3.2 Inflow processes influencing air quality over Western North America: Progress Report

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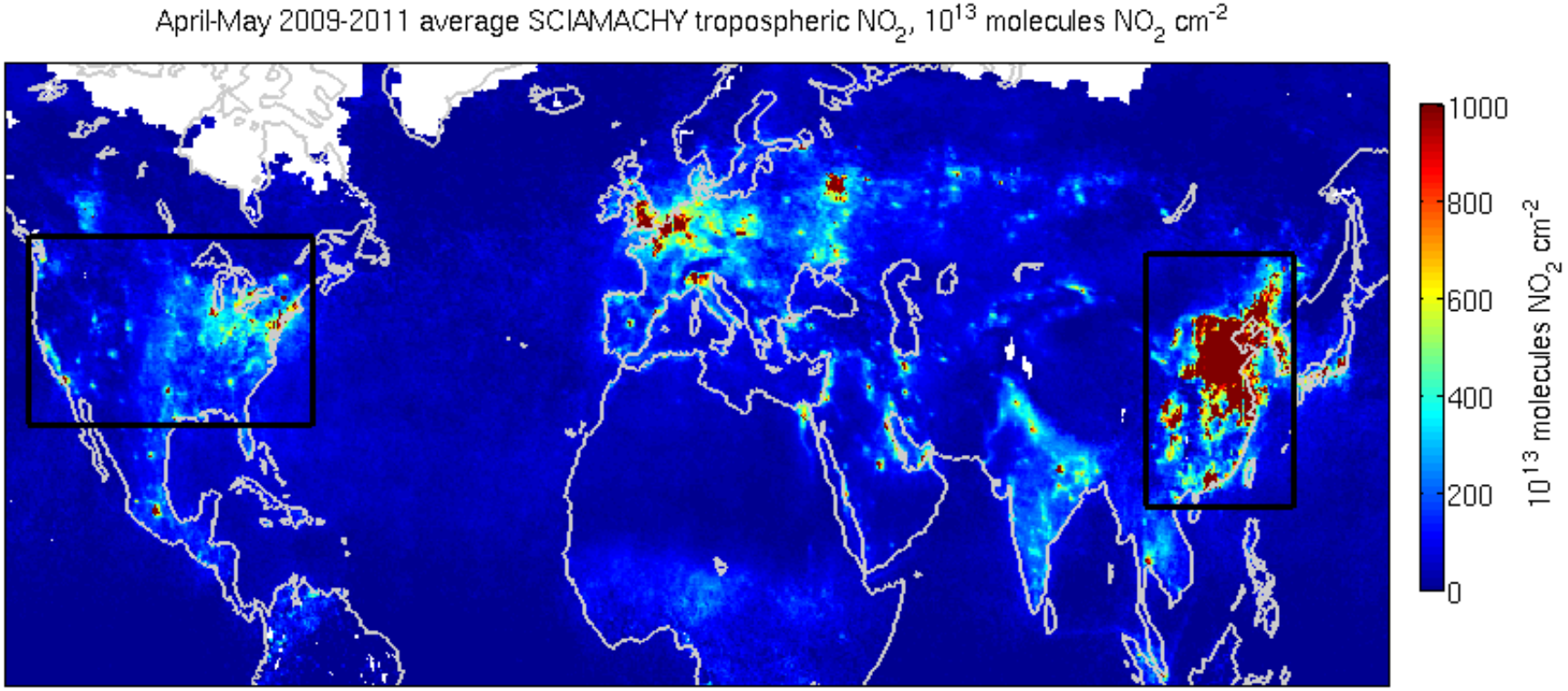
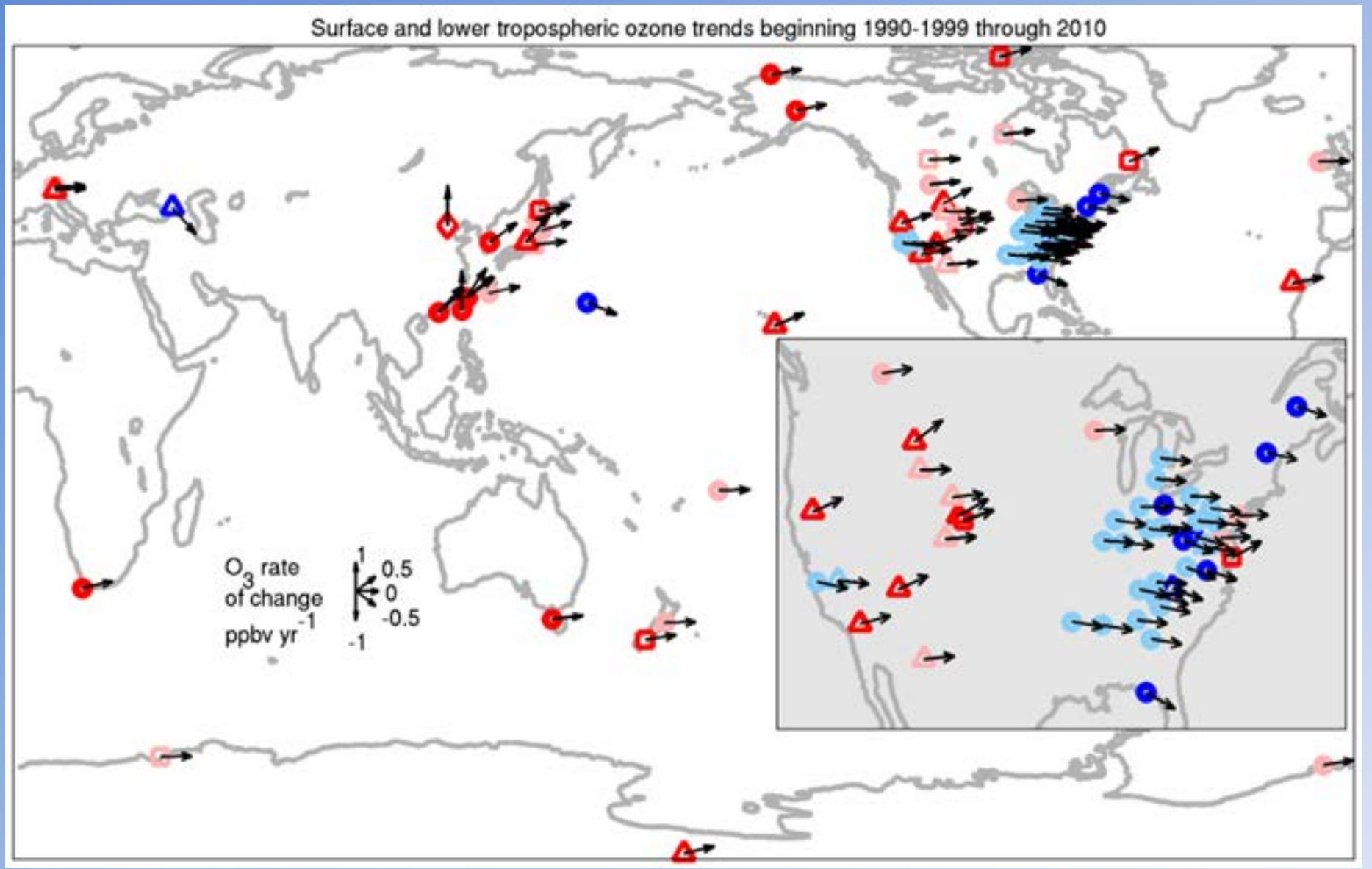
Task Force on Hemispheric Transport of Air Pollution Global and Regional Modeling Workshop
5-6 December 2013, San Francisco, California



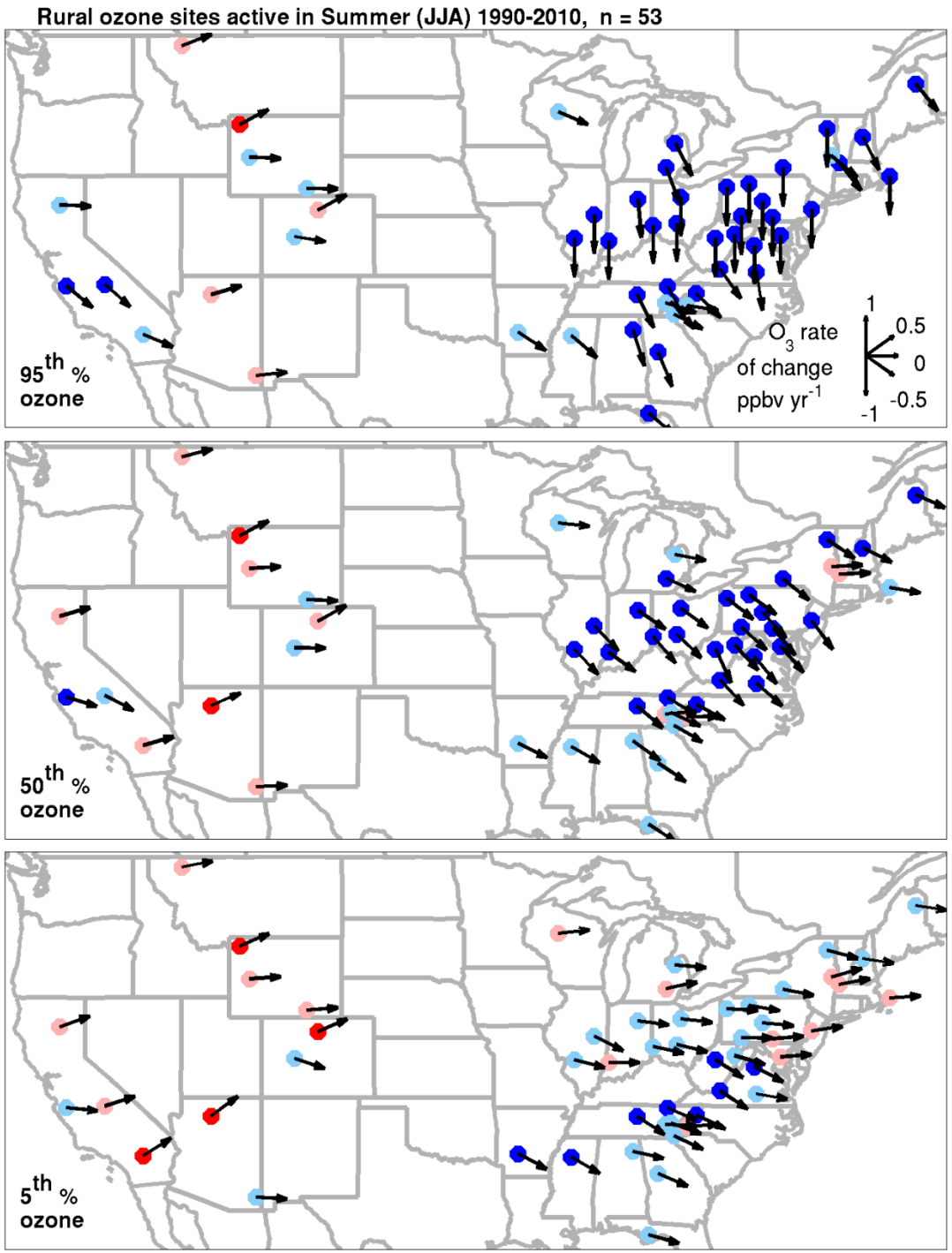
NO_x emissions in China doubled from 1990-2005 and are currently increasing at the same relative rate as CO_2 emissions.

Tropospheric NO_2 column data from the GOME and SCIAMACHY sensors were freely downloaded from: www.temis.nl
For methodology see:
Boersma, K. F., et al. (2004), Error analysis for tropospheric NO2 retrieval from space, J. Geophys. Res., 109, D04311,
Richter, A., et al.(2005), Increase in tropospheric nitrogen dioxide over China observed from space, Nature, 437

Surface ozone trends, beginning 1990-1999 and ending 2000-2010.
All trends are from the peer-reviewed literature.



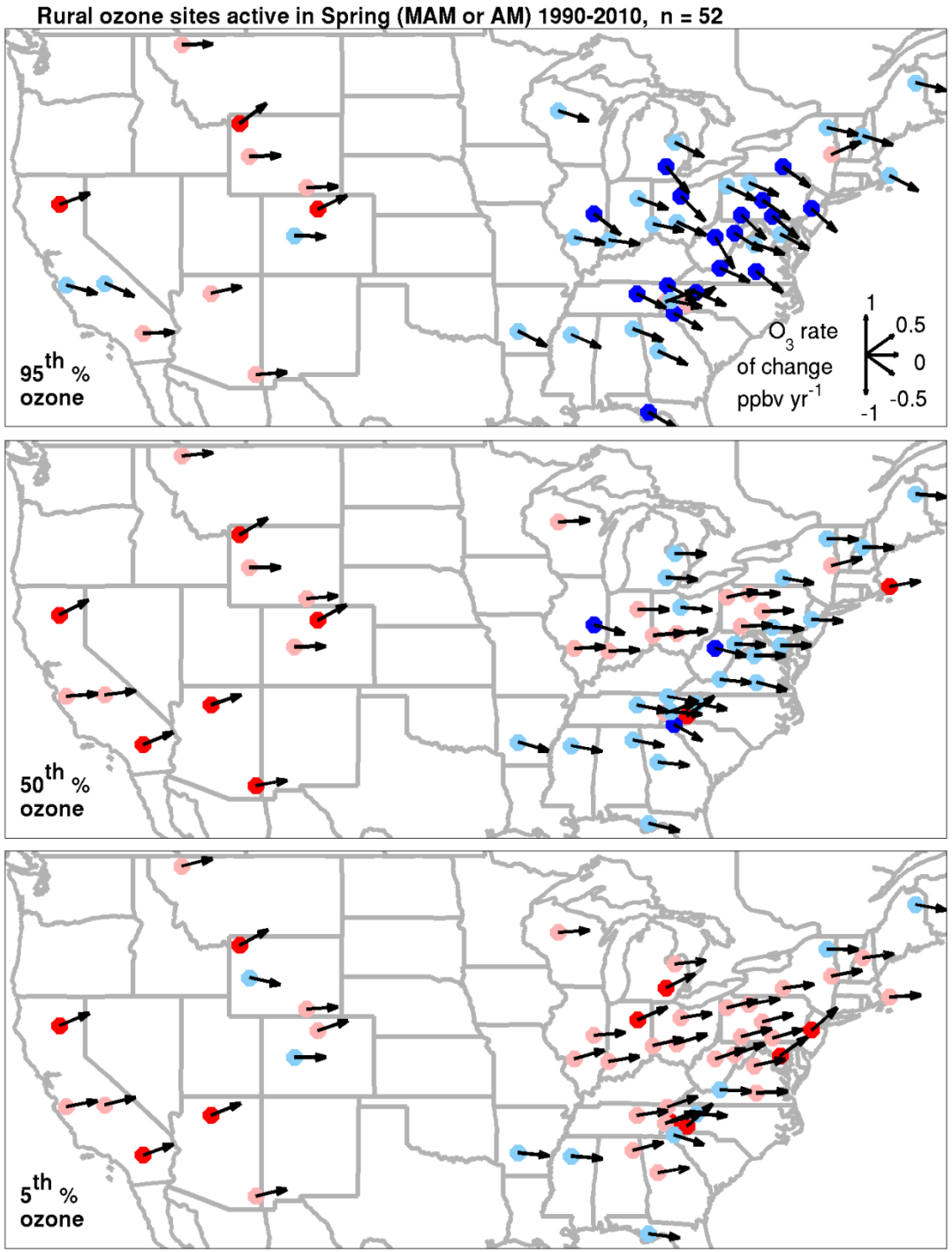
Summer 1990-2010
Rural ozone trends



- significant increase
- insignificant increase
- significant decrease
- insignificant decrease

Cooper, O. R., et al. (2012), Long-term ozone trends at rural ozone monitoring sites across the United States, 1990–2010, J. Geophys. Res., 117, D22307

Spring 1990-2010
Rural ozone trends



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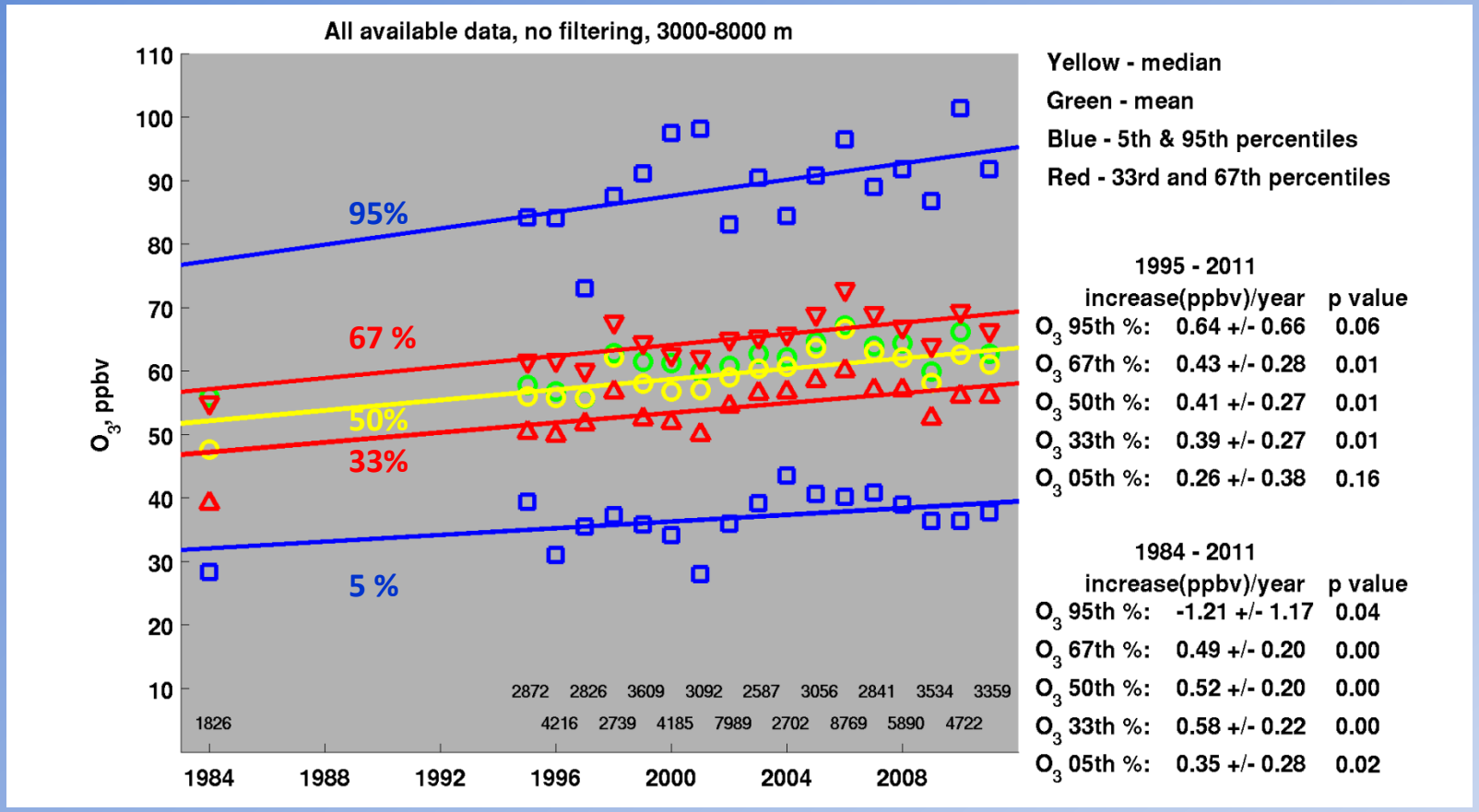
Free tropospheric ozone trend above western North America



- All available data above western North America, regardless of transport history.
- Measurements were made between 3.0 – 8.0 km above sea level during April-May
- Ozone has increased by 29% from 1984-2011.

Cooper, O. R., et al. (2012), Long-term ozone trends at rural ozone monitoring sites across the United States, 1990–2010, J. Geophys. Res., 117, D22307

3.2 Science Goals

A science question to be answered under Theme 3 is:

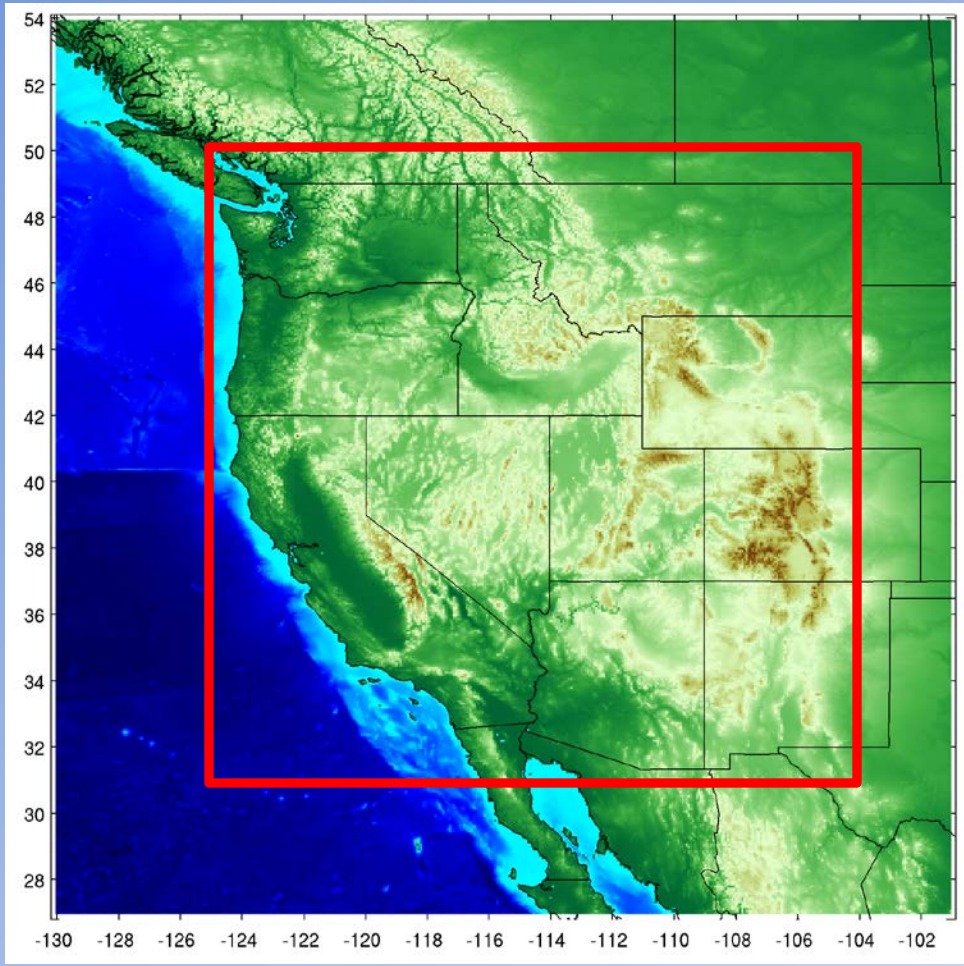
How well do current global and regional chemical transport models (CTMs) simulate the atmospheric boundary layer (ABL) processes that transport intercontinental pollution plumes from the free troposphere down to the surface of a receptor region?

To address this question, TF HTAP participants developed Work Package 3.2: Inflow processes influencing air quality over western North America.

Objectives:
To evaluate the ability of global and regional models to represent processes driving the import of intercontinental air pollution into western North America and its influence on surface air quality using observations from intensive field campaigns in May-June 2010.

Task 3.2.1

Identify the model outputs needed to perform the model to observation comparisons needed in Task 3.2.3.



Output domain for HTAP Regional Model intercomparison

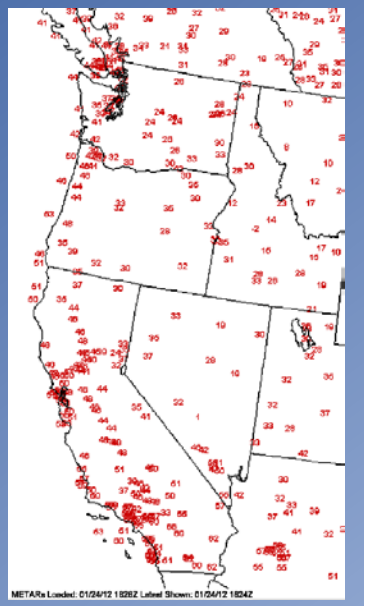
31 N to 50 N and -125 W to -104 W

Task 3.2.2

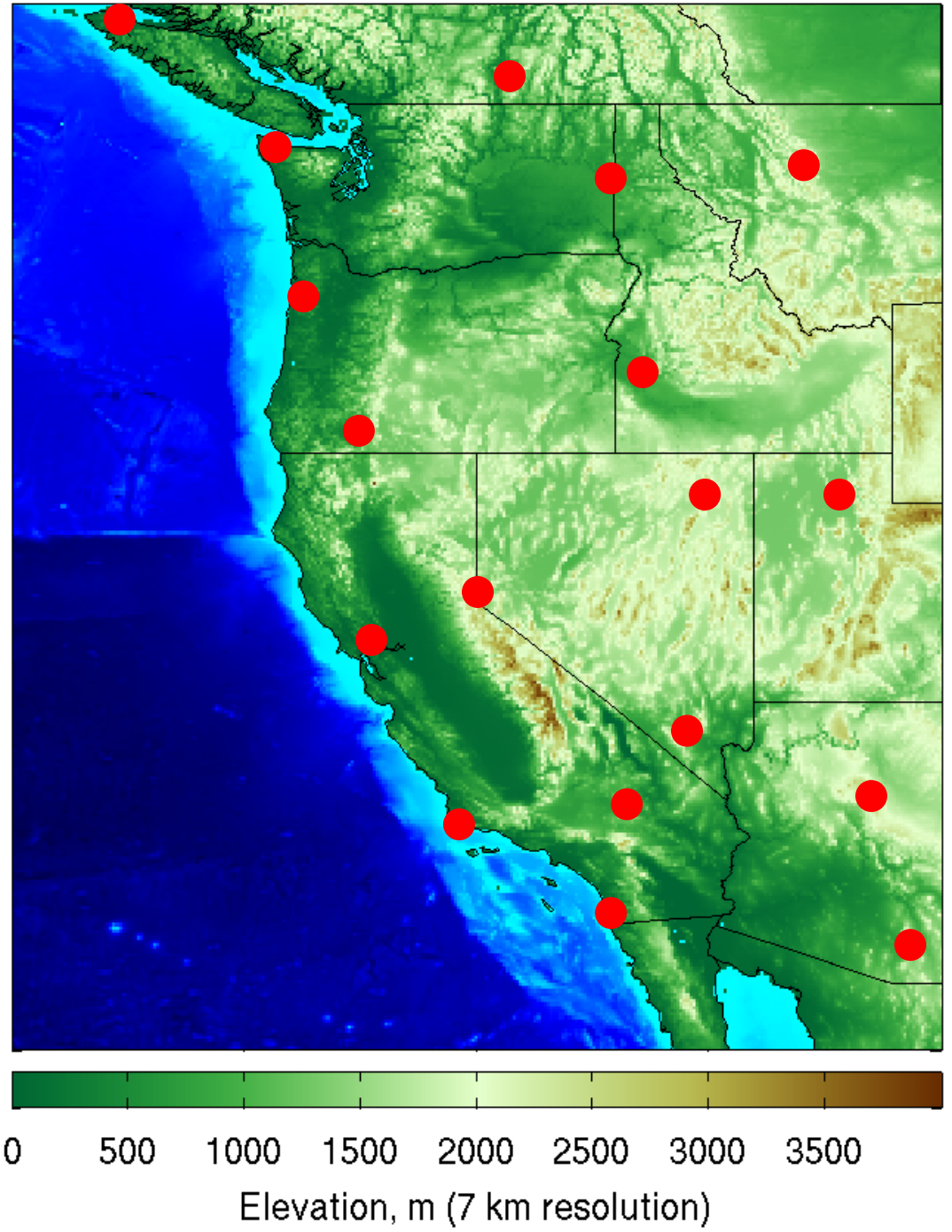
Collect relevant measurement data and make available in networked archive

Western North America: Routine meteorological measurements

Hourly surface observations at dozens of sites

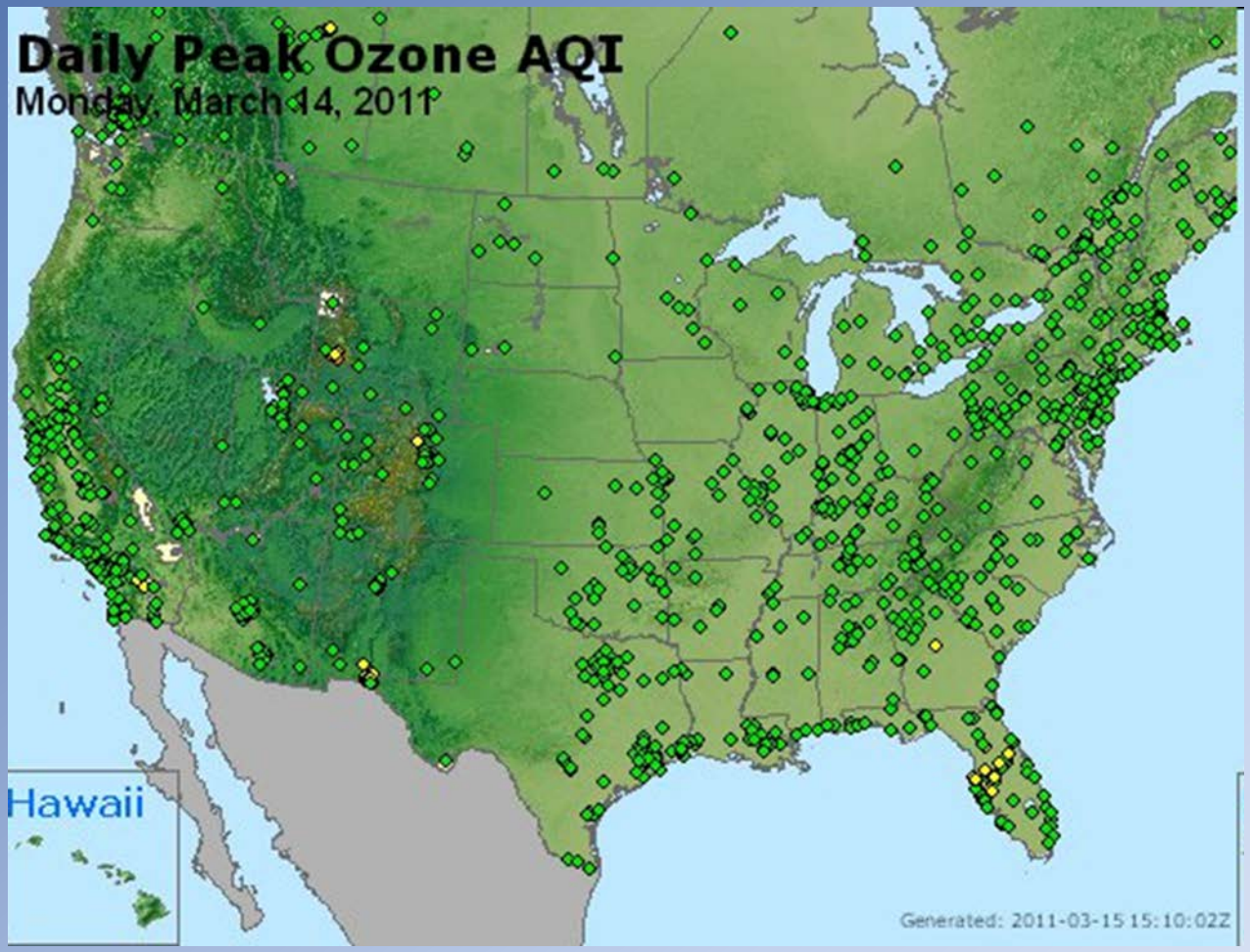


18 rawinsonde sites, launched twice daily at 4:00 and 16:00 PST



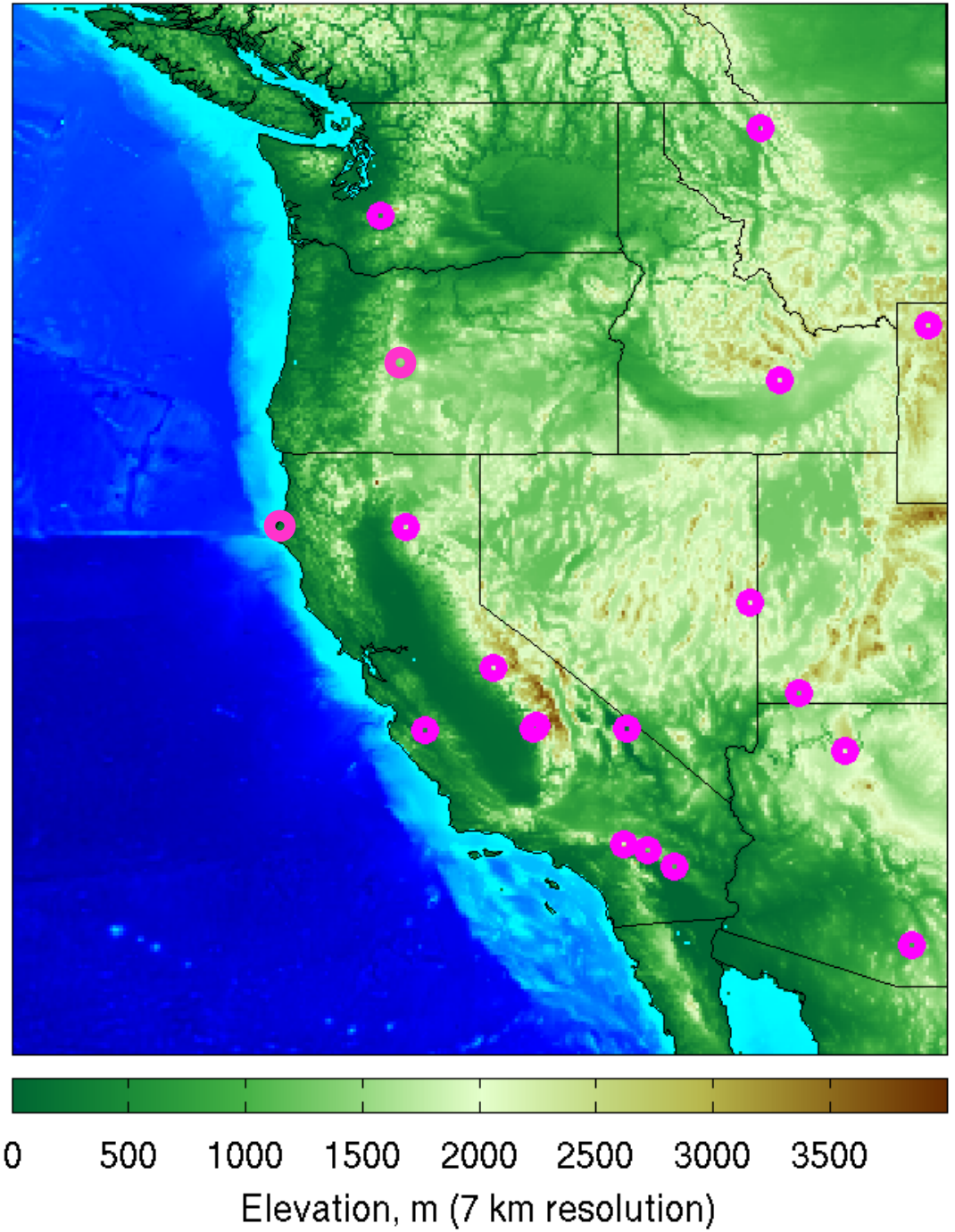
Western North America: Urban O_3 measurements

The US EPA maintains a database of hourly ozone measurements from ~200 urban ozone monitors across the western USA



Western North America: Routine O_3 measurements

Rural surface ozone:
19 sites: CASTNET, National Park Service, Trinidad Head (NOAA), Mt. Bachelor (D. Jaffe): plus CO and total Hg



Western North America: Routine Remote Aerosol Measurement Sites

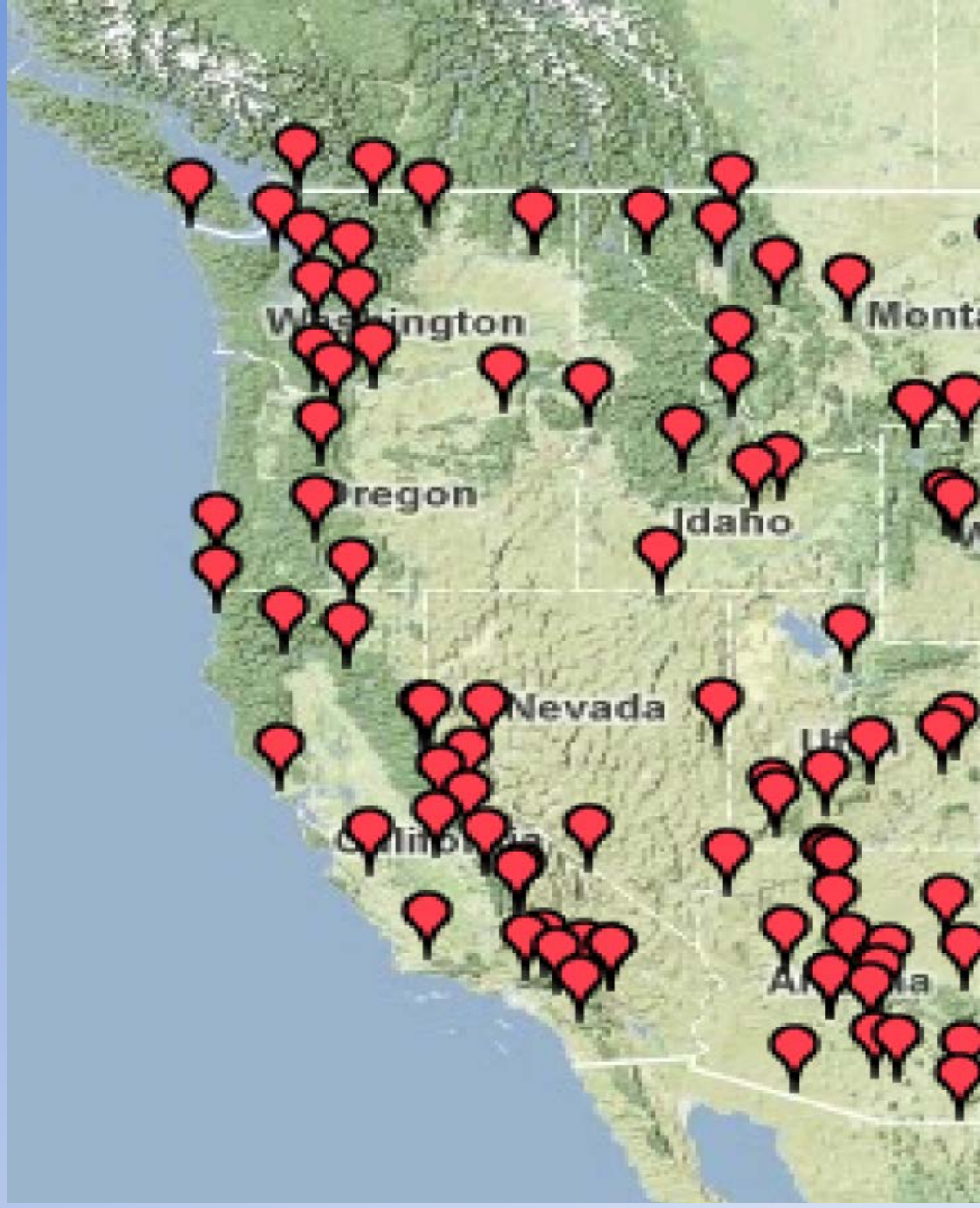
IMPROVE:

24 – Hour Sample, Every 3 Days

PM10 Mass

PM2.5 MASS, XRF, Cl^-, NO3-, $SO4^=$, OC/LAC (TOR), B_{sp}, B_{ap}

RURAL, REMOTE,
MANY HIGH ALTITUDE SITES



Slide courtesy of Tony VanCuren
UC Davis, Air Quality Research Center

IMPROVE data are available for download from http://views.cira.colostate.edu/fed/.

CALNEX Experiment
May-June 2010

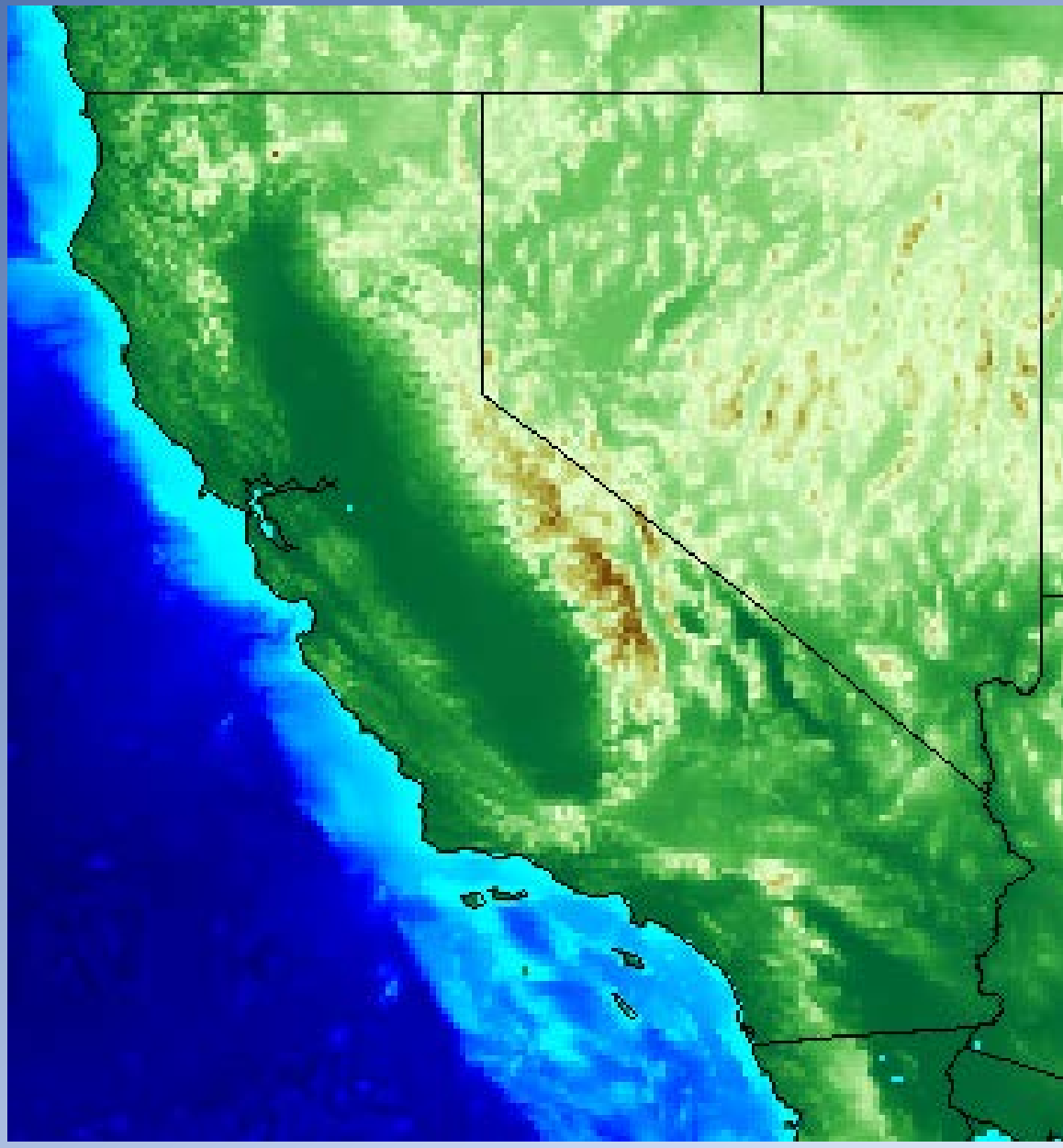
Purpose: To provide information for integrated regional decision-making on air quality and climate.

Major participants: NOAA, California Air Resources Board and partner universities

CARES Experiment
June 2010

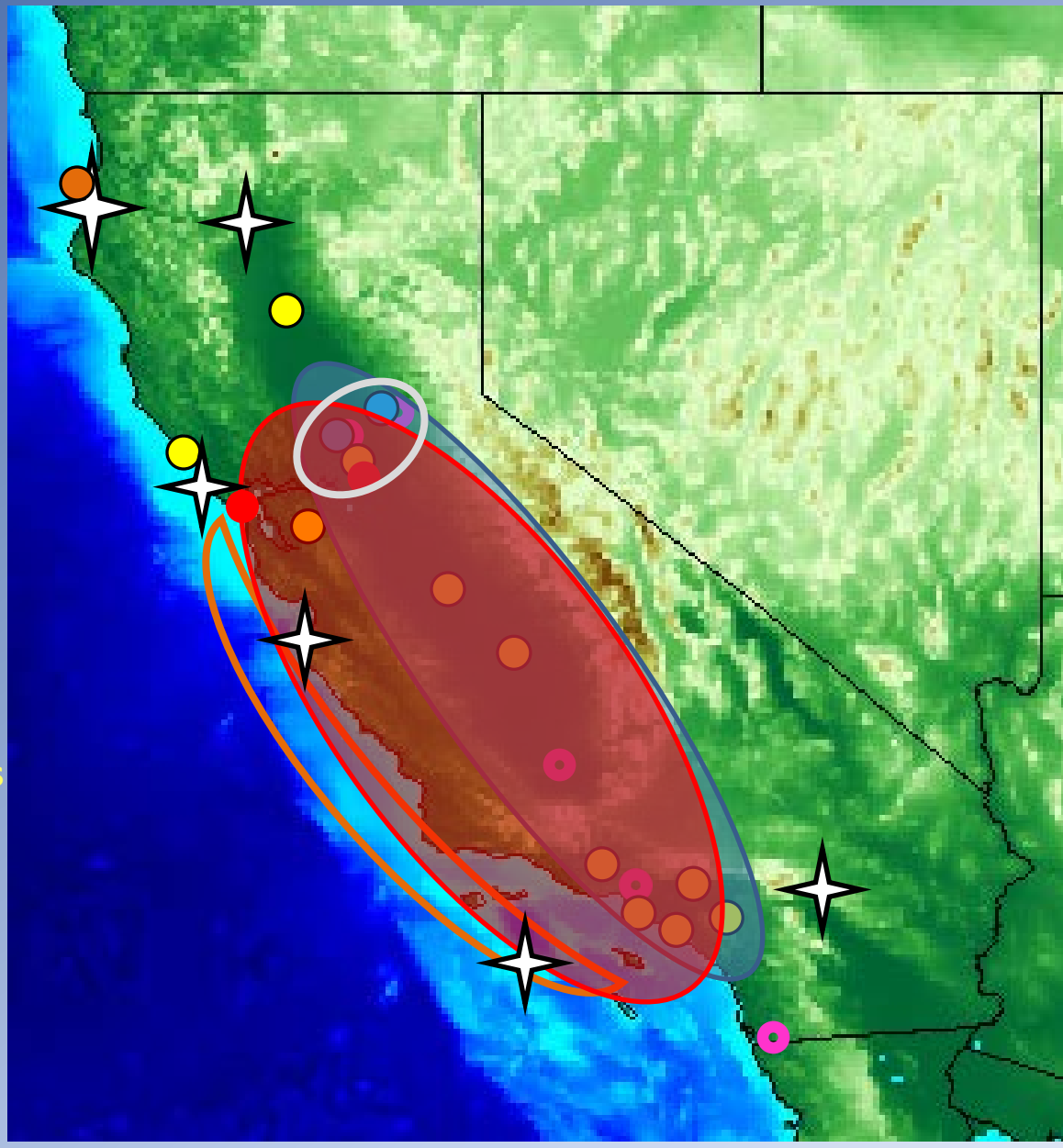
Purpose: Investigate the evolution of secondary organic and black carbon aerosols and their climate-related properties in the Sacramento urban plume.

Major Participants: Department of Energy, NASA, NOAA, partner universities



Enhanced measurements May-June 2010

- Aerosol lidar at Trinidad Head
- 5 Surface sites: trace gases, aerosols
- 2 Tall Towers: carbon cycle gases
- 11 radar wind profilers
- 2 afternoon rawinsondes sites
- Research Vessel *Atlantis*: gases, aerosols & rawinsondes
- NOAA P3 aircraft: gases & aerosols
- NOAA Twin Otter: ozone lidar
- DOE G-1: HSRL aerosol lidar
  NASA King Air: gases & aerosols
- 6 daily ozonesonde sites



Task 3.2.3
Conduct analysis of 2010 model simulations in comparison to observations

Primary Goal: Evaluate the ability of global and regional scale CTMs to represent processes driving the import of intercontinental air pollution into western North America and its influence on surface air quality.

The goal is not to determine which model is most accurate but to evaluate how the range of regional scale models in use today simulate pollution inflow processes and to gauge the improvement in accuracy afforded by regional models in comparison to the range of global scale model simulations.

To meet this objective several global and regional-scale CTMs will be used to study the impact of terrain (large mountain chains vs. broad valleys) and ABL depth (marine boundary layer, daytime mixed layer, nighttime inversion) on the transport of intercontinental pollution plumes down to the surface.

Another important goal is to quantify the impact of intercontinental plumes on surface chemistry in rural and urban areas. These processes will be studied with global scale models at 1-2.5 degree horizontal resolutions and with regional scale models that operate on horizontal scales of 50 – 12 km.

Task 3.2.3
Conduct analysis of 2010 model simulations in comparison to observations

Specific analyses that will be conducted include:

1) Compare model daytime boundary layer depth to temperature and humidity profiles from the rawinsonde network. Do the models accurately simulate the entrainment of free tropospheric air into the ABL?

2) Use the rawinsonde network to identify the general structure of the subsidence inversion associated with the eastern North Pacific anticyclone. How do the models simulate this inversion and what effect does it have on the quantity of pollutants entrained into the ABL?

3) Compare modeled ozone and PM to the ozonesondes and to the measured values at high and low elevation surface sites across western North America. What is the influence of terrain on the quantity of pollution transported to the surface?

4) Perturbation experiments: What is the impact of 20% reduction and 20% increases in East Asian emissions on ozone and PM in western N. America? Are impacts proportional at high/low elevation sites, or at rural/urban sites?

5) To be most relevant to impacts on human health, particular attention will be paid to daytime conditions and the 8-hour maximum daily average ozone values.

3.2 Participant List

Regional-scale (half degree and finder resolutions)

Greg Carmichael and Min Huang, U. of Iowa
STEM CTM, 12 km resolution with RAQMS boundary conditions

Tracy Holloway, U. of Wisconsin
CMAQ CTM

Meiyun Lin, Princeton/NOAA GFDL
NOAA FDL AM3 global chemistry-climate model, half degree resolution

Joshua Fu and Xinyi Dong, U. of Tennessee-Knoxville
CMAQ CTM, two ways including direct and indirect in CMAQ, down to 4x4 km

Yuhang Wang and Yuzhong Zhang, Georgia Tech
REAM, 36 km resolution. Standard domain covers contiguous US and parts of Canada/Mexico

Si-Wan Kim, U. of Colorado/NOAA ESRL:
WRF-Chem 12 km, with boundary conditions from MOZART/GEOS-Chem/AM3

Brad Pierce, NOAA/NESDIS
RAQMS

Daven Henze, University of Colorado, Boulder
GEOS-CHEM nested: 0.5° x 0.667°

Global or N. Hemisphere scale (resolutions coarser than half degree)

Greg Carmichael and Min Huang, U. of Iowa
STEM CTM, 60 km resolution over CONUS with GEOS-Chem boundary conditions

Meiyun Lin, Princeton/NOAA GFDL
NOAA GFDL AM3 global chemistry-climate model, 2 degree resolution

Joshua Fu and Xinyi Dong, U. of Tennessee-Knoxville
Hemispheric CMAQ, 1 degree resolution

Louisa Emmons, NCAR
Cam-Chem

Rokjin Park, School of Earth and Environmental Sciences, Seoul National University
GEOS-CHEM, with CONUS nest

Brad Pierce, NOAA/NESDIS
RAQMS

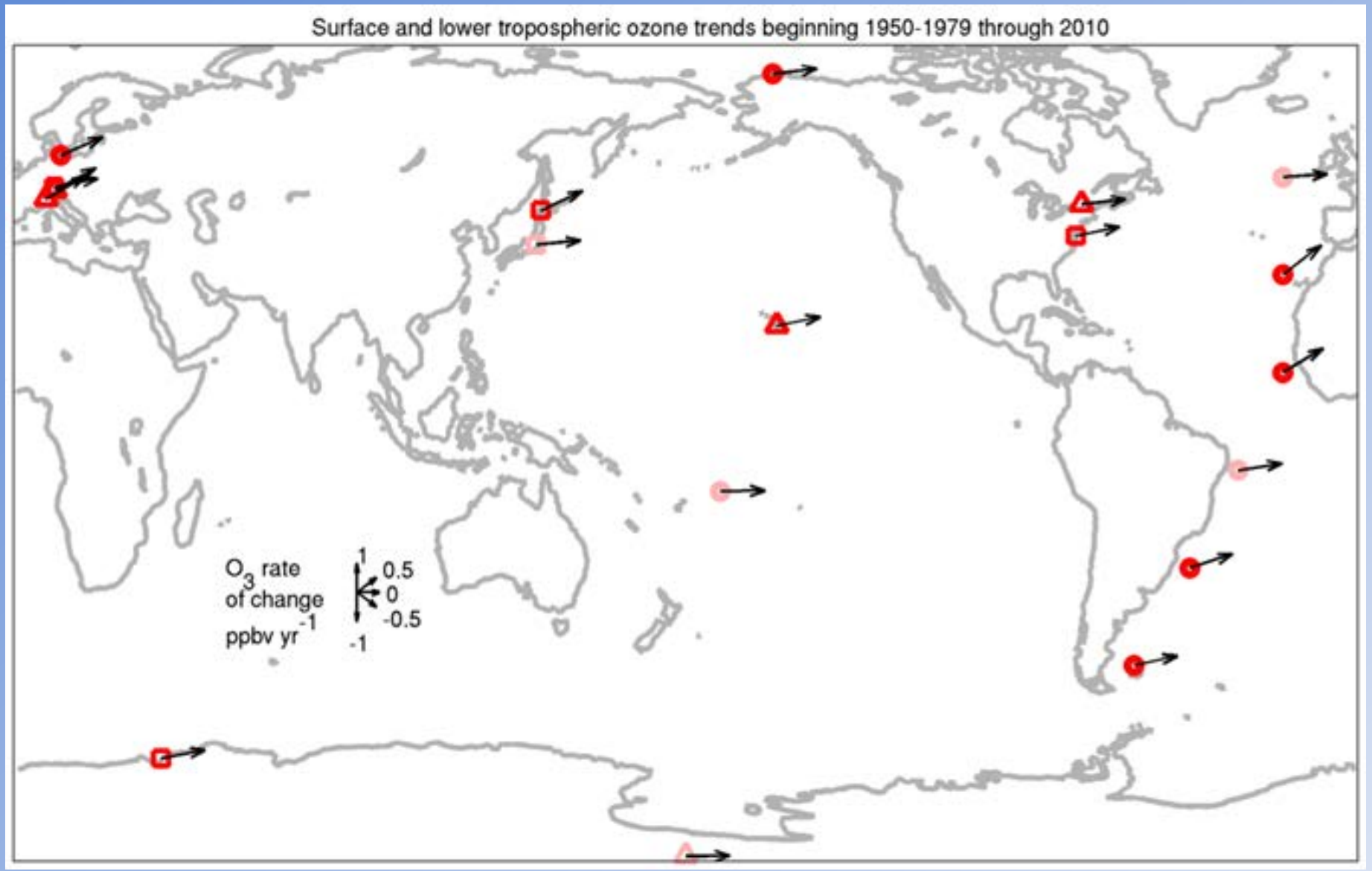
Daven Henze, University of Colorado, Boulder
GEOS-CHEM nested: 2° x 2.5°

Questions and comments from the Global Modelers

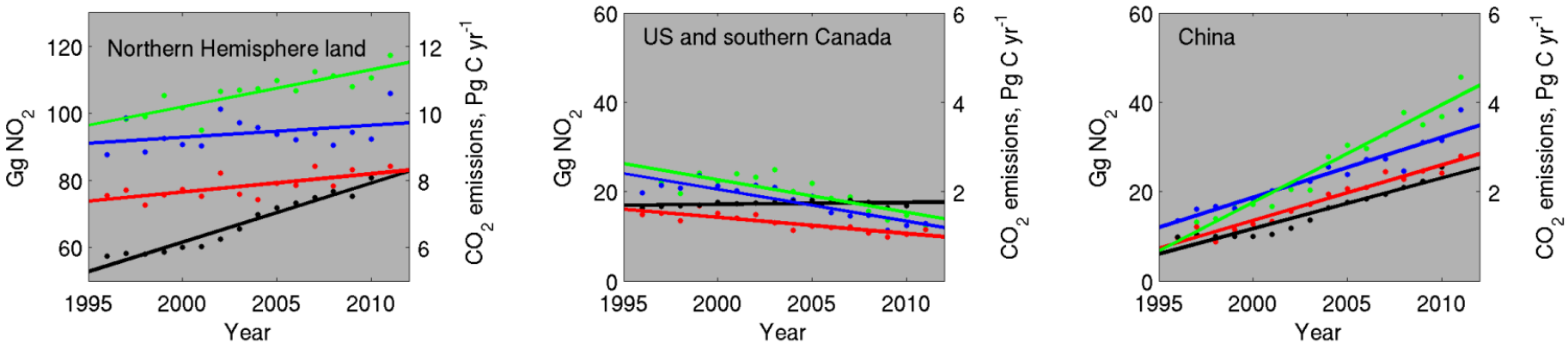
1. There is some confusion over the method of speciating VOCs. On the HTAP wiki, *Work Package 1.1 HTAP harmonized emissions database 2006-2010* provides some guidance on VOC speciation for Europe, Asia and N. America. Is this the preferred guidance or just a suggestion? How would these methods fit with the new sector classifications?
2. One participant disagreed with the direction that each group speciate VOCs according to their preferred method: would introduce too much variability between models. Their recommendation was to use the EPA speciation for the whole globe.
3. Another participant used the native GEOS-Chem speciation, but rescaled the total VOCs to match the HTAP inventory.
4. Aircraft emissions were not provided with a vertical distribution, therefore one group chose to use the CCMI aircraft emission inventory.

Extra Slides

Surface ozone trends, beginning 1950-1979 and ending 2000-2010.
All trends are from the peer-reviewed literature.



GOME/SCIAMACHY tropospheric column NO_2, Gg per region with annual fossil fuel CO_2 emissions, Pg C



NO_x emissions in China doubled from 1990-2005 and are currently increasing at the same relative rate as CO_2 emissions.

Green - NO_2 spring (Mar Apr May)

Red - NO_2 summer (Jun Jul Aug)

Blue - NO_2 autumn (Sep Oct)

Black - annual CO_2 emissions

Tropospheric NO_2 column data from the GOME and SCIAMACHY sensors were freely downloaded from: www.temis.nl

For methodology see:

Boersma, K. F., et al. (2004), Error analysis for tropospheric NO2 retrieval from space, J. Geophys. Res., 109, D04311,

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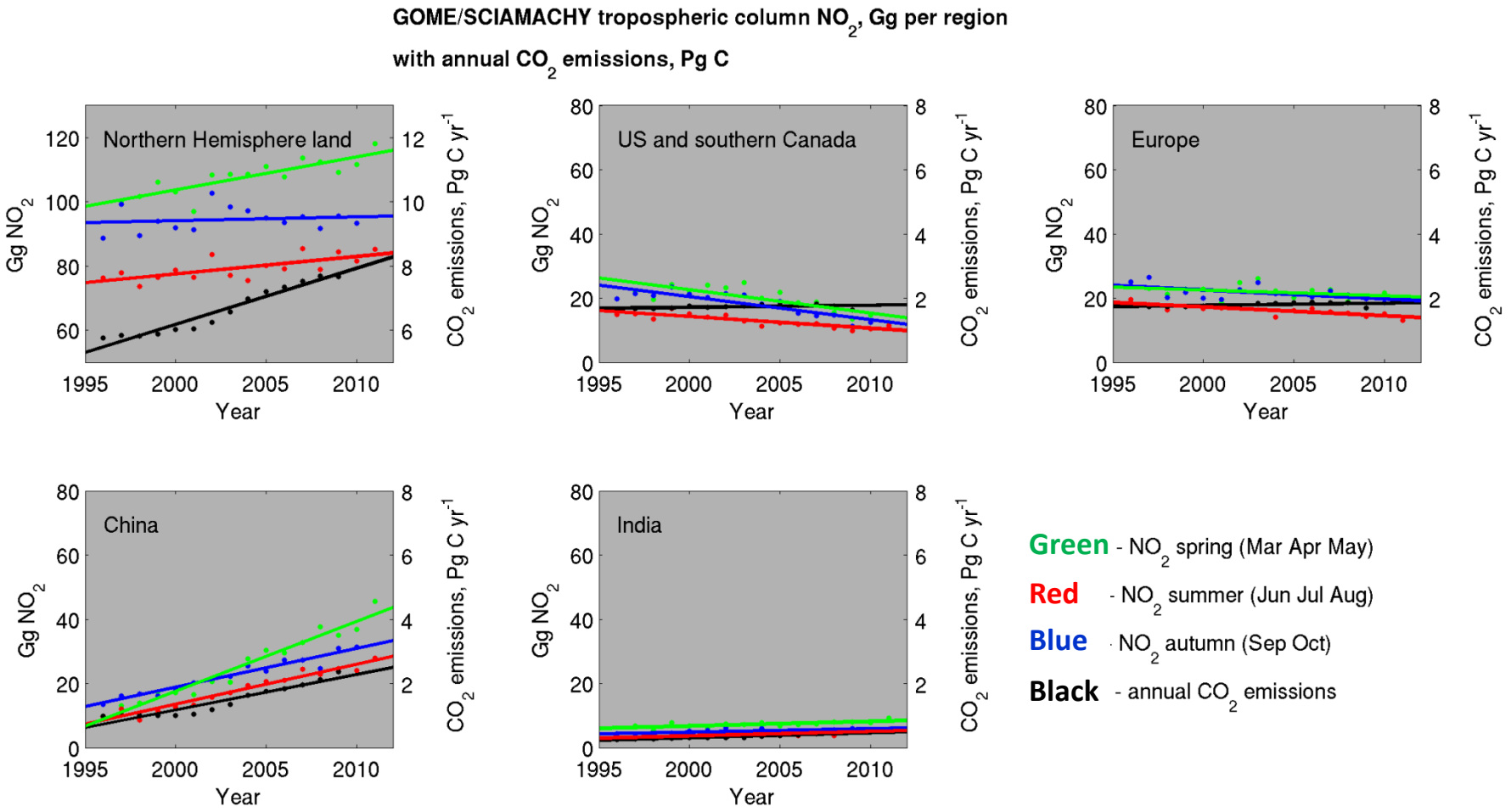
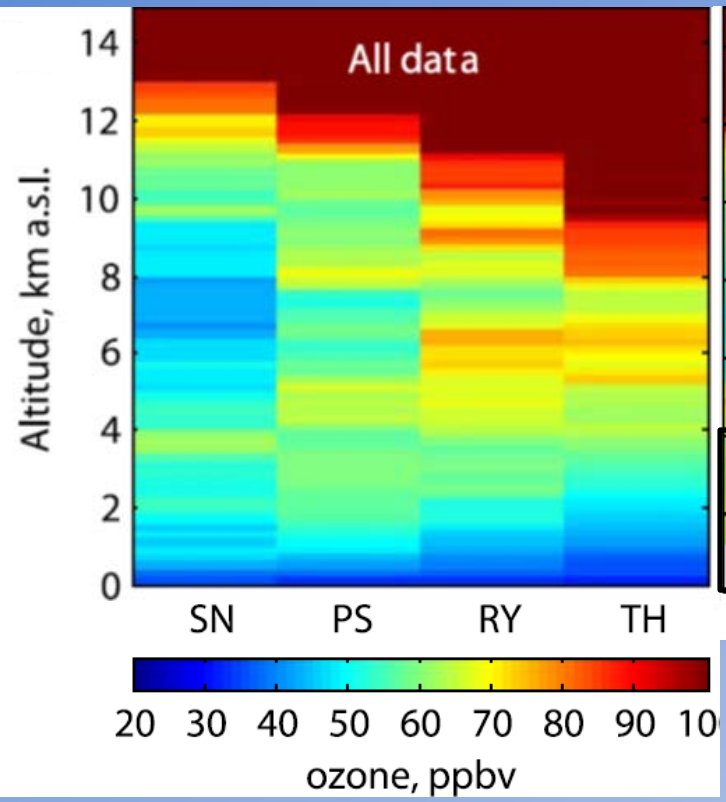
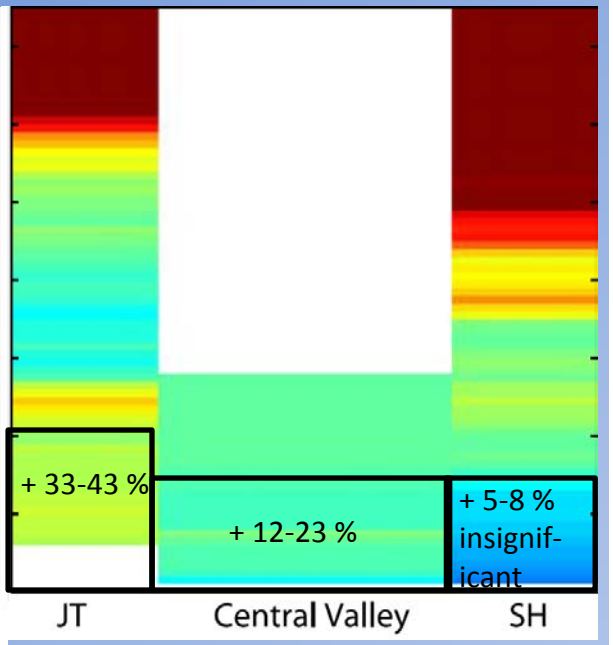


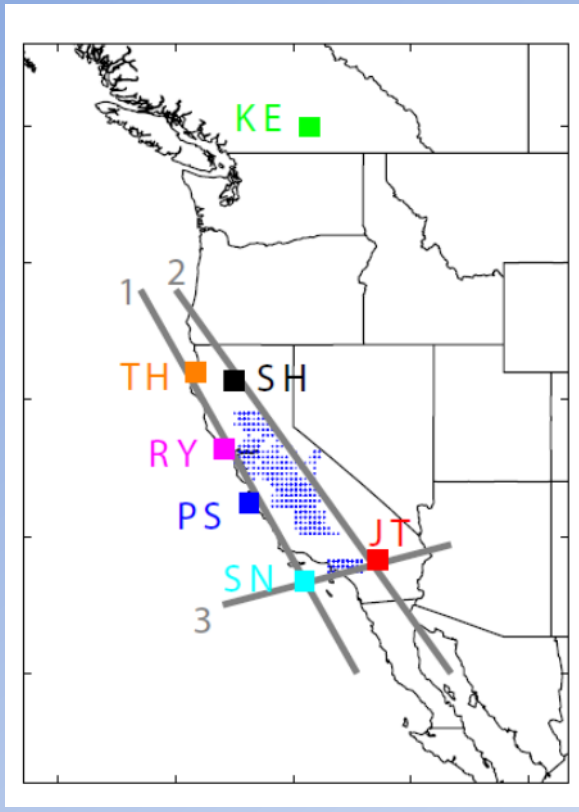
- Emission controls in China have greatly reduced power plant SO_2 emissions since 2006 [*Lu et al*. 2010].
- Aggressive NO_x controls have not yet been implemented
- Column NO_2 across China is increasing at the same rate as CO_2 emissions.

- Tropospheric NO_2 column data from the GOME and SCIAMACHY sensors were freely downloaded from: www.temis.nl
- CO_2 emission data were retrieved from the U.S. Energy Information Agency
- Lu et al., Sulfur dioxide emissions in China and sulfur trends in East Asia since 2000, ACP, 2010, 6311-6331.

Comparison of ozone above the California coast to ozone above polluted inland regions.



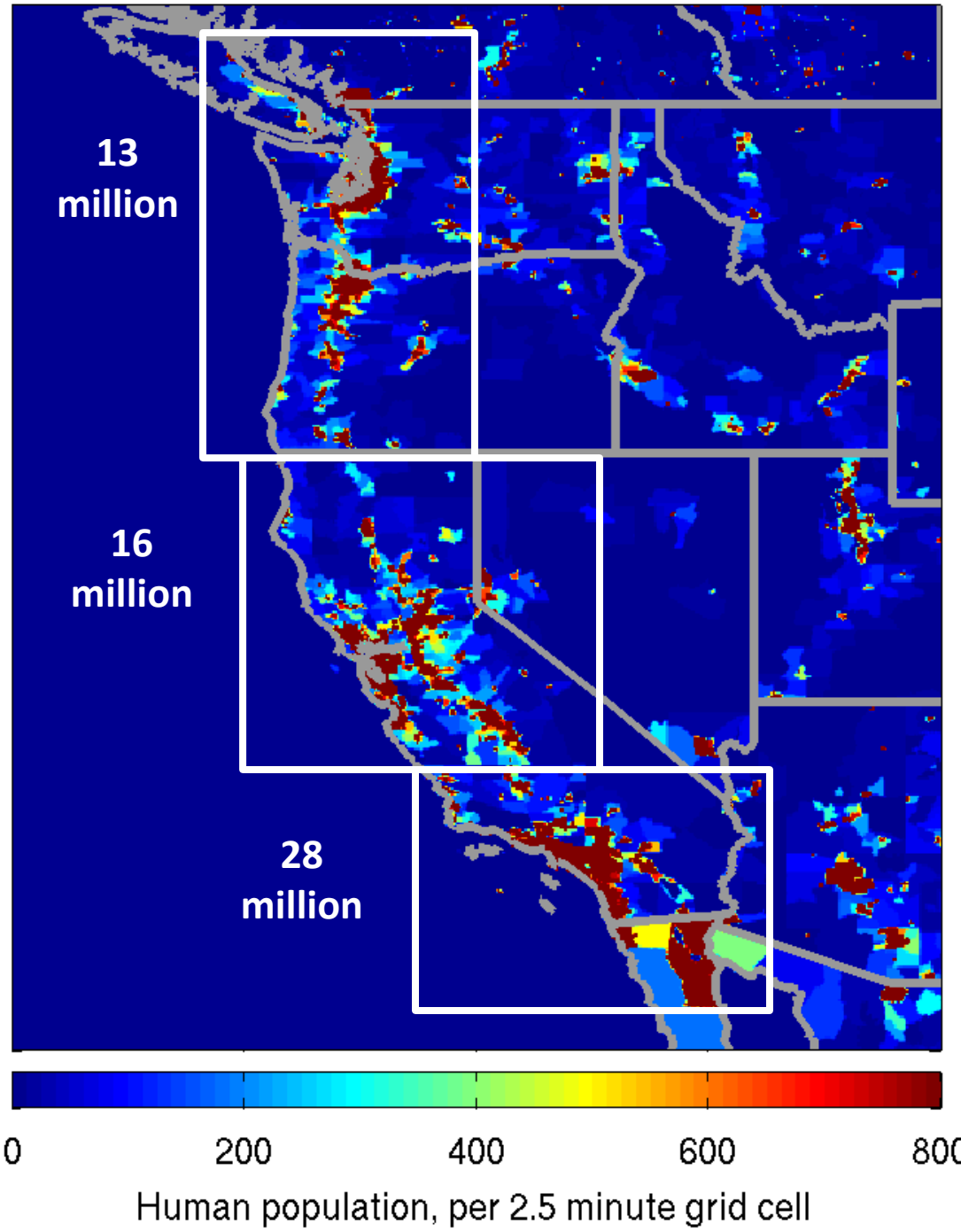




Cooper et al. (2011), Measurement of western U.S. baseline ozone from the surface to the tropopause and assessment of downwind impact regions, J. Geophys. Res., 116, D00V03, doi:10.1029/2011JD016095..

Western North America: Human Population

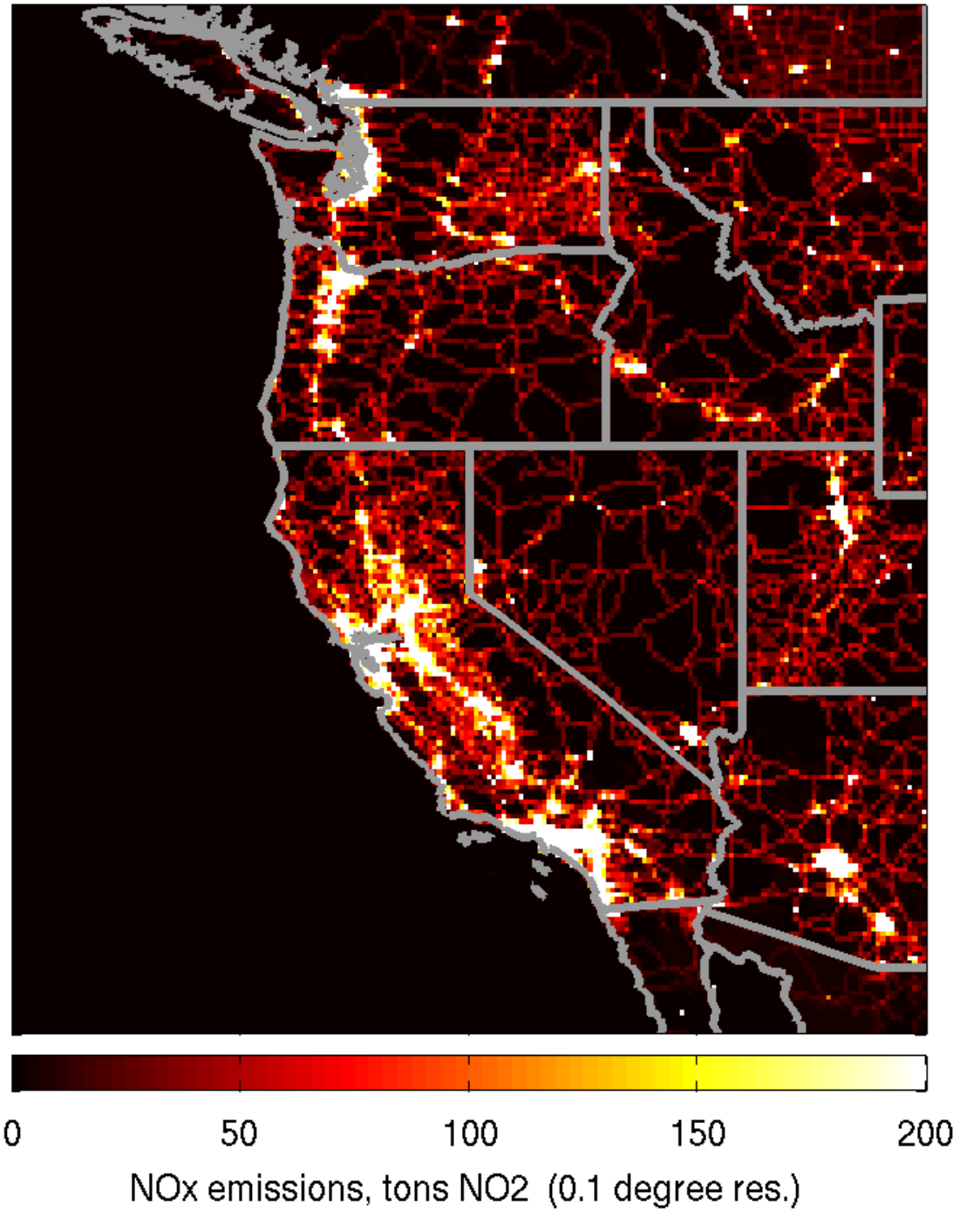
57 million people live within 350 km of the west coast



Data courtesy of:
Center for International Earth Science Information Network (CIESIN), Columbia University

Western North America: Anthropogenic NO_x emissions

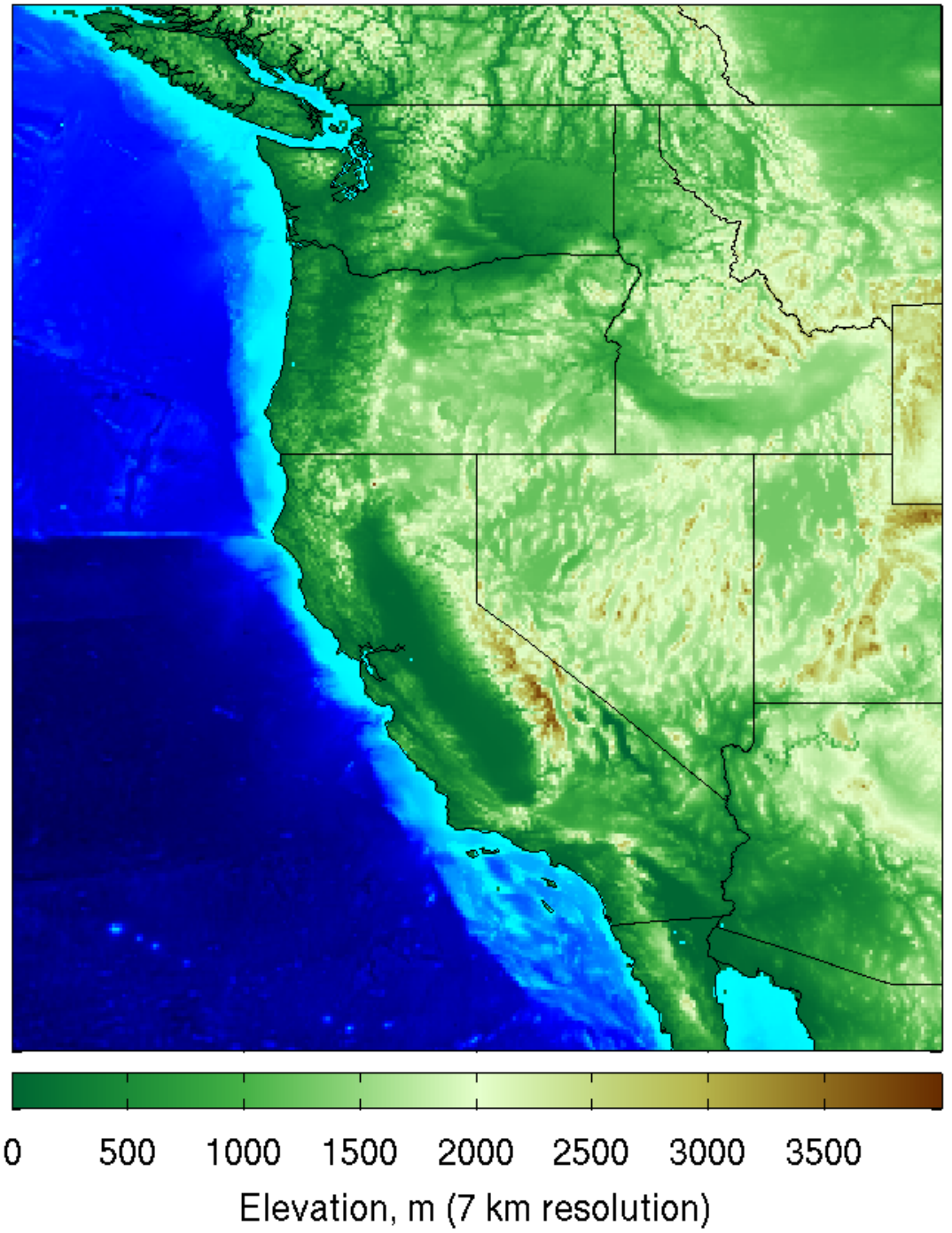
EDGAR v4.1 2005 emission inventory



Western North America: Topography

7 km resolution

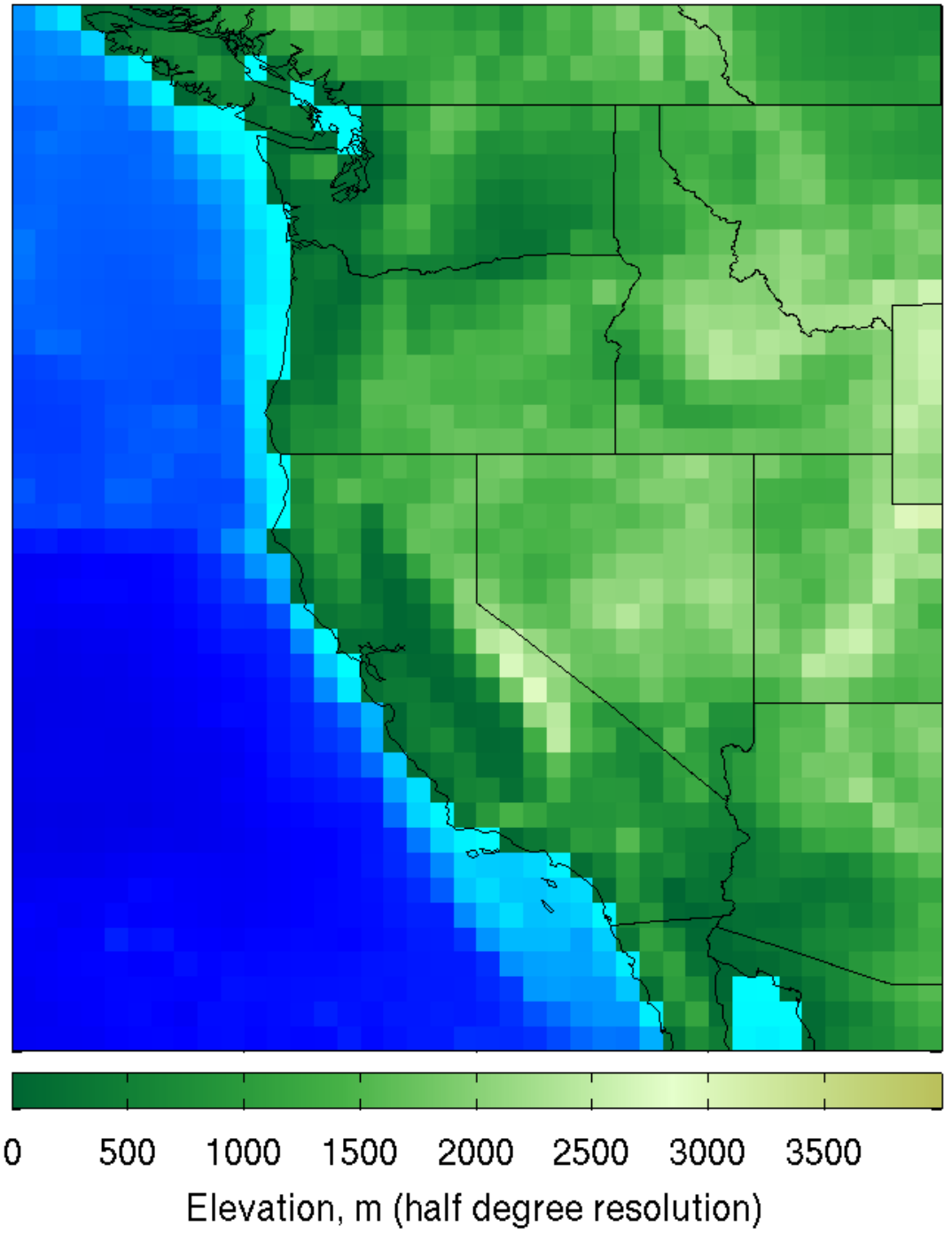
Data courtesy of:
NOAA National Geophysical Data Center, Boulder



Western North America: Topography

Half-degree resolution

Data courtesy of:
NOAA National Geophysical Data Center, Boulder



Western North America: Long Term Research Remote Aerosol Measurement Sites

UC Davis ROTATING DRUM IMPACTOR (RDI):

Continuous, 3-hr resolution

8-Stages 10 μm to 90 nm

XRF, Light Absorption

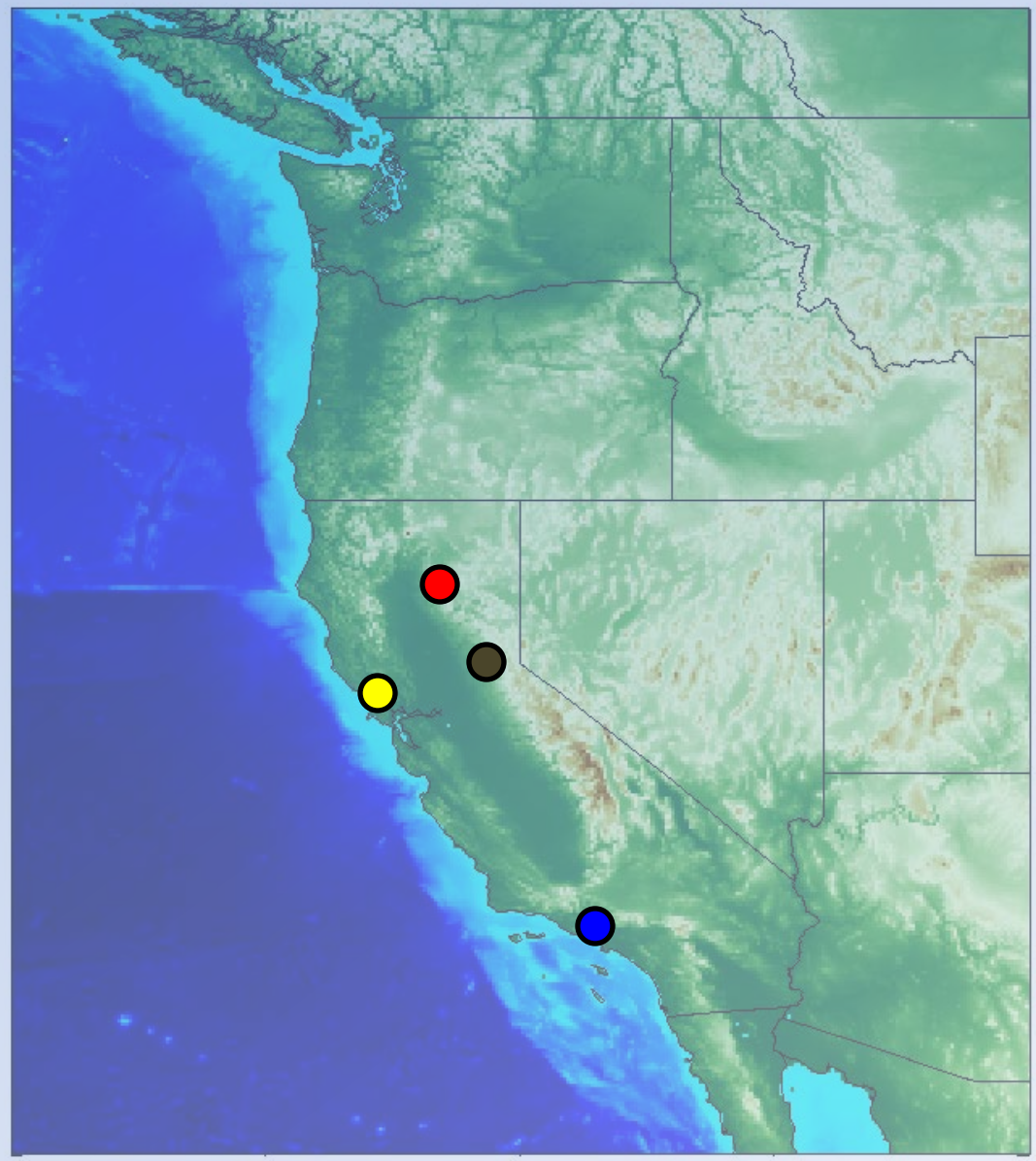
Selected Sites:

03/21/09 – 10/27-09;
11/26/09 - 09/24/10 — 1754 m

08/05/08 – 12/01/10 — 780 m (>MBL)

02/20/09 – 05/08/09
02/06/10 – 03/12/10 — 1100 m

05/12/10 – 07/19/10 — 260 m



Slide courtesy of Tony VanCuren
UC Davis, Air Quality Research Center