Emission Inventory Assessments

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Needs and capabilities of inventory assessment

- Air quality and climate models require accurate inventories
- Observations provide independent, direct assessment of inventories
  - ✓ Relative and absolute fluxes of pollutants
  - ✓ Spatial distributions of emissions
  - ✓ Emission variability on hourly, daily, seasonal, and annual timescales

Evaluation of emissions using aircraft observations

- Examples from Texas (2000, 2006) and from California (2002)
- Possibilities for California 2010
  - Criteria pollutants and greenhouse gases
  - Urban, industrial, and agricultural sources

Evaluation of NO_x emissions using satellite observations and models

- Power plants: in-situ emission observations allow tests of retrievals and models
- Urban areas: investigate inventory biases and emission trends

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Evaluating Emissions using Aircraft Observations

2000 and 2006 Texas Air Quality Studies

Aircraft observations

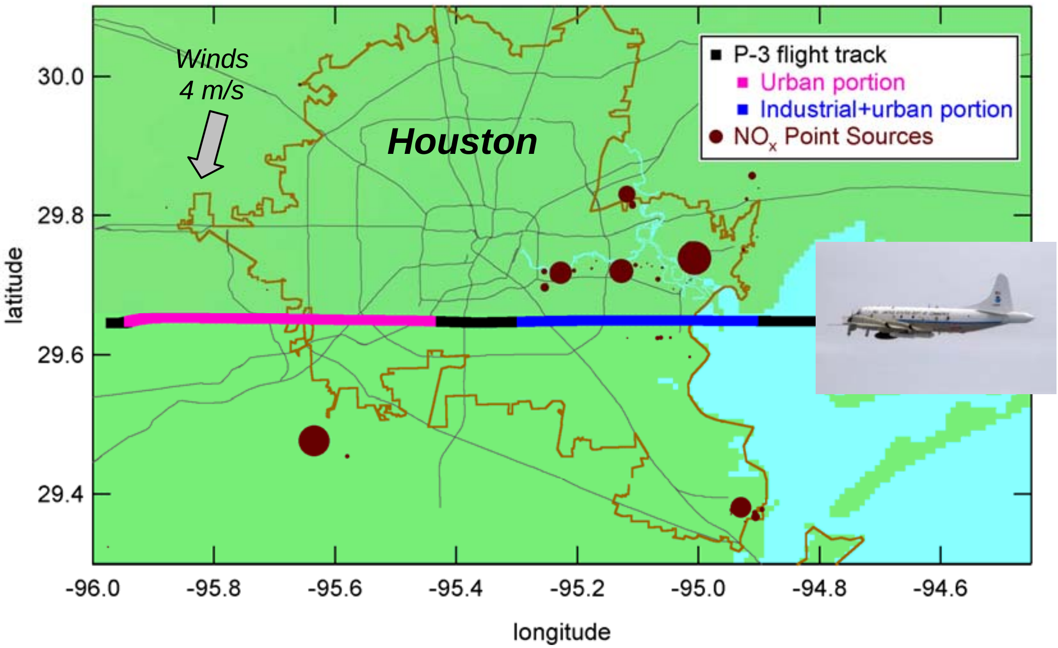
- •Isolate urban emission ratios from aircraft transects
- •TexAQS 2000 and 2006: 49 urban samples

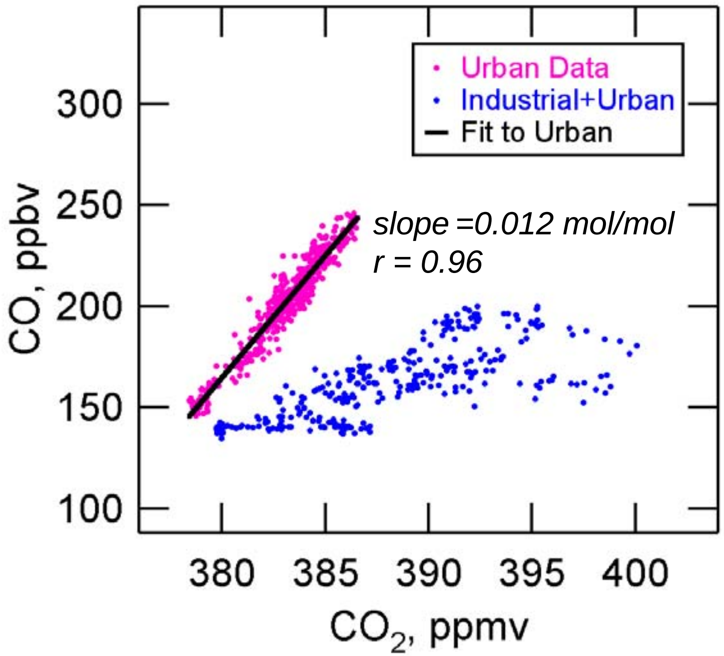
Surface observations

- •Washburn tunnel, 2000 (*McGaughey et al., 2006)*

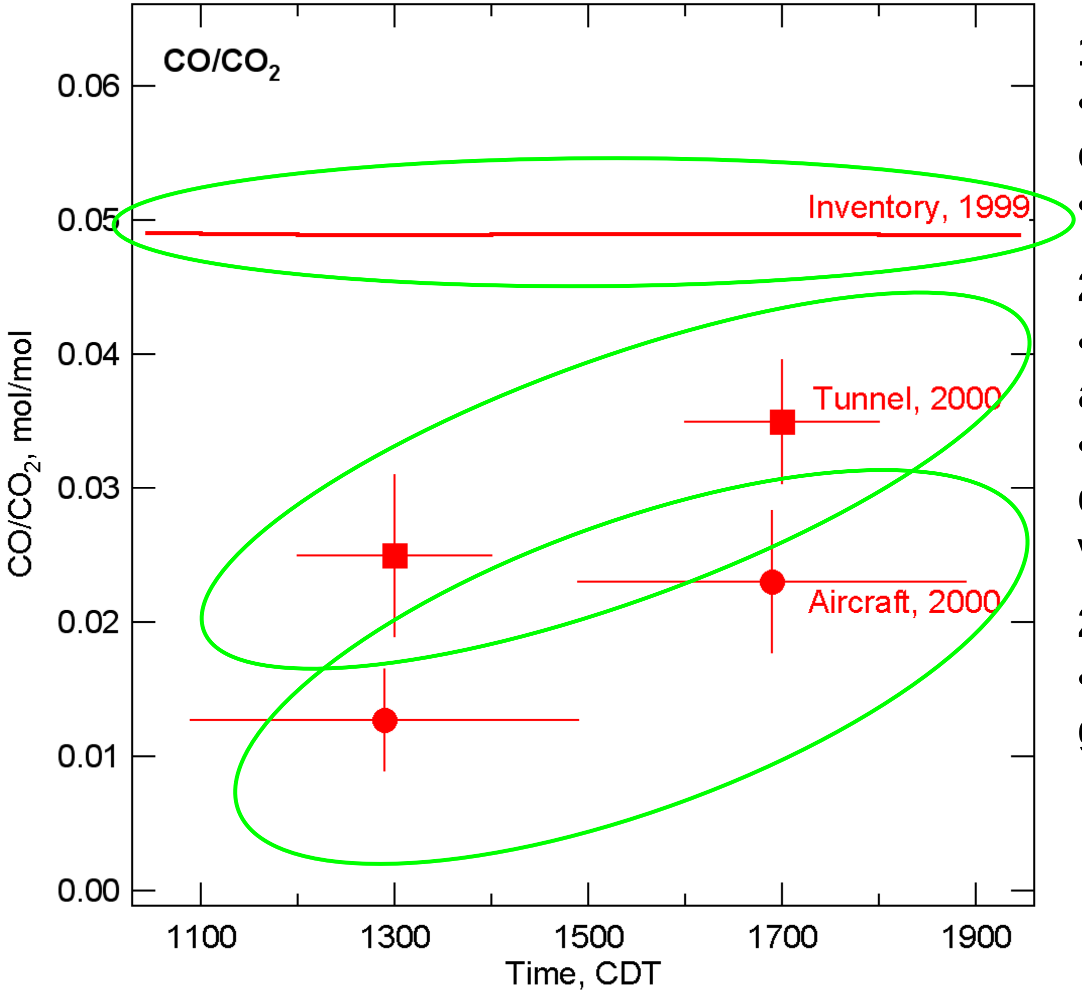
Emission inventories

- •NEI 1999 and 2005
- •CO_2 needed in inventory





Texas Urban CO/CO_2 Evaluation: 2000



1999 Inventory

- 2-3 times higher than 2000 observations
- No diurnal variation

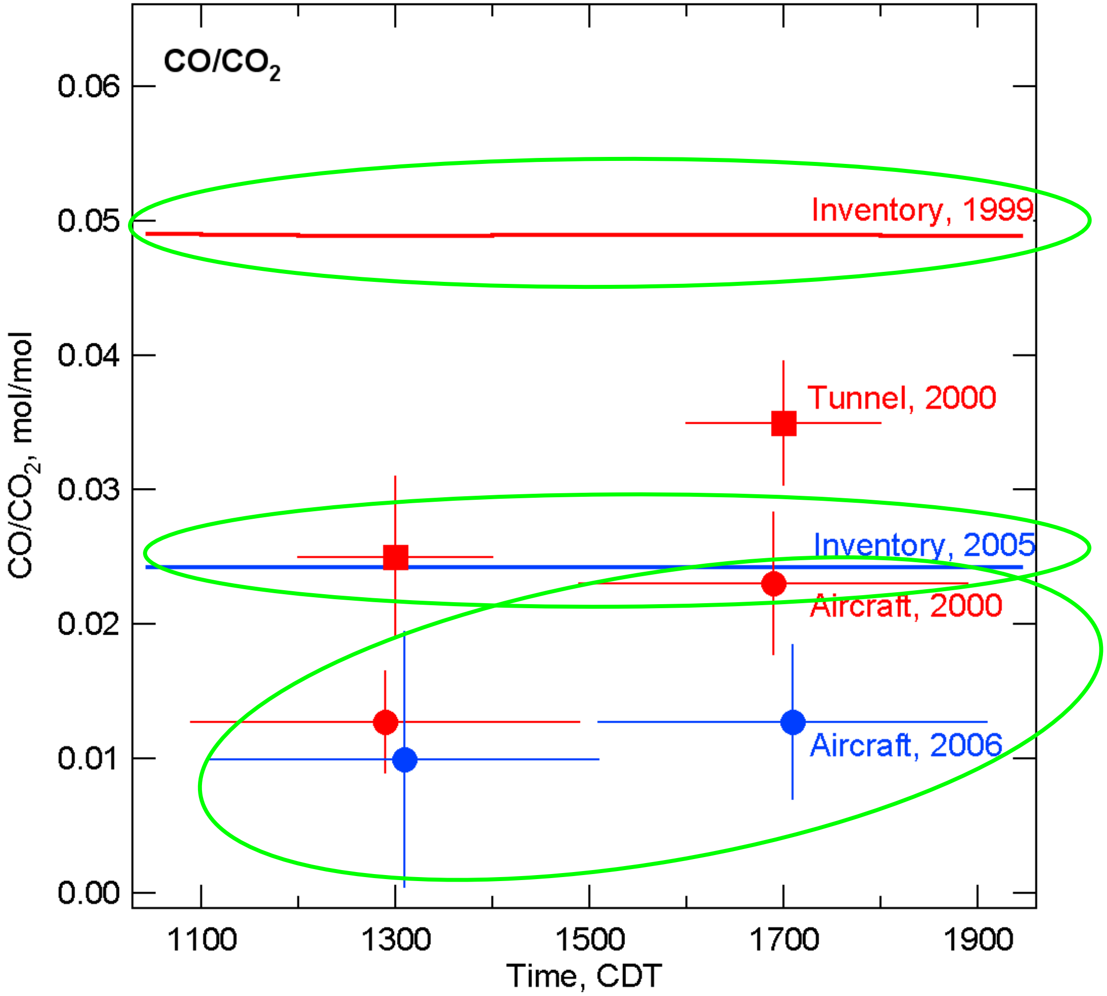
2000 Tunnel Observations

- Same diurnal variation as aircraft observations
- Offset from aircraft: sampling different mix of gasoline & diesel vehicles

2000 Aircraft Observations

- Afternoon increase in CO: more gasoline vehicles

Texas Urban CO/CO_2 Evaluation: 2000 vs 2006



2005 vs 1999 Inventories

•~50% lower CO emissions

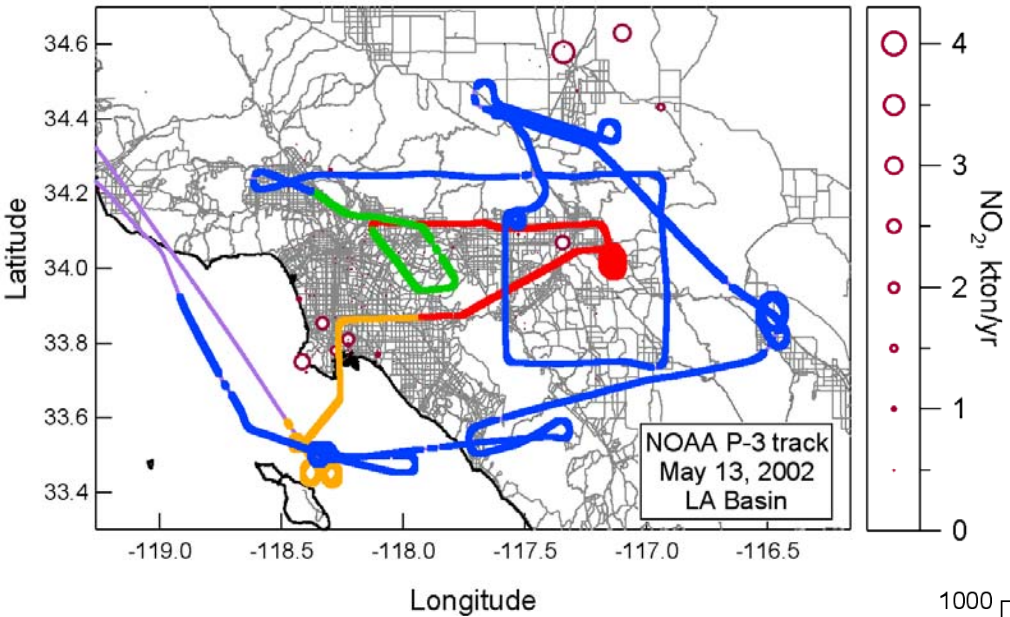
2005 Inventory

•2 times larger than 2006 observations

2006 vs 2000 Observations

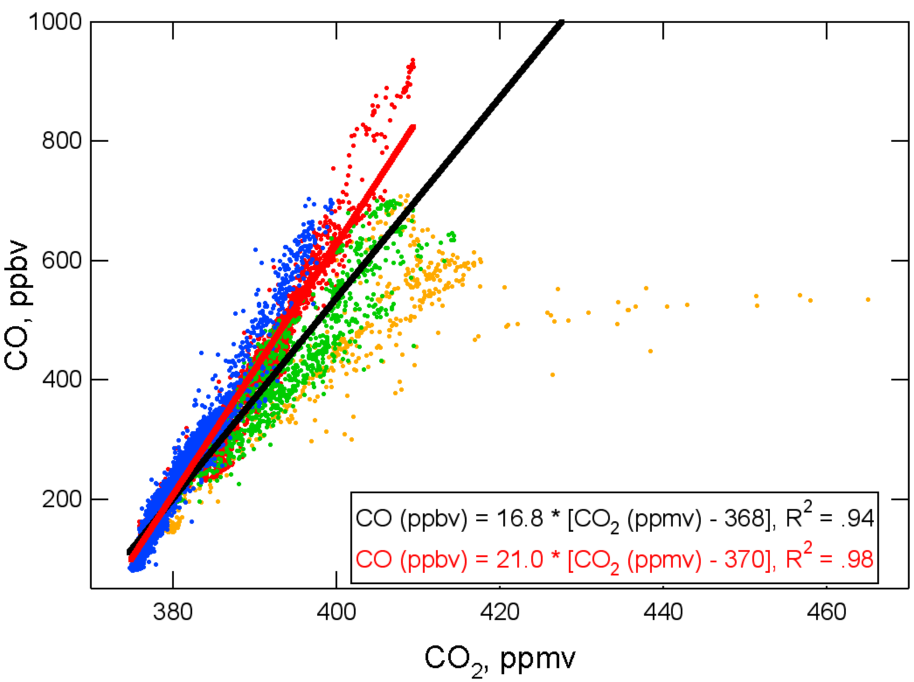
•CO emissions declined ~50% when dominated by light-duty gasoline vehicles

Evaluating California Urban and Industrial Emissions using the P-3



Anthropogenic enhancements relative to CO_2 can be compared directly to inventories

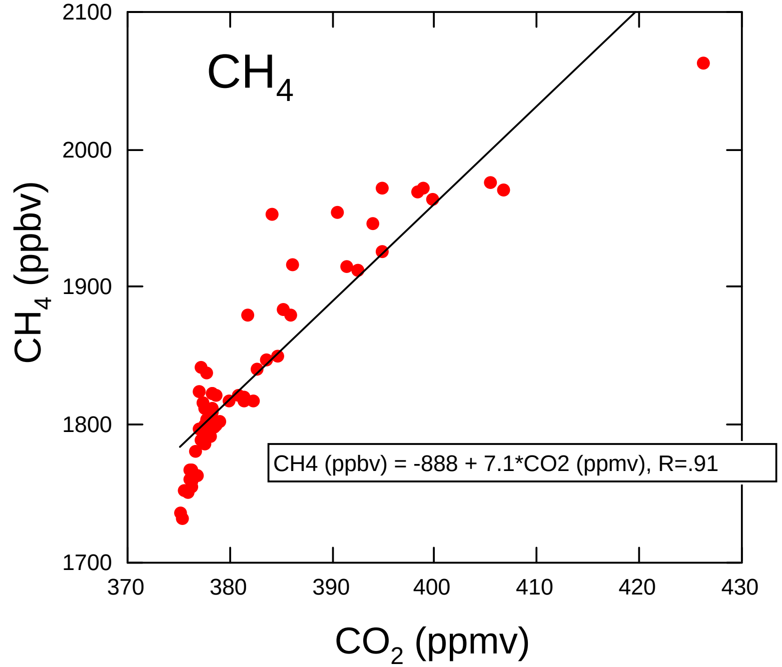
- *CO, VOCs, NOx, CH_4, halocarbons, N_2O*
- *use 2002, 2008, & 2010 aircraft data*
- *compare to downtown LA ground site data*
- *compare to LBL/NOAA tall tower data*

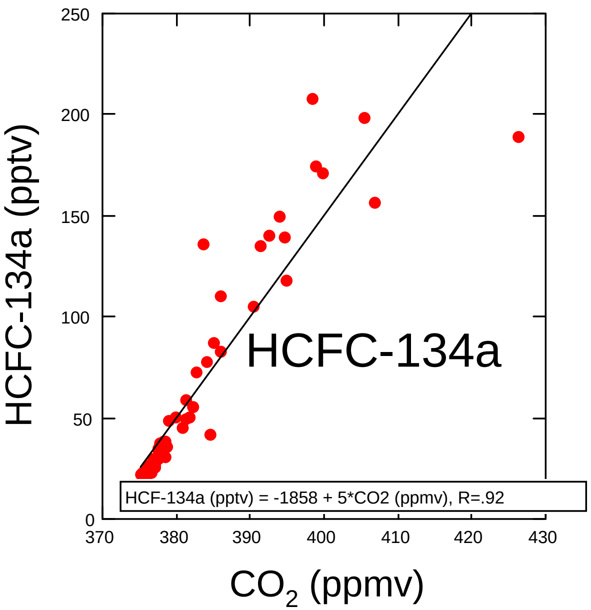


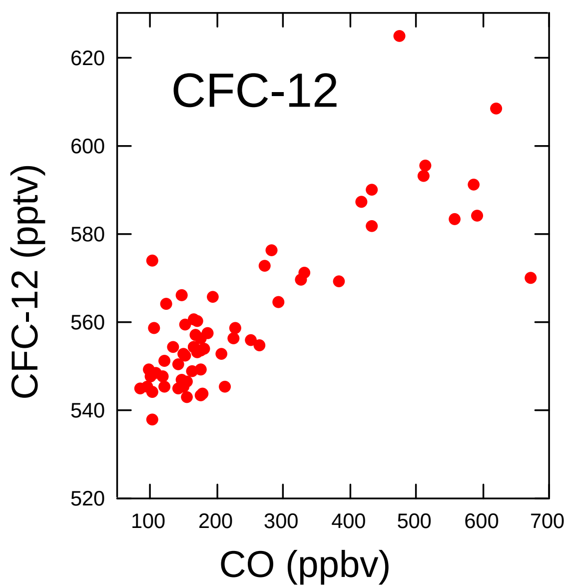
Evaluating California Greenhouse Gas Emissions using the P-3

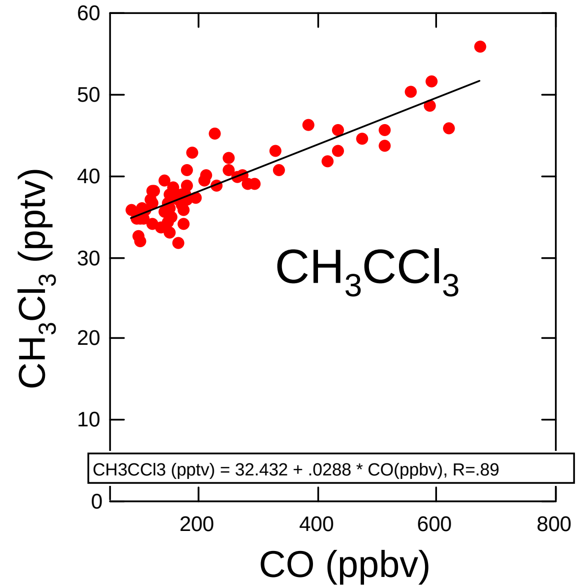
From 13 May 2002 P-3 flight over LA

- *urban sources of CO, CO_2, and other GHGs*
- *compare to LBL/NOAA tall tower data*









Evaluating California Greenhouse Gas Emissions using the P-3

Compare to bottom-up calculations of global warming potential (GWP)

CH_4:

Slope of CH_4 vs. CO_2 plot = 7×10^{-3} mol/mol

GWP(CH_4) = 23 x (16/44)

GWP(CH_4) x slope = 0.06

HCFC-134a:

Slope (HCFC-134a vs. CO_2) = 5×10^{-6} mol/mol

GWP(HCFC-134a) = 1300 x (102/44)

GWP(HCFC-134a) x slope = 0.016

N_2O 7%

High GWP gases 4%

CH_4 6%

CO_2 (electricity imports) 10%

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

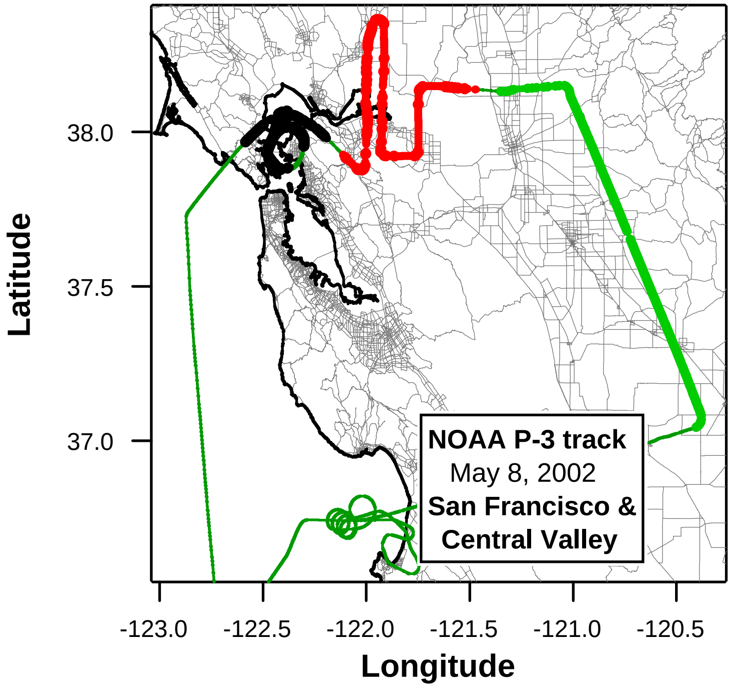
CO_2 73%

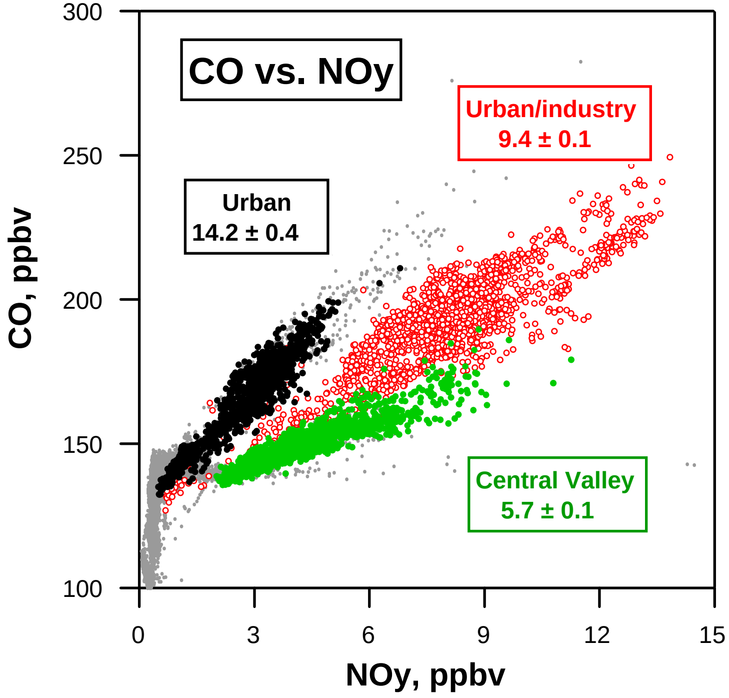
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Evaluating California Agricultural Emissions using the P-3

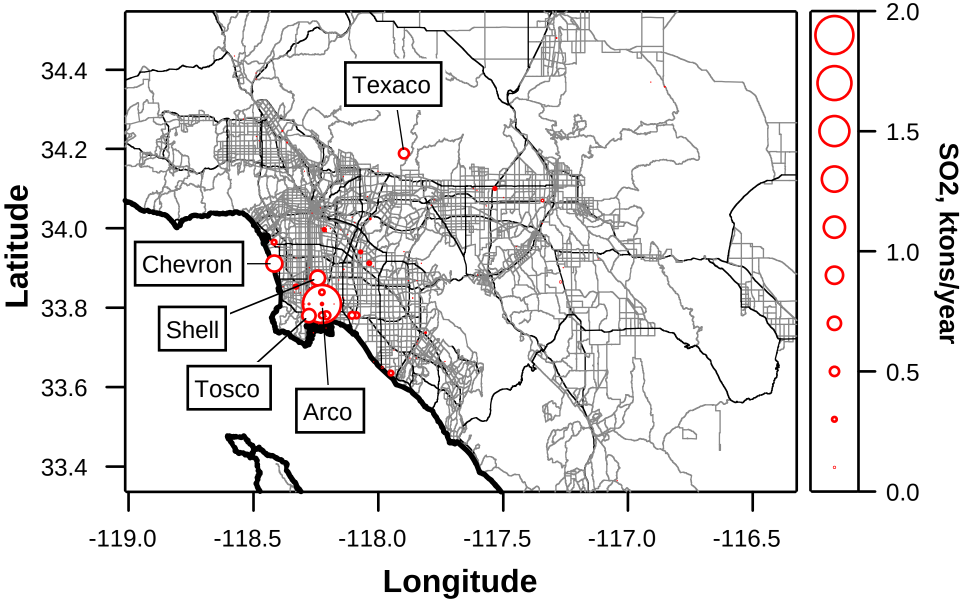
Can we quantify NO_x, NH_3, CH_4, & N_2O emissions from the agricultural sector?

- *include Imperial Valley flights*
- *compare to San Joaquin Valley ground site data*
- *compare to tall tower data*
- *compare to satellite columns*



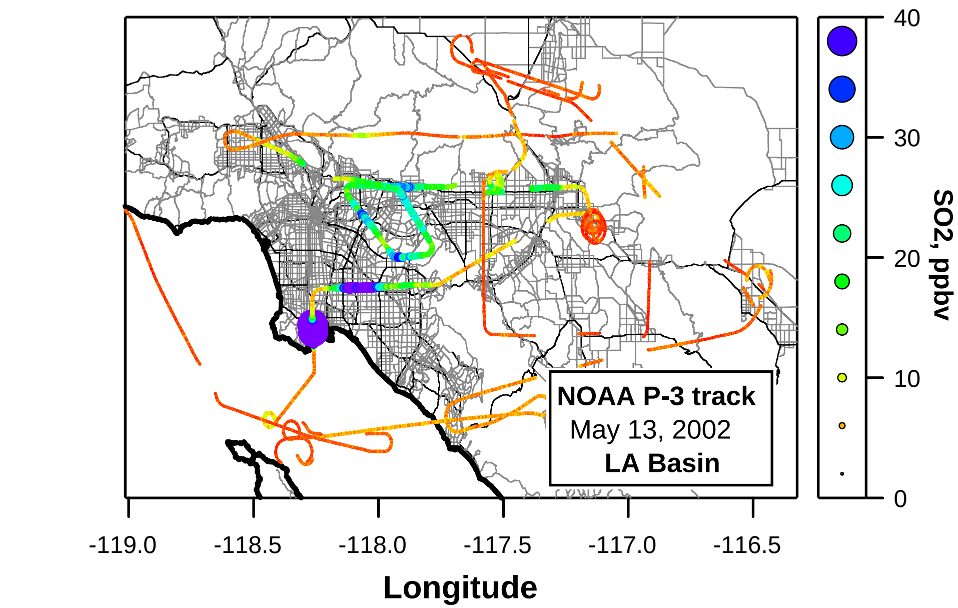


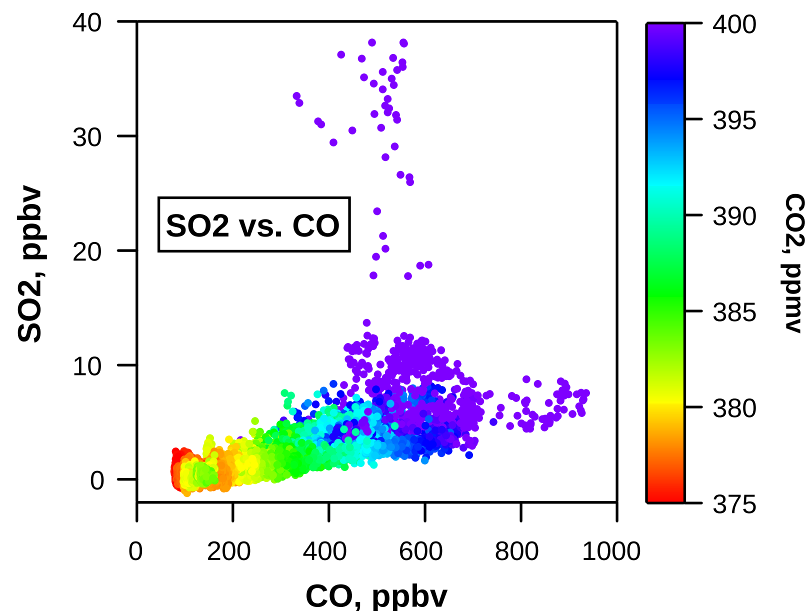
Evaluating California Sulfur Emissions using the P-3



Quantifying sulfur budget of LA Basin & San Francisco Bay Area

- *SO_2 from shipping, industry, and mobile sources*
- *DMS from phytoplankton*

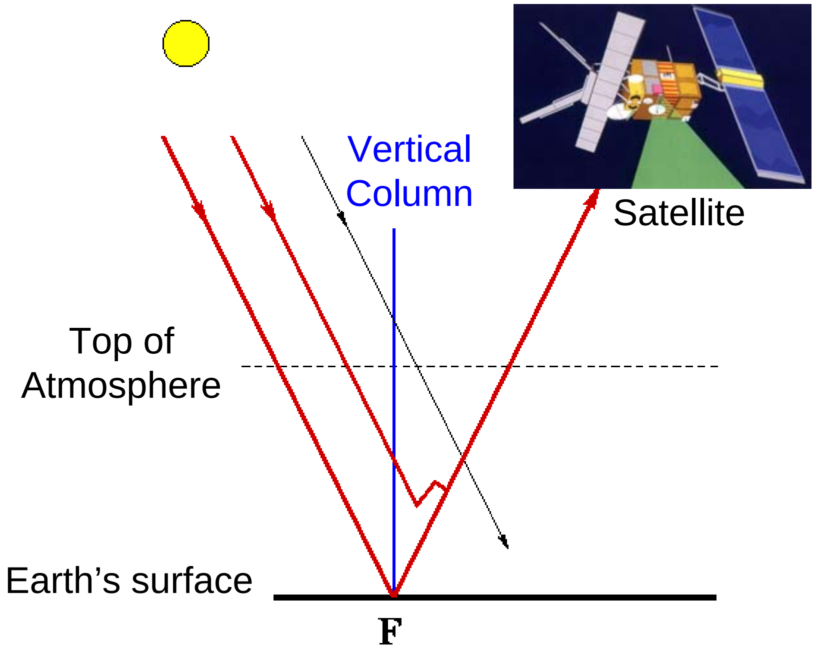




Evaluation of NO_x Emissions using Satellite Observations and Models

Use discrete satellite signals in Western US to evaluate NO_x emissions from individual power plants and urban areas

- Steady, well-known power plant emissions
  - "Calibrate" satellite and model
  - Test satellite retrieval calculations and model treatments
- Rapidly growing urban areas with large motor vehicle source
  - Do bottom-up inventories accurately capture urban NO_x emissions?
  - What are the trends in urban NO_x emissions?



Key Assumption:

NO_x emissions $\propto$ NO_2 vertical columns (summer $\Rightarrow$ short NO_x lifetime)

NO_2 Vertical Columns from Satellites

Instrument (Satellite)	***Operational Period***	***Overpass time (LT)***	***Days for global coverage***	***Pixel size (km^2)***
GOME (ERS-2)	Apr 1995-Jun 2003	10:30	3	340 x 40
SCIAMACHY (ENVISAT)	Mar 2002-present	10:00	6	60 x 30
OMI (AURA)	Jul 2004-present	13:30	1	27 x 13 (nominal)
GOME-2 (METOP)	Mar 2007-present	09:30	1.5	80 x 40

NO_2 retrievals from these instruments produced by various groups, including University of Bremen (UB) and NASA

Near real-time satellite products available during CalNex 2010

Satellite Vertical Column Retrieval Process

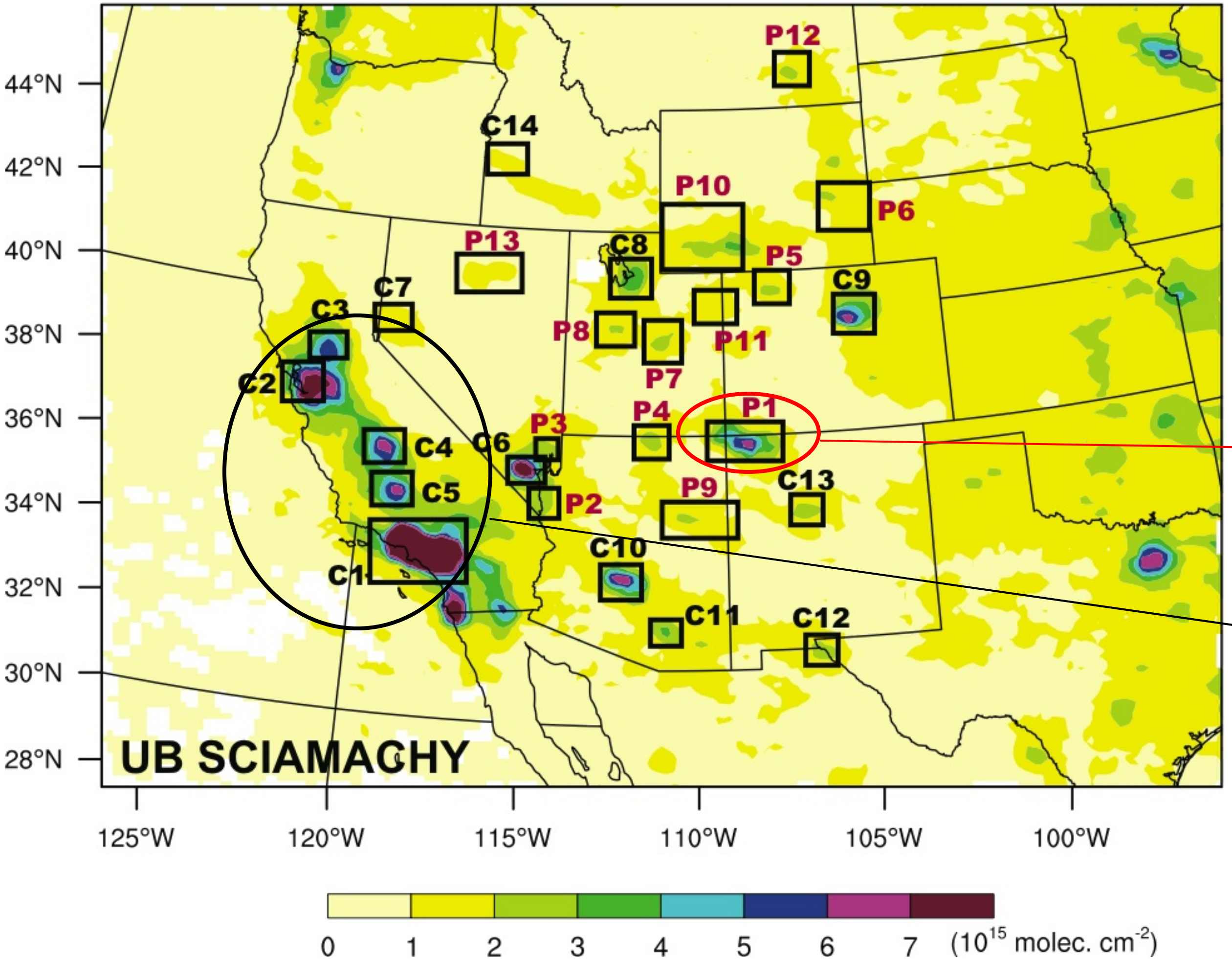
1. Spectral fitting of radiance
   - ➢ NO_2 slant column (S)
2. Subtract stratospheric NO_2 column
3. Filter cloudy pixels
4. Calculate air mass factor (AMF)
5. Calculate NO_2 vertical column (V)
   - ➢ $V = S / AMF$

AMF calculation needs:

- *A priori* NO_2 profile (global & regional models)
- *A priori* aerosol profile
- Aerosol optical depth
- Terrain height
- Surface albedo
- Temperature & pressure
- Radiative transfer equation (LOWTRAN etc.)

Western US NO_2 Columns: Summer 2005

P = power plant, C = city

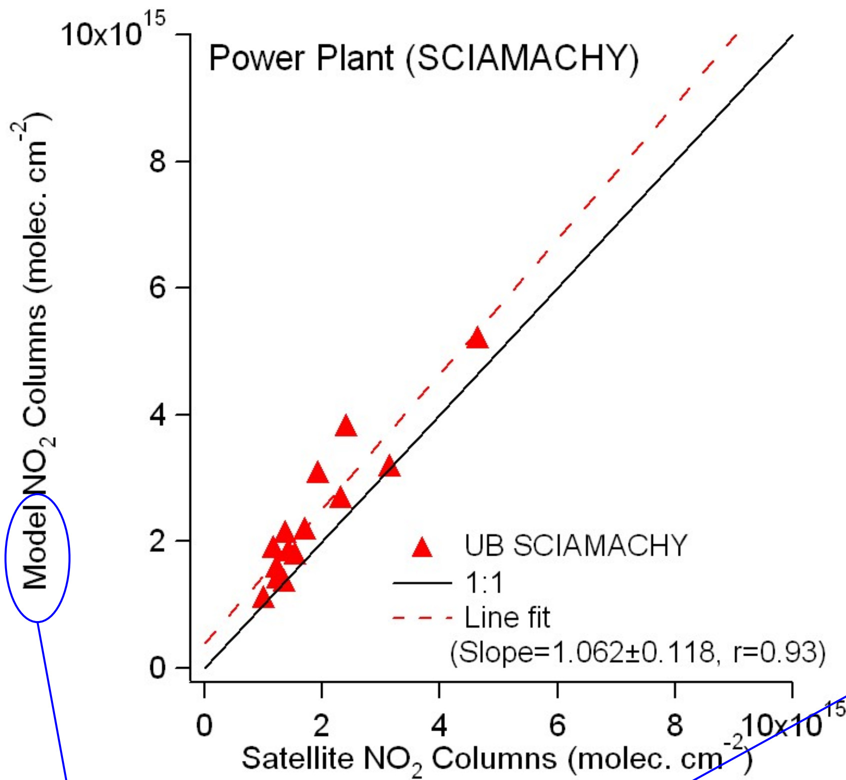


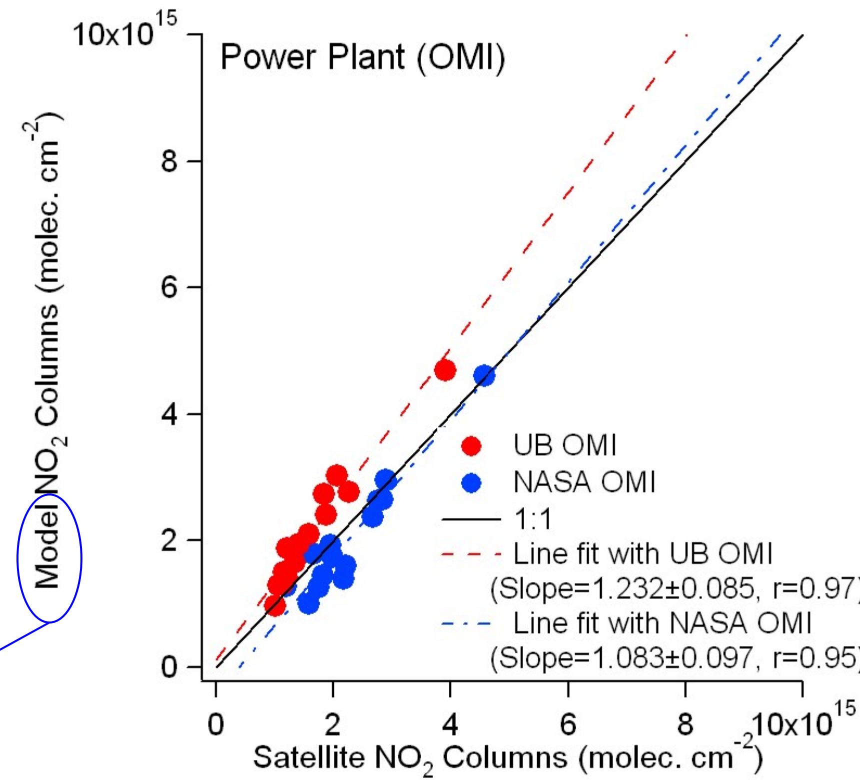
NO_x emissions from western US power plants and cities can be distinguished in three satellite retrievals (UB SCIAMACHY, UB OMI, NASA OMI)

Four Corners & San Juan power plants: largest US power plant NO_x source

Cities in California show strong signals

Test of Satellite Retrievals: Power Plant Emissions



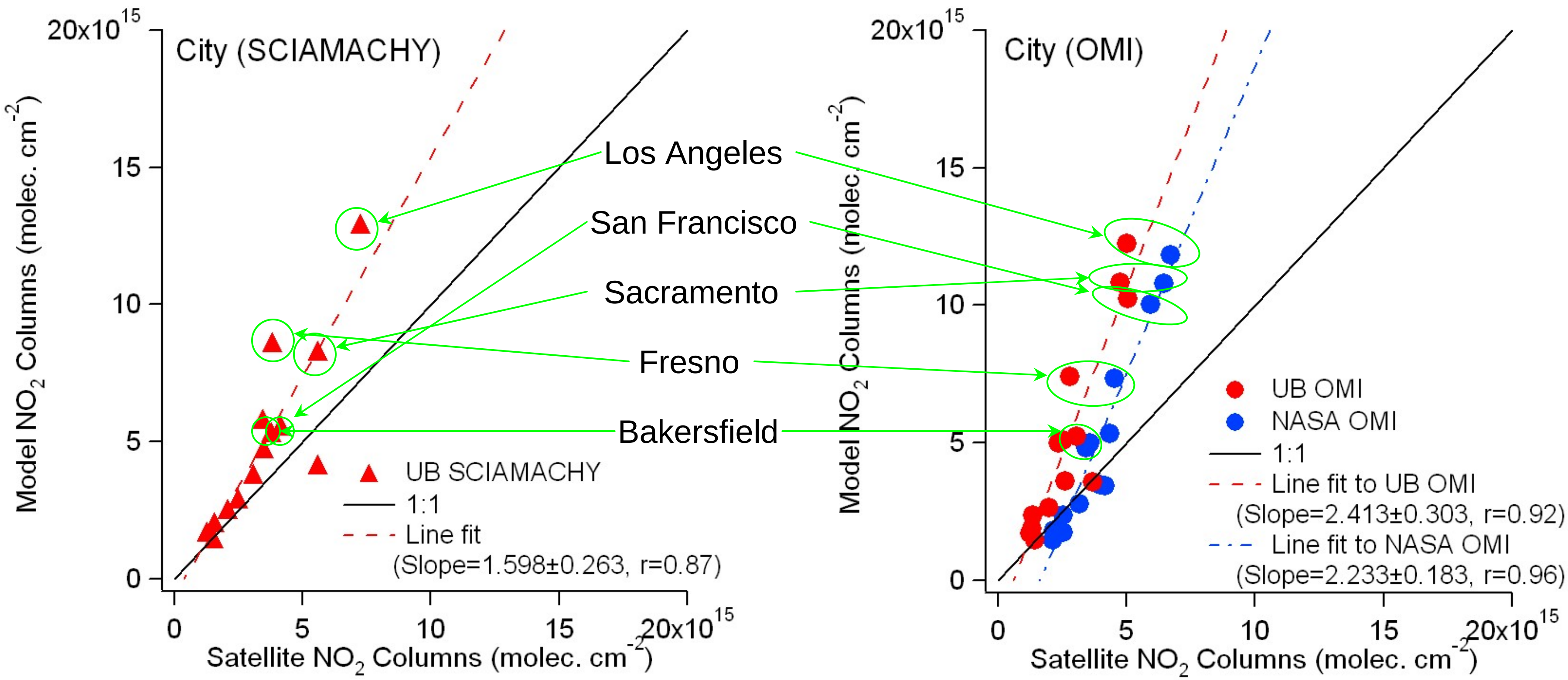


***W**eather **R**esearch and **F**orecasting - **Chem**istry regional air quality model*
- uses measured NO_x emissions (CEMS) for power plants

Satellite and model columns agree to within ±25% over Western US power plants

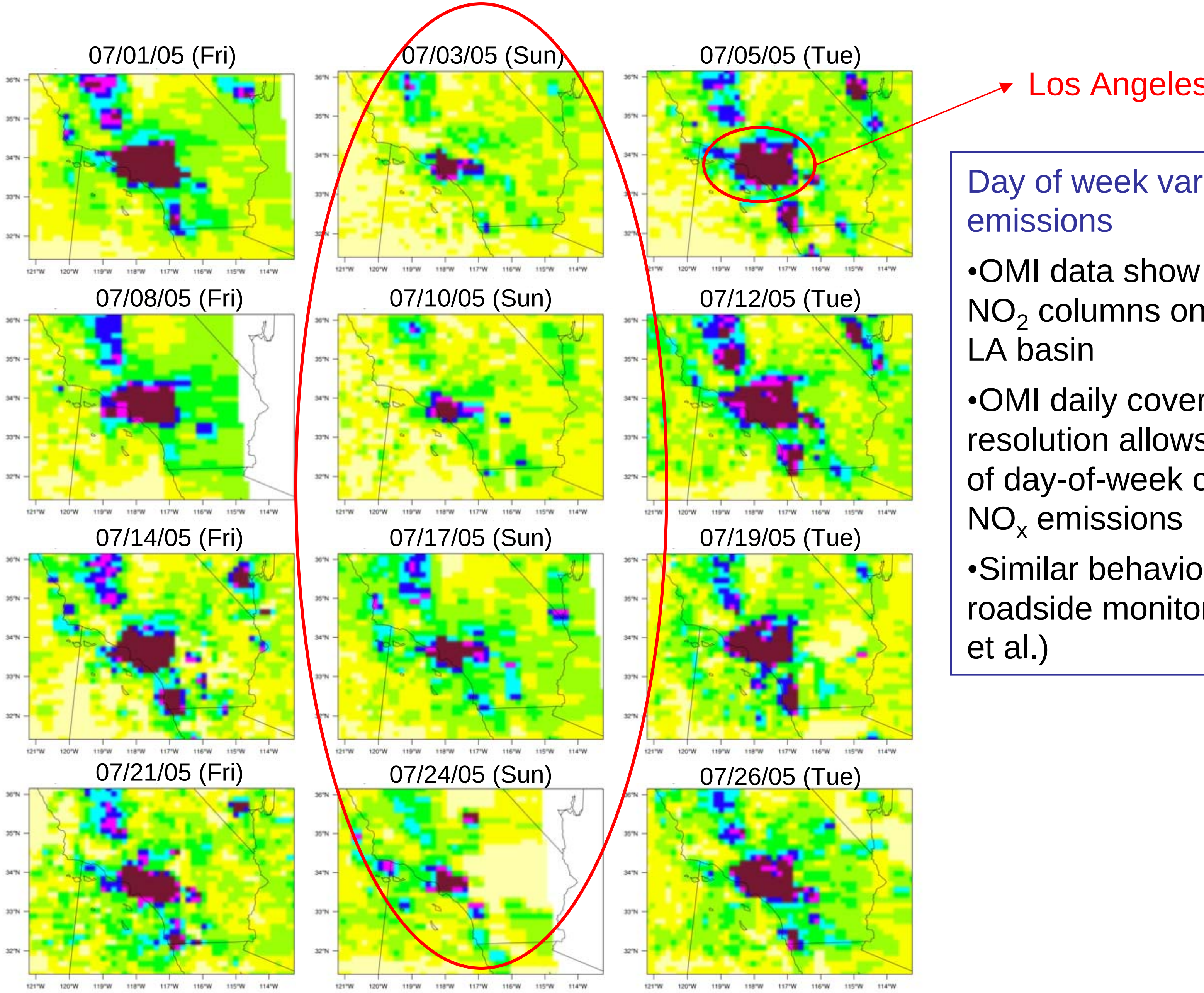
- Optimize satellite retrievals and model parameterizations
- Compare different satellite retrieval approaches using model
- Consistency between methods provides basis for inferring emissions from other sources

Urban Emissions Evaluated Against Satellite Retrievals



- Model NO_2 columns for cities are 60-140% higher than satellite retrievals
- Emission changes between 1999 (model inventory) and 2005 (satellite data)
  - ➢emission reductions over California cities
- Uncertainties in NEI1999 emissions?
- Use satellite to understand inventory biases and dominant sources
  - •Annual trends
  - •Day-of-week variability

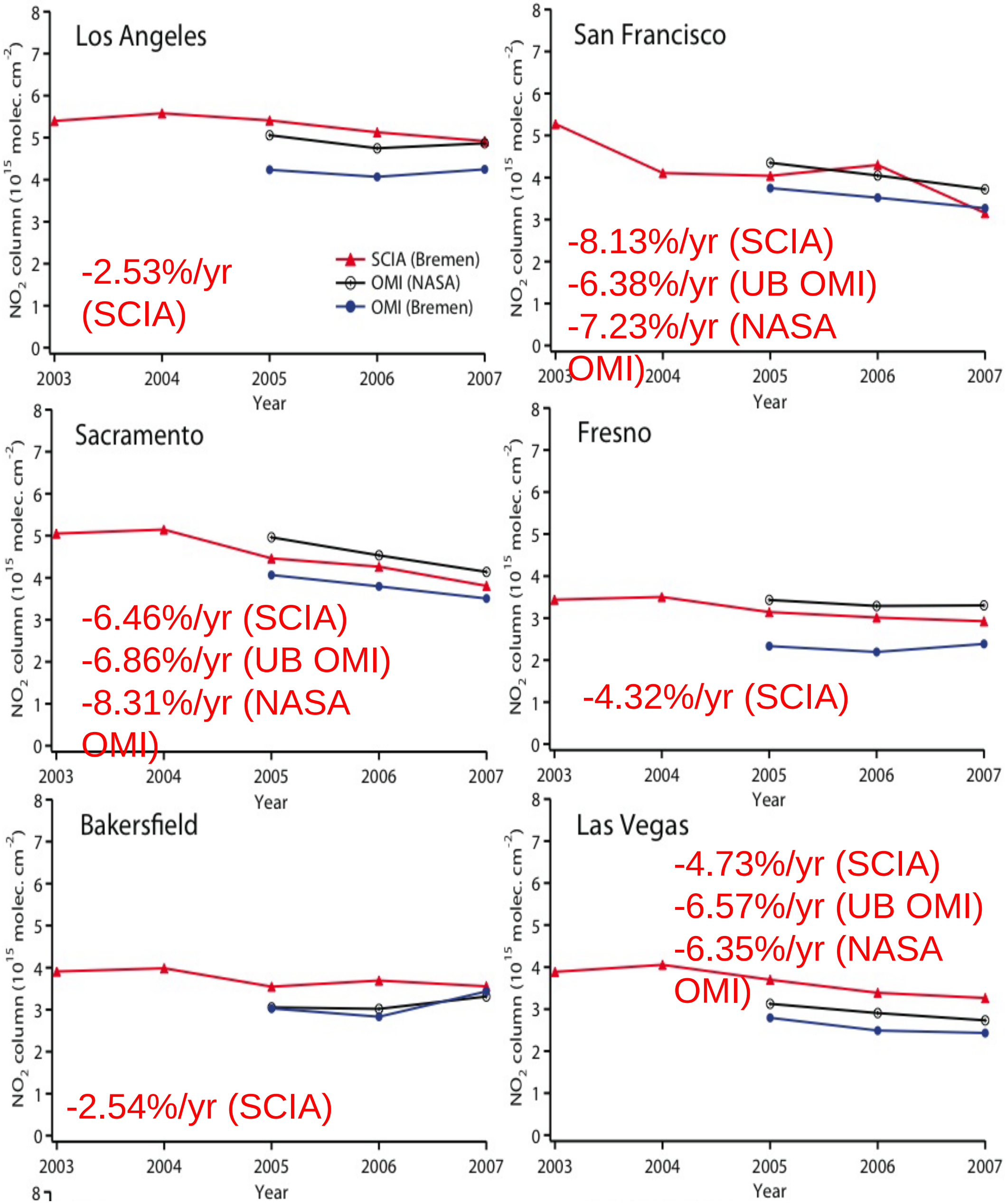
Day-of-Week Cycles in NO_2 Detected from Space



Day of week variations in NO_x emissions

- OMI data show reduction in NO_2 columns on Sunday over LA basin
- OMI daily coverage and fine resolution allows assessment of day-of-week cycles in urban NO_x emissions
- Similar behavior seen in roadside monitors (*e.g.* Harley et al.)

Year-to-Year Trends in Satellite NO_2 Columns



- Declining satellite NO_2 trends over several western US cities
  - ➢ Similar to roadside monitoring (Ban-Weiss et al., 2008; Bishop and Stedman, 2008)
- Inventories for California indicate similar trends (not shown)
  - ARB inventories
  - measured emission factors and reported fuel-use
- Some cities and retrievals: trends not significant
  - ➢ Longer period needed?
  - ➢ Biases in NEI99?
- Declining trends in aerosols over California not included in retrievals
  - ➢ Satellite NO_2 declines may be underestimated

Using Satellite Observations to Evaluate California Emissions

- 2010: Two more years of satellite data to evaluate trends in emissions
- CalNex 2010: investigate possible reasons for discrepancies between model and satellite NO_2 columns over California urban areas
  (1) mobile and surface-based NO_2 observations could validate both model and satellite NO_2 columns (e.g. Stutz et al., Volkamer et al.)
  (2) tests of satellite retrievals over complex terrain: accurate NO_2 profiles, aerosol optical depth, and better characterization of ground albedo (e.g. Pilewski et al.)
  (3) closer look at day-of-week variations for several California cities with satellite and in-situ data (e.g. Harley et al.)
- Agricultural NO_x emissions could be estimated from satellite data along with other measurement platforms (e.g. SJV ground site)
- Use model to investigate impacts of NO_x emission changes on ozone
- Satellite HCHO and CHOCHO retrievals: assess VOC emissions and constrain sources of SOA