



Central California Ozone Study (CCOS) Data Validation

FINAL REPORT

Prepared for:

San Joaquin Valleywide Air Pollution Study Agency

c/o California Air Resources Board
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1. EXECUTIVE SUMMARY

This report summarizes results of the validation of the air quality data collected during the period June 1 through September 30, 2000 as assembled in the Central California Ozone Study (CCOS) database and as previously validated to Level 1 by each reporting contractor. Level 2 applies consistency tests based on known physical relationships between variables to the assembled data. These tests fall into three categories: detection of extreme values; consistency between redundant measurements and co-pollutants; and examination of temporal and spatial variations. CCOS supplemental data were resubmitted, as necessary, to reflect adjustments that may have been required as a result of the data validation. Validation results that indicate problems with other data sets were forwarded to appropriate measurement groups for review and possible adjustment to their data.

1.1 Background

The Central California Ozone Study (CCOS) is a multi-year program of meteorological and air quality monitoring, emission inventory development, data analysis, and air quality simulation modeling. CCOS includes analysis of existing data; execution of a large-scale field study in summer 2000 to acquire a comprehensive database to support modeling and data analysis; analysis of the data collected during the field study; and the development, evaluation, and application of an air quality simulation model for northern and central California. The results of CCOS modeling provide much of the technical basis for the State Implementation Plan (SIP) updates for ozone nonattainment areas of the San Francisco Bay Area, Sacramento Valley and the San Joaquin Valley. CCOS also provides progressive improvements in the understanding of the relationships among emissions, transport, and ozone standard exceedances in the study area during the decade since the 1990 San Joaquin Valley Air Quality Study (SJVAQS) Atmospheric Utility Signatures, Predictions and Experiments (AUSPEX) and SJVAQS/AUSPEX Regional Model Adaptation Program (SARMAP) modeling. The CCOS field measurement program was conducted in conjunction with the California Regional PM10/PM2.5 Air Quality Study (CRPAQS), a major study of the origin, nature and extent of excessive levels of fine particles in central California.

The CCOS field measurement program was conducted during a four-month period from 06/01/00 to 10/02/00. During this study period, a network of upper-air and surface meteorological monitoring stations supplemented the existing routine meteorological and air quality monitoring network. Additional measurements were made during meteorological scenarios that were conducive to high ambient ozone concentrations. These periods of intensive measurements were known as intensive operational periods, or IOPs. IOP measurements were made on 07/23 - 07/24 (IOP #1), 07/30 - 08/02 (IOP #2), 08/14 (IOP #3), 09/14 (IOP #4), and 09/17 - 09/21 (IOP #5). In addition, additional boundary condition flights were made during 09/30 - 10/2. Summary of Field Operations - CCOS Volume III (Fujita et al., 2001), documents the meteorological and air quality conditions during the summer 2000 ozone season and during individual IOPs, describes the daily forecasting and making-decision protocols for launching IOPs, and documents the parameters that were measured, locations, measurement methods, times, and levels of data capture. This document is available at the following web site: <http://www.arb.ca.gov/airways/ccos/ccos.htm>. The Field Study Plan - CCOS Volume I (Fujita et al., 1999 - version 1, 06/11/99; version 2, 09/07/99; and version 3, 11/24/99) and the Field

Operations Plan - CCOS Volume II (Fujita et al., 2000 - version 1, 04/28/00; and version 2, 05/31/00) are also available at this web site.

The California Air Resources Board and local air pollution control districts operated 185 air quality monitoring stations throughout northern and central California during CCOS. Of the active sites, 130 measured ozone and 76 measured NO_x. Carbon monoxide and hydrocarbons were measured at 57 and 11 sites, respectively. Data from these sites were routinely acquired and archived by the ARB and Districts. The supplemental air quality measurements were made to fill in key areas of the modeling domain where ozone and nitrogen oxides were not monitored routinely (S0), to establish boundary and initial conditions for input into air quality models (S1), and to characterize interbasin transport and intrabasin gradients near the downwind edge of urban centers (S2). In addition to the three categories of supplemental air quality measurement sites, three “research” (R) sites were established to provide the maximum extent of high-quality, time-resolved chemical and other aerometric data for use in diagnostic evaluations of the air quality model simulations. Table 1-2 lists the measurements made at each of type of supplemental monitoring sites along with operating period and the groups that are responsible for equipment procurement and testing, installation and training, and laboratory analysis. The measurement method and specific instruments used in CCOS are given in Table 1-3. This table also provides nominal precision, detection limit, range, and averaging or sampling times. Tables 1-4a to 1-4c show the instrument configuration at each of the CCOS supplemental air quality monitoring sites.

Supplemental measurements of ozone (O₃), nitric oxide (NO), nitrogen dioxide (NO₂), peroxyacetyl nitrate (PAN) and total oxidized nitrogen (NO_y) were phased in throughout the study area during late June through mid-July and continued through 9/30/00. The Bay Area AQMD sponsored additional supplemental measurements of O₃, NO/NO_y and aloft meteorology at several locations in the Bay Area. Continuous measurements of carbon monoxide (CO), carbon dioxide (CO₂), black carbon, particulate nitrate, and volatile organic compounds (with an automated gas chromatograph with mass spectrometer, GC/MS) were made at the three research sites during July through September. Nitric acid (HNO₃) was estimated with dual channel NO_y analyzers at the research sites and tunable diode laser absorption spectrometers (TDLAS) were used to measure NO₂, HNO₃, formaldehyde (HCHO), and hydrogen peroxide (H₂O₂) at the Parlier research site. Additional data were collected during IOPs to better understand the dynamics and chemistry of the formation of high ozone concentrations. These measurements included several instrumented aircraft, canister samples for speciated hydrocarbons, dinitrophenylhydrazine (DNPH) cartridges for C₁ to C₇ carbonyl compounds, tenax cartridge samples for C₈ to C₁₈ hydrocarbons, and radiosonde measurements in Sacramento and Fresno. IOPs were forecasted during days leading up to and during ozone episodes and during specific ozone transport scenarios. A network of 13 radar wind profilers (RWP) with radio acoustic sounding systems (RASS) and 5 Sodars supplemented existing upper-air meteorological monitoring networks in the study area (RWP/RASS at six CRPAQS sites, 4 RWP/RASS and 1 sodar at ARB or District sites, and 3 RWP and 10 NEXRAD at military and federal agency sites). Supplemental surface meteorological monitoring stations were also established at ten sites.

The data collected during CCOS were assembled by the California Air Resources Board (ARB) into a master database for subsequent data analysis and modeling. Prior to their use in data analysis and modeling the quality of the data were validated through a process by which data are filtered and accepted or rejected based on a set of criteria. This process consists of procedures that identify deviations from measurement assumptions and procedures. Three levels of validation are applied which will result in the assignment to each measurement of one of the following ratings: 1) valid; 2) valid but suspect; or 3) invalid.

Level 1 data validation normally takes place in the field or in the laboratory and consists of: 1) flagging samples when significant deviations from measurement assumptions have occurred; 2) verifying computer file entries against data sheets; 3) eliminating values for measurements which are known to be invalid because of instrument malfunctions; 4) adjustment of measurement values for quantifiable calibration or interference biases; 5) determining measurement precision by replicate analyses, and collection of field blanks and collocated samples. Measurement assumptions and calibration biases are independently assessed through systems and performance audits that were performed by the CCOS quality assurance team.

Level 2 validation, which is the subject of this report, take place after the data from various measurement methods have been assembled in a master database. Level 2 applies consistency tests based on known physical relationships between variables to the assembled data. These tests fall into three categories: detection of extreme values; consistency between redundant measurements and co-pollutants; and examination of temporal and spatial variations.

Level 3 validations are part of the subsequent data interpretation process. Receptor modeling, factor and other statistical analyses, and photochemical air quality simulation models are several examples. Unusual values are identified during the data interpretation process as: 1) extreme values; 2) values which would otherwise normally track the values of the other variables in a time series; and 3) values for observables which would normally follow a qualitatively predictable spatial or temporal pattern.

1.2 Project Scope and Summary of Results

This report summarizes the level 2 validation of the CCOS aerometric data collected during the period June 1 through September 30, 2000 with emphasis on IOPs. Prior to the validation check, we reviewed the results of the systems and performance audit that were conducted by the California Air Resources Board, Bay Area Air Quality Management District and Parson Engineering Science, Inc. (2001), and the reported precision and accuracy of the measurements.

Flag invalid and suspect CCOS data and submit the flagged data sets to the CCOS data manager. Summarize the results of the level 2 validation checks in tasks 1 through task 5 and their potential implications for subsequent data analysis and modeling.

1.2.1 Validation of Surface Ozone Data.

Our review of the ozone datasets focused on temporal and spatial patterns and relationships between copollutants. Validation checks of the CCOS ozone data show that the data

are consistent with our expectations of the temporal and spatial variations of ozone during the study. The few problems and anomalies are noted below.

IOP Days

- BodegaBay (BODB) - most of 9/16 flagged as suspect at Level 1
- LambieRd (LAMB) - many periods (12% of minutes) from 8/15 to 9/28 flagged as suspect at Level 1. 2908 minutes between 9/24 and 9/28 inclusive (40%) - according to Parsons QA report instrument was 'prone to periods where the analyzer response became erratic'.
- Maricopa School (MCS) - reported values anomalously low for all hours during 8/1-8/2 IOP, not flagged in data file received.
- Tracy (TPP) - second ozone peaks occur around midnite each day of 9/17-9/20 IOP. Not flagged in data file received.

Study Period

- Maricopa School (MCS) - anomalously low values for all hours during first half of June 2000 and entire month of August 2000.
- Yreka – anomalously high values on 9/1/00 to 9/3/00 and 9/25/00.
- Morro Bay – anomalously low values 6/24/00 to 7/11/00.

1.2.2 Validation of Surface Nitrogen Species.

- NO_x is consistently higher than NO with a positive offset at NO = 0 of up to about 75 ppb with an average of about 30 ppb. There is a strong, nearly 1:1 correlation when NO_x is greater than 200 ppb, which is consistent with the presence of fresh emissions of NO in urban areas.
- Hourly ozone is inversely correlated to the corresponding hourly NO.
- NO₂ by luminol is reported as zero for several periods during August at Parlier while NO_x-NO > 10 ppb. NO₂ typically peaks up to 60% higher than NO_x-NO suggesting a calibration problem. The luminol NO₂/PAN data were subsequently reprocessed by CE-CERT under separate contract.
- TDLAS HNO₃: Peaks are higher than NO_y*-NO_y by about a factor of 4.

1.2.3 Validation of Surface Volatile Organic Compounds.

- PAMS hydrocarbon species measured by Biospheric Research Corporation and Desert Research Institute for collocated canister samples are in good agreement with a slope of 0.92 with an R-square of 0.97. These results are similar to comparisons that were conducted between these two laboratories during SCOS97-NARSTO and NARST-Northeast.
- The distributions of total NMHC among the monitoring sites are generally consistent with expectation of lower values at rural sites and higher values in urban locations.
- NMHC levels at Bodega Bay were consistently low with values mostly ranging between 20 and 50 ppbC. In contrast, Piedras Blancas appears to be influenced by some local source of VOCs and should not be considered representative of coastal background conditions.
- Samples that have anomalously high NMHC relative to other samples from that site include 06-09 sample on 7/31/00 from Shafter (2296 ppbC), 00-03 sample on 8/14/00 from San Andreas (1026.7 ppbC) and 00-03 sample on 7/31/00 from Bethel Island (1284.3 ppbC).
- Ethylene and acetylene, which are primarily emitted by motor vehicles, are higher in urban areas and are well correlated to each other during times and at location with fresh motor vehicle emissions in samples analyzed by DRI, BRC and ARB. The upper edges of the cluster of points in each plot represent the ratios of ethylene to acetylene in fresh emissions and are approximately unity in all three scatterplots.
- Points that deviate significantly from the cluster of points should be viewed as suspect. These include the value for acetylene in the DRI analysis of the 13-16 sample from Bethel Island on 8/1/00 and ethylene in the DRI analysis of the samples from White Cloud for the 00-03 sampling period on 7/23/00, 7/30/00 and 8/14/00. As noted earlier, the samples from Piedras Blancas seem to be affected by some unknown local source. The anomalously high NMHC values at this site are accompanied by unusually high and low ethylene/acetylene ratios.
- Because mobile sources are typically the dominant source of VOC emissions in urban areas, the composition of VOC at these locations consistently resemble vehicle emissions (e.g., Sacramento Del Paso, Sacramento Natoma, Folsom, Granite Bay, Fresno First St. Clovis, Turlock, Bakersfield Golden State). Several samples from San Leandro deviate from this pattern with unusually high amounts of aromatic compounds and higher molecular weight n-alkanes.

1.2.4 Validation of Semi-Continuous GC/MS Data at CCOS Research Sites

The GC/MS data were originally submitted on 6/12/02. Problems revealed by our initial evaluations of this dataset were traced to variations in calibrations due to instability of the standard mixture in the transfer standard as well as potential biases that may have been caused by

the operational protocol of the instrument. Examination of the calibration data confirmed that calibration shifts did occur and that corrections to the originally submitted data base were necessary. The corrections were performed by multiplying the measured values by the ratios of the reference calibration mixture concentrations versus the observed mixture concentrations in the transfer standard. This approach was used to derive species-specific correction factors for each sample. Based on the observed concentration of the calibration checks, the measured values were subsequently corrected and the data were resubmitted on 2/4/03. Scatter plots for the three sites showed the correlations between the canister and GC/MS data improved after the correction process. Box plots for all three sites showed that the distribution between the canister data and the GC/MS data improved after correction.

1.2.5 Validation of Aloft Air Quality Data

Data validation of the in-situ aircraft data was performed by plotting time series of all measured pollutants for each flight and examining the plots for inconsistencies such as spikes in only one parameter, invalid relationships between parameters (e.g. NO greater than NO_x), or temporal variations that did not track other parameters. Overall relationships between measured species were also examined using scatter plots of all data for each aircraft. Data points that fell outside physically reasonable relationships were identified and possible explanations for the discrepancies were proposed, where possible, based on examination of corresponding flight data.

- With the exception of NO_z, all species measured by TVA track each other extremely well with time and the relative magnitudes appear reasonable. Time plots of ozone, NO_x, and SO₂ show good temporal coordination of the measured species. All other flights with complete data showed similar behavior.
- All parameters appear to be temporally coordinated for both STI aircraft. The relationships between NO and NO_y, and between NO and ozone are generally reasonable.
- While the ozone and nitrogen oxides measured by UCD generally track each other well, there are indications in the data that the ozone analyzer in the UCD172 aircraft was malfunctioning intermittently throughout the study. Large sharp spikes in ozone concentration occur and do not appear to correspond to any particular portion of the flight pattern and reach values substantially larger than any measured in the other aircraft. In addition, these spikes sometimes preceded or followed periods during which the reported ozone was consistently near zero. Given that this behavior occurred repeatedly throughout the study all of the ozone data from UCD172 should be considered suspect unless the cause of the malfunction is known and those periods in which it occurred can be definitively flagged.
- The UCD NO_y tracks the ozone data well in the absence of the malfunctions, and NO is consistently less than NO_y with one exception (an anomaly occurred on September 17 at 13:23). Since the event lasted more than one minute it cannot be attributed to a sharp gradient in NO concentration and the data should be flagged as invalid and instrument diagnostics examined to determine the cause. Despite the malfunctions in the ozone

analyzer, the relationship between measured ozone and NO is generally consistent, with peaks in NO corresponding to low ozone levels.

- All data for the UCD182 aircraft appear to be valid with the exception of the NO and NO_y data from the afternoon flight on September 19. During this flight reported NO, and occasionally NO_y, concentrations are negative. Although the zero of the NO/NO_y instrument apparently drifted between -1 and 1 during the study, these values are substantially outside of that range, and appear to be due to some sort of brief transient events NO and NO_y data for this flight should be considered suspect or invalid.

1.2.6 Validation of Meteorological Data.

Audits of the CCOS upper-air meteorological measurements were conducted by Parsons Engineering Science and are documented in their QA report (2001). In addition, the data have been validated through Level 1A and 1B processing by NOAA ETL (Neff et al., 2003). Level 1A processing of the radar and RASS data was accomplished by running the moments data through a modified Weber-Wuertz algorithm to remove obvious spurious data for wind speed, wind direction, and temperature. Level 1B processing involved visually inspecting daily wind and temperature files for inconsistencies not discovered with the Weber-Wuertz algorithm. In addition to the QA audits and level 1 validation, the meteorological data have been analyzed by T&B Systems (Lehrman et al., 2003).

**Table 1-1. CCOS ground-based sites in pollutant database grouped by air basin.
Stations not otherwise indicated are routine monitoring sites.**

Site	SiteCode	Station Type	basin code	basin name	Location Type
Anderson Stn (North Street)	ANDE		SV	Sacramento Valley	Rural
Bella Vista Stn	BELV	S0/CCOS	SV	Sacramento Valley	Rural
Chico Stn (Manzanita)	CHM		SV	Sacramento Valley	Suburban
Colusa Stn (100 Sunrise Blvd.)	CSS		SV	Sacramento Valley	Rural
Davis/UCD Campus Stn	DVS		SV	Sacramento Valley	Rural
Elk Grove Stn (Bruceville Rd.)	ELK	S1/PAMS	SV	Sacramento Valley	Rural
Folsom Stn (Natoma St.)	FLN	PAMS	SV	Sacramento Valley	Suburban
Granite Bay Stn	GNBY	R/CCOS	SV	Sacramento Valley	Suburban
Lambie Road Stn	LAMB		SV	Sacramento Valley	Rural
Lassen Volcanic NP Stn	LNP		SV	Sacramento Valley	Rural
Sacramento/Natoma Stn (3801 Airport Rd.)	NAT	PAMS	SV	Sacramento Valley	Urban / Center City
Pleasant Grove Stn (4 SW)	PGV		SV	Sacramento Valley	Rural
Redding Stn	RDG		SV	Sacramento Valley	Rural
Rocklin Stn (5000 Rocklin Rd.)	ROC		SV	Sacramento Valley	Rural
Roseville Stn (151 N Sunrise)	ROS		SV	Sacramento Valley	Suburban
Sacramento Stn (1309 T St.)	S13	CRPAQS	SV	Sacramento Valley	Urban / Center City
Sacramento Stn (Del Paso Manor)	SDP	CRPAQS/PAMS	SV	Sacramento Valley	Suburban
Sloughouse Rd. Stn	SLU	S0	SV	Sacramento Valley	Rural
Sacramento-North Highlands Stn (Blackfoot Way)	SNH		SV	Sacramento Valley	Suburban
Sutter Buttes Stn	SUTT	S1/CCOS	SV	Sacramento Valley	Rural
Tuscan Butte Stn	TSB		SV	Sacramento Valley	Rural
Woodland Stn	WLN		SV	Sacramento Valley	Rural
Willows Stn (E Laurel St.)	WLW		SV	Sacramento Valley	Suburban
Yuba City Stn (Almond St.)	YAS		SV	Sacramento Valley	Suburban
Arvin Stn	ARV	S2/PAMS	SJV	San Joaquin Valley	Rural
Bakersfield Stn (5558 California St.)	BAC	CRPAQS	SJV	San Joaquin Valley	Urban / Center City
Bakersfield Stn (1128 Golden State)	BGS	CRPAQS/PAMS	SJV	San Joaquin Valley	Urban / Center City
Clovis Stn (908 N Villa Ave.)	CLO	CRPAQS/PAMS	SJV	San Joaquin Valley	Urban / Center City
Edison Stn	EDS		SJV	San Joaquin Valley	Rural
Fresno Stn (North Perimeter Rd.)	FNP		SJV	San Joaquin Valley	Rural
Fresno Stn (Drummond)	FSD	CRPAQS	SJV	San Joaquin Valley	Suburban
Fresno Stn (3425 First St.)	FSF	CRPAQS/PAMS	SJV	San Joaquin Valley	Suburban
Fresno Stn (Sierra Skypark #2)	FSS		SJV	San Joaquin Valley	Suburban
Hanford Stn (Irwin St.)	HAN	CRPAQS	SJV	San Joaquin Valley	Rural
Kettleman City Stn	KETC	S0/CCOS	SJV	San Joaquin Valley	Rural
Trimmer Stn	KRV	CRPAQS	SJV	San Joaquin Valley	Rural
Mineral King Lookout Point Stn	LMK		SJV	San Joaquin Valley	Rural
Modesto Stn (814 14th St.)	M14	CRPAQS	SJV	San Joaquin Valley	Urban / Center City
Madera Stn (29 1/2 No. of Ave 8)	M29	PAMS	SJV	San Joaquin Valley	Rural
McKittrick Stn	MCKI	S0/CCOS	SJV	San Joaquin Valley	Rural
Maricopa School/Stanislaus Stn	MCS		SJV	San Joaquin Valley	Suburban
Merced Stn (385 S Coffee Ave.)	MRA		SJV	San Joaquin Valley	Rural
Oildale Stn (3311 Manor)	OLD	CRPAQS	SJV	San Joaquin Valley	Suburban
Parlier Stn	PLR	R/PAMS	SJV	San Joaquin Valley	Rural
Shafter Stn (Walker St.)	SHA	PAMS	SJV	San Joaquin Valley	Suburban
Sequoia Stn (Giant Forest)	SLK		SJV	San Joaquin Valley	Rural
Stockton Stn (Hazelton St.)	SOH	CRPAQS	SJV	San Joaquin Valley	Urban / Center City
Stockton Stn (13521 E Mariposa)	SOM		SJV	San Joaquin Valley	Urban / Center City
Tracy Stn (24371 Patterson Pass)	TPP		SJV	San Joaquin Valley	Rural
Turlock Stn (900 S Minaret)	TSM	S1	SJV	San Joaquin Valley	Suburban
Visalia Stn (Church St.)	VCS	CRPAQS	SJV	San Joaquin Valley	Urban / Center City
Bodega Bay Stn	BODDB	CRPAQS/S1	SFB	San Francisco Bay Area	Rural
Bethel Island Stn	BTI	CRPAQS/S2	SFB	San Francisco Bay Area	Rural
Concord Stn (2975 Treat Blvd.)	CCD		SFB	San Francisco Bay Area	Suburban
Fremont Stn (Chapel Way)	FCW		SFB	San Francisco Bay Area	Suburban
Livermore Stn (Old First St.)	LVF		SFB	San Francisco Bay Area	Urban / Center City
Livermore Stn-793 Rincon at Pine	LVR1	CRPAQS	SFB	San Francisco Bay Area	Urban / Center City
Napa Stn(Jefferson Ave)	NAP		SFB	San Francisco Bay Area	Rural
Patterson Pass Stn	PATP	S2/CCOS	SFB	San Francisco Bay Area	Rural
Pittsburg Stn (10th Street)	PBG		SFB	San Francisco Bay Area	Urban / Center City
Pacheco Pass Stn	PCP	S2	SFB	San Francisco Bay Area	Rural
Redwood City Stn	RED		SFB	San Francisco Bay Area	Suburban
San Francisco Stn(10 Arkansas St.)	SFA	CRPAQS	SFB	San Francisco Bay Area	Urban / Center City
San Jose Stn (4th St.)	SJ4	CRPAQS	SFB	San Francisco Bay Area	Urban / Center City
San Martin Stn	SMN	S0	SFB	San Francisco Bay Area	Suburban
Santa Rosa Stn (837 Fifth St.)	SRF		SFB	San Francisco Bay Area	Urban / Center City
San Rafael Stn	SRL		SFB	San Francisco Bay Area	Urban / Center City
Sunol Station Stn	SUNO	R/CCOS	SFB	San Francisco Bay Area	Rural
Vallejo Stn (304 Tuolumne St.)	VJO		SFB	San Francisco Bay Area	Urban / Center City

Table 1-1. Cont'd

Site	SiteCode	Station Type	basin code	basin name	Location Type
Atascadero Stn (Lewis Ave.)	ATL		SCC	South Central Coast	Suburban
Capitan Stn/Las Flores Canyon #1	CA1		SCC	South Central Coast	Rural
Carpinteria Stn (Gobernador Rd.)	CRP		SCC	South Central Coast	Rural
El Capitan Beach Stn	ECP		SCC	South Central Coast	Rural
El Rio Mesa School #2 Stn	ELM		SCC	South Central Coast	Rural
Grover City Stn (Lesage Drive)	GCL		SCC	South Central Coast	Suburban
Goleta Stn (N Fairview Ave.)	GNF		SCC	South Central Coast	Suburban
Gaviota TC-Site B Stn	GVB		SCC	South Central Coast	Rural
Lompoc Stn(HS & P)	LHS		SCC	South Central Coast	Rural
Lompoc Stn (128 South H St.)	LOM		SCC	South Central Coast	Urban / Center City
Los Padres NF Stn (Paradise Rd.)	LPD		SCC	South Central Coast	Rural
Morro Bay Stn	MBP		SCC	South Central Coast	Urban / Center City
Ojai Stn (Ojai Rd.)	OJO		SCC	South Central Coast	Suburban
Piedras Blancas Stn	PIED	S1/CCOS	SCC	South Central Coast	Rural
Piru Stn (2 mi SW)	PIR		SCC	South Central Coast	Rural
Paso Robles Stn (235 Santa Fe)	PRF		SCC	South Central Coast	Suburban
Santa Barbara Stn (3 W Carillo)	SBC		SCC	South Central Coast	Urban / Center City
Simi Valley Stn	SIM		SCC	South Central Coast	Suburban
San Luis Obispo Stn (Marsh)	SLM		SCC	South Central Coast	Urban / Center City
Santa Maria Stn (906 S Broadway)	SMAR		SCC	South Central Coast	Rural
Santa Ynez Airport Stn	SYN		SCC	South Central Coast	Rural
Nipomo Stn (Tefft and Pomeroy St.)	TEF		SCC	South Central Coast	Rural
Thousand Oaks Stn (Moorpark Rd.)	THM		SCC	South Central Coast	Suburban
Vandenberg STS Power Plant Stn	VBS		SCC	South Central Coast	Rural
Ventura Co./W Casitas Pass Stn	VTA		SCC	South Central Coast	Rural
Ventura Stn (Emma Wood St. BE.)	VTE		SCC	South Central Coast	Suburban
Santa Clarita Stn (County Fire Station)	SCFS		SC	South Coast	Suburban
Yreka Stn (Foothill Drive)	YREK		NEP	Northeast Plateau	Rural
Carmel Valley Stn (Ford Road)	CMV		NCC	North Central Coast	Suburban
Davenport Stn	DVP		NCC	North Central Coast	Rural
Hollister Stn (1979 Fairview)	HST		NCC	North Central Coast	Rural
Monterey/Fort Ord Stn-Silver Cloud Ct.	MON		NCC	North Central Coast	Rural
Pinnacles National Monument Stn	PIN		NCC	North Central Coast	Rural
Salinas Stn (High School)	SALH		NCC	North Central Coast	Suburban
Santa Cruz Stn (2544 Soquel Drive)	SCQ		NCC	North Central Coast	Suburban
Watsonville (444 Airport) Stn	WAA		NCC	North Central Coast	Suburban
Barstow Stn	BSW		MD	Mojave Desert	Rural
Lancaster Stn (W. Pondera St.)	LWP		MD	Mojave Desert	Suburban
Mojave Stn (923 Poole St.)	MOP	CRPAQS	MD	Mojave Desert	Rural
Trona Stn (Athol and Telegraph)	TRON		MD	Mojave Desert	Rural
Victorville Stn (14306 Park Avenue)	VICT		MD	Mojave Desert	Rural
Cool Stn (1400 American River Trail)	CUS		MC	Mountain Counties	Rural
Sonora - Five Mile Learning Center	FML		MC	Mountain Counties	Rural
Grass Valley Stn- Litton Building Site	GVL		MC	Mountain Counties	Suburban
Jackson Stn (201 Clinton Road)	JAC		MC	Mountain Counties	Suburban
Jerseydale Stn	JSD		MC	Mountain Counties	Rural
Placerville Stn (Gold Nugget)	PGN		MC	Mountain Counties	Suburban
Quincy Stn	QUI		MC	Mountain Counties	Rural
San Andreas Stn (Gold Strike Rd.)	SGS	S1	MC	Mountain Counties	Rural
Sonora Stn (251 S Barretta St.)	SNB		MC	Mountain Counties	Urban / Center City
Truckee Fire Station Stn	TRU		MC	Mountain Counties	Urban / Center City
White Cloud Mtn. Stn	WCM	S1	MC	Mountain Counties	Rural
Yosemite NP/Turtleback Dome Stn	YOT		MC	Mountain Counties	Rural
Echo Summit Stn (21200 HWY 50)	ECHO		LT	Lake Tahoe	Rural
South Lake Tahoe Stn (3337 Sandy)	LTY		LT	Lake Tahoe	Urban / Center City
Lakeport Stn (Lakeport Blvd)	LKL		LC	Lake County	Suburban
Death Valley Stn	DVL		GBV	Great Basin Valleys	Rural
Mammoth Lakes/Gateway HC Stn	MAG		GBV	Great Basin Valleys	Urban / Center City

Table 1-2. CCOS supplemental surface measurements.

Code	Observable and Method	Period	Site Types	Equipment Procurement & Testing	Equipment Installation and Training	Laboratory Analysis
A	Surface Meteorology (WS,WD, T and RH) at 10 m	6/15/00 to 9/15/00	S0, S1, S2, R	NOAA	NOAA	--
B	Ozone (ultraviolet absorption monitor)	6/15/00 to 9/15/00	S0, S1, S2, R	DRI	DRI	--
C	Trace level NO, NOx (chemiluminescent monitor)	6/15/00 to 9/15/00	R	CE-CERT	CE-CERT/DRI	--
D	NO, NOy (high sensitivity chemiluminescent monitor with external converter)	6/15/00 to 9/15/00	S0, S1, S2	CE-CERT	CE-CERT/DRI	--
E	NOy, NOy-HNO ₃ (high sensitivity chemiluminescent monitor with dual converters w/ & w/o NaCl impregnated fiber denuder)	6/15/00 to 9/15/00	R	CE-CERT	CE-CERT	--
F	NO ₂ , PAcNs (GC - Luminol)	7/2/00 to 9/2/00	S2, R	CE-CERT	CE-CERT	--
G	NO ₃ ⁻ (flash vaporization)	7/2/00 to 9/2/00	R	CRPAQS/AD	AD/DRI	--
H	CO (nondispersive infrared)	6/15/00 to 9/15/00	R	DRI	DRI	--
I	CO ₂ (nondispersive infrared)	6/15/00 to 9/15/00	R	DRI	DRI	--
J; J'	CO, CO ₂ , CH ₄ , C ₂ -C ₁₂ hydrocarbons (canister/GC-FID); 55 target HC and NMOC for PAMS	15 IOP days	S1, S2; PAMS	DRI/BRC	DRI/BRC	DRI/BRC & ARB for PAMS
K	C ₈ -C ₂₀ hydrocarbons (Tenax GC-FID, MSD)	15 IOP days	R	DRI	DRI	DRI
L	VOC (Automated-GC/ion trap mass spectrometer)	7/2/00 to 9/2/00	R	DRI	DRI	DRI
M	HCHO (dihydrolutinine derivative/fluorescent detection)	7/2/00 to 9/2/00	S2, R	CE-CERT	CE-CERT	--
N; N'	C ₁ -C ₇ carbonyls(DNPH-HPLC/UV); C ₁ -C ₂ for PAMS	15 IOP days	S1, S2; PAMS	AtmAA	AtmAA	AtmAA & ARB for PAMS
P	NO ₂ , HNO ₃ (TDLAS)	15 IOP days	R (Parlier)	CE-CERT	CE-CERT	--
Q	H ₂ O ₂ , HCHO (TDLAS)	15 IOP days	R (Parlier)	CE-CERT	CE-CERT	--
R	PM _{2.5} light absorption (aethalometer)	6/15/00 to 9/15/00	R	CRPAQS/DRI	DRI	--
S	PM _{2.5} light scattering (portable nephelometer)	6/15/00 to 9/15/00	R	CRPAQS/DRI	DRI	--
T	Scanning Radiometers	6/15/00 to 9/15/00	R	DRI	DRI	--
U	PM _{2.5} mass (beta attenuation)	12/1/99 to 1/31/01	CRPAQS Anchor	CRPAQS	CRPAQS	--
V	PM ₁₀ mass (beta attenuation)	12/1/99 to 1/31/02	CRPAQS Anchor	CRPAQS	CRPAQS	--
W	PM _{2.5} Organic and Elemental Carbon	12/1/99 to 1/31/03	CRPAQS Anchor	CRPAQS	CRPAQS	--

Table 1-3. Detection limits, ranges, and averaging times for CCOS supplemental measurements.

Observable	Method (Instrument)	Expected 1 σ Precision	Detection Limit	Range	Averaging or Sampling Time
O ₃	UV absorption (API 400A)	± 10%	0.6 ppb	500 ppb	1 minute, 5 minutes, and 1 hour
NO/NO _y	chemiluminescence (TEI 42C TL with external converter)	± 10%	0.1 ppb	500 ppb	1 minute, 5 minutes, and 1 hour
NO _y /NO _y *	chemiluminescence (TEI 42C TL with dual external converters and HNO ₃ denuder)	± 10%	0.1 ppb	500 ppb	1 minute, 5 minutes, and 1 hour
NO/NO _x	chemiluminescence (TEI 42C TL)	± 10%	0.1 ppb	500 ppb	1 minute, 5 minutes, and 1 hour
CO	infrared gas filter correlation (TEI 48C TL)	± 10%	0.04 ppm	10 ppm	1 minute, 5 minutes, and 1 hour
CO ₂	infrared gas filter correlation (TEI 41C HL)	± 10%	0.1 ppm	1000 ppm	1 minute, 5 minutes, and 1 hour
NO ₂ , PAN and PAcNs	chemiluminescence and luminol (CE-CERT)	± 20%	1 ppb	500 ppb	One instantaneous sample every 5 minutes
HCHO	dihydrulutidine derivative fluorescence (Alpha-Omega MA-100)	± 20%	0.5 ppb	50 ppbv	One 3 minute sample and 7 minute zero every 10 minutes
PM _{2.5} nitrate	flash volatilization (R&P)	± 15%	0.1 µg/m ³	100 µg/m ³	10 minutes and 1 hour
Light scattering	nephelometers (Radiance Research M903)	± 10%	1 Mm ⁻¹	200 Mm ⁻¹	5 minutes and 1 hour
Light absorption	aethalometers (Andersen RTAA-1000, Magee Scientific AE31)	± 5 to 20%	35 ng (black carbon)/m ³	1000 µg (black carbon)/m ³	5 minutes and 1 hour
Actinic flux (280-700 nm)	spectro radiometer (Metcon 2-pi diode array spectrometer)	± 0.1% flux, ± 2.5 nm λ	1 % of full scale W/cm ² /sec/nm	1000 W/m ² for entire λ range	10 sec, 5 minutes, 1 hour averages in 512 λ bins
C ₂ -C ₁₂ hydrocarbons and oxygenated organic compounds	automated GC/MS (Varian 3800 GC/ Saturn 2000 Ion Trap MS with Entech 7100 preconcentrator)	± 10%	0.2 ppbC	100 ppbC for individual HC	One hour
C ₂ -C ₁₂ hydrocarbons from canisters	gas chromatography with flame ionization detection	± 10%	0.2 ppbC	100 ppbC for individual HC	One three hour sample four times on intensive period days
C ₈ -C ₂₀ hydrocarbons from Tenax cartridges	thermal desorption into GC with FID or MSD (HP 5890 GC with HP 5970 MSD)	± 10%	0.2 µg/m ³	50 µg/m ³ for individual species	One three hour sample four times on intensive period days
C ₁ -C ₇ carbonyls from DNPH cartridges	HPLC with UV detection	± 10%	0.2 ppbv	50 ppbv per compound	One three hour sample four times on intensive period day
Wind speed	anemometer	± 0.3 m/s	0.3 m/s	44.7 m/s	5 minutes and 1 hour
Wind direction	wind vane	± 10° from North	1 degree	0 to 360	5 minutes and 1 hour
Temperature	platinum resistance or thermister	±0.1 °C	0.1 °C	-30 to 50 °C	5 minutes and 1 hour
Relative humidity	capacitance	±2%		100%	5 minutes and 1 hour

Table 1-4a. CCOS supplemental surface air quality monitoring sites and measurements in the Sacramento Valley and Northern Sierra Nevada Foothills.

Site	Site Code	County	Type	Measurements			Facilities Installation	Operation			
				Existing or Special	CRPAQS	CCOS		Met	Continuous Analyzers	VOC Sampling ⁽⁴⁾	VOC Analysis
Shasta Lake	SHL	Shasta	ozone only	B (ARB)		A	ENSR	NOAA	Shasta APCD		
Bella Vista	BEV	Shasta	S0	--	--	ABD	ENSR	NOAA	Shasta APCD		
Sutter Buttes	SUT	Sutter	S1	AB	--	DJN	ENSR	ARB	ARB	DRI	DRI, AtmAA
Lambie Road	LAR	Solano	S0	--	--	ABD	ENSR	NOAA	BAAQMD		
Walnut Grove Tower	WAG	Sacramento	ozone only	AB	--	--	Parsons	Parsons	Parsons		
Elk Grove	ELK	Sacramento	S1'	ABC'J'N'	--	D	SMAQMD	SMAQMD	SMAQMD	SMAQMD	ARB, ARB
Sloughhouse	SLU	Sacramento	S0	AB	--	D	SMAQMD	SMAQMD	SMAQMD		
Granite Bay	GRB	Placer	R	--	--	ABCEFGHI JKLMNOPRST	ENSR	NOAA	DRI	DRI ^(5,6)	DRI, AtmAA
White Cloud	WHC	Nevada	S1	AB	--	DJN	ARB	ARB	DRI	DRI	DRI, AtmAA

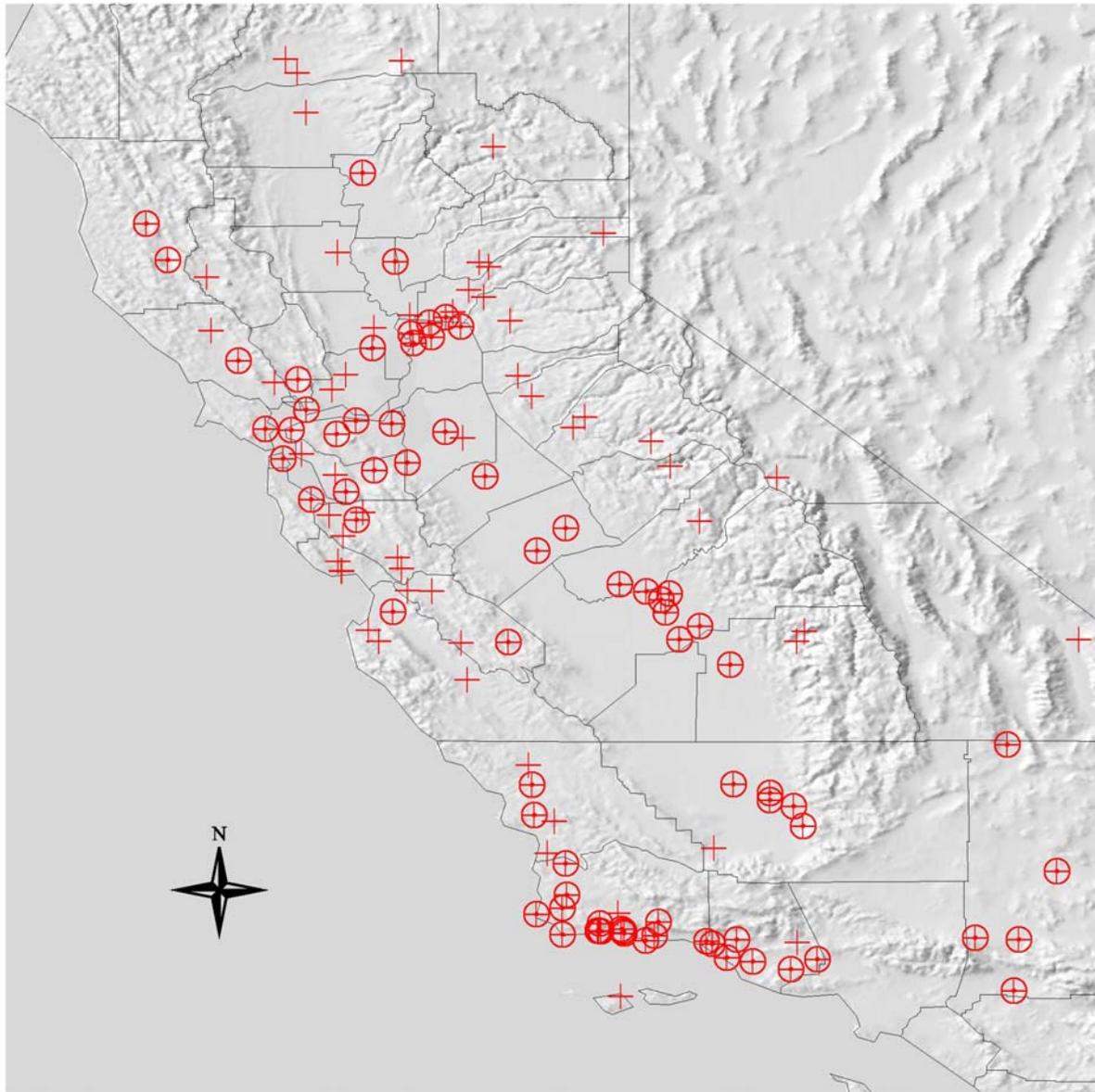
Table 1-4b. CCOS supplemental surface air quality monitoring sites and measurements in the San Francisco Bay Area.

Site	Site Code	County	Type	Measurements			Facilities Installation	Operation			
				Existing or Special	CRPAQS	CCOS		Met	Continuous Analyzers	VOC Sampling ⁽⁴⁾	VOC Analysis
Bodega Bay	BODB	Sonoma	S1	--	RSJ ⁽¹⁾	ABDJN	ENSR	CRPAQS	T&B	T&B	BRC, AtmAA
Pt Reyes	POR	Marin	Met only	--	--	A		NOAA			
Bethel Island	BTI	Contra Costa	S2	ABC'H'	S	DFJMN	BAAQMD/ ENSR	BAAQMD	BAAQMD	BAAQMD	DRI, AtmAA
San Leandro	SLE	Alameda	S1	ABC	--	JN	BAAQMD	BAAQMD	BAAQMD	BAAQMD	DRI, AtmAA
Lake Chabot	LAC	Alameda	S0	A		BD	BAAQMD	BAAQMD	T&B		
Livermore	LIV	Alameda	S0	ABC'H'		D	BAAQMD	BAAQMD	T&B		
Camp Parks	CAP	Alameda	ozone only	A		B	BAAQMD	BAAQMD	T&B		
Mobile Van	MOV	Livermore area	S1			ABDJ	BAAQMD	BAAQMD	BAAQMD	BAAQMD	BAAQMD
San Jose 4th Street	SJO	Santa Clara	S1	ABCH	S	J ⁽²⁾ N ⁽²⁾	BAAQMD	BAAQMD	BAAQMD	BAAQMD	BA, AtmAA
Sunol	SUN	Alameda	R	--	S	ABCEFGHI JKLMNRT	ENSR	BAAQMD	UCB	DRI ^(5,6)	DRI, AtmAA
Patterson Pass	PAP	Alameda	S2	--	ASU	BDFJMN	ENSR	NONE	UCB	UCB	DRI, AtmAA
San Martin	SNM	Santa Clara	S0	AB	--	D	BAAQMD	BAAQMD	BAAQMD		
Pacheco Pass	PAP	Merced	S2	--	AS	BDJNMN	CRPAQS/ ENSR	CRPAQS	T&B	T&B	BRC, AtmAA

Table 1-4c. CCOS supplemental surface air quality monitoring sites and measurements in the San Joaquin Valley , Central Sierra Nevada Foothills, and South Central Coast..

Site	Site Code	County	Type	Measurements			Facilities Installation	Operation			
				Existing	CRPAQS	CCOS		Met	Continuous Analyzers	VOC Sampling ⁽⁴⁾	VOC Analysis
Turlock	TSM	Stanislaus	S1	ABCH	--	DJN	SJVUAPCD	SJVUAPCD	T&B	T&B	BRC, AtmAA
San Andreas	SGS	Calaveras	S1	ABH	--	DJN	ARB	ARB	ARB	ARB	BRC, AtmAA
Kettleman City	KCH	Kings	S0	--	S	ABD	ENSR	NOAA	SJVUAPCD		
Angiola	ANGI	Tulare	S1+	--	ABDJ ⁽¹⁾ S RUVW	JN	CRPAQS	CRPAQS	CRPAQS	SJVUAPCD	BRC, AtmAA
Trimmer	TRIM	Fresno	S2	--	A ⁽³⁾ S	BDFJMN	CRPAQS/ ENSR	CRPAQS	ARB	ARB	DRI, AtmAA
Parlier	PLR	Fresno	R'	ABC'JN'	--	EFGHI KLMPQRST	SJVUAPCD/ ENSR	SJVUAPCD	SJVUAPCD	SJVAPCD ^(5,6) SJVAPCD	DRI, AtmAA ARB, ARB
Arvin	ARV	Kern	S2'	ABCJ'	--	DFM	ARB	ARB	ARB	ARB	ARB
McKittrick	MCK	Kern	S0	--	--	ABD	ENSR	NOAA	SJVUAPCD		
Red Hills	RDH	San Luis Obispo	S0	AB	S	D	SLOAPCD	SLOAPCD	SLOAPCD		
Camp Roberts	CRO	San Luis Obispo	S1	AB			SLOAPCD	SLOAPCD	SLOAPCD		
Piedras Blancas	PIB	San Luis Obispo	S1	--	--	ABDJN	ENSR	NOAA	SLOAPCD	SLOAPCD	BRC, AtmAA

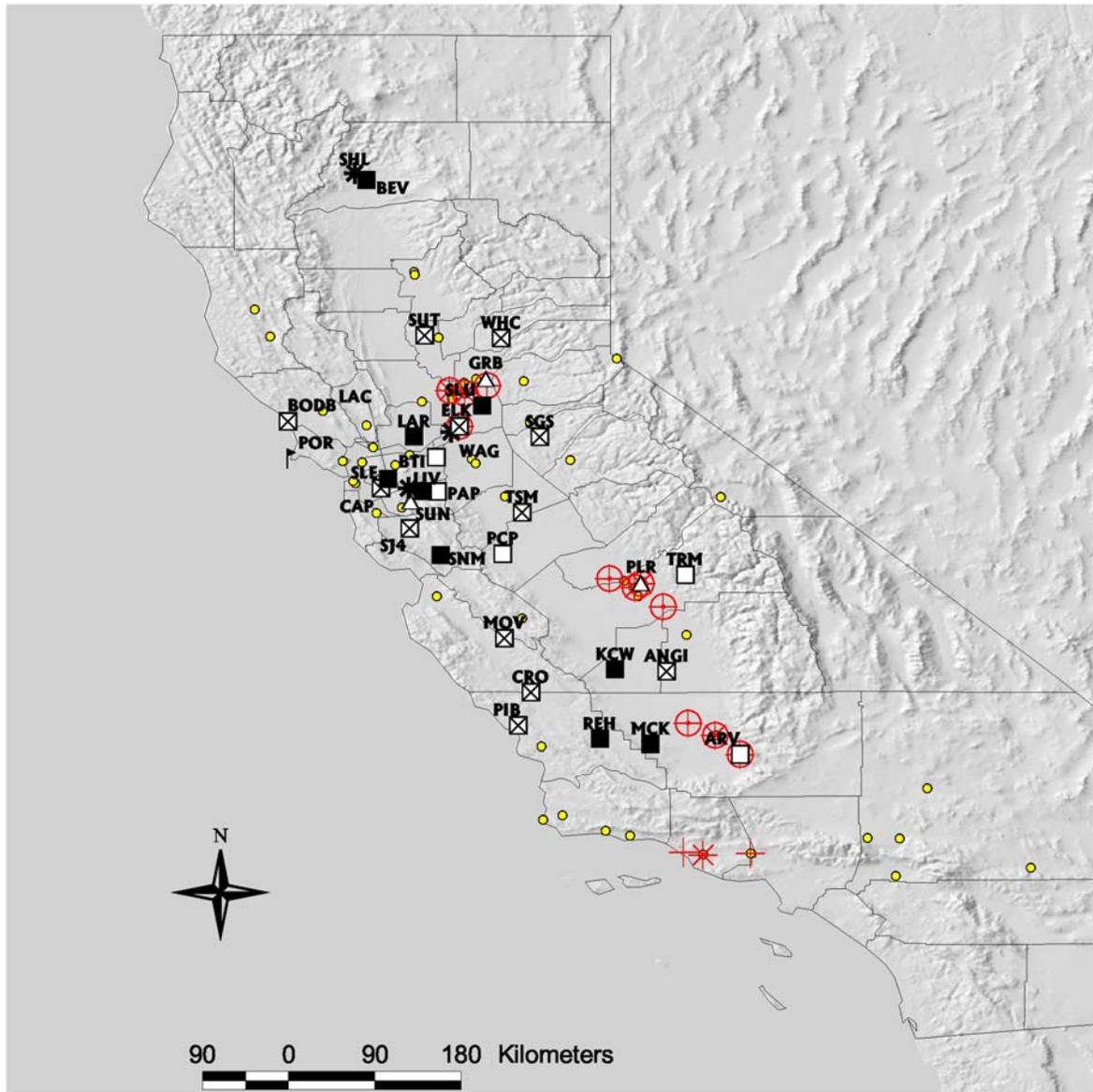
- (1) CRPAQS Annual Site, 24-hour canister sample every 6th day.
- (2) Bay Area component of CCOS, samples collected and analyzed by BAAQMD.
- (3) 10-m meteorological tower located nearby.
- (4) Four canister and DNPH samples daily on 15 IOP days (0000-0300, 0600-0900, 1300-1600, 1700-2000, PDT).
- (5) Two canister samples per day on 5 IOP days (0600-0900, 1300-1600, PDT) and daily auto-GC/MS from 7/2/00 to 9/2/00 (23 hourly on IOP days and seven 3-hr on non IOP days).
- (6) Four Tenax and DNPH samples daily on 15 IOP days (0000-0300, 0600-0900, 1300-1600, 1700-2000, PDT).



-  NO2 Monitoring Site
-  O3 Monitoring Site
-  County Boundary

90 0 90 180 Kilometers
scale 1:7,500,000

Figure 1-1. Existing routine O3 and NOx monitoring sites.



scale 1:7,500,000

CCOS Sites

- △ **Research**
- **Type 2 Supplemental (S2)**
- ⊠ **Type 1 Supplemental (S1)**
- **Type 0 Supplemental (S0)**
- ↑ **Met Only**
- * **Ozone Only**

PAMS

- ⊙ **HC**
- + **NMHC ***
- × **Carb ***
- **CO Monitoring Site**
- **County Boundary**

***Note: Four 3-hr samples (0000, 0600, 1300, 1700 LT)**

Figure 1-2. CCOS supplemental air quality and meteorological monitoring sites and Photochemical Assessment Monitoring Stations.

2. SUPPLEMENTAL SURFACE OZONE

The California Air Resources Board and local air pollution control districts operated 130 ozone analyzers at air quality monitoring stations throughout northern and central California during CCOS. Additional ozone analyzers were deployed as part of the CCOS supplemental monitoring in coastal background sites (Bodega Bay and Piedras Blancas), interbasin transport locations (Lambie Road, Patterson Pass, Pacheco Pass), downwind edge of urban areas (Sunol, Granite Bay, and Parlier) and in key downwind rural areas that lacked existing monitoring (Bella Vista, McKittrick, Kettleman City and Trimmer). BAAQMD sponsored additional ozone monitoring at downwind sites at Lake Chabot and Camp Parks and CRPAQS made ozone measurements in central San Joaquin Valley at Angiola. This section describes the measurement methods and summarizes the results of audits conducted by the California Air Resources Board as documented by Parsons Engineering Science, Inc. (2001) and the validation checks conducted for this report.

2.1 Measurement Method

Ozone is continuously measured either by ultraviolet absorption photometry or by gas-phase ethylene-ozone chemiluminescence. All of the analyzers operated by the Air Pollution Control Districts in the CCOS area employ the UV photometric method. The following analyzers are deployed in the networks: Thermo Environmental Inc., model 49; Dasibi Environmental, model 1003; and Advanced Pollution Instrumentation, Inc. (API), model 400. Eleven API model 400A UV adsorption ozone analyzers were purchased for CCOS and deployed at supplemental monitoring sites.

In the UV analyzer, a mercury vapor lamp is used to produce ultraviolet radiation at 254 nm which is absorbed by the ozone in the air sample. The ozone signal is determined by the difference between ambient air containing ozone and ambient air with the ozone removed or scrubbed. The ultraviolet analyzer is calibrated by comparison with an ozone photometer which is certified as a transfer standard. The transfer standard is certified against absolute ozone photometers located at the California Air Resources Board test and laboratory facilities. The minimum detectable level of UV monitors is about 2-5 ppbv. Accuracies and precisions are on the order of 10-15 percent or 2-5 ppbv, whichever is larger. The API model 400A has a reported lower detectable limit of 0.6 ppb and precision of 1 ppb or 0.5% of reading above 50 ppb (whichever is greater).

Interferences with the UV measurement method include any gas or fine particle that absorbs or scatters light at 254 nm. Gaseous inorganic compounds normally found in the atmosphere, including NO₂ and SO₂, do not interfere, and particles are largely removed by a pre-filter. The most likely interferent is gaseous hydrocarbon compounds that are strong absorbers at 254 nm and are either partially or completely absorbed onto the scrubber. Examples are aromatic compounds, such as benzene and substituted benzenes. Interferences from hydrocarbons can account for a positive bias in the UV measurement for ozone of up to 40 ppb based on the concentration of the interferences occurring during peak ozone periods (Leston and Ollison, 1992). Kleindienst et al. (1993) observed about a 3 percent interference with ozone measurements under hydrocarbon loadings typical of ambient smoggy conditions. Water vapor may also interfere with the UV method when water vapor concentrations are high and variable.

These interferences appear to be due to the condensation of water vapor on imperfect absorption cell windows.

2.2 Performance Audits

Performance audits of the ozone analyzers were conducted by the Air Resources Board for ozone monitoring sites in the San Joaquin Valley and Sacramento Areas and by the BAAQMD in the Bay Area. Results of the audits are summarized in the CCOS quality assurance report by Parsons Engineering. The mean percent differences for surface ozone analyzers operated by DRI (8), T&B (2) STI (1), and District (12) were $-2.9 \pm 2.2\%$, $-1.1 \pm 7.9\%$, $2.7 \pm 1.2\%$ and $-0.8 \pm 3.3\%$, respectively. The numbers in parentheses indicate the numbers of analyzers that passed the performance audits. Audit results for instruments with known problems or for audits where the results have been questioned were removed prior to calculating the average audit results. Specific problems or issues at specific sites and their resolution are documented in Section 4.5 of the Parsons QA report.

2.3 Validation Checks

Our review of the ozone datasets focused on temporal and spatial patterns and relationships between copollutants. Tables 2-1a and 2-1b show daily maximum 1-hour and 8-hour average ozone (ppb) statistics during the CCOS study period for monitoring sites in the Bay Area, North Central Coast, South Central Coast sites, Sacramento Valley, Mountain Counties, and San Joaquin Valley. The sites are listed by air basins and include CCOS supplemental or research sites, CRPAQS sites, and routine monitoring stations. The sites are listed within each air basin in approximate order of north to south and west to east. The site codes are those specified in the CCOS data archive and are used in tables and figures throughout this report. Figure 2-1 shows the mean daily maximum 1-hour and 8-hour average ozone mixing ratios during study period at all sites with bars indicating the seasonal maximum value. The sites are grouped in the plot by basins as in Table 2-1. The spatial patterns of ozone values in the study region are consistent with conceptual expectations with lower values along coastal areas and generally higher values in the central valley with the highest levels in areas downwind of urban areas. The spatial variations in the timing of maximum 1-hour average ozone are consistent with general transport patterns. These average times (hour in PDT) in the SFBA, NCC, SCC, SV, MC and SJV are 13.0 ± 1.3 , 12.9 ± 0.9 , 13.0 ± 0.7 , 14.1 ± 0.4 , 14.1 ± 1.2 and 14.6 ± 0.6 , respectively. The ozone values in boxes in Table 2-1 indicate suspect data. The seasonal high at Yreka is too high and the seasonal mean 1-hour and 8-hour ozone at Maricopa is too low. Time series plots of daily maximum 1-hour ozone were shown for each of the air basins in the CCOS domain in Figures 2-2a through 2-2f. Boxes indicate suspect data.

The ratios of the mean 1-hour ozone during CCOS IOPs to the corresponding mean values during the entire study period (6/1/00 to 9/30/00) at all monitoring sites in the San Francisco Bay Area, Sacramento Valley, Mountain Counties and San Joaquin Valley are 1.36, 1.15, 1.15 and 1.20, respectively. Figure 2-3 shows the mean daily maximum 1-hour and 8-hour average ozone mixing ratios during CCOS IOPs with bars indicating the maximum value. Figure 2-6 shows a scatter plot of the hourly ozone versus the corresponding NO during IOP days at all

sites. The expected inverse relationship is evident for all data. Most of the outliers are from the Sacramento-Airport Rd site (NAT).

Spatial plots of 1-hour maximum ozone levels within the CCOS domain are shown in Figure 2-5a through 2-5k for the IOP days that are candidates for modeling. The evolution of spatial and temporal patterns of ozone levels within the CCOS study area is consistent with the meteorological conditions for each of the following episodes.

IOP#1 – July 23-24, 2000

An upper air pattern developed with a high amplitude ridge across the west and a mean trough over the east and a series of shortwave troughs embedded within the ridge over the southwestern US. Rotation around a Four Corners High fostered southerly gulf flow bringing in subtropical moisture, and the shortwaves helped to kick-off precipitation events over the southern Great Basin and the Colorado Plateau. The atmosphere generally was less stable than needed for high ozone in the southern San Joaquin, and even some precipitation was observed over California. However, even with these less than favorable conditions, Bakersfield still reached 112 and 119 ppb for daily maximums on July 23 and 24, respectively. Further to the north and further away from the monsoonal influence, Parlier reached 120 and 144 ppb for daily maximums on July 23 and 24, respectively. In the Sacramento Valley, Cool and Sloughhouse both reached 110 ppb on the second day, July 24. Onshore flow kept the Bay Area clean for the two-day period.

IOP#2 – July 30 through August 2, 2000

A typical Great Basin High occurred during this IOP. This strong ridge brought favorable ozone conditions to the study region. The high persisted for four days before a trough off the Pacific Northwest Coast moved the high eastward, leaving approximately zonal flow over most of the study region by August 3. Favorable off-shore gradients developed during the period, bringing a Cluster 1 day and a 1 hour exceedance of 126 ppb at Livermore on July 31. A cluster 3 day¹ occurred on August 1, with calm winds in the southern Sacramento Valley and a 1 hour exceedance of 130 ppb to the Sloughhouse monitoring station. On August 2, the southern SJV

¹ Designation of the type of ozone episodes from cluster analysis (See CCOS Conceptual Program Plan)

Cluster 1 - The San Francisco Bay Area (SFBA) has its highest basin-wide ozone values, though still less in absolute magnitude than San Joaquin Valley. This cluster is characterized by the weakest sea breeze (lowest west-to-east component through Carquinez Strait), and the lowest Oakland inversion base heights. Among the cluster days, North Central Coast ozone is also highest during Cluster 1.

Cluster 2 - The San Joaquin Valley (SV) has its highest basin-wide values while the Bay Area and Sacramento Valley are relatively cleaner. A stronger sea breeze, relatively to Cluster 1, keeps the pollutants moving through the Bay Area and the Sacramento Valley, but may increase transport into the SV. Among the cluster days, Mountain Counties ozone is lowest during Cluster 2

Cluster 3 – Sacramento Valley (SV) has its highest basin-wide ozone values, as does the Mountain Counties Air Basin. As with Cluster 2, a stronger sea breeze is present, relative to Cluster 1, but surface temperatures in Sacramento Valley are significantly higher, indicating less and/or later intrusion of the sea breeze, allowing more time for photochemistry before evening transport to the Mountain Counties.

experienced a 1 hour exceedance of 151 ppb at the Edison station, and westerly winds increased somewhat, transporting pollutants into the foothills, bringing a 130 ppb at Grass Valley.

IOP#5 – September 17-21, 2000

A relatively strong Eastern Pacific High developed during this IOP. September 17 was a relatively clean ramp-up day. The SJV experienced high ozone in the central region, with 1 hour exceedances of 171 ppb and 136 ppb at Parlier on September 18 and 19, respectively. Similarly, the southern SJV experienced exceedances at both Arvin and Edison on the 18th and 19th. The offshore gradient strengthened on the 19th and Livermore reached 100 ppb for a daily maximum. Concord did experience a 1 hour state exceedance of 95 ppb on the 19th. However, sufficient northwesterly flow continued aloft to reinforce the sea breeze and prevent ozone significant buildup along the coast. Operations continued through the 21st when the high had regressed back westward leaving strong northerly flow through a trough axis from Hudson Bay to San Francisco Bay by September 22.

2.4 Summary of Validation Results

Validation checks of the CCOS ozone data show that the data are consistent with our expectations of the temporal and spatial variations of ozone during the study. The few problems and anomalies are noted below.

IOP Days

- BodegaBay (BODB) - most of 9/16 flagged as suspect at Level 1
- LambieRd (LAMB) - many periods (12% of minutes) from 8/15 to 9/28 flagged as suspect at Level 1. 2908 minutes between 9/24 and 9/28 inclusive (40%) - according to Parsons QA report instrument was 'prone to periods where the analyzer response became erratic'.
- Maricopa School (MCS) - reported values anomalously low for all hours during 8/1-8/2 IOP, not flagged in data file received.
- Tracy (TPP) - second ozone peaks occur around midnite each day of 9/17-9/20 IOP. Not flagged in data file received.

Study Period

- Maricopa School (MCS) - anomalously low values for all hours during first half of June 2000 and entire month of August 2000.
- Yreka – anomalously high values on 9/1/00 to 9/3/00 and 9/25/00.
- Morro Bay – anomalously low values 6/24/00 to 7/11/00.

Table 2-1a. Daily maximum ozone (ppb) statistics during CCOS study period at monitoring sites in the San Francisco Bay area, North Central Coast and South Central Coast.

SiteName	Code	Basin	Daily 1-Hour Ozone					Daily 8-Hour Ozone				
			Mean	high	95%	90%	Time	Mean	high	95%	90%	Time
Bodega Bay Stn	BODB	SFB	31	48	44	37	14.9	28	44	41	36	13.3
Santa Rosa (837 Fifth St.)	SRF	SFB	35	78	55	48	11.8	30	57	42	39	11.0
Napa Stn(Jefferson Ave)	NAP	SFB	44	77	71	62	13.5	37	63	55	51	10.3
San Rafael Stn	SRL	SFB	29	67	52	43	11.5	24	59	39	34	10.5
San Francisco (Arkansas St.)	SFA	SFB	27	58	38	36	9.1	23	40	35	30	11.4
Vallejo (304 Tuolumne St.)	VJO	SFB	34	79	58	52	13.0	29	56	45	39	10.2
Redwood City Stn	RED	SFB	31	83	52	42	12.5	25	64	42	36	10.8
San Jose (4th St.)	SJ4	SFB	36	73	59	52	12.7	29	60	43	40	10.0
Bethel Island Stn	BTI	SFB	56	93	86	81	12.3	47	82	70	65	10.3
Pittsburg (10th Street)	PBG	SFB	53	91	79	75	14.0	44	80	67	60	10.7
Fremont (Chapel Way)	FCW	SFB	40	102	67	58	13.7	32	73	47	43	10.2
Concord (2975 Treat Blvd.)	CCD	SFB	51	95	82	75	13.1	40	71	63	61	10.4
Sunol Station Stn	SUNO	SFB	49	99	81	70	13.9	39	78	59	53	10.2
Livermore (Old First St.)	LVF	SFB	53	137	90	79	13.3	42	111	66	60	9.8
Livermore Stn-793 Rincon at Pine	LVR1	SFB	54	152	94	81	13.2	43	115	66	61	9.9
Patterson Pass Stn	PATP	SFB	64	126	105	88	14.2	53	101	83	76	11.7
Pacheco Pass Stn	PCP	SFB	61	117	98	88	14.1	53	97	82	78	10.4
Davenport Stn	DVP	NCC	32	55	45	43	12.9	29	45	41	38	10.2
Santa Cruz (2544 Soquel Drive)	SCQ	NCC	39	78	55	52	13.1	33	61	44	43	10.6
Watsonville (444 Airport) Stn	WAA	NCC	39	81	62	51	12.4	34	60	49	43	10.7
Hollister (1979 Fairview)	HST	NCC	49	94	77	68	12.8	42	77	66	61	10.0
Monterey/Fort Ord	MON	NCC	36	95	55	48	12.5	32	73	47	42	10.4
Salinas (High School)	SALH	NCC	36	68	50	46	12.0	32	55	44	41	10.9
Carmel Valley (Ford Road)	CMV	NCC	39	88	63	54	12.3	35	79	50	45	10.2
Pinnacles National Monument Stn	PIN	NCC	62	96	89	83	15.0	54	82	74	72	11.1
Capitan Stn/Las Flores Canyon #1	CA1	SCC	60	128	82	78	13.4	53	85	72	68	10.9
Piedras Blancas Stn	PIED	SCC	33	63	46	42	15.1	30	51	43	39	12.5
Paso Robles (235 Santa Fe)	PRF	SCC	55	83	81	76	12.5	48	76	68	65	10.2
Atascadero (Lewis Ave.)	ATL	SCC	55	84	78	76	11.8	48	81	67	64	9.5
Morro Bay Stn	MBP	SCC	33	60	48	46	13.4	30	57	45	42	11.0
San Luis Obispo (Marsh)	SLM	SCC	38	75	59	53	12.6	34	69	51	45	11.2
Grover City (Lesage Drive)	GCL	SCC	35	68	46	43	13.2	32	58	42	39	10.7
Los Padres NF (Paradise Rd.)	LPD	SCC	65	94	90	85	13.3	58	88	79	76	10.3
Nipomo (Teft and Pomeroy St.)	TEF	SCC	42	78	60	54	13.0	38	66	52	49	10.4
Santa Maria (906 S Broadway)	SMAR	SCC	36	63	48	45	12.2	33	52	44	42	10.7
Vandenberg STS Power Plant Stn	VBS	SCC	38	76	54	48	12.2	35	56	47	44	10.1
Lompoc Stn(HS & P)	LHS	SCC	44	99	64	56	12.4	40	78	60	50	9.7
Lompoc (128 South H St.)	LOM	SCC	39	74	54	48	12.4	35	58	48	43	10.6
Santa Ynez Airport Stn	SYN	SCC	50	79	75	70	12.2	43	71	64	62	9.9
Gaviota TC-Site B Stn	GVB	SCC	47	86	75	66	12.8	40	70	59	55	10.0
El Capitan Beach Stn	ECP	SCC	49	76	66	65	12.9	43	66	60	52	10.0
Goleta (N Fairview Ave.)	GNF	SCC	50	80	69	62	12.8	42	68	57	50	10.1
Santa Barbara (3 W Carillo)	SBC	SCC	44	88	63	58	12.8	36	70	55	46	10.2
Carpinteria (Gobernador Rd.)	CRP	SCC	54	94	74	69	13.3	46	76	61	60	10.0
Ojai (Ojai Rd.)	OJO	SCC	73	109	100	98	13.5	66	101	90	86	10.0
Ventura Co./W Casitas Pass Stn	VTA	SCC	60	110	87	85	13.6	52	96	75	70	11.3
Ventura (Emma Wood St. BE.)	VTE	SCC	49	82	68	65	13.4	43	73	59	55	10.4
El Rio Mesa School #2 Stn	ELM	SCC	52	84	73	69	12.9	45	72	62	57	10.0
Thousand Oaks (Moorpark Rd.)	THM	SCC	66	102	89	83	13.6	58	87	77	73	10.3
Piru (2 mi SW)	PIR	SCC	64	104	86	82	12.9	54	87	74	70	10.0
Simi Valley Stn	SIM	SCC	79	128	109	101	12.9	68	105	91	88	10.0

Table 2-1b. Daily maximum ozone (ppb) statistics during CCOS study period at monitoring sites in the Sacramento Valley, Mountain Counties and San Joaquin Valley.

SiteName	Code	Basin	Daily 1-Hour Ozone					Daily 8-Hour Ozone				
			Mean	high	95%	90%	Time	Mean	high	95%	90%	Time
Yreka (Foothill Drive)	YREK	NEP	52	143	78	66	13.3	43	80	60	56	9.9
Redding Stn	RDG	SV	71	102	93	91	14.1	63	88	81	78	10.7
Bella Vista Stn	BELV	SV	65	93	89	83	14.3	58	87	77	75	10.6
Anderson (North Street)	ANDE	SV	59	90	81	77	14.2	53	82	72	68	10.6
Lassen Volcanic NP Stn	LNP	SV	60	91	79	76	14.2	56	83	72	68	11.4
Tuscan Butte Stn	TSB	SV	67	94	89	84	14.1	61	88	80	78	13.2
Chico (Manzanita)	CHM	SV	61	96	82	80	14.0	54	84	74	69	10.5
Willows (E Laurel St.)	WLW	SV	61	86	81	74	14.3	54	78	71	67	10.5
Colusa (100 Sunrise Blvd.)	CSS	SV	55	92	75	71	15.0	48	73	66	61	10.8
Yuba City (Almond St.)	YAS	SV	62	108	88	81	14.7	53	87	79	72	10.8
Woodland Stn	WLN	SV	63	100	90	80	13.3	53	84	75	72	10.4
Pleasant Grove (4 SW)	PGV	SV	65	108	93	87	14.4	55	93	79	74	10.6
Sacramento/Natoma (Airport Rd.)	NAT	SV	62	99	90	83	14.3	52	90	76	73	10.6
Lambie Road Stn	LAMB	SV	54	102	86	79	13.7	46	82	76	66	10.2
Davis/UCD Campus Stn	DVS	SV	62	103	93	87	14.0	51	90	75	71	10.1
Elk Grove (Bruceville Rd.)	ELK	SV	57	104	83	77	14.2	48	95	70	66	10.4
Sacramento (1309 T St.)	S13	SV	56	101	84	78	14.0	46	80	71	64	10.4
Sacramento (Del Paso Manor)	SDP	SV	67	123	99	92	14.1	56	101	84	76	10.8
Sloughouse Rd. Stn	SLU	SV	73	133	107	103	14.3	62	109	91	86	10.8
Sacramento-North Highlands	SNH	SV	68	120	98	90	14.1	58	100	85	79	10.7
Folsom (Natoma St.)	FLN	SV	68	126	105	97	14.3	58	102	89	85	10.9
Granite Bay Stn	GNBY	SV	75	126	116	104	14.6	65	108	98	92	11.0
Roseville (151 N Sunrise)	ROS	SV	68	128	109	99	13.7	57	100	90	82	10.4
Rocklin (5000 Rocklin Rd.)	ROC	SV	68	118	103	98	14.3	58	98	87	84	10.6
Truckee Fire Station Stn	TRU	MC	55	81	67	66	14.0	48	62	60	58	10.5
Quincy Stn	QUI	MC	59	81	73	71	14.0	53	77	69	65	10.3
White Cloud Mtn. Stn	WCM	MC	71	118	95	87	12.5	66	108	90	81	11.6
Grass Valley - Litton Building Site	GVL	MC	78	130	102	95	12.5	72	113	95	90	11.9
Cool (1400 American River Trail)	CUS	MC	79	128	120	109	14.7	70	114	99	95	10.7
Jackson (201 Clinton Road)	JAC	MC	73	121	103	94	15.6	66	103	91	86	11.0
Jerseydale	JSD	MC	73	117	95	91	13.2	68	100	89	85	11.1
Placerville (Gold Nugget)	PGN	MC	73	113	102	97	14.7	65	101	92	87	11.8
San Andreas (Gold Strike Rd.)	SGS	MC	74	134	105	98	16.0	66	105	94	87	11.4
Sonora - Five Mile Learning Center	FML	MC	77	109	100	94	12.4	72	105	92	89	12.6
Sonora (251 S Barretta St.)	SNB	MC	69	108	95	89	14.5	62	94	83	80	10.8
Yosemite NP/Turtleback Dome	YOT	MC	72	121	90	87	14.6	66	100	83	80	12.3
Stockton (Hazelton St.)	SOH	SJV	56	107	85	78	14.4	45	81	69	62	10.4
Stockton (13521 E Mariposa)	SOM	SJV	59	108	88	79	14.8	49	85	69	67	10.8
Tracy (24371 Patterson Pass)	TPP	SJV	61	122	91	84	14.2	51	94	74	71	10.6
Turlock (900 S Minaret)	TSM	SJV	73	131	105	96	15.4	61	108	90	83	11.0
Modesto (814 14th St.)	M14	SJV	67	131	96	91	15.4	55	102	80	74	10.9
Merced (385 S Coffee Ave.)	MRA	SJV	83	120	112	107	15.7	74	112	97	95	11.4
Madera (29 1/2 No. of Ave 8)	M29	SJV	70	104	94	92	14.4	63	95	85	81	10.7
Clovis (908 N Villa Ave.)	CLO	SJV	87	153	127	120	13.8	75	132	100	97	10.6
Fresno (North Perimeter Rd.)	FNP	SJV	80	116	106	101	15.0	69	95	88	86	10.2
Fresno (Drummond)	FSD	SJV	79	131	113	108	14.1	69	104	92	90	10.9
Fresno (3425 First St.)	FSF	SJV	85	143	122	116	13.9	74	110	101	97	10.7
Fresno (Sierra Skypark #2)	FSS	SJV	93	139	125	118	14.3	84	125	108	105	10.9
Shafter (Walker St.)	SHA	SJV	78	123	101	95	14.9	71	106	91	86	10.5
Parlier Stn	PLR	SJV	96	165	131	127	14.6	81	120	105	100	10.6
Hanford (Irwin St.)	HAN	SJV	86	124	115	105	15.2	78	111	102	96	11.1
Kettleman City Stn	KETC	SJV	70	105	91	87	14.3	63	94	83	79	10.3
Trimmer Stn	KRV	SJV	90	125	117	112	14.9	80	108	101	98	10.8
Mineral King Lookout Point	LMK	SJV	89	116	110	107	15.7	81	106	99	98	11.1
Visalia (Church St.)	VCS	SJV	84	129	110	105	15.1	73	100	95	90	10.9
Sequoia (Giant Forest)	SLK	SJV	77	108	97	94	15.5	70	94	89	84	11.4
McKittrick Stn	MCKI	SJV	82	124	105	103	14.8	75	115	97	94	10.5
Oildale (3311 Manor)	OLD	SJV	83	124	108	100	14.5	76	107	98	94	10.9
Bakersfield (5558 California St.)	BAC	SJV	83	125	106	103	14.5	76	107	99	95	10.7
Bakersfield (1128 Golden State)	BGS	SJV	83	117	109	103	14.2	75	101	96	94	10.9
Edison Stn	EDS	SJV	94	151	127	121	13.2	80	117	103	100	10.2
Arvin Stn	ARV	SJV	98	145	127	122	14.8	84	117	107	104	11.0
Maricopa School/Stanislaus	MCS	SJV	43	112	100	93	13.6	37	99	91	87	10.6

Note: Suspect data indicated by boxes.

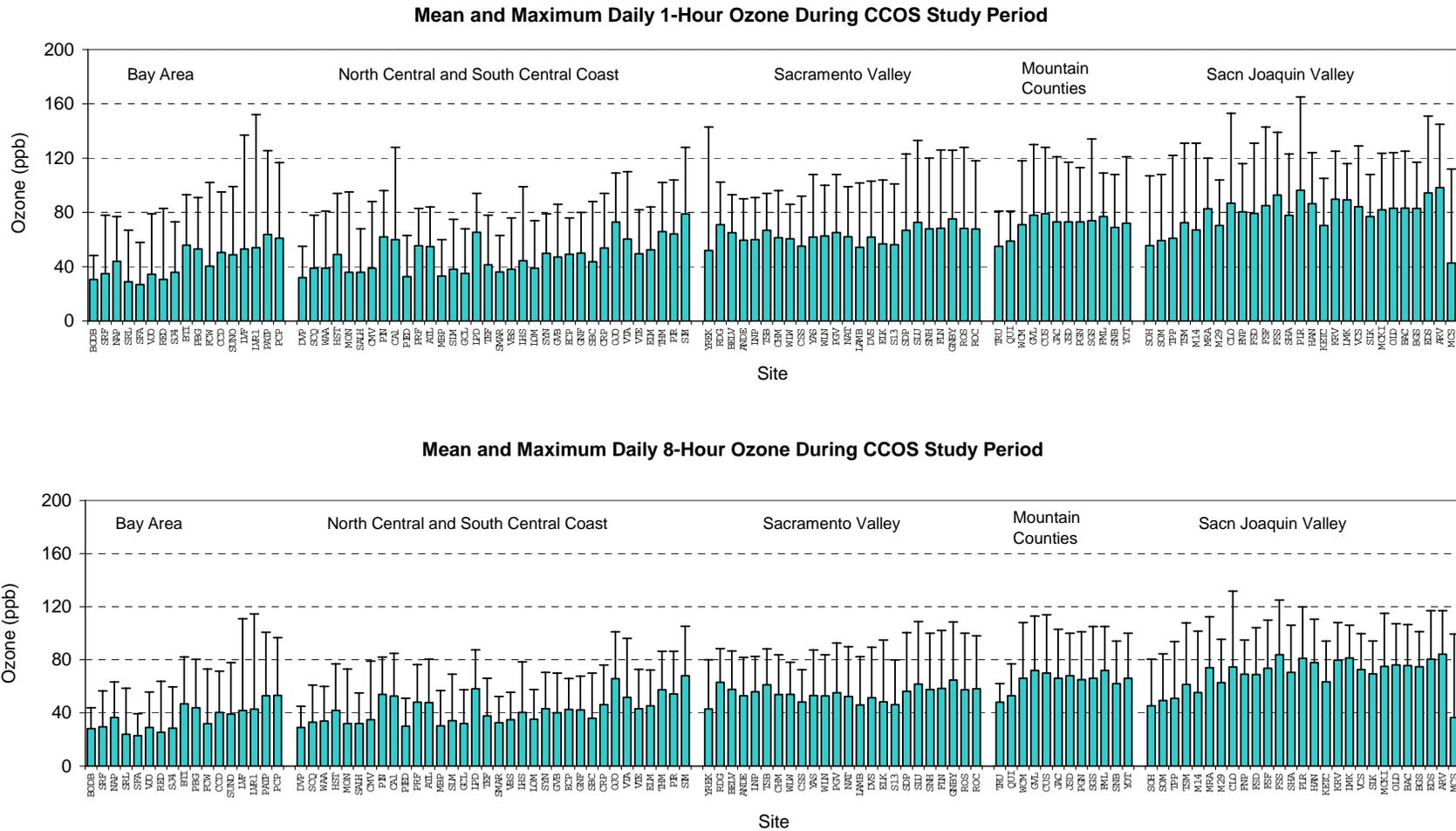


Figure 2-1. Mean (bars) and maximum (whiskers) daily 1-hour ozone mixing ratios (ppb) during CCOS Study Period (6/1/00 to 9/30/00). Sites are grouped by basins as in Table 2-1, and are arranged approximately from north to south within each basin going from left to right.

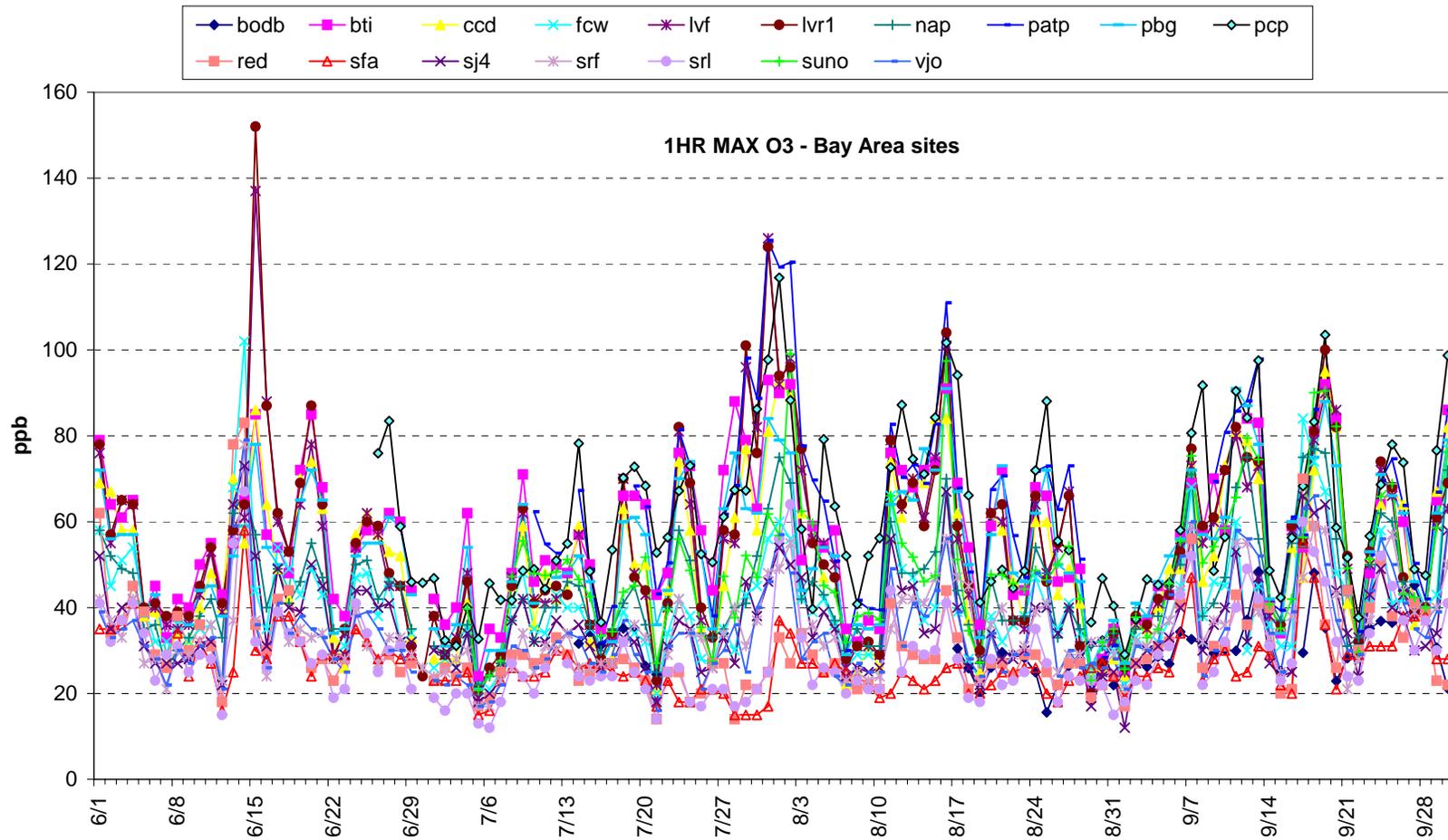


Figure 2-2a. Time series plot of daily maximum 1-hour ozone at sites in San Francisco Bay air basin during CCOS.

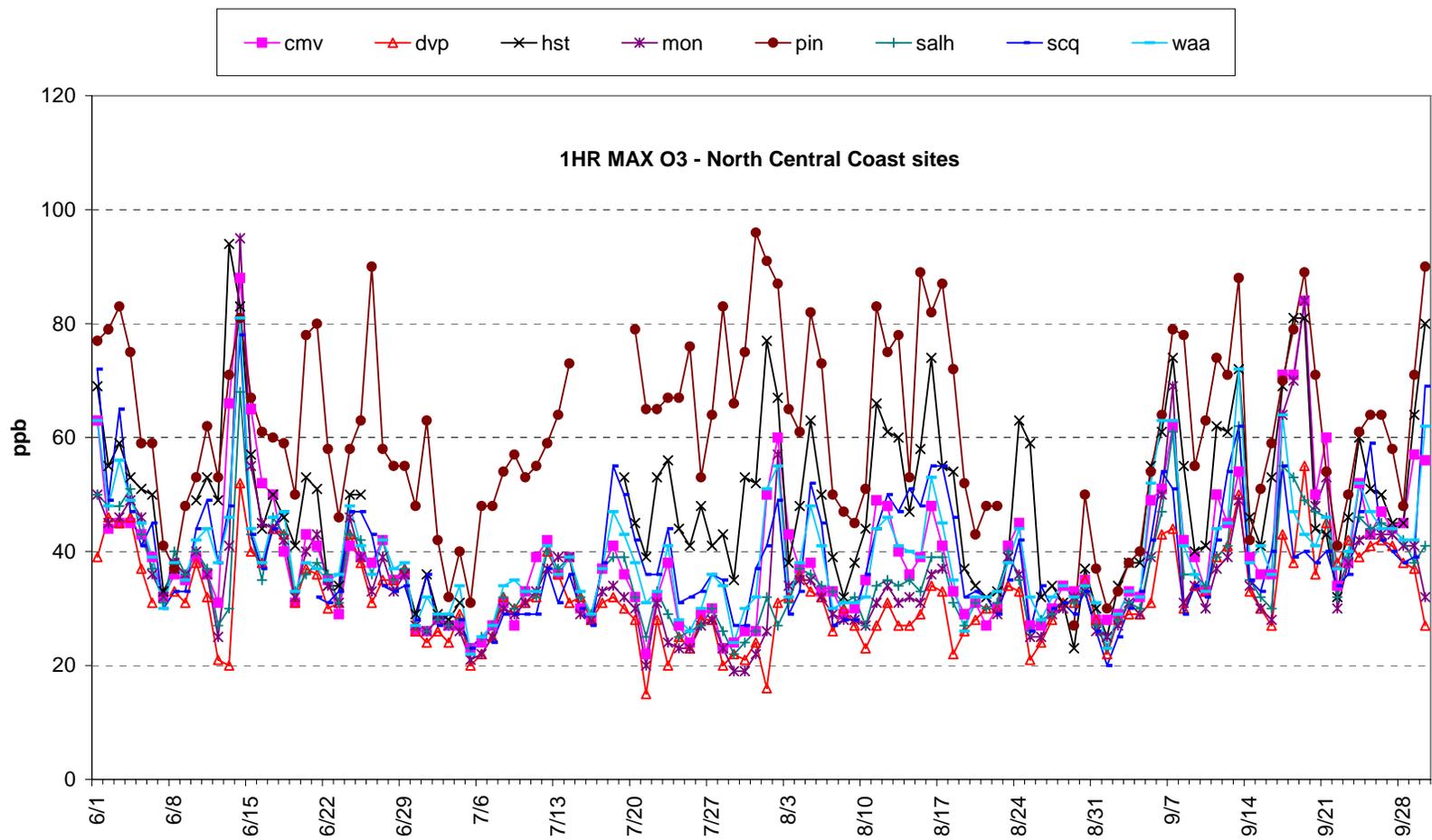


Figure 2-2b. Time series plot of daily maximum 1-hour ozone at sites in the North Central Coast air basin during CCOS.

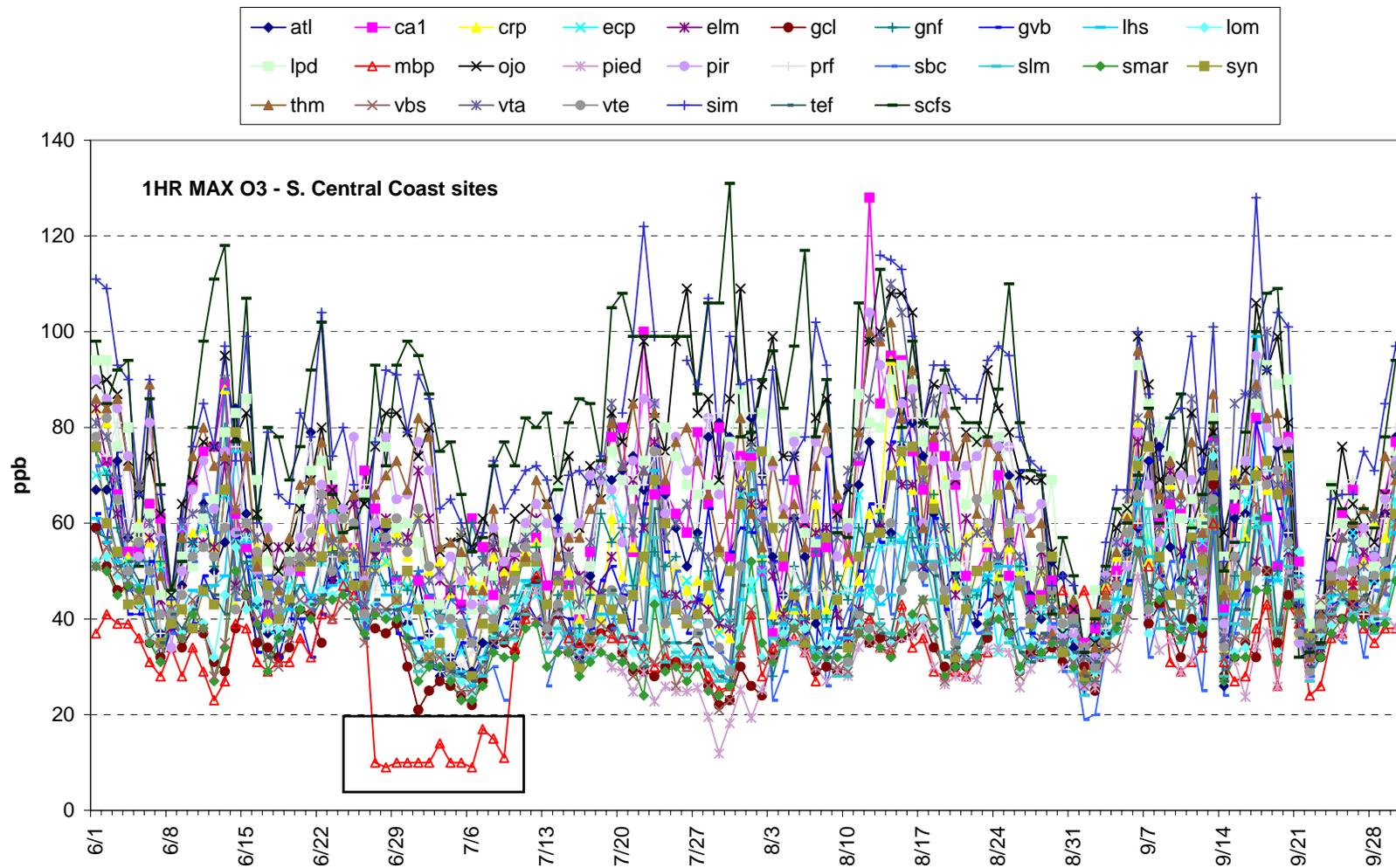


Figure 2-2c. Time series plot of daily maximum 1-hour ozone at sites in South Central Coast air basin during CCOS. Box indicates questionable data from Morro Bay (MBP).

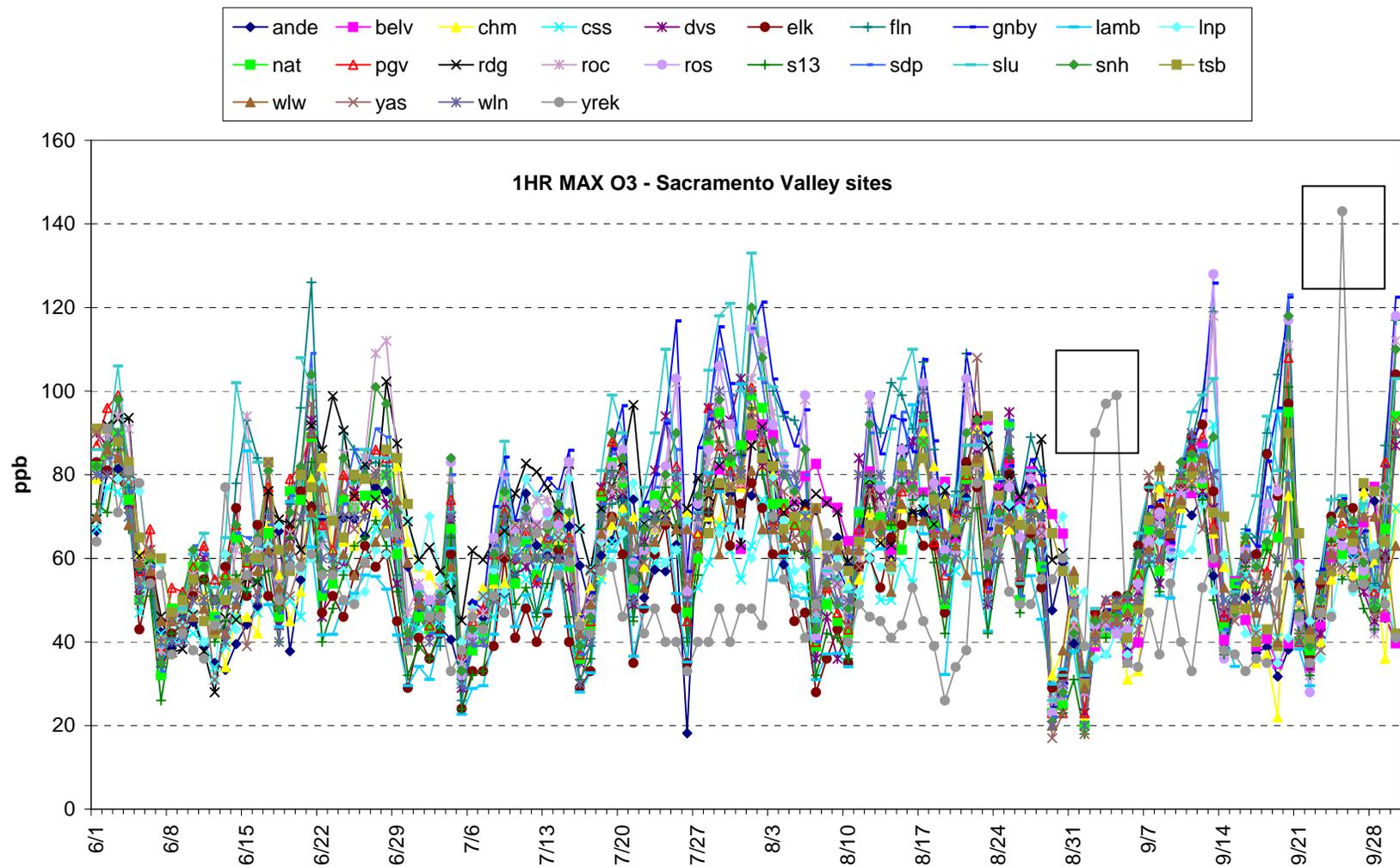


Figure 2-2d. Time series plots of daily maximum 1-hour ozone at sites the Sacramento Valley air basin during CCOS. Boxes indicate questionable data from Yreka.

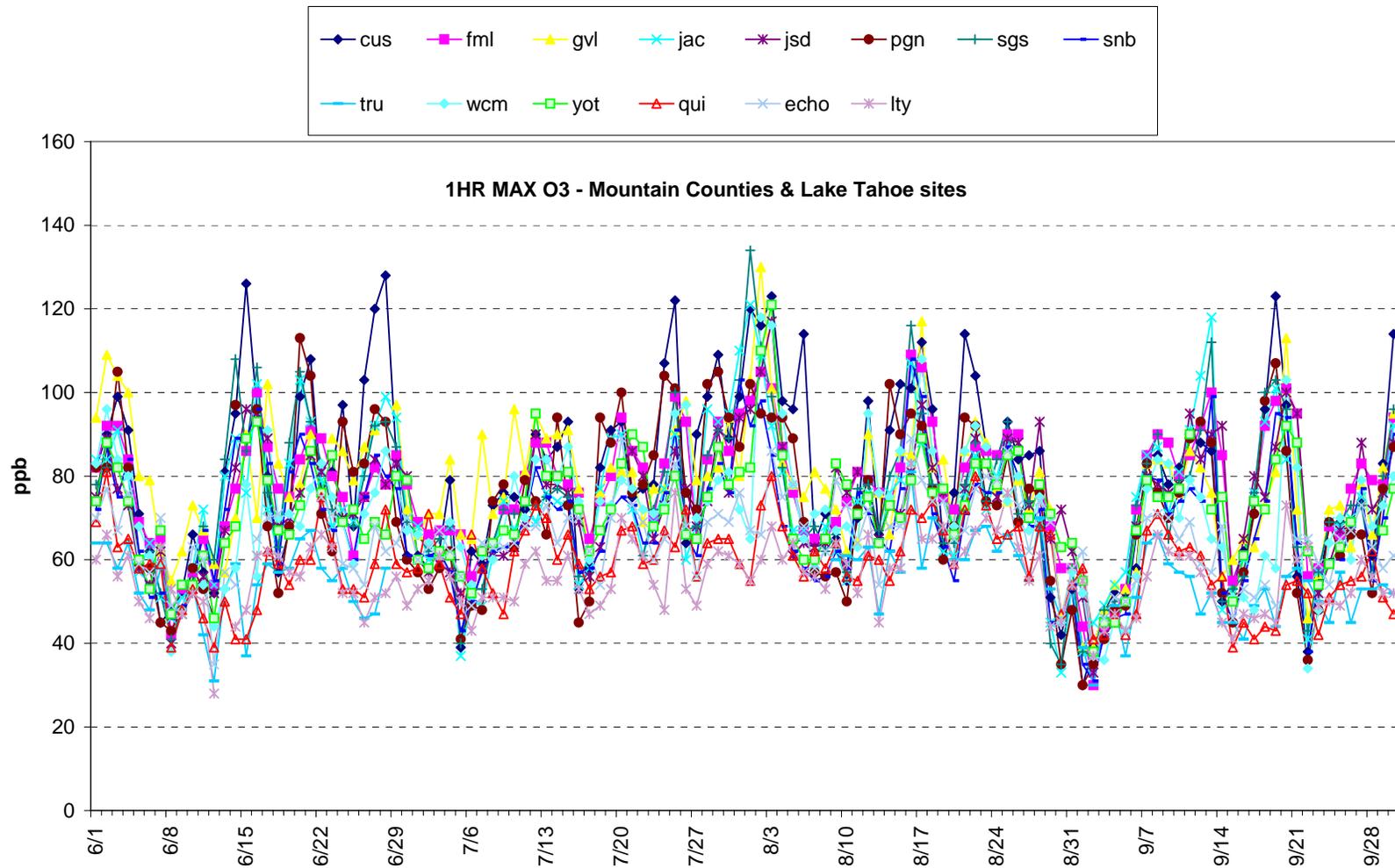


Figure 2-2e. Time series plot of daily maximum 1-hour ozone at sites in the Mountain Counties and Lake Tahoe air basins during CCOS.

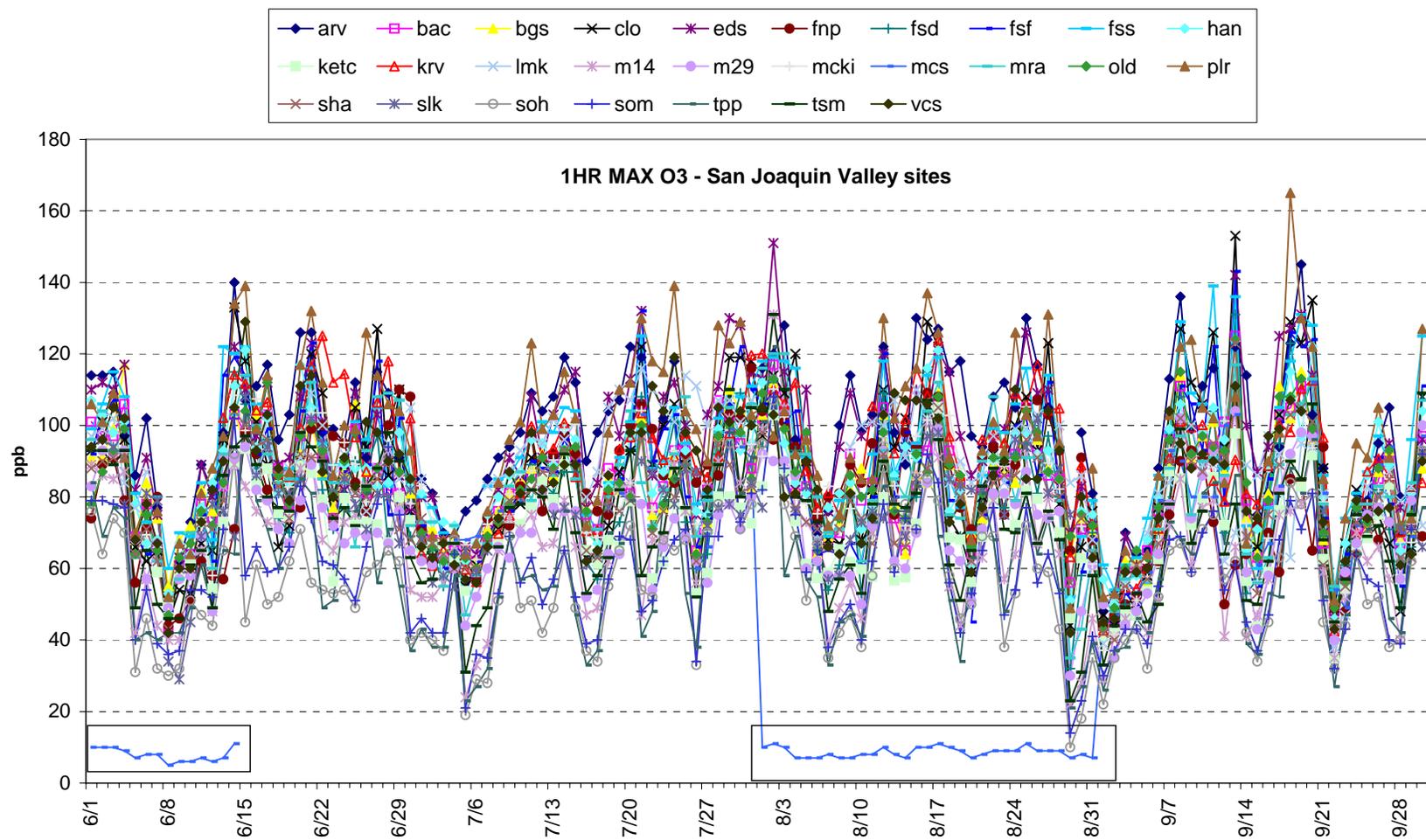


Figure 2-2f. Time series plot of daily maximum 1 hr ozone at sites in San Joaquin Valley air basin during CCOS. Boxes indicate questionable data from Maricopa station (MCS).

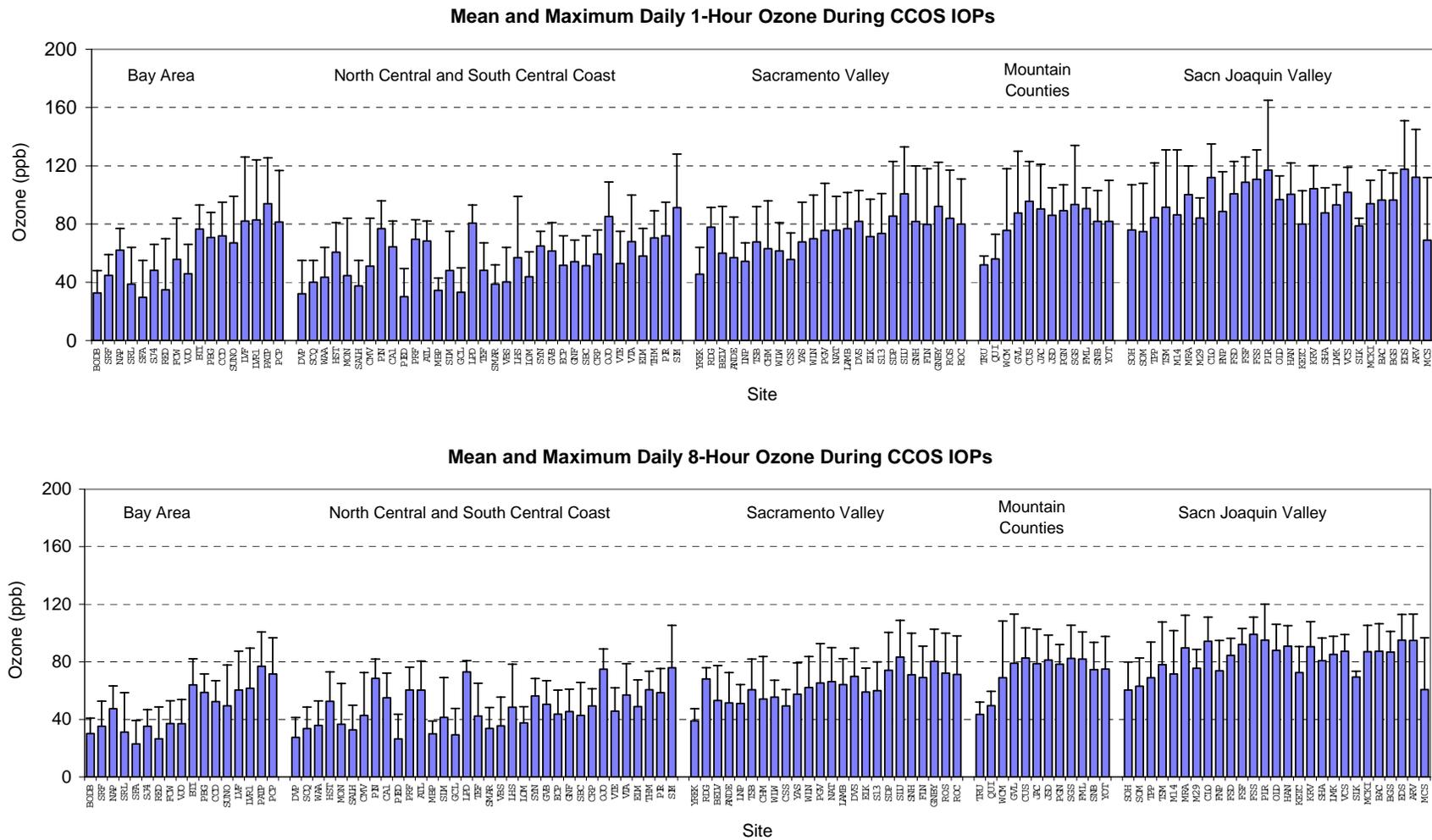


Figure 2-3. Mean (bars) and maximum (whiskers) daily 1-hour ozone mixing ratios (ppb) during CCOS IOPs. Sites are grouped by basins as in Table 2-1, and are arranged approximately from north to south within each basin going from left to right.

hourly data from all CCOS sites - primary IOP days

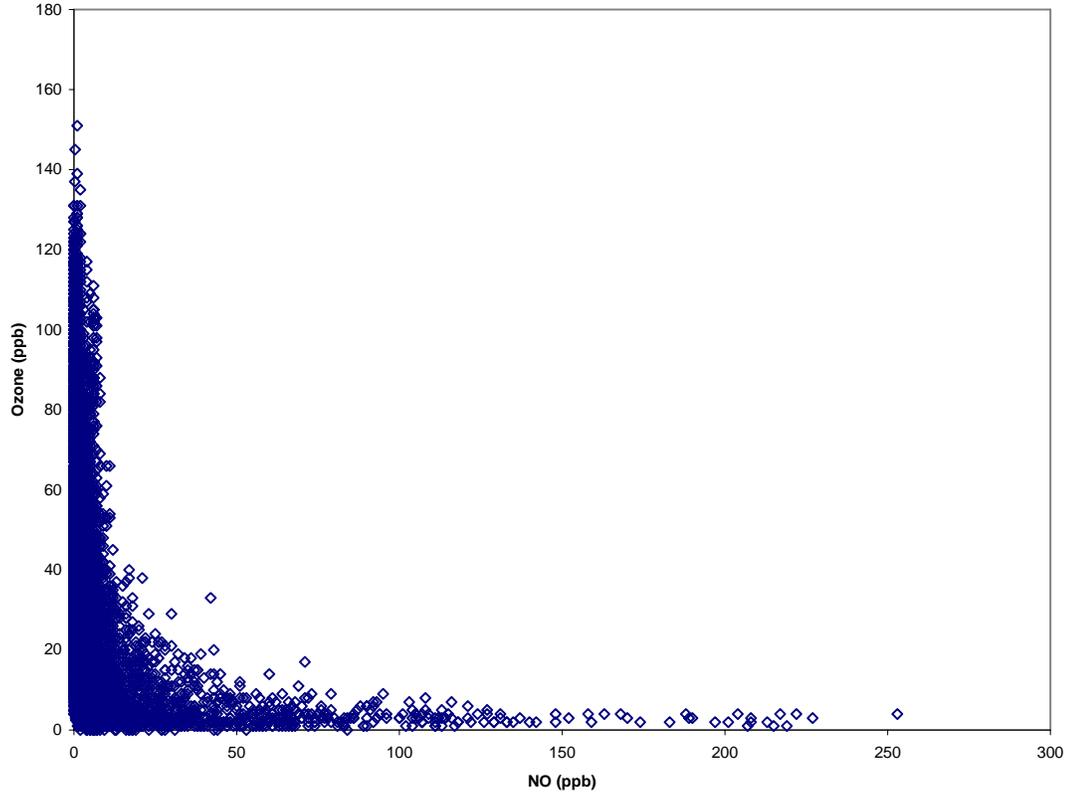


Figure 2-4. Scatter plot of hourly ozone vs NO during IOP days at all sites. The expected inverse relationship is evident for all data. Most of the outliers are from the Sacramento-Airport Rd site (NAT).

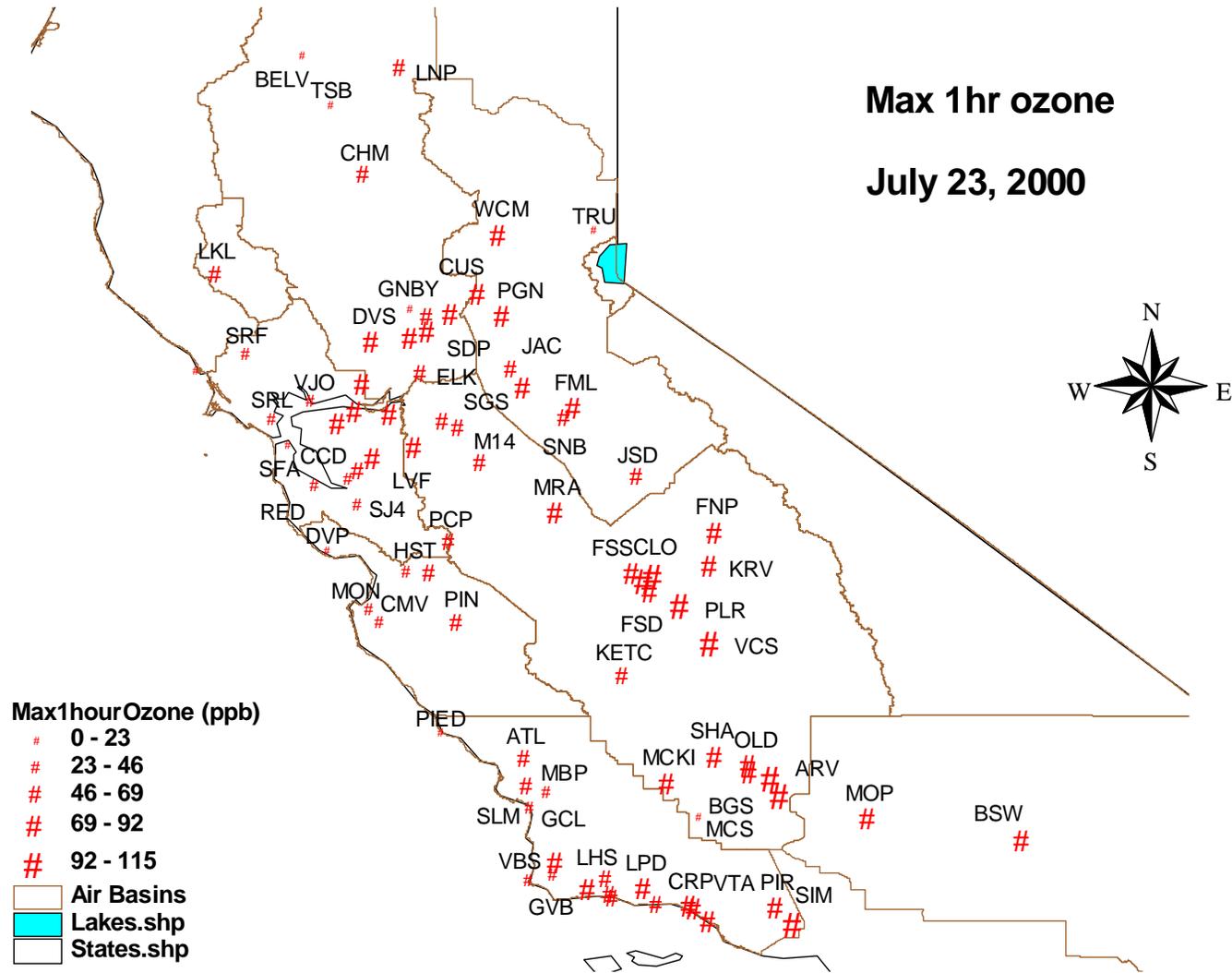


Figure 2-5a. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during July 23, 2000.

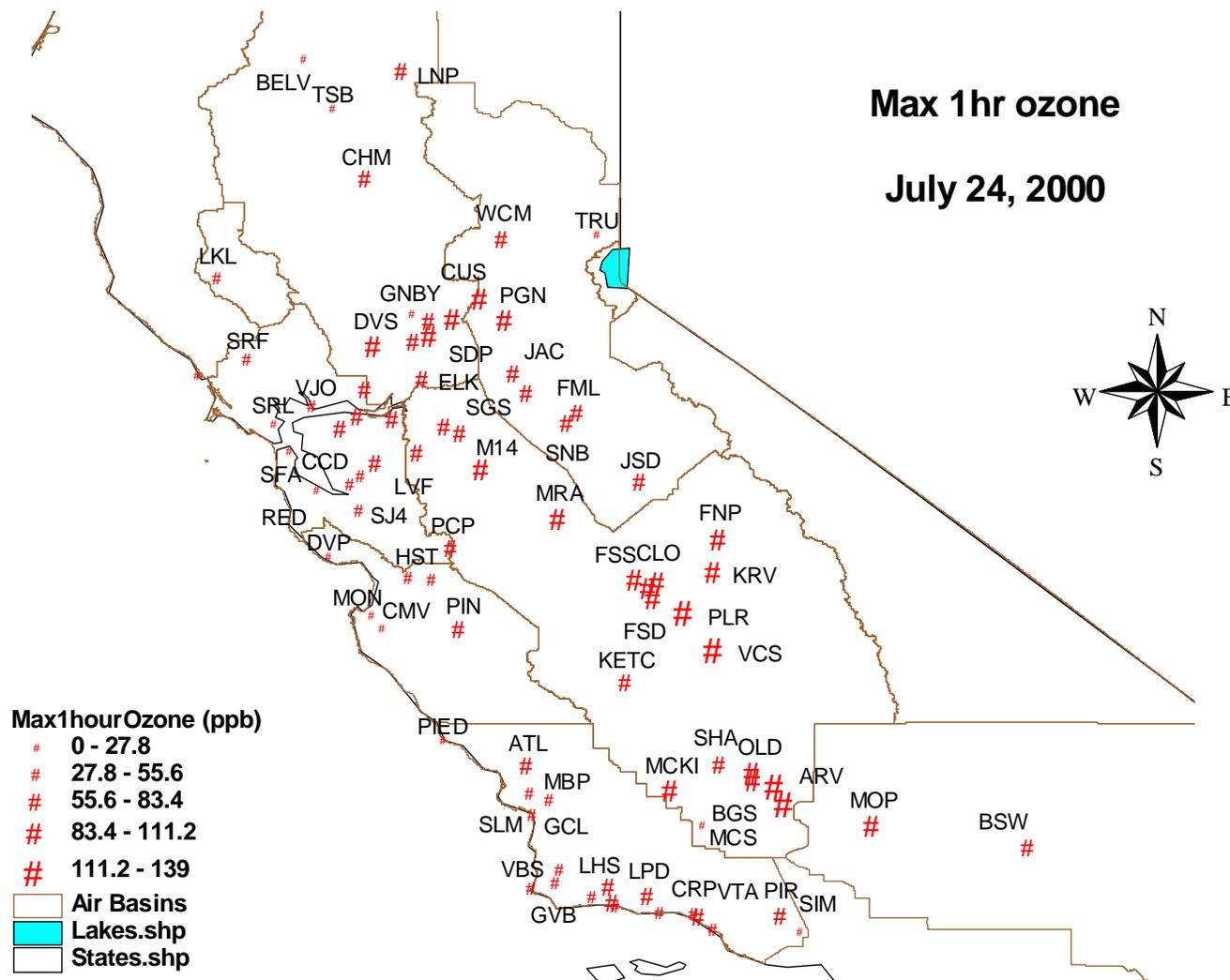


Figure 2-5b. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during July 24, 2000.

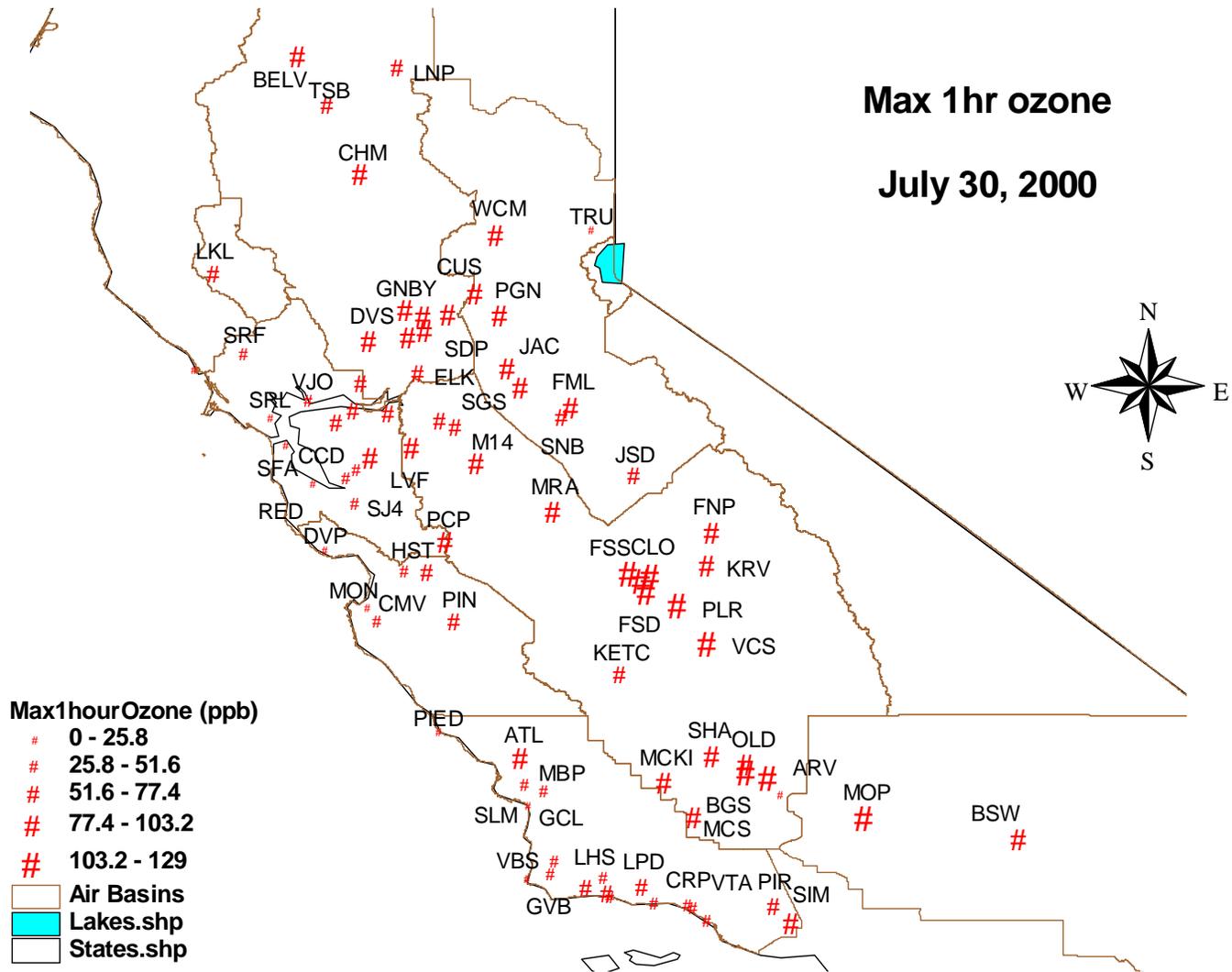


Figure 2-5c. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during July 30, 2000.

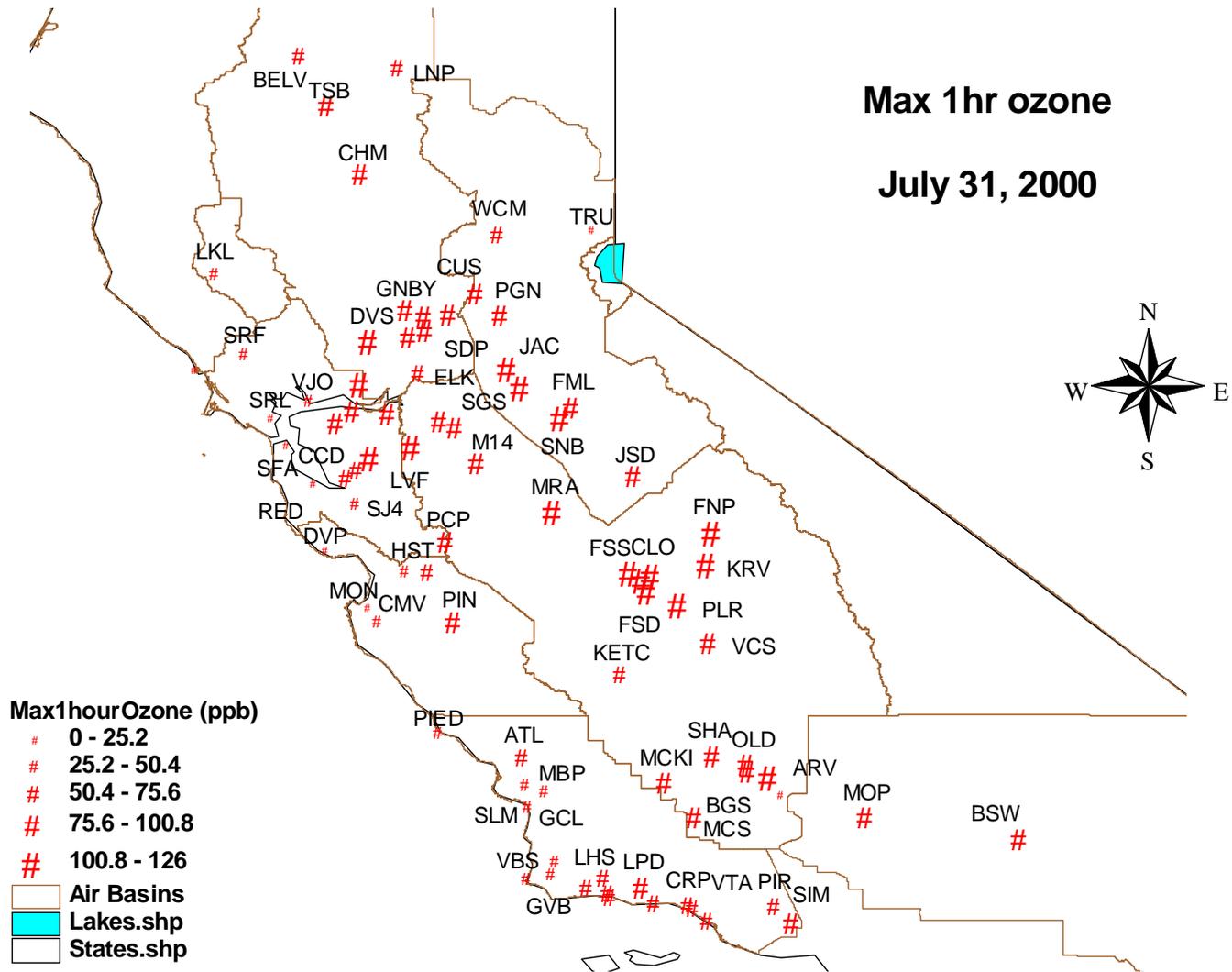


Figure 2-5d. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during July 30, 2000.

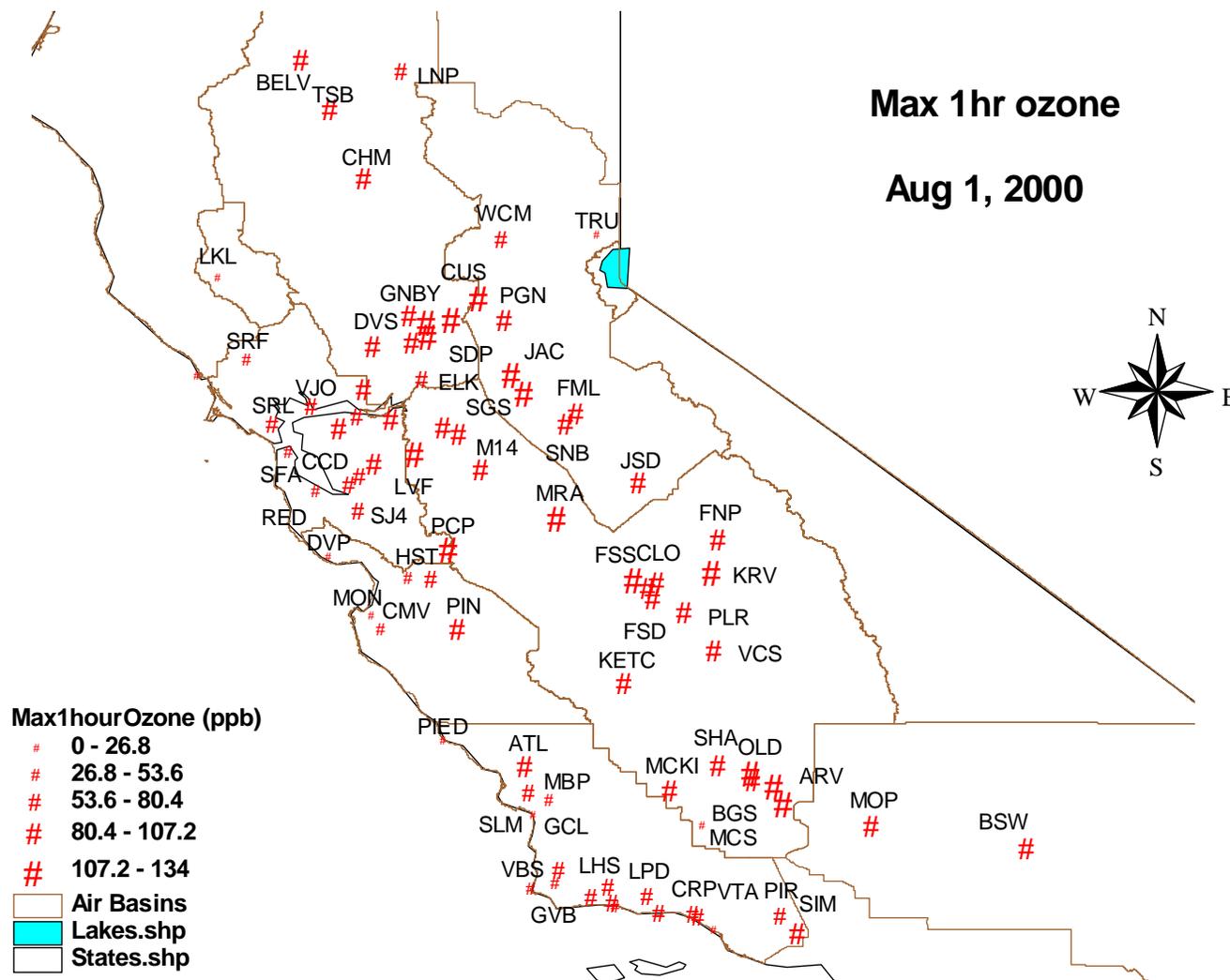


Figure 2-5e. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during August 1, 2000.

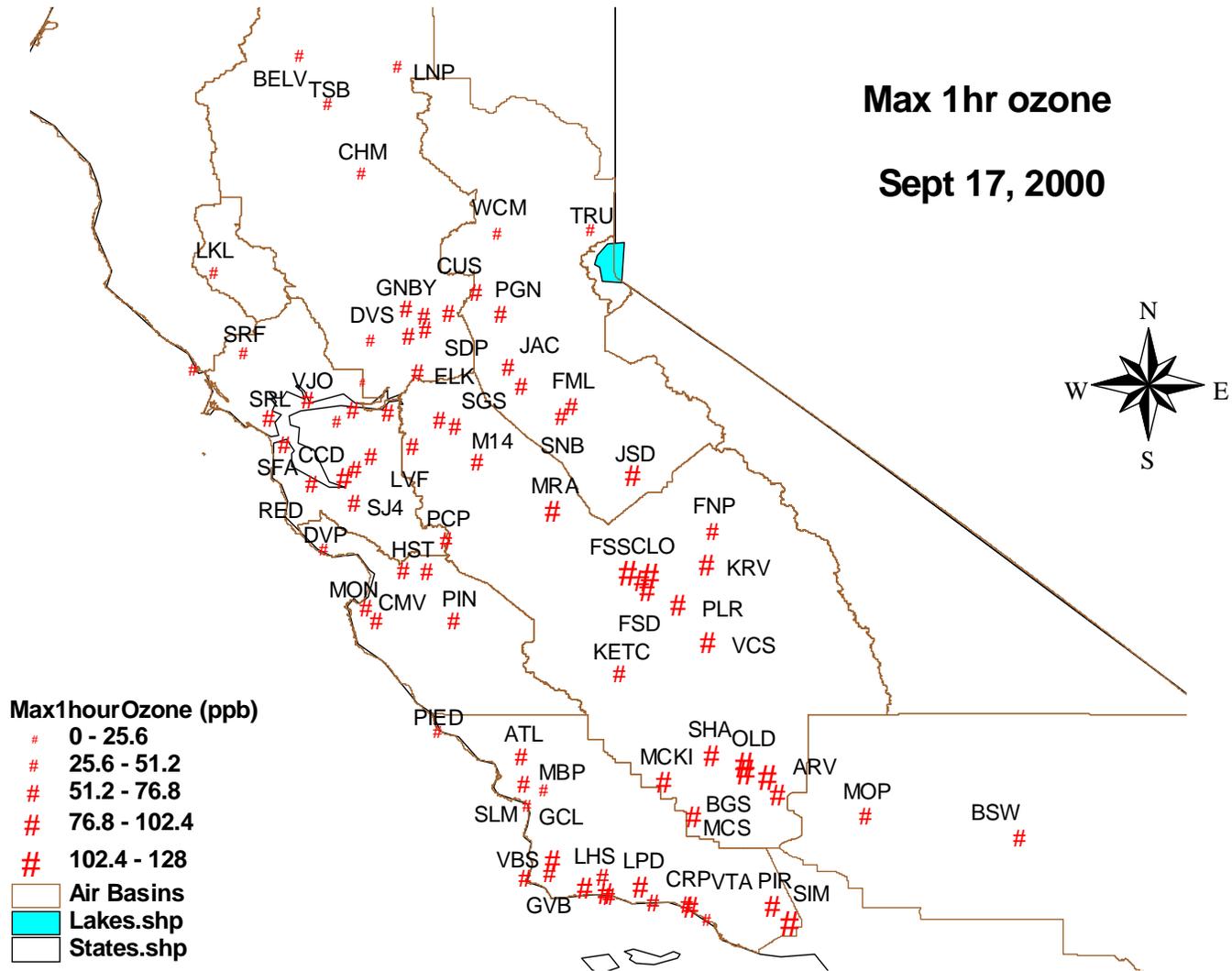


Figure 2-5g. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during September 17, 2000.

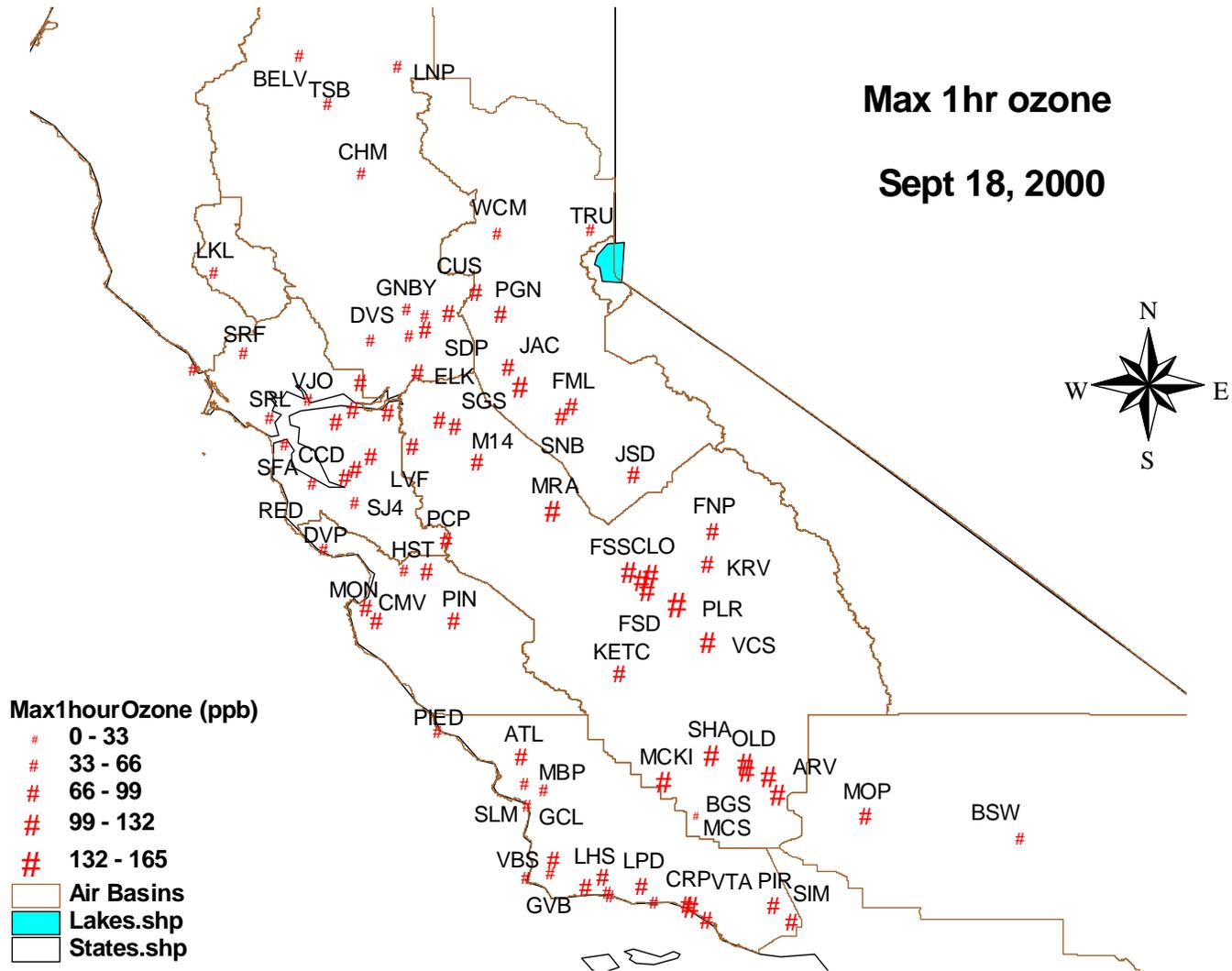


Figure 2-5h. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during September 18, 2000.

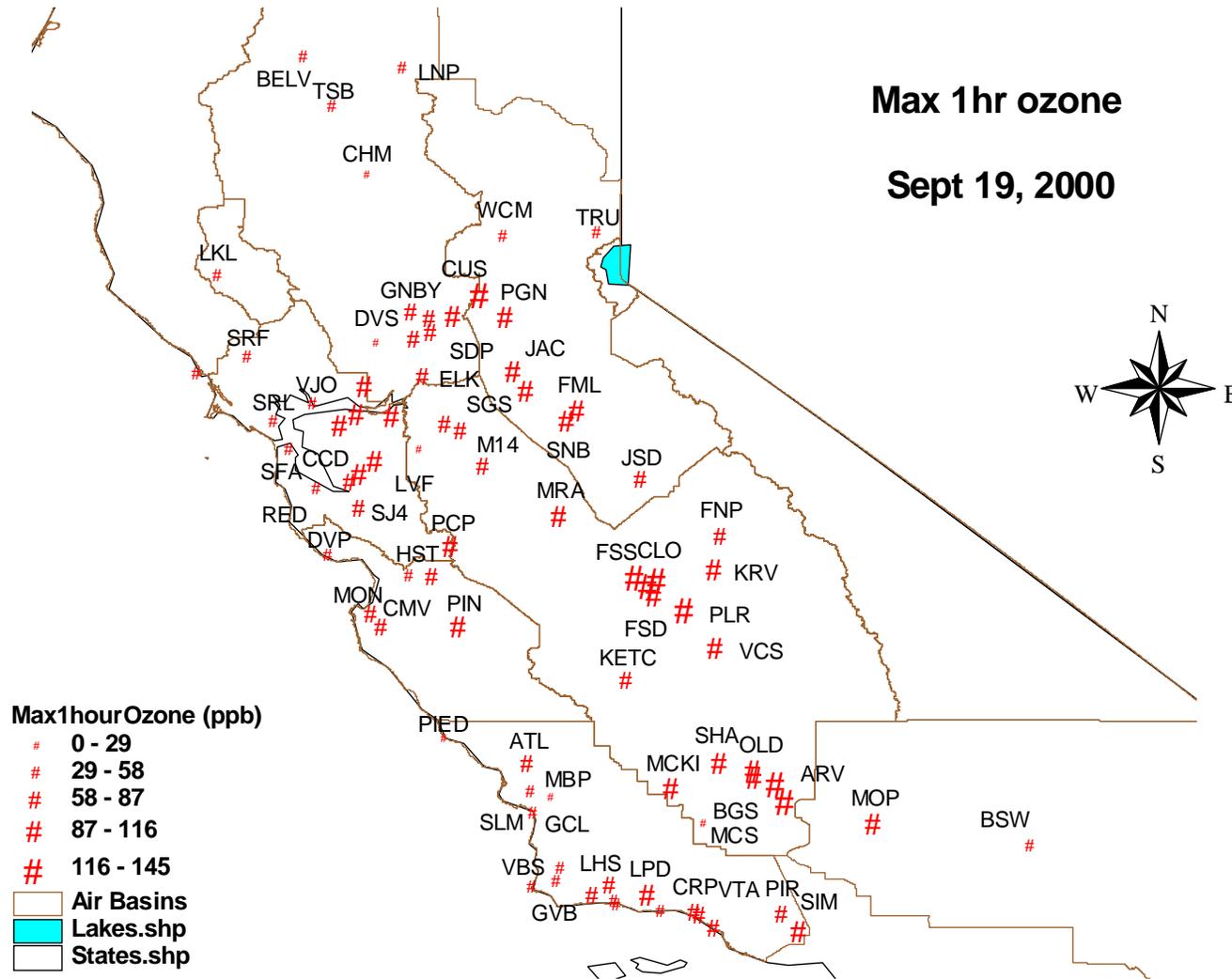


Figure 2-5i. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during September 19, 2000.

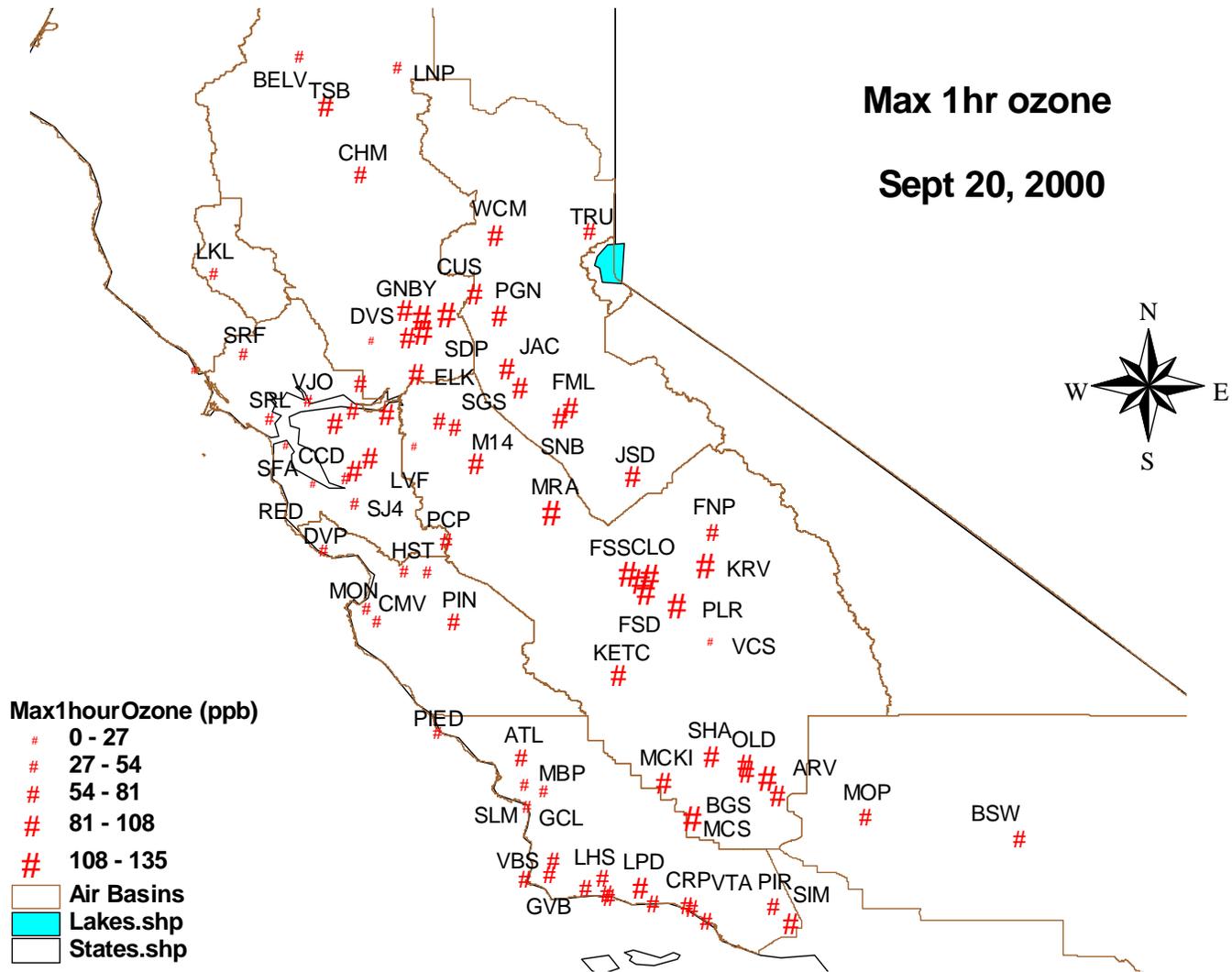


Figure 2-5j. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during September 20, 2000.

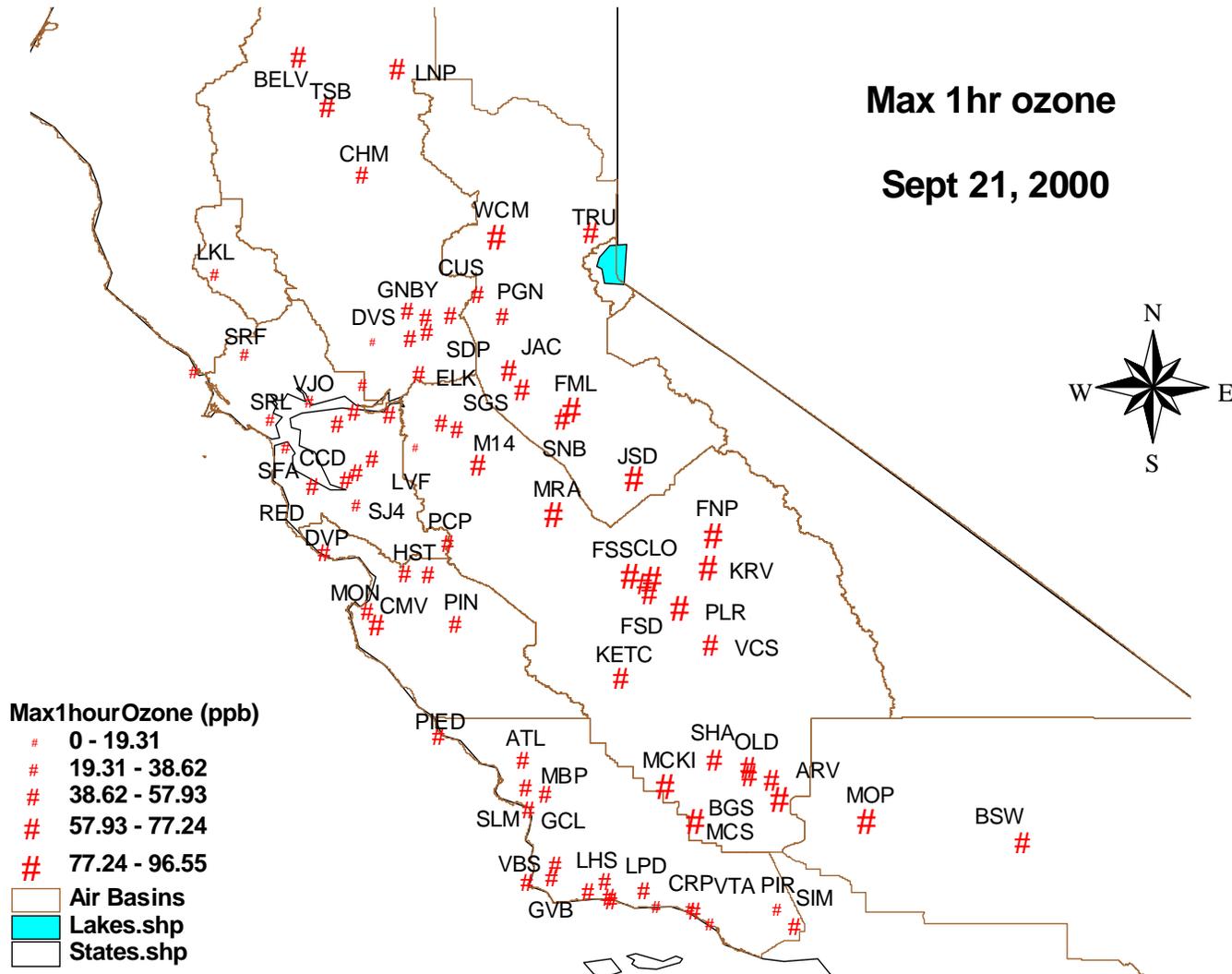


Figure 2-5k. Spatial plots of 1-hour maximum ozone at sites in CCOS domain during September 21, 2000.

3. SUPPLEMENTAL SURFACE NITROGEN OXIDES AND OTHER NITROGENOUS SPECIES

The California Air Resources Board and local air pollution control districts operated 76 NO/NO_x analyzers throughout northern and central California during CCOS. Nineteen TEI Model 42 CY NO/NO_x/NO_y analyzers, 3 TEI Model 42 CY dual converter NO/NO_y* analyzers and 2 TEI Model 42C-TL NO/NO_x analyzers were deployed at various CCOS supplemental monitoring sites. NO₂, PAN and PACNs were monitored at CCOS Supplemental Type 2 and Research sites by chemiluminescence and luminal. Redundant measurement of HNO₃ was obtained by tunable diode laser absorption spectroscopy (TDLAS) at Parlier. This section describes the measurement methods and summarizes the results of performance audits conducted by the California Air Resources and Parsons Engineering Science, Inc. (2001) and the validation checks conducted for this report.

3.1 Measurement Methods

Nitric oxide (NO) is continuously measured by the chemiluminescence nitric oxide-ozone method (OCM). This method is based on the gas-phase chemical reaction of NO with ozone. In this method an ambient air is mixed with a high concentration of ozone so that any NO in the air sample will react and thereby produce light. The light intensity is measured with a photomultiplier and converted into an electronic signal which is proportional to the NO concentration. To measure NO_x concentrations, the sum of NO and NO₂ (nitrogen dioxide), the air sample is first reduced to NO, either by a heated catalyst (molybdenum or gold in the presence of CO) or chemically using FeSO₄, adding to the NO already present in the sample, then into the reaction chamber for measurement as described above. The NO₂ concentration is derived by subtracting the NO concentration measurement from the NO_x concentration measurements.

Standard sensitivity instruments have detection limits of about 0.5 to 3 ppb (60 sec averaging times) and are suitable for air quality monitoring in urban and suburban areas. Thermo Environmental Instruments, Inc. (TEI) Model 42C and Monitor Labs 8440 and 8840 are examples of this type of instrument. These and similar instruments from Columbia Scientific and Bendix have been used widely by federal, state, and local agencies for routine monitoring of NO and NO₂ (actually NO_x minus NO plus other interfering nitrogen oxides). Trace level instruments, such as the TEI Model 42C-TL have detection limits of about 50 ppt (120 sec averaging times) and are better suited in rural and background sites, and onboard instrumented aircrafts.

The reduction of NO₂ to NO by these methods is not specific and a number of other nitrogen-containing species are reduced to NO that can interfere with the measurement of NO₂ (e.g., HNO₃, PAN, N₂O₅, HONO, and NO₃). Therefore the thermal catalytic method is used to measure NO, and then NO plus other nitrogen oxides as a group. If the group is not well defined, it is referred commonly as NO_x, since the species included in the group depend on factors such as inlet and line losses and environmental factors. HNO₃ is most prone to line losses. Placing the converter as close to the sample inlet as possible minimizes these losses. Chemiluminescence analyzers that are configured in this manner are commonly known as NO_y analyzers. NO_y, or reactive nitrogen oxides, consists of a variety of species, the most abundant

of which are NO, NO₂, PAN and HNO₃. TEI Model 42CY is configured with dual converters, which allows estimates of HNO₃ by difference between the signals with and without an in-line nylon filter or NaCl impregnated fiber denuder.

NO₂ and PAN by Gas Chromatography with Luminol Chemiluminescence Detection

The Luminol NO₂ analyzer operates on the principle that gaseous NO₂ undergoes a surface reaction with a specially formulated solution containing water, luminol, sodium sulfate, sodium hydroxide, and alcohol ("Luminol II" solution). The luminol is oxidized and the product chemiluminesces in the 425 nm region. The luminol solution is presented to the air stream on a wick which is replenished with solution from a reservoir. The solution is introduced at the top of the wick and removed to a waste container by a two channel peristaltic pump. A 250 ml reservoir holds sufficient solution for about 3 days of operation. The light emitted by the chemiluminescence reaction is detected by a photomultiplier tube, amplified and output to a chart recorder and data logger. The signal is very sensitive, with a detection limit of 5 pptv if zeroed every 30 minutes or 50 ppt if zeroed daily.

Although luminol can produce chemiluminescence with other oxidants, these reactions usually require the presence of metal ion catalyst. Use of deionized water in the solution formulation prevents chemiluminescence from other oxidizers such as hydrogen peroxide. Only O₃ and PAN were found to produce luminescence, and addition of other substances to the solution, such as sodium sulfite, make the response to O₃ negligible for NO₂ mixing ratios above 1 ppbv. The interference by PAN is a constant fraction of the PAN mixing ratio, although the fraction may depend on the formulation, batch, and age of the luminol solution.

The LCM method has been adapted to measure PAN as well as NO₂. In this method, PAN is separated from NO₂ and other organonitrates by gas chromatography, thermally reduced to NO₂, and measured using the same luminol detector described above for the luminol chemiluminescence measurement of NO₂. The more reactive oxides of nitrogen, such as HNO₃, HONO, NO₃, and other reactive interfering species such as ozone are retained on the column. NO, while passing through the GC column, is not detected by the luminol detector. One major advantage of this method is that the instrument can be calibrated in the field with NO₂ rather than the thermally unstable PAN, which is required for the GC/electron capture detector method. Eight NO₂/PAN analyzers were prepared by CE-CERT and deployed at CCOS S2 and Research sites.

NO₂ and HNO₃ by Tunable Diode Laser Absorption Spectroscopy

The TDLAS method takes advantage of the high monochromaticity and rapid tunability of a Pb salt diode laser to measure absorptions from single rotational-vibrational lines in the middle infrared spectrum of a molecule. Almost all gases absorb radiation in this spectral region. However, since many gases absorb in this region, very high spectral resolution is required to prevent interferences from other gases in the sampled air. The atmospheric sample is pumped rapidly at the reduced pressure through a White cell, which also provides the long optical path lengths required to achieve the desired detection limits. The tunable diode laser is a small Pb crystal with variable amounts of Sn, Se, Te or S. The wavelength region at which the laser emits radiation is governed by the proportions of the three elements in the crystal. Techniques of

measuring NO, NO₂ and HNO₃ by TDLAS has been described by Hasties (1983) and Mackay (1993) and measuring H₂O₂ and HCHO by MacKay (1994). The precision of the measurements is experimentally found to be better than ± 1 percent. The accuracy depends on the ability to accurately measure the various flows and on the ability to determine the mixing ratio of the calibration standard. The computed accuracy for H₂O₂, HCHO and HNO₃ is ± 15 percent (MacKay, 1994).

3.2 Performance Audits

Performance audits of the standard NO/NO_x analyzers were conducted by the Air Resources Board for ozone monitoring sites in the San Joaquin Valley and Sacramento Areas and by the BAAQMD in the Bay Area. Results of the audits are summarized in the CCOS quality assurance report by Parsons Engineering Science, Inc. (2001). The mean percent differences for various nitrogen species were as follows.

Method	Species	DRI	T&B	CE-CERT	STI	District
Standard Analyzer	NO	2.2 ± 5.5 % (2)				
Standard Analyzer	NO _x	2.4 ± 5.2 % (2)				
Standard Analyzer	NO ₂	1.7 ± 5.7 % (2)				0.6 ± 4.9 % (4)
TEI 42CY NO	NO	4.4 ± 3.8 % (14)	5.2 ± 7.4 % (2)		-0.4 ± 0.2 % (1)	3.9 ± 0.6 % (1)
TEI 42CY NO _y	NO _y	4.3 ± 3.7 % (14)	6.1 ± 5.8 % (2)		1.6 ± 0.1 % (1)	2.8 ± 0.5 % (1)
TEI 42CY NO _y	NO ₂	3.2 ± 4.7 % (14)	6.2 ± 4.6 % (2)		-5.0 ± 1.2 % (1)	2.2 ± 0.5 % (1)
Luminol	NO ₂ /PAN			2.3 ± 4.0 % (3)		
Dual TEI 42CY	NO _y *	-1.9 ± 5.8 % (3)				
Dual TEI 42CY	NO _y	4.4 ± 3.8 % (14)				

The numbers in parentheses indicate the numbers of analyzers that passed the performance audits. Audit results for instruments with known problems or for audits where the results have been questioned were removed prior to calculating the average audit results. Specific problems or issues at specific sites and their resolution are documented in Section 4.5 of the Parsons QA report. Audit results for several NO_y analyzer operated by DRI in the CCOS supplemental monitoring network exceeded the ± 15 % limit. Because of the geographic extent of the network, DRI chose to not adjust the analyzer's response if the response was stable. The data were adjusted by DRI during post-processing. Adjusting the audit results using DRI-supplied factors obtained from routine calibrations of the analyzers brought the NO₂ results to within the acceptable limit.

3.3 Validation Checks

Figure 3-1 shows a scatterplot of NO_x versus NO measured by chemiluminescence method at routine and supplemental sites. Data with NO_x mixing ratios below 10 ppb have been screened out. As expected, NO_x is consistently higher than NO with a positive offset at NO = 0 of up to about 75 ppb with an average of about 30 ppb. There is a strong, nearly 1:1 correlation when NO_x is greater than 200 ppb (regression line), which is consistent with the presence of fresh emissions of NO in urban areas of Fresno, Sacramento, and Modesto. In the previous

section, the expected inverse relationship between hourly ozone versus the corresponding NO is shown in Figure 2-6.

The scatterplot of NO_y versus collocated NO_x in Figure 3-2 shows that NO_y is generally higher, indicating the presence of PAN. Occasional low NO_y values at ELK may be indicative of operational problems not reported in initial QA. The generally 1:1 correlation at SUNO may be an artifact of the biases in instrument response reported in Parsons' QA audit.

CE-CERT built eight analyzers to measure nitrogen dioxide (NO₂) and peroxyacetyl nitrate (PAN) for use in the CCOS supplemental monitoring network. Figure 3-3 shows a scatterplot of 1-hour average NO₂ measured by the Luminol method versus the corresponding NO_x-NO by chemiluminescence. Data for entire study period is shown. Although NO_x-NO method is known to overestimate NO₂, the Luminol method gives equal or higher NO₂ values in most cases suggesting that the Luminol NO₂ data may need a calibration adjustment. The time series of this comparison is shown for Parlier in Figure 3-4 to illustrate the bias that exists between the two datasets. The luminol instrument tends to overestimate peak values of NO₂. These results were presented by DRI to the CCOS Technical Committee in October 2002.

Based upon conversations with CE-CERT, it was apparent that reduction of NO₂ and PAN data from the luminol-GC instrument was not straightforward. Furthermore, our initial evaluations of the NO₂ data indicate that adjustment factors should be considered in order to correct possible for drifts in calibration. Shifting retention times for the NO₂ and PAN peaks and a varying baseline due to noise from the pump also complicated data reduction. Because manual processing of the data is very time consuming, CE-CERT provided a preliminary version of the PAN data for IOPs only. Because of the unforeseen complications with the luminol-GC instrument, CE-CERT did not have the funding to devote the time that would be necessary to properly process the data for non-IOP days. CE-CERT applied for and was granted additional funds to develop a computer program that would allow batch-processing of the PAN data, taking into account shifts in GC retention times and variable baselines (Fitz, 2003). The refined data were submitted to the CCOS data manager in June 2003.

Figure 3-5a shows the hourly averaged HNO₃ at Parlier on 8/14 showing typical behaviour of TDLAS measurement relative to HNO₃ by chemiluminescence method (NO_y-NO_y*). Total nitrogen species (NO_y) is also shown, indicating that the TDLAS method significantly overestimates HNO₃ during peak hours. A scatterplot of (NO_y-NO_y*) versus HNO₃ by TDLAS is shown in Figure 3-5b, which includes all valid data collected during IOPs. This plot shows the tendency of TDLAS to overestimate HNO₃ by about a factor of four. Figure 3-6 shows the comparison of NO₂ mixing ratios at Parlier measured by three different methods. The x-axis is the standard chemiluminescence differential method, which should slightly overestimate NO₂. The regressions indicate that the direct measurement of NO₂ by TDLAS is typically lower than NO_x-NO, as expected, while the Luminol method appears to overestimate NO₂ as it typically gives larger values than NO_x-NO.

3.4 Summary of Validation Results

- NO_x is consistently higher than NO with a positive offset at NO = 0 of up to about 75 ppb with an average of about 30 ppb. There is a strong, nearly 1:1 correlation when NO_x

is greater than 200 ppb, which is consistent with the presence of fresh emissions of NO in urban areas.

- Hourly ozone is inversely correlated to the corresponding hourly NO.
- NO₂ by luminol is reported as zero for several periods during August at Parlier while NO_x-NO > 10 ppb. NO₂ typically peaks up to 60% higher than NO_x-NO suggesting a calibration problem. The luminal NO₂/PAN data were subsequently reprocessed by CE-CERT under separate contract.
- TDLAS HNO₃: Peaks are higher than NO_y*-NO_y by about a factor of 4.

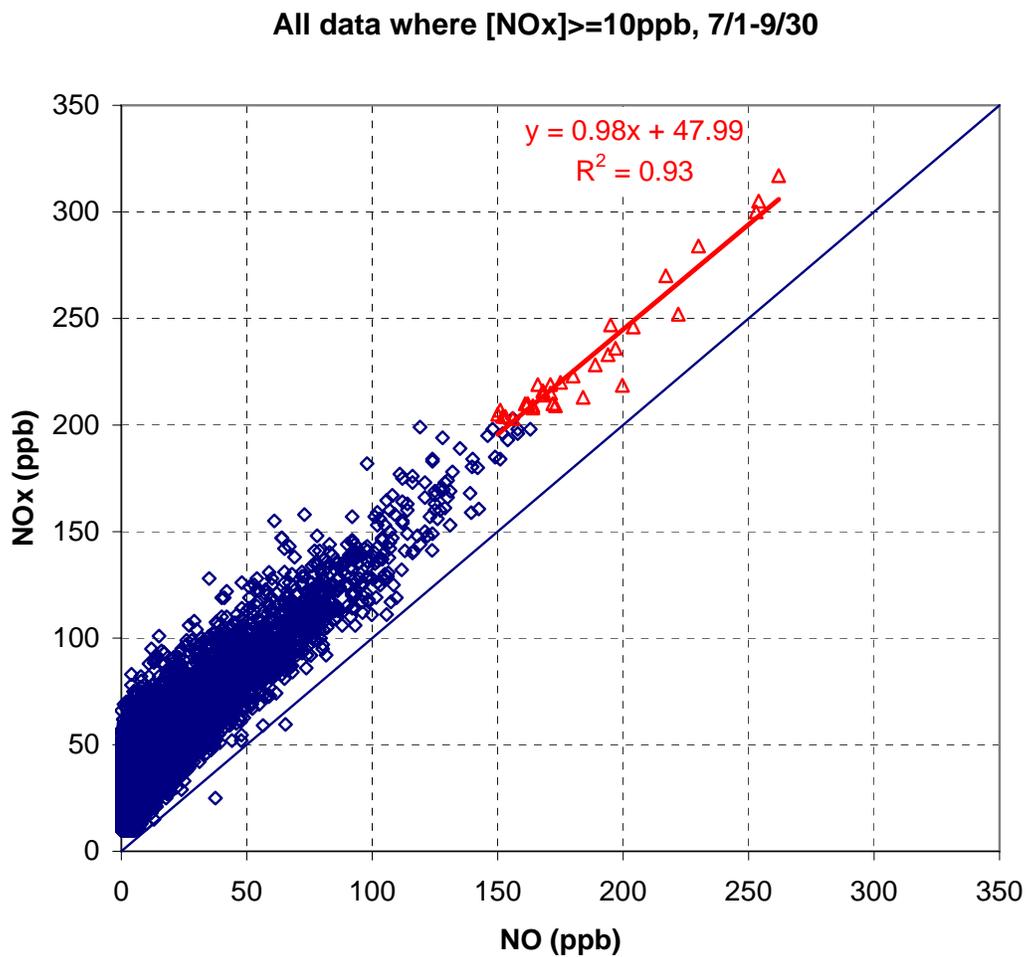


Figure 3-1. Scatter plot of NOx vs NO measured by chemiluminescence method at routine and supplemental sites. Data with NOx mixing ratios below 10 ppb have been screened out.

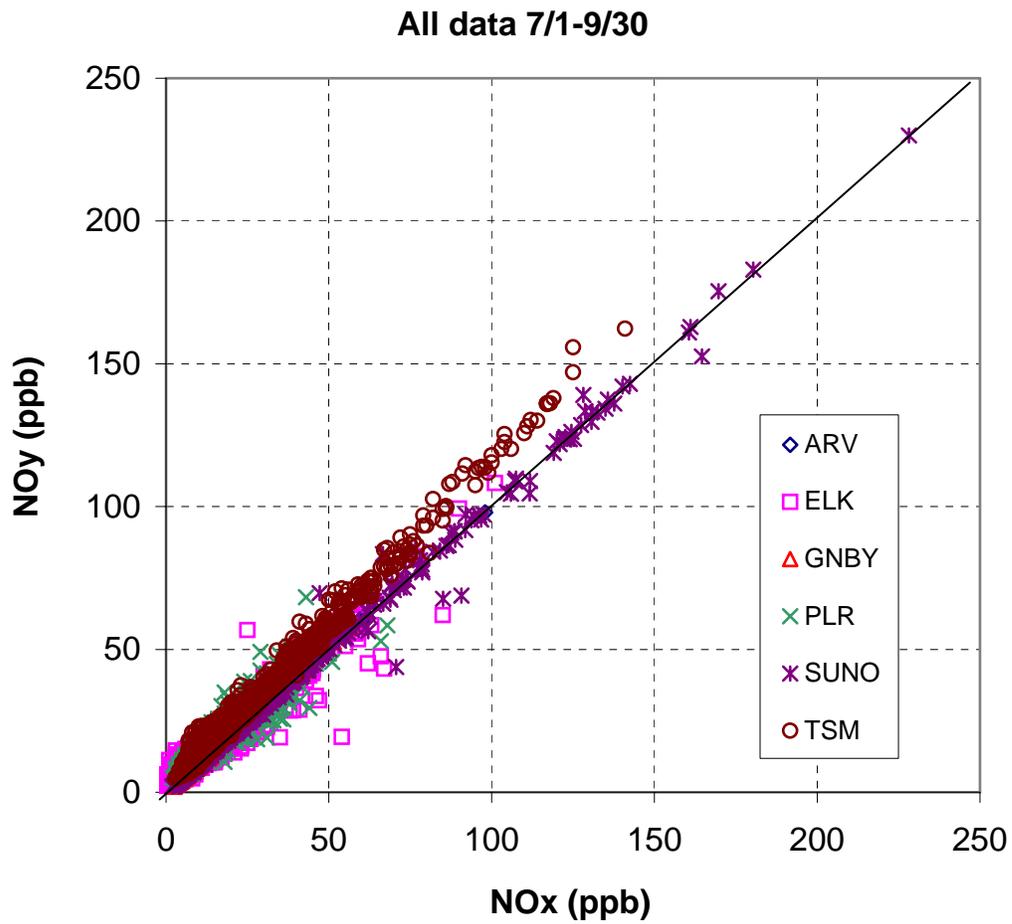


Figure 3-2. Scatter plot of NO_y vs NO_x measured by chemiluminescence method at sites where instruments were collocated.

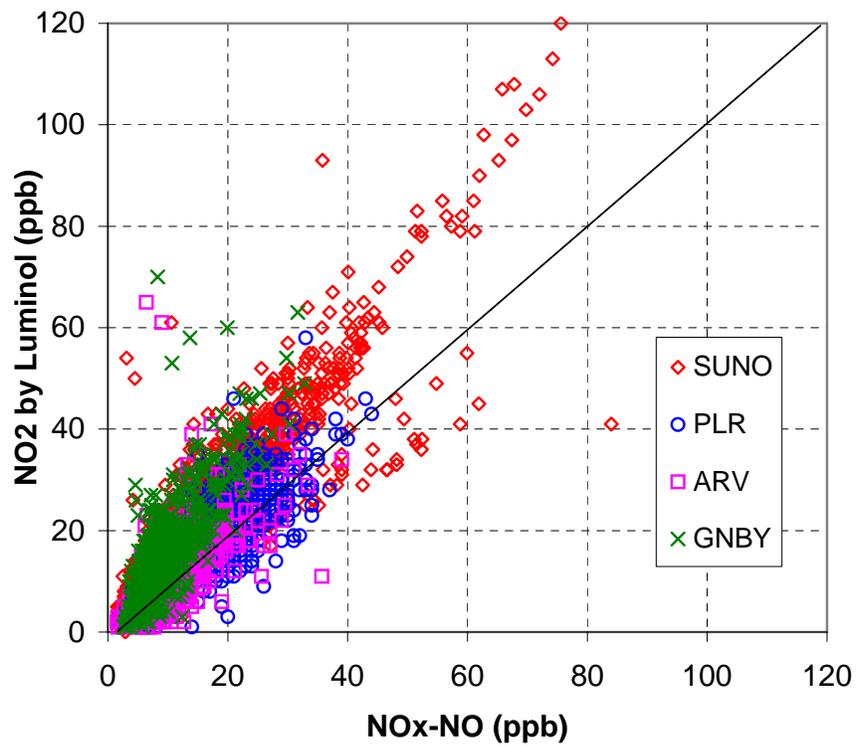


Figure 3-3. Scatter plot of 1 hour average NO₂ measured by Luminol method vs NO_x-NO by chemiluminescence.

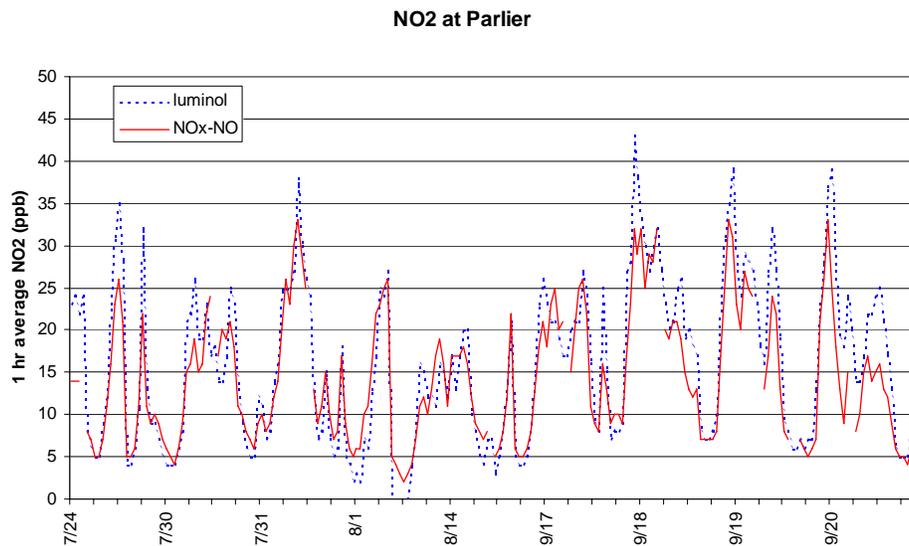


Figure 3-4. Time series plot of NO₂ at Parlier during study period. The luminol instrument tends to overestimate peak values of NO₂.

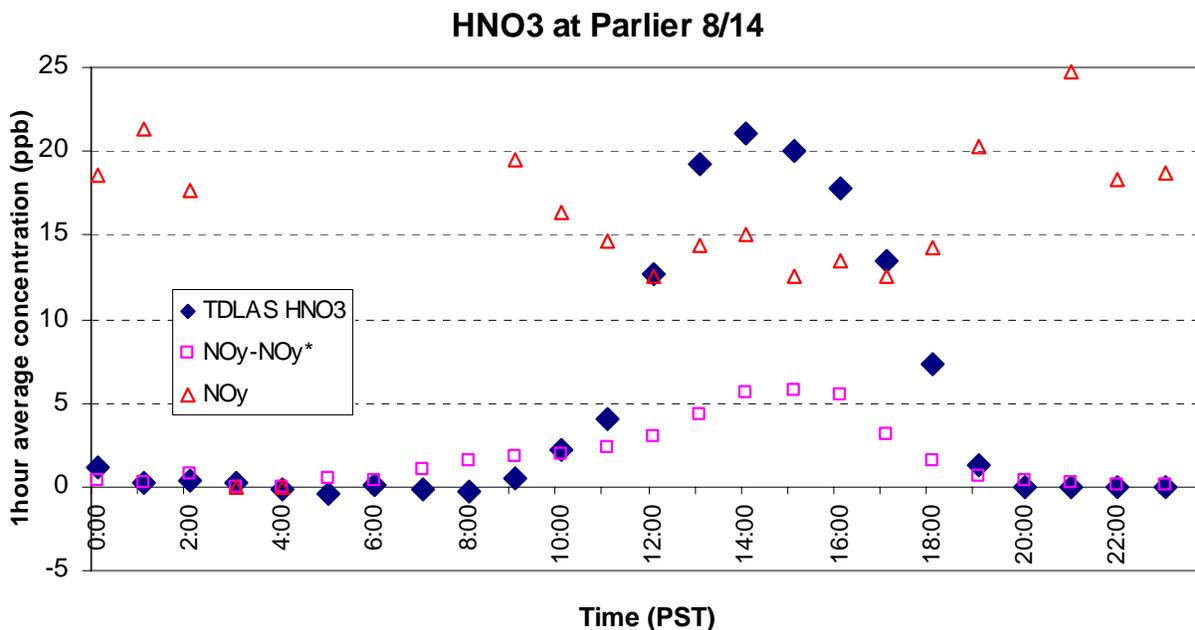


Figure 3-5a. Hourly averaged HNO₃ at Parlier on 8/14 showing typical behaviour of TDLAS measurement relative to HNO₃ by chemiluminescence method (NO_y-NO_y*). Total nitrogen species (NO_y) is also shown, indicating that the TDLAS method overestimated HNO₃ during peak hours.

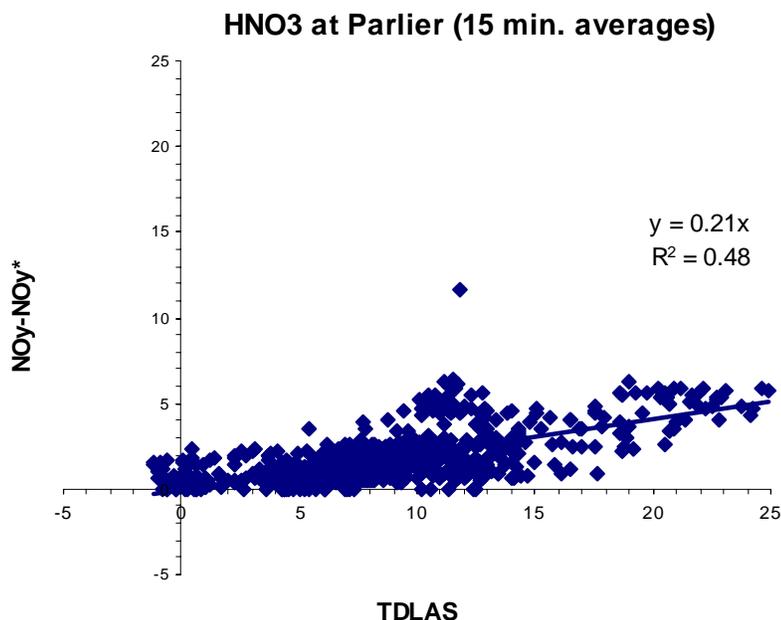


Figure 3-5b. Scatter plot of HNO₃ by chemiluminescence method (NO_y-NO_y*) versus TDLAS method. All valid data collected during IOPs are included in this plot showing the tendency of TDLAS to overestimate HNO₃ by about 5 times.

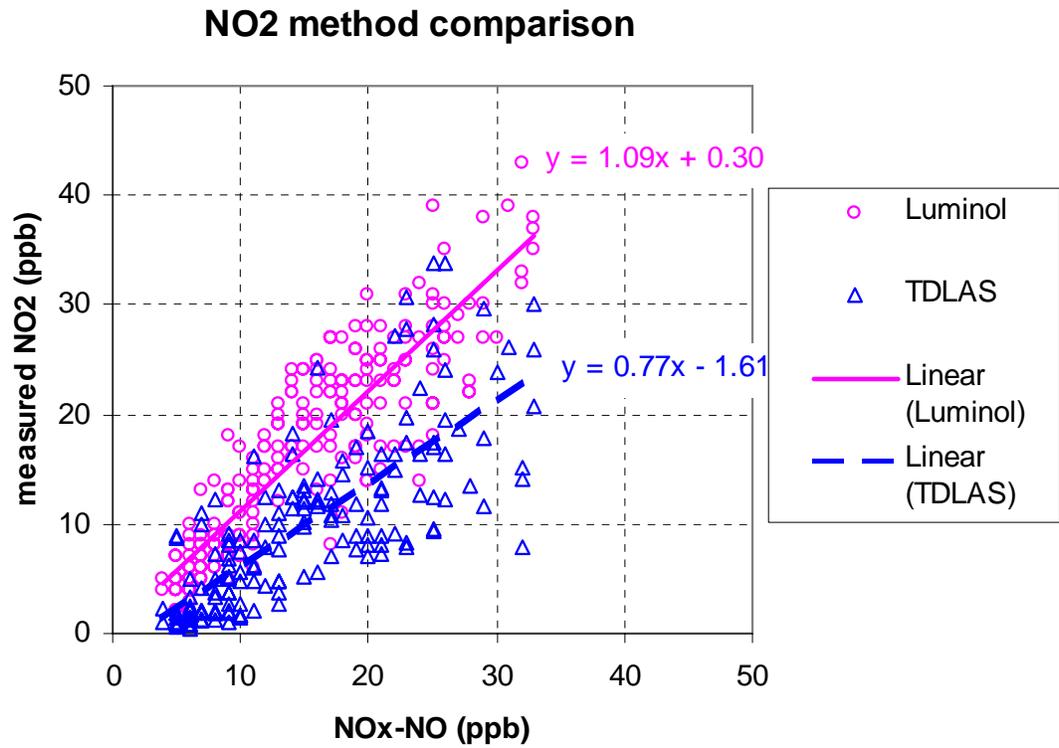


Figure 3-6. Comparison of NO₂ mixing ratios at Parlier measured by 3 different methods. The x axis is the standard chemiluminescence differential method, which should slightly overestimate NO₂. The regressions indicate that the direct measurement of NO₂ by TDLAS is typically lower than NO_x-NO, as expected, while the Luminol method appears to overestimate NO₂ as it typically gives larger values than NO_x-NO.

4. PAMS AND SUPPLEMENTAL SURFACE SPECIATED HYDROCARBONS AND TOTAL NMOC

States with areas classified as serious, severe, or extreme for ozone attainment are required to establish photochemical assessment monitoring stations (PAMS) as part of their State Implementation Plan. Each station measures speciated hydrocarbons and carbonyl compounds, ozone, oxides of nitrogen, and surface meteorological data. Additionally, each area must monitor upper air meteorology at one representative site. PAMS precursor monitoring is conducted annually in California during the peak ozone season (July, August and September). Eleven PAMS sites were in operation during summer 2000 (four in Sacramento County, four in Fresno County, and three in Kern County). EPA methods TO-14 and TO-11 are specified by the EPA for sampling and analysis of speciated hydrocarbons and carbonyl compounds, respectively (EPA, 1991). Table.4-1 contains the minimum list of targeted hydrocarbon species. For carbonyl compounds, state and local agencies are currently required to report only formaldehyde, acetaldehyde and acetone.

Under the California Alternative Plan, four 3-hour samples (0000-0300, 0600-0900, 1300-1600, and 1700-2000, PDT) were collected every third day during the monitoring period at all PAMS sites for speciated hydrocarbons and at Type 2 sites only for carbonyl compounds. These sampling periods were the same as the CCOS supplemental VOC sampling periods. In addition to the regularly scheduled measurements, samples were collected on a forecast basis during up to five high-ozone episodes of at least two consecutive days. Episodic measurements consist of four samples per day (0600-0900, 0900-1200, 1300-1600, and 1700-2000, PDT) for speciated hydrocarbons at all PAMS sites and for carbonyl compounds at Type 2 sites. Because the ARB laboratory had a limited number of canisters and had to recycle them during the PAMS season, a relaxation of the regularly scheduled PAMS sampling was necessary to accommodate multi-day IOPs of three or more consecutive days. Instead of the sampling schedule in the California Alternative Plan, the U.S. Environmental Protection Agency approved a request by the ARB to modify the normal PAMS sampling schedule in order to accommodate more episodic sampling in coordination with the CCOS IOPs.

The implementation of PAMS by the local APCDs in central California during summer 2000 is outlined in Table 4-2. The new sampling plan retained only the 6-9 a.m (PDT) sample, every third day, to preserve the analysis of long-term trend. PAMS samples collected during IOPs as listed in Tables 4-3 and 4-4. Total nonmethane hydrocarbon (NMHC) concentrations are also monitored continuously on an hourly basis at all Sacramento and San Joaquin Valley PAMS sites by either automated-Preconcentration Direct Injection Flame Ionization Detection (PDFID) (e.g., Xontech 850) or TEI 55C. Modifications of the TEI55C (Ventura option) provided improved limit of detection (from 150 ppbC to 75 ppbC). Figure 1-2 shows the locations of existing monitoring stations measuring carbon monoxide and PAMS speciated hydrocarbons and carbonyl compounds in relation to CCOS supplemental monitoring sites.

The VOC measurements that were made in the CCOS supplemental monitoring network are summarized in Table 4-5. DRI analyzed the canister samples from the supplemental monitoring sites in the Sacramento Valley and the San Francisco Bay Area and Biospheric Research analyzed the canister samples from the San Joaquin Valley and the two coastal

background sites (Bodega Bay and Piedras Blancas). All of the supplemental carbonyl samples were analyzed by Atmospheric Assessment Associates (see Section 5). DRI also collected a limited number of canister and Tenax samples at the three Research Sites for comparison with the semi-continuous GC/MS data (see Section 6).

4.1 Measurement Methods

The experiences from laboratory comparisons that were conducted for COAST (Fujita et al., 1995a), NARSTO-Northeast (Fujita et al., 1997b), and SCOS97-NARSTO (Fujita et al., 1999c; Fujita et al., 2003c) demonstrate that measurements of ambient hydrocarbon speciation are not routine, and that the quality and completeness of measurements vary among different laboratories using essentially the same samplers and analytical instrumentation. Potential problems include: positive and negative artifacts due to sampler or sampling media; incomplete resolution or loss of C₂-C₃ hydrocarbons due to introduction of excess moisture in the column or improper sample loading and injection; under-reporting of true concentrations due to selection of incorrect integration thresholds; loss of material in the analytical system due to poor chromatographic technique (particularly for very light and heavy hydrocarbons) or prolonged storage in canisters prior to analysis (especially olefins and polar organics); incorrect or incomplete peak identification due to limitations of peak identification software (particularly for olefins and >C₈ hydrocarbons); and systematic bias due to calibration problems. These comparison studies show that the values reported for the 55 PAMS target species are generally consistent among the various PAMS analytical laboratories. However, there often exist considerable variations for total nonmethane hydrocarbons (NMHC) or nonmethane organic compounds (NMOC) due to differences in analytical and data processing procedures.

4.1.1 Canister Samples

Hydrocarbon speciation measurements consisted of canister sampling followed by gas chromatographic analysis with flame ionization detection (Method TO-14). Laboratories employed commercial gas chromatographic systems equipped with flame ionization detectors (GC-FID), a cryogenic concentration step, and computerized data acquisition systems. Procedures used for instrument calibration varied among the laboratories. For calibration of the FID, propane is commonly used for C₂ to C₄ hydrocarbons and benzene or hexane is used for greater than C₄ hydrocarbons. The systematic differences resulting from variations in FID response among different calibration gases are typically less than 5 percent. With the exception of BRC, all laboratories calibrated their chromatographs in volume concentration units (area response/ppbC). The calibration by BRC is in terms of mass (area response/ng) of an internal standard that is added to each sample. Besides selection of the endpoint of the gas chromatographic run, factors that can affect total measured mixing ratios include selection of threshold levels for peak integration and losses during cryogenic concentration and desorption and surface adsorption within the inlet system..

4.1.2 Tenax Samples

Volatile organic compounds exhibit a wide range of volatility and are hence distributed in the atmosphere between the gas and particle phases. Hydrocarbons with vapor pressures less than n-undecane are not currently quantified in the PAMS program. Zielinska and Fujita (1994) found

that semi-volatile hydrocarbons accounted for 7 to 15 percent of the C₁₀ to C₁₈ hydrocarbons in Los Angeles and about 16 percent of the total ozone forming potential of NMHC. It has been shown that hydrocarbons in the range of C₁₀-C₂₀ are important components of the total hydrocarbons emitted from heavy-duty diesel vehicles.

Semi-volatile hydrocarbons C₁₃-C₂₀, were collected by DRI using Tenax solid adsorbent. Prior to use, the Tenax solid adsorbent is cleaned by Soxhlet extraction with hexane/acetone mixture, packed into Pyrex glass tubes and thermally conditioned for four hours by heating at 300 °C under nitrogen purge. Approximately 10% of the precleaned Tenax cartridges are tested by GC/FID for purity prior to sampling. After sampling, the Tenax cartridges are capped tightly using clean Swagelok caps (brass) with graphite/vespel ferrules, and placed in metal containers with activated charcoal on the bottom. Tenax samples were analyzed by the thermal desorption-cryogenic preconcentration method, followed by quantification by high resolution gas chromatography and Fourier transform infrared detection (IRD) – mass spectrometry detection (MSD) (Hewlett Packard 5890II GC, 5965 IRD and 5970 MSD). Before analysis, each sample was spiked with 1 µl of an internal standard, 1-fluoronaphthalene, then flushed with ultra high purity helium for 2 minutes. Compounds were quantified using the mass spectrometer. A standard mixture was analyzed each day to account for any detector drift.

4.2 Performance Audits

Through-the-probe performance audits were conducted by the California Air Resources Board at each hydrocarbon monitoring site to assess the integrity of the sampling equipment and transport system, and the accuracy of the analytical methods used by the laboratory to measure the ambient concentrations (Parson Engineering Science, Inc., 2001). In a TTP audit, a gaseous mixture of standards prepared by NIST is mixed with humidified purified air under controlled conditions and introduced into the sampling probe inlet of a hydrocarbon sampler. The samples were collected into a stainless steel canister over a 3-hour period and shipped to the laboratory along with regular ambient samples. Results of audits are summarized on Table 5-2 of the Parsons QA report..

The results show that both Biospheric Research Corp. (BRC) and Desert Research Institute (DRI), the analytical laboratories for the supplemental sites, had mixed results. In general, a sample either failed for all compounds, or passed for all compounds. The fact that both CCOS contractors had at least one canister that agreed with the audit input concentrations implies that the analysis is accurate, and that the variability in the audit results is more likely due to problems with obtaining the audit sample. Due to scheduling problems, it was rarely possible for a site operator to be available at the site during the audit. Consequently, auditors were responsible for operating the canister sampling equipment and collecting the audit samples. A review of the samples that did not meet the audit criteria showed that the ratio of the measured compound concentrations relative to each other was essentially the same as the ratios of the input concentrations. For example, if the concentrations for the samples are normalized against m/p-Xylene, the overwhelming majority (60 out of 70) of the failed parameters for the Angiola, Piedras Blancas, Trimmer, and White Cloud samples would pass the audit criteria. This implies some sort of dilution of the sample, which a variety of sampling problems could have caused.

Both DRI and BRC have participated in several laboratory intercomparisons within the past decade. These include the International Hydrocarbon Intercomparison Experiment, organized by the National Center for Atmospheric Research (Apel et al., 1994) and comparison studies conducted as part of the quality assurance program for the Coastal Oxidant Assessment for Southeast Texas (Fujita et al., 1995a), NARSTO-Northeast (Fujita et al., 1997b), and the 1997 Southern California Ozone Study-NARSTO (Fujita et al., 1999c; Fujita et al., 2003c). These comparison studies included PAMS VOC monitoring sites in the northeast states, Texas, and Southern California. DRI also participates in the annual VOC performance audits conducted by the ARB. Agreements between most laboratories are generally within 10 percent for mixing ratios above 1 ppbC. Identification and quantification of the 55 PAMS target species are normally consistent among PAMS laboratories. However, there are greater variations for sums of NMHC and NMOC.

4.3 Validation Checks

The initial review of the VOC data focused on potential calibration problems. These problems are best identified by laboratory comparisons of collocated samples and measurements of the same sample by different methods (e.g., canister versus auto GC/MS). Figure 4-6 shows a scatterplot of the individual 55 PAMS hydrocarbon species measured by Biospheric Research Corporation and Desert Research Institute for collocated canister samples at Parlier. The slope of the correlation is 0.92 with an R-square of 0.97. These results are similar to comparisons that were conducted between these two laboratories during SCOS97-NARSTO and NARST-Northeast.

Table 4-5 is a summary of the total nonmethane hydrocarbon levels observed during CCOS IOP days at Photochemical Assessment Monitoring Stations and supplemental CCOS sites. The table also provides an inventory of the data capture. The type of site and the laboratory performing the chemical analysis are also included in the table. Note that limited numbers of canister samples (up to eight) were collected at the three CCOS research sites as part of quality assurance in order to provide comparisons with the automated gas chromatograph with mass spectrometer (auto GC/MS). The distributions of total NMHC among the monitoring sites are generally consistent with expectation of lower values at rural sites and higher values in urban locations. NMHC levels at Bodega Bay were consistently low with values mostly ranging between 20 and 50 ppbC. In contrast, the other site that was chosen to represent coastal background, Piedras Blancas, had NMHC values ranging up to few hundreds ppbC. This site is likely influenced by some local source of VOCs and should not be considered representative of coastal background conditions. Samples that have anomalously high NMHC relative to other samples from that site include 06-09 sample on 7/31/00 from Shafter (2296 ppbC), 00-03 sample on 8/14/00 from San Andreas (1026.7 ppbC) and 00-03 sample on 7/31/00 from Bethel Island (1284.3 ppbC).

Ethylene and acetylene are primarily emitted by motor vehicles. Ambient levels of these two hydrocarbons should be higher in urban areas and they should be well correlated to each other in fresh motor vehicle emissions. The ethylene/acetylene ratios will be lower in the afternoon due to greater photochemical reactive of ethylene relative to acetylene. Figures 4-2a, 4-2b, and 4-2c show scatterplots of ethylene versus acetylene from samples analyzed by DRI, BRC and ARB, respectively. The upper edges of the cluster of points in each plot represent the

ratios of ethylene to acetylene in fresh emissions. This ratio is approximately unity in all three scatterplots. Note that the higher values are associated with urban locations while lower values near the origin are associated with rural locations. Points to the right of the upper edge correspond to afternoon samples. Several points that deviate significantly from the cluster of points should be viewed as suspect. These include the value for acetylene in the DRI analysis of the 13-16 sample from Bethel Island on 8/1/00 and ethylene in the DRI analysis of the samples from White Cloud for the 00-03 sampling period on 7/23/00, 7/30/00 and 8/14/00. As noted earlier, the samples from Piedras Blancas seem to be affected by some unknown local source. The anomalously high NMHC values at this site are accompanied by unusually high and low ethylene/acetylene ratios.

The profiles of the 55 PAM species are plotted in Figures 4.3a through 4.3d for samples collected during 06-09. Because mobile sources are typically the dominant source of VOC emissions in urban areas, the composition of VOC at these locations consistently resemble vehicle emissions (e.g., Sacramento Del Paso, Sacramento Natoma, Folsom, Granite Bay, Fresno First St. Clovis, Turlock, Bakersfield Golden State). Several samples from San Leandro deviate from this pattern with unusually high amounts of aromatic compounds and higher molecular weight n-alkanes.

4.4 Summary of Validation Results

- PAMS hydrocarbon species measured by Biospheric Research Corporation and Desert Research Institute for collocated canister samples are in good agreement with a slope of 0.92 with an R-square of 0.97. These results are similar to comparisons that were conducted between these two laboratories during SCOS97-NARSTO and NARST-Northeast.
- The distributions of total NMHC among the monitoring sites are generally consistent with expectation of lower values at rural sites and higher values in urban locations.
- NMHC levels at Bodega Bay were consistently low with values mostly ranging between 20 and 50 ppbC. In contrast, Piedras Blancas appears to be influenced by some local source of VOCs and should not be considered representative of coastal background conditions.
- Samples that have anomalously high NMHC relative to other samples from that site include 06-09 sample on 7/31/00 from Shafter (2296 ppbC), 00-03 sample on 8/14/00 from San Andreas (1026.7 ppbC) and 00-03 sample on 7/31/00 from Bethel Island (1284.3 ppbC).
- Ethylene and acetylene, which are primarily emitted by motor vehicles, are higher in urban areas and are well correlated to each other during times and at location with fresh motor vehicle emissions in samples analyzed by DRI, BRC and ARB. The upper edges of the cluster of points in each plot represent the ratios of ethylene to acetylene in fresh emissions and are approximately unity in all three scatterplots.

- Points that deviate significantly from the cluster of points should be viewed as suspect. These include the value for acetylene in the DRI analysis of the 13-16 sample from Bethel Island on 8/1/00 and ethylene in the DRI analysis of the samples from White Cloud for the 00-03 sampling period on 7/23/00, 7/30/00 and 8/14/00. As noted earlier, the samples from Piedras Blancas seem to be affected by some unknown local source. The anomalously high NMHC values at this site are accompanied by unusually high and low ethylene/acetylene ratios.
- Because mobile sources are typically the dominant source of VOC emissions in urban areas, the composition of VOC at these locations consistently resemble vehicle emissions (e.g., Sacramento Del Paso, Sacramento Natoma, Folsom, Granite Bay, Fresno First St. Clovis, Turlock, Bakersfield Golden State). Several samples from San Leandro deviate from this pattern with unusually high amounts of aromatic compounds and higher molecular weight n-alkanes.

Table 4-1. PAMS target species.

1	Ethylene	29	2,3-Dimethylpentane
2	Acetylene	30	3-Methylhexane
3	Ethane	31	2,2,4-Trimethylpentane
4	Propene	32	n-Heptane
5	Propane	33	Methylcyclohexane
6	Isobutane	34	2,3,4-Trimethylpentane
7	1-Butene	35	Toluene
8	n-Butane	36	2-Methylheptane
9	trans-2-Butene	37	3-Methylheptane
10	cis-2-Butene	38	n-Octane
11	Isopentane	39	Ethylbenzene
12	1-Pentene	40	m&p-Xylene
13	n-Pentane	41	Styrene
14	Isoprene	42	o-Xylene
15	trans-2-Pentene	43	n-Nonane
16	cis-2-Pentene	44	Isopropylbenzene
17	2,2-Dimethylbutane	45	n-Propylbenzene
18	Cyclopentane	46	1-ethyl 3-methylbenzene
19	2,3-Dimethylbutane	47	1-ethyl 4-methylbenzene
20	2-Methylpentane	48	1,3,5-Trimethylbenzene
21	3-Methylpentane	49	1-ethyl 2-methylbenzene
22	2-Methyl-1-Pentene	50	1,2,4-Trimethylbenzene
23	n-Hexane	51	n-decane
24	Methylcyclopentane	52	1,2,3-Trimethylbenzene
25	2,4-Dimethylpentane	53	m-diethylbenzene
26	Benzene	54	p-diethylbenzene
27	Cyclohexane	55	n-undecane
28	2-Methylhexane		Total NMOC

Table 4-2. PAMS sites in the CCOS area.

Site	Type of Site	Sampling Schedule for 2000 (CCOS)					
		HC ^a	Carb ^b	00	06	13	17
Sacramento							
Elk Grove-Bruceville	PAMS - 1	x		1	1	0	0
Sacramento-Airport Rd.	PAMS - 2	x	x	0	1	0	1
Sacramento-Del Paso	PAMS - 2A	x	x	1	1	0	1
Folsom-50 Natoma Street	PAMS - 3	x		0	1	0	1
Fresno							
Madera	PAMS - 3/1	x		0	0	0	0
Clovis Villa	PAMS - 2	x	x	1	1	0	1
Fresno-1st Street	PAMS - 2	x	x	1	1	0	1
Parlier	PAMS - 3	x		0	1	0	0
Bakersfield							
Bakersfield-Golden State	PAMS - 2	x	x	1	1	0	1
Arvin	PAMS - 3/1	x		1	1	0	1
Shafter	PAMS - 1	x		1	1	0	0
				7	10	0	7

Type 1 - Upwind background.

Type 2 - Maximum precursor emissions (typically located immediately downwind of the central business district).

Type 3 - Maximum ozone concentration.

Type 4 - Extreme downwind transported ozone area that may contribute to overwhelming transport in other areas.

a - Canisters collected every third day (one 3-hr sample beginning at 0600 PDT) plus CCOS IOPs as indicated.

b - DNPH cartridges collected every third day (one 3-hr sample beginning at 0600 PDT) plus CCOS IOPs as indicated.

Table 4-3. PAMS trends NMOC sampling record

DATE	Bakersfield		Shafter	Clovis	Parlier	Madera	Sacramento - Airport	Sacramento - Bruceville Rd	Sacramento - Del Paso	Sacramento - Folsom	Fresno - First St	Fresno - First St Collocated
	- California Ave	- Golden St Hwy										
07/02/00	X	X	X	INV #1	X	X	X	INV #1	NR	X	X	X
07/05/00	X	X	NR	X	X	INV #1	X	X	NR	X	X	X
07/08/00	X	X	X	X	X	INV #1	INV #1	INV #1	INV #1	X	X	X
07/11/00	X	X	X	X	X	INV #1	X	INV #1	INV #2	X	INV #2	X
07/14/00	X	X	INV #1	X	X	X	X	INV #1	INV #2	X	X	X
07/17/00	X	X	X	X	X	X	X	INV #1	INV #2	X	X	X
07/20/00	X	X	X	INV #1	X	INV #3	X	INV #1	INV #2	X	X	X
07/23/00	X	X	X	INV #1	X	X	X	NR	INV #2	X	X	NR
07/26/00	X	X	X	NR	X	X	X	INV #1	X	X	X	X
07/29/00	X	X	NR	X	X	X	X	INV #1	X	NR	X	X
08/01/00	X	X	NR	INV #1	X	X	X	INV #1	X	X	X	X
08/04/00	INV #1	X	X	X	X	X	X	INV #1	X	X	X	X
08/07/00	INV #4	X	X	X	X	X	X	NR	X	NR	X	X
08/10/00	X	X	X	X	X	X	X	NR	X	X	X	X
08/13/00	X	X	X	X	X	X	X	NR	X	X	X	X
08/16/00	X	X	X	X	X	X	X	X	X	X	X	X
08/19/00	X	X	X	X	NR	X	X	INV #1	X	X	X	X
08/22/00	X	X	X	NR	X	X	X	X	X	X	X	X
08/25/00	X	X	X	X	X	X	NR	NR	NR	NR	X	X
08/28/00	X	X	NR	X	X	X	NR	NR	NR	NR	X	X
08/31/00	X	X	X	X	X	X	NR	NR	NR	NR	X	X
09/03/00	NR	X	X	X	X	X	NR	NR	NR	NR	X	X
09/06/00	X	X	X	X	NR	X	NR	NR	NR	NR	X	X
09/09/00	X	X	X	X	NR	X	NR	NR	NR	NR	NR	X
09/12/00	INV #4	X	X	X	X	X	NR	NR	NR	NR	X	X
09/15/00	X	NR	X	INV #1	INV #1	X	NR	NR	NR	NR	X	X
09/18/00	X	X	NR	X	X	X	NR	NR	NR	NR	X	X
09/21/00	X	X	X	X	X	X	NR	NR	NR	NR	X	X
09/24/00	NR	NR	X	NR	X	X	NR	NR	NR	NR	X	X
09/27/00	NR	NR	X	X	X	X	NR	NR	NR	NR	X	X
09/30/00				X	X	X					X	X

Table 4-3 (continued). PAMS trends NMOC sampling record.

	Bakersfield - California Ave	Bakersfield - Golden St Hwy	Shafter	Clovis	Parlier	Madera	Sacramento - Airport	Sacramento - Bruceville Rd	Sacramento - Del Paso	Sacramento - Folsom	Fresno - First St	Fresno - First St Collocated
09/03/00	NR	X	X	X	X	X	NR	NR	NR	NR	X	X
09/06/00	X	X	X	X	NR	X	NR	NR	NR	NR	X	X
09/09/00	X	X	X	X	NR	X	NR	NR	NR	NR	NR	X
09/12/00	INV #4	X	X	X	X	X	NR	NR	NR	NR	X	X
09/15/00	X	NR	X	INV #1	INV #1	X	NR	NR	NR	NR	X	X
09/18/00	X	X	NR	X	X	X	NR	NR	NR	NR	X	X
09/21/00	X	X	X	X	X	X	NR	NR	NR	NR	X	X
09/24/00	NR	NR	X	NR	X	X	NR	NR	NR	NR	X	X
09/27/00	NR	NR	X	X	X	X	NR	NR	NR	NR	X	X
09/30/00				X	X	X					X	X
Total Expected	30	30	30	30	30	30	30	30	30	30	30	30
Total Valid Received	24	27	24	22	26	26	17	3	10	16	28	29
Total Invalidated	3	0	1	5	1	4	1	11	6	0	1	0
Total Not Received	3	3	5	3	3	0	12	16	14	14	1	1
% Efficiency	80%	90%	80%	73%	87%	87%	57%	10%	33%	53%	93%	97%

4-10

- █ Indicates that a sample is both PAMS and CCOS
- NR Not received as of 10/4/00
- X Sample received and is not invalid
- INV #1 Invalid due to received with pressure less than 5.0 psi
- INV #2 Invalid due to sampling equipment being inoperative
- INV #3 Invalid due to sampling duration out of range
- INV #4 Invalid due to sampler malfunction
- INV #5 Invalid due to sample leak in transit
- ** Samples were received for 9/30/00 although the last official PAMS sampling date was 9/27/00
- NOTE: As of 8/25/00 we no longer supported the Sacramento sites due to their switching to 3L canisters

Table 4-4 PAMS/CCOS NMOC sampling record.

DATE	TIME	Bakersfield - California Ave	Bakersfield - Golden St Hwy	Shafter	Sacramento - Airport	Sacramento - Bruceville Rd	Sacramento - Del Paso	Sacramento - Folsom	Fresno - First St
07/22/00	23:00	X	X	X	N/A	NR	NR	N/A	X
07/23/00	5:00	X	X	X	X	INV #1	INV #2	X	X
07/23/00	16:00	X	X	N/A	X	N/A	NR	X	X
07/23/00	23:00	X	X	X	N/A	NR	NR	N/A	NR
07/24/00	5:00	X	X	X	X	INV #1	NR	X	X
07/24/00	16:00	X	X	N/A	INV #4	N/A	NR	X	X
07/29/00	5:00							X	
07/29/00	23:00	X	X	X	N/A	INV #1	X	N/A	X
07/30/00	5:00	X	X	X	X	INV #1	X	X	X
07/30/00	16:00	X	X	N/A	X	N/A	X	X	X
07/30/00	23:00	X	X	X	N/A	INV #1	X	N/A	X
07/31/00	5:00	X	X	X	X	INV #1	X	X	X
07/31/00	16:00	X	X	N/A	X	N/A	X	X	X
07/31/00	23:00	X	X	NR	N/A	NR	NR	N/A	X
08/01/00	5:00	X	X	NR	NR	NR	NR	NR	X
08/01/00	16:00	X	X	N/A	NR	N/A	NR	NR	X
08/13/00	23:00	X	X	X	X		X	X	
08/14/00	5:00	X	X	X	X		X	X	
08/14/00	12:00	X	X	X	X		X	X	
08/14/00	16:00	X	X	X	X		X	X	
09/12/00	23:00			X					
09/13/00	23:00	X	X	NR					
09/14/00	5:00	X	X	X					
09/14/00	12:00	X	X	X					
09/14/00	16:00	X	X	X					
09/16/00	23:00	X	X	NR					
09/17/00	5:00	X	X	NR					
09/17/00	12:00	X	X	NR					
09/17/00	16:00	X	X	NR					

Table 4-4 (continued). PAMS/CCOS NMOC Sampling Record

DATE	TIME	Bakersfield - California Ave	Bakersfield - Golden St Hwy	Shafter	Sacramento - Airport	Sacramento - Bruceville Rd	Sacramento - Del Paso	Sacramento - Folsom	Fresno - First St
09/17/00	23:00	X	X	NR					
09/18/00	5:00	X	X	NR					
09/18/00	12:00	X	X	X					
09/18/00	16:00	X	X	INV #1					
09/18/00	23:00	X	X	X					
09/19/00	5:00	X	X	X					
09/19/00	12:00	X	X	X					
09/19/00	16:00	X	X	X					
09/19/00	23:00	X	X	X					
09/20/00	5:00	X	X	X					
09/20/00	12:00	X	X	X					
09/20/00	16:00	X	X	X					
09/20/00	23:00	X	X	X	X	INV #1	X	X	
09/21/00	5:00	X	X	X	X	INV #1	X	X	
09/21/00	12:00	X	X	X	X	INV #1	X	X	
09/21/00	16:00	X	X	X	X	INV #1	X	X	
09/23/00	23:00			X					
09/24/00	5:00			X					
09/24/00	12:00			X					
09/24/00	16:00			X					
TOTAL VALID SAMPLES		43	43	33	15	0	14	17	14

4-12

- █ Indicates that a sample is both PAMS and CCOS
- N/A Indicates that there is no sample scheduled for this sampling time
- NR Not received as of 10/4/00
- X Sample received and is not invalid
- INV #1 Invalid due to received with pressure less than 5.0 psi
- INV #2 Invalid due to sampling equipment being inoperative
- INV #3 Invalid due to sampling duration out of range
- INV #4 Invalid due to sampler malfunction
- INV #5 Invalid due to sample leak in transit

Table 4-5. CCOS supplemental surface VOC monitoring sites and measurements.

Site	Site	Operations and Sample Collection				Chemical Analysis		
		Canister ⁽¹⁾	DNPH ⁽¹⁾	Tenax ⁽¹⁾	Automated GC/MS ⁽²⁾	Canister	DNPH	Tenax
Sutter Buttes	S1	ARB	ARB			DRI	AtmAA	
White Cloud	S1	DRI	DRI			DRI	AtmAA	
Bruceville	PAMS, S1'	SMAQMD				ARB		
Granite Bay	R	DRI ⁽³⁾	DRI ⁽³⁾	DRI	DRI	DRI ⁽³⁾	AtmAA ⁽³⁾	DRI
Bodega Bay	S1	T&B	T&B			BRC	AtmAA	
Bethel Island	S2	BAAQMD	BAAQMD			DRI	AtmAA	
San Leandro	S1'	BAAQMD	BAAQMD			DRI	AtmAA	
San Jose 4th Street	S1'	BAAQMD	BAAQMD			BAAQMD ⁽⁴⁾	AtmAA ⁽⁴⁾	
Sunol	R	DRI ⁽³⁾	DRI ⁽³⁾	DRI	DRI	DRI ⁽³⁾	AtmAA ⁽³⁾	DRI
Patterson Pass	S2	UC Berkeley	UC Berkeley			DRI	AtmAA	
Pacheco Pass	S2	T&B	T&B			BRC	AtmAA	
Turlock	S1	T&B	T&B			BRC	AtmAA	
San Andreas	S1	ARB	ARB			BRC	AtmAA	
Trimmer	S2	ARB	ARB			DRI	AtmAA	
Parlier	R	DRI ⁽³⁾	DRI ⁽³⁾	DRI ⁽³⁾	DRI ⁽³⁾	DRI ⁽³⁾	AtmAA ⁽³⁾	DRI
Parlier	PAMS, R'	SJUAPCD				ARB		
Angiola	S1+	SJUAPCD	SJUAPCD			BRC	AtmAA	
Arvin	PAMS, S2'	ARB				ARB		
Piedras Blancas	S1	SLOAPCD	SLOAPCD			BRC	AtmAA	

(1) Four samples per day on 15 IOP days (0000-0300, 0600-0900, 1300-1600, 1700-2000, PDT).

(2) Daily auto-GC/MS from 7/2/00 to 9/2/00 (23 hourly on IOP days and seven 3-hr on non IOP days).

(3) Two samples per day on 4 IOP days (0600-0900, 1300-1600, PDT). Second IOP day of first four episodes

(4) Analyze samples collected during ozone episodes in the Bay Area.

Table 4-6. Total NMHC (ppbC) by GC-FID analysis of canisters from CCOS and PAMS sites during IOPs.

IOP #	Date	Hour (PST)	Bodega Bay	San Leandro	Sunol	Bethel Island	Patterson Pass	Pacheco Pass	Sutter Buttes	Elk Grove	Sac Del Paso
Site Type			S1	S1	R	S2	S2	S2	S1	S1, PAMS	PAMS
Analysis Laboratory			BRC	DRI	DRI	DRI	DRI	BRC	DRI	BRC	BRC/ARB
1	7/22/00	23	36.9	99.7		99.4	31.6		133.6		
1	7/23/00	5	34.6	55.5		112.7	30.1	89.4			
1	7/23/00	12	56.3	123.1		78.9	36.5	77.4	135.1		
1	7/23/00	16	55.7	132.6		67.3	43.8	103.6	77.9		
1	7/23/00	23	33.9	152.8		63.8	36.6		68.6		
1	7/24/00	5	26.5	154.5	82.3	165.4	22.0	133.5			
1	7/24/00	12	24.9	169.3	128.0	36.7	45.0	70.3	143.9		
1	7/24/00	16	26.2	108.3		54.3	42.9	97.2	273.9		
2	7/29/00	23		134.8		136.9	68.4				102
2	7/30/00	5		521.0		90.1	39.5	75.5			83
2	7/30/00	12				63.6	42.9	72.6			
2	7/30/00	16				150.9	71.3	297.8	55.8		81
2	7/30/00	23	20.4	199.3		1284.3	25.7	170.1	27.4		127
2	7/31/00	5	36.5	157.6	157.2	205.0	42.7	91.9	86.0		267
2	7/31/00	12	35.0	203.0	143.3	49.8	43.9	67.0	52.1		
2	7/31/00	16	30.4	203.8		120.1	39.4	75.5	52.2		106
2	7/31/00	23	29.2	250.8		163.4	25.0	70.6	31.7		141
2	8/1/00	5	23.9	252.1		221.5	29.6	74.8	38.2		
2	8/1/00	12	24.1	209.1		94.8	55.6	110.7	266.8		
2	8/1/00	16		184.6		82.4	76.5	100.3	53.3		
3	8/13/00	23	28.7	86.5		115.3	21.6	235.2	41.4		
3	8/14/00	5	32.2	115.5		132.2	27.7	154.4	84.0		158
3	8/14/00	12	24.1	150.3		124.1	44.2	45.1	44.8		89
3	8/14/00	16	34.8	97.0			35.7	72.9	27.3		86
4	9/13/00	23	55.4								
4	9/14/00	5	35.6					88.6			
4	9/14/00	12	47.3					251.0			
4	9/14/00	16	37.7					236.4			
5	9/16/00	23	56.9	184.1		424.4	36.8	45.7	30.8		
5	9/17/00	5	63.8	101.9	159.8	253.3	26.6	60.6		296.9	608.3
5	9/17/00	12	61.7	124.6	36.5	50.0	41.6	64.5	31.6	75.0	54.3
5	9/17/00	16	62.4	179.7		130.1	46.1	64.5	25.8	118.3	175.4
5	9/17/00	23	49.7	115.4		369.8	48.9	41.8	33.8	125.7	90.9
5	9/18/00	5	59.1	94.0	88.5	181.0	31.2	79.2		112.3	714.2
5	9/18/00	12	39.0	271.5	108.8	44.1	50.9	67.2	64.6	60.5	248.8
5	9/18/00	16	31.5	116.3		131.5	35.5	61.3		83.5	293.1
5	9/18/00	23	43.5	138.5		107.4	61.8	91.4		129.8	674.8
5	9/19/00	5	18.0	980.6		263.1	24.6	99.8	27.2	163.3	561.2
5	9/19/00	12	57.2	203.4		35.3	45.1	62.6	39.8	102.2	
5	9/19/00	16	41.7	240.9		130.5	80.5	359.4	28.1	133.7	242.9
5	9/19/00	23	80.2	144.2		166.9	19.0	74.2	28.6	134.0	368.7
5	9/20/00	5	54.8	391.0		232.1	28.4	81.1	28.6		385.3
5	9/20/00	12	45.0	94.8		72.9	74.2	74.4	42.0		117.2
5	9/20/00	16	40.8	72.7		68.2	55.4	53.5	36.0		108.8
5	9/20/00	23	44.6	69.8		40.4	49.0	46.4	32.1		248.2
5	9/21/00	5	38.8	97.9		37.9		30.8			
5	9/21/00	12	53.9			38.2		67.7	23.4		51
5	9/21/00	16	60.0			48.2		61.8	336.2		62

Table 4-6 (continued). Total NMHC (ppbC) by GC-FID analysis of canisters from CCOS and PAMS sites during IOPs.

IOP #	Date	Hour (PST)	Sac		Granite	White	San	Turlock	Madera	Fresno	Clovis
			Airport	Folsom	Bay	Cloud	Andreas		PAMS	First St.	
Site Type			PAMS	PAMS	R	S1	S1	S1	PAMS	PAMS	PAMS
Analysis Laboratory			BRC/ARB	BRC/ARB	DRI	DRI	BRC	BRC	BRC	ARB	BRC
1	7/22/00	23				45.9	156.9	145.2		95	
1	7/23/00	5				28.5	156.3			125	108.7
1	7/23/00	12				55.5	92.1	132.2	143.1		148.8
1	7/23/00	16	58	62		75.0	94	243.2	83.0	75	91.8
1	7/23/00	23				56.8	62.2	444.2	85.0		133.2
1	7/24/00	5	199	104	118.4	27.5	163.9	399.4	166.3	240	269.8
1	7/24/00	12			62.0	53.5		151.6	86.7		283.5
1	7/24/00	16		66		72.5		167.2	66.4	90	158.3
2	7/29/00	23				104.1	134.4	157.0	84.8	159	148.6
2	7/30/00	5	121	103		37.7	142.5	198.8	158.5	179	134.0
2	7/30/00	12				58.9	83.3	186.9	104.5		105.7
2	7/30/00	16		81		85.0	99.1	116.8	53.3	87	70.1
2	7/30/00	23				38.3	70.8	215.3	107.8	95	162.9
2	7/31/00	5	187	161	132.0	40.3	261.9	164.1	166.3	229	420.6
2	7/31/00	12			199.3	57.6	112.1	147.8	87.6		125.4
2	7/31/00	16	86	104		75.8	111.3	184.0	84.2	110	353.9
2	7/31/00	23				49.3		130.5	91.1	690	
2	8/1/00	5				54.4	178	193.6	175.2		
2	8/1/00	12				62.5	127.5	205.1	75.7		
2	8/1/00	16				110.8	97.4	129.0	162.4	229	
3	8/13/00	23	93	119		52.1	1026.7				
3	8/14/00	5	204	96		29.0			222.0		556.4
3	8/14/00	12		105		60.1		107.0	80.4		123.1
3	8/14/00	16	54	78		55.7	69.9	112.3	54.4		
4	9/13/00	23					202.8		413.1		111.2
4	9/14/00	5					403.6		108.9		116.5
4	9/14/00	12					96.8		53.1		145.6
4	9/14/00	16					55		49.3		88.4
5	9/16/00	23				73.8	207.1	180.7	105.2		191.0
5	9/17/00	5	148.4	105.0	60.3	39.1	172.9	243.1	310.9		405.7
5	9/17/00	12	61.9	89.0	63.6	107.9	83	104.3	67.4		109.7
5	9/17/00	16	98.0	184.8		116.7	124.5	138.8	72.6		163.3
5	9/17/00	23		94.8		38.4	66.4	385.9	497.1		580.7
5	9/18/00	5	323.8	202.5	79.6	40.7	222.7	371.1	180.3		584.5
5	9/18/00	12	100.0		74.1	202.7	142.5	107.6	64.0		306.0
5	9/18/00	16	125.1	87.4		140.1	89.1	178.6	91.0		161.5
5	9/18/00	23	417.6			36.0		267.8	421.3		450.2
5	9/19/00	5	440.1	317.9		47.7	216.1	578.3	277.2		
5	9/19/00	12	106.1	141.0		75.9	91.3	97.0	90.5		172.8
5	9/19/00	16	141.2	146.0		282.0	98.6	161.8	87.1		132.5
5	9/19/00	23	669.2			42.7	106.6	392.6	232.0		625.5
5	9/20/00	5	147.1	130.6		52.2	215.2	363.1	390.0		614.1
5	9/20/00	12	340.2	103.9		48.0	89	111.9	74.7		272.1
5	9/20/00	16	350.1	135.6		95.9	106.8	214.8	72.7		121.5
5	9/20/00	23	350.9	118.2		36.7		113.4			121.4
5	9/21/00	5				108.9	65.9	136.9			124.1
5	9/21/00	12	50	61		27.1	74.2	75.1			94.9
5	9/21/00	16	64	54		64.3	49.4	88.0			145.0

Table 4-6 (continued). Total NMHC (ppbC) by GC-FID analysis of canisters from CCOS and PAMS sites during IOPs

IOP #	Date	Hour (PST)	Parlier	Parlier	Trimmer	Shafter	Angiola	Bakersfld	Arvin	Piedras
			PAMS	R	S2	PAMS	S1	PAMS	S2, PAMS	S1
Analysis Laboratory			BRC	DRI	DRI	ARB	BRC	ARB	ARB	BRC
1	7/22/00	23			141.1		114.2	325	84	228.6
1	7/23/00	5	215.1		56.5		108.4			180.2
1	7/23/00	12	91.9		103.8		86.2			341.6
1	7/23/00	16	112.0		92.7			80	70	155.6
1	7/23/00	23	157.5		29.7	165	76.1	421	114	125.7
1	7/24/00	5	321.8	264.6	66.5	422		421	162	231.6
1	7/24/00	12	95.0	90.2	72.7		79.8			474
1	7/24/00	16			39.2		60.0	86	69	131.1
2	7/29/00	23			70.9		113.0		498	
2	7/30/00	5	197.8		67.2	177	115.2	377	109	
2	7/30/00	12	160.1		88.0		67.1			761.9
2	7/30/00	16	89.2		76.1		74.8	179	240	
2	7/30/00	23			41.4	255		536	90	136
2	7/31/00	5		295.5	60.9	2296		446	182	
2	7/31/00	12	85.7	90.7	72.4		57.7			728.2
2	7/31/00	16	61.1		81.9	127	80.4	106	169	
2	7/31/00	23	117.6		164.9	224			152	
2	8/1/00	5	169.7		59.0	392			83	
2	8/1/00	12	100.5		172.0	96	159.9			
2	8/1/00	16	159.7		84.2		71.7		94	
3	8/13/00	23			46.6		109.5	430	61	
3	8/14/00	5	217.8		63.4		191.7	492	99	
3	8/14/00	12	83.6		75.2		88.7	119	89	
3	8/14/00	16	79.7		70.4		93.3	108	66	
4	9/13/00	23				101	287.0	189		
4	9/14/00	5	252.4			239	51.3	295	215	
4	9/14/00	12	66.2			69	90.1	250	98	
4	9/14/00	16	113.3			117		140	110	
5	9/16/00	23			40.8		97.9		61	117.5
5	9/17/00	5	361.5		30.9		82.5	290	124	140.9
5	9/17/00	12	87.4		66.2		75.4	131	100	128.6
5	9/17/00	16	102.0		71.2		76.2	94	71	134.4
5	9/17/00	23	329.0		38.2		111.8	601	68	74.1
5	9/18/00	5	320.5	298.9	37.5					210.3
5	9/18/00	12	123.4	85.6	49.0	81	56.3	221	107	340.3
5	9/18/00	16			45.6		108.9	138	172	83.9
5	9/18/00	23	287.5		31.5			529	108	107.8
5	9/19/00	5			145.8	460		688	121	209.3
5	9/19/00	12	184.0		56.7	111		197	750	148.2
5	9/19/00	16	100.8		54.3	136		407	111	82.8
5	9/19/00	23			38.6	165		477	96	74.9
5	9/20/00	5	249.5		59.6	475		651	80	113.3
5	9/20/00	12	75.5		49.5	89	61.9	159	72	150.8
5	9/20/00	16	102.7		56.8	114	72.8	186	73	82.5
5	9/20/00	23	209.3		114.8	376	97.6	444	73	200.3
5	9/21/00	5	146.8		43.9		43.5			116.9
5	9/21/00	12	56.7		55.2	79	40.8	112	74	189
5	9/21/00	16	58.0		46.6	62		76	63	73.8

Individual PAMS Hydrocarbons at Parlier

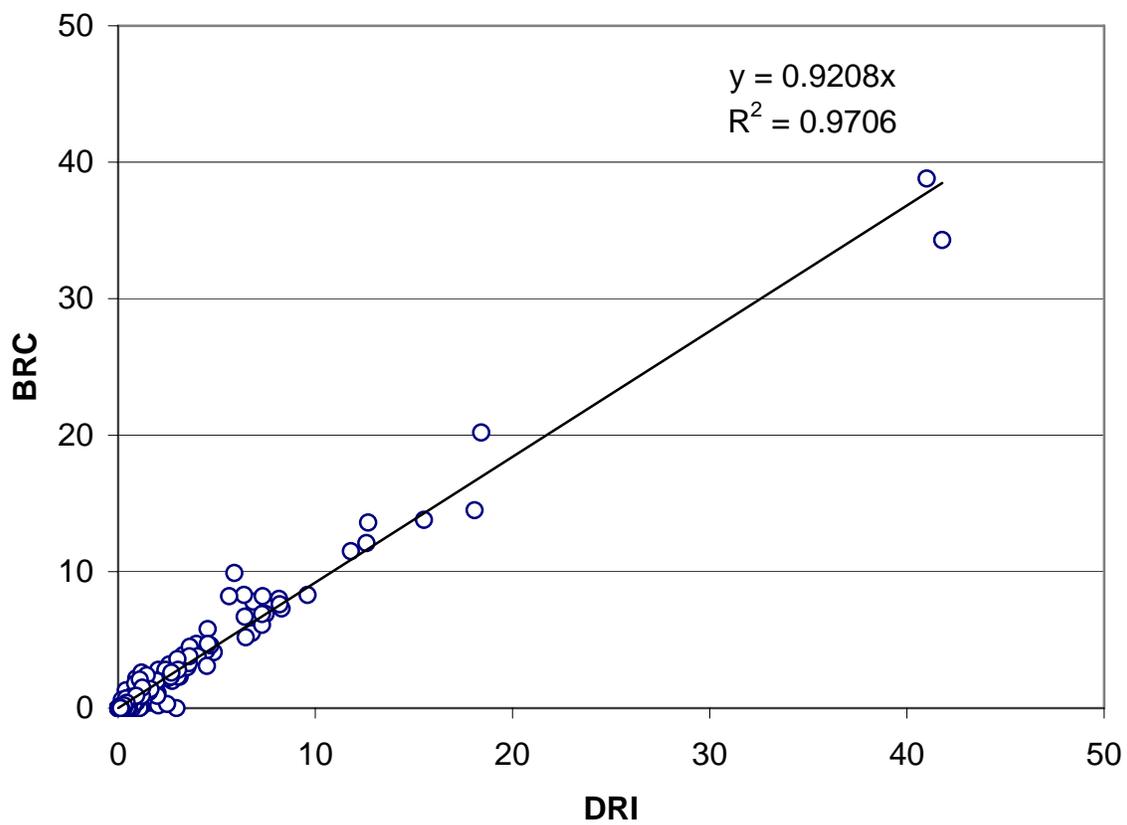


Figure 4-1. Scatterplot of individual 55 PAMS hydrocarbon species measured by Biospheric Research Corp. and Desert Research Institute for collocated canister samples at Parlier.

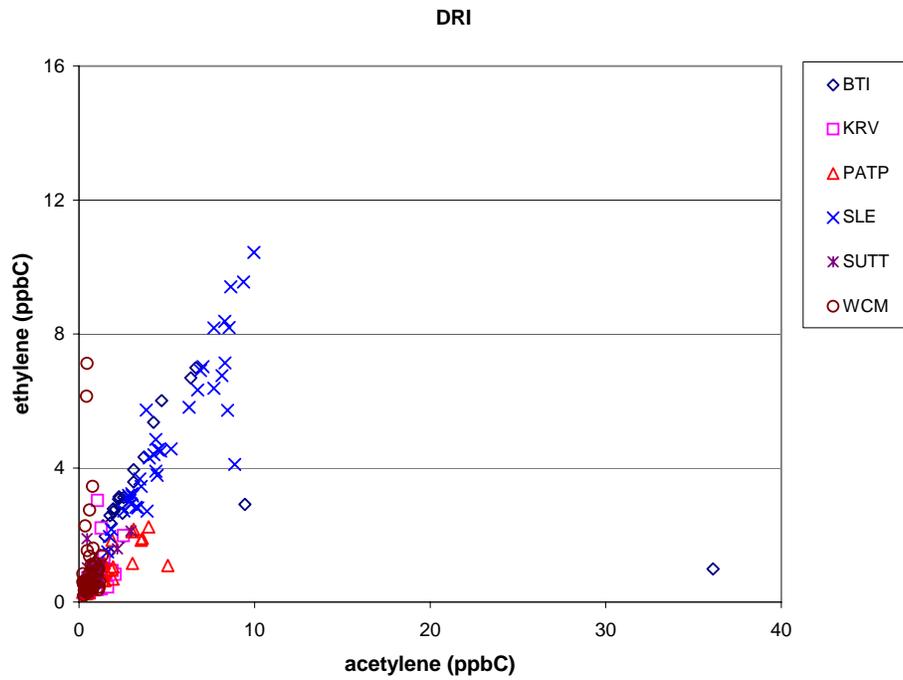


Figure 4-2a. Scatterplot of ethylene and acetylene for CCOS supplemental canister samples analyzed by Desert Research Institute.

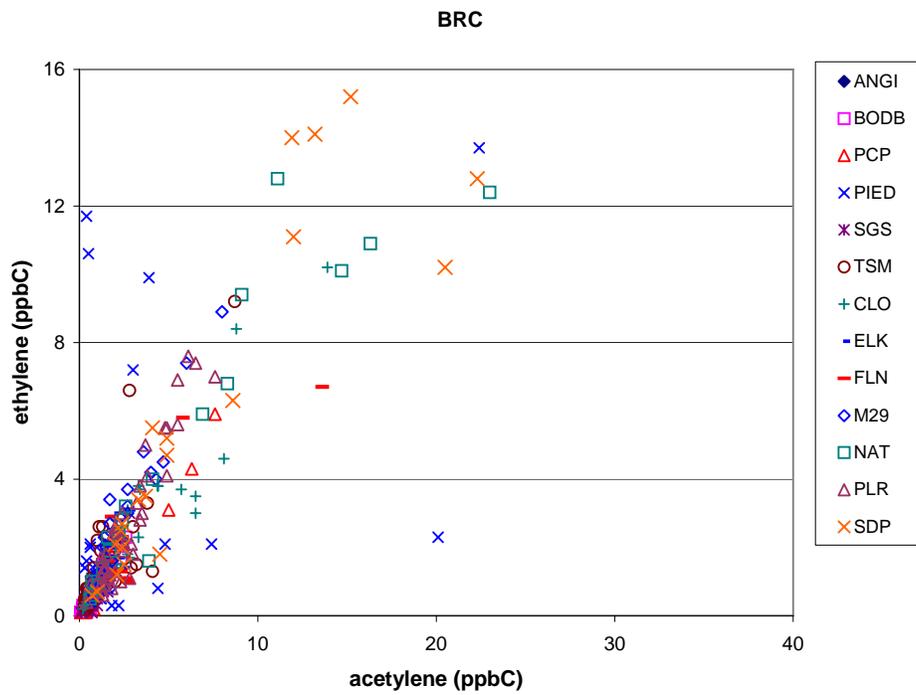
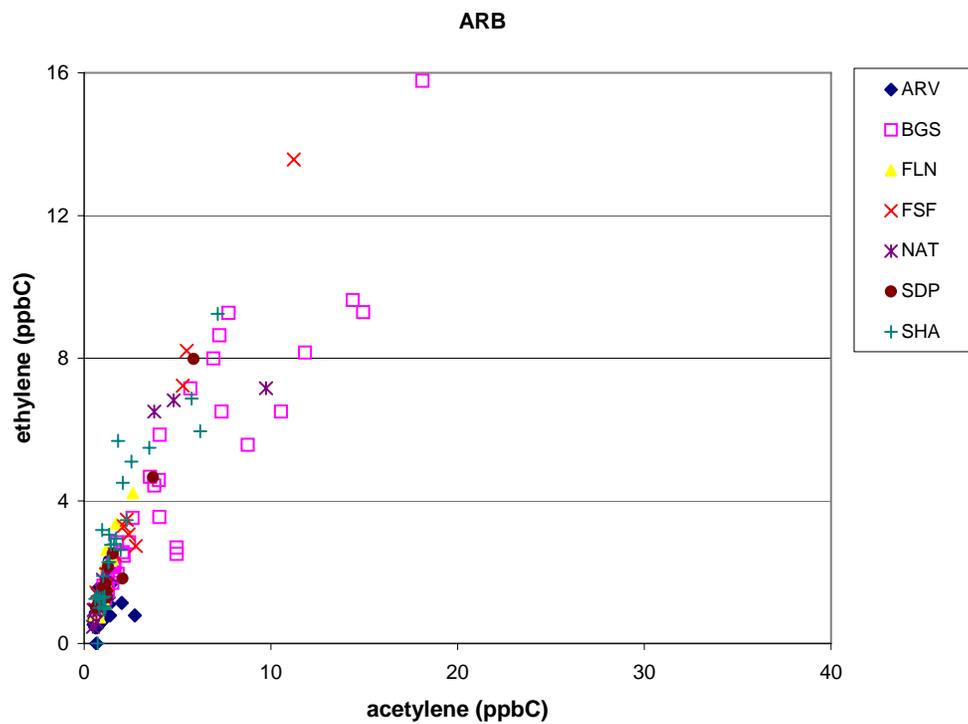


Figure 4-2b. Scatterplot of ethylene and acetylene for CCOS supplemental canister samples analyzed by Biospheric Research Corp.



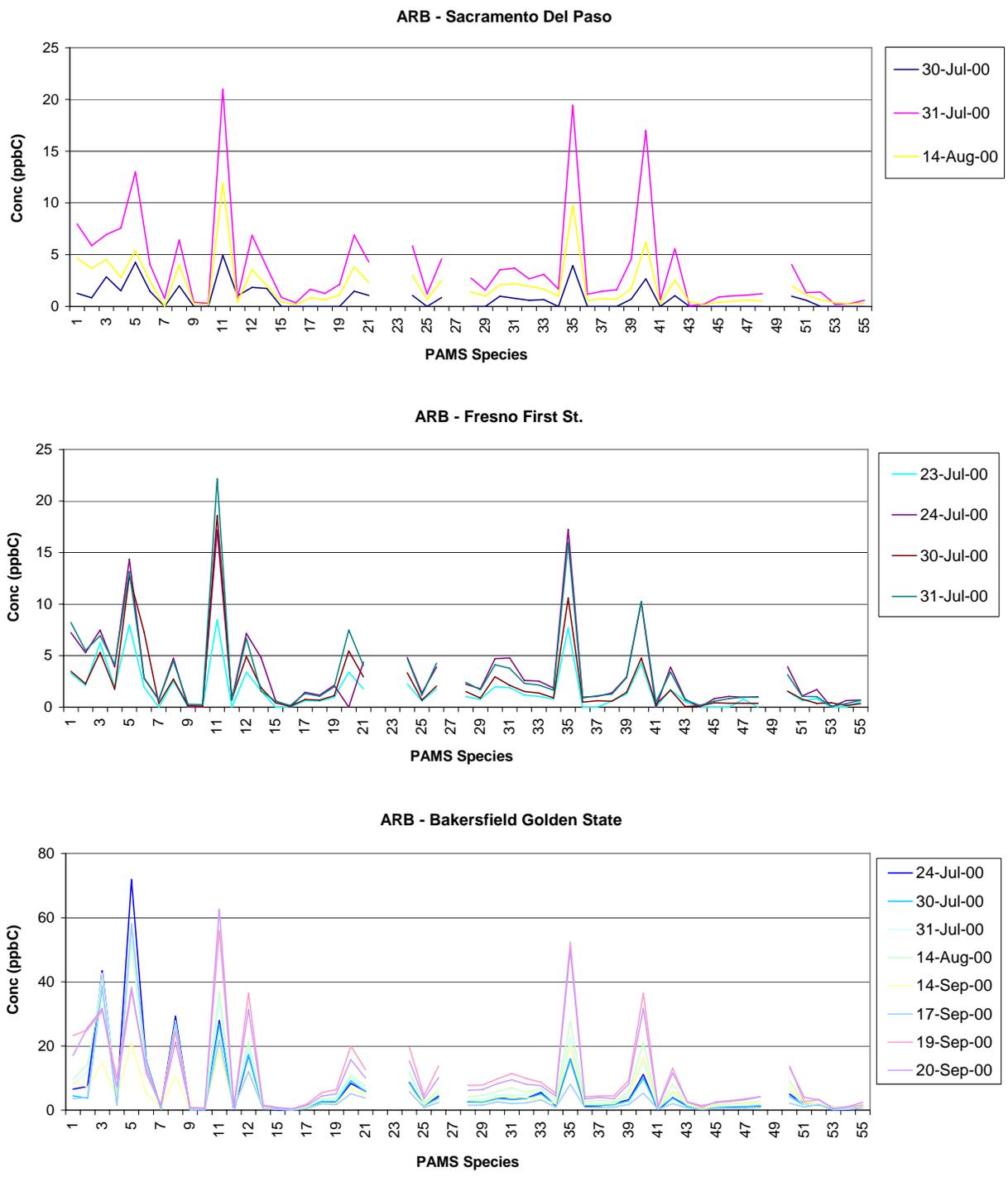


Figure 4.3a. Profiles of 55 PAM species measured by the California Air Resources Board for 6-9 a.m. canister samples at Sacramento Del Paso, Fresno First St. and Bakersfield Golden State.

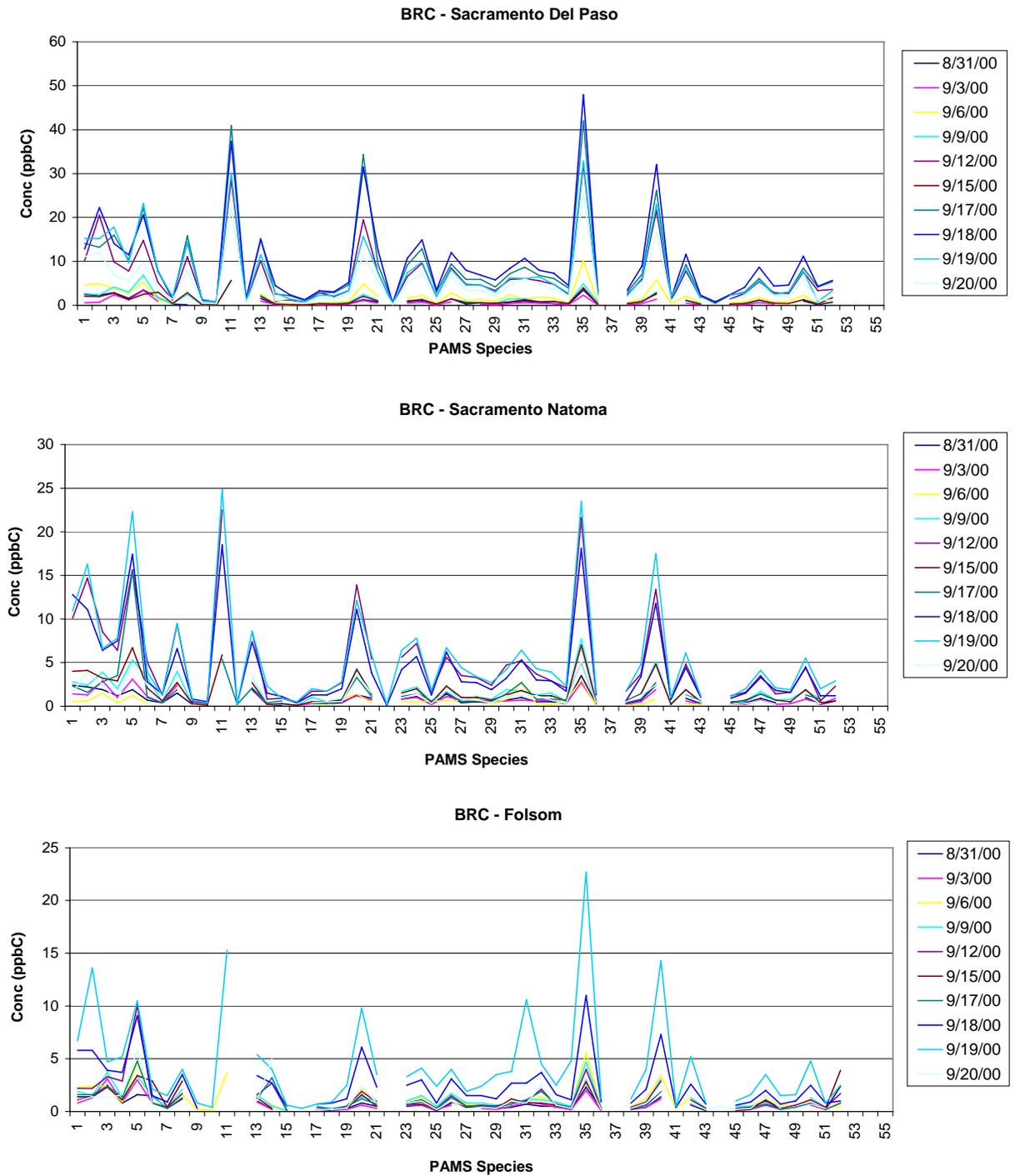


Figure 4.3b. Profiles of 55 PAM species measured by the Biospheric Research Corp for 6-9 a.m. canister samples from Sacramento Del Paso, Sacramento Natoma and Folsom.

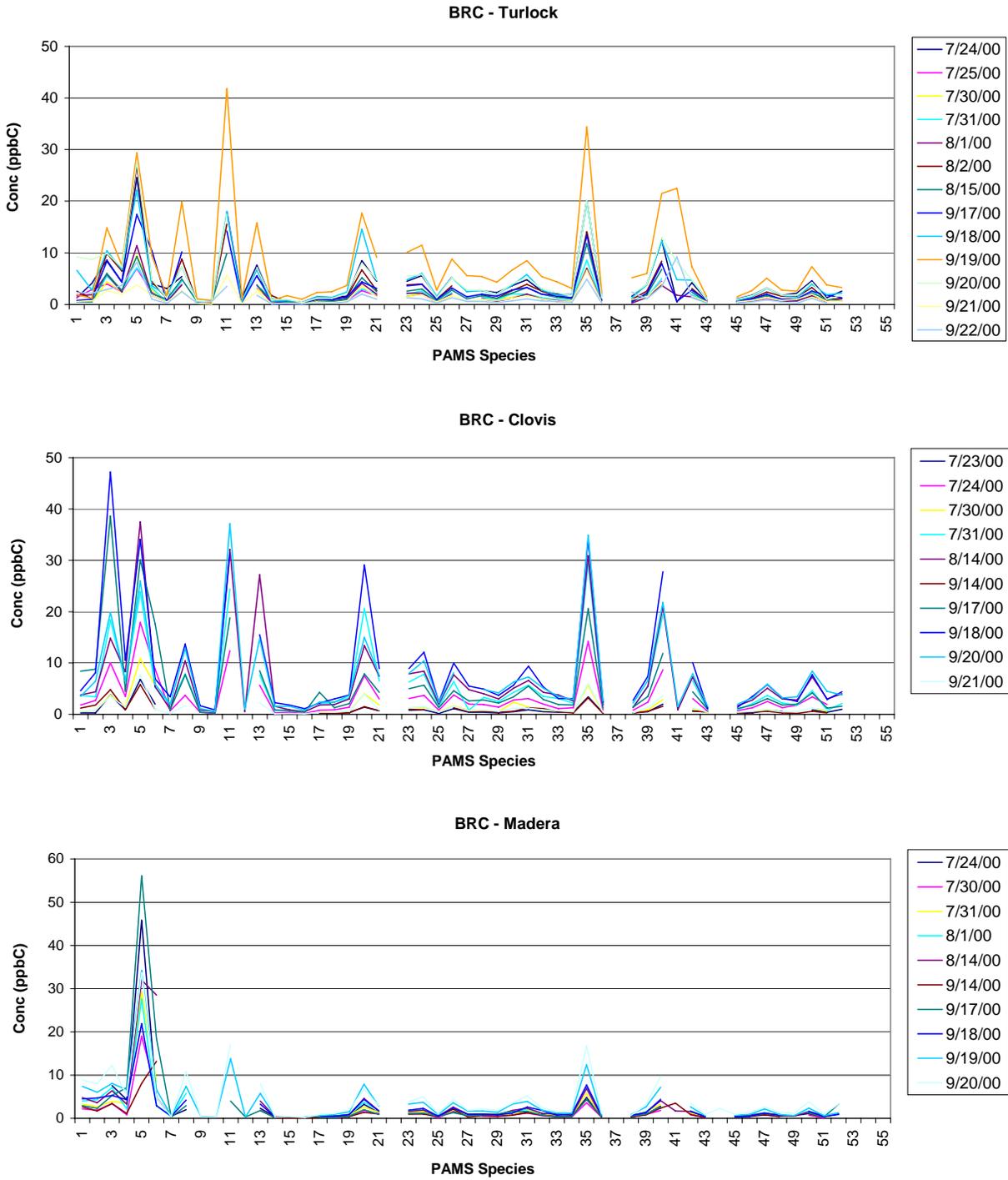


Figure 4.3c. Profiles of 55 PAM species measured by the Biospheric Research Corp for 6-9 a.m. canister samples from Turlock, Clovis and Madera.

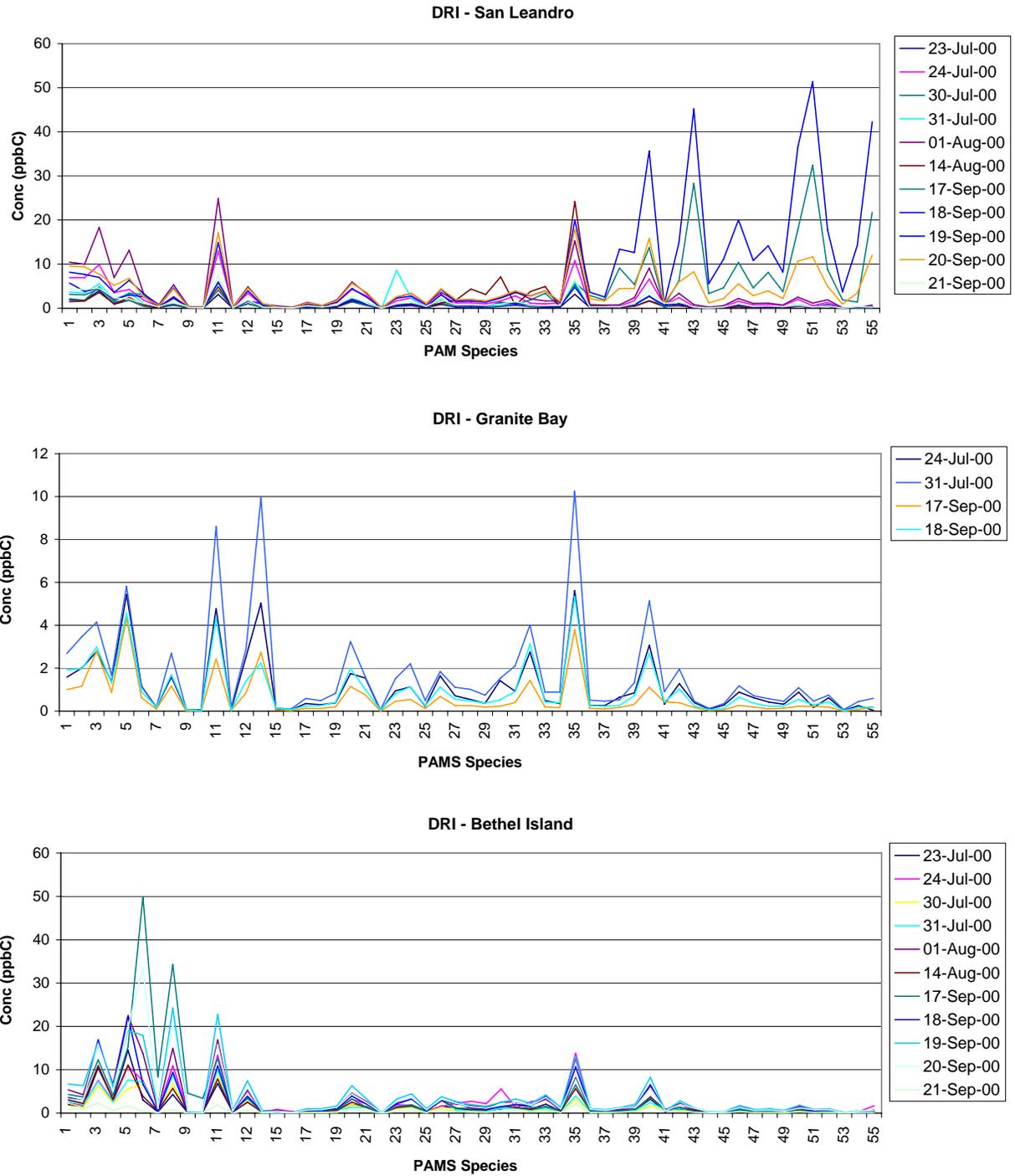


Figure 4.3d. Profiles of 55 PAM species measured by the Desert Research Institute for 6-9 a.m. canister samples from San Leandro, Granite Bay and Bethel Island.

5. SUPPLEMENTAL SURFACE CARBONYL COMPOUNDS

The carbonyl measurements that were made in the PAMS and CCOS supplemental monitoring networks are summarized in Table 4-2 and 4-5. All of the PAMS samples were analyzed by the ARB and supplemental carbonyl samples were analyzed by Atmospheric Assessment Associates. In addition, UC, Riverside measure formaldehyde continuously by Tunable Diode Laser Absorption Spectroscopy at Parlier.

5.1 Measurement Methods

The standard method used in PAMS to measure carbonyl compounds involves derivatization of carbonyl compounds by 2,4-dinitrophenylhydrazine (DNPH) followed by liquid chromatography and U.V. detection according to EPA Compendium Method TO-11. The method recommends DNPH-impregnated silica Sep-Pak cartridges with an ozone scrubber upstream of the impregnated cartridge since silica cartridges were found to have significant negative ozone artifacts (Arnst and Tejada, 1989).

Collection of carbonyl compounds by the DNPH method is based on the acid-catalyzed derivatization of carbonyls by nucleophilic addition of the DNPH to a C=O bond, followed by 1,2-elimination of water to form 2,4-dinitrophenylhydrazone. The DNPH-hydrazones, formed during sampling, are non-volatile and remain on the sampling medium, which is a reagent-impregnated cartridge charged with the reagent solution. The yellow to deep-orange colored DNPH-hydrazones have UV absorption maxima in the 360-375 nm range and can be analyzed by the high performance liquid chromatography (HPLC) method coupled with UV detection. This method offers very high selectivity and sensitivity of analysis. The analytical method is well established, and questions regarding the accuracy of the DNPH method are mainly concerned with sampling. The major concerns are: 1) incomplete collection of carbonyls, 2) loss of carbonyl compounds by physical processes such as adsorption or chemical reaction with copollutants such as ozone, 3) generation of carbonyl compounds as sampling artifacts, and 4) variable blanks resulting from contamination of the reagent and sampling equipment. Several recent review articles treat the subject of carbonyl compound sampling and analysis in detail (Vairavamurthy et al, 1993; and Zielinska and Fujita, 1995, Apel et al., 1998). The C₁-C₇ carbonyl compounds that can be quantified include formaldehyde, acetaldehyde, acetone, acrolein, propionaldehyde, crotonaldehyde, methyl ethyl ketone, methacrolein, butyraldehyde, benzaldehyde, valeraldehyde, tolualdehyde, and hexanaldehyde.

The TDLAS method takes advantage of the high monochromaticity and rapid tunability of a Pb salt diode laser to measure absorptions from single rotational-vibrational lines in the middle infrared spectrum of a molecule. Almost all gases absorb radiation in this spectral region. However, since many gases absorb in this region, very high spectral resolution is required to prevent interferences from other gases in the sampled air. The atmospheric sample is pumped rapidly at the reduced pressure through a White cell, which also provides the long optical path lengths required to achieve the desired detection limits. The tunable diode laser is a small Pb crystal with variable amounts of Sn, Se, Te or S. The wavelength region at which the laser emits radiation is governed by the proportions of the three elements in the crystal. Technique of measuring HCHO by TDLAS has been described by MacKay (1994). The precision of the measurements is experimentally found to be better than ± 1 percent. The accuracy depends on

the ability to accurately measure the various flows and on the ability to determine the mixing ratio of the calibration standard. The computed accuracy for HCHO is ± 15 percent (MacKay, 1994).

5.2 Performance Audits

Carbonyl sampler through-the-probe audits were conducted by the ARB Quality Assurance staff. A sample of audit gas with known (assigned) concentrations was collected on a carbonyl cartridge for a three-hour period and then analyzed by the laboratory. The sample was run, wherever possible, in conditions duplicating a routine ambient run. In general, the results of the ARB through-the-probe carbonyl audits were good. Operational problems were experienced at several of the sites, invalidating the audit sample. Once these samples are removed, the audit results are very good, with all audit samples agreeing to within 3.1% of the ARB audit acetaldehyde concentration (Parsons Engineering Science Inc., 2001)

5.3 Validation Checks

Figure 5-1 show the mean formaldehyde and acetaldehyde by sampling period for DNPH cartridge samples collected at CCOS supplemental monitoring sites. Levels of both formaldehyde and acetaldehyde are both about 1 ppbv or less at the two coastal background sites, Bodega Bay and Piedras Blancas, and at San Jose. Ambient concentrations of carbonyl compounds are substantially higher at site downwind of urban areas and are highest in the afternoon samples, which are consistent with photochemical reactions as the primary source of carbonyl compounds.

The mean concentration of the DNPH formaldehyde at Parlier agrees well with the time-series of the hourly average CE-CERT TDLAS formaldehyde data in Figure 5-2. The diurnal variation in HCHO concentration correlates well with the diurnal variation in ozone at Parlier.

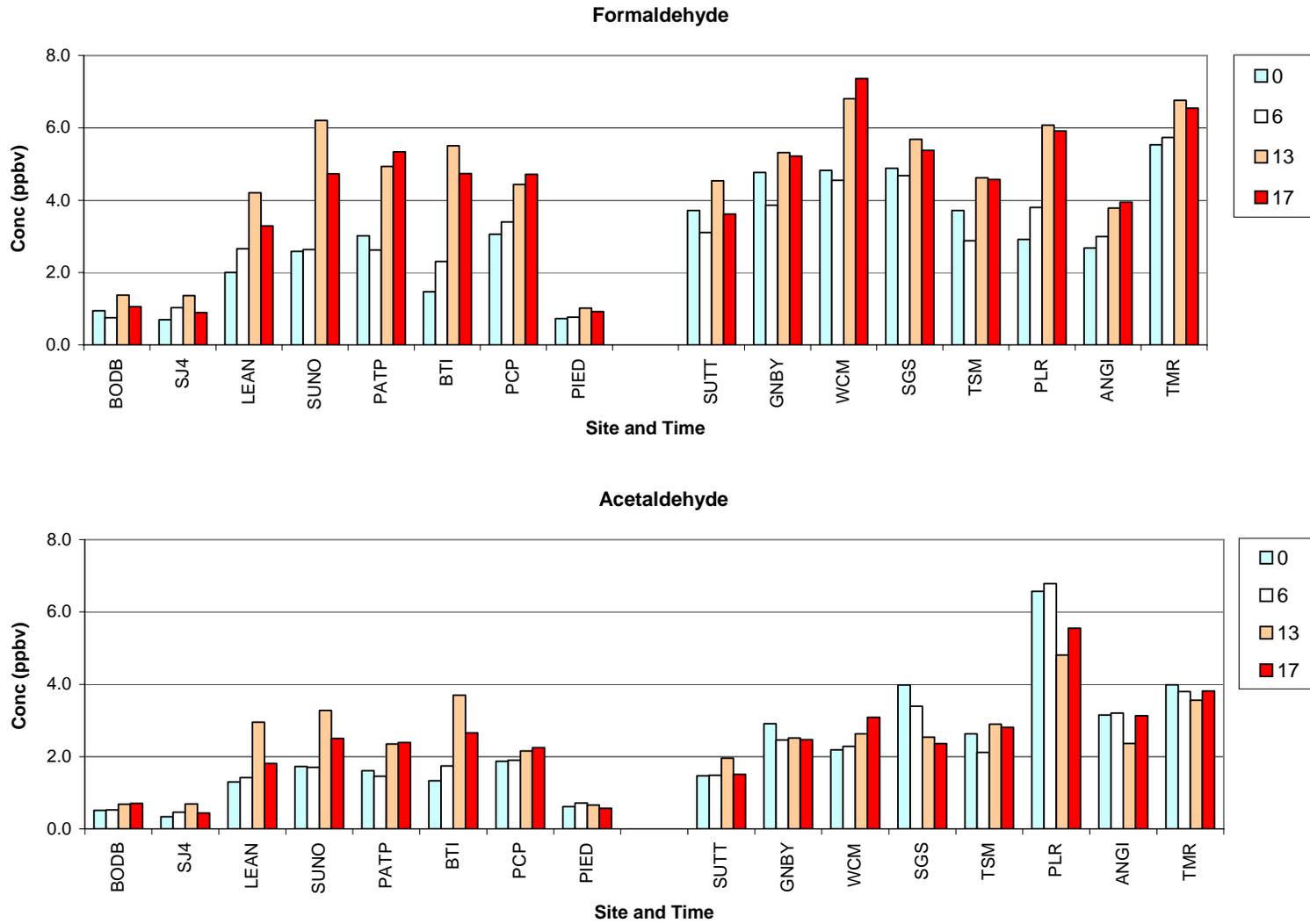


Figure 5-1. Mean formaldehyde and acetaldehyde by sampling period at CCOS supplemental monitoring sites.

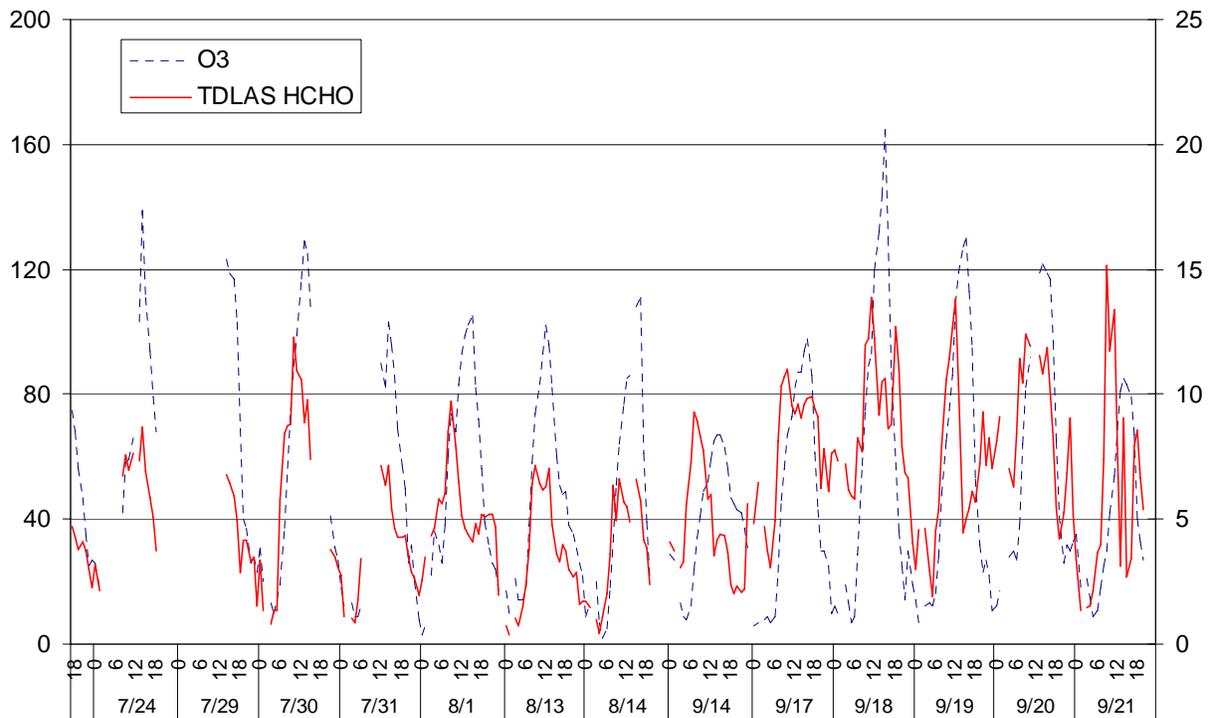


Figure 5-2. Time-series of hourly average CE-CERT TDLAS formaldehyde (ppbv) versus ozone mixing ratios (ppb) at Parlier.

6. SEMI-CONTINUOUS SPECIATED VOC BY AUTOMATED GC/MS

An automated semi-continuous Gas Chromatograph/Mass Spectrometer (GC/MS) system was used at the three CCOS Research sites (Granite Bay, Sunol and Parlier). The samples were collected with 1-hour resolution during intensive operational periods (IOP) and 3-hour resolution during the remaining days of the two-month study period or non-intensive operational periods (non-IOP). The continuous GC/MS systems were calibrated for 126 organic compounds including hydrocarbons from C₂ to C₁₂, oxygenated hydrocarbons, and halogenated compounds. C₂ and C₃ hydrocarbons were quantified using a FID detector and the remaining compounds were identified and quantified by MS (Ion Trap) detector.

6.1 Measurement Methods

The GC/MS system consisted of an Entech real-time integrator with an Entech 7100 preconcentrator and a Varian 3800 gas chromatograph with a flame ionization detector (FID) and column switching valve interfaced to a Varian Saturn 2000 ion trap mass spectrometer. Under operational conditions, the real-time integrator collected a sample in a 6 L canister by using a vacuum to draw the sample. Samples were integrated over 3-hours non-IOP or 1 hour IOP. At a predetermined time, the preconcentrator collected a 300 ml subsample from the 6 L canister, focus it and inject it into the gas chromatograph. The trapping and focusing process consisted of three traps. The first trap (50% glass beads/50% Tenax) trapped sample at -100 °C. The sample was then desorbed from the first trap at 10 °C and transferred to a second trap of 100% Tenax held at -40 °C. The second trap desorbed the sample at 200 °C and transferred it to a third, final focusing trap (a piece of silicosteel capillary) at -180 °C. The sample on the final trap was desorbed at approximately 70 °C to a transfer line heated to 110 °C and connected to the head of the first column. The objective of three-stage trapping process was as follows: 1) the first trap limited the amount of water entering the column by the relatively low desorption temperature, 2) the second trap eliminated CO₂, and 3) the third trap focused the sample so that the injection was made as narrow as possible to limited band broadening. The GC was configured to inject the sample at the head of a 60 m x 0.32 mm polymethylsiloxane column (CPSil-5, Varian, Inc.). This column led into the switching valve set so the effluent went into a 30 m x 0.53 mm GS-GasPro column (J&W Scientific). After approximately 7 minutes, the column switched and the effluent from the first column eluted onto a second 15 m x 0.32 mm polymethylsiloxane column into the mass spectrometer. The column switch was timed to elute the C₂ and C₃ compounds on the FID and all C₄ and higher compounds onto mass spectrometer (Figure 2.1-1).

Calibration of the system was conducted with a 112 component mixture that contained the most commonly found hydrocarbons (75 compounds from ethane to n-undecane), halocarbons (23 compounds from F12 to the dichlorobenzene), and oxygenated compounds (14 compounds from acetaldehyde to nonanal, including MTBE). The standards were prepared in 6 L silco-steel canisters (Restek, Bellefonte, PA) by mixing three different standards through a multi-valve manifold using a Baratron absolute capacitance manometer (MKS Instruments, Andover, MA) to determine the pressure each standard added to the mixture. Prior to mixing, approximately 0.2 ml of ultrapure water was added to the canister to humidify the mixture—in prior experiments without the added humidity the oxygenated compounds were much lower in response. A 74 component hydrocarbon mix was purchased

from Air Environmental, Inc. with compounds from 0.2 to 10 ppbv. A 14 component oxygenated compound standard (1.0 ppbv) with one hydrocarbon for reference was also purchased from Air Environmental, Inc. The 23 component halocarbon mixture was purchased from Scott Specialty Gases with concentrations between 5 and 10 ppbv. The minimum detection limits (MDL) for volatile hydrocarbons and halocarbons were 0.1 ppbv and 0.01 ppbv for carbonyl compounds.

After the instruments were operational, a three-point calibration was conducted and a sampling sequence for ambient samples was started (every three hours starting at midnight). One calibration check and one blank of zero air were analyzed daily (at 0400 and 0500 hr). During IOPs, ambient samples were collected every hour and three-point calibrations were generally run prior to each IOP. Personnel were generally on-site during all IOPs, partly because of the need to run other instrumentation, and were generally not on-site during non-IOPs. When personnel were not present, remote access software was used to check instrument status and confirm that it was operating normally. Occasionally the instruments were taken off-line to bake out the ion trap or perform other maintenance, i.e., data capture was not 100% (Sagebiel and Zielinska, 2001). Two ion traps had to be disassembled and cleaned during the study and columns needed replacement, but generally the instruments performed well. Instrument tuning was also very important for consistent data since the instruments were not stable over the entire study period. Autotuning is timely, however, and was difficult to perform on a regular basis.

6.2 Validation Checks

The initial comparison of the auto GC/MS data with the corresponding canister samples showed large differences with no consistent bias. Comparison by site and sampling period revealed several problems. The correlations for IOP #1 at Granite Bay (Figure 6-1) show that the some values for GC/MS are significantly higher. While the other pairs of data are better correlated, there is a consistent bias with the auto GC/MS reporting about 25 percent higher than the GC-FID. This bias is reversed in IOP #5, with the GC-FID values being 25 percent higher than the auto-GC. Varying bias between the two methods indicate possible drifts in calibration.

A species-by-species comparison (Figure 6-2a,b,c) shows that the largest discrepancies between the two measurements occurred at Granite Bay during IOP #1 and were confined to higher molecular weight hydrocarbons. The higher readings for heavy hydrocarbons were likely due to the loss of these compounds in the standard hydrocarbon mixture that was used to calibrate the auto GC/MS. The primary standard was kept at DRI in a 55-liter tank under high pressure. At high pressure, all of the compounds in the standard mixture were expected to remain stable during the entire summer field study. Aliquots of the standard were transferred by DRI to six-liter canisters at one atmosphere positive pressure and used at each of the three Research sites for multipoint calibrations prior to the start of each IOP and for daily single-point calibration checks. The pressure of the transfer standard decreased with each successive calibration and eventually reached a pressure at which stability could have been compromised.

6.3 GC/MS Data Correction

The GC/MS data were originally submitted on 6/12/02 for all IOP and non IOP days. The problems revealed by our initial evaluations of this dataset were discussed with DRI staff that obtained the GC/MS data. The calibration data was reviewed to account for possible variation in calibrations due to stability of the standard as well as potential biases that may have been caused by the operational protocol of the instrument. Their examination of the calibration data confirmed that calibration shifts did occur and that corrections to the originally submitted data base were necessary. The corrections were performed by multiplying the measured values by the ratios of the reference calibration mixture concentrations versus the observed calibration mixture concentrations. This approach was used to derive species-specific correction factors for each sample. The 6 a.m. sample from 7/24/00 of Episode 1 is used in this section as an example of the magnitude of the correction. Based on the observed concentration of the calibration checks, the measured values were subsequently corrected and the data were resubmitted on 2/4/03.

Granite Bay

Figure 6-3a shows the ratios of reference calibration mixture concentration versus observed gas mixture concentrations for various VOCs (target ratio = 1). The ratio decreases for heavy hydrocarbons and increases for light hydrocarbons. When the ratio decreases, the observed gas mixture concentration is higher than the actual calibration mixture concentration.

Sunol

For Sunol, the light hydrocarbons were overestimated especially for isoprene. The difference in isoprene concentrations was due to incorrect SATURN programming—the sequence cut was on the isoprene peak itself causing incorrect calibration. Alkenes gave higher values for GC/MS data than for canister data. The double bonded compounds were probably more effected by the change in pressure of the calibration mixture. The C₅ hydrocarbon had problems with tailing peaks caused by either a high or low injection temperature, or low oven temperature. The Module 3 Entech heater had problems due to lack of nitrogen gas, according to the log book, and was corrected.

A propane generator was located on the roof near the GC/MS that may have been a source of light hydrocarbons possibly effecting the measurements. The inlet to the canister sampler, however, was at ground level resulting in no added affect to the samples. The generator at Sunol ran once a week every Tuesday (except 9/12/00 and 9/19/00) for about 20 minutes from 10:00 to 10:30 PST. The propane concentration was not significantly higher for measurements taken on 7/25/00 and 8/1/00, days when the generator was scheduled to run.

The incorrect sequence cut for the isoprene peak caused the incorrect quantification of isoprene concentrations. After calculating the linear formula for isoprene, the data was corrected. The linear formula for the Saturn method was $y=1.2760X$, and the linear formula of the calibration was $y=167.69X$. The data was corrected by multiplying the measure value

by the ratio of the actual gas mixture concentration versus observed gas mixture concentration. Figure 6-3b shows the ratio for various hydrocarbons.

Parlier

The Parlier data had inconsistent light hydrocarbon and heavy hydrocarbon data. The inconsistencies were possibly caused by improper heating of the Entech Module 3 due to insufficient liquid nitrogen tank pressure. According to the logbook, the GC/MS ran out of liquid nitrogen on 9/17/00 and 9/18/00. The Parlier data also has high background ions in the spectra possibly due to column bleed that effected the calibration and caused misidentification of the peaks. Parlier also had problems with the air conditioner resulting in high freon values. The correction of the data was done by multiplying the measured value by the ratio of the actual gas mixture concentration versus the observed gas mixture concentration. Figure 6-3c shows the observed gas mixture concentration has lower concentration than the actual calibration mixture concentration for most light hydrocarbons and higher concentrations for heavy hydrocarbons.

6.3.1 Result of GC/MS Data Corrections

Granite Bay

Figures 6-4a and 6-4b compare the mixing ratios (ppbC) of the 55 PAMS compounds before and after correction, respectively. Figure 3.3-2 shows the GC/MS heavy hydrocarbons are better correlated to the canister heavy hydrocarbons after correction. Figures 6-5a and 6-5b show scatter plots of 55 PAMS compounds before correction and after correction, respectively. Figure 3-9 shows the correlation between the GC/MS data and the canister data is poor ($R^2 = 0.296$). The corrected data in Figure 6-5b is much improved ($R^2 = 0.844$).

Sunol

Figure 6-6a shows a large difference between the isoprene and C5 hydrocarbons concentrations of the GC/MS and canister data before correcting the calibration. Figure 6-6b shows the concentrations of the 55 PAMS compounds of the corrected GC/MS data compared to the canister data. The GC/MS and canister data are more comparable, especially for isoprene. Figures 3-13 and 3-14 show scatter plots comparing the GC/MS data and canister data before and after correction, respectively. Figure 6-7a shows a correlation between the GC/MS data and the canister data ($R^2 = 0.4341$). Figure 6-7b shows the correlation between GC/MS data and the canister data has improved after correction ($R^2 = 0.8903$).

Parlier

Figure 6-8a shows the canister and GC/MS data before correction. There is a large difference in light hydrocarbon (namely isoprene, 2,3-dimethylbutane, and 2-methylpentane concentrations) and heavy hydrocarbon concentration between the canister and GC/MS data. Figure 6-8b shows after correction the difference between the canister and GC/MS data is markedly improved. Before correction, Figure 6-9a shows a poor correlation between the GC/MS data and the canister data ($R^2 = 0.190$). After correction, Figure 6-9b shows a good correlation between the GC/MS and canister data ($R^2 = 0.964$).

Data for total VOC is shown in Table 6-1. The data for selected hydrocarbons at three research sites for IOP 4 are presented in Tables 6-2 and 6-3. Table 6-2 shows the concentrations (ppbC) of selected hydrocarbons and the total nonmethane hydrocarbons for the three research sites. The concentrations of these compounds are presented in order to show the importance of photochemistry downwind of urban areas. Higher concentrations of isoprene in the afternoon samples are an indication of biogenic sources, as vegetation emissions of isoprene increase with increasing temperature and light intensity.

6.4 Summary of Validation Results

The GC/MS data were originally submitted on 6/12/02. Problems revealed by our initial evaluations of this dataset were traced to variations in calibrations due to instability of the standard mixture in the transfer standard as well as potential biases that may have been caused by the operational protocol of the instrument. Examination of the calibration data confirmed that calibration shifts did occur and that corrections to the originally submitted data base were necessary. The corrections were performed by multiplying the measured values by the ratios of the reference calibration mixture concentrations versus the observed mixture concentrations in the transfer standard. This approach was used to derive species-specific correction factors for each sample. Based on the observed concentration of the calibration checks, the measured values were subsequently corrected and the data were resubmitted on 2/4/03. Scatter plots for the three sites showed the correlations between the canister and GC/MS data improved after the correction process. Box plots for all three sites showed that the distribution between the canister data and the GC/MS data improved after correction.

Table 6-1. Automated Gas Chromatograph/Mass Spectrometer Data at CCOS Research Sites

IOP #	Date	Hour (PST)	Sunol (SUNO)		Granite Bay (GNBY)		Parlier (PLR)			
			Sample ID	NMHC (ppbC)	Sample ID	NMHC (ppbC)	Sample ID	NMHC (ppbC)		
1	22-Jul-00	23	SU000723-00	23.8	GB000723-00	86.3				
1	23-Jul-00	0								
1	23-Jul-00	1	SU000723-02	9.7	GB000723-02	72.7				
1	23-Jul-00	2	SU000723-03	46.5	GB000723-03	102.3				
1	23-Jul-00	3	calibrations							
1	23-Jul-00	4	calibrations							
1	23-Jul-00	5	SU000723-06	63.8	GB000723-06	102.2				
1	23-Jul-00	6	SU000723-07	68.1	GB000723-07	116.3				
1	23-Jul-00	7	SU000723-08	23.9	GB000723-08	126.0				
1	23-Jul-00	8	SU000723-09	18.1	GB000723-09	77.8				
1	23-Jul-00	9			GB000723-10	79.6				
1	23-Jul-00	10	SU000723-11	22.5	GB000723-11	86.1	PA000723-11	200.3		
1	23-Jul-00	11	SU000723-12	26.0	GB000723-12	86.3	PA000723-12	175.2		
1	23-Jul-00	12			GB000723-13	78.1				
1	23-Jul-00	13	SU000723-14	25.0	GB000723-14	77.4				
1	23-Jul-00	14	SU000723-15	21.3	GB000723-15	73.0				
1	23-Jul-00	15	SU000723-16	19.5	GB000723-16	62.5				
1	23-Jul-00	16	SU000723-17	28.2	GB000723-17	66.6				
1	23-Jul-00	17	SU000723-18	70.9	GB000723-18	74.6	PA000723-18	243.0		
1	23-Jul-00	18	SU000723-19	109.5	GB000723-19	76.6	PA000723-19	347.7		
1	23-Jul-00	19	SU000723-20	104.1	GB000723-20	89.2	PA000723-20	292.8		
1	23-Jul-00	20	SU000723-21	110.0	GB000723-21	108.1				
1	23-Jul-00	21			GB000723-22	185.7				
1	23-Jul-00	22	SU000723-23	54.6	GB000723-23	145.0				
1	23-Jul-00	23	SU000724-00	55.0	GB000724-00	115.5	PA000724-00	209.1		
1	24-Jul-00	0	SU000724-01	60.7	GB000724-01	120.5				
1	24-Jul-00	1	SU000724-02	75.0	GB000724-02	112.6				
1	24-Jul-00	2	SU000724-03	87.9	GB000724-03	106.0				
1	24-Jul-00	3	calibrations							
1	24-Jul-00	4	calibrations							
1	24-Jul-00	5	SU000724-06	56.5	GB000724-06	127.7				
1	24-Jul-00	6	SU000724-07	69.6	GB000724-07	142.6	PA000724-07	547.1		
1	24-Jul-00	7	SU000724-08	75.3	GB000724-08	159.2	PA000724-08	550.5		
1	24-Jul-00	8	SU000724-09	124.2	GB000724-09	116.2	PA000724-09	470.5		
1	24-Jul-00	9	SU000724-10	129.2	GB000724-10	111.5	PA000724-10	360.0		
1	24-Jul-00	10	SU000724-11	138.6	GB000724-11	113.6	PA000724-11	205.6		
1	24-Jul-00	11	SU000724-12	128.3	GB000724-12	118.6	PA000724-12	187.0		
1	24-Jul-00	12	SU000724-13	172.8	GB000724-13	128.9				
1	24-Jul-00	13	SU000724-14	139.1	GB000724-14	92.5				
1	24-Jul-00	14			GB000724-15	92.5	PA000724-15	306.6		
1	24-Jul-00	15			GB000724-16	77.7				
1	24-Jul-00	16			GB000724-17	75.3	PA000724-17	225.7		
1	24-Jul-00	17					PA000724-18	191.2		
1	24-Jul-00	18								
1	24-Jul-00	19			GB000724-20	89.7				
1	24-Jul-00	20								
1	24-Jul-00	21								
1	24-Jul-00	22								
2	29-Jul-00	23					PA000730-00	142.9		
2	30-Jul-00	0								
2	30-Jul-00	1								
2	30-Jul-00	2	SU000730-03	118.3						
2	30-Jul-00	3	calibrations							
2	30-Jul-00	4	calibrations							
2	30-Jul-00	5	SU000730-06	111.6						
2	30-Jul-00	6	SU000730-07	110.8						
2	30-Jul-00	7	SU000730-08	103.1			PA000730-08	197.4		
2	30-Jul-00	8	SU000730-09	104.9			PA000730-09	87.3		
2	30-Jul-00	9	SU000730-10	92.2			PA000730-10	67.1		
2	30-Jul-00	10	SU000730-11	81.2			PA000730-11	39.8		
2	30-Jul-00	11	SU000730-12	70.1			PA000730-12	61.3		
2	30-Jul-00	12	SU000730-13	62.8			PA000730-13	51.1		
2	30-Jul-00	13	SU000730-14	60.2			PA000730-14	36.9		
2	30-Jul-00	14	SU000730-15	51.6			PA000730-15	35.4		
2	30-Jul-00	15	SU000730-16	36.5			PA000730-16	32.9		
2	30-Jul-00	16	SU000730-17	50.2						
2	30-Jul-00	17	SU000730-18	66.9			PA000730-18	31.1		
2	30-Jul-00	18	SU000730-19	78.3			PA000730-19	28.4		
2	30-Jul-00	19	SU000730-20	76.3			PA000730-20	39.6		

Table 6-1 (continued). Automated Gas Chromatograph/Mass Spectrometer Data at CCOS Research Sites

IOP #	Date	Hour (PST)	Sunol (SUNO)		Granite Bay (GNBY)		Parlier (PLR)			
			Sample ID	NMHC (ppbC)	Sample ID	NMHC (ppbC)	Sample ID	NMHC (ppbC)		
2	30-Jul-00	20	SU000730-21	80.9			PA000730-21	98.0		
2	30-Jul-00	21	SU000730-22	52.2			PA000730-22	73.2		
2	30-Jul-00	22	SU000730-23	56.1			PA000730-23	95.8		
2	30-Jul-00	23	SU000731-00	49.3			PA000731-00	90.8		
2	31-Jul-00	0	SU000731-01	58.7			PA000731-01	80.4		
2	31-Jul-00	1	SU000731-02	78.0						
2	31-Jul-00	2	SU000731-03	82.3						
2	31-Jul-00	3	calibrations							
2	31-Jul-00	4	calibrations							
2	31-Jul-00	5	SU000731-06	74.1						
2	31-Jul-00	6	SU000731-07	67.6			PA000731-07	479.2		
2	31-Jul-00	7	SU000731-08	76.4			PA000731-08	399.5		
2	31-Jul-00	8	SU000731-09	106.0			PA000731-09	238.6		
2	31-Jul-00	9	SU000731-10	84.3			PA000731-10	132.0		
2	31-Jul-00	10	SU000731-11	100.0			PA000731-11	125.1		
2	31-Jul-00	11	SU000731-12	92.7			PA000731-12	103.5		
2	31-Jul-00	12	SU000731-13	76.0			PA000731-13	98.1		
2	31-Jul-00	13	SU000731-14	77.4	GB000731-14	137.2	PA000731-14	119.9		
2	31-Jul-00	14	SU000731-15	101.8	GB000731-15	60.8	PA000731-15	133.4		
2	31-Jul-00	15	SU000731-16	96.2	GB000731-16	53.1	PA000731-16	144.6		
2	31-Jul-00	16	SU000731-17	81.8	GB000731-17	46.0	PA000731-17	76.7		
2	31-Jul-00	17	SU000731-18	118.6	GB000731-18	54.4	PA000731-18	91.7		
2	31-Jul-00	18	SU000731-19	144.3	GB000731-19	58.7	PA000731-19	85.3		
2	31-Jul-00	19	SU000731-20	168.5	GB000731-20	80.2	PA000731-20	93.7		
2	31-Jul-00	20	SU000731-21	155.4	GB000731-21	64.9	PA000731-21	191.5		
2	31-Jul-00	21	SU000731-22	79.0	GB000731-22	143.4	PA000731-22	526.9		
2	31-Jul-00	22	SU000731-23	83.7	GB000731-23	170.2	PA000731-23	344.4		
2	31-Jul-00	23	SU000801--00	100.5	GB000801-00	84.0	PA000801-00	317.4		
2	01-Aug-00	0	SU000801--01	95.2	GB000801-01	81.3	PA000801-01	320.5		
2	01-Aug-00	1	SU000801--02	84.2	GB000801-02	60.5	PA000801-02	306.0		
2	01-Aug-00	2	SU000801--03	94.1	GB000801-03	66.3	PA000801-03	318.9		
2	01-Aug-00	3	calibrations							
2	01-Aug-00	4	calibrations							
2	01-Aug-00	5	SU000801--06	114.2	GB000801-06	54.0	PA000801-06	159.5		
2	01-Aug-00	6	SU000801--07	108.8	GB000801-07	59.1	PA000801-07	186.5		
2	01-Aug-00	7	SU000801--08	102.9	GB000801-08	79.5	PA000801-08	258.6		
2	01-Aug-00	8	SU000801--09	114.3	GB000801-09	56.2	PA000801-09	146.6		
2	01-Aug-00	9	SU000801--10	76.2	GB000801-10	42.7	PA000801-10	102.7		
2	01-Aug-00	10	SU000801--11	149.4	GB000801-11	40.7				
2	01-Aug-00	11	SU000801--12	275.2	GB000801-12	37.6	PA000801-12	241.0		
2	01-Aug-00	12	SU000801--13	268.0	GB000801-13	38.0	PA000801-13	137.2		
2	01-Aug-00	13	SU000801--14	209.6	GB000801-14	40.9	PA000801-14	116.7		
2	01-Aug-00	14	SU000801--15	197.7	GB000801-15	53.8	PA000801-15	92.7		
2	01-Aug-00	15	SU000801--16	161.4	GB000801-16	54.1	PA000801-16	82.1		
2	01-Aug-00	16	SU000801--17	139.7	GB000801-17	52.8	PA000801-17	129.3		
2	01-Aug-00	17	SU000801--18	105.1	GB000801-18	40.6	PA000801-18	224.2		
2	01-Aug-00	18	SU000801--19	78.4	GB000801-19	63.8	PA000801-19	298.5		
2	01-Aug-00	19	SU000801--20	147.7	GB000801-20	70.0	PA000801-20	459.7		
2	01-Aug-00	20								
2	01-Aug-00	21								
2	01-Aug-00	22								
3	13-Aug-00	23			GB000814-00	135.0	PA000814-00	420.9		
3	14-Aug-00	0	SU000814-01	46.2	GB000814-01	126.3	PA000814-01	326.6		
3	14-Aug-00	1	SU000814-02	26.6	GB000814-02	86.1	PA000814-02	312.4		
3	14-Aug-00	2	SU000814-03	39.4	GB000814-03	98.0	PA000814-03	354.3		
3	14-Aug-00	3	calibrations							
3	14-Aug-00	4	calibrations							
3	14-Aug-00	5	SU000814-06	9.8	GB000814-06	117.9	PA000814-06	360.5		
3	14-Aug-00	6	SU000814-07	9.6	GB000814-07	94.0	PA000814-07	434.0		
3	14-Aug-00	7	SU000814-08	106.7			PA000814-08	499.2		
3	14-Aug-00	8					PA000814-09	323.2		
3	14-Aug-00	9					PA000814-10	289.0		
3	14-Aug-00	10					PA000814-11	263.7		
3	14-Aug-00	11			GB000814-12	75.6	PA000814-12	308.0		
3	14-Aug-00	12			GB000814-13	68.7	PA000814-13	260.4		
3	14-Aug-00	13			GB000814-14	52.9	PA000814-14	174.0		
3	14-Aug-00	14			GB000814-15	60.1	PA000814-15	264.3		
3	14-Aug-00	15			GB000814-16	63.4	PA000814-16	243.7		
3	14-Aug-00	16			GB000814-17	58.6	PA000814-17	267.2		

Table 6-1 (continued). Automated Gas Chromatograph/Mass Spectrometer Data at CCOS Research Sites

IOP #	Date	Hour (PST)	Sunol (SUNO)		Granite Bay (GNBY)		Parlier (PLR)		
			Sample ID	NMHC (ppbC)	Sample ID	NMHC (ppbC)	Sample ID	NMHC (ppbC)	
3	14-Aug-00	17			GB000814-18	72.5	PA000814-18	295.9	
3	14-Aug-00	18					PA000814-19	191.5	
3	14-Aug-00	19					PA000814-20	220.2	
3	14-Aug-00	20							
3	14-Aug-00	21							
3	14-Aug-00	22							
5	16-Sep-00	23	SU000917-00	81.0			PA000917-00	145.6	
5	17-Sep-00	0	SU000917-01	83.4					
5	17-Sep-00	1	SU000917-02	70.6			PA000917-02	198.9	
5	17-Sep-00	2	SU000917-03	81.1					
5	17-Sep-00	3	calibrations						
5	17-Sep-00	4	calibrations						
5	17-Sep-00	5	SU000917-06	77.6			PA000917-06	197.3	
5	17-Sep-00	6	SU000917-07	91.1	GB000917-07	31.4	PA000917-07	211.3	
5	17-Sep-00	7	SU000917-08	89.2	GB000917-08	28.4	PA000917-08	201.3	
5	17-Sep-00	8	SU000917-09	115.3	GB000917-09	28.0	PA000917-09	120.3	
5	17-Sep-00	9	SU000917-10	52.5	GB000917-10	28.6	PA000917-10	43.4	
5	17-Sep-00	10	SU000917-11	36.3	GB000917-11	37.5	PA000917-11	54.7	
5	17-Sep-00	11	SU000917-12	24.0	GB000917-12	29.0	PA000917-12	53.9	
5	17-Sep-00	12	SU000917-13	37.8	GB000917-13	23.7			
5	17-Sep-00	13	SU000917-14	31.9	GB000917-14	20.9	PA000917-14	20.8	
5	17-Sep-00	14	SU000917-15	37.5	GB000917-15	22.7	PA000917-15	17.4	
5	17-Sep-00	15	SU000917-16	51.3	GB000917-16	21.1	PA000917-16	16.2	
5	17-Sep-00	16	SU000917-17	39.1	GB000917-17	23.7	PA000917-17	15.7	
5	17-Sep-00	17	SU000917-18	34.9	GB000917-18	29.1	PA000917-18	20.3	
5	17-Sep-00	18	SU000917-19	83.9	GB000917-19	40.7	PA000917-19	23.1	
5	17-Sep-00	19	SU000917-20	101.0	GB000917-20	49.8	PA000917-20	63.6	
5	17-Sep-00	20	SU000917-21	54.9	GB000917-21	115.8	PA000917-21	42.2	
5	17-Sep-00	21	SU000917-22	43.5	GB000917-22	127.2	PA000917-22	65.5	
5	17-Sep-00	22	SU000917-23	42.9	GB000917-23	68.7			
5	17-Sep-00	23	SU000918-00	29.4	GB000918-00	83.8	PA000918-00	75.5	
5	18-Sep-00	0	SU000918-01	33.4	GB000918-01	81.1	PA000918-01	109.8	
5	18-Sep-00	1	SU000918-02	36.3	GB000918-02	37.6	PA000918-02	77.5	
5	18-Sep-00	2	SU000918-03	34.1	GB000918-03	42.9	PA000918-03	121.4	
5	18-Sep-00	3	calibrations						
5	18-Sep-00	4	calibrations						
5	18-Sep-00	5	SU000918-06	53.4	GB000918-06	30.7	PA000918-06	104.0	
5	18-Sep-00	6	SU000918-07	42.4	GB000918-07	50.2			
5	18-Sep-00	7	SU000918-08	78.6	GB000918-08	50.4	PA000918-08	147.6	
5	18-Sep-00	8	SU000918-09	79.1	GB000918-09	34.1	PA000918-09	116.4	
5	18-Sep-00	9	SU000918-10	65.9	GB000918-10	42.4	PA000918-10	53.5	
5	18-Sep-00	10	SU000918-11	56.3	GB000918-11	40.9			
5	18-Sep-00	11	SU000918-12	62.9	GB000918-12	35.5	PA000918-12	88.4	
5	18-Sep-00	12	SU000918-13	43.5	GB000918-13	36.0			
5	18-Sep-00	13	SU000918-14	58.4	GB000918-14	51.0	PA000918-14	60.7	
5	18-Sep-00	14	SU000918-15	85.0	GB000918-15	46.0	PA000918-15	65.5	
5	18-Sep-00	15	SU000918-16	101.6	GB000918-16	22.7	PA000918-16	30.7	
5	18-Sep-00	16	SU000918-17	129.0	GB000918-17	20.0	PA000918-17	37.0	
5	18-Sep-00	17	SU000918-18	164.4	GB000918-18	26.6	PA000918-18	70.8	
5	18-Sep-00	18	SU000918-19	158.8	GB000918-19	39.2	PA000918-19	29.3	
5	18-Sep-00	19	SU000918-20	164.9	GB000918-20	49.7	PA000918-20	60.9	
5	18-Sep-00	20	SU000918-21	149.4	GB000918-21	131.9			
5	18-Sep-00	21	SU000918-22	131.3	GB000918-22	117.5	PA000918-22	138.3	
5	18-Sep-00	22	SU000918-23	114.2	GB000918-23	46.7	PA000918-23	83.2	
5	18-Sep-00	23	SU000919-00	79.5	GB000919-00	44.4	PA000919-00	90.6	
5	19-Sep-00	0	SU000919-01	85.4	GB000919-01	43.1			
5	19-Sep-00	1	SU000919-02	68.9	GB000919-02	31.3	PA000919-02	89.8	
5	19-Sep-00	2	SU000919-03	72.0	GB000919-03	29.2	PA000919-03	112.7	
5	19-Sep-00	3	calibrations						
5	19-Sep-00	4	calibrations						
5	19-Sep-00	5	SU000919-06	77.5	GB000919-06	34.1	PA000919-06	130.6	
5	19-Sep-00	6	SU000919-07	114.8	GB000919-07	36.2			
5	19-Sep-00	7	SU000919-08	135.8	GB000919-08	43.2			
5	19-Sep-00	8	SU000919-09	96.4	GB000919-09	61.9	PA000919-09	56.5	
5	19-Sep-00	9	SU000919-10	74.6	GB000919-10	24.4	PA000919-10	64.3	
5	19-Sep-00	10	SU000919-11	70.6	GB000919-11	29.7	PA000919-11	63.9	
5	19-Sep-00	11	SU000919-12	38.6	GB000919-12	9.3	PA000919-12	32.1	
5	19-Sep-00	12	SU000919-13	29.1	GB000919-13	27.9	PA000919-13	41.4	
5	19-Sep-00	13	SU000919-14	26.0	GB000919-14	36.0	PA000919-14	24.4	

Table 6-1 (continued)
Automated Gas Chromatograph/Mass Spectrometer Data at CCOS Research Sites

IOP #	Date	Hour (PST)	Sunol (SUNO)		Granite Bay (GNBY)		Parlier (PLR)			
			Sample ID	NMHC (ppbC)	Sample ID	NMHC (ppbC)	Sample ID	NMHC (ppbC)		
5	19-Sep-00	14	SU000919-15	98.5	GB000919-15	16.8				
5	19-Sep-00	15	SU000919-16	79.2	GB000919-16	21.4	PA000919-16	21.1		
5	19-Sep-00	16	SU000919-17	88.1	GB000919-17	20.7	PA000919-17	58.6		
5	19-Sep-00	17	SU000919-18	65.2	GB000919-18	23.4	PA000919-18	27.3		
5	19-Sep-00	18	SU000919-19	51.2	GB000919-19	79.3				
5	19-Sep-00	19	SU000919-20	60.9	GB000919-20	63.5				
5	19-Sep-00	20	SU000919-21	58.2	GB000919-21	127.5				
5	19-Sep-00	21	SU000919-22	46.8	GB000919-22	83.0				
5	19-Sep-00	22	SU000919-23	44.8	GB000919-23	80.7				
5	19-Sep-00	23	SU000920-00	84.3	GB000920-00	55.1				
5	20-Sep-00	0	SU000920-01	55.8	GB000920-01	52.3				
5	20-Sep-00	1	SU000920-02	42.4	GB000920-02	29.6				
5	20-Sep-00	2	SU000920-03	29.4	GB000920-03	24.4				
5	20-Sep-00	3	calibrations							
5	20-Sep-00	4	calibrations							
5	20-Sep-00	5	SU000920-06	11.3	GB000920-06	28.4				
5	20-Sep-00	6	SU000920-07	11.3	GB000920-07	32.6				
5	20-Sep-00	7	SU000920-08	11.5	GB000920-08	39.1				
5	20-Sep-00	8	SU000920-09	11.0	GB000920-09	52.2	PA000920-09	59.0		
5	20-Sep-00	9			GB000920-10	27.3	PA000920-10	46.6		
5	20-Sep-00	10			GB000920-11	24.2	PA000920-11	53.3		
5	20-Sep-00	11			GB000920-12	22.8				
5	20-Sep-00	12			GB000920-13	20.4	PA000920-13	18.4		
5	20-Sep-00	13			GB000920-14	25.2	PA000920-14	38.9		
5	20-Sep-00	14			GB000920-15	23.0	PA000920-15	60.4		
5	20-Sep-00	15			GB000920-16	24.9	PA000920-16	33.3		
5	20-Sep-00	16	SU000920-17	66.2	GB000920-17	26.9	PA000920-17	86.0		
5	20-Sep-00	17	SU000920-18	116.6	GB000920-18	38.2	PA000920-18	23.7		
5	20-Sep-00	18	SU000920-19	113.8	GB000920-19	55.0	PA000920-19	29.8		
5	20-Sep-00	19	SU000920-20	74.5	GB000920-20	40.9	PA000920-20	56.8		
5	20-Sep-00	20	SU000920-21	81.4	GB000920-21	33.3	PA000920-21	43.2		
5	20-Sep-00	21	SU000920-22	88.3	GB000920-22	24.4	PA000920-22	96.1		
5	20-Sep-00	22	SU000920-23	62.6	GB000920-23	24.2	PA000920-23	53.1		
5	20-Sep-00	23	SU000921-00	58.8	GB000921-00	24.7	PA000921-00	54.3		
5	21-Sep-00	0	SU000921-01	47.3	GB000921-01	27.6	PA000921-01	49.3		
5	21-Sep-00	1	SU000921-02	31.3	GB000921-02	22.8	PA000921-02	40.4		
5	21-Sep-00	2	SU000921-03	29.0	GB000921-03	19.6	PA000921-03	85.5		
5	21-Sep-00	3	calibrations							
5	21-Sep-00	4	calibrations							
5	21-Sep-00	5	SU000921-06	24.5	GB000921-06	11.0	PA000921-06	34.4		
5	21-Sep-00	6	SU000921-07	46.0	GB000921-07	20.9	PA000921-07	36.7		
5	21-Sep-00	7	SU000921-08	36.2	GB000921-08	16.9	PA000921-08	38.2		
5	21-Sep-00	8	SU000921-09	50.6	GB000921-09	15.2	PA000921-09	35.9		
5	21-Sep-00	9	SU000921-10	33.5	GB000921-10	12.1	PA000921-10	37.9		
5	21-Sep-00	10	SU000921-11	31.8	GB000921-11	13.5	PA000921-11	39.9		
5	21-Sep-00	11	SU000921-12	35.5	GB000921-12	13.7	PA000921-12	23.0		
5	21-Sep-00	12	SU000921-13	27.9	GB000921-13	2.7	PA000921-13	26.8		
5	21-Sep-00	13	SU000921-14	25.3	GB000921-14	3.0	PA000921-14	22.3		
5	21-Sep-00	14	SU000921-15	24.4	GB000921-15	16.1	PA000921-15	29.8		
5	21-Sep-00	15	SU000921-16	26.4	GB000921-16	14.8	PA000921-16	16.5		
5	21-Sep-00	16	SU000921-17	30.5	GB000921-17	15.0	PA000921-17	36.5		
5	21-Sep-00	17	SU000921-18	29.0	GB000921-18	16.6	PA000921-18	13.3		
5	21-Sep-00	18	SU000921-19	31.7	GB000921-19	18.4	PA000921-19	35.3		
5	21-Sep-00	19	SU000921-20	26.6	GB000921-20	23.8	PA000921-20	47.2		
5	21-Sep-00	20			GB000921-21	21.4	PA000921-21	25.8		
5	21-Sep-00	21					PA000921-22	111.7		
5	21-Sep-00	22					PA000921-23	42.6		
Number of Samples Analyzed				197		183		172		
Total (22 hours on 11 days)				242		242		242		
Data Capture Rate				81.4%		75.6%		71.1%		

Table 6-2
Concentrations (ppbC) of selected hydrocarbons for three research sites.

day	time	propene	acetylene	isoprene	benzene	toluene	mp-xylene	Tot NMHC
Parlier								
9/18/2000	600-900	3.51	7.3	0.54	3.62	11.8	7.33	223.75
9/18/2000	1300-1600	0.3	3.04	0.34	1.13	2.7	0.92	70.71
9/19/2000	1300-1600	0.13	1.79	0.15	0.99	1.65	0.39	62.01
Granite Bay								
9/17/2000	600-900	0.87	1.16	2.74	0.68	3.79	1.11	47.12
9/17/2000	1300-1600	0.28	0.91	4.36	0.58	1.53	0.64	34.32
9/18/2000	600-900	1.31	1.97	2.25	1.12	5.35	2.7	70.29
9/18/2000	1300-1600	0.5	2.99	4.78	1.37	4.75	1.83	66.23
Sunol								
9/17/2000	600-900	6.8	8.01	0.84	3.62	11.14	5.99	146.85
9/17/2000	1300-1600	0.33	0.64	6.09	0.7	0.87	0.42	29.72
9/18/2000	600-900	5.85	3.16	1.3	2.05	4.86	3.18	81.28
9/18/2000	1300-1600	2.99	4.71	3.88	2.36	6.53	3.12	95.55

Table 6-3
Ratios of propene to acetylene and toluene to benzene for three research sites.

site	day	time	propene/acetylene	toluene/benzene	Total xylene/benzene
Parlier	9/18/2000	600-900	0.48	3.26	2.78
	9/18/2000	1300-1600	0.10	2.39	1.19
	9/19/2000	1300-1600	0.07	1.67	0.61
Granite Bay	9/17/2000	600-900	0.75	5.57	2.21
	9/17/2000	1300-1600	0.31	2.64	1.57
	9/18/2000	600-900	0.66	4.78	3.33
	9/18/2000	1300-1600	0.17	3.47	1.93
Sunol	9/17/2000	600-900	0.85	3.08	2.31
	9/17/2000	1300-1600	0.52	1.24	0.86
	9/18/2000	600-900	1.85	2.37	2.12
	9/18/2000	1300-1600	0.63	2.77	1.86

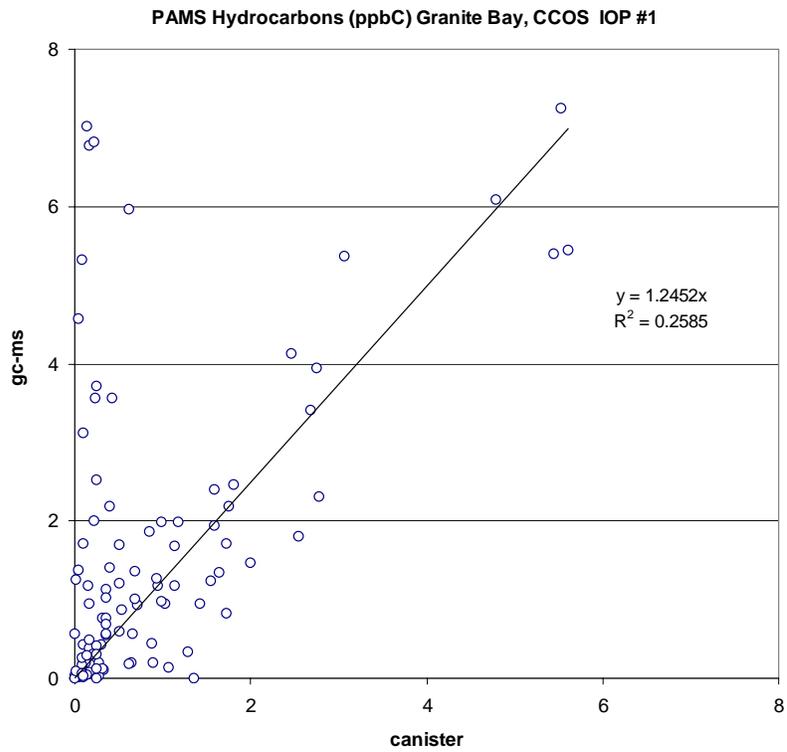
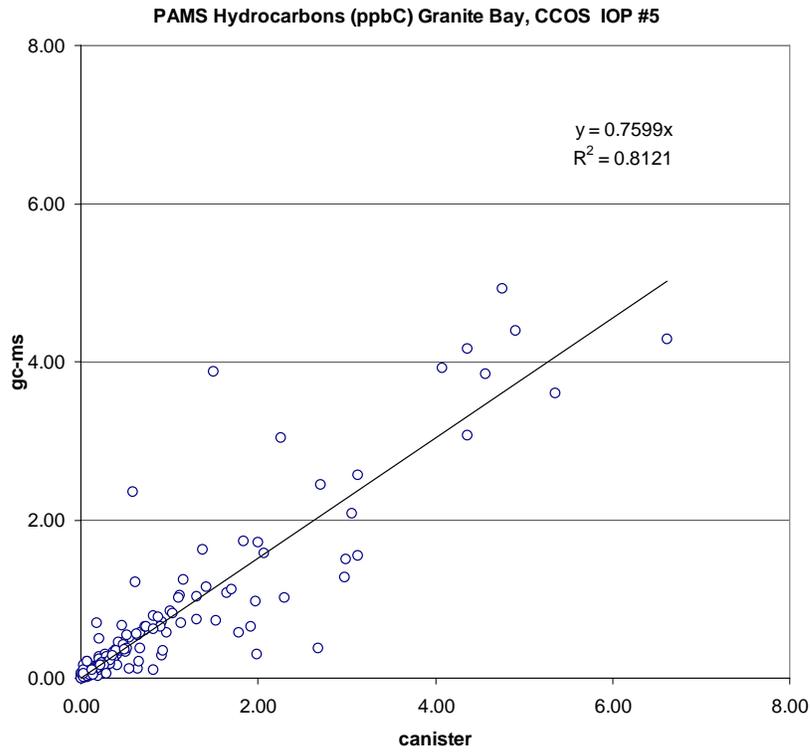


Figure 6-1. Scatterplot of collocated canister and automated GC/MS data for individual 55 PAMS hydrocarbon species measured by Desert Research Institute at Granite Bay during IOP #1 and IOP #5.

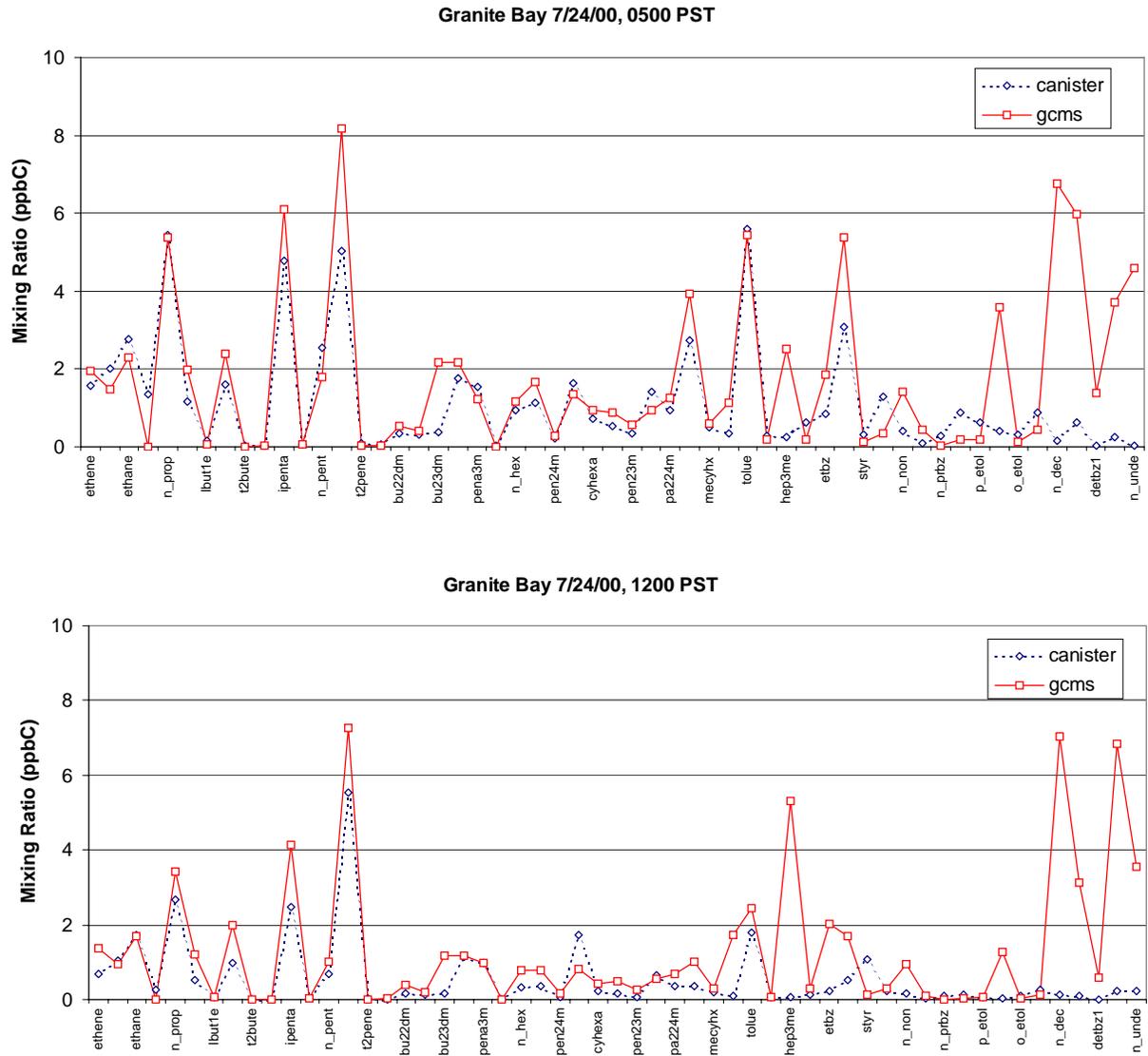


Figure 6-2a. Comparison by species between Granite Bay GC/MS data and corresponding canister sample during July 24, 2000 IOP day. Note large differences for heavier hydrocarbons.

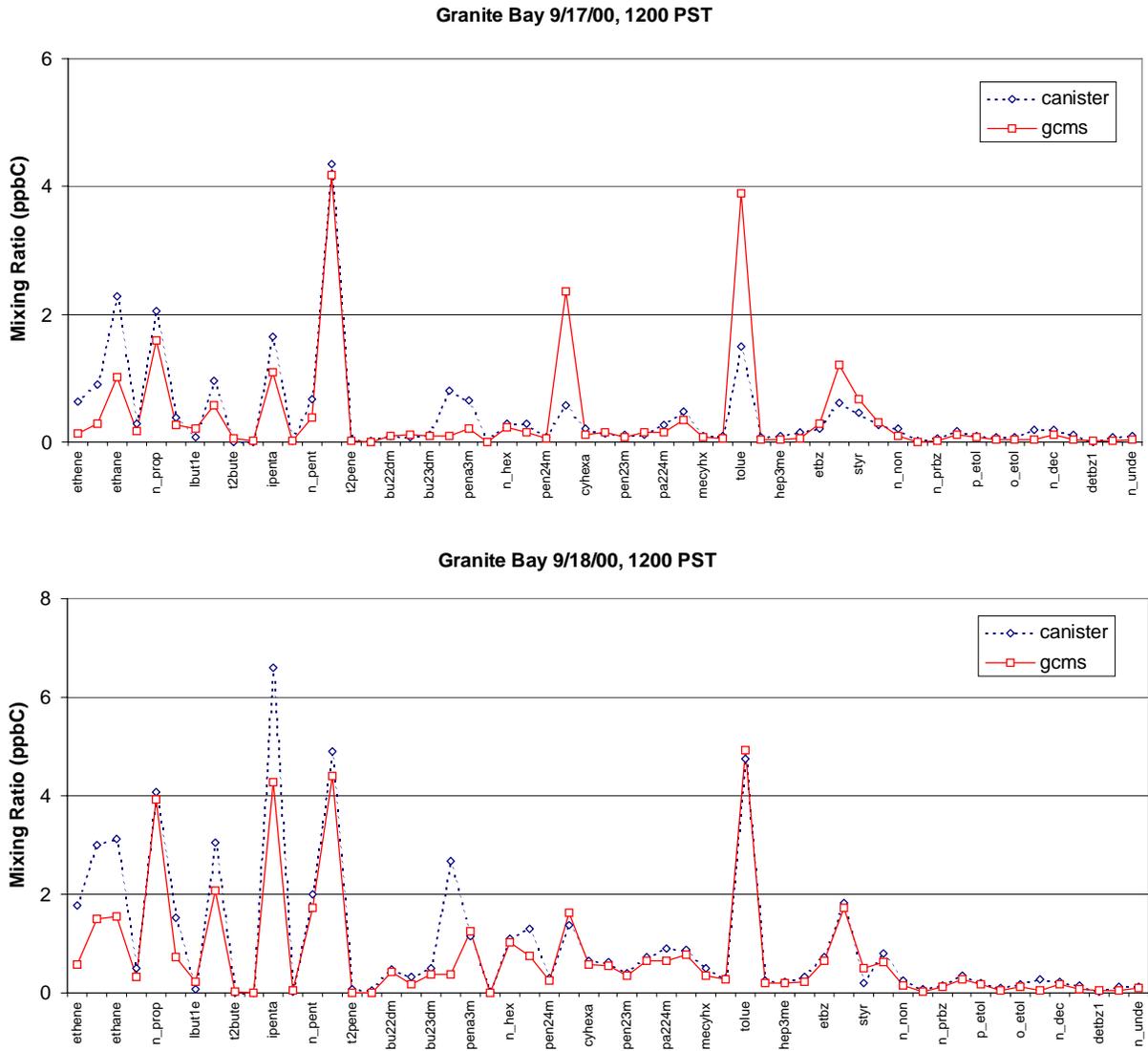


Figure 6-2b. Comparison by species between Granite Bay GC/MS data and corresponding canister sample during September 17 and 18 IOP day. Note better agreement for heavier hydrocarbons but larger bias for lighter hydrocarbons.

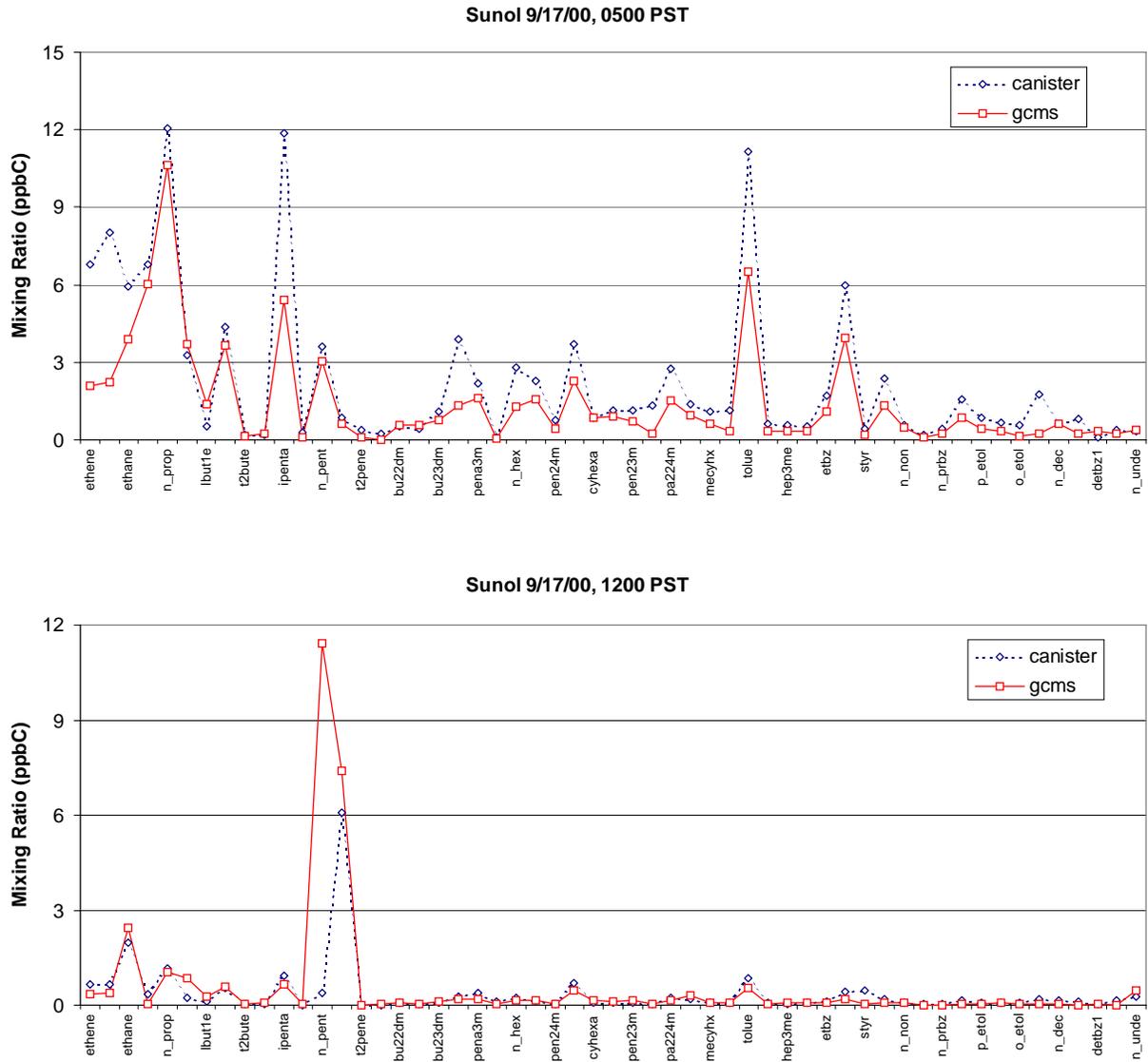


Figure 6-2c. Comparison by species between Sunol GC/MS data and corresponding canister sample during September 17 IOP day.

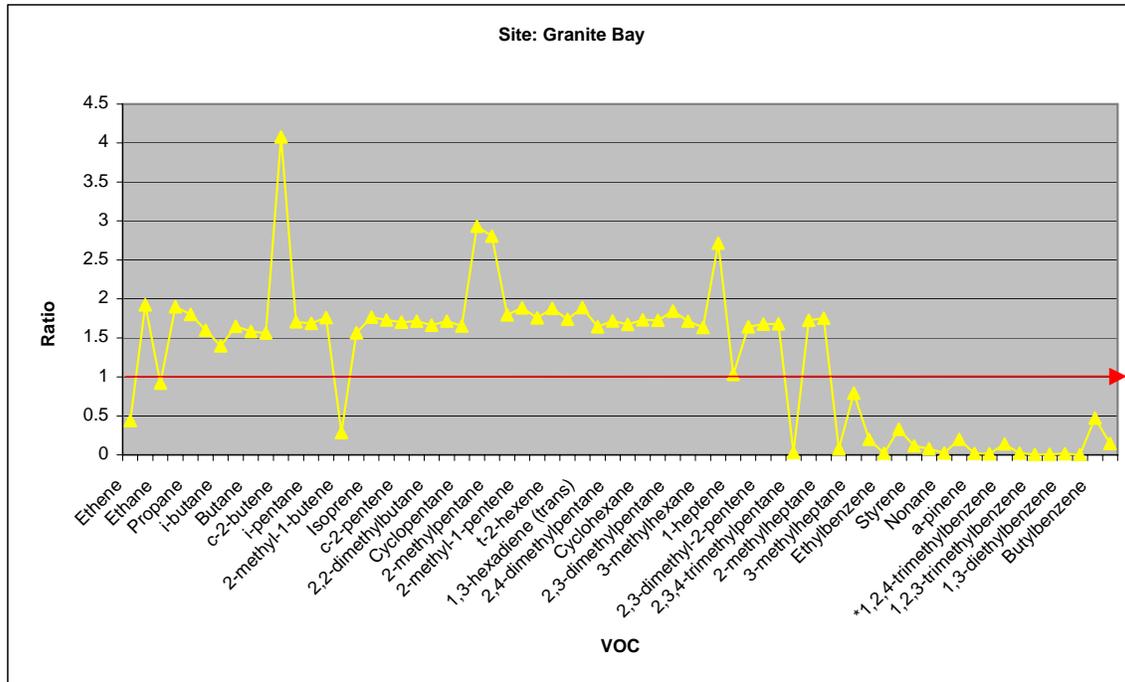


Figure 6-3a Ratio of actual calibration mixture concentration versus observed gas mixture concentration for various VOCs.

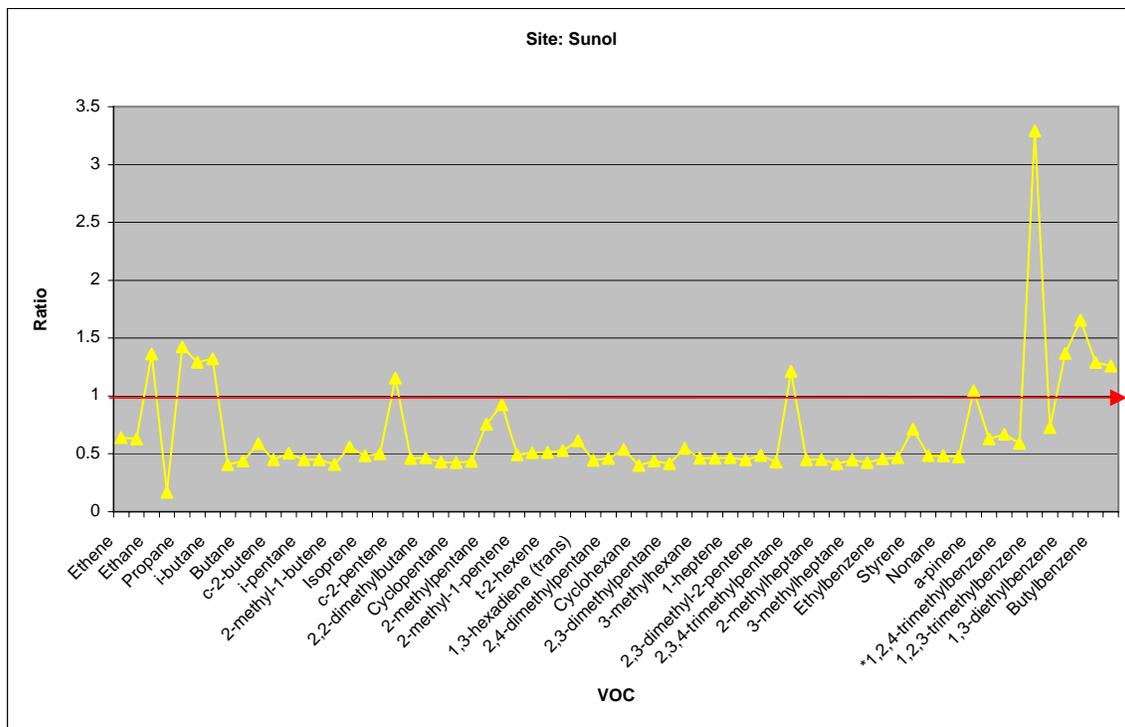


Figure 6-3b Ratio of actual calibration mixture concentration versus observed gas mixture concentration for various VOCs.

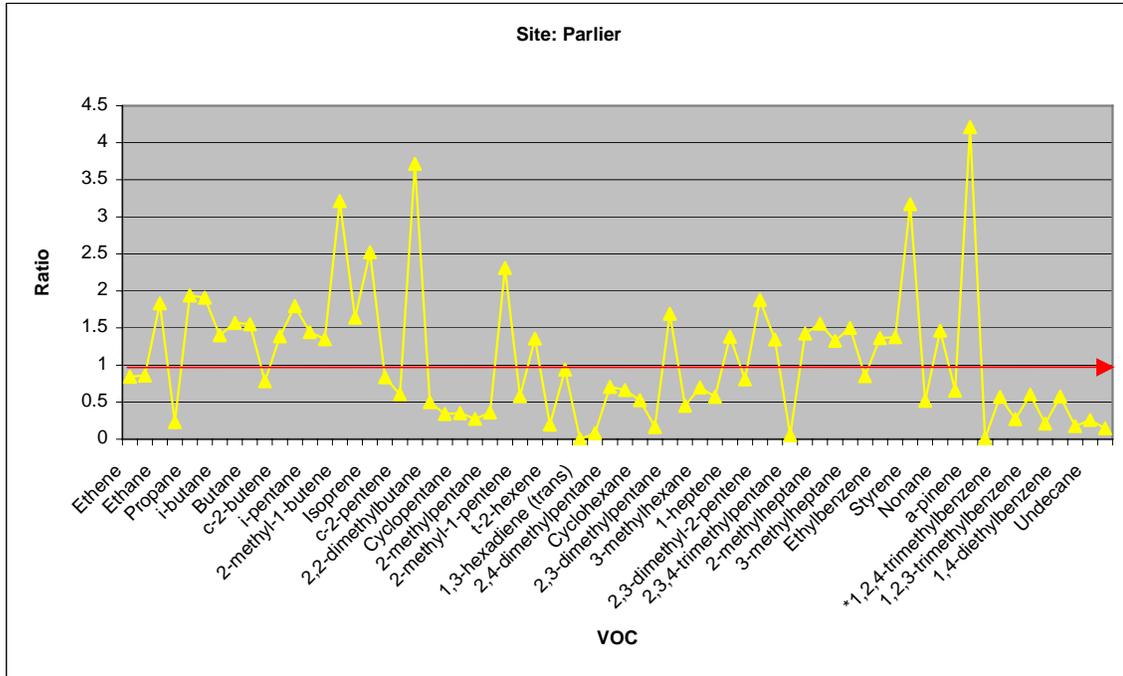


Figure 6-3c Ratio of actual calibration mixture concentration versus observed gas mixture concentration for various VOCs.

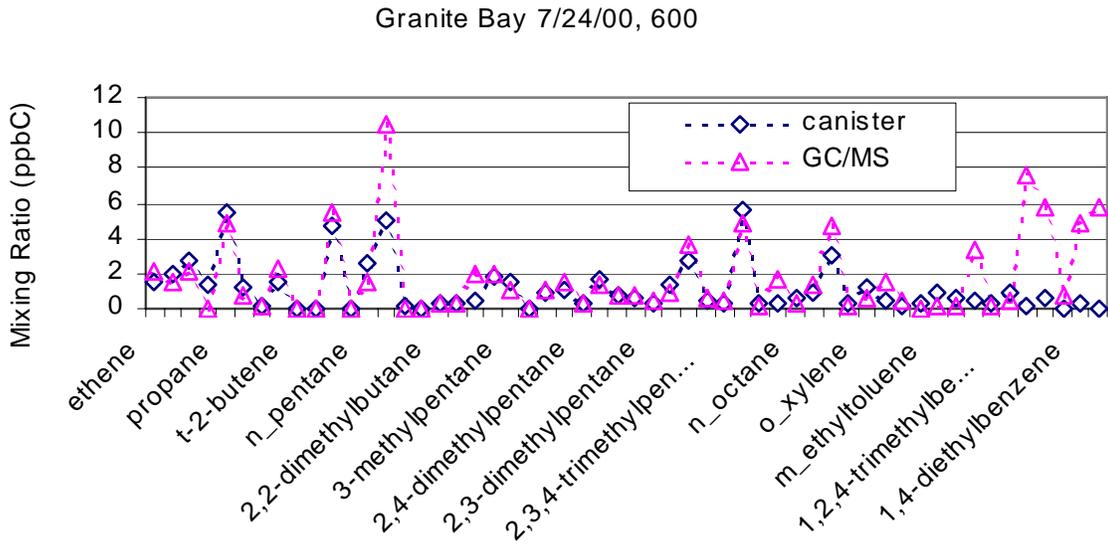


Figure 6-4a. The comparison of the 55 PAMS species at Granite Bay before correction.

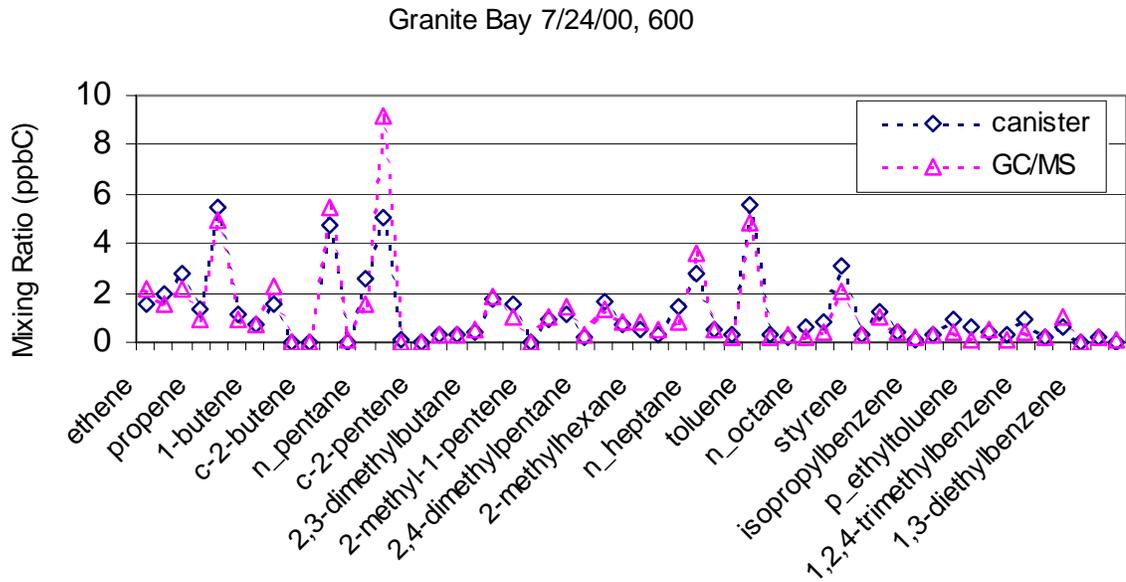


Figure 6-4b The comparison of the 55 PAMS species at Granite Bay after correction.

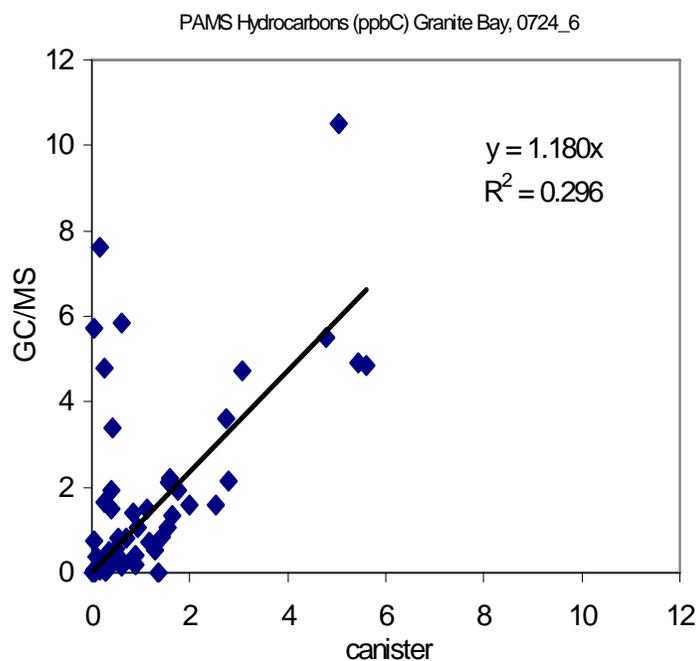


Figure 6-5a. Scatter plot comparing canister data versus GC/MS data at Granite Bay before correction.

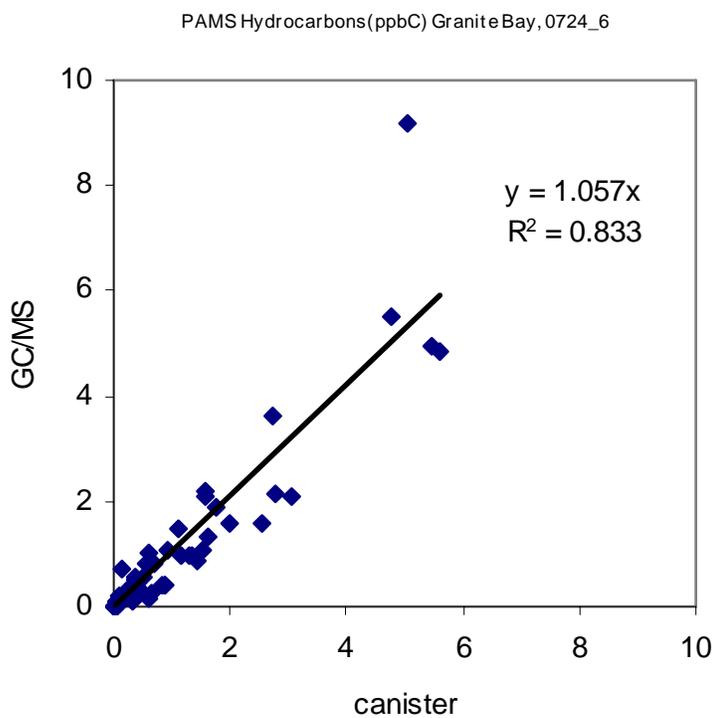


Figure 6-5b. Scatter plot comparing canister data versus GC/MS data at Granite Bay after correction.

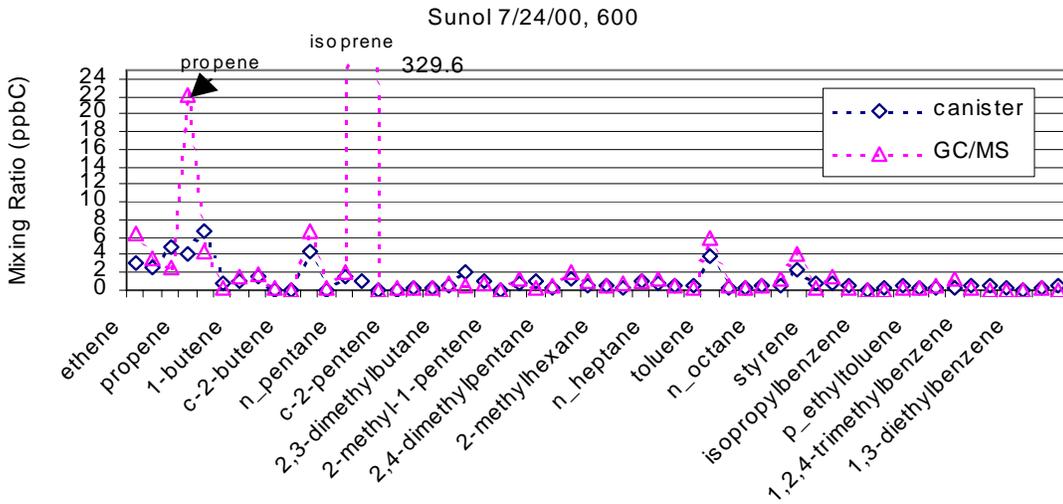


Figure 6-6a. The comparison between canister data and GC/MS data at Sunol for the 55 PAMS compounds before correcting the calibration.

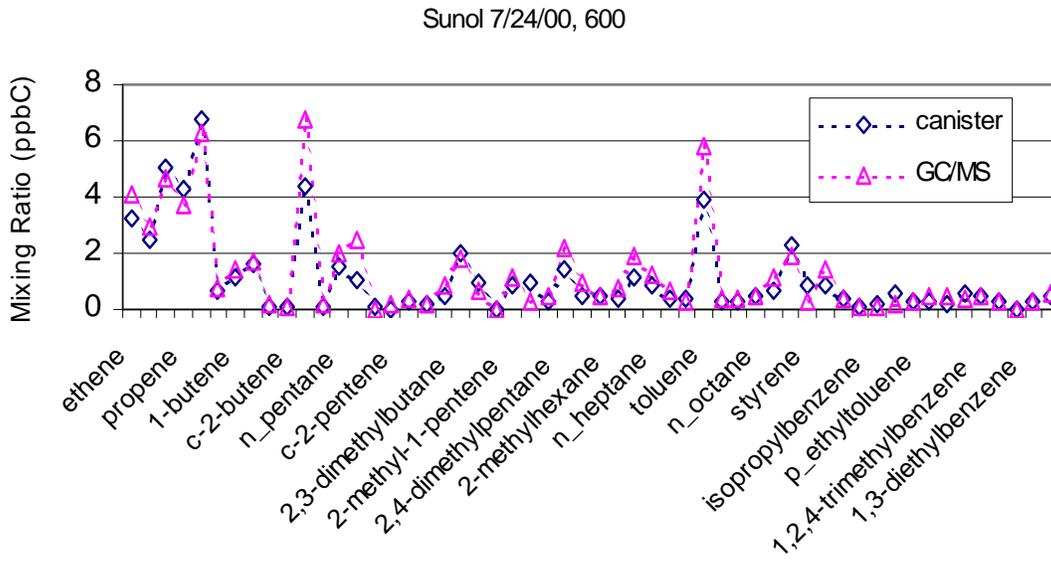


Figure 6-6b. The comparison between canister data and GC/MS data at Sunol for the 55 PAMS compounds after correction.

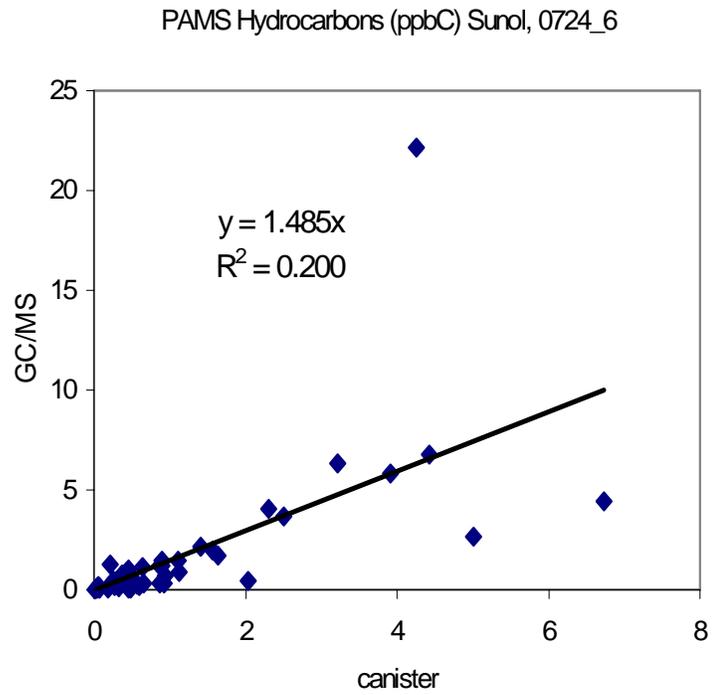


Figure 6-7a. Scatter plot between GC/MS data and canister data at Sunol before correction.

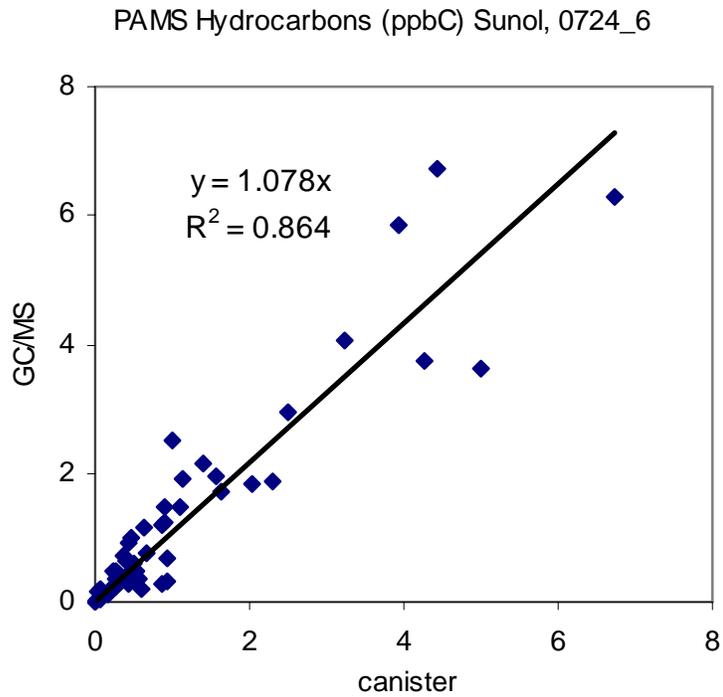


Figure 6-7b. Scatter plot after correction between the canister data at Sunol and the GC/MS data.

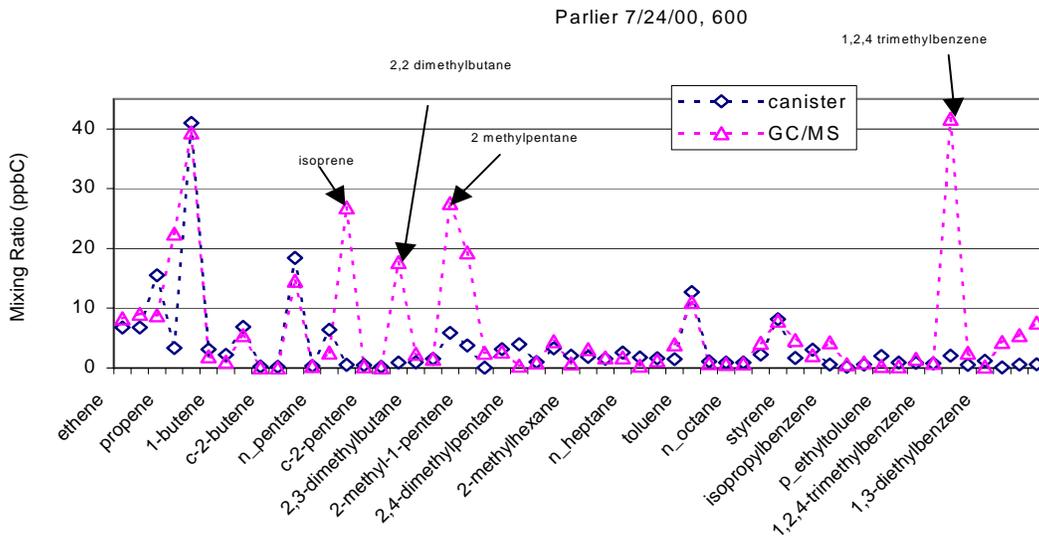


Figure 6-8a. The comparison before correction between canister data and GC/MS data at Parlier for the 55 PAMS compounds.

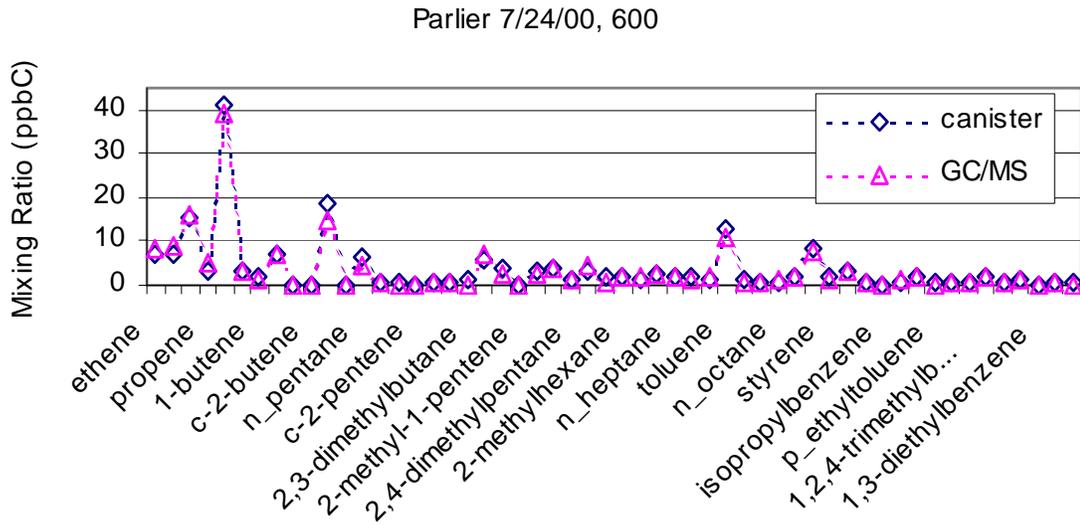


Figure 6-8b. The comparison after correction between canister data and GC/MS data at Parlier for the 55 PAMS compounds.

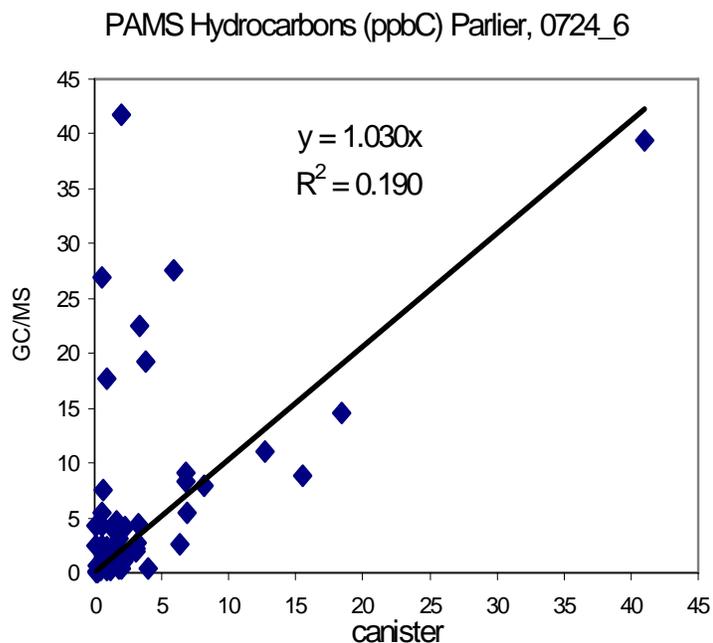


Figure 6-9a. Scatter plot between the canister data and the GC/MS data at Parlier before correction.

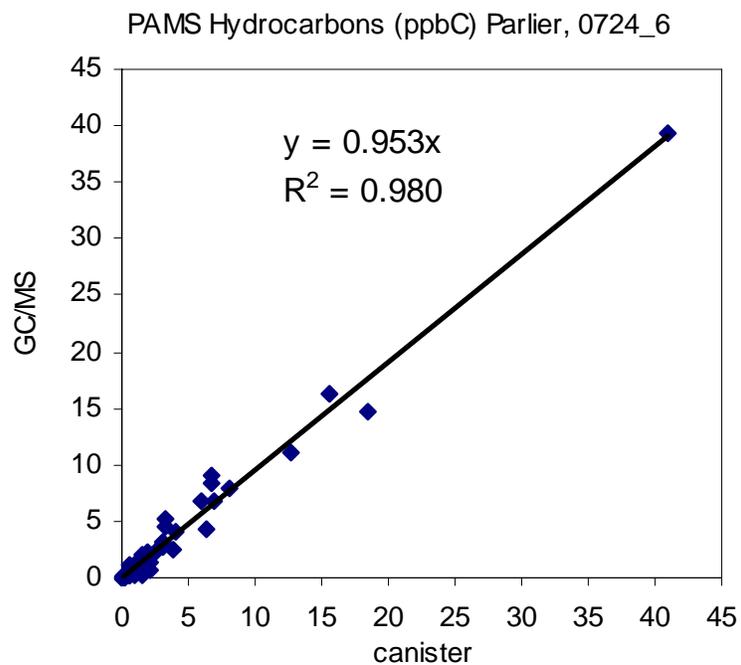


Figure 6-9b. Scatter plot between the canister data and the GC/MS data at Parlier after correction.

7. CONTINUOUS GASEOUS POLLUTANT DATA FROM IN-SITU AIRCRAFT MEASUREMENTS

Specific objectives of the aircraft flights during CCOS were to collect data pertinent to the following meteorological conditions and processes.

1. Boundary conditions along western edge of the modeling domain.
2. Intra-valley transport within the San Joaquin Valley by eddies and slope-flows.
3. Boundary condition along northern edge of the modeling domain.

Four instrumented aircraft were used to measure the vertical and horizontal gradients of temperature and humidity in the study region during CCOS IOPs. These aircraft included two Cessna 182 operated by University of California, Davis (UCD), and a Cessna 182 and Piper Aztec operated by Sonoma Technology, Inc. (STI). These aircraft were to provide information at the boundaries and document the vertical gradients, the mixed layer depth, and nature of elevated pollutant layers throughout the CCOS modeling domain. One additional aircraft (Twin Otter), flown by the Tennessee Valley Authority (TVA), made measurements in power plant plumes. These data will be used to evaluate the plume-in-grid (PiG) parameterizations used in air quality models.

7.1 Measurement Methods and Protocols

Alternate flight plans were developed for the two UCD and two STI aircraft corresponding to the type of ozone episode that is forecast for the IOP day. The three types of ozone episodes are described in Section 3 and are summarized here. Figures 7-1, 7-2, and 7-3 show diagrams of the flight paths for the two UCD Cessna, STI Aztec, STI Cessna, and PNNL G-1 (western boundary flights only). One UCD Cessna captured the flow through the Carquinez Strait, through the delta and into the northern SJV, and the flow approaching and leaving Sacramento. The second UCD Cessna documented the conditions in the Bay Area in the morning and in locations east of the Berkeley Hills in the afternoon. It captured the flow in and around the Livermore Valley and the flow through Altamont Pass to Tracy. The STI Piper Aztec documented conditions along the western and northern boundaries and the STI Cessna covered the San Joaquin Valley. Boundary measurements were made during both non-episode and episode days. When the Aztec was not flying along the boundaries, it participated in flux plane measurements.

7.1.1 University of California, Davis

The aircraft are both single engine Cessnas, 172RG and 182, based in Davis. They carried instrumentation to measure position (Garmin GPS); humidity, temperature, wind speed, and wind direction (Aventech AIMMS-10); ozone (Dasibi 1008); NO, NO_y (TEI 42S); hydrocarbons (3 canisters per flight, analyzed by BRC); carbonyl compounds (3 DNPH cartridges from 40 liter Tedlar bags, analyzed by AtmAA). UCD#1 also carries an instrument to measure particle concentration (Climet). Performance audits of O₃ and NO_y analyzers were performed by ARB quality assurance section.

The area of coverage was the delta, Sacramento, and downwind of Sacramento plus some flights in Sacramento Valley. Both UCD aircraft flew during each IOP with all instruments operating. Morning flights were scheduled to depart at 0600, returning by 0930 PDT, and afternoon flights to depart 1300 and return 1630 PDT. Basic flight patterns were to spiral climb over Davis followed by vertical saw tooth patterns: ascents along the straight lines shown in the figures and descending spirals (actually squares) at the rectangles shown. Note these boxes are approximately to scale or a little larger than the actual expected pattern. Altitude variation was to be from (near) the surface to about 4500' AGL. While the aircraft paths sometimes cross or spiral near the same locations they were displaced in time by 45 to 75 minutes. After 7/31/00, the Concord spiral on UCD #2 PM flights were switched to San Pablo Bay for the remainder of the study due to traffic problems. On two mornings, low clouds/showers forced them to skip most of the Bay Area part of the route. UCD aircraft planned to depart within 5 minutes of each other, to afford daily cross-comparisons on climb out, and coordinate parallel flight with STI aircraft and fly by radar wind profilers.

7.1.2 Sonoma Technology Inc.

The aircraft used were a twin engine Piper Aztec and a single engine Cessna 182. They each carried instrumentation to measure position (Garmin 250); humidity, temperature, wind speed, and wind direction (Aventech AIMMS-10); dew point (Cambridge Systems 137-C); Temperature (YSI/MRI); Temperature backup (Rosemont 102); ozone (Monitor Labs 8410E); NO, NO_y (TEI 42S); b_{scat} (MRI 1560 modified by Waggoner); particle concentration (Climet); hydrocarbons (3-4 canisters per flight, analyzed by BRC); carbonyl compounds (3-4 DNPH cartridges from Tedlar bags, analyzed by AtmAA), and collect VOC samples. Performance audits of O₃ and NO_y analyzers by ARB quality assurance section. The Aztec was based in Santa Rosa to cover the western and northern boundaries of the study area, and the Cessna in Bakersfield to cover the San Joaquin.

7.1.3 Pacific Northwest National Laboratory Gulfstream 159 (G-1)

The G-1 twin-engine turboprop aircraft was based at the Fresno Air Terminal. Onboard measurements included position (Trimble GSP/Loran C), temperature (Rosemount), pressure (Rosemount), wind (differential pressure gust probe and GPS), humidity (General Eastern chilled mirror; AIR Lyman- α), SO₂ (TEI 43S), O₃ (TEI 49-100), CO (TEI 48), particle size spectrum (PMS FSSP & PCASP-100X), particle concentration (TSI 3010), particle optical properties (TSI 3563 nephelometer, Radiance PSAP), PAN/NO₂ (ANL), formaldehyde (BNL), up/down total UV (Eppley TUV), HC canisters (ANL). ARB provided a TEI 42CY NO/NO_y instrument for use during CCOS. Quality assurance audits were conducted by the ARB quality assurance section on 7/6/00 in Fresno. There were two sets of basic flight plans for the G-1 in CCOS: 1) Fresno and central San Joaquin Valley and 2) Western In-Flow Boundary. Within each there were separate morning and afternoon flight patterns. Portions of the ferry flights between Pasco, WA and Fresno, CA, were used for sampling within the Central Valley. The following activity report was submitted by PNNL.

7.1.4 Tennessee Valley Authority

A package designed by Tennessee Valley Authority (TVA) Atmospheric Sciences staff was installed in a twin engine de Havilland Twin Otter Aircraft. It consisted of 6 TEI instruments, 4 for the measurement of various nitrogen oxides, one for “fast” ozone measurements, and one for ambient CO measurements. A LiCor instrument for CO₂ was on board, along with a TSI 3-wavelength nephelometer, a solar radiation device, and probes for temperature, relative humidity, (GPS) position, and (pressure) altitude. Samples of hydrocarbons were taken in canisters at selected intervals beginning with the 31 July mission, and for a subset of the canister-filling locations, bags were filled for post-flight collection on DNPH cartridges and analysis for carbonyls, beginning with the 1 August mission. Collection of hydrocarbon and carbonyl samples was controlled by the datalogger program and initiated by keystroke from the on-board display computer. Real-time position was displayed using the flight-mapping program running on a second on-board computer. Performance audits of gaseous analyzers by ARB quality assurance section. Coordinate parallel flight with other aircraft as desired. TVA onboard calibrator can be used to intercompare with other aircraft when at the same airport.

The objectives of the TVA program were to map detailed ozone, precursor, and products in power plant plumes and in regional airmasses during ferries and supplemental add-ons. 40 hours of flight time were planned, with additional hours possible if time and budget permit. Flights were targeted at Moss Landing and Pittsburg natural gas generating stations. Flight air speed was near 125 kts for ferries and near 95 kts for plume traversing. Ferries were also to provide detailed gaseous speciation. TVA submitted the following activity report.

7.2 Performance Audits

Performance audits were conducted by the California Air Resources Board for ozone and NO/NO_x/NO_y analyzers on board each of the aircraft. All of the audited instruments were within the acceptable limit of $\pm 15\%$ with the exception of the TVA SO₂ analyzers and four NO/NO_y analyzers, which were found to be inoperable (Parsons Engineering Science inc., 2001).

7.3 Validation Checks

Data validation of the in-situ aircraft data was performed by plotting time series of all measured pollutants for each flight and examining the plots for inconsistencies such as spikes in only one parameter, invalid relationships between parameters (e.g. NO greater than NO_x), or temporal variations that did not track other parameters. Overall relationships between measured species were also examined using scatter plots of all data for each aircraft. Data points that fell outside physically reasonable relationships were identified and possible explanations for the discrepancies were proposed, where possible, based on examination of corresponding flight data.

7.3.1 TVA aircraft data

Plume sampling missions were conducted by TVA Atmospheric Sciences during the Central California Ozone Study. These missions were conducted during the period of July 24-August 11, 2000, using a base at the Monterey Peninsula Airport, Monterey, CA. Data were

inspected for consistency between the various parameters measured. In general, the expected relationships were observed with the exception of the reported NO_z values which often did not appear to follow the patterns of any other nitrogen species measured. As shown in Figure 7-4, there is evidence of an interference by ozone which may be responsible for the discrepancies in NO_z measurements.

NO₂ is commonly estimated as the difference between NO_x and NO, however, a number of data points were observed in which the sum of reported NO and NO₂ exceeded NO_x, as shown in Figure 7-5. Such occurrences may be due to the time lag between the measurement of NO and NO_x when concentrations were rapidly changing.

NO_y is measured by a method similar to that used for NO_x, except that the instrument is re-configured to minimize the loss of nitric acid by deposition prior to conversion to NO. Therefore, NO_y should ideally equal the sum of NO_x and HNO₃. The actual relationship between the measured parameters varied somewhat from the ideal during various flights, suggesting that the calibrations of either the NO_x or NO_y instrument (or both) was not completely stable. Figure 7-6 gives several examples of the relationship between NO_y and NO_x+HNO₃. It is suggested that the instrument calibrations should be reviewed and adjusted as necessary for each flight.

Figure 7-7 shows the one minute average concentrations of the various nitrogen species measured during two flights. With the exception of NO_z, all species track each other extremely well with time and the relative magnitudes appear reasonable. Time plots of ozone, NO_x, and SO₂ for two flights in Figure 7-8 also show good temporal coordination of the measured species. All other flights with complete data showed similar behavior.

7.3.2 STI aircraft data

The aircraft used were a twin engine Piper Aztec and a single engine Cessna 182. They each carried instrumentation to measure position, humidity, temperature, wind speed, and wind direction, dew point, temperature, ozone, NO, NO_y, bscat (Cessna only), and CO (Aztec only). The Aztec was based in Santa Rosa to cover the western and northern boundaries of the study area, and the Cessna in Bakersfield to cover the San Joaquin Valley. For both aircraft all parameters appear to be temporally coordinated as shown in Figures 7-9 and 7-12. The relationships between NO and NO_y, and between NO and ozone are generally reasonable as shown in Figures 7-10 to 7-14

7.3.3 UC Davis Cessna data

The aircraft are both single engine Cessna 182s based in Davis. The area of coverage was the delta, Sacramento, and downwind of Sacramento plus some flights in Sacramento Valley. In the data set the two aircraft were identified as UCD172 and UCD182. While the measured ozone and nitrogen oxides are generally track each other well, there are indications in the data that the ozone analyzer in the UCD172 aircraft was malfunctioning intermittently throughout the study. Figure 7-16 shows the typical behavior observed, in which large sharp spikes in ozone concentration occur. These spikes do not appear to correspond to any particular portion of the

flight pattern and reach values substantially larger than any measured in the other aircraft. In addition, these spikes sometimes preceded or followed periods during which the reported ozone was consistently near zero. Given that this behavior occurred repeatedly throughout the study all of the ozone data from UCD172 should be considered suspect unless the cause of the malfunction is known and those periods in which it occurred can be definitively flagged.

The problem with the ozone data does not appear to have affected the NO and NO_y data. NO_y tracks the ozone data well in the absence of the malfunctions just described and NO is consistently less than NO_y with one exception. As shown in Figure 7-17, an anomaly occurred on September 17 at 13:23. Since the event lasted more than one minute it cannot be attributed to a sharp gradient in NO concentration and the data should be flagged as invalid and instrument diagnostics examined to determine the cause. Despite the malfunctions in the ozone analyzer, the relationship between measured ozone and NO is generally consistent, with peaks in NO corresponding to low ozone levels as shown in Figure 7-18.

All data for the UCD182 aircraft appear to be valid with the exception of the NO and NO_y data from the afternoon flight on September 19 (see Figures 7-19 to 7-22). During this flight reported NO, and occasionally NO_y, concentrations are negative. Although the zero of the NO/NO_y instrument apparently drifted between -1 and 1 during the study, these values are substantially outside of that range, and appear to be due to some sort of brief transient events as shown in Figure 7-20. NO and NO_y data for this flight should be considered suspect or invalid and should receive additional level 1 QA.

The time series from the July 25 northern boundary flight by UCD Cessna 182 are shown in Figure 7-23 and Figure 7-24 show the corresponding average vertical profiles. NO_y decreased from 7 ppb near the surface to about 2 ppb at 850 mb. In contrast, the vertical profile of ozone is more uniform with about 80 ppb at the surface and 60 ppb at 850 mb. Variations in the vertical profiles of ozone on the eastern boundary (Figure 7-25 and 7-26) are smaller due to Sierra Nevada.

7.3.4 PNNL Gulfstream

Figure 7-27 show the mean vertical profiles from offshore flights by PNNL. In contrast to the northern and eastern boundary data, the western boundary had very low ozone levels near the surface of about 25 ppb and increased to 50 to 55 ppb at 850 mb.

7.3.5 Comparisons of Vertical Ozone Profiles by Instrumented Aircraft Versus Ozonesondes

T&B Systems staff, assisted by in-kind personnel at the Sacramento site, released six ozonesondes at one site and four ozonesondes at the other during each of 14 IOP days. On one IOP day (for a total of 15), six soundings were made at both Fresno and Bakersfield sites. Sounding release times on the six/day schedule were 05, 08, 11, 14, 17, and 22 PDT. Sounding release times on the four/day schedule were 05, 11, 14, 17, and 22 PDT. The schedule was determined from the forecast episode characteristics. If the episode was expected have a greater

impact the northern area of the Central Valley, the more frequent schedule was implemented at Sacramento. Conversely, the frequent schedule occurred at Fresno if impacts are forecast to be greater in the south. On one day, it is anticipated that six soundings will be made at both sites.

7.4 Summary of Validation Results

Data validation of the in-situ aircraft data was performed by plotting time series of all measured pollutants for each flight and examining the plots for inconsistencies such as spikes in only one parameter, invalid relationships between parameters (e.g. NO greater than NO_x), or temporal variations that did not track other parameters. Overall relationships between measured species were also examined using scatter plots of all data for each aircraft. Data points that fell outside physically reasonable relationships were identified and possible explanations for the discrepancies were proposed, where possible, based on examination of corresponding flight data.

- With the exception of NO_z, all species measured by TVA track each other extremely well with time and the relative magnitudes appear reasonable. Time plots of ozone, NO_x, and SO₂ show good temporal coordination of the measured species. All other flights with complete data showed similar behavior.
- All parameters appear to be temporally coordinated for both STI aircraft. The relationships between NO and NO_y, and between NO and ozone are generally reasonable.
- While the ozone and nitrogen oxides measured by UCD generally track each other well, there are indications in the data that the ozone analyzer in the UCD172 aircraft was malfunctioning intermittently throughout the study. Large sharp spikes in ozone concentration occur and do not appear to correspond to any particular portion of the flight pattern and reach values substantially larger than any measured in the other aircraft. In addition, these spikes sometimes preceded or followed periods during which the reported ozone was consistently near zero. Given that this behavior occurred repeatedly throughout the study all of the ozone data from UCD172 should be considered suspect unless the cause of the malfunction is known and those periods in which it occurred can be definitively flagged.
- The UCD NO_y tracks the ozone data well in the absence of the malfunctions, and NO is consistently less than NO_y with one exception (an anomaly occurred on September 17 at 13:23). Since the event lasted more than one minute it cannot be attributed to a sharp gradient in NO concentration and the data should be flagged as invalid and instrument diagnostics examined to determine the cause. Despite the malfunctions in the ozone analyzer, the relationship between measured ozone and NO is generally consistent, with peaks in NO corresponding to low ozone levels.
- All data for the UCD182 aircraft appear to be valid with the exception of the NO and NO_y data from the afternoon flight on September 19. During this flight reported NO, and occasionally NO_y, concentrations are negative. Although the zero of the NO/NO_y instrument apparently drifted between -1 and 1 during the study, these values are

substantially outside of that range, and appear to be due to some sort of brief transient events NO and NO_y data for this flight should be considered suspect or invalid.

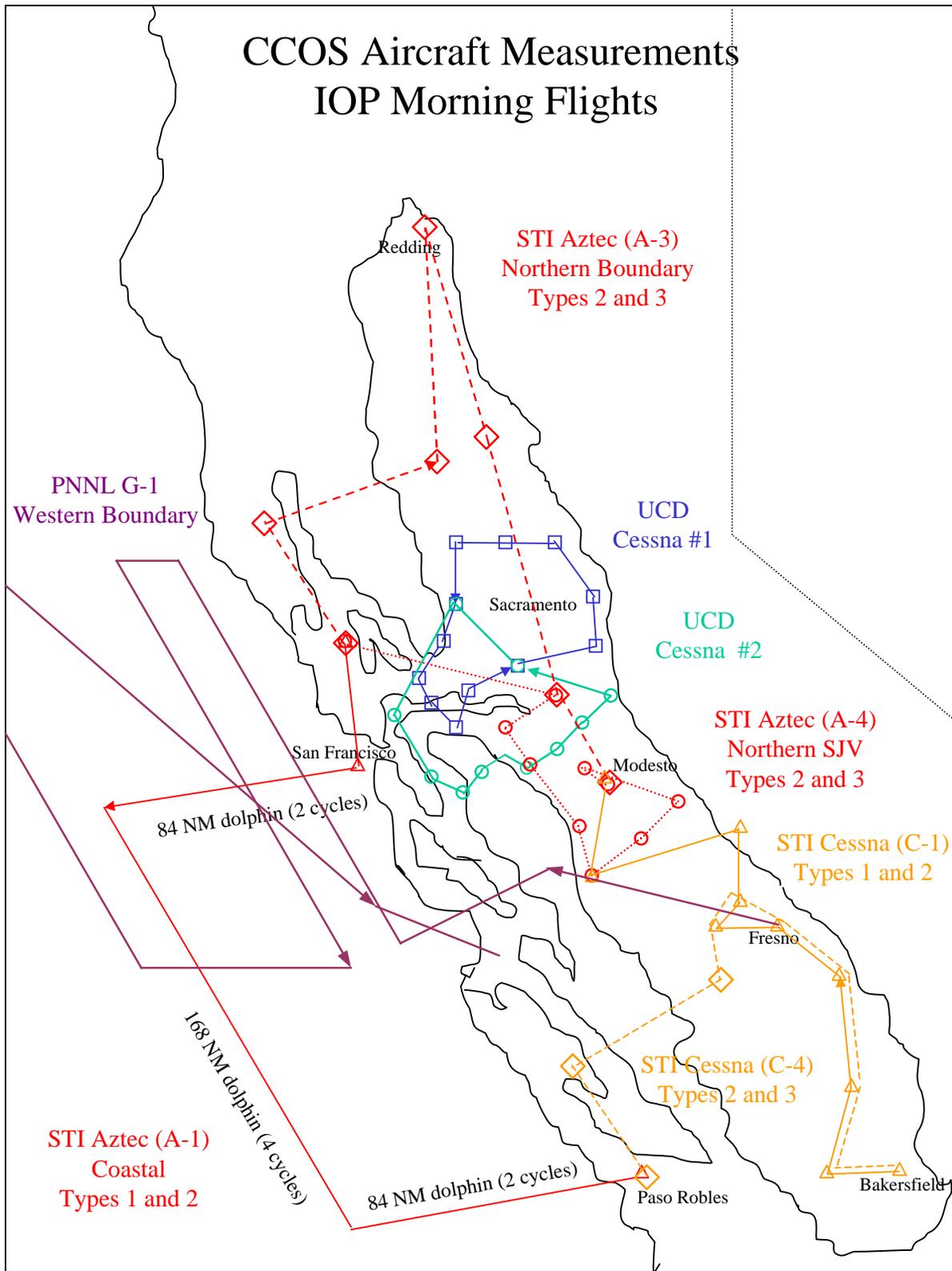


Figure 7-1. Morning flight paths for CCOS IOPS.

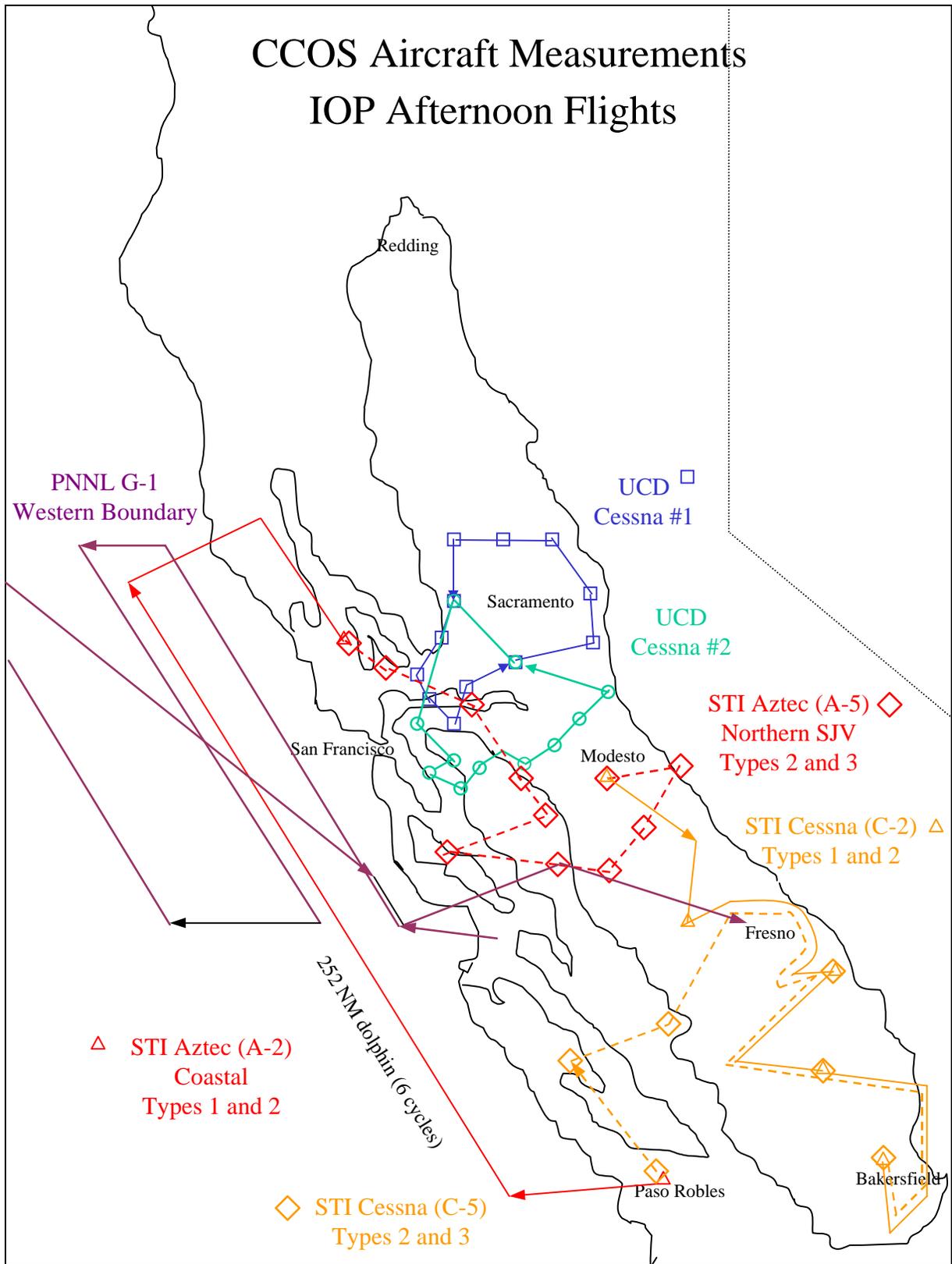


Figure 7-2. Afternoon flight path for CCOS IOPs.

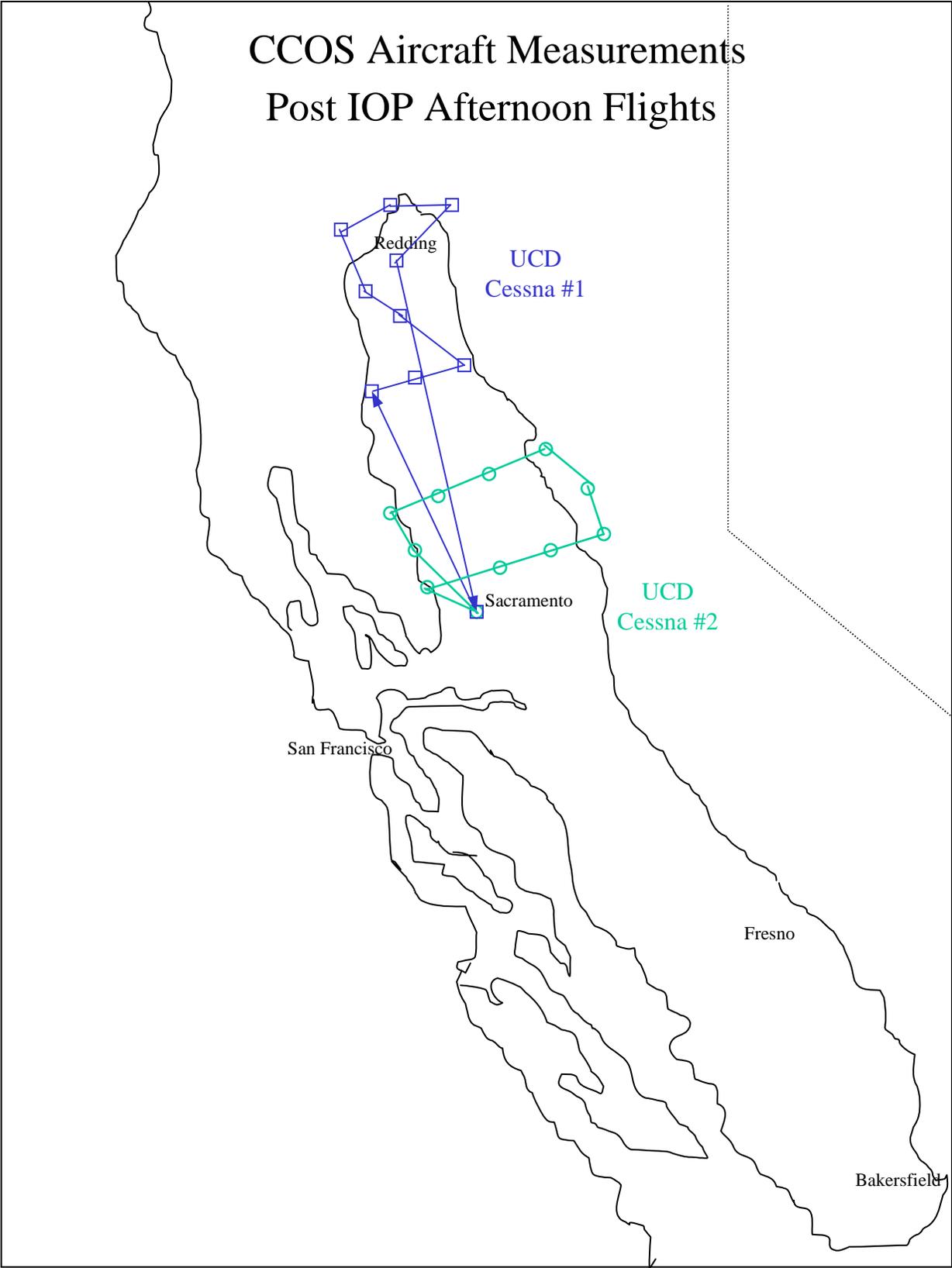


Figure 7-3. Afternoon flight path for post CCOS IOPs.

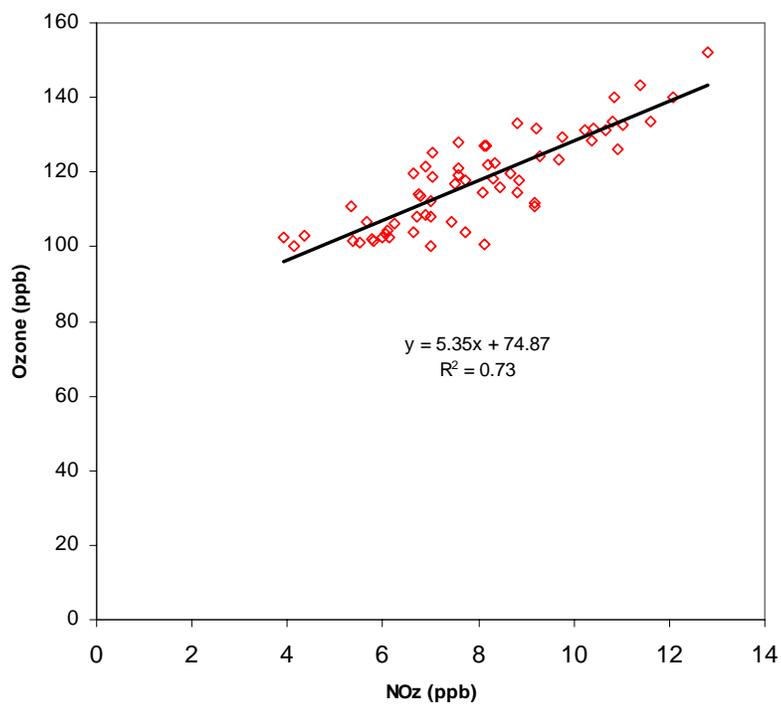


Figure 7-4. NOz shows strong relationship to ozone, suggesting possible interference when ozone concentrations are high. Data is filtered for ozone mixing ratios greater than 100 ppb from all TVA aircraft flights.

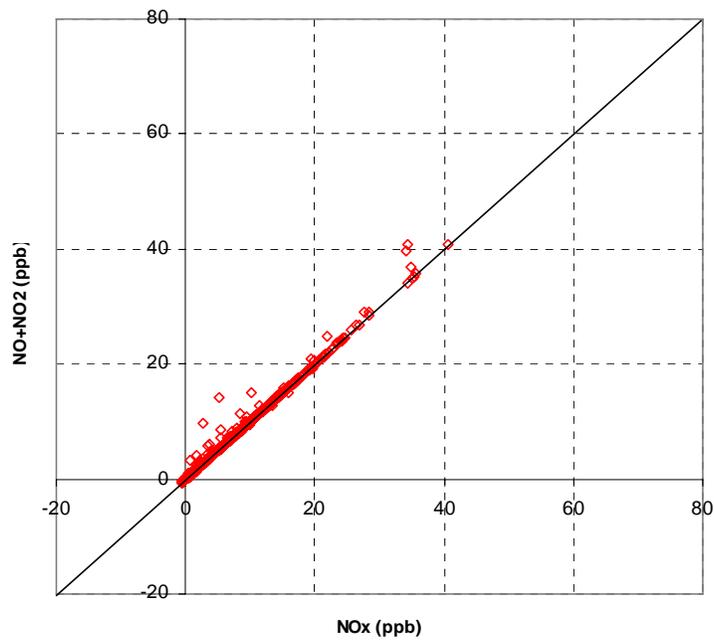


Figure7-5. Scatter plot of NO_x vs sum of NO and NO₂ for all TVA aircraft data. Points lying significantly off the 1:1 line occurred during several flights.

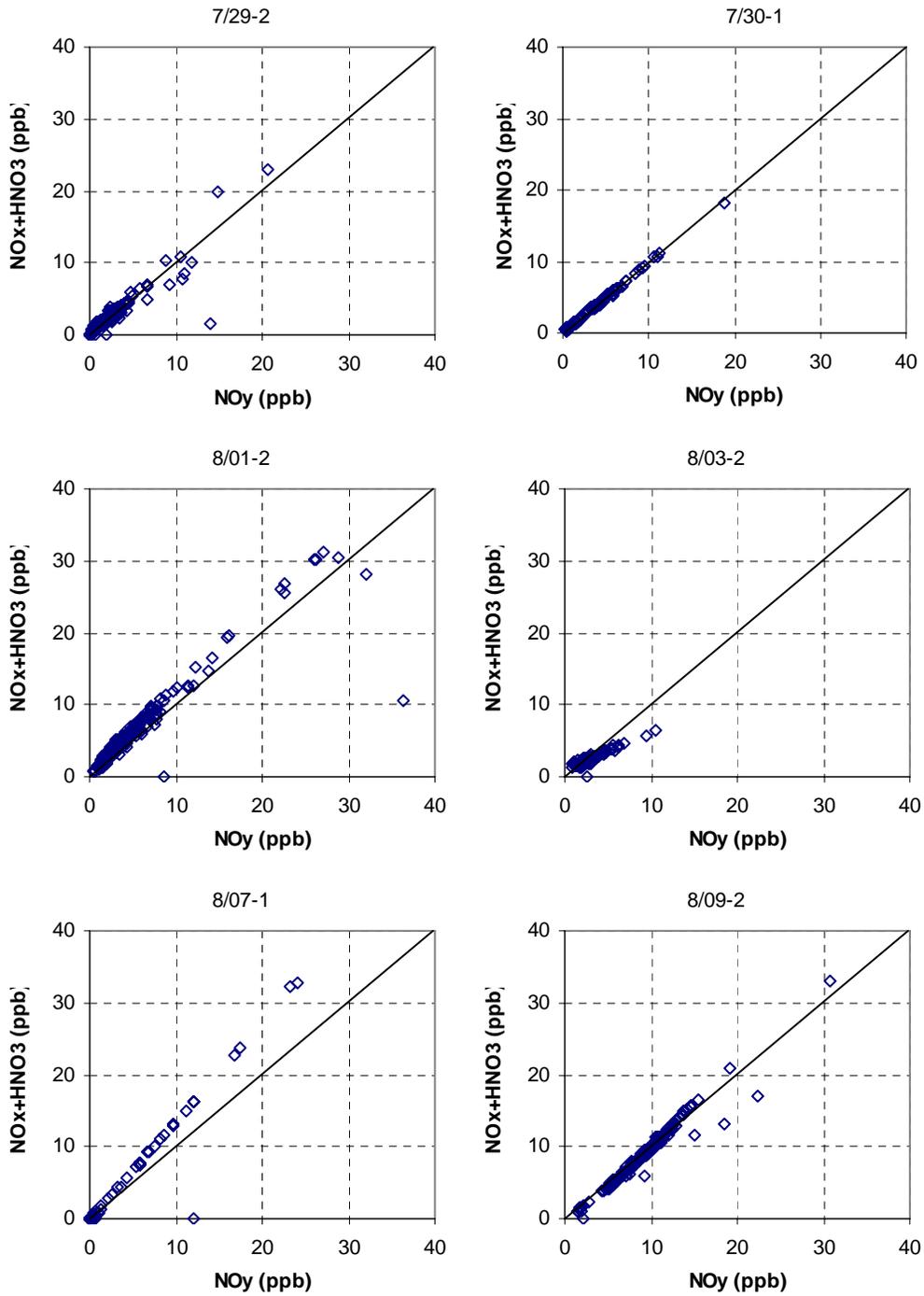


Figure 7-6. Scatter plots showing variation in correlation of NOy to sum of NOx and HNO₃ for various TVA aircraft flights. Solid lines indicate 1:1 correlation. Figure headings give flight date and order.

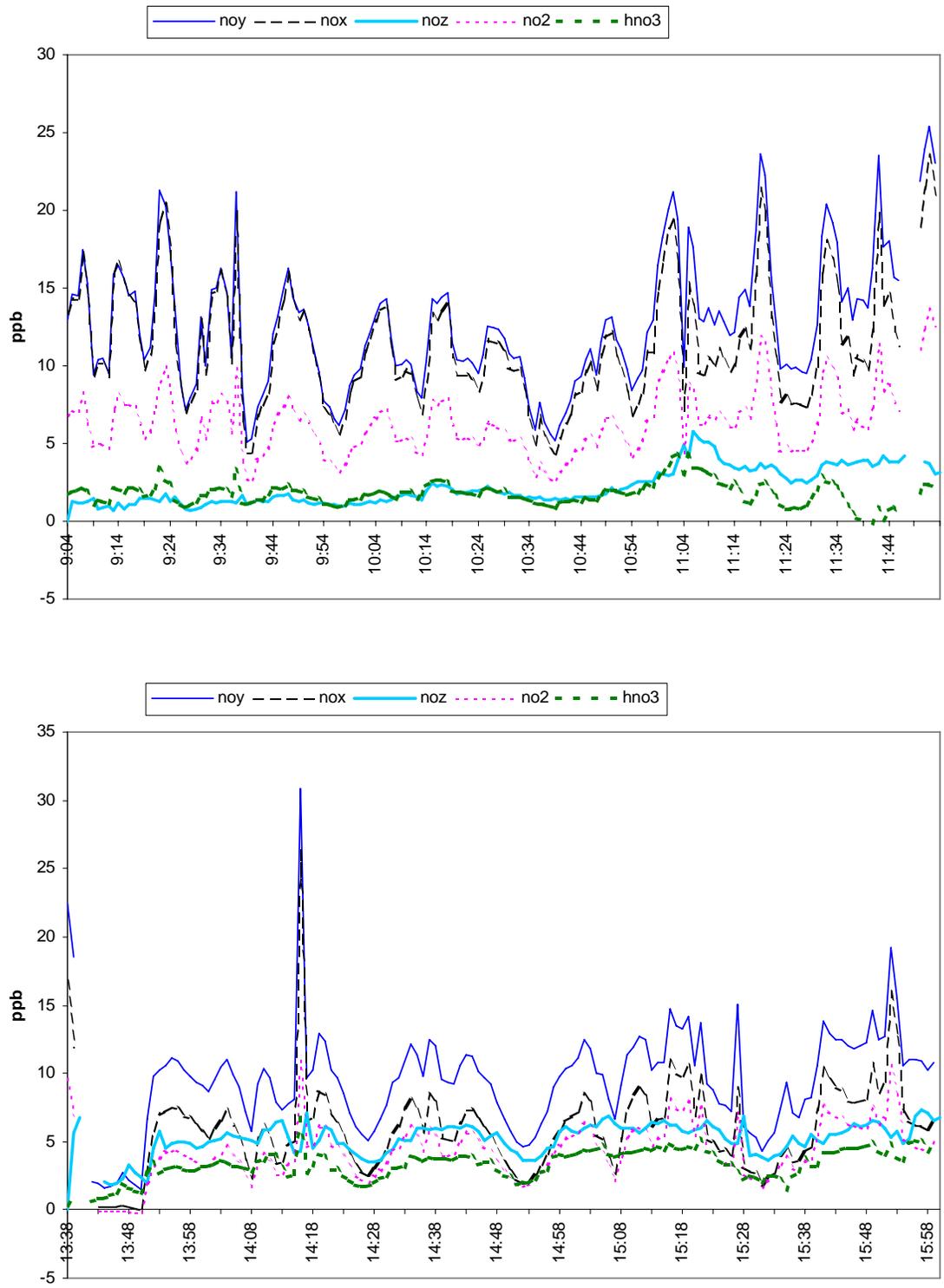


Figure 7-7. Time series plots of nitrogen species components during two TVA aircraft flights on August 9. As with other flights, all species track well except NOz.

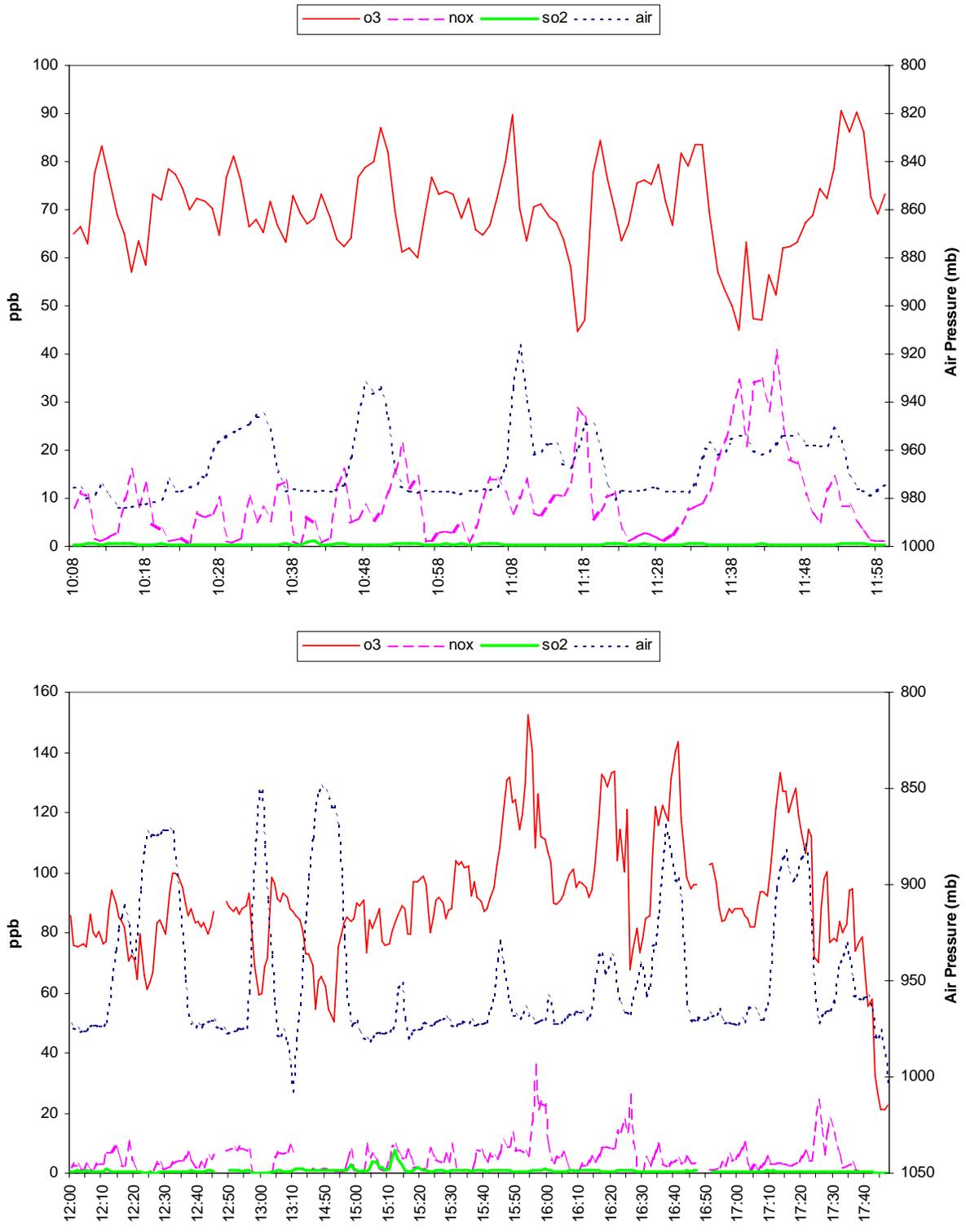


Figure 7-8. Time series plots of ozone, nitrogen oxides, sulfur dioxide, and elevation (air pressure) during the two TVA aircraft flights on July 31.

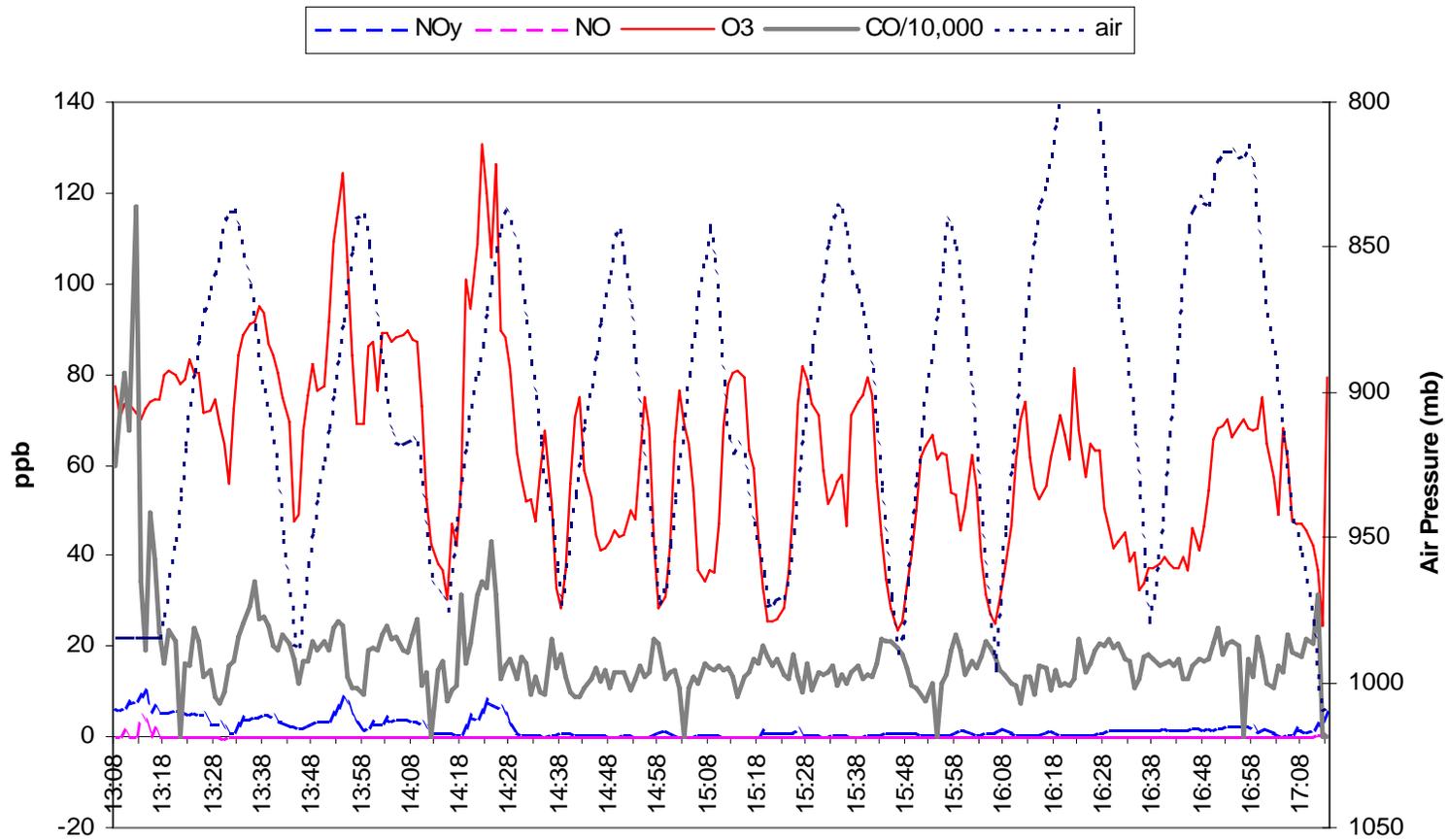


Figure 7-9. Example of STI Aztec aircraft flight data. All parameters are well coordinated. The high CO at the start of flight is assumed to be during take-off. Data shown is for PM flight on July 23.

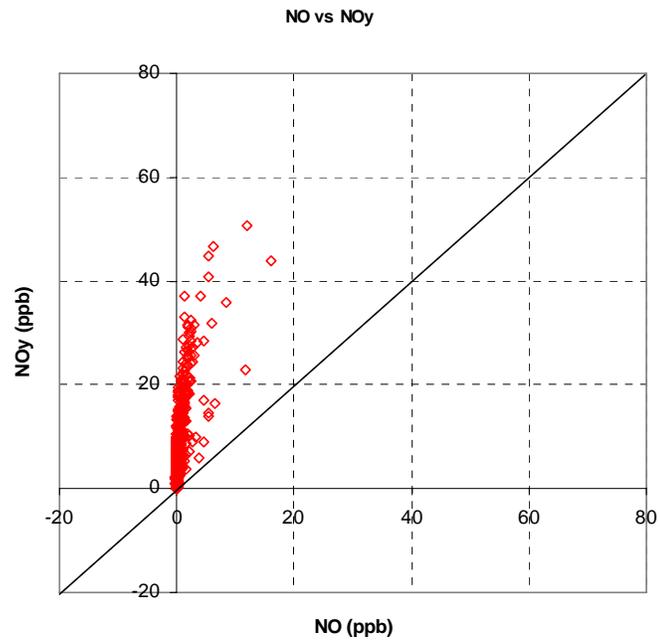


Figure 7-10. Scatter plot of NO vs NOy for all STI Aztec aircraft flight data. NOy is larger than NO for all data.

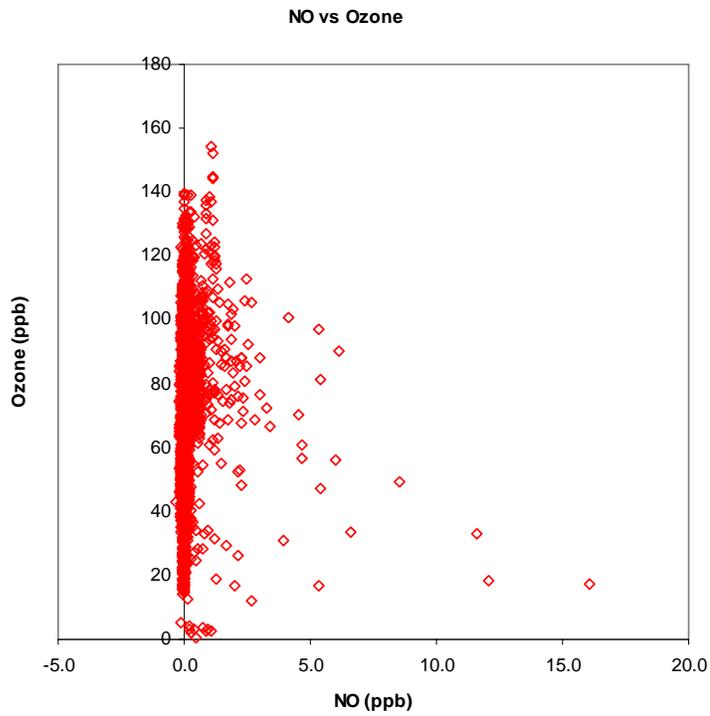


Figure 7-11. Scatter plot of NO vs ozone for all STI Aztec aircraft flight data. Highest NO values all correspond to low ozone.

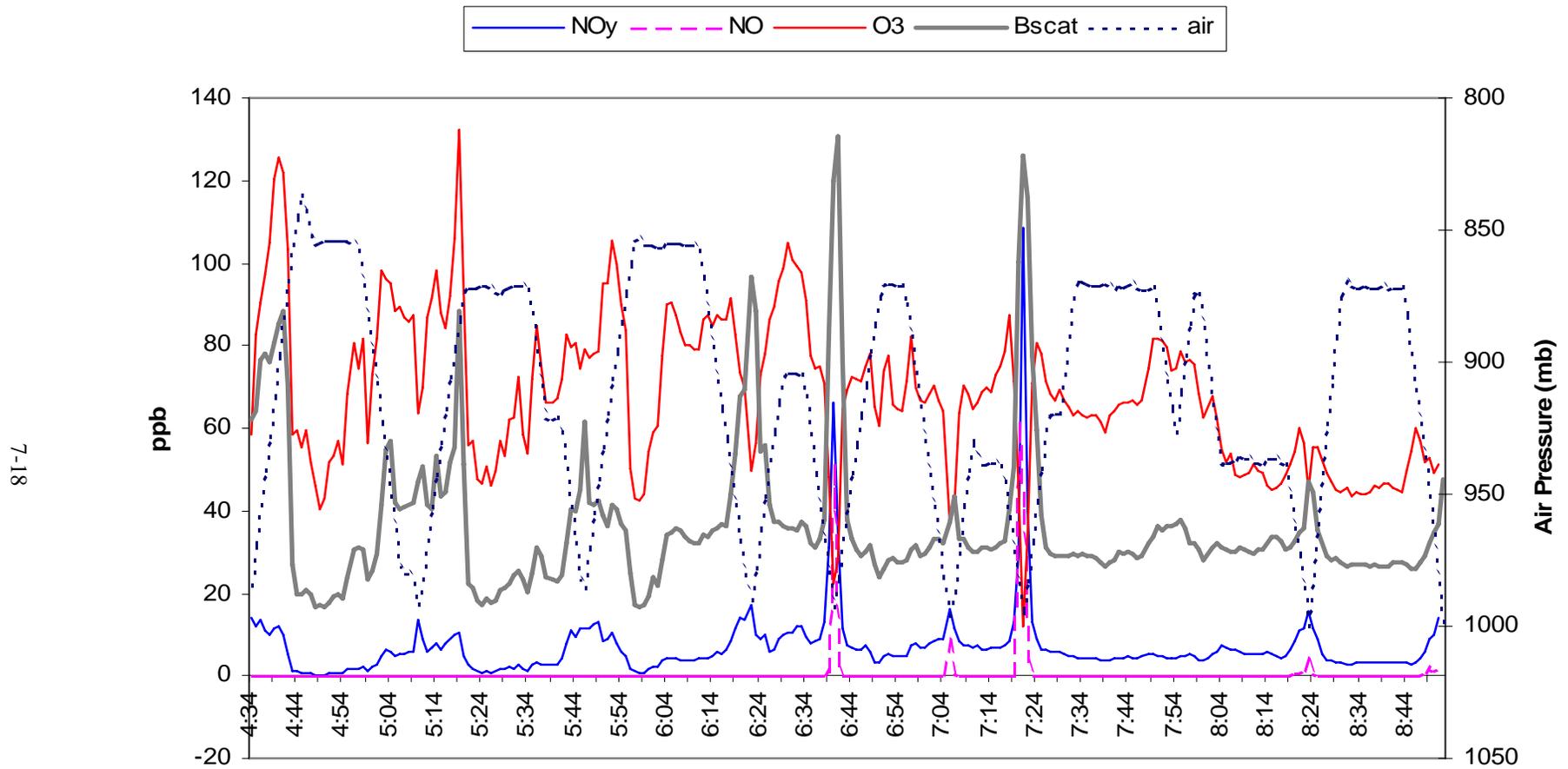


Figure 7-12. Example of STI Cessna aircraft flight data. All parameters are well coordinated. Data shown is for AM flight on Sept. 19.

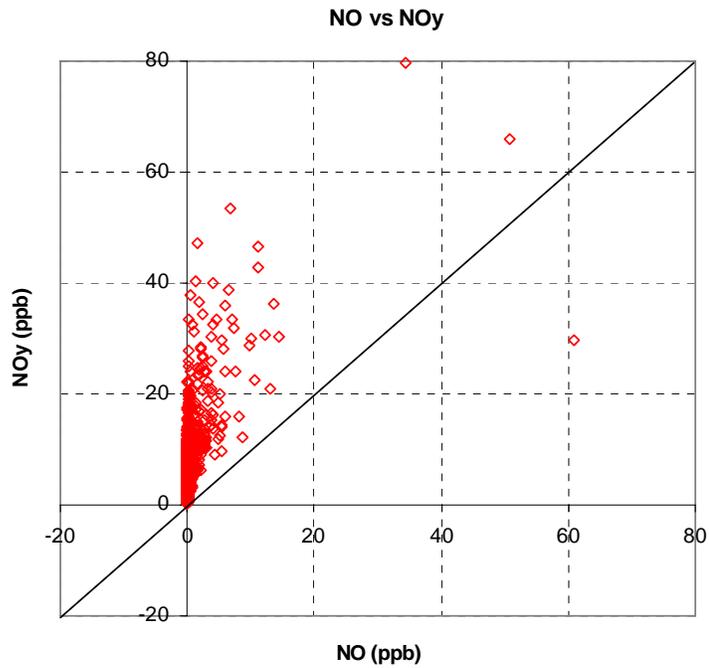


Figure 7-13. Scatter plot of NO vs NO_y for all STI Cessna aircraft flight data. NO_y is larger than NO for all data (except one value due to a sharp spike in NO at 07:20 on Sept. 19).

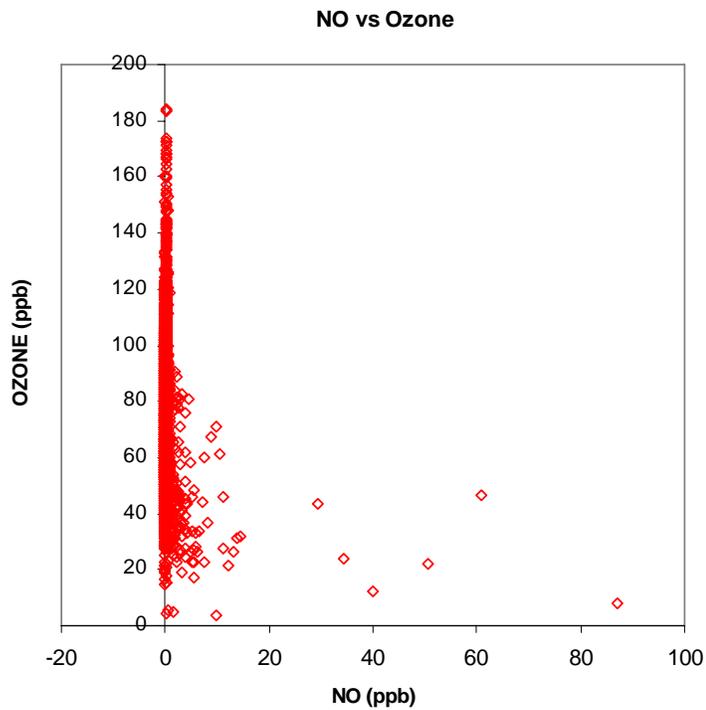


Figure 7-14. Scatter plot of NO vs ozone for all STI Cessna aircraft flight data. Highest NO values all correspond to low ozone.

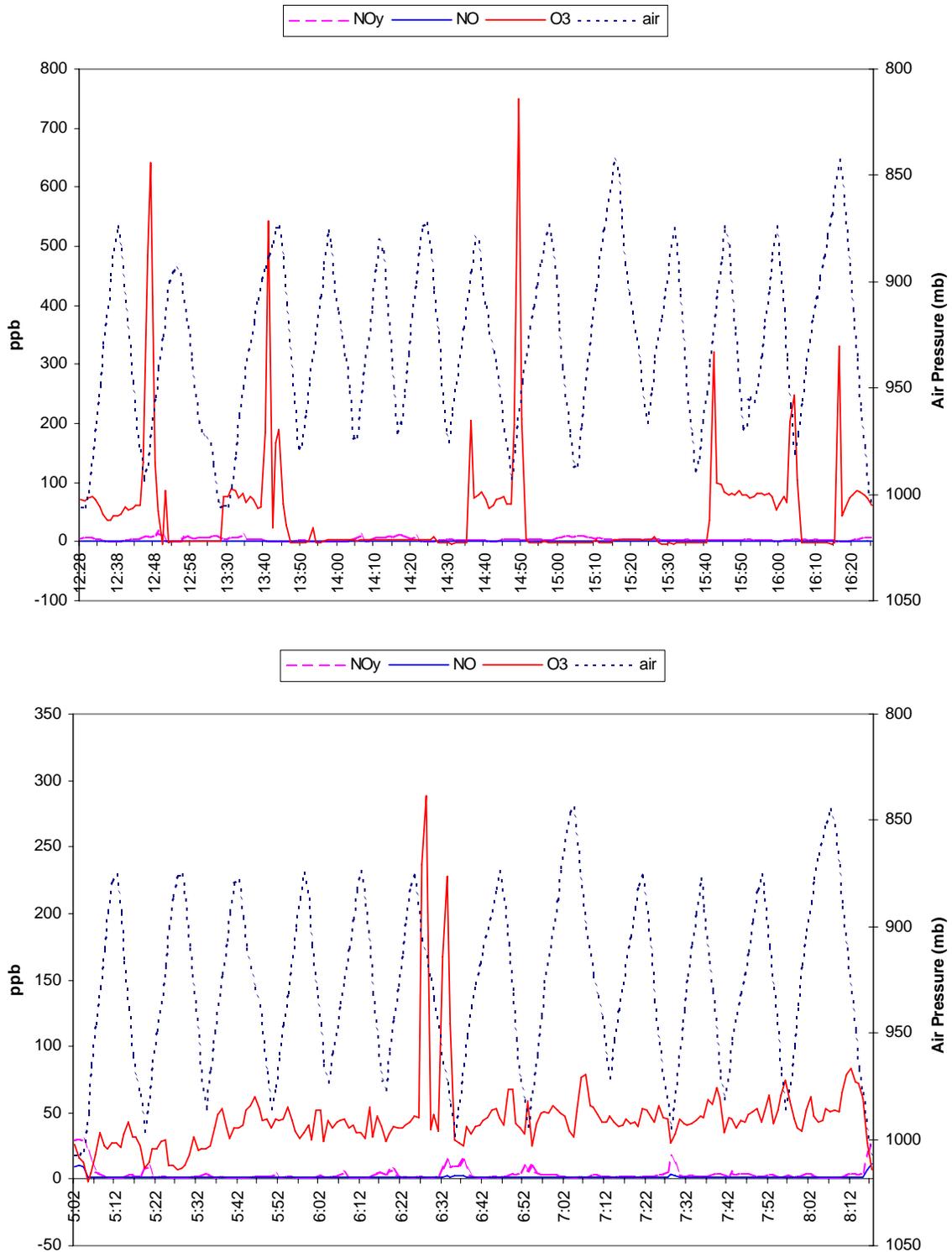


Figure 7-15. Time series plots of UCD172 aircraft flight data showing anomalous spikes in ozone concentration. Data shown are from July 30 and August 14 flights. Note that the second spike on Aug. 14 occurs during a measured increase in NO.

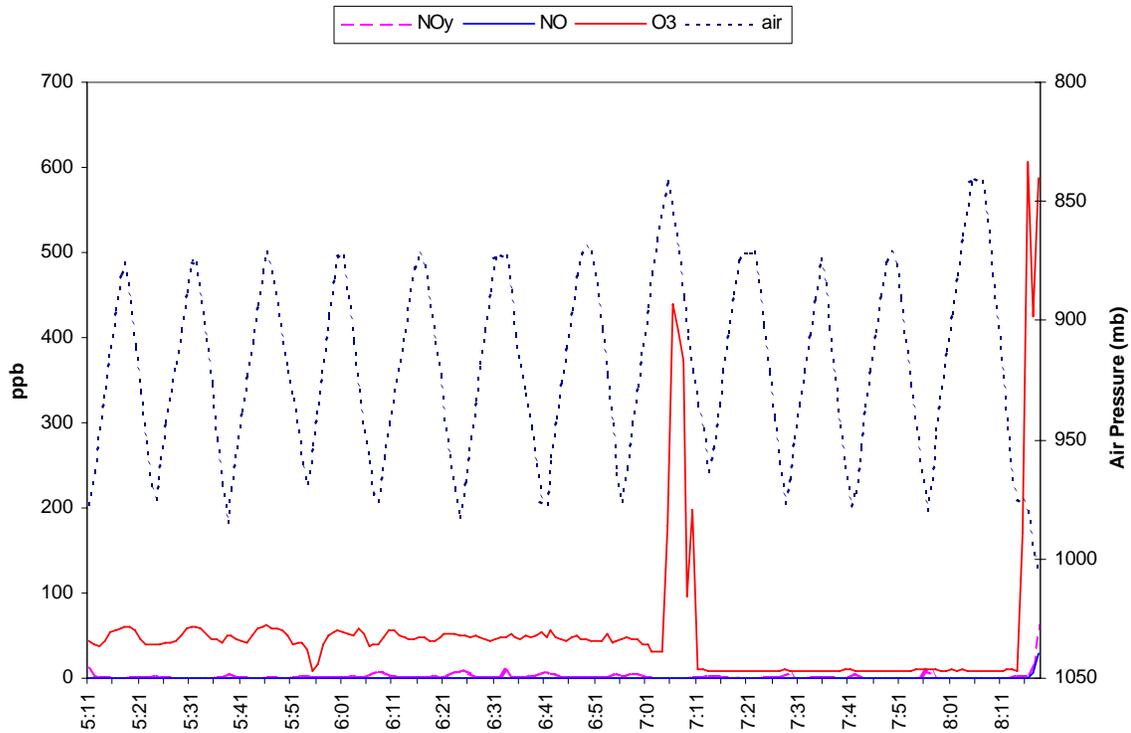


Figure 7-16. Time series plots of UCD172 aircraft flight data for September 19 showing malfunction of ozone analyzer.

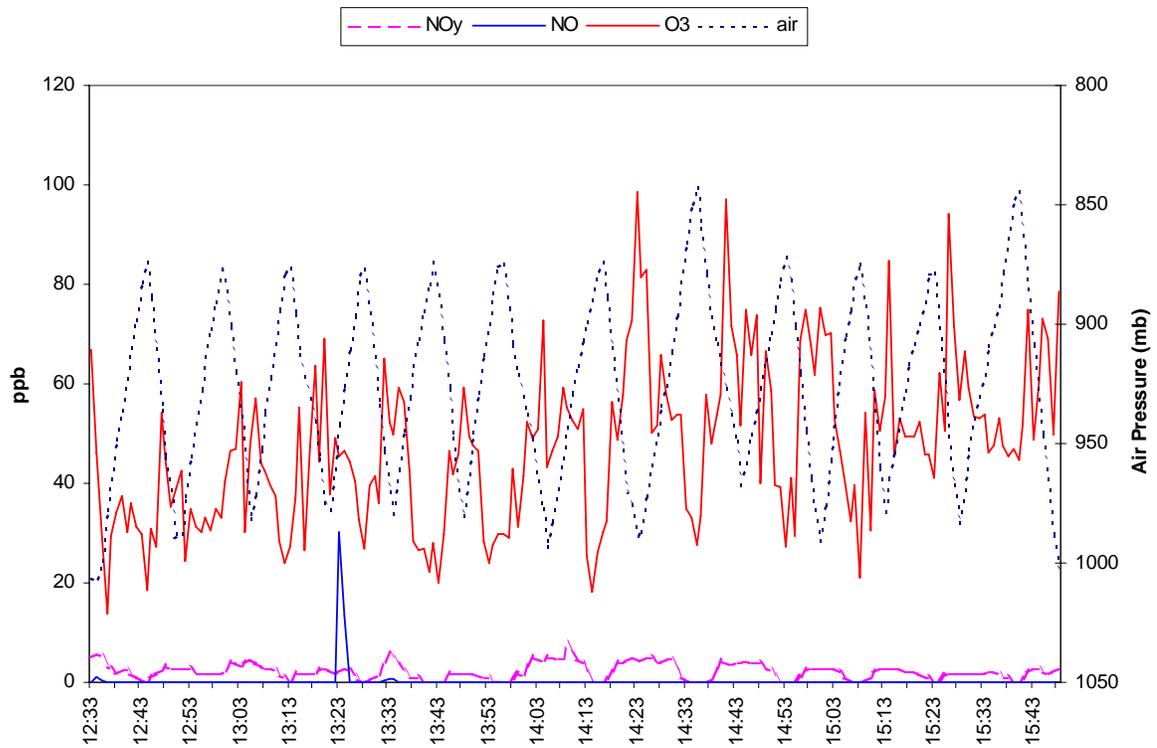


Figure 7-17. Time series plot of UCD172 aircraft flight data for September 17 showing suspect NO concentration spike at 13:23.

NO vs Ozone

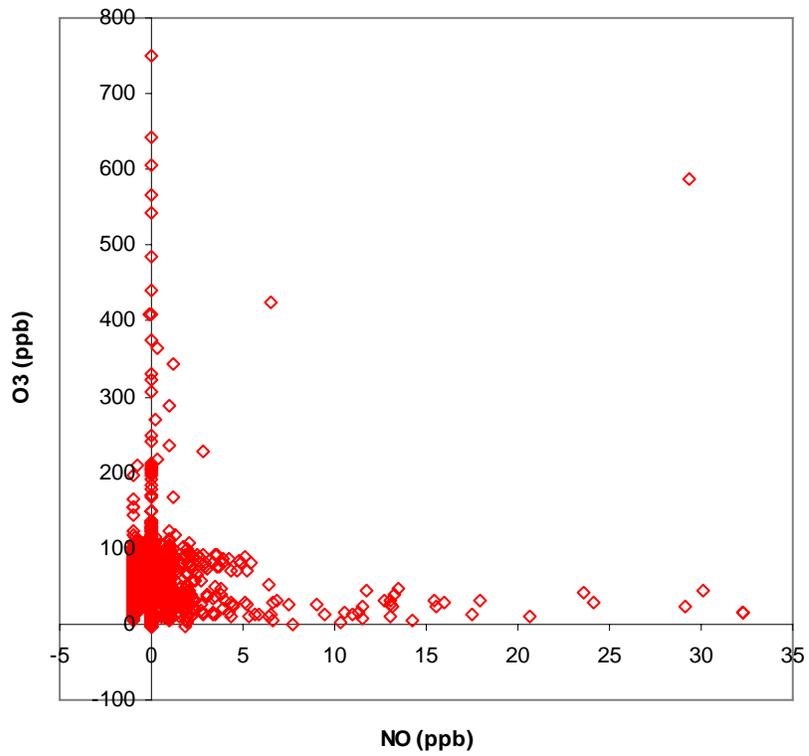


Figure 7-18. Scatter plot of all UCD172 aircraft flight data showing generally inverse relationship of ozone to NO concentrations.

7-23

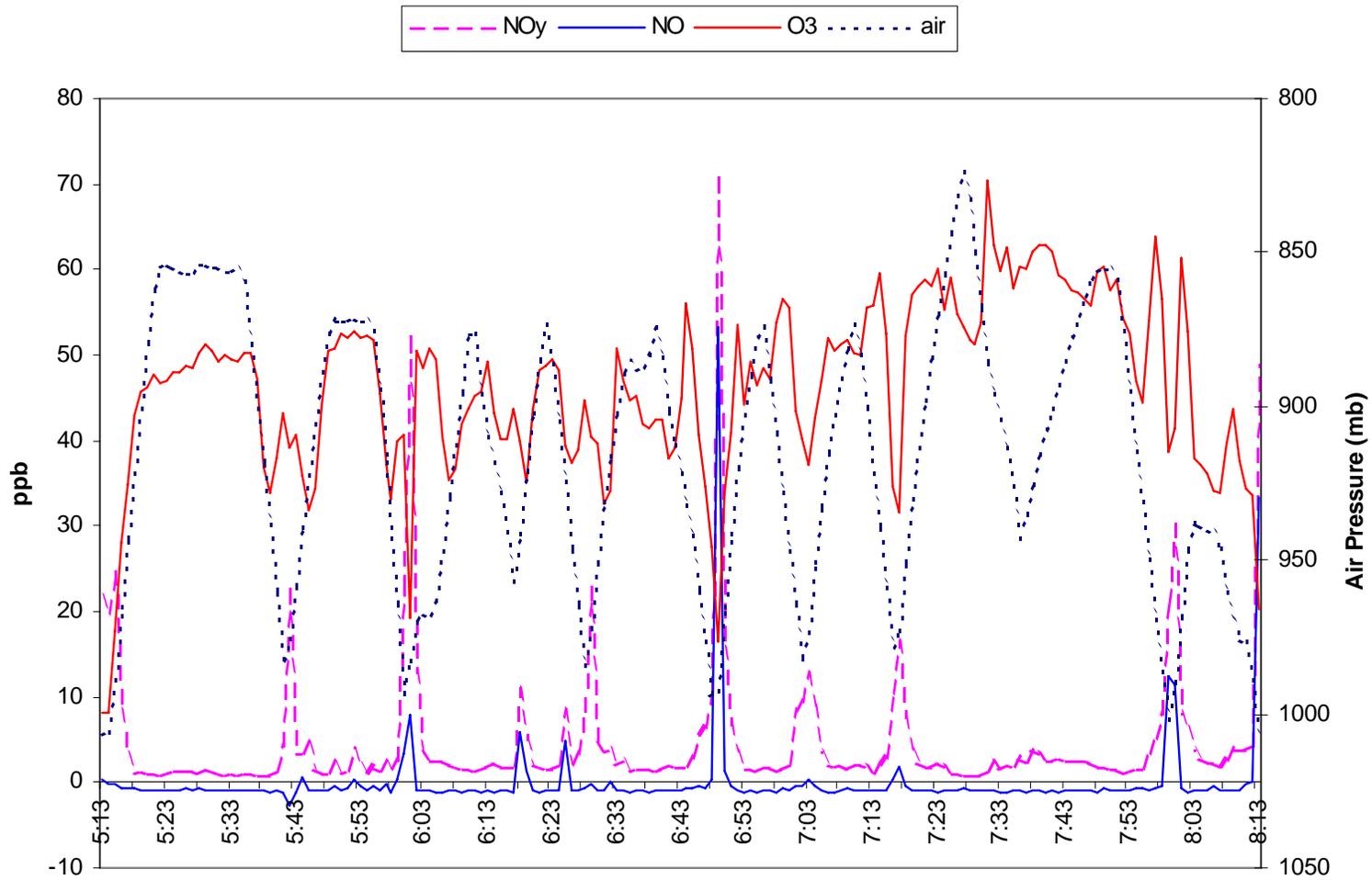


Figure 7-19. Example of UCD182 aircraft flight data. All parameters are well coordinated. Data shown is for AM flight on Sept. 19.

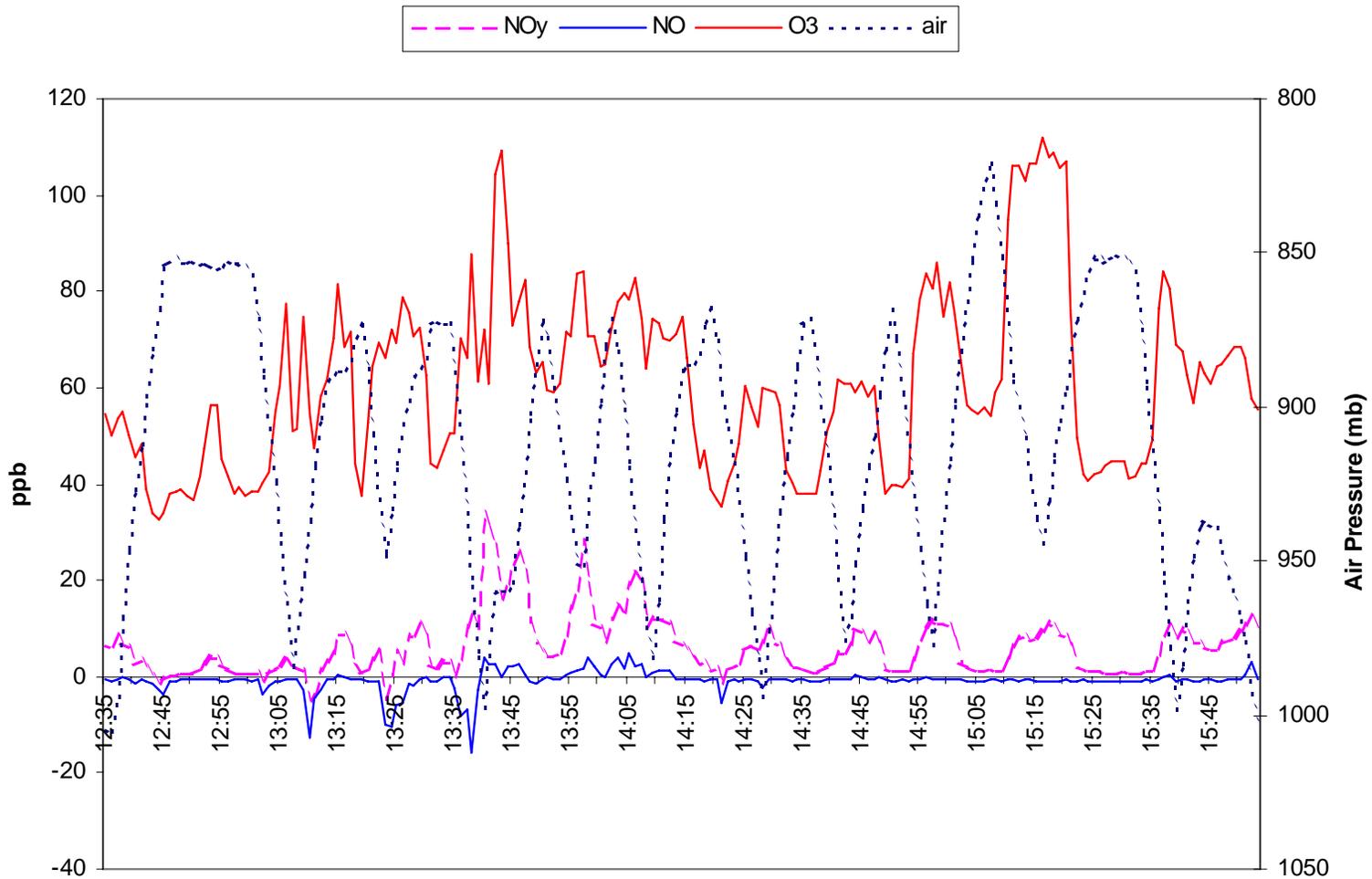


Figure 7-20. UCD182 aircraft flight data for PM flight on Sept. 19. Note negative NO and NOy concentrations. Invalid data of this type only occurred for this flight.

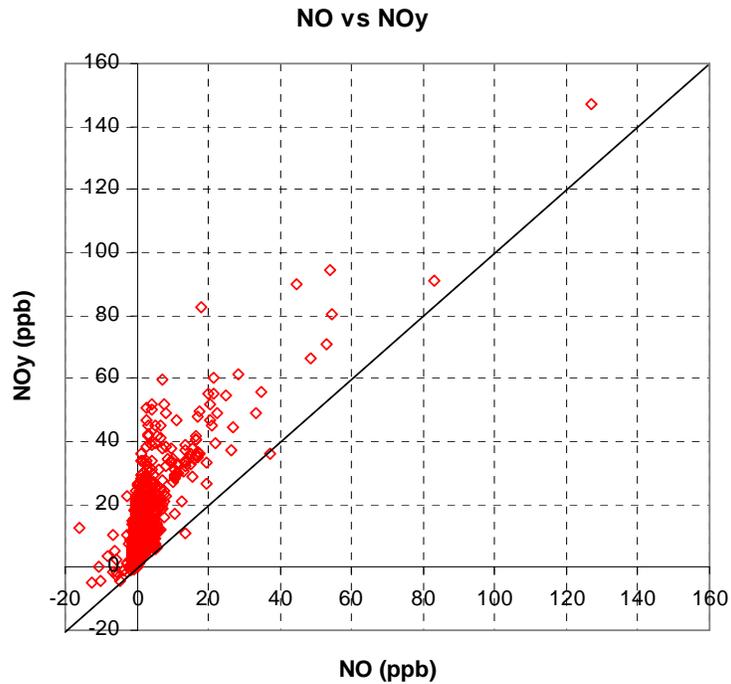


Figure 7-21. Scatter plot of NO vs NO_y for all UCD182 aircraft flight data. NO_y is larger than or equal to NO for all data.

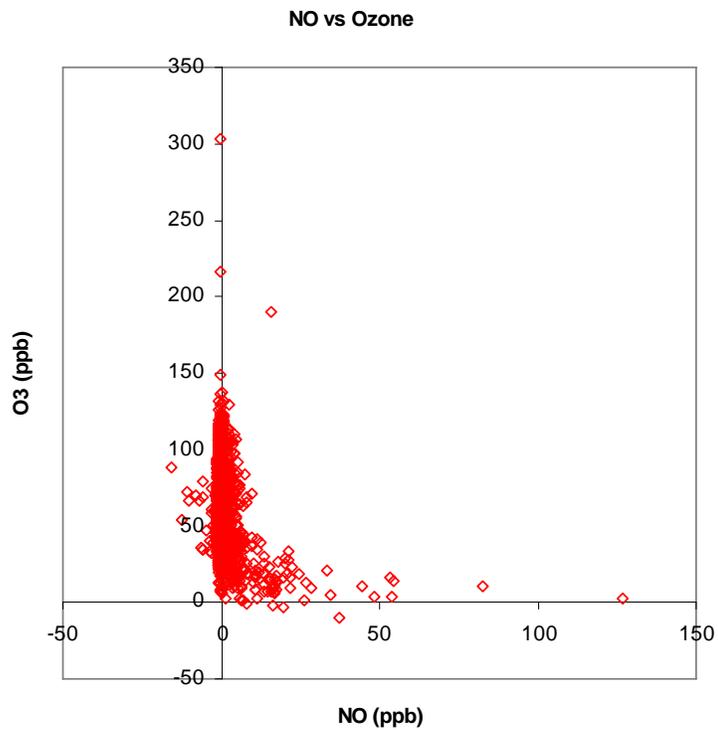


Figure 7-22. Scatter plot of all UCD182 aircraft flight data showing inverse relationship of ozone to NO concentrations.

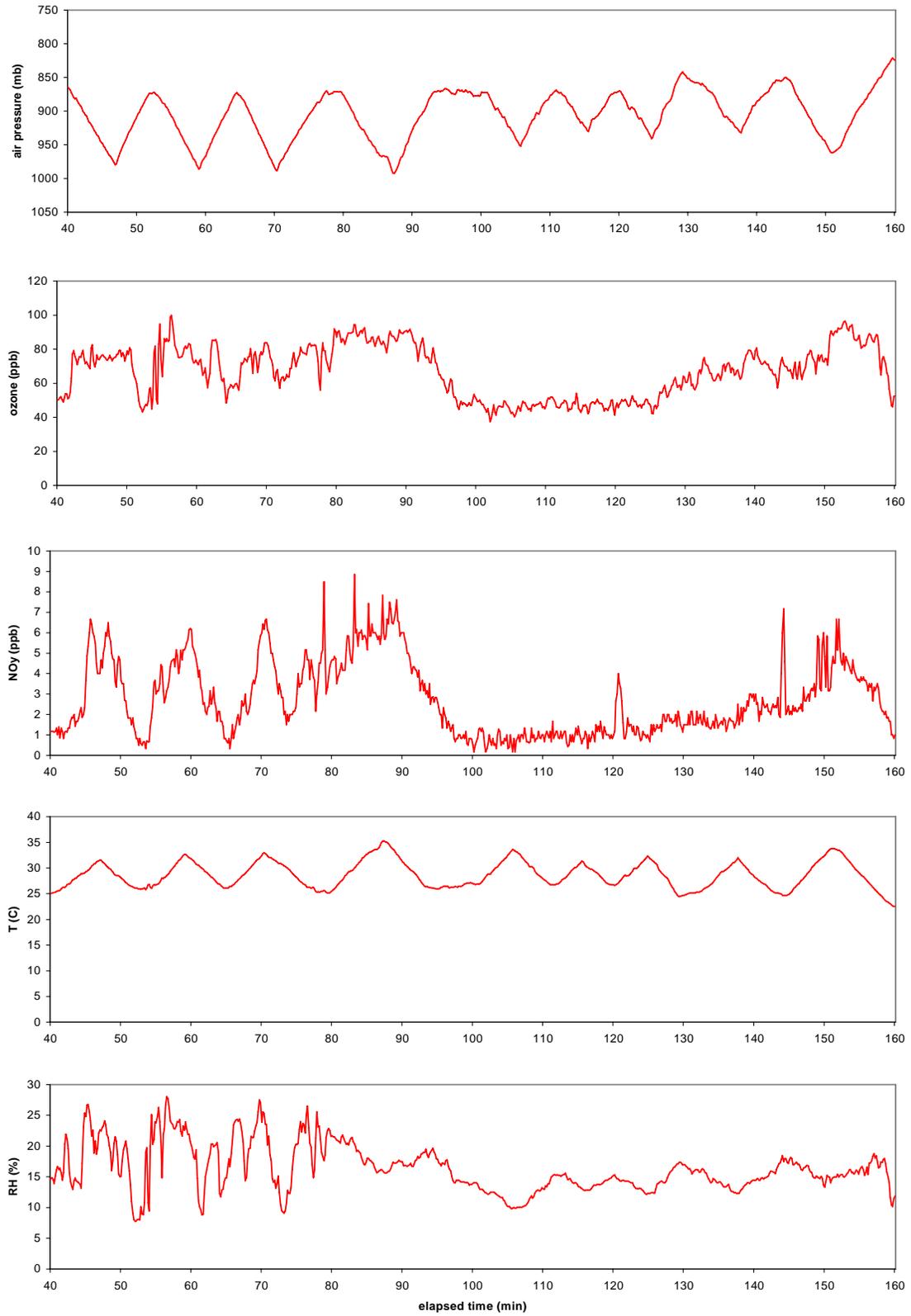


Figure 7-23. Time Series from July 25 Northern Boundary Flight by UCD Cessna 182.

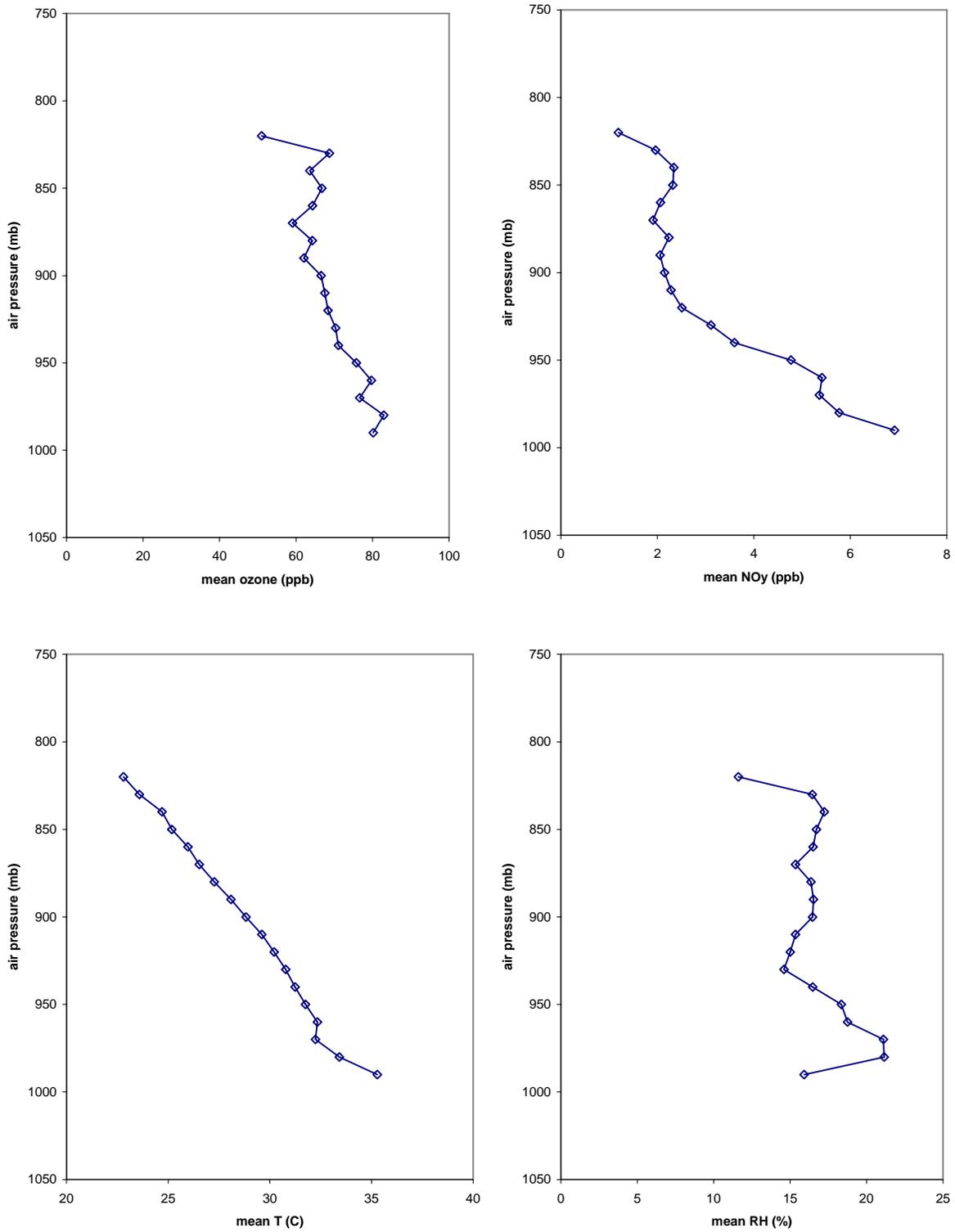


Figure 7-24. Vertical Profiles from July 25 Northern Boundary Flight by UCD Cessna 182

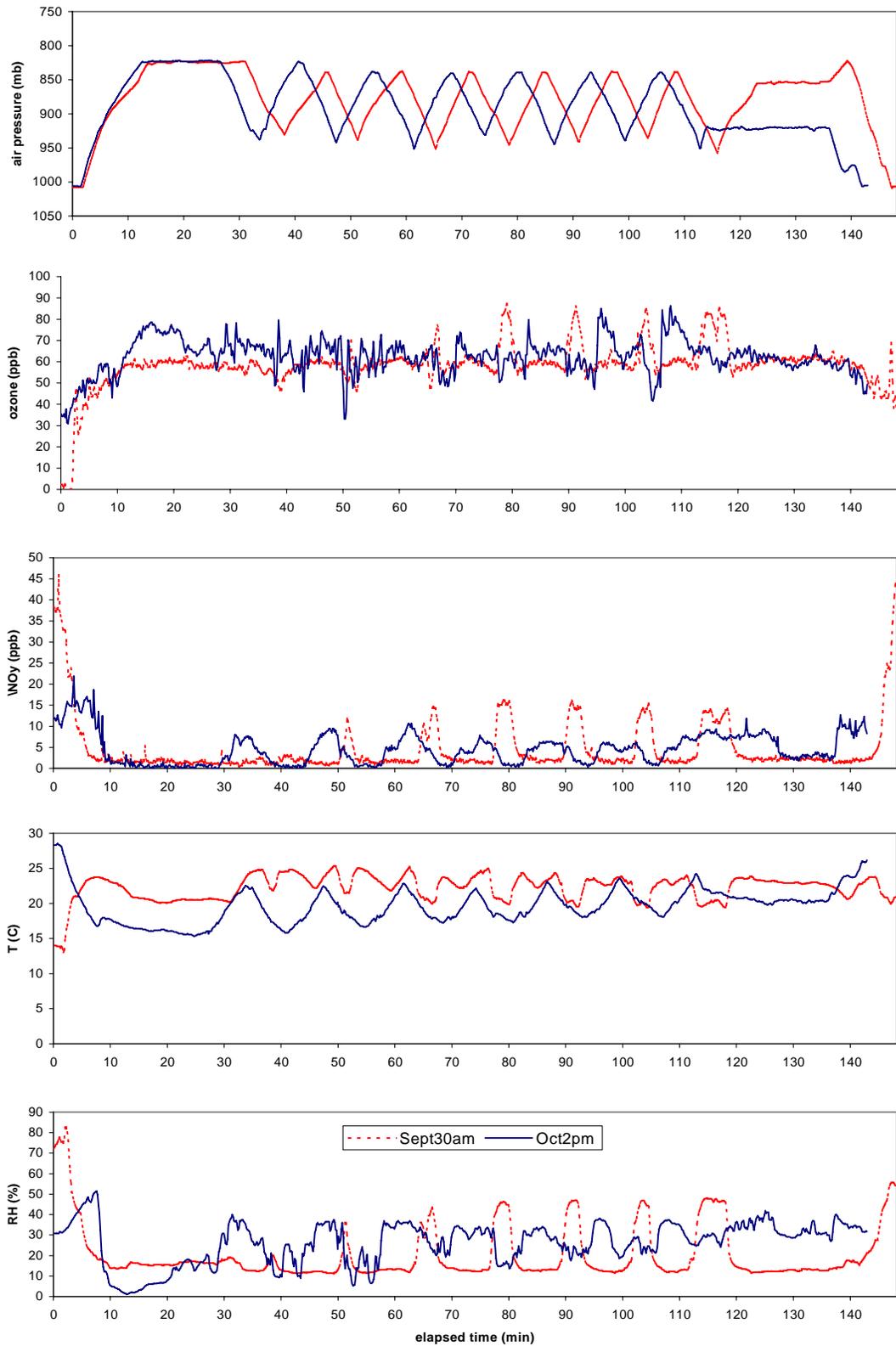


Figure 7-25. Time Series from Eastern Boundary Flights by UCD Cessna 182.

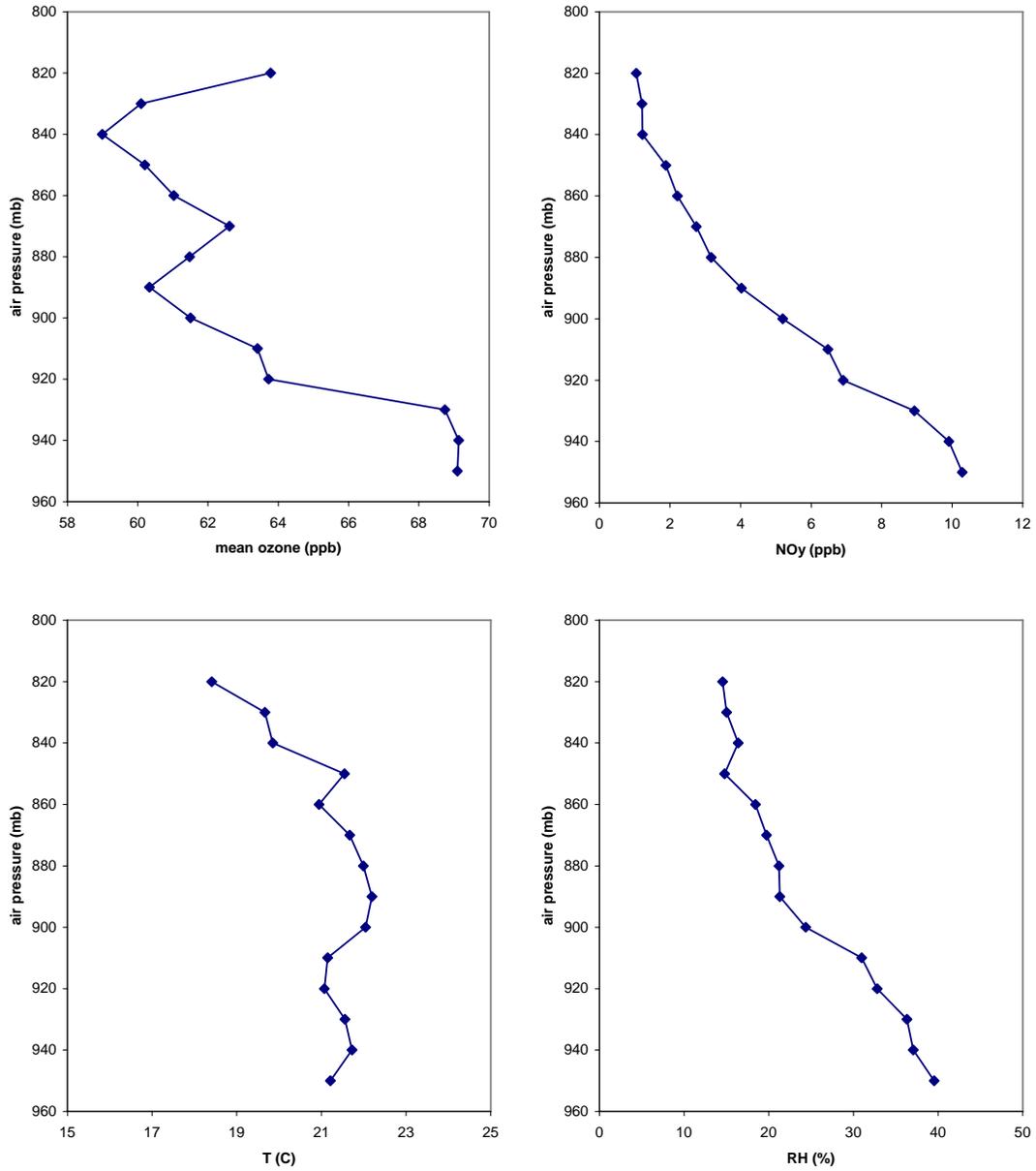


Figure 7-26. Mean Vertical Profiles from Eastern Boundary Flights by UCD Cessna 182

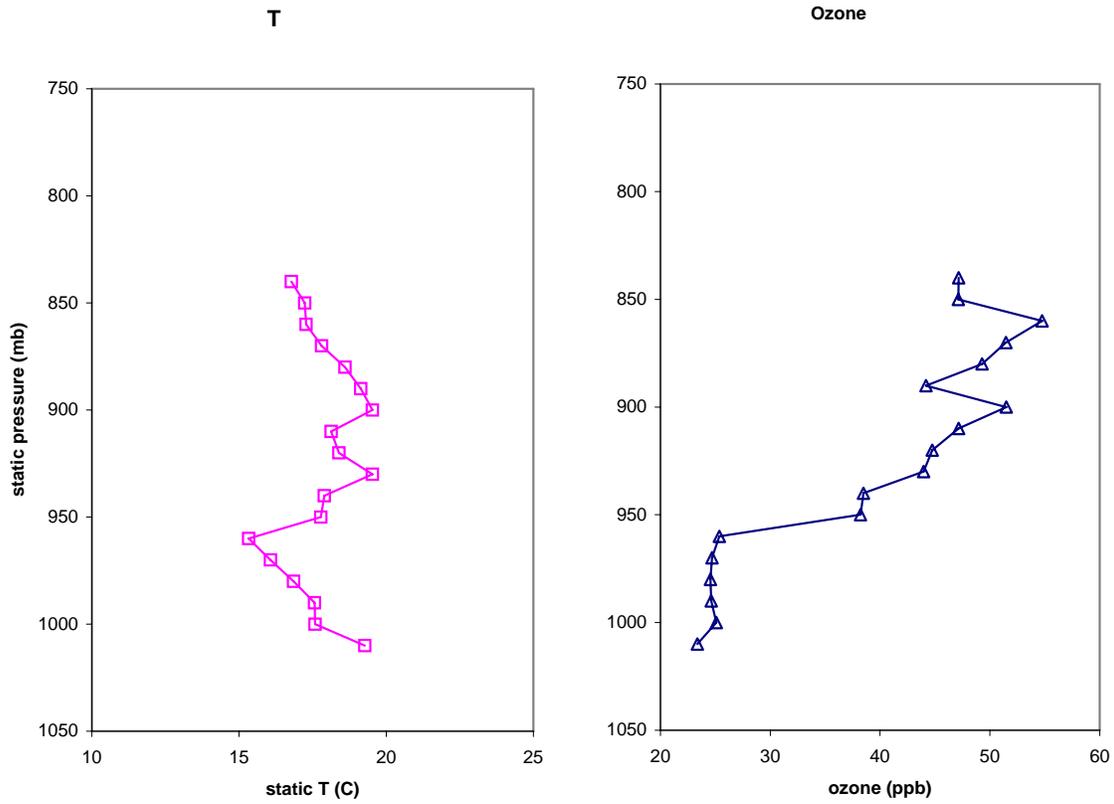


Figure 7-27. Mean Vertical Profiles from PNNL Offshore Flights.

8. METEOROLOGICAL DATA

The ARB operated two profilers (with RASS) in the San Joaquin Valley, and the San Joaquin Unified APCD and Sacramento Metropolitan AQMD operated one profiler/RASS each as part of their PAMS monitoring program. SJVAPCD also operated a profiler at Tracy during CCOS. Military facilities with operational profilers include Travis AFB, Vandenberg AFB, and the Naval Post Graduate School in Monterey. As part of CRPAQS, NOAA upgraded existing equipment, as required, at these facilities, and coordinated data collection to ensure compatibility with the CRPAQS/CCOS upper-air database. Six profiles/RASS were installed and operated during summer 2000 as part of the CRPAQS. In addition, nine profilers/RASS and 5 sodars were installed for the CCOS summer 2000 field study. Another Sodar was located in the vicinity of the Pittsburgh power plant stacks to ensure that the local 3D winds are well defined for model simulation during the early stages of plume dispersion. Table 8-1 provides a summary of the aloft meteorological measurements that were made by local agencies and by the CCOS contractors, Environmental Technology Laboratory (ETL, Boulder, CO) and Air Resources Laboratory (ARL, Idaho Falls, ID) of the National Oceanic and Atmospheric Administration (NOAA), Sonoma Technology, Inc. (STI), and T&B systems.

8.1 Performance Audit Results

Audits of the CCOS upper-air meteorological measurements were conducted by Parsons Engineering Science and are documented in their QA report (2001). In addition, the data have been validated through Level 1A and 1B processing by NOAA ETL (Neff et al., 2003). Level 1A processing of the radar and RASS data was accomplished by running the moments data through a modified Weber-Wuertz algorithm to remove obvious spurious data for wind speed, wind direction, and temperature. Level 1B processing involved visually inspecting daily wind and temperature files for inconsistencies not discovered with the Weber-Wuertz algorithm. Radian Corporation's LapGraph software was used. Approximately 5 days of data were displayed at once. Time and height consistency checks were performed and suspect data were marked as invalid. Once a site has been processed to level 1B, the data were run through an in-house algorithm in order to send to CARB in their prescribed format. In addition to the QA audits and level 1 validation, the meteorological data have been analyzed by T&B Systems (Lehrman et al., 2003).

8.2 Climatology During CCOS

This section provides an overview of synoptic meteorology and overall air quality during the CCOS study period and the Intensive Operational Periods (IOPs). Climatology during summer 2000 was a bit cooler than normal. Also, the duration of high pressure ridging, which fosters ozone production, was somewhat shorter than in previous summers. Table 8-2 shows selected meteorological parameters for days of interest during the study period and some descriptive statistics for the IOP days, the summer period (6/21/00-9/21/00), and the full study period (06/01/00-09/30/00). The table lists maximum temperature data at Fresno airport (FAT), San Francisco airport (SFO), the pressure gradient (Prgrad) between Reno (RNO) and Fresno, and the 500mb height and 850mb temperature from the morning (0400 PST) Oakland sounding.

Table 2.2-2 provides the meteorological scenarios and, where applicable, the type of cluster for the IOP days.

When compared to the 30-year climatology for June to September for Fresno and San Francisco, (Table 8-2, CCOS Field Study Plan, Fujita et al. 1999), the inland temperatures are statistically cooler during CCOS, while the coastal temperatures are not. For example the study period daily temperature maximum at Fresno, 91.4 ± 0.7 F, is more than three standard deviations below the climatological value of 94.8 F. The study period daily temperature maximum at San Francisco, 71.5 ± 0.7 F, is below but not statistically different from the climatological value of 72.0 F. This can be explained by less high pressure ridges and/or ridging of shorter duration passing over the western United States, where the inland sites are not as influenced by the mitigating effects of the Pacific Ocean.

Inspection of 500-mb (and surface) daily weather maps shows that low pressure troughs, cut-off lows, and zonal flow occurred during the first 7 weeks of the study period, except for one brief incursion of an Eastern Pacific High which brought some ridging over the West Coast. That occurred on June 14-15, which became the Practice IOP in Table 8-2. After this slow start to the study period, ridging during IOP#1, July 23-24, brought a Four Corners High. Unfortunately this 500-mb high positioning can also foster monsoonal flow. Too much positive vorticity (lifting) kept ozone concentrations low over much of the study area, in particular the southern San Joaquin. This high persisted the next week and moved over the Great Basin during IOP#2, July 30-Aug 2. By August 6, the high had weakened and moved east leaving troughs or zonal flow over California for almost another week. IOP#3 was conducted on August 14 when the high had broadened to include southern California. But IOP#3 lasted one day only as the high retreated from a trough moving down from the Gulf of Alaska by August 19. As the high retreated further east to Texas, Oklahoma, and Arkansas, a trough remained over the Pacific Coast as far south as Northern California, but cut-off lows and zonal flow over southern California kept ozone concentrations relatively low. Because of the lack of suitable episodes during the originally scheduled end of the IOP window of 09/03/00, the study was extended to late September.

On September 11, zonal flow over the Pacific Northwest and a weak cut-off low off the California coast were adjacent to a new high expanding up from the south over Northern Mexico. Due to the slow start in the study period, IOP#4 was called for September 14. Unfortunately, a relatively strong cut-off low developed off-shore of the US-Canadian border and kept the high to the east. As the cut-off low moved east over Idaho, a relatively strong high built in behind it over the eastern Pacific. IOP#5 was initiated on September 17, a ramp-up day, and continued through the 21st when the high had regressed back westward leaving strong northerly flow through a trough axis from Hudson Bay to San Francisco Bay. As the trough gave way to zonal flow over the next week, flights were conducted to monitor boundary conditions during zonal flow conditions during Sep 30 – Oct 2.

Practice IOP – June 14-15, 2000

Amid the unfavorable synoptic conditions that characterized the beginning of the study, one brief incursion of an Eastern Pacific High passed over the West Coast on June 14-15. It was a strong ridge over the Pacific with a 600 dm center at 38°N and 130°W . Oakland 500mb heights

in dm reached the high 590s with 850mb temperature over 26 C. However, its influence was short and pollutants didn't have a sufficient chance to build over a multi-day period.

IOP#1 – July 23-24, 2000

Figure 8-1 shows the 500mb analysis at 0400 PST on the morning of the second IOP day. An upper air pattern developed with a high amplitude ridge across the west and a mean trough over the east and a series of shortwave troughs embedded within the ridge over the southwestern US. Rotation around a Four Corners High fostered southerly gulf flow bringing in subtropical moisture, and the shortwaves helped to kick-off precipitation events over the southern Great Basin and the Colorado Plateau. The atmosphere generally was less stable than needed for high ozone in the southern San Joaquin, and even some precipitation was observed over California. However, even with these less than favorable conditions, Bakersfield still reached 112 and 119 ppb for daily maximums on July 23 and 24, respectively. Further to the north and further away from the monsoonal influence, Parlier reached 120 and 144 ppb for daily maximums on July 23 and 24, respectively. In the Sacramento Valley, Cool and Sloughhouse both reached 110 ppb on the second day, July 24. Onshore flow kept the Bay Area clean for the two-day period.

IOP#2 – July 30 through August 2, 2000

Figure 8-2 shows the 500mb analysis at 0400 PST on the morning of the first IOP day. A typical Great Basin High occurred during this IOP. Figure 8-2 shows this strong ridge that brought favorable ozone conditions to the study region. The high persisted for four days before a trough off the Pacific Northwest Coast moved the high eastward, leaving approximately zonal flow over most of the study region by August 3. Favorable off-shore gradients developed during the period, bringing a Cluster 1 day and a 1hr exceedance of 126 ppb at Livermore on July 31. A cluster 3 day occurred on August 1, with calm winds in the southern Sacramento Valley and a 1hr exceedance of 130 ppb to the Sloughhouse monitoring station. On August 2, the southern SJV experienced a 1hr exceedance of 151 ppb at the Edison station, and westerly winds increased somewhat, transporting pollutants into the foothills, bringing a 130 ppb at Grass Valley.

IOP#3 – August 14, 2000

Figure 8-3 shows the 500mb analysis at 0400 PST on the morning of IOP#3 on August 14, when a high over New Mexico and the Texas Panhandle had broadened to include southern California. Two 8hr exceedances of 90 ppb were observed at Folsom and Placerville with westerly flow above the high associated with an incoming trough. IOP#3 lasted one day only as the high retreated eastward with the trough moving onshore.

IOP#4 – September 14, 2000

Figure 8-4 shows the 500mb analysis at 0400 PST on the morning of IOP#4. On September 11, zonal flow over the Pacific Northwest and a weak cut-off low off the California coast were adjacent to a new high expanding up from the south over Northern Mexico. It was unclear which pattern would win out over the next 2-4 days. Due to the slow start in the study period, IOP#4 were called to begin on September 14. The high expanded on September 13, which was a promising beginning to an episode, with 8hr exceedances over the San Joaquin

Valley. Unfortunately, by the 14th, a relatively strong cut-off low developed offshore of the Oregon-California border and kept the high to the east. Operations were suspended after 1 day. This was not a typical summer ozone scenario, and 850mb temperature and 500mb heights at Oakland were very low on September 14.

IOP#5 – September 17-21, 2000

Figure 8-5 shows the 500mb analysis at 0400 PST on the morning of the second IOP day. A relatively strong Eastern Pacific High built over the IOP#5 period. September 17 was a relatively clean ramp-up day. The SJV experienced high ozone in the central region, with 1hr exceedances of 171 ppb and 136 ppb at Parlier on September 18 and 19, respectively. Similarly, the southern SJV experienced exceedances at both Arvin and Edison on the 18th and 19th. The offshore gradient strengthened on the 19th and Livermore reached 100 ppb for a daily maximum. Concord did experience a 1hr state exceedance of 95 ppb on the 19th. However, sufficient northwesterly flow continued aloft to reinforce the sea breeze and prevent ozone significant buildup along the coast. Operations continued through the 21st when the high had regressed back westward leaving strong northerly flow through a trough axis from Hudson Bay to San Francisco Bay by September 22.

Boundary Condition Flights – September 30 through October 2, 2000

Three days of flights were conducted to monitor boundary conditions during primarily zonal flow conditions during Sep 30 – Oct 2. On September 30, the zonal flow was over northern California and the Pacific Northwest with a weak cut-off low over San Diego. By October 2, the zonal flow had dropped south to central California with the cut-off low strengthening but also moving south and further offshore.

Table 8-1. Upper Air Meteorological Measurements for CCOS.

Site ID	Name	Purpose	Justification	Operator ^a	Contractor	Radar ^b	RASS ^b	Sodar ^{b,c}	Sonde ^{b,d}	Nexrad
ABK	Arbuckle	Intrabasin transport	Location provides coverage of predominant summer flow through Sacramento Valley.	CCOS	NOAA-ETL	SC	SC			
ABU	N. of Auburn, S. of Grass Valley	Upslope/downslope flow, downwind of major area source	Site to monitor possible summer eddy flow, vertical temperature structure evolution, model input and evaluation data. Downwind of Sacramento area source.	CCOS	NOAA-ETL	SC	SC			
ACP	Angel's Camp	Upslope/downslope flow, complex terrain for challenging model evaluation	Served as site to capture eddy flow, mixing, vertical temperature structure, model input and evaluation data during SJVAQS/AUSPEX	CCOS	NOAA-ETL			SC		
ANGI	Angiola	Intrabasin transport, vertical mixing, micrometeorology	Positioned to monitor transport up the valley, low level nocturnal jet flow, and Fresno eddy flow patterns. Collocated with tall tower.	CRPAQS-rwp, CCOS-sodar	NOAA-ETL	AC	AC	SC		
BBX	Beale AFB-Oro Dam Blvd West	Northern boundary transport, synoptic conditions	Fulfill needs of National Weather Service and Beale AFB flight operations; existing long-term site.	BAFB						AC
BHX	Humboldt County	Onshore/offshore transport	Fulfill needs of National Weather Service; existing long-term site	NWS						AC
CAR	Carizo Plain	Interbasin transport.	Monitor transport between San Joaquin Valley and South Central Coast Air Basins.	CCOS	NOAA-ARL	SC	SC	SC		
CRG	Corning	Northern Valley barrier, characterize Northern SV convergence zone.	To observe southerly barrier winds along the Sierra Nevada which may be a transport mechanism. May characterize extent of northerly flow into SV for some scenarios.	CCOS	NOAA-ETL	SC	SC			
DAX	Sacramento	Intrabasin transport	Fulfill needs of National Weather Service; existing long-term site	NWS						AC
EDI	Edison	Interbasin transport through Tehachapi Pass. Downwind of major source.	Site to observe possible divergence flow at southern end of the valley, low level jet flow, and eddy flows. Data from SJVAQS/AUSPEX taken at Oildale supports these observations. Downwind of Bakersfield area source.	ARB		AC	AC			
EDW	Edwards AFB	Intrabasin transport	Existing long term site. Transport through Tehachapi Pass, desert mixed layer, synoptic conditions.	EAFB					AS SE	

Table 8-1 (continued). Upper Air Meteorological Measurements for CCOS.

Site ID	Name	Purpose	Justification	Operator ^a	Contractor	Radar ^b	RASS ^b	Sodar ^{b,c}	Sonde ^{b,d}	Nexrad
EYX	Edwards AFB	Intrabasin transport	Fulfill needs of National Weather Service and Edwards AFB flight operations; existing long-term site.	EAFB						AC
FAT	Fresno Air Terminal	Intrabasin transport	Capture the Fresno eddy, characterize urban mixing heights, transport from major Fresno area source.	CCOS	NOAA_ETL	SC-449	SC	SC		
FSF	Fresno-First Street	Urban Heat Island, Intrabasin Transport, Synoptic Conditions. Characterize	Site to monitor possible summer eddy flow, vertical temperature structure evolution, model input and evaluation data. Flow out of Fresno.	CCOS	T&B				SE	
HNX	Hanford-edge of town between fairgrounds and municipal	Intrabasin Transport	Fulfill needs of National Weather Service; existing long-term site.	NWS						AC
HUR	Huron	Intrabasin transport	This is to monitor daily transport from north to south with average surface winds during afternoons and early evening and the low level nocturnal jet on the western side of the SJV; models should do well with topographic	CRPAQS or ARB	NOAA-ETL or ARB	AC	AC			
LGR	Lagrange	Upslope/downslope flow	This site represents valley/Sierra interaction in northern SJV. Monitor possible upslope flow transport of pollutants during day and possible recirculation via Mariposa River Valley exit jet by night. Also completes the west to east transect across SJV from SNA to LIV sites.	CCOS	NOAA_ETL	SC	SC			
LHL	Lost Hills	Intra&interbasin transport across Carizo Plain	Situated east of the coastal range and represents uniform flow aloft at 1000m as opposed to a site on the Tremblor Range. Good position to detect the direction of flow between the Carrizo Plain and the SJV	ARB or NOAA		AC	AC			
LIV	Livingston	Intrabasin transport	Representative of mid SJV flow since variation in flow is small along the valley's central axis.	CRPAQS-rwp, CCOS-coder	NOAA_ETL	AC	AC	SC		
LVR	Livermore	Intrabasin transport	Monitor flow through Castro Valley between San Leandro/Oakland and Livermore.	CCOS	STI	SC	SC			

Table 8-1 (continued). Upper Air Meteorological Measurements for CCOS.

Site ID	Name	Purpose	Justification	Operator ^a	Contractor	Radar ^b	RASS ^b	Sodar ^{b,c}	Sonde ^{b,d}	Nexrad
MJD	Mojave Desert	Interbasin transport	Chosen to monitor interbasin flow out of the San Joaquin Valley to the desert via Tehachapi Pass. Previous monitoring studies have shown a clear exit jet out of the SJV in this region. The exact site is to be determined.	CRPAQS	NOAA_ETL	AC	AC			
MKR	Mouth Kings River	Upslope/downslope flow	The current suspicion is that the mountain exit jets flow along the axis of the valley over Trimmer. A site between Academy and Humphrey's Station is more likely to observe the flow than a site at Piedra.	CRPAQS	NOAA_ETL	AC	AC			
MON	Monterey	Onshore/offshore transport	Existing long term site. Transport through Tehachapi Pass, desert mixed layer, synoptic conditions.	USNPGS		AC	AC			
MUX	Santa Clara	Interbasin transport	Fulfill needs of National Weather Service; existing long-term site.	NWS						AC
NTD	Point Mugu USN	Onshore/offshore transport, synoptic conditions.	Existing long term site	USN					AS SE	
OAK	Oakland airport	Onshore/offshore transport, synoptic conditions.	Fulfill needs of National Weather Service; existing long-term site.	NWS					AS SE	
PLE	Plesant Grove	Intra- and interbasin transport.	Monitor transport between Sacramento and Upper Sacramento Valley and North Mountain	CCOS	NOAA-ETL	SC	SC			
POR	Pt. Reyes	On-shore flow, along coast flow	Coastal meteorology impacts air quality not only in coastal regions but by modulating the strength, and intrusion extent of the sea breeze.	CCOS	STI	SC	SC			
REV	Reno National Weather Service Office	Northern boundary transport, synoptic conditions	Fulfill needs of National Weather Service; existing long-term site.	NWS					AS	
RGX	Washoe County-Virginia Peak	Northern boundary transport, synoptic conditions	Fulfill needs of National Weather Service; existing long-term site	NWS						AC
RIC	Richmond	Onshore/offshore transport.	Monitor possible deeper mixed layer.	CCOS-p, CCOS-sodar	NOAA-ETL	SC	SC	AC		

Table 8-1 (continued). Upper Air Meteorological Measurements for CCOS.

Site ID	Name	Purpose	Justification	Operator ^a	Contractor	Radar ^b	RASS ^b	Sodar ^{b,c}	Sonde ^{b,d}	Nexrad
SAC	Sacramento	Intra and interbasin transport	Monitor N-S flow within Sacramento Valley, afternoon sea breeze intrusion, and flow from San Francisco Bay Area; help resolve northern boundary of SV/SJV divergence zone.	SMUAPCD/ARB		AC	AC		SE	
SHA	Shasta	Intrabasin transport	Monitor flow at the northern end of the Sacramento Valley. Eddy flows.	CCOS	NOAA-ETL	SC	SC			
SNA	Santa Nella, E of I-5 toward Los Banos	Interbasin transport from Pacheco Pass, model QA.	May represents flow through Pacheco pass during some coastal valley intrusions; represents along-valley flow on western side at other times. Models should handle channeled, along-valley flow well at this point.	CRPAQS or ARB	NOAA-ETL or ARB	AC	AC			
SNM	San Martin	Intra- and interbasin transport, flow through Santa Clara Valley	Monitor transport from SFBA to NCC via Santa Clara Valley south of San Jose.	CCOS	STI	SC	SC			
SOX	Orange County	Onshore/offshore transport.	Fulfill needs of National Weather Service; existing long-term site	NWS						AC
TRA	Travis AFB	Interbasin transport between San Joaquin Valley and Bay	Existing long term site	TAFB		AC		WC		
TRC	Tracy, W of Tracy, S of I-205, W of I-580	Interbasin transport through Altamont Pass.	Monitor flow through Altamont Pass for San Francisco Bay Area to SJV transport in p.m.; also help monitor less frequent off-shore flow.	CCOS	STI	SC	SC			
VBG	Vandenberg AFB	Onshore/offshore transport, synoptic conditions.	Existing long term site	VAFB		AC			AS SE	
VBX	Orcutt Oil field-Vandenberg	Onshore/offshore transport.	Fulfill needs of National Weather Service and Vandenberg operations; existing long-term site.	VAFB						AC
VIS	Visalia	Intrabasin transport.	Existing long term site	SJVUAPCD		AC	AC			
VTX	Ventura County	Intrabasin transport-onshore/offshore transport.	Fulfill needs of National Weather Service; existing long-term site.	NWS						AC
	Pittsburg	Plume Study		PG&E	PG&E	SC	SC			
	Moss Landing	Plume Study		PG&E	PG&E	SC	SC			

Table 8-1 (continued). Upper Air Meteorological Measurements for CCOS.

	Operator^a	Contractor	Radar^b	RASS^b	Sodar^{b,c}	Sonde^{b,d}	Nexrad
Totals by Operator:	CCOS		13	13	5	2	
	CRPAQS		6	6			
	ARB/Districts		4	4	1		
	Military/U.S.		3	1		4	10
	TOTALS		26	24	6	6	10

Footnotes

^aCCOS=Central California Ozone Study (this study); ARB=Air Resources Board, BAAQMD=Bay Area Air Quality Management District; USNPGS=U.S. Navy Post Graduate School; SJVUAPCD=SJV Unified Air Pollution Control District, NWS=National Weather Service; SMAQMD=Sacramento Metropolitan Air Quality Management District, CRPAQS=California Regional PM10/PM2.5 Air Quality Study; VAF=Vandenberg Air Force Base, TAF=Travis Air Force Base, EAF=Edwards Air Force Base, USN=U.S. Navy.

^bAC=Annual continuous measurements; AS=Annual sporadic measurements, SC=Summer continuous, 6/1/2000-9/30/2000; SE=Summer episodic measurements on forecasted days.

^cSummer campaign sodars added at some sites as part of CRPAQS/CCOS except at RIC.

^dBalloon launch on episode days. Frequency should be 4-8 times per day but include 0700 and 1900 PST.

Table 8-2. Selected meteorological parameters for the CCOS study period*

IOP	Date	MaxTemp FAT (F)	MaxTemp SFO (F)	RNO-FAT Prgrad (mb)	500mb Height OAK (dm)	850mb Temp OAK (C)
Practice	14-Jun-00	101	105	-10.5	598	26.6
	15-Jun-00	103	79	-5.8	597	26.2
IOP#1	23-Jul-00	96	71	-3.0	589	19.6
	24-Jul-00	100	70	-3.0	591	21.2
IOP#2	30-Jul-00	100	71	-0.8	590	23.0
	31-Jul-00	97	79	-3.3	591	24.8
	01-Aug-00	101	88	-2.5	596	26.8
	02-Aug-00	102	81	-4.5	593	26.2
IOP#3	14-Aug-00	97	75	9.0	585	21.4
IOP#4	14-Sep-00	89	74	-2.1	582	13.0
IOP#5	17-Sep-00	92	91	-5.7	590	20.2
	18-Sep-00	98	91	1.0	593	22.0
	19-Sep-00	99	93	-8.0	596	25.0
	20-Sep-00	99	79	-8.4	591	24.6
	21-Sep-00	83	73	1.5	580	22.0
Boundary	30-Sep-00	87	76	-6.3	586	23.4
Condition	01-Oct-00	91	60	-3.8	586	22.0
Flights	02-Oct-00	92	67	-0.7	582	20.6
IOP Mean		96.4	79.7	-2.3	589.8	22.3
Summer 2000 Mean		92.8	71.4	-1.9	583.6	18.9
Summer 2000 StDev.		6.1	6.5	2.7	5.7	4.0
Study Period Mean		91.4	71.5	-2.0	583.2	18.1
Study Period StDev.		7.2	7.2	3.2	6.6	4.7
Study Period StErr.		0.7	0.7	0.3	0.6	0.4

*Note: data in this table are preliminary and unvalidated. Aloft measurements are taken at 4:00 a.m. PST.
Aug. 1, 2 – higher moisture aloft (dew point > 8 °C at 850 mb and > -4 °C at 700 mb). High pressure over western U.S, but with some zonal flow.
Aug. 14 – synoptic pattern was almost zonal with high centered over eastern Colorado.
Sept. 30 and Oct. 1 – closed low offshore of San Diego, which may be affecting the southern part of study area.
Oct. 2 – flow is disorganized in the region. Zonal flow at the Oregon border.

Table 8-3. Meteorological scenarios and cluster type for the CCOS IOPs.

IOP	Date	Meteorological Scenario	Ozone Cluster
Practice	14-Jun-00	Eastern Pacific Hi (IIa)	2
	15-Jun-00	Eastern Pacific Hi (IIa)	2
IOP#1	23-Jul-00	Monsoonal Flow (IIIb)	2 or 3
	24-Jul-00	Monsoonal Flow (IIIb)	2 or 3
IOP#2	30-Jul-00	Western U.S. Hi (Ib)	-
	31-Jul-00	Western U.S. Hi (Ib)	1
	01-Aug-00	Western U.S. Hi (Ib)	3
	02-Aug-00	Western U.S. Hi (Ib)	2
IOP#3	14-Aug-00	Western U.S. Hi (Ic)	-
IOP#4	14-Sep-00	Pre-Frontal (Va)	-
IOP#5	17-Sep-00	Trough Passage (VIb)	-
	18-Sep-00	Eastern Pacific Hi (IIa)	2
	19-Sep-00	Eastern Pacific Hi (IIa)	2
	20-Sep-00	Eastern Pacific Hi (IIa)	2
	21-Sep-00	Trough Passage (VIa)	-
Boundary	30-Sep-00	Zonal (IVc)	-
Condition	01-Oct-00	Zonal (IVc)	-
Flights	02-Oct-00	Zonal (IVc)	-

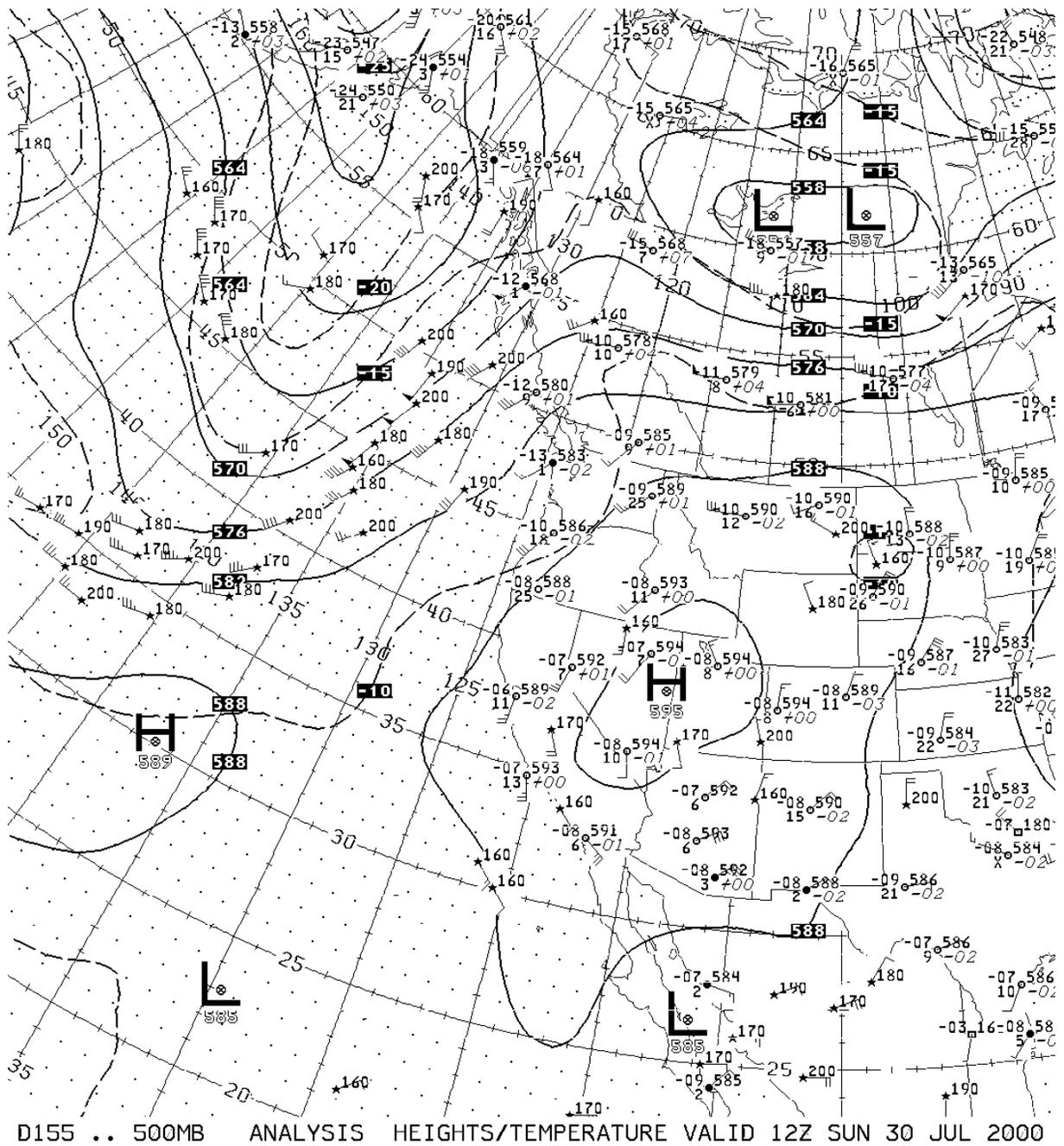


Figure 8-2. Western U.S. 500mb analysis from 0400 PST on July 30, 2000 during IOP#2. The Great Basin High fosters off-shore gradients.

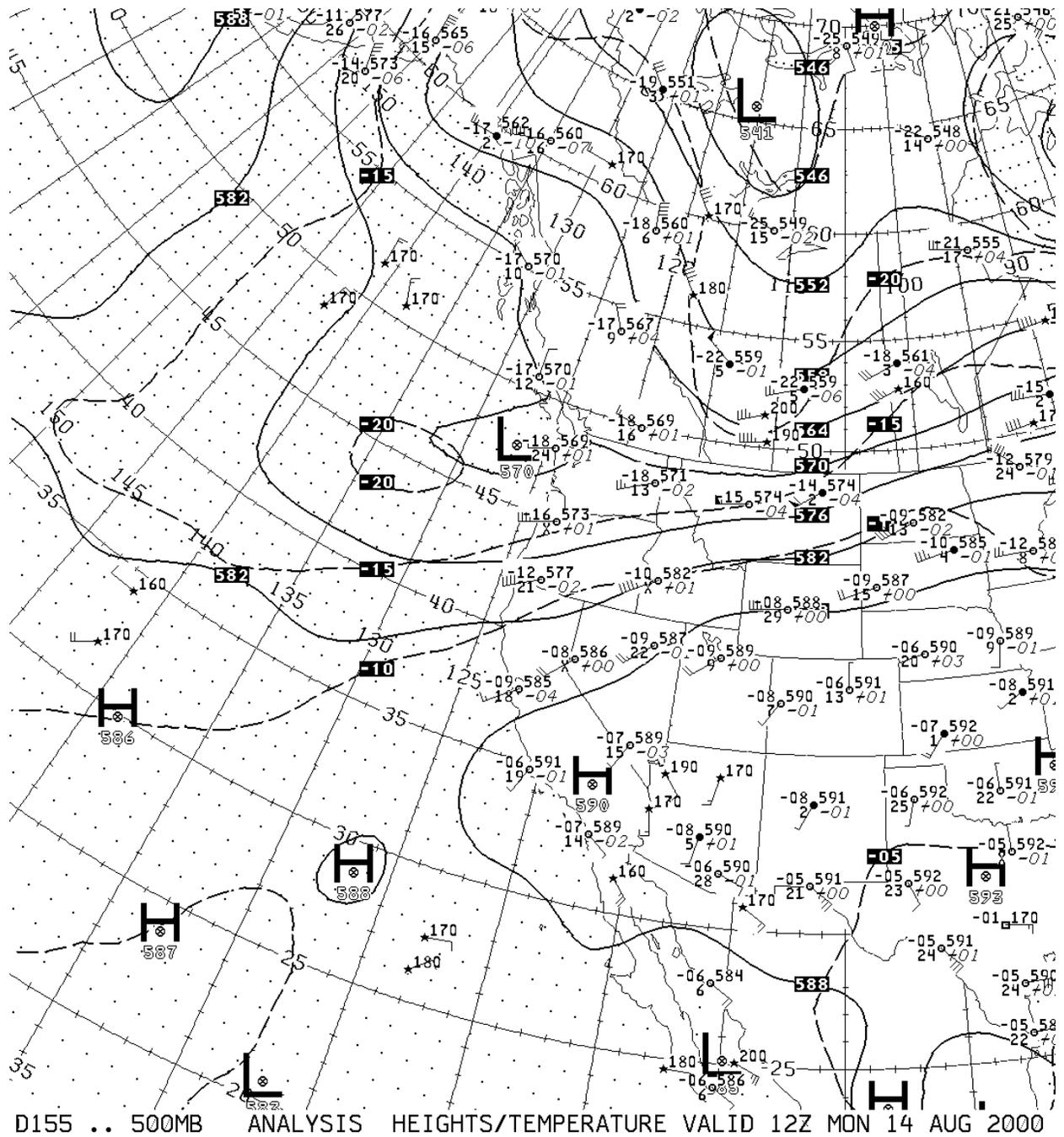
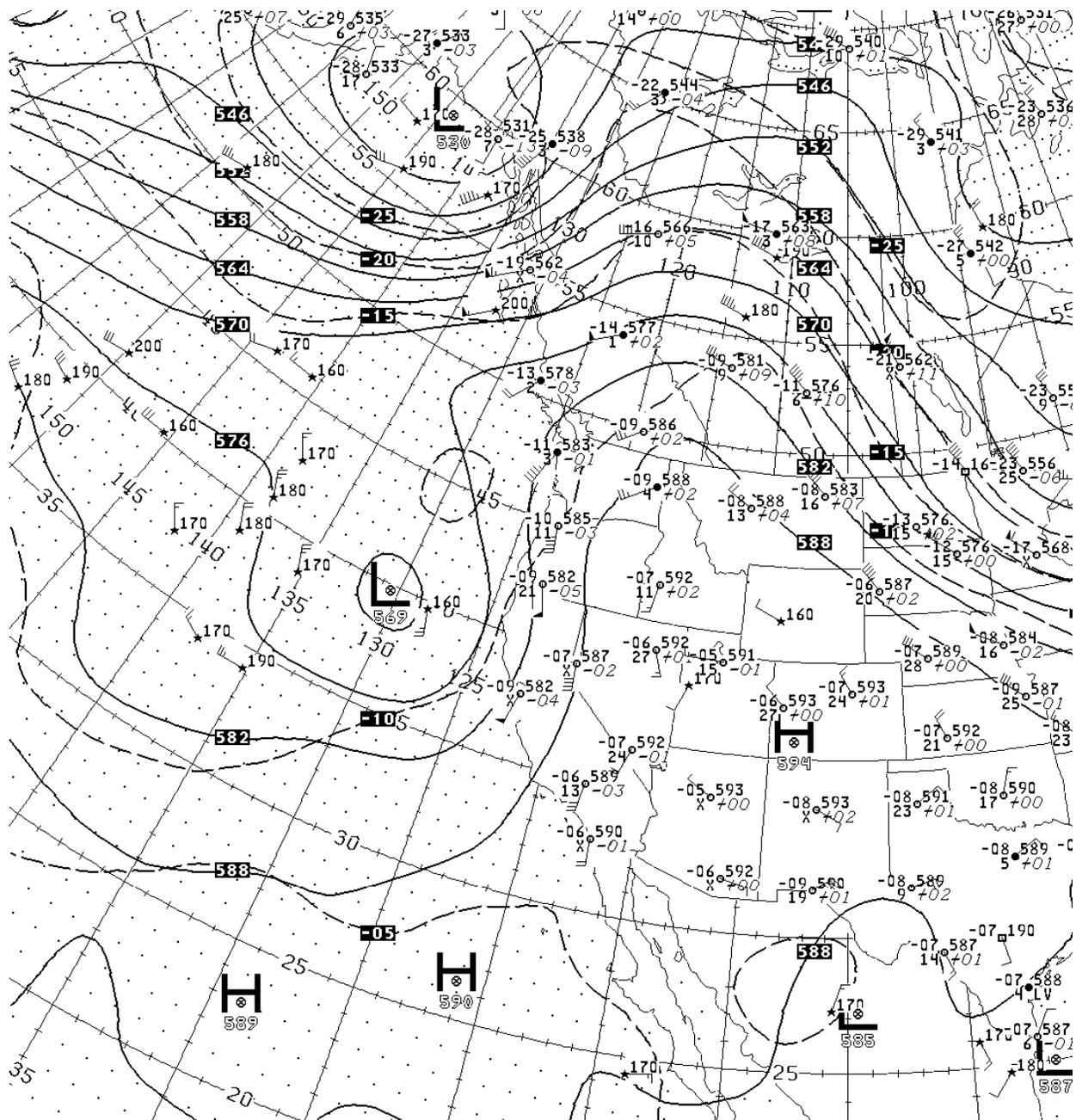


Figure 8-3. Western U.S. 500mb analysis from 0400 PST on August 14, 2000 during IOP#3. The area of high pressure extends well across the southern United States to Eastern Tennessee and Mississippi. The slack gradients under this broad system make classification more difficult.



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Figure 8-4. Western U.S. 500mb analysis from 0400 PST on September 14, 2000 during IOP#4. The strong cut-of low off the northern California coast kept 500mb heights and 850mb temperatures low. The high had moved too far east.

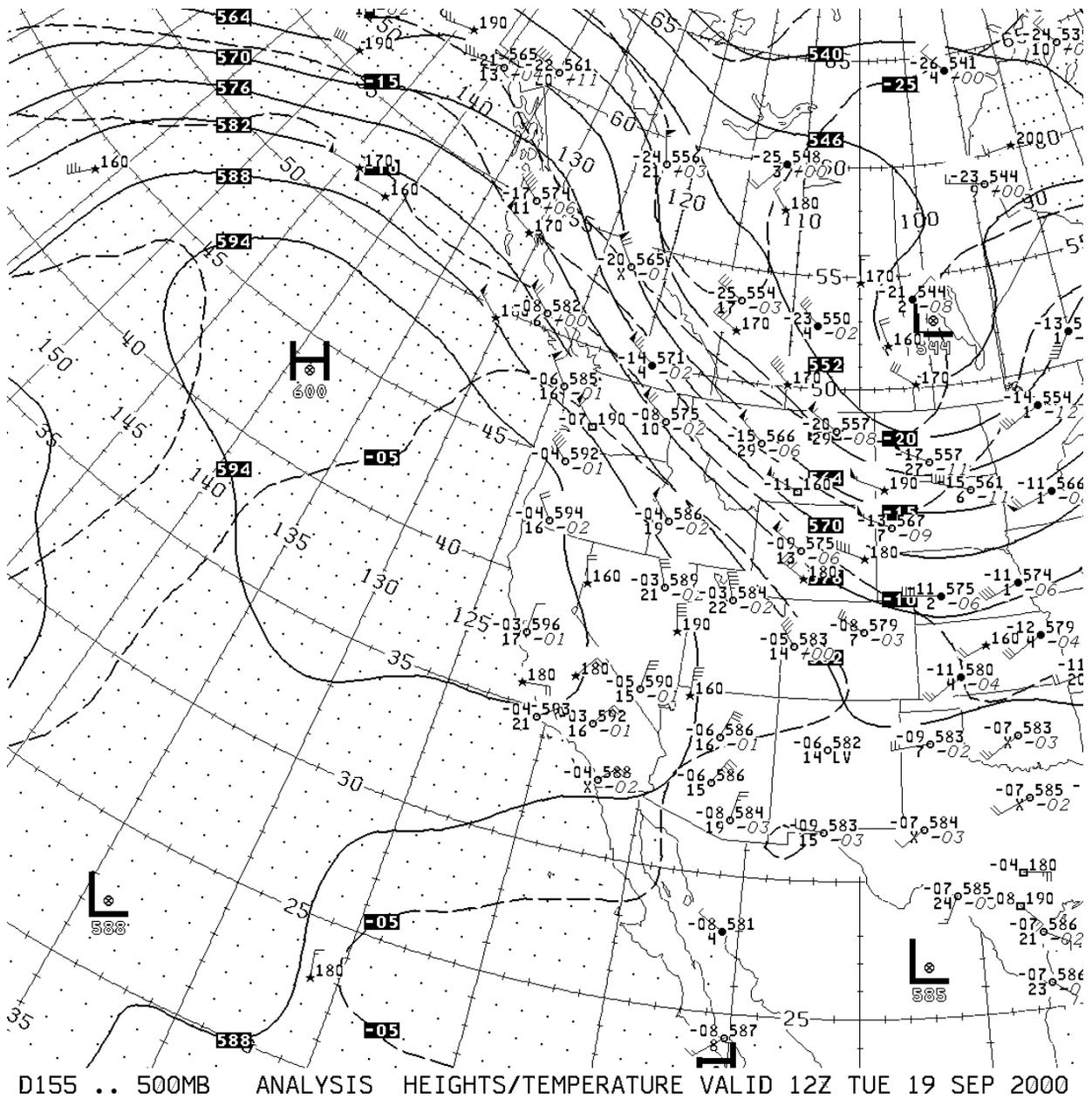


Figure 8-5. Western U.S. 500mb analysis from 0400 PST on September 19, 2000 during IOP#5. The Eastern Pacific High brought favorable conditions for ozone formation to the study region. Bay Area ozone was low despite the favorable offshore gradients on September 18 and 19.

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