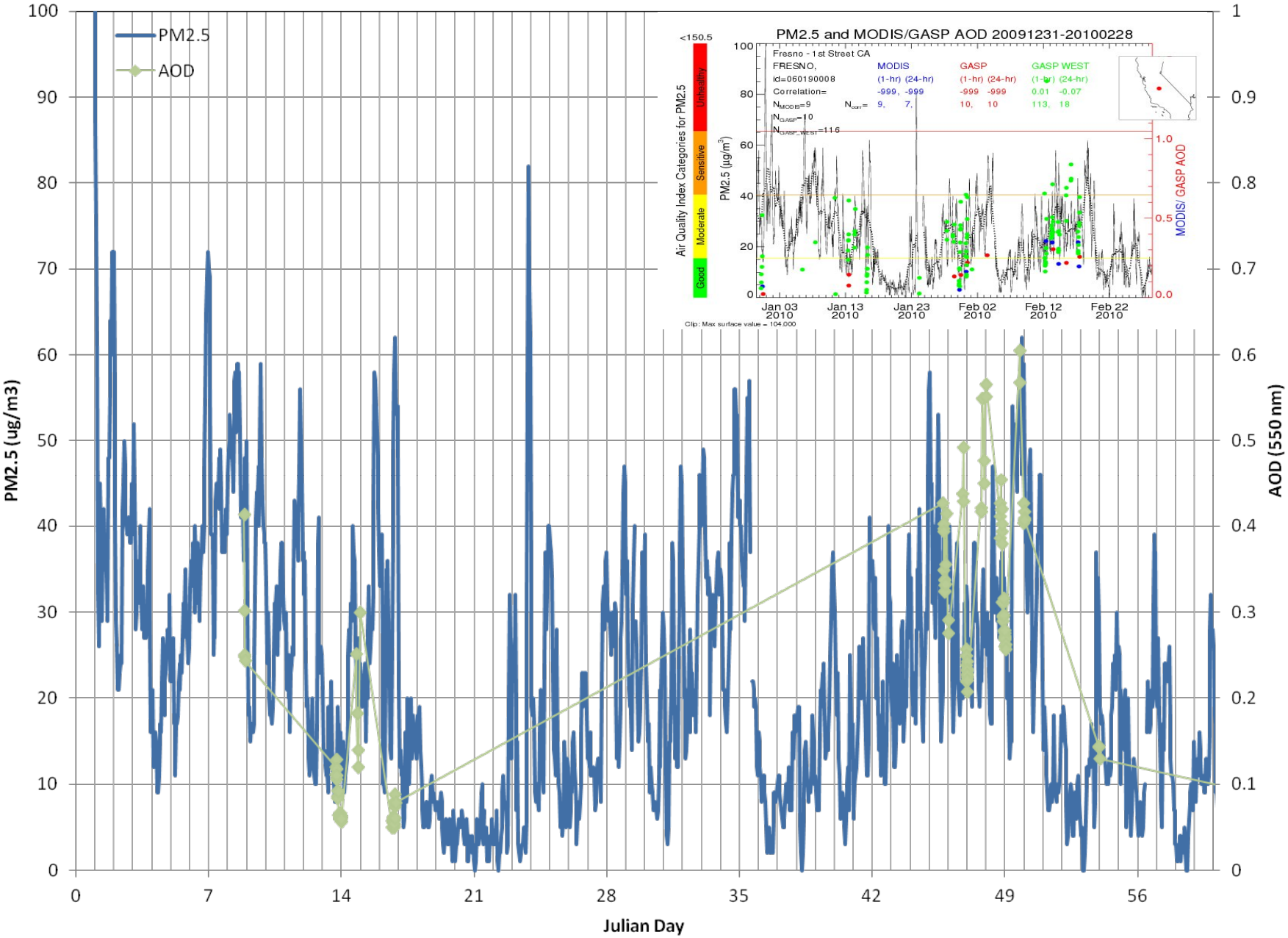
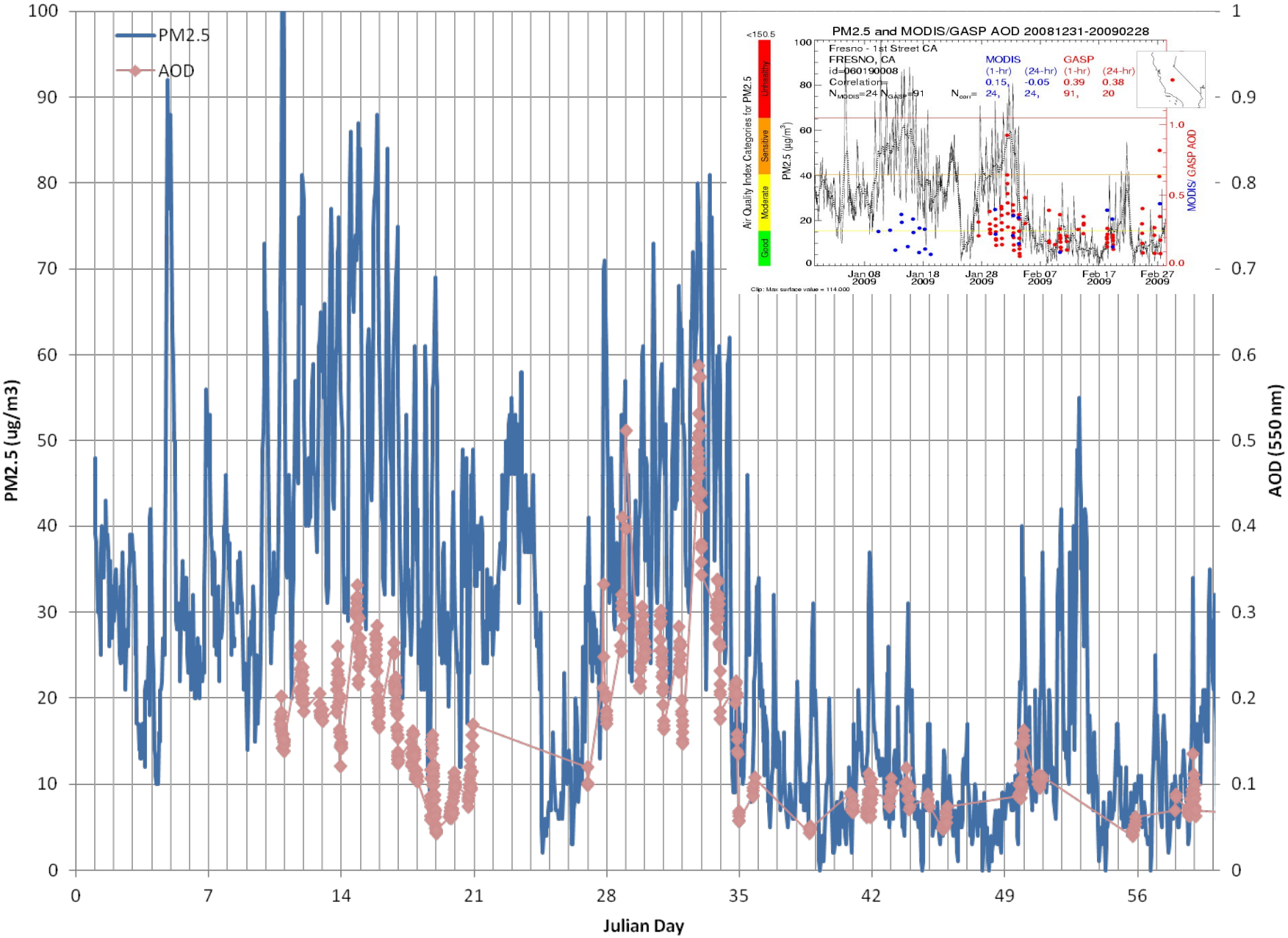
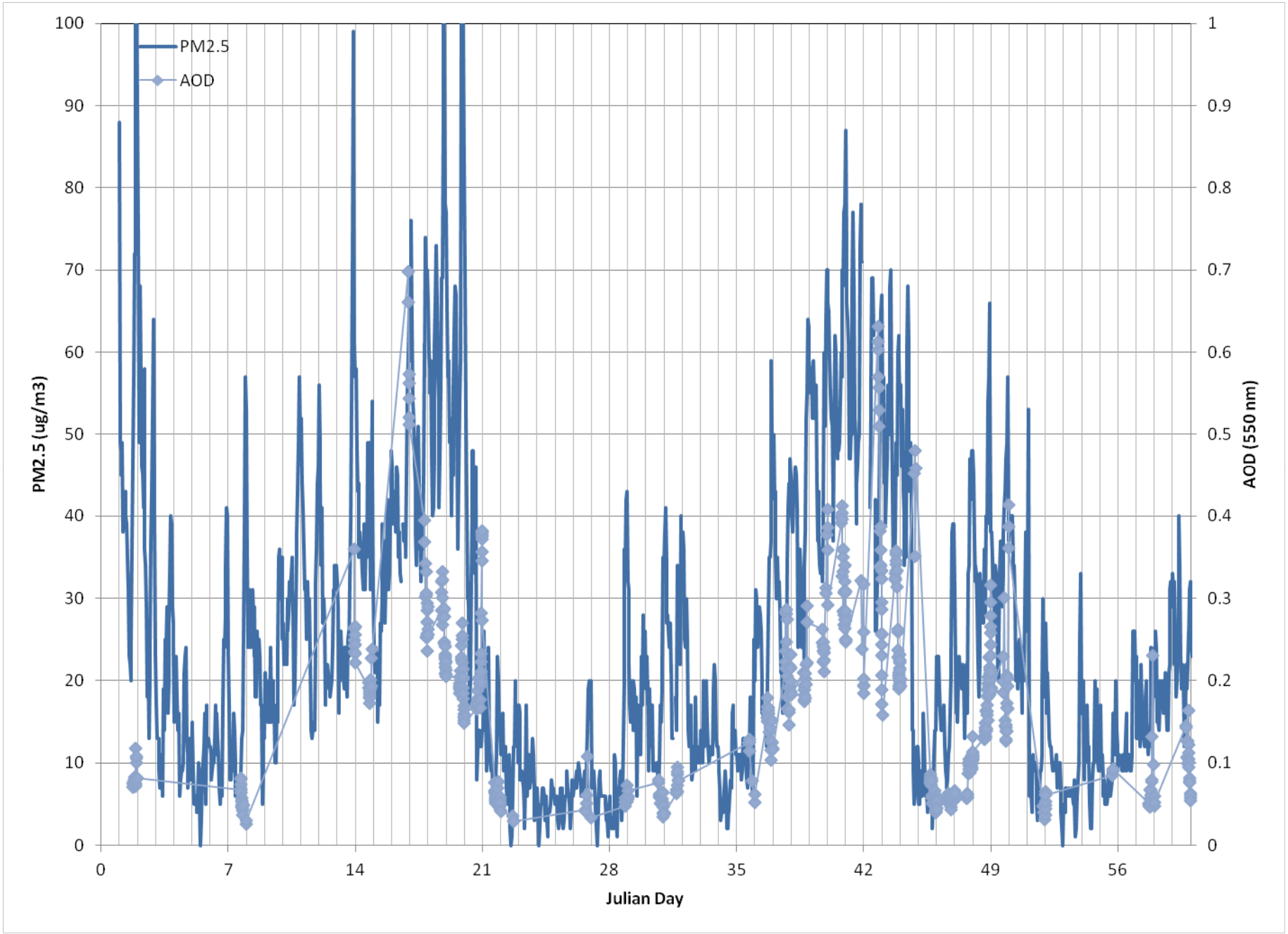
Fresno PM2.5 and Aeronet AOD, Jan-Feb 2010



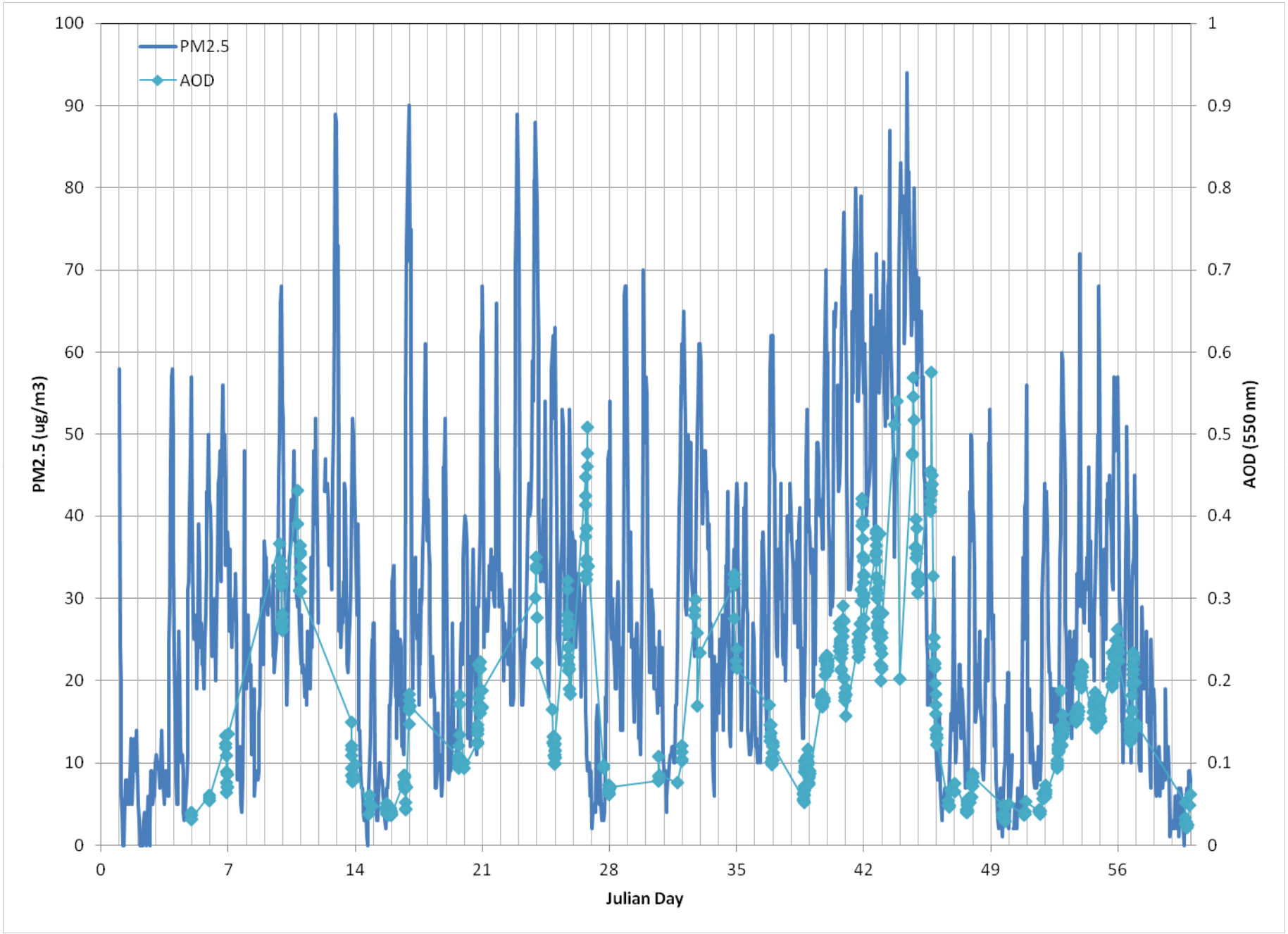
Fresno PM2.5 and Aeronet AOD, Jan-Feb 2009



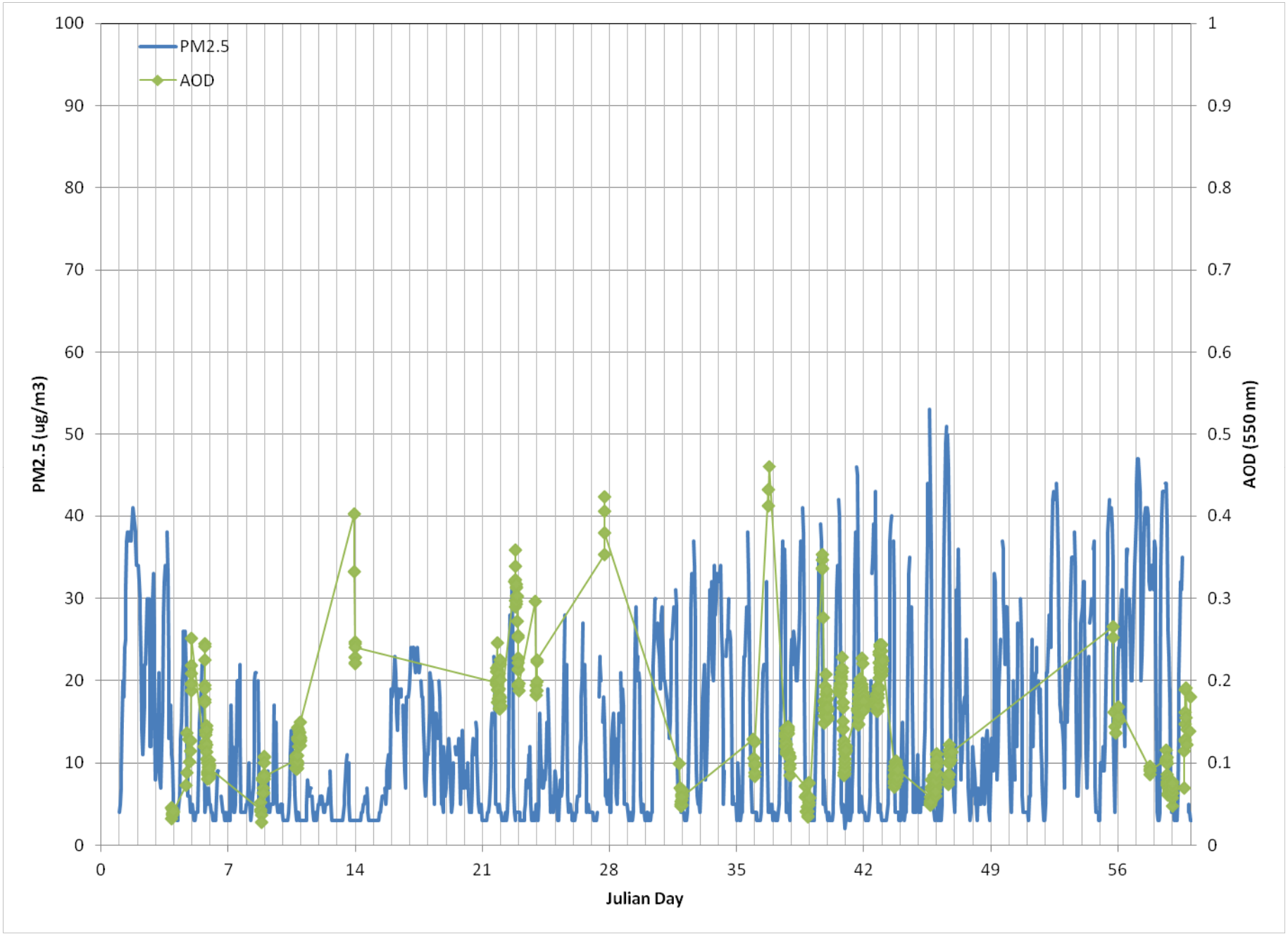
Fresno PM2.5 and Aeronet AOD, Jan-Feb 2008



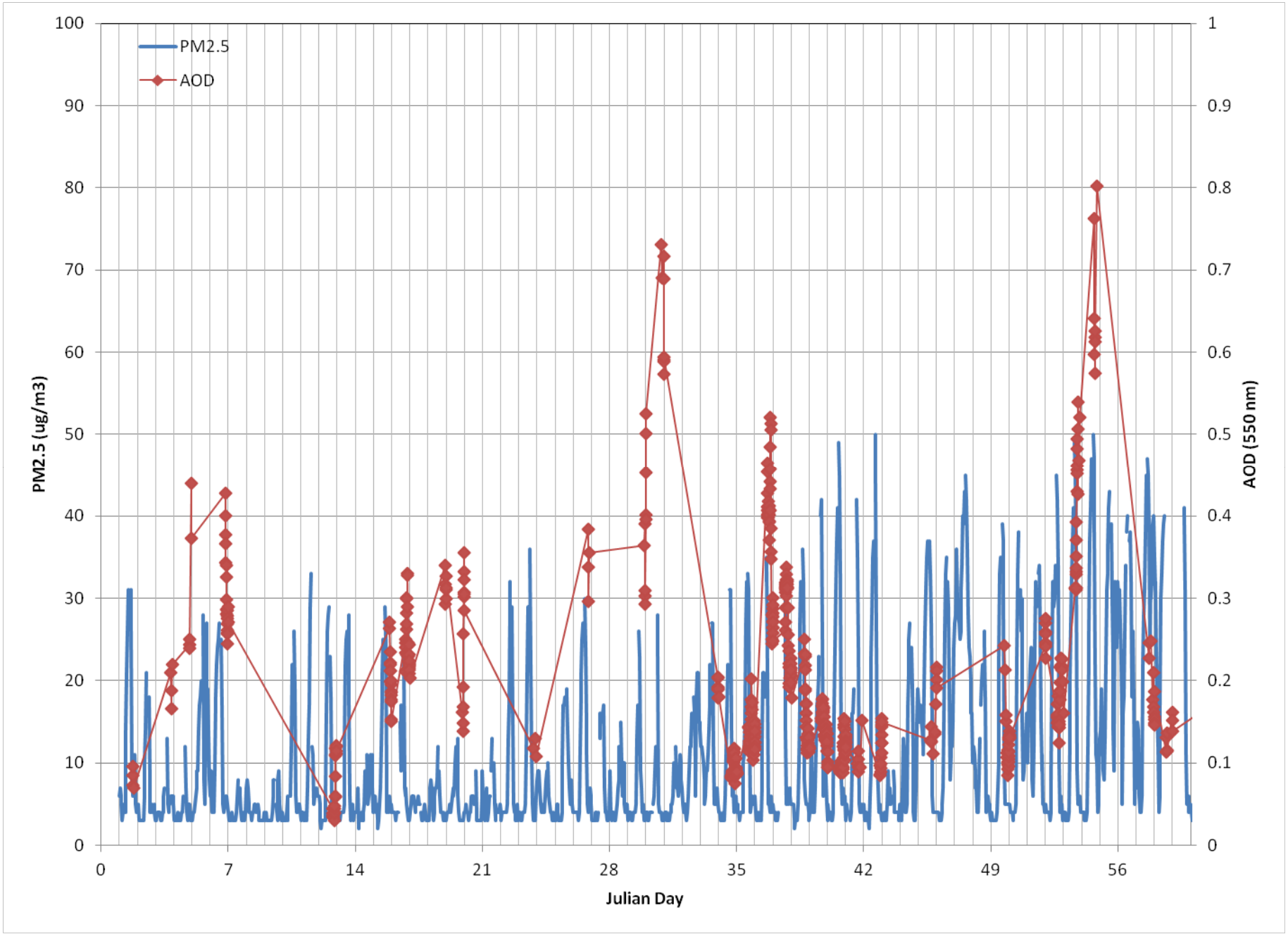
Fresno PM2.5 and Aeronet AOD, Jan-Feb 2006



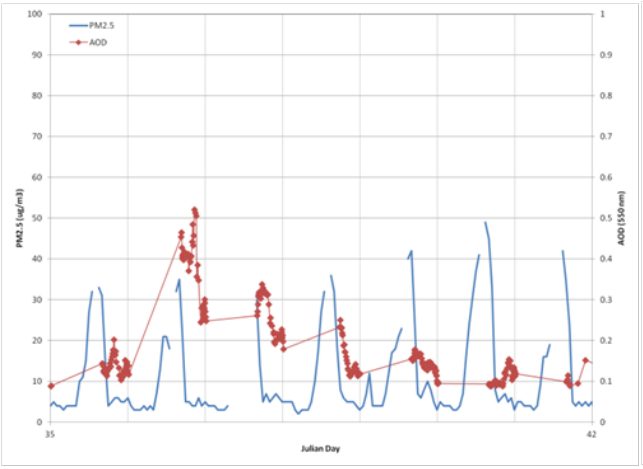
Fresno PM2.5 and Aeronet AOD, Jan-Feb 2004



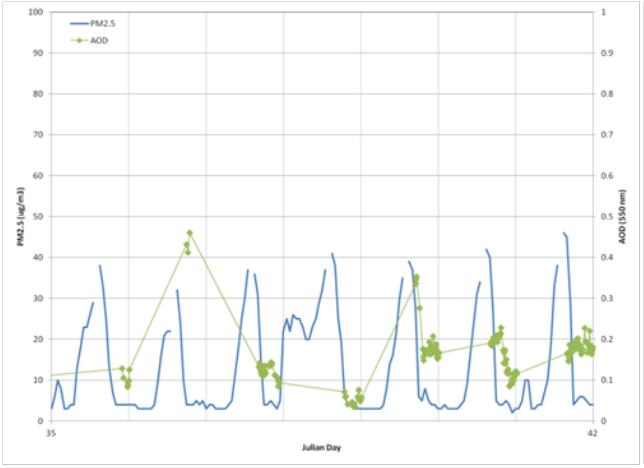
Fresno PM2.5 and Aeronet AOD, Jan-Feb 2003



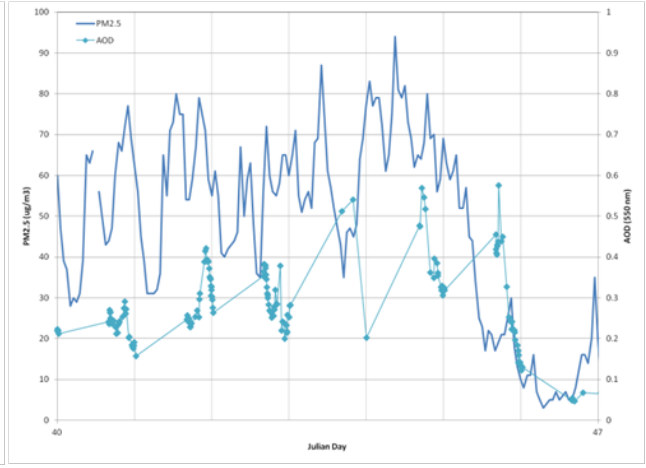
2003



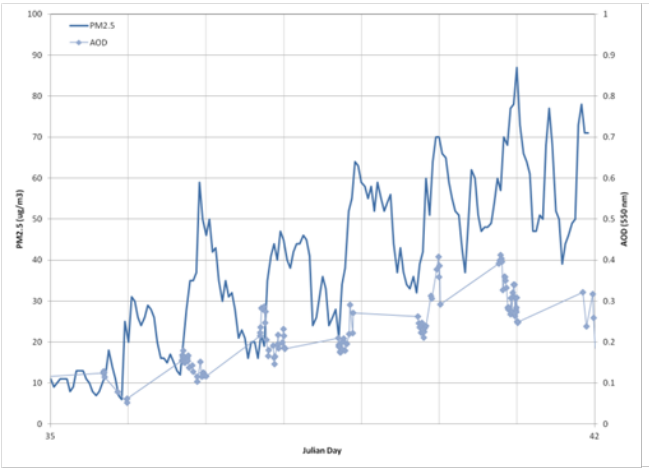
2004



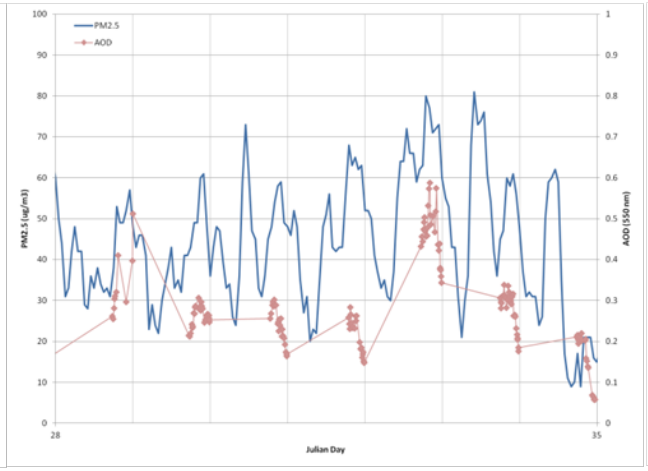
2006



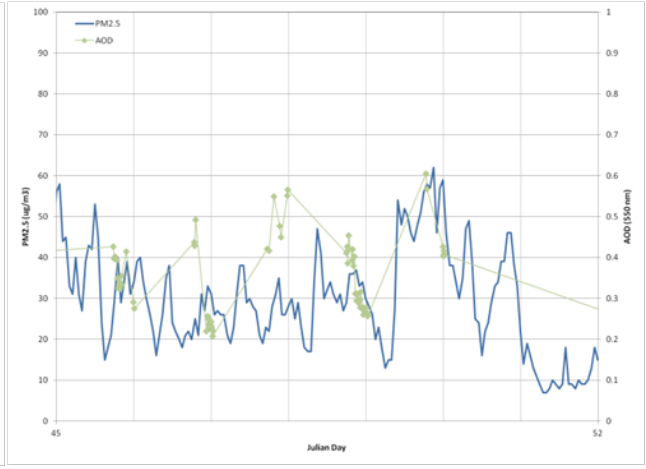
2008



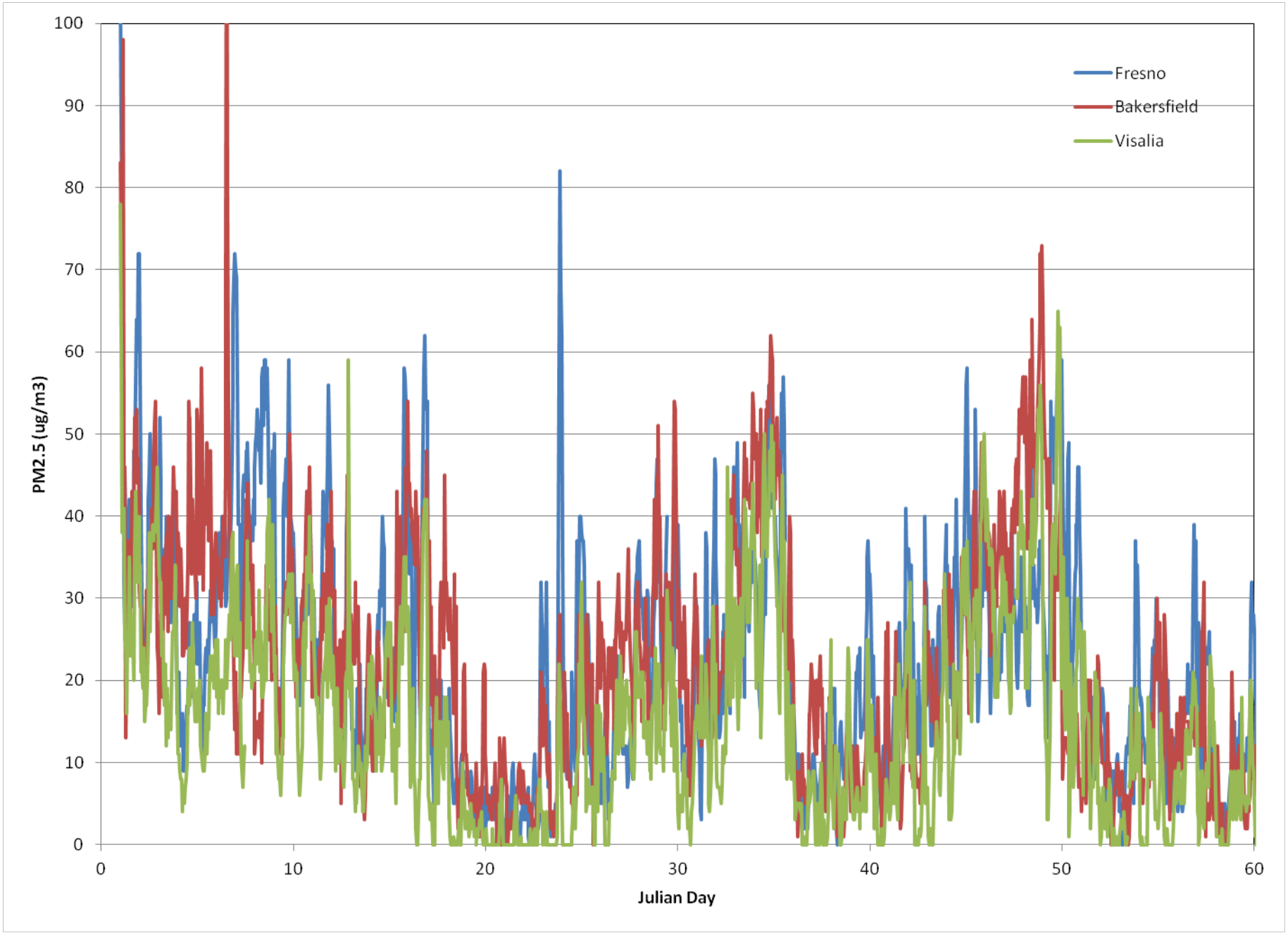
2009



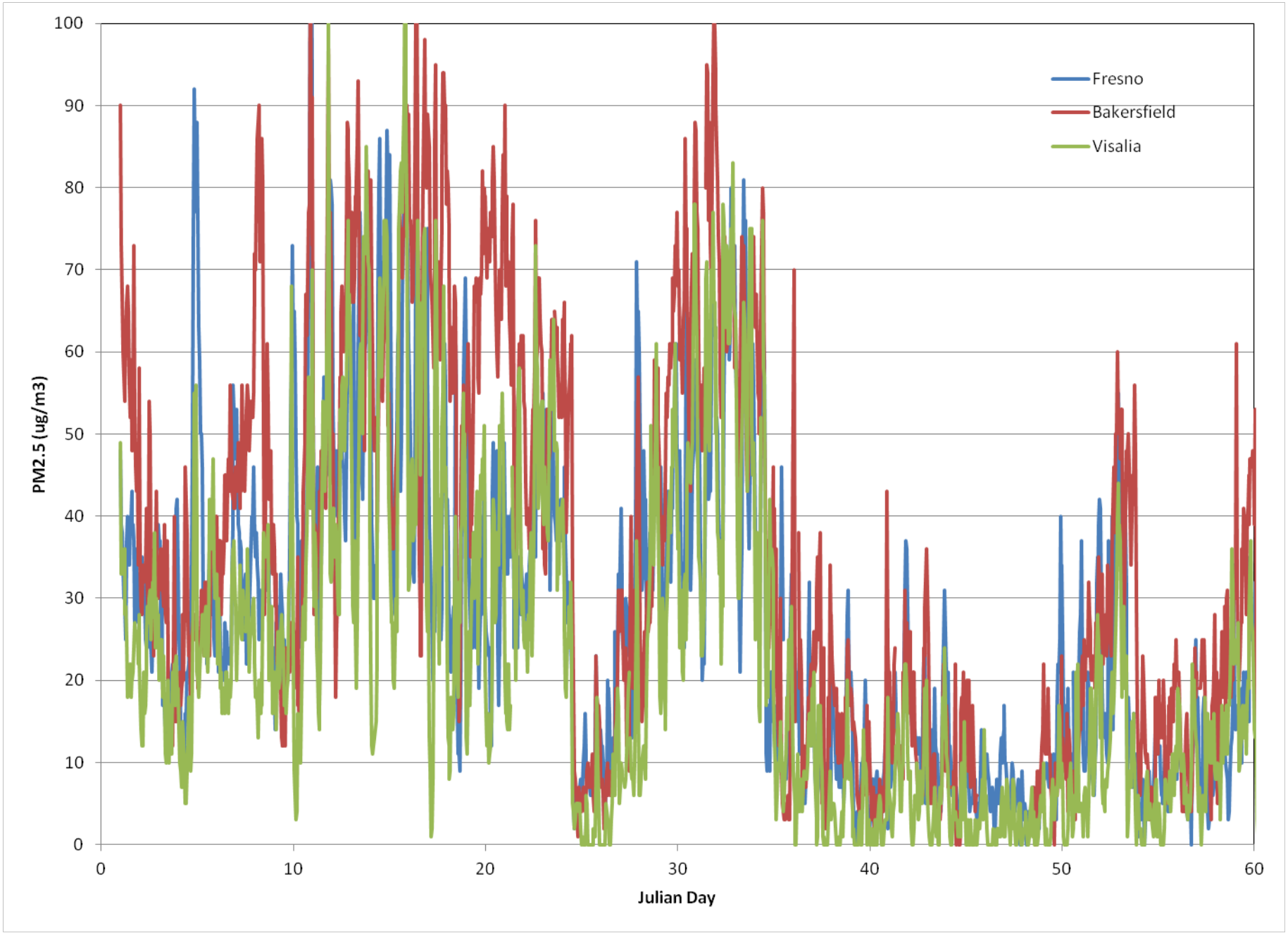
2010



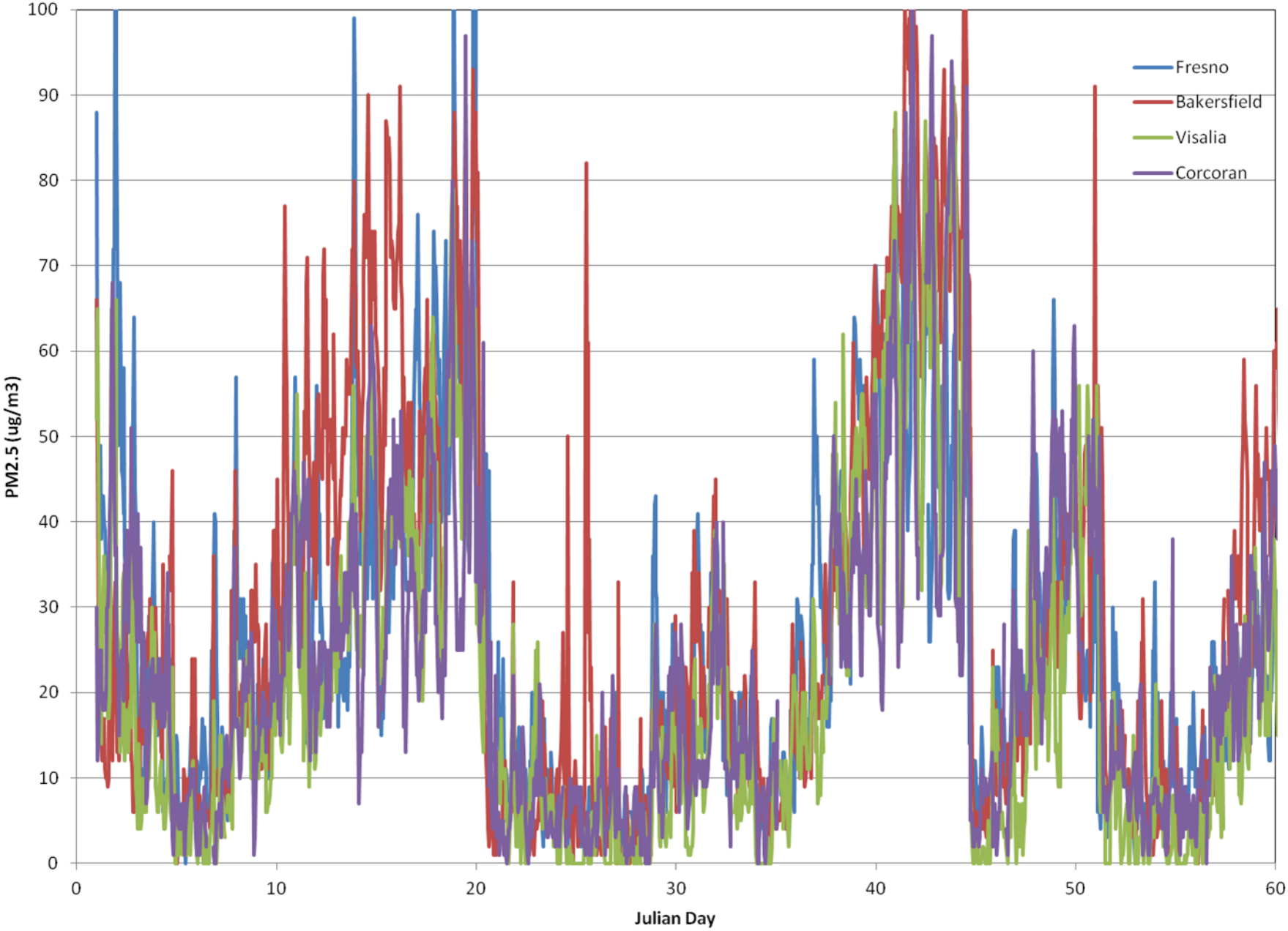
Southern San Joaquin PM2.5, Jan-Feb 2010



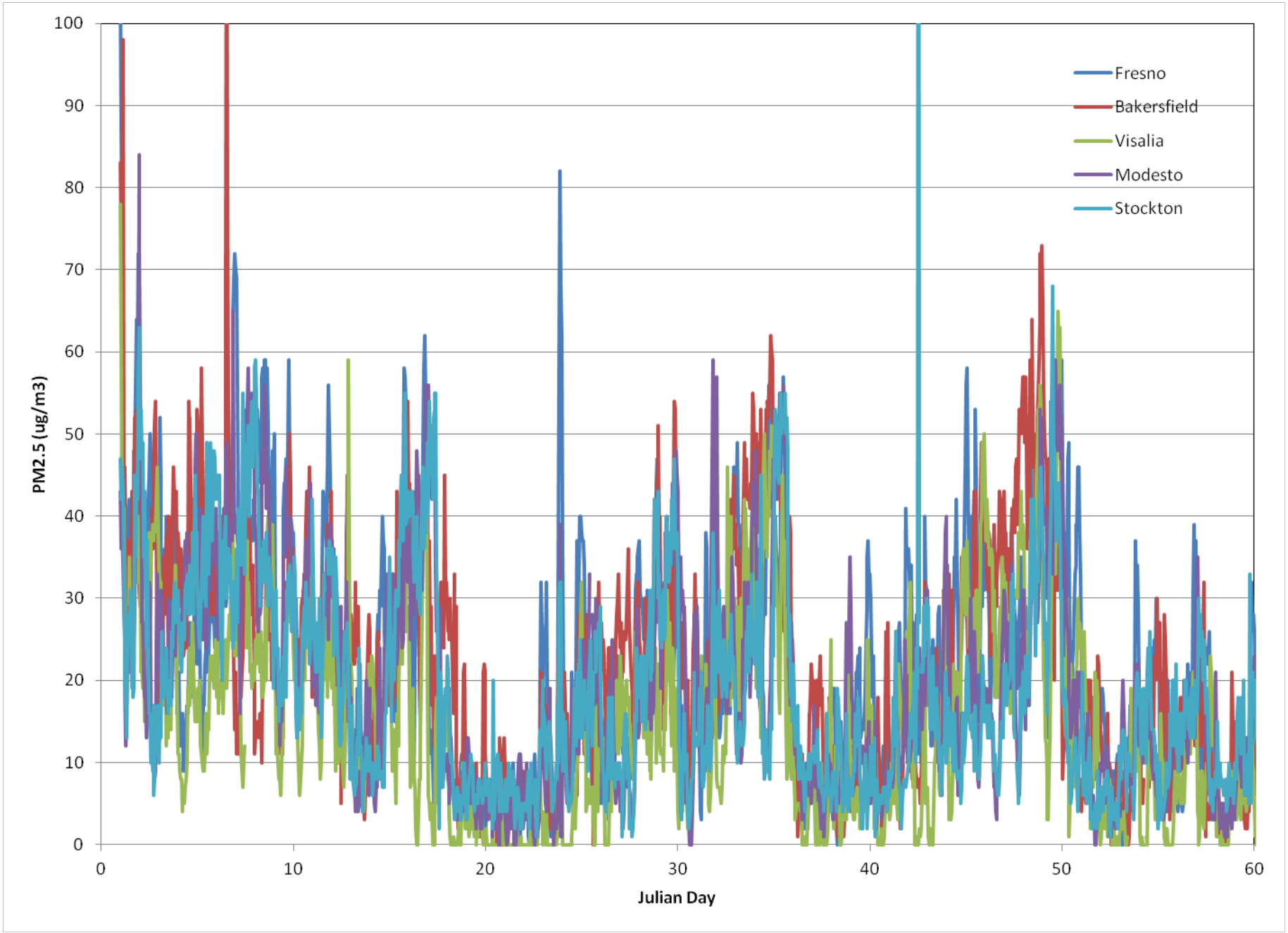
Southern San Joaquin PM2.5, Jan-Feb 2009



Southern San Joaquin PM2.5, Jan-Feb 2008



Southern San Joaquin PM2.5, Jan-Feb 2010



California Central Valley
Fog Statistics

Sacramento, CA

AVERAGE SUNSHINE, CLOUDINESS AND FOG
(January 1948 - August 2010)

	SUNSHINE	SKY COVER (Sunrise-Sunset)				DENSE FOG#		
			NUMBER OF DAYS WITH:					
Month	Percent Possible	Sky Cover#	Clear	Partly Cloudy	Cloudy	Monthly Mean	Record	Year
January	48%	5.7	6.5	5.9	18.7	10.2	23	1961
February	65%	5.0	7.6	7.0	13.6	4.6	13	1963**
March	74%	4.5	9.9	8.7	12.4	1.7	6	1986
April	82%	3.8	11.9	9.6	8.4	0.3	2	1965**
May	90%	2.9	16.9	8.6	5.5	0.1	2	1971
June	94%	1.8	21.7	5.9	2.4	0.0	0	----
July	97%	0.9	26.9	3.2	1.0	0.0	0	----
August	96%	1.1	25.1	4.1	1.3	0.0	1	1966
September	93%	1.5	23.2	4.2	2.1	0.1	2	1963
October	86%	2.6	18.9	6.0	5.4	1.0	11	1962
November	66%	4.5	9.8	7.4	12.4	4.9	11	1982
December	49%	5.5	7.6	5.8	17.0	9.4	22	1989**
Annual	78%	3.3	186.0	76.4	100.2	32.3	64	1962

* Averages based on Climatological Normals 1971-2000
** Also occurred in previous years.
# sunrise to sunset

#**Dense fog** is when the visibility is restricted to 1/4 mile or less for at least part of the day. **Sky Cover** is expressed in fractions of eights, (since July 1996), in order to conform to international standards. A definition of "Clear", Partly Cloudy", and "Cloudy" is as follows:

Clear	0/8 to 2/8 sky cover
Partly Cloudy	3/8 to 6/8 sky cover
Cloudy	7/8 or 8/8 sky cover

Sacramento, CA

GREATEST NUMBER OF CONSECUTIVE DAYS WITH DENSE FOG# WITH MONTH AND YEAR OF OCCURRENCE

(November 1949 - August 2010) Only periods with 8 or more days are tabulated.

Days	Period	Year	Days	Period	Year
17	December 12-28	1985	9	January 12-20	1965
14	December 23 - January 5	2000-01	9	January 17-25	1961
13	January 13-25	1975	9	Novenber 25-December 3	1949
12	December 9-20	2004	9	February 3-11	1954
11	December 3-13	1962	8	February 3-10	1991
10	December 2-11	1977	8	December 23-30	1989
10	December 27 - January 5	1962-63	8	January 29-February 5	1962
9	December 23-31	2000	8	December 14-21	1956
9	January 6-14	1986	8	December 14-21	1954
9	February 6-14	1971			

Sacramento, CA

GREATEST NUMBER OF NON-CONSECUTIVE DAYS WITH DENSE FOG# WITH MONTH AND YEAR OF OCCURRENCE

(November 1949 - August 2010) (Only periods with 14 or more days are tabulated).

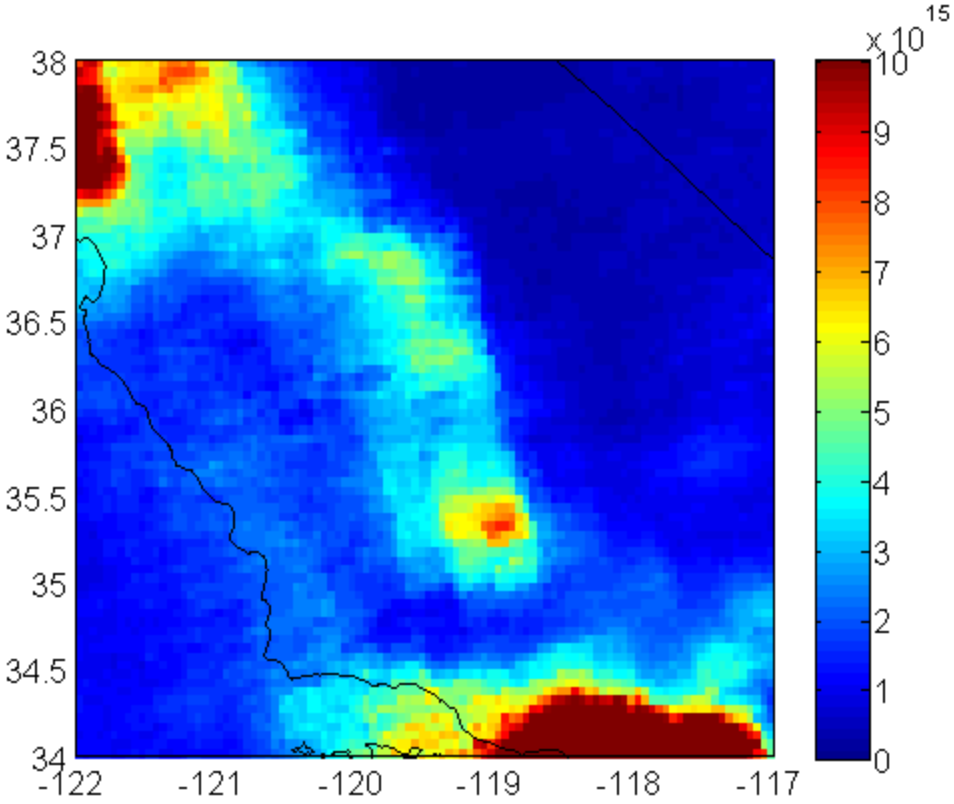
Days	Period	Days	Period	Days	Monthly Avg*
				10.2	January
23	January 1961	16	January 1955	4.6	February
22	December 1989	15	January 1975	1.7	March
22	December 1985	15	January 1972	.3	April
20	December 2000	15	January 1965	.1	May
20	December 1962	14	December 1986	0	June
19	December 1963	14	January 1986	0	July
19	January 1958	14	January 1983	0	August
18	January 1985	14	January 1964	.1	September
17	January 2003	14	January 1963	1.0	October
16	December 2004	14	January 1962	4.9	November
16	December 1977			9.4	December
				32.3	Annual

Daily Dense Fog Events
NCDC Archive
Stockton, Fresno, Bakersfield
California

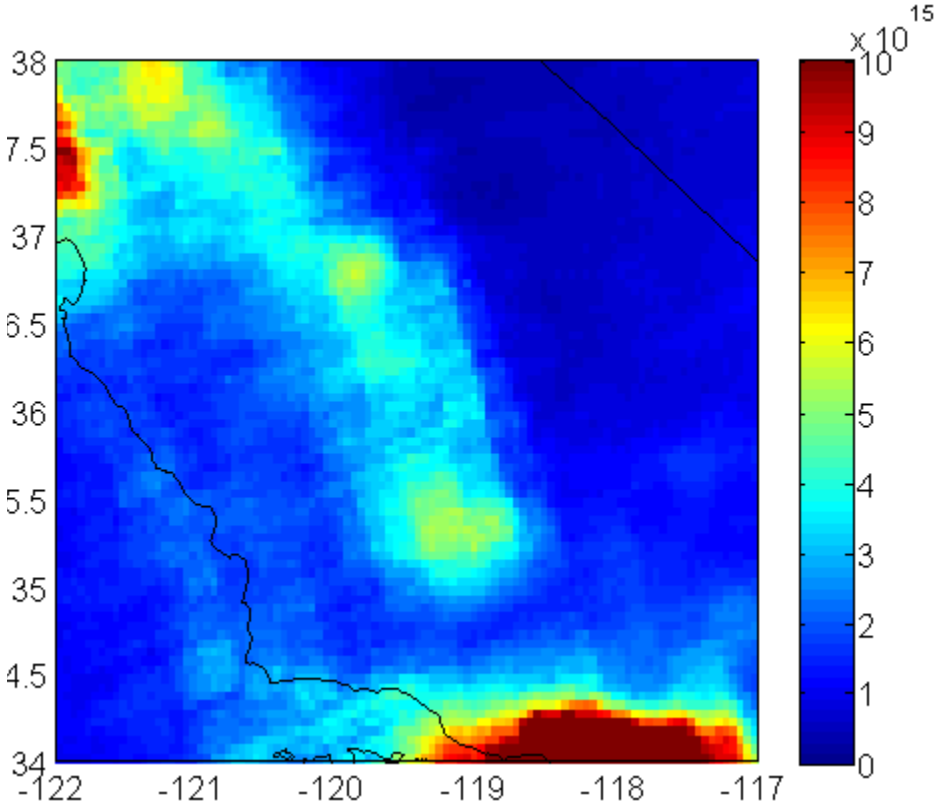
(dense fog = visibility ≤ 0.25 mi)

Average over Years 2000-2011

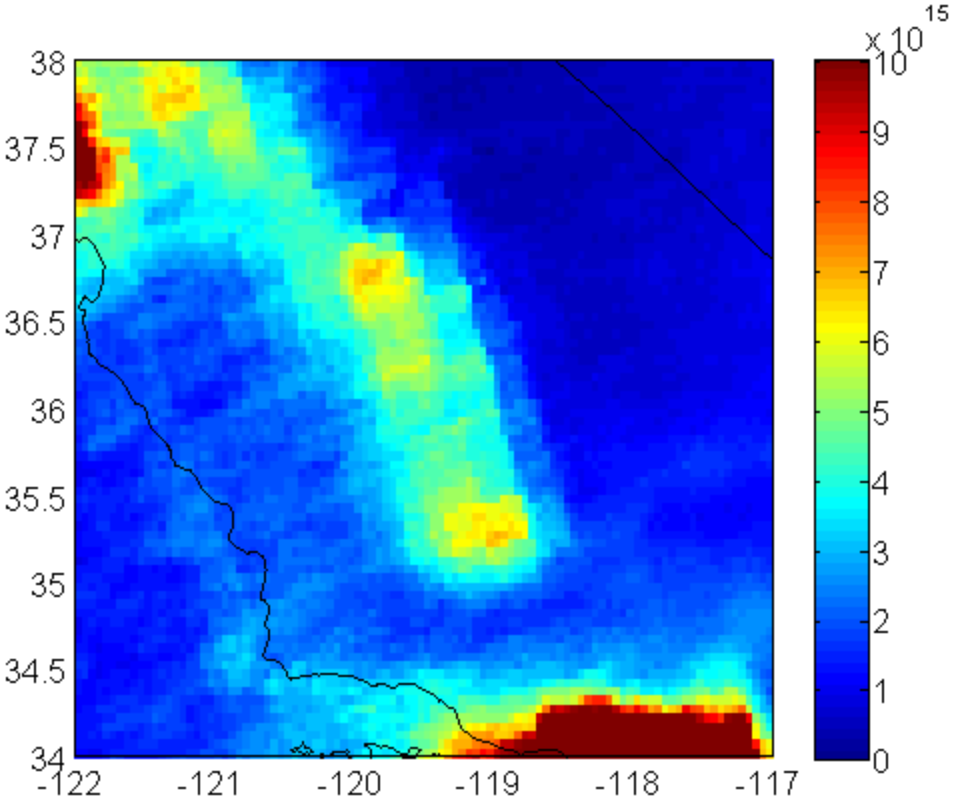
	January (days/month)	February (days/month)
Bakersfield	7.583 (± 4.870)	1.182 (± 0.874)
Fresno	8.833 (± 5.424)	2.727 (± 2.102)
Stockton	7.5 (± 6.289)	4.182 (± 3.737)



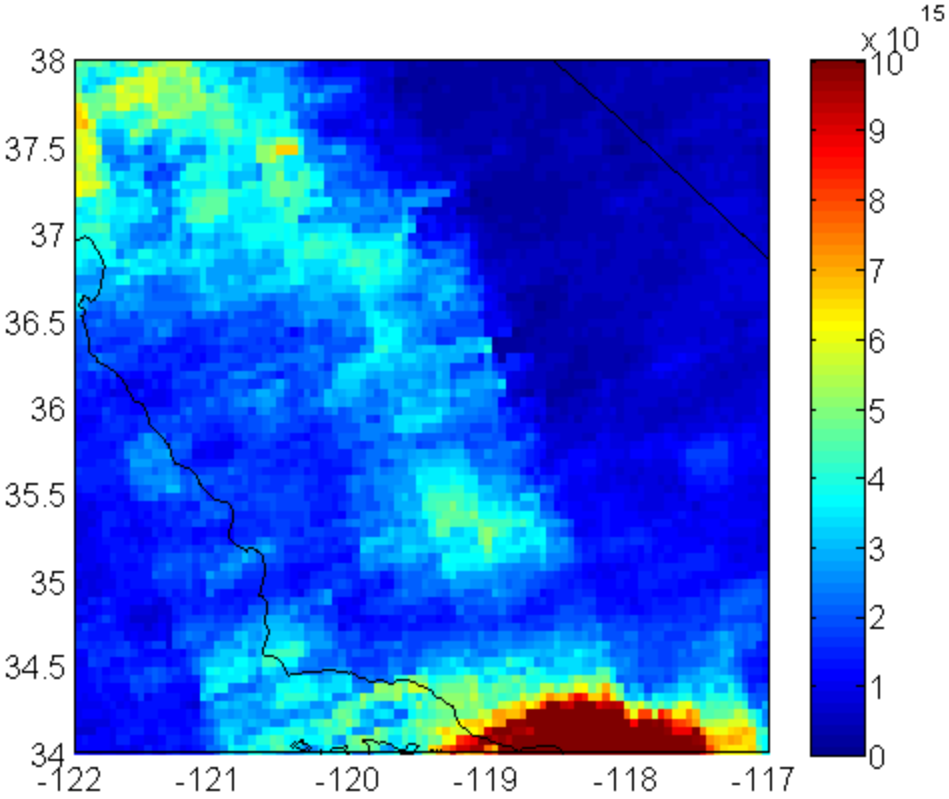
Jan-Feb 2005



Jan-Feb 2011



Jan-Feb 2010-2011
Weekdays

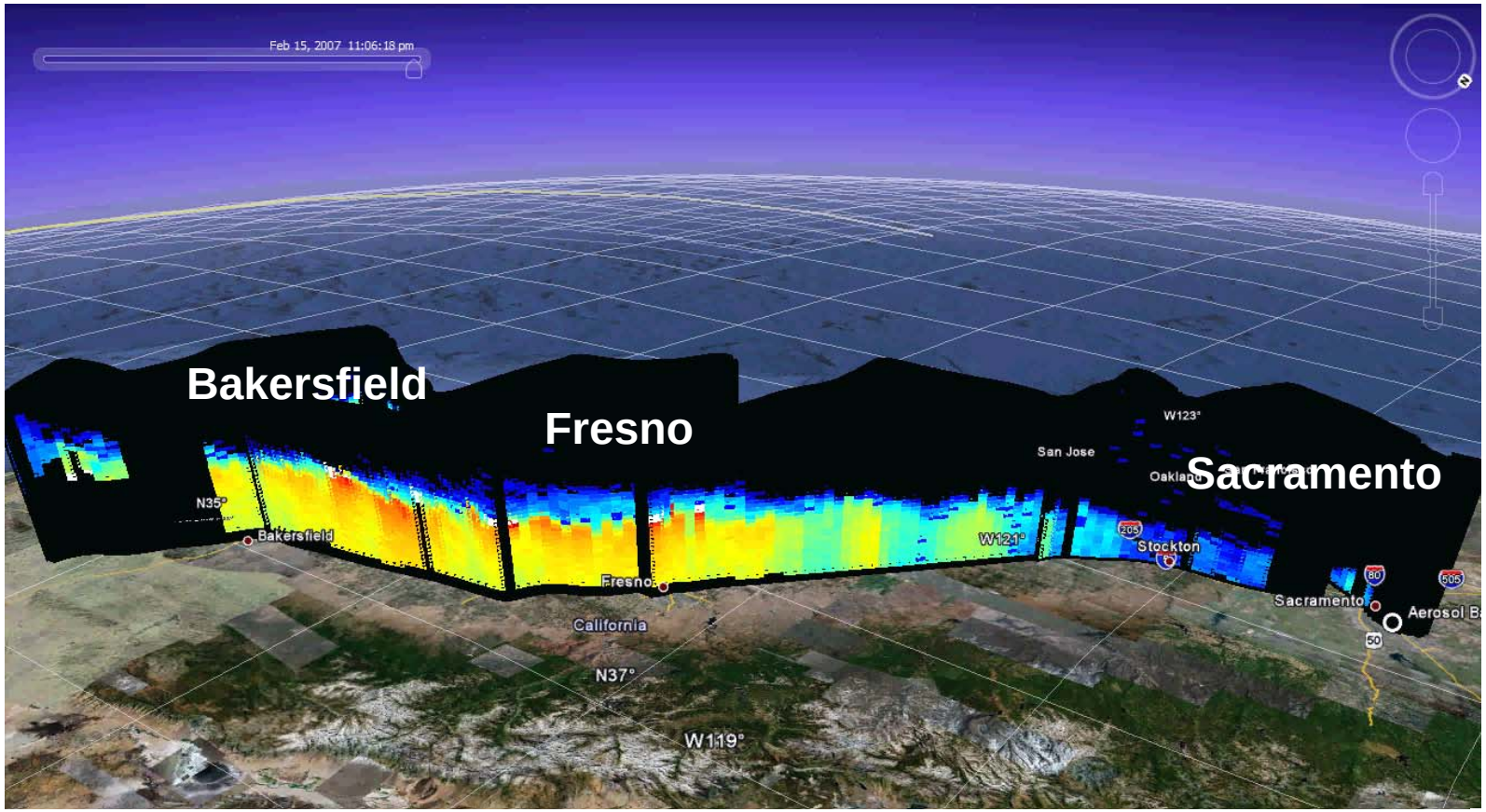


Jan-Feb 2010-2011
Weekends

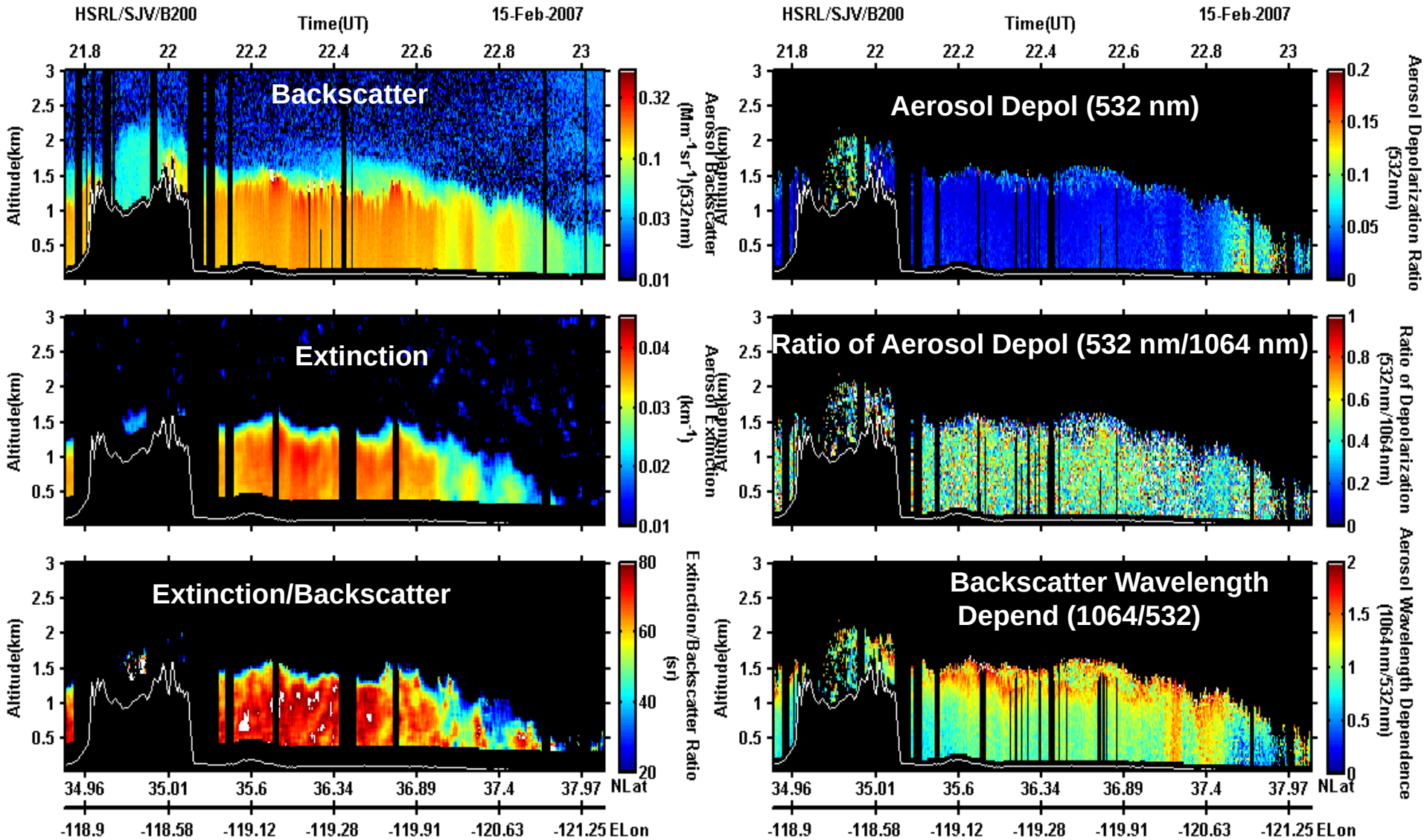
Past California ~~Air Quality~~ Observations by HSRL

NASA Langley Airborne HSRL Aerosol Backscatter Profiles Acquired on February 15, 2007 During Flight over San Joaquan Valley (SJV)

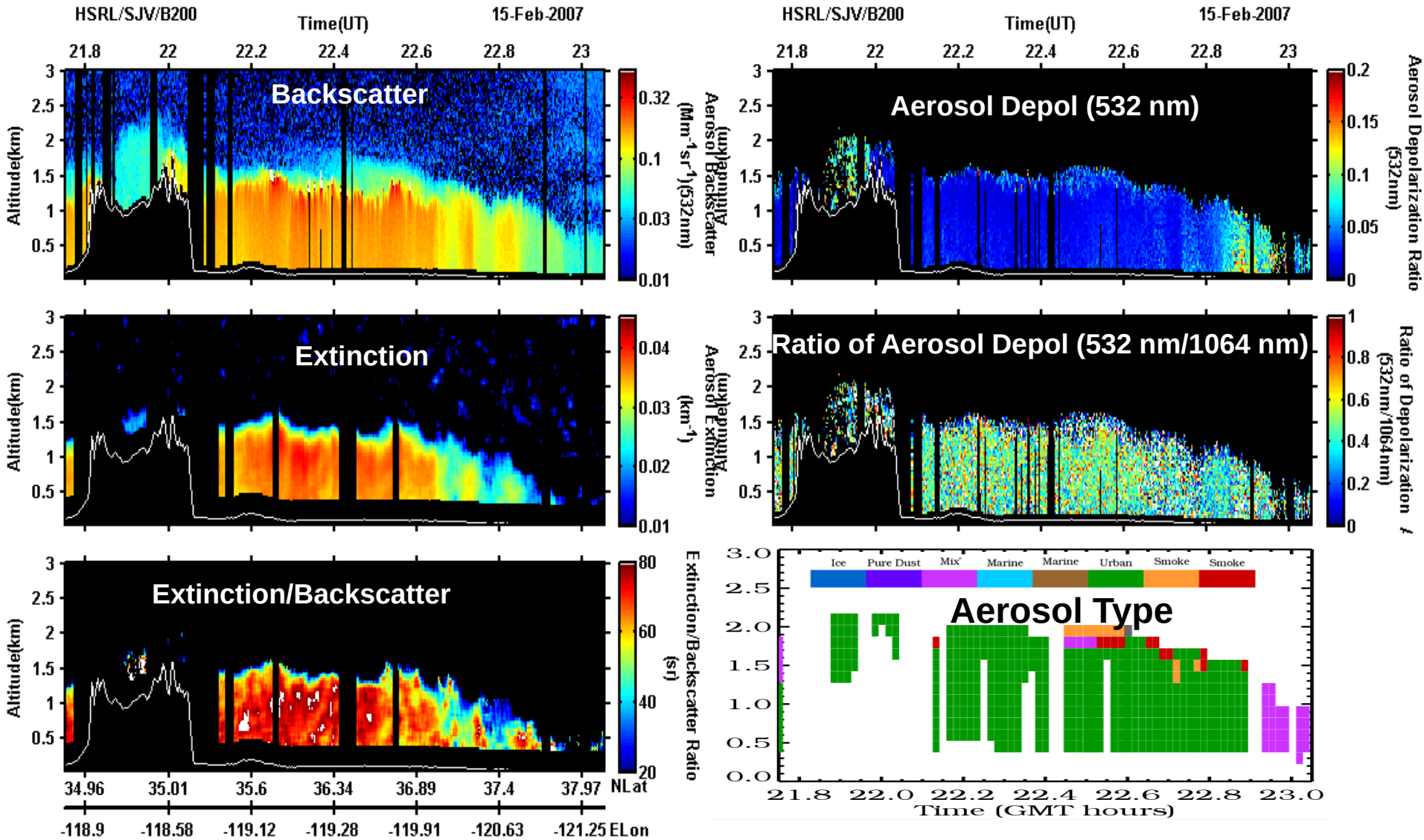
- Airborne HSRL aerosol backscatter measurements Feb. 15, 2007
- Highest AOT and PBL heights between Bakersfield and Fresno
- Low aerosol backscatter, extinction, AOT and PBL height in Sacramento region



NASA Langley Airborne HSRL Aerosol Backscatter Profiles Acquired on February 15, 2007 During Flight over San Joaquan Valley (SJV)

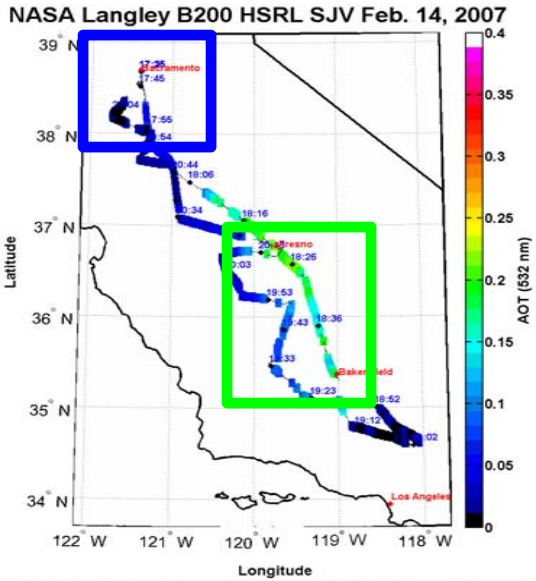


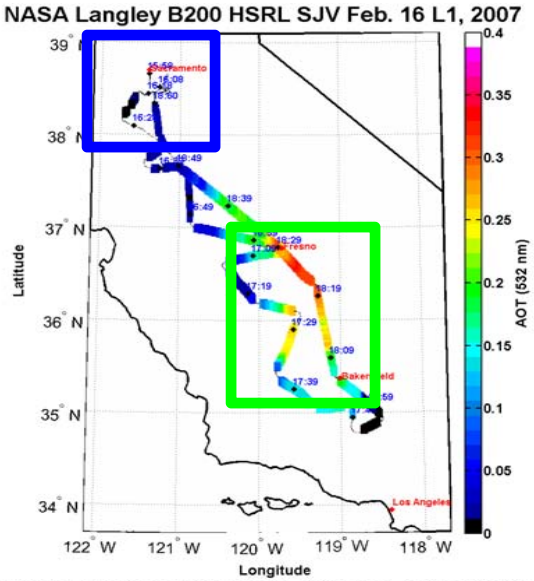
NASA Langley Airborne HSRL Aerosol Backscatter Profiles Acquired on February 15, 2007 During Flight over San Joaquan Valley (SJV)

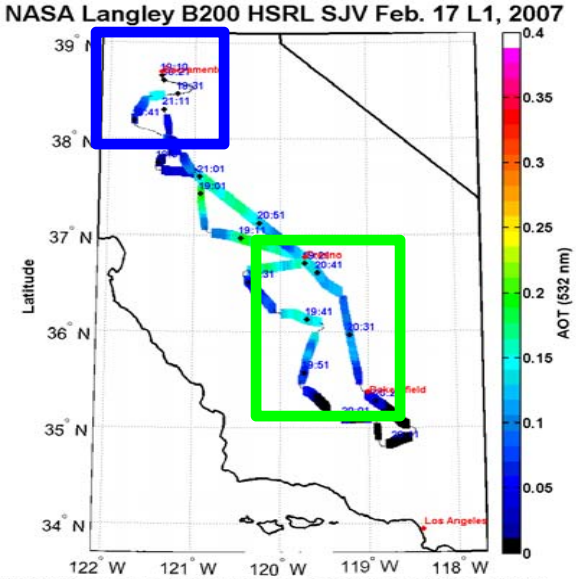


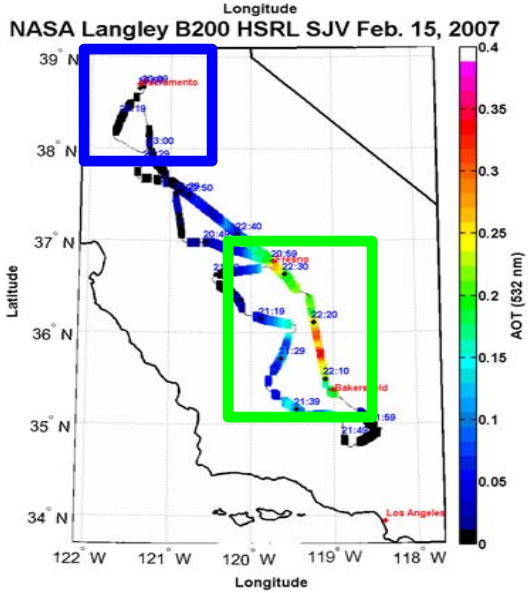
NASA Langley Airborne HSRL Aerosol Optical Thickness (AOT) Acquired on Several Flights During February 2007 over SJV

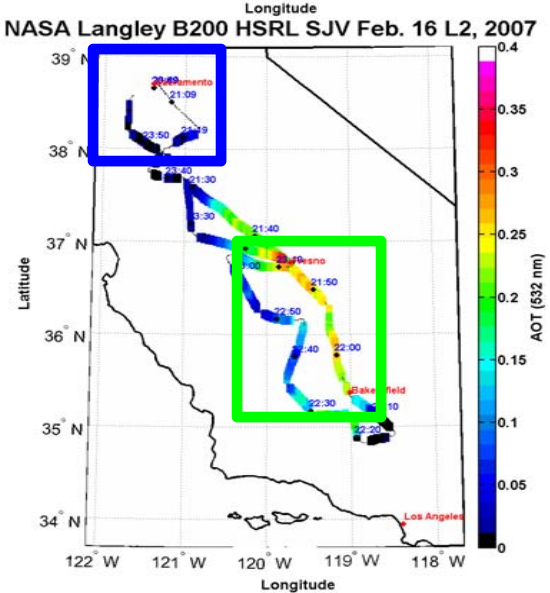
Highest AOT in SJV region; little AOT observed over or near Sacramento

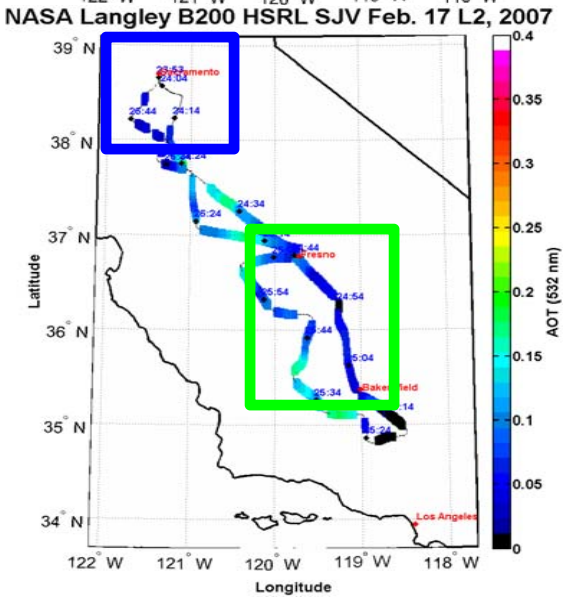




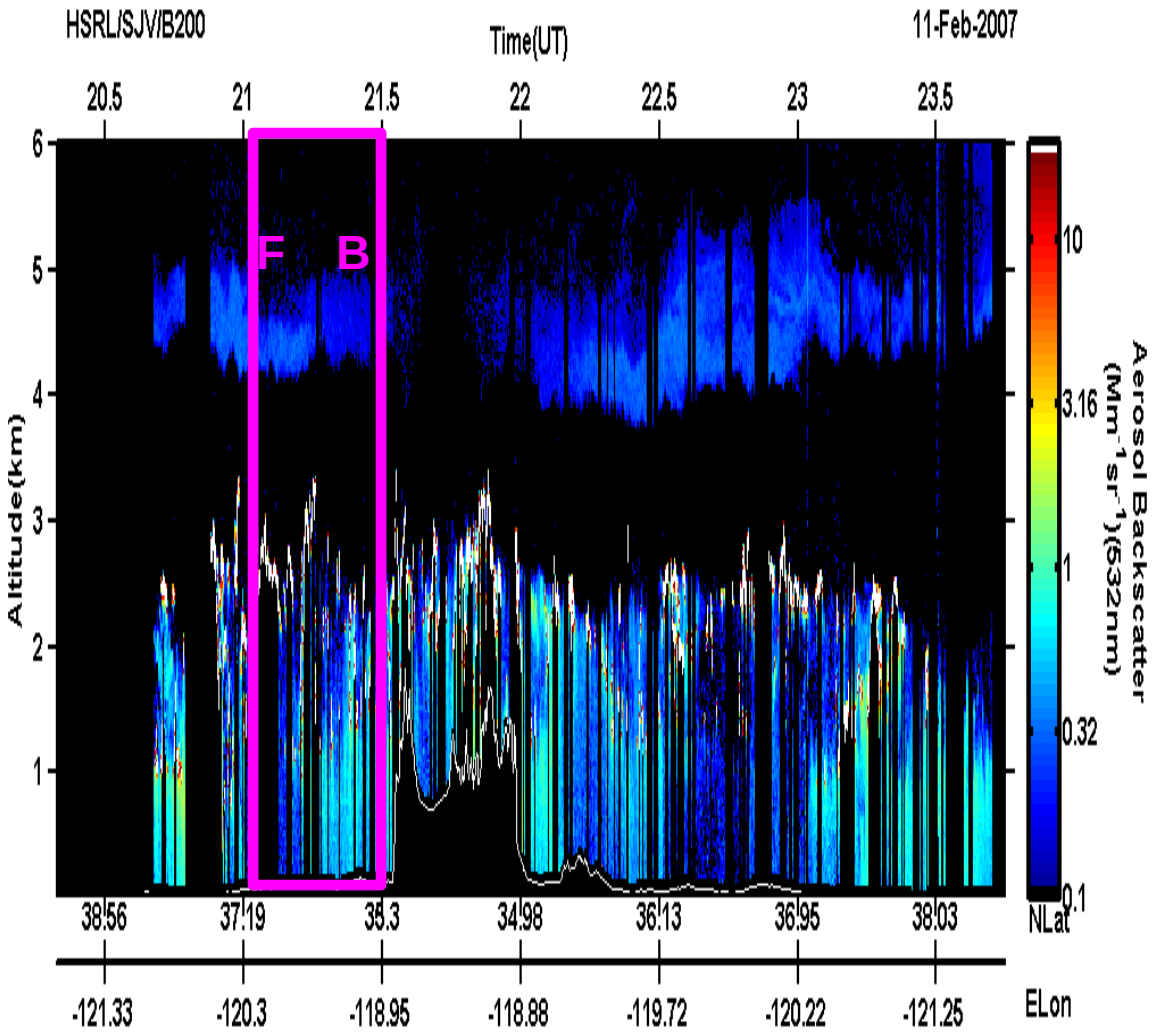


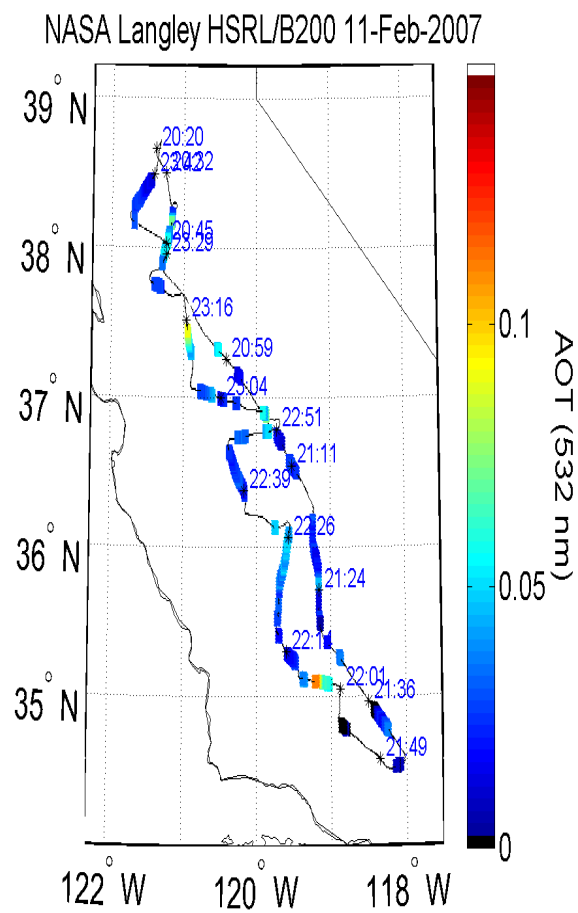




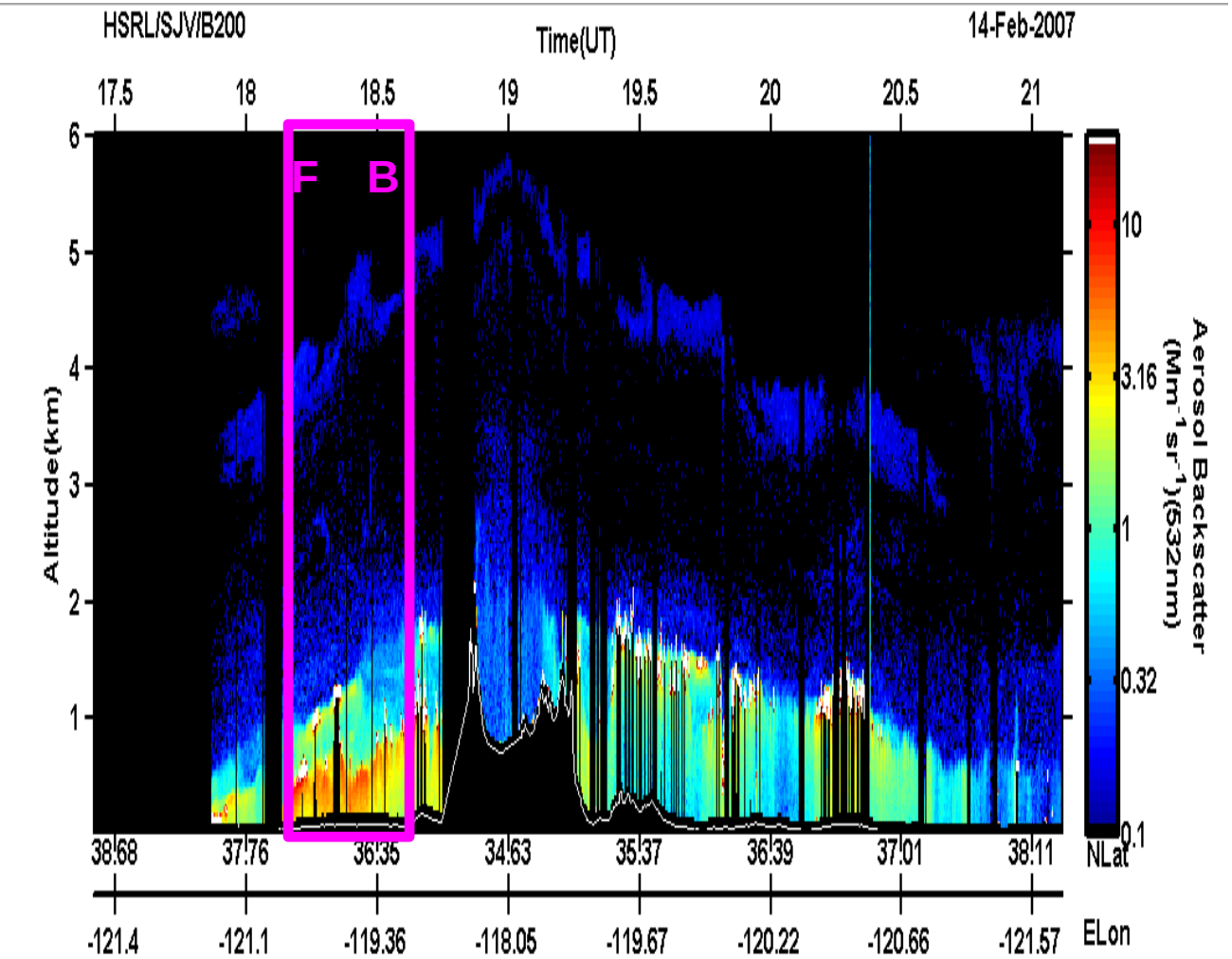


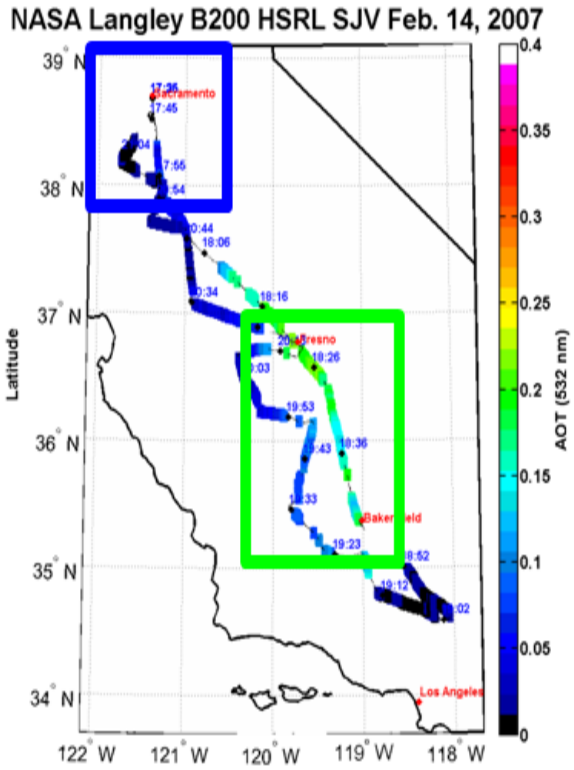
February 11, 2007 L1



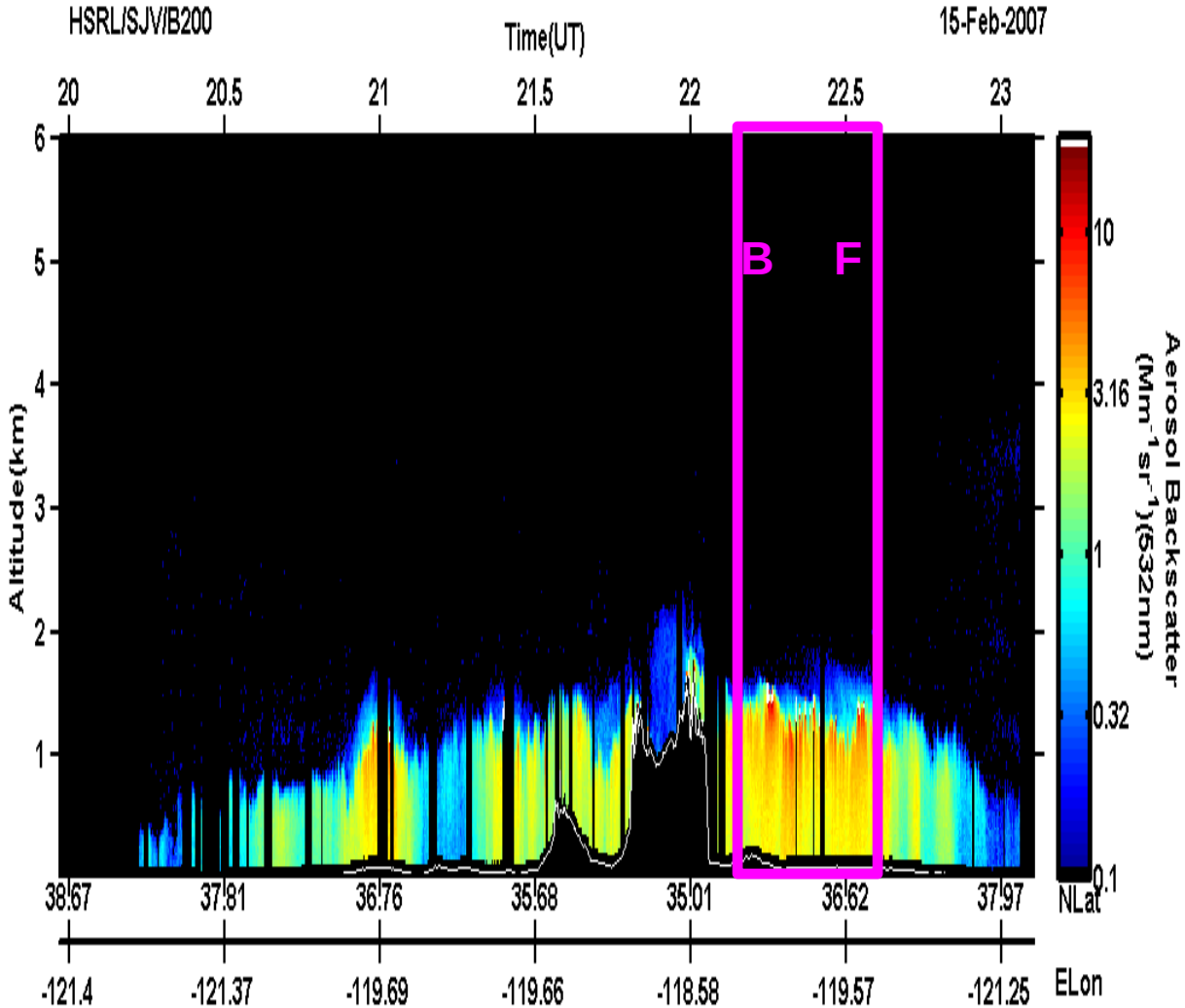


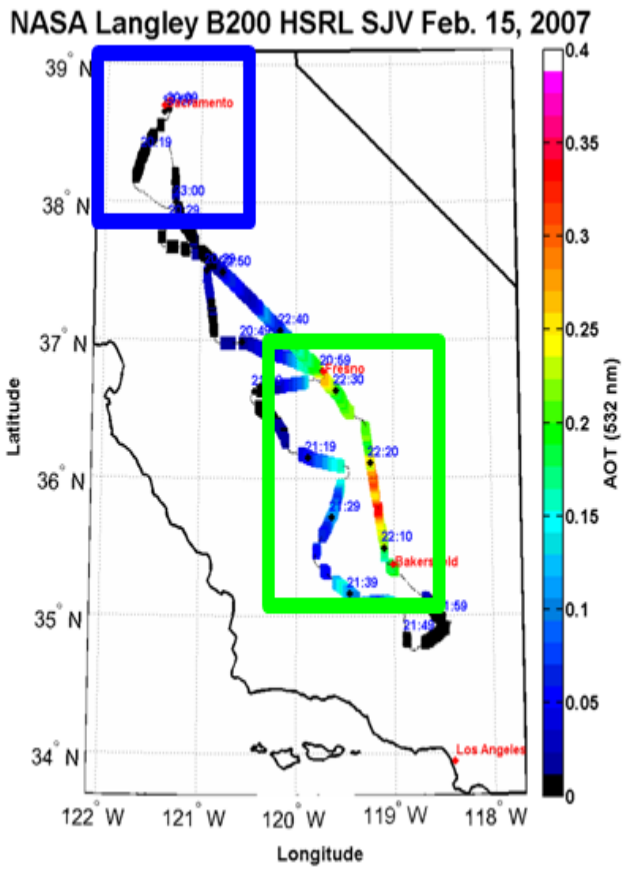
February 14, 2007 L1



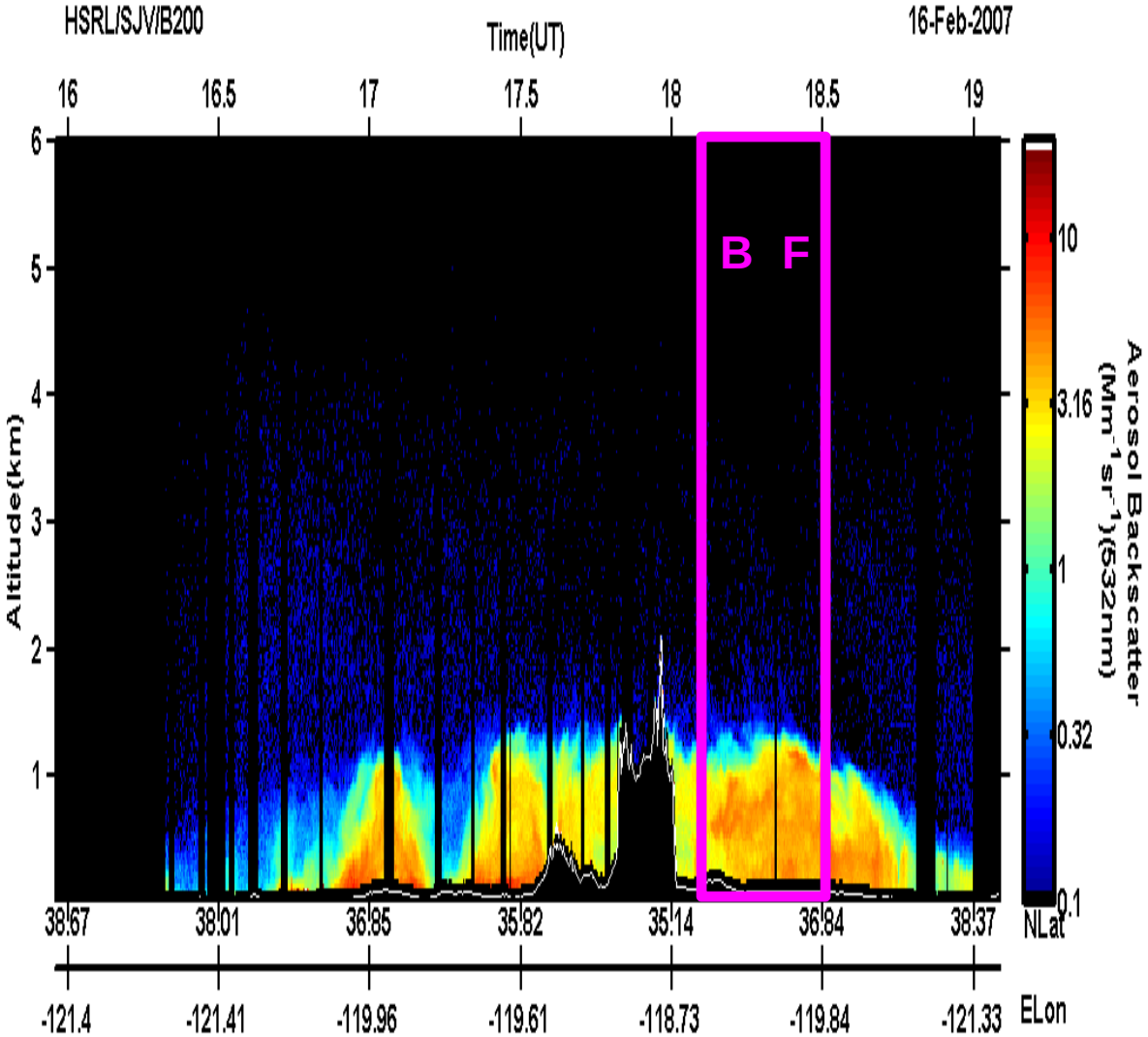


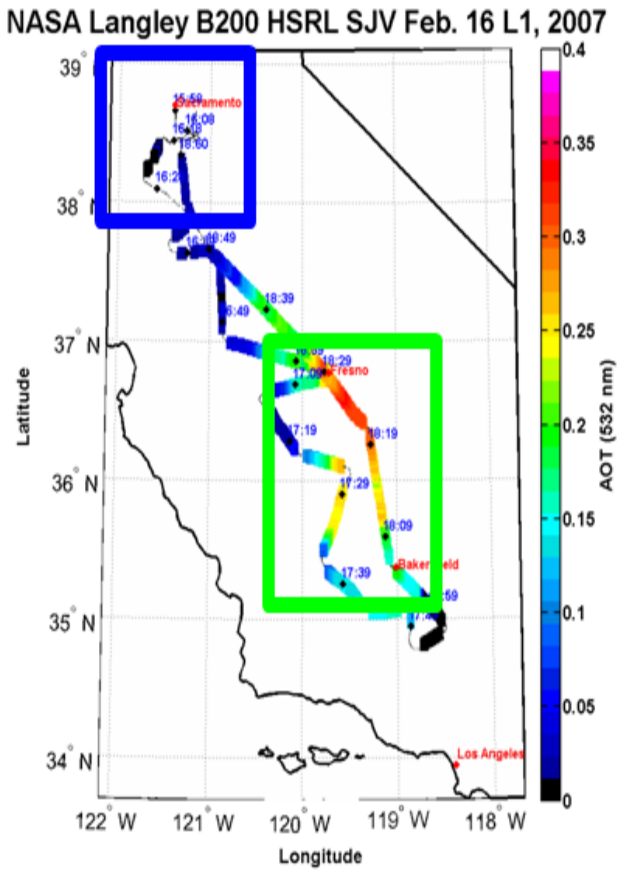
February 15, 2007 L1



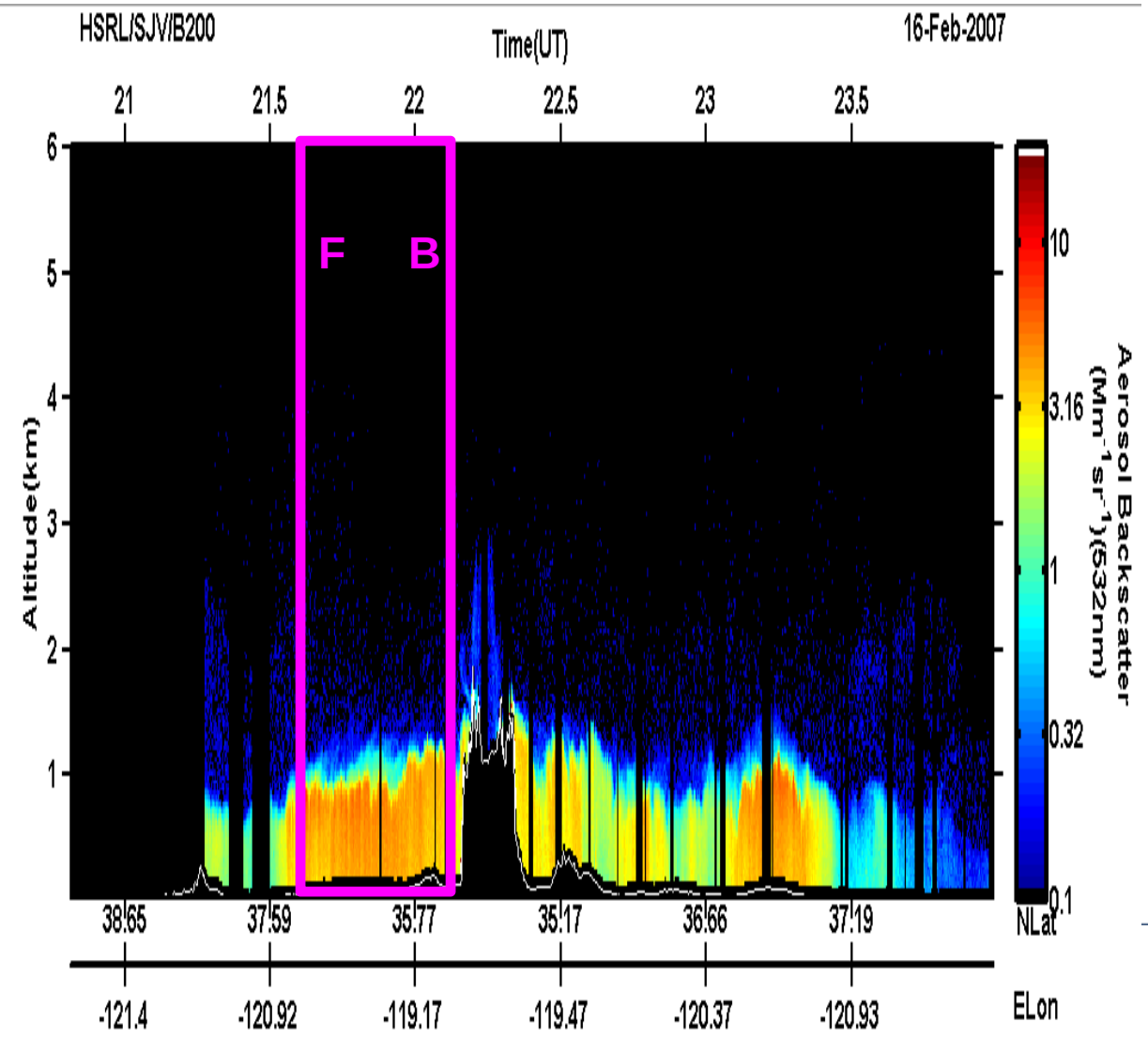


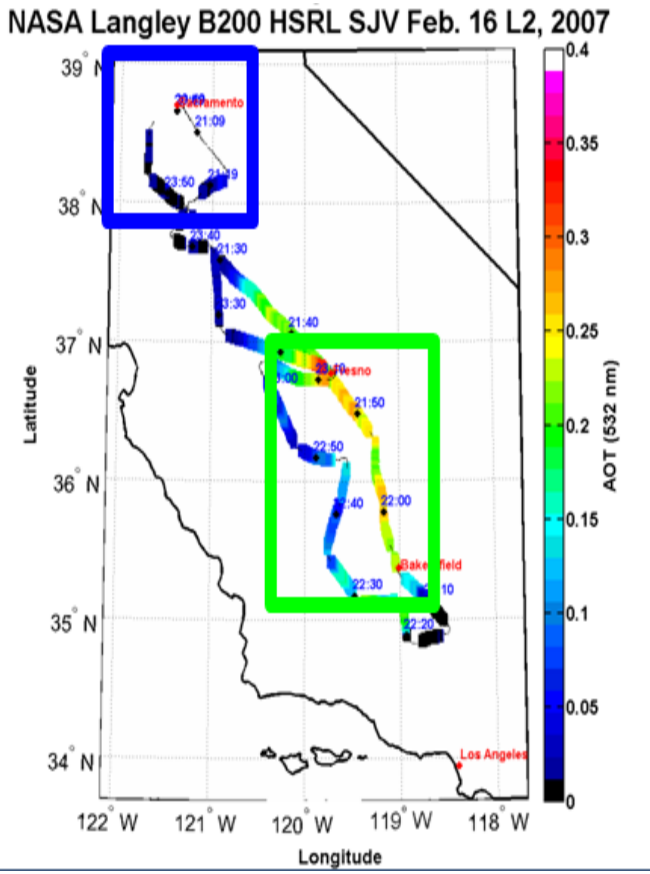
February 16, 2007 L1



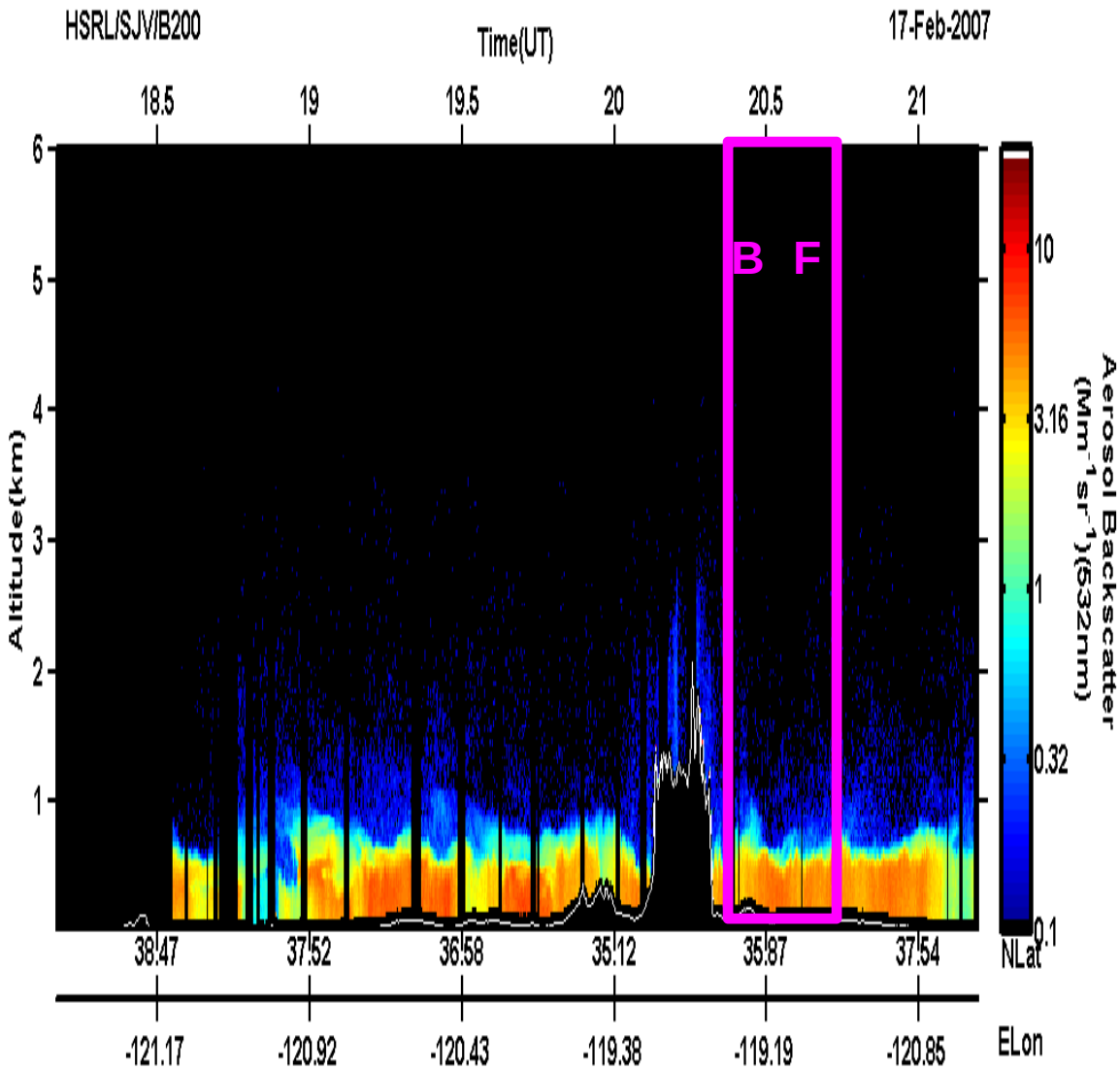


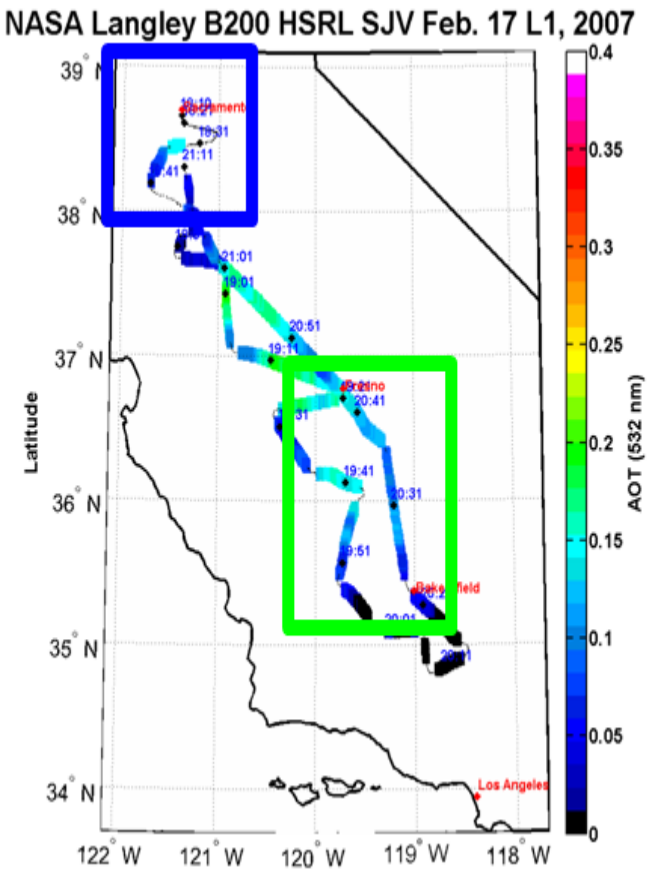
February 16, 2007 L2



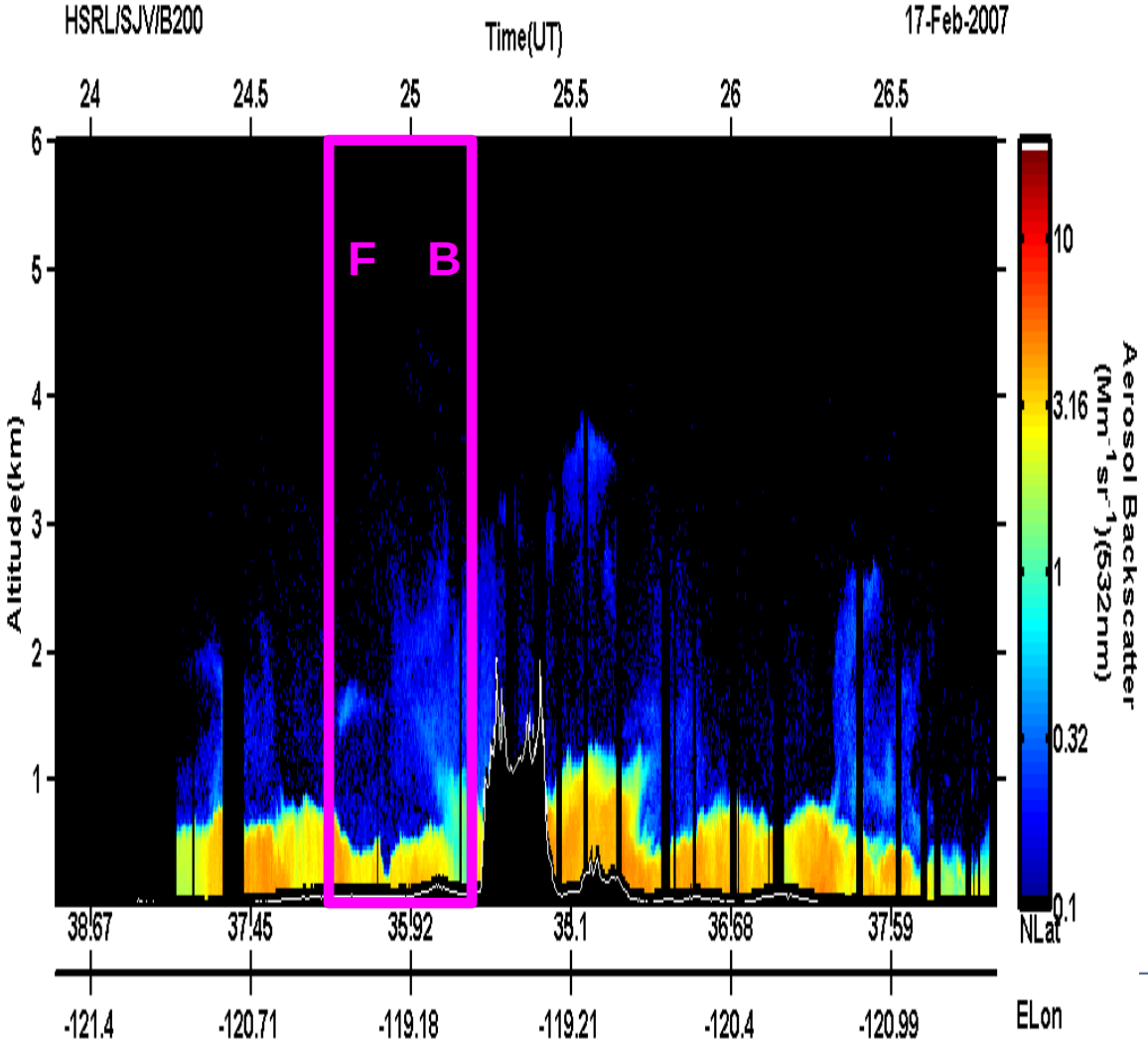


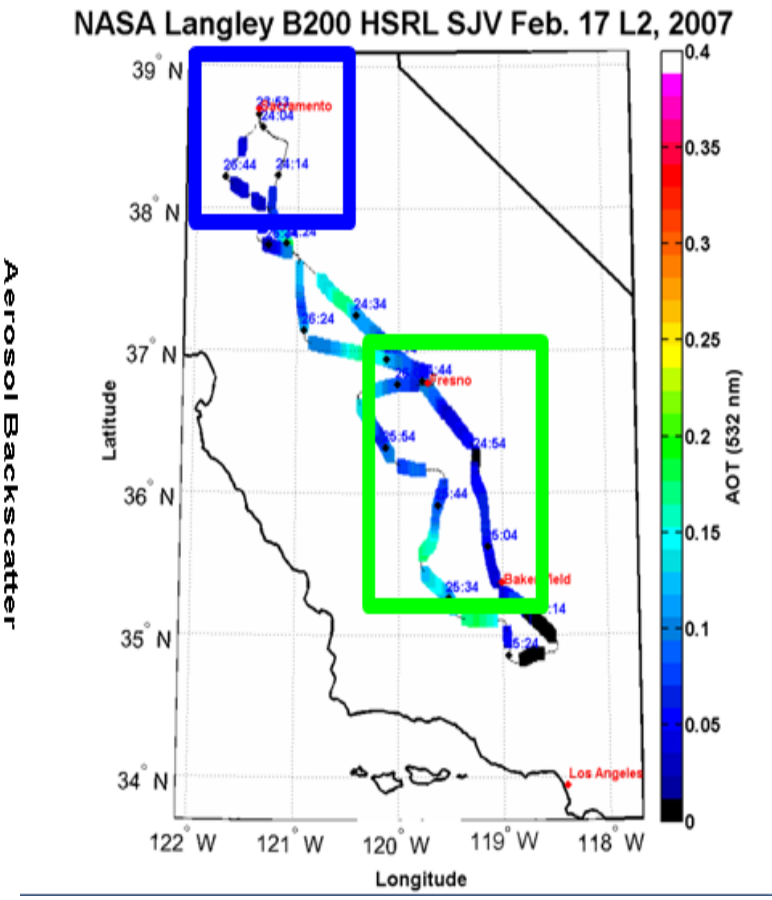
February 17, 2007 L1





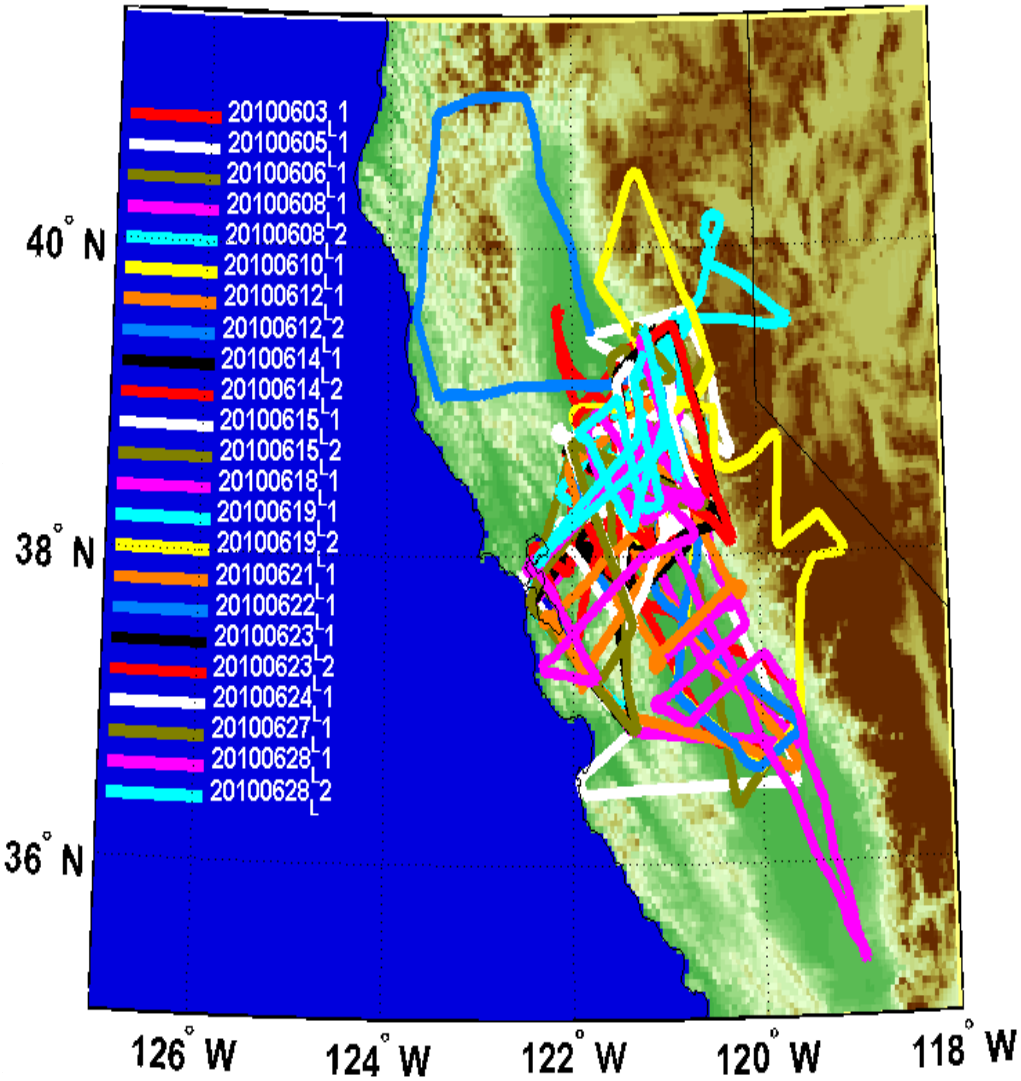
February 17, 2007 L2





B200/HSRL Deployment during DOE CARES Mission June 2010

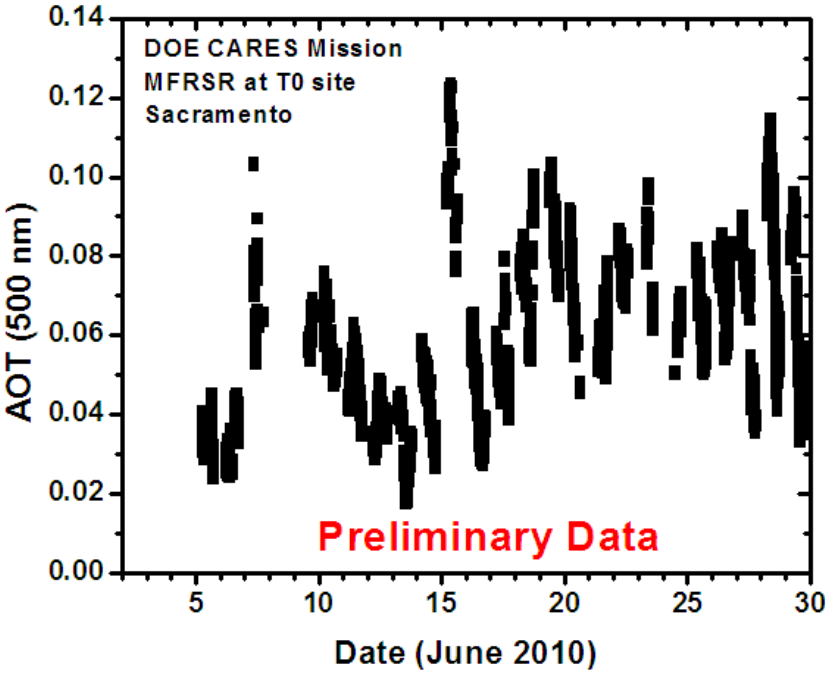
- Sacramento, California
- June 3 - 28
- 23 science flights (~68 hours)
  - 19 with DOE G1
  - 1 with NOAA R/V Atlantis
  - 2 with NOAA P3
  - 6 with NOAA Twin Otter
  - 11 with MODIS and/or MISR

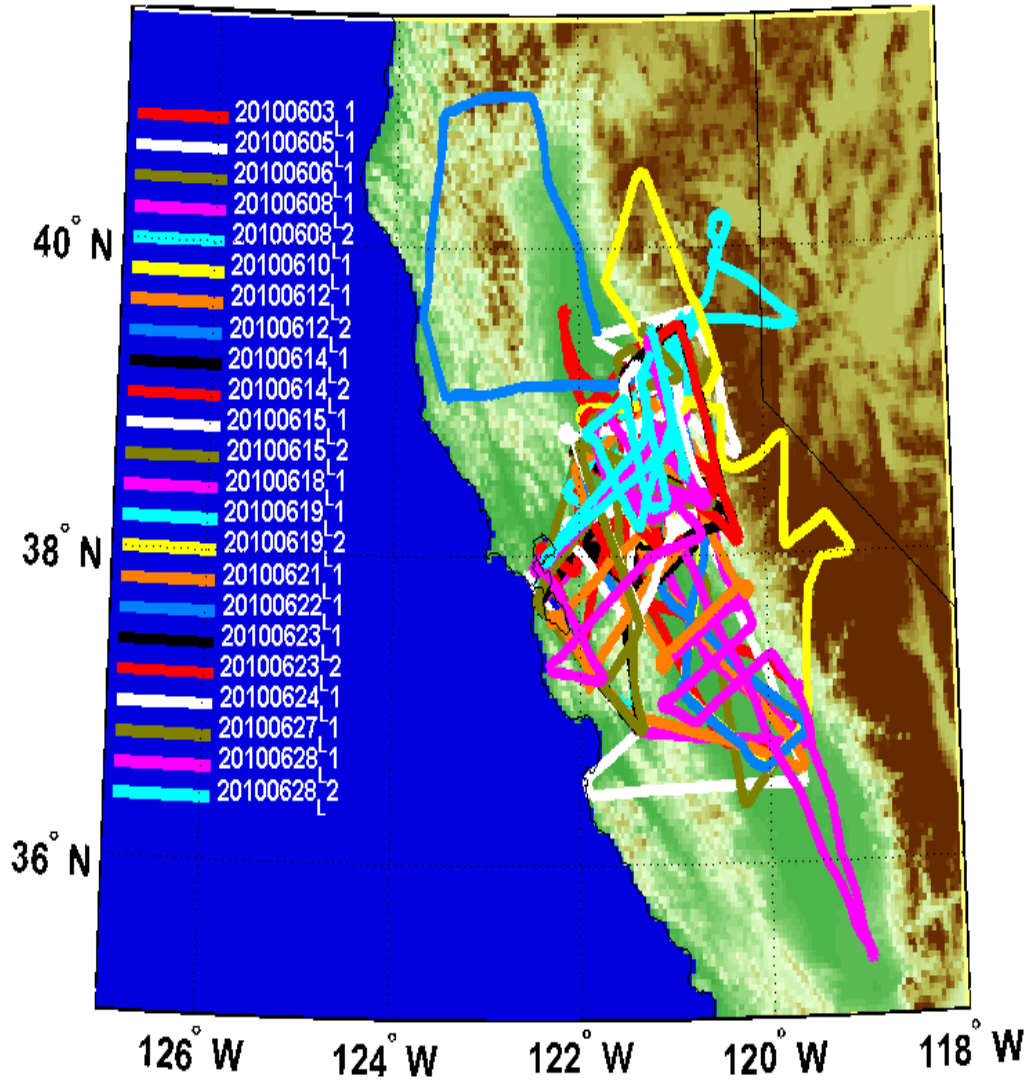


B200/HSRL Deployment during DOE CARES Mission June 2010

- Sacramento, California
- June 3 - 28
- 23 science flights (~68 hours)
  - 19 with DOE G1
  - 1 with NOAA R/V Atlantis
  - 2 with NOAA P3
  - 6 with NOAA Twin Otter
  - 11 with MODIS and/or MISR

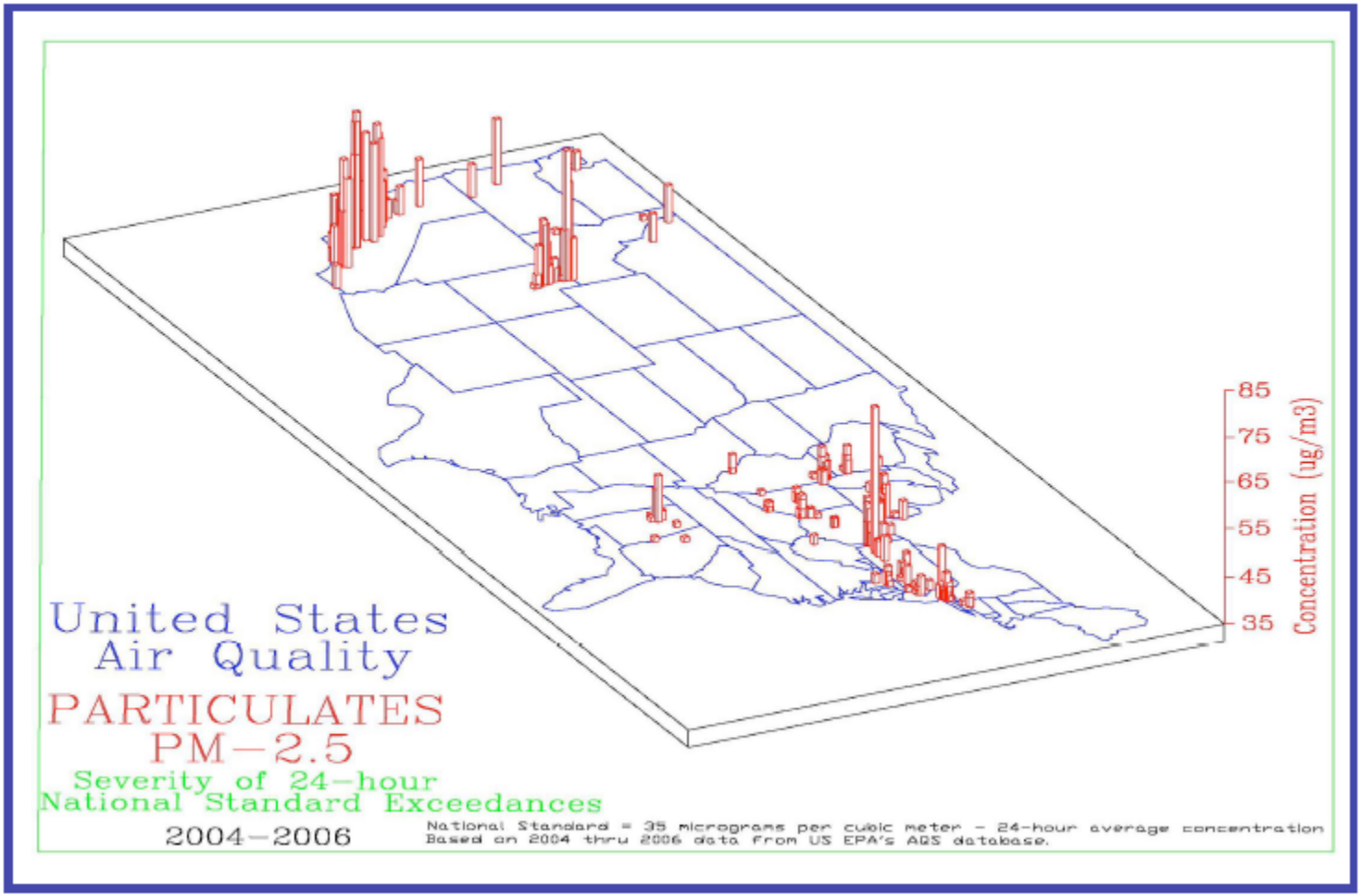
AOT was low!





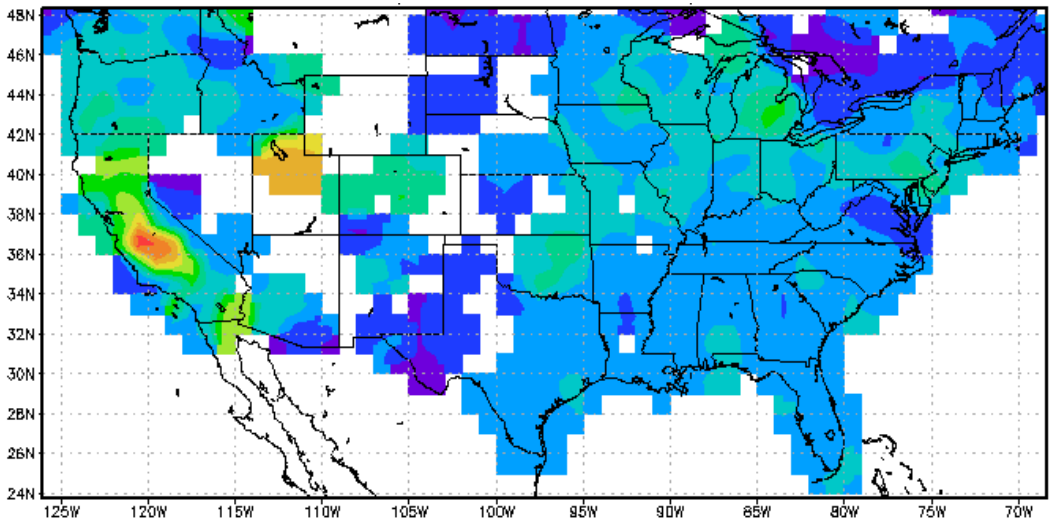
High PM2.5 Concentrations

High $PM_{2.5}$ Concentrations: 2004-2006 Exceedances

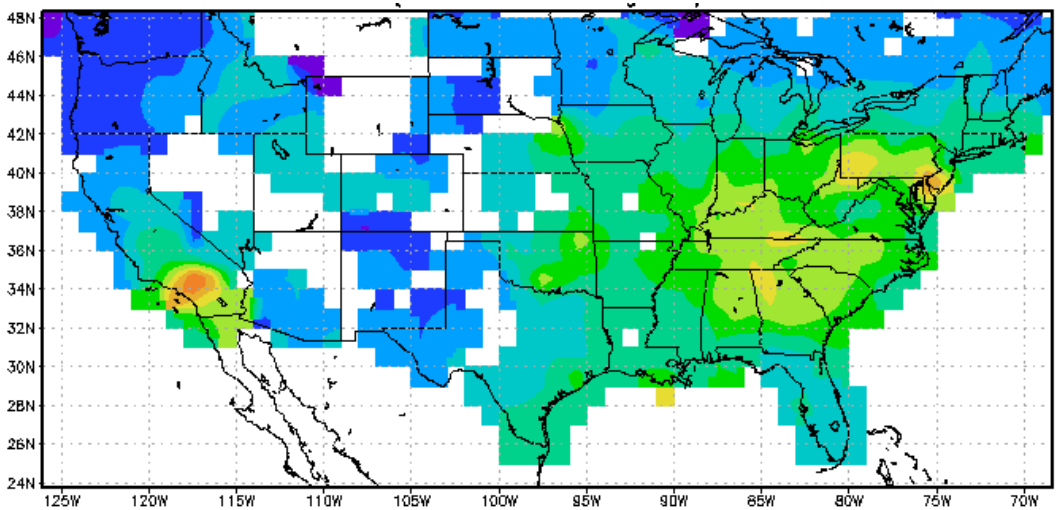


From Al-Saadi et al. AMS Meeting Presentation 2008

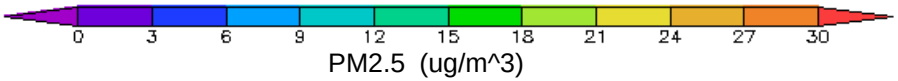
Average PM2.5 Concentrations During 2007



Jan-Feb 2007



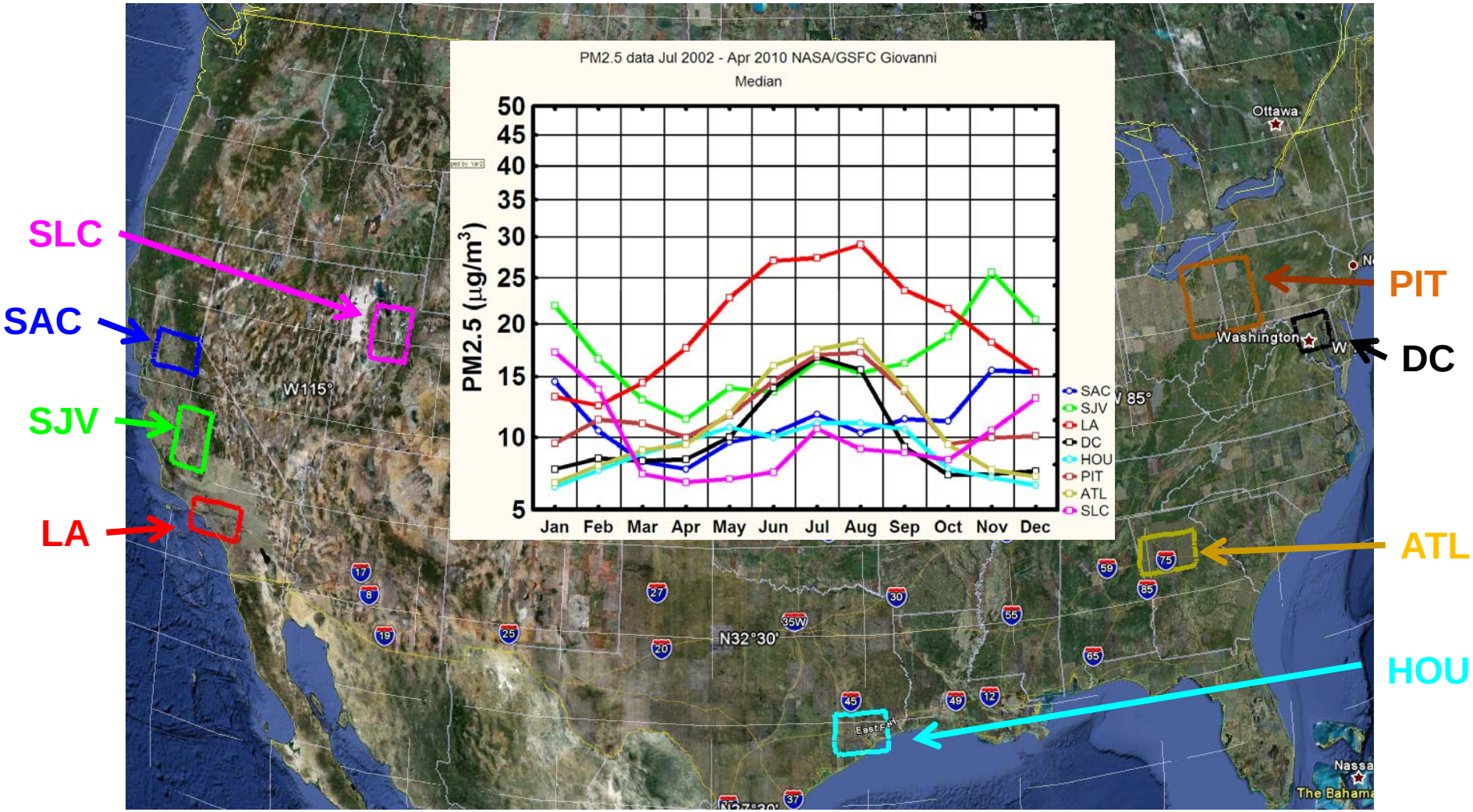
Jun-Aug 2007



NASA/GSFC Giovanni visualization of AirNow data

Monthly Median PM2.5 Concentrations for Selected Regions of Interest

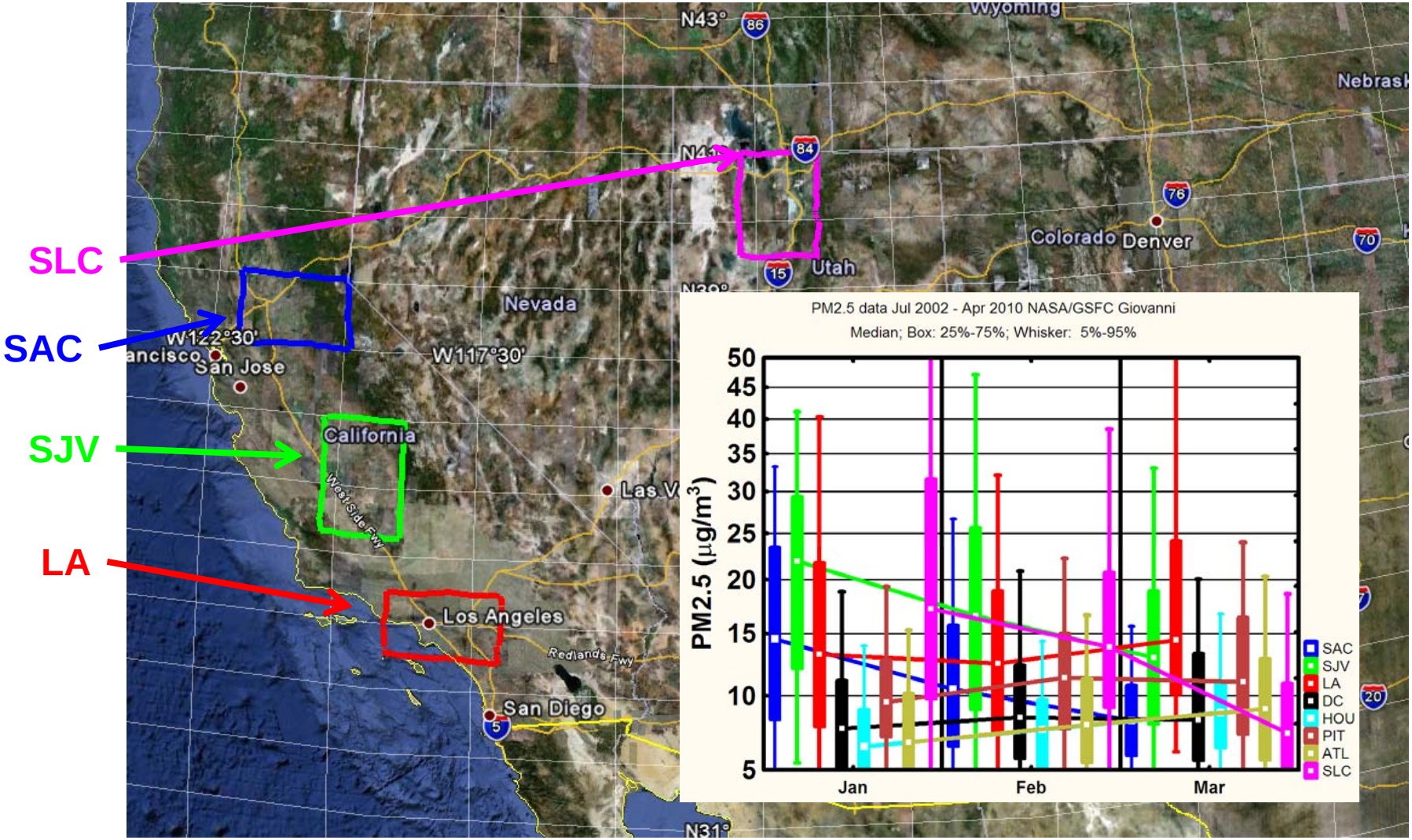
- Monthy median PM2.5 levels for locations of interest (7/2002-4/2010)



Data provided by NASA/GSFC Giovanni site

Box Plots Showing Monthly PM2.5 Concentrations During January-March for Selected Regions of Interest

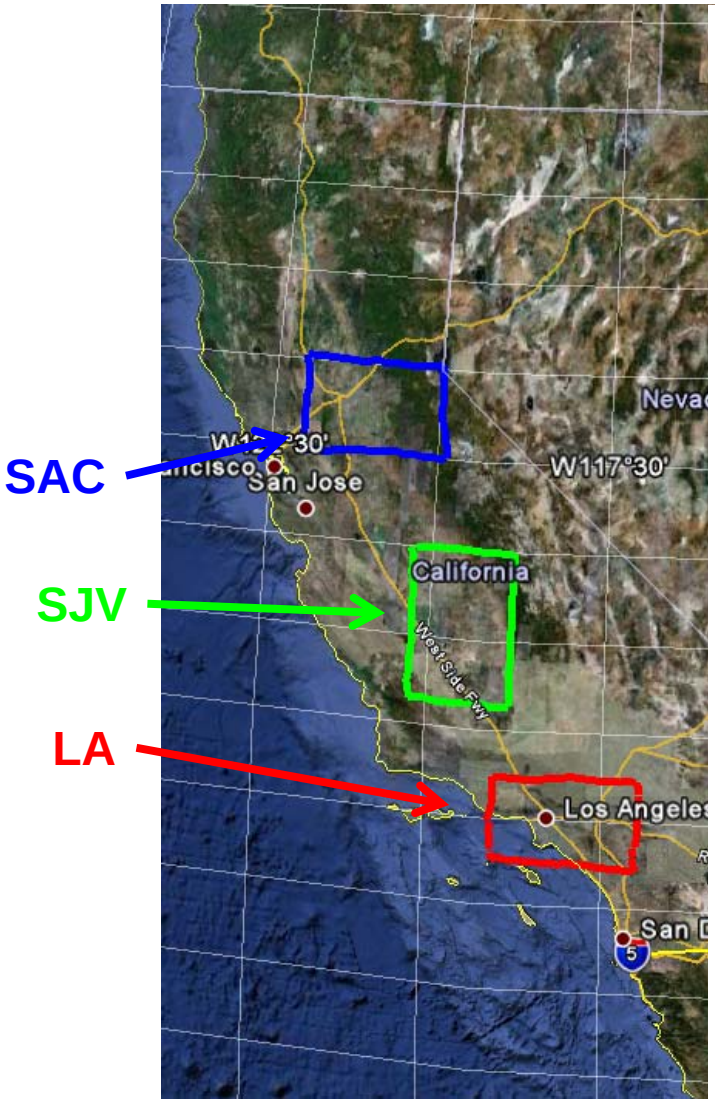
- January-March PM2.5 levels for locations of interest (7/2002-4/2010)
- SJV has highest median values, followed by SLC

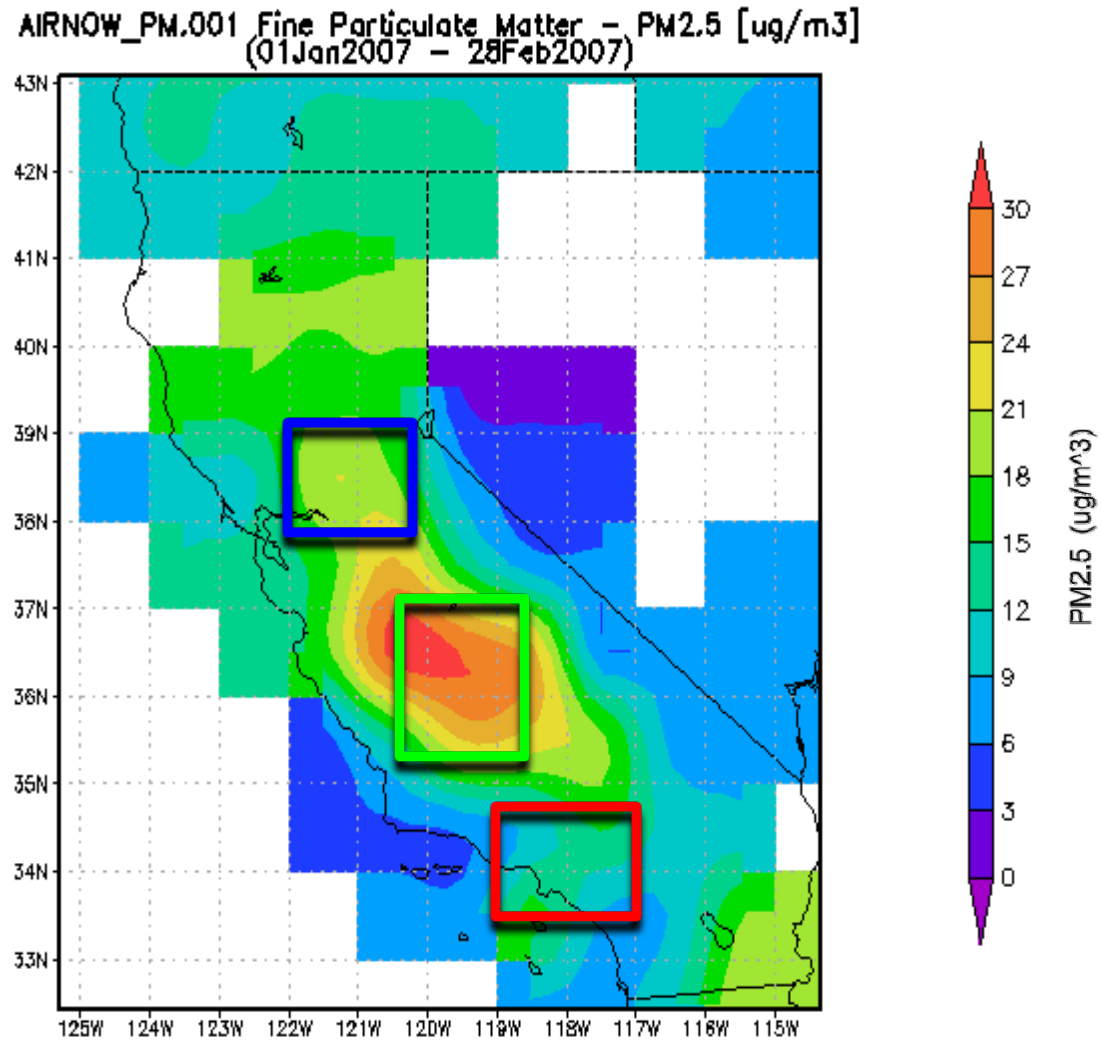


Data provided by NASA/GSFC Giovanni site

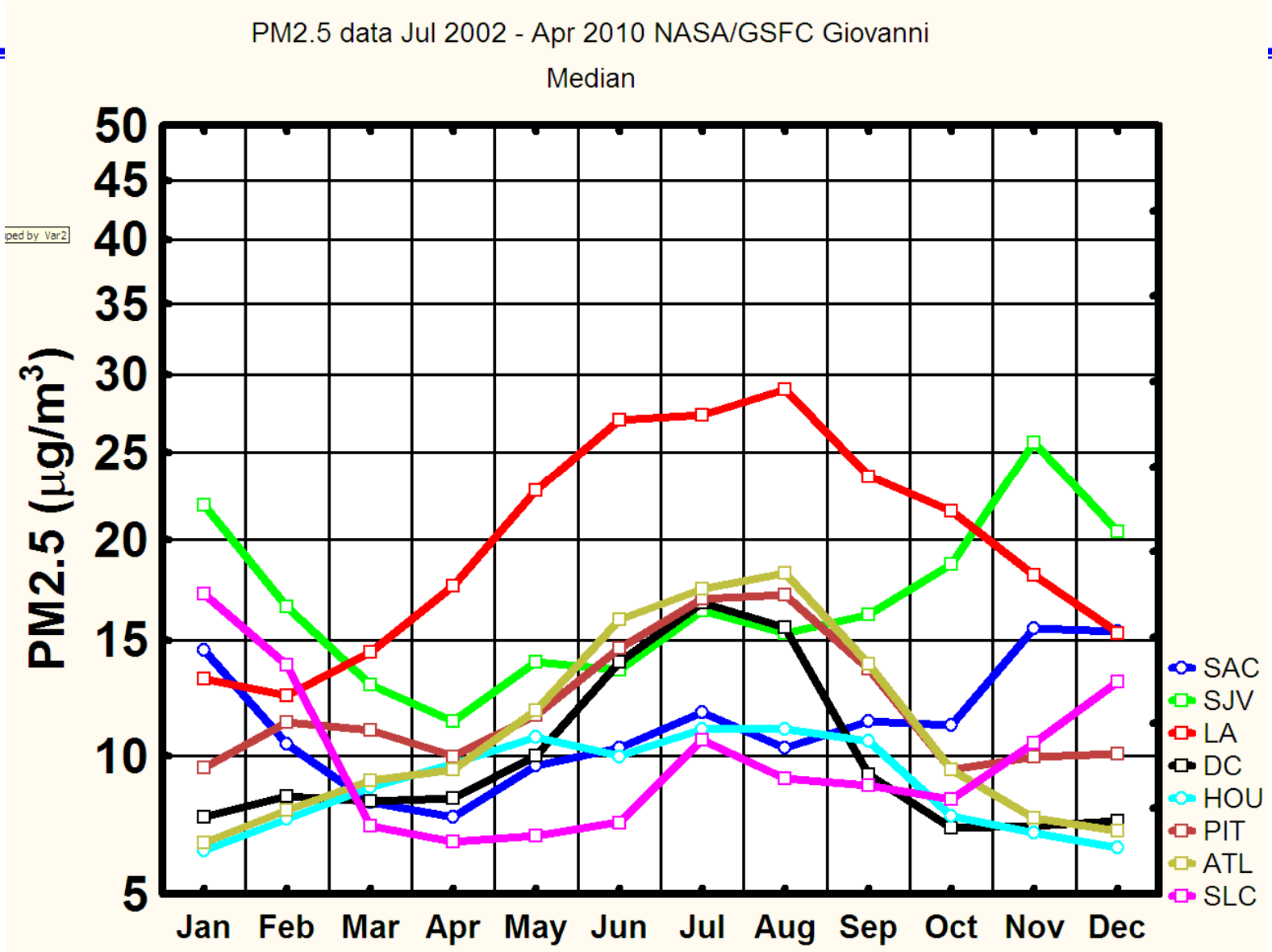
PM2.5 Concentrations Over California During January-February 2007 March for Selected Regions of Interest

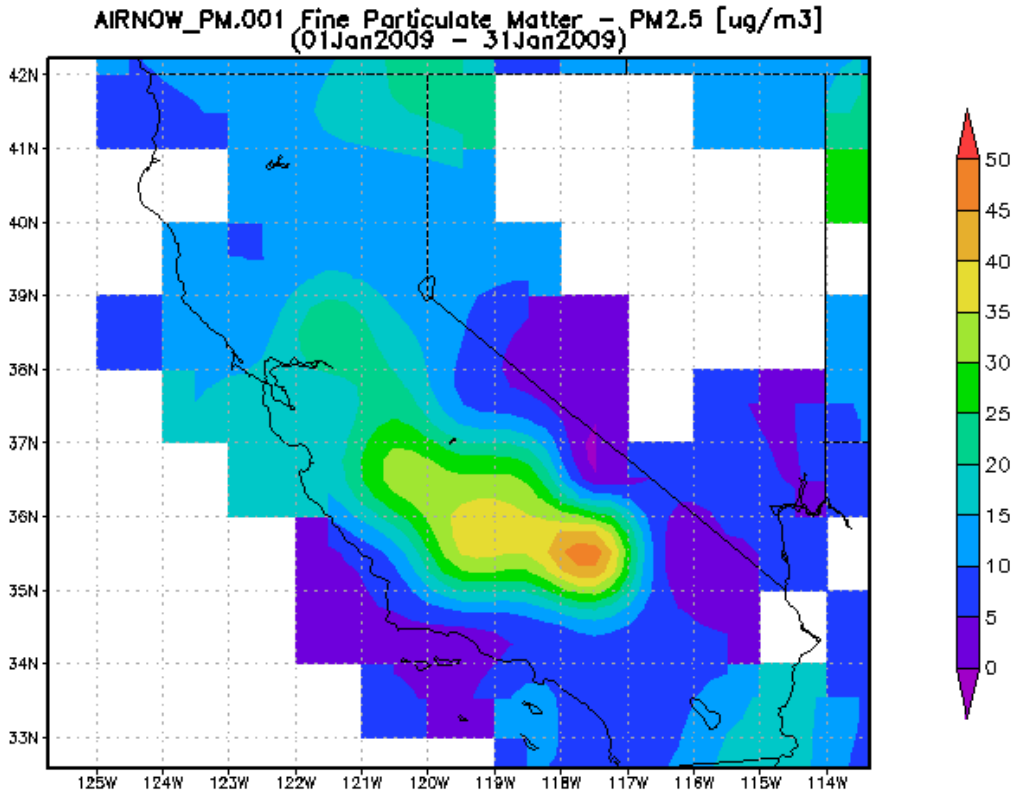
- SJV region has highest values

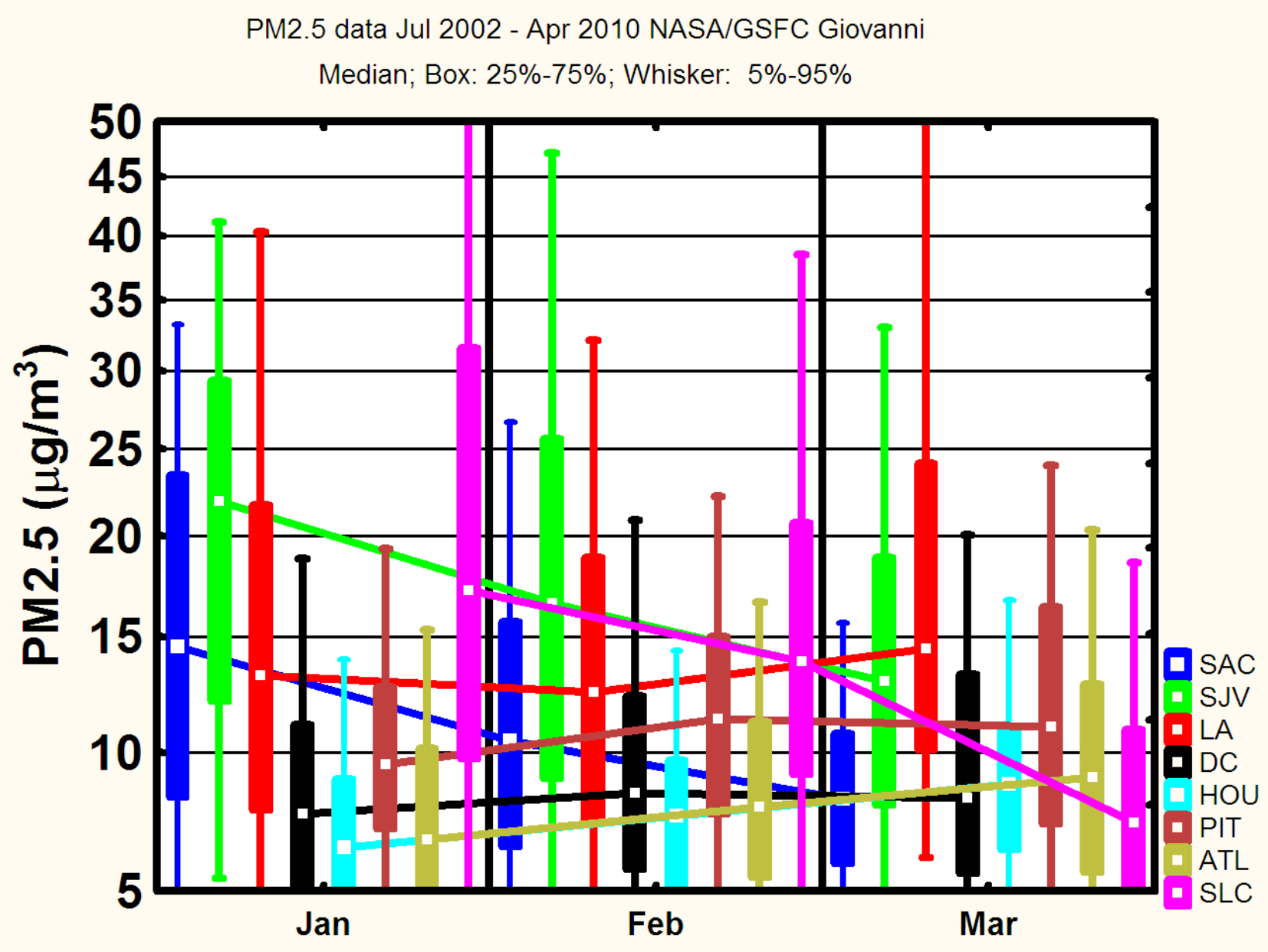


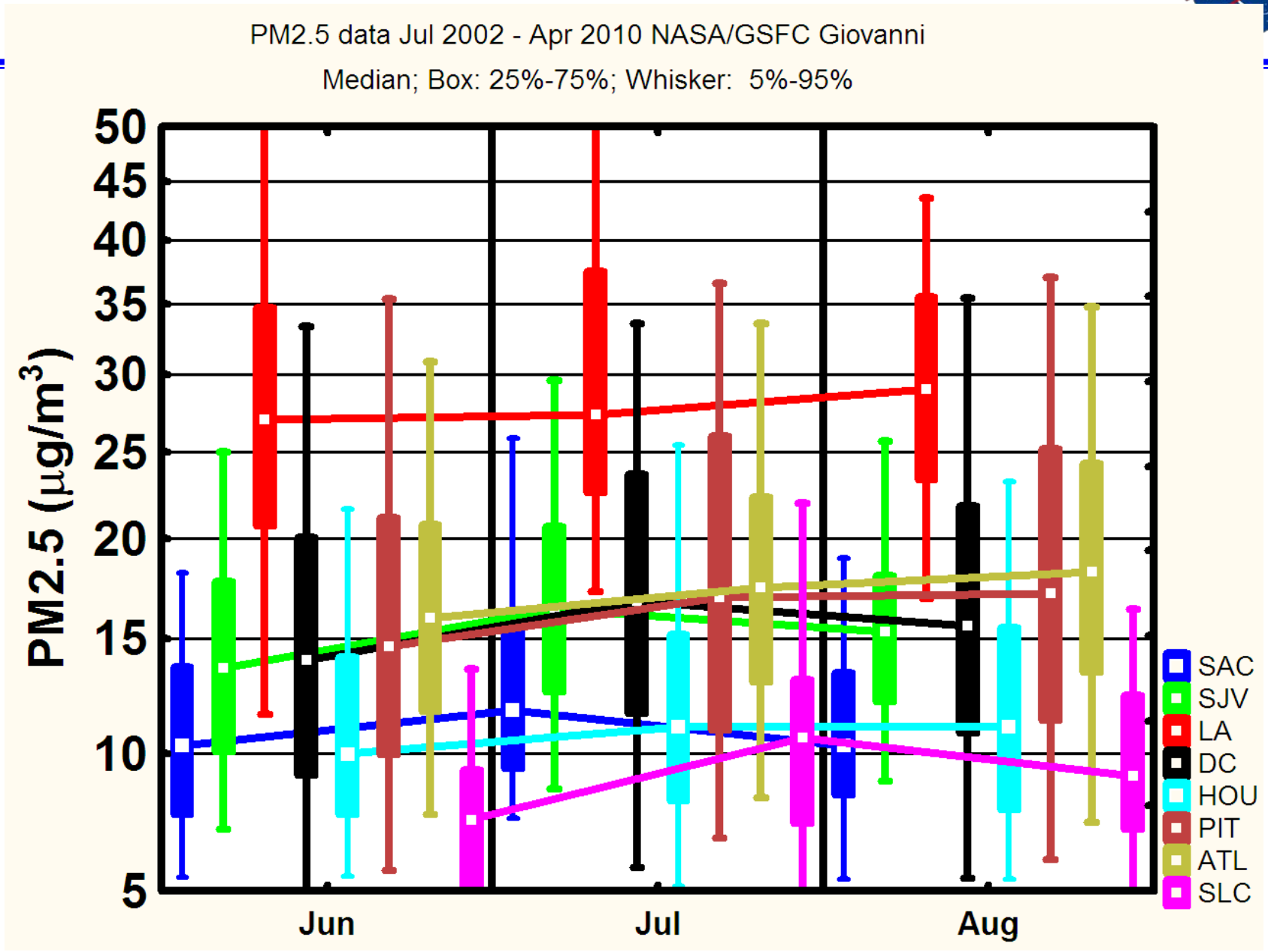


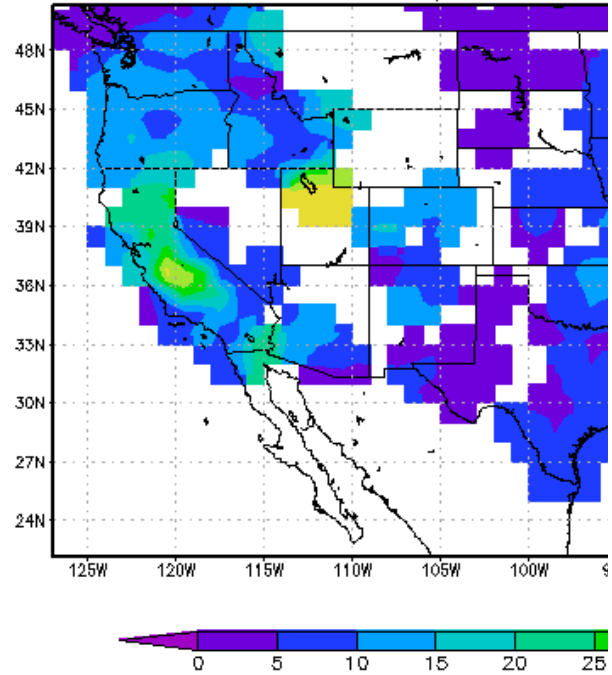
Data provided by NASA/GSFC Giovanni site

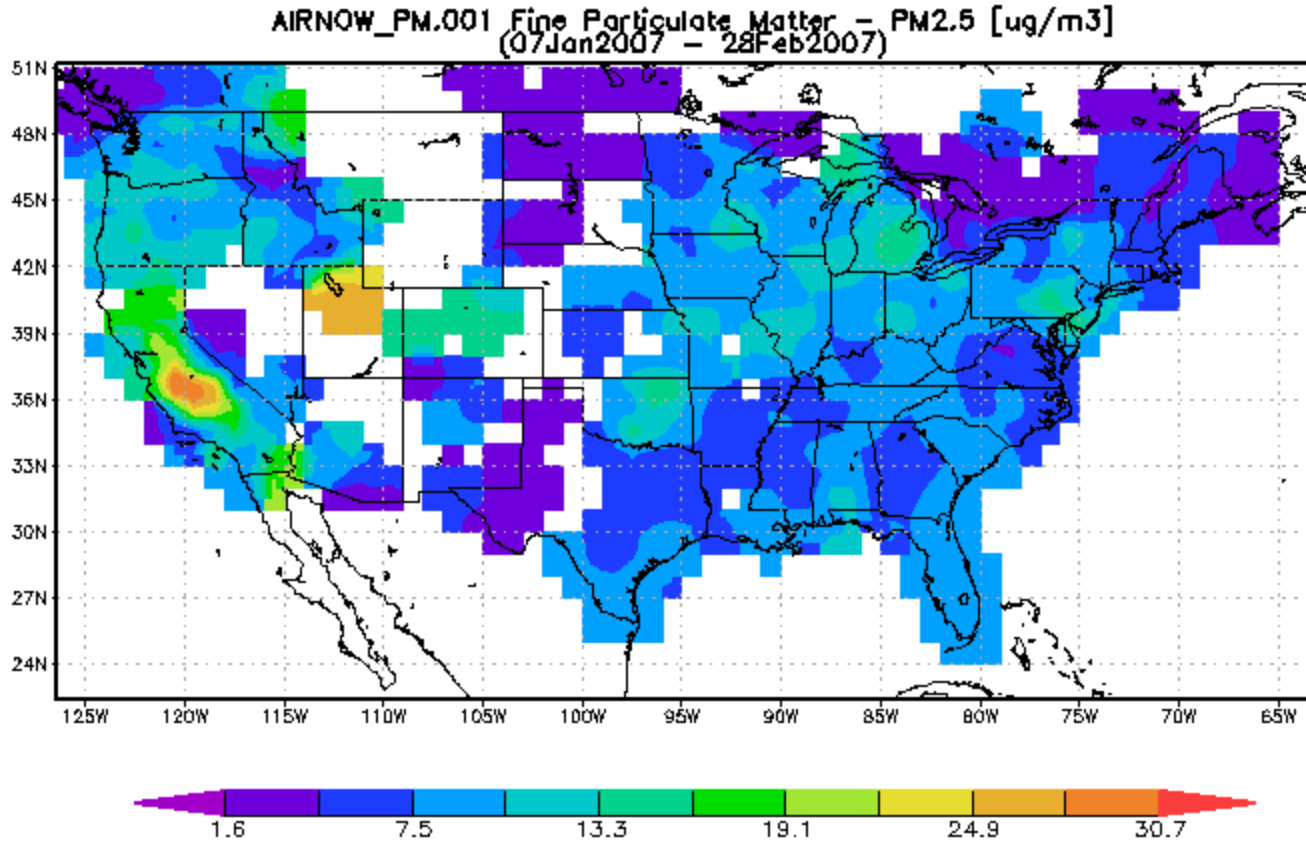

PM2.5 data Jul 2002 - Apr 2010 NASA/GSFC Giovanni
Median
PM2.5 (µg/m³)
50
45
40
35
30
25
20
15
10
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
SAC
SJV
LA
DC
HOU
PIT
ATL
SLC

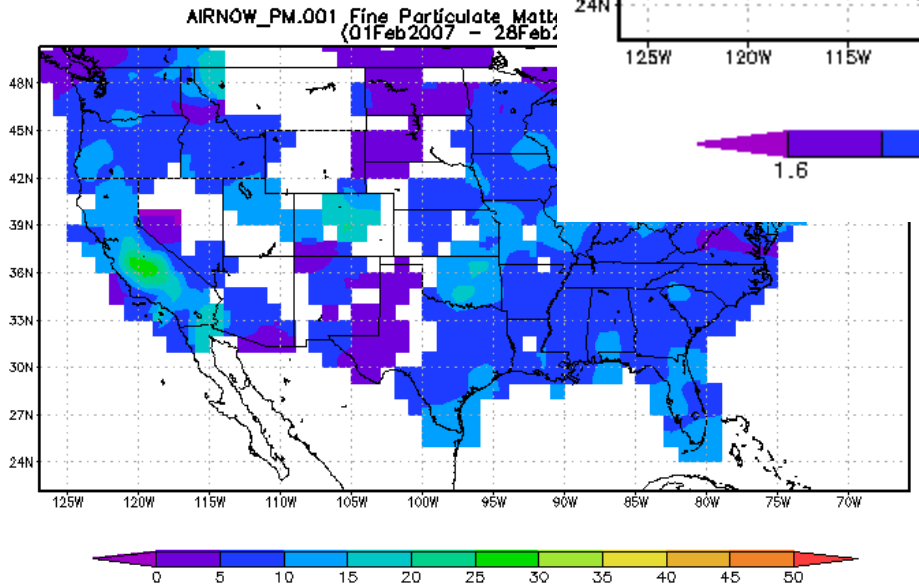

AIRNOW_PM.001 Fine Particulate Matter - PM2.5 [ug/m3]
(01Jan2009 - 31Jan2009)
42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
125W
124W
123W
122W
121W
120W
119W
118W
117W
116W
115W
114W
50
45
40
35
30
25
20
15
10
5
0

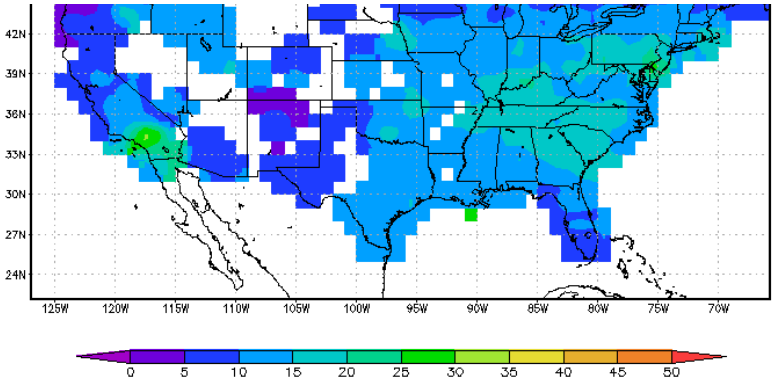

PM2.5 data Jul 2002 - Apr 2010 NASA/GSFC Giovanni
Median; Box: 25%-75%; Whisker: 5%-95%
PM2.5 (μg/m3)
50
45
40
35
30
25
20
15
10
5
Jan
Feb
Mar
SAC
SJV
LA
DC
HOU
PIT
ATL
SLC


PM2.5 data Jul 2002 - Apr 2010 NASA/GSFC Giovanni
Median; Box: 25%-75%; Whisker: 5%-95%
PM2.5 (μg/m3)
50
45
40
35
30
25
20
15
10
5
Jun
Jul
Aug
SAC
SJV
LA
DC
HOU
PIT
ATL
SLC


48N
45N
42N
39N
36N
33N
30N
27N
24N
125W
120W
115W
110W
105W
100W
0
5
10
15
20
25


AIRNOW_PM.001 Fine Particulate Matter - PM2.5 [ug/m3]
(07Jan2007 - 28Feb2007)
51N
48N
45N
42N
39N
36N
33N
30N
27N
24N
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
65W
1.6
7.5
13.3
19.1
24.9
30.7


AIRNOW_PM.001 Fine Particulate Matt
(01Feb2007 - 28Feb2
48N
45N
42N
39N
36N
33N
30N
27N
24N
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
0
5
10
15
20
25
30
35
40
45
50


42N
39N
36N
33N
30N
27N
24N
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
0
5
10
15
20
25
30
35
40
45
50

Photochemical Modeling Investigation of an Extended Winter PM Episode in Central California

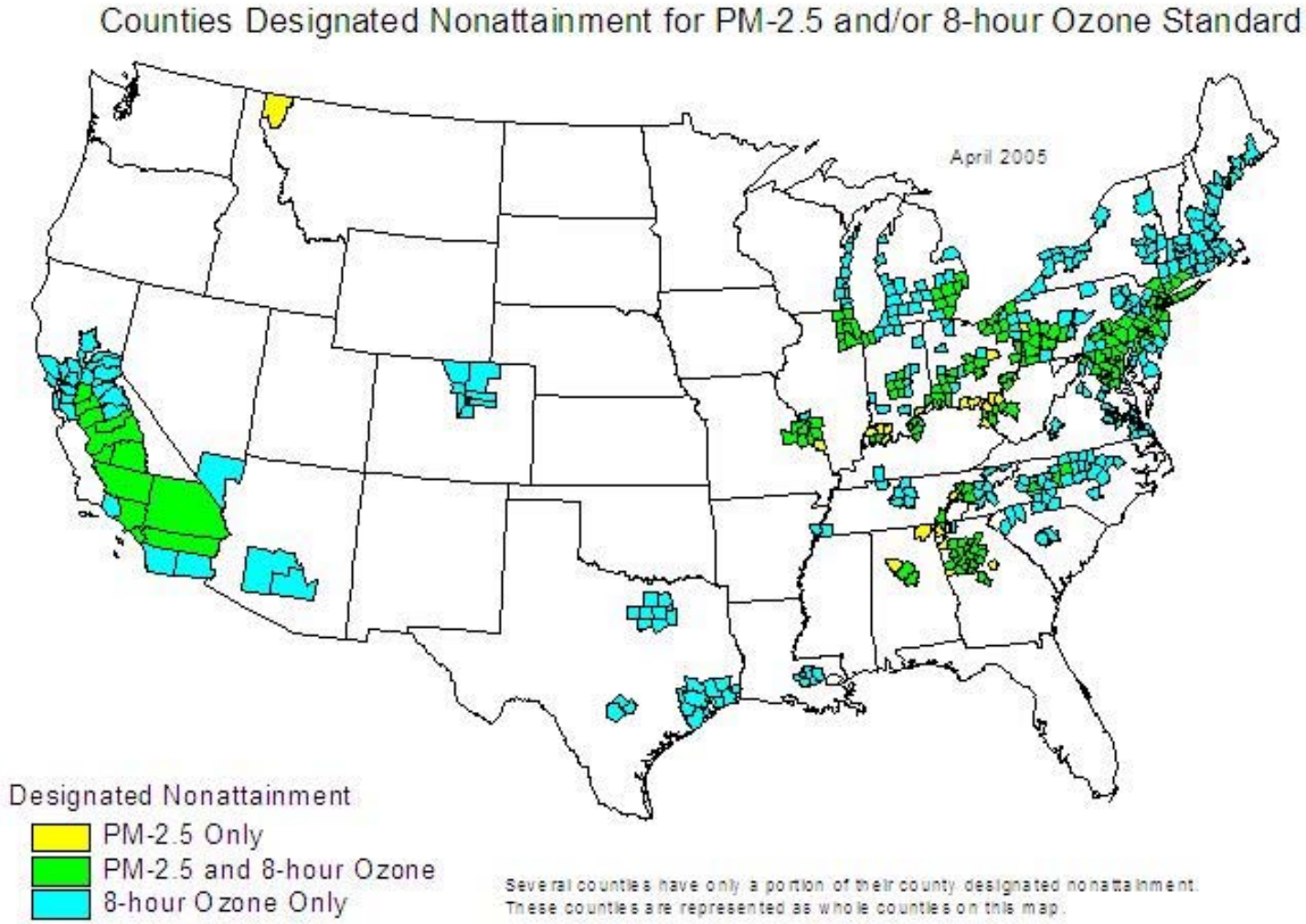
Jinyou Liang[1], Kemal Gürer[1], Ajith Kaduwela[1,2], K. Max Zhang[3,#], Qi Ying[1], Paul D. Allen[1], Michael Kleeman[4], and Anthony Wexler[2,3,4]

1. Air Resources Board, California Environmental Protection Agency
2. Department of Land, Air, and Water Resources, University of California at 2 Davis
3. Department of Mechanical and Aeronautical Engineering, Univ. California at Davis
4. Department of Civil and Environmental Engineering, University of California at Davis

Now at Sibley School of Mechanical and Aerospace Engineering, Cornell University

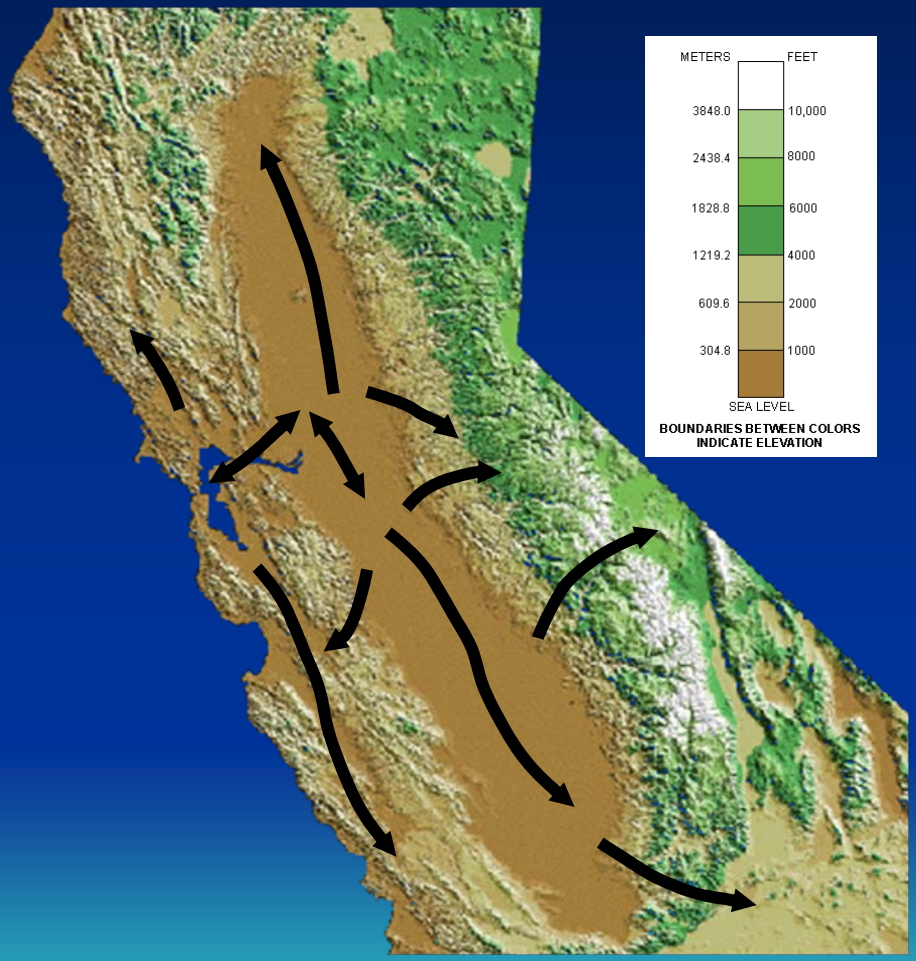
Outline

- $PM_{2.5}$ problem in the SJV
  - Geography
  - Seasonality
- Air Quality Modeling with CMAQ
  - Inputs
  - Improvements
  - Performance
- Future Directions


Counties Designated Nonattainment for PM-2.5 and/or 8-hour Ozone Standard
April 2005
Designated Nonattainment
PM-2.5 Only
PM-2.5 and 8-hour Ozone
8-hour Ozone Only
Several counties have only a portion of their county designated nonattainment.
These counties are represented as whole counties on this map.

The San Joaquin Valley

- One of the most productive agricultural regions in the world – Cadillac Dessert
- Major goods movement corridors
- Oil production in the southern Valley
- Air Quality: Second most polluted area in the US and second most studied area in the world
- Ozone pollution in the summer and PM pollution in the winter (but the annual PM standard is more restrictive)

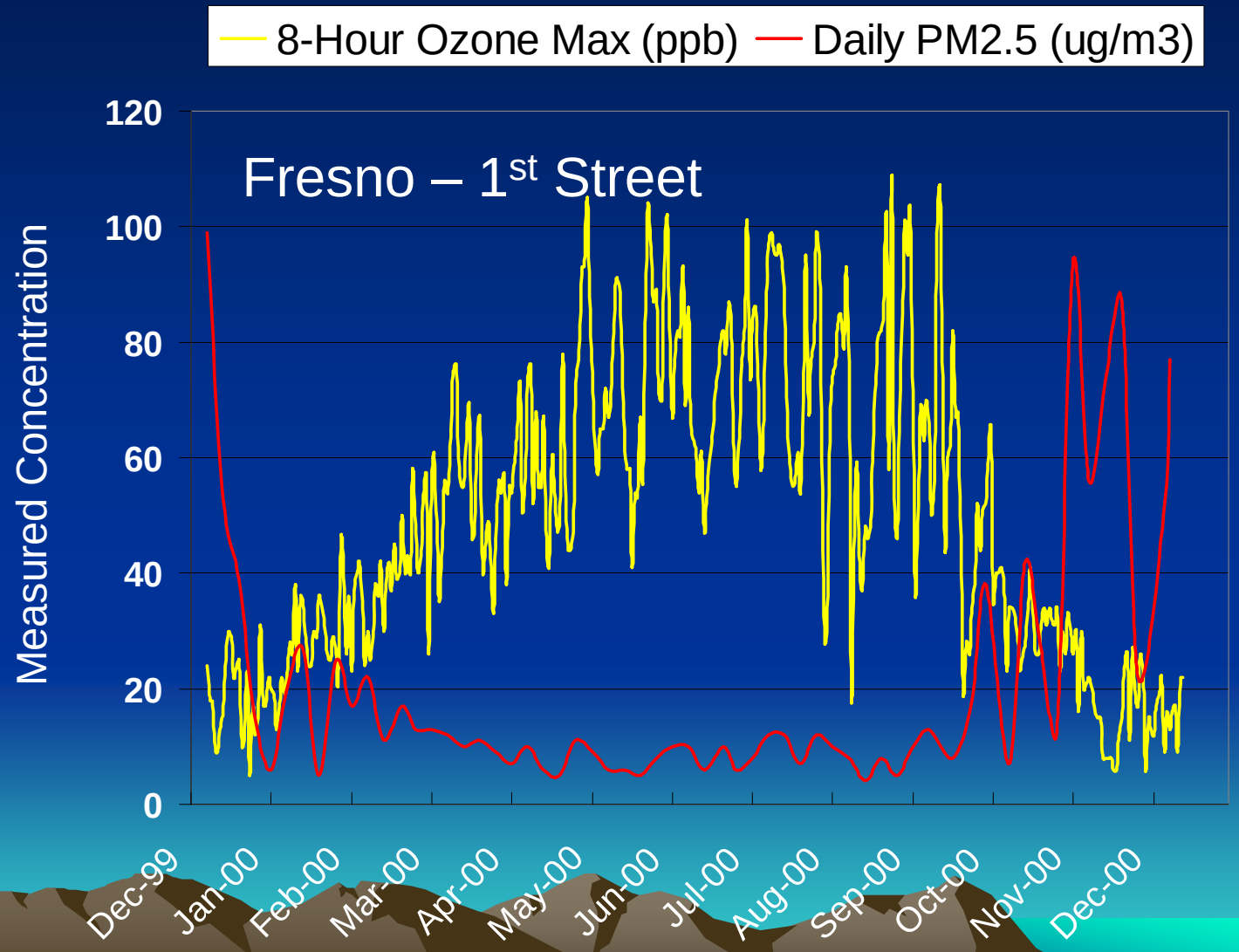


Prof. John Watson, DRI

Major field studies

- 1970: Project Lo-Jet (identified summertime low-level jet and Fresno eddy)
- 1972: Aerosol Characterization Experiment (ACHEX, first TSP chemical composition and size distributions)
- 1979-1980: Inhalable Particulate Network (first long-term $PM_{2.5}$ and PM_{15} mass and elemental measurements in Bay Area, Five Points)
- 1978: Central California Aerosol and Meteorological Study (seasonal TSP elemental composition, seasonal transport patterns)
- 1979-1982: Westside Operators (first TSP sulfate and nitrate compositions in western Kern County)
- 1984: Southern SJV ozone study (first major characterization of O_3 and meteorology in Kern County)
- 1986-1988: California Source Characterization Study (quantified chemical composition of source emissions)
- 1988-89: Valley Air Quality Study (first spatially diverse, chemical characterized, annual and 24-hour $PM_{2.5}$ and PM_{10} seasonal)
- Summer 1990: San Joaquin Valley Air Quality Study/Atmospheric Utilities Signatures Predictions and Experiments (SJVAQS/AUSPEX, first central California regional study of O_3 and $PM_{2.5}$) – Also known as SARMAP (SJVAQS/AUSPEX Regional Modeling Adaptation Project)
- Winter 1995: CRPAQS Pilot Study (IMS95, first sub-regional winter study)
- December 1999 to February 2001: CRPAQS and CCOS (first year-long, regional-scale effort)
- December 1999 to present: Fresno Supersite (first multi-year experiment with advanced monitoring technology)

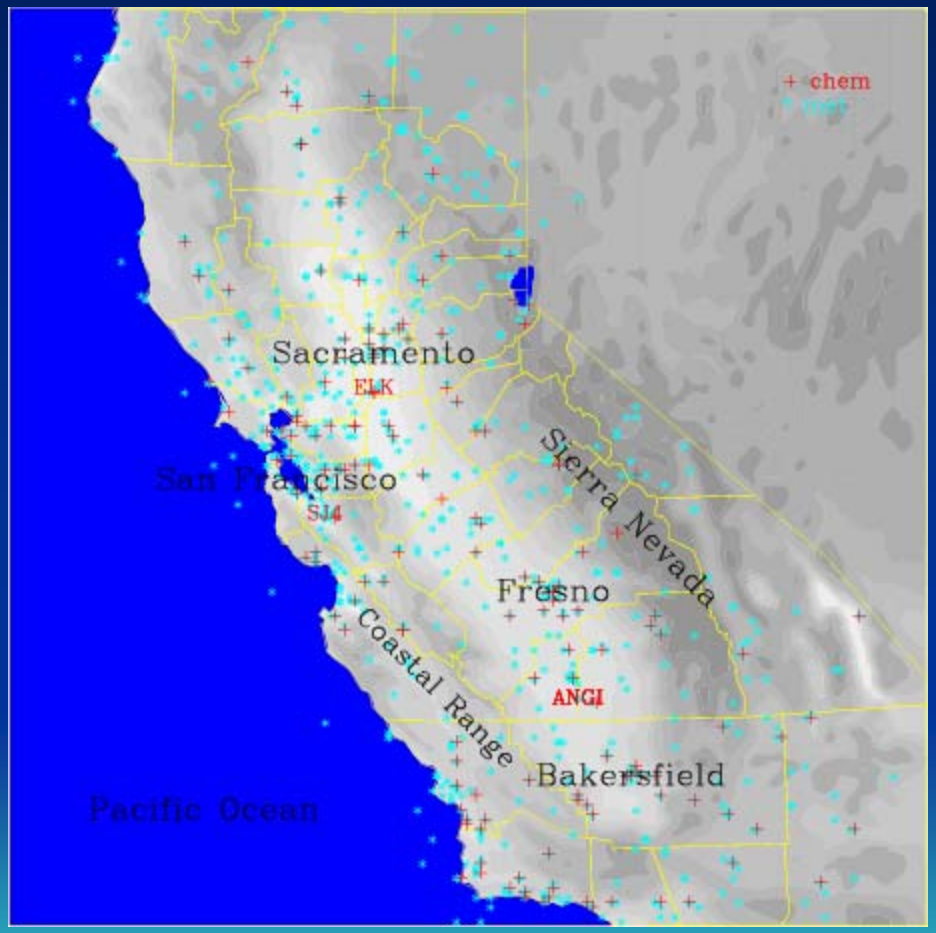
Seasonality of O_3 and $PM_{2.5}$



Measurements

162 Air Quality Stations

365 Meteorology Stations



Modeling Approach

- Use data from California Regional PM10/PM2.5 Air Quality Study (CRPAQS)
  - www.arb.ca.gov/ccaqs
- MM5 meteorology with FDDA (NWS data)
- ARB/UC Davis emissions inventory
- Several AQ modeling approaches
  - CMAQ (with ARB modifications)
  - CMAQ-UCD
  - CMAQ-MADRID
  - CIT/UCD

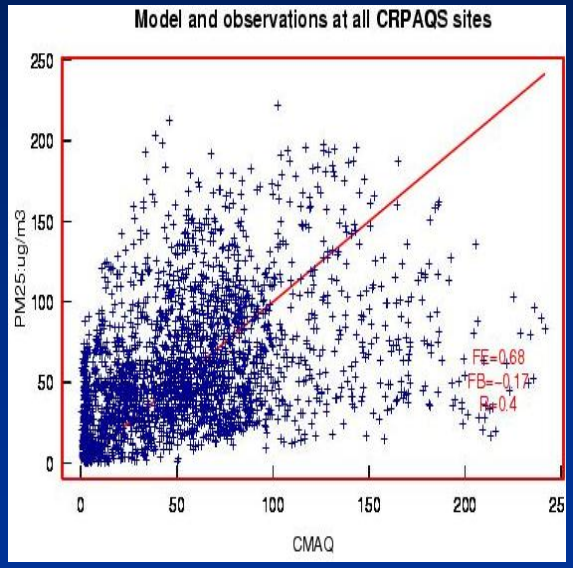
Meteorology Model Performance

	MB	MGE
Wind speed (ms^{-1})	0.49 (0.5)	1.53 (0.5)
Wind direction (º)	3.54 (10)	57.21 (30)
Temperature (K)	0.76 (0.5)	2.5 (2)

ARB CMAQ Model Setup

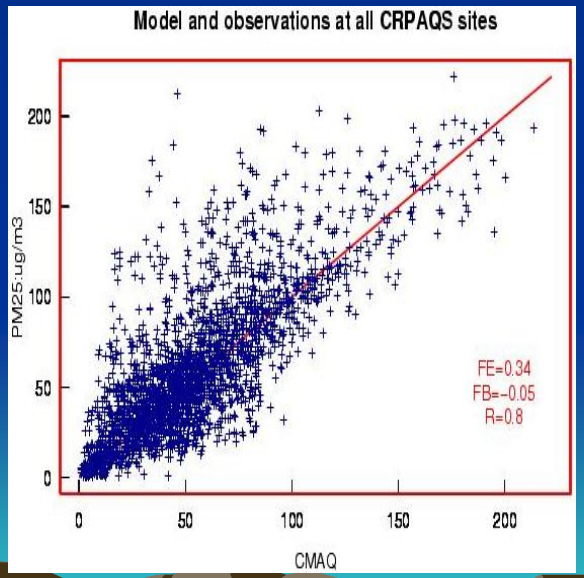
- 4 km^2 horizontal grid (185x185) with 15 vertical layers up to 15 km
- Internal mixture, modal approach, SAPRC99_ae3_aq
- Some code modifications
- ~22-day run on 16-CPU Linux cluster in ~2 days

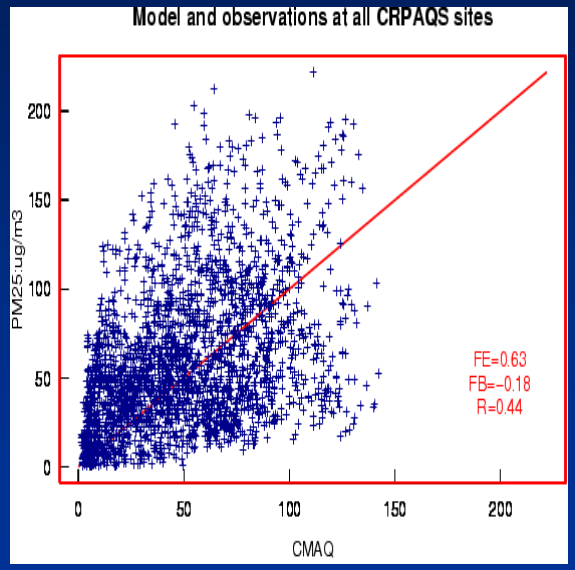
$PM_{2.5}$ Mass



Grid Cell

Best Match within 49 Cells





49-Cell Average

PM Mass and Key Components

	mFE		mFB		R	
	n=0	n=3	n=0	n=3	n=0	n=3
NH_4^+	0.73	0.44	-0.19	-0.14	0.44	0.59
NO_3^-	0.79	0.49	0.05	0.09	0.44	0.63
$SO_4^=$	0.77	0.45	-0.54	-0.33	0.18	0.63
TC	0.83	0.45	-0.71	-0.37	0.71	0.82
PM_{25}	0.68	0.37	-0.26	-0.09	0.41	0.74
PM_{10}	0.78	0.53	-0.21	-0.18	0.55	0.78

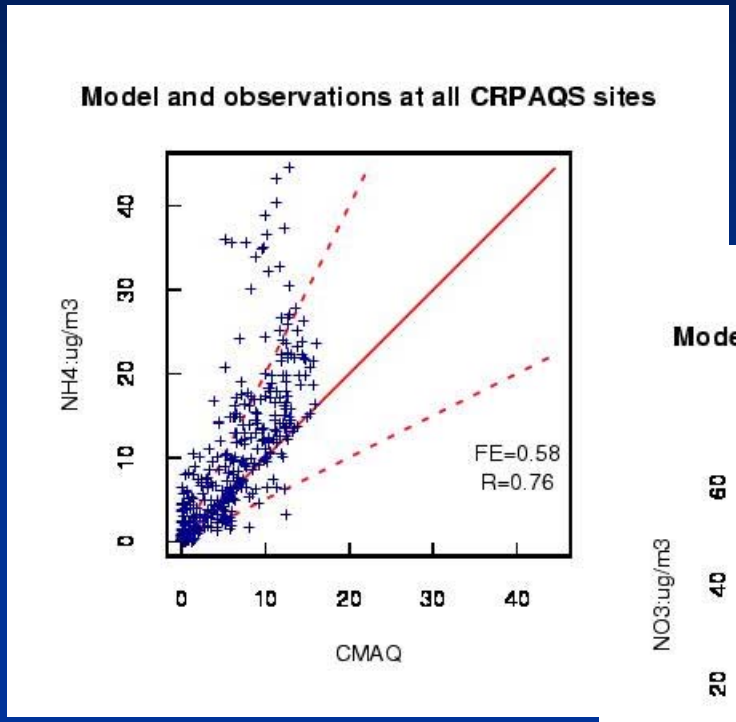
Inorganic Gas Species

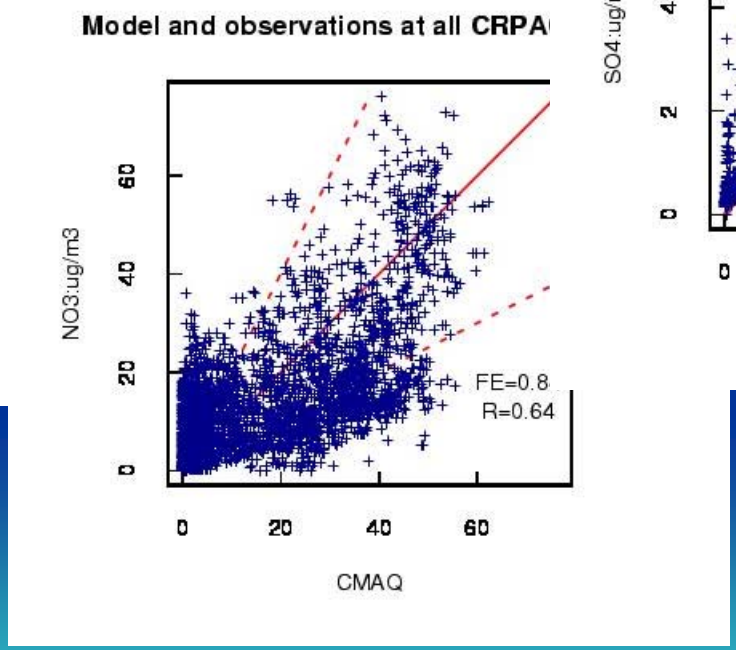
	mFE		mFB		R	
	n=0	n=3	n=0	n=3	n=0	n=3
CO	0.85	0.59	-0.73	-0.48	0.39	0.57
HNO3	***0.90***	***0.75***	***-0.63***	***-0.61***	***0.14***	***0.33***
NH_3	0.94	0.54	0.07	0.10	0.23	0.84
NO_2	0.77	0.33	-0.37	-0.16	0.46	0.80
NO	***1.30***	***0.90***	***-0.90***	***-0.67***	***0.23***	***0.55***
O_3	0.79	0.49	0.50	0.33	0.49	0.76
SO_2	0.96	0.39	-0.57	-0.20	0.06	0.76

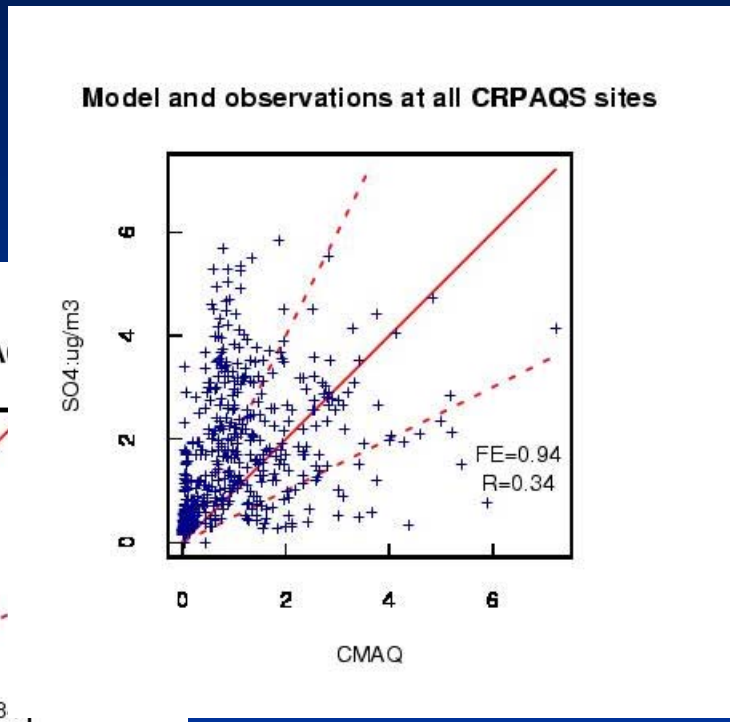
Organic Gas Species

	mFE		mFB		R	
	n=0	n=3	n=0	n=3	n=0	n=3
ALK1	0.75	0.26	0.23	0.09	0.42	0.77
ALK2	***1.60***	***1.30***	***-1.60***	***-1.30***	***0.44***	***0.54***
ALK3	1.10	0.53	-1.00	-0.52	0.56	0.71
ALK4	0.87	0.33	-0.73	-0.31	0.42	0.59
ALK5	0.67	0.23	-0.12	-0.04	0.54	0.84
ARO1	0.90	0.37	-0.78	-0.36	0.48	0.65
ARO2	0.94	0.40	-0.82	-0.38	0.53	0.68
OLE1	0.81	0.24	-0.27	-0.15	0.68	0.95
OLE2	1.10	0.36	-0.65	-0.32	0.40	0.61
TERP	0.37	0.05	-0.24	-0.02	0.64	0.99

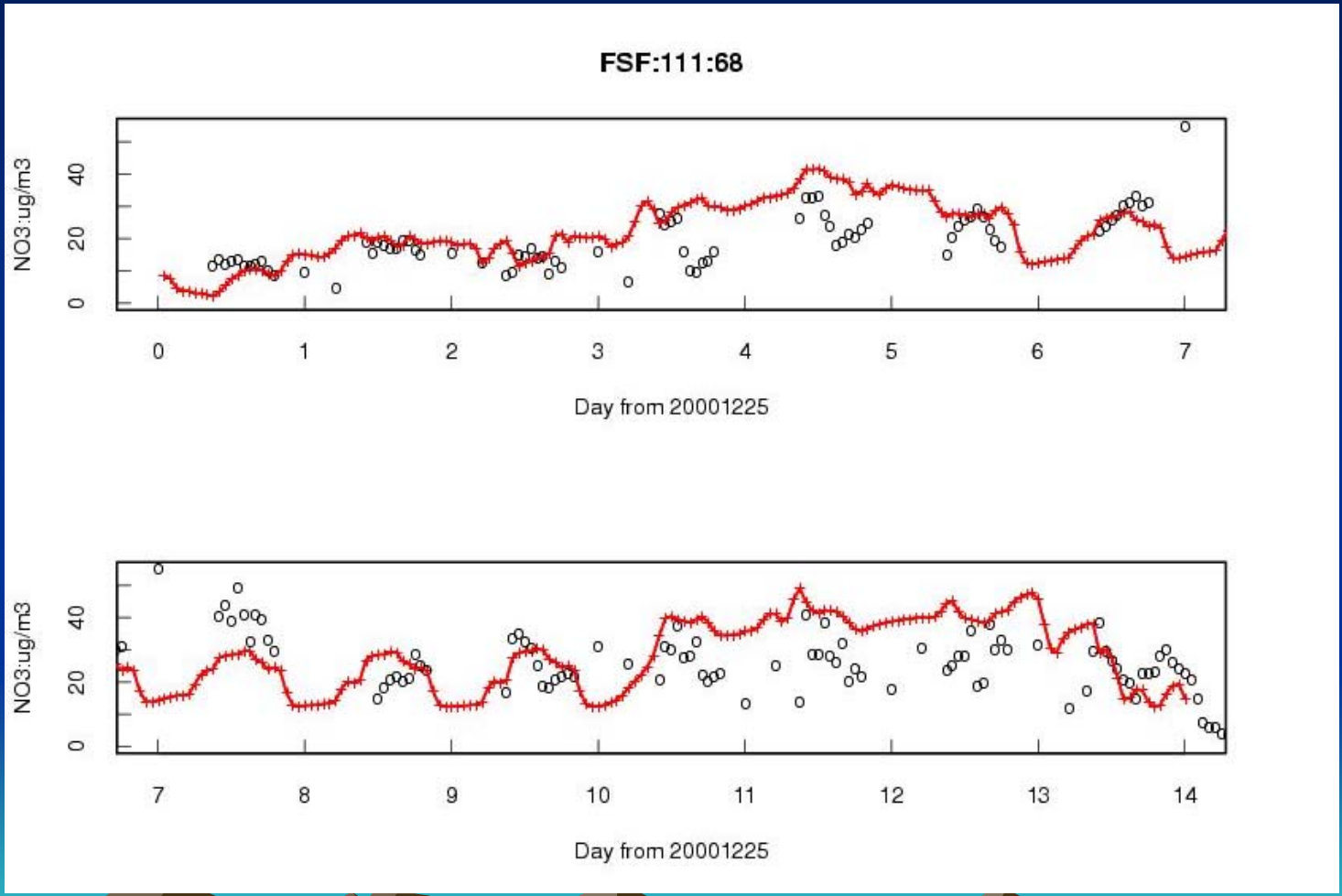
Individual Components



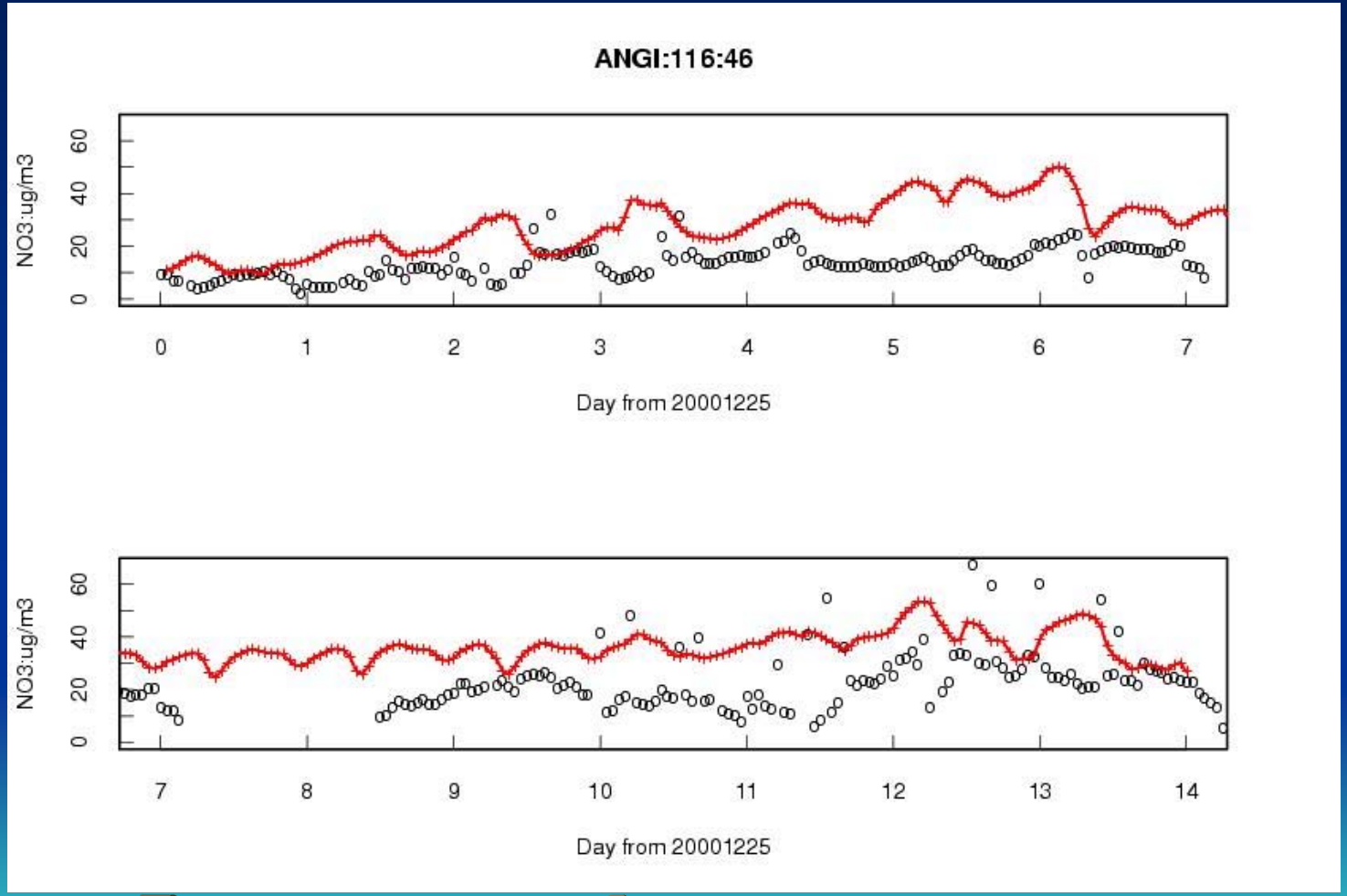




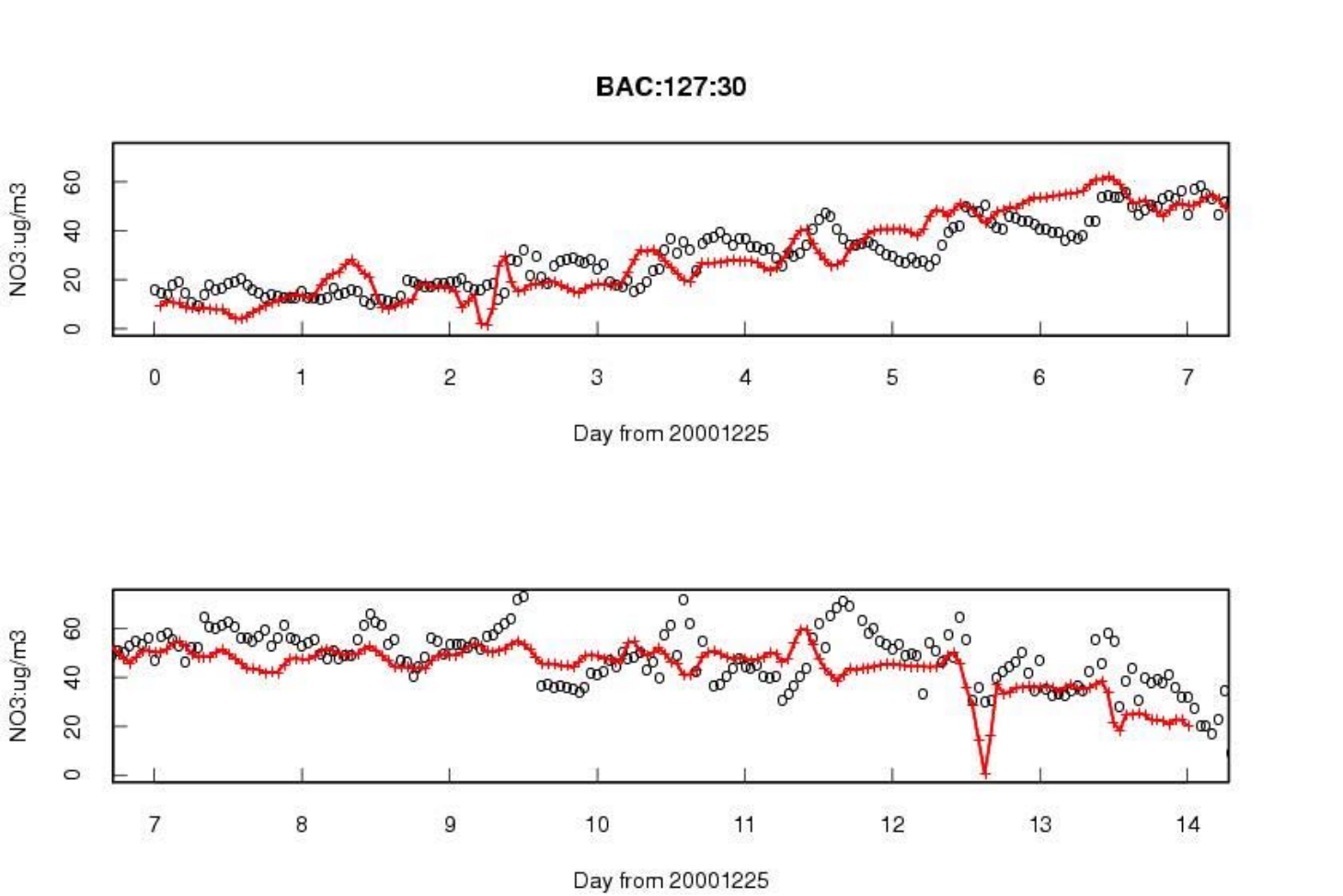
Nitrate at Fresno



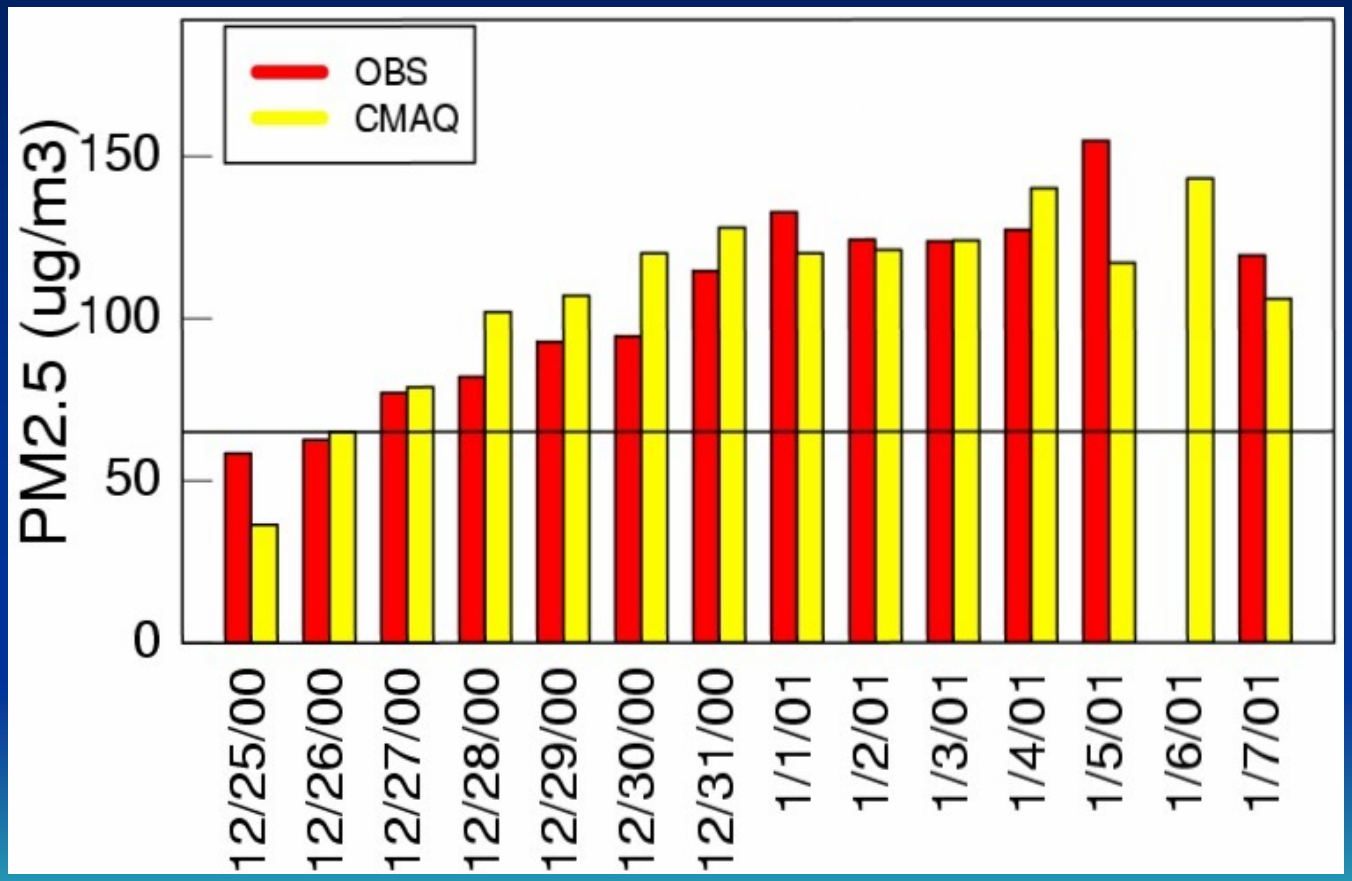
Nitrate at Angiola



Nitrate at Bakersfield



24-Hour $PM_{2.5}$ - Bakersfield



Control Strategy

- The dominant component of $PM_{2.5}$ was NH_4NO_3
- During this episode, NH_4NO_3 was
  - most sensitive to NO_x controls
  - less sensitive to anthropogenic VOC controls
  - least sensitive to NH_3 controls
- Carbonatious matter, which was dominant where wood burning was prevalent, was mostly primary
- Sulfate was not a major component

Next Steps

- Improvements to emissions
- Improved methods for meteorological modeling
- Improvements to chemical mechanisms
- Evaluation of aloft model performance
- Mass conservation/consistency in meteorology and air quality models and related issues
- Modeling of an entire year or longer
- Use of satellite products for model inputs and evaluation
- Corroboration of modeled results

International Conference on Atmospheric Chemical Mechanisms

- December 6-8, 2006, just before the AGU meeting in San Francisco (with events planned for the weekend)
- Held at University of California, Davis
- Impressive list of U.S. and international invited speakers
- Information at www.cmascenter.org (go to Conferences and Meetings)