughout the periods leading up to transport events, consistent with the HYSPLIT back-trajectories, and inconsistent with local sources impacting Jean ozone concentrations.
- Well-defined boundaries between regional background concentrations and Southern California urban plumes with higher concentrations, consistent with plume dynamics. This includes a plume of 85 ppb identified adjacent to air with clean background concentrations of 40 ppb, though this occurred in a narrowly layered plume which may have been more concentrated.

In general plume boundaries showed between 10 ppb and 30 ppb difference between the plume and the “background” in which the plume was imbedded. Differences of 20 ppb were typical, and almost all of the identified plumes were very deep with little vertical variability in concentration, and thus capable of impacting large areas. Thus, a contribution of 20 ppb to existing regional ozone concentrations appears likely under the transport scenarios describe above.

If 2007 is representative of other years, cases of overwhelming transport of ozone into Clark County will occur primarily during June. This is consistent with the synoptic conditions considered critical for transport, namely periods of high pressure over the source areas allowing buildup of ozone concentrations, followed by weak troughs passing through the region.

Finally, it is worth noting that evidence gathered during SLOTS brings up the possibility that high concentrations of ozone might be impacting areas in Nevada west of Las Vegas, in particular the Pahrump area. The MOP site demonstrated that high ozone is possible west of the Spring Mountains that border the western edge of the Las Vegas urban area. Ozone measurements at the MOP site, while not made using a reference method, repeatedly reported ozone concentrations exceeding the 8-hour standard. In addition, several of the IOP flights showed regional maximums over Pahrump.

7.2 Smoke-related Ozone

The 2007 ozone season provided only limited opportunities to study the effect that smoke from wildfires has on ozone concentrations in Clark County. Ideally, large, multi-day Southern California wildfires located within approximately 150 km south-southwest of Las Vegas would have provided the best opportunity for studying ozone concentrations using the SLOTS enhanced measurements. Such fires would have provided smoke plumes that could be easily sampled by the aircraft, and would likely have provided opportunities for definitively differentiating between smoke-related ozone contributions and urban plume contributions.

As it happened, however, only two fires occurred in Southern California during the study period. The first was the White fire located on the south slope of the Tehachapi Mountains, approximately 300 km west-southwest of Las Vegas, which began on June 24 and was contained on July 2 after burning approximately 12,000 acres. The much larger Zaca fire began on July 4 and was not contained until September 2. The Zaca fire was located approximately 400 km west-southwest of Las Vegas, and over the course of two months burned over 240,000 acres. Both of these fires had visible plumes that at times could be seen in satellite photos impacting Clark County. However, the transport paths for the smoke plumes coincided with the urban plume transport paths from greater Los Angeles and the Southern San Joaquin Valley, making it difficult to differentiate between smoke-related and urban contributions to ozone concentrations.

Nevertheless, despite these limitations, some potentially interesting smoke-related findings can be found in the SLOTS data. One of the more interesting observations noted in the ozone data obtained from the SLOTS supplemental sites at Mt. Pass and the MOP (Modeled Ozone Peak) location is shown in **Figure 7-67**. Looking at the maximum daily one-hour average reported at each site, one can see remarkably good agreement between the two sites up through July 5. After July 5, the MOP site consistently measured maximum ozone levels 10 to 20 ppb higher than those at Mt. Pass, located only 40 miles south of the MOP site. Averaging all days from the beginning of SLOTS monitoring through July 5, there is no net difference between Mt. Pass and MOP (0 ppb). Similarly averaging the days from July 6 through the end of the study, ozone concentrations at the MOP site were on average 12 ppb higher than those at Mt. Pass.

Thus, the immediate question that comes to mind is whether or not it is significant that these differences begin at the same time that the Zaca fire began, possibly providing insight into the role that wildfires have on ozone concentrations. **Figures 7-68** and **7-69** show HYSPLIT 24-hour forward trajectories for the Zaca fire for July and August, respectively. There is a trajectory for each day which is color-coded as shown on the bottom of the figures. An initial plume height of 3500 meters agl was assumed, which was consistent with reports viewed on the Internet. As can be seen, trajectories typically take a more northerly to northeasterly route, relative to Las Vegas' location essentially due east of the fire. Thus, as the plume is smeared out, there is a potential for a gradient in the vicinity of Las Vegas of higher pollution concentrations to the north and lower concentrations to the south. This is graphically demonstrated in **Figure 7-70,** which presents a composite view of the satellite smoke analysis between August 10 and August 21.

Again looking at the HYSLPIT trajectories from the Zaca fire, one sees that there are only three days when trajectories headed directly to the Las Vegas area: August 5, 22 and 23. During these "direct hits", one would expect that gradients within the SLOTS monitoring area would be minimized, with both sites seeing essentially the same concentrations. Indeed, these three days turn out to be three of the seven days during the period when MOP and Mt. Pass maximum ozone concentrations agreed to within 5 ppb. The trajectories on August 22 and 23 are confirmed by the satellite smoke analysis for these days **(Figure 7-71**), though the smoke analysis for August 5 (**Figure 7-72**) has the plume north of the study area. Two of the other days of agreement were September 3 and 4, the final two days of monitoring at these sites, and interestingly immediately after the official end of the Zaca fire on September 2. The sixth day fell on August 1, which Figure

7-67 shows had the required westerly winds, though of a magnitude insufficient to reach the state line in 24 hours. Though the final day of agreement (July 17) cannot be similarly explained, the timing and the overall correlation between trajectories and the noted differences between the two sites implies a relationship and the possibility that smoke was influencing ozone concentrations. Still, while the smoke plume trajectories may indeed have played a role, it may be that factors other than smoke caused the differences in concentrations, such as differences in regional mixing brought on by the different trajectories.

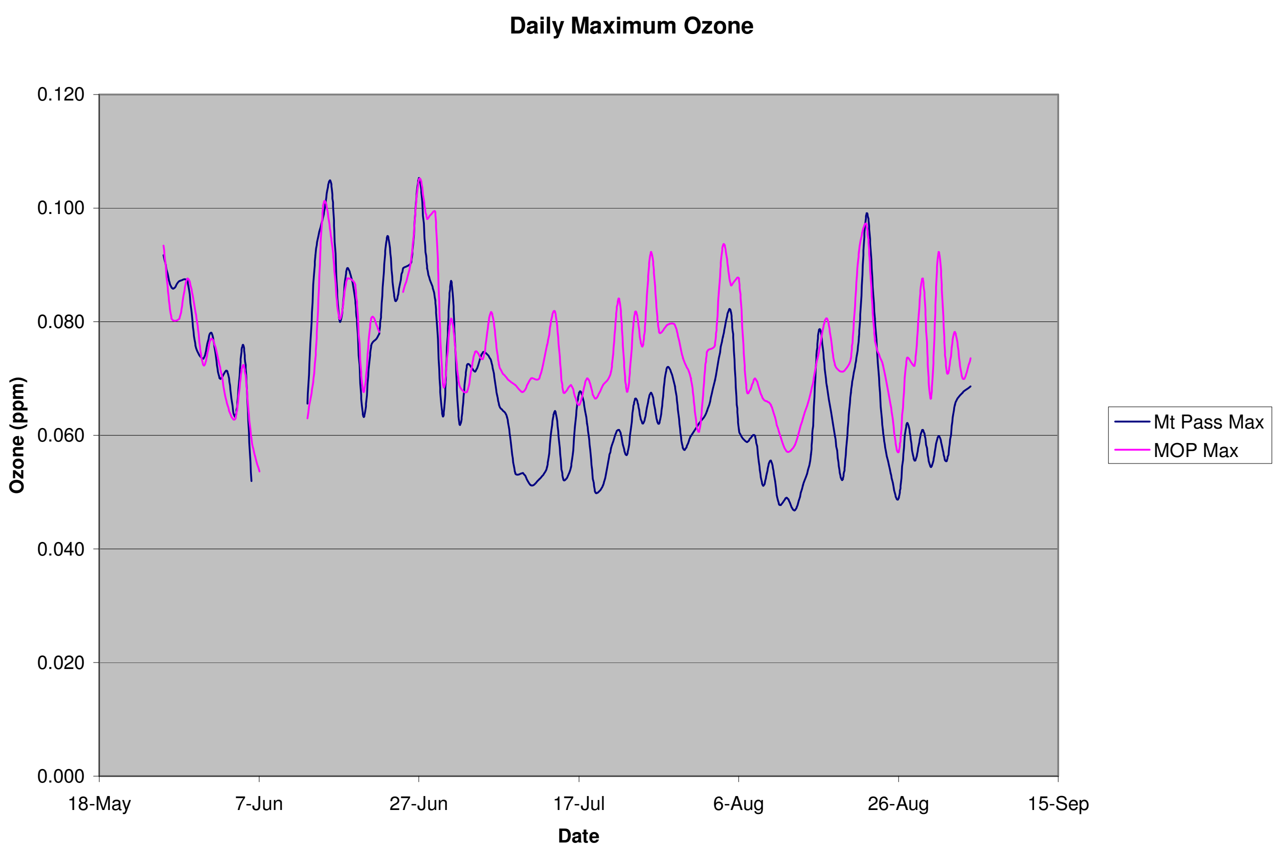

Figure 7-67. Daily Maximum 1-hour Average for SLOTS Sites

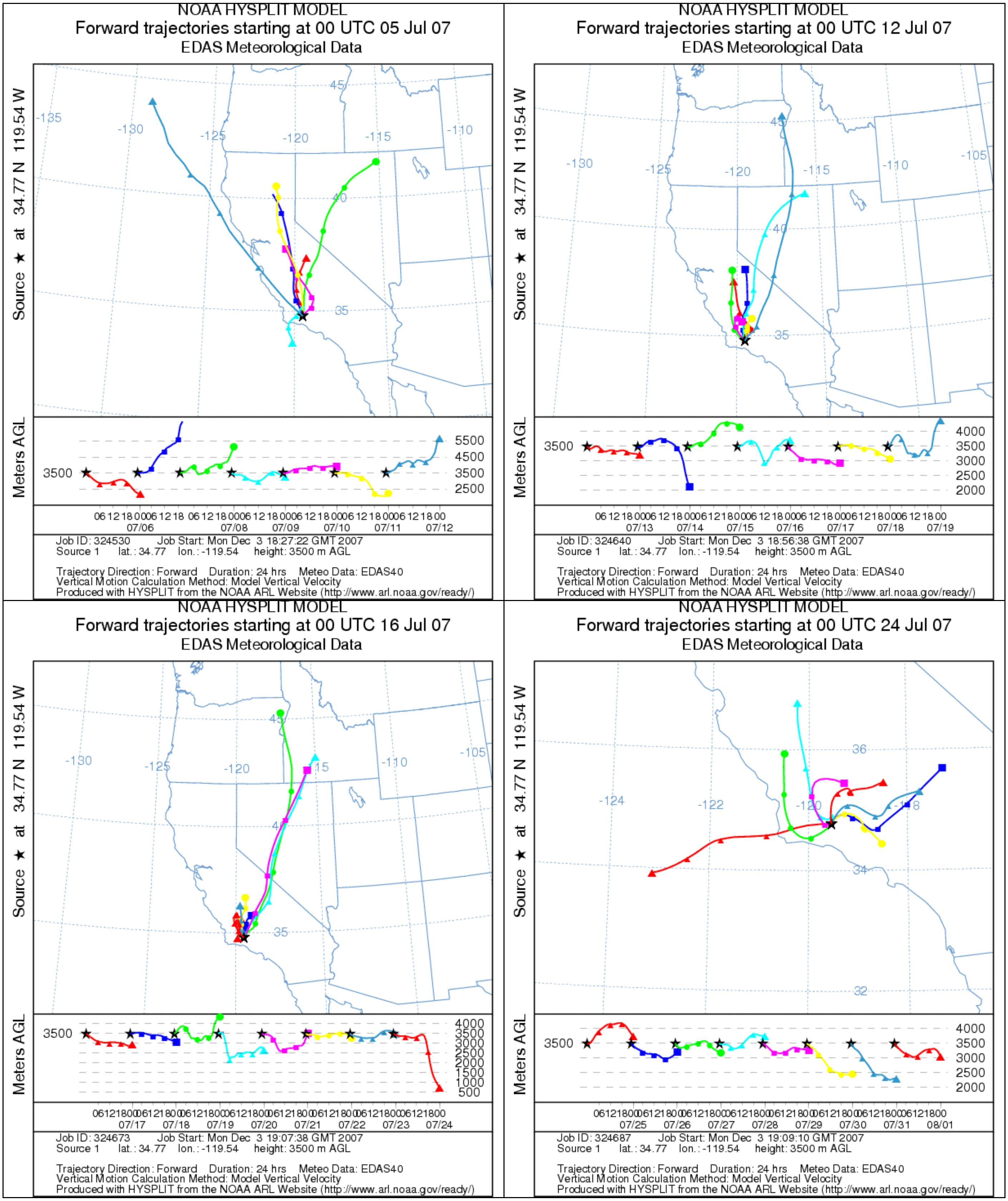

Figure 7-68. Zaca Fire Forward Trajectories – July 2007

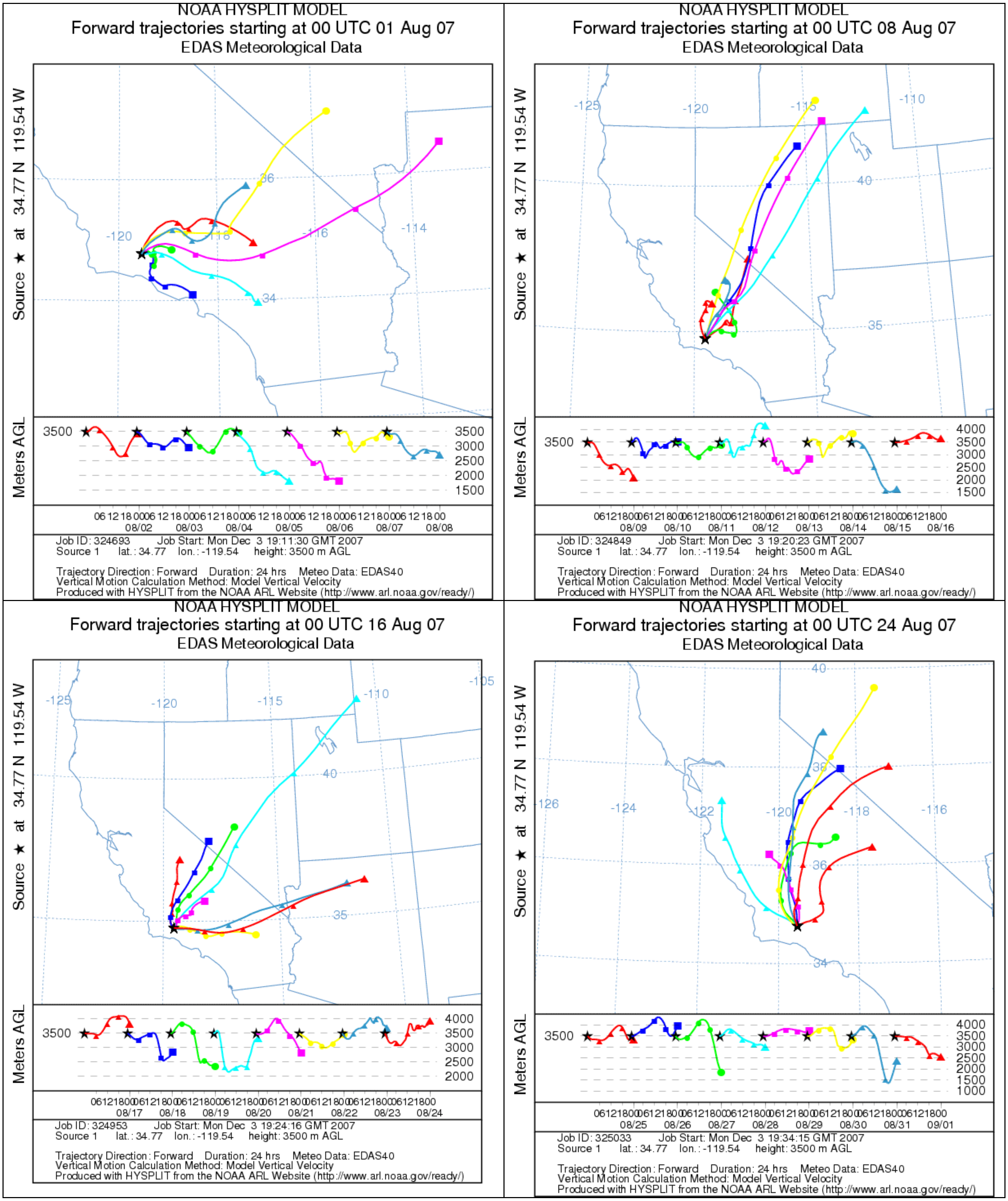

Figure 7-69. Zaca Fire Forward Trajectories – August 2007

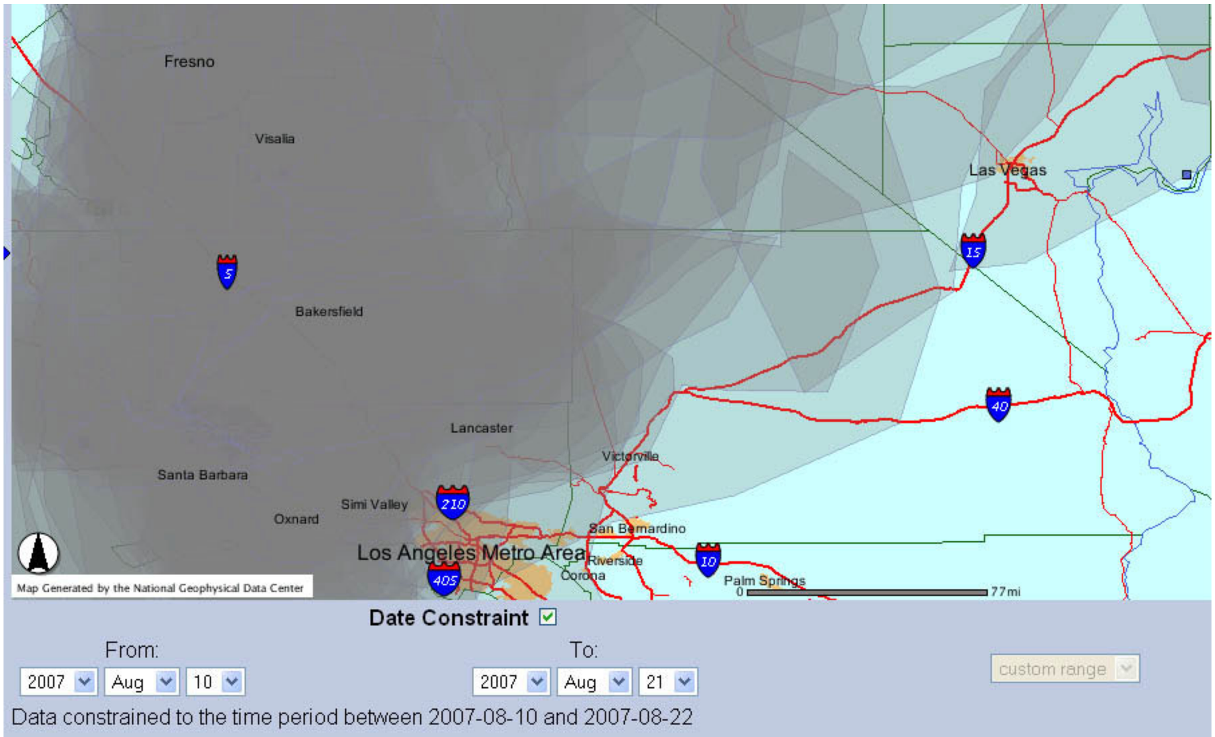

Figure 7-70. Composite Satellite Smoke Analysis for August 10 through 21

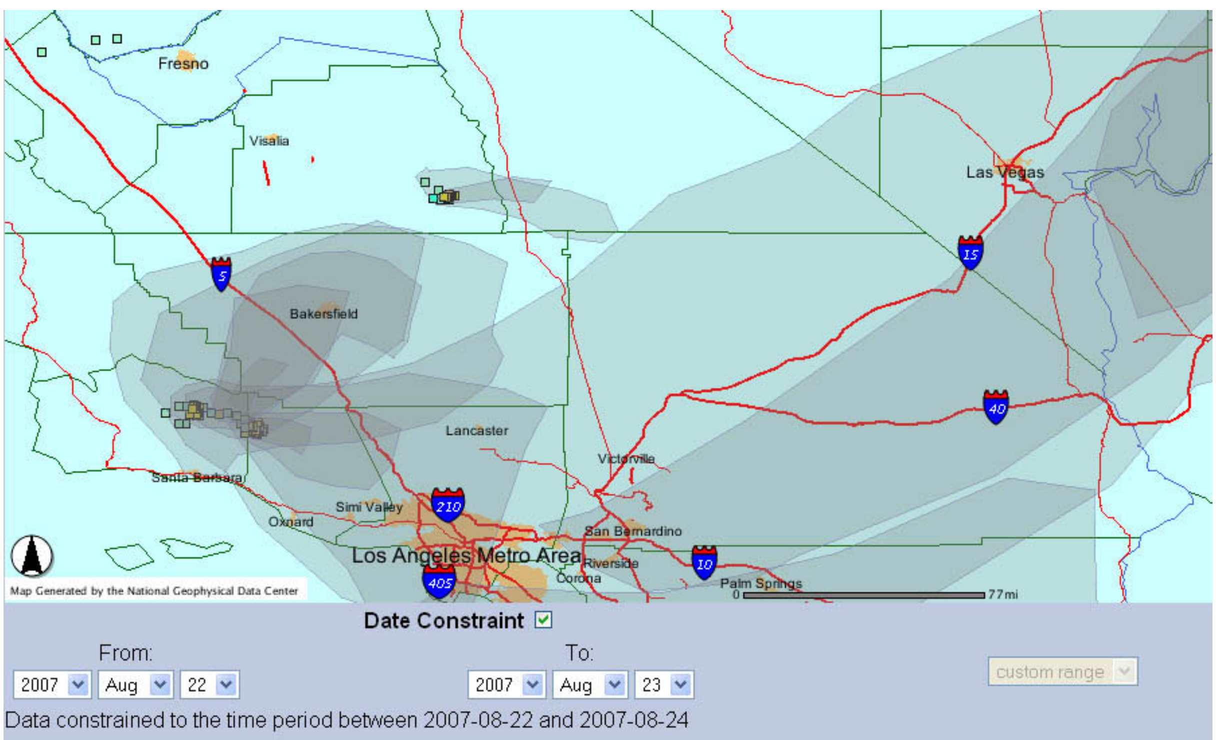

Figure 7-71. Satellite Smoke Analysis for August 22 and 23

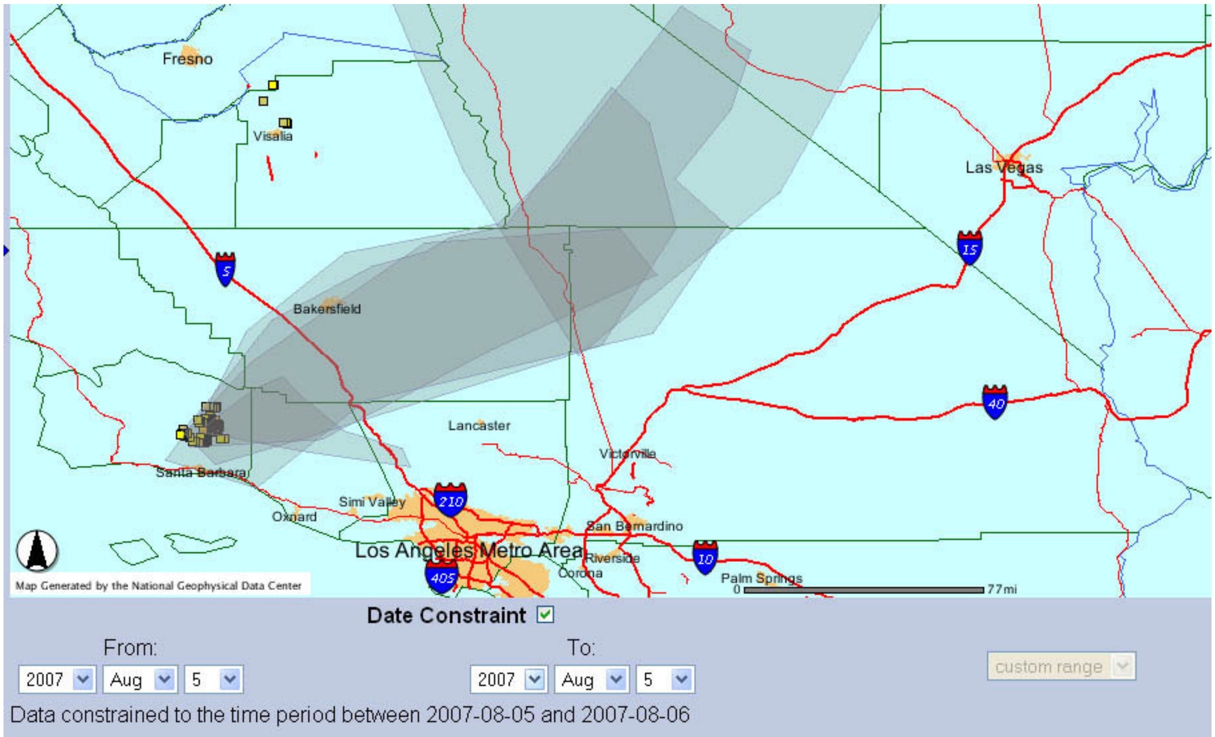

Figure 7-72. Satellite Smoke Analysis for August 5

7.2.1 Analysis of IOPs

<u>June 25 – June 26, 2007 (White Fire)</u>

<u>Synoptic Description</u>

The synoptic weather patterns affecting the Southwestern region of the U.S. during the White fire IOP measurement period are presented in the NWS 700 mb constant pressure analyses charts shown in **Figures 7-73 through 7-75**. The southern end of a trough of lower pressure that had been located along the west coast during the previous 3 or 4 days had been fluctuating in strength. The trough near the coast coupled with a broad flat ridge of higher pressure extending eastward from the southern Great Basin, resulted in a flow pattern at and below 700 mb level that was light west-southwesterly to southwesterly throughout the region on the morning of June 25th. This pattern remained relatively static through most of that day, but by evening, slightly higher pressure began to build into southern Arizona. By the morning of the 26th, the southern Arizona ridge had strengthened while the Pacific trough had broadened into central California. As a result, the synoptic winds aloft shifted to a more south-southwesterly direction.

Figures 7-76 through **7-78** show rawinsonde plots from Desert Rock on the 25thand 26th of June. At 0400 PST on the 25th, winds were light and southwesterly between 2,100 m-msl and 3,200 m-msl (~700 mb), which was just above the approximate centerline height of the White fire smoke plume. Although there was no well-defined subsidence stable layer defining the top of the boundary layer, mixing was limited to about the 700 mb level. By late afternoon on the 25th, mixing became more vigorous due to surface heating but remained limited to the 700 mb layer. Winds aloft during the day shifted into a more south-southwesterly direction resulting in the smoke plume being transported to the north of the Las Vegas Valley. Subsequent rawinsondes taken during the next few days indicate that the wind flow at the smoke plume elevations continued shifting slowly into the southerly quadrant.

The synoptic features described above and satellite imagery indicate that the White fire smoke plume was initially transported into the Las Vegas area. The smoke plume remained intact aloft due to limited mixing. As mixing became more vigorous during the day, smoke fumigated to the surface. By the evening of the 25th, the smoke plume was directed north of the Las Vegas Valley.

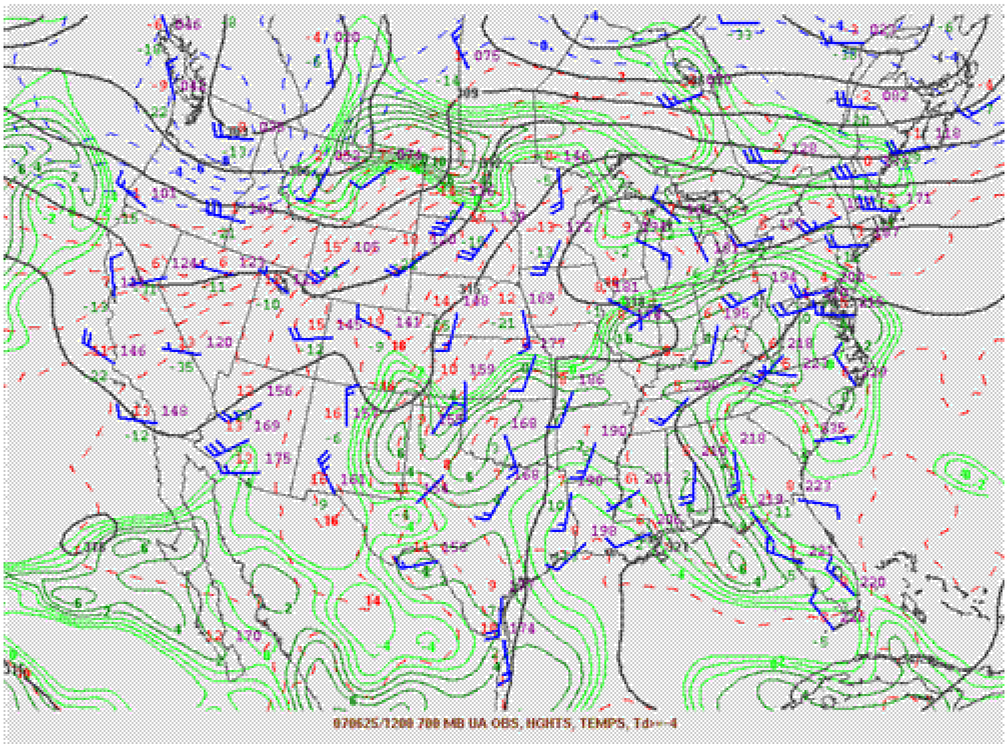

Figure 7-73. 700 mb Analysis for 06/25/07/0400 PST

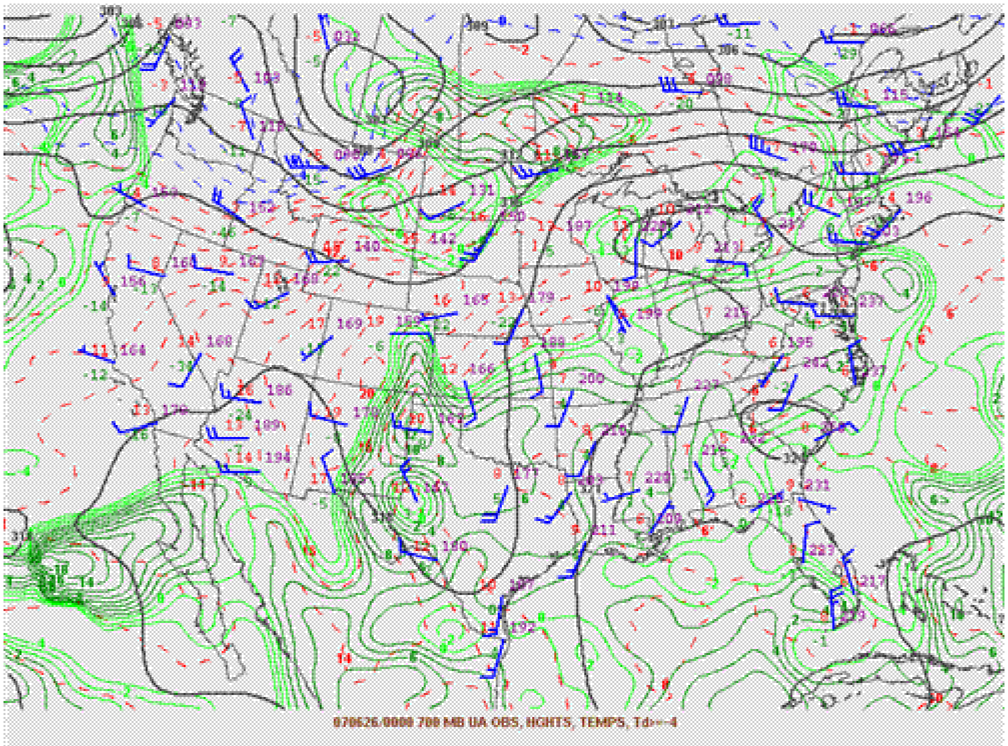

Figure 7-74. 700 mb Analysis for 06/25/07/1600 PST

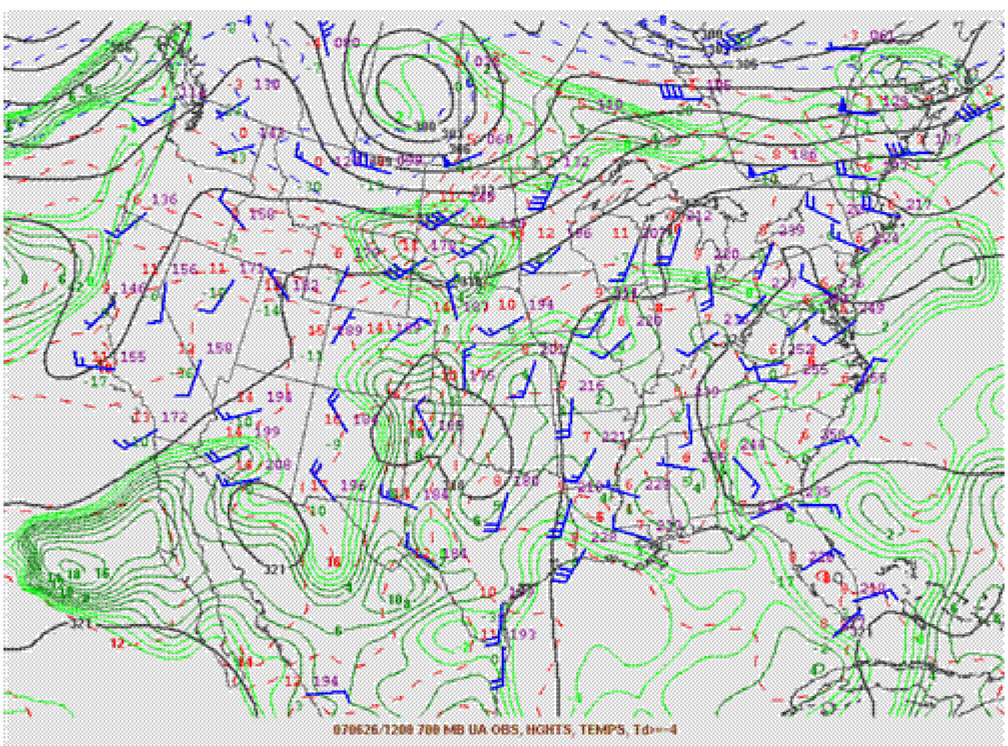

Figure 7-75. 700 mb Analysis for 06/26/07/0400 PST

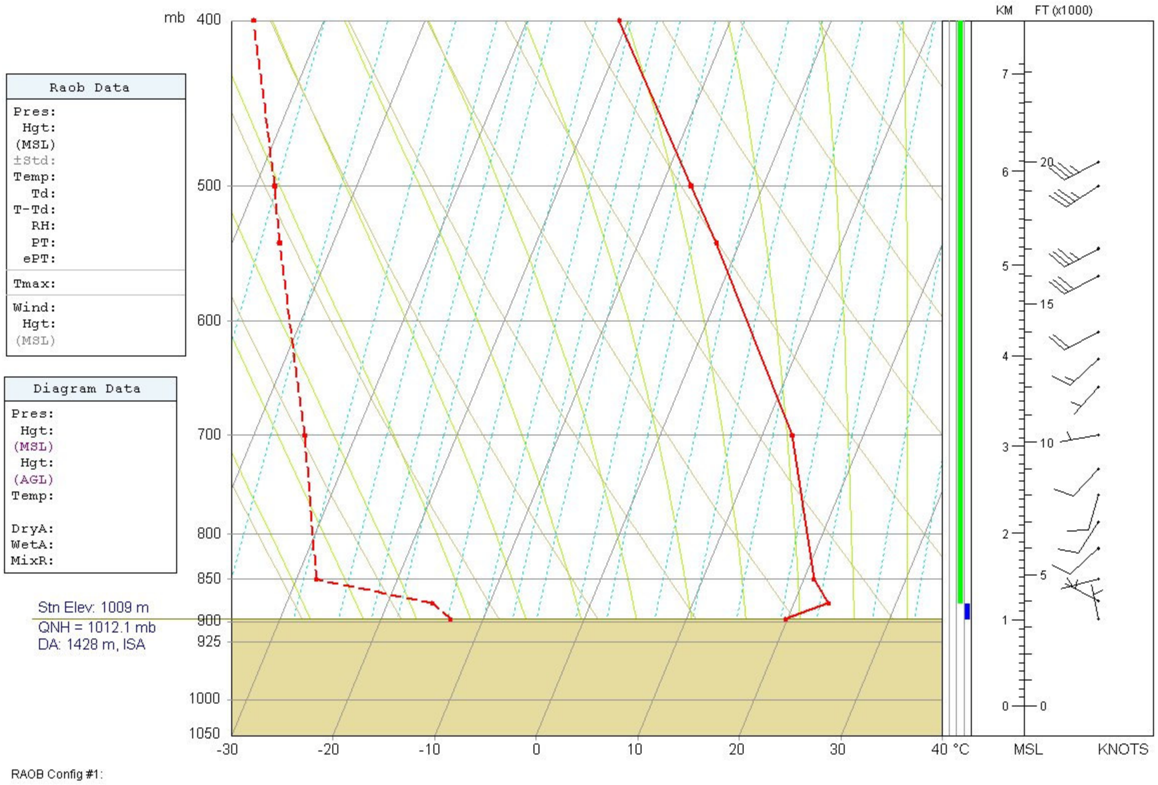

Figure 7-76. Desert Rock Rawinsonde, 06/25/07/0400 PST

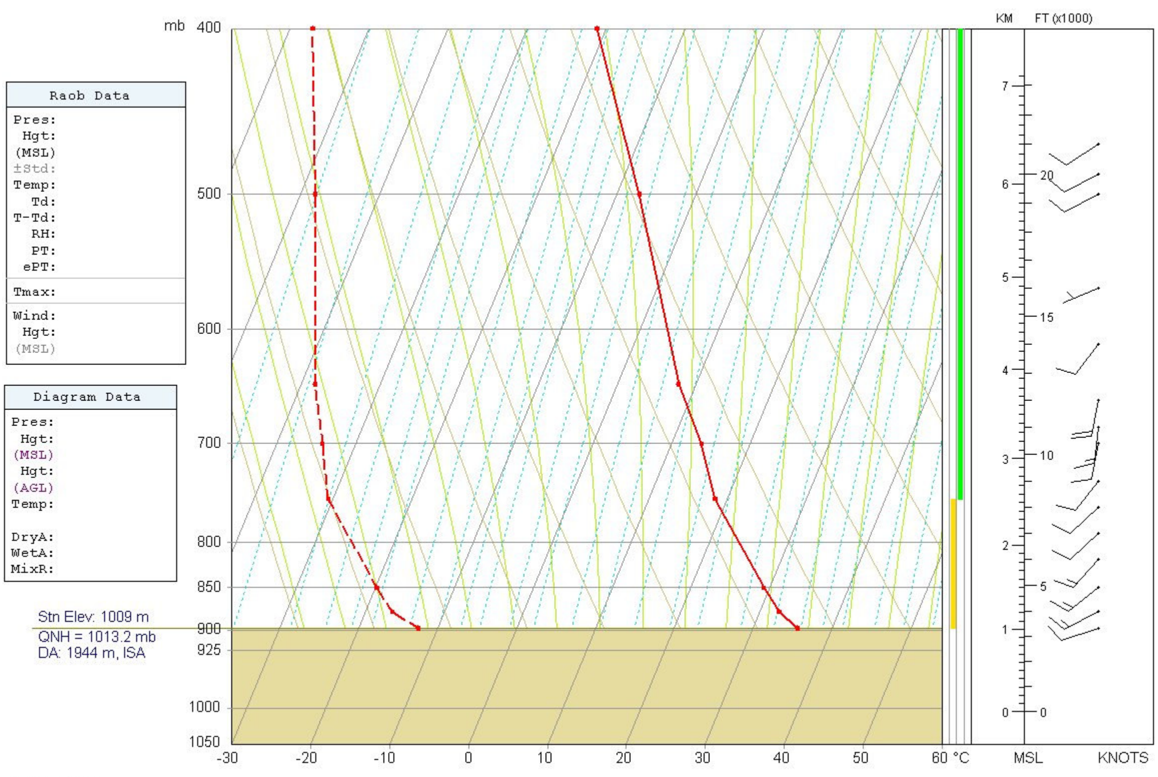

Figure 7-77. Desert Rock Rawinsonde, 06/25/07/1600 PST

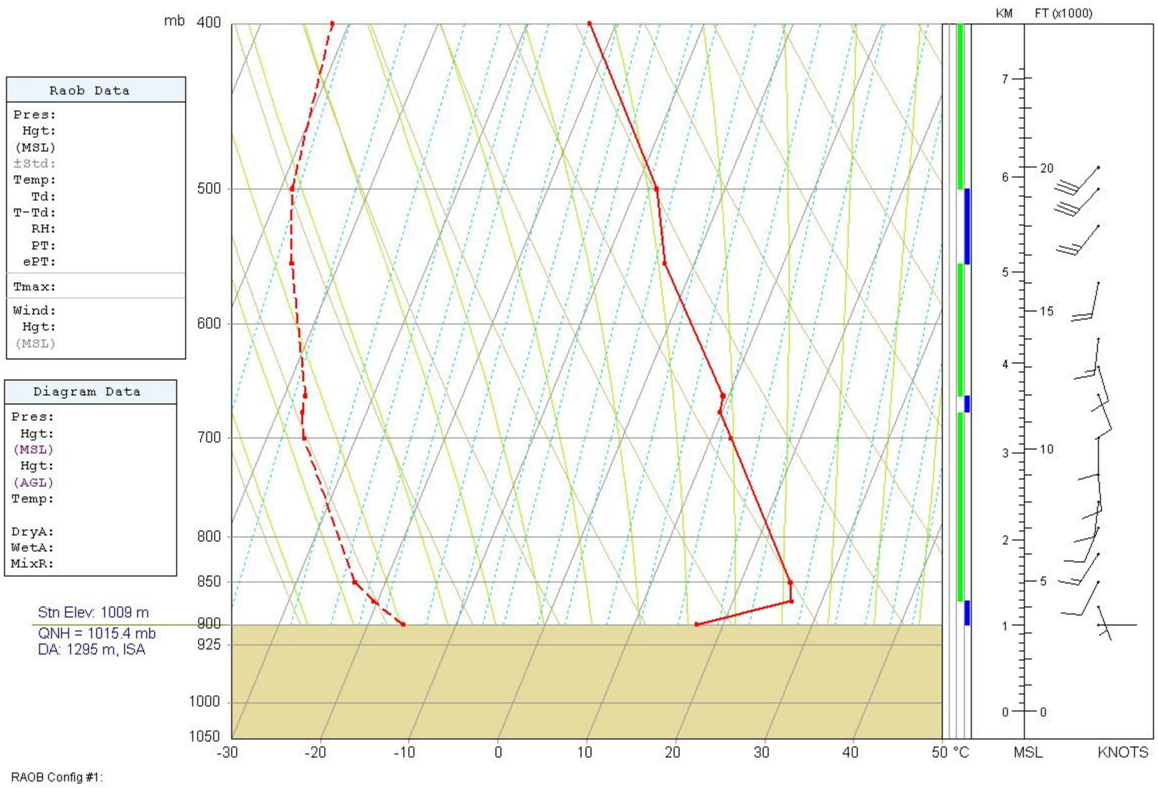

Figure 7-78. Desert Rock Rawinsonde, 06/26/07/0400 PST

<u>Aircraft Measurements and Summary of Results</u>

The June 25 afternoon flight (**Figures 7-79** and **7-80**) started with a shallow sounding out of NLV where ozone in the 80 to 90 ppb range was observed. The flight proceeded upwind to Jean where a sounding was performed to look at the ozone and PM being transported to the Las Vegas Valley. Following the Jean sounding the flight proceeded to the northwest along the CA/NV border to a location just short of Death Valley. The intent was to cross the fire plume from the White fire. The aircraft then moved about 25 miles to the west and proceeded with a traverse to the south-southeast through Baker and on to I-40. The flight then proceeded along I-40 to Daggett where another sounding was performed prior to heading to the town of Mojave by way of Palmdale airport. During the traverse along I-40 and following the Daggett sounding, an ozone plume exiting the South Coast Air Basin (SoCAB) was observed. Sampling in the Mojave/Tehachapi area was somewhat restricted as this was a controlled air space with advisories warning to watch for the tankers fighting the White fire. Visually, it appeared that the smoke plume, and any associated ozone generated, could remain aloft in layers that may not become will mixed while traveling across the desert. This layering will result in a variety of impacts when it arrives in Clark County and depending on the time of day, may or may not mix to the surface.

The June 25 evening flight (**Figures 7-81** and **7-82**) started with a sounding out of the airport at Mojave under restrictions due to the controlled airspace at Edwards AFB and China Lake Naval Weapons Center. The flight proceeded through a corridor of controlled airspace to Trona at a fixed altitude. This traverse passed directly through the plume of the White fire where visibility was extremely limited due to smoke. The flight continued through Trona and out into the southern portion of Death Valley and then turned south back to I-15 near Baker, then back to NLV through Jean. The flight concluded in the dark.

The primary observations from sampling are:

- The smoke plume was tracked from its origin into the Las Vegas Valley.
- The smoke plume remained intact and associated ozone levels persisted in rather significant concentrations (>90 ppb) across the desert.
- The observed reduction in PM concentration was far greater than the corresponding decrease in ozone concentration.
- The final sounding at Jean showed a shallow surface layer (~45m deep) where the concentrations dropped from an average of about 90 ppb aloft to 66 ppb at the at the surface.

On the morning of June 26, visible satellite pictures showed the fire plume heading north of the Las Vegas Valley. The flight was thusly designed to fly to the state line from NLV, head to the northwest and attempt to cross the plume and fly back to NLV along highway 95 (**Figures 7-83** and **7-84**). Along the flight path soundings were performed at NLV, at Jean, at a location west of Death Valley, at Beatty, NV and again at NLV at the conclusion of the flight.

As can be seen from the figures, the remnants of the fire plume and associated smoke and ozone were measured to the northwest of Las Vegas in the Amargosa Valley, but in lower concentrations than the prior day. The main smoke plume and associated ozone generated was now mainly to the northwest of Las Vegas. It is noteworthy that remnants from the prior day's ozone were still present over the Las Vegas Valley, as shown by the elevated values of ozone and PM observed during the morning sounding out of NLV.

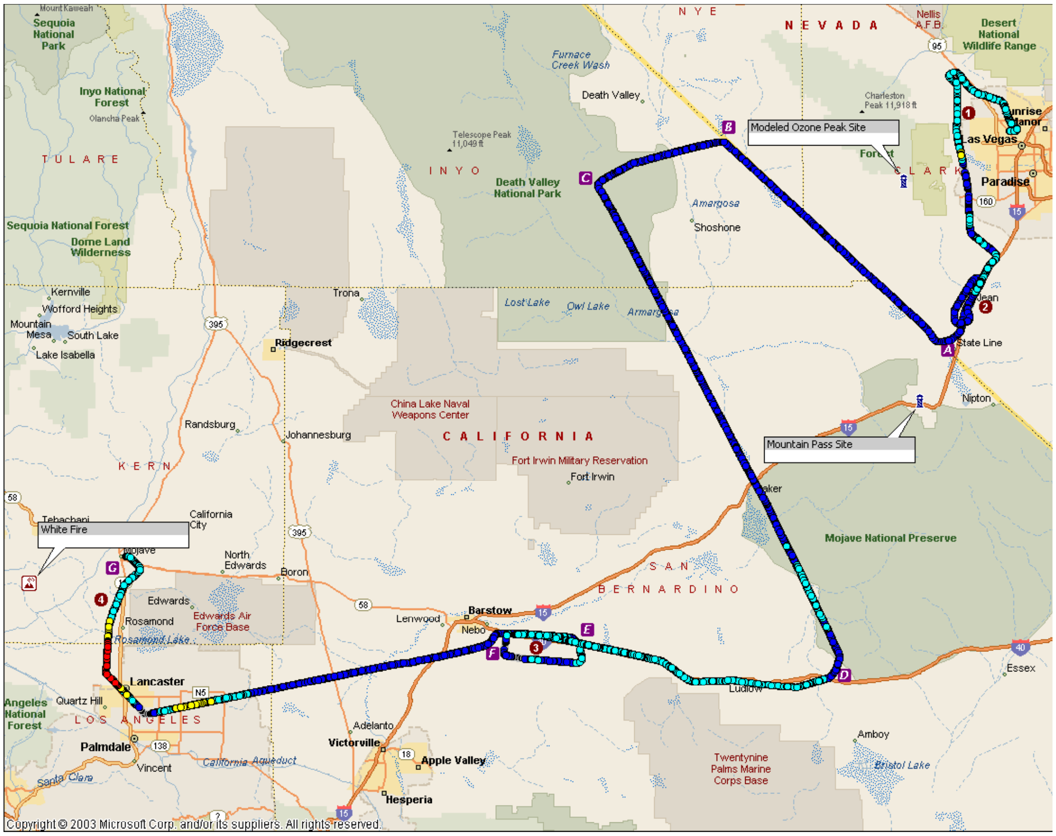

Figure 7-79. July 25 – Afternoon Flight

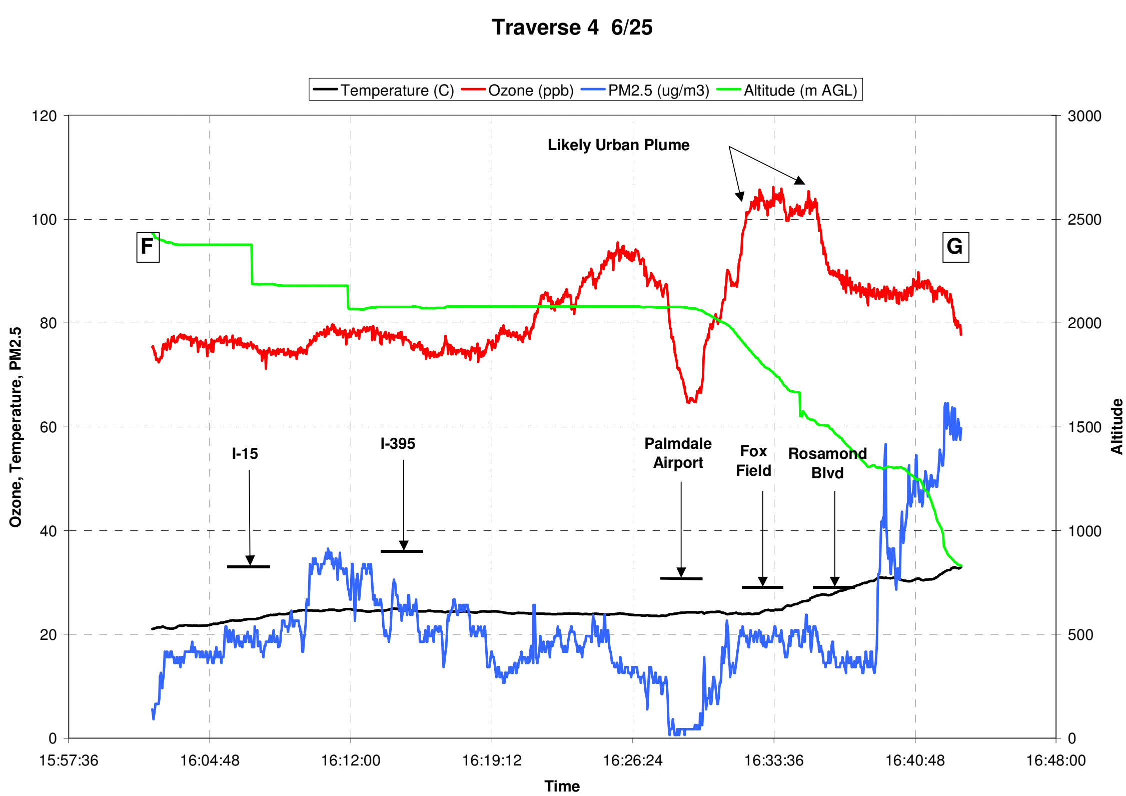

Figure 7-80. Traverse during June 25, Afternoon Flight

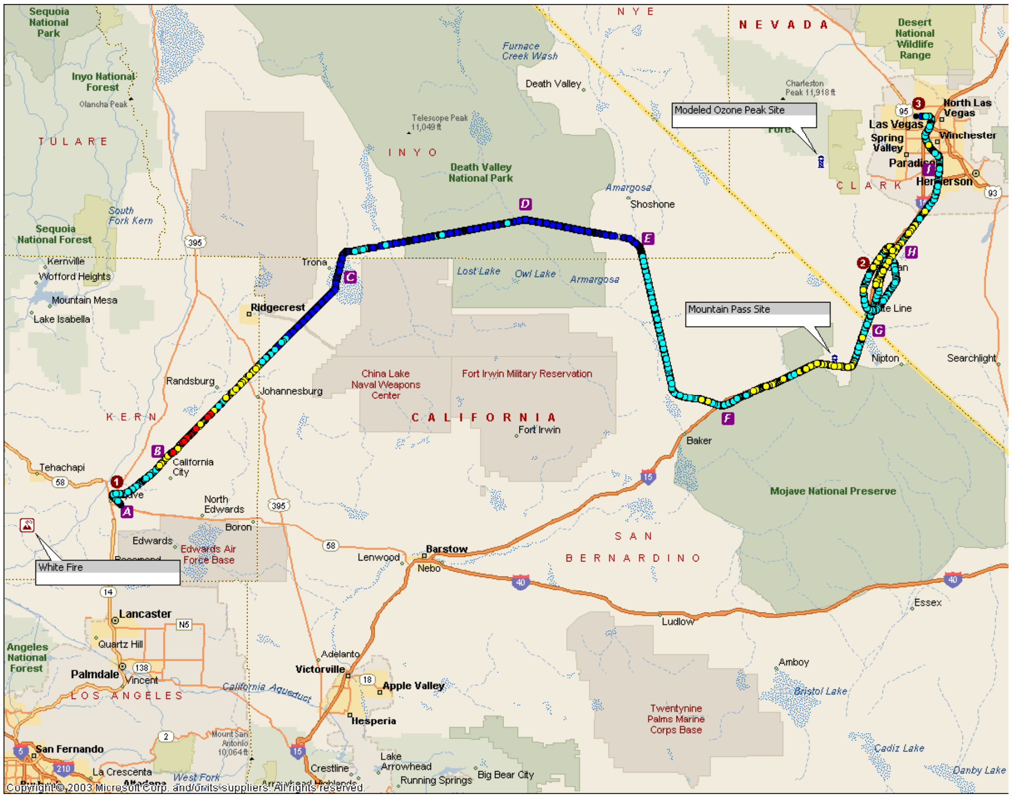

Figure 7-81. June 25 – Evening Flight

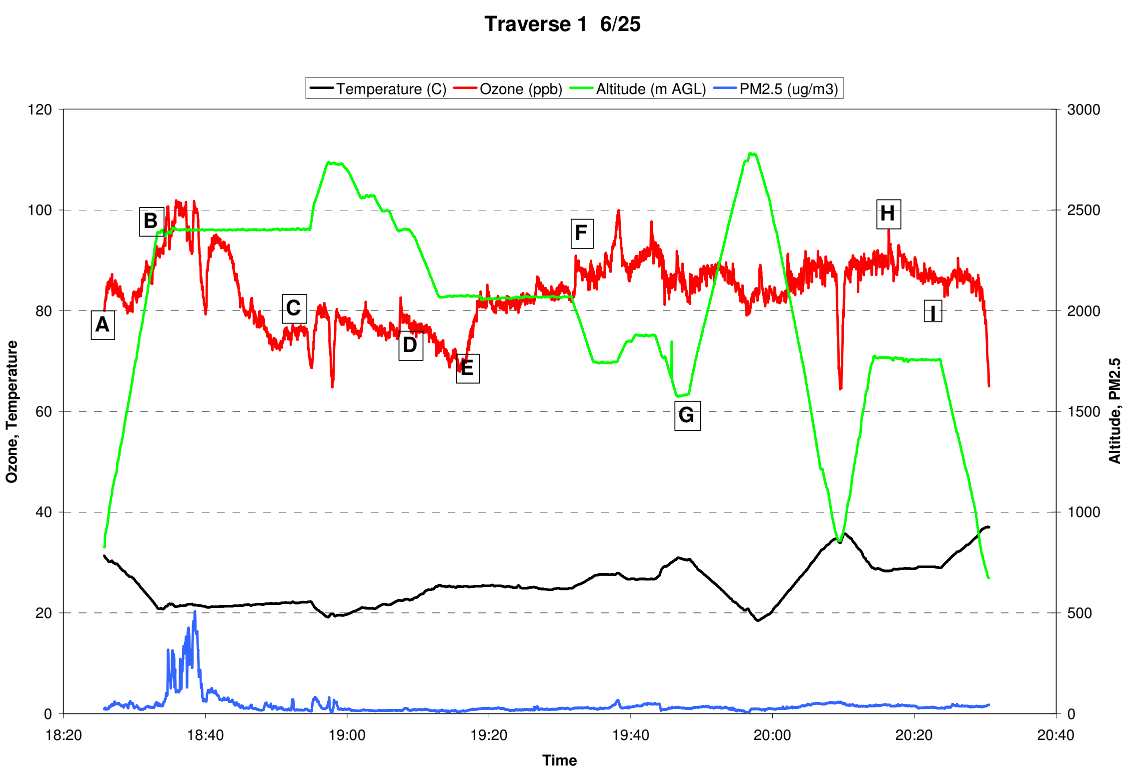

Figure 7-82. Traverse during June 25, Evening Flight

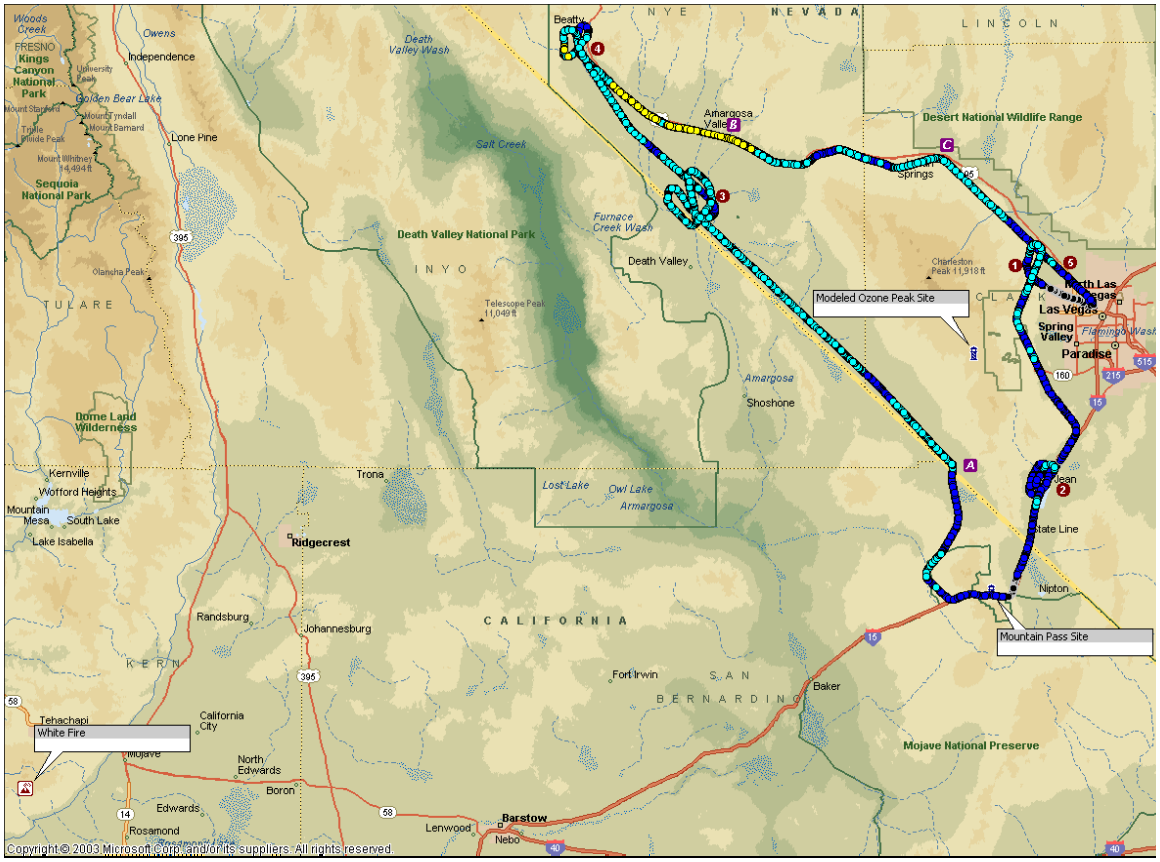

Figure 7-83. June 26 – Morning Flight

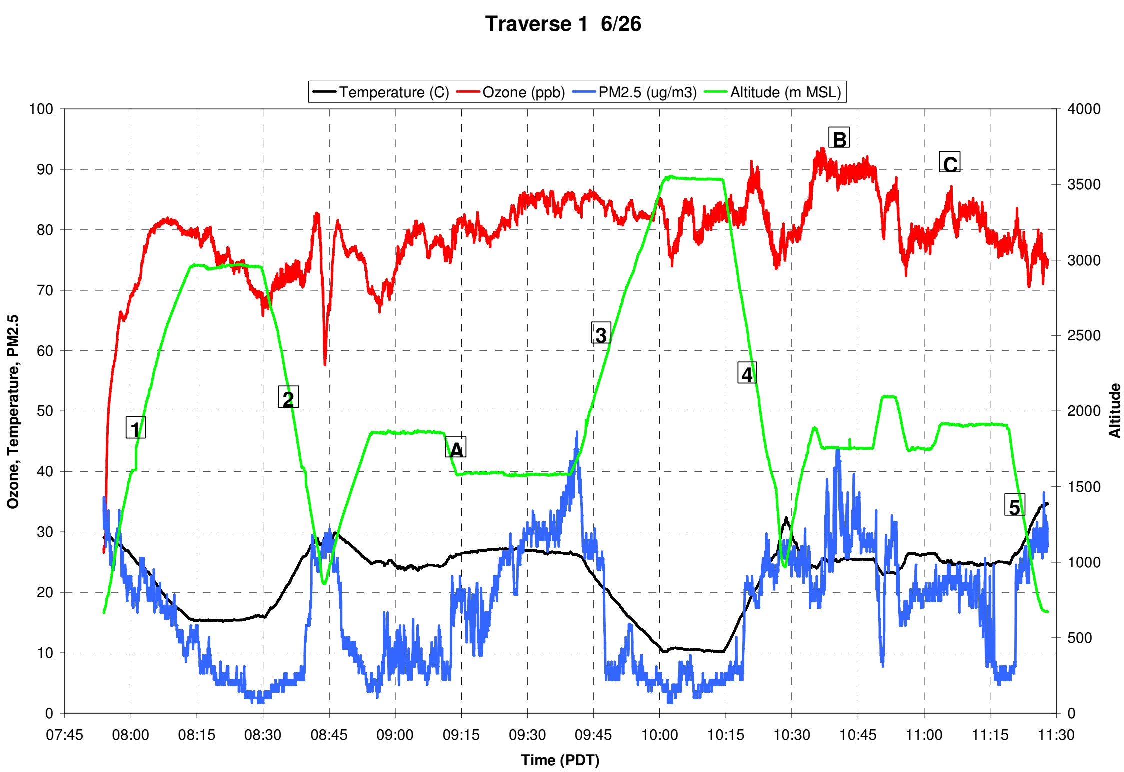

Figure 7-84. Traverse during June 26, Morning Flight

Additional analysis concentrated on the plumes identified during the airplane sampling discussed above. **Figure 7-85** presents 24-hour forward trajectories from the White fire at 6 hour starting intervals spanning the duration of the sampling. For these trajectories, a plume height consistent with the flight height when entering the wildfire smoke plume during the evening flight on June 25 was used. The trajectories agree with the observed location of the fire plume northwest of the fire at approximately 0000 UTC, as well as the basic location of the plume identified on the morning of June 26 (approximately 1500 UTC) extending into Death Valley.

Of particular interest and consternation is the definitive source of the ozone in the plume identified over Lancaster during the first flight on June 25 (see Figure 7-77), originally considered to be an urban plume. Ozone concentrations in this plume were actually slightly higher than those measured in the visually-confirmed smoke plume (see Figure 7-79). This lead to the concern that ozone concentrations in the smoke plume could in reality be simply an extension of the "urban" plume. To investigate this, HYSPLIT back-trajectories were calculated starting at the point and time of maximum concentration for each plume. These trajectories are shown in **Figure 7-86**. The figure clearly demonstrates the complexity in understanding specific features in plumes attributable to fires due to the complex terrain and multiple sources in the region. Both trajectories lead back to almost the exact location of the White fire. However, both trajectories continue back to the southern San Joaquin Valley. **Figure 7-87a** is a map showing peak hourly ozone concentrations in the region. It is seen that the southern San Joaquin Valley did have ozone concentrations in the 90 to 100 ppb range, which could have been the source of the ozone noted in both plumes rather than the wildfire, making it impossible to definitively define its source. The second flight clearly went through the White fire smoke plume, as the on-board personnel visually confirmed and consistent with the extremely high $PM_{2.5}$ measured during the flight (note the scale change in Figure 7-81). In contrast, the plume over Lancaster was visually more of a haze with much lower $PM_{2.5}$ readings. It is within the uncertainty of the trajectory analysis that the parcel passed upwind, somewhat to the west of the fire.

It is import to note that, regardless of the source of the ozone, this IOP provides clear evidence of transport along a route from the Southern California / Southern San Joaquin Valley that clearly impacts southern Nevada based on the visible smoke analysis **(Figure 87b).**

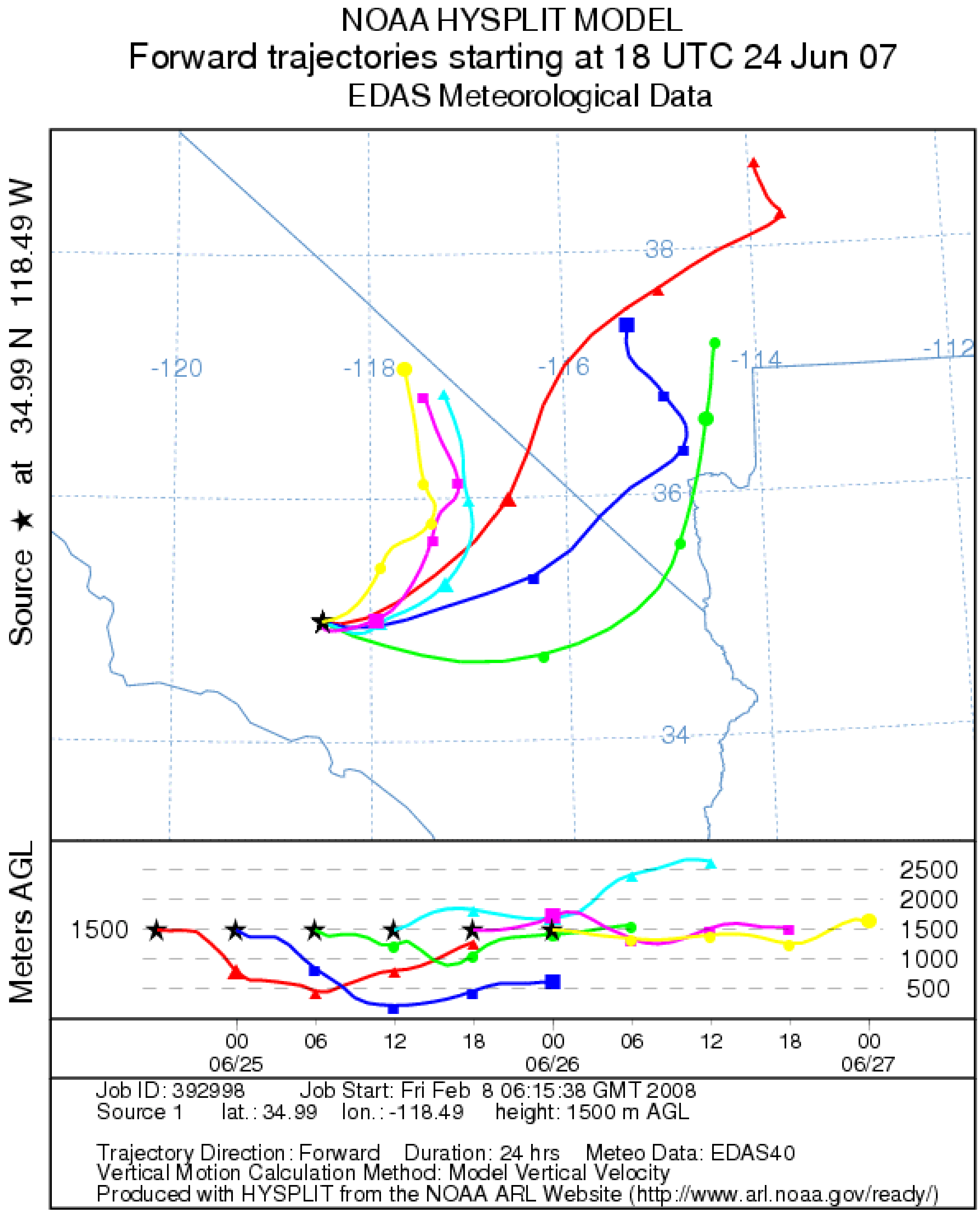

Figure 7-85. 24-hour Forward Trajectories from the White Fire, Every 6 Hours during June 25 and June 16 IOP

Figure 7-86. Back-trajectories from Ozone Plume Maximums Measured During June 25 Flights

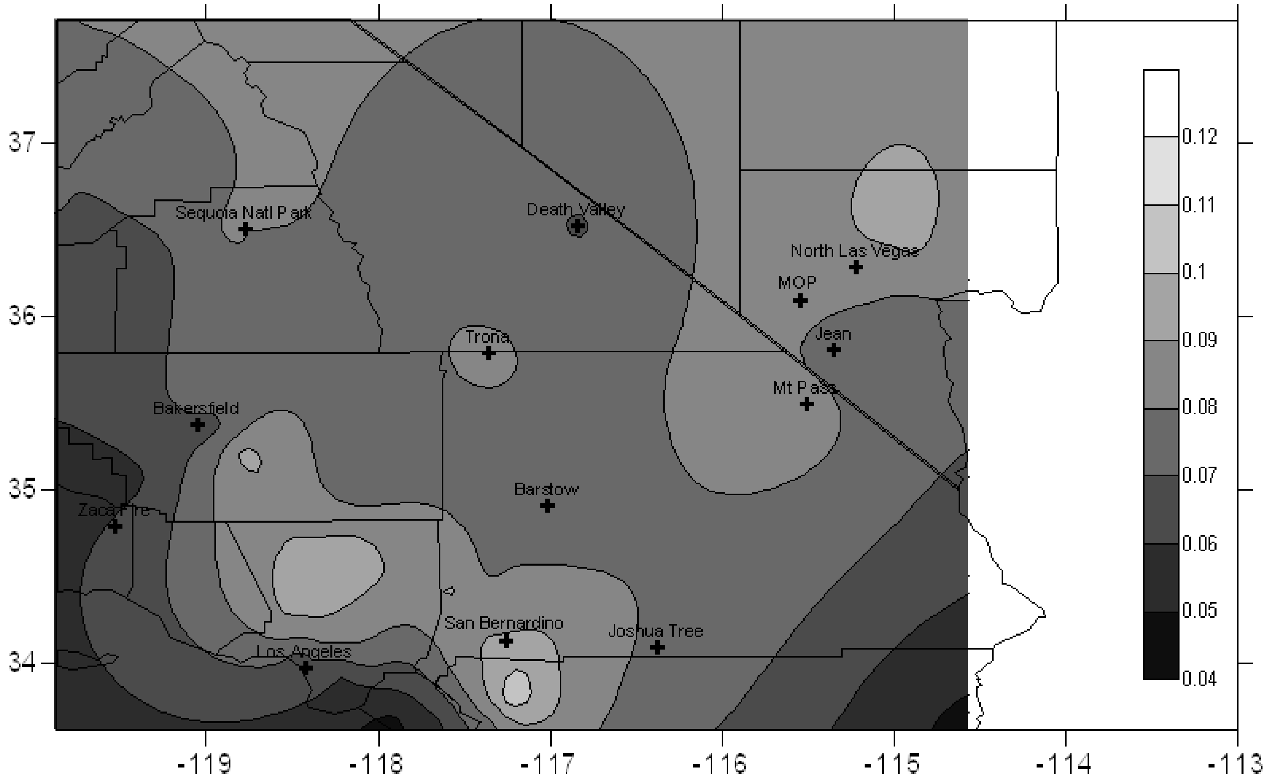

Figure 7-87a. Peak Hourly Ozone (ppm) – June 25, 2007

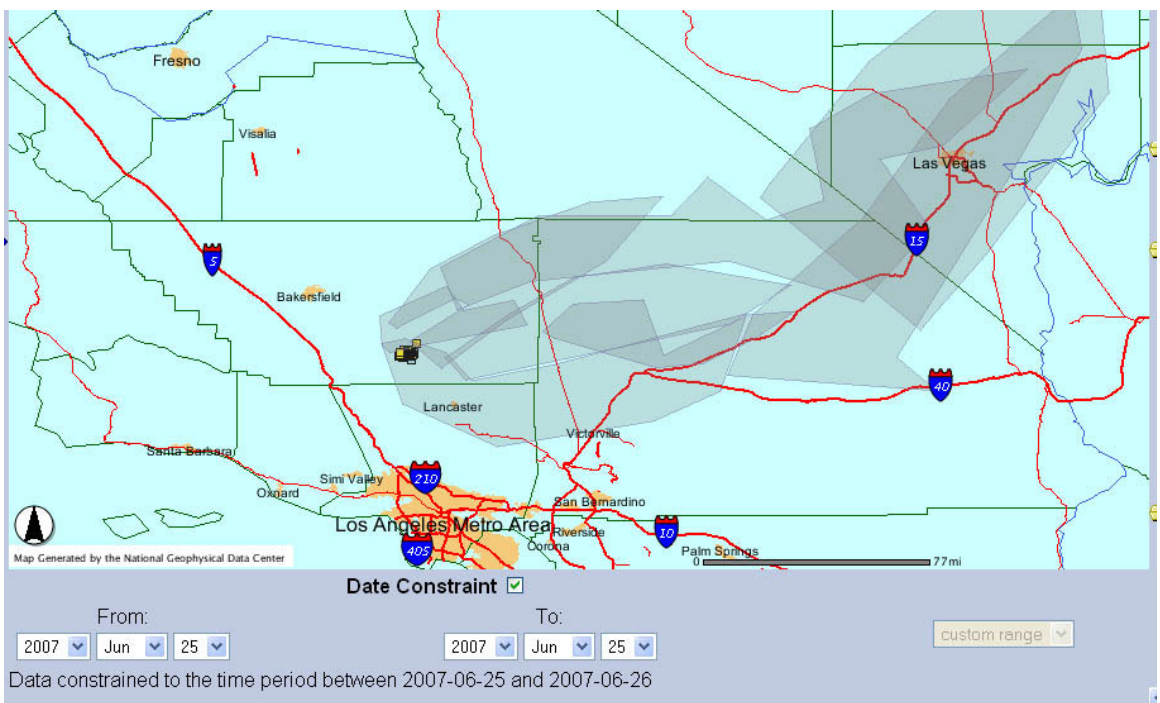

Figure 7-87b. Visible Smoke Analysis during the White Fire

August 8 – August 9, 2007 (Zaca Fire)

Synoptic Description

The synoptic weather patterns affecting the southern half of California and the Great Basin during the Zaca fire IOP on August 8^{th} and 9^{th} are depicted in the NWS 700 mb constant pressure charts shown in Figures **7-88** through **7-91**. Prior to the afternoon of August 8^{th}, the entire Southwest US had been under the influence of a large flat area of high pressure that extended from the Pacific Ocean to the southern Plains. Pressure gradients were weak, producing light and rather variable winds, particularly over the southern Great Basin. However, by the afternoon of the 8^{th}, a weak trough of lower pressure began to extend southward from British Columbia into the northern half of California. These changing conditions developed an increased southerly flow over the California deserts and southern Nevada. A quasi-stationary weak short wave trough that extended the length of California persisted on the 9^{th}. This feature resulted in a generally southerly flow over the region.

Figures 7-92 and **9-93** are plots of two of the rawinsonde soundings from Desert Rock on the 8^{th} and 9^{th}. **Figure 7-94** shows a project-specific sounding taken at Pahrump on the evening of the 9^{th}. The rawinsondes show the evolution of the increasing southerly flow from the very light and variable initial conditions early on the 8^{th} to the consistent southerly flow pattern developing later on the 8^{th} and continuing on the 9^{th}. The rawinsondes also indicate a persistent temperature inversion at approximately 690 mb (~ 3300 m-msl) effectively defining the boundary layer.

The winds aloft suggest that the smoke plume from the Zaca fire was subjected to very light and somewhat variable flow prior to and into the early morning of August 8^{th}. A more organized southerly flow regime developed that likely resulted in a more intact smoke plume transported north. The smoke likely remained in California during this period, drifting into the San Joaquin Valley, or up the Owens Valley and Death Valley.

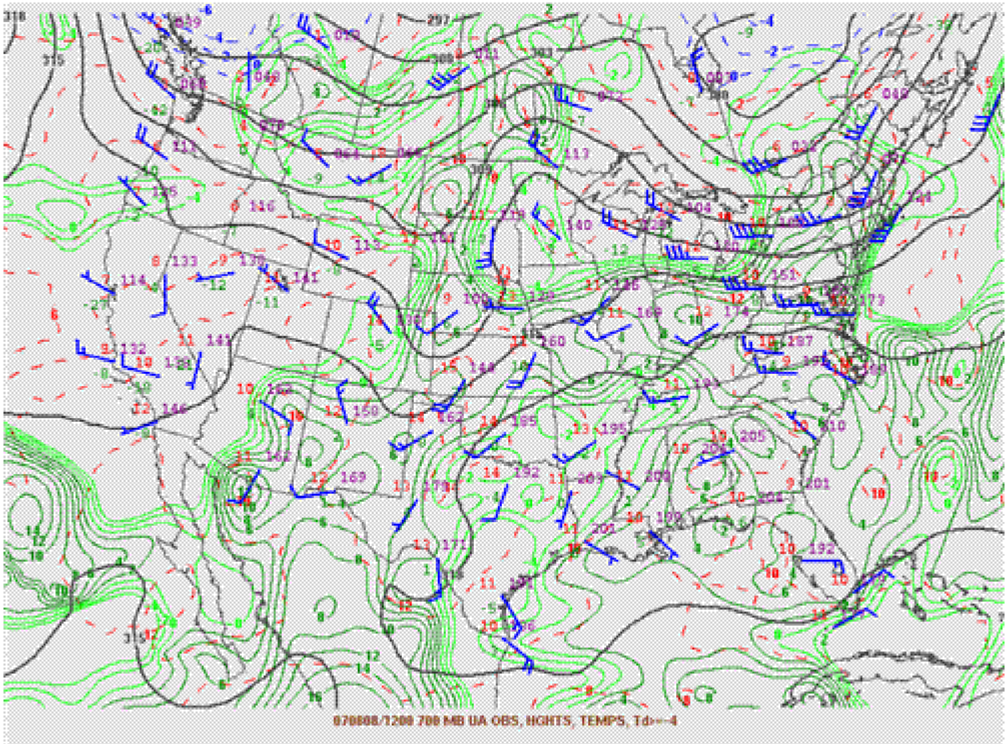

Figure 7-88. 700 mb Analysis for 08/08/07/0400 PST

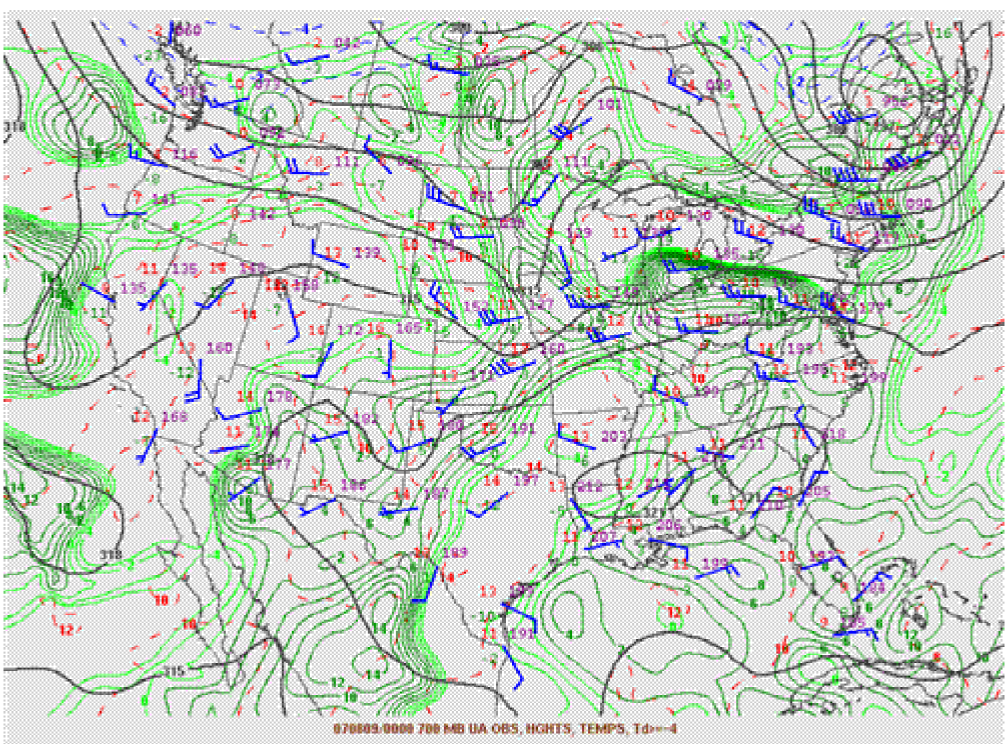

Figure 7-89. 700 mb Analysis for 08/08/07/1600 PST

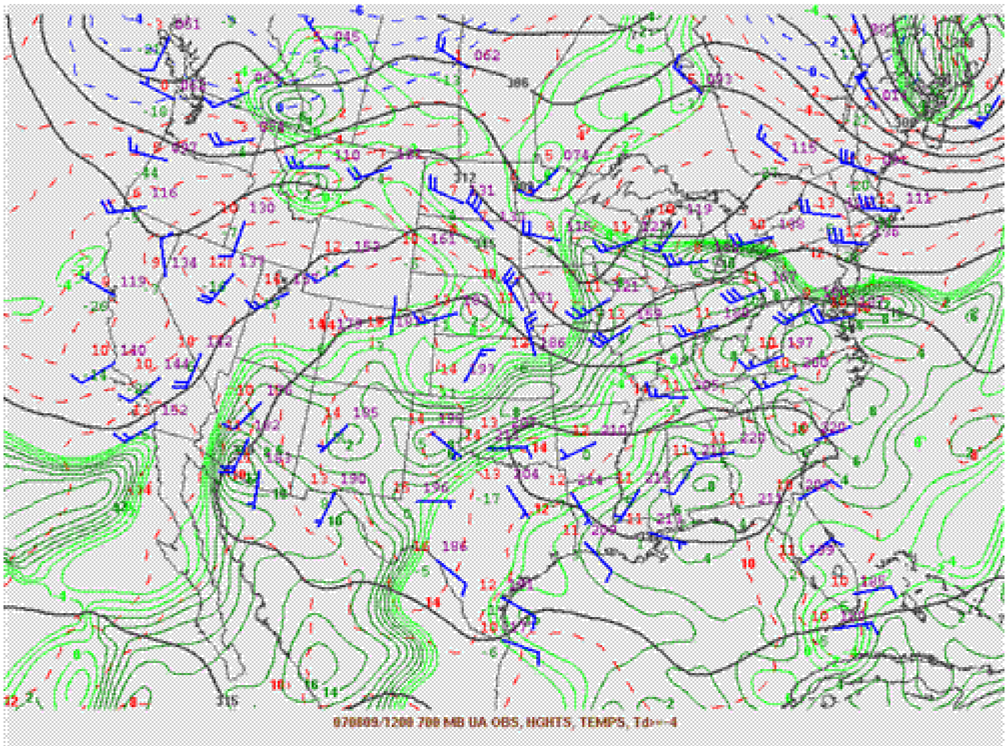

Figure 7-90. 700 mb Analysis for 08/09/07/0400 PST

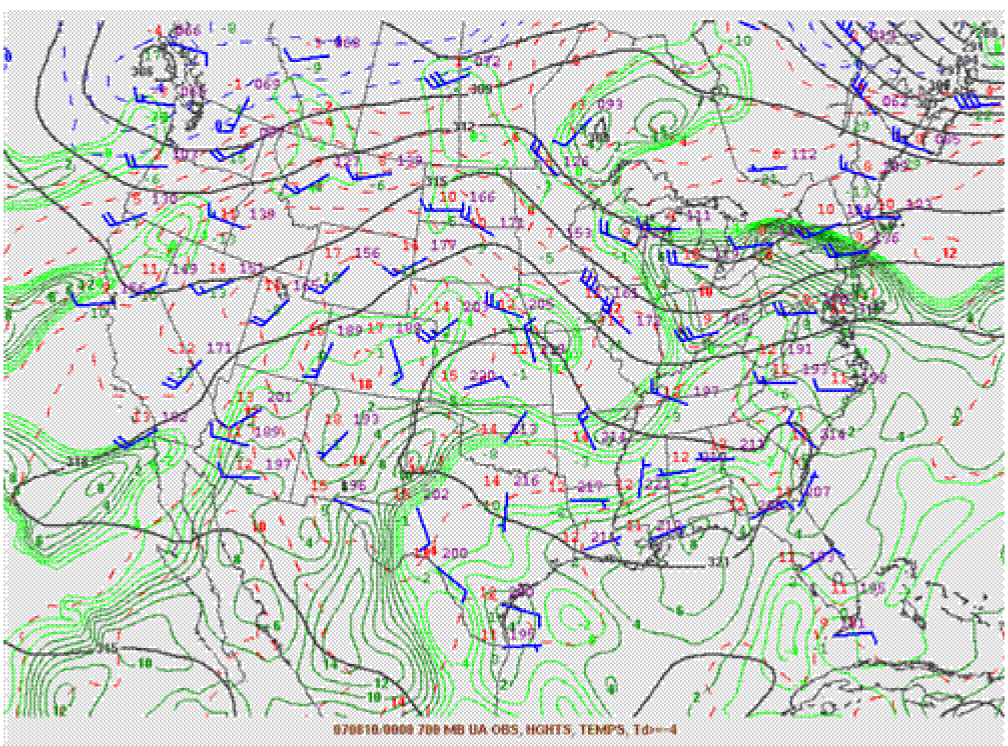

Figure 7-91. 700 mb Analysis for 08/09/07/1600 PST

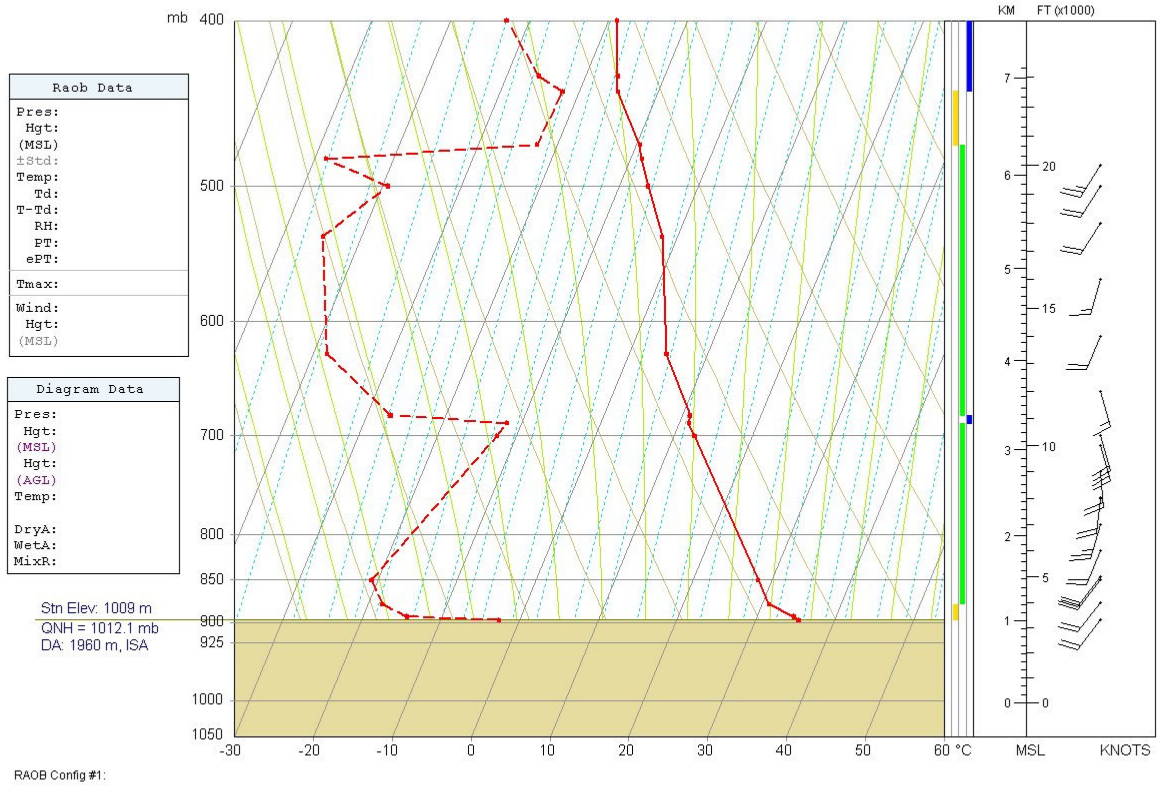

Figure 7-92. Desert Rock Rawinsonde, 08/08/07/1600 PST

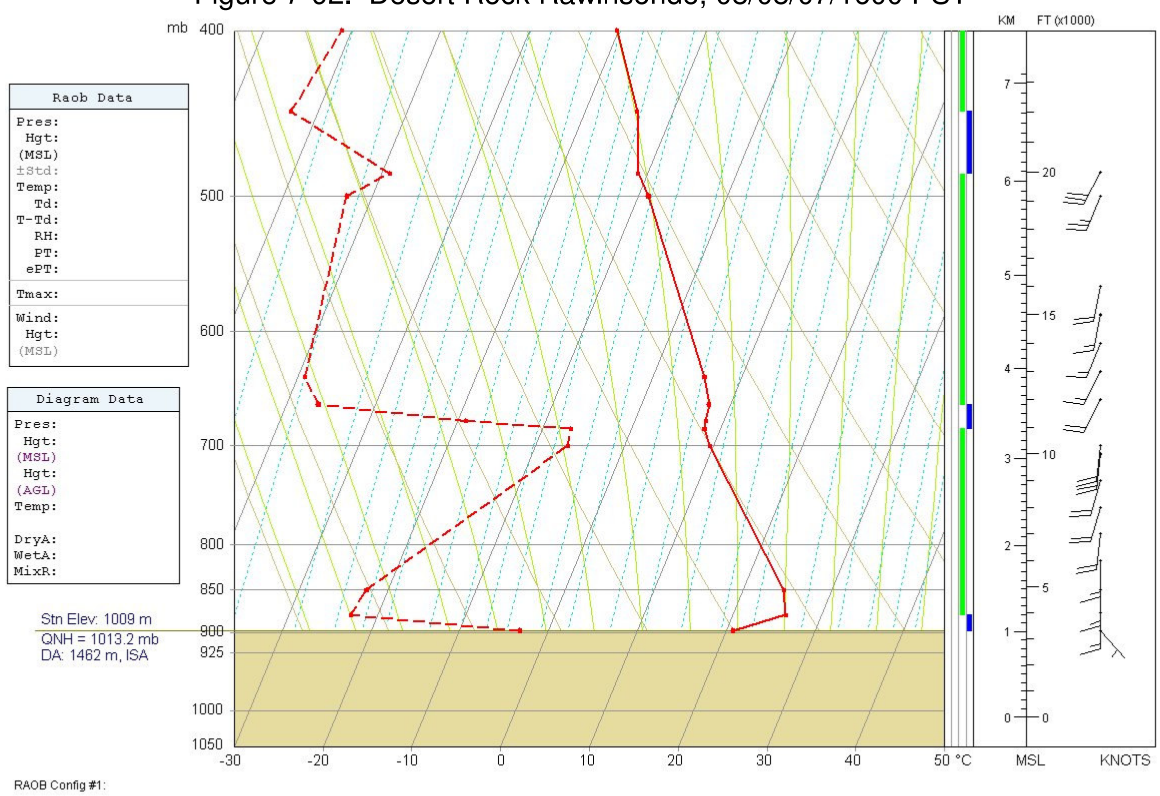

Figure 7-93. Desert Rock Rawinsonde, 08/09/07/0400 PST

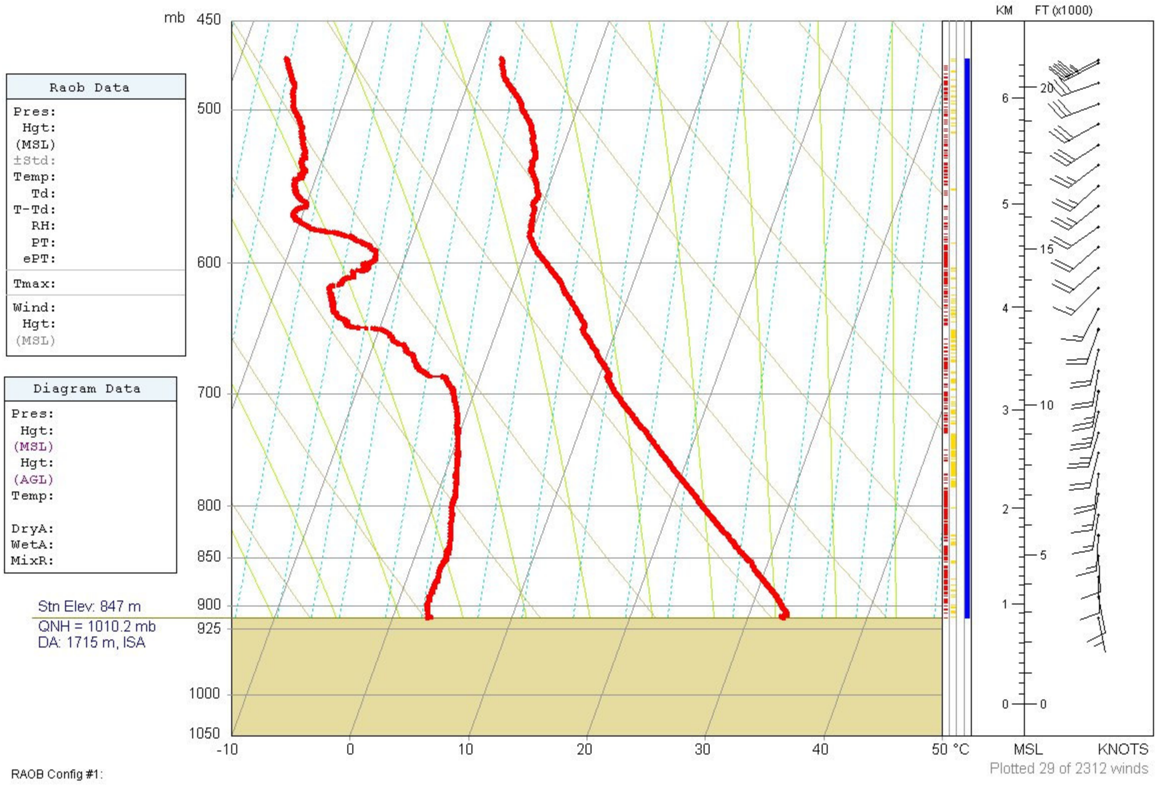

Figure 7-94. Pahrump Rawinsonde, 08/09/07/2000 PST

Aircraft Measurements

The August 8 morning flight began with the sounding out of NLV airport and continued with a traverse to the northwest, paralleling the California/Nevada border (**Figure 7-95**). Figure 7-93 shows the aircraft flight path with the ozone concentrations identified by the color-coding. The highest concentrations are represented by the light blue (60 – 70 ppb), yellow (70 – 80 ppb) and red (greater than 80 ppb). About 25 miles northwest of Beatty, the flight path turned southwest to the top of Death Valley, then to the southeast down Death Valley to Furnace Creek, where a second sounding was performed. This sounding showed the ozone and PM to be at a level of 2000 meters and below. The traverse then continued down Death Valley at an altitude of about 1400 meters where the smoke plume was identified by both significant $PM_{2.5}$ and ozone peaks. Continuing further to the southeast out of Death Valley to I-15, ozone and PM levels defined the extent of the smoke plume. A minor secondary ozone plume was identified near the southern most extent of this traverse, which may have been due to a transported urban plume from Southern California. This plume did not have the associated rise in $PM_{2.5}$ concentrations as was observed in wildfire plumes. Notable during the flight was the identification of the smoke plume and the increase in ozone of about 20 ppb over the values on either side of the plume. This is significant considering the fire was over 200 miles distant. **Figure 7-96** shows the time series plot with the numerical locations on the Figure 7-93 map identified on the plot.

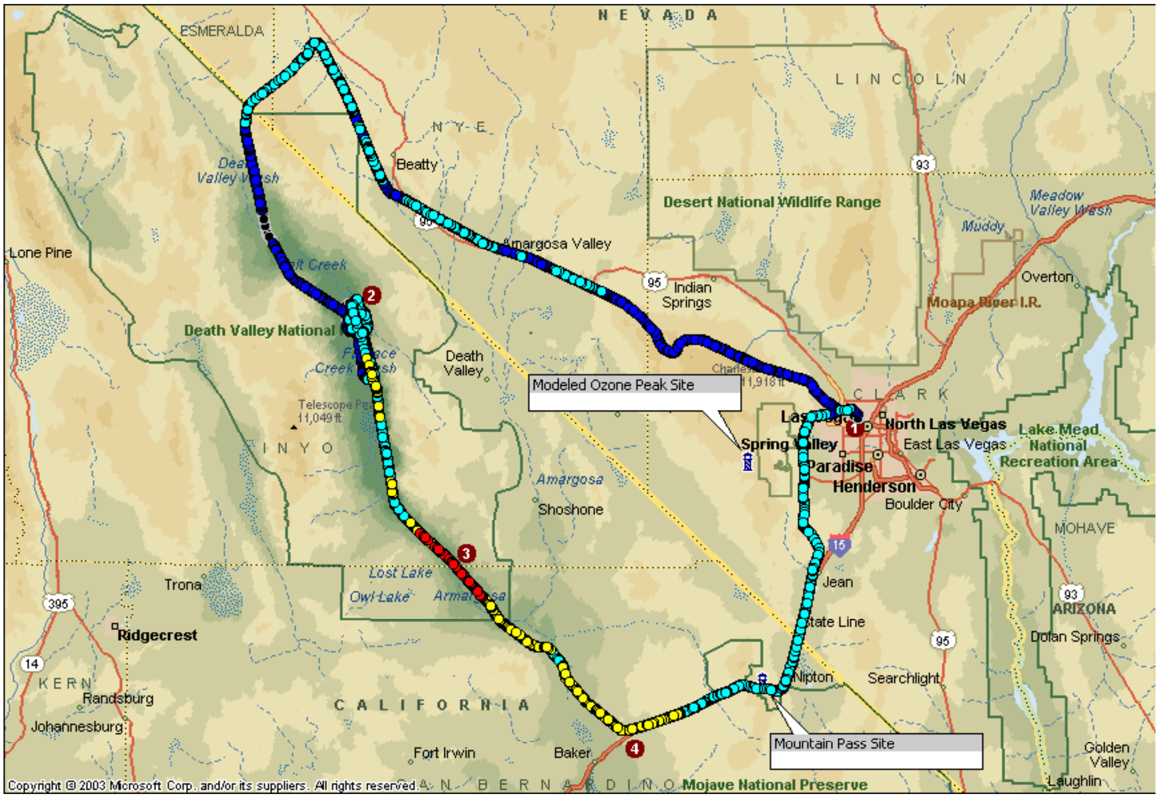

Figure 7-95. Flight Path and Ozone Concentrations Observed from the Aircraft during the Morning of August 8

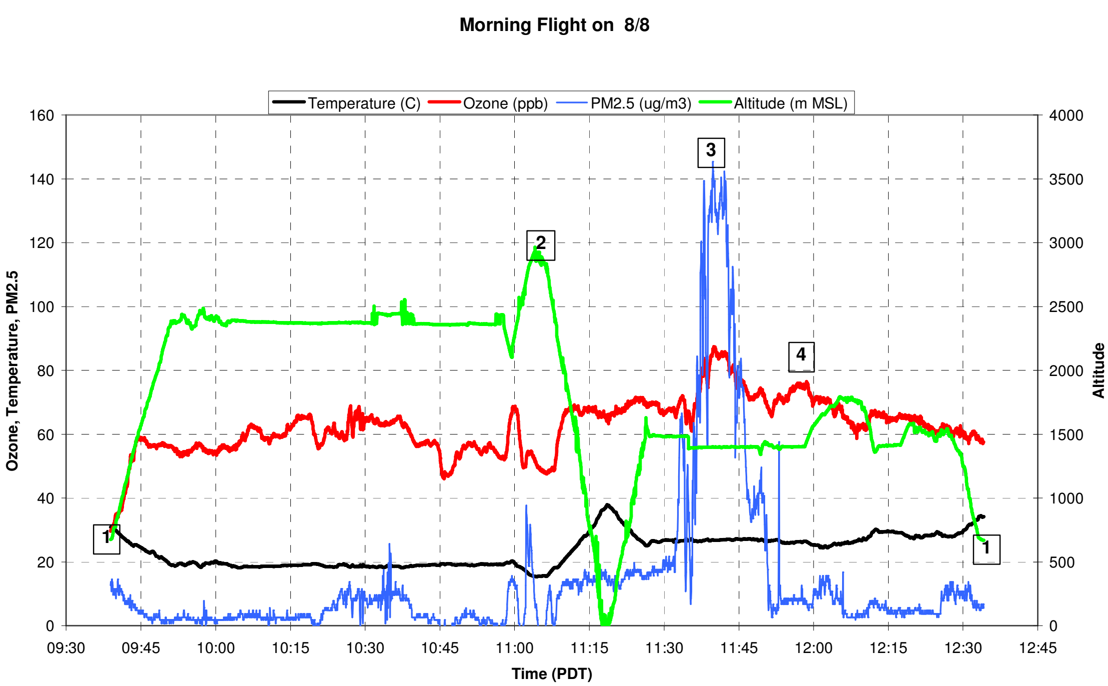

Figure 7-96. Time Series Plot of the Morning Flight on August 8

The August 8 evening flight began with the usual sounding out of NLV airport. The flight path then went generally southwest to Death Valley, crossing near the MOP site. The aircraft then traversed Death Valley to the northwest, with relatively low observed ozone values but notably increased $PM_{2.5}$ concentrations more likely associated with smoke than with the Las Vegas Valley air mass. With the overall values being relatively low, the flight turned back to the Las Vegas Valley along I-95 after exiting Death Valley on the north. The highest values for both ozone and $PM_{2.5}$ were seen in the northwestern part of the flight. It appeared that the smoke plume had moved far to the north of Clark County. **Figure 7-97** shows the aircraft flight path with the ozone concentrations identified by the color-coding. **Figure 7-98** shows the time series plot with the numerical locations on the map identified on the plot.

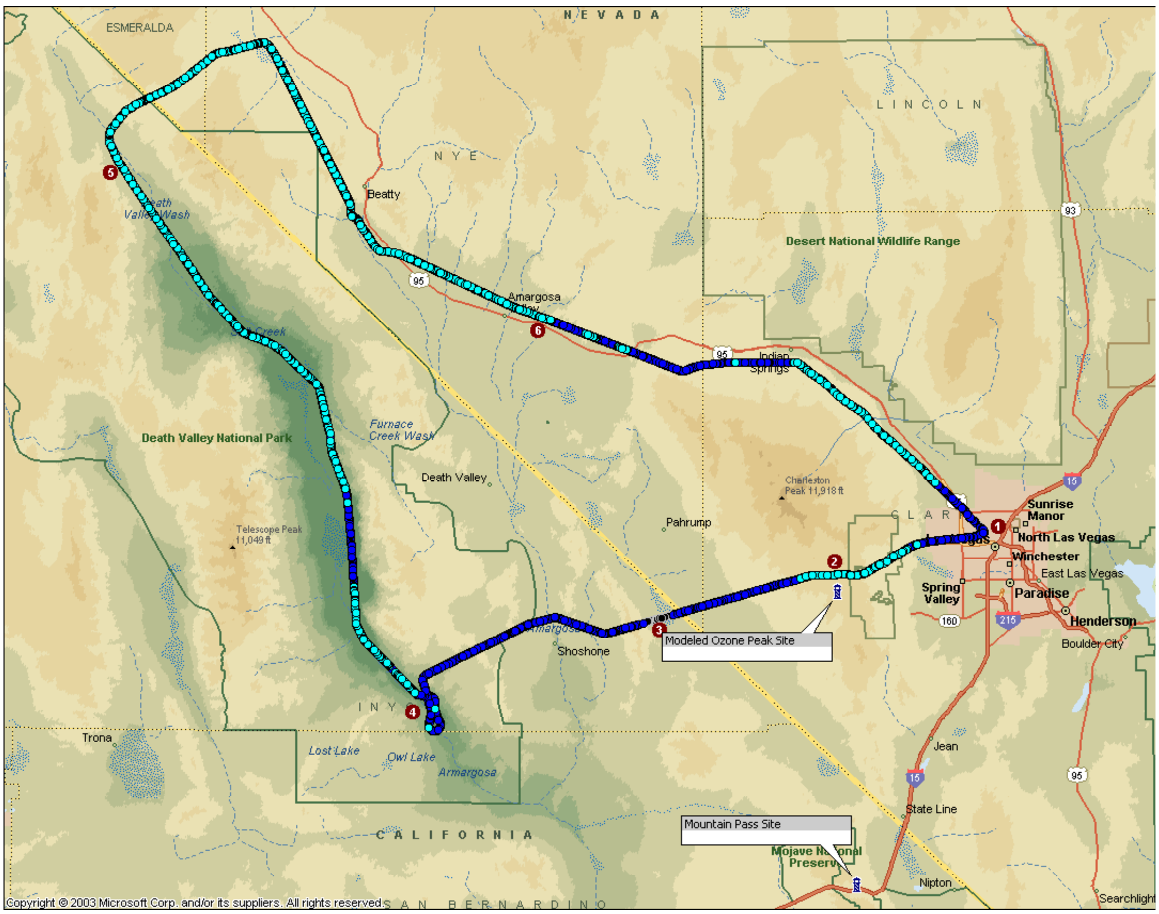

Figure 7-97. Flight Path and Ozone Concentrations Observed from the Aircraft during the Evening of August 8

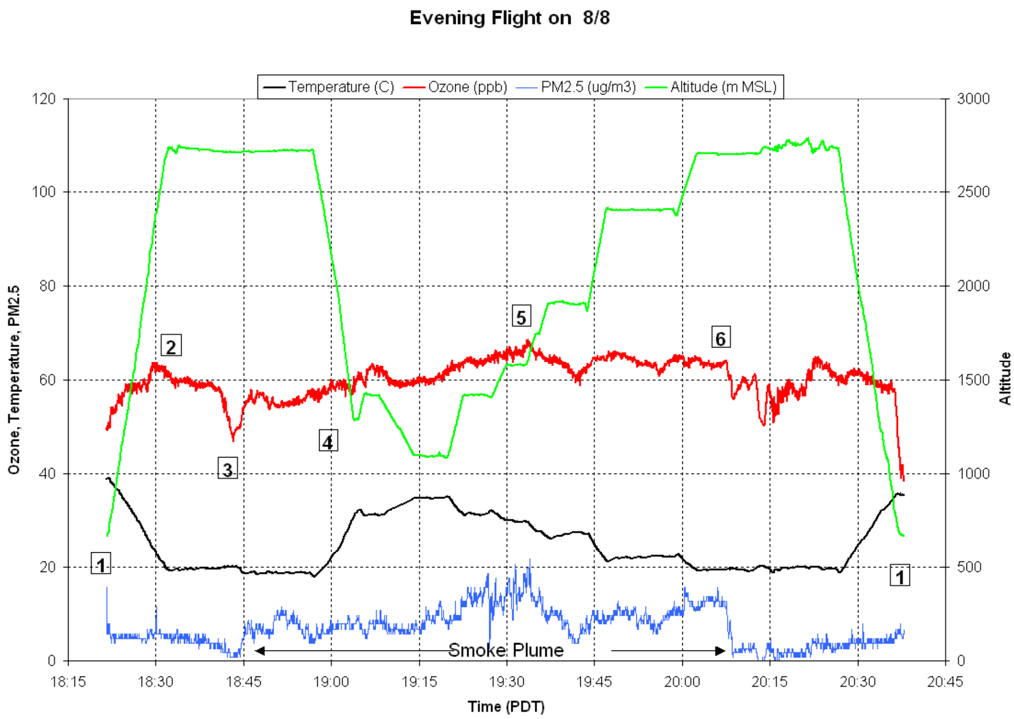

Figure 7-98. Time Series Plot of the Evening Flight on August 8

On August 9, the winds had a southerly component, which accounted for the turn of the plume to the north prior to reaching the California/Nevada border. This flight noted what appeared to be two different ozone plume characteristics. The plume at the southern end was not tagged with $PM_{2.5}$, and may have been more due to transport from SoCAB whereas the plume to the northern part of the flight had a $PM_{2.5}$ tag which marked the fire related ozone.

A map of the sampling route and ozone measured is shown on **Figure 7-99**. Time-series plots of the measurables are given on **Figure 7-100.** The flight began with the sounding out of the NLV airport, crossing near the MOP site, and continuing southwest to Death Valley. A minor peak in ozone was observed in the southern end of Death Valley that was not associated with any increase in the $PM_{2.5}$. The traverse then continued through Trona and to the south of Ridgecrest, turning to the north for a traverse toward Bishop. The highest concentrations in both ozone and $PM_{2.5}$ were observed at the southern most location prior to heading up the Owens Valley. Decreased ozone and $PM_{2.5}$ were observed in the southern to middle portions of the Owens Valley with increases in both $PM_{2.5}$ and ozone north of the town of Lone Pine. A broad peak for both ozone and $PM_{2.5}$ was observed between Independence and Big Pine, which appeared to be of fire origin. A sounding was then performed at Bishop from the surface at Bishop Airport to about 4,375 meters (~14,300 feet). The sounding showed a well-mixed column of air from just above the surface to the top of the sounding with a layer of slightly increased $PM_{2.5}$ from about 3500 meters (~11,500 feet) to the top of the sounding. This suggests that a portion of the smoke plume was aloft, but there was not much change in the concentrations of ozone. What was observed was a very deep layer (likely above the top of the observed sounding) of ozone (70 to 75 ppb) and $PM_{2.5}$. The fact that the layer is very deep (to at least 14,000 feet) would account for the lower ozone values when compared to prior observations with ozone in the 80 to 90 ppb range and higher with relatively shallower mixing depths. It is suspected that the topography with mechanical mixing in the lee of the Sierras may account for the deeper mixing of the ozone and PM.

Figure 7-99. Flight Path and Ozone Concentrations Observed from the Aircraft during the Evening of August 9

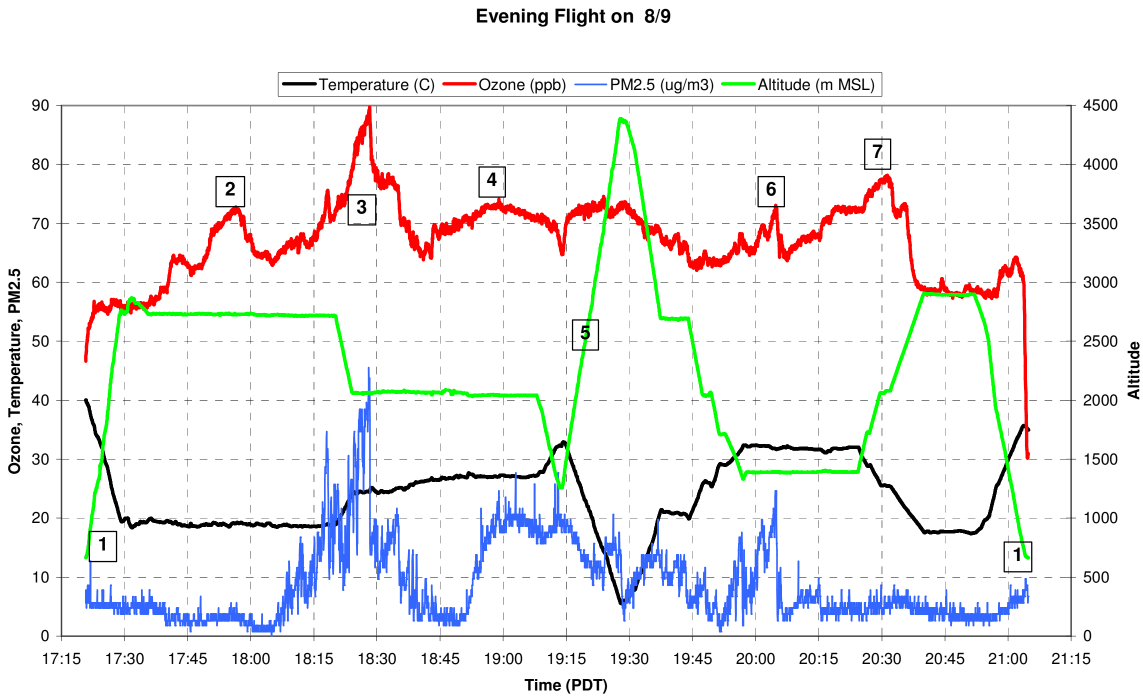

Figure 7-100. Time Series Plot of the Evening flight on August 9

7.2.2 Analysis of 2007 Exceedances

August 21

There were only three exceedances in Clark County during the periods the White and Zaca fires in California were active: June 27, July 28, and August 21. As noted above, the June 27 exceedance was a good case for urban transport from California and the July 28 exceedance under stagnant conditions that often result in increased ozone concentrations from local sources. The August 21 exceedance has a number of circumstances that set it apart from being due to local sources:

- The exceedance occurred only at Apex, which is very unusual in the historical record.
- While an exceedance only occurred at Apex, high readings concurrent with those at Apex were experienced throughout the Las Vegas Valley (see **Table 7-5**). This basin-wide response is classic for transport scenarios (in this case the possible transport of smoke).
- Peak ozone concentrations throughout the network were typically 15 to 20 ppb higher on August 21 than they were on August 20.
- The exceedance occurred near the end of August, which is very late in the traditional Clark County ozone season.

Table 7-5. Hourly Ozone Concentrations in Clark County on August 21, 2007

	9	10	11	12	13	14	15	16	17	18	19	Peak 8-hr
Apex	52	68	82	87	88	88	92	91	84	54	42	85.0
Craig Rd	53	54	62	79	88	82	88	89	79	52	32	77.6
JD Smith	44	56	67	81	91	93	96	94	80	45	28	82.3
Jean	69	78	78	74	77	81	83	83	76	68	67	78.8
Joe Neal	59	60	57	71	86	91	89	87	73	57	35	76.8
Lone Mt.	57	65	70	79	85	82	78	76	71	50	46	76.8
Mesquite	38	49	50	55	61	63	64	58	46	36	23	55.8
Orr	32	45	58	76	90	95	91	79	66	49	51	75.5
Paul Meyer	48	62	74	82	81	79	79	76	77	74	56	77.8
SE Valley	31	51	68	82	82	87	82	74	72	72	77	78.5
Walter Johnson	58	68	77	86	84	80	79	77	72	63	47	77.9
Winterwood	33	45	57	82	86	88	90	84	73	52	37	76.5

Evidence that this exceedance was influenced by smoke is mixed. Unfortunately, satellite smoke analysis is missing for August 21. Smoke analysis for August 20 show a dense plume moving to the east towards Las Vegas, and analysis for August 22 show a well defined plume impacting Clark County (**Figure 7-101**). 24-hour back-trajectories (**Figure 7-102**) are mixed, showing favorable transport winds from the Zaca fire area on August 20 and 22, but lighter wind on August 21. Upper air winds measured by the North Las Vegas radar profiler were lighter on August 21, confirming the shorter HYSPLIT trajectories. Surface winds measured at North Las Vegas averaged 1.6 m/s in contrast to 2.5 m/s on August 20. These low wind speeds traditionally have favored locally impacted exceedance events.

However, the 48-hour forward trajectory from the Zaca fire (**Figure 7-103**) shows the distinct possibility that smoke could have been transported to Clark County. The trajectory begins with light winds, consistent with the smoke analysis for August 20 (**Figure 7-104**), followed by higher wind speeds that may have brought the accumulating smoke into Clark County. Time-lapse movies from the camera located at the North Las Vegas radar profiler site show a layer of what appears to be smoke moving into the area throughout the mid-day hours of August 21, following the back-trajectory identified in Figure 7-100. While the possibility remains that this could be a layer of very thin, disorganized high clouds, the layer is not present in the time-lapse movies for August 20. While identification of the layer requires movement that still photographs cannot provide, photographs of the two days show the overall reduction of visibility and the bleached sky associated with the identified layer (Figure 7-102)

Figure 7-105 shows peak hourly ozone contours for August 21. Once again, the traditional buildup of ozone in the Los Angeles basin is apparent. However, there is also considerable buildup of ozone east of the Zaca fire, with a plume-like structure spreading eastward toward Death Valley and into Clark County, somewhat consistent with what would be expected from a plume from the Zaca fire following the trajectory in Figure 7-101. However, the generally high buildup of ozone throughout southern California certainly brings up the possibility of an urban plume contribution.

In summary, evidence for a contribution from wildfires to the exceedance at Apex on August 21 is mixed, with some evidence supporting transport of smoke from the Zaca fire to Clark County, and other evidence supporting more local influences. A combination of the two most likely led to this unusual exceedance.

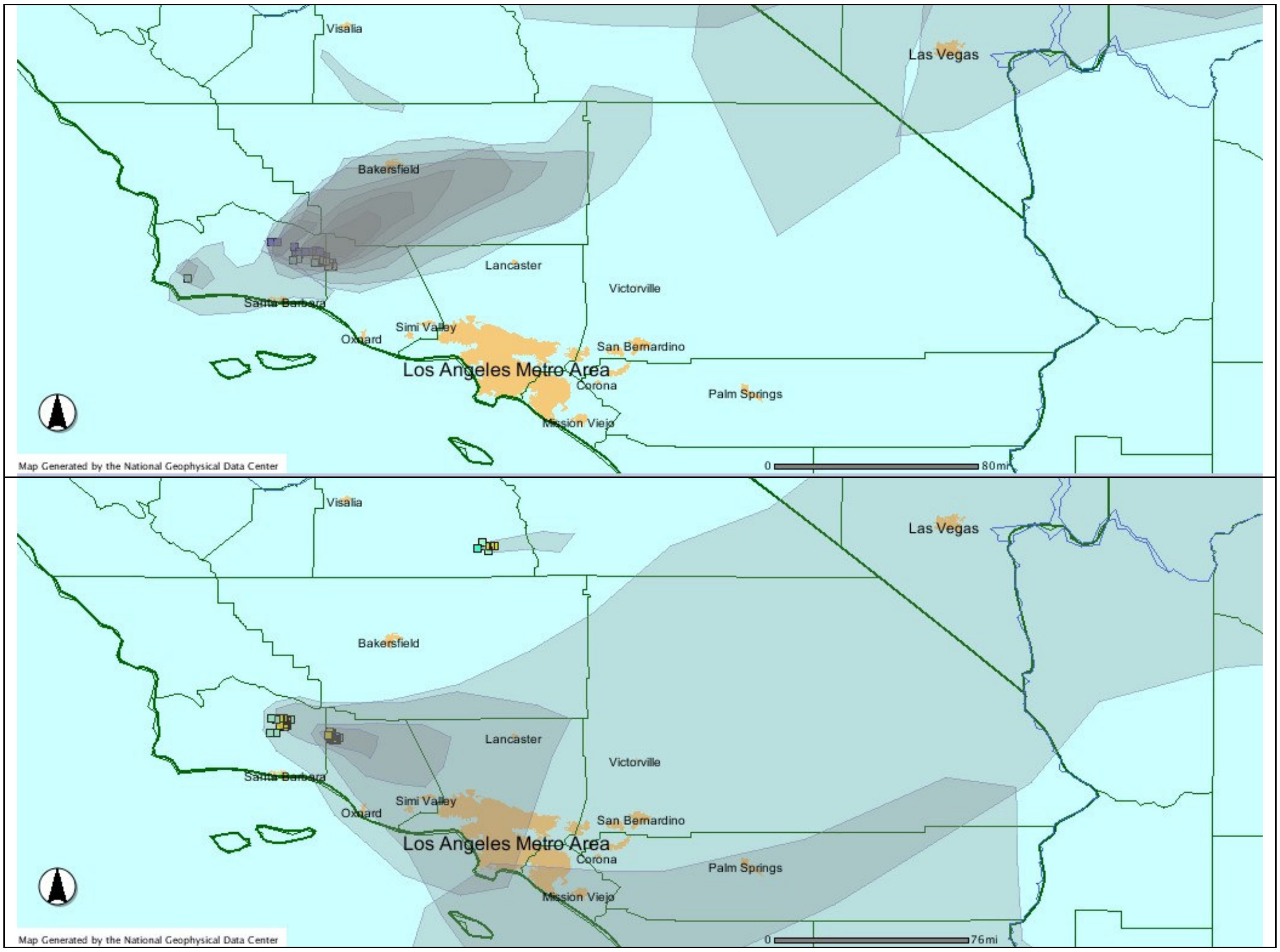

Figure 7-101. Satellite Smoke Analysis for August 20 (top) and August 22 (bottom)

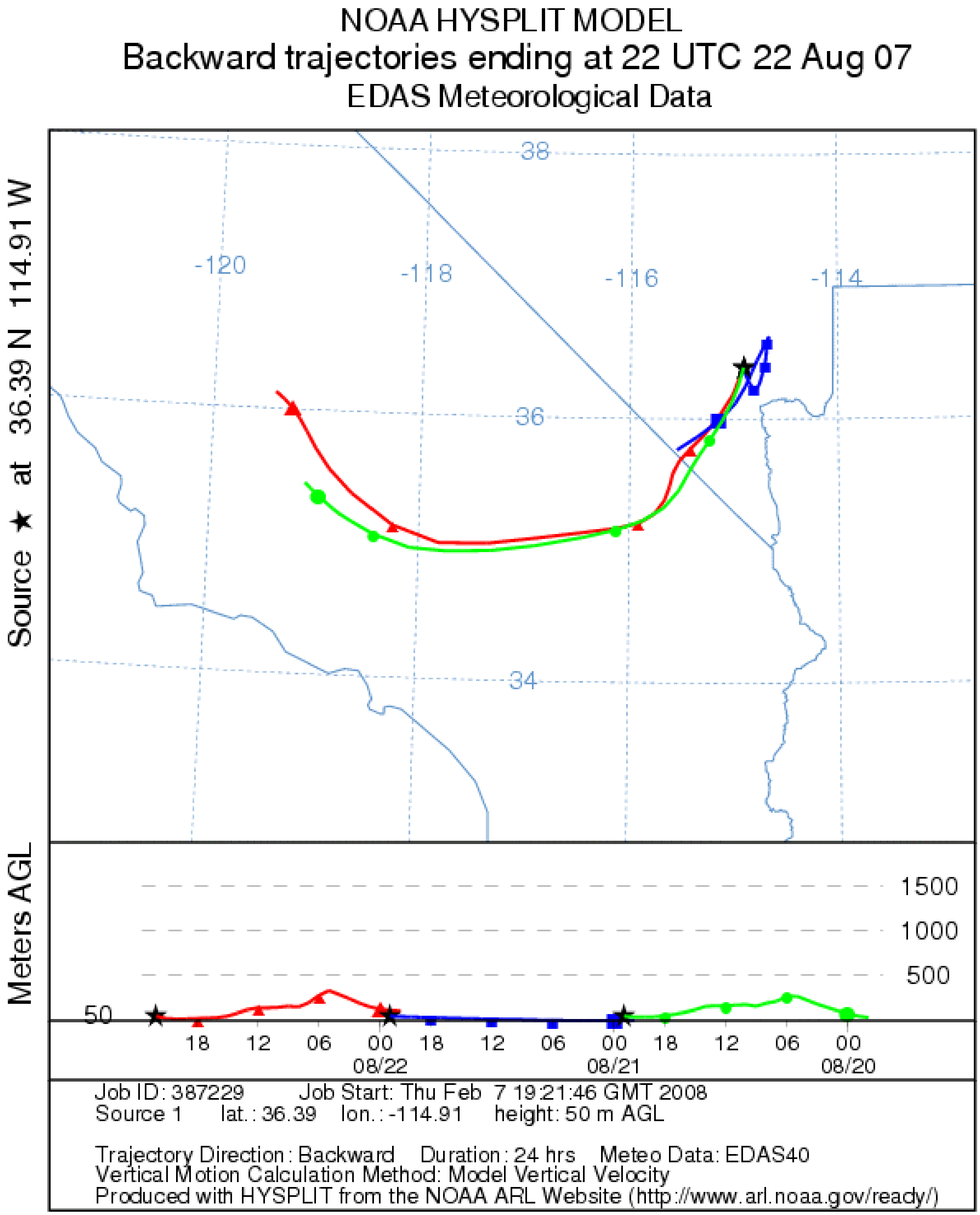

Figure 7-102. 24-hour Back-trajectories during August 21 Exceedance

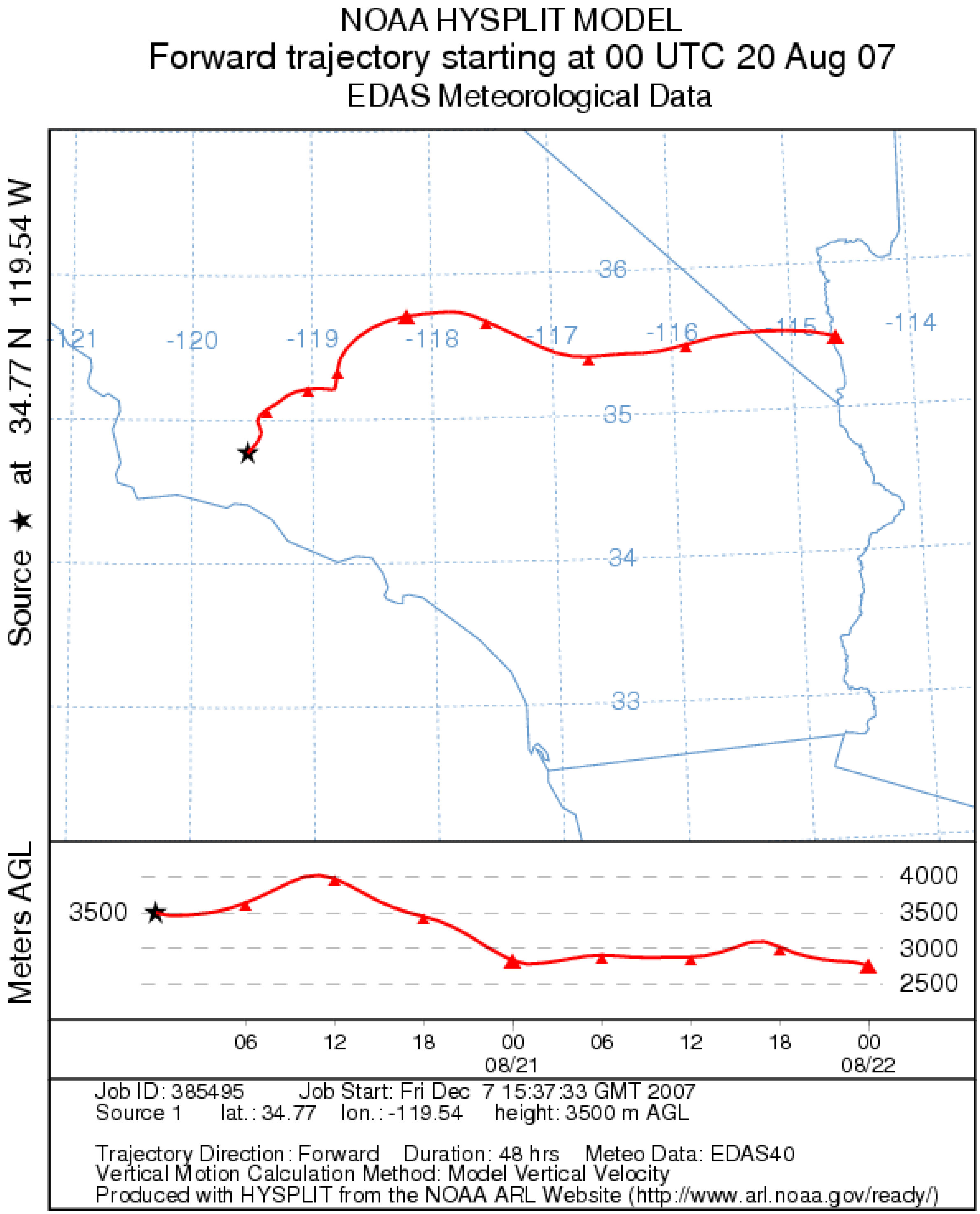

Figure 7-103. 48-hour Forward-trajectory from the Zaca Fire Ending August 21, 1600 PST

20.08.07 14:02:02

21.08.07 14:01:37

Figure 7-104. Photos From NLV Airport Showing Sky to the Southwest

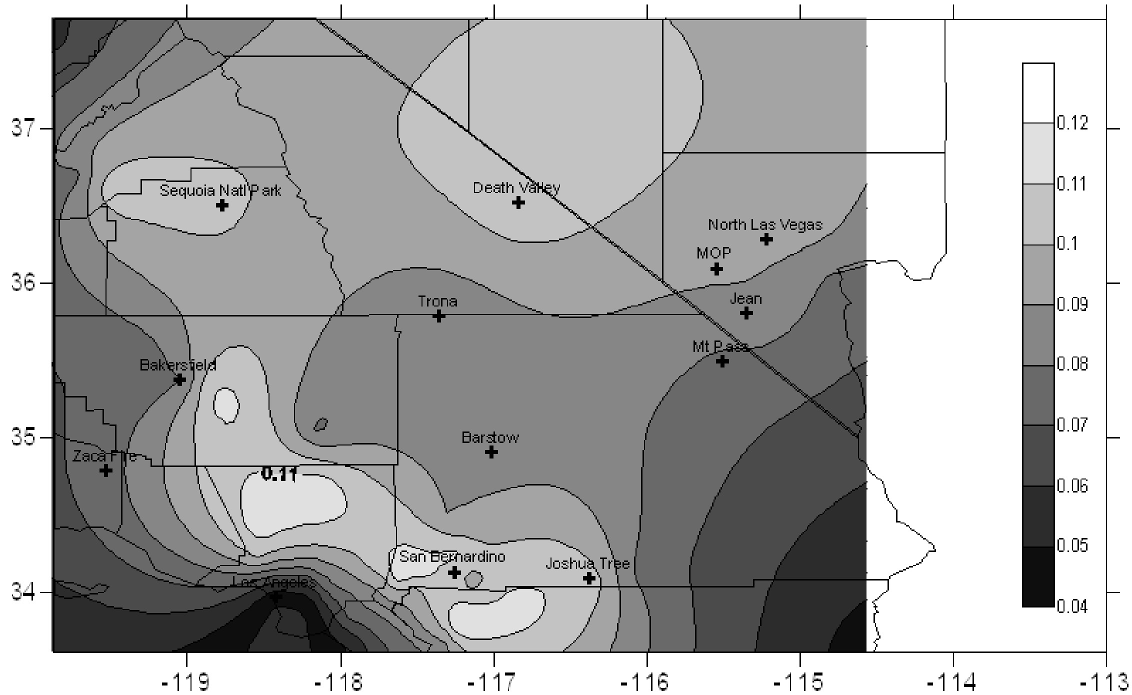

Figure 7-105. Peak Hourly Ozone (ppm) – August 21, 2007

7.3 Exceptional Events Protocol

The Environmental Protection Agency is currently reviewing proposed rule changes to their National Ambient Air Quality Standards (NAAQS). As a part of the review, they are currently developing new standards for natural and "exceptional" events such as wildfire. Both prescribed fires and wildfires use produce smoke that is often in violation of state air quality standards; classifying these incidents as natural or exceptional events would allow states more flexibility in applying air permitting and fire management practices. Smoke from wildfire events contains ozone precursors which under certain conditions can elevate surface ozone levels above the NAAQS. The challenge for regulatory agencies is to develop the capability to document those instances. Not only will local air quality regulatory agencies thus not be penalized for events they have no control over but, in this process, the knowledge necessary to forecast in advance imminent public health risks will be gained.

The objective of this section is to provide preliminary standard procedures for documenting potential periods during which local air quality has been significantly impacted. The documentation must provide an adequate body of scientific evidence for Federal and State regulators to determine whether or not the exceedance would have occurred had the wildfire(s) not been a major contributor to the local ozone burden. These procedures are preliminary and dynamic in that, as experience is gained, they will be modified and added to as necessary.

In this section, various tools routinely available on the Internet and locally for forecasting and documenting a potential exceptional wildfire event are discussed and measurements that should be included in the body of evidence are detailed. A procedural list of daily tasks are recommended to identify periods when wildfires can potentially have a significant impact on local air quality, and the actions to be taken after the potential has been identified.

7.3.1. Internet Products

7.3.1.1 Real Time Monitoring of Fire Events

Real-time information regarding wildfire events is provided by the USDA Forest Service, NOAA and State agencies such as the California Department of Forestry (CDF). Information available from Forest Service products is best illustrated by the MODIS mapping chart shown on **Figure 7-106**. On the figure, both active and prior burns are shown. Locations of prior burns are important because they are a potential indication of smoldering fires. Smoldering fires involve the slow combustion of surface fuels without generating flame, spreading slowly and steadily. They can linger for days or weeks after flaming has ceased, resulting in potential large quantities of fuel consumed and becoming a global source of emissions to the atmosphere. MODIS is an imaging satellite system that has a wide viewing swath such that it sees every point on our world every 1 to 2 days in a number of spectral bands enabling it to track a wider array of the earth's vital signs than any other earth sensor. Anomalous hot spots as shown on Figure 1 are one of the MODIS products. Another MODIS product provided by NOAA is high-resolution imaging of smoke plumes. These maps provide tracking of smoke plumes over a large area, and can be easily downloaded and archived to document wildfire plume trajectories. A dramatic example is shown on **Figure 7-107** which shows a large number of wildfire plumes over Idaho in 2007 that obviously impacted a large area. A more relevant example of wildfires in California and southern Nevada impacting the air quality in Clark County is shown on **Figure 7-108.**

The CDF provides daily updates on the status of all wildfires in California that include the area burned, date the fire started and status of containment. An example of the information provided and format of this CDC Internet page is shown in **Figure 7-109**.

Another particularly useful web-based product NOAA provides for detecting and documenting the potential of impacts from wildfires is composite imaging from visual satellite pictures as shown in **Figure 7-110**. Features which make these products particularly useful are the ability to select the areal scale and geographic features shown (i.e. state and county boundaries, roads, etc), and the ability to generate composite of smoke plumes from more than one day, or even the entire fire season. The images are not easily archived electronically. The image in Figure 7-110 was captured by pasting a screen image into a photo editor and cropping before saving as an image file.

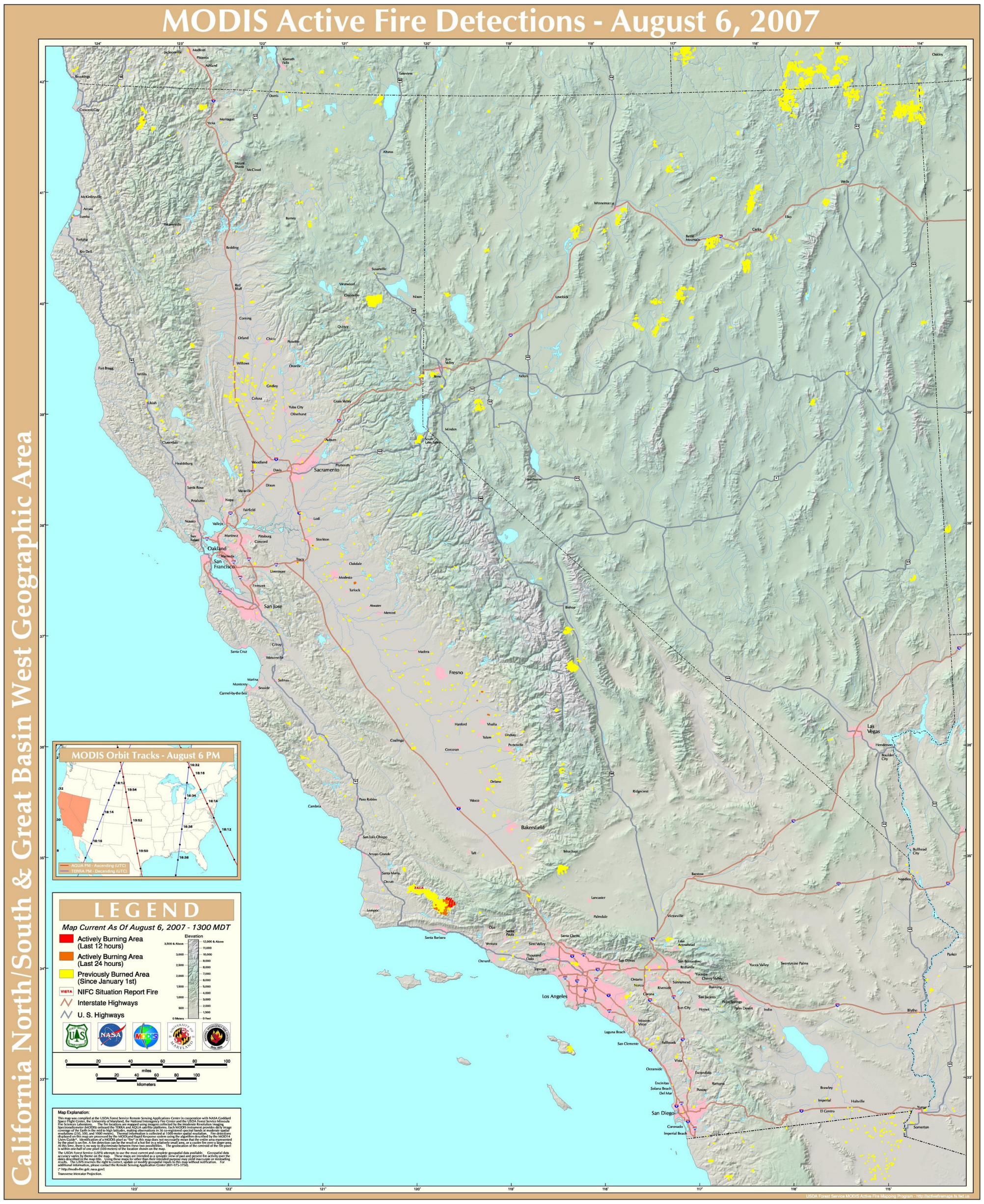

Figure 7-106. Example of MODIS Active Fires Map

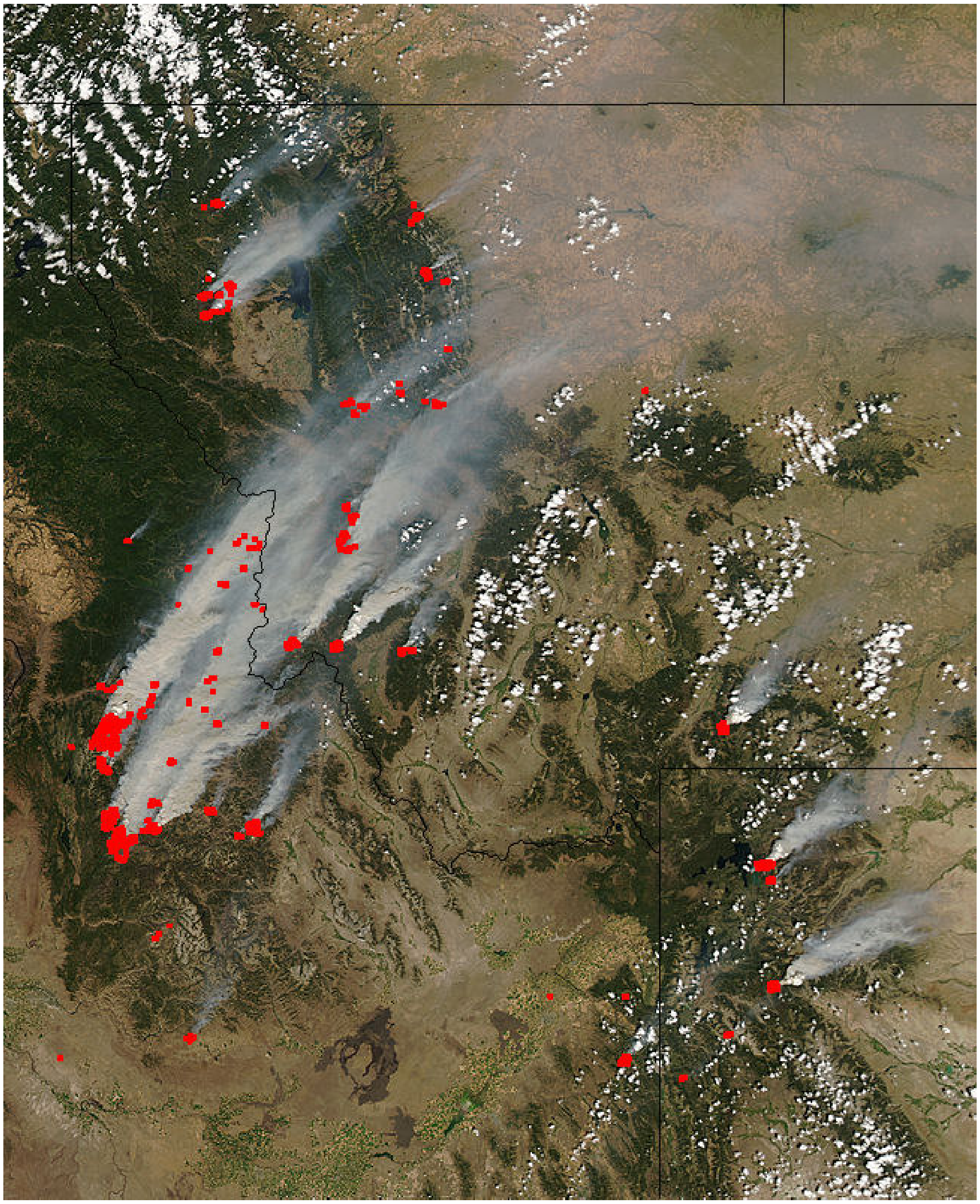

Figure 7-107. Example of MODIS Image Showing Wildfire Plumes over Idaho

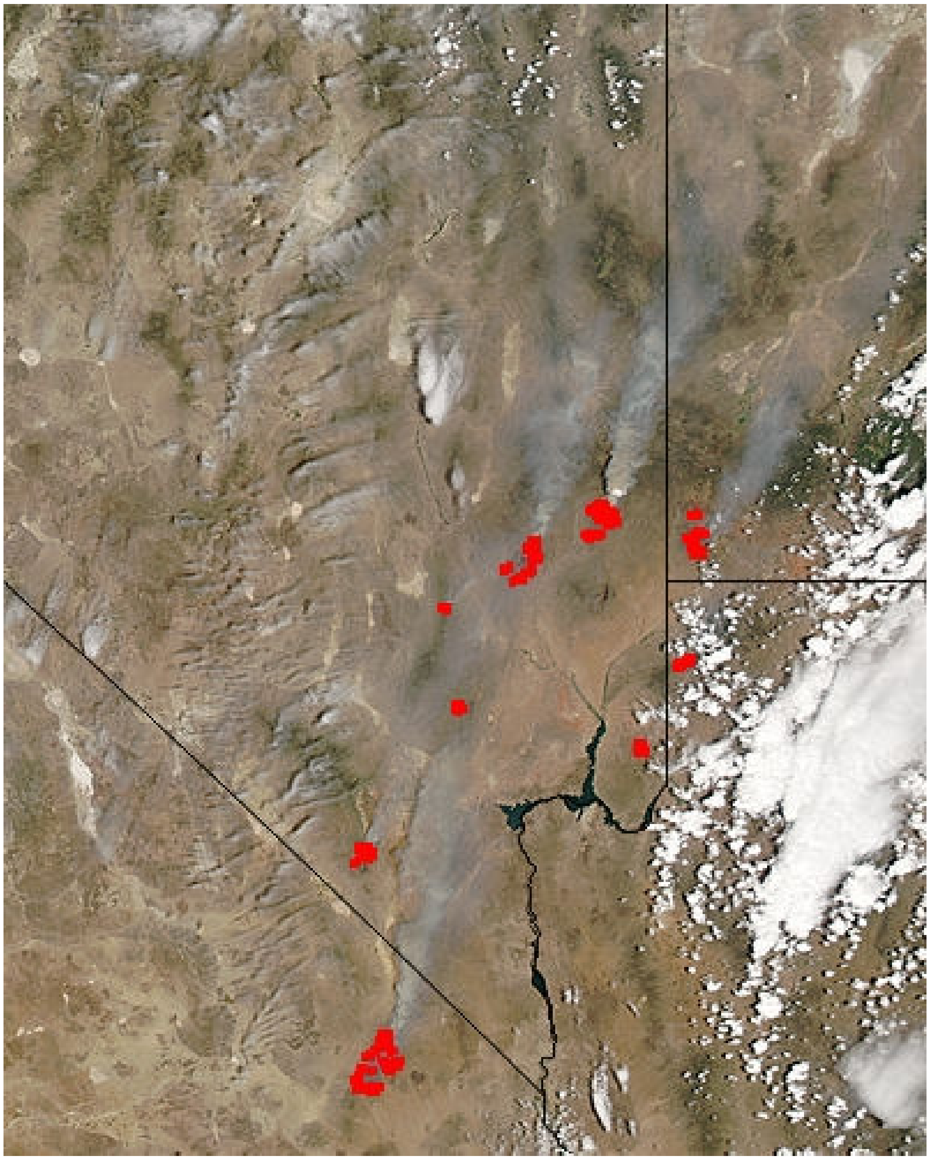

Figure 7-108. Example of MODIS Image Showing Wildfire Plumes Impacting Clark County During an Ozone Exceedance Event

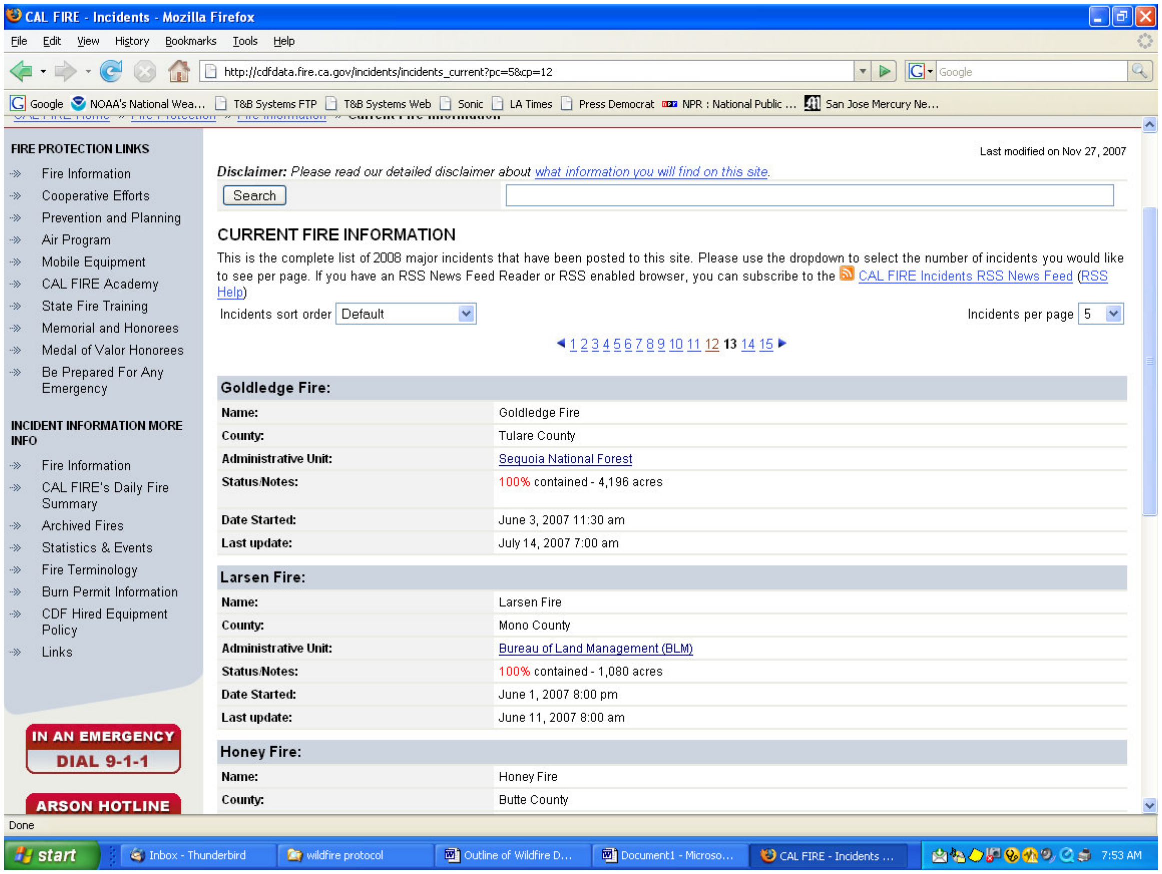

Figure 7-109. Example of CDC Current Fire Information Web Page

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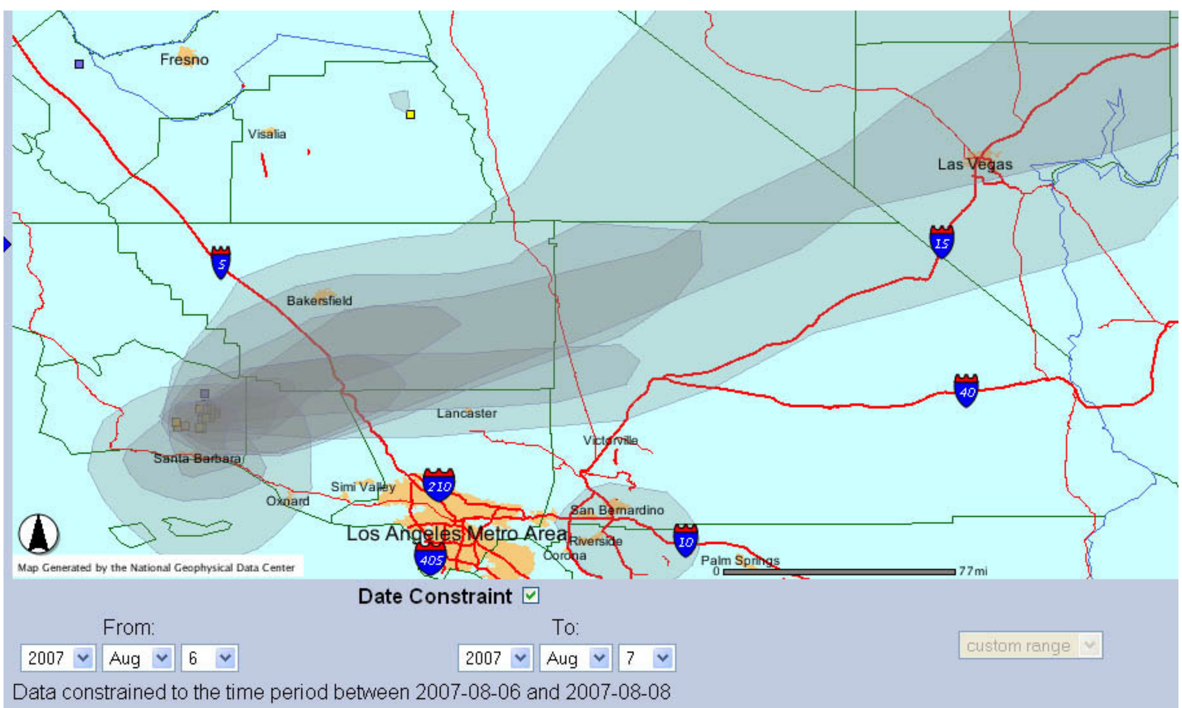

Figure 7-110. Example of NOAA's SSD Fire Detection and Plume Map

7.3.1.2 Forecast Tools

Wildfire plume transport and dispersion forecasts are also available on the Internet. Smoke forecasts are produced by NOAA's Air Resources Laboratory using the Ready HYSPLIT dispersion model. The dispersion model is preconfigured to run over the entire country once-a-day using the daily meteorological forecast. Hourly average output maps of primary $PM_{2.5}$ air concentration are produced using the actual fire locations from the previous day. Simulations are carried out to 48 hours. The 48-hour forecast assumes that yesterday's fires will continue to burn today and. .The smoke particle positions at the end of each analysis period are used to initialize the next day's simulation. NOAA recognizes that the amount of particulate emission associated with biomass burning is quite uncertain and depends upon many factors. They use normalized estimates obtained from the literature for various types of fires. An example of a forecast during one major fire event in 2007 is given in **Figure 7-111**. Images are available as animated GIF files which enhances the users' ability to assess potential impacts.

A number of meteorological products are available to assist in assessing the likelihood of emissions from any specific wildfire being transported to Southern Nevada and impacting surface air quality. As fire plume heights often extend to 10,000 ft-agl, it is useful to examine the 12 to 24 hour forecast wind field charts at the 850 mb and 700 mb standard-pressure heights. Plume trajectories will change accordingly in response to synoptic-scale weather pattern changes. Other useful products include the NWS Desert Rock rawinsonde measurements used in conjunction with NWS forecast surface temperatures to compute afternoon mixing heights in Clark County. The primary measurements for determining/documenting boundary layer development and mixing heights should be the local remote sensing data discussed below. The Desert Rock sounding provides an alternative method.

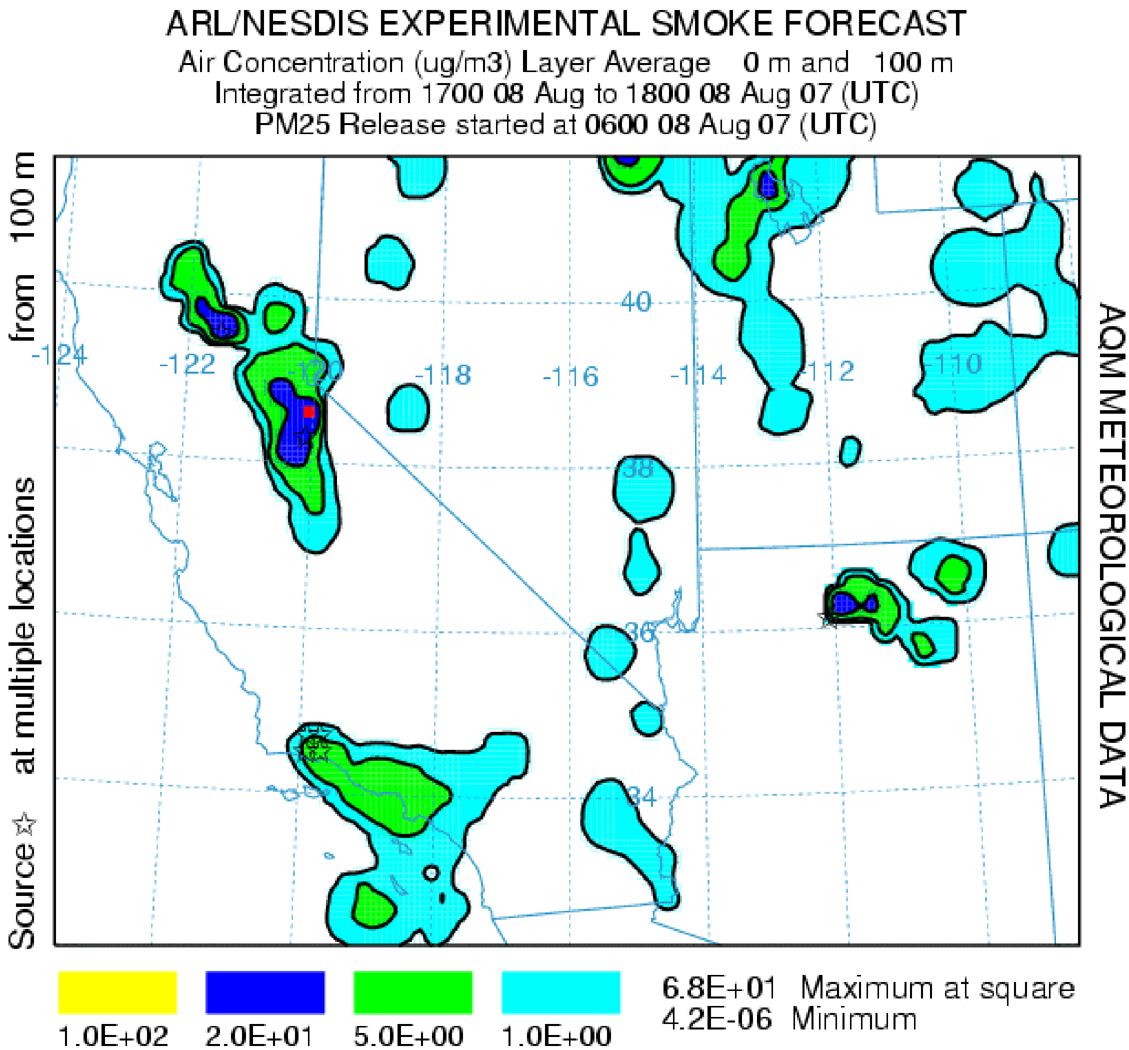

Figure 7-111. Example of the NOAA ARL Ready Smoke Forecast Model Output

7.3.2 Clark County Monitoring Products for Analysis of Impacts

7.3.2.1 Surface Measurements

The Clark County DAQEM currently operates a monitoring network that includes 13 sites with continuous surface ozone and meteorological measurements, five (5) sites continuously measuring $PM_{2.5}$ using Beta-attenuation monitors (BAM), and five sites making $PM_{2.5}$ filter-based 24-hour integrated measurements (plans are to operate only four sites in 2008). There are also 12 sites where PM_{10} is measured. However, measurements at the latter sites are coordinated with the standard EPA six-day schedule, which may not occur on fire-impact days.

The ozone monitoring network is particularly dense in populated areas but also includes sites throughout the county. An historical perspective of the location and timing of peak ozone during episodes is well known and documented by Lehrman et al. (2006), Bush, et al. (2006) and Bush et al. (2008) to name a few. The areal distribution and time of peak ozone during wildfire events are typically anomalous when viewed in an historical perspective and for the most part can only be explained as an exceptional event occurrence

High particulate loading can occur due to high winds (blowing dust), local soil disturbance (construction or off-road vehicles), local fire events (including fireworks), and wild fires. High wind events are easily identifiable as are isolated activities that cause fugitive dust. Attributing high particulate levels to wild fires has until recently been problematic. The Clark County DAQEM recently demonstrated that $PM_{2.5}$ sampler filters, with appropriate sampling media and properly handled, can be analyzed for PM source attribution (Zielinska, 2008). Zielinska not only associated high ozone/PM events with wildfires, but also demonstrated the capability to assist in identifying a specific fire (i.e., due to primarily desert scrub or conifers, etc). A sampling of the source attribution analysis performed by Zielinska is shown in **Figure 7-112.** In this particular analysis, the contribution from wood smoke to particulate loading on June 23rd, 29th and 30th are clearly shown by the elevated levels of levoglucos and other markers.

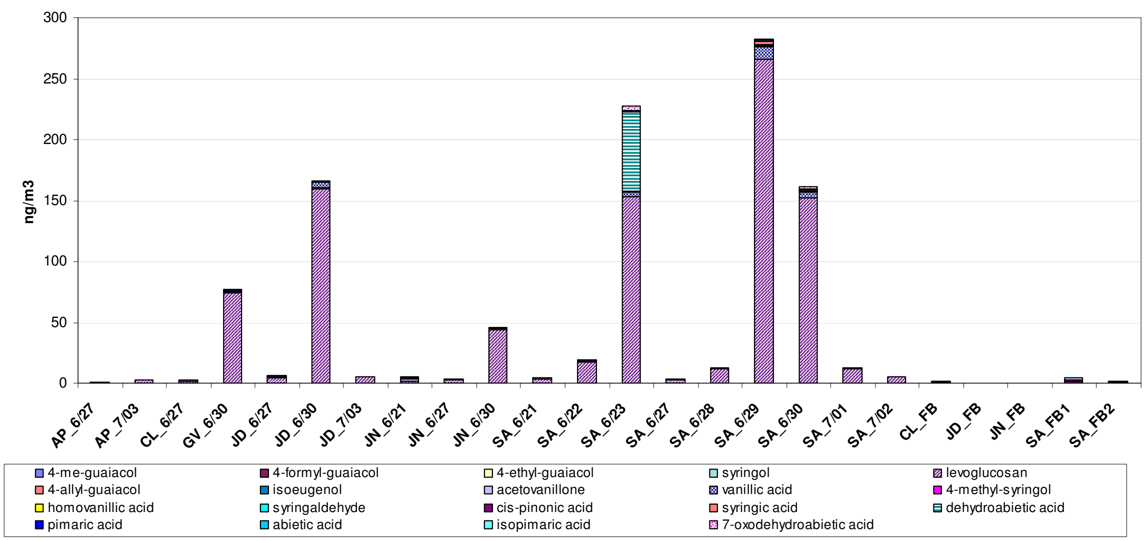

Figure 7-112. Biomass Burning Tracers for All Analyzed Clark County Samples (from Zielinska, 2008)

The *continuous* BAM data can then be used to associate high particulate loading with high ozone levels. Three periods of particularly high particulate levels in the Las Vegas Valley can be seen from the diagram on **Figure 7-113**: June 21-24, June 29-30, and July 4-5. The first two periods experienced high ozone levels and were demonstrated by the DAQEM to have been impacted directly by wildfires based on visual evidence, satellite imagery, aircraft measurements, and laboratory analyses of ambient particulate. The high PM loading on July 4-5 was obviously due to Independence Day celebration.

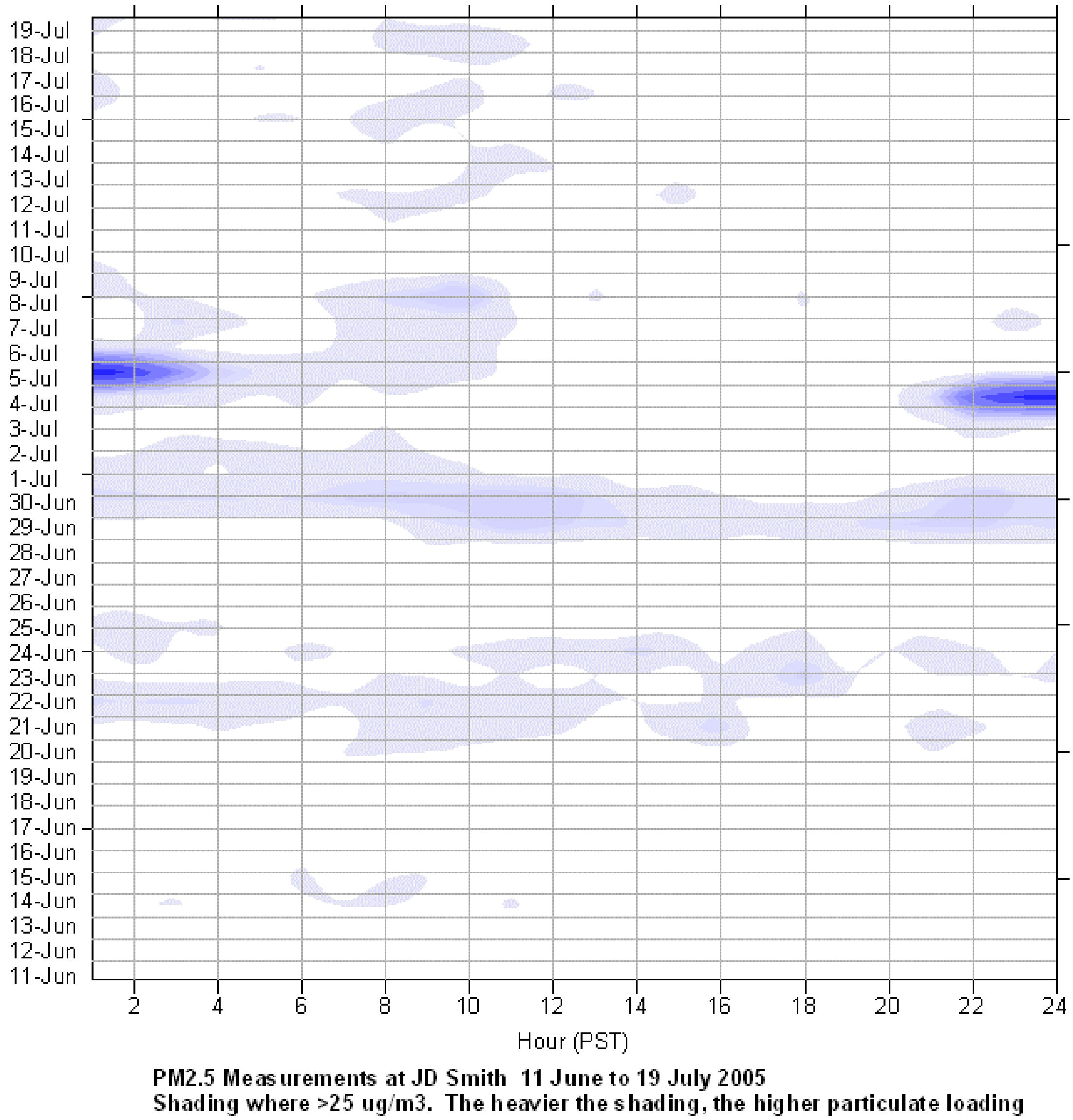

Figure 7-113. $PM_{2.5}$ Measurements at JD Smith 11 June to 19 July 2005

7.3.2.2 Upper Air Measurements in Clark County

By the 2008 fire season, the Clark County DAQEM plans to have a continuous upper air monitoring station at the North Las Vegas airport. High-resolution winds, temperature and humidity aloft will be available on a real-time basis which will provide both forecasting and documenting of conditions that are conducive to impacts from both local and distant wildfires. From the radar wind profiler, miniSodar, and microwave radiometer continuous vertical profiles such as shown in **Figure 7-114** will be routine. The temperature and relative humidity profiles will document the growth and extent of the surface boundary layer; and whether or not elevation smoke plumes impact surface air quality. Winds aloft document the local transport conditions within the boundary layer and provide additional layering definition.

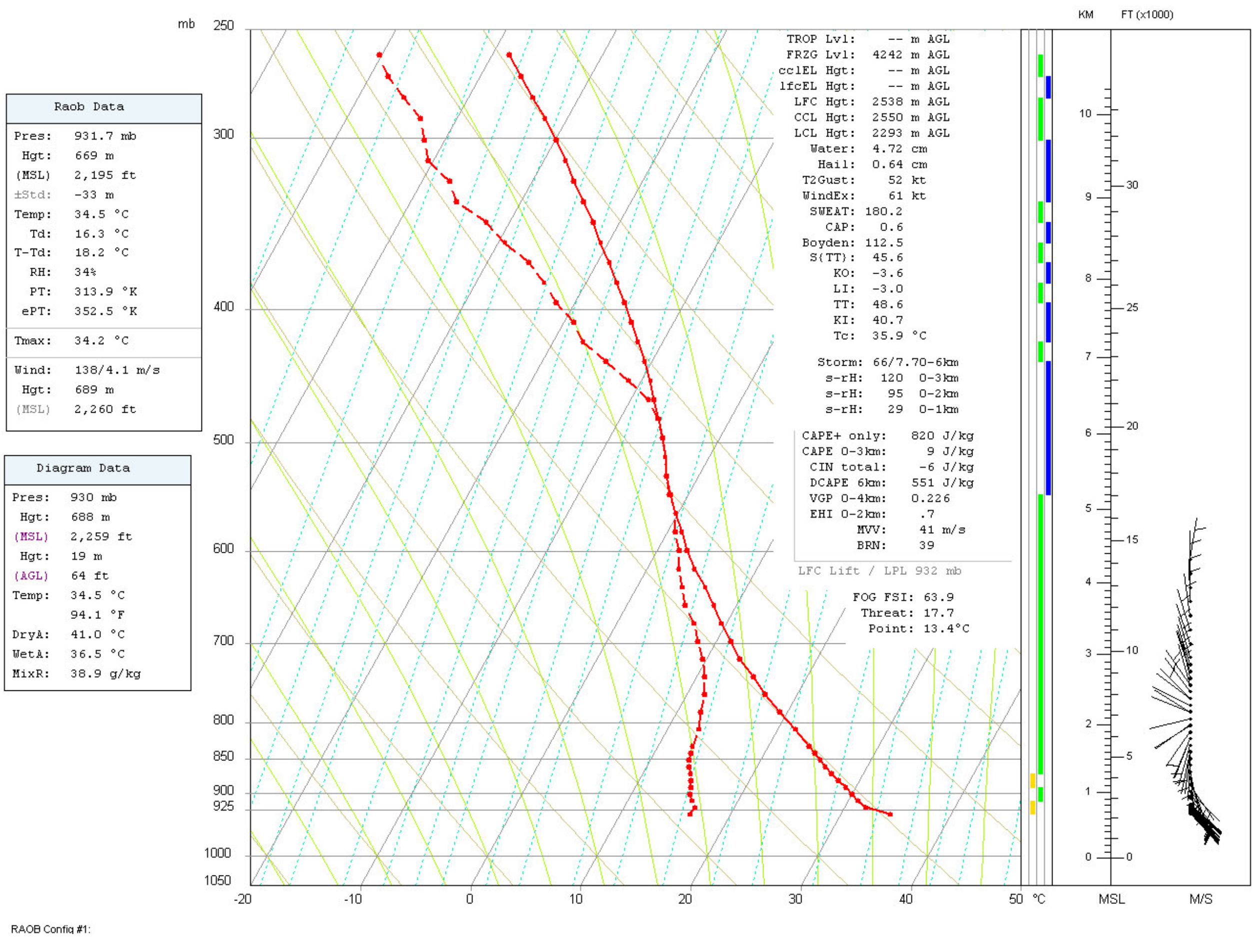

Figure 7-114. Showing Upper Air Diagram with North Las Vegas Airport Measurements

7.3.2.3 Cameras For Smoke Confirmation

It was demonstrated during a 2007 field study (Bush et al., 2008), that video cameras are useful for documenting smoke events in Clark County. A camera, interfaced to the Internet, was operated at the North Las Vegas airport. Real-time images were available on the Internet and over the course of the study, video segments when smoke was present were archived. Smoke was distinguishable from clouds allowing plume movement to be observed over the daytime cycle.

It is noteworthy that numerous third-party video cameras are operated in the Las Vegas Valley and are a source of free information on the Internet. Some Internet web sites are given below:

Still Pictures: Self-documented with date and time. Easily captured and downloaded.

- Top of Stratosphere Hotel http://www.klas-tv.com/Global/link.asp?L=85315&nav=168cFTC6
- Weatherbug Red Rock Visitors Center Cam
- Weatherbug Lake Mead Marina Resort Cam

- Weatherbug Wetlands Park Cam
- Weatherbug Alexander Dawson School Cam
- Weatherbug Eileen Brookman Elementary School Cam Particularly good view looking west across the Valley
- Weatherbug Fitzgerald's on Fremont Street
- Weatherbug O.K. Adcock Elementary School Cam
- Weatherbug Centennial Academy Cam
- Weatherbug Carl Elementary School Cam
- Weatherbug Findlay Cadillac, Henderson, NV Cam
- Weatherbug Southern Highlands Golf Club Cam

All Weatherbug sites have the capability to provide time lapse animation for the past two days, typically based on a 5-minute picture frequency.

Streaming video: advantages over still pictures are that plumes are more easily identified but not always self-documenting and not easily downloaded as video loop.

• Silverton Casino http://www.silvertoncasino.com/categories/3A9B7073-0815-66EC-39A7275DCF4FC5A6/i_15_northbound.htm

• Silverton Casino http://www.silvertoncasino.com/categories/3A9A2A0B-B560-FB13-887658D7A951EDE7/i_15_southbound.htm

7.3.3 Protocol for Monitoring and Documenting Wildfire Events

7.3.3.1 Daily Procedures

A qualified atmospheric scientist should check daily for fire impact potential by viewing at the minimum the following:

1. http://activefiremaps.fs.fed.us/ is MODIS Active Fire Mapping Program- Large fires – can mouse click on noted fires to obtain more specific information but does not show plumes

2. http://cdfdata.fire.ca.gov/incidents/incidents_current provides detailed information on current California wildfires

3. http://activefiremaps.fs.fed.us/imagery.php?op=fire&fireID=ca-south-000 provides MODIS satellite high-definition images showing the areal extent of smoke plumes over selectable areas.

If there are large active fires of note or smoke plumes directed towards Clark County, the following procedures are suggested:

1. Examine and archive the map produced by the Experimental Smoke Forecasting model at http://www.arl.noaa.gov/smoke/forecast.html which forecasts particulate plume impacts from active wildfires.

2. Ensure that the critical components of the Clark County monitoring network are operational:

   - BAM monitors are operating properly and $PM_{2.5}$ FRM filter samplers are loaded with fresh filters and operational.
   - North Las Vegas suite of upper air monitors (radiometer, radar wind profiler, and mini-Sodar) are operating properly.
   - DAQEM cameras are operational and recording.

3. Routinely throughout the day, download the images from a select set of third-party video cams (see Section 7.3.2.2). There is no guarantee that archived images will be available after the fact.

7.3.3.2 Documentation of Fire Impacts

In the event that an ozone (or particulate) exceedance of the NAAQS is experienced or forecast to occur in Clark County, the following steps, at a minimum, are recommended for further examination and analyses in order build a body of evidence sufficient to demonstrate an ozone exceedance qualifies as an exceptional event:

1. The network of $PM_{2.5}$ FRM samplers is currently setup to routinely take integrated 24-hour samples every 3 days from four sites. If wildfires are forecast to impact air quality in Clark County on one of the 2 days not scheduled for operations, every effort should be made to activate sampling immediately at all four sites. It is not critical that the sampler run for a full 24-hours, and if the next day is a scheduled sampling day, the filters should be changed out that evening. Extra precautions should be made to carefully unload, label, and store filter-based measurements when operational.

2. Filter samples taken for prior and subsequent periods should be carefully handled and stored as well to assist in the ability to distinguish wildfire particulate matter from local and/or background particulate material.

3. The complete set of filter samples should be analyzed by a qualified laboratory for biomass composition. (It should be noted that if an exceedance is not experienced it may be advantages to analyze the set of filters to obtain a set of baseline data.

4. If the high-volume (PM_{10}) every sixth-day sampling schedule happens to coincide with these operations, the gravimetric analyses of the network filters should be incorporated in this data set. Particulate loading even without speciation is useful to document the occurrence and areal extent of a pollution event.

5. Save the image from the MODIS Active Fire Mapping Program at http://activefiremaps.fs.fed.us/ which is a good visual map of the location of fires over entire US or by regions (e.g. western great basin) but does not show fire plumes.

6. Save the MODIS 250-meter Geo-referenced Surface Reflectance Maps at http://activefiremaps.fs.fed.us/imagery.php?op=fire&fireID=ca-south-000 are outstanding high-resolution visual mapping of smoke plumes.

7. Save the NOAA Composite Satellite-derived map http://www.firedetect.noaa.gov/viewer.htm which shows high-resolution smoke plumes from another source and provides another interpretation of "hot spots" from satellite information.

8. Save the map loop produced by the Experimental Smoke Forecast model showing particulate plume movement http://www.arl.noaa.gov/smoke/forecast.html

9. Archive DAQEM and third-party video cam pictures.

10. Archive hourly air quality data, particularly ozone, from sources other than Clark County DAQEM monitoring network:

11. CARB provides hourly data from throughout California. Ozone data from all Southern California and San Joaquin Valley sites (not just air basin summaries) should be gathered from http://www.arb.ca.gov/aqd/aqdpage.htm. CARB also provides 8-hour averaged data for the prior day.

12. The National Park Service (NPS) monitoring data is available at http://www2.nature.nps.gov/air/monitoring/ . Key rural monitoring sites are Death Valley, Joshua Tree (2 sites), and Lake Mead. It is recommended that both ozone, PM and meteorological measurements be included.

13. Hourly and 8-hour averaged data are available from the EPA national archives or the Air Quality System (AQS) which gives you access to air pollution data for the entire United States.

7.3.4 Section Summary

A procedural list of daily tasks were recommended to identify periods when wildfires can potentially have a significant impact on local air quality, and the actions to be taken after the potential has been identified sufficient to build a body of evidence that supports a demonstration of an exceptional event occurrence.

Clark County DAQEM is working with EPA Region 9 to define more precisely what constitutes a demonstration that supports and builds a case for an exceptional event. As expectations and policy become clearer, this protocol will evolve correspondingly.

8. SUMMARY AND RECOMMENDATIONS

The SLOTS monitoring consisted of augmenting the Clark County network with two additional surface ozone and meteorological sites, two sites operating sodars at upwind locations, and state-of-the-art remote upper-air measurements of temperature, humidity, and winds in the Las Vegas Valley. These sites were operated continuously.

When pollution transport conditions were forecast—either from populous urban centers in California or wildfires, special measurements were initiated that included airplane measurements of ozone and particulate matter, and balloon-borne meteorological measurements of temperature, humidity, and winds from select locations.

These special measurements or IOPs occurred during four episodes. The June 22-24 and July 16-17 events were initiated to measure urban plumes that were directed towards Clark County. The June 25-26 and August 8-9 events were initiated to map the pollution concentrations and area extent of wildfires that potentially could significantly impact Clark County air quality.

Two noteworthy wildfires occurred during SLOTS, the White fire which was located in the Tehachapi Mountains of California and the Zaca fire which burned for nearly two months in the mountains near Santa Barbara, California. IOP's were initiated during portions of each wildfire event.

Preliminary results of the interstate urban transport investigation are summarized follows:

- Synoptic patterns occurred during the study that were consistent with the conceptual model developed in past studies, which include the passing of a low pressure trough that initiates southwesterly transport winds from population centers in Southern California into Clark County. HYSPLIT back-trajectories during these conditions showed trajectories from Las Vegas Valley leading to source areas including the Los Angeles Basin, the western Mojave Desert, and the southern San Joaquin Valley. These synoptic patterns typically occurred in June.
- Buildup of ozone concentrations in the above source areas was noted on days preceding the transport events, and was a necessary mechanism for significant ozone transport. These transport events lead to elevated ozone levels in Clark County but not necessarily exceedance levels.
- "Fenceline monitoring" on the California/Nevada border showed elevated ozone concentrations entering the area from the southwest. These measurements were recorded by the aircraft during IOPs on June 22-24 and July 18 and 19. The SLOTS Mt. Pass site on the California border also showed high ozone concentrations on these days, as well as during two transport-favorable periods when exceedances of the 8-hour standard were reported in Clark County.
- Upper air measurements at Jean showed basically steady southwesterly flow throughout the periods leading up to transport events, consistent with the HYSPLIT back-trajectories, and <u>inconsistent</u> with local sources impacting Jean ozone concentrations.
- Well-defined boundaries were noted between regional background concentrations and Southern California urban plumes with higher concentrations, consistent with plume dynamics. This includes an urban plume with measured 85 ppb ozone adjacent to air with clean background ozone concentrations of 40 ppb. Its noteworthy that the urban air

was confined to a narrowly layered plume which may have been more concentrated than the measurements showed.

- Transported urban plume ozone concentrations were typically around approximately 20 ppb above those of the background air in which the plume was imbedded. This is consistent with values seen in previous studies for the DAQEM.
- $PM_{2.5}$ associated with urban ozone plumes are typically very low and not particularly correlated with ozone concentrations.

Preliminary results of the wildfire smoke investigation are summarized as follows:

- The wildfire season in 2007 was limited in terms of fires in the study area. Two fires in California, the White fire and the Zaca fire, provided some opportunity to investigate wildfire contribution to ozone concentrations. Since these fires had only a minor impact of Las Vegas at best, investigation required flying into California to study impacts closer to the fires.
- Because the fires were located close to the urban ozone sources identified in the urban transport investigation (specifically the western Mojave Desert and the southern San Joaquin Valley), it was difficult to definitively attribute ozone concentrations within fire plumes to the plumes themselves. However, rises in ozone concentration of 10 to 20 ppb were noted within the smoke plumes.
- Persistent differences in measured ozone concentrations between the MOP and the Mt. Pass site during the Zaca fire also hint at a possible 10 to 20 ppb increase in ozone concentration by wildfire smoke, thought the evidence is primarily circumstantial.
- Documentation of smoke impacts within the Las Vegas Valley will be critical evidence for exceptional event justification. A list of currently available resources and recommendations for a documentation protocol were provided.

Recommendations resulting from the study include, but are not limited, to the following:

- The DAQEM should finalize a protocol for documenting smoke impacts on Clark County.
- A critical element of the wildfire smoke documentation is particulate speciation for compounds associated with wildfires. A database of particulate composition should be developed on high pollution days to increase our understanding of the origins of pollution in Clark County.
- Special study ozone data from the National Park Service for sites in the Mojave Desert were received near the end of the writing and analysis of that data has not been included in this report. Analysis of this data could be useful in characterizing the movement of urban plumes along the identified transport paths.
- Additional monitoring at key locations in the Mojave Desert along identified transport paths would be useful for further characterizing the transport mechanism.
- Additional characterization of ozone in wildfire smoke is recommended, as there were only marginal opportunities during SLOTS for conducting this investigation.

9. REFERENCES

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