2006 TexAQS Campaign and Rapid Science Synthesis: characterization of regional influences using global/regional assimilation systems

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Presenter: Jay Al-Saadi

TexAQS Background

- Texas Commission on Environmental Quality (TCEQ) responsible for State Implementation Plans (SIPs) by which to attain the 8-hour National Ambient Air Quality Standards (NAAQS) for Ozone and Related Photochemical Oxidants

- A primary mission objective was to provide data for "weight of evidence" for the SIP, accomplished through "rapid synthesis" of preliminary data from the mission

- Rapid Science Synthesis Team (RSST) charged to address 12 high priority SIP-relevant science questions for 2 very different ozone non-attainment areas in Texas:

    - Houston-Galveston-Brazoria (HGB), a COASTAL city of about 4 million people. HGB consists of eight counties in southeastern Texas and is subject to very distinctive sea-breeze meteorological conditions and extraordinarily large petrochemical sources of industrial emissions (especially the Houston Ship Channel and other nearby sources of industrial emissions).

    - Dallas-Forth Worth (DFW) is an INLAND city, also of about 4 million people. The DFW non-attainment area includes 8 counties in north-central Texas, with relatively typical inland metropolitan meteorological conditions and only limited industrial sources within the non-attainment counties but with several power plants in upwind locations within northeastern Texas.

http://esrl.noaa.gov/csd/2006/

NASA Involvement

- NASA/NOAA/TCEQ meeting November 2005 to explore opportunities to more fully integrate in situ and space-borne measurements of trace gases and aerosols during the TexAQS II intensive

- Project plan developed in follow-on discussions with members of the OMI, TES, and AIRS science teams, NASA HQ Airborne and Applied Sciences management, and US EPA and NOAA partners

- Proposed to provide
  1. NRT satellite data for TexAQS flight planning
  2. Model-based (RAQMS) "rapid synthesis" of airborne, ground-based, and remotely sensed data for verification of air quality modeling tools used in the SIP process

- Expectation that results would be used to define more formal procedures for integration of NASA satellite data, in conjunction with data from airborne field campaigns, into Decision Support Systems of State and Local planning offices

- Project closely linked to NASA Airborne Science projects funded under the Aura Validation program and to an EPA-funded Advanced Monitoring Initiative (AMI) Pilot Project entitled "Application of Integrated O_3 Observing System to Houston-Galveston-Gulf Shore Region and Eastern Great Lakes Region"

Focus Areas of our Team and Collaborators

- Our studies address Questions G and H of the TEXAQS-II rapid science synthesis: **How do emissions from local and distant sources interact to determine the air quality in Texas,** and **which areas outside of Texas adversely affect the air quality of non-attainment areas within Texas?**

- Synthesis of the Real-time Air Quality Modeling System (RAQMS), satellite data, airborne measurements, and surface data. *A unique aspect of the RAQMS analyses is the incorporation of satellite data to improve the chemical analysis and the use of fire counts from the MODIS instrument onboard the NASA Terra and Aqua satellites to generate biomass burning emissions.*

TES Observations – Aug 30, 2006

> TES Global Survey

> High ozone in the troposphere over the Gulf of Mexico seen in Trop Column

> Lower values over East TX

Tropospheric O3 Column - Run 4948 - Aug 30, 2006
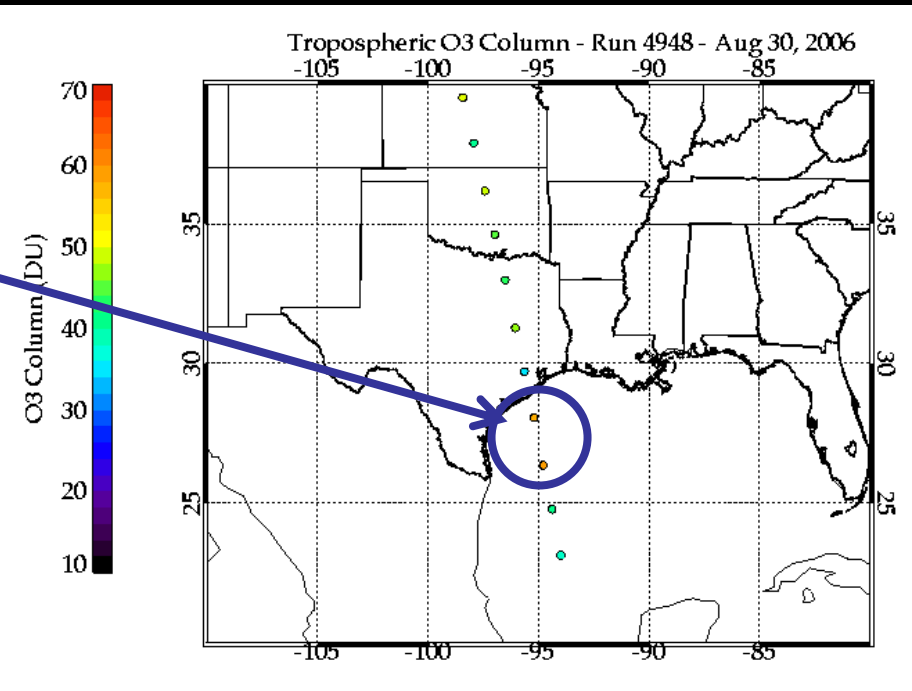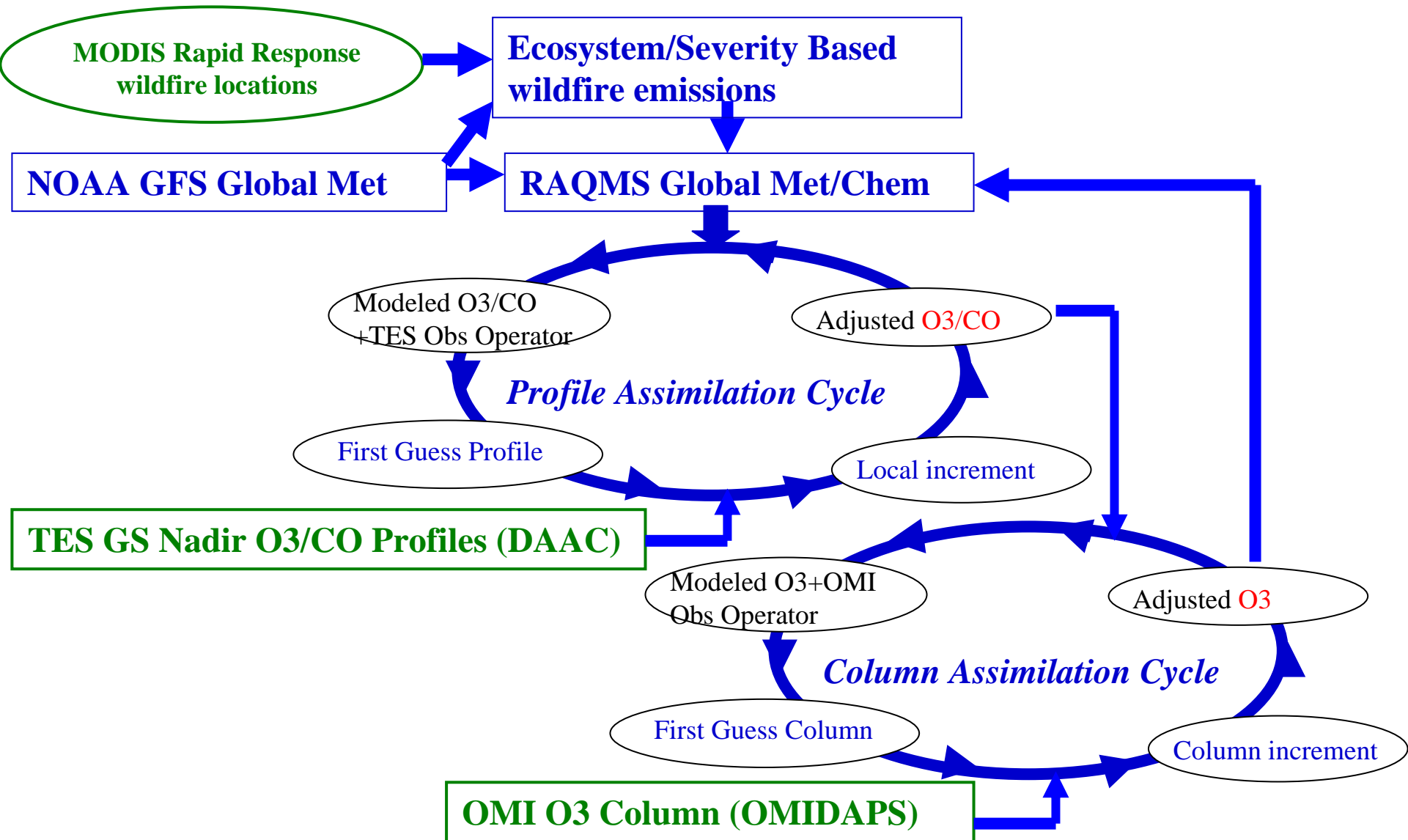
TES Step & Stare - RunID 4948
Ozone
Aug 30, 2006
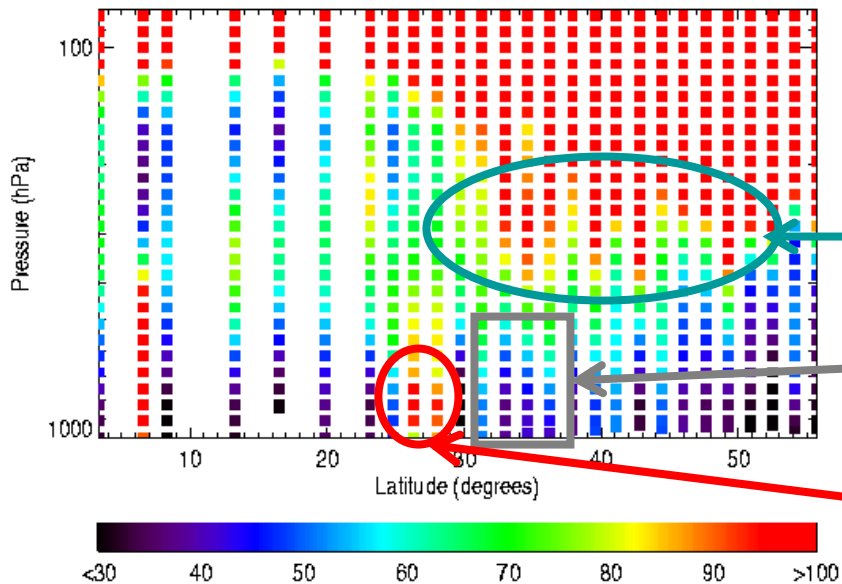
> Enhancement in ozone in middle troposphere over TX, OK, KA

> Low ozone in lower troposphere over East Texas, Central Oklahoma

> High ozone in lower troposphere over the Gulf (still under investigation)

Greg Osterman (JPL)

Impacts of background ozone on Houston and Dallas Air Quality during the NOAA 2006 TEXAQS field mission

The global component of RAQMS is used to investigate the impact of continental scale ozone production on Houston and Dallas air quality from July 15 through October 15, 2006

1. NASA satellite and NOAA airborne measurements are used to determine the fidelity of the RAQMS chemical analyses.

2. Ensemble Lagrangian trajectory analysis is used to determine the source regions associated with enhanced regional ozone production for the Houston and Dallas receptor regions.

RAQMS$_{global}$ (2x2) OMI/TES Reanalysis O3/CO Assimilation Procedure

MODIS Rapid Response wildfire locations

Ecosystem/Severity Based wildfire emissions

NOAA GFS Global Met

RAQMS Global Met/Chem

Modeled O3/CO +TES Obs Operator

Adjusted O3/CO

Profile Assimilation Cycle

First Guess Profile

Local increment

TES GS Nadir O3/CO Profiles (DAAC)

Modeled O3+OMI Obs Operator

Adjusted O3

Column Assimilation Cycle

First Guess Column

Column increment

OMI O3 Column (OMIDAPS)

Biomass Burning Emission Estimates = (Area Burned) x (Available Fuel)

Estimated using MODIS Rapid Response fire detections (ftp://mapsftp.geog.umd.edu)

Databases of the amount of Carbon fuel consumed in each ecosystem under three classes of fire weather severity (low, medium and high)

Haines Index (moisture and stability of the local atmosphere)

Emissions of other species (NOX, NMHC's) are calculated from these carbon emissions using ecosystem dependent emission factors.
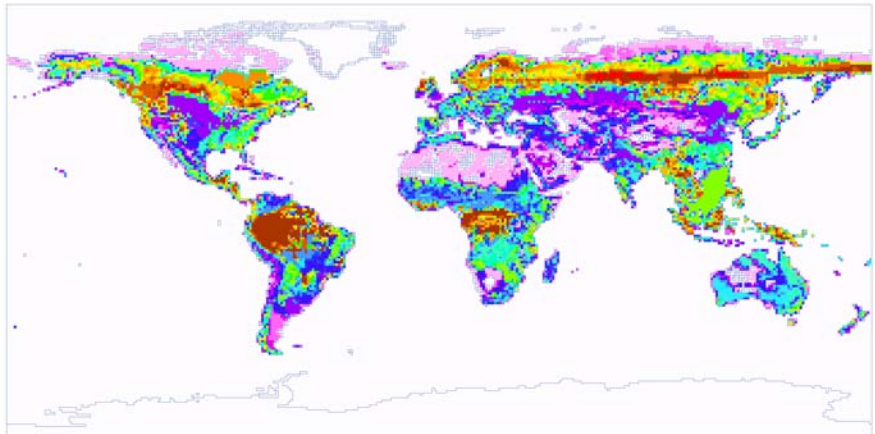
Example: Global carbon consumption estimates for *high-severity* fires

Global Carbon Consumption Estimates Hsv_kgC_m2			
0.000000 - 0.203000	1.030001 - 1.320000	2.995001 - 3.385000	6.280001 - 7.163000
0.203001 - 0.440000	1.320001 - 1.595000	3.385001 - 3.805000	7.163001 - 8.250000
0.440001 - 0.720000	1.595001 - 1.905000	3.805001 - 4.275000	8.250001 - 9.701000
0.720001 - 1.030000	1.905001 - 2.240000	4.275001 - 4.840000	9.701001 - 13.300000
	2.240001 - 2.615000	4.840001 - 5.518000	
	2.615001 - 2.995000	5.518001 - 6.280000	

RAQMS Tropospheric NO2 CONUS August, 2006
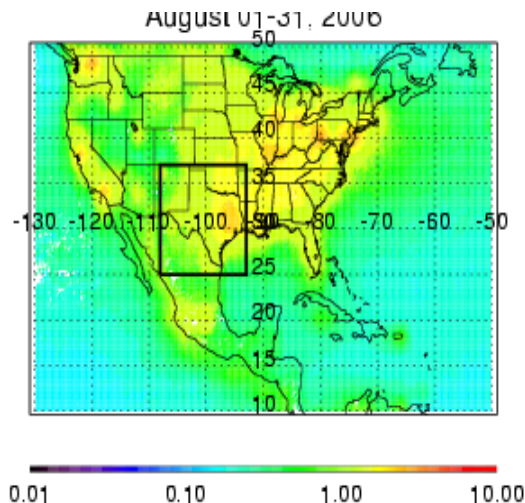
OMI Tropospheric NO2 CONUS August, 2006
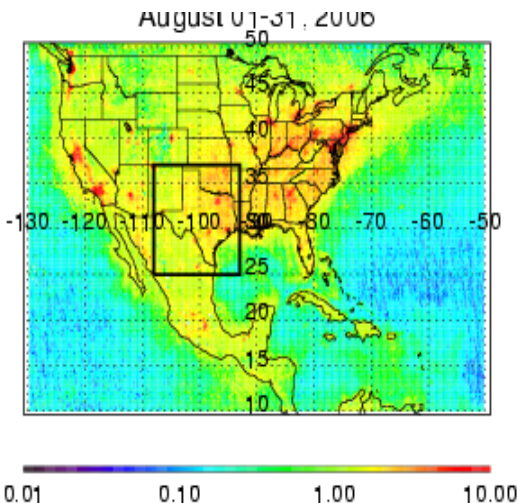
RAQMS Tropospheric NO2 vs. NOAA P3
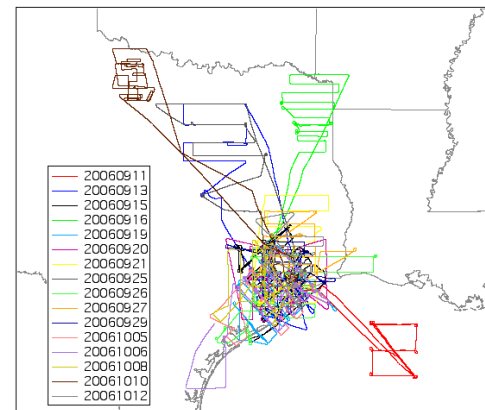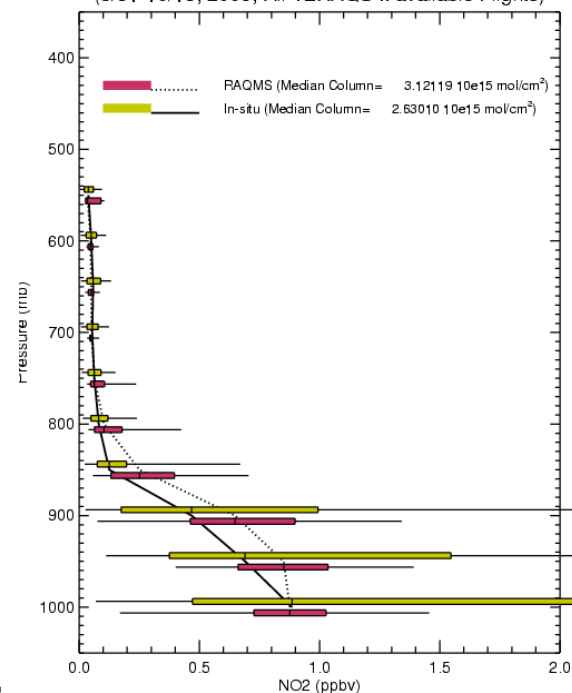
- RAQMS <u>mean</u> trop NO2 column is <u>low</u> by a factor of up to 2 relative to OMI over TX
- RAQMS <u>median</u> boundary layer NO2 profile is <u>high</u> by ~30% relative to P3 measurements
- Similar comparisons with OMI O3, MOPITT CO, and P3 measurements

# RAQMS vs EPA AIRNow July 15-Oct 15, 2006
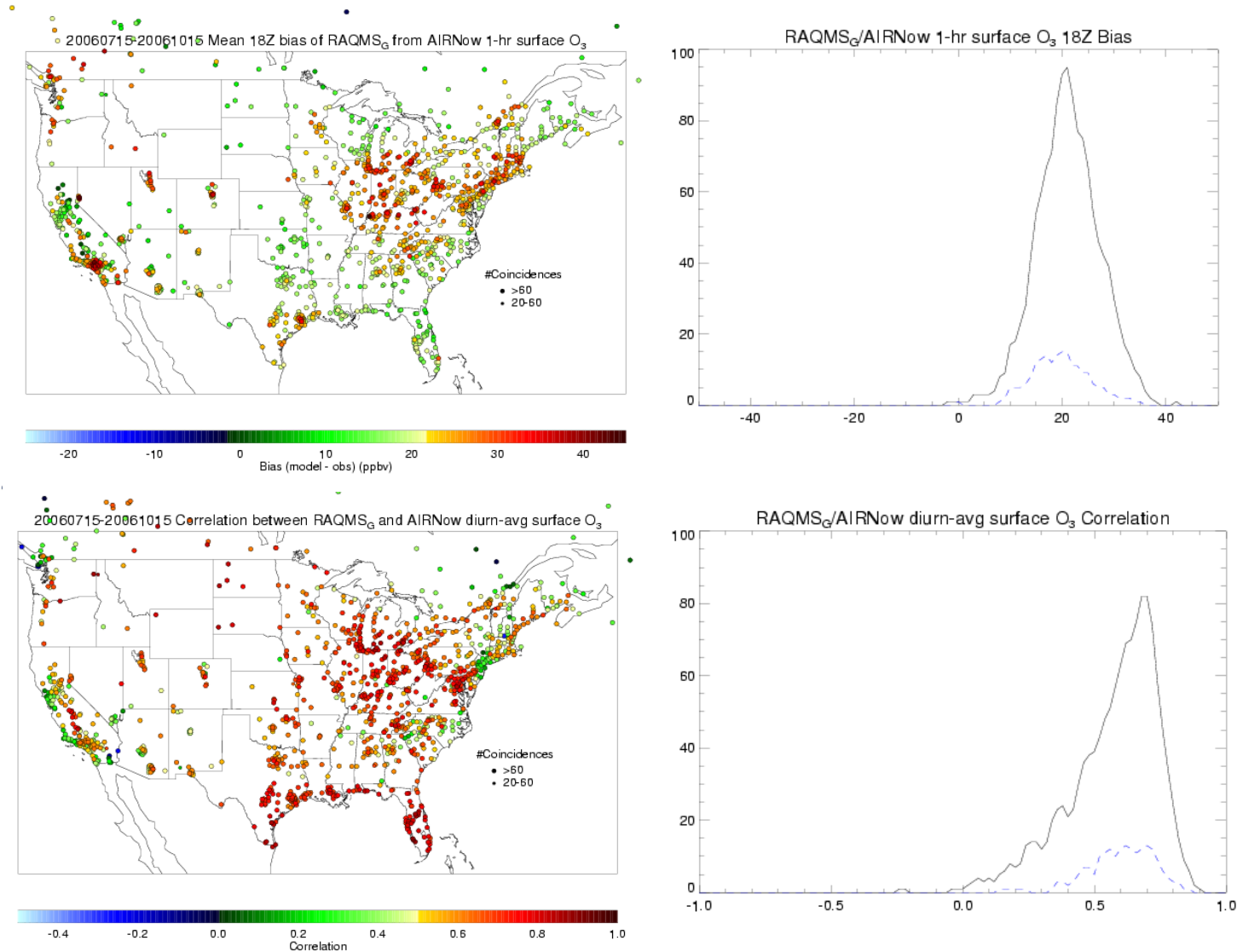
RAQMS diurnally averaged surface O3 analyses are reasonably correlated (>0.7) with EPA AIRNow observations over the eastern US but show 18Z median biases of up to 30ppbv over the eastern US

Approach

- Ensemble back trajectories are initialized at 18Z from surface EPA AIRNOW ozone monitoring stations within the Houston and Dallas metropolitan statistical areas (MSA)

- Lagrangian averaged estimates of composition and net O3 production rates (P-L) are computed along the back trajectories using the bias-corrected RAQMS chemical analyses

- Lagrangian averaged O3 P-L rates computed during time periods when the back trajectories are outside the respective MSA are used as a metric to classify regional background O3 influence
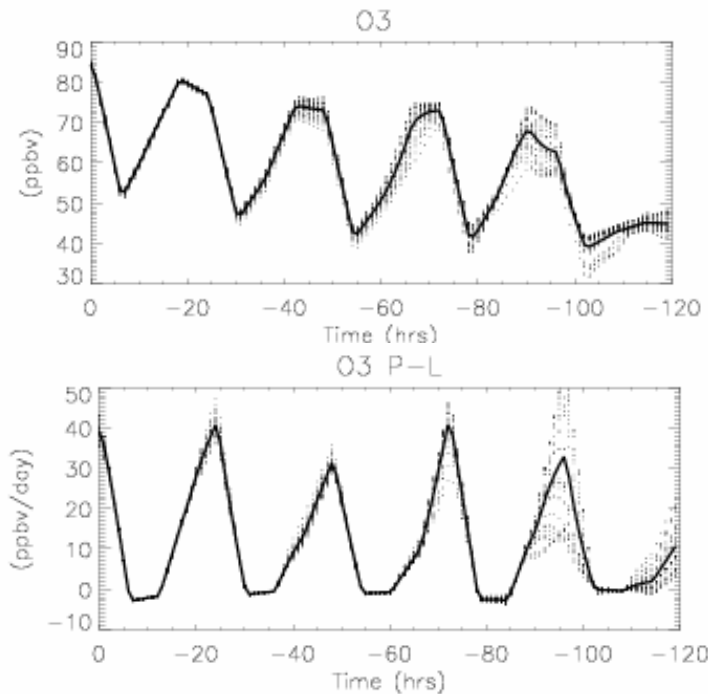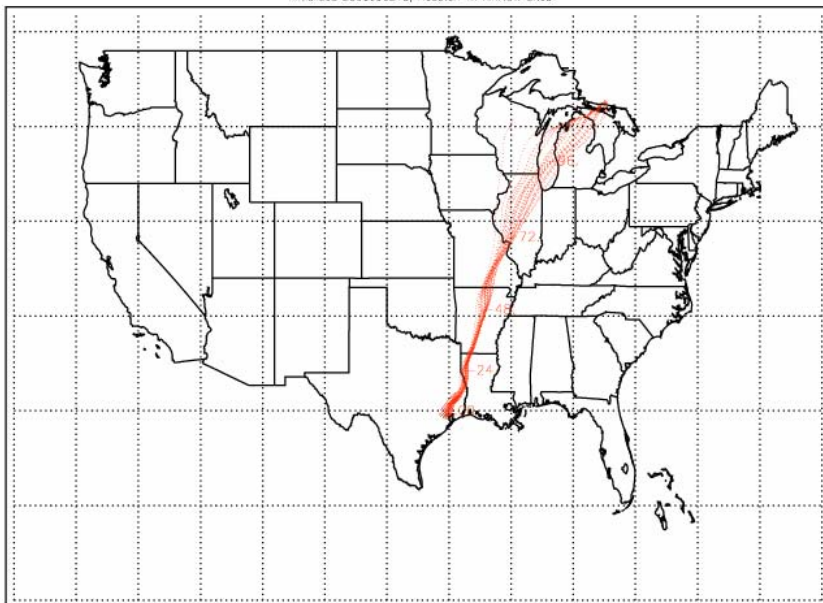
Impacts of background ozone production: Houston July 15-October 15, 2006

Classifications:

Class 1: Enhanced background ozone production (ensemble mean 5-day Lagrangian averaged O3 P-L > 10 ppbv/day)

Class 2: Moderate background ozone production (ensemble mean 5-day Lagrangian averaged O3 P-L > 0 ppbv/day and < 10 ppbv/day)
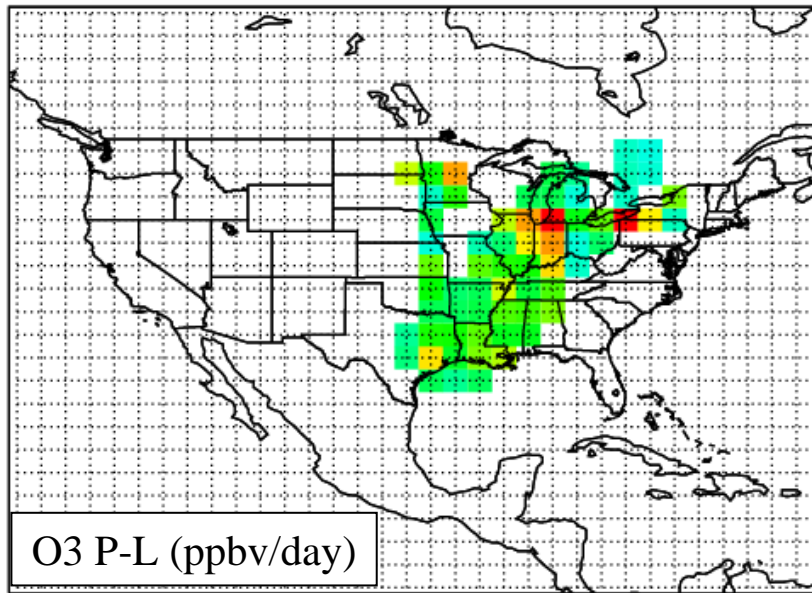
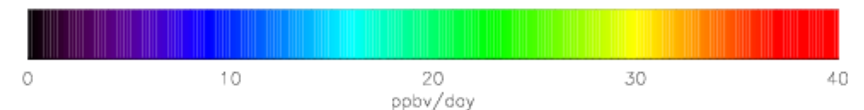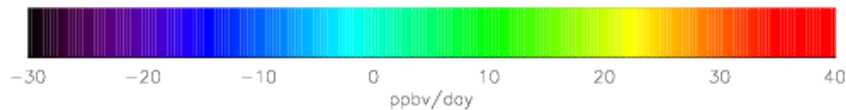**Class 3:** Background ozone destruction (ensemble mean 5-day Lagrangian averaged O3 P-L < 0 ppbv/day)

Houston 18Z O3 Timeseries Jul 15-Oct 15 2006

Red=AIRNow MSA mean+Std
Blue=RAQMS MSA (solid) and Regional (dashed) bias corrected mean
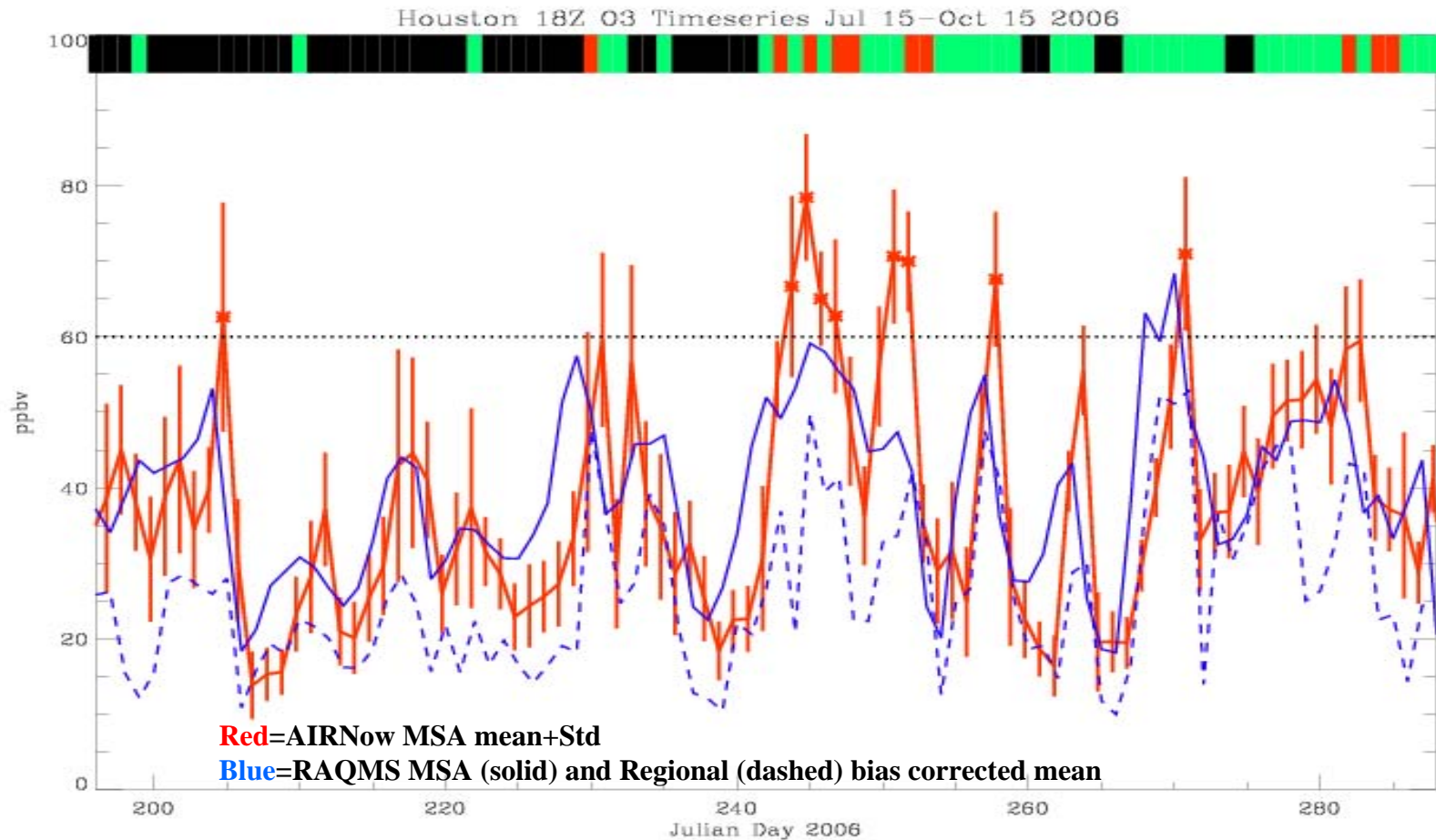
Houston Class 1 (Enhanced background ozone production) Source/Region Contributions July 15-Oct 15, 2006
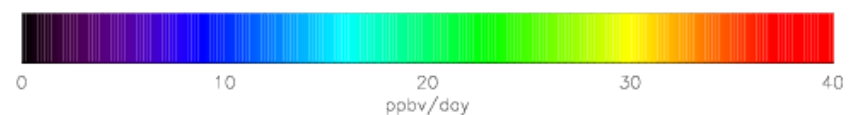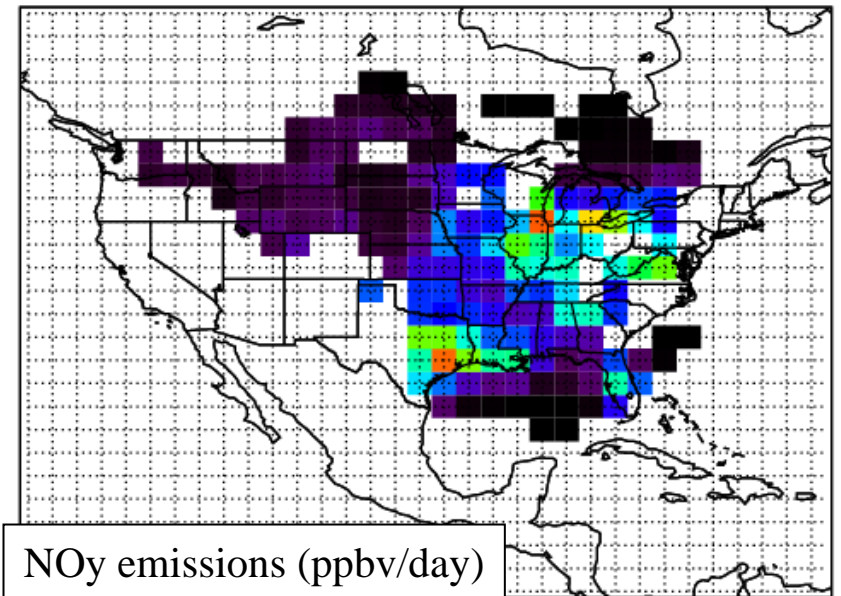

Class 1→Midwest/Ohio River Valley source with significant O3 P-L (40ppbv/ day) due to NOx sources along the southern Great Lakes.

Houston Class 2 (Moderate background ozone production) Source/Region Contributions July 15-Oct 15, 2006


- **Class 2** ➔ Distributed Eastern US sources and also moderate (10ppbv/day) O3 P-L due to biomass burning NOx sources in Pacific NW.

Houston Class 3 (background ozone destruction)
Source/Region Contributions July 15-Oct 15, 2006

Source Contribution to Jul 15 – Oct 15 2006 Houston Background O3 Production
Class: 5–day Lagrangian mean O3 P–L < 0 ppbv/day
(48.2989 % of Cases)

O3 P-L (ppbv/day)

Source Contribution to Jul 15 – Oct 15 2006 Houston Background NOy
Class: 5–day Lagrangian mean O3 P–L < 0 ppbv/day
(48.2989 % of Cases)

NOy emissions (ppbv/day)
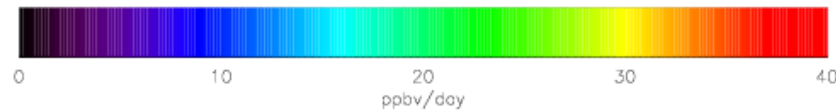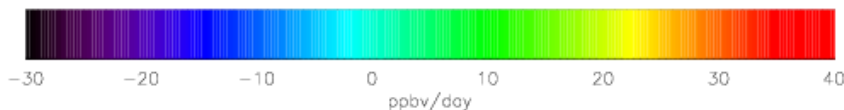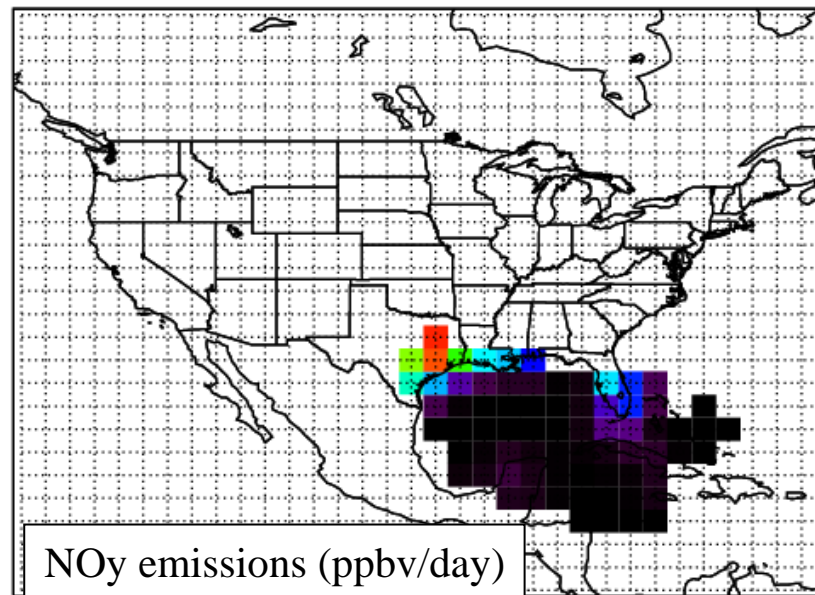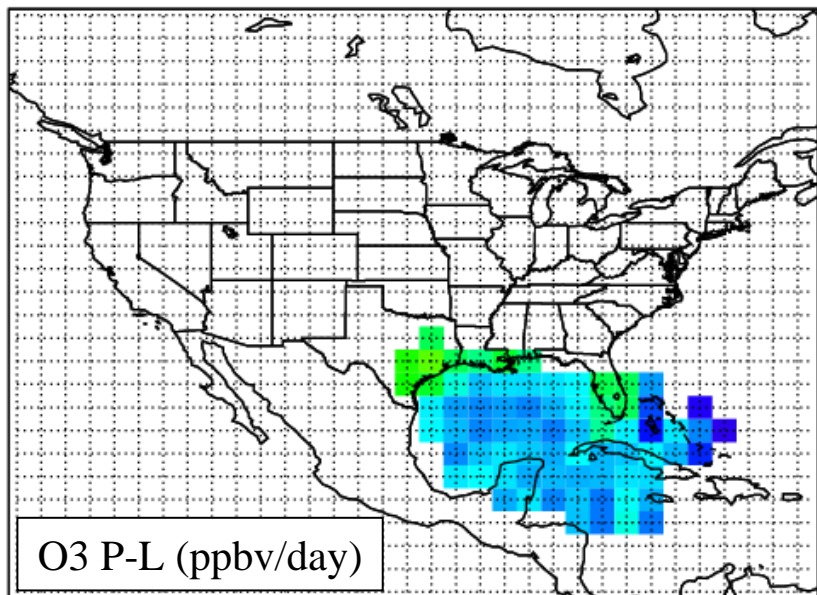
Class 3➡Net maritime O3 loss over Gulf of Mexico with moderate (10ppbv/day) O3 P-L due to NOx sources in Florida and Louisiana.

Summary

Continental US source contributions to daily 18Z mean Houston and Dallas ozone mixing ratios were estimated during July 15-Oct 15, 2006 using Lagrangian approaches

Three distinct regional influence classifications are developed based on the AIRNow ensemble mean 5-day Lagrangian averaged O3 P-L

Class 1 (Background O3 P-L > 10ppbv/day)
Class 2 (Background 0<O3 P-L<10ppbv/day)
Class 3 (Background O3 P-L<0ppbv/day)

Class 1 events: 10% (12%) of the Houston (Dallas) back trajectories.
Class 2 events: 42% (60%) of the Houston (Dallas) back trajectories.
Class 3 events: 48% (28%) of the Houston (Dallas) back trajectories.

Periods of enhanced regional ozone production (Class 1) precede 66% (6 out of 9) and 46% (7 out of 15) of the periods with elevated (Mean >60ppbv) AIRNOW ozone within the Houston and Dallas MSAs, respectively
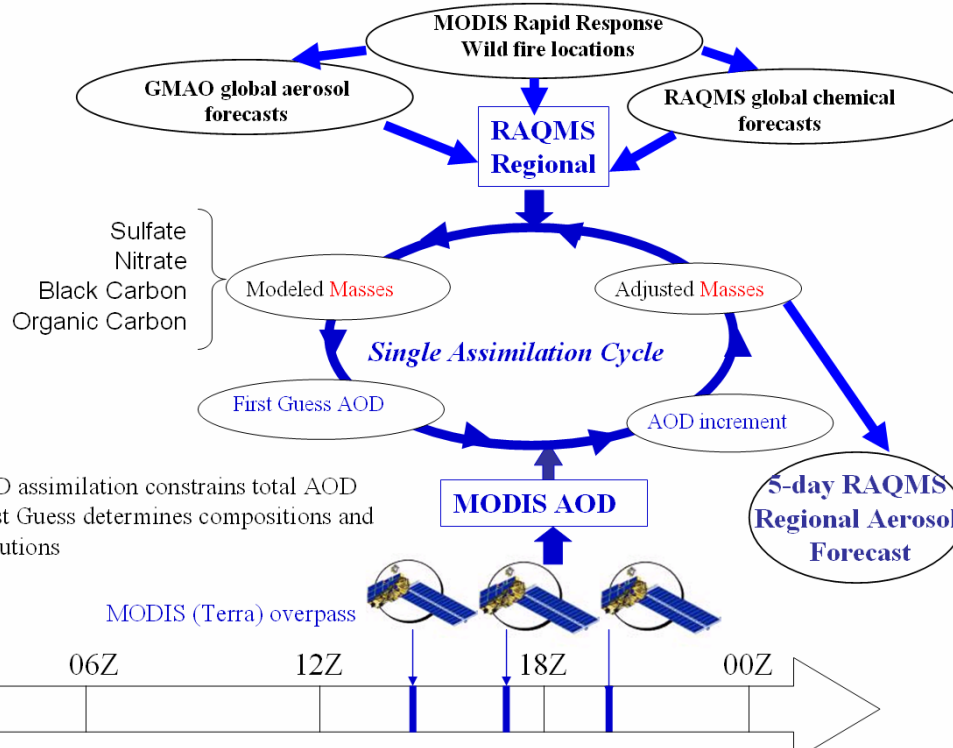
Synthesis of NASA King Air, MODIS, and CALIPSO aerosol observations during TexAQS II

R. Bradley Pierce (NOAA/NESDIS), Chieko Kittaka,
Jassim Al-Saadi, Chris Hostetler, Richard Ferrare, John Hair,
Dave Winker (NASA LaRC), Bryan Lambeth (TCEQ)

Modeling system used in Analysis (Chieko Kittaka, Lead)

Real-time Air Quality Modeling System (RAQMS)

RAQMS_regional (80km) AOD Assimilation/Forecast Procedure

- MODIS AOD assimilation constrains total AOD
- RAQMS First Guess determines compositions and vertical distributions

- **Assimilation of MODIS Direct Broadcast AOD**
- **CONUS domain (80km×80km×0.4km)**

- **RAQMS global analyses used for chemical constraints**

- **GMAO global aerosol analysis/forecast products used for lateral boundary conditions**

- **Convective transport due to fires is represented based on total carbon burned with the conversion factor of 8000 BTU/lb. The heat flux is partitioned into two components, sensible heat flux and radiative heat flux, and added to the soil layer of fire locations. Relative humidity is assumed to be 100 % where a fire location is.**

RAQMS Aerosol Mechanism:

- **Sulfate [Kittaka, 2004],**
- **Dust, Sea Salt, Carbonaceous Aerosol from GOCART [provided by Mian Chin, GSFC]**
- **Nitrate and Ammonium from GEOS-CHEM [provided by Rokjin Park, Harvard]**
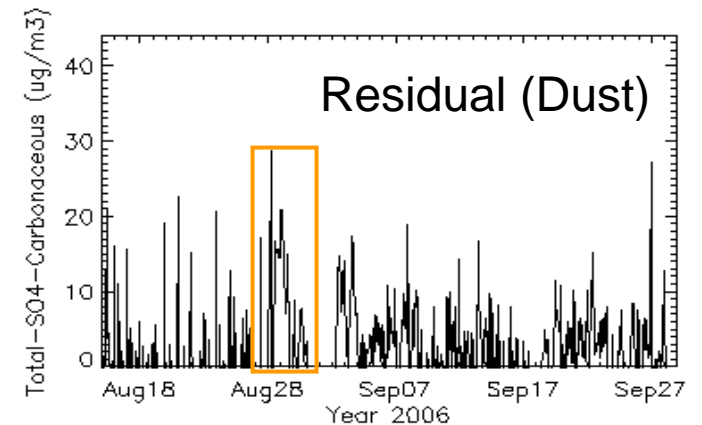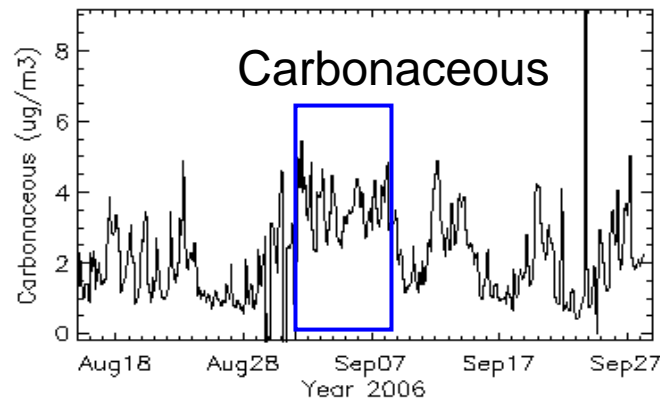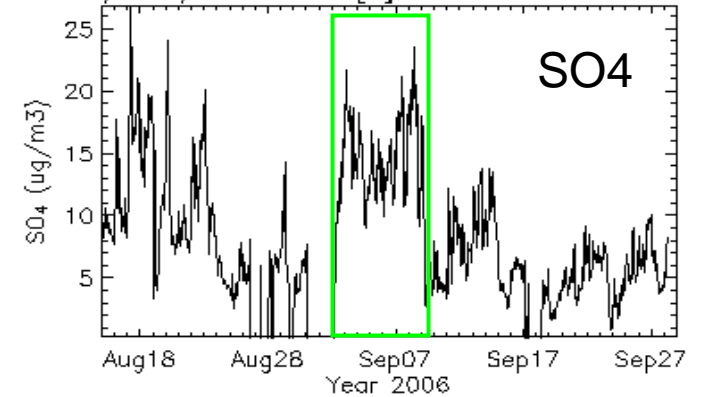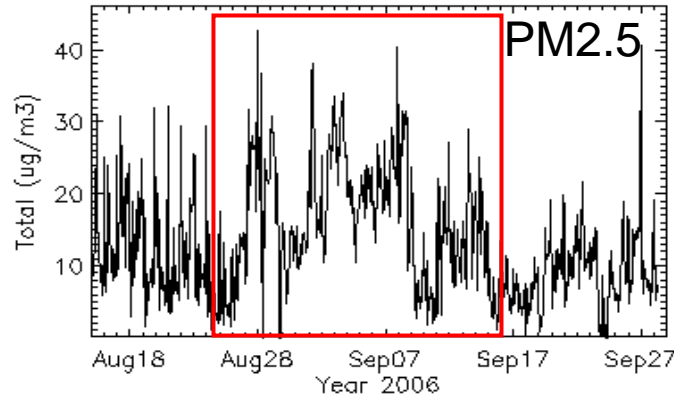
Deer Park surface data provided by TCEQ

Deer Park site

Analysis period: August 23-Sep 15th, 2006
August 28: Dust event
Sept 02-09: Sulfate/Carbonaceous event

CAMS 35, Region 12 Houston, EPA Site: 48-201-1039
Site: Hous.Deer Park 2 C35/1001/AFH139F239 [H]
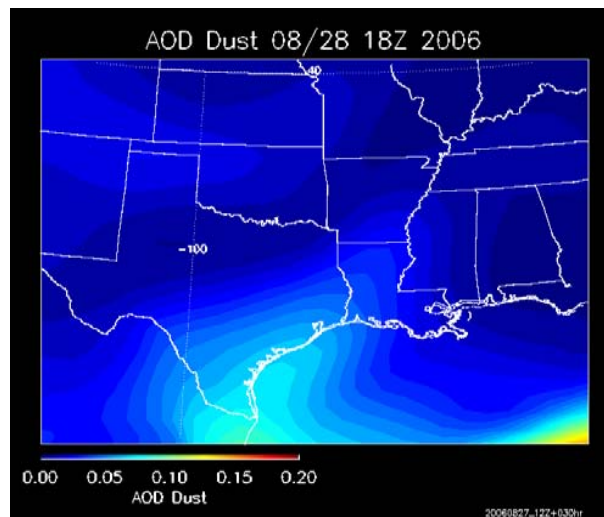
Dust Event: August 28th, 2006

RAQMS Dust analysis is in
reasonable agreement with
TCEQ residual dust estimates

Shows onshore transport
of dust from Gulf accounts for
Significant fraction of AIRNow
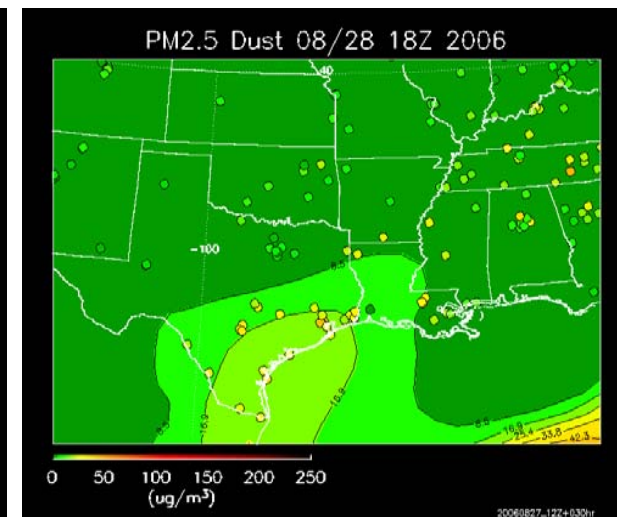total PM2.5 observations in
SE Texas on August 28th

CAMS 35, Region 12 Houston, EPA Site: 48-201-1039
Site: Hous.Deer Park 2 C35/1001/AFH139F239 [H]

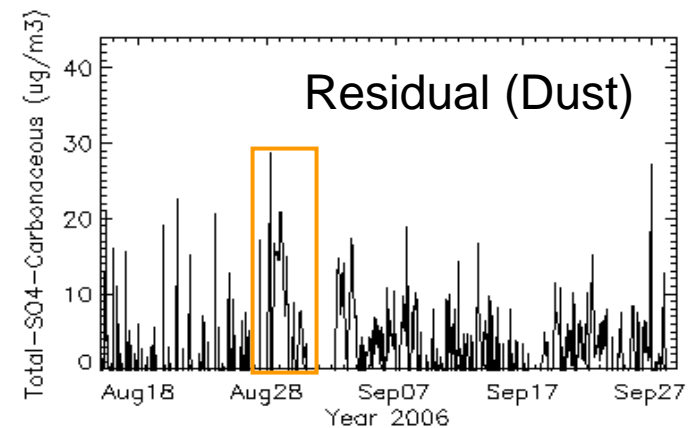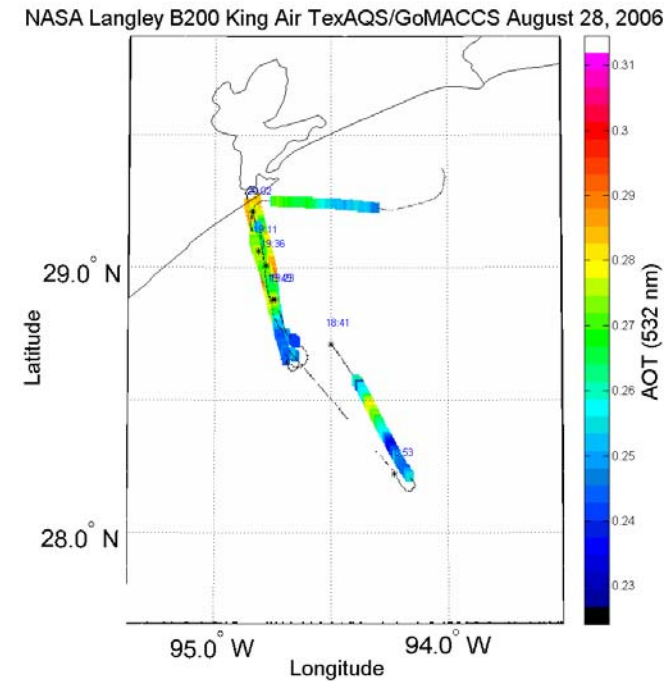Initialization from GMAO
(Overestimates Dust)

Residual (Dust)
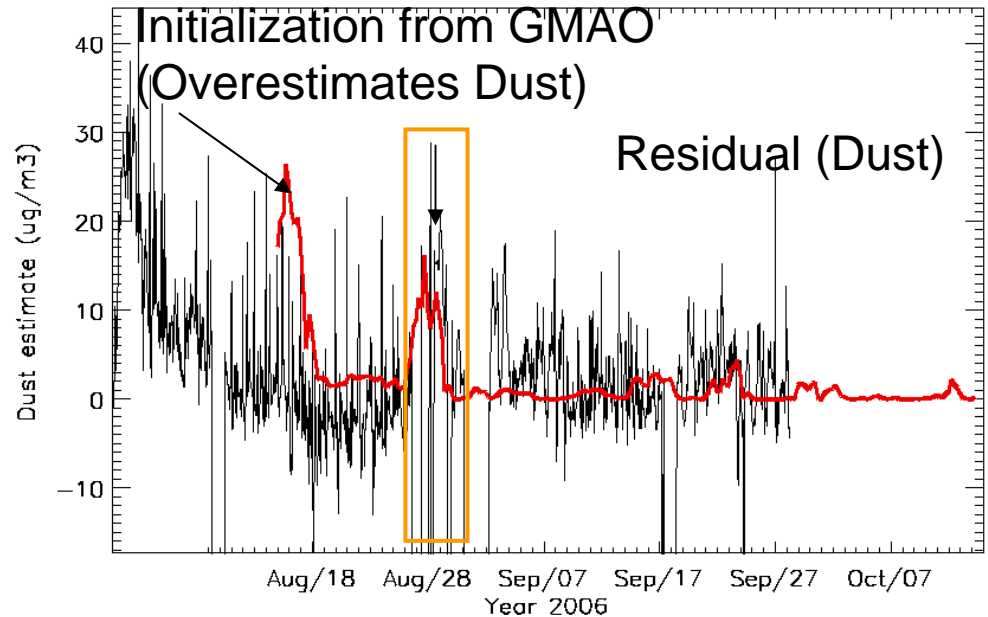
RAQMS Dust AOD   **RAQMS vs AIRNow PM2.5**

AOD Dust 08/28 18Z 2006

PM2.5 Dust 08/28 18Z 2006
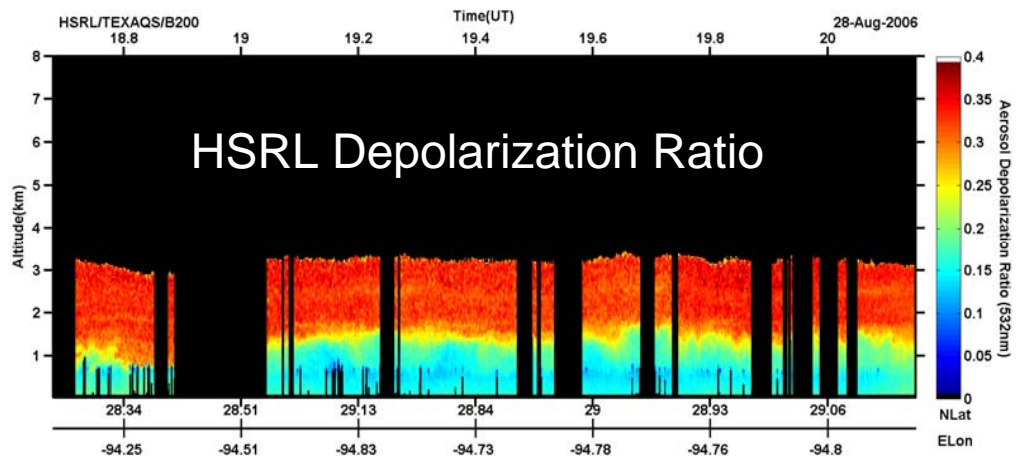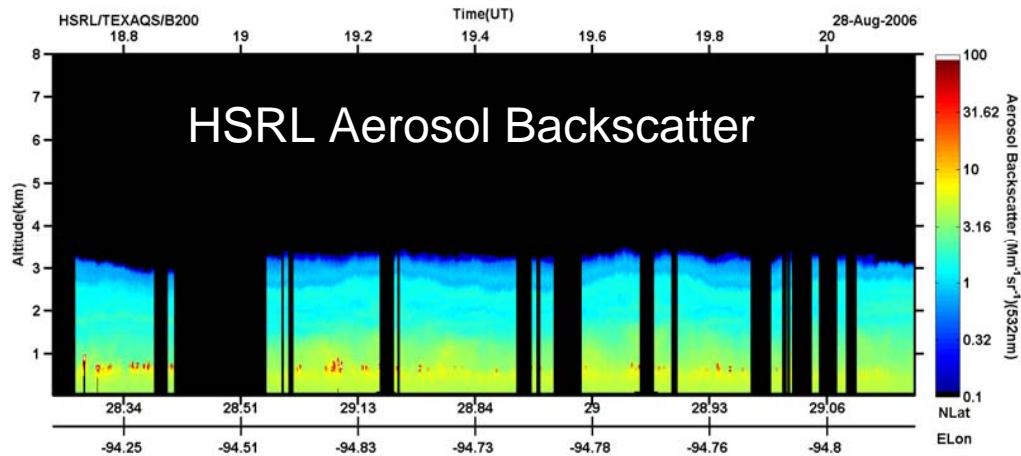
Dust Event: August 28th, 2006

Very High (>0.3) to High (>.15)
depolarization Ratios below 3km indicate Dust

HSRL Aerosol Backscatter

HSRL Depolarization Ratio

NASA Langley B200 King Air TexAQS/GoMACCS August 28, 2006

Residual (Dust)

CALISPO Backscatter profiles for August 17-28, 2006
Boundary Layer back trajectories from August 28 CALIPSO track shown in red

Aug 17

Aug 18

Aug 19

Aug 20

Aug 21

Aug 22

Aug 25

Aug 28
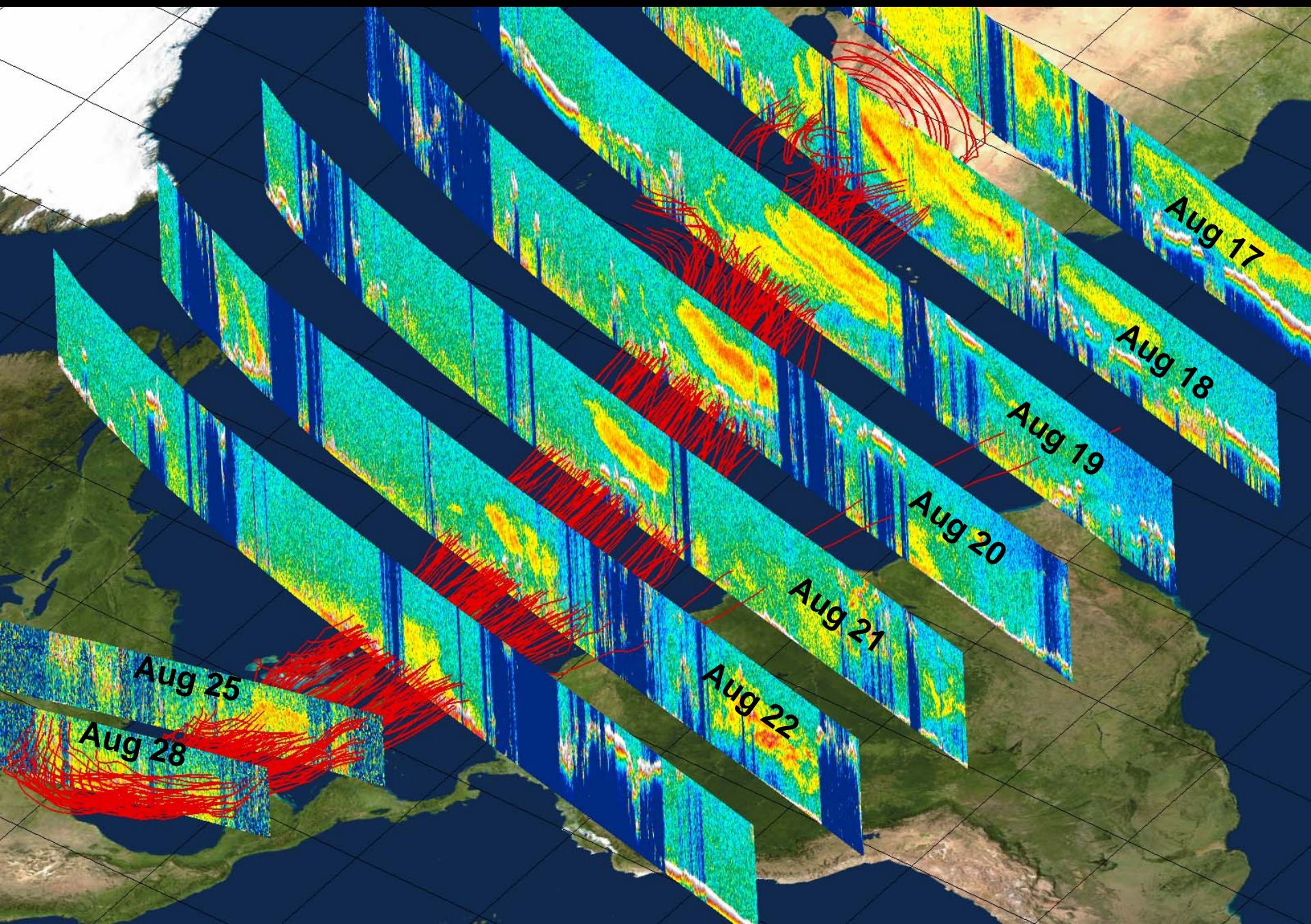
Summary

- The results from the O3 analysis were used to quantify the contributions of regional background ozone production on Houston and Dallas Air Quality within the TEXAQS II Rapid Science Synthesis Team (RSST) (**http://esrl.noaa.gov/csd/2006/rss/rsstprelimreport103106.pdf**)

- Analyses illustrating the importance of integrating observations from diverse platforms using advanced modeling/assimilation techniques for characterizing the impact of emissions from remote sources on local Texas air quality have been incorporated in the RSST report

- Enhancements in surface PM2.5 in Houston during early September were shown to be influenced by long-range transport of Saharan dust, primary aerosols (OC/BC) from wildfires in the Pacific NW, and sulfate production during transport from the eastern US

- The collaborations established during this work have lead to 2 proposals to the Applications "Decisions" component of ROSES 2007

- Programmatic Aside: discussion about whether this "Air Quality Rapid Prototype" fit the intent of the Applications Program Rapid Prototyping Capability (RPC)