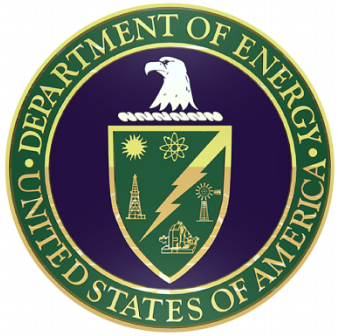
Carbonaceous Aerosol and Radiative Effects Study (CARES)

DOE ASRP Field Campaign in 2010

Rahul Zaveri, Will Shaw, Dan Cziczo

Pacific Northwest National Laboratory

ASRP Aerosol Working Group Meeting
Boulder, October 2, 2009



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List of Participants/Collaborators

- PNNL
- BNL
- LANL
- LBNL
- NASA Langley
- Aerodyne
- University of Arkansas
- University of Nevada / DRI
- Portland State University
- Washington State University
- University of California at San Diego

- NOAA and CARB: CalNex 2010

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CARES 2010 Objectives

- **Investigate evolution of:**
  - Anthropogenic and biogenic SOA (interactions)
  - Aerosol mixing states (especially light of absorbing carbon)
  - Optical and CCN activation properties (role of organics)
  - Biomass burning aerosols (target of opportunity)
- **Evaluate and improve process modules:**
  - Local closure modeling (optical and CCN activation properties)
  - Constrained plume modeling (SOA formation & mixing state evolution)
  - WRF-Chem modeling (3D picture, radiative forcing)

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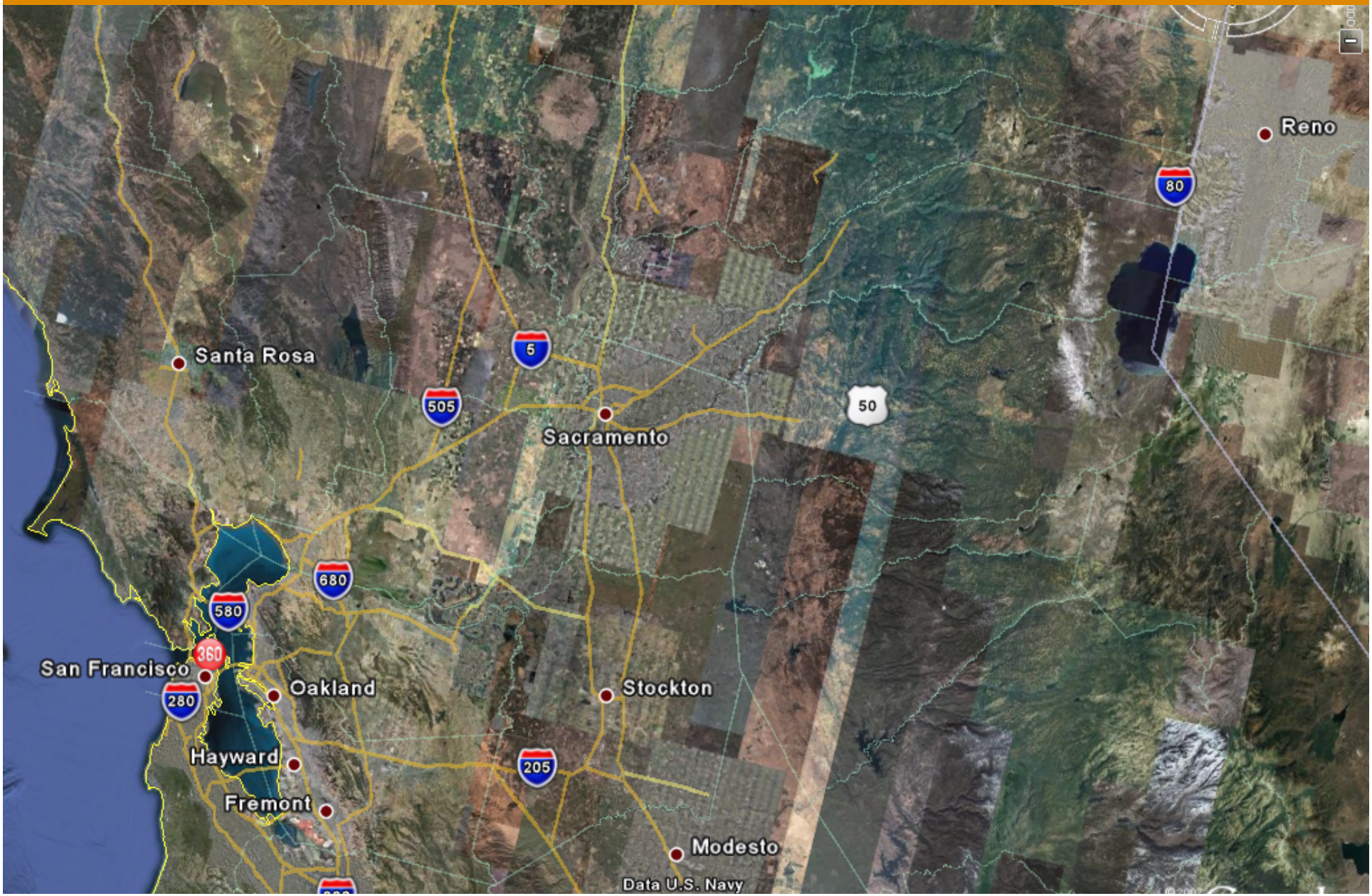
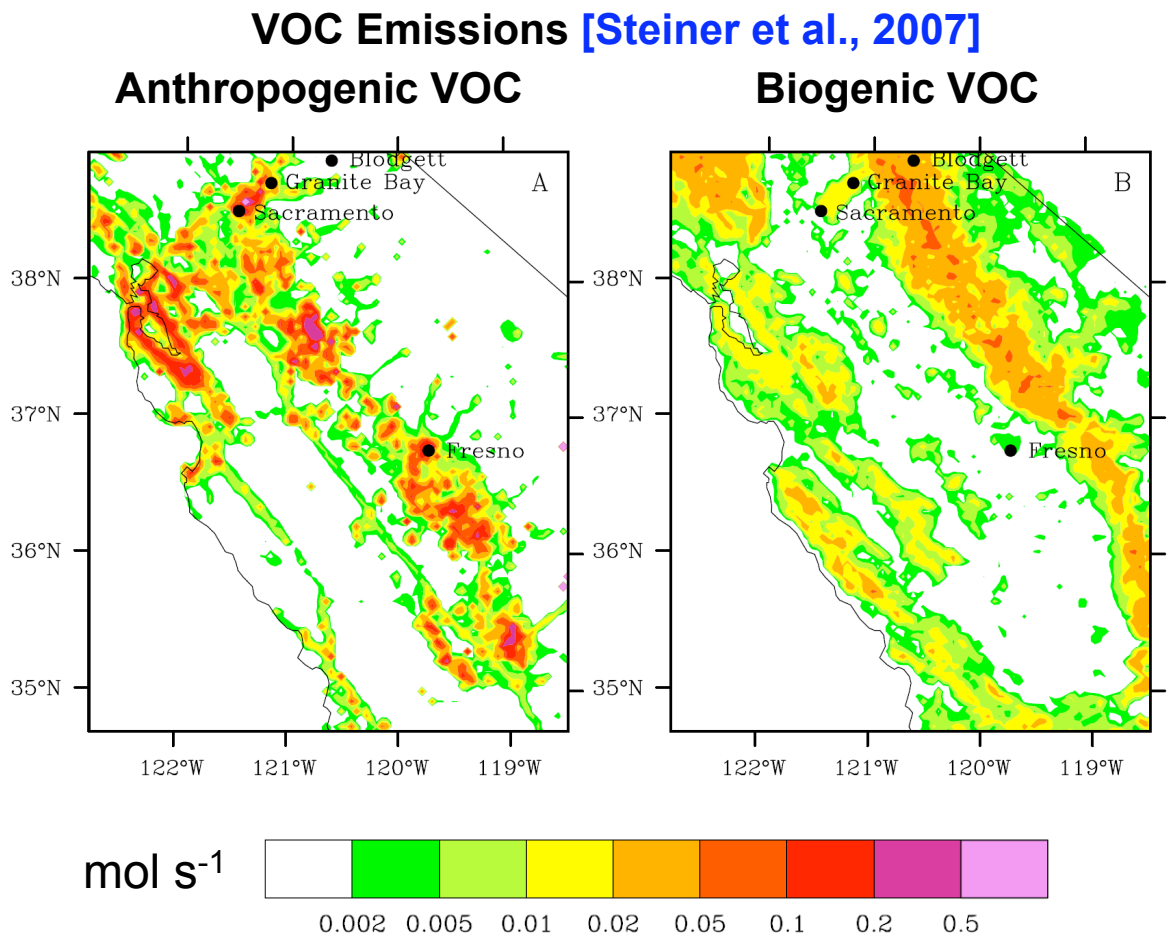
Region of Interest for CARES



Central Valley VOC Emissions



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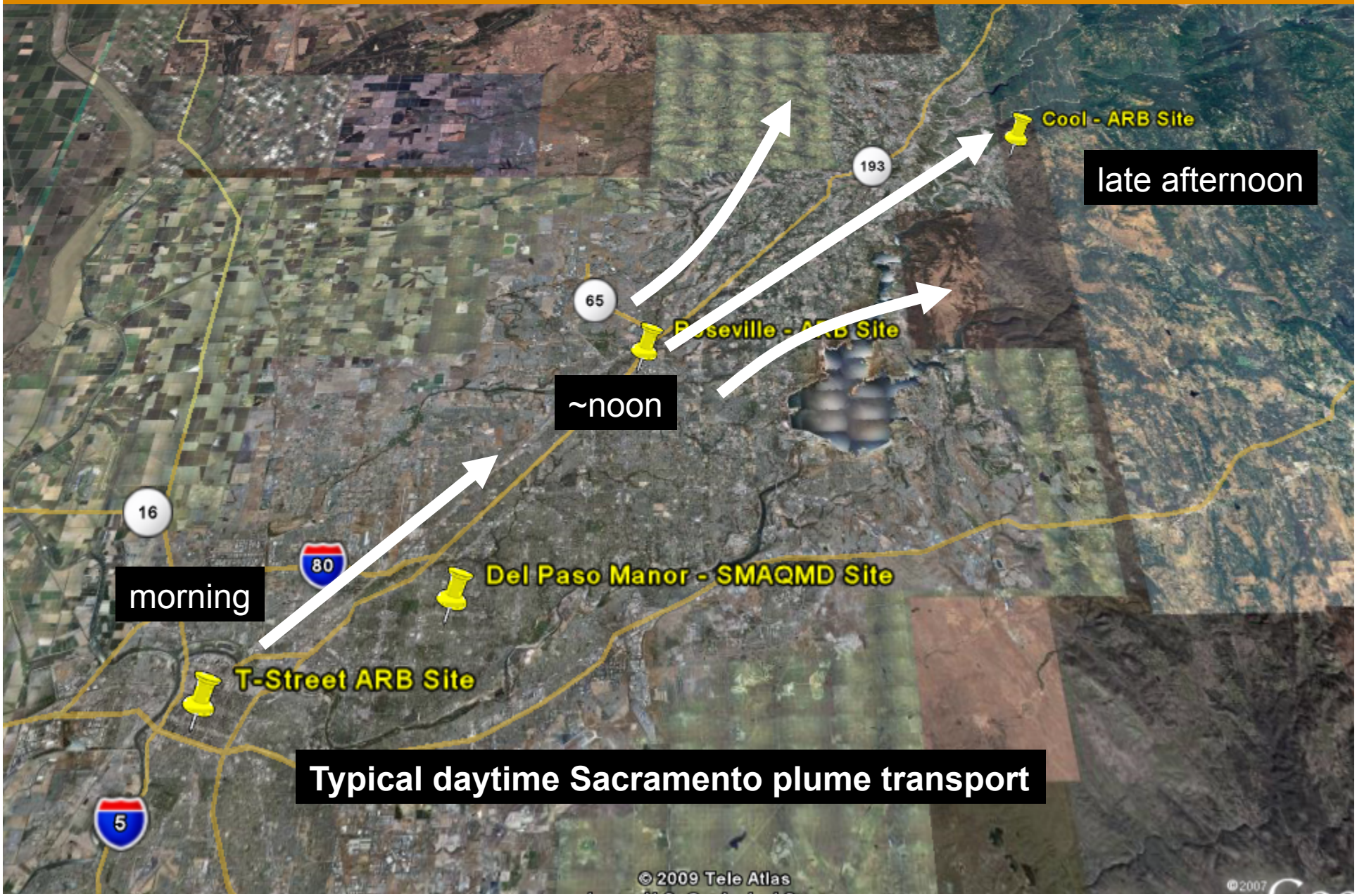
Lagrangian Observations in the Sacramento Urban Plume



Scientific and Logistical Motivations

- Clear skies and highly regular wind patterns in summer
- Convenient to deploy ground sites and aircraft
- Detailed CARB emissions inventory (a big plus for modeling!)
- Several previous ground-based studies at this location provide a good foundation for an intensive ASP field project in 2010
  [e.g., Dillon et al., 2002; Murphy et al., 2006; Steiner et al., 2007; BEARPEX]
- Collaboration with NOAA, CARB, others.
  Contrast CARES findings with CalNex/LA results.

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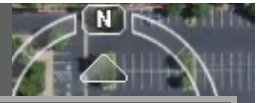
CARES Logistics

- Duration: 30 days
- Dates: TBD; window: June 1 – July 15, 2010
- Measurements Platforms
  - DOE G-1 aircraft: Two flights per day (total ~10-12 days)
  - NASA B-200 aircraft: Coordinated with the G-1
  - T0 Ground Site at Del Paso Manor (still tentative)
  - T1 Ground Site at Cool
- Aircraft Base
  - McLellan Airport or Mather Airport

T0 Site: Del Paso Manor (tentative)



Proposed Suite

▶ Trace Gases			
▫ PTR-MS & GC-MS		VOCs and SVOCs	WSU
▫ CO		VUV fluorescence	WSU
▫ SO_2		research grade	PNNL
▫ O_3	research grade	WSU	
▫ NO, NO_2, NO_y	research grade	WSU	
▶ Aerosol Size/Composition			
▫ SMPS		particle size distribution	PNNL
▫ HR-ToF-AMS + thermal denuder		non-refractory aerosol comp	PNNL
▫ Sunset OC/EC		organic/elemental carbon mass	PNNL
▫ SPLAT-II		single-particle mass spec	EMSL
▫ SP2		black carbon mass	DMT
▫ TRAC, DRUM Samplers		microspectroscopic analyses	EMSL, LBNL
▫ PILS Auto-sampler		high-res MS, WSOC, WSON	EMSL
▫ Radiocarbon Sampler		^{13}C and ^{14}C analysis	Univ. of Arkansas
▶ Optical Properties			
▫ PASS-3		absorption	DRI
▫ 3-λ Nephelometer, 3-λ PSAP, CN		scattering, absorption	PNNL
▫ 3-λ Cavity Ring Down		extinction, scattering	Portland State Univ.
▫ RSS, photolysis, MFRSR		radiation	PNNL
▫ UV-MFRSR		radiation	?
▶ Hygroscopic & CCN Properties			
▫ HTDMA		aerosol hygroscopic properties	?
▫ CCN Counter		CCN activation	PNNL
▶ Meteorology			
▫ Wind Profiler		wind velocity vertical profile	PNNL
▫ Radiosonde		wind velocity, P, T, RH profiles	PNNL

T1 Site: Cool

Proposed Suite

▶ Trace Gases			
☐ PTR-MS		VOCs	Alexander/EMSL
☐ CO		VUV fluorescence	?
☐ O_3	research grade	?	
☐ SO_2		research grade	?
☐ NO_x, NO_y	research grade	?	
▶ Aerosol Size/Composition			
☐ SMPS		particle size distribution	PNNL
☐ HR-ToF-AMS + thermal denuder		non-refractory aerosol comp.	Aerodyne
☐ Sunset OC/EC		organic/elemental carbon mass	PNNL
☐ PALMS		single-particle mass spec	PNNL
☐ SP2		black carbon mass	DMT
☐ TRAC, DRUM Samplers		microspectroscopic analyses	EMSL, LBNL
☐ PILS Auto-sampler		high-res MS, WSOC, WSON	EMSL
☐ Radiocarbon Sampler		^{13}C and ^{14}C analysis	Univ. of Arkansas
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☐ PASS-3		absorption	DRI
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☐ RSS, photolysis, MFRSR		radiation	PNNL
☐ UV-MFRSR		radiation	Univ. of Arkansas
▶ Hygroscopic & CCN Properties			
☐ HDTMA		aerosol hygroscopic properties	PNNL
☐ CCN Counter		CCN activation	PNNL
▶ Meteorology			
☐ Sodar		wind velocity vertical profile	PNNL
☐ Radiosonde		wind velocity, P, T, RH profiles	PNNL

DOE G-1

- **Platform**
  - Gulfstream 159, N701BN
  - Nominal flight altitude: 25 kft (7.6 km)
  - Useful load: ~4000 lb
  - Sampling speed: 195 knots (100 m/s)
  - Mission duration: ~4 hours
  - Science flight hours: ~70 h
  - Based in Sacramento

G-1 Administered by PNNL's Airborne Facility and Programs Office

- **Basic Instruments**
  - total temperature
  - static pressure
  - gust-probe differential pressures
  - platform position/velocity/attitude
  - dew-point temperature
  - isokinetic aerosol inlet
  - static temperature
  - potential temperature
  - winds

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DOE G-1

Proposed Suite

- **Trace Gases**

PTR-MS	VOCs		PNNL
CO	VUV fluorescence		BNL
O_3	research grade	BNL	
SO_2	research grade		BNL
NO_x, NO_2, total NO_y	research grade	BNL	

- **Aerosol Size/Composition**

CPC	particle number concentration		PNNL
FIMS	particle size distribution		BNL
UHSAS	particle size distribution		PNNL
FSSP	particle size distribution		PNNL
HR-ToF-AMS	non-refractory aerosol comp.	EMSL	
SP2	black carbon mass		BNL
ATOFMS	aerosol mixing state		UCSD
TRAC, DRUM Samplers	microspectroscopic analyses		EMSL, LBNL
PILS Auto-sampler	high-res MS, WSOC, WSON		EMSL

- **Optical Properties**

PASS-3	absorption	LANL
3-λ Nephelometer	scattering	PNNL
PSAP	absorption	PNNL

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NASA B-200 Deployment for CARES 2010

- **Platform**
  - NASA Langley King Air B-200
  - Nominal flight altitude: 28 kft (~ 9 km)
  - Aircraft speed: 200-220 knots
  - Aircraft duration: 4-5 hours
  - Science flight hours: ~70 h
  - Based in Sacramento with DOE G-1

- **Instruments**
  - High Spectral Resolution Lidar — Ferrare/Hostetler NASA Langley
  - Digital Camera — Ferrare/Hostetler NASA Langley
  - Research Scanning Polarimeter — (possible) Cairns NASA/GISS)

- **Objectives**
  - Support DOE G-1 operations (reconnaissance and real-time direction)
  - Characterize the vertical and horizontal distribution of aerosols and aerosol optical properties
  - Provide the vertical context for G-1 and ground in situ measurements
  - Infer aerosol type and apportion optical depth by type
  - Investigation of new active + passive (lidar + radiometer) aerosol retrieval techniques
  - Characterize the PBL height and distribution of aerosols within and above PBL
  - Assess aerosol model transport simulations
  - CALIPSO/CALIOP & GLORY/APS Validation

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Questions and Future Updates on CARES 2010?

Science Questions:

Rahul Zaveri – rahul.zaveri@pnl.gov

Platform/Logistics Questions:

G-1 Aircraft: Beat Schmid – beat.schmid@pnl.gov

Ground Sites: Will Shaw – will.shaw@pnl.gov

Website: http://acrf-campaign.arm.gov/cares

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Key Science Questions: SOA

- SVOC concentrations in a fresh urban emissions?
- Chemical composition (O/C, O/N ratios), volatility spectrum, and oligomeric fraction in observed OA?
- Enhanced biogenic SOA mass in the urban plume compared to outside of the urban plume?
- Correlations of modern and old carbon fractions with urban, biogenic, and biomass burning tracers?
- Vertical profiles of SOA?

Key Science Questions: Aerosol Mixing State

- Aerosol mixing state as a function of particle size in fresh and aged urban plumes?
- Morphology of aerosols as a function of mixing state?
- Relative roles of condensation and coagulation processes in shaping the aerosol composition and size distribution?
- Effect of aerosol mixing states on the ensemble aerosol optical properties, hygroscopicity, and CCN activity?
- Vertical profiles of aerosol mixing state?

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Key Science Questions: Aerosol Optical Properties

- Scattering and absorption as a function of aerosol mixing state?
- Enhanced near-UV and visible absorption in OA?
- Correlation of enhanced absorption to urban POA, biomass burning OA, and SOA?

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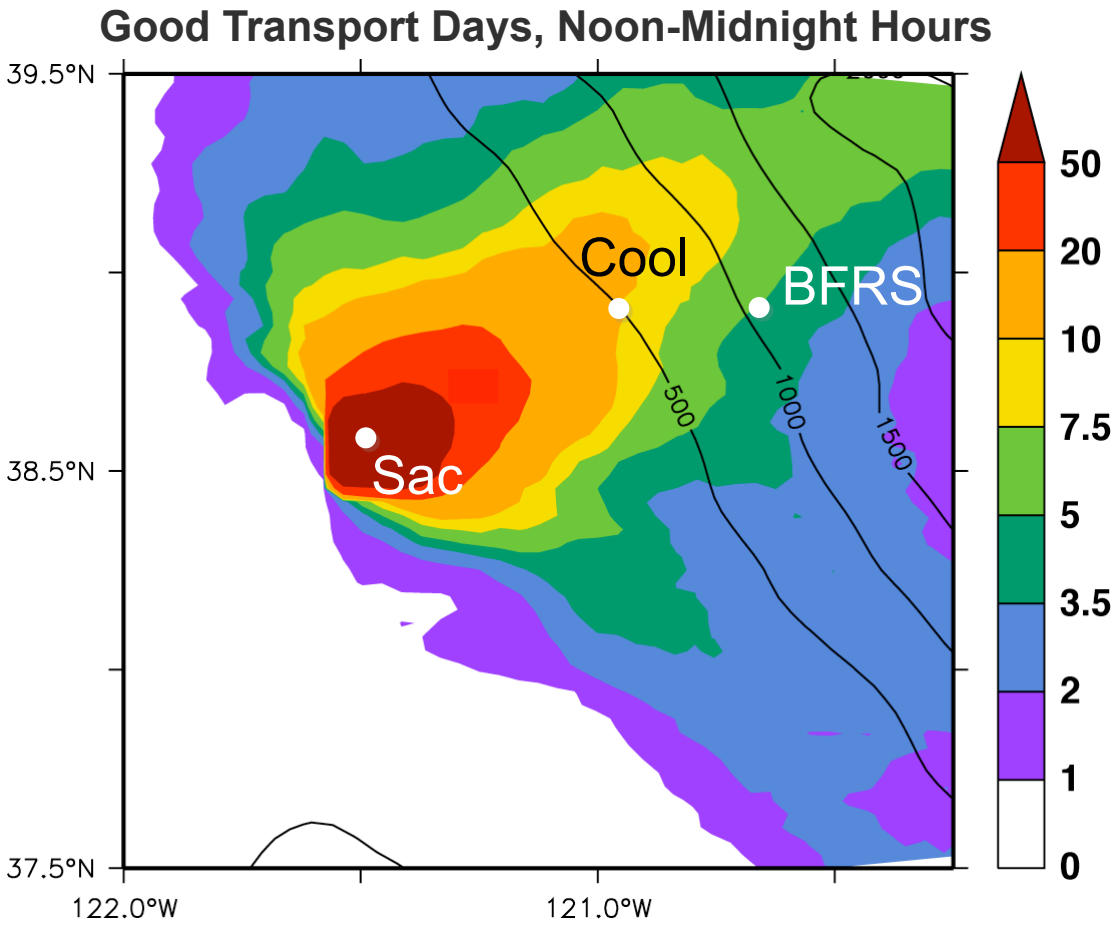
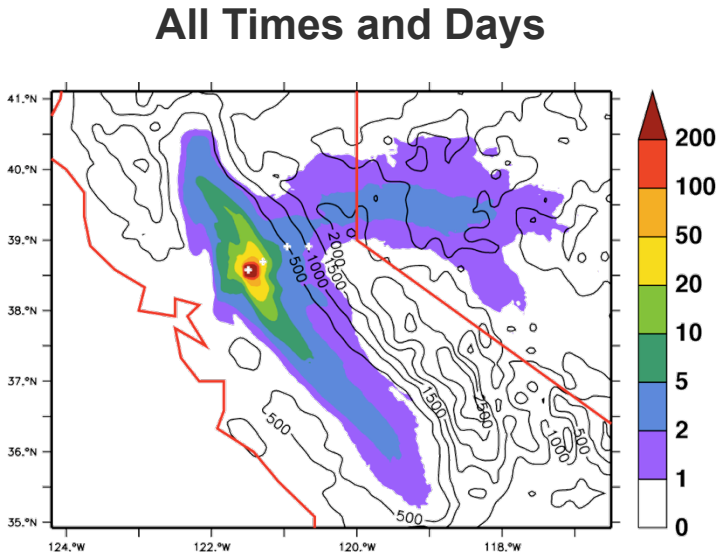
Pre-CARES Modeling: Footprint of Sac Emissions – June 2008





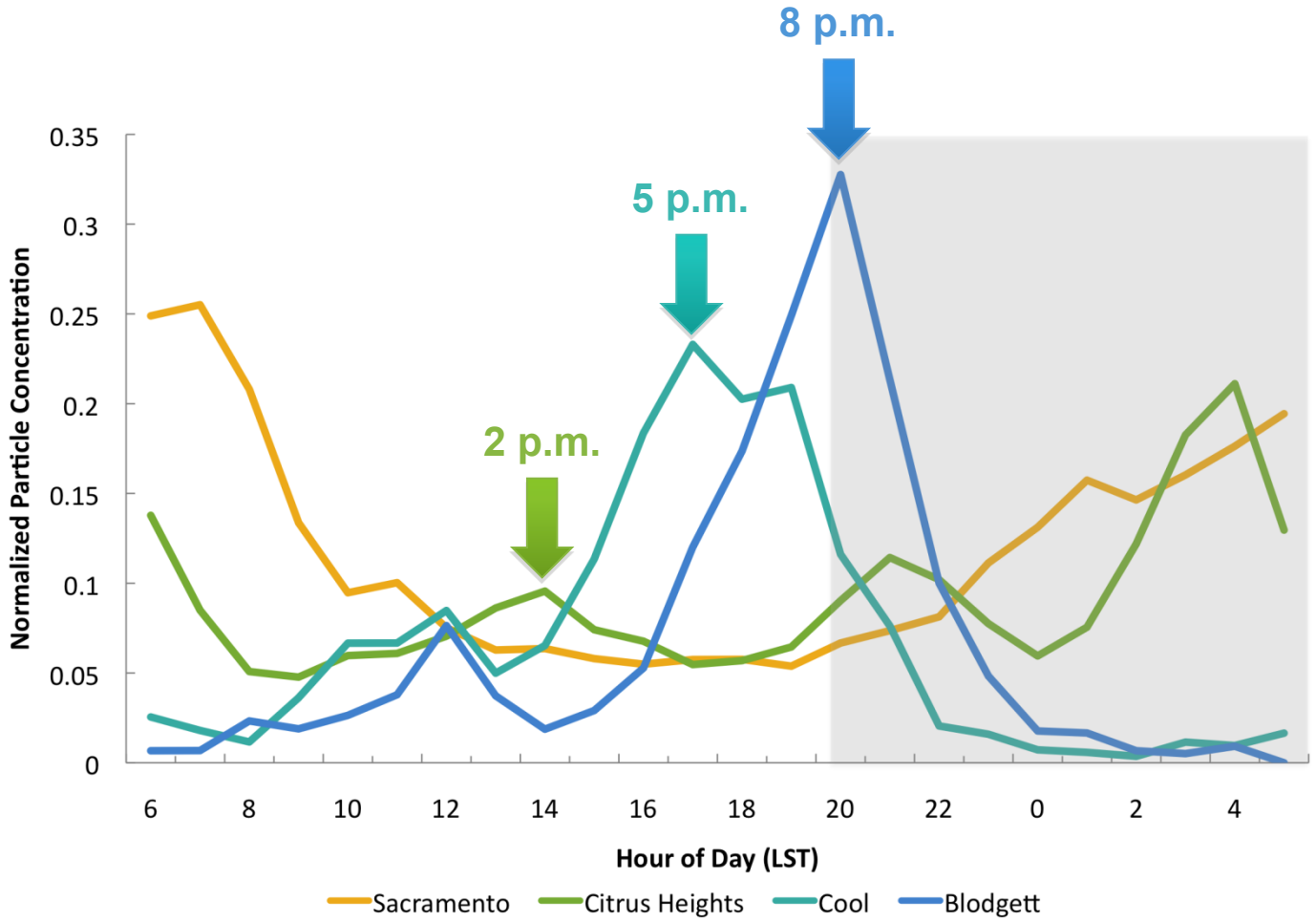
Sites from west to east:

- **Sacramento**
- **Cool**
- **Blodgett Forest**

Based on maximum transport time of 48 hours.

Analysis by W.I. Gustafson, Jr.

Composited Normalized Particle Concentrations



Composite includes 14 of 30 simulated days

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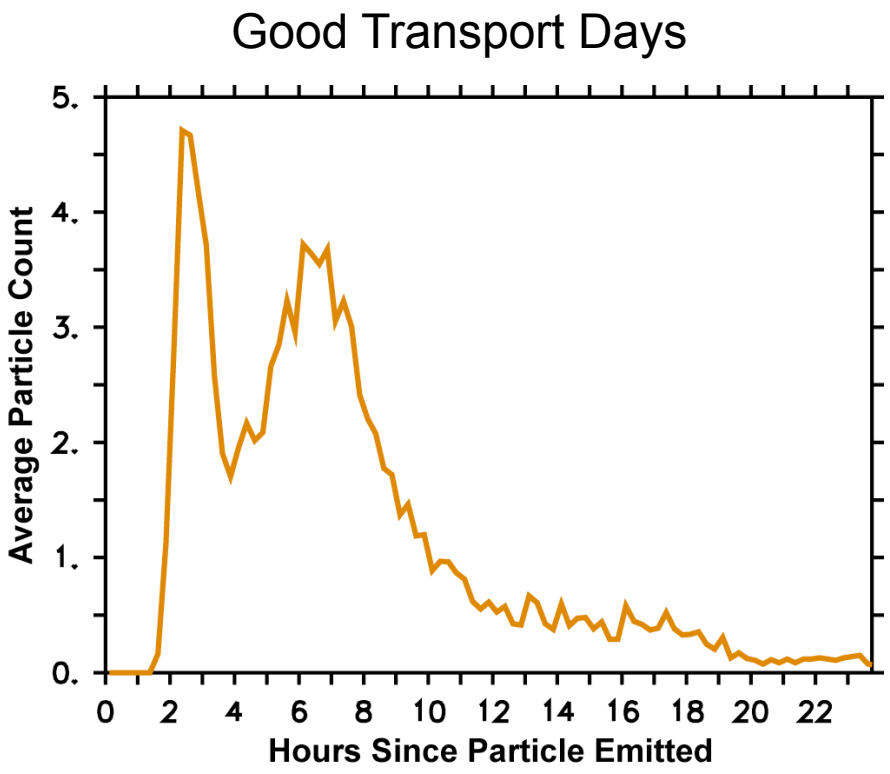
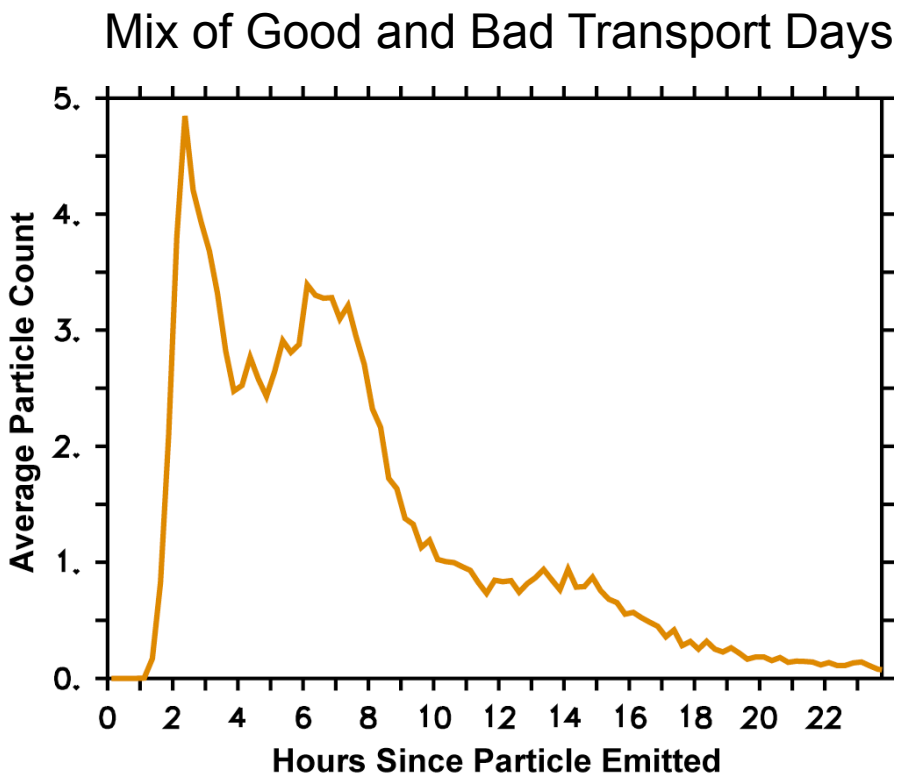
Analysis by W.I. Gustafson, Jr.

Particle Ages at Cool





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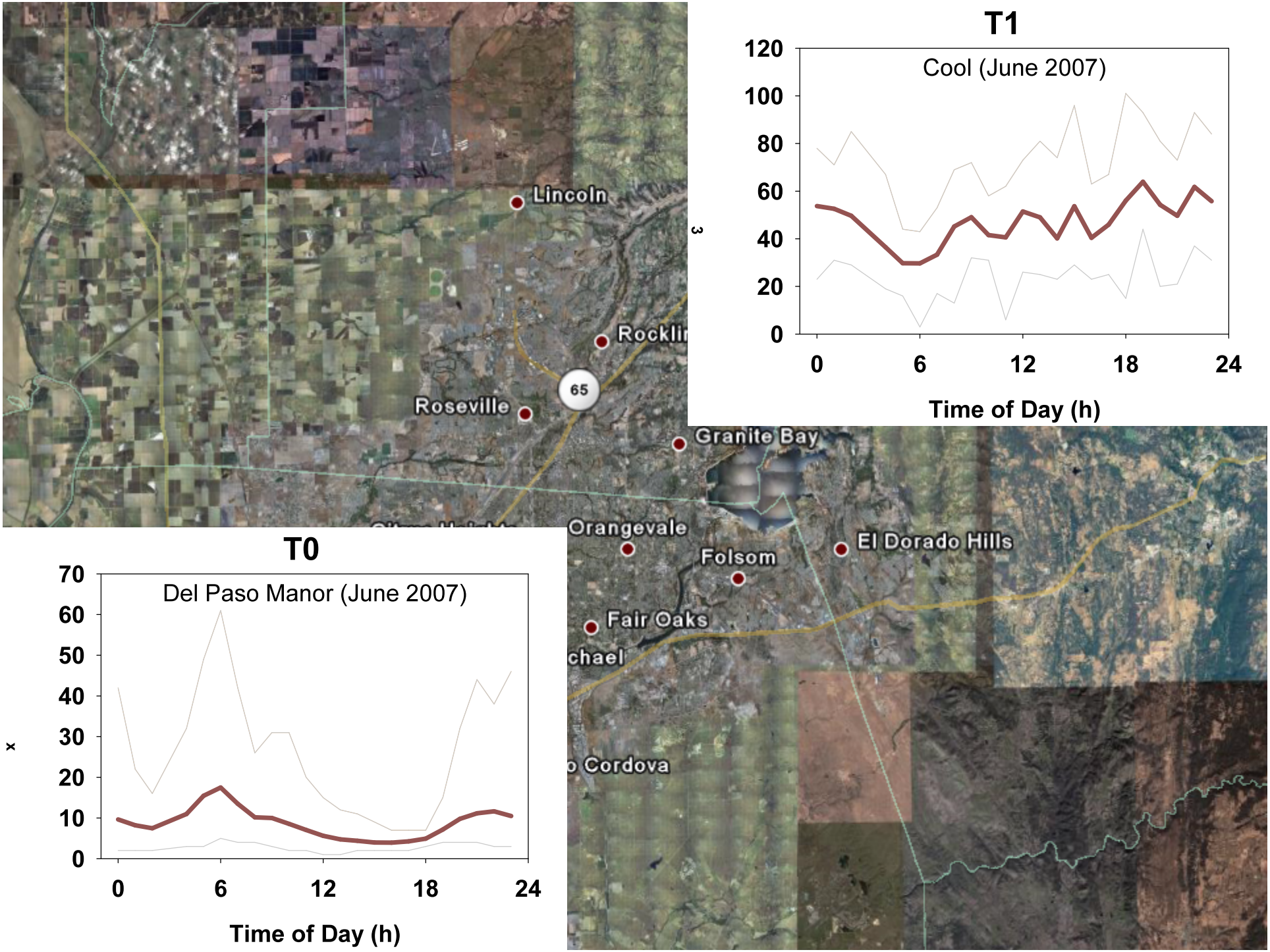

Lincoln
Roseville
65
Granite Bay
Orangevale
Folsom
El Dorado Hills
Fair Oaks
chael
o Cordova

T1
Cool (June 2007)
120
100
80
60
40
20
0
0
6
12
18
24
Time of Day (h)

T0
Del Paso Manor (June 2007)
70
60
50
40
30
20
10
0
0
6
12
18
24
Time of Day (h)

Pre-campaign Activities

- **CARB Emissions inventories**
  - Obtain anthropogenic/urban emissions of trace gases
  - Work with CARB/SMAQMD to develop a detailed biogenic VOC inventory
  - Develop size-resolved primary aerosol emissions
- **Pre-campaign modeling**
  - Box-model and 3-D WRF-Chem simulations
- **Prepare flight plan playbook for G-1 and B-200**
  - Sac-Cool Corridor – upwind, over, downwind
  - Along the Central Valley and over other CalNex sites
  - Coordinated with NOAA WP-3

NASA Langley Airborne High Spectral Resolution Lidar (HSRL)

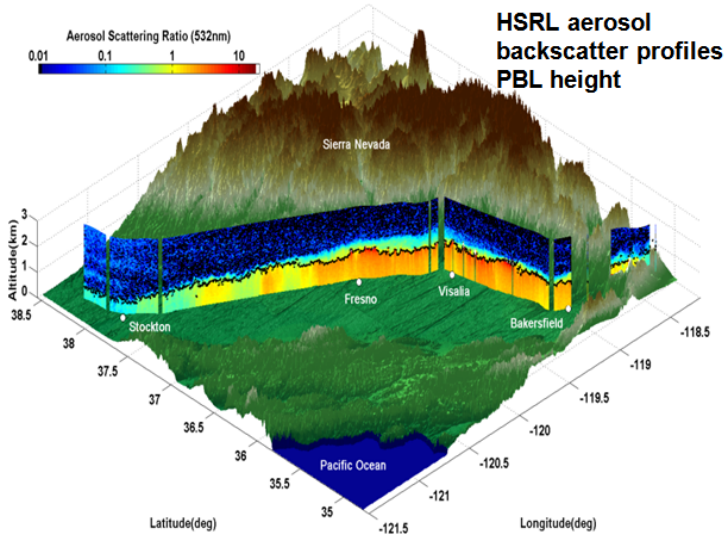
HSRL Technique (Hair et al., AO, 2008):

- Relies on spectral separation of aerosol and molecular backscatter in lidar receiver
- Independently measures aerosol backscatter, extinction, and optical thickness
- Internally calibrated
- Provides intensive aerosol parameter to help determine aerosol type

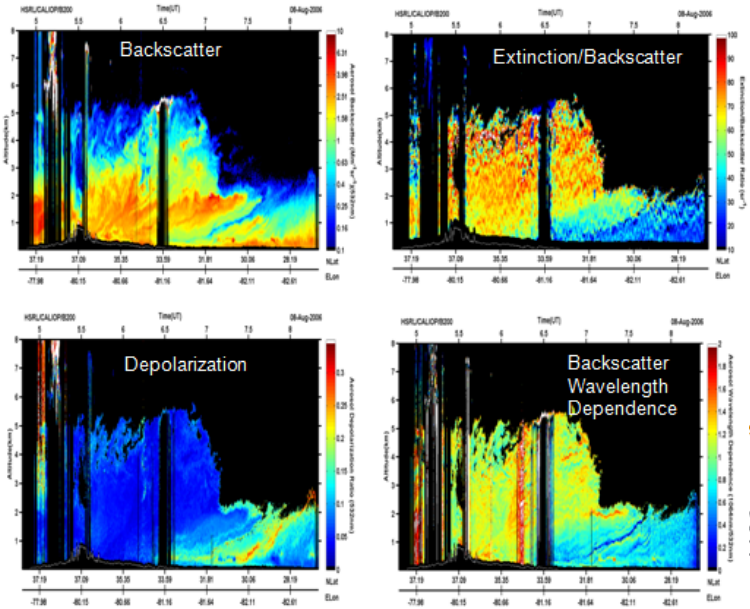
HSRL Aerosol Data Products:

- Scattering ratio (532 nm)
- Backscatter coefficient (532, 1064 nm)
- Extinction Coefficient (532 nm)
- Backscatter Wavelength Dependence (532/1064 nm)
- Extinction/Backscatter Ratio ("lidar ratio") (532 nm)
- Depolarization (532, 1064 nm)

February 15, 2007 Flight over San Joaquin Valley



August 8, 2006 CALIPSO Validation Flight



NASA GISS Research Scanning Polarimeter (RSP): Possible Deployment for CARES

Measurements

- Total and linearly polarized reflectance in nine spectral channels
- 152 viewing angle samples over 120 deg angular range

Derived parameters

- Aerosols
  - optical depth
  - location and width of both modes of bimodal size distribution
  - refractive index
  - estimates of size and amount of accumulation mode aerosols above clouds
- Clouds
  - optical depth
  - effective radius, variance
  - liquid water path
  - cloud drop number concentration

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