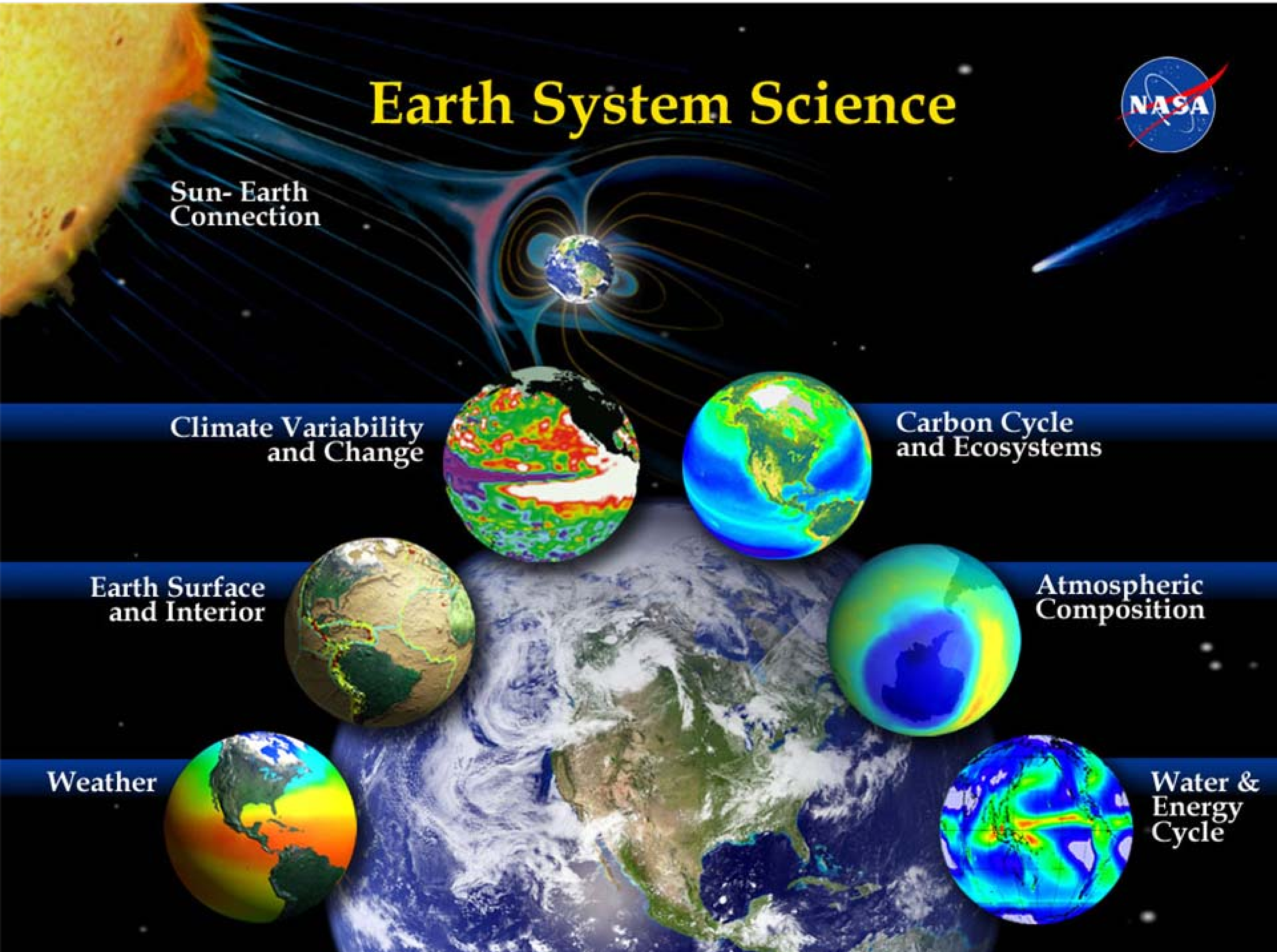
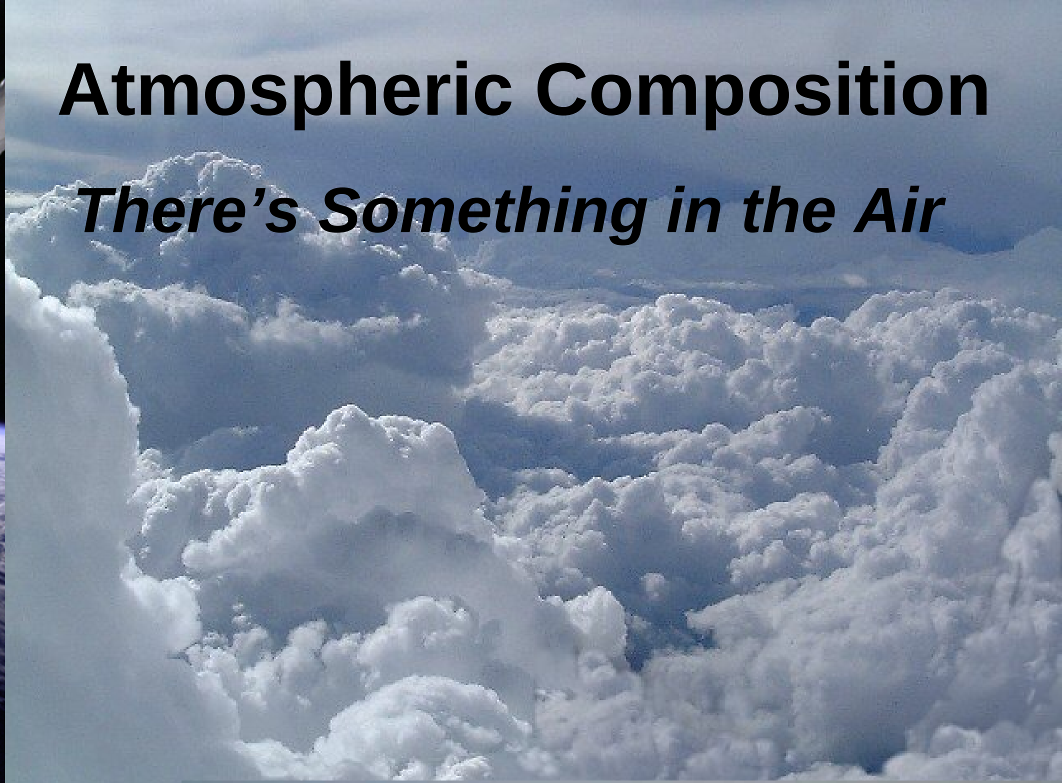

Earth System Science
NASA
Sun- Earth Connection
Climate Variability and Change
Carbon Cycle and Ecosystems
Earth Surface and Interior
Atmospheric Composition
Weather
Water & Energy Cycle

Atmospheric Composition

There's Something in the Air



Atmospheric Composition

Component R&A Programs:

Upper Atmosphere Research Program (UARP)
Ozone recovery; UT & stratosphere chemical / physical process; Chemistry-Climate connections;

Radiation Sciences Program (RSP)
Climate impacts of aerosols and clouds –aerosol morphology & chemistry, convective transport, etc.

Tropospheric Chemistry Program (TCP)
Transport and transformation of gases and aerosols influencing Climate and Air Quality

Atmospheric Chemistry Modeling and Analysis Program (ACMAP)
Data analysis and modeling integrating satellite, aircraft, balloon, and ground-based observations

Observational Assets:

Satellites: Aura, CALIPSO, CloudSat, Terra, Aqua, Parasol, ENVISAT, ACE, EUMetSat, OCO, Glory, NPP, GOSAT

Aircraft: DC-8, WB-57F, ER-2, P-3B, UAVs, other agency and international aircraft

Balloons: High-Altitude/Heavy-Lift for remote sensing, in situ soundings for ozone, T, H_2O, aerosols

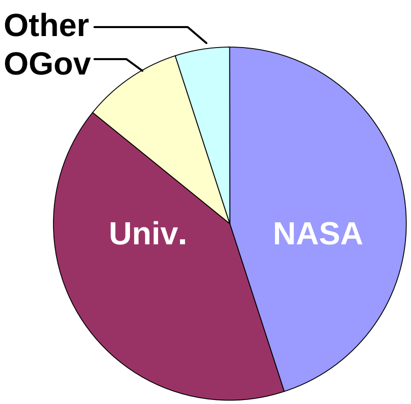
Ground: AGAGE, NDAAC, AERONET, MPLNet, NATIVE, SMART-COMMIT, other agency networks

Other Investments: Laboratory studies, model and instrument development

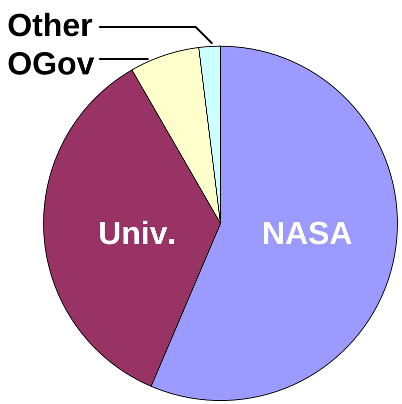
FY07 R&A Budget: $36.5M for ~250 tasks

~40% reduction in science-buying power from FY04

Number of Funded Tasks



Allocation of Research Funds



Key Roles played by NASA centers and non-NASA organizations

	GSFC	LaRC	ARC	MSFC	JSC	WFF	DRFC	JPL	non-NASA
Satellite Mgmt.	X	X						X	
Satellite Data	X	X						X	X
Suborbital Mgmt.					X	X	X		X
Suborbital Data	X	X	X	X		X		X	X
Field Support			X						
Science Leadership	X	X	X					X	X
Modeling	X	X	X					X	X
Laboratory Studies		X	X					X	X

Scientific Activities/Key Results in Air Quality

Satellites

- **Aura – Significant global observations connecting ozone chemistry, air quality, and climate**
- **CALIPSO/CloudSat - Detailed vertical profiles of cloud and aerosol properties on a global scale**
- **MODIS - Global coverage of areal distribution of clouds and aerosols**
- **MISR - Global multi-angle measurements of the areal and vertical distribution of cloud and aerosol properties**
- **MOPITT - Global observations of carbon monoxide quantifying anthropogenic and natural sources**
- **Constellation Science - improve cross-platform opportunities for A-Train and International Constellation (CEOS)**

Suborbital Field Campaigns for Science and Validation

- **INTEX-B/MILAGRO- Campaign examining North American inflow/outflow of pollution**
- **Small-scale campaigns, i.e., IONS, EAST-AIRE, TexAQS/GoMACCS**

Long-term Observation Networks for Science and Validation

- **AGAGE - Global network for tracking atmospheric burdens of Montreal and non-CO_2 Kyoto Protocol gases**
- **NDAAC - Remote-sensing research network for observing and understanding the physical / chemical state of the stratosphere and UT to assess the impact of stratospheric changes on the troposphere and on global climate**
- **AERONET - Global network of aerosol optical depth measurements for climate research and satellite validation**
- **MPLNet - Network for aerosol and cloud vertical profile measurements for climate research and satellite validation**

Modeling and Data Analysis

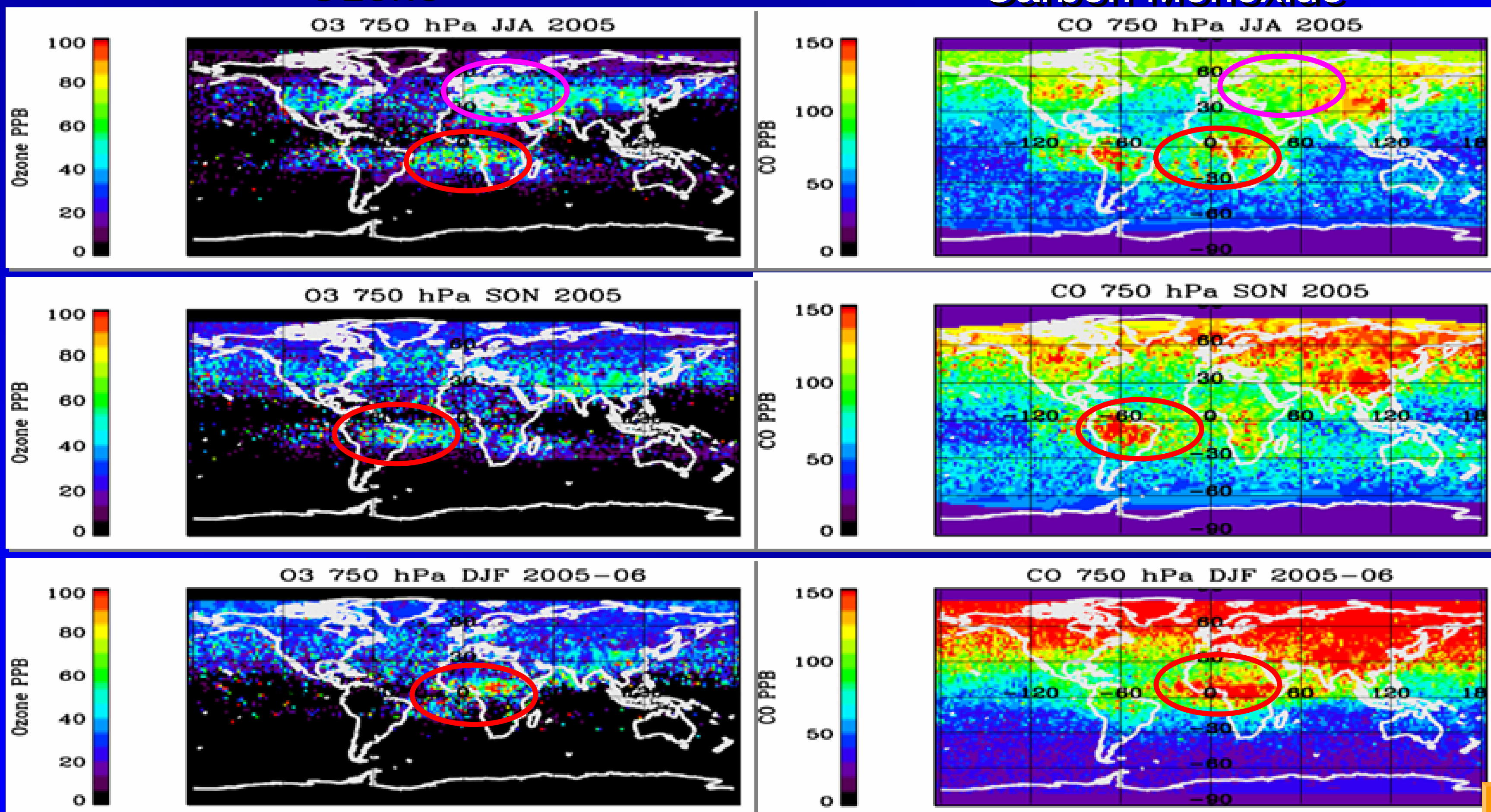
- **GEOS-Chem – Global tropospheric CTM playing a key role in the interpretation of NASA satellite data and used by over 30 research groups worldwide in a wide range of applications including chemistry/climate coupling**
- **GOCART - Simulates aerosols and related species to analyze NASA observations for aerosol-climate studies**
- **AC&C / Aerocom / CCMVAL - Continued intercomparison of models to validate and improve chemistry/climate assessment and prediction**

TES: Maps of Tropospheric Ozone & Carbon Monoxide

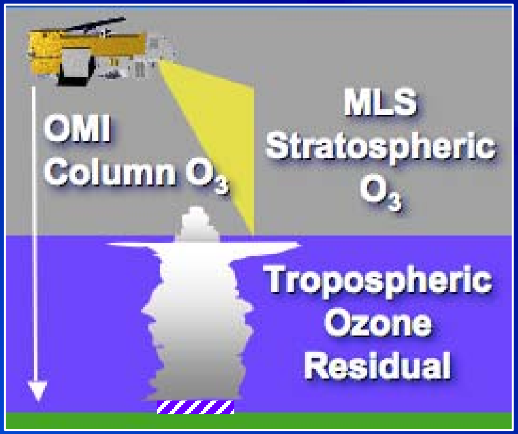
Coincident measurements of tropospheric ozone and carbon monoxide are critical for understanding chemical and dynamical processes. Note the tropical high ozone coincident with CO which is associated with biomass burning.

Ozone | Carbon Monoxide

Summer 05 | Fall 05 | Winter 05-06

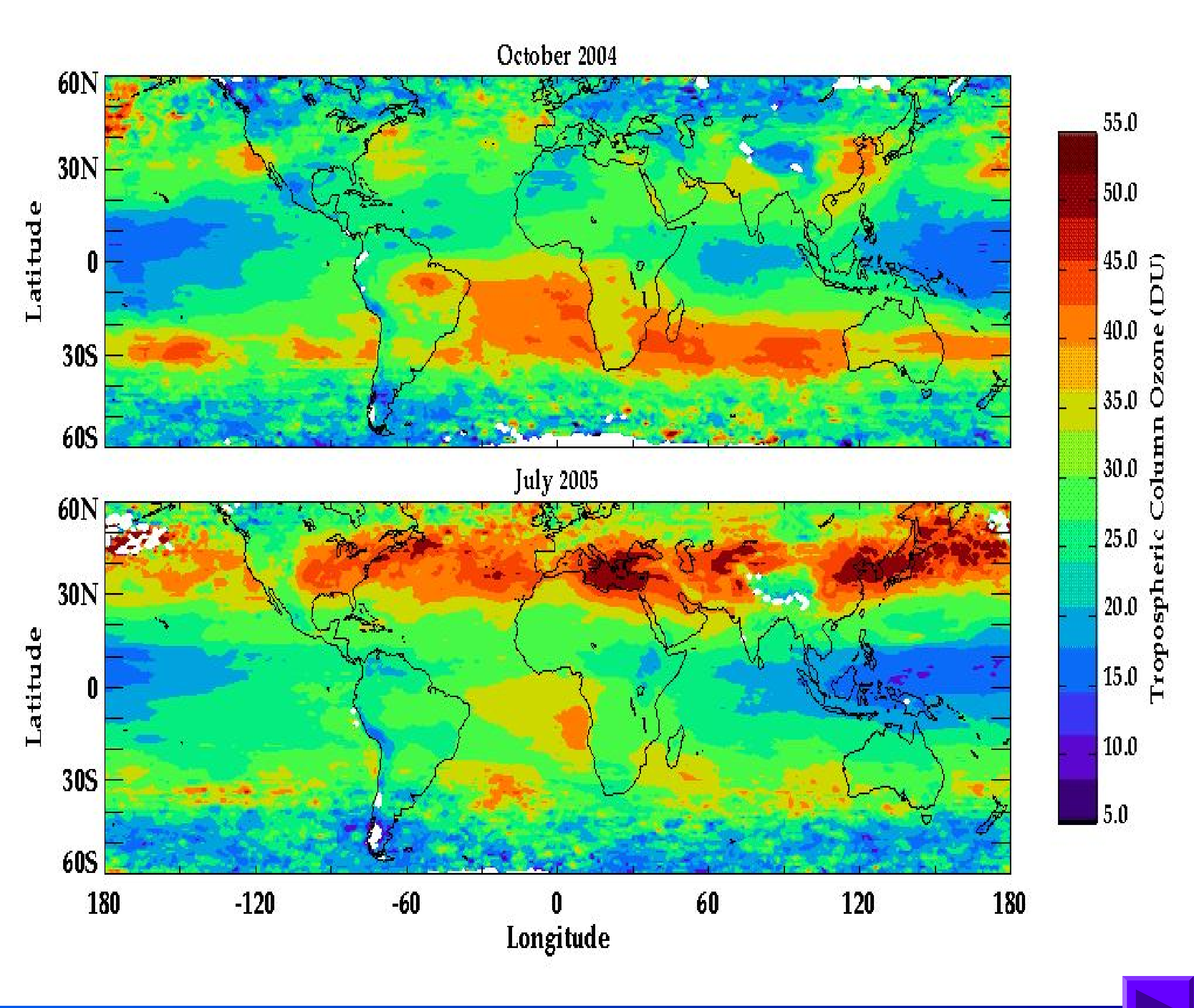


OMI & MLS: Global Tropospheric Ozone Residual



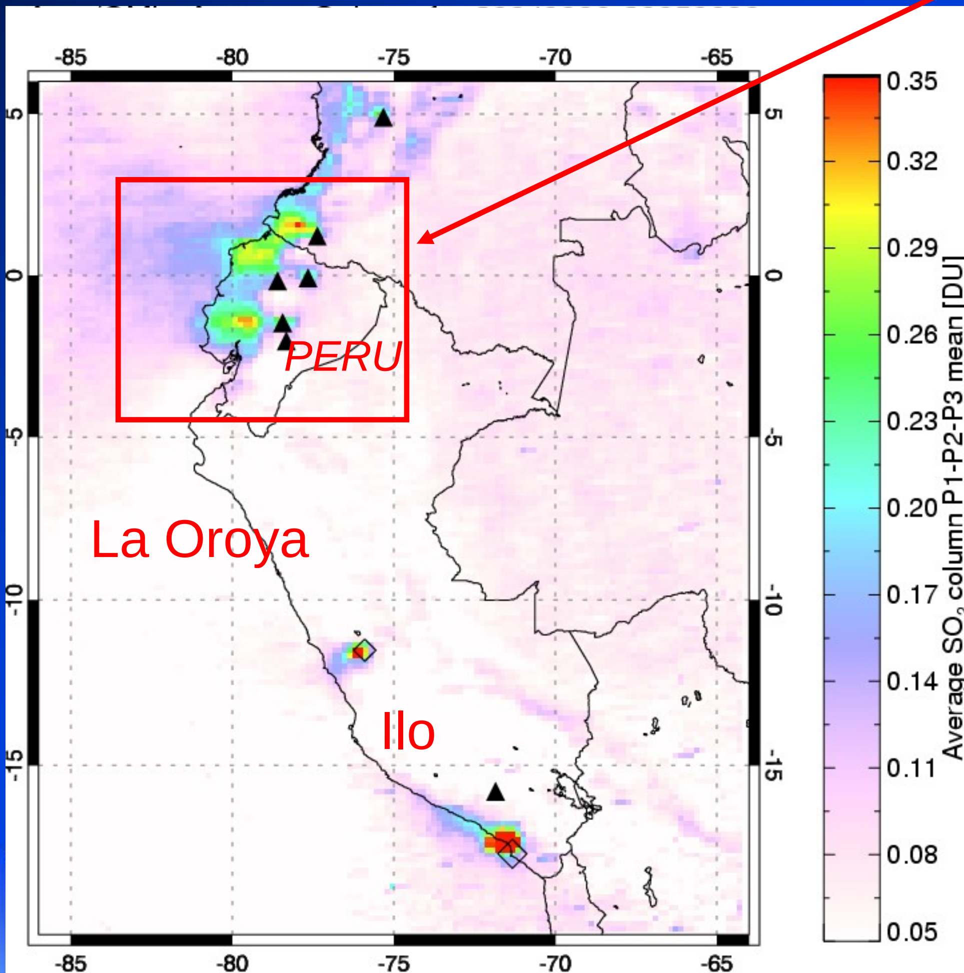
OMI & MLS produce a tropospheric ozone product by subtracting the MLS stratospheric ozone from OMI column ozone.

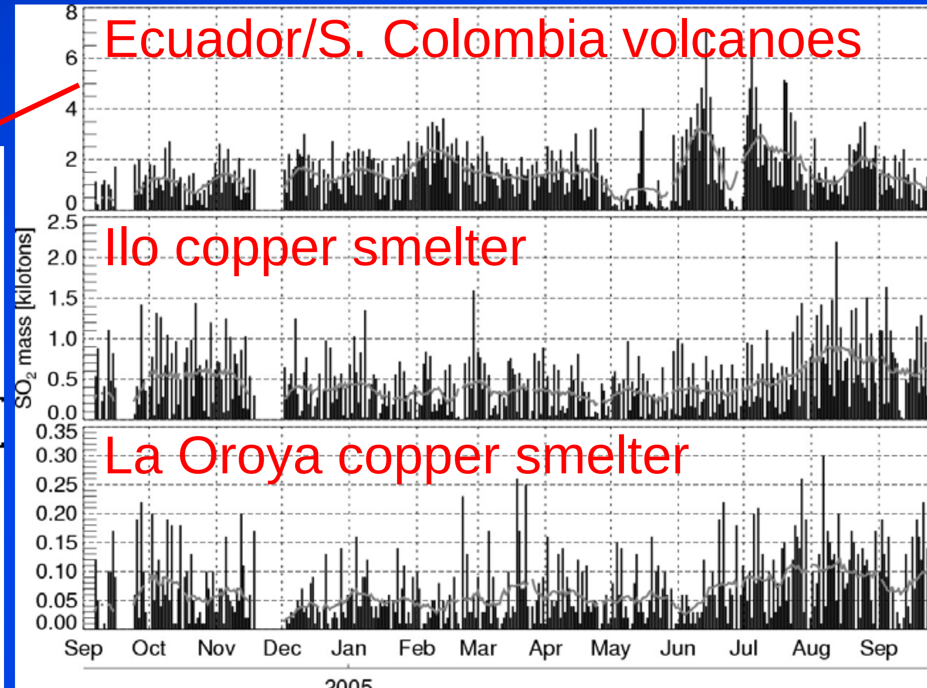
This can be compared to the more sparse but direct observations from TES



OMI: SO2 emissions from smelters and volcanoes

Average OMI SO_2 vertical column
Sep 2004 - June 2005





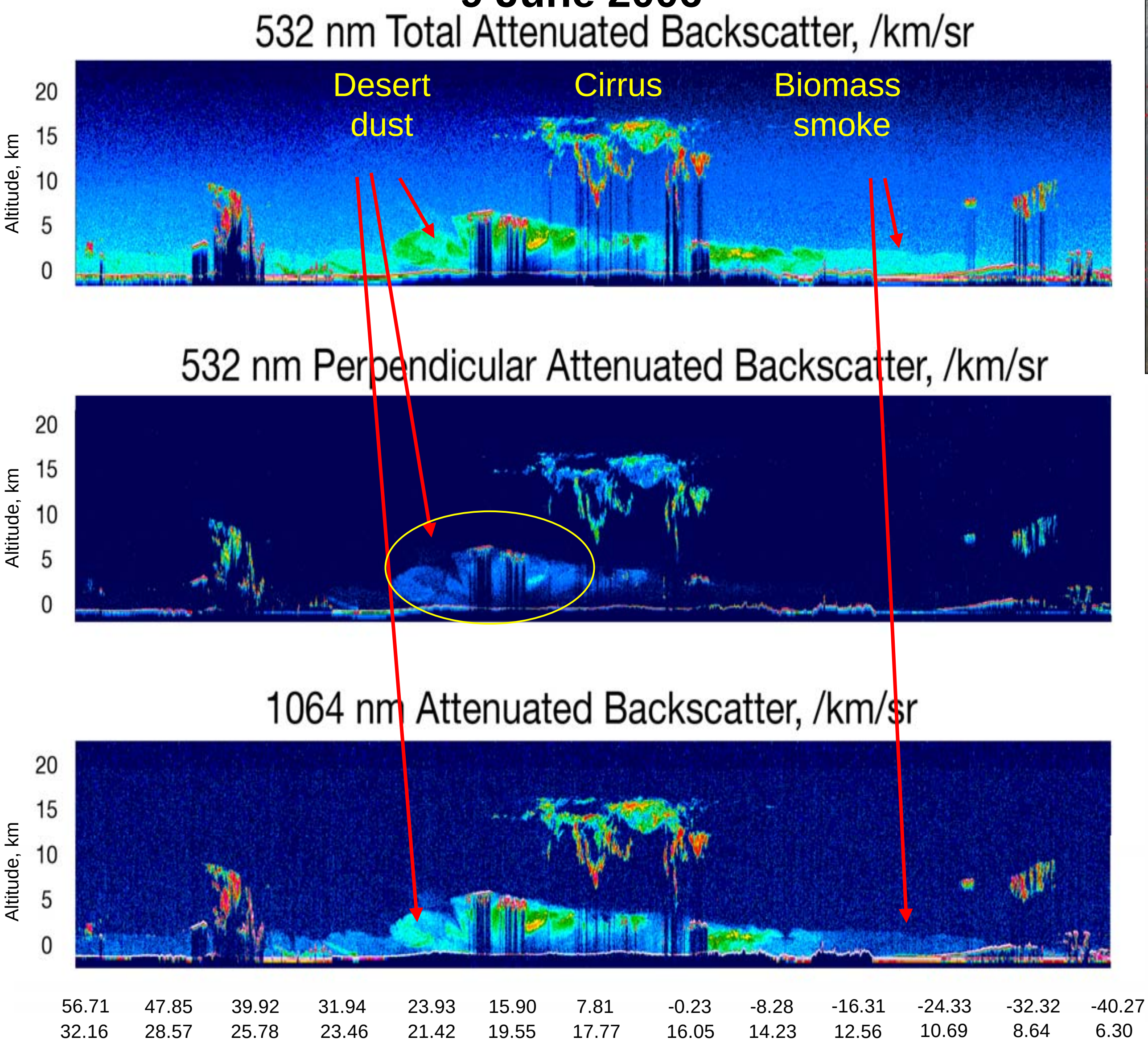
Daily SO_2 burdens for 3 source regions
Sept. 2004 - June 2005

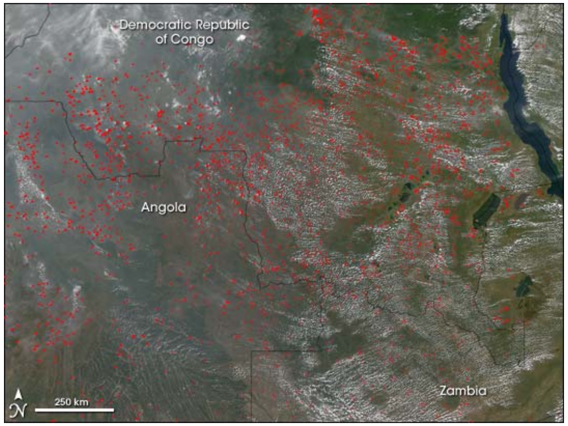
- Daily monitoring of SO_2 emissions is possible with OMI.
- The Peruvian copper smelters are among the world's largest industrial point sources of SO_2.

Carn *et al.*, in prep

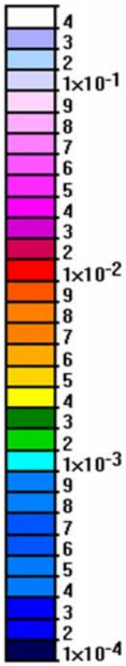
CALIPSO Observations – All 3 Lidar Channels

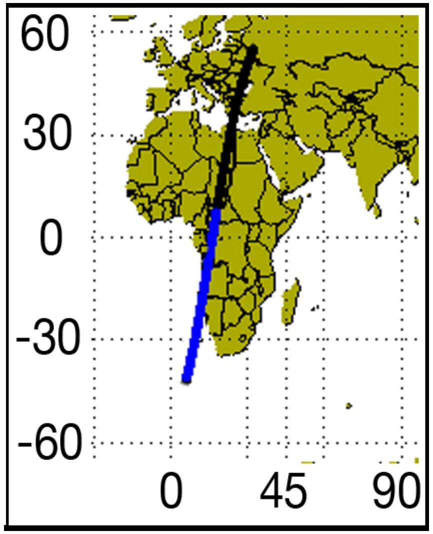
9 June 2006





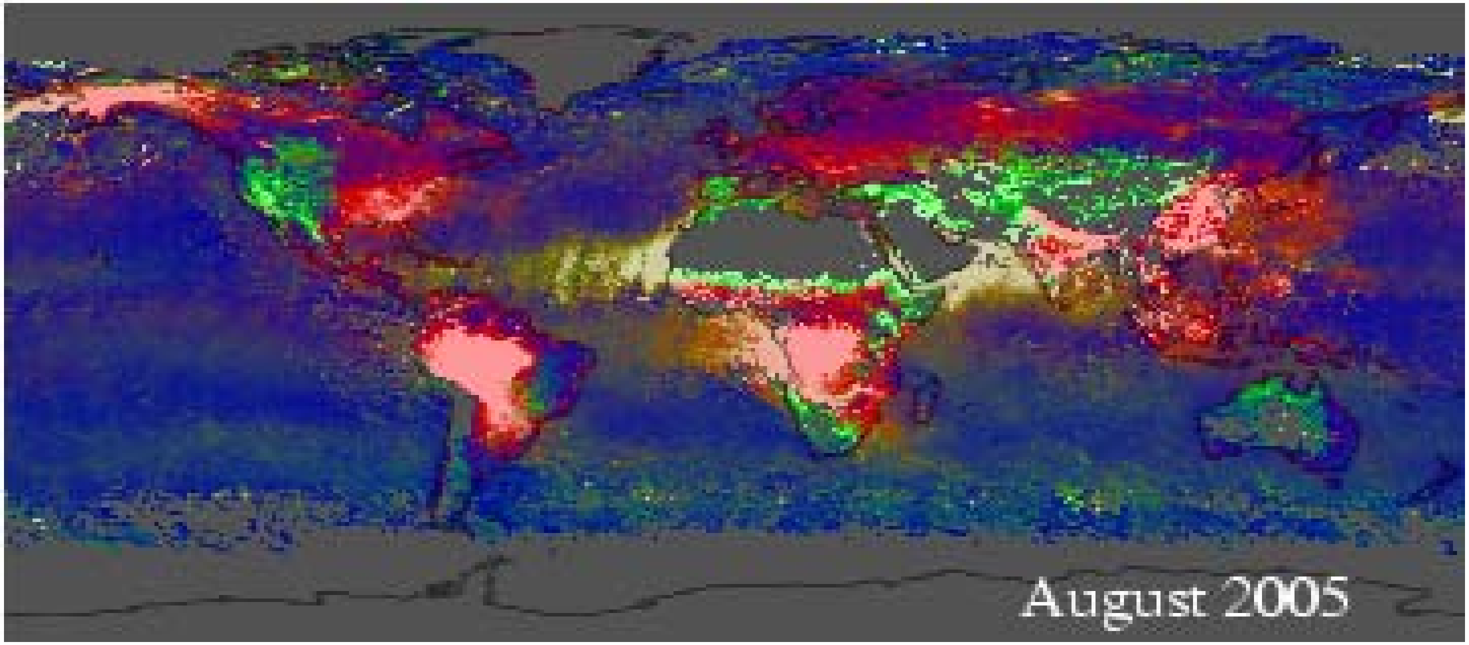
Fire locations in southern Africa from MODIS 10 June 2006



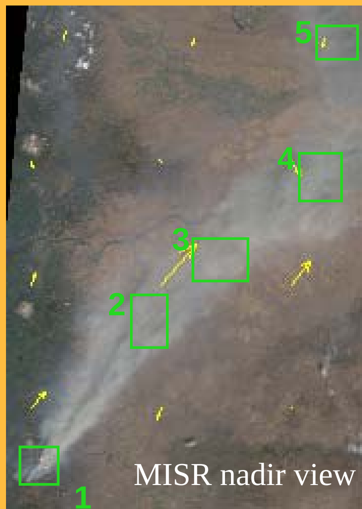


MODIS Aerosol Products View the Global Aerosol System in an Entirely New Way

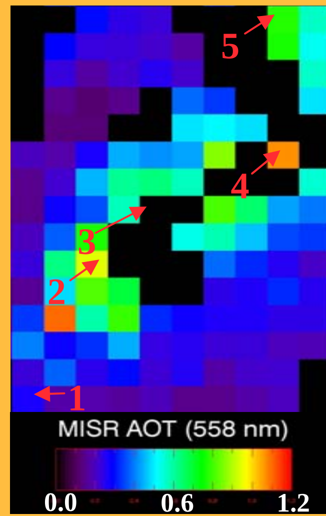
- Quantitatively calculate intercontinental transport of dust (Kaufman et al., 2005) or pollution (Yu et al. in preparation)
- Observationally-based estimate of aerosol direct radiative effect (Remer and Kaufman, 2006; Yu et al., 2006; Bellouin et al.2005; Chung et al., 2005)
- Observationally-based estimate of oceanic aerosol <u>anthropogenic</u> component or direct forcing (Kaufman et al. 2006)
- Tool for operational air quality forecasts (Al Saadi et al. 2005)



Aerosol Source Plume Physical Characteristics from Space-based Multi-angle Imaging

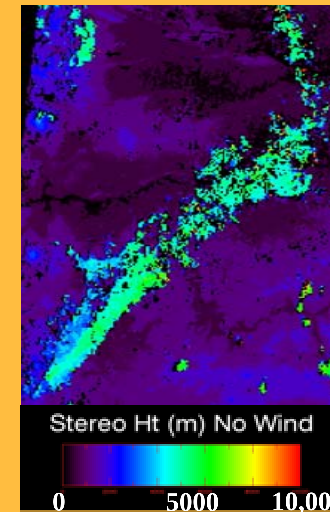


Oregon wildfire Sept 04 2003

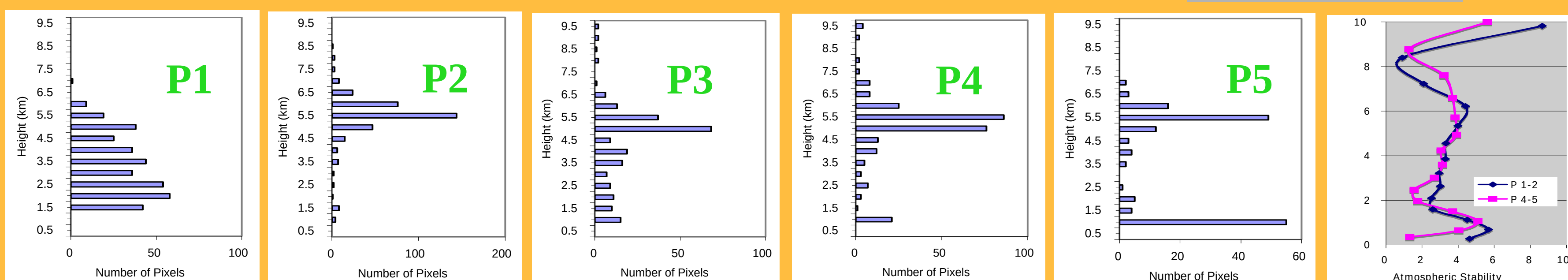


Smoke & bkgd aerosol amount

~Particle Size



Smoke Plume Height

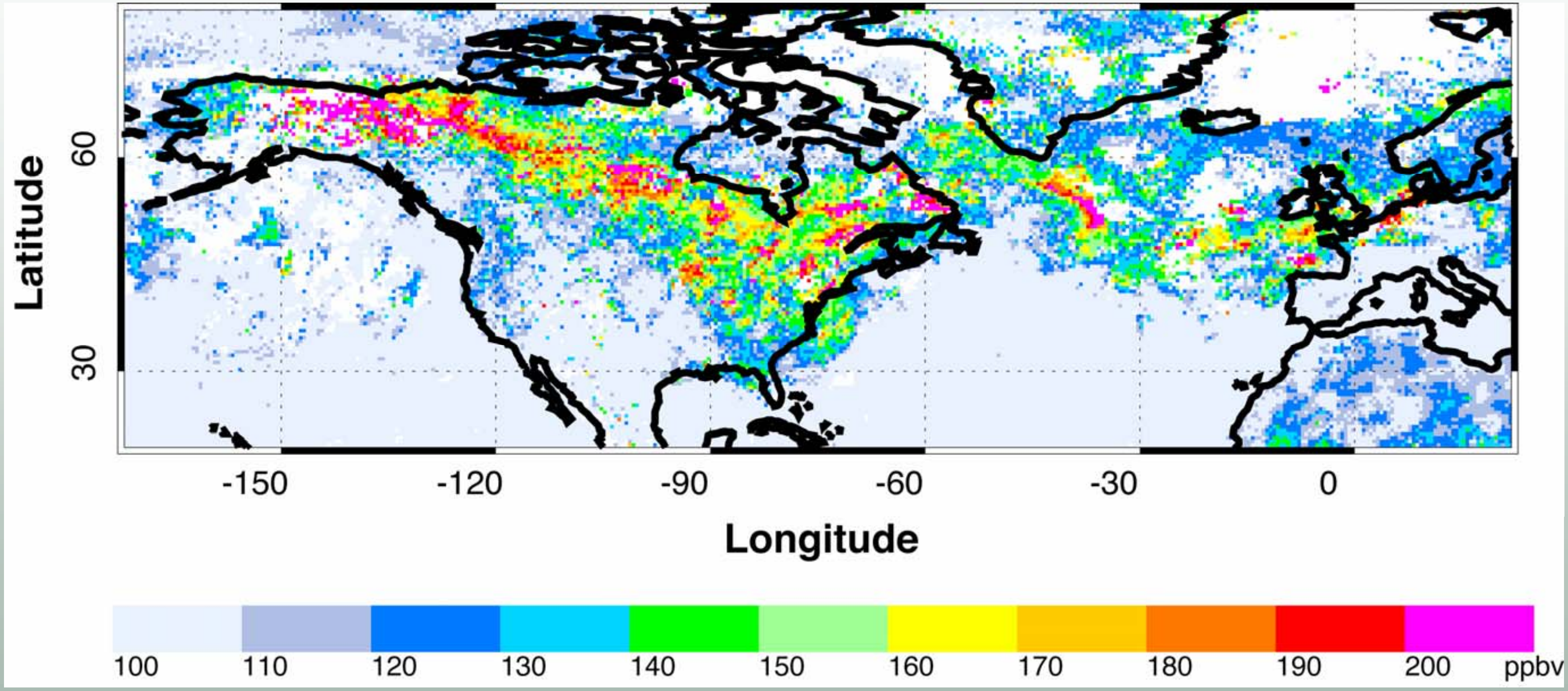


MISR Stereo-Derived Smoke Plume Height histograms for five patches, plus model-derived atmospheric stability profile

- Wildfire smoke plumes tend to concentrate in **layers of high relative atmospheric stability**.
- With sufficient buoyancy from a **fire or volcano**, can they reach **upper levels** in the atmosphere.
- The measurements can be used **directly in models that predict aerosol transport**, or as a guide for **model aerosol vertical distribution** where measurements are absent.

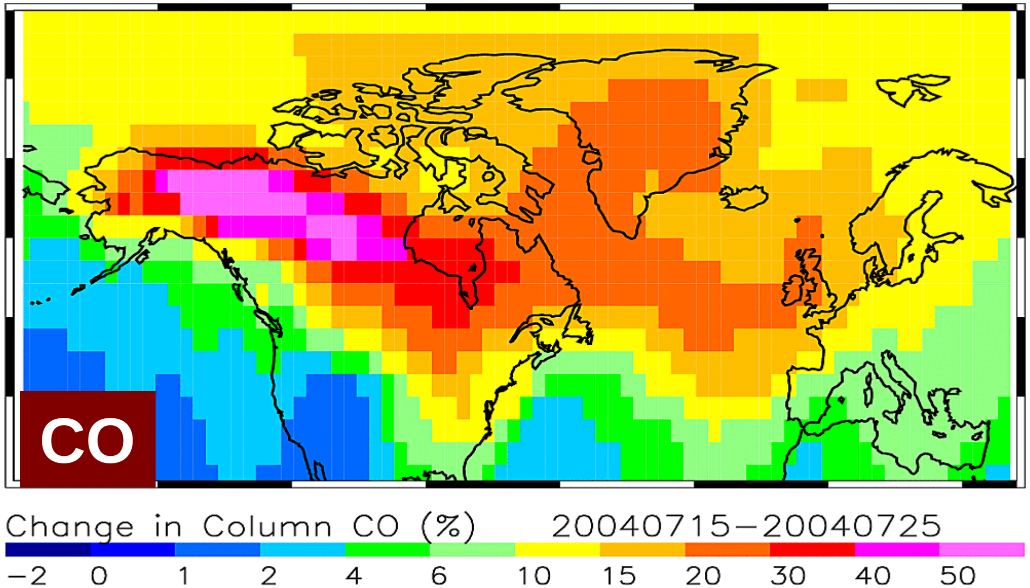
R. Kahn, W-H Li, C. Moroney, D. Diner, J. Martonchik, and E. Fishbein, **JGR 2007**, in press

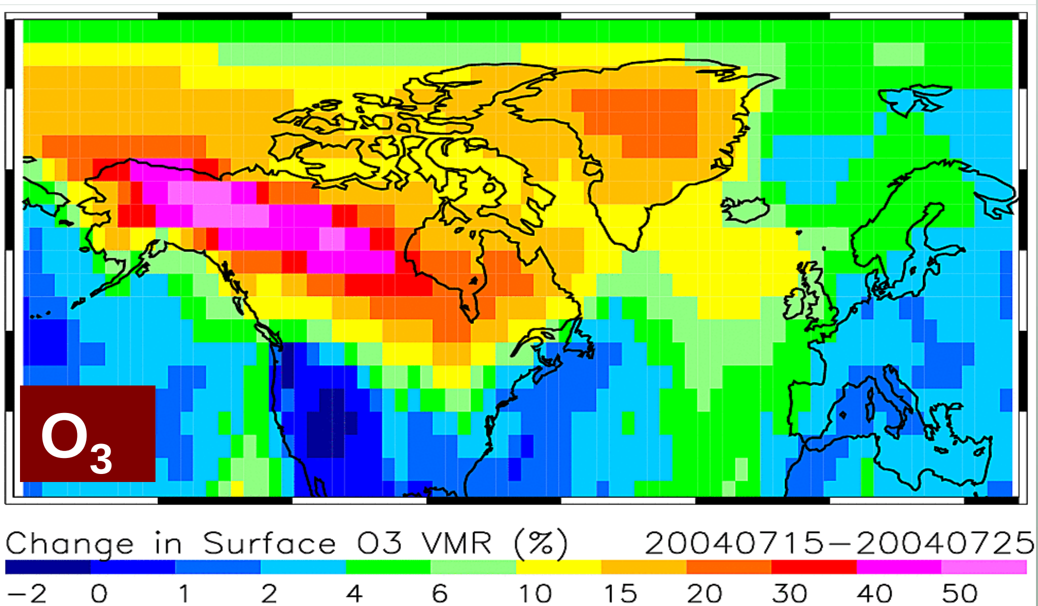
The 2004 Alaska Fires



MOPITT 700 hPa CO mixing ratio for the period 15-23 July, 2004, during the INTEX-A field campaign. The intense wildfires in Alaska produced plumes of carbon monoxide pollution that can be traced across North America and the Atlantic Ocean.

MOPITT improves estimates for boreal fire emissions and their impact on CO and O_3





- Inverse modeling of MOPITT observations using the MOZART CTM showed that the fires emitted about as much CO as did human-related activities in the continental USA during the same time period, about 30 Tg CO June-August
- Because of the wildfires, ground-level concentrations of O_3 increased by 25% or more in parts of the northern continental USA and by 10% as far away as Europe

Enhancements to CO column and surface O_3 due to fires, July 15-25, 2004.

Pfister et al., GRL, 2005

INTEX-B & MILAGRO: NASA Airborne Observations and Satellite Validation in 2006

INTEX- B Web Site   http://cloud1.arc.nasa.gov/intex-b/
MILAGRO Web Site   http://www.joss.ucar.edu/milagro/

Goal: To understand the transport, transformation, & impacts of gases & aerosols on air quality & climate from local to global scales

- **MILAGRO: March 2006**
  - **Mexico City during dry season**
  - **Megacity plume evolution**
- **INTEX-B: April-May 2006**
  - **maximum Asian inflow to North America**
  - **seasonal contrast**

MILAGRO

MCMA-2006

MAX-Mex

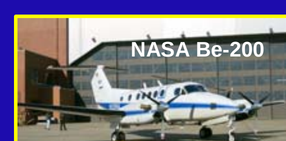
MIRAGE-Mex

INTEX-B/1

INTEX-B

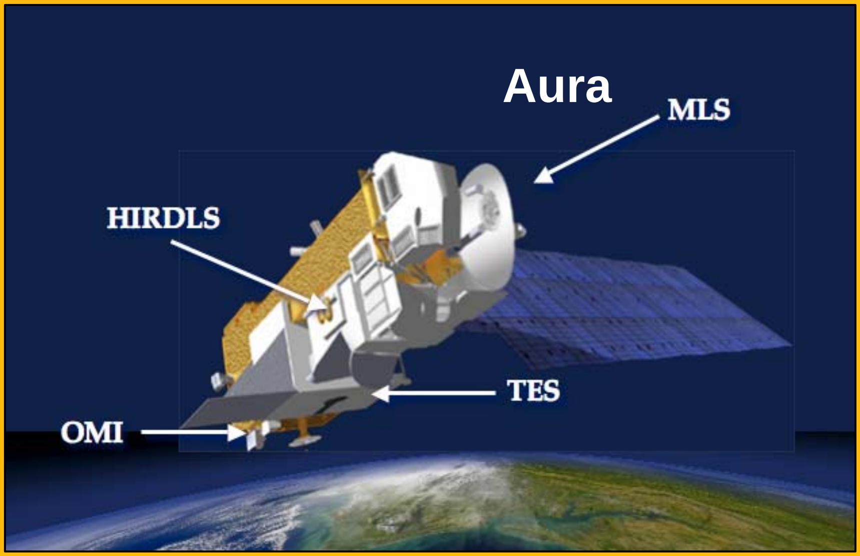
INTEX-B/2 (IMPEX)
ITOP

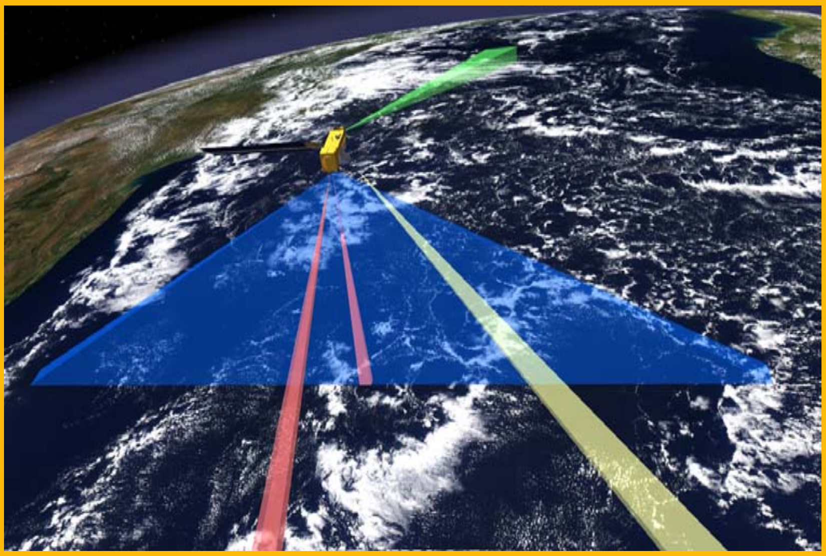
Partners: NASA, NSF, DOE, US NGOs, MEX, CAN, GER; MEX NGOs



INTEX-B Targeted Aura Satellite Validation Activities

(CO, O_3, HCHO, NO_2, HNO_3, H_2O, HCN, Aerosol)





	DC-8															C-130					
	3/4	3/9	3/12	3/16	3/19	3/21	4/17	4/23	4/25	4/26	4/30	5/4	5/7	5/9	5/12	4/24	4/28	5/1	5/3	5/8	5/11
TES*	●	●	●	●	●		●	●	●	●	●		●	●	●						
OMI	●	●	●	●	●		●	●				●				●	●		●	●	●
HIRDLS#						●					●										
MLS									●				●								
Others**	●	●		●	●	●	●	●		●	●	●	●		●			●		●	●

* TES validation performed for both Nadir and Limb measurements

Night flights required for HIRDLS validation

** Mainly AIRS, SCIAMACHY and TERRA

Strategic Ozonesonde Networks in Integrated Observations

<http://croc.gsfc.nasa.gov/intexb/ions06.html>

Design raises traditional instrument to "state-of-art" tool for integrating models, in-situ, satellite data

March 2006 – Milagro

Is there a Mexico-to-Houston Ozone connection?

April-May 2006 – INTEX-B

Is there an Asia-to-North America Ozone connection?

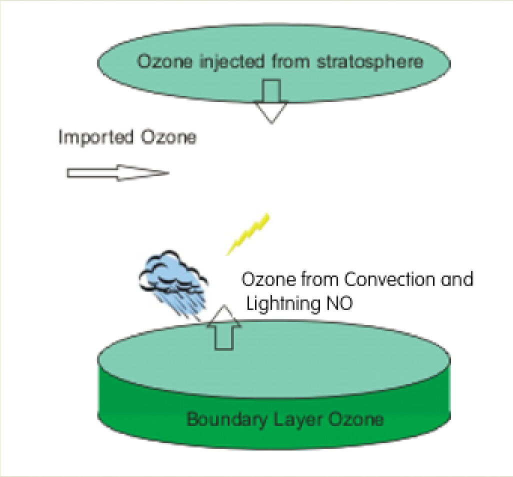
August 2006 – TEXAQS-GOMACCS

What is upwind-downwind of Houston Ozone?

IONS-06 Sites

1 - Kelowna, BC
2 - Stonyplain, AB
3 - Bratt's Lake, Sask.
4 - Egbert, ON
5 - Walsingham, ON
6 - Paradox, NY
7 - Narragansett, RI
8 - Yarmouth, NS
9 - Sable Is. NS
10 - Valparaiso, IN
11 - Beltsville, MD
12 - Wallops Is., VA
13 - Trinidad Head, CA
14 - Table Mountain, CA
15 - Imperial Valley, CA
16 - Boulder, CO
17 - Los Alamos, NM
18 - Huntsville, AL
19 - Houston, TX
20 - R/V Ron Brown
21 - Barbados
22 - Tecamec, Mexico

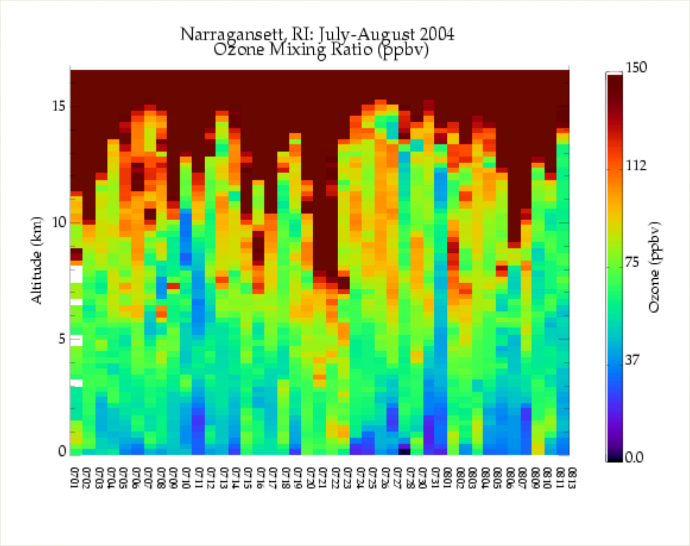
Tropospheric Ozone Budgets Computed For Each IONS Sounding

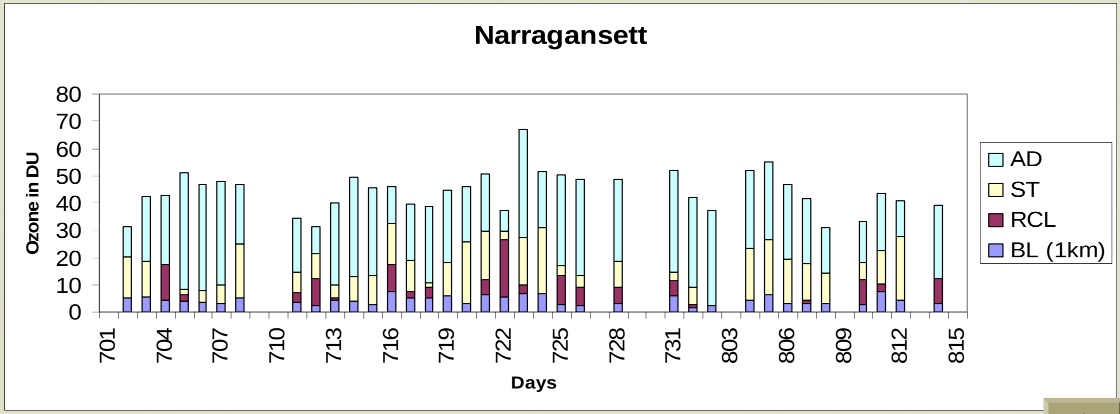


IONS-04 Budgets:

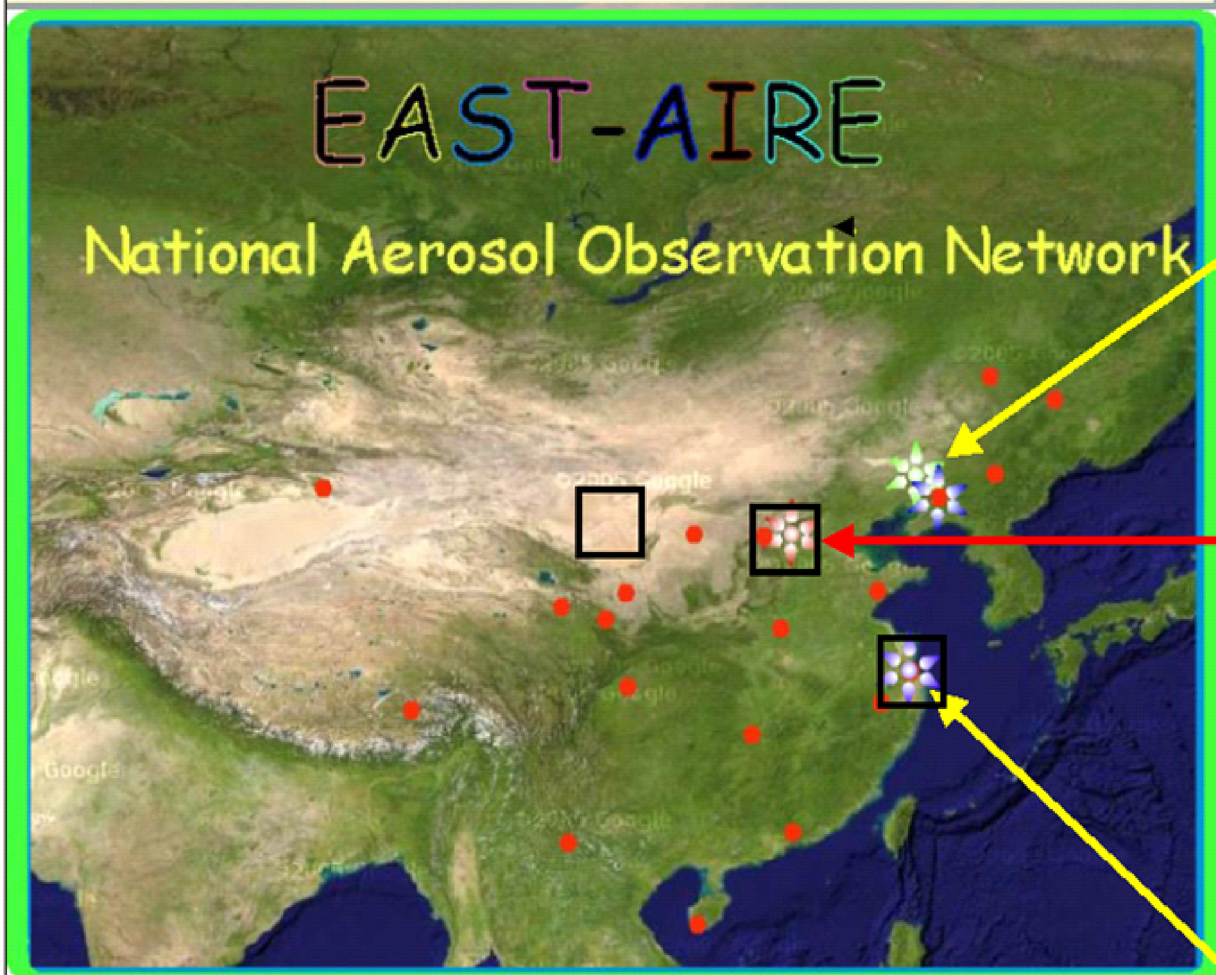
- 25% from Stratosphere
- 15% RCL – regional convection & lightning
- 10% - Boundary layer – local pollution
- 50% - Advected fresh and aged pollution

Thompson et al., *JGR*, 2007a,b





EAST-AIRE Observation

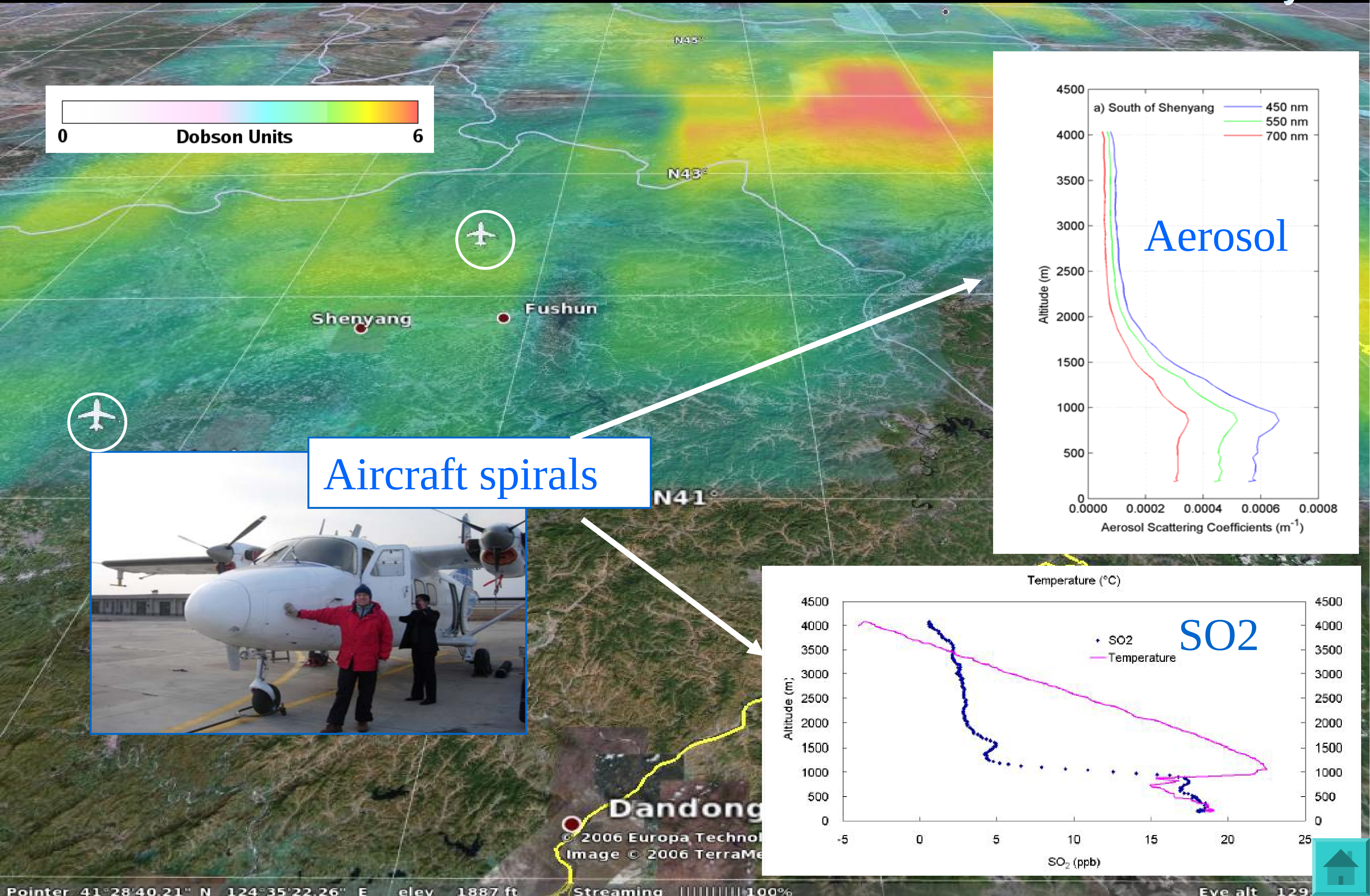


Planned AMF and AAF deployment sites

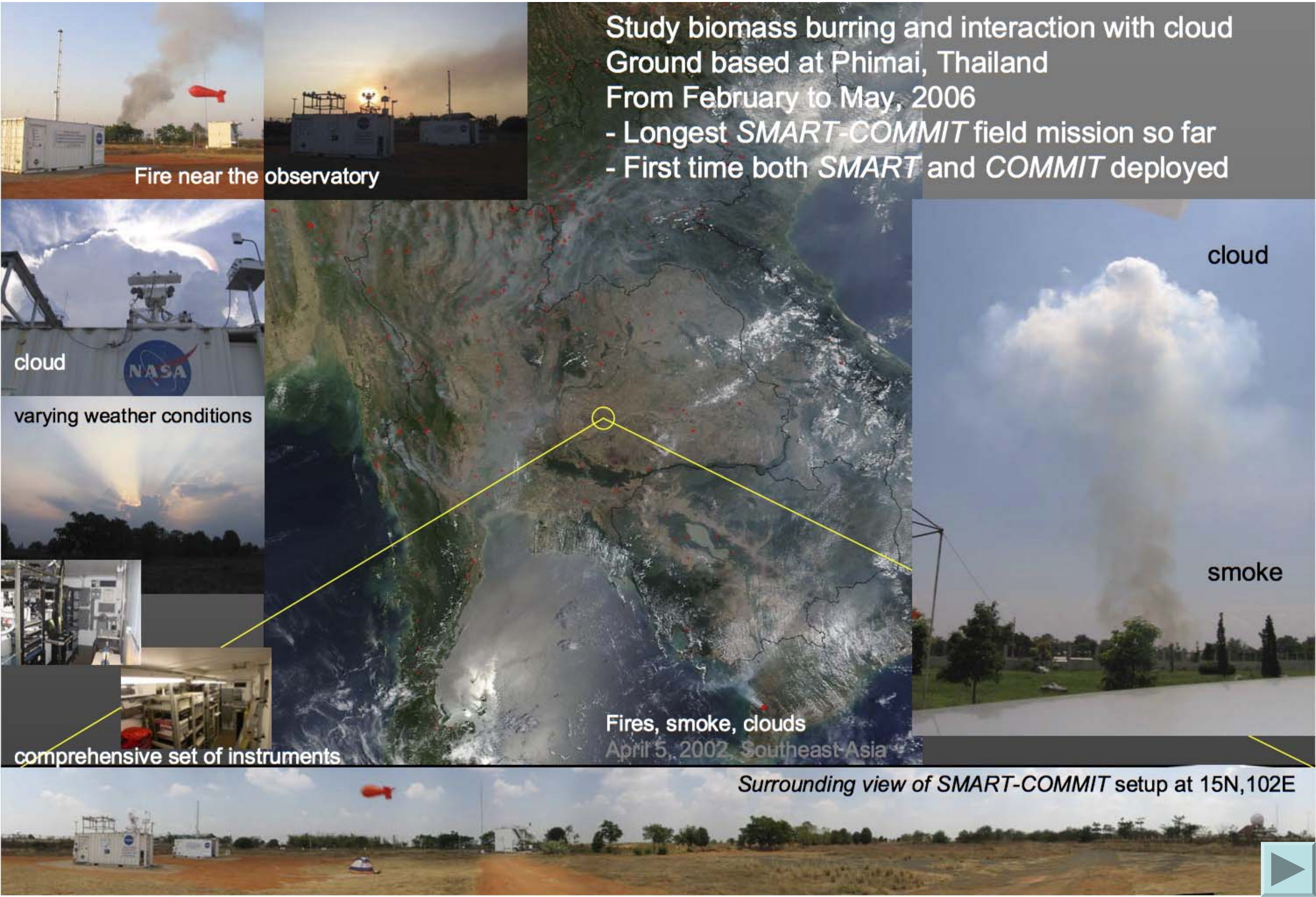
Existing extensive observation stations

Nation-wide aerosol observation network

EAST-AIRE experiment over NE China in April 2005 provide the first in-situ SO_2 measurements to validate and improve AURA OMI by Flying American Instruments on a Chinese Aircraft for the first time in history



Summary: *Biomass-burning Aerosols in South East-Asia: Smoke Impact Assessment* (BASE-ASIA)

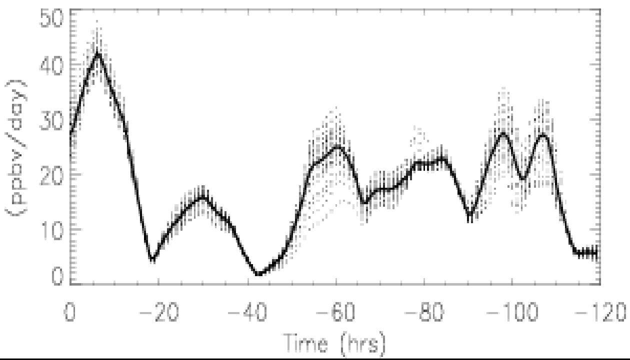


TEXAQS 2006 Ensemble Lagrangian Trajectory Analysis

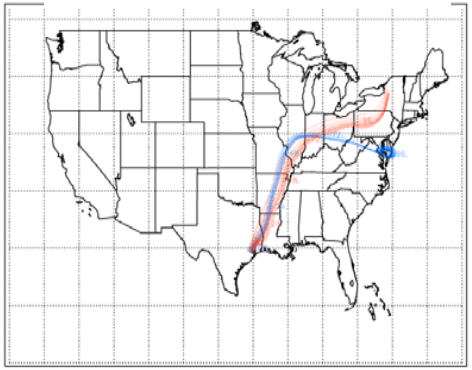
Enhanced regional ozone production was present 16% of days during the study in Houston and preceded 3 of the 6 periods of locally high O3

Back trajectory Chemistry 2006090418

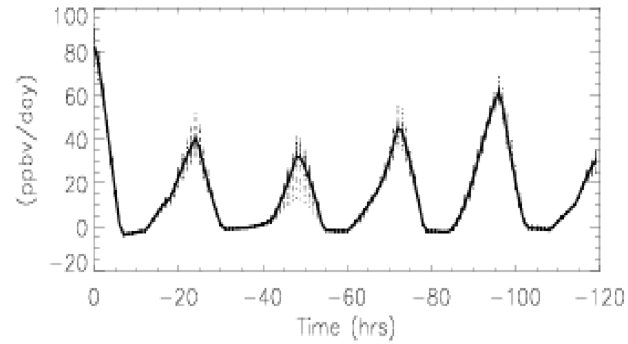
NOy Emissions



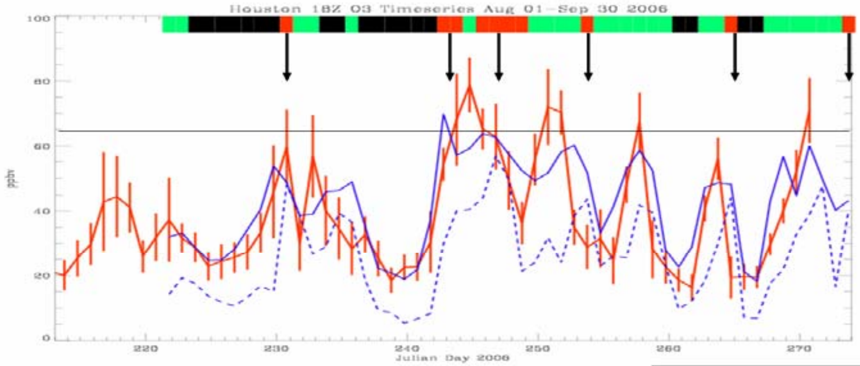
SFC (red) and 850 (blue)



O3 P-L



RAQMS$_{global}$ Back-trajectory analysis of regional influences on Houston 18Z Ozone Aug-Sept, 2006



Red=Observed AIRNOW mean and MSA variability
Solid=Predicted AIRNOW mean (bias corrected)
Dashed=Predicted Background mean (bias corrected)
(immediately prior to entering Houston MSA)

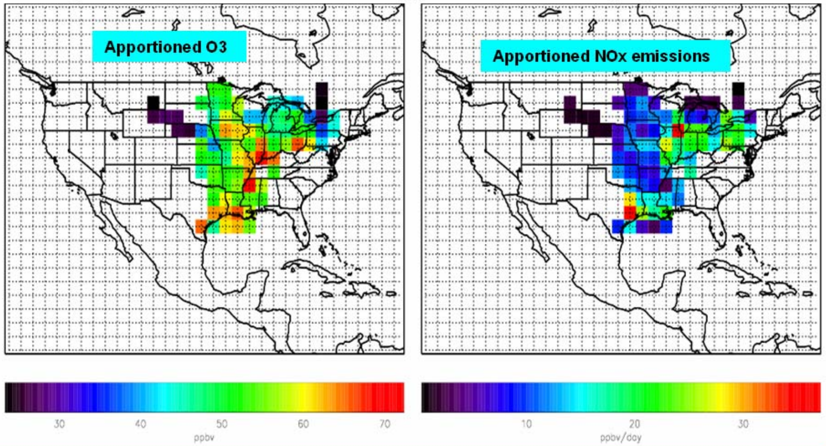
Trajectory Classification

- Black = Net O3 Loss
- Green = 5<P-L<10 ppbv/day
- Red = P-L>10 ppbv/day

- Enhanced regional ozone production was present 16% of days during the study in Houston.
- Enhanced regional ozone production events preceded 3 out of 6 Houston periods with elevated O3.

Source Apportionment for O3 (P-L)>10 ppbv/day

Binning the NOy sources and ozone mixing ratios along the trajectories results in source apportionment maps for each class

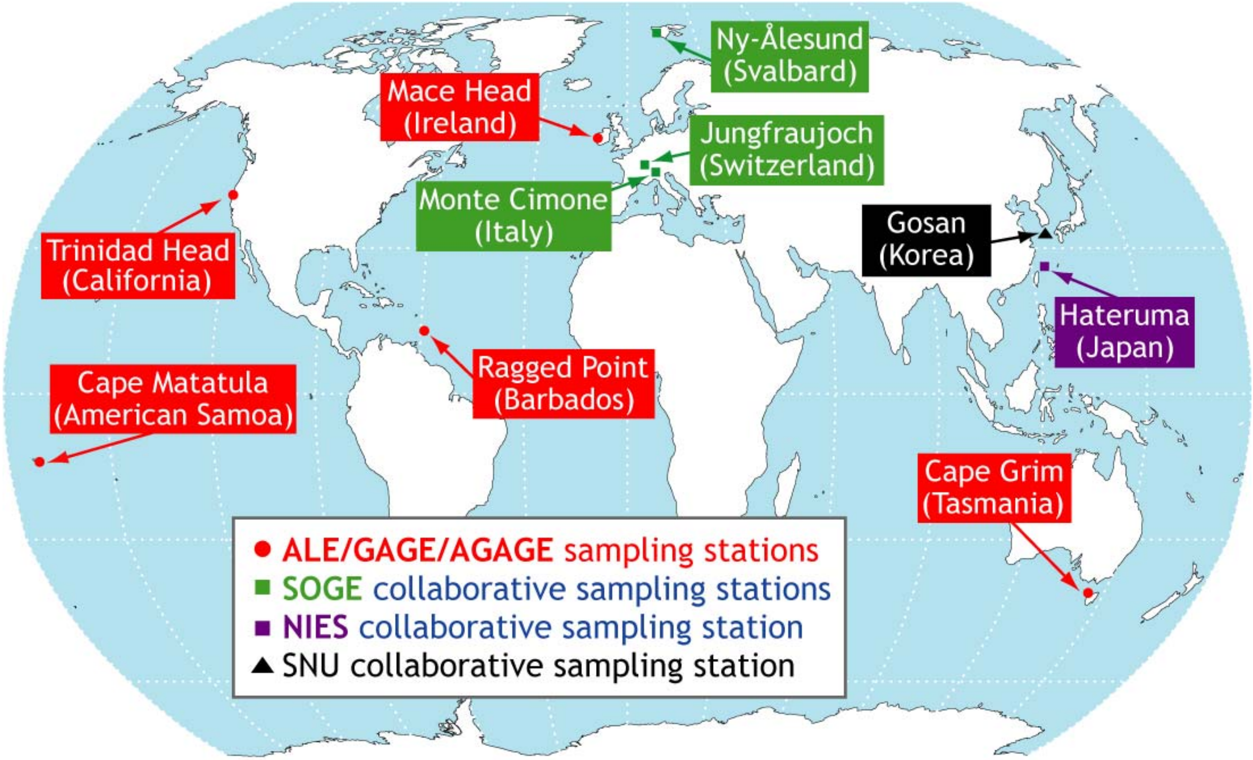


Enhanced background ozone production is associated with NOy emissions from the Western Gulf and Central Midwest with Chicago and Houston contributing more then 30ppbv/day on average over the study period.

Advanced Global Atmospheric Gases Experiment

The Advanced Global Atmospheric Gases Experiment (AGAGE), and its predecessors (the Atmospheric Lifetime Experiment, ALE, and the Global Atmospheric Gases Experiment, GAGE) have been measuring the composition of the global atmosphere continuously since 1978.

AGAGE is distinguished by its capability to measure over the globe at high frequency almost all of the important species in the Montreal Protocol to protect the ozone layer and almost all of the significant non-CO_2 gases in the Kyoto Protocol to mitigate climate change.



The ALE/GAGE/AGAGE stations occupy coastal & mountain sites around the world chosen to provide accurate measurements of trace gases whose lifetimes are long compared to global atmospheric circulation times.

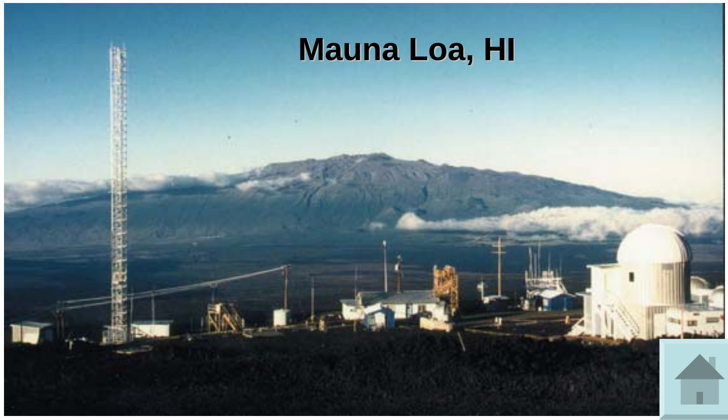
SOGE: System for Observation of Halogenated Greenhouse Gases in Europe. NIES: National Institute for Environmental Studies, Japan. SNU: Seoul National University, Korea.

AGAGE WEB SITE at http://agage.eas.gatech.edu

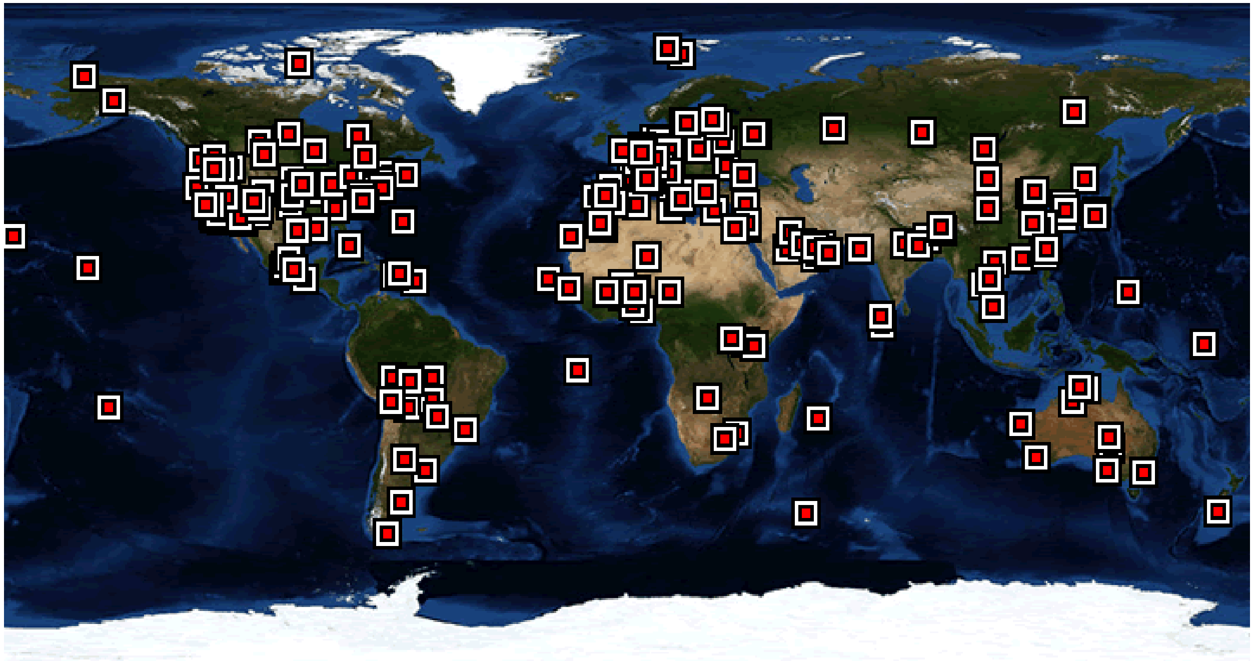
Network for the Detection of Atmospheric Composition Change:
Exploring the Interface Between Changing Atmospheric Composition and Climate

Priorities:

- studying the temporal and spatial variability of atmospheric composition and structure
- detecting trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere,
- establishing links between climate change and atmospheric composition,
- calibrating and validating space-based measurements of the atmosphere,
- supporting process-focused scientific field campaigns, and
- testing and improving theoretical models of the atmosphere.

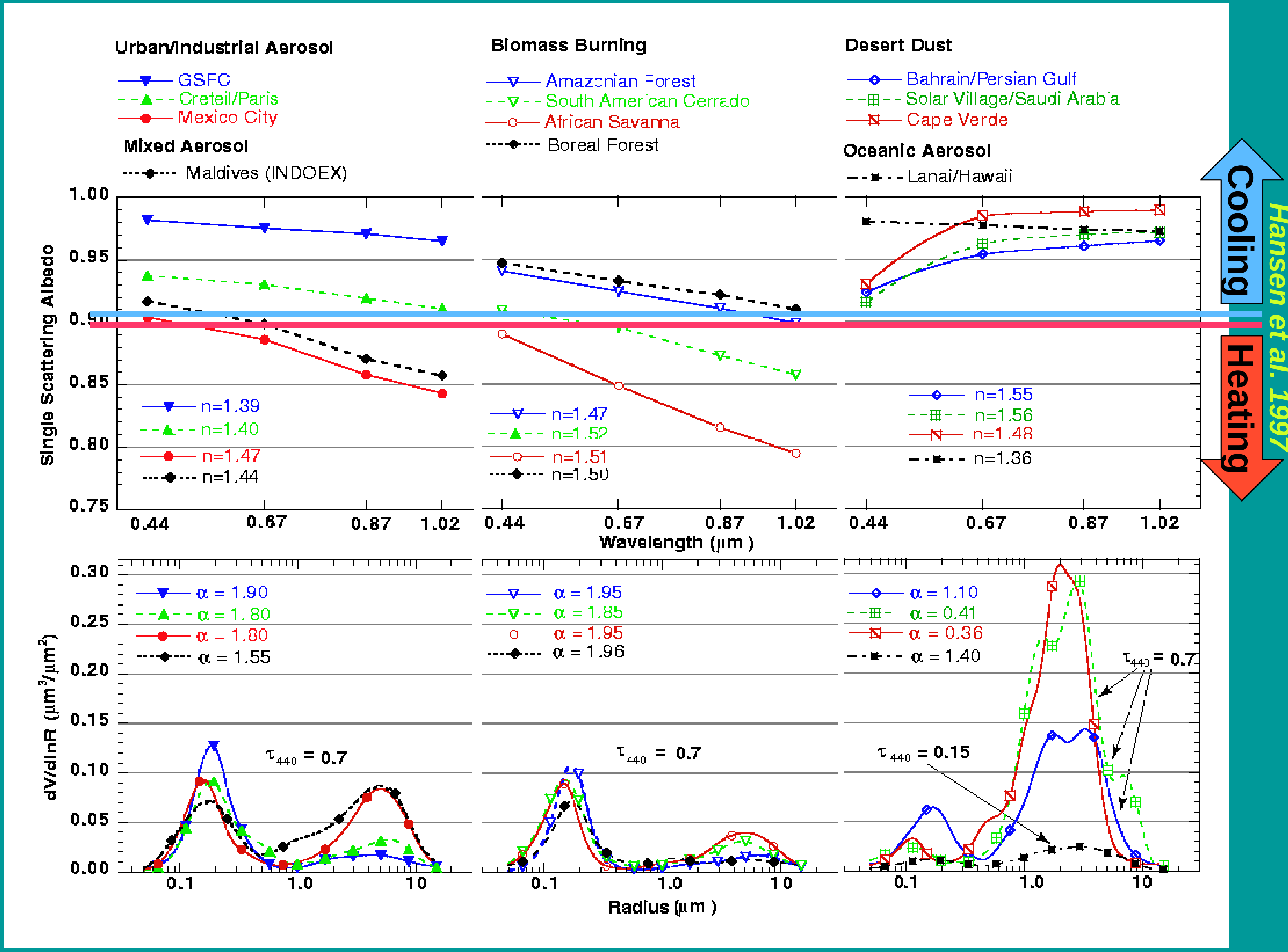


AERONET-An Internationally Federated Network



- **Aerosol Optical Properties Research & Enabling Project**
  - **Program of long term systematic network measurements**
  - **Homepage access http://aeronet.gsfc.nasa.gov/**
- **Mission Objectives**
  - **Validation of satellite aerosol retrievals**
  - **Characterization of aerosol optical properties**
  - **Synergism with satellite observations and climate models**

The Dynamic Atmosphere: AERONET-Defining Aerosol Optical Properties



Micro-Pulse Lidar Network (MPLNET)

Objective: Long-term, local - regional - worldwide aerosol and cloud profile observations using common instrument & data processing in a federated network

Status:

12 active sites
6 planned sites (in preparation)
6 proposed sites (funding dependent)
12 short-term field campaigns
1 ocean cruise (two cruises pre-dating MPLNET are available)

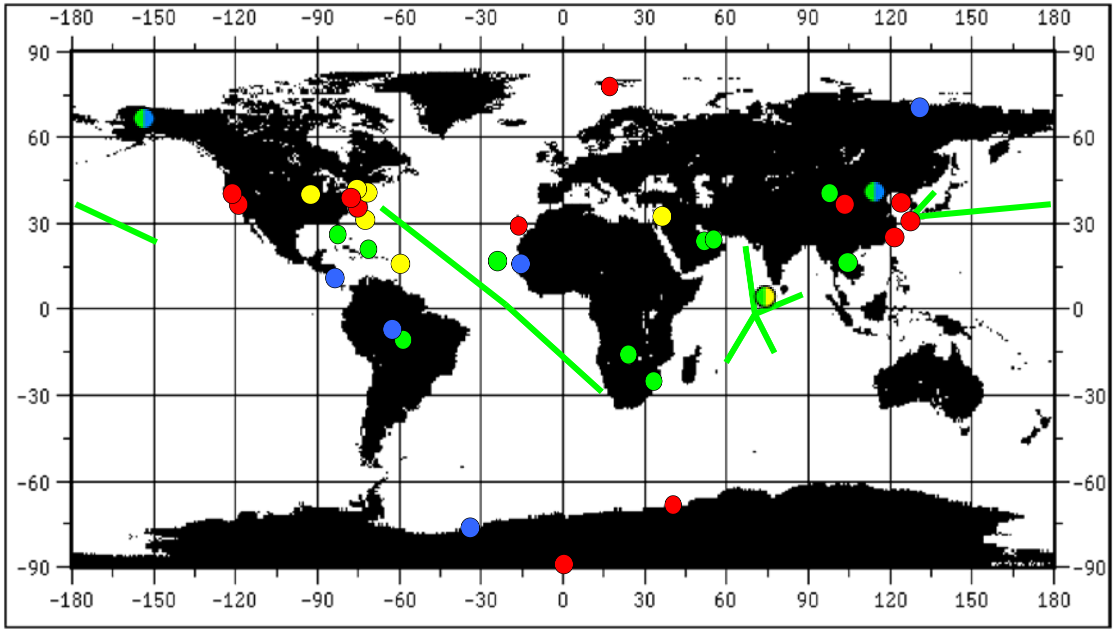
Accomplishments:

- MPLNET has generated and contributed to over 30 peer reviewed publications since 2000.
- Validation & algorithm development for ICESat & TOMS. CALIPSO pending.
- Cooperation with AERONET, modeling, and satellite groups led to formulation of new Synergy Tool (online aerosol database)

Goddard team + 13 Partners compose MPLNET:

NASA LaRC
NOAA ESRL
Naval Research Lab - Monterey
Japan's National Institute of Polar Research
Spain's Instituto Nacional de Técnica Aeroespacial - INTA
4 US Universities
2 Korean Universities
1 Taiwan University
1 Chinese University

other partners pending



active sites
field campaigns
planned sites
proposed sites

former campaign, permanent site planned
former campaign, permanent site proposed

* Most sites are co-located with AERONET

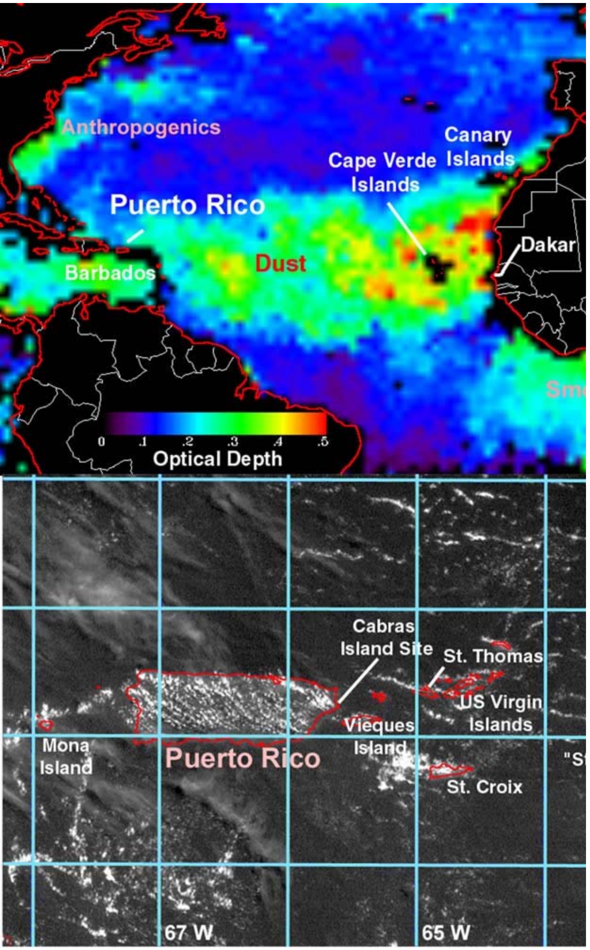
* Campaigns utilize SMART-COMMIT and/or MAARCO platforms

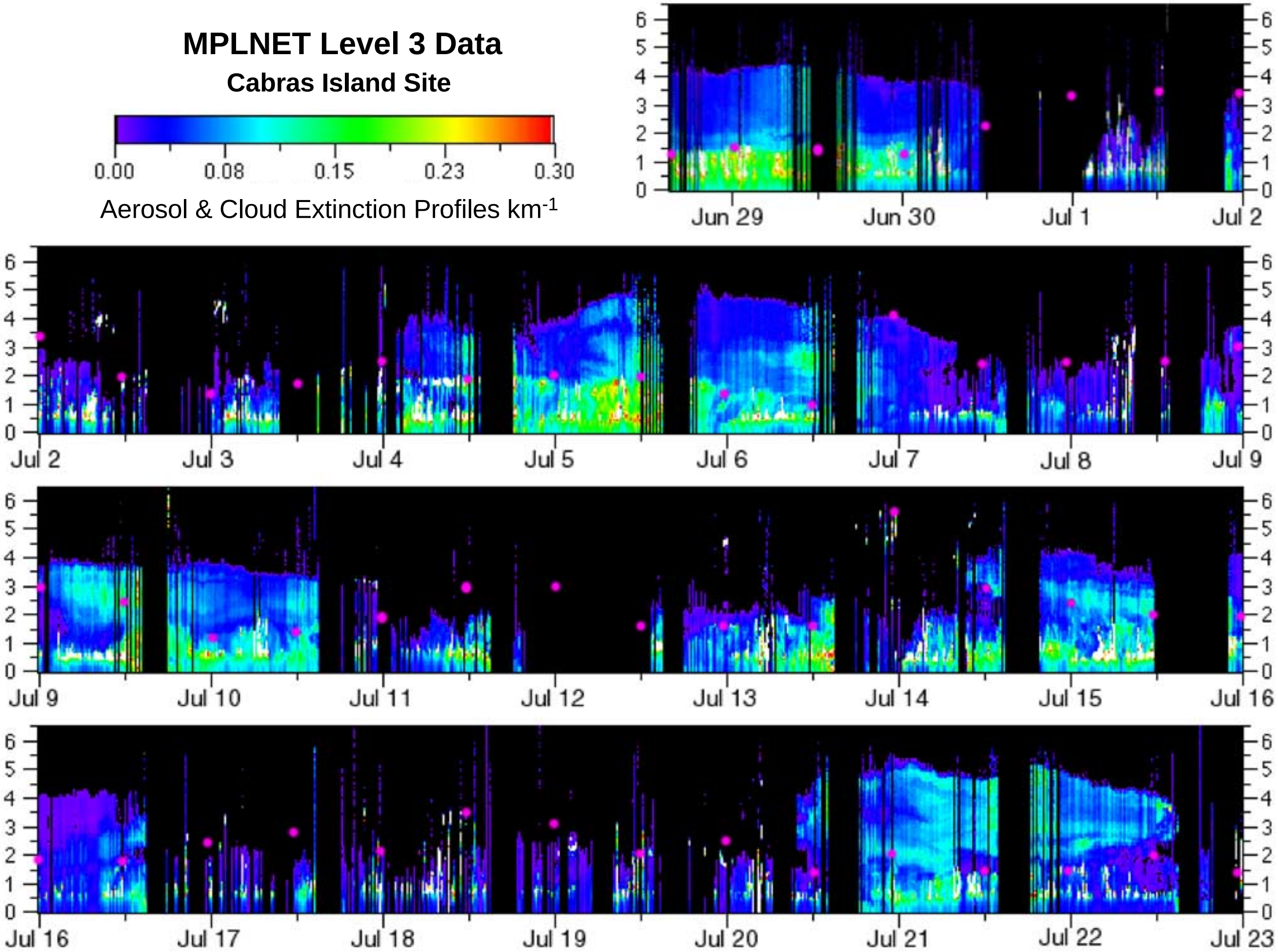
* line denotes research cruise

http://mplnet.gsfc.nasa.gov

Observations of Saharan Dust Transport

Reid et al., *JGR*, 2003: Puerto Rico Dust Experiment (PRIDE) in 2000

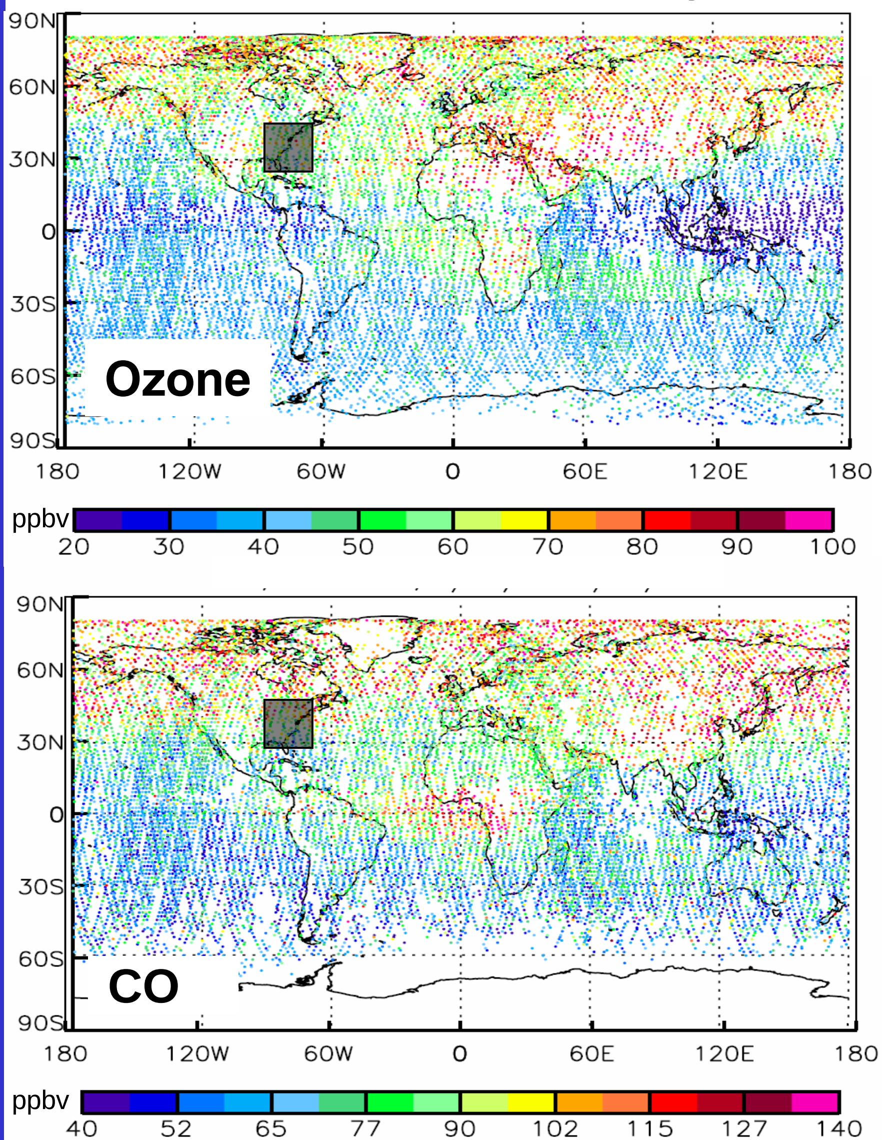




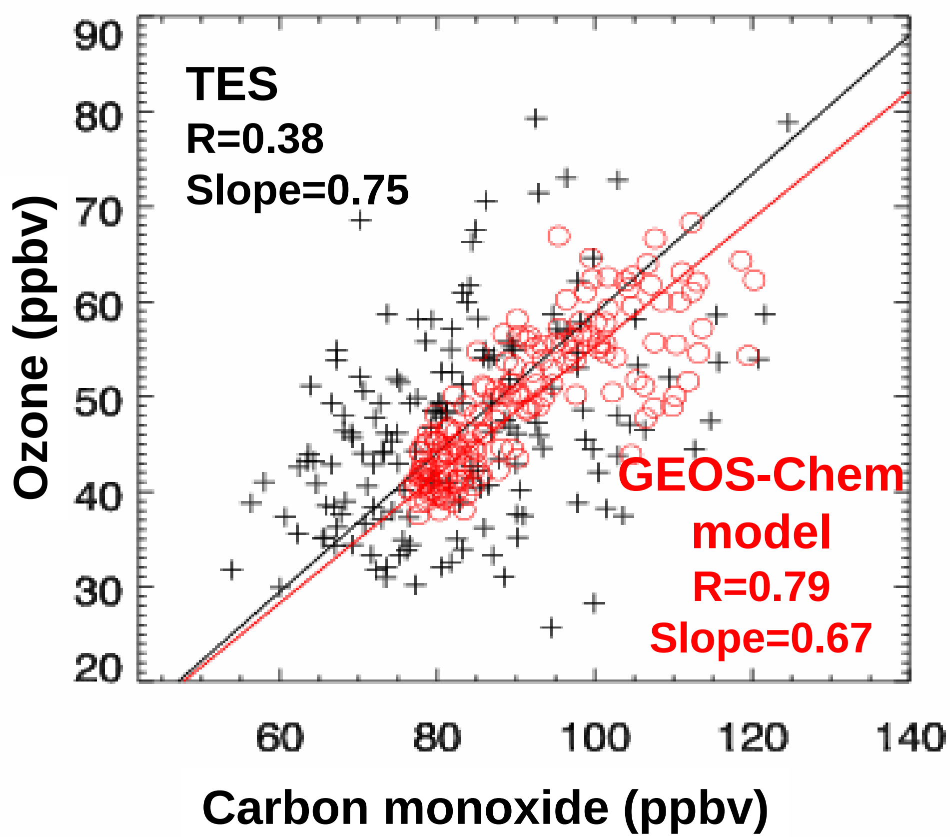
Pink dots indicate Marine Boundary Layer heights from nearby radiosonde

Using O3-CO Correlations from TES to Test Model Representation of Ozone Sources

602 hPa TES observations, July 2005



Ozone-CO relationship downwind of eastern N. America



Zhang, Jacob, et al., GRL 2006

Using O3-CO Correlations from TES to Test Model Representation of Ozone Sources

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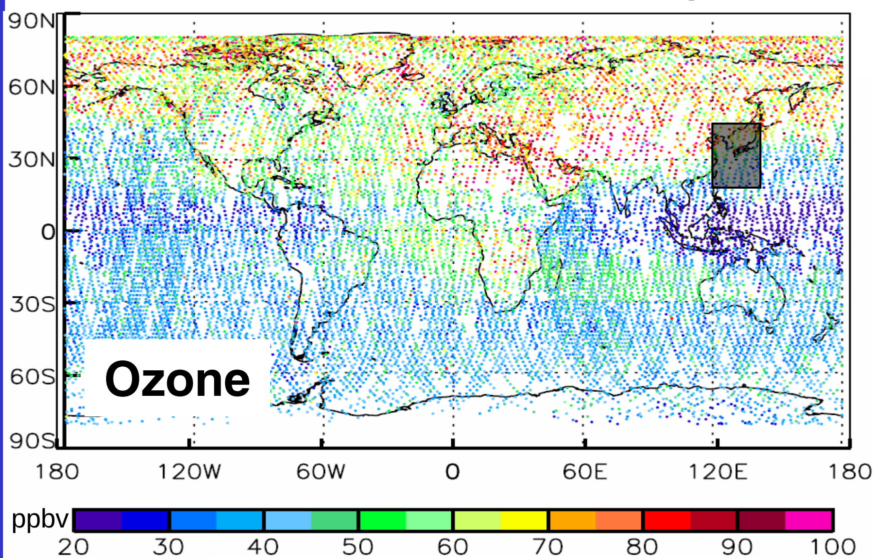
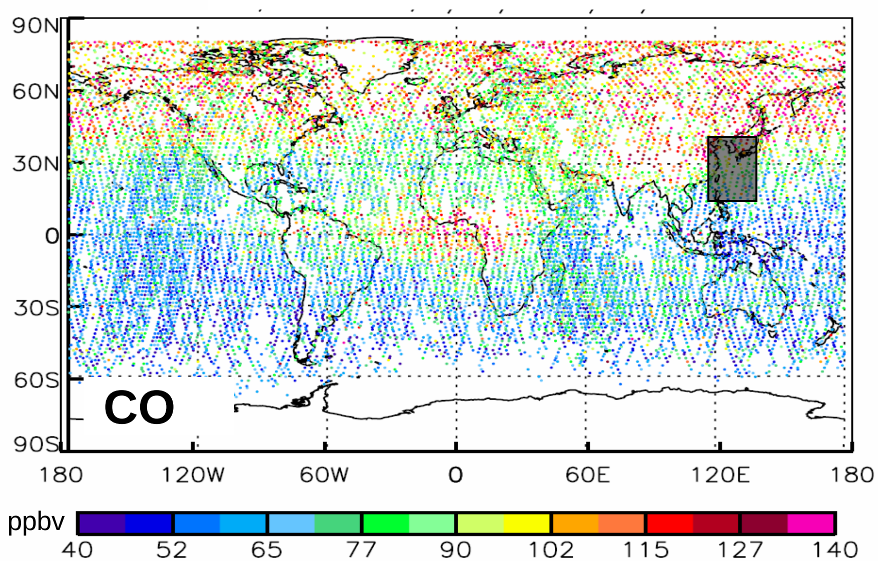
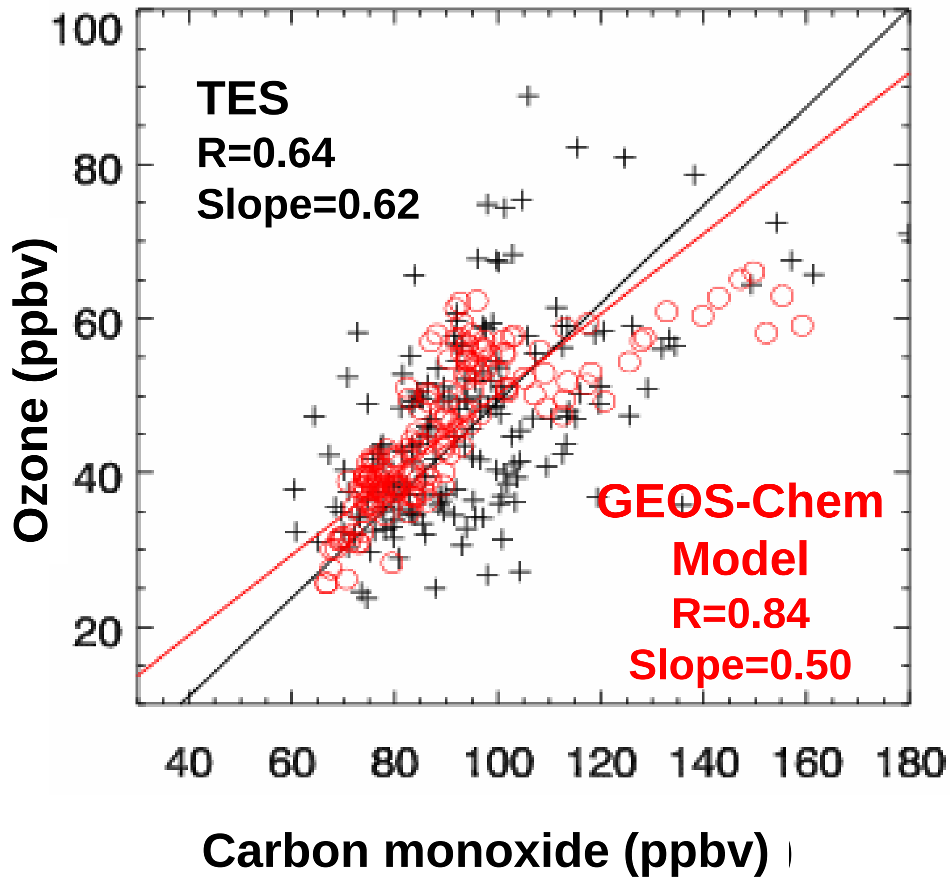




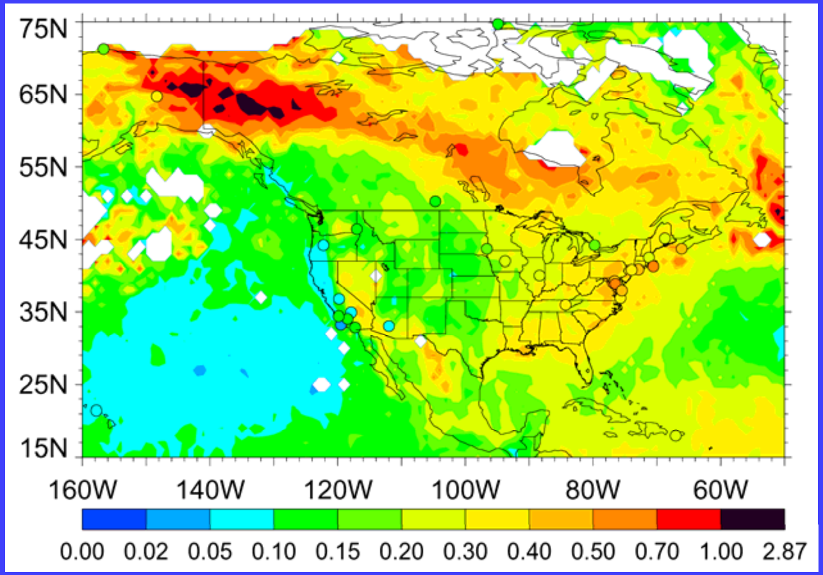
Ozone-CO relationship downwind of Asia



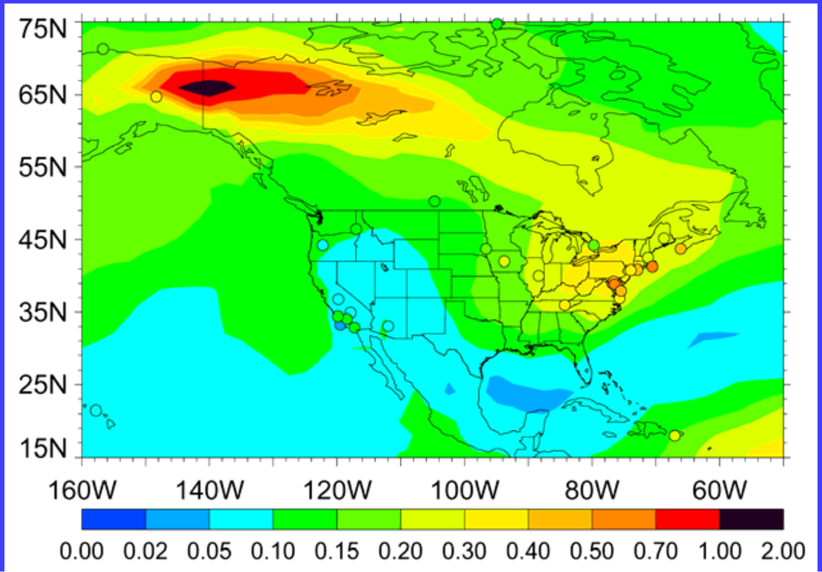
Zhang, Jacob, et al., GRL 2006

Long-range transport of smoke affects air quality
Comparison of MODIS and GOCART

MODIS AOT 550 nm 200407



GOCART AOT 550 nm 200407

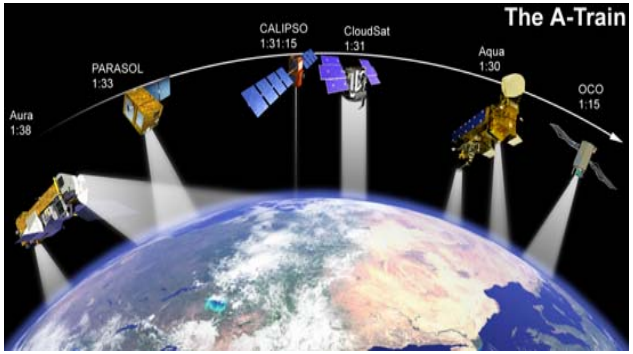


- Pollutants from forest fires (e.g., aerosol particles and ozone) can be transported long distances, affecting surface air quality downwind.
- In July 2004, large forest fires occurred in Alaska and western Canada. Smoke aerosols were transported across Canada and to large areas of continental U.S., affecting regional air quality.
- Event was observed by MODIS and simulated by the GOCART model, which showed a similar pattern and intensity for aerosol optical thickness.

Constellation Science

Unique opportunity for conducting Atmospheric Composition science for societal benefit using multiple instruments across international platforms

- **Collaboration efficiency: take advantage of each instrument's unique capability**
- **Cross instrument validation**
- **Improved spatial and temporal coverage: e.g. different equator crossing times**
- **Enhanced data products: e.g. aerosol and cloud characteristics, pollution and its transport**
- **More accurate trends by comparing and combining data sets**

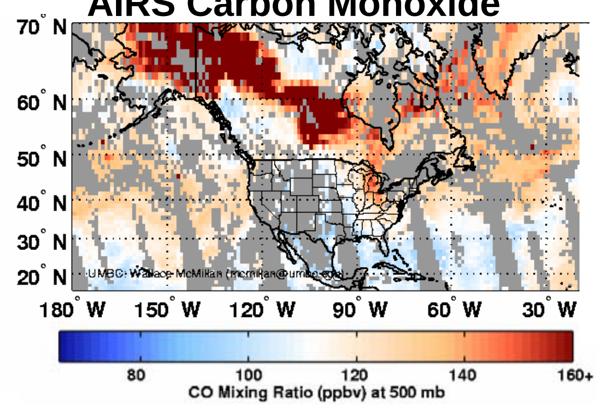


A-train is a good example of Constellation Science

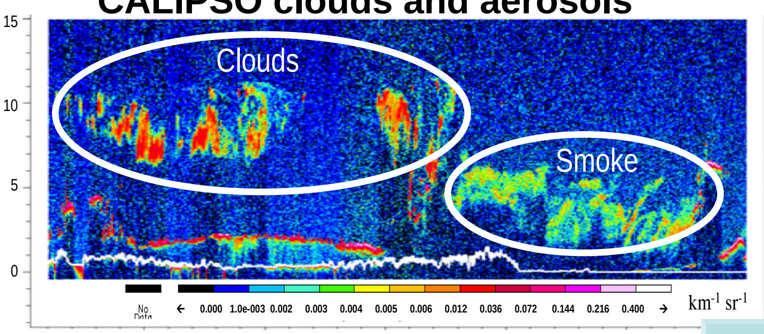
CEOS provides an opportunity to extend collaboration internationally

Potential Application:
Geographic extent of CO from biomass burning in combination with vertical distribution of smoke could improve assessment of total fire emissions and their downwind transport

AIRS Carbon Monoxide



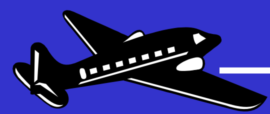
CALIPSO clouds and aerosols



Airborne Field Campaign Strategy: Use aircraft to increase the value of satellite data for improving models of atmospheric composition and climate.

Satellites: CALIPSO, Cloudsat, OMI, TES, HIRDLS, MLS, MODIS, AIRS, MISR, MOPITT

- Aerosol optical depth, properties
- CO, ozone, NO_2, HCHO, SO_2, BrO

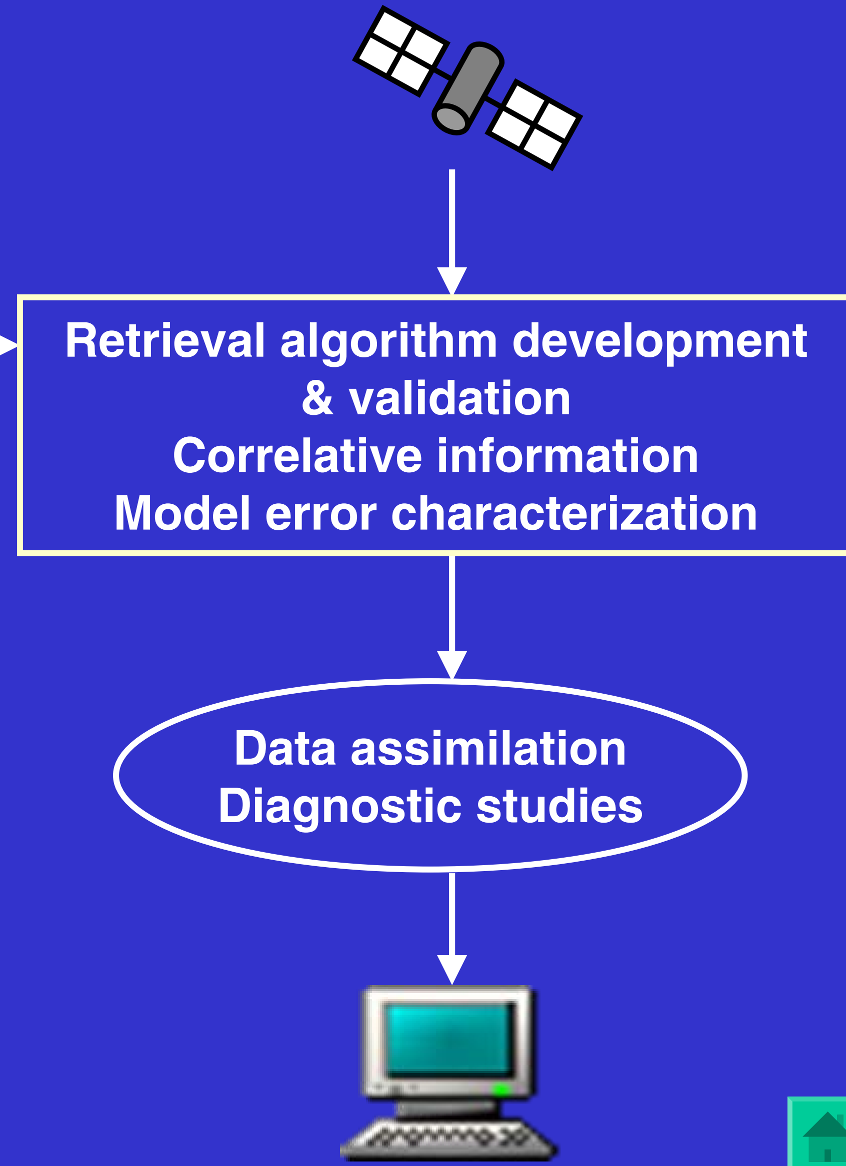


Aircraft: DC-8, WB-57, ER-2, P-3B

- Comprehensive in situ chemical and aerosol measurements
- Passive remote sensing of aerosol impacts on radiation
- Active remote sensing of ozone and aerosol optical properties

Models: CTMs, GCMs, ESMs

- Source-receptor relationships for pollution
- Inverse modeling for estimating emissions
- Aerosol radiative forcing
- Detailed chemical processing



WCRP-SPARC/IGBP-IGAC
Atmospheric Chemistry and Climate Initiative

Research Implementation Bodies

CCM-Val
(stratospheric gas-phase chemistry)

AEROCOM
(tropospheric aerosols)

"Tropos Chem"
(tropospheric gas-phase chem)

Overarching Activities

1) Emissions Harmonization Committee
2) Data Center Committee
3) AC&C Web page & "E-newsletter"

AC&C Research Activities

1) 20 year hindcast for tropospheric gases/aerosols
2) What controls the distribution of tropospheric aerosols/gases? (Step 1: Focus on 5km to tropopause distribution)
3) Cloud/aerosol/chemical interactions
4) Future scenarios; sensitivities & uncertainties

Unifying thematic areas

Composition impacts on climate
Climate impacts on chemistry
Climate impacts on surface-level ozone & aerosols ("air quality")

> Motivated but not funded by "international" organizations

> The success of these activities is contingent on buy-in from the scientific community, including us

> By participating, we take advantage of the community as well

- **Share progresses on model improvement and development**
- **Better evaluate the model performance**
- **Better access to emission, observations, etc.**
- **More relevant to international community**

>The ensemble of model results are proven to be more robust than a single "best" model (if there is any). Therefore, these exercises can be used for

- **Analyzing data from past and current missions to better understand global and regional aerosol trends, emissions, processes, and impacts**
- **Identifying common needs or problems among the models that can be used to recommend or emphasize future observation priorities**
- **Forming an international assessment body (e.g., IPCC, WMO, CCSP) providing guidance for research and policies**