Regional Influences on Houston and Dallas Air Quality During TEXAQS II

Synthesis of measurements from
EPA AIRNOW, NOAA P3, NASA AIRS, TES, OMI, MODIS, CALIPSO, HSRL and RAQMS chemical/aerosol analyses

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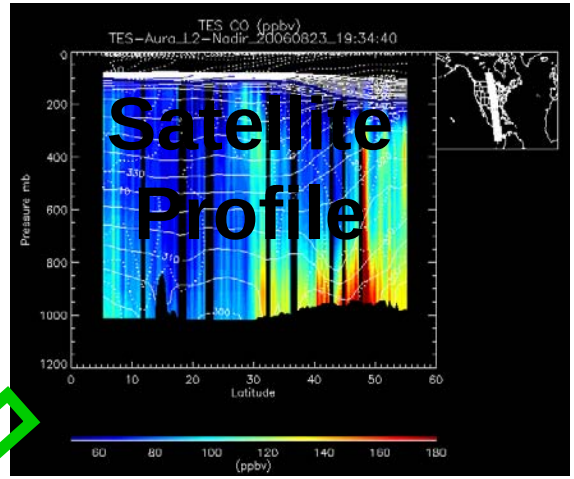
Tom Ryerson, John Holloway, Bryan Lambeth, Jim Szykman,
Lorraine Remer, David Winker, Chris Hostetler, Arlindo daSilva, Chris Barnet
For providing
insitu measurements, satellite retrievals, and model forecasts used in this analysis

Addressing RSS Science Questions G, H
"Background ozone and aerosol concentrations and the role of regional transport"

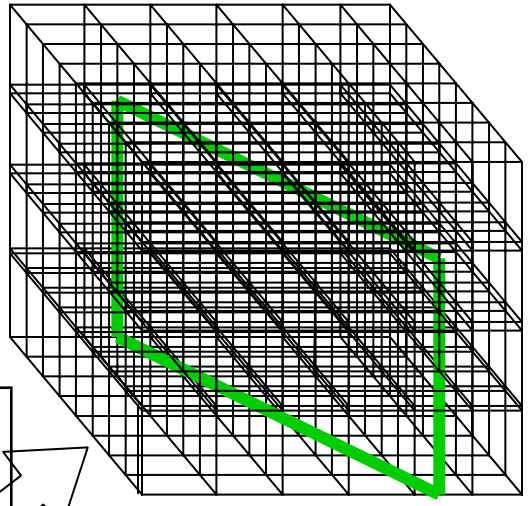
Approach:

•**Surface and airborne measurements** are used to characterize receptor region and verify model forecasts on local scale
•**Satellite measurements** are used to quantify source strengths and verify model forecasts on a regional to global scale.
•**Nested (global-to-regional) chemical and aerosol forecast models** are used to provide estimates of background composition
•**Ensemble Lagrangian trajectories** are used to identify remote source regions. Trajectories sample forecasted chemical and aerosol fields to understand chemical transformation during transport.

Local Characterization

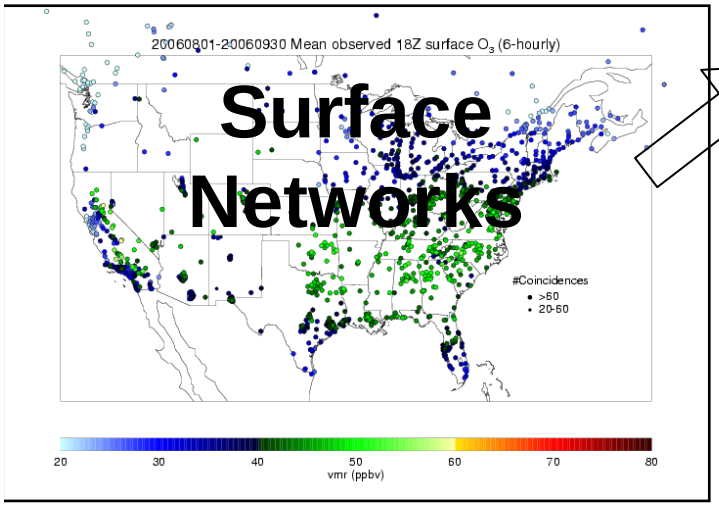


Vertical Structure

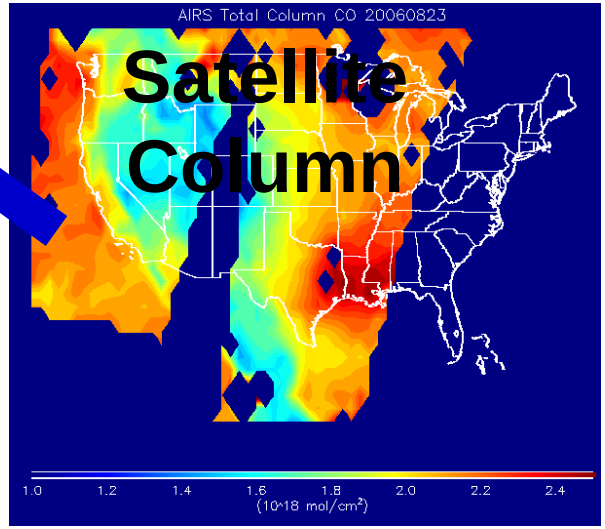


3D Model
Trajectory Model

Analysis and Prediction



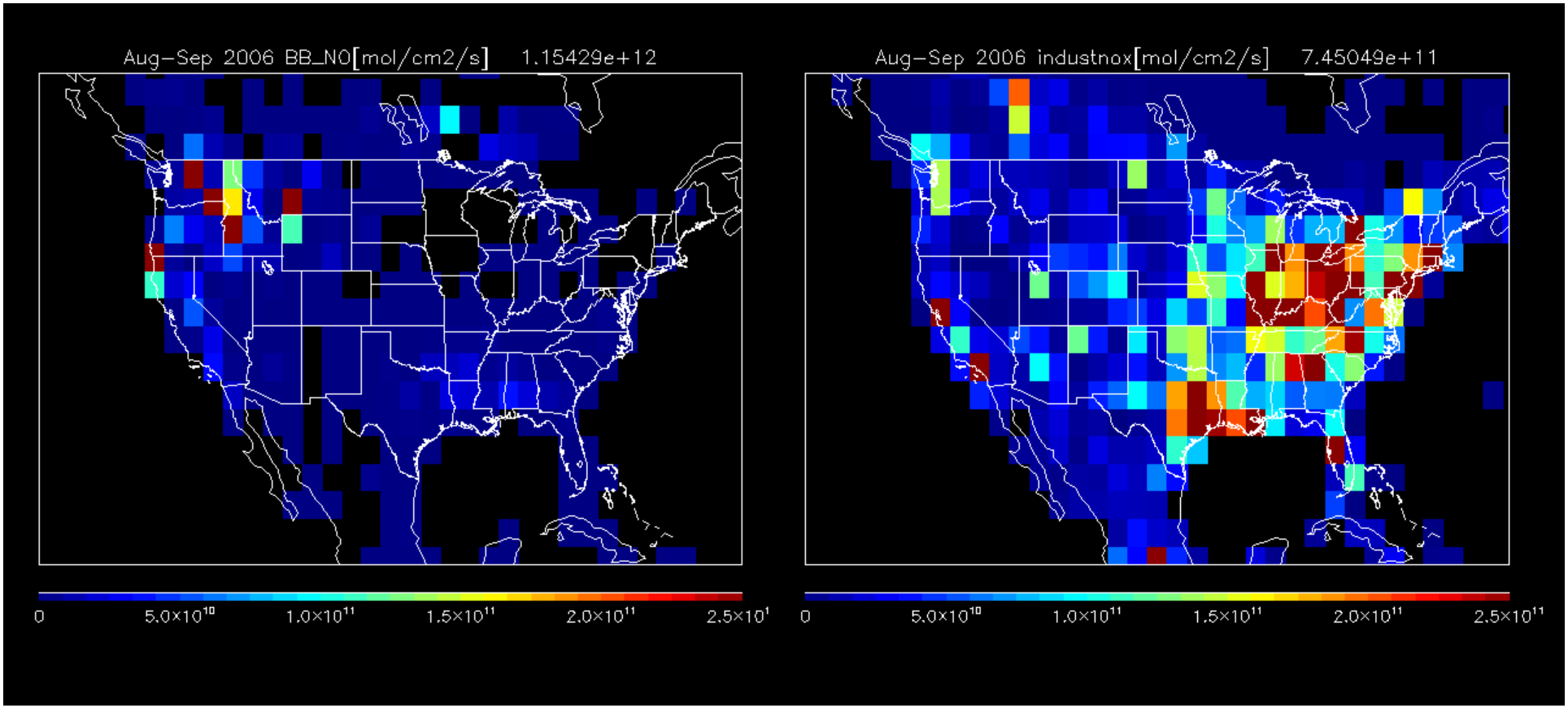
Regional Characterization



Column Abundances

Use chemical/aerosol forecast models and trajectory analysis to link local airborne lidar and insitu observations within receptor regions (Texas) to satellite observations in source regions (CONUS)

NOx emission inventory for $RAQMS_{global}$ TEXAQS 2006 Analysis



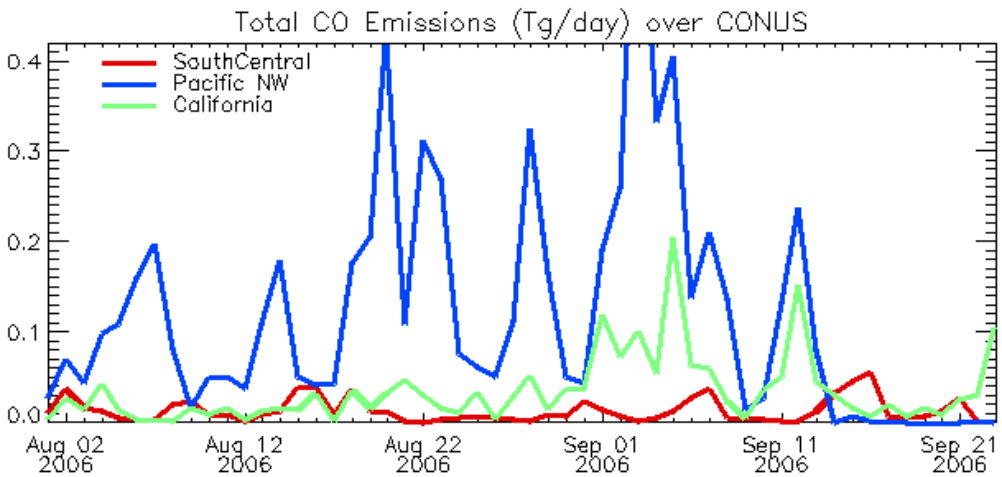
The RAQMSglobal industrial emissions are within 10% of the 2002 EPA National Emissions Inventory [Pierce et al., 2006] but do not account for reductions in NOx emissions in the Ohio River valley since 2002.

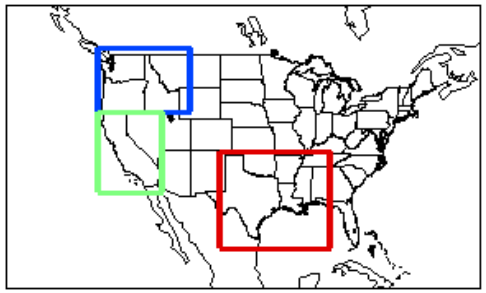
The RAQMSglobal biomass burning emissions used a spatially and temporally explicit model that incorporates a satellite-based (MODIS) fire database and ecoregion-specific carbon consumption estimates for three classes of severity to estimate a range of total direct carbon and trace gas emissions from wild fires.

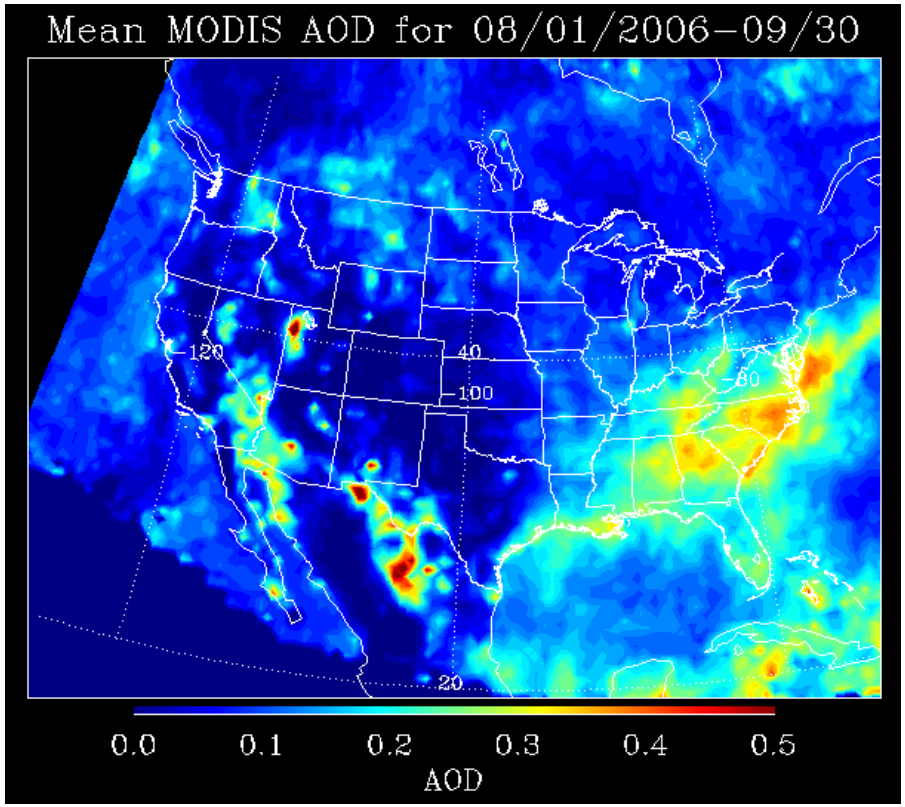
National Interagency Fire Center (http://www.nifc.gov/fireinfo/nfn.html)
Year-to-date Statistics:

2006 (1/1/06 - 9/29/06) Fires: 83,752 Acres: 9,074,358
2005 (1/1/05 - 9/29/05) Fires: 53,175 Acres: 8,160,688
2004 (1/1/04 - 9/29/04) Fires: 60,934 Acres: 7,737,472
2003 (1/1/03 - 9/29/03) Fires: 49,180 Acres: 3,167,289
2002 (1/1/02 - 9/29/02) Fires: 67,265 Acres: 6,578,985
2001 (1/1/01 - 9/29/01) Fires: 63,067 Acres: 3,221,391
2000 (1/1/00 - 9/29/00) Fires: 80,158 Acres: 6,862,561

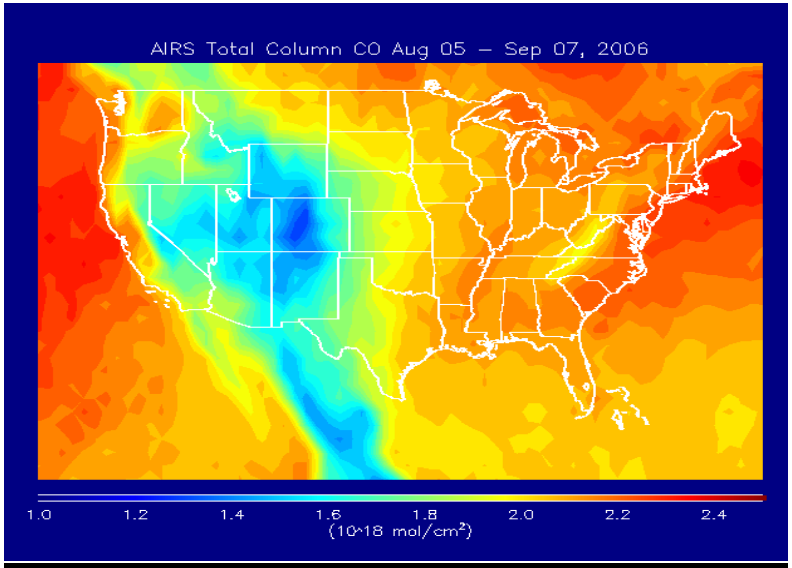
Wild fire influences during 2006 where higher than the previous 6 years by 110 -280%

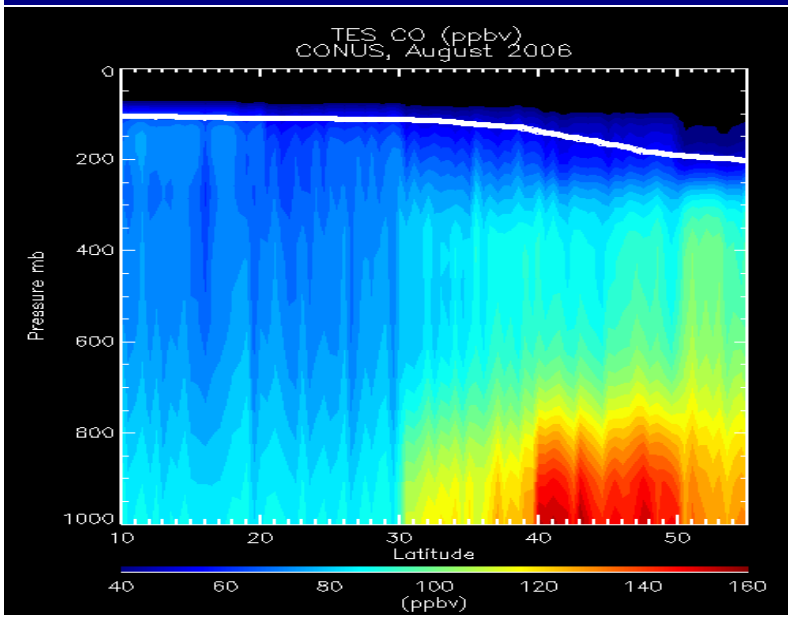




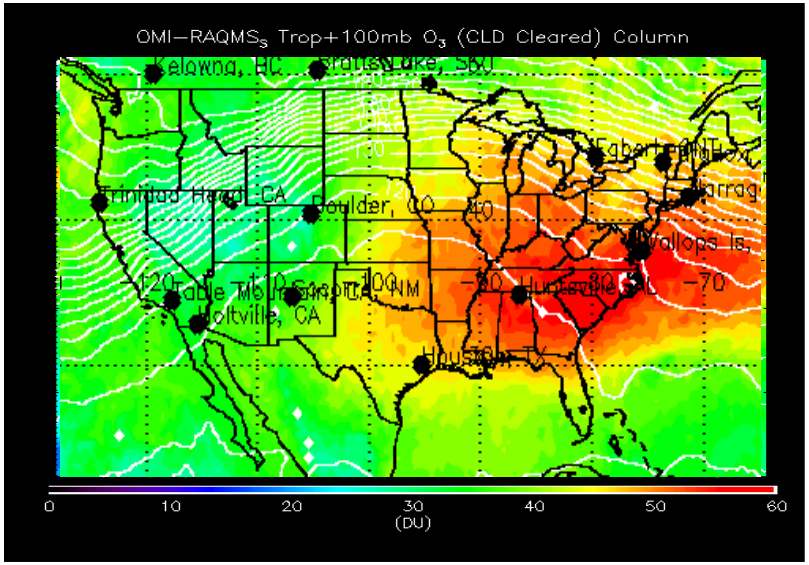


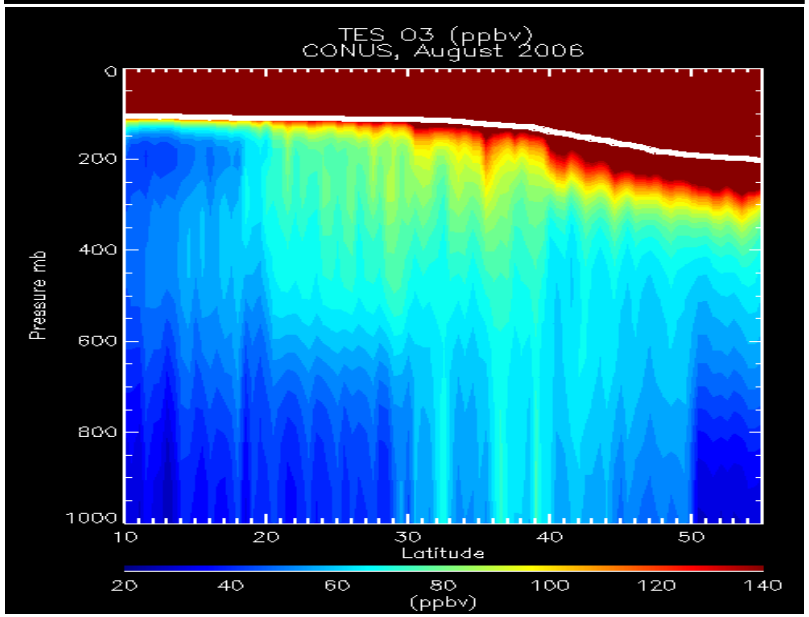
Mean AIRS CO Column and TES CO Profile





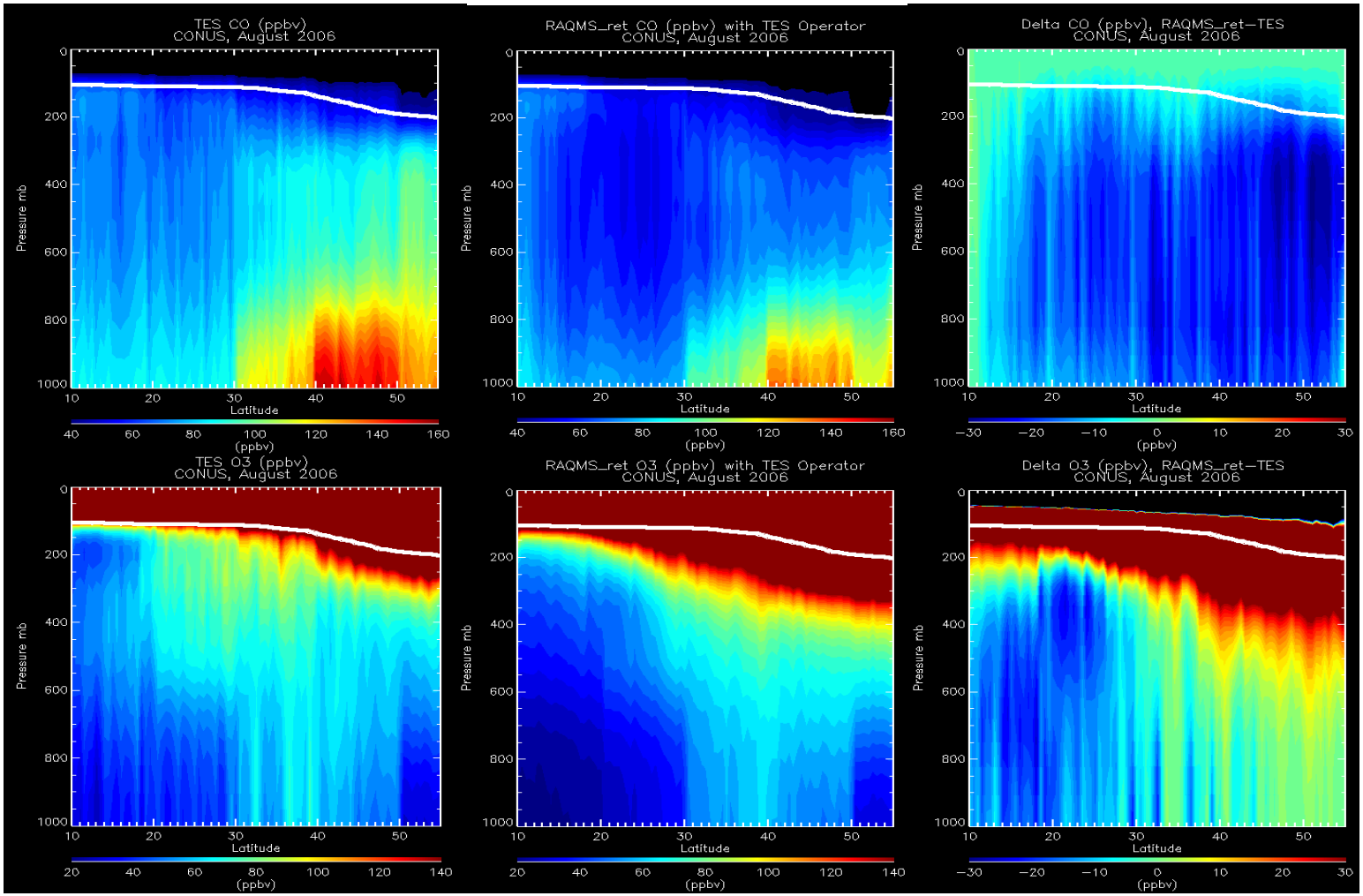
Mean OMI-RAQMS$_{strat}$ O3 and TES O3 Profile





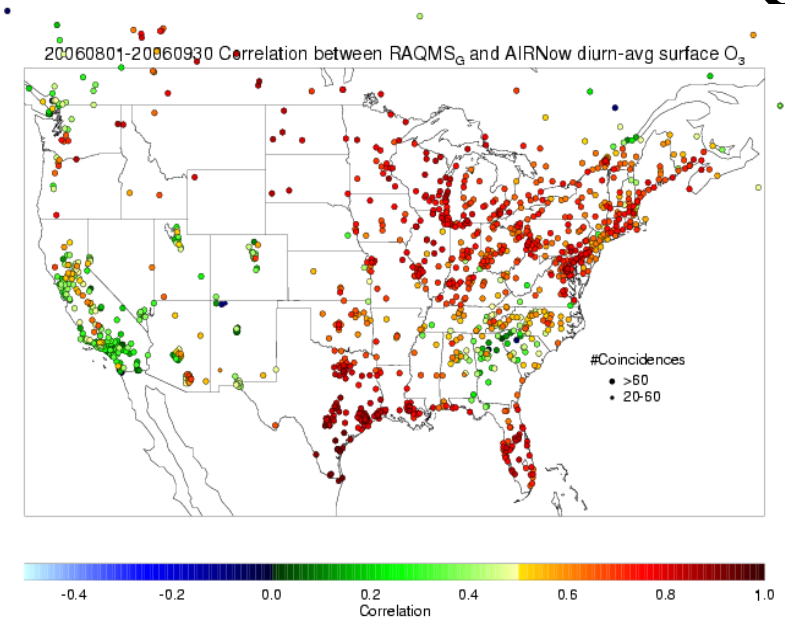
Combining AIRS, OMI and TES observations shows lower tropospheric O3 and CO enhancements over the Midwest, Mississippi River Valley and Eastern US during TEXAQS

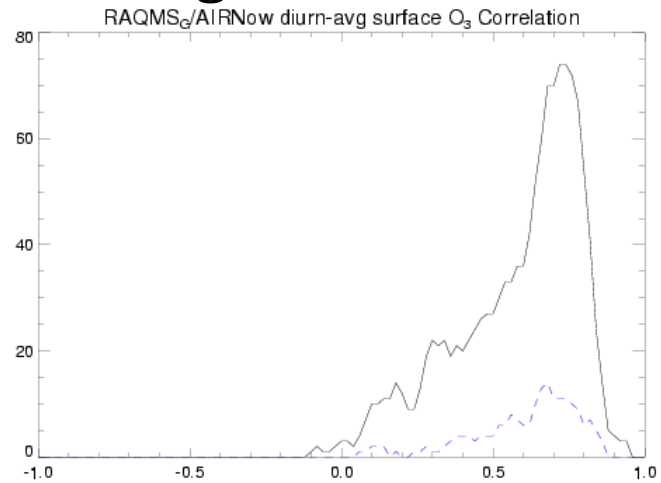
Evaluation of RAQMS Tropospheric CO &O3 using TES



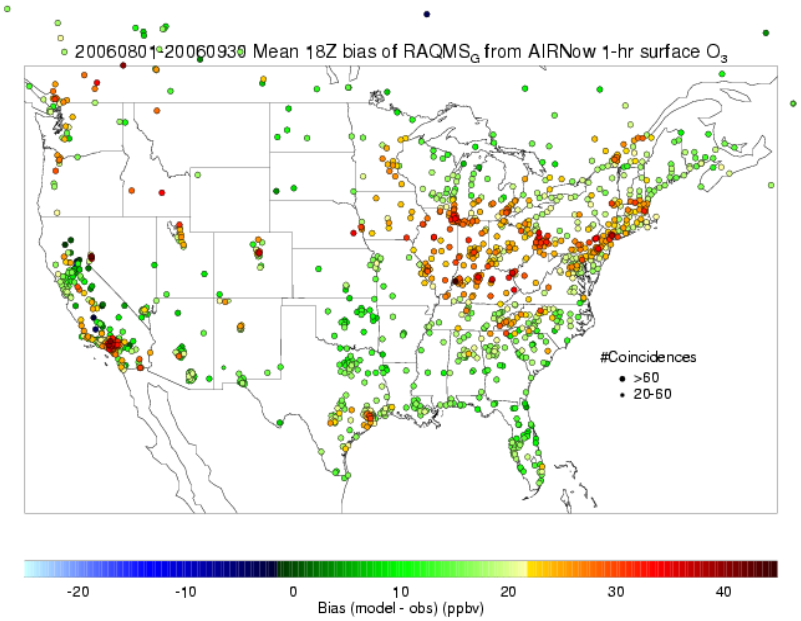
- Mean $RAQMS_{retrieved}$ CO is generally low by 10-20ppbv compared to TES
  (Low biases reach 30ppbv above 600mb north of 45N)
- Mean $RAQMS_{retrieved}$ O3 is generally within +/- 10ppbv of TES
  (Low biases reach 30ppbv above 400mb south of 30N with high biases UTLS)

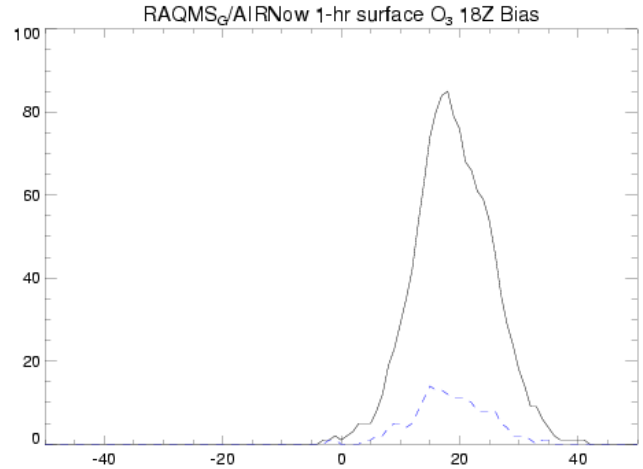
Evaluation of RAQMS Surface O3 using AIRNOW





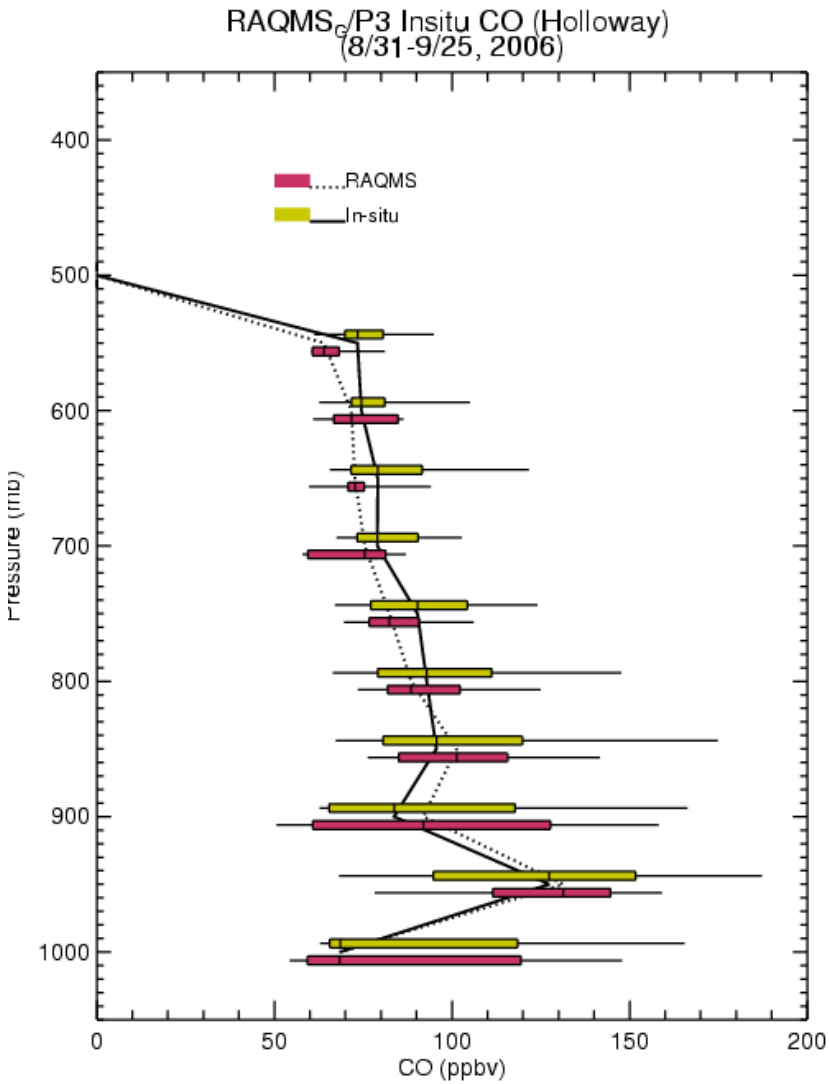
RAQMS SFC O3 is highly correlated with diurnally averaged AIRNOW measurements in TX, the Gulf Coast, Mid-west, and NE US.

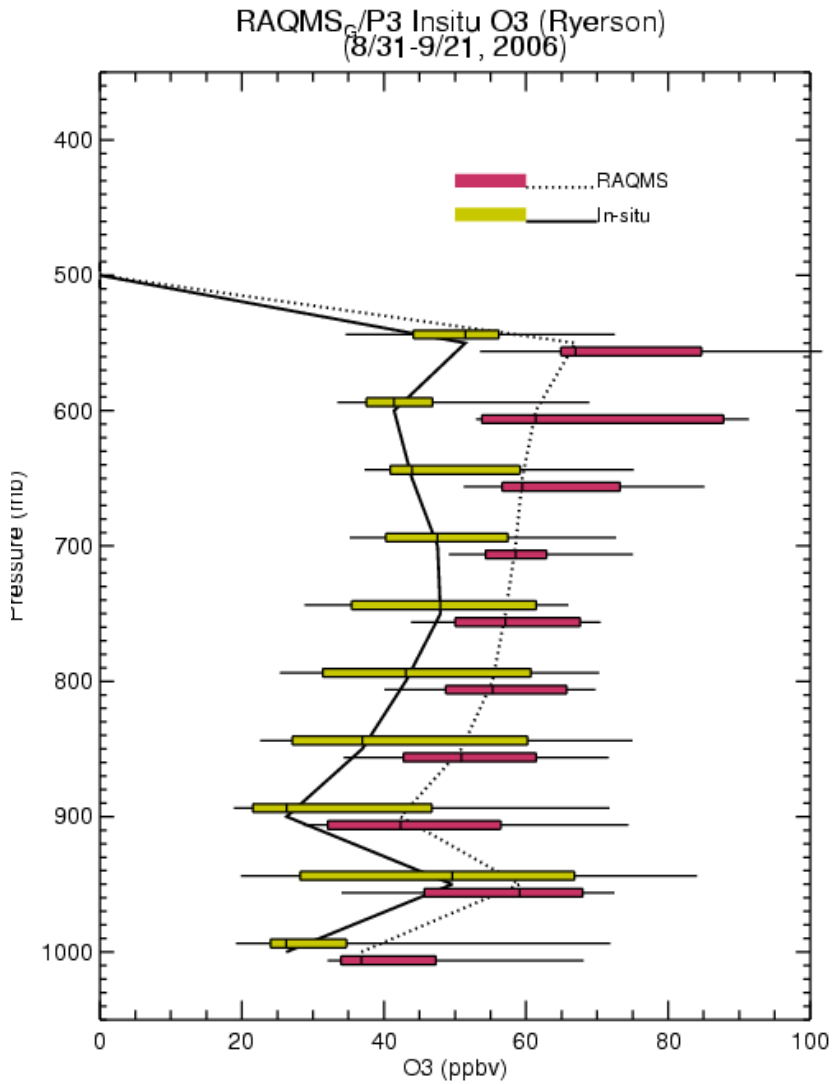




RAQMS 18Z SFC O3 is high by 15 ppbv throughout most of the SE US and high by 30 ppbv over much of the Ohio River Basin and NE corridor

Evaluation of RAQMS Houston/Dallas CO and O3 using P3 insitu





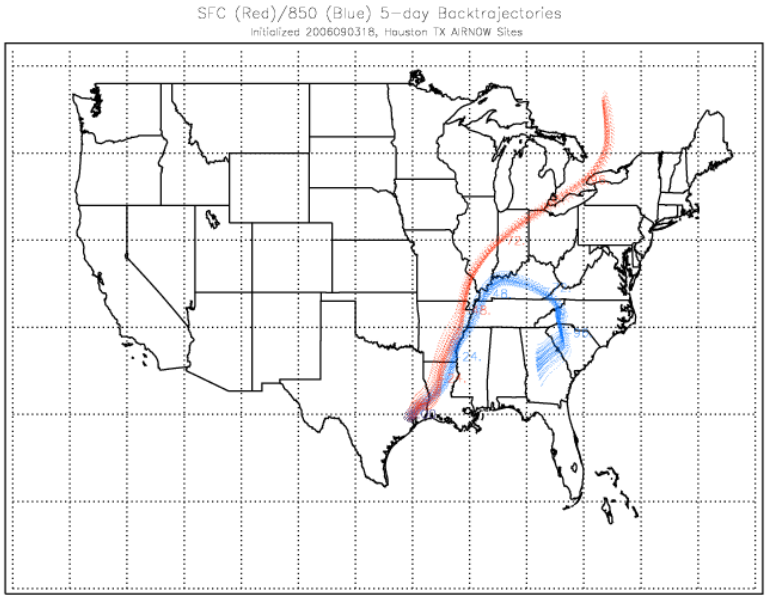
RAQMS predictions of East Texas median CO profiles are in very good agreement
RAQMS predictions of East Texas median O3 profiles are systematically high by 10-20 ppbv

TEXAQS 2006 Ensemble Lagrangian Trajectory Analysis

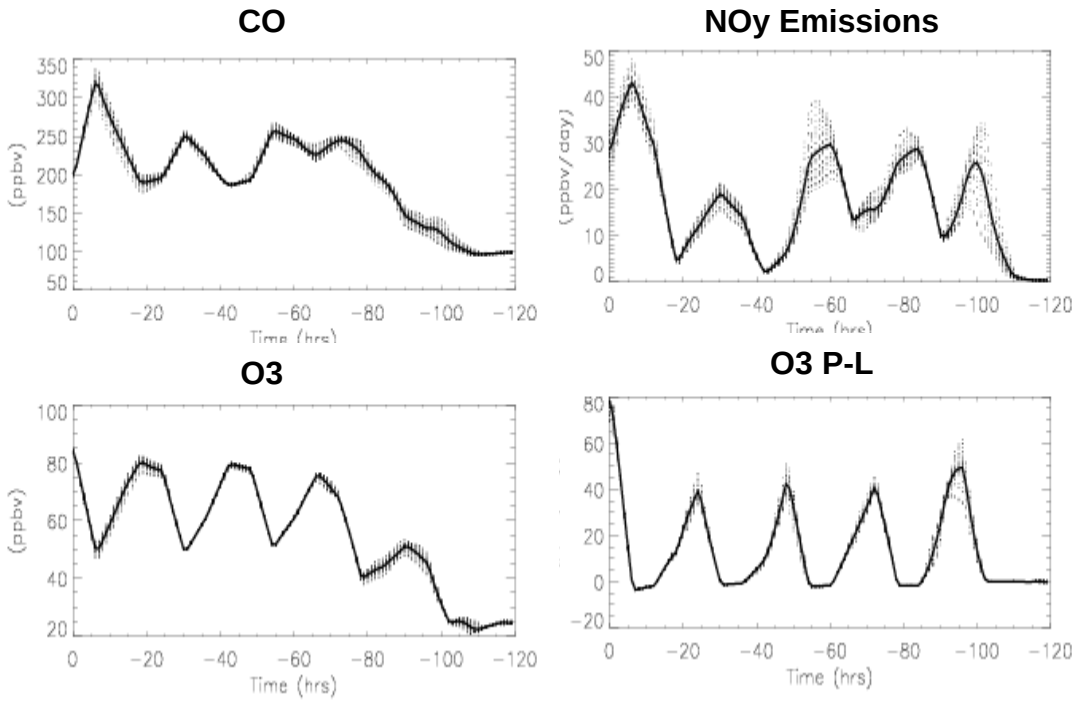
•Trajectories sample forecasted chemical and aerosol fields to understand chemical transformation during transport.

•Lagrangian averaged O3 P-L is used to classify back trajectories

SFC/850mb Houston Back-trajectories 2006090318

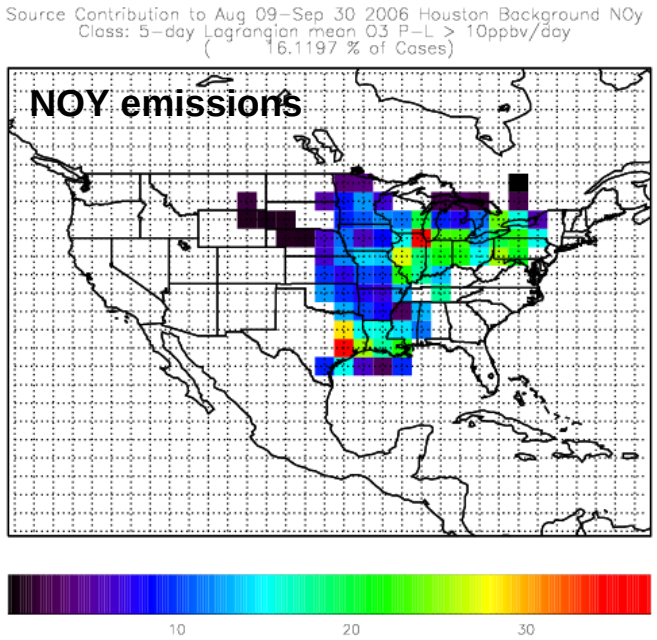


SFC Houston Back trajectory Chemistry 2006090318



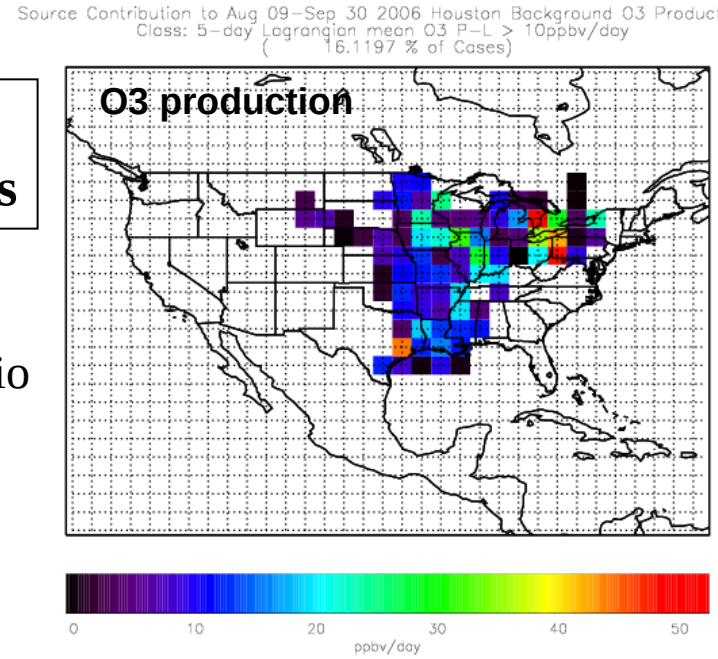
Chemical histories for each class are binned in latitude and longitude to identify dominate source regions.

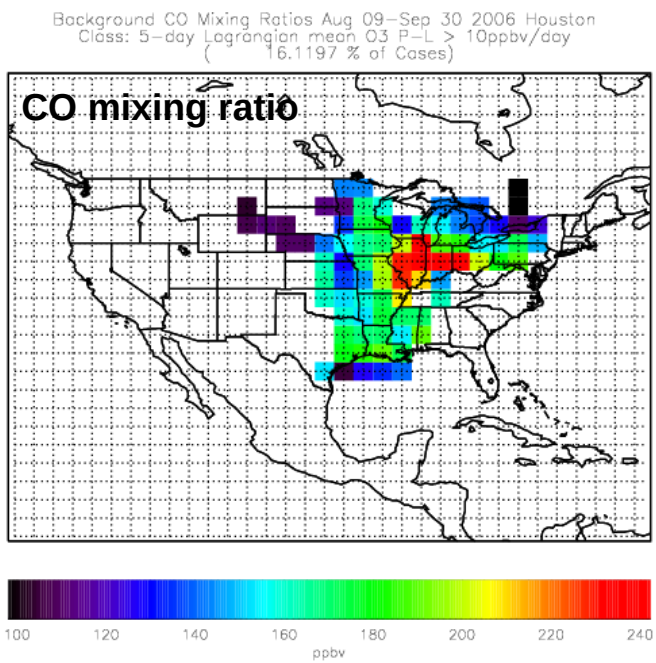
Source Attribution for Class: High Lagrangian Mean O3 Production During Transit to Houston

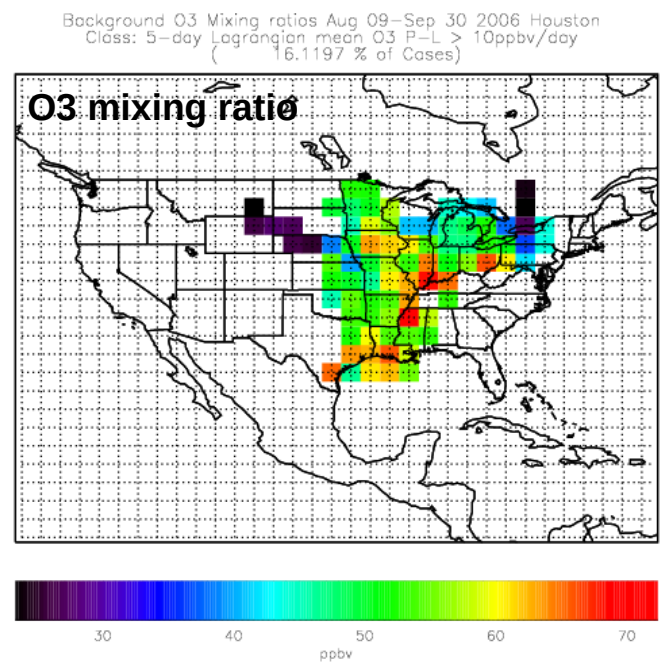


16% of Houston Back trajectories

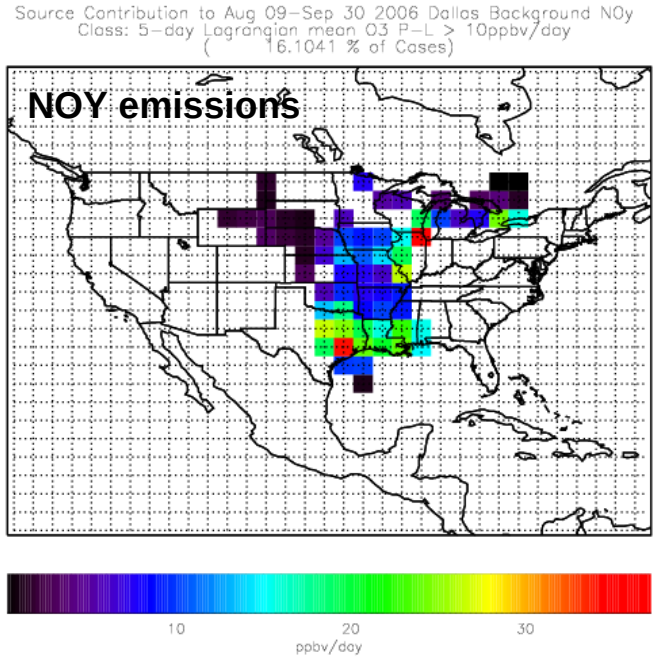
Mid-western and Ohio River Valley NOx emissions lead to regional ozone production during transport along Ohio River and Lower Mississippi River Valleys prior to arrival in Houston





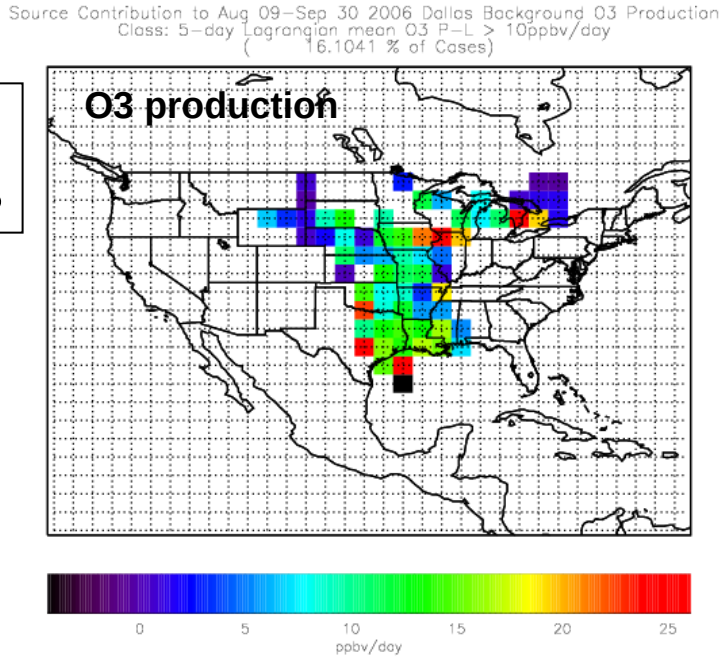


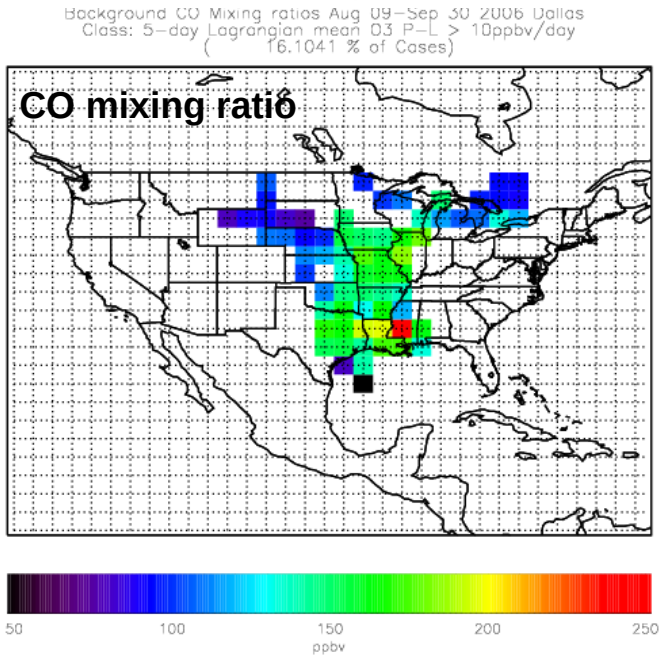
Source Attribution for Class: High Lagrangian Mean O3 Production During Transit to Dallas

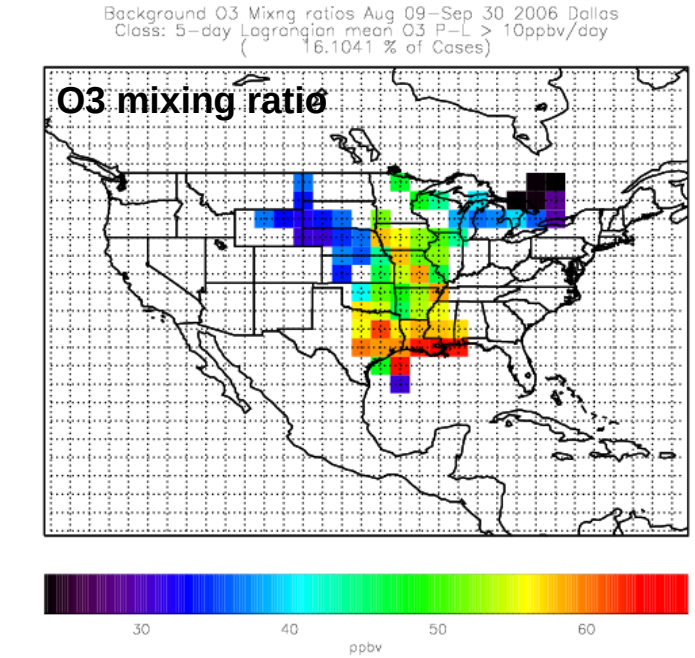


16% of Dallas Back trajectories

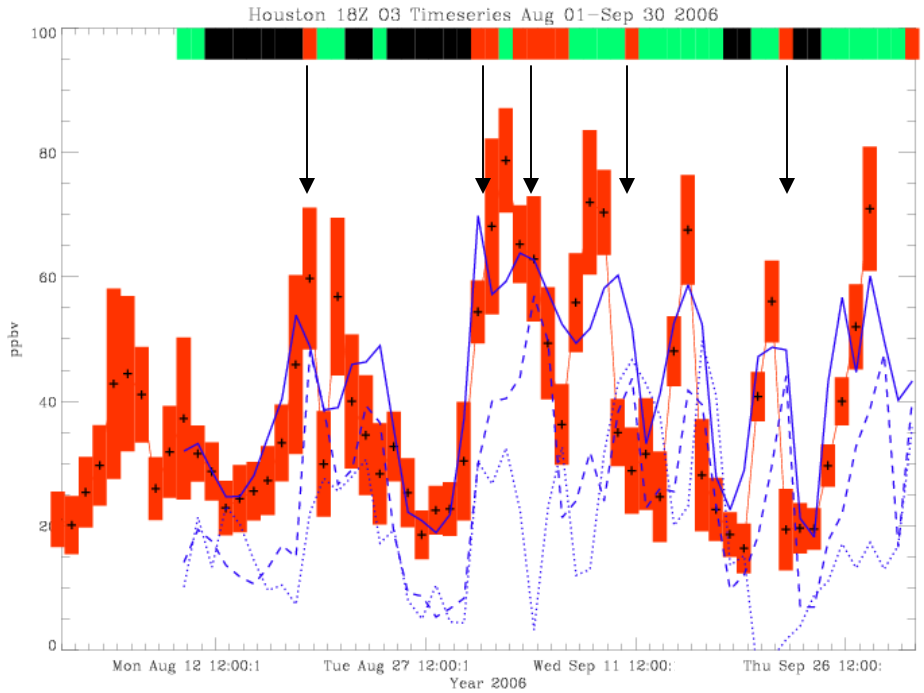
Mid-western NOx emissions lead to regional ozone production during transport to Dallas. Westward shift in region of O3 production and more wild fire impact than Houston.

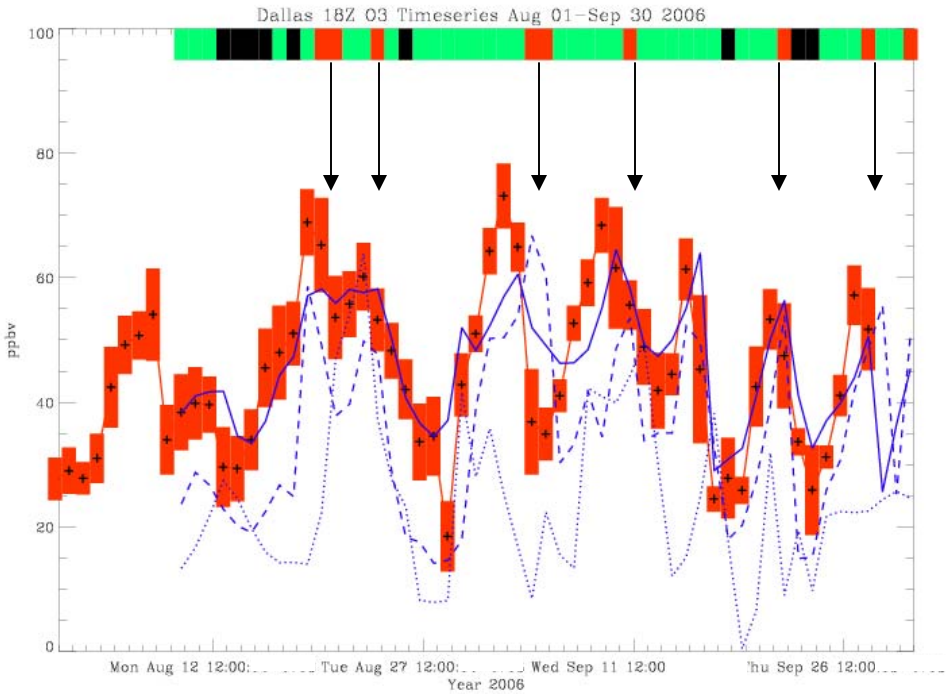






$RAQMS_{global}$ Back-trajectory analysis of regional influences on Houston and Dallas 18Z Ozone





Red=Observed AIRNOW mean and MSA variability
Solid=Predicted AIRNOW mean (bias corrected)
Dotted=Predicted Background mean (bias corrected) (5 days prior to entering Houston MSA)
Dashed=Predicted Background mean (bias corrected) (immediately prior to entering Houston MSA)

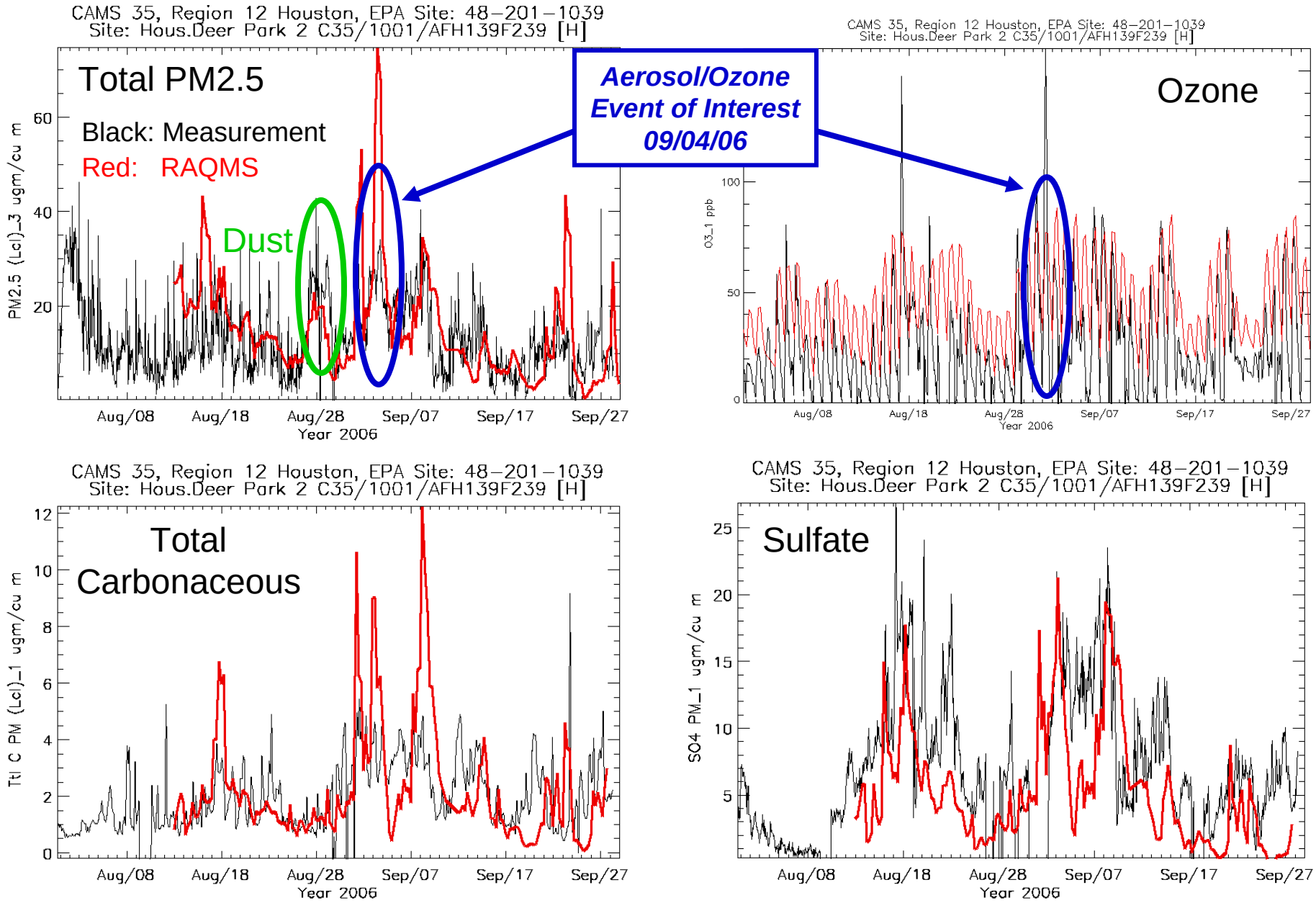
Trajectory Classification

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

Significant (5-day Lagrangian averaged O3 P-L > 10 ppbv/day) regional ozone production precedes 50% (3 out of 6) and 83% (5 out of 6) of the periods with elevated AIRNOW ozone within the Houston and Dallas MSAs respectively.

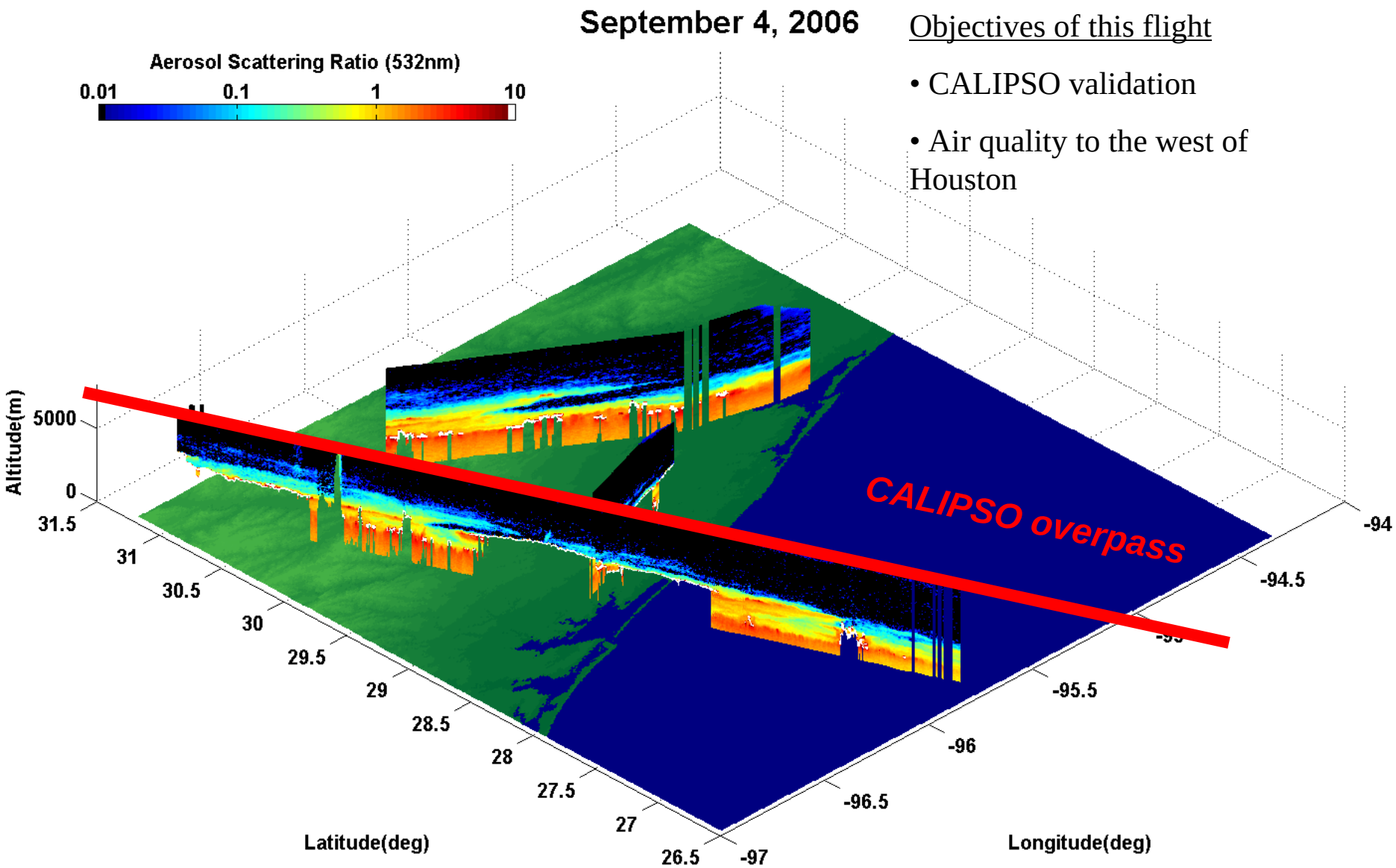
RAQMS aerosol and O3 comparisons with TCEQ monitors

Deer Park surface data provided by Bryan Lambeth (TCEQ)



Case Study: Sept 04, 2006: Elevated sulfate and OC aerosols during period of significant O3 production along Houston back trajectories

HSRL Aerosol Backscattering Ratio

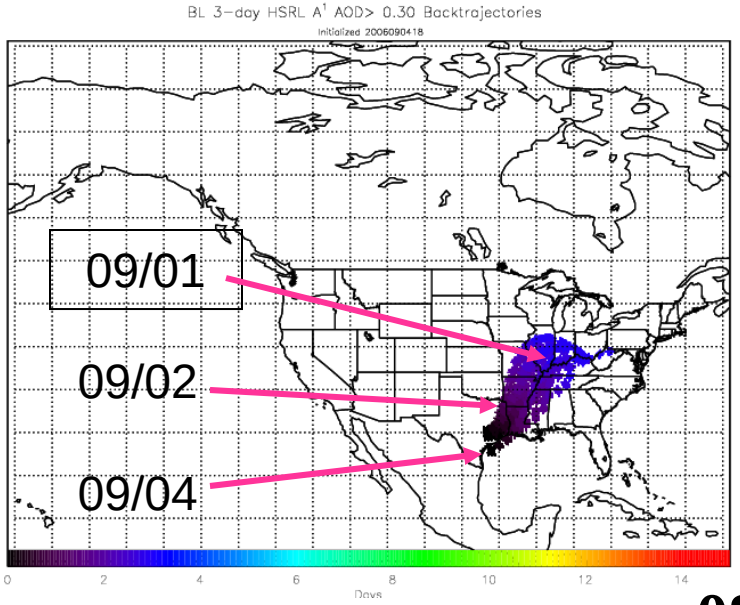


Objectives of this flight

- CALIPSO validation
- Air quality to the west of Houston

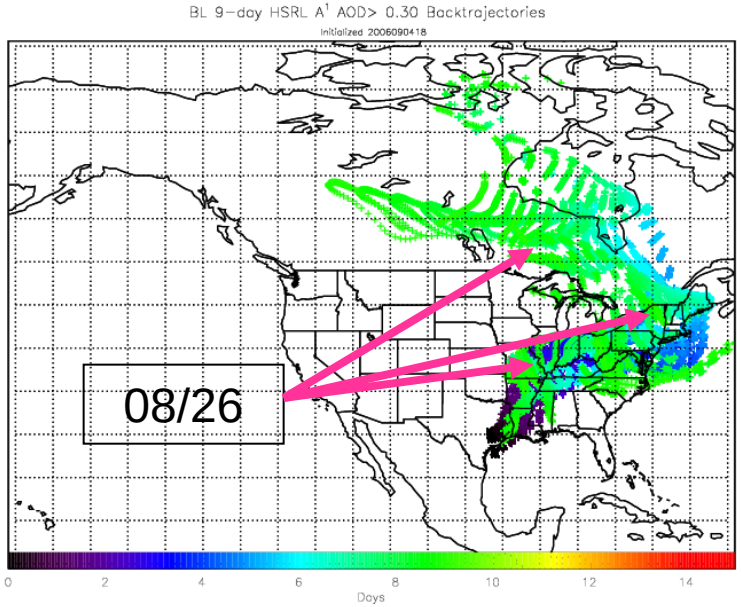
09/01/2006

3-day Back trajectories



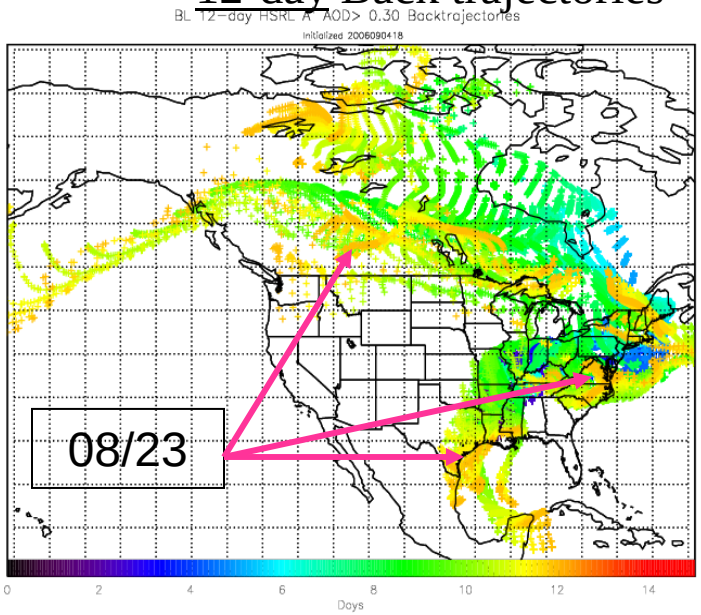
08/26/2006

9-day Back trajectories



08/23/2006

12-day Back trajectories

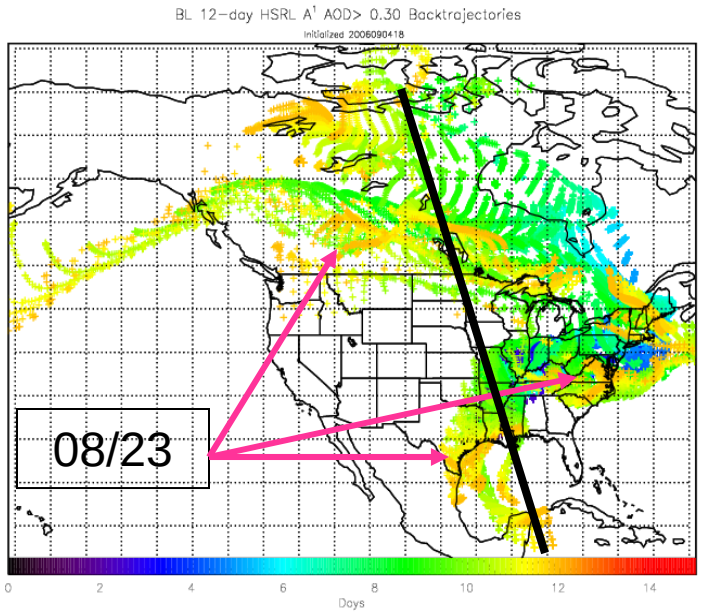


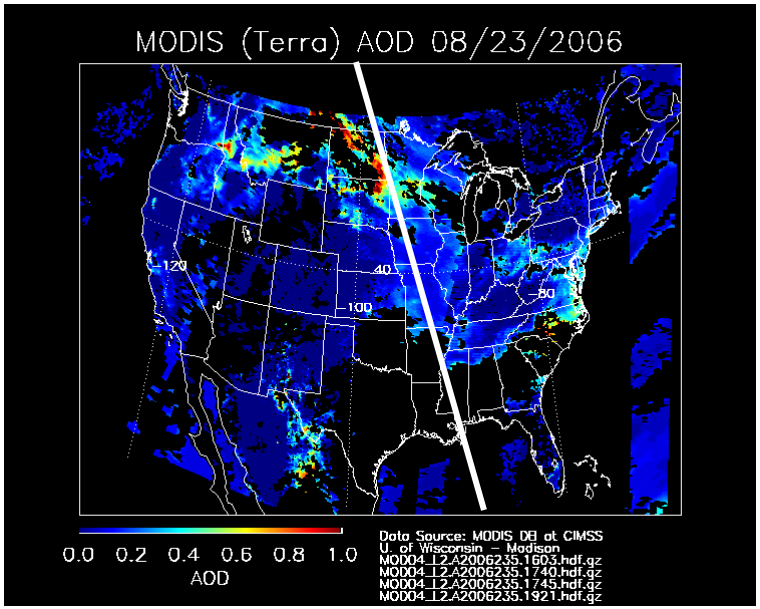
Back trajectories are initialized along HSRL flight track within BL where the column AOD is > 0.3

- HSRL backtrajectories originated from Ohio River valley 3-days earlier.
- The Ohio River airmass was composed of two distinct airmasses, one originated from Canada and one originated from the lower Mississippi River valley 6 day's earlier.
- The origin of the Canadian airmass was north of Idaho/Montana and the origin of the Lower Mississippi airmass was just off the TX coast 3-days earlier

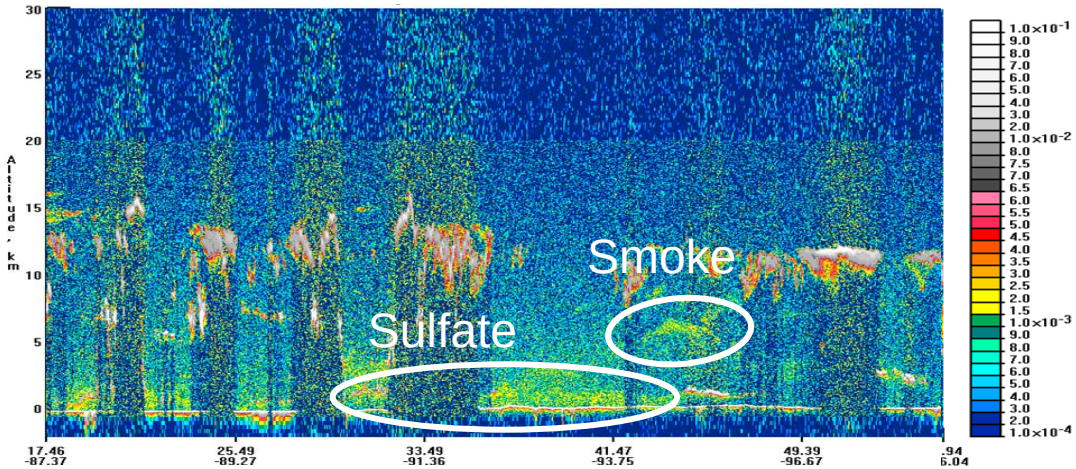
08/23/2006

12-day Back trajectories

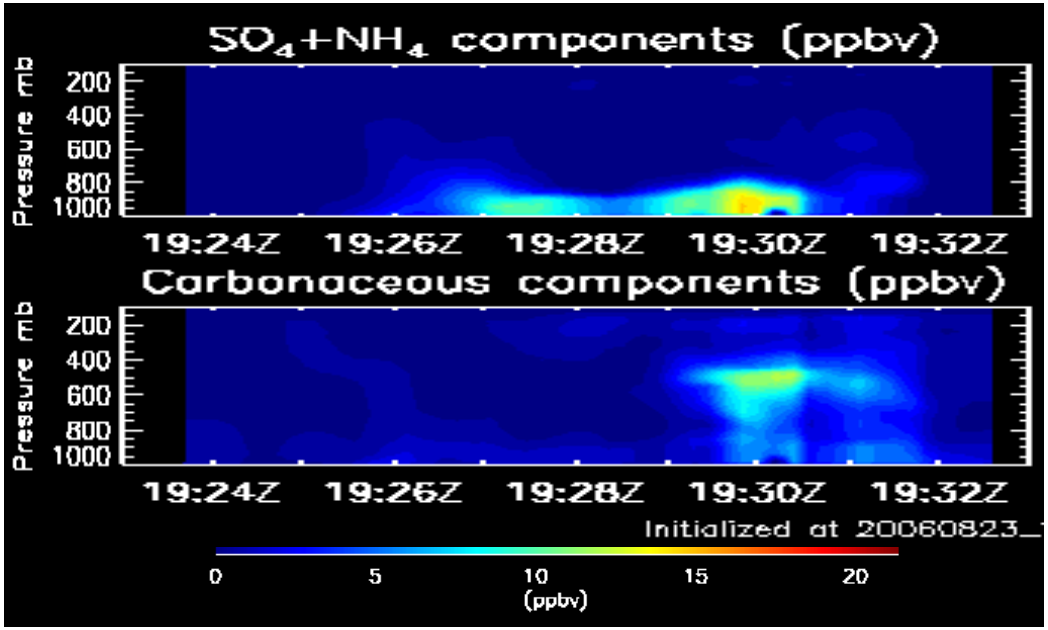




CALIPSO Attenuated Backscatter

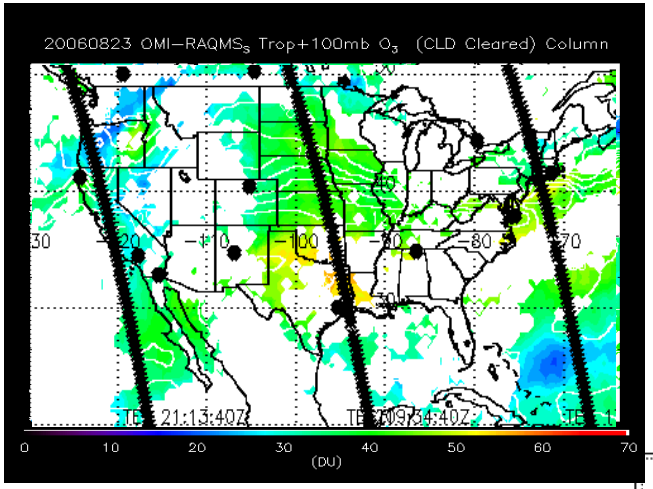


RAQMS aerosol speciation



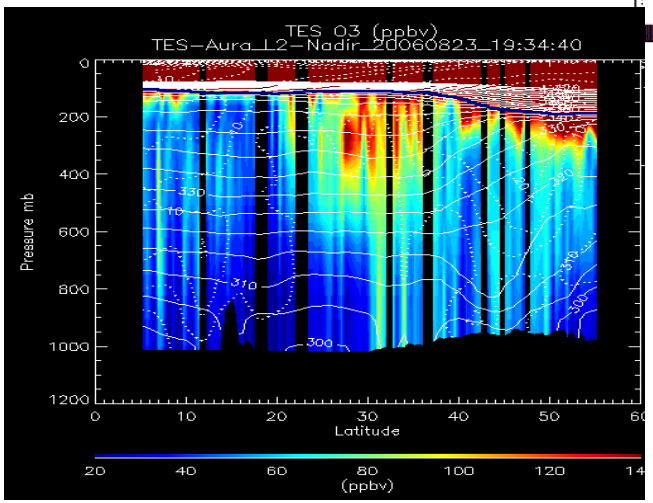
Canadian airmass was influenced by Pacific NW wild fires
Gulf airmass was influenced by SE US sulfate production

08/23/2006

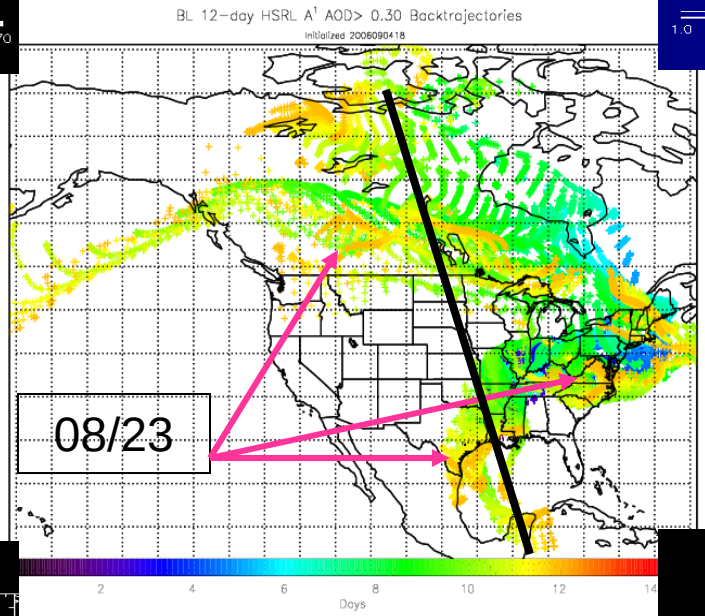


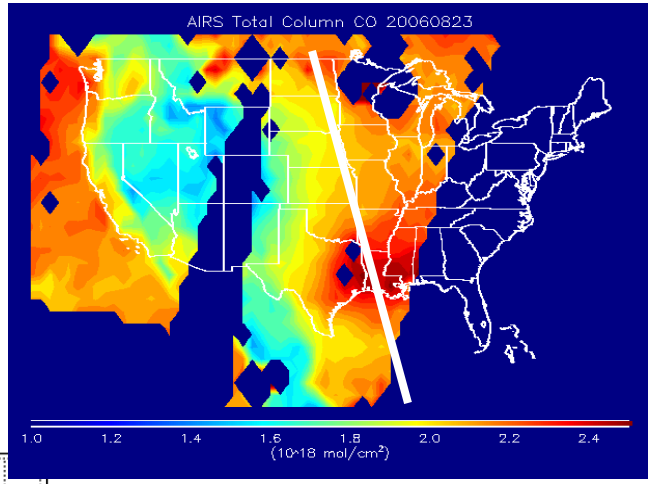
OMI shows enhancements in tropospheric ozone within the Gulf Coast airmass.

TES shows that the Gulf Coast enhancements are largely in the upper troposphere



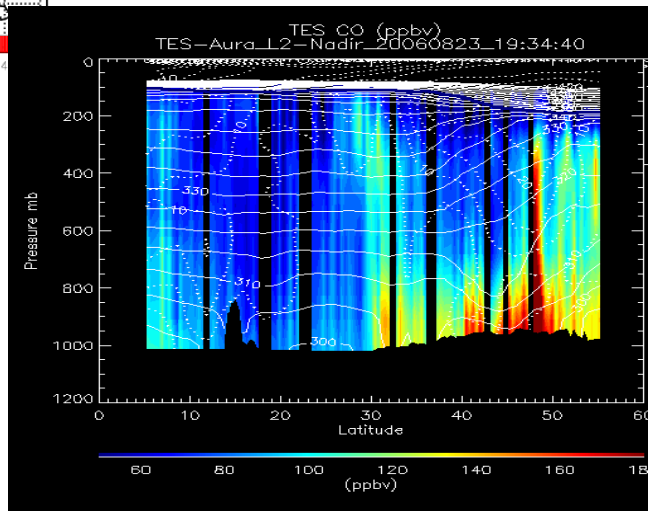
12-day Back trajectories





AIRS shows CO enhancements in both The Canadian airmass and the Gulf Coast airmass.

TES shows that much of the CO enhancement is within the BL.



Summary

We have conducted a Synthesis of measurements from EPA AIRNOW, NOAA P3, NASA AIRS, TES, OMI, MODIS, CALIPSO, HSRL and RAQMS chemical/aerosol analyses collected during TEXAQS 2006 to investigate regional Influences on Houston and Dallas Air Quality During Aug-Sept, 2006.

The results demonstrate the utility of satellite aerosol and trace gas observations in tracking long-range transport of pollutants, particulary when regional column measurements (AIRS, OMI, MODIS) are combined with profile information (TES, CALIPSO)

Chemical and aerosol assimilation/forecasting systems, combined with Lagrangian trajectory analysis, provide a link between the regional scale satellite observations, surface networks, and airborne measurements.

Conclusions:

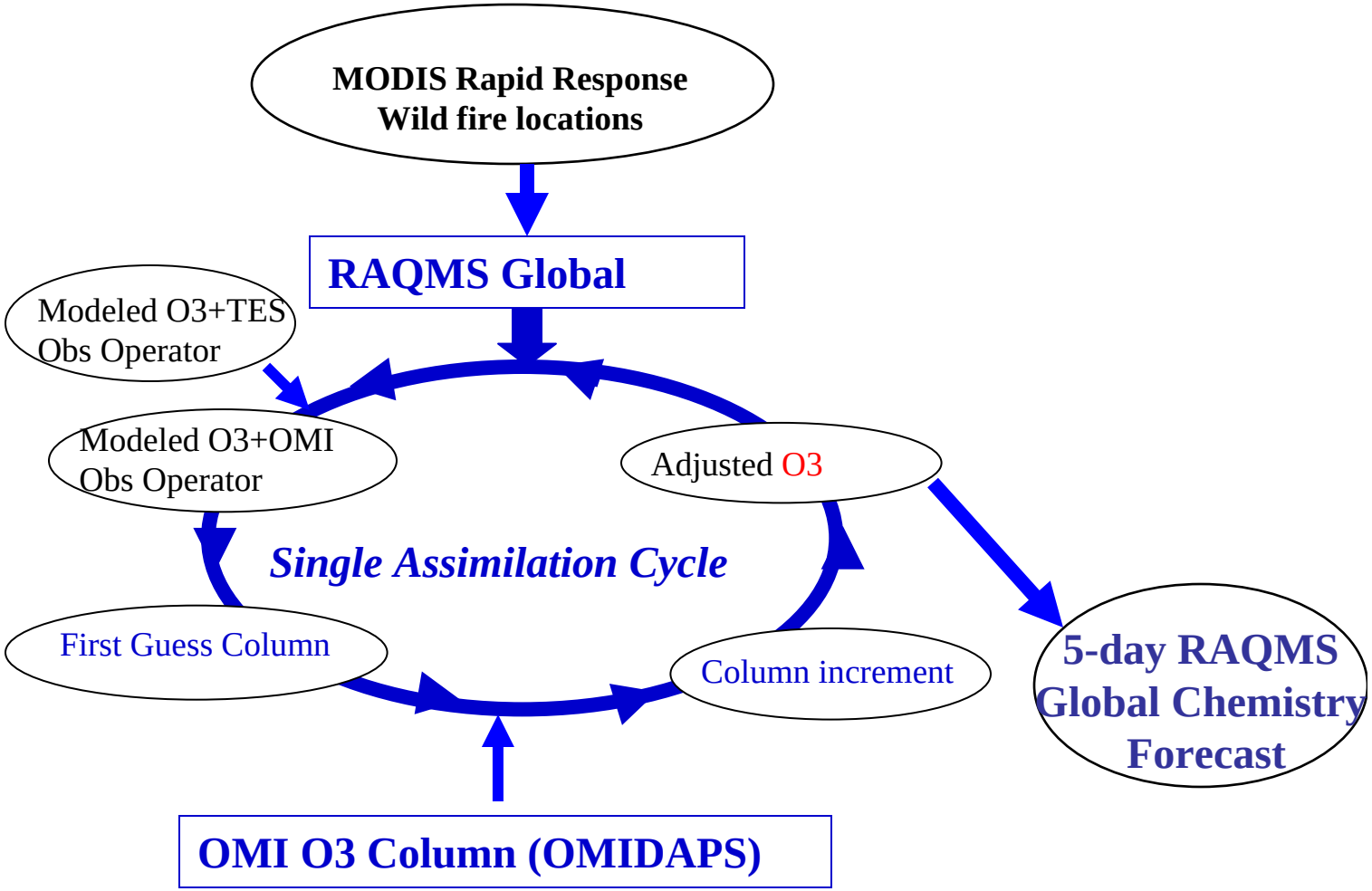
Lagrangian source attribution studies show that:

Mid-western and Ohio River Valley NOx emissions lead to enhanced (5-day Lagrangian averaged O3 P-L > 10 ppbv/day) regional ozone production during transport along Ohio River and Lower Mississippi River Valleys prior to arrival in Houston during 16% of the days between Aug – Sep 2006

Mid-western NOx emissions lead to enhanced regional ozone production during transport to Dallas during 16% of the days between Aug- Sep 2006. There is a westward shift in region of enhanced O3 production and more wild fire impacts than Houston.

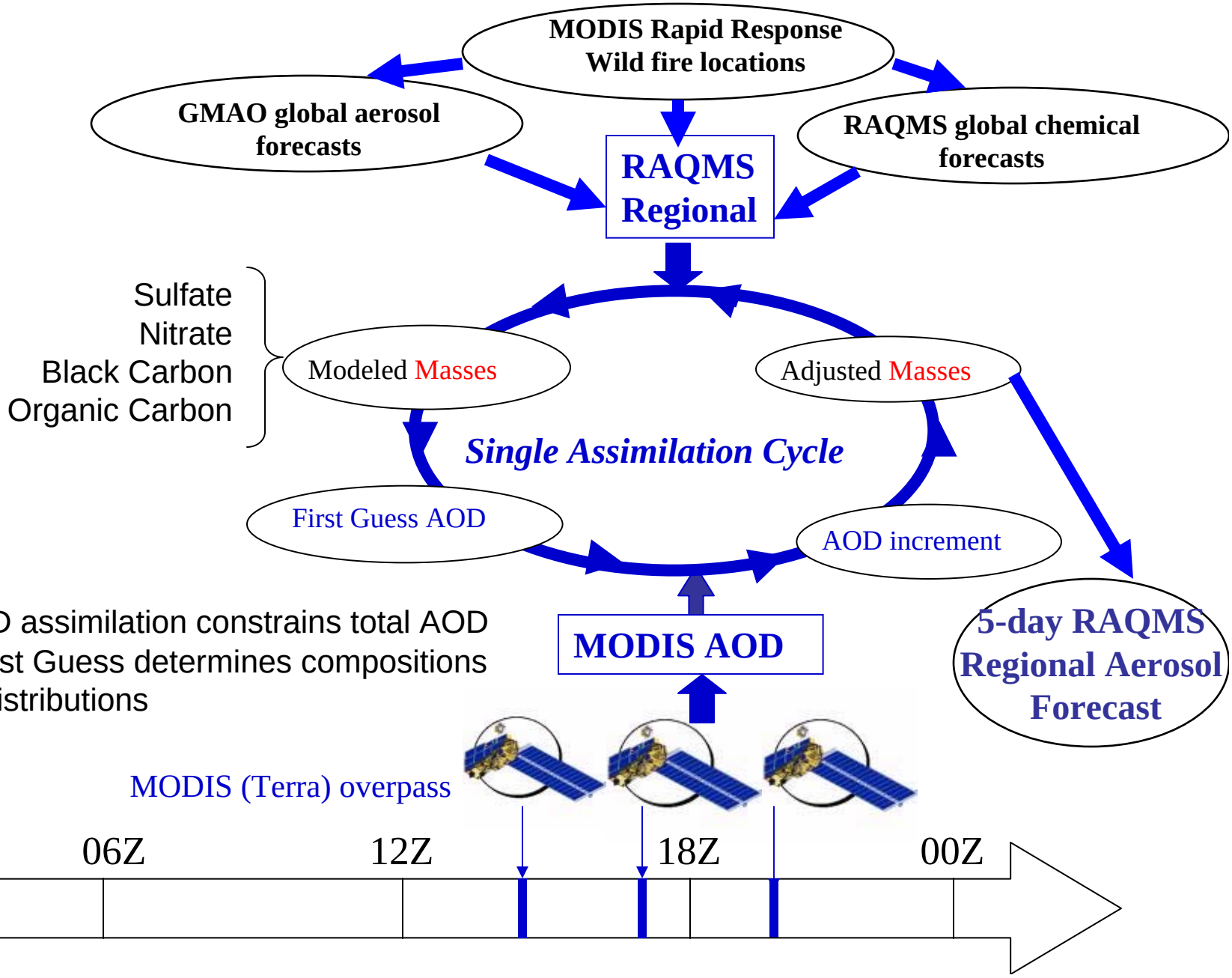
These periods of enhanced regional ozone production preceed 50% (3 out of 6) and 83% (5 out of 6) of the periods with elevated AIRNOW ozone within the Houston and Dallas MSAs respectively.

$RAQMS_{global}$ (2x2) Ozone Assimilation/Forecast Procedure



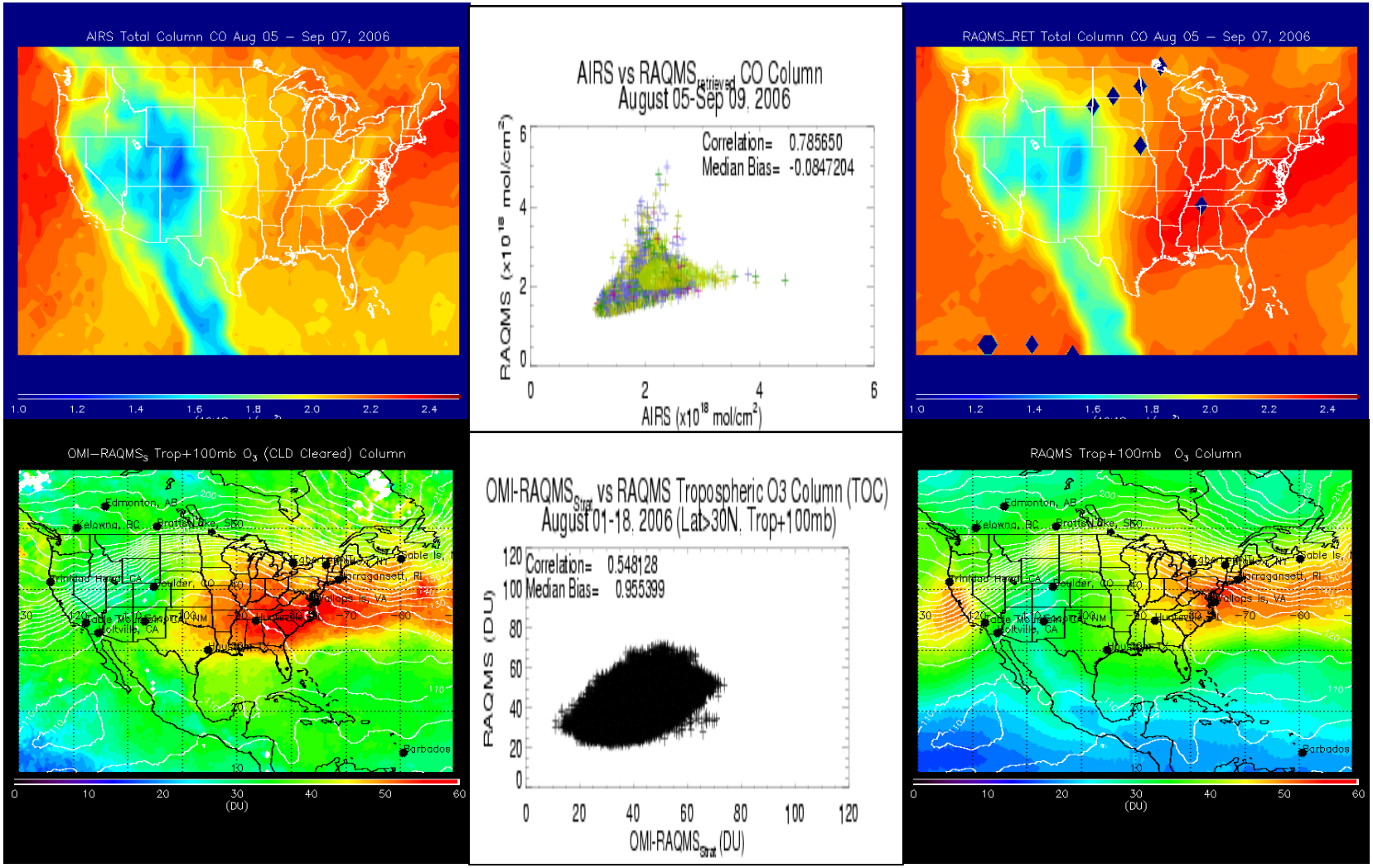
Real-time OMI Cloud-cleared column assimilation conducted at 2x2 degrees, analysis increment applied as percentage adjustment to mixing ratio resulting in minimal impact on troposphere.

$RAQMS_{regional}$ (80km) AOD Assimilation/Forecast Procedure



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

Evaluation of RAQMS Column CO using AIRS and OMI



- Mean RAQMS and AIRS CO columns are within 5% and highly correlated
- RAQMS CO column is slightly higher over Mississippi River Valley
- Mean RAQMS and OMI-RAQMS$_{strat}$ TOC are 2.5% and are reasonably correlated
- RAQMS TOC is lower in the SE US and higher over the Pacific