CalNex 2010
science goals, dates, and strategies

Tom Ryerson – NOAA ESRL
Chemical Sciences Division

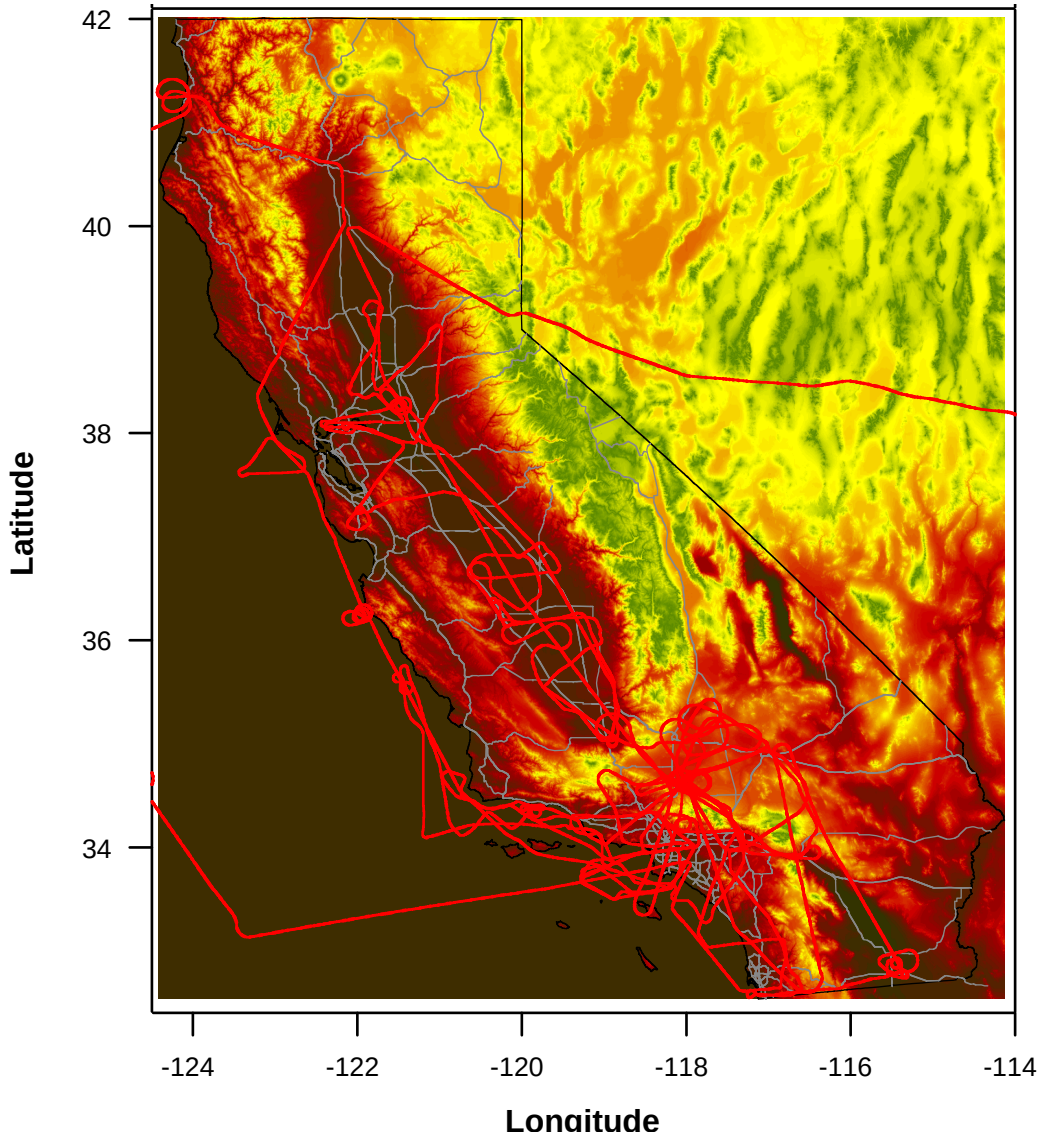
Major field study in May-June 2010

Led by ARB and NOAA; many partners with independent goals
University researchers, NASA, DOE, NSF, NRL, USFS, NPS

Surface-, aircraft-, ship-, and space-based measurements; complemented by Lagrangian and Eulerian modeling studies

Will need to build on decades of existing research in California

ARCTAS-CA DC-8 flight tracks

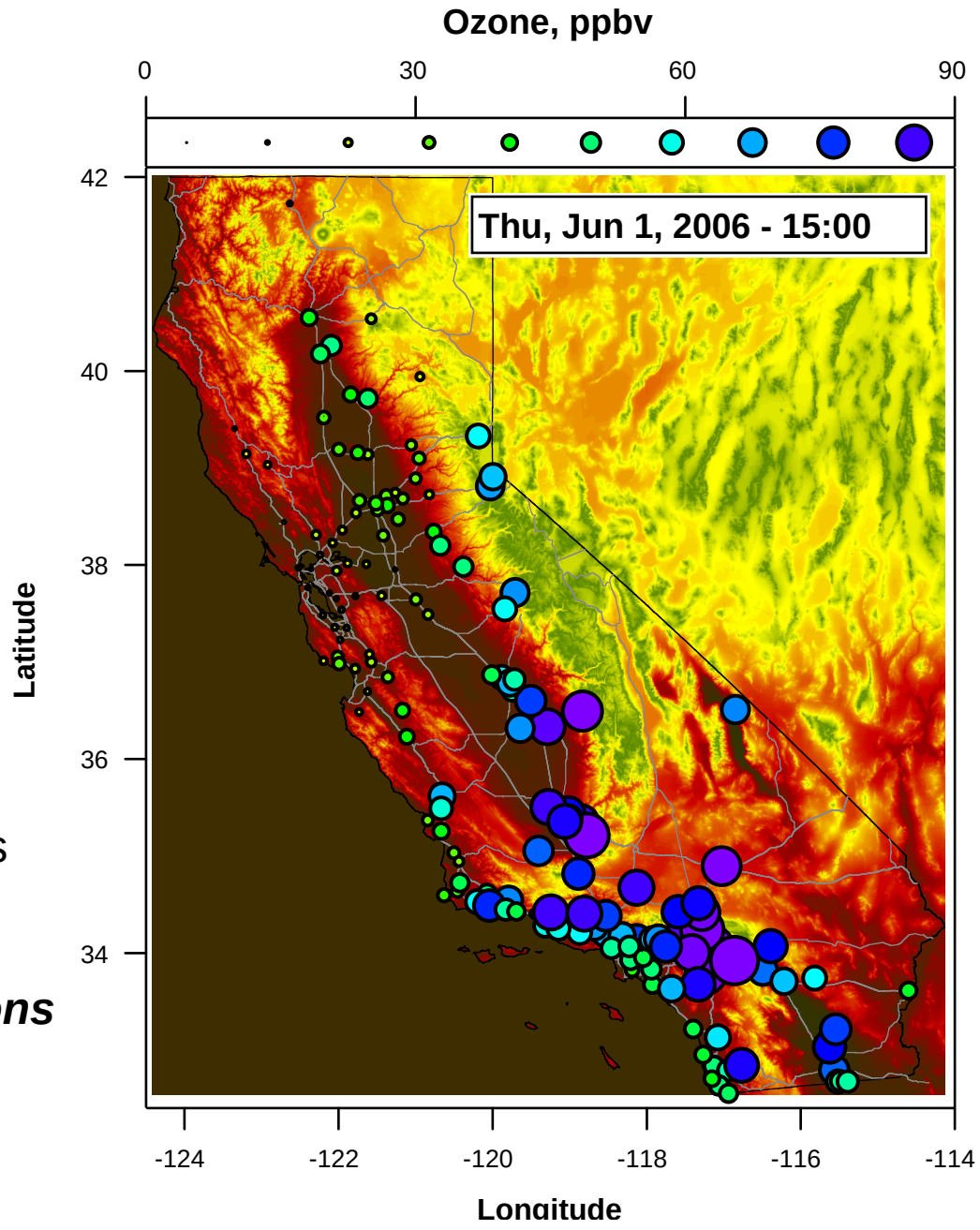


CalNex 2010

Spatial and temporal pattern of ozone and SOA is driven by:

- background mixing ratios
- diurnal transport patterns
- precursor emissions distributions
- rates and yields of chemical production pathways
- deposition and removal processes

Improved understanding of the complexity of these interactions in California is a daunting task



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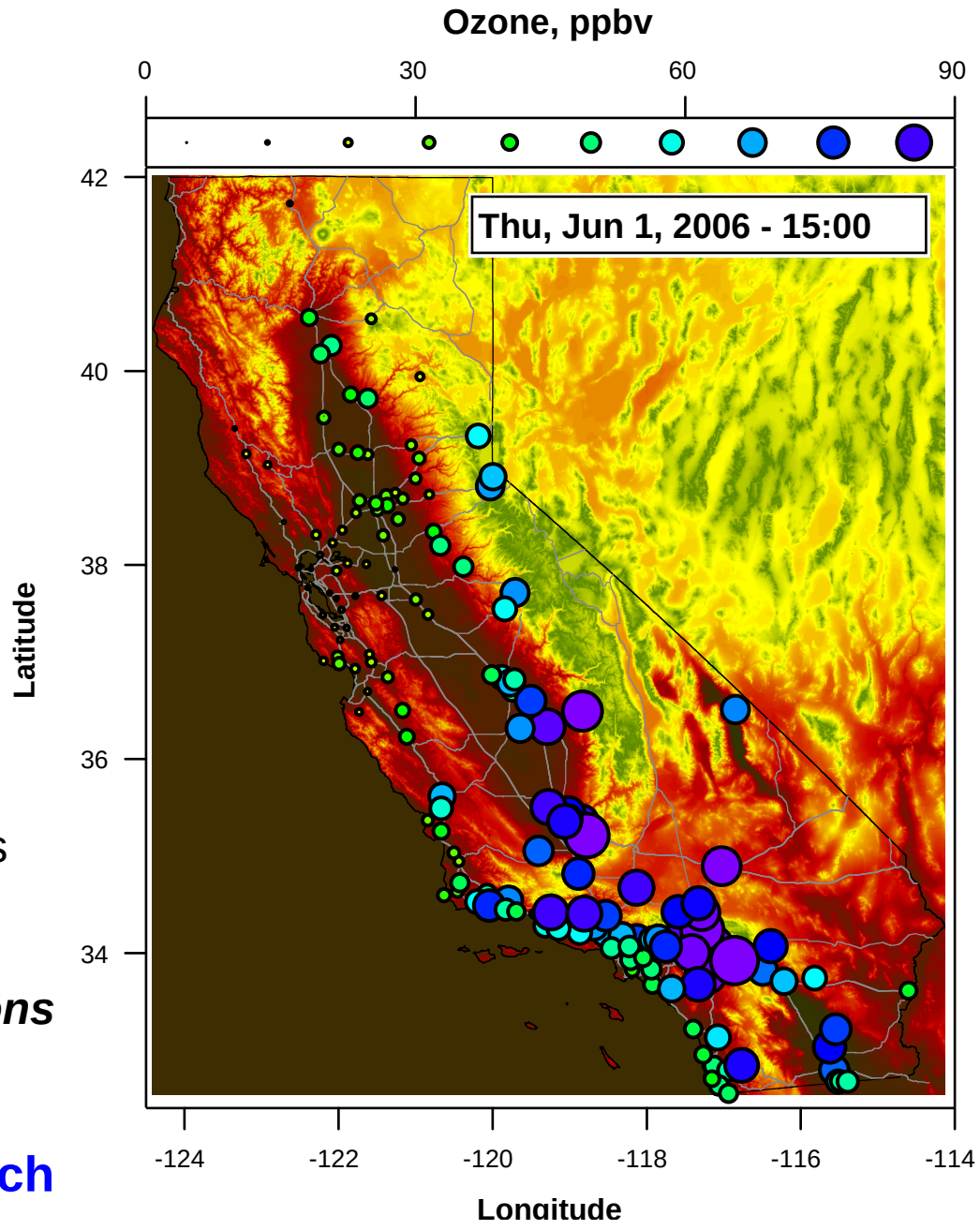
CalNex - an integrated approach

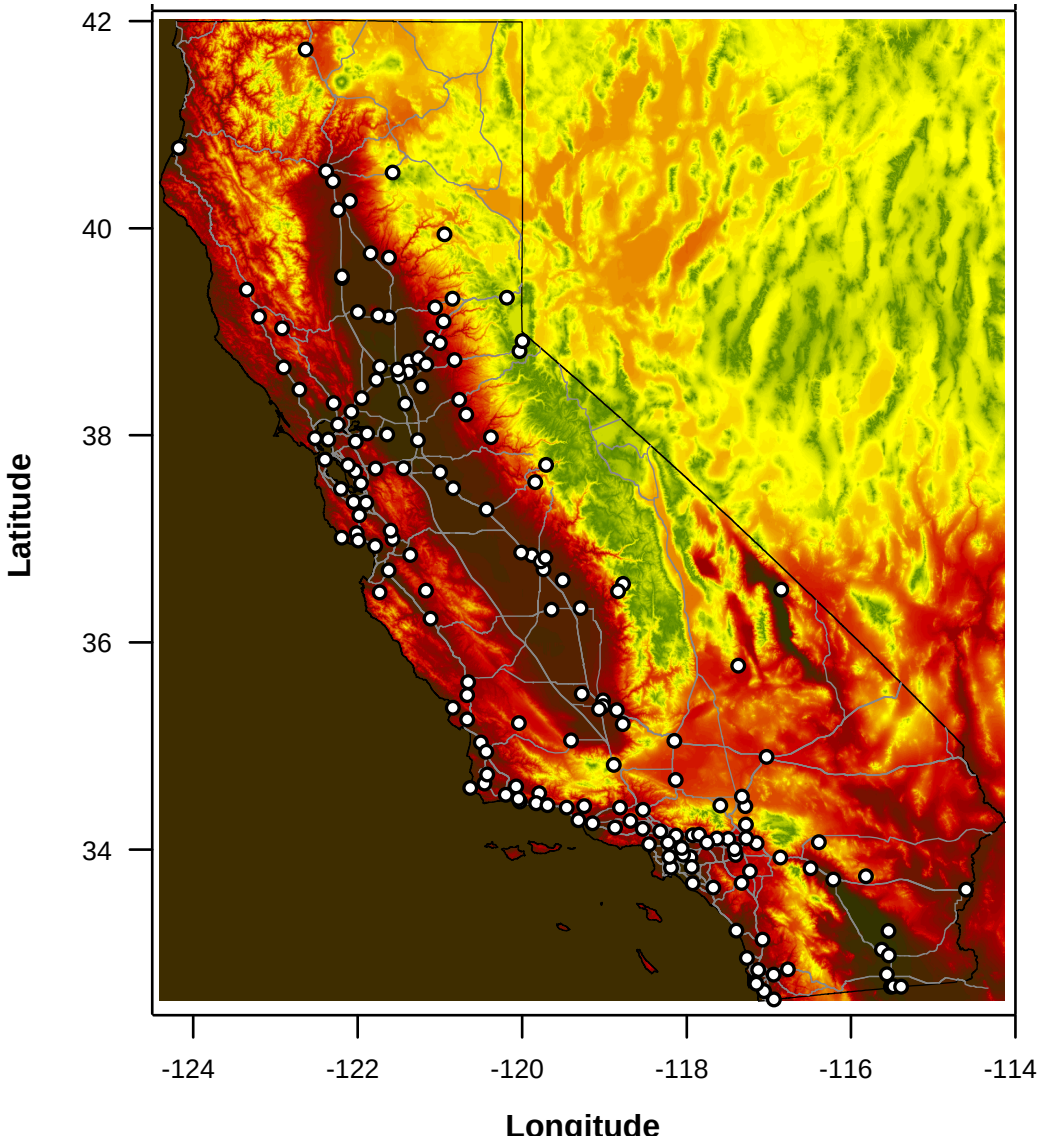


CalNex 2010

Measurements during CalNex:

Long-term surface observations

Ground-based monitoring stations



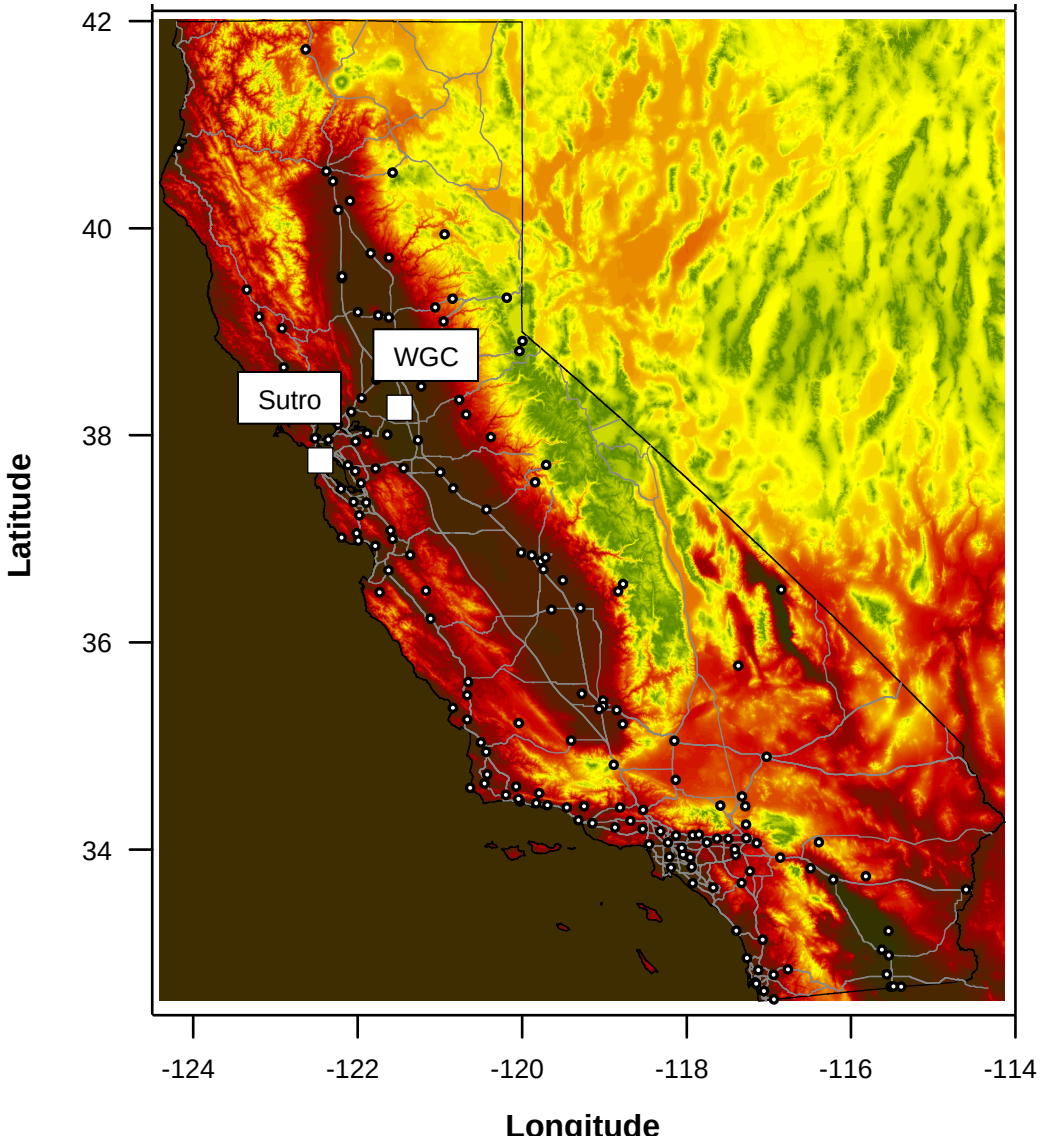
CalNex 2010

Measurements during CalNex:

Long-term surface observations

Instrumented tall towers

CALGEM (LBNL/NOAA) tall tower sites



CalNex 2010

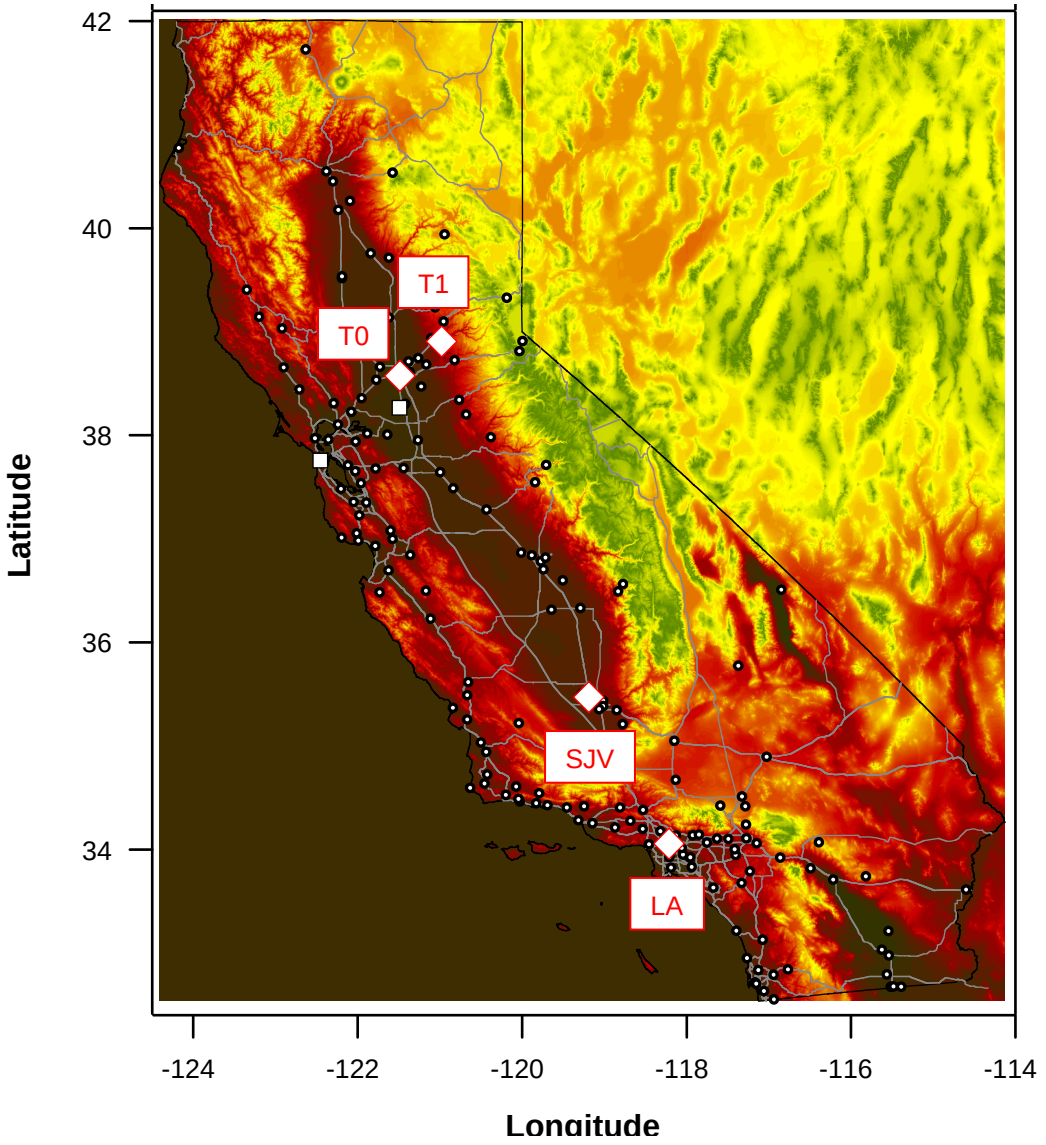
Measurements during CalNex:

Long-term surface observations

Instrumented tall towers

Major intensive ground sites

CalNex and CARES major ground sites



CalNex 2010

Measurements during CalNex:

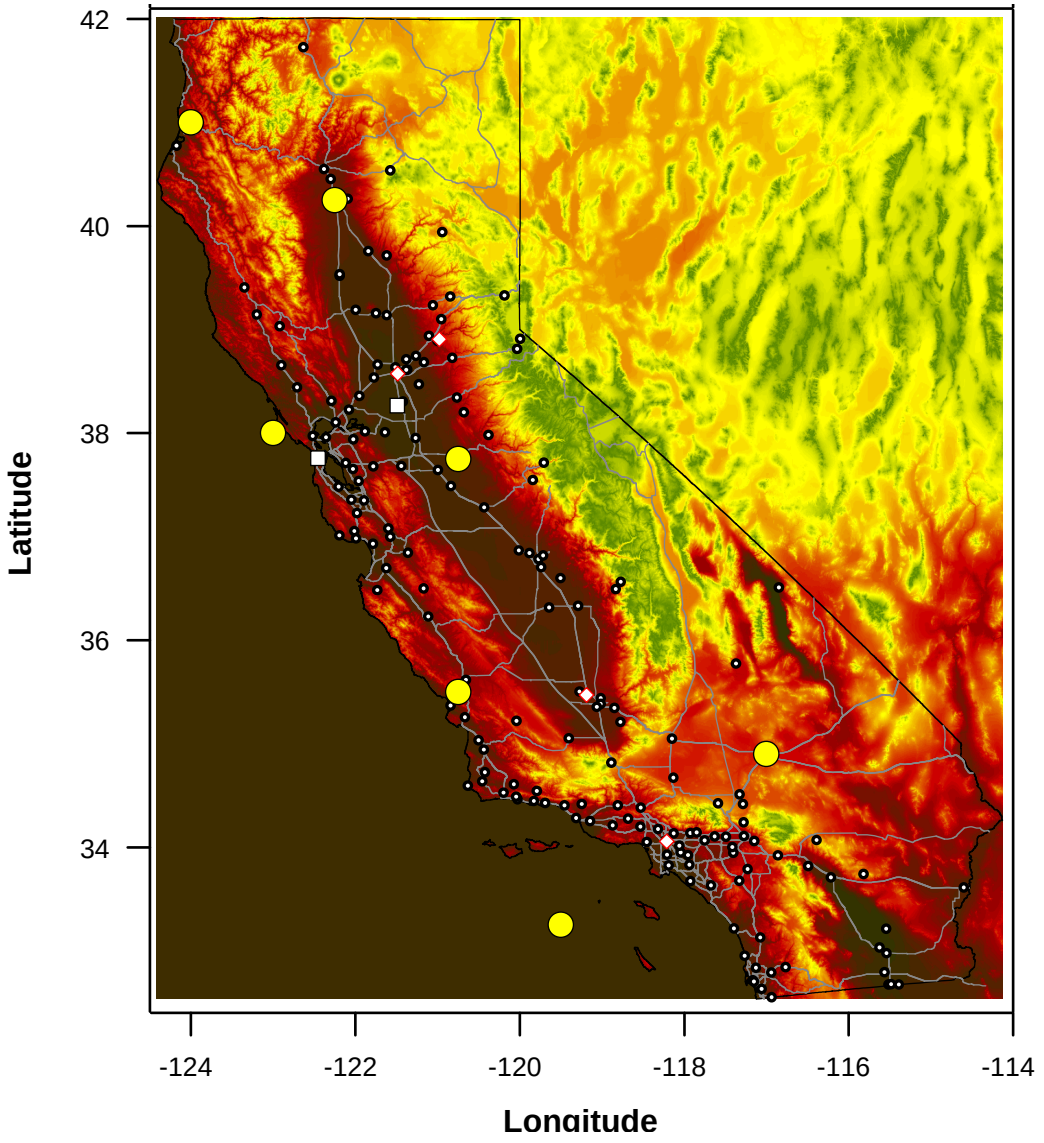
Long-term surface observations

Instrumented tall towers

Major intensive ground sites

Daily ozonesonde launches

IONS-2010 ozonesonde network



CalNex 2010

Measurements during CalNex:

Long-term surface observations

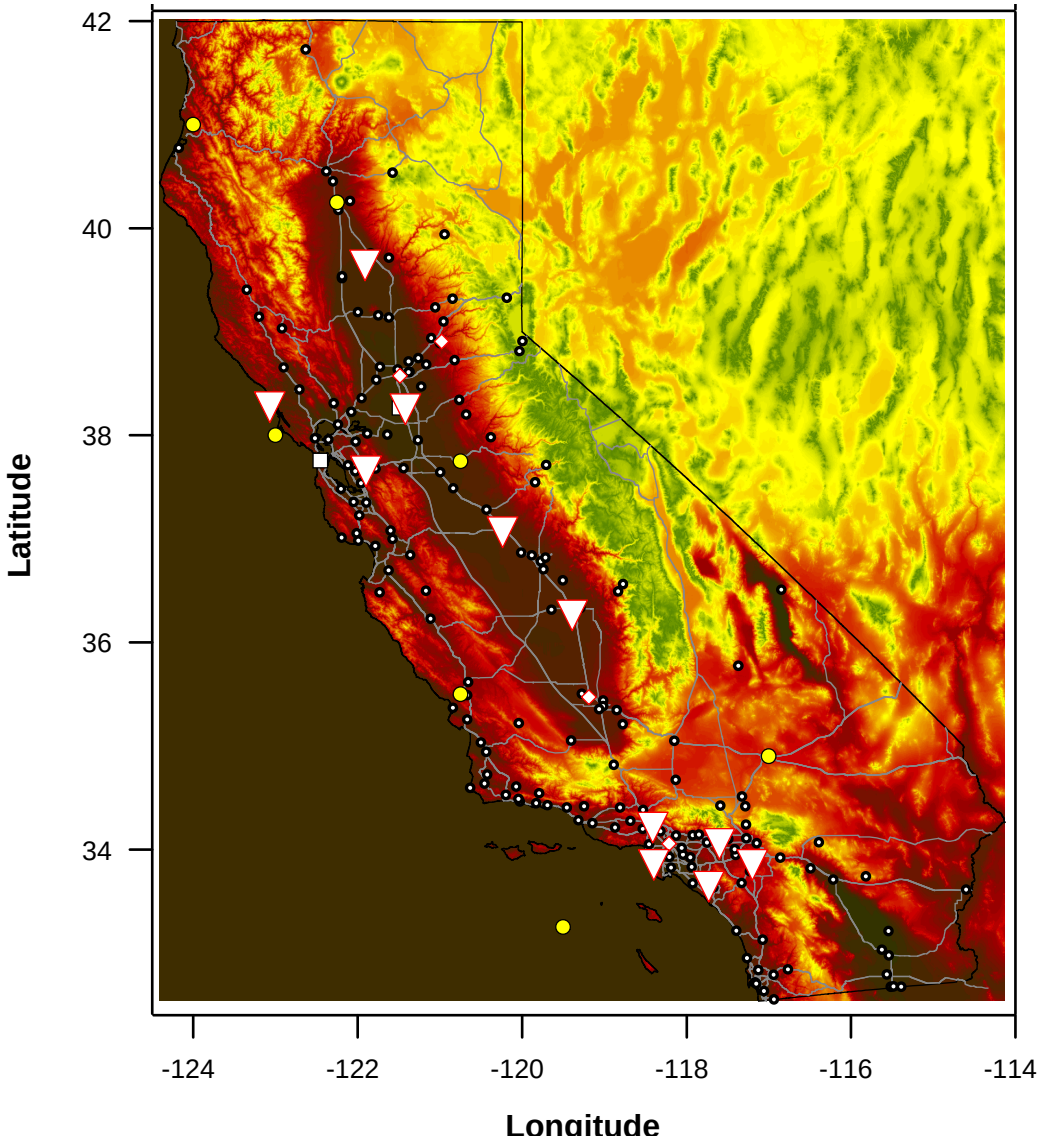
Instrumented tall towers

Major intensive ground sites

Daily ozonesonde launches

Radar profiler network

Upper-air profiling sites



CalNex 2010

Measurements during CalNex:

Long-term surface observations

Instrumented tall towers

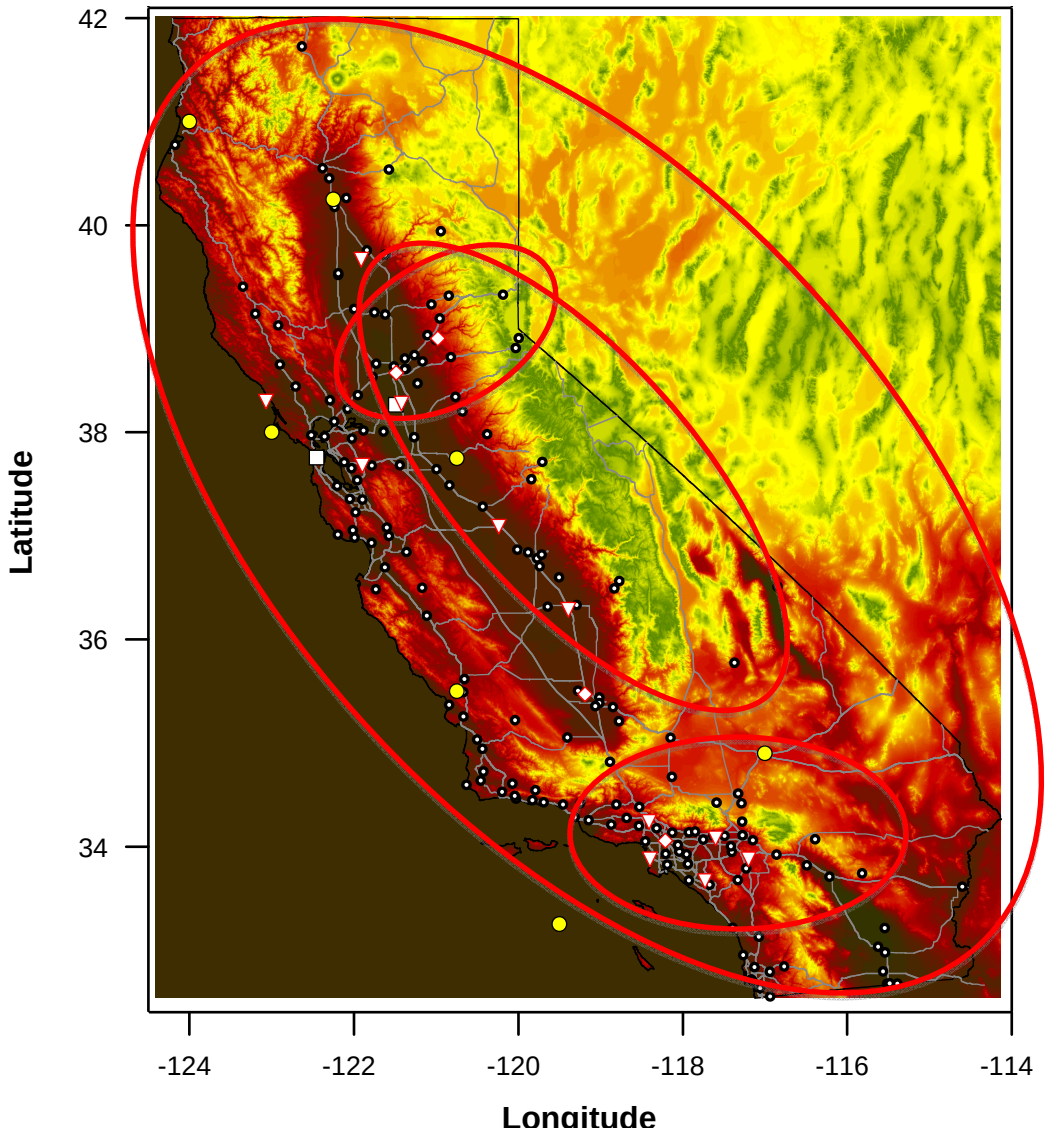
Major intensive ground sites

Daily ozonesonde launches

Mobile research platforms
- NOAA WP-3D & Twin Otter
- CIRPAS Twin Otter
- NASA King Air
- DOE G-1
- USFS Cessna
- NOAA *Ron Brown*

Satellite observations
- TES, OMI, Sciamachy, IASI

CalNex and CARES aircraft operations



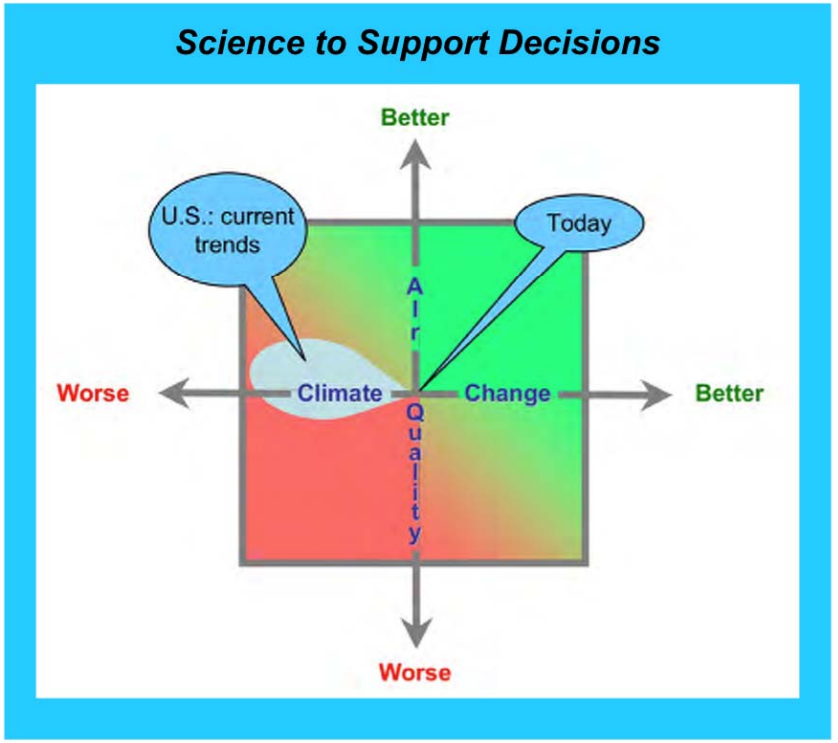
CalNex 2010
NOAA science goals

- **Emissions evaluation**
- **Chemical processing**
  - *ozone production*
  - *aerosol radiative effects*
  - *SOA chemistry*
  - *nighttime processing*
  - *halogen activation*
- **Transport and meteorology**
- **Forecast model evaluation**

Today: a brief tour, with a few examples of study plans

noaaresearch

2010 CalNex
Science and Implementation Plan



Research at the Nexus of Air Quality and Climate Change

6 October 2008

http://esrl.noaa.gov/csd/calnex/scienceplan.pdf

NOAA WP-3D payload - CalNex 2010

Instrument	*Measurement*	*Time resolution*
O_3	ozone	1 sec
CO	**carbon monoxide**	**1 sec**
SO_2	**sulfur dioxide**	**3 sec**
CO_2 and CH_4	**carbon dioxide and methane**	**1 sec**
AWAS	**VOCs, halocarbons,** alkyl nitrates	**72/flight**
PTRMS	**oxy-VOCs, aromatics, acetonitrile**	**15 sec**
HCHO	**formaldehyde**	**1 sec**
NO, NO_2, and NO_y	**nitrogen oxides**	**1 sec**
PANs and $ClNO_2$	peroxyacyl nitrates and nitryl chloride	1 sec
NO_3 and N_2O_5	nocturnal nitrogen oxides	1 sec
HNO_3	nitric acid	1 sec
NH_3	**ammonia**	**1 sec**
LTI	aerosol low turbulence inlet	1 sec
NMASS/UHSAS/WLOPC	**0.004 to 8 μm aerosol size distribution**	**1 sec**
CRD-AES	3-λ aerosol extinction as f(RH)	1 sec
PSAP	3-λ aerosol absorption (filter)	15 sec
PAS	**3-λ aerosol absorption (photoacoustic)**	**5 sec**
SP2	**aerosol black carbon**	**1 sec**
PILS	aerosol chemical composition	80/flight
AMS	aerosol chemical composition	10 sec
UV-VIS spectrometer	spectral actinic flux from 280-689 nm	1 sec
TDL H_2O	water vapor	1 sec
cloud probes	drop size and morphology	1 sec
position and meteorology	aircraft location, T, P, winds, etc.	1 sec

Emissions evaluation will be a focus in CalNex

anthropogenic

biogenic

biomass burning

agricultural

GHGs and soot

short-lived species linking AQ and climate

Addressing CalNex science questions

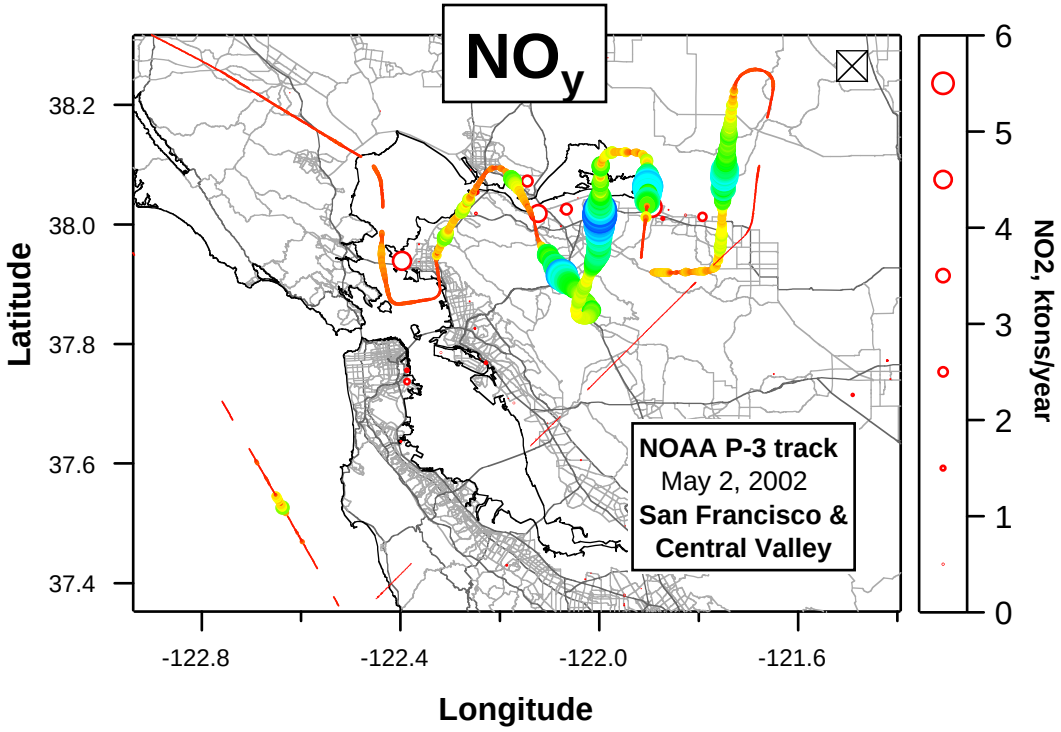
Emissions

A. How can we improve the emissions inventory for greenhouse gases, ozone and aerosol precursors including emissions from soil, ships, agriculture and other non-industrial or transportation related processes? What measurements can help validate the use of satellite data for biogenic VOC and NOx emission inventories?

Critical uncertainties remain in our understanding of 1) the processes by which primary emissions are transformed within and removed from the atmosphere, and 2) how aerosols interact with the radiation flux in the atmosphere.

B. What emissions (natural and anthropogenic) and processes lead to sulfate formation over California coastal waters and in urbanized coastal areas? What is the contribution from ship emissions? How does Southern California compare and contrast with the San Francisco Bay Area?

C. What sources and processes contribute to atmospheric mercury concentrations in California?



Emissions studies

Enhancement ratios relative to CO and CO_2 can be compared directly to inventory values for anthropogenic emissions

- VOCs, NOx, CH_4, halocarbons, N_2O
- use 2002, 2008, & 2010 aircraft data
- link to long-term WGC tower record

• Detailed P-3 chemical data can be used to

- differentiate between sources
- differentiate transport pathways
- quantify chemical processing

Addressing CalNex science questions

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Emissions studies

Can we better quantify NO_x, NH_3, CH_4, & N_2O emissions from the agricultural sector?

include Imperial Valley flights
compare to satellite columns

Stoichiometry of CH_4 and CO_2 flux in a California rice paddy

Andrew M. S. McMillan,[1] Michael L. Goulden,[1] and Stanley C. Tyler[1]

Received 12 March 2006; revised 27 September 2006; accepted 19 October 2006; published 3 February 2007.

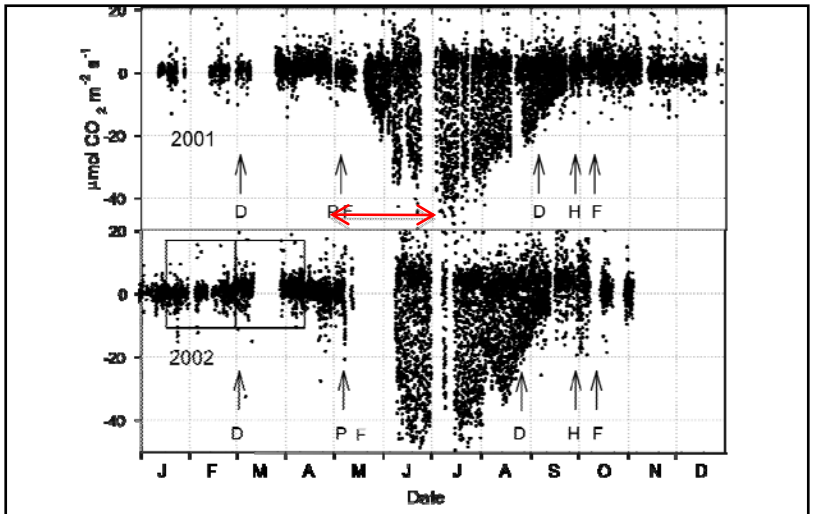

Figure 3. Half-hourly values of F_{CO2} for 2.8 years. A negative value indicates the loss of CO_2 from the atmosphere to the crop. Arrows indicate timing of planting (P), crop harvest (H), post-harvest flooding (F) and drainage prior to planting or harvest (D). The two boxes in the bottom panel indicate the 45-day period prior to drainage when the daily average of F_{CO2} was 0.3 μmol m^{-2} s^{-1} (left box) and the 45-day period after drainage when the daily average of F_{CO2} was 1.7 μmol m^{-2} s^{-1} (right box).

Agricultural emissions

Blake VOC sampling grids and 2008 ARCTAS DC-8 data show the **high spatial variability** of sources

High temporal variability is driven by planting, irrigation, and fertilization cycles

SJV supersite will anchor P-3 flights

Repeat P-3 flights through growing season to observe changes in ag. activity over time

Addressing CalNex science questions

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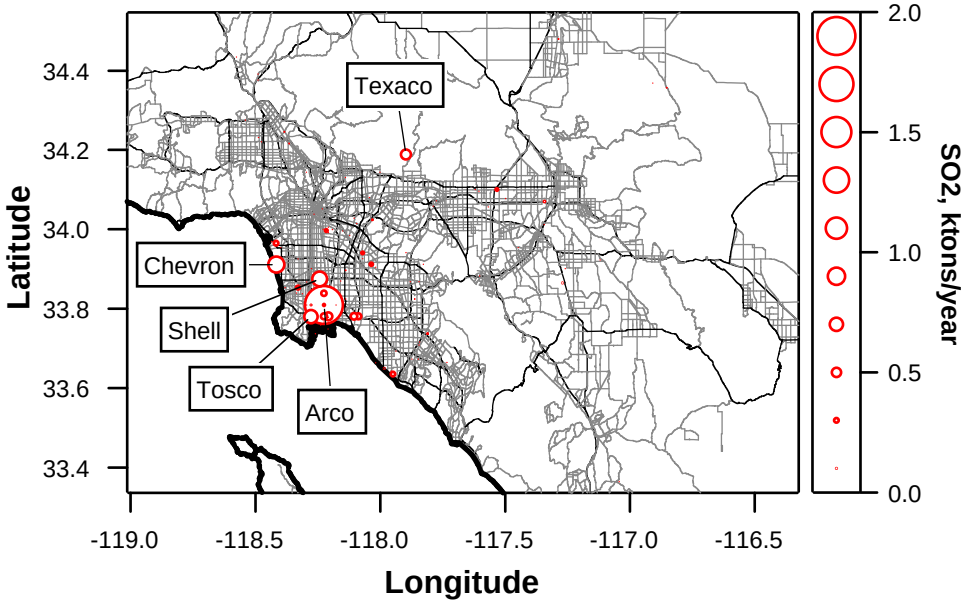
Emissions studies

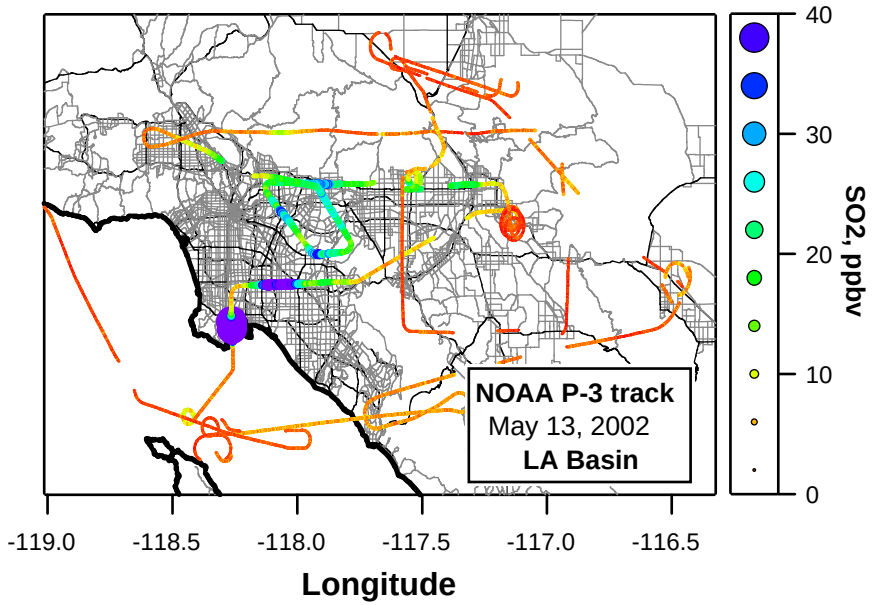
Sulfur budget of LA Basin

Research vessel will sample ship emissions (ports, offshore)

combine with WP-3D data

Track changes (2002-2008-2010)





Addressing CalNex science questions

Chemical Transformation and Climate Processes

D. How important are chemical processes occurring at night in determining transport and / or loss of nitrogen oxides, reactive VOC and ozone? Do regional models in California adequately represent these processes and their effect on air quality?

E. What are the sources and physical mechanisms that contribute to high ozone concentrations aloft that have been observed in Central and Southern California?

F. Are there significant differences between Central Valley and South Coast Air Basin precursors or ozone formation chemistry? Will meteorological and/or precursor differences between the Central Valley and the South Coast Air Basin lead to different chemical transformation processes and different responses to emissions reductions? What is the importance of natural emissions to the ozone formation process? Are there regional differences in the formation rates and efficiency for particulate matter as well?

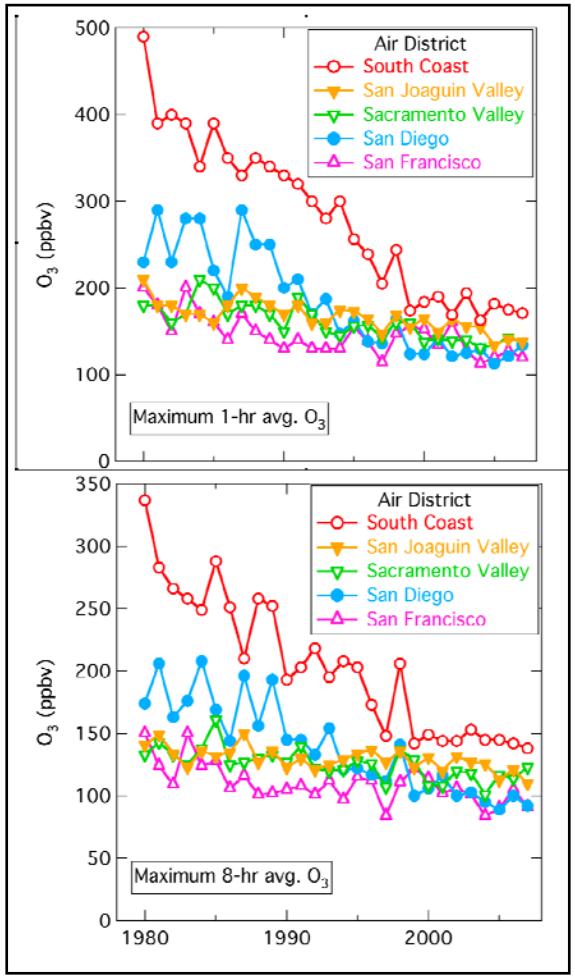
G. What are the impacts of aerosols in California on radiative forcing and cloud formation? What are the most important precursors and formation processes for secondary

Both climate change and air quality problems originate from society's increased emissions of radiative forcing agents (CO_2, CH_4, N_2O, halocarbons, black carbon, aerosols) and air pollutants and their precursors (VOC, NOx, SO_2, CO, air toxics). Our understanding of these emissions on both regional and global scales is critically limited.

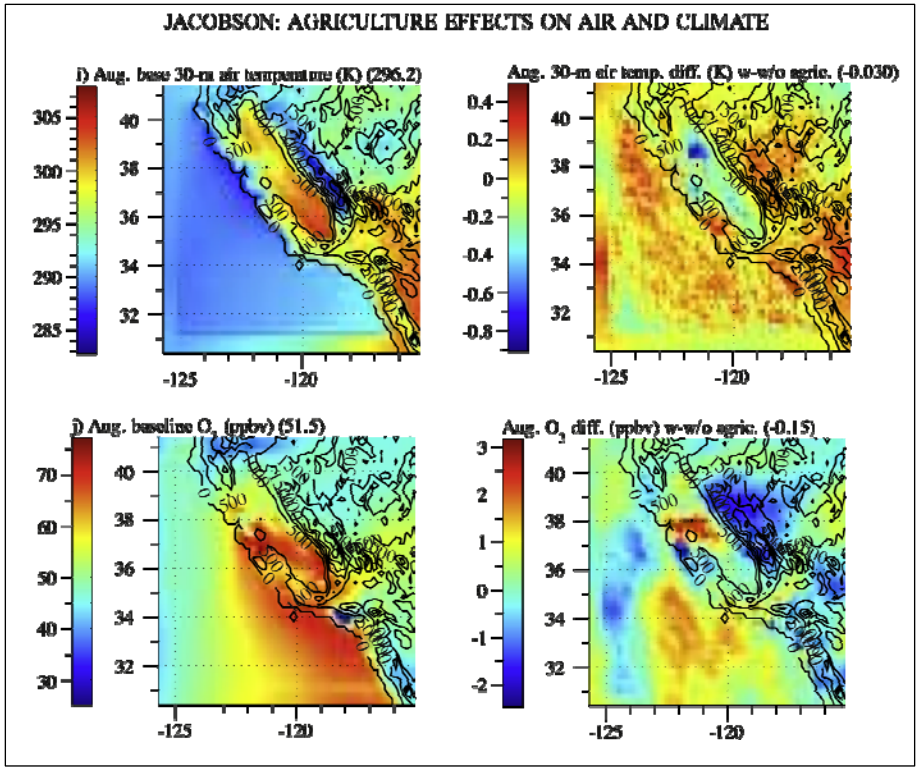
- Use P-3 to connect LA and SJV supersite observations during CalNex
- Emissions mixes are quite different between the two basins
- How will this be reflected in differences between secondary photoproducts?
  P-3: *O_3, HCHO, CH_3CHO, OVOCs, $RONO_2$, PANs, (PAN/HNO_3), etc.*

Processing studies

→ Oxidation rates and secondary product formation
LA-SJV differences?



Addressing CalNex science questions



Processing studies

→ Oxidation rates and secondary product formation
LA-SJV differences?

Gas-to-particle conversion of HNO_3 and NH_3

Nocturnal chemistry and transport

Aerosol-cloud interactions

Central Valley aging and layers aloft

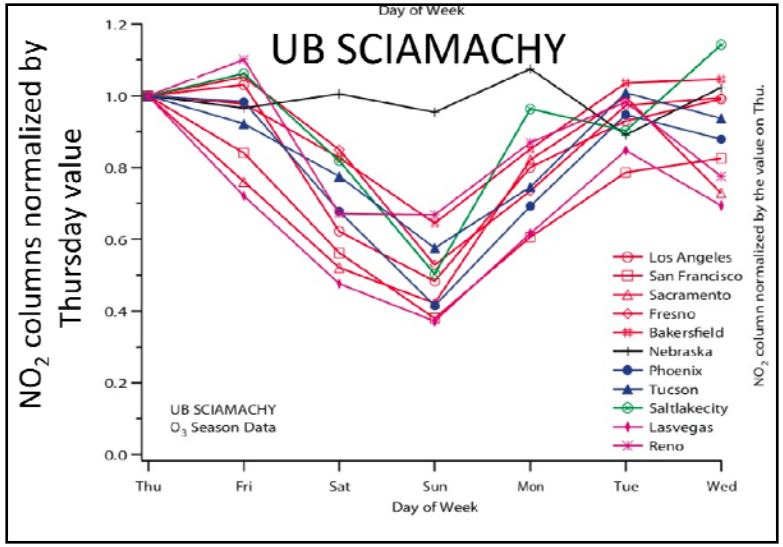
Repeatedly sample fresher vs. more oxidized air within South Coast and Central Valleys in the mixed layer & aloft (day and night flights)

Evaluate biogenic influences on CO_2 & CH_4 via Lagrangian flights anchored by WGC tower

Determine effects of anthropogenic vs. agricultural emissions on ozone and SOA

Addressing CalNex science questions

Satellite-derived day-of-week differences in California urban tropospheric NO_2 columns



Opportunity for studying multiday events (day – night – day studies)

Frontal passage (rare, but they do happen) gives a chance to observe pollutant buildup after clearing out

Basin exchange times from multiple looks

Processing studies

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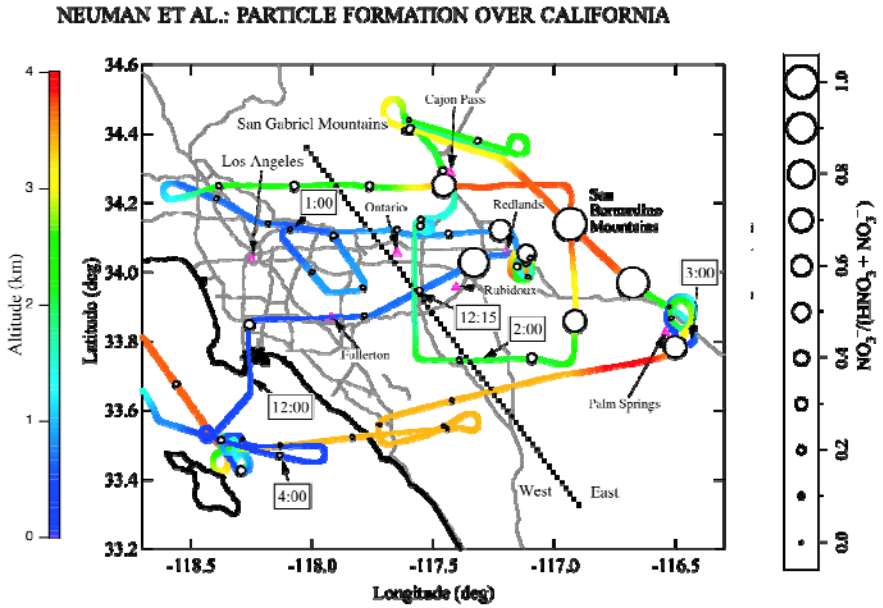


LA aerosol and ozone formation

Transects upwind and above LA ground site; continue through Riverside and downwind

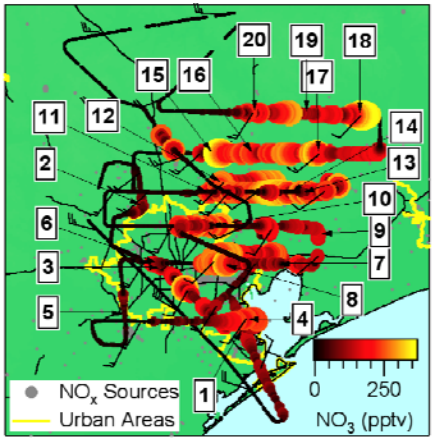
Should have measurements that fully constrain

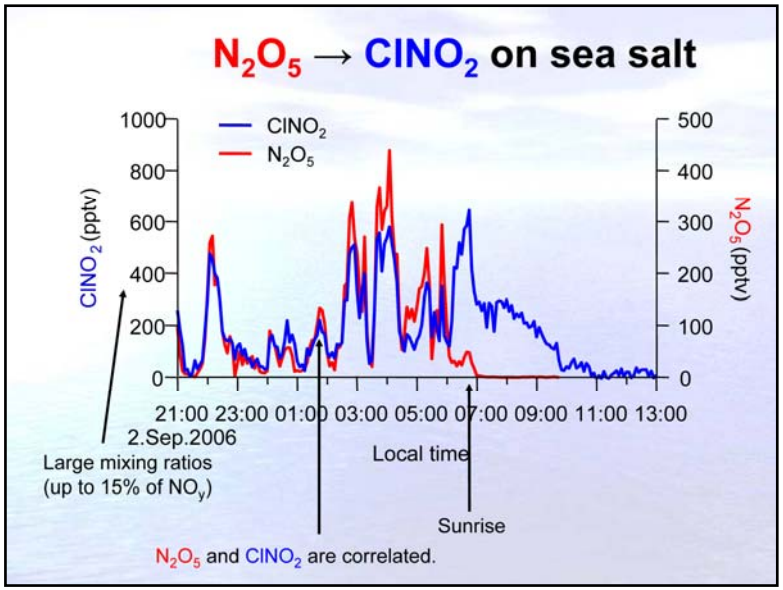
$NH_3 + HNO_3 \Leftrightarrow NH_4NO_3$

The P-3 in 2010 will bring aerosol extinction, absorption, and soot mass to this classic aging experiment

Addressing CalNex science questions

Examples of nighttime data
(Houston, 2006)





Processing studies

Oxidation rates and
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LA-SJV differences?

Gas-to-particle conversion
of HNO_3 and NH_3

→ Nocturnal chemistry and transport

Aerosol-cloud interactions

Nighttime chemistry of NO_3 and N_2O_5

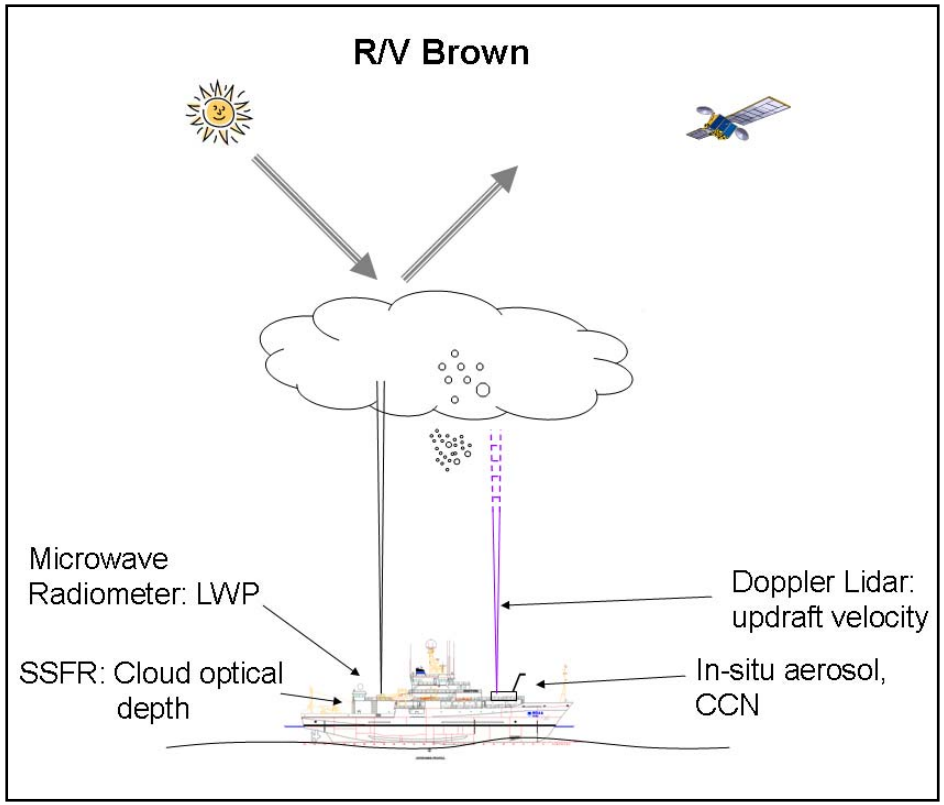
Sample urban plumes aloft after dark

determine $\gamma(N_2O_5)$ on NH_4NO_3 particles

evaluate NO_x and O_x loss vs. transport

study VOC sinks and halogen activation

Addressing CalNex science questions



Aerosol-cloud interaction studies:
contrast clean and polluted marine stratus

in situ and remote sensing from the NOAA research vessel

remote sensing from NOAA WP-3D

Processing studies

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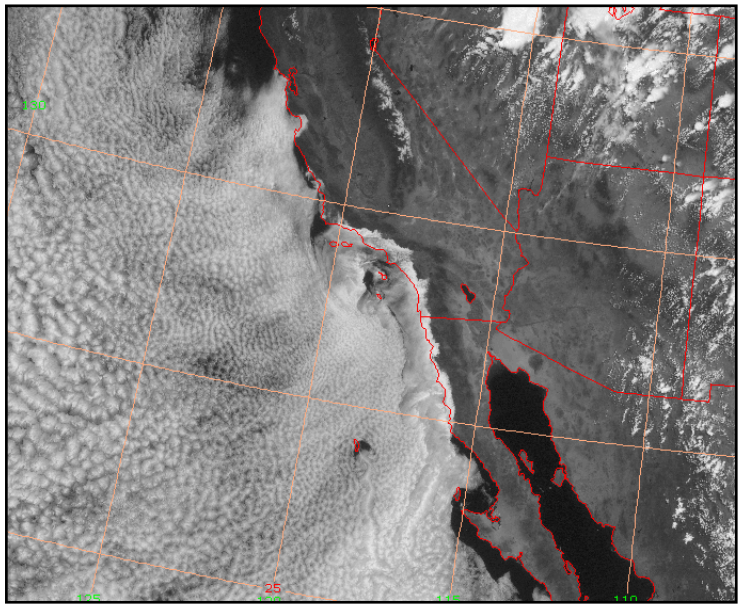
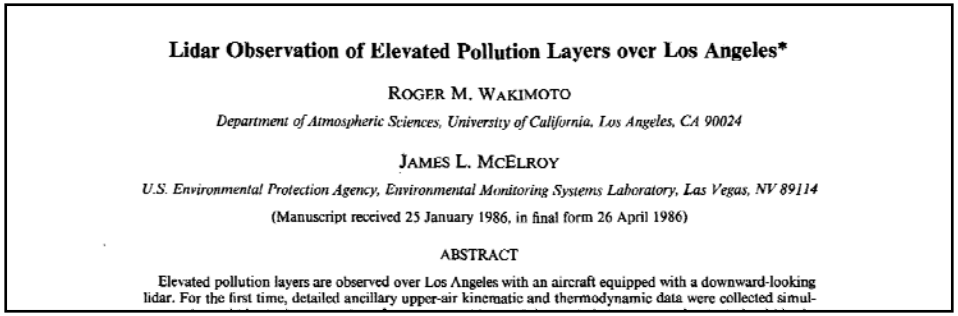


Addressing CalNex science questions



Lidar Observation of Elevated Pollution Layers over Los Angeles*

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JAMES L. MCELROY
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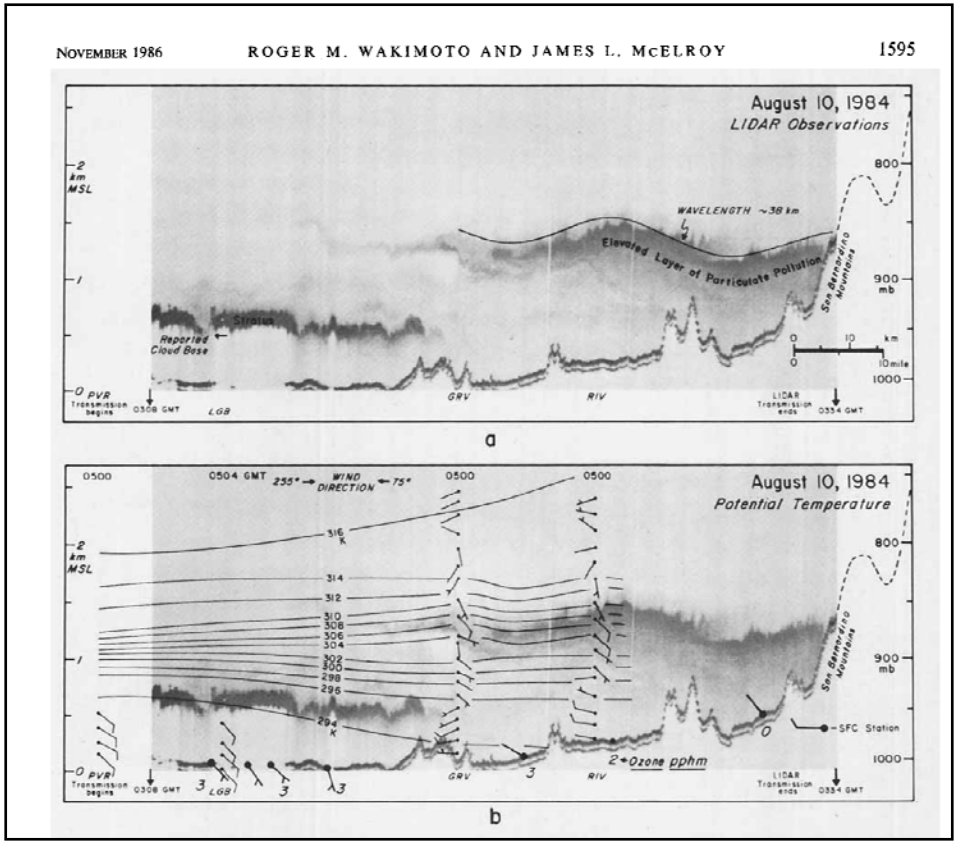
(Manuscript received 25 January 1986, in final form 26 April 1986)

ABSTRACT

Elevated pollution layers are observed over Los Angeles with an aircraft equipped with a downward-looking lidar. For the first time, detailed ancillary upper-air kinematic and thermodynamic data were collected simul-



Transport studies

use chemical measurements to define pathways for export of LA Basin and Central Valley pollution

- Long history of studying transport aloft in the LA Basin:

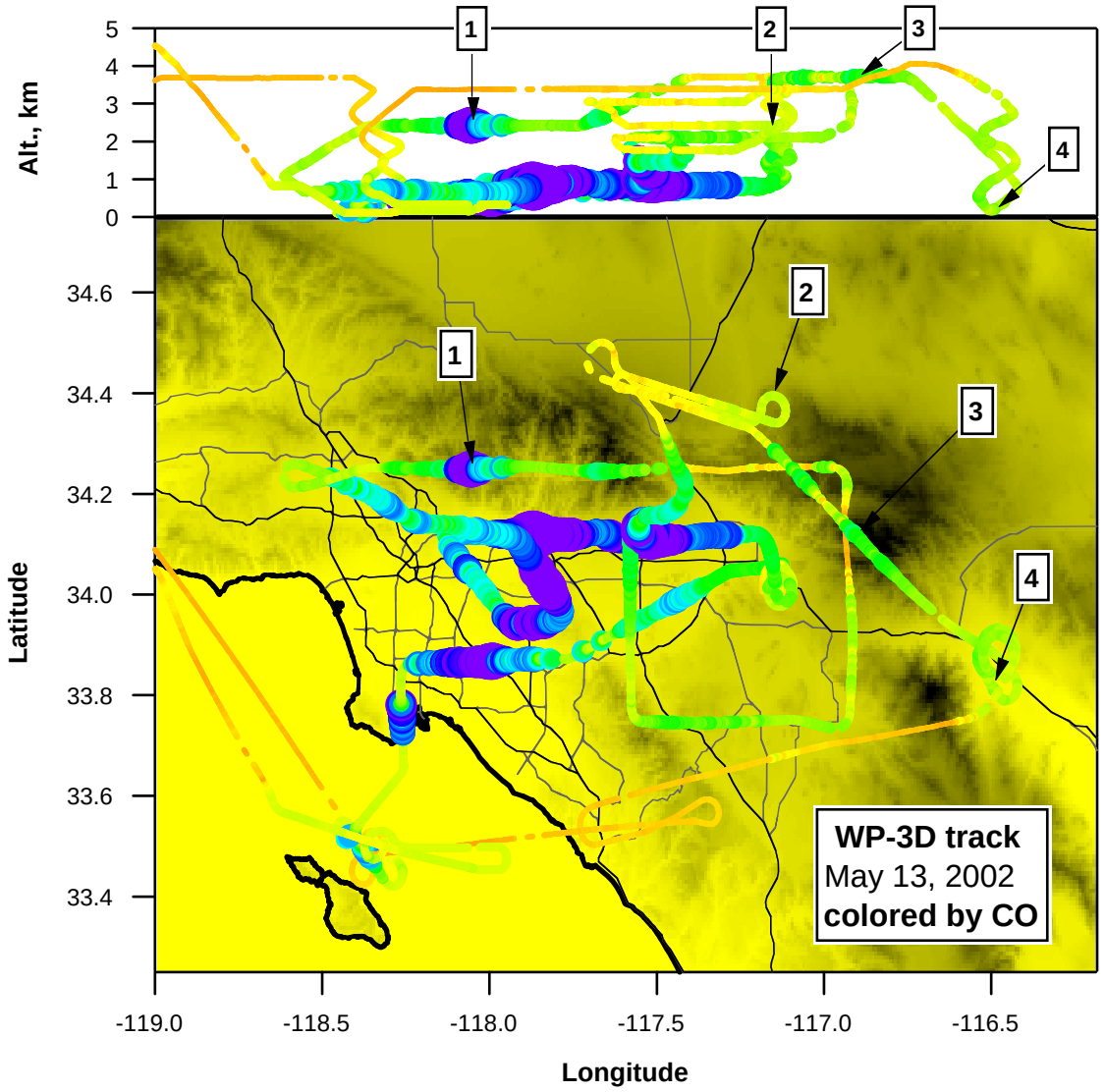
  - *1984 UCLA/EPA airborne lidar*

  - *1997 Caltech/CIRPAS in-situ aerosol measurements*

- Hope to extend existing studies by joint work with NOAA Twin Otter airborne lidar, CIRPAS Twin Otter aerosol, and combined aerosol and gas-phase data from the NOAA P-3

Addressing CalNex science questions

NOAA WP-3D in-situ data - 2002



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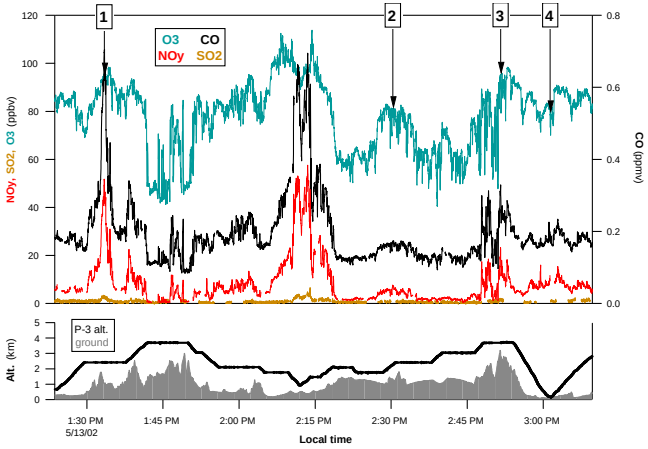


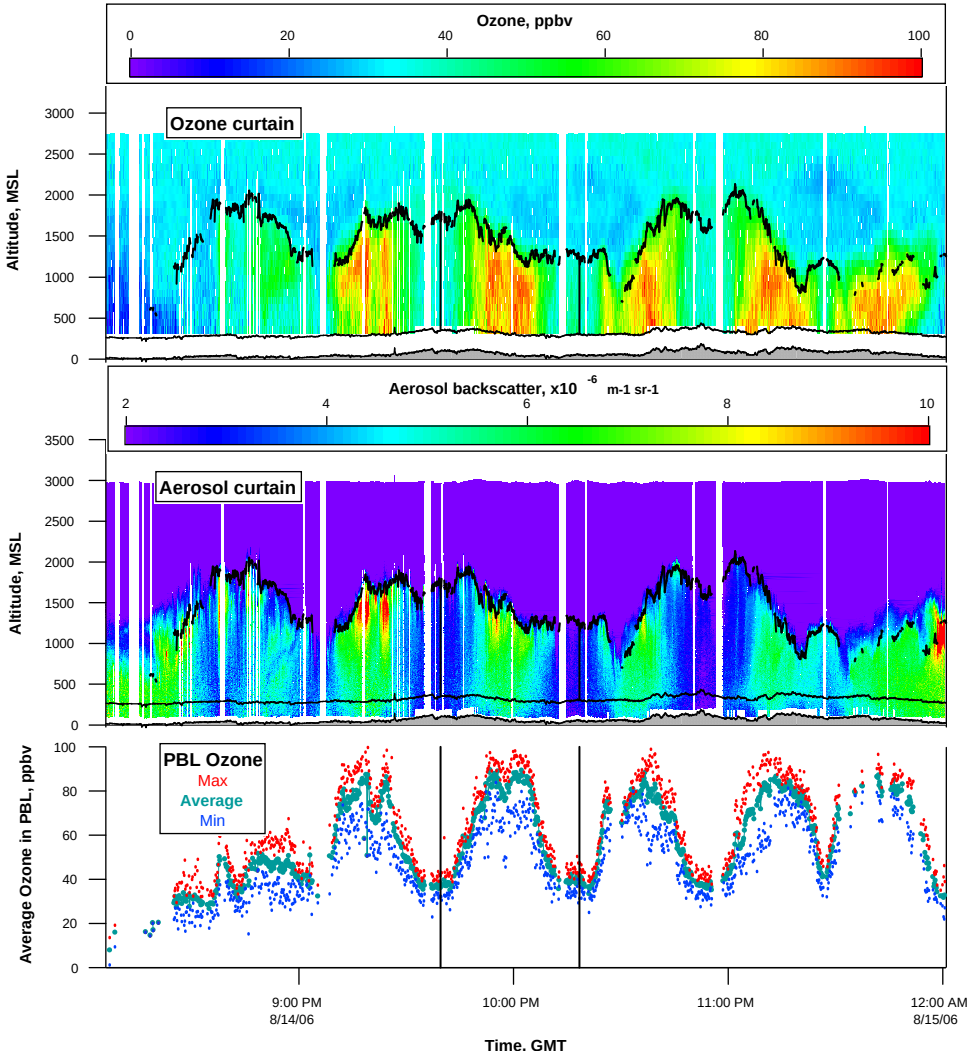
Chem. data shows export is highly variable in time

- need vertical profiles over same locations at different times e.g., near Catalina & over San Bernardino Mountains

Repeat often to build stats; even better with several aircraft

Addressing CalNex science questions

NOAA Twin Otter airborne lidar data - 2006



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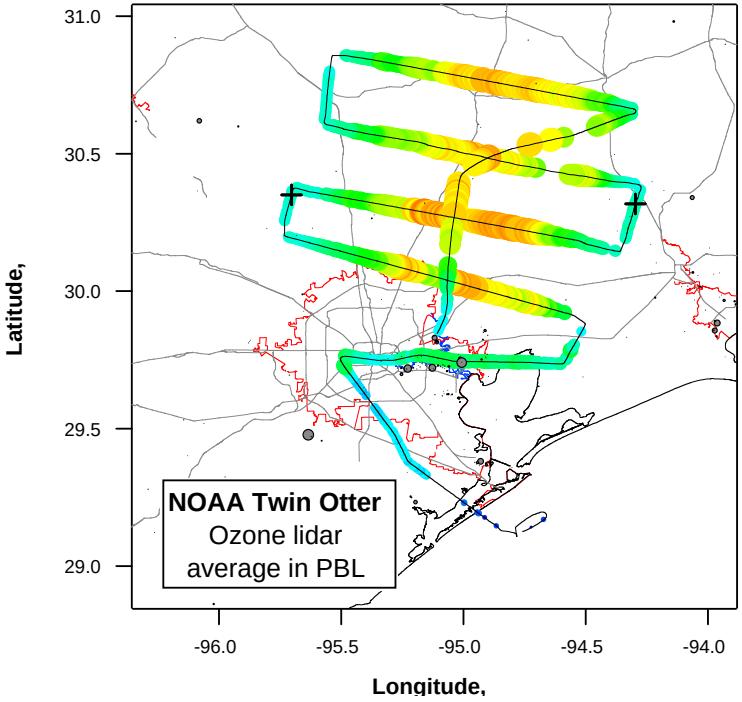

Joint flights with P-3, Twin Otter, and NASA King Air will be useful

Addressing CalNex science questions

The CalNex study will need to build on findings from ARCTAS

- emissions characterization
- chemical processing
- transport and mixing
- model performance evaluation

CalNex will add unique capabilities:

- agricultural emissions
- NH_3-HNO_3-NH_4NO_3 cycling
- nighttime chemistry
- halogen activation
- transport between basins
- BL-FT exchange processes

An invitation to the ARCTAS community to participate