Challenges of Characterizing and Forecasting the Outbreak of Pollution Episodes: Defining Requirements for Spaceborne Air Quality Observations

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Remote Sensing from Space
Boulder, Colorado
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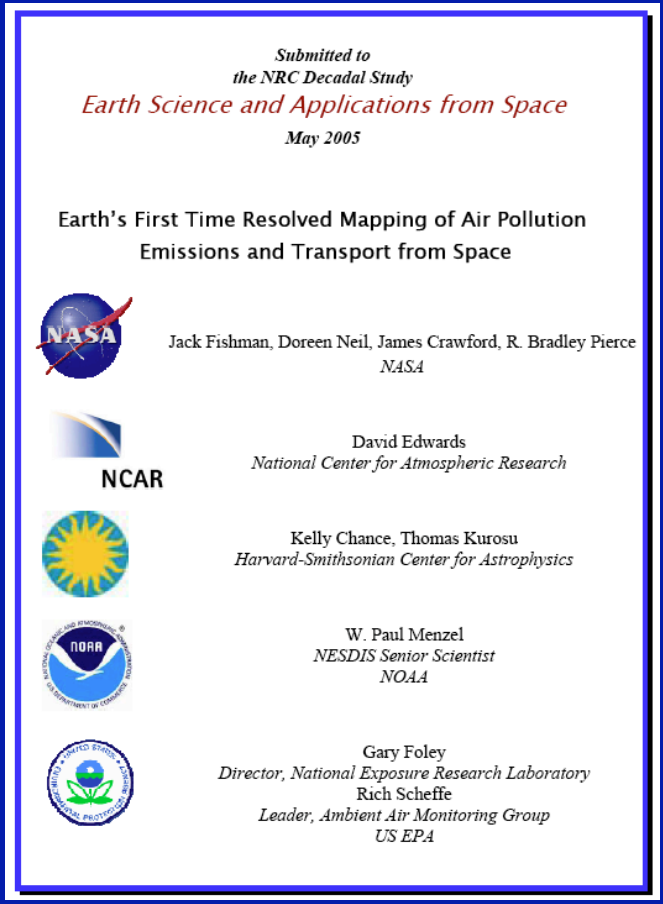
The National Research Council Has Been Issued a Challenge

- Use a Decadal Survey to "generate consensus recommendations from the Earth and environmental science and applications community regarding a systems approach to space-based and ancillary observations that encompasses the research programs of NASA and the related operational programs of NOAA."



Submitted to
the NRC Decadal Study
Earth Science and Applications from Space
May 2005

Earth's First Time Resolved Mapping of Air Pollution Emissions and Transport from Space

Jack Fishman, Doreen Neil, James Crawford, R. Bradley Pierce
NASA

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National Center for Atmospheric Research

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Gary Foley
Director, National Exposure Research Laboratory
Rich Scheffe
Leader, Ambient Air Monitoring Group
US EPA

- Decadal Survey Submission in Response to the NRC RFI Describes the **GeoTRACE** Mission

GeoTRACE Mission Concept: Time-resolved Tropospheric Chemistry

- **GeoTRACE measures tropospheric columns of chemically linked atmospheric constituents: O_3, CO, NO_2, SO_2, HCHO and aerosols**
- **GeoTRACE measures all of these constituents every hour across the entire continent at the same time**
- **~5 km spatial resolution provides insight into processes that drive local pollution events**

Additional Challenges Have Been Put Forth

- by the International Observational Community
  - by U.S. Operational Agencies
  - to the Scientific Community

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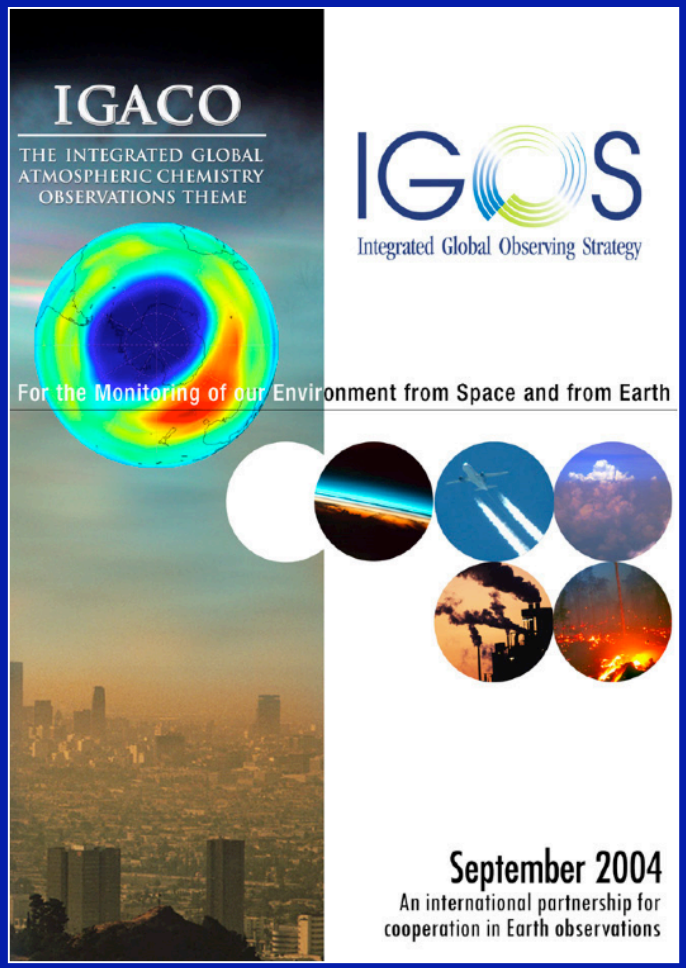
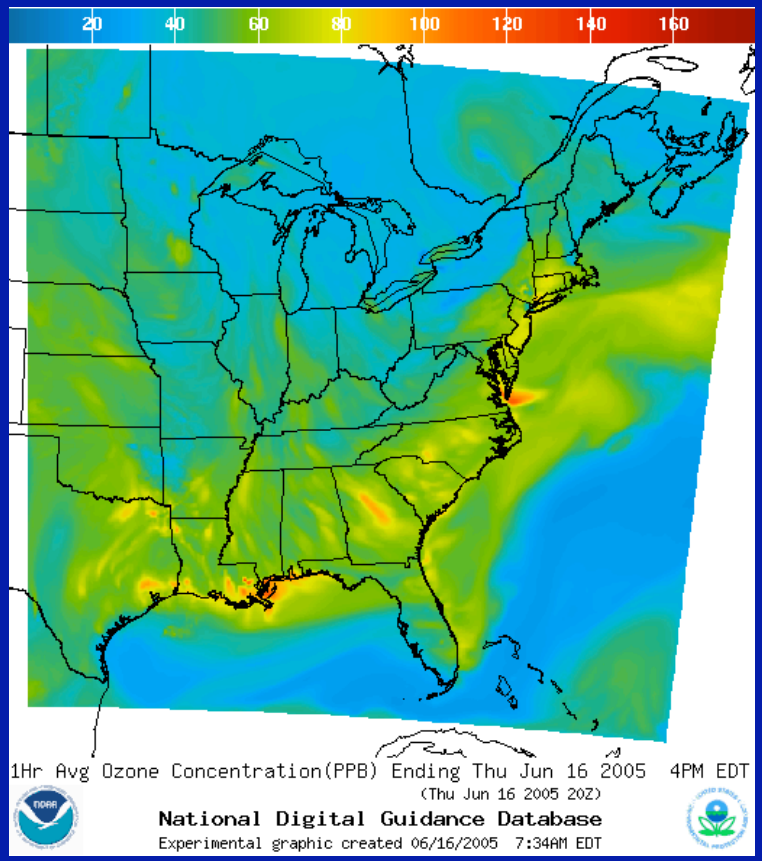
The IGOS/IGACO "Grand Challenge"



"Develop satellite instrumentation to provide measurements with sufficient temporal and spatial resolution to understand the globalisation of tropospheric pollution"

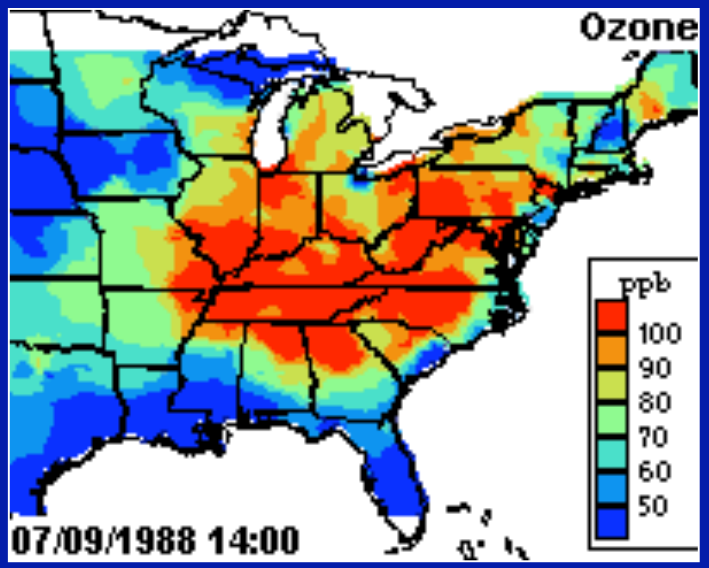
The NOAA/EPA Operational Challenge



- Extend the air quality forecast range to 48-72 hours and include pollutants in addition to O_3 and $PM_{2.5}$ by 2015

-Davidson and Meagher, Fall AGU, Dec. 2005

The Underlying Scientific Challenge



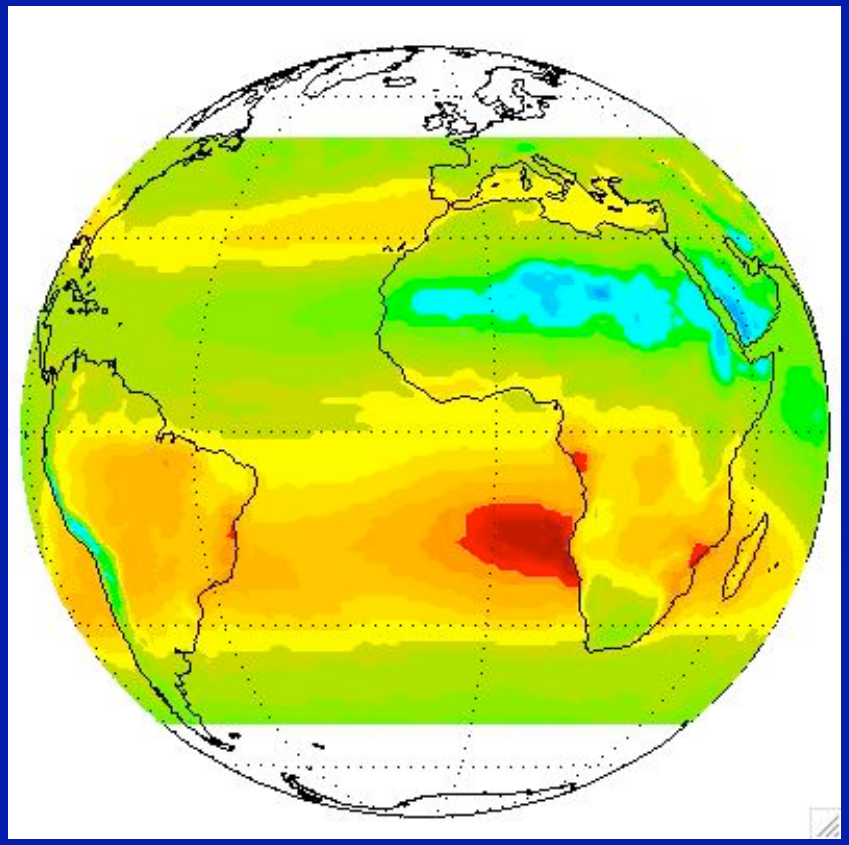
- Develop an understanding of how widespread air pollution episodes develop
- Understand relationship between synoptic meteorological forcing and regional scale episodes

Addressing the Scientific Challenge

1. Examine Permanently Polluted Region [Fishman et al., 1996]
2. Examine Region Prone to Widespread Pollution Formation by Synoptic-Scale Meteorological Forcing [Fishman and Balok 1999]
3. Examine 2005 Local Event in East Texas Captured by Regional CMAQ Regional Model and OMI Satellite Measurements [Ongoing study]

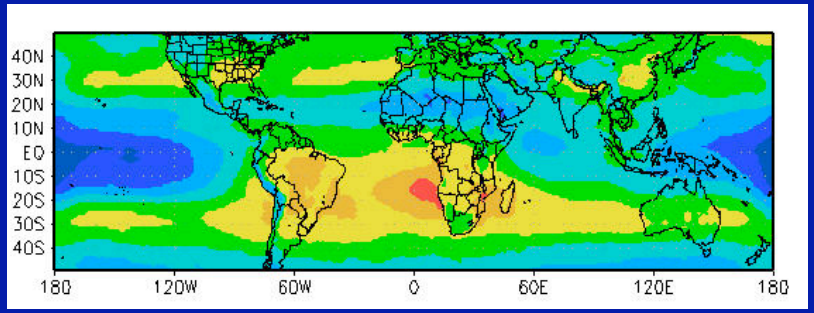
How do Widespread Air Pollution Episodes Develop?

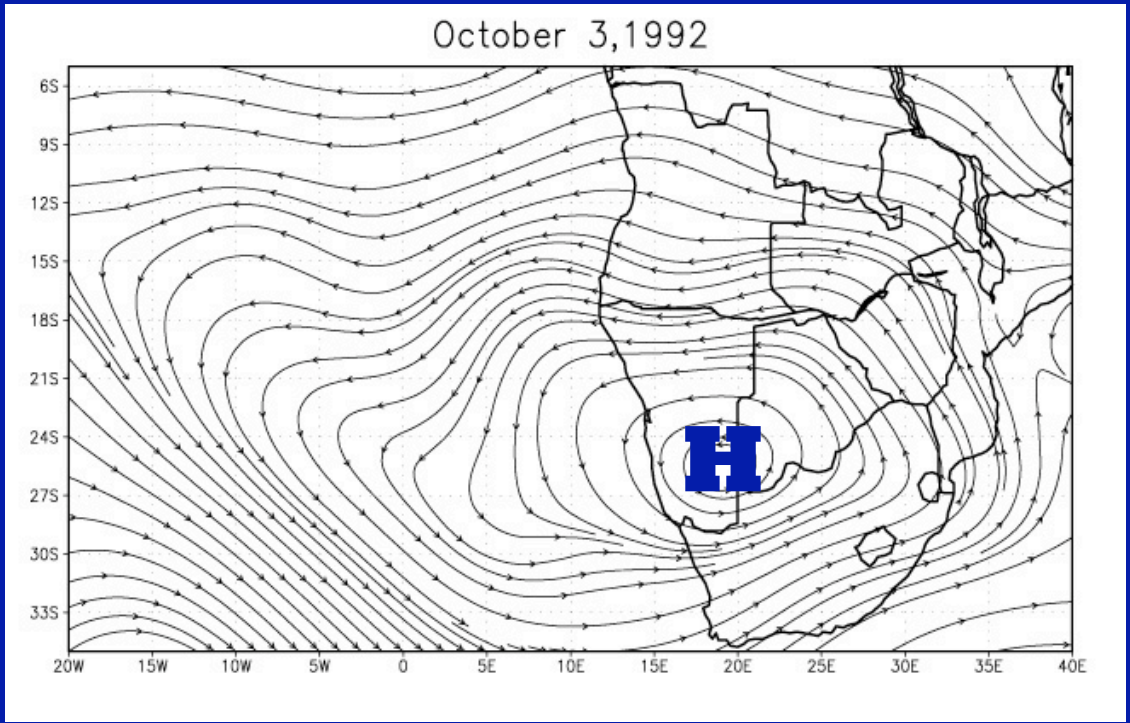
To answer this question, let's examine the most persistent polluted region on the planet



The austral springtime enhancement of tropospheric ozone off the southwest coast of Africa

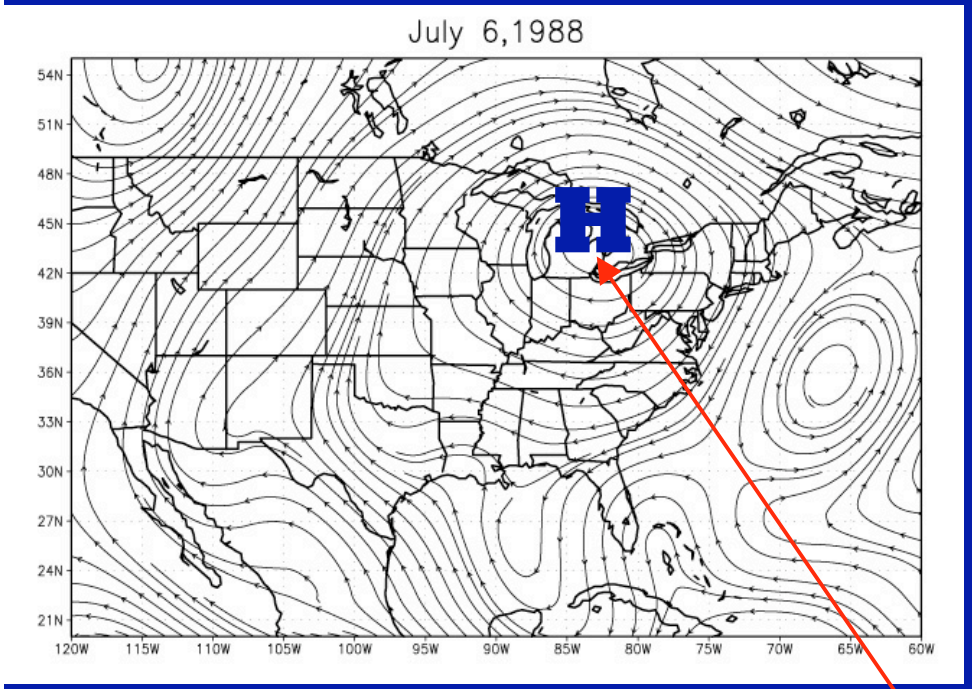
Feature off Southern African Coast Exists Because of the Permanence of Anticyclone Forced by Combination of Topography and Land-Sea Temperature Contrast

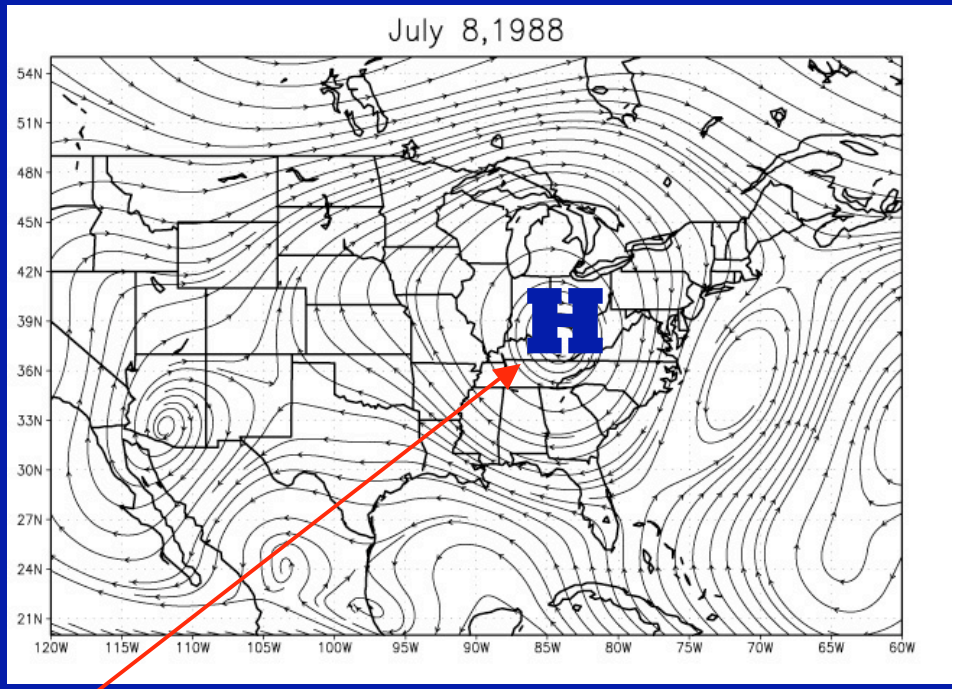




Analogously

Widespread Air Pollution Episodes Develop over Eastern U.S. when Transient Anticyclones Persist over Source Region

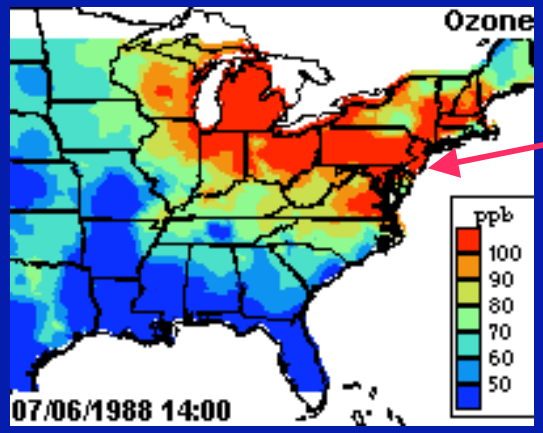




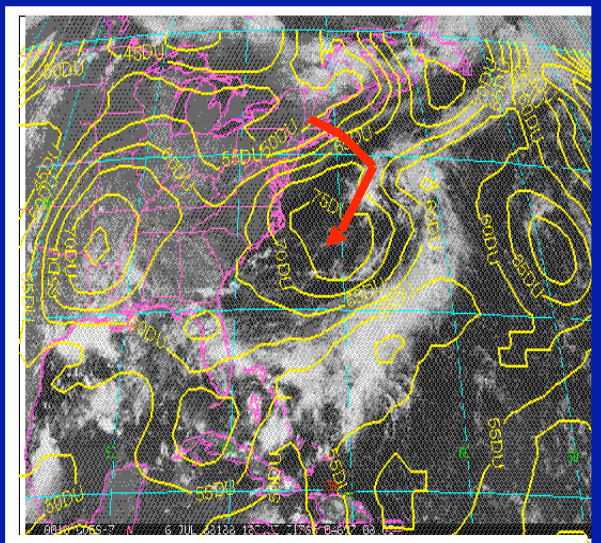
Intense anticyclone over Eastern U.S. provided synoptic backdrop for record pollution in 1988

Use of Satellite Measurements Helped Demonstrate Evolution of Widespread Pollution Episode in 1988 Case Study

July 6

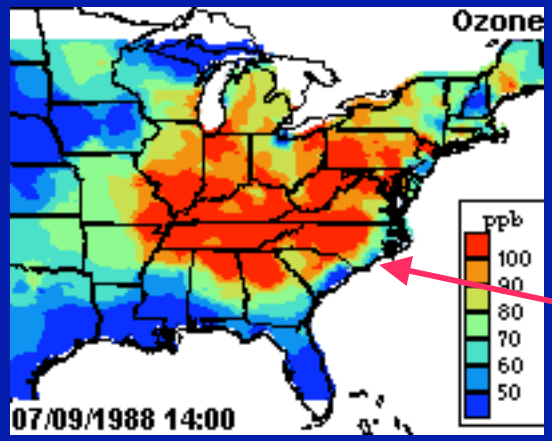


Pollution from northern states pools off North Carolina coast

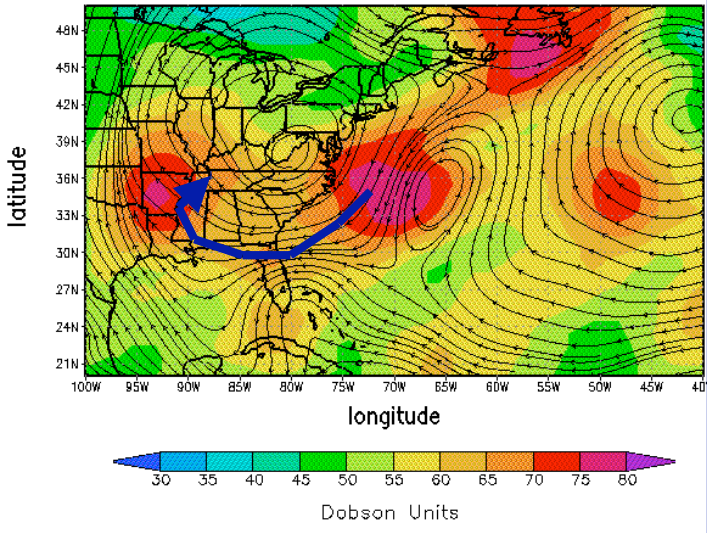


July 6

July 9

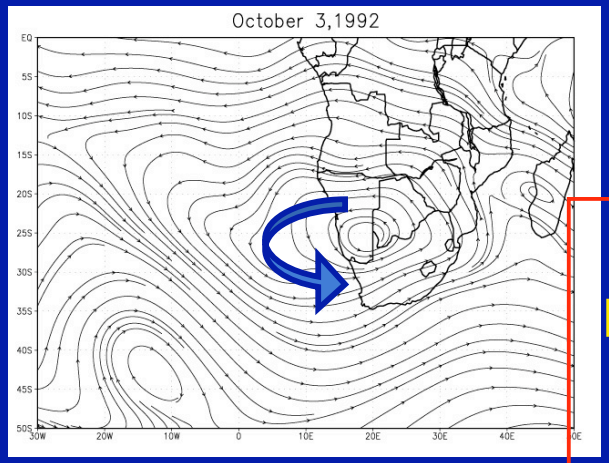


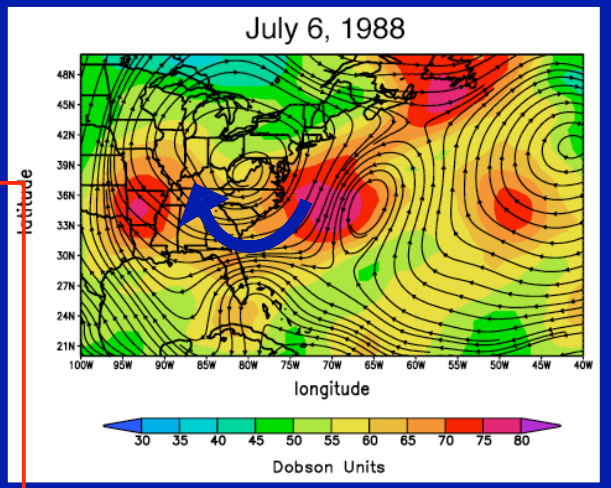
Unique transport situation carries off-shore pollution to southern states



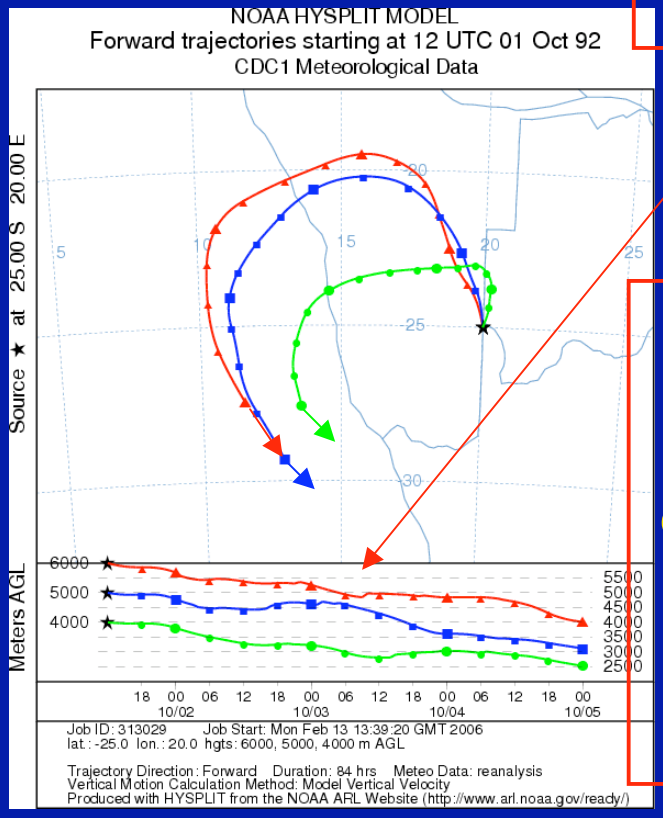
from Fishman and Balok [1999, *JGR,* 104, pp. 30,319]

Strong Subsidence Dominates Within Anticyclone



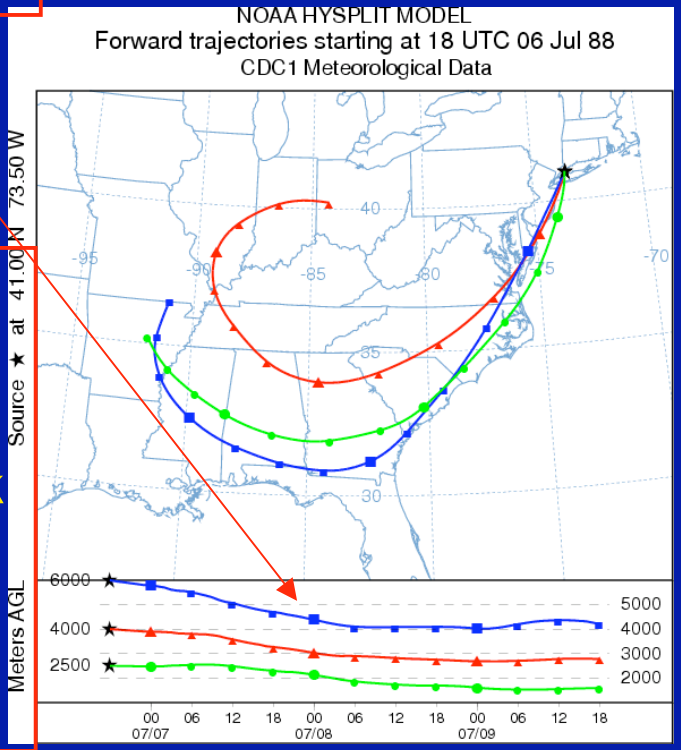


In both cases, parcels starting at 6000 m descend dramatically into polluted regions!



Strong subsidence inversion allows emissions to cook for several days:

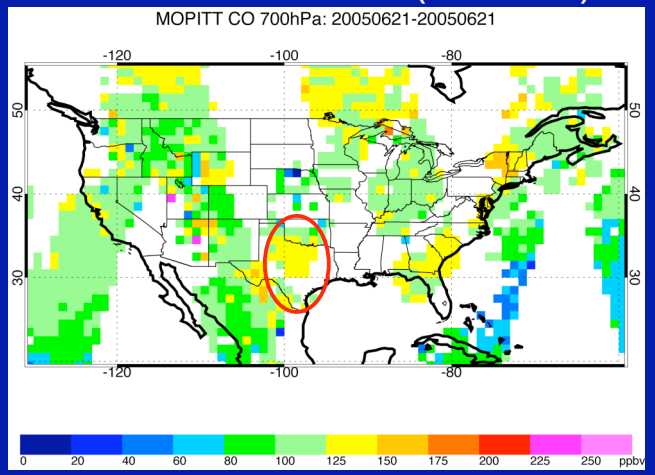
Result is high O_3 at surface



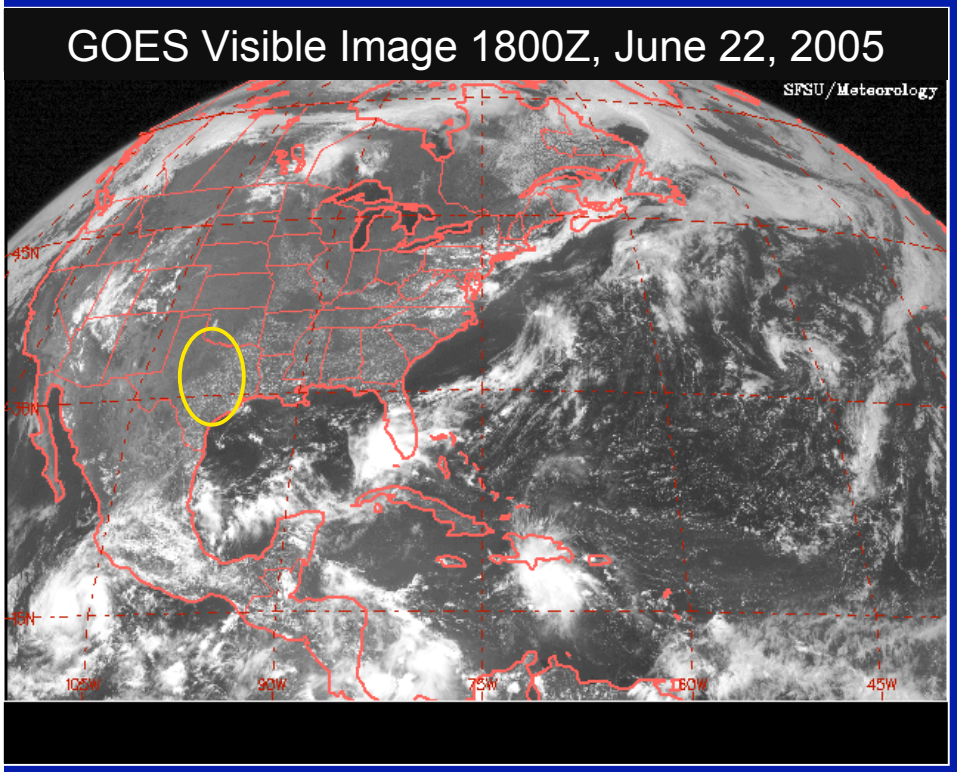
Ongoing Research

Current Capabilities Show that Measurements Provide Some Information on Distribution of Key Pollutants for Widespread Pollution Episode Formation

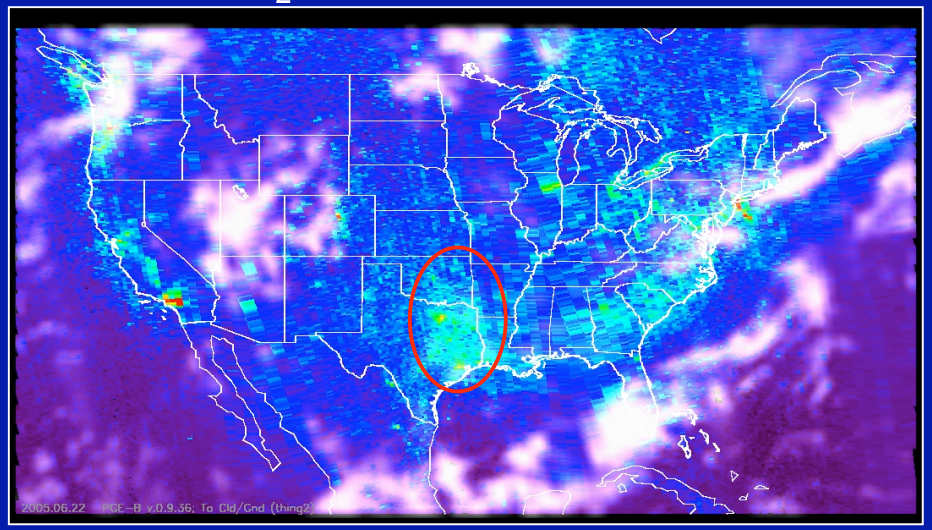
CO from MOPITT (June 21)



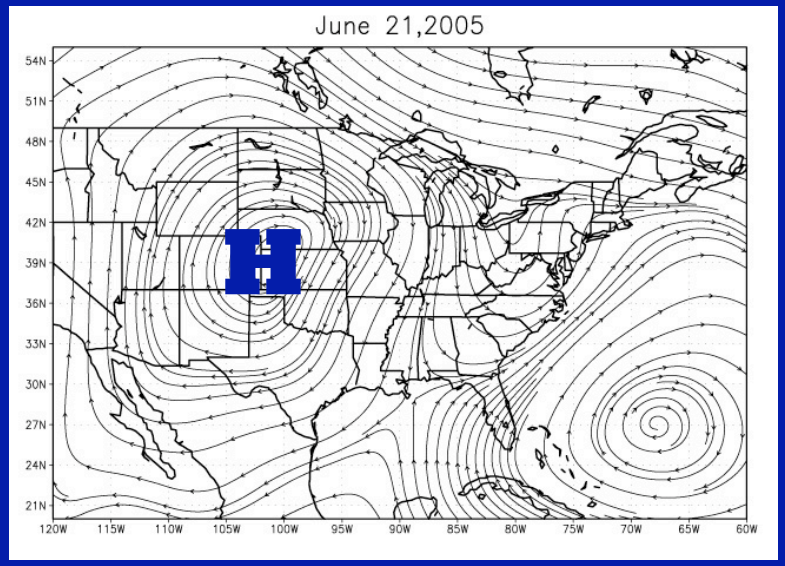
GOES Visible Image 1800Z, June 22, 2005

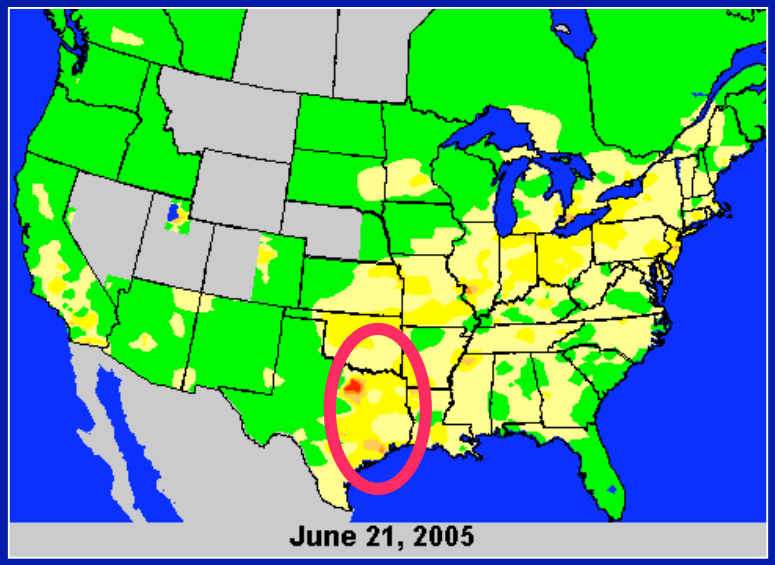


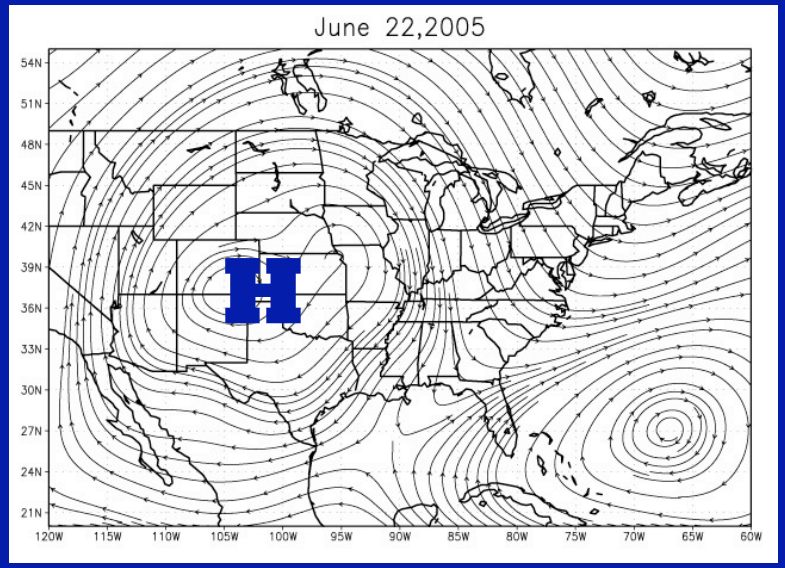
NO_2 from OMI on June 22

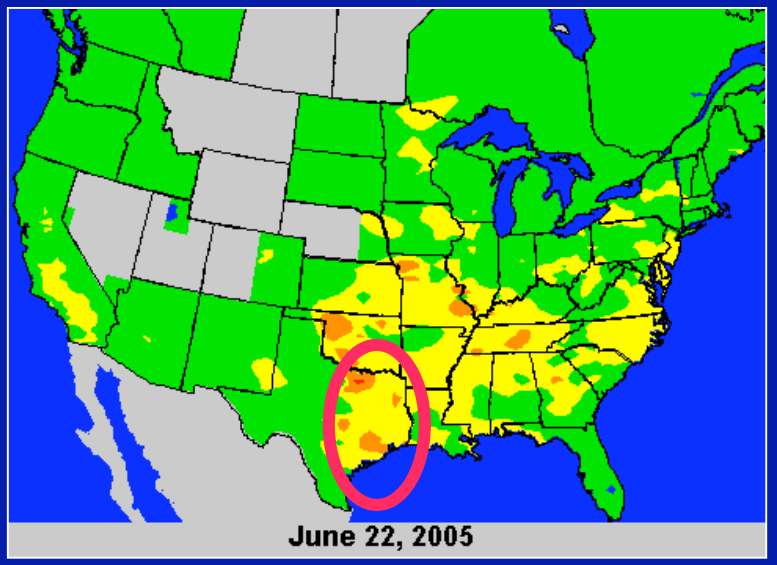


Stagnant High Pressure Sets Stage for Pollution Episode over East Texas: June 21-22, 2005



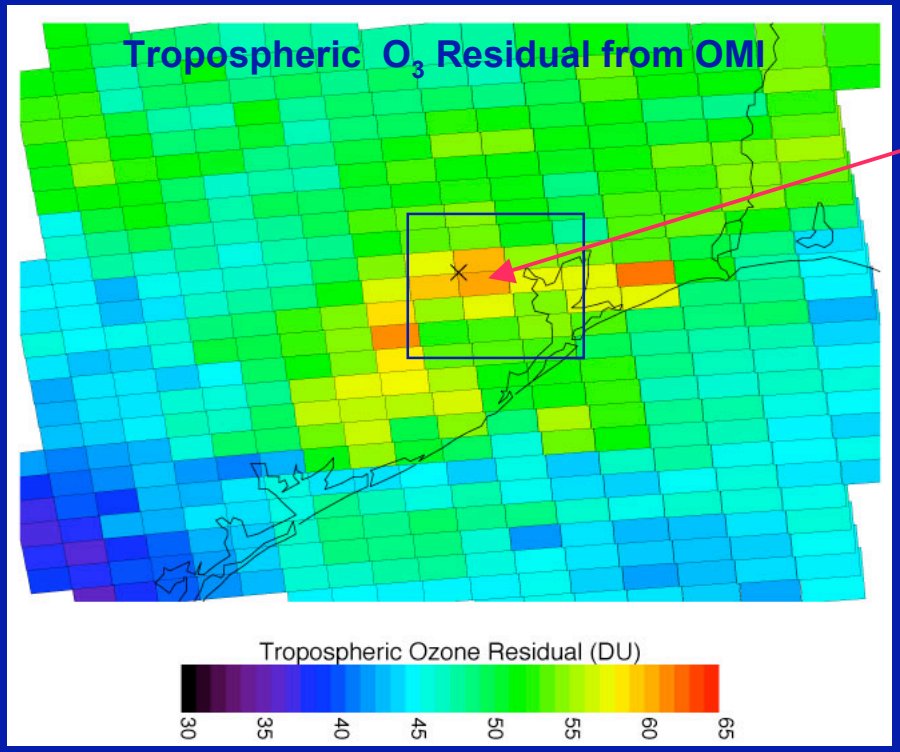






Current Capability from Low-Earth Orbit

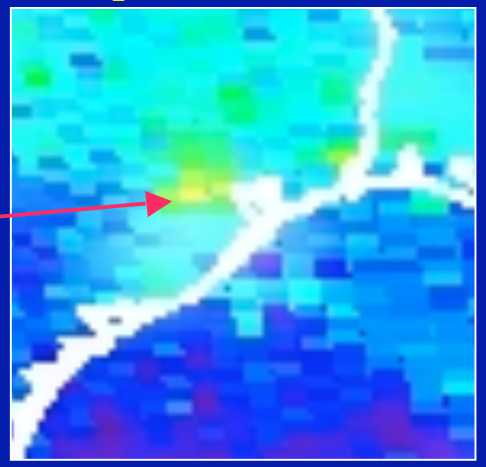
OMI Measurements Capture Pollution Event In Houston Area for June 22



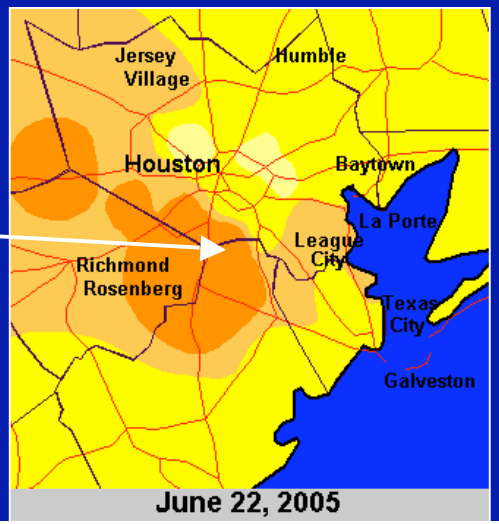
Elevated TOR from OMI

Elevated NO_2 from OMI

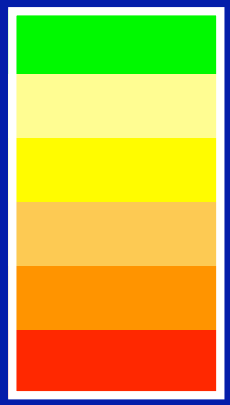
NO_2 Column from OMI



Elevated Surface O_3 from EPA Sites



Surface O_3 Concentrations



0-60 ppb

61-79 ppb

80-99 ppb

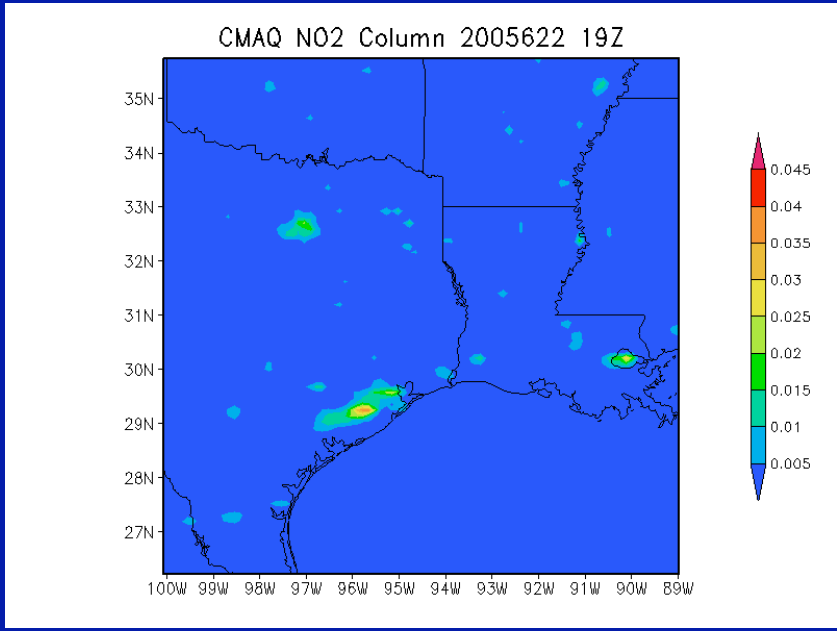
100-110 ppb

111-124 ppb

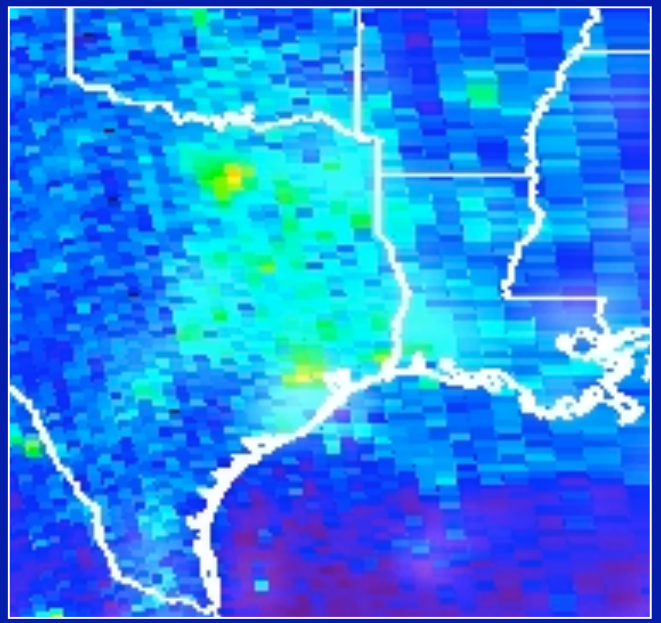
125+ ppb

Good Agreement Between NO_2 Column from OMI and CMAQ Simulation

June 22, 2005, 1900 Z



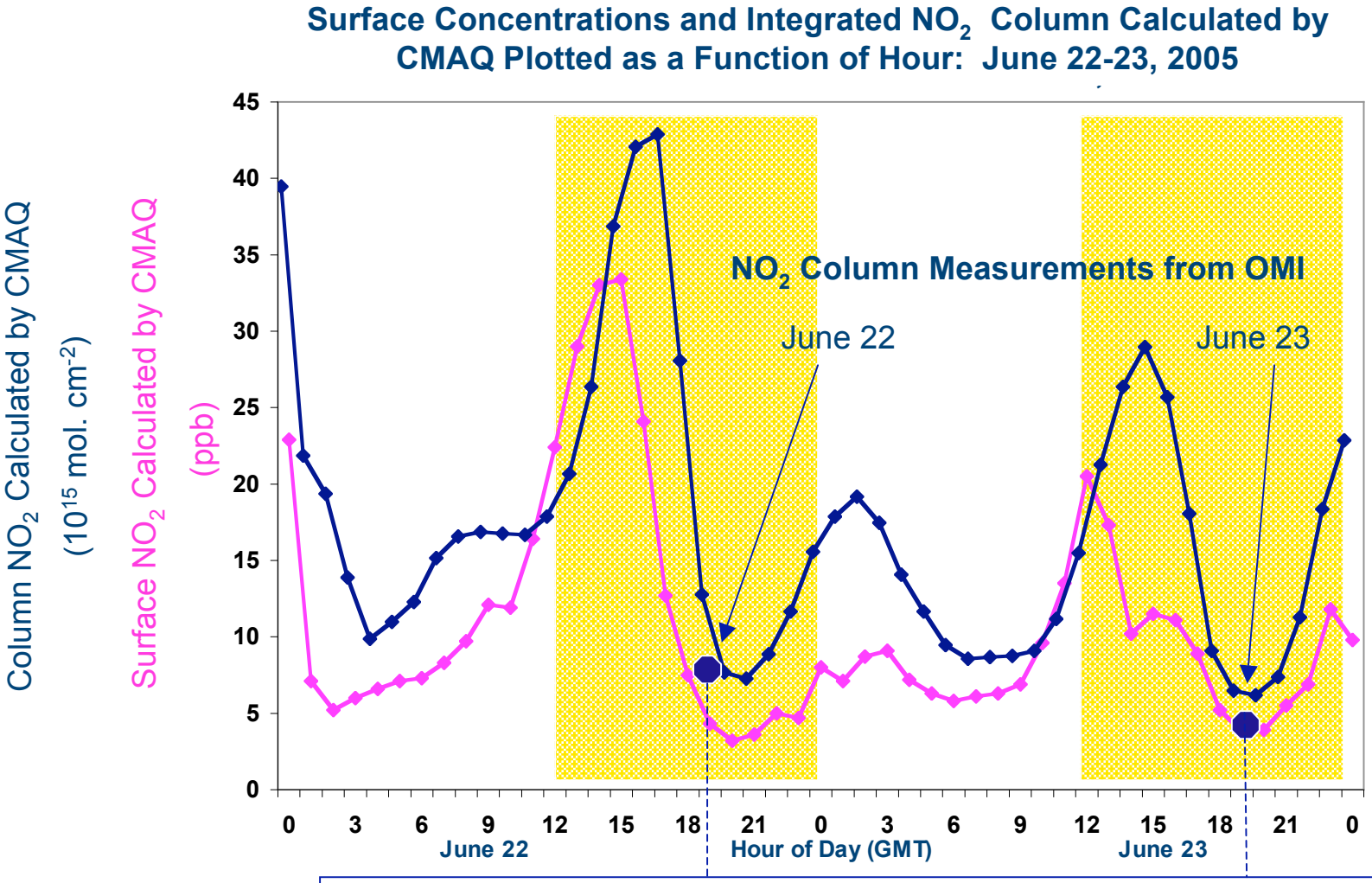
Model-Integrated NO_2 from CMAQ (12-km resolution)



OMI NO_2

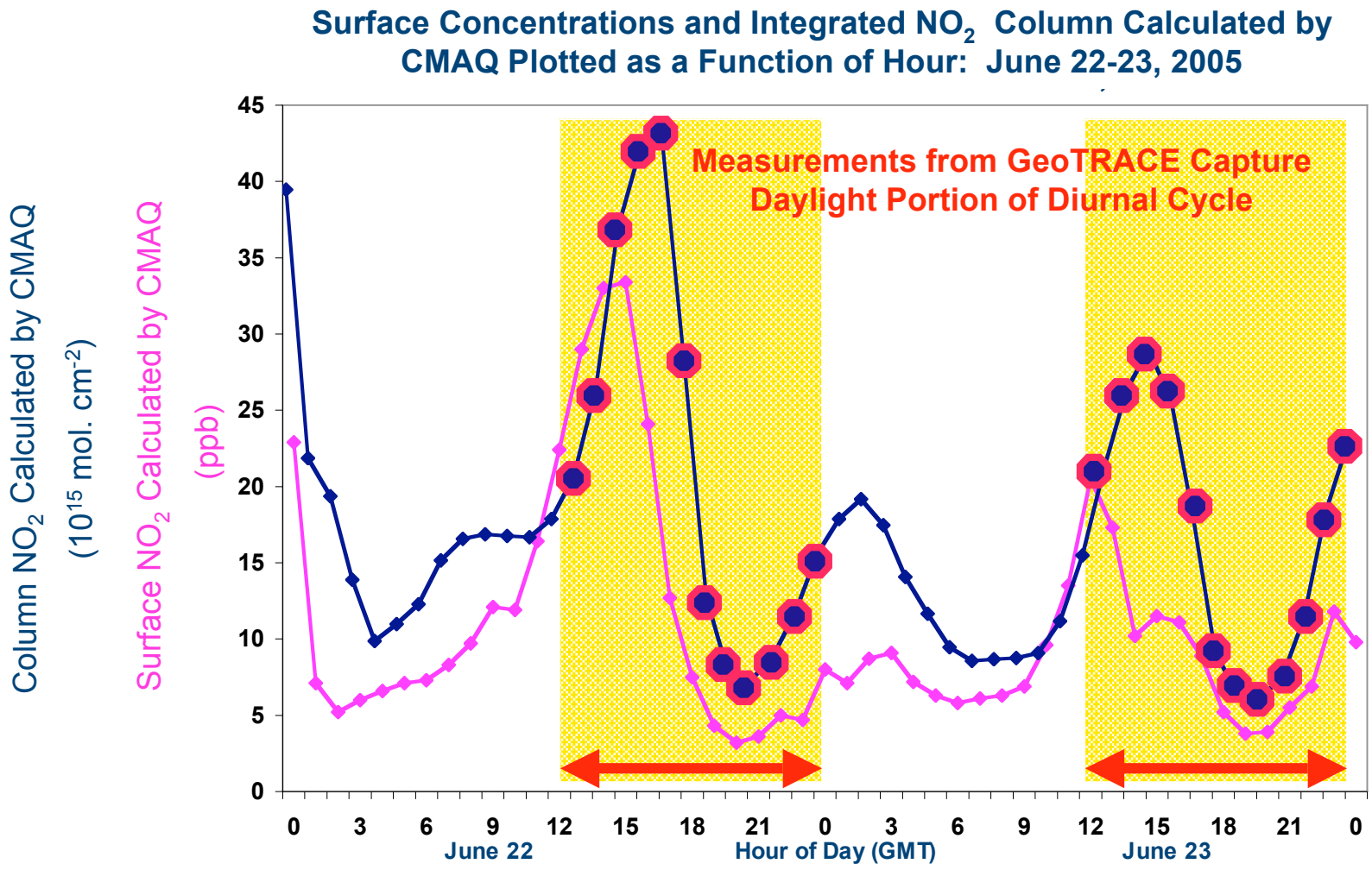
The OMI Measurement Can Only Capture a Snapshot at One Moment

Integrated Column NO_2 Accurately Captures Diurnal Behavior



Measurements provided only once per day provide relatively little information that can be used to examine how well AQ models perform

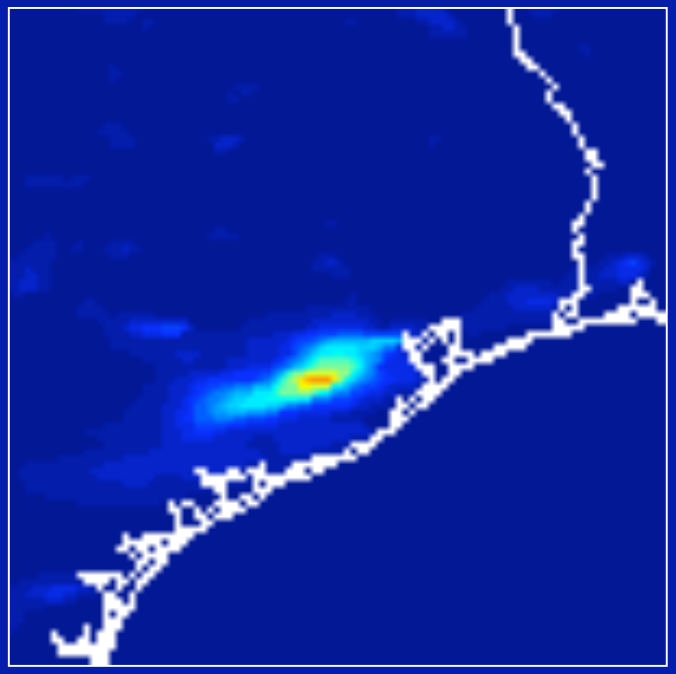
Integrated Column NO_2 Accurately Captures Diurnal Behavior



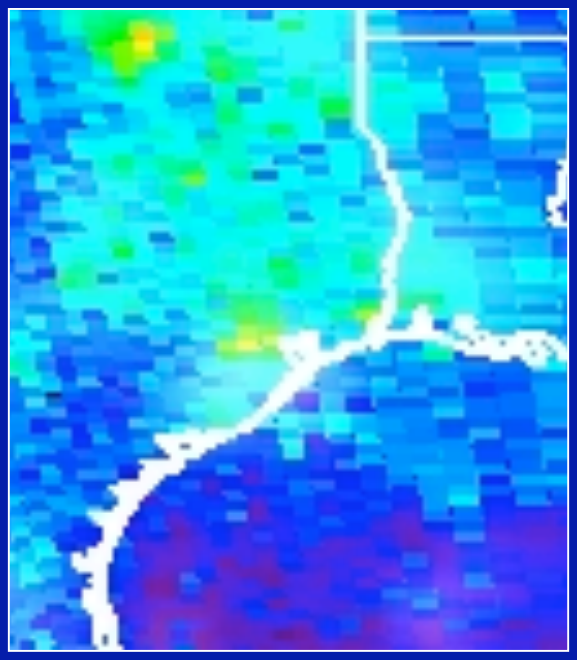
GeoTRACE Makes NO_2 Measurements Every 30-60 Minutes Throughout Sunlit Hours

CMAQ Simulation and NO_2 from OMI in Good Agreement

June 22, 2005, 1900 Z



12-km resolution from CMAQ

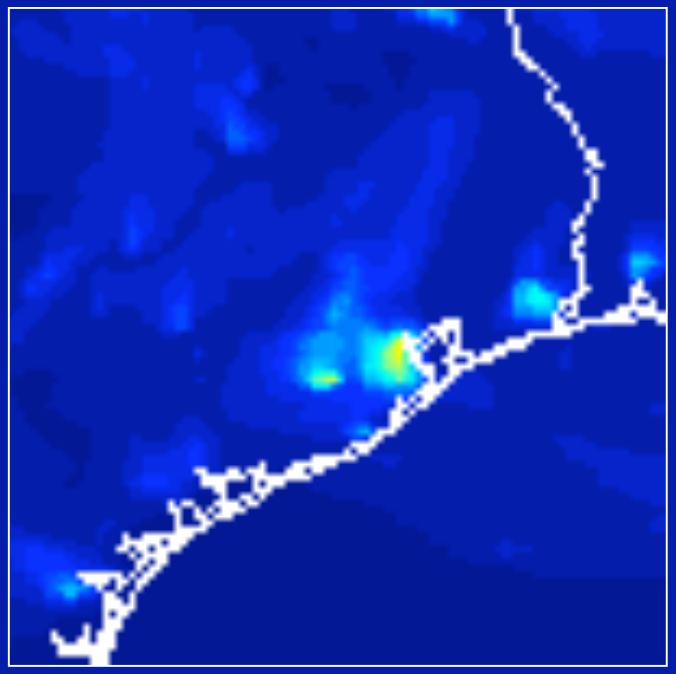


OMI NO_2

Geostationary Measurements Capture the Evolution of the NO_2 Distribution

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 1200 Z

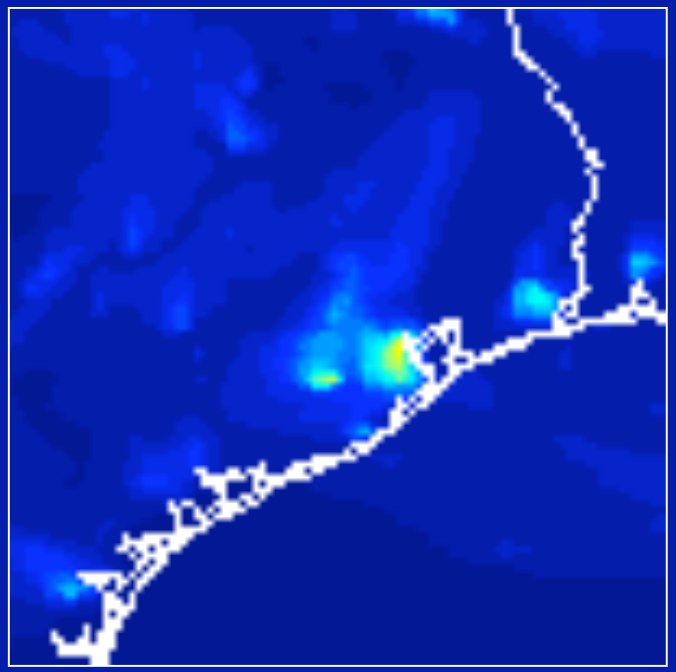


12-km resolution from CMAQ

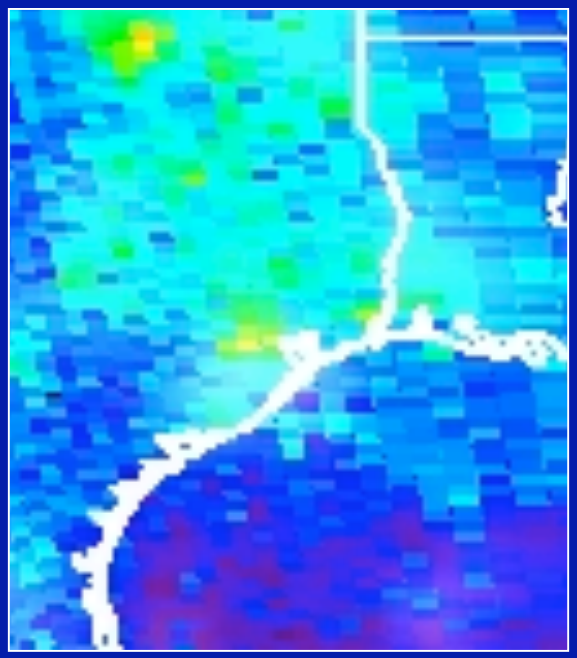
This image is what would be seen by GeoTRACE ~1 hour after sunrise over Houston

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 1200 Z



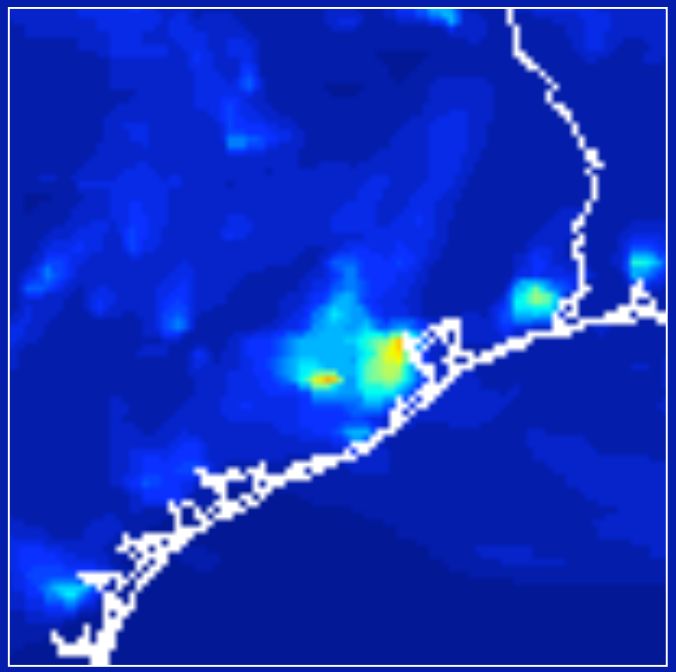
12-km resolution from CMAQ



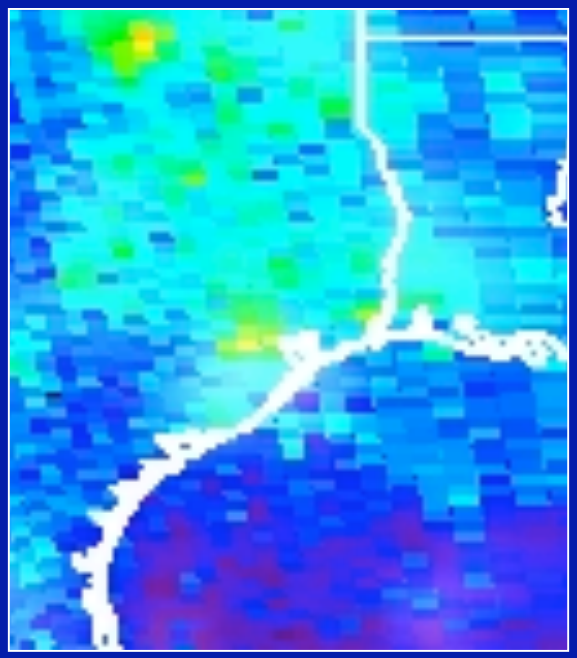
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 1300 Z



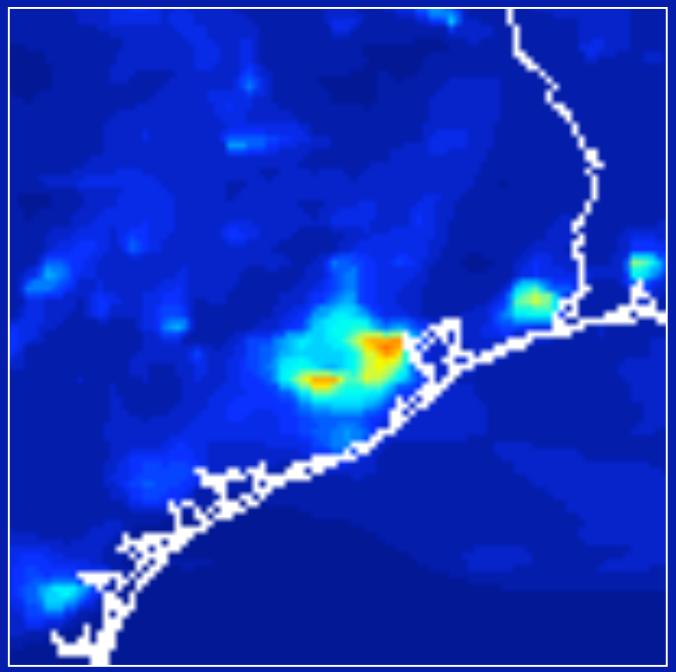
12-km resolution from CMAQ



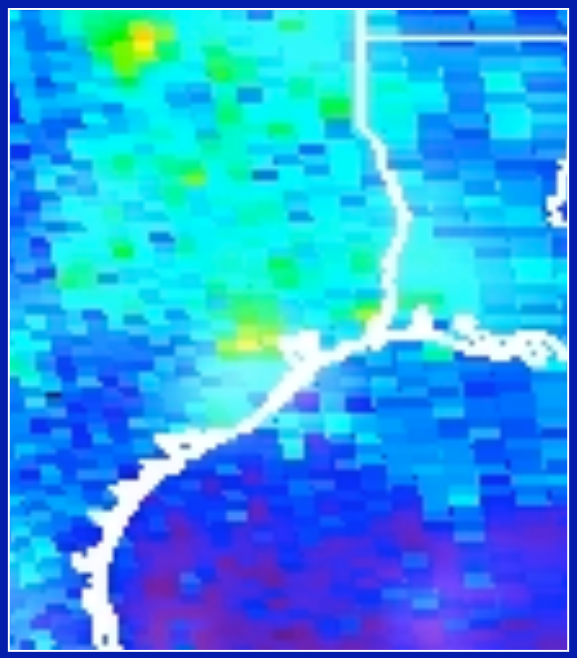
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 1400 Z



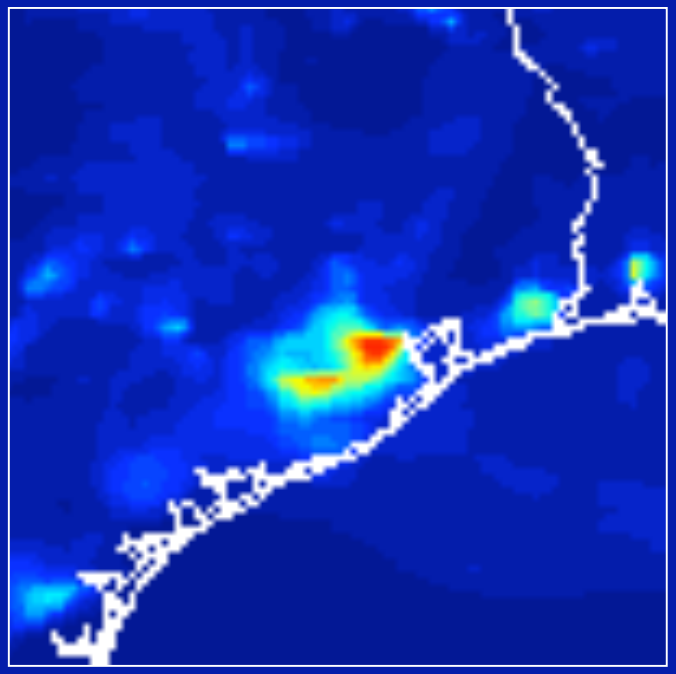
12-km resolution from CMAQ



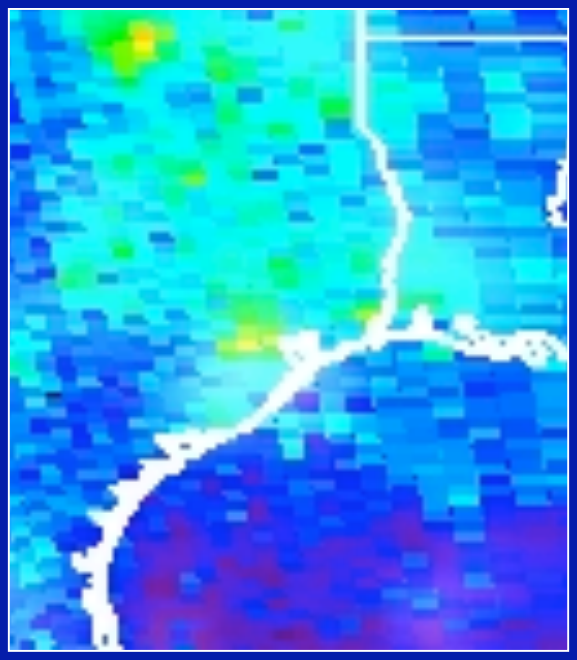
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 1500 Z



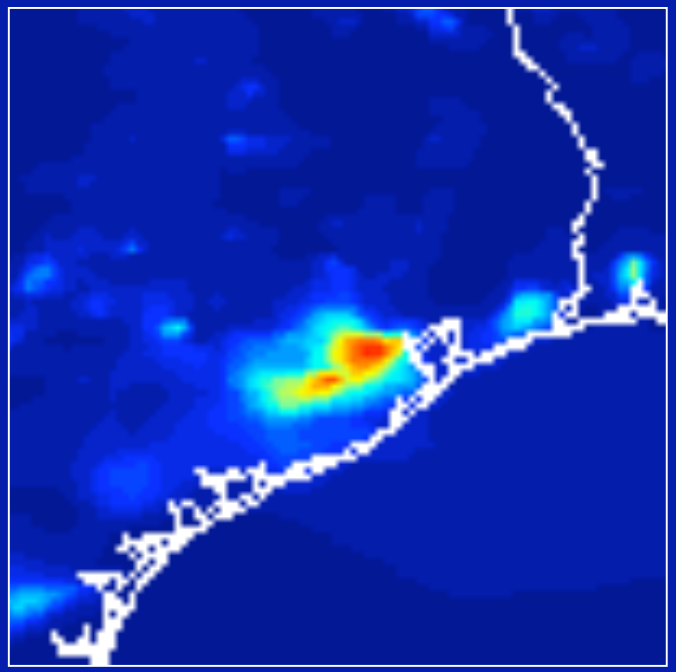
12-km resolution from CMAQ



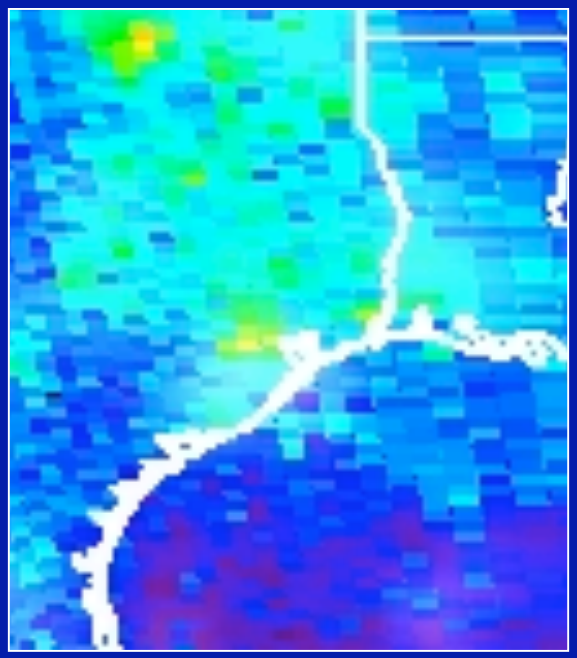
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 1600 Z



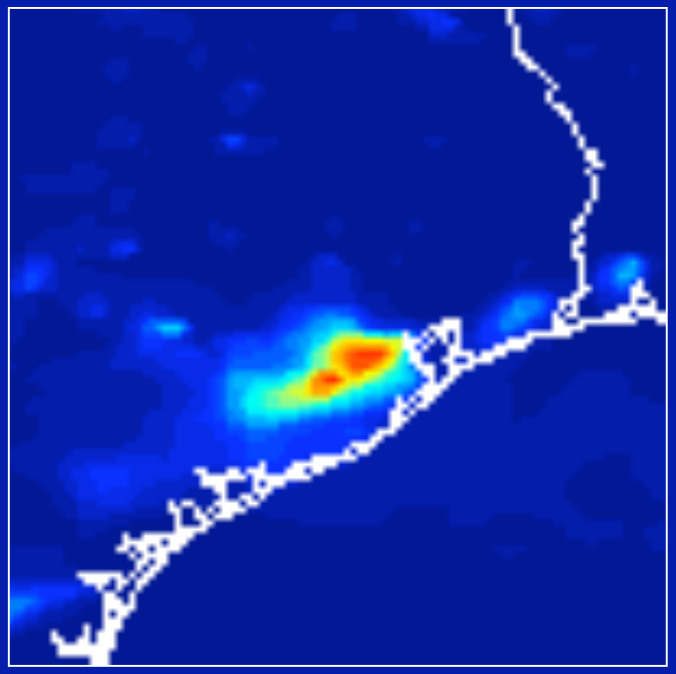
12-km resolution from CMAQ



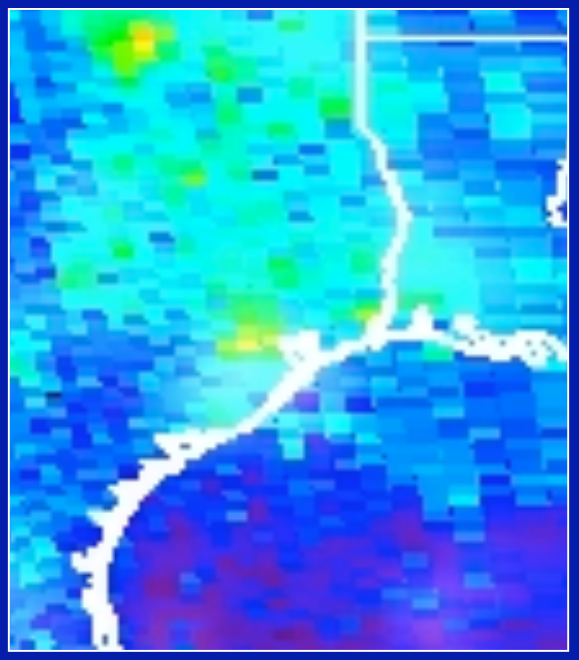
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 1700 Z



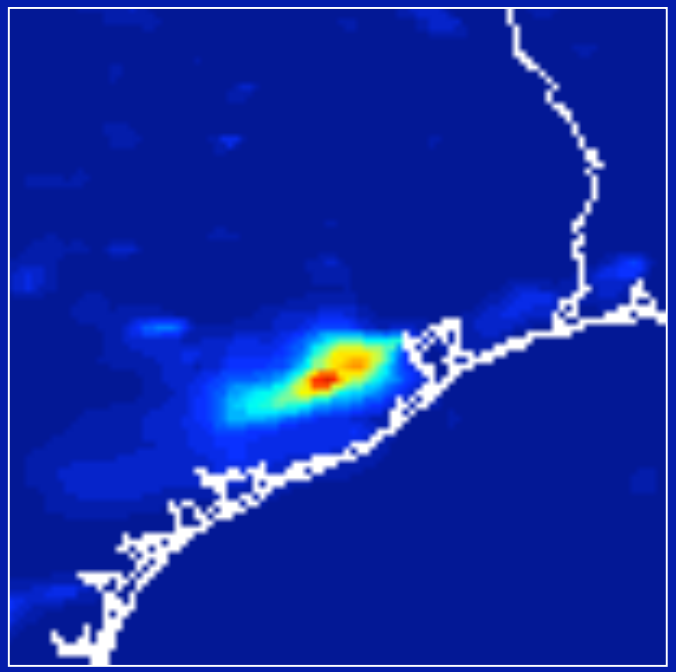
12-km resolution from CMAQ



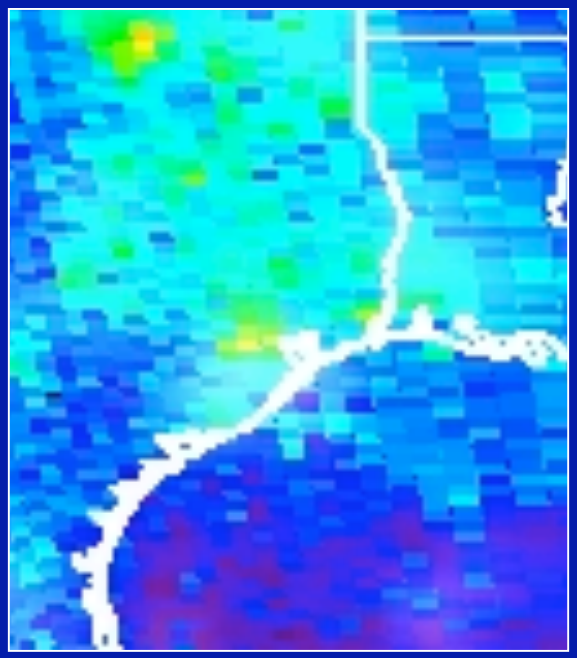
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 1800 Z



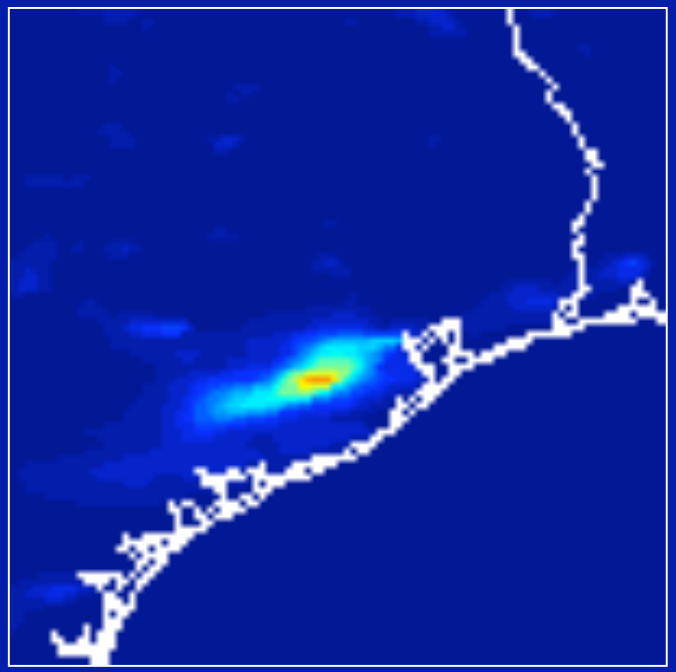
12-km resolution from CMAQ



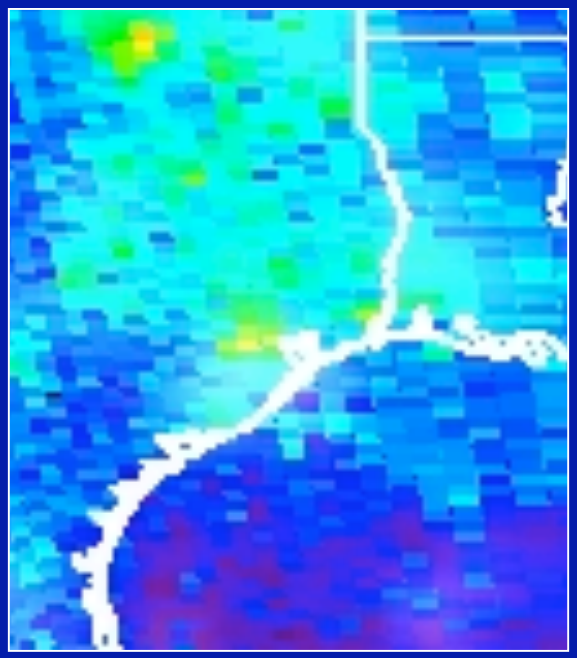
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 1900 Z



12-km resolution from CMAQ

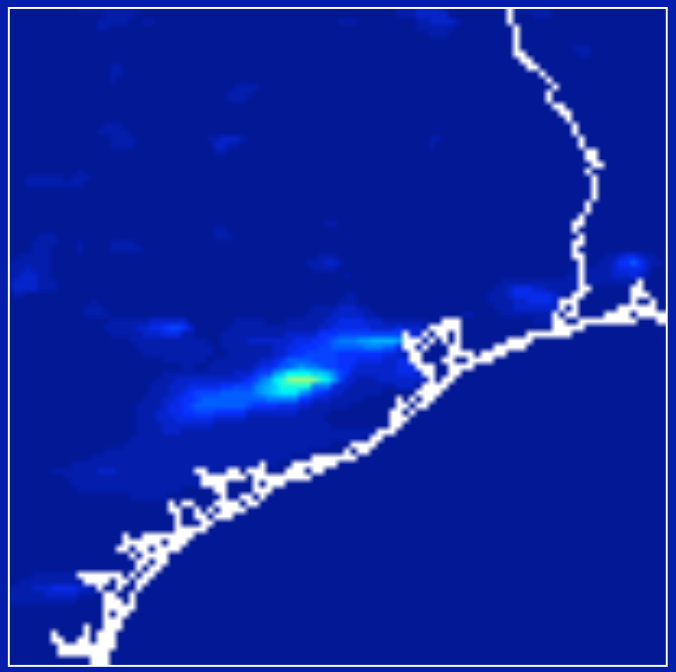


OMI NO_2

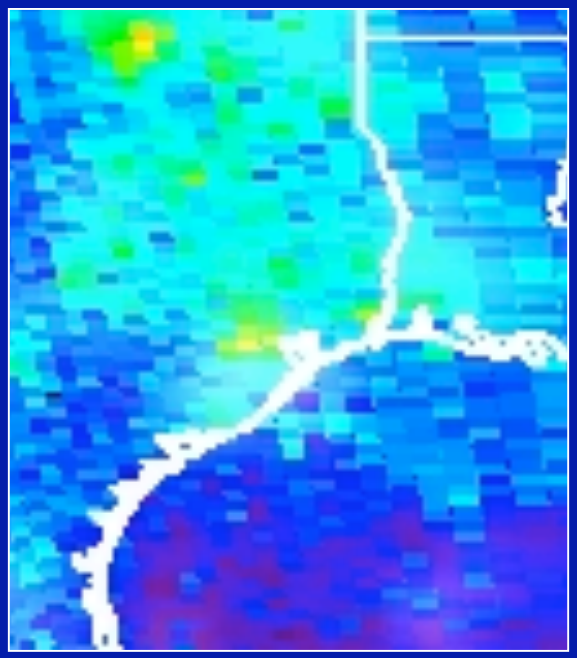
Distribution Coincident with time of OMI Overpass

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 2000 Z



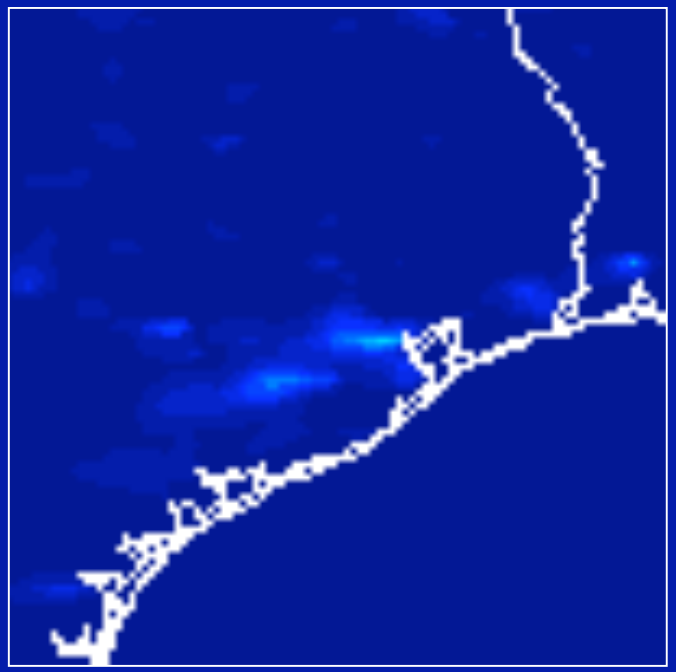
12-km resolution from CMAQ



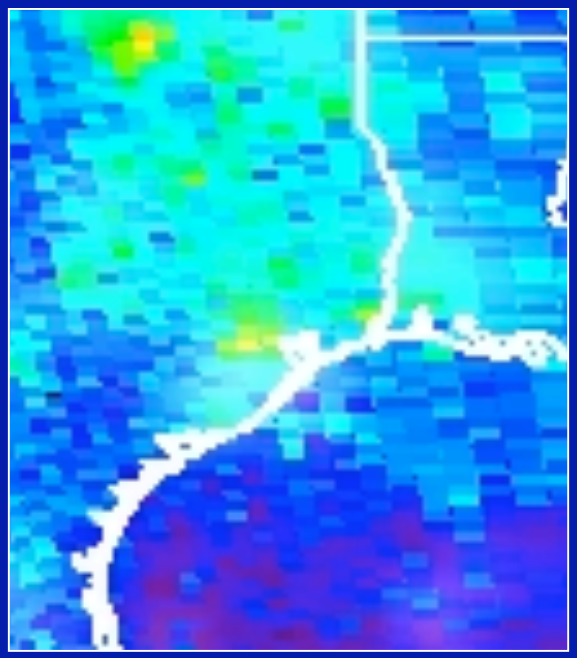
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 2100 Z



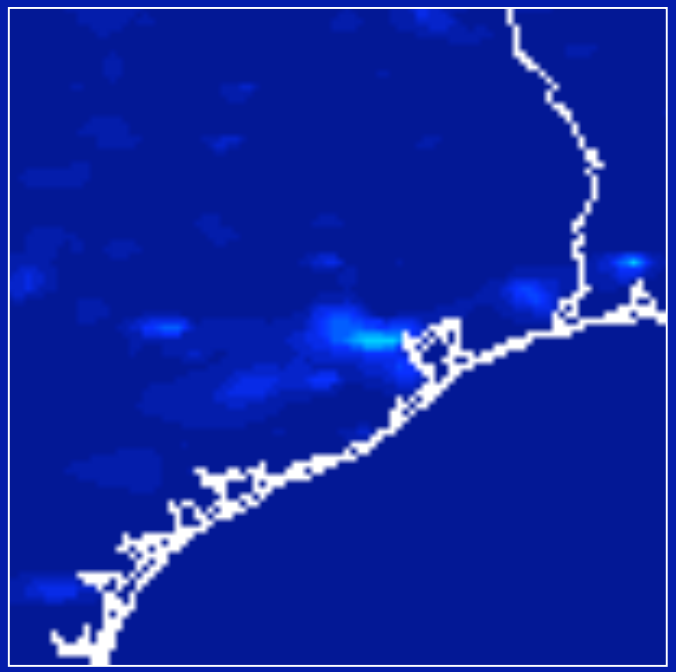
12-km resolution from CMAQ



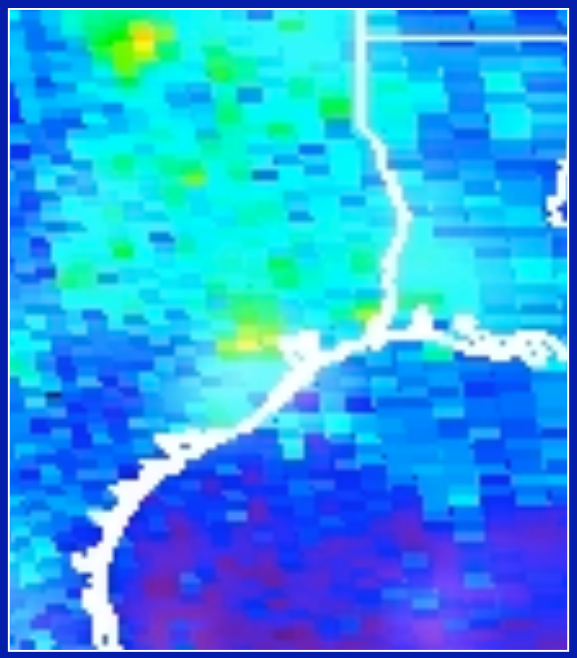
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 2200 Z



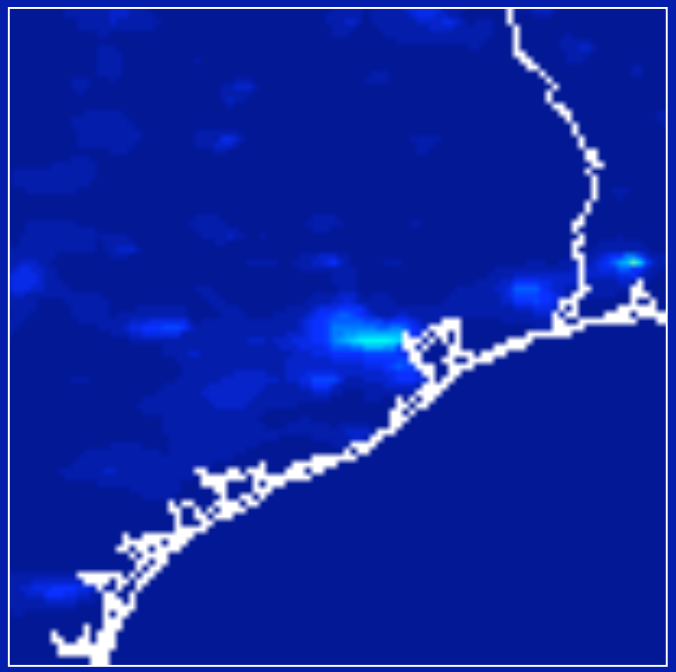
12-km resolution from CMAQ



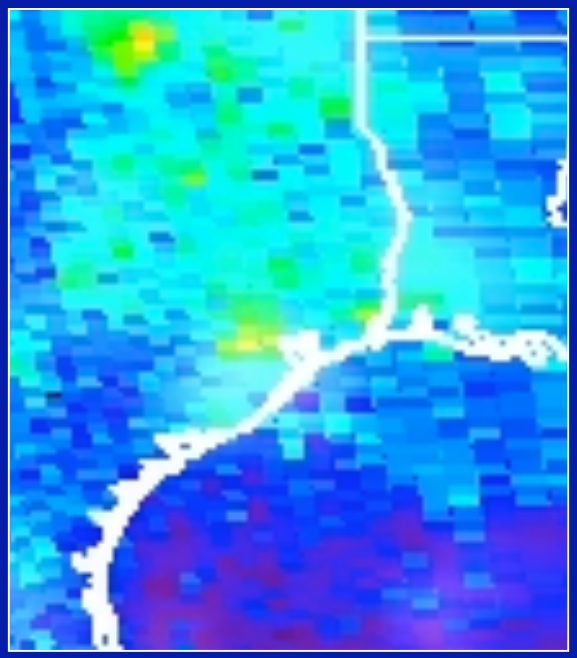
OMI NO_2

CMAQ Simulation and NO_2 from OMI

June 22, 2005, 2300 Z

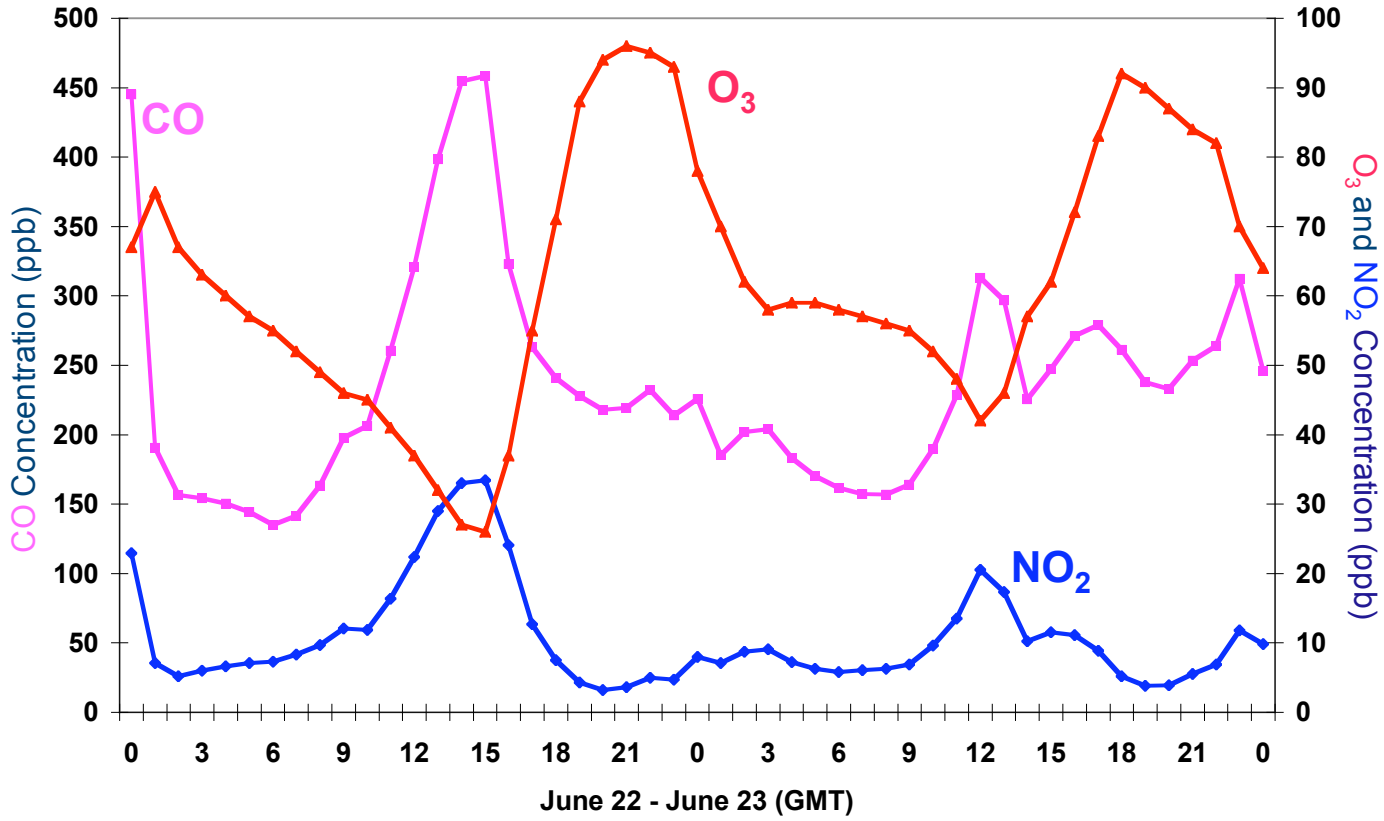


12-km resolution from CMAQ

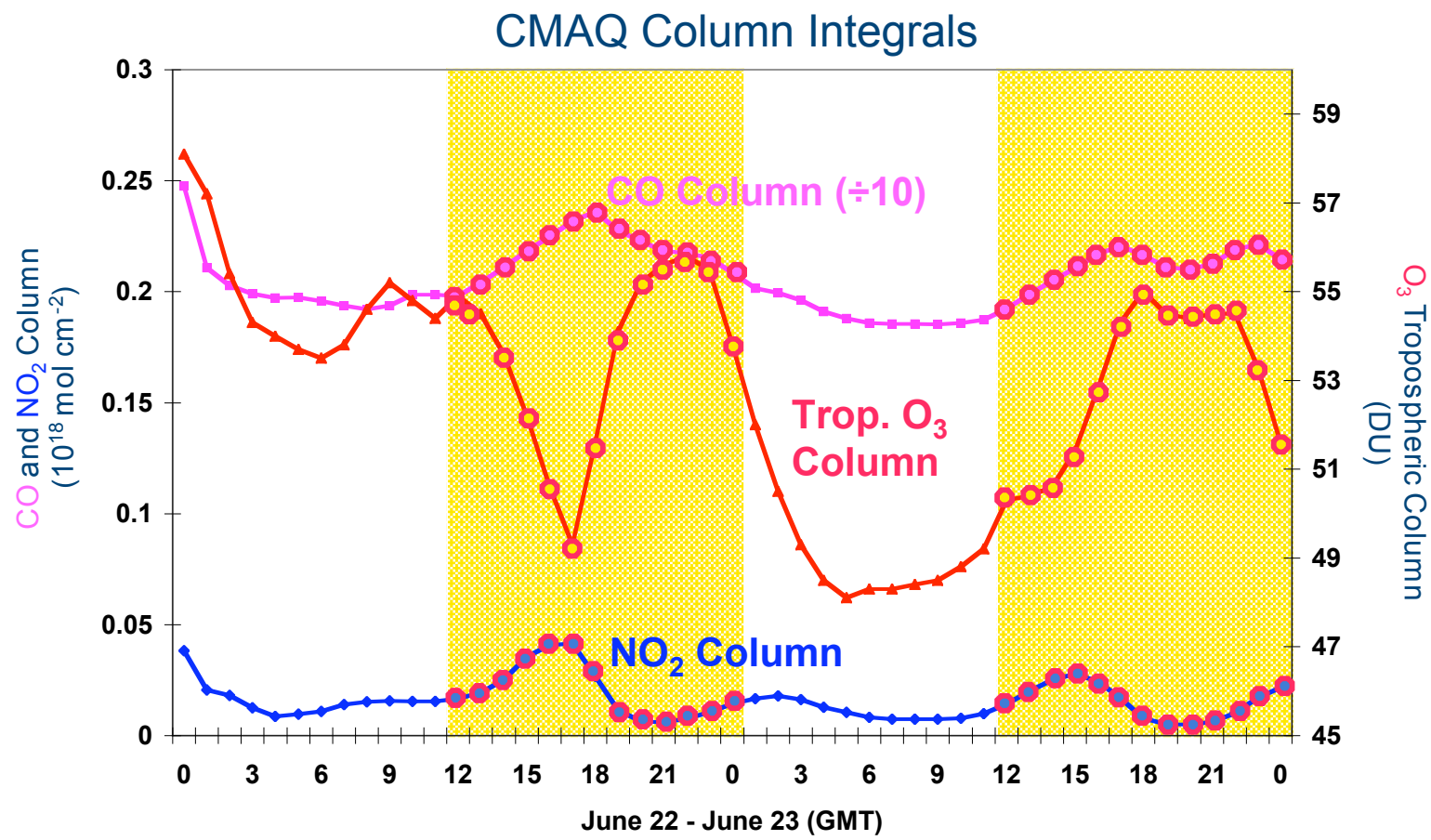


OMI NO_2

CMAQ Simulation Shows Significant Diurnal Variability for NO_2, CO and O_3 at Surface

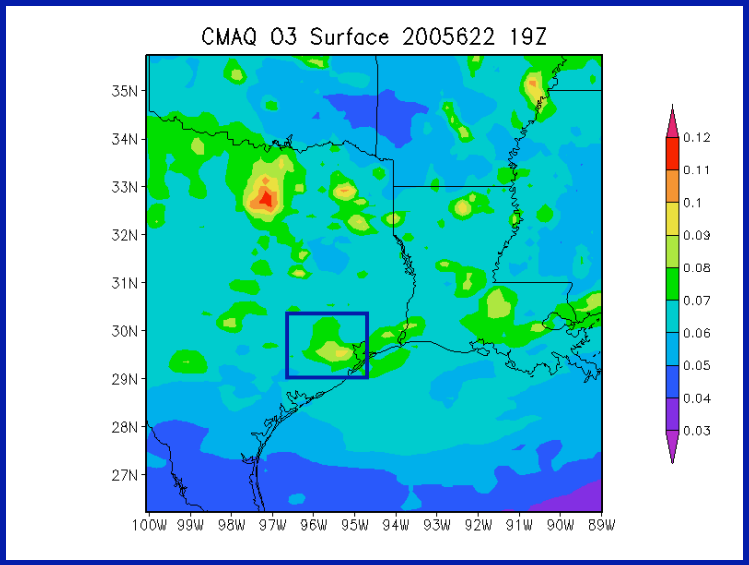


GeoTRACE Captures Diurnal Variability at Surface through Its Column Measurements

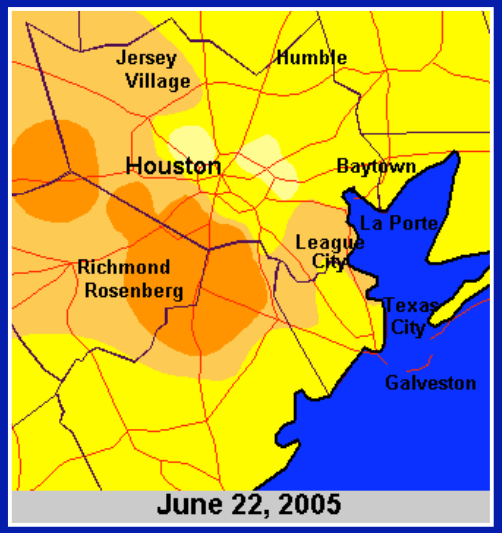


What is the State of Air Quality Forecasting, Where Do We Go From Here, and How Can Measurements from GeoTRACE Contibute?

CMAQ Captures Urban-Scale Ozone Gradient Near Houston at Surface and throughout Tropospheric Column



Model-Derived Surface O_3

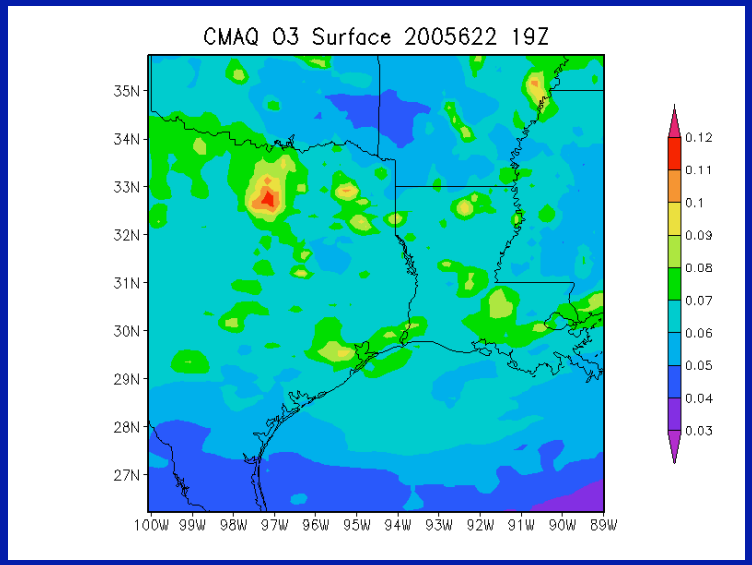


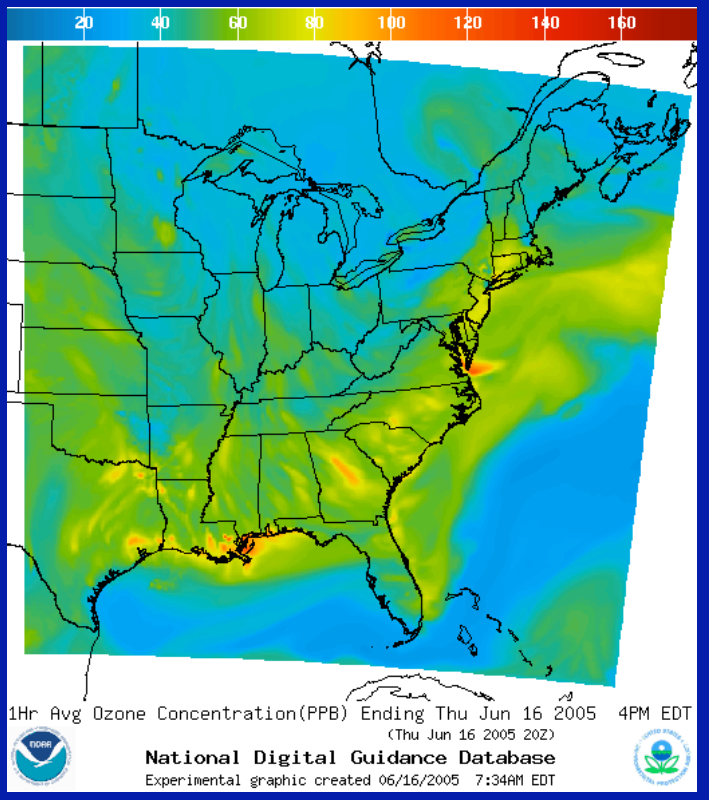
Observed Surface O_3 (Daily max)

Good Agreement between CMAQ Simulation and Surface Observations

The Scientific and Operational Challenge

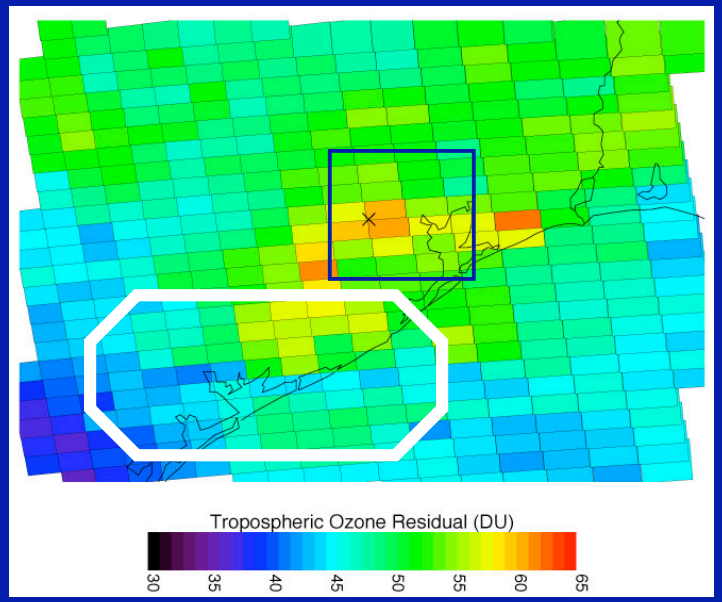
Expand Regional Scales like CMAQ to Synoptic-Scale Domains

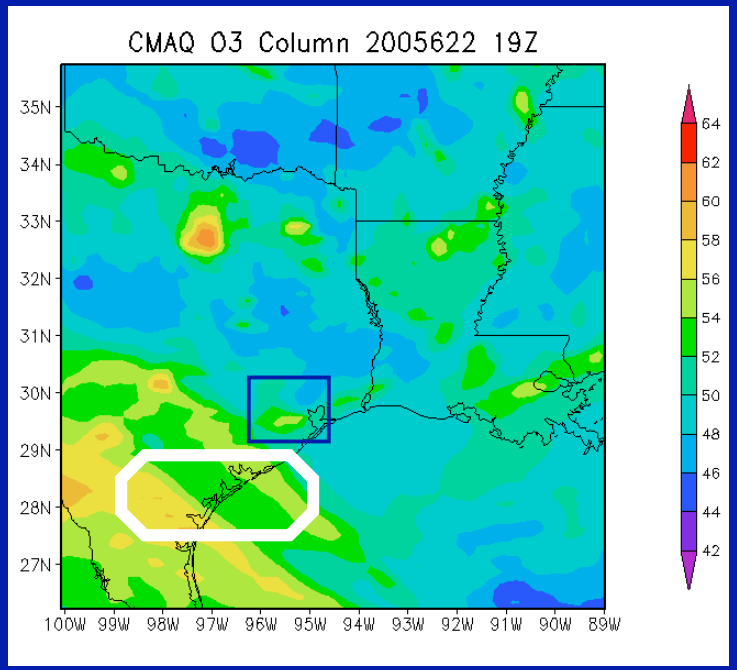




Despite Good Agreement within Metropolitan Houston Area

Simulation of larger-scale model domain needs improvement

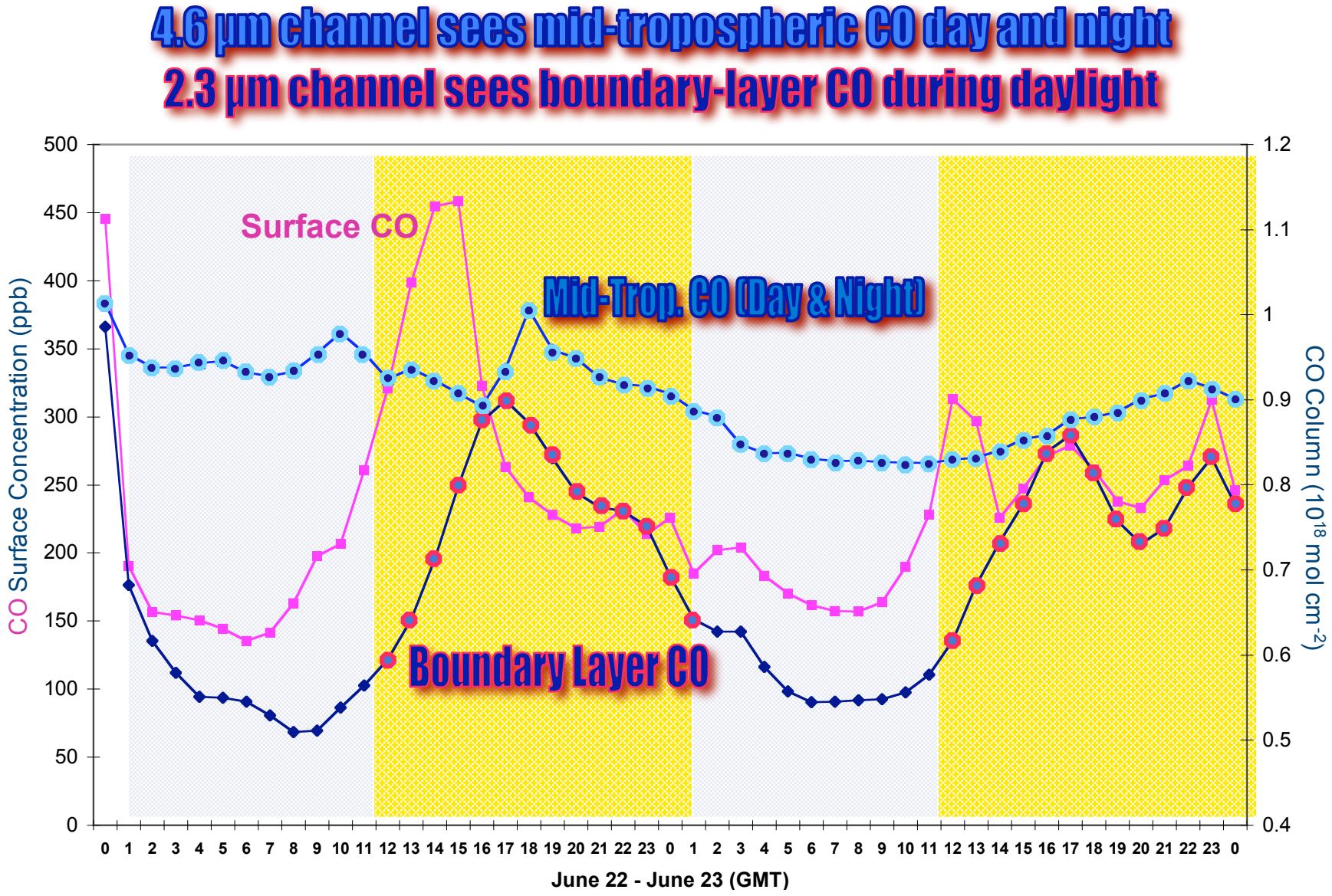




-Independent measurement in free troposphere provides important constraint

- Long-range transport - primarily a process in the free troposphere
- Model development requires synthesis of models that simulate physical processes on different spatial and temporal scales

GeoTRACE Provides Key Information by Measuring CO in Two Distinct Layers

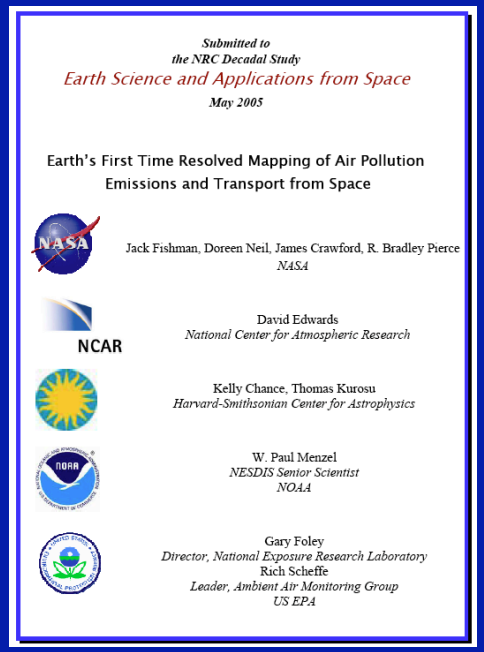


Summary

This Presentation Has Focused on the Many Challenges Facing the Air Quality Community to Provide *"Observations that encompass the research programs of NASA and the related operational programs of NOAA"*

- In response to these challenges, we have described a mission that responds to the NRC Decadal Survey's RFI:

"Earth's First Time Resolved Mapping of Air Pollution Emissions and Transport from Space"



Submitted to
the NRC Decadal Study
Earth Science and Applications from Space
May 2005

Earth's First Time Resolved Mapping of Air Pollution Emissions and Transport from Space

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Harvard-Smithsonian Center for Astrophysics

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NESDIS Senior Scientist
NOAA

Gary Foley
Director, National Exposure Research Laboratory
Rich Scheffe
Leader, Ambient Air Monitoring Group
US EPA

- The measurement concepts put forth in this RFI describe

GeoTRACE Mission Concept: Time-resolved Tropospheric Chemistry

- GeoTRACE measures tropospheric columns of chemically linked atmospheric constituents: O_3, CO, NO_2, SO_2, HCHO and aerosols
- GeoTRACE will provide two independent pieces of information about CO to uniquely provide insight on long-range pollution transport and the impact of the synoptic-scale environment on regional pollution formation
- GeoTRACE measures all of these constituents every hour across the entire continent at the same time
- ~5 km spatial resolution provides insight into processes that drive local pollution events
- GeoTRACE responds to the vision put forth by IGOS/IGACO
- In cooperation with the challenges facing NOAA and EPA, GeoTRACE is an integral part in the envisioned GEOSS ("system of systems")