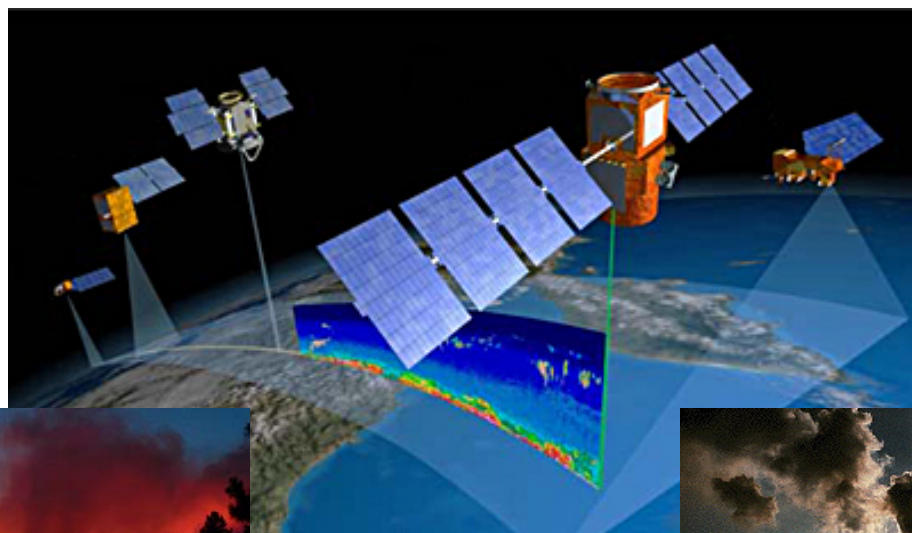


# ***Synthesis of CALIPSO, HSRL and MODIS observations using regional scale modeling***

***Chieko Kittaka<sup>1</sup>, Brad Pierce<sup>2</sup>, Jassim Al-Saad<sup>2</sup>, Chris Hostetler<sup>2</sup>, John Hair<sup>2</sup>,  
Rich Ferrare<sup>2</sup>, Todd Schaack<sup>3</sup>, Greg Tripoli<sup>3</sup>, Jim Szykman<sup>4</sup>, Amber Soja<sup>5</sup>,  
Arlindo da Silva<sup>6</sup>, Dave Winker<sup>2</sup>, Tahllee Baynard<sup>7</sup>, Ryan Spackman<sup>7</sup>, Bryan Lambeth<sup>8</sup>***



*<sup>1</sup>SAIC, <sup>2</sup>NASA Langley,  
<sup>3</sup>University of Wisconsin-Madison,  
<sup>4</sup>US EPA, <sup>5</sup>NIA, <sup>6</sup>NASA GSFC,  
<sup>7</sup>NOAA, <sup>8</sup>TCEQ*

## **Acknowledgements:**

**Liam Gumley, Allen Huang  
(CIMSS, UW-Madison) for MODIS  
DB products**

**Lorraine Remer (NASA GSFC)  
for MODIS AOD**

**Mian Chin (NASA GSFC) for  
providing us with GOCART  
aerosol modules**

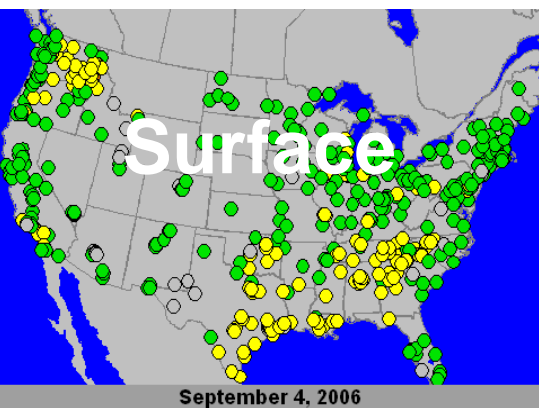
**CALIPSO Team for CALIPSO  
images**





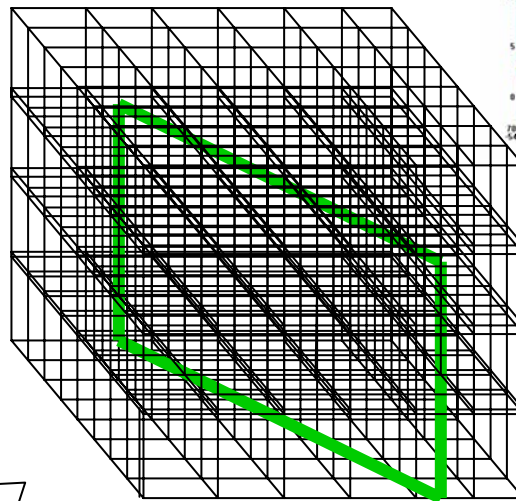
# Field Experiments

**Detailed Model Verification and Characterization**



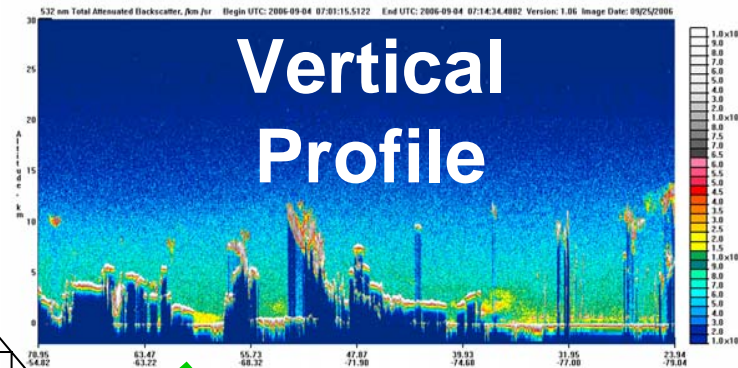
# Surface

September 4, 2006



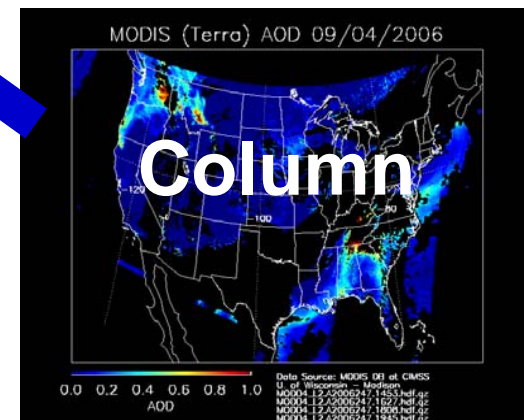
**3D Model Trajectory Model**

**Analysis and Prediction**



# Vertical Profile

**MODIS AOD Assimilation**



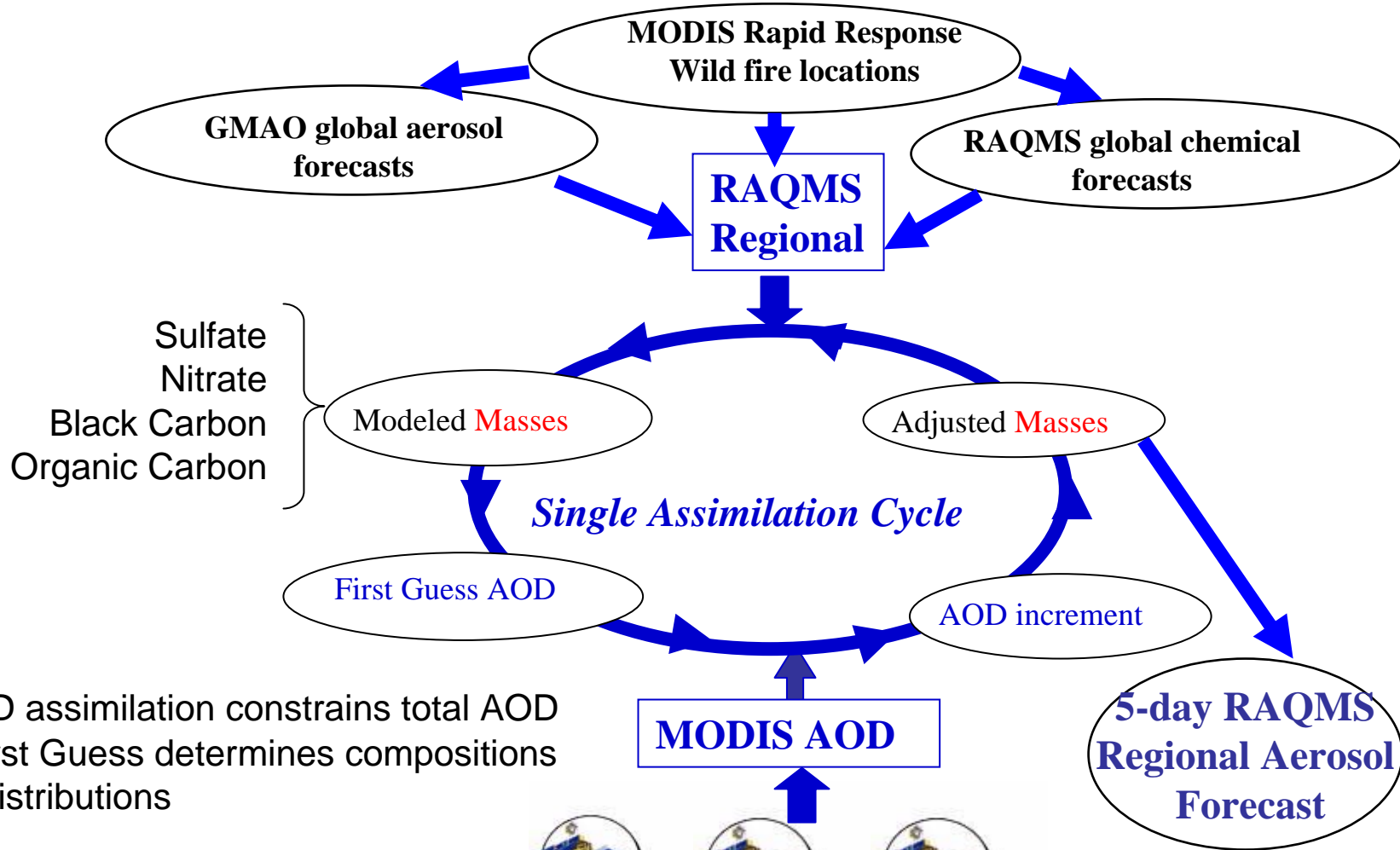
MODIS (Terra) AOD 09/04/2006

# Column

0.0 0.2 0.4 0.6 0.8 1.0  
AOD  
Data Source: MODIS 01 of CIMSS  
U. of Wisconsin - Madison  
MOD04\_12\_20060904\_1455.hdf.gz  
MOD04\_12\_20060904\_1627.hdf.gz  
MOD04\_12\_20060904\_1800.hdf.gz  
MOD04\_12\_20060904\_1942.hdf.gz

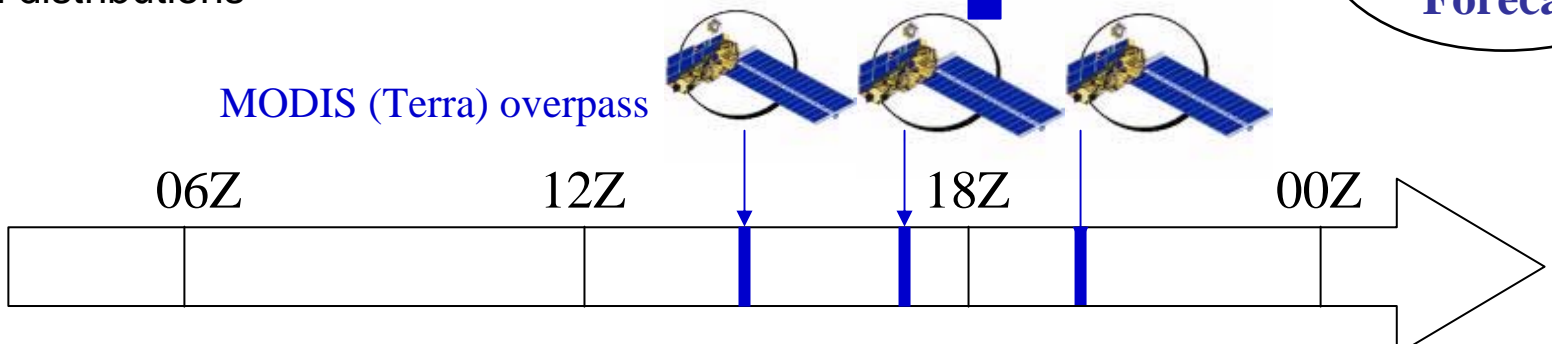
**Use chemical/aerosol forecast models and trajectory analysis to link receptor regions to source regions**

# RAQMS<sub>regional</sub> (80km) AOD Assimilation/Forecast Procedure

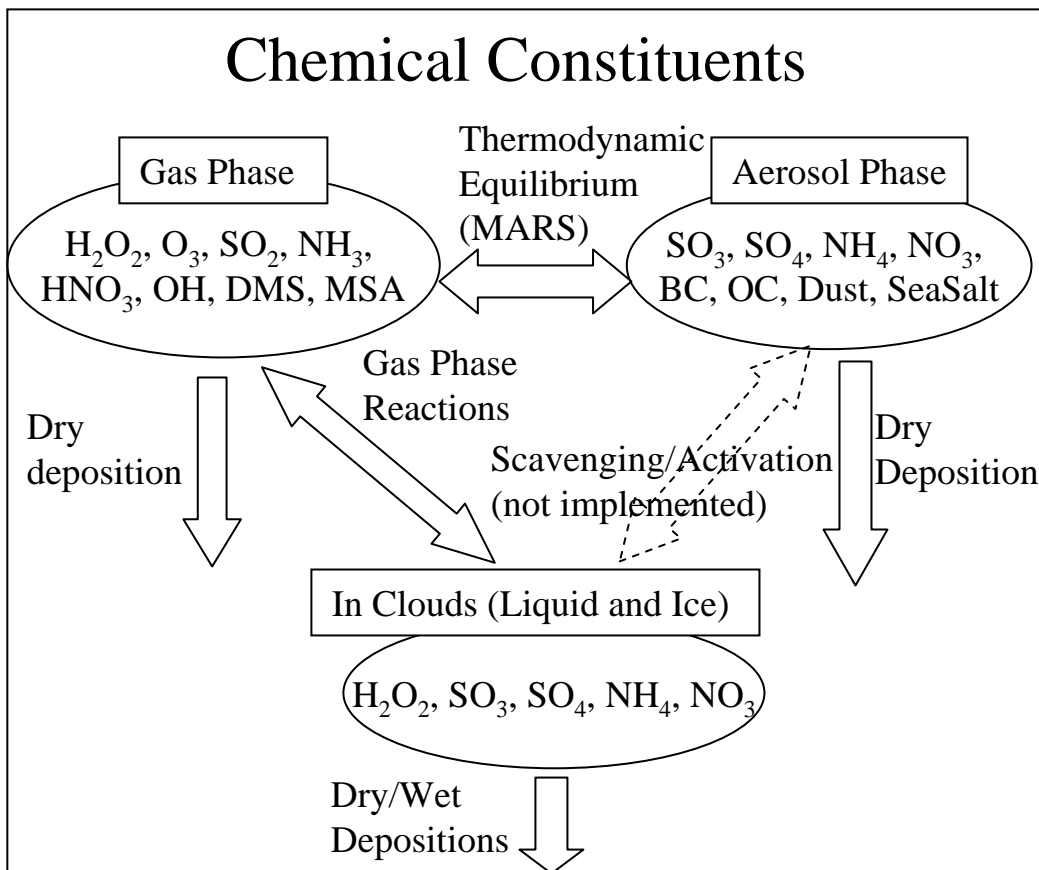


Sulfate  
Nitrate  
Black Carbon  
Organic Carbon

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



# Description of RAQMS Aerosol Modules



- **CONUS domain (80kmx80kmx0.4km)**
- **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:

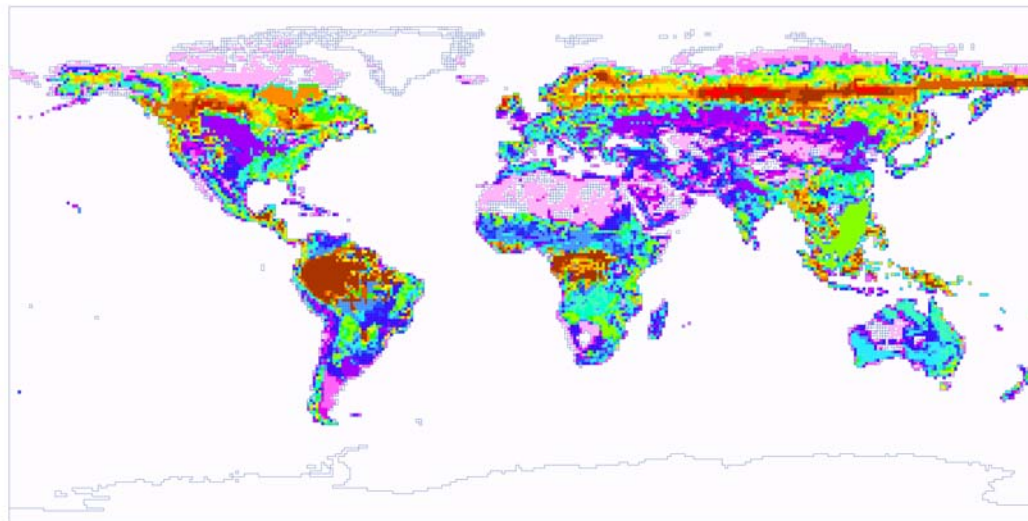
- **Sulfate [Kittaka, 2004],**
- **Dust, Sea Salt, Carbonaceous Aerosol from GOCART [provided by Mian Chin, GSFC]**
- **Nitrate and Ammonium from GEOS-CHEM [provided by Rokjin Park, Harvard]**

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

Estimated using the MODIS Thermal Anomaly data

Calculated by estimating the amount of fuel that is consumed in each ecosystem under three classes of fire weather severity (low, medium and high)

Haines Index (moisture and stability of the local atmosphere)

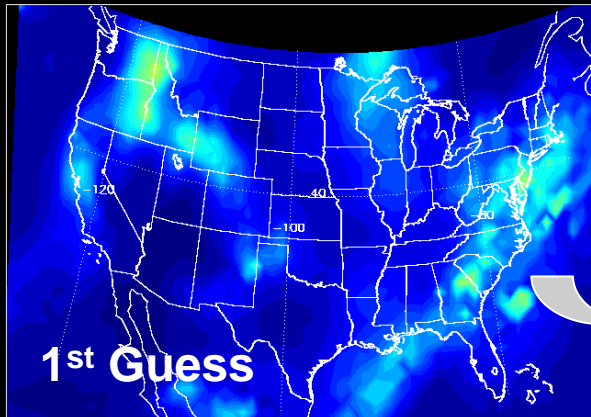


Global *high-severity* carbon consumption estimates

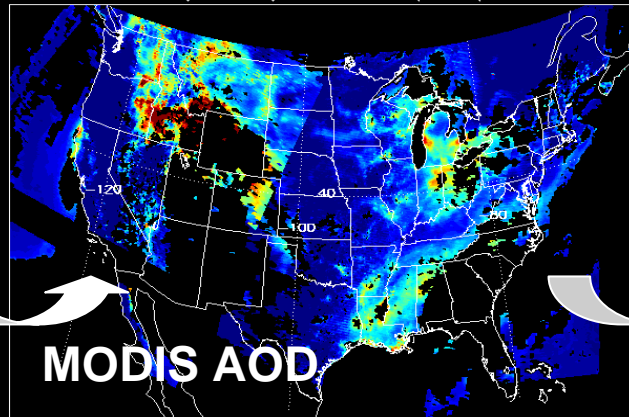


# RAQMS<sub>regional</sub> MODIS AOD Assimilation cycle 09/07/06

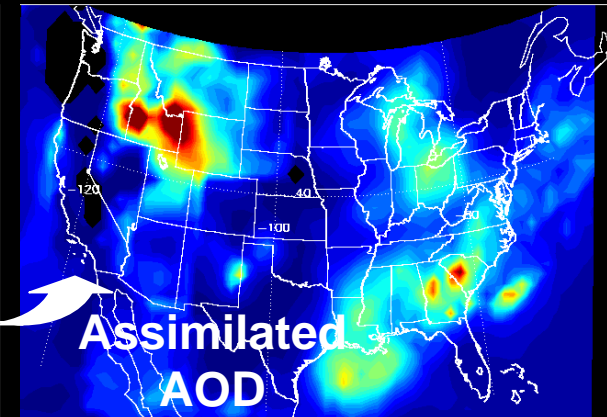
1st Guess AOD 09\_07\_2006\_1521Z



MODIS (Terra) AOD 09/07/2006



Assimilated AOD for 09\_07\_2006\_1838Z



0.0 0.2 0.4 0.6 0.8 1.0  
AOD

0.0 0.2 0.4 0.6 0.8 1.0  
AOD

Data Source: MODIS DB at CIMSS  
U. of Wisconsin - Madison  
MOD04\_L2\_A2006250\_1521 hdf.gz  
MOD04\_L2\_A2006250\_1838 hdf.gz  
MOD04\_L2\_A2006250\_1838 hdf.gz  
MOD04\_L2\_A2006250\_2016 hdf.gz

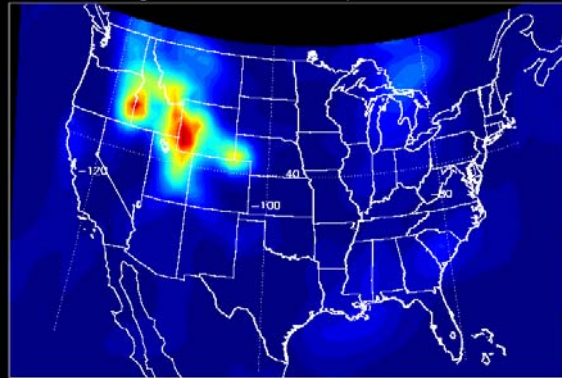
0.2 0.4 0.6 0.8 1.0  
AOD

AOD assimilation improved estimate of smoke from NW biomass burning and SE sulfate aerosol distributions

Organic Carbon

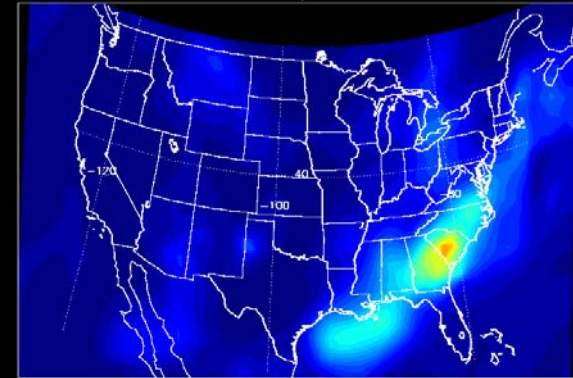
Sulfate

AOD Organic Carbon 09/08 00Z 2006



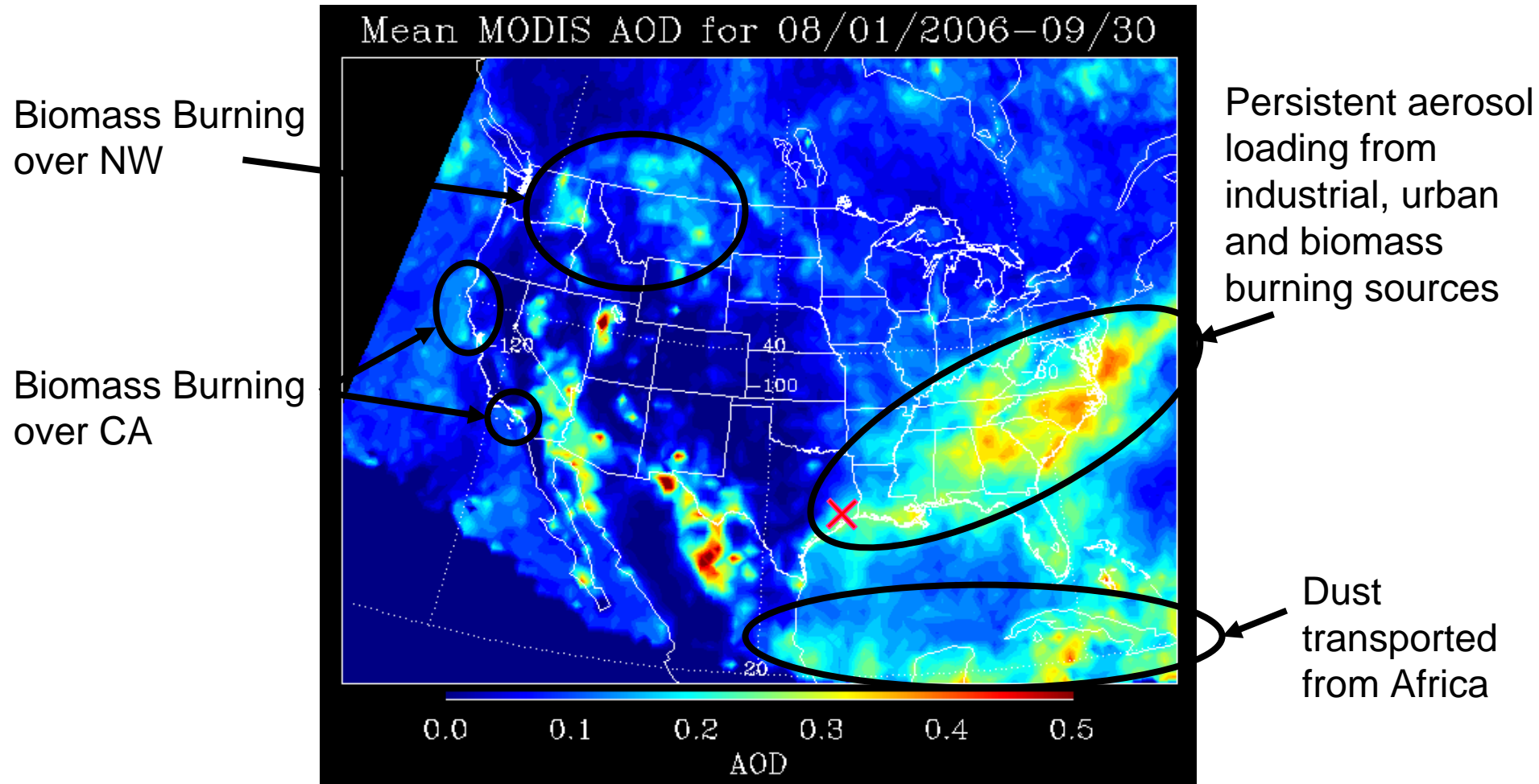
0.0 0.2 0.4 0.6 0.8 1.0  
AOD Organic Carbon

AOD Sulfate 09/08 00Z 2006



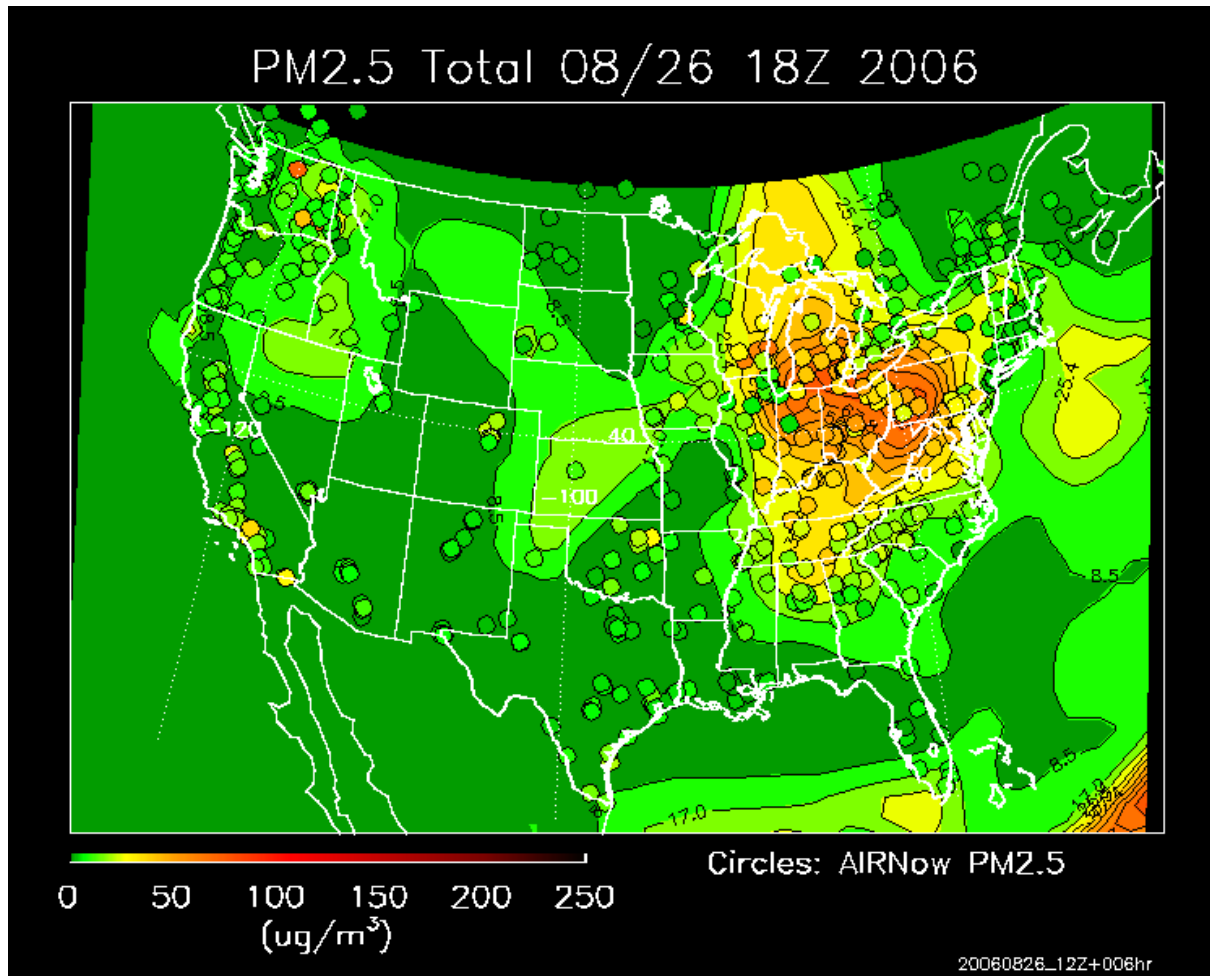
0.0 0.2 0.4 0.6 0.8 1.0  
AOD Sulfate

# MODIS AOD observations for Summer 2006



× Houston

**Aug 26: Worst Particulate Pollution Day  
over E. US during Aug-Sept, 2006  
RAQMS vs AIRNow**





# Fire Statistics

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

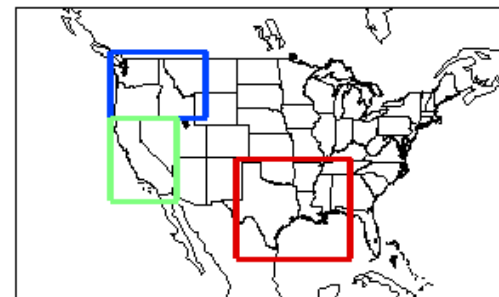
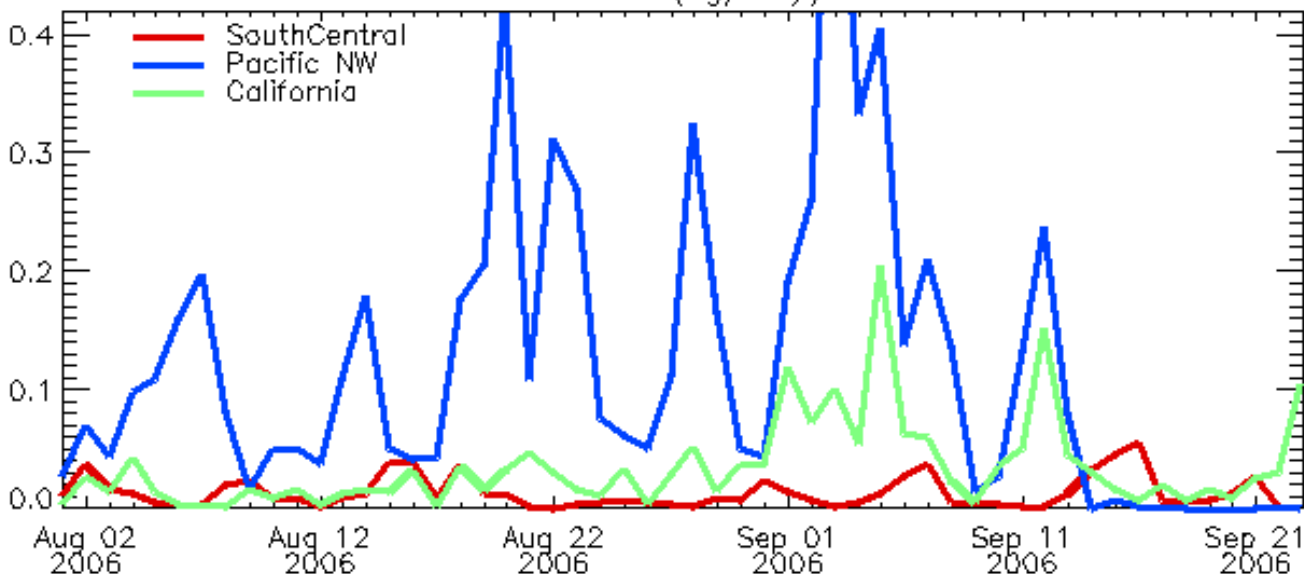
2002 (1/1/02 - 9/29/02) Fires: 67,265 Acres: 6,578,985

2001 (1/1/01 - 9/29/01) Fires: 63,067 Acres: 3,221,391

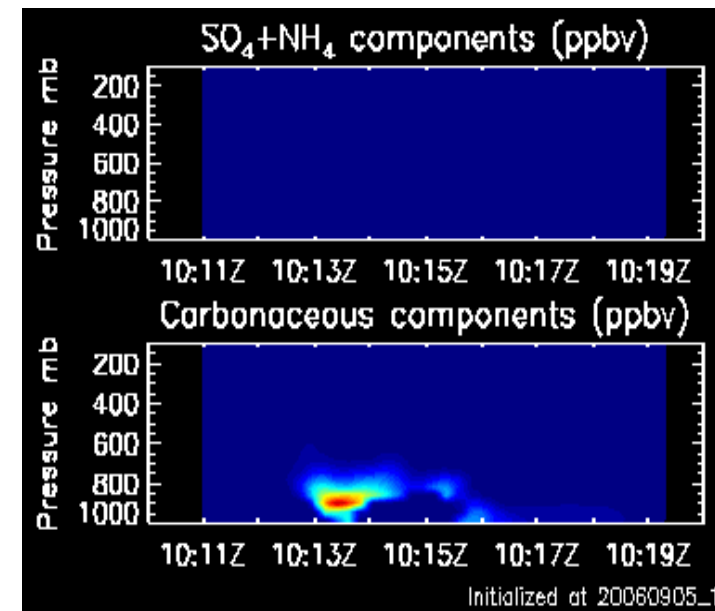
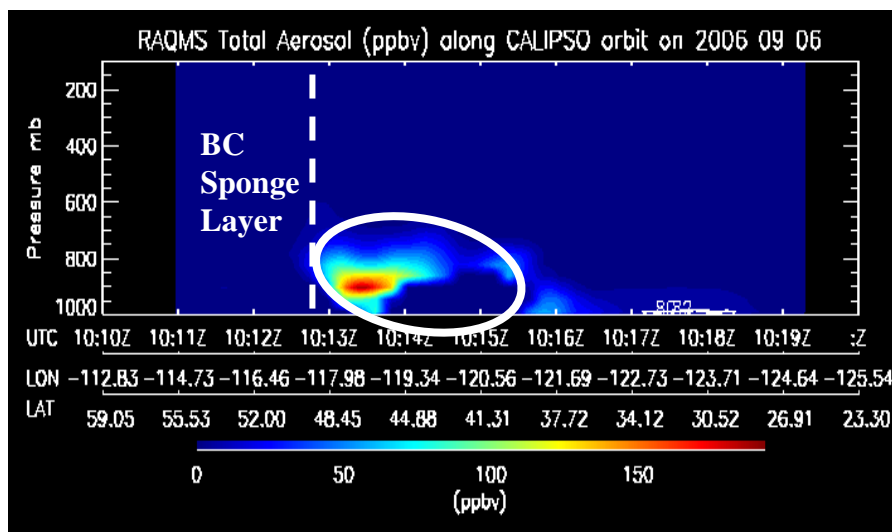
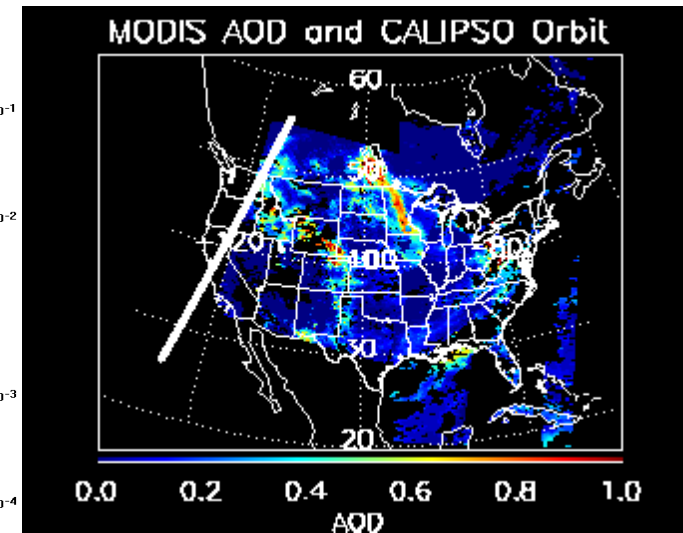
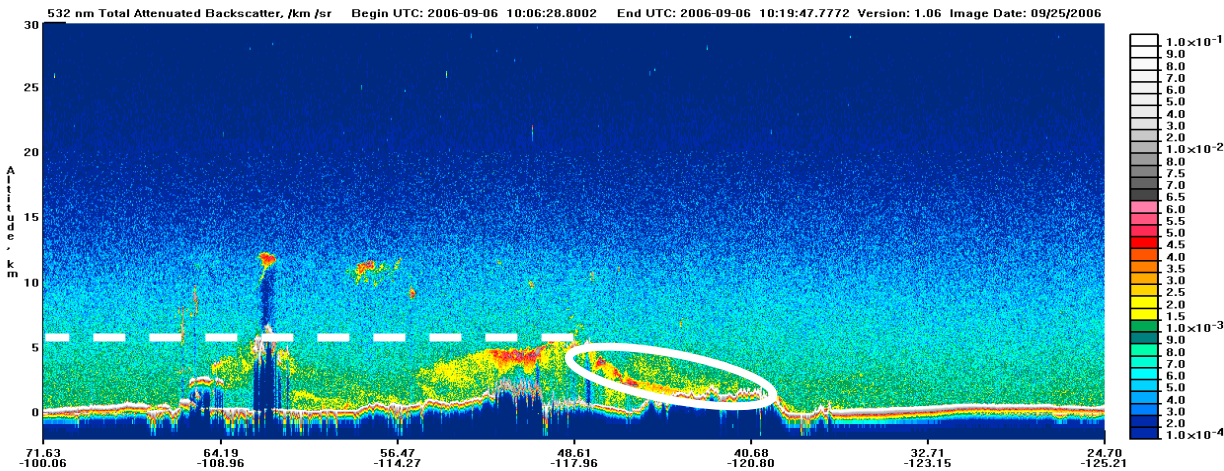
2000 (1/1/00 - 9/29/00) Fires: 80,158 Acres: 6,862,561

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

Total CO Emissions (Tg/day) over CONUS



# Smoke plume heights over NW: Vertical Profile along CALIPSO overpass - Sept 6, 2006

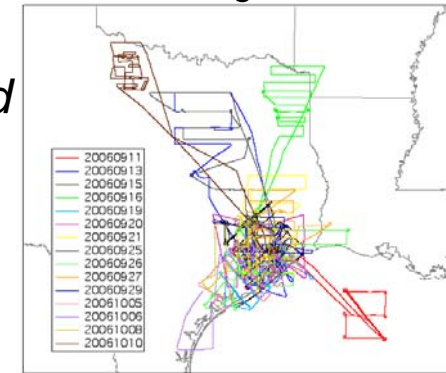


# Model Verification:

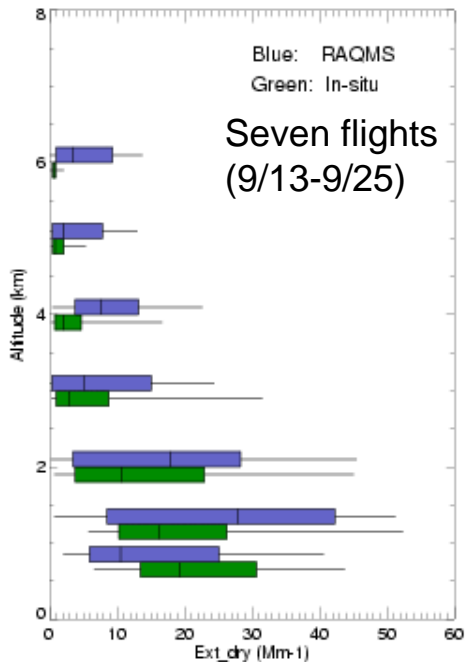
Comparisons between RAQMS aerosol (80km x 80km x 0.4km) and In-Situ Measurements on P3 during TexAQS2006

***In-situ data are preliminary. Work in progress***

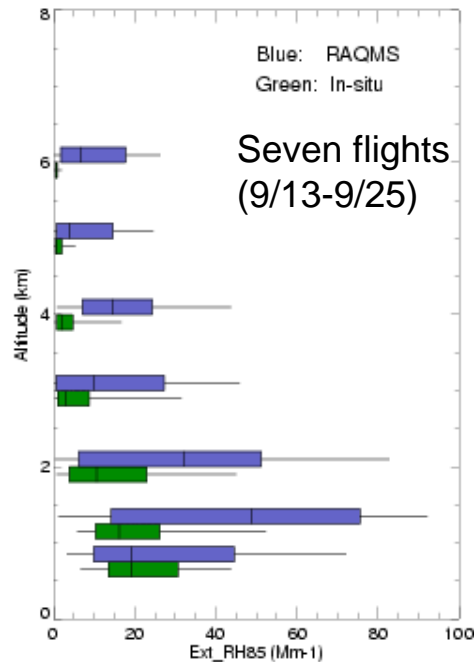
NOAA P3 Flight Tracks



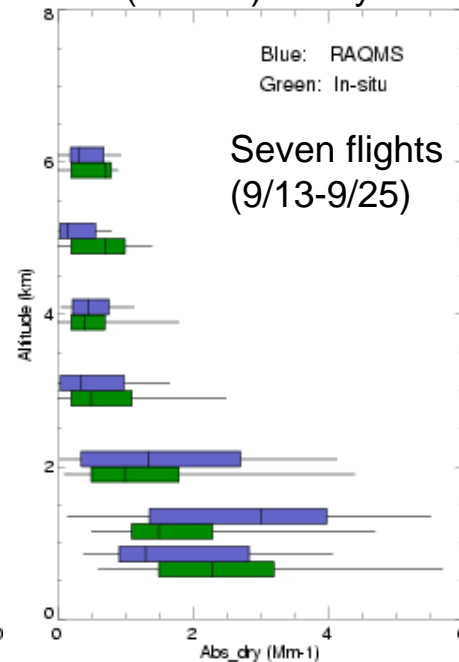
Extinction (532nm) at Dry



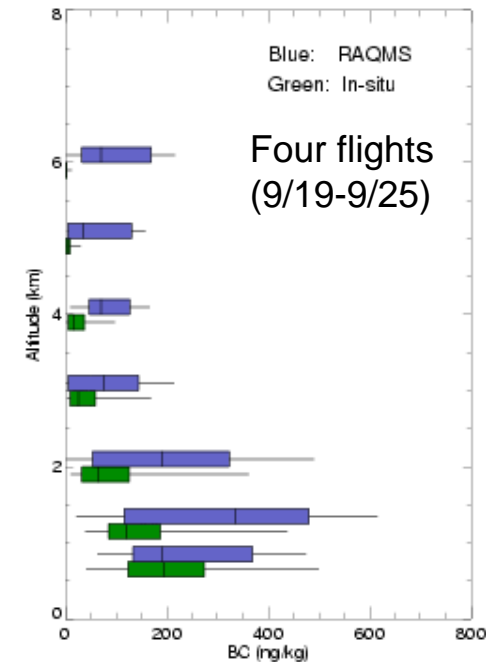
Extinction (532nm) at 85%



Absorption (530nm) at Dry



Black Carbon Mass Concentration



- Extinction measured with Cavity Ring-down Aerosol Extinction Spectrometer (CRD-AES) on P3
- Absorption measured with Particle Soot Absorption Photometer (PSAP) on P3

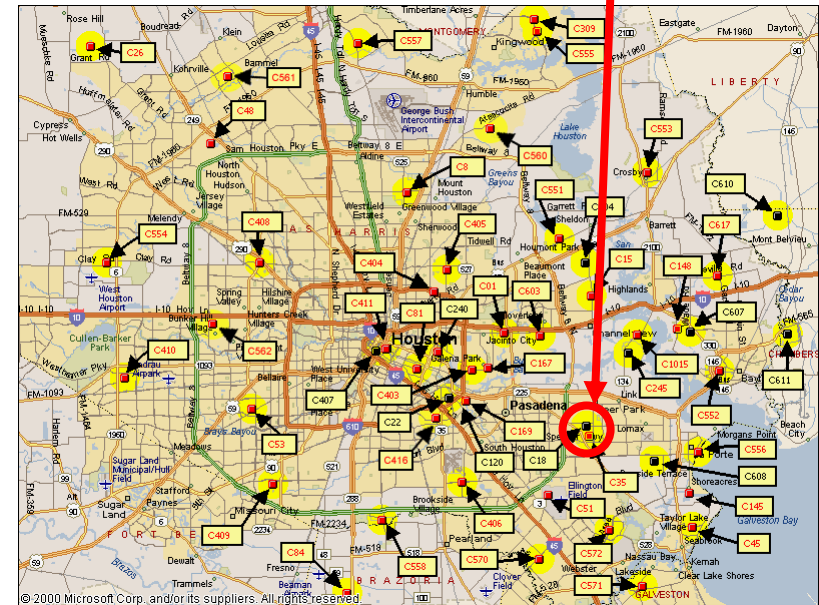
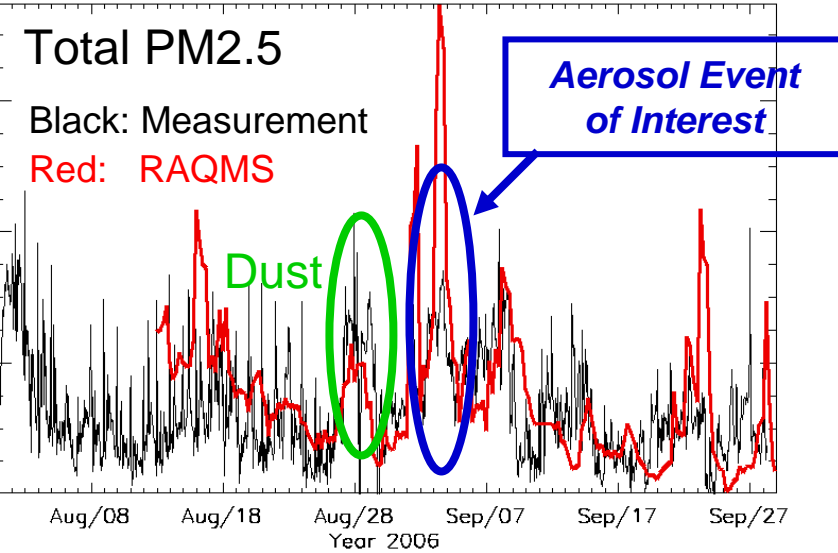
- Black carbon mass concentrations are based on 30-s bins of individual black carbon particle data from the Single-Particle Soot Photometer (SP2).

# Model Verification: RAQMS aerosol and Surface measurement comparisons

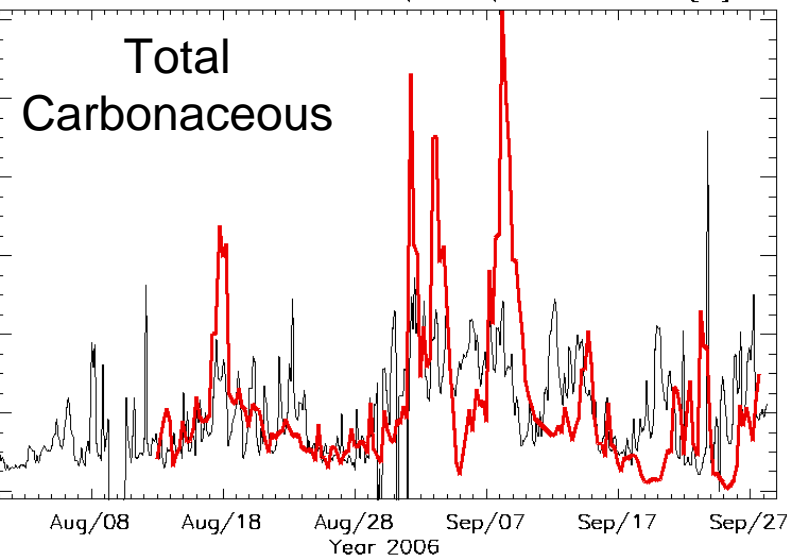
## Surface Data provided by TCEQ

### Deer Park site

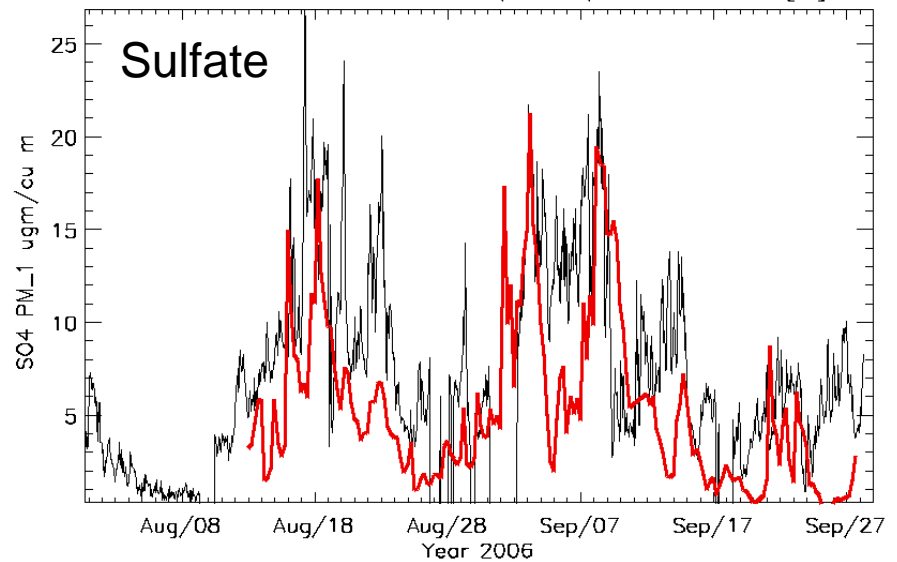
CAMS 35, Region 12 Houston, EPA Site: 48-201-1039  
 Site: Hous.Deer Park 2 C35/1001/AFH139F239 [H]



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



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



# RAQMS Aerosol Forecast with MODIS AOD Assimilation 08/27 – 08/29 - Saharan Dust

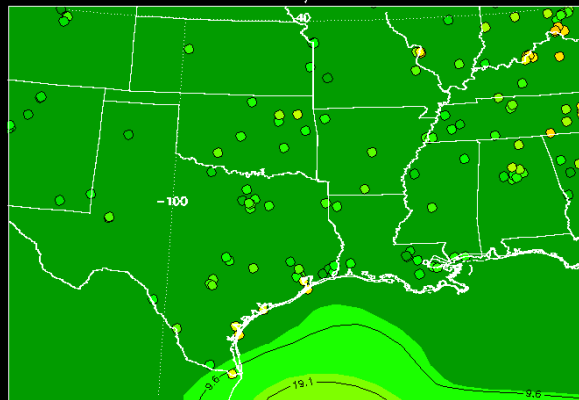
RAQMS vs AIRNow PM2.5

08/27

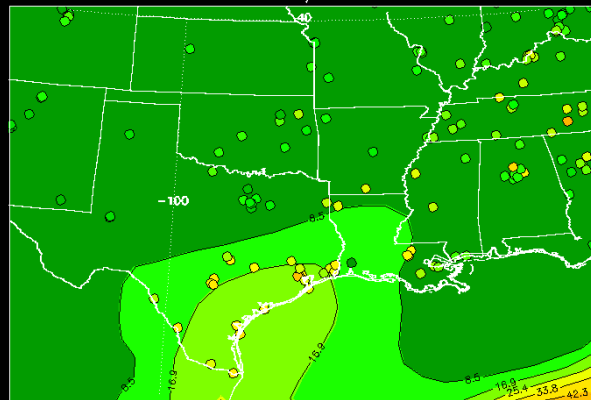
08/28

08/29

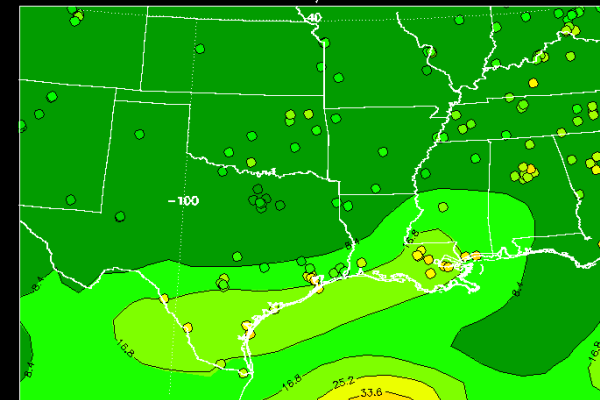
PM2.5 Dust 08/27 18Z 2006



PM2.5 Dust 08/28 18Z 2006



PM2.5 Dust 08/29 18Z 2006



0 50 100 150 200 250  
( $\mu\text{g}/\text{m}^3$ )

20060827\_12Z+006

0 50 100 150 200 250  
( $\mu\text{g}/\text{m}^3$ )

20060827\_12Z+030hr

0 50 100 150 200 250  
( $\mu\text{g}/\text{m}^3$ )

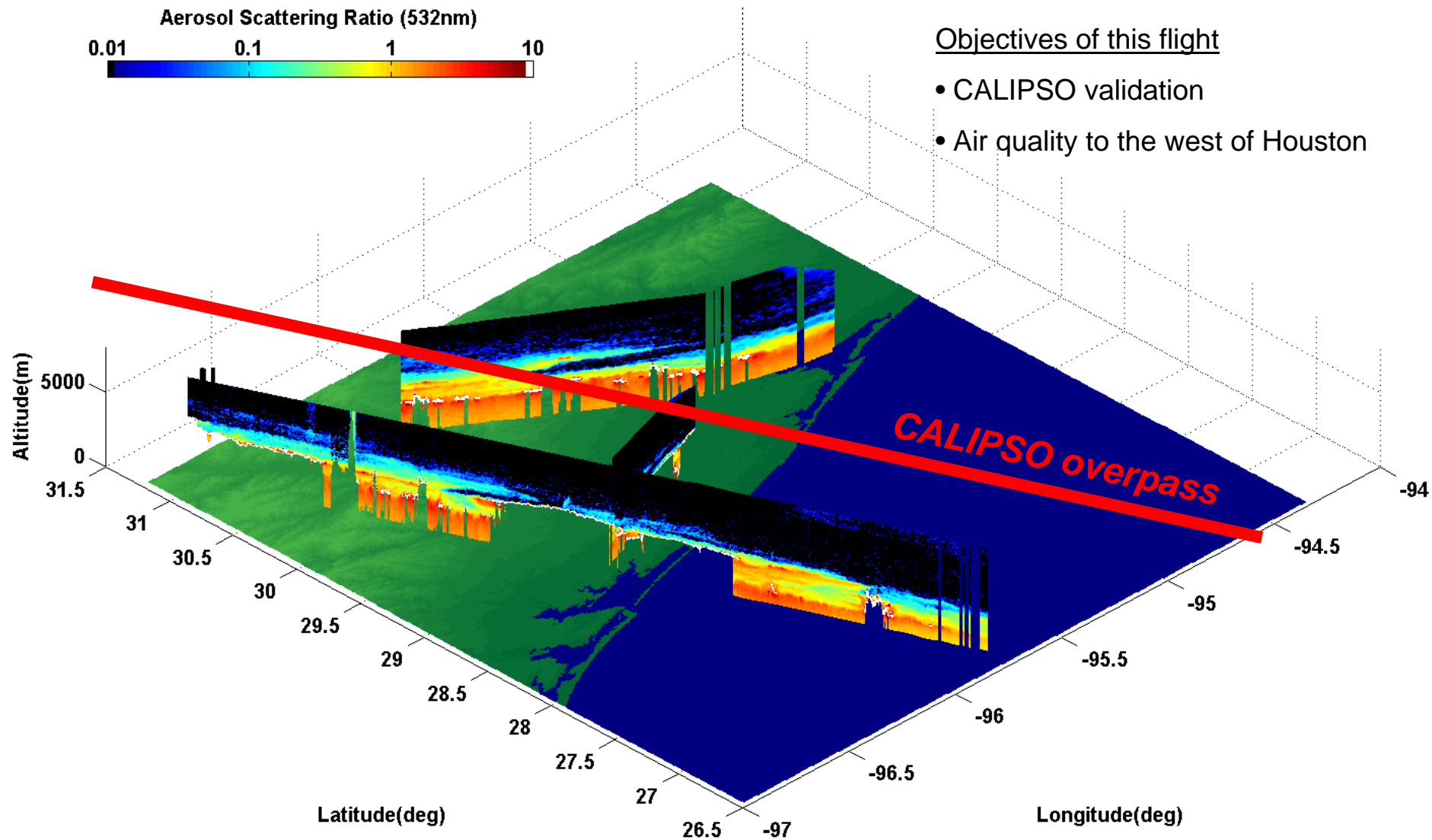
20060827\_12Z+054hr

# HSRL Aerosol Backscattering Ratio

September 4, 2006

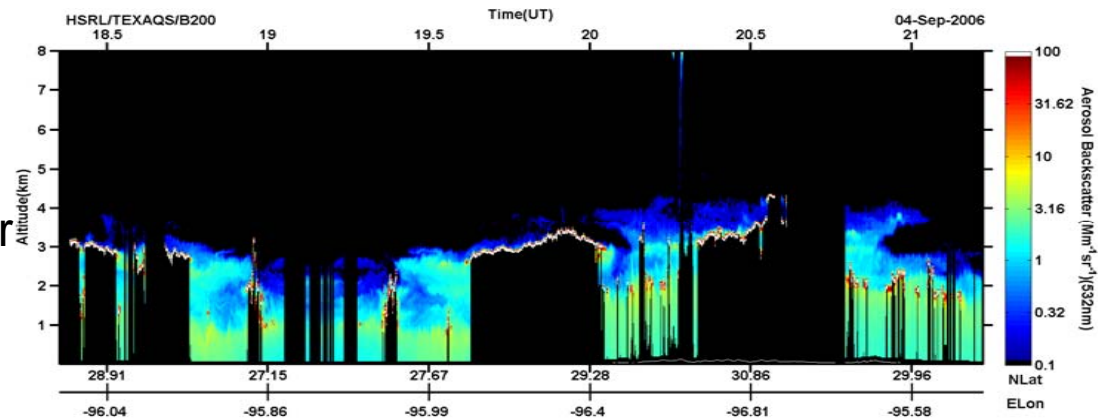
## Objectives of this flight

- CALIPSO validation
- Air quality to the west of Houston

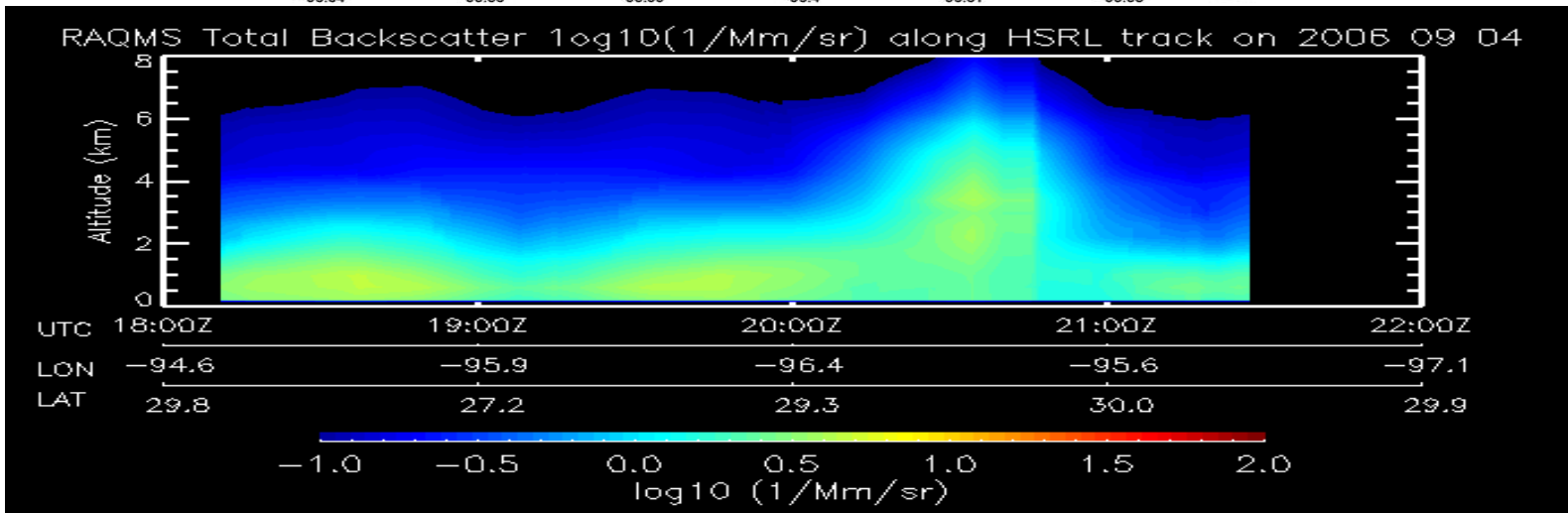


09/04/2006

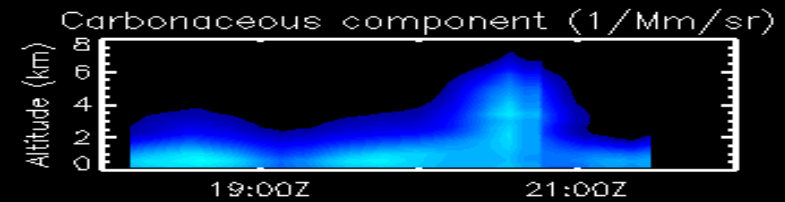
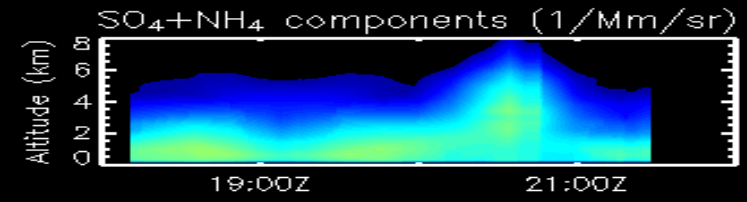
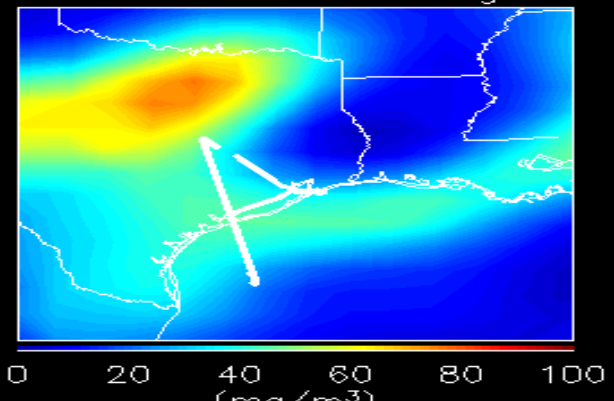
HSRL  
Aerosol Backscatter



RAQMS  
Aerosol  
Backscatter  
along HSRL  
Flight Track

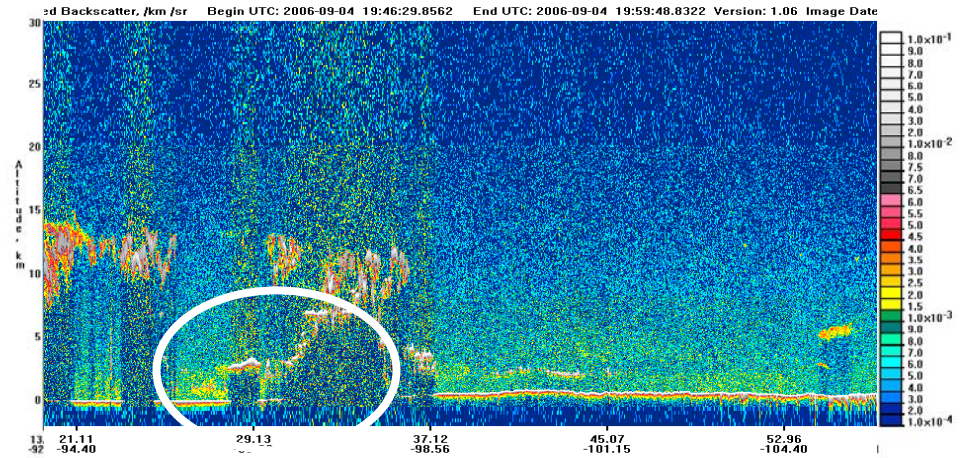


RAQMS Column and HSRL flight track

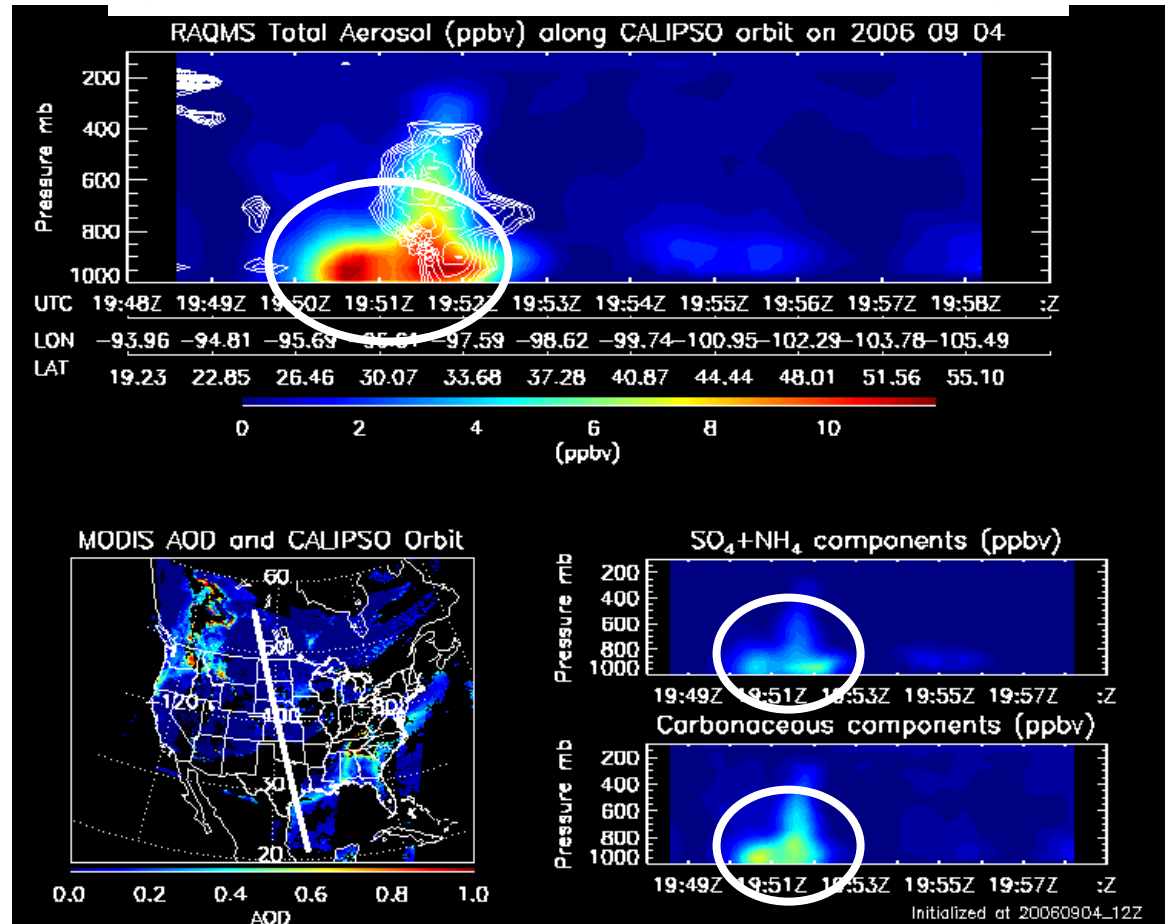


09/04/2006

# CALIPSO Attenuated Backscatter



## RAQMS Aerosol along CALIPSO Flight Track



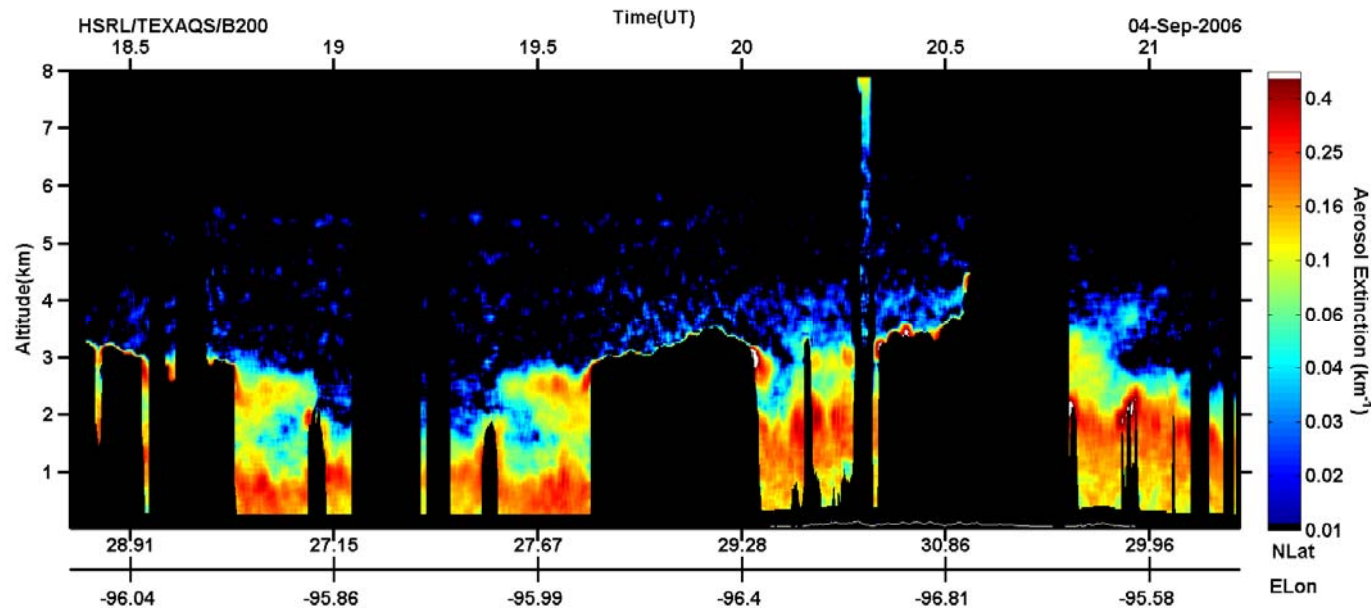


# Trajectory Analysis:

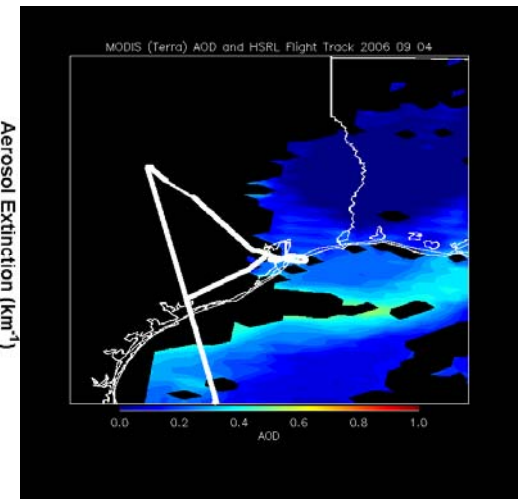
## Identify transport paths and source regions

- Run a trajectory model **backward** in time for 12 days
- Trajectories initialized at all points with Aerosol Extinction  $> 0.3 \text{ km}^{-1}$  within the boundary layer

HSRL Aerosol Extinction for 09/04/2006



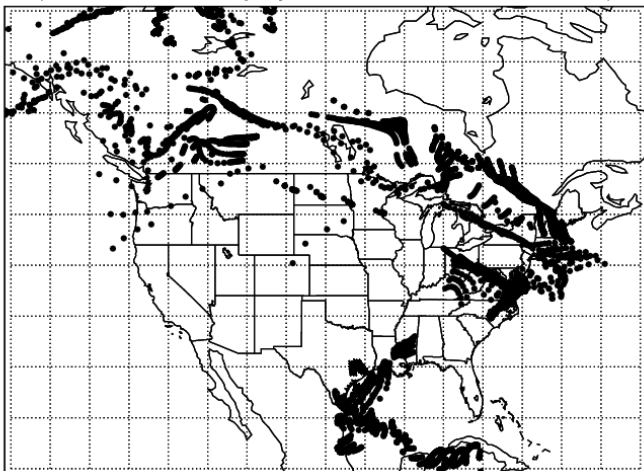
HSRL Flight Track



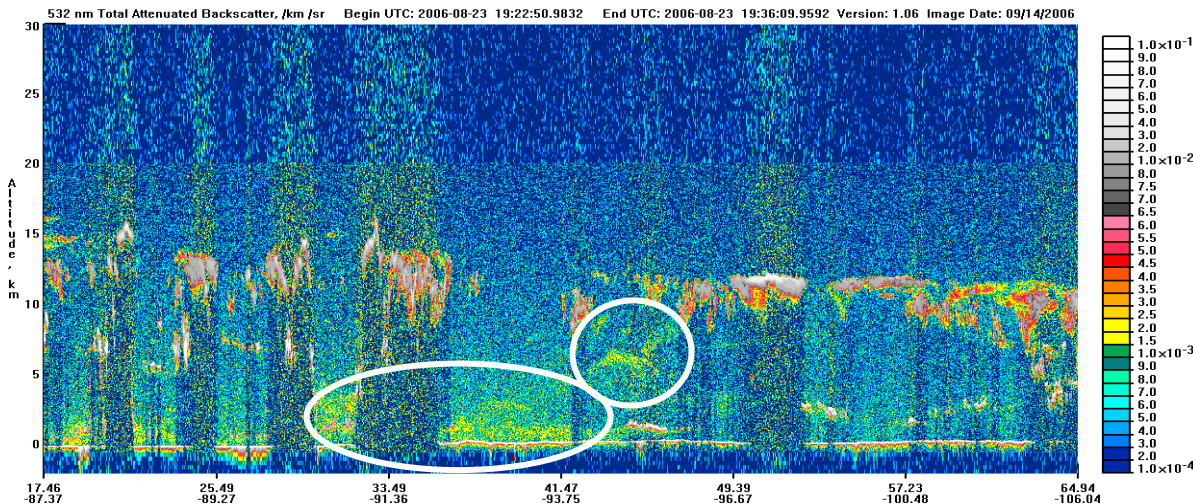
# 12 days back: Aug 23, 2006

## 12-day Backtrajectories

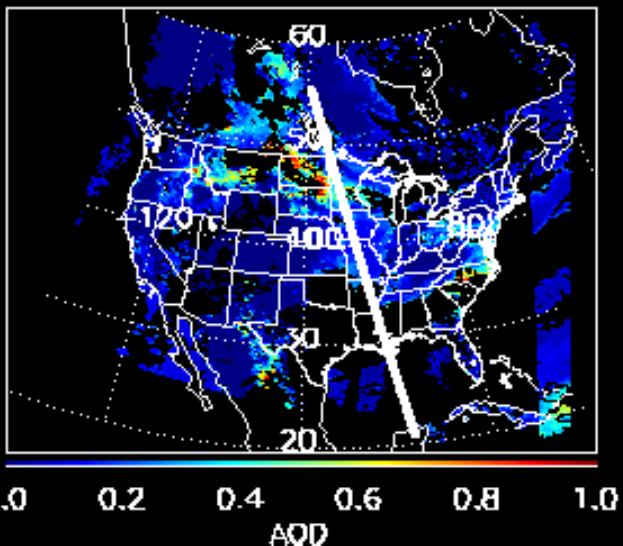
HSRL Back trajectories valid 00–18Z August 23, 2006  
(Initialized from Boundary Layer HSRL measurements with AOD > 0.30)



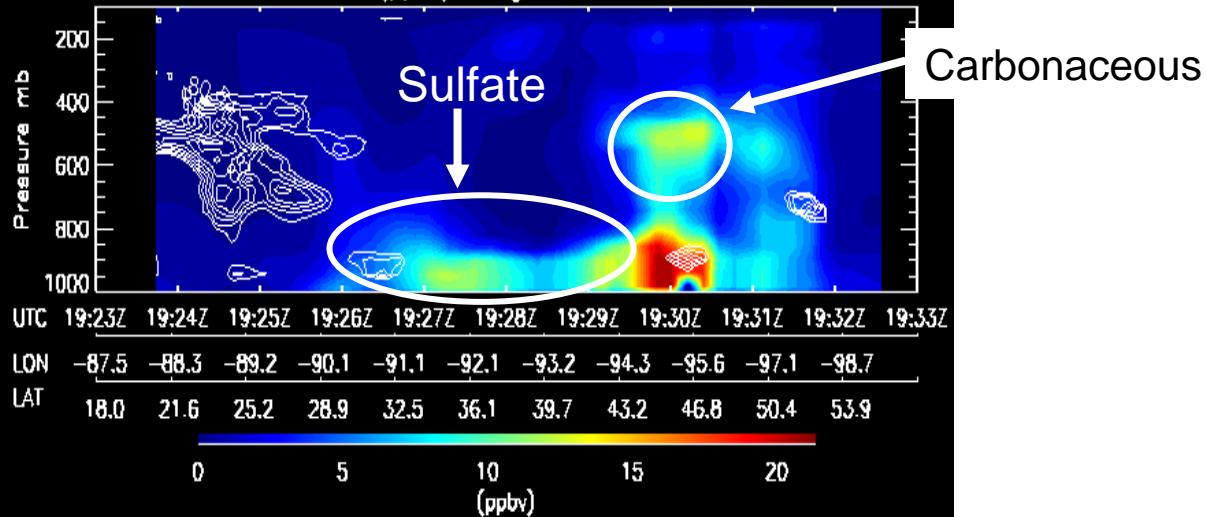
## CALIPSO Attenuated Backscatter



## MODIS AOD and CALIPSO Orbit



## RAQMS Total Aerosol (ppbv) along CALIPSO orbit on 2006 08 23



## **Summary:**

- This synthesis shows that enhancements in surface PM<sub>2.5</sub> and Boundary layer extinction in Houston during early September were influenced by long-range transport of primary aerosols (OC/BC) from wild fires in the Pacific NW and sulfate production during transport over the eastern US.
- CALIPSO aerosol backscatter vertical profiles, combined with MODIS AOD are shown to provide an unique view of the evolution of aerosols over the continental US during this aerosol event, which resulted in surface PM<sub>2.5</sub> levels that were “unhealthy for sensitive groups” in the Midwest and “moderate” in the Houston area.

## **Future Plans:**

- Compare RAQMS analysis with CALIPSO data (when available)
- Implement aerosol modules in global model
- Assimilate CALIPSO data

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**Brad Pierce: [r.b.pierce@larc.nasa.gov](mailto:r.b.pierce@larc.nasa.gov)**