Synthesis of multiple observations using a regional aerosol assimilation/forecast model (RAQMS) and assessment of biomass burning emission estimates

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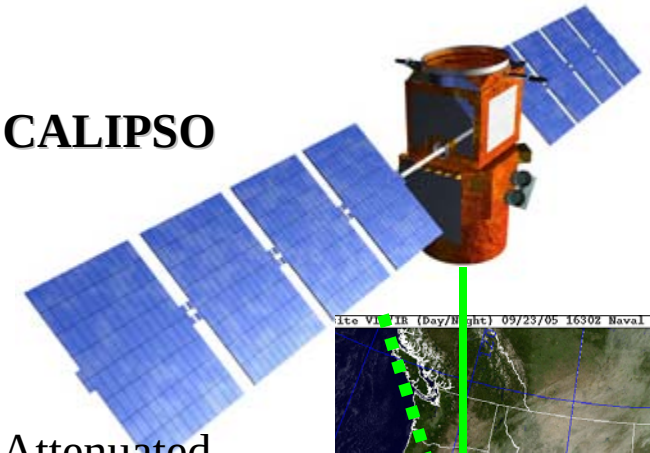
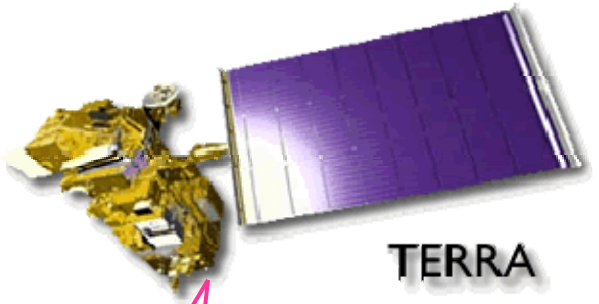
5) Department of Atmospheric and Oceanic Sciences, University of Wisconsin, Madison, WI
6) NASA Goddard Space Flight Center, Greenbelt, MD
7) US EPA, Research Triangle Park, NC
8) Texas Commission on Environmental Quality, Austin, TX
9) NOAA/NESDIS

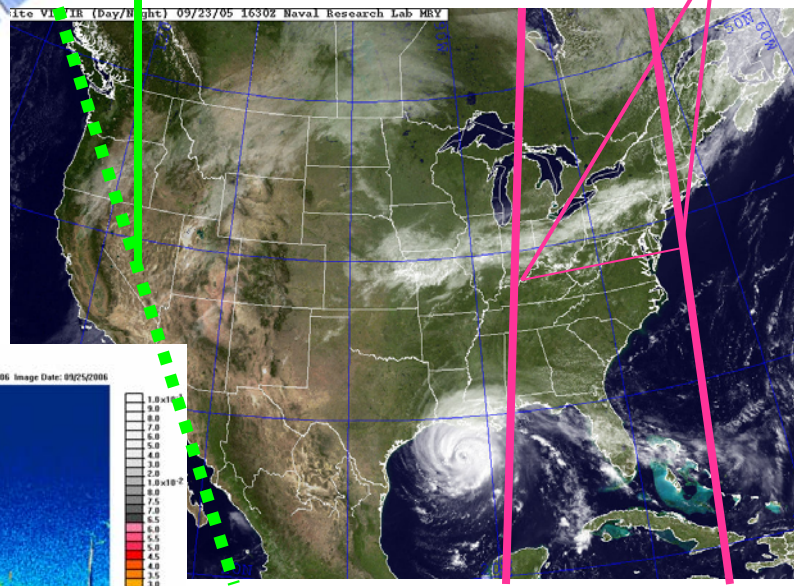
- **Smoke influence on aerosol distribution over the western/central US in early Sept., 2006**
- **Sensitivity studies on wildfire emission estimate**
- **Evaluation of altitude of aerosol transport**

Satellite data used in Analysis:

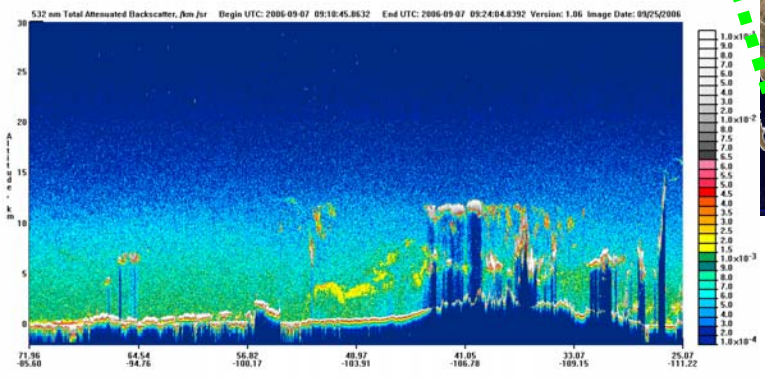
CALIPSO



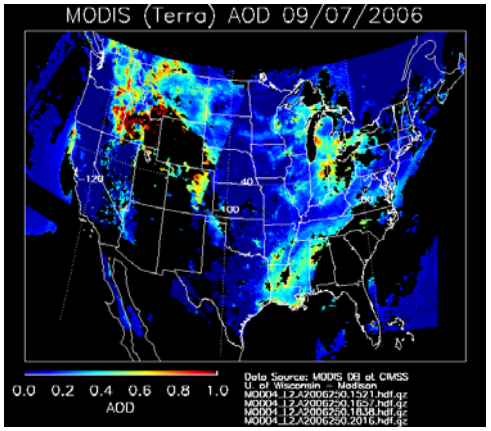




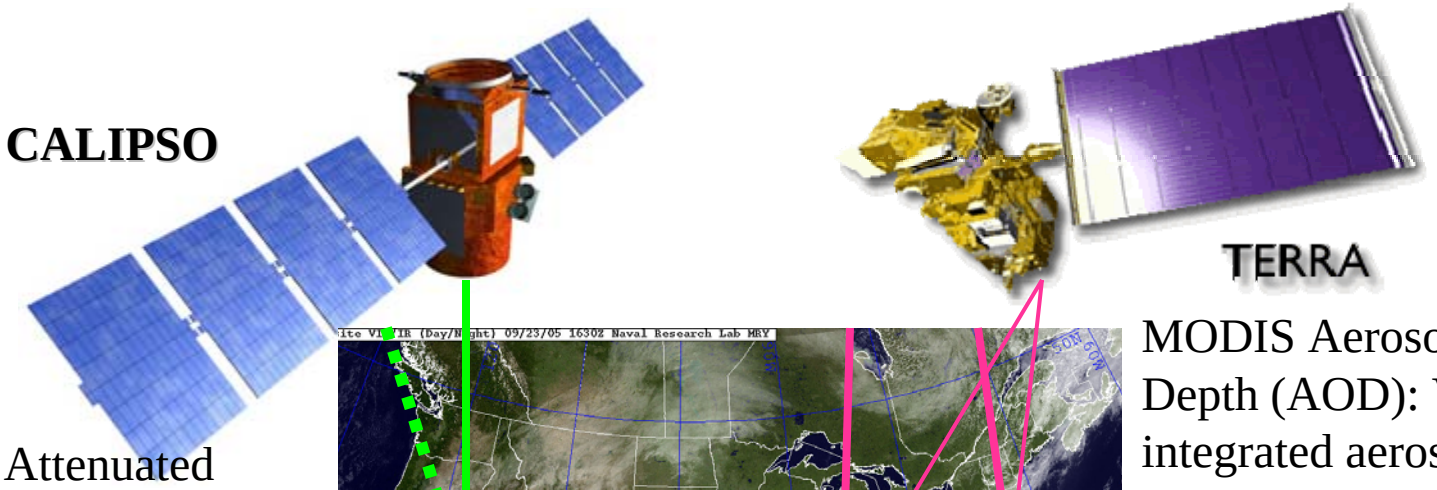
Integrated Attenuated Backscatter (IAB): Vertically resolved aerosol loading



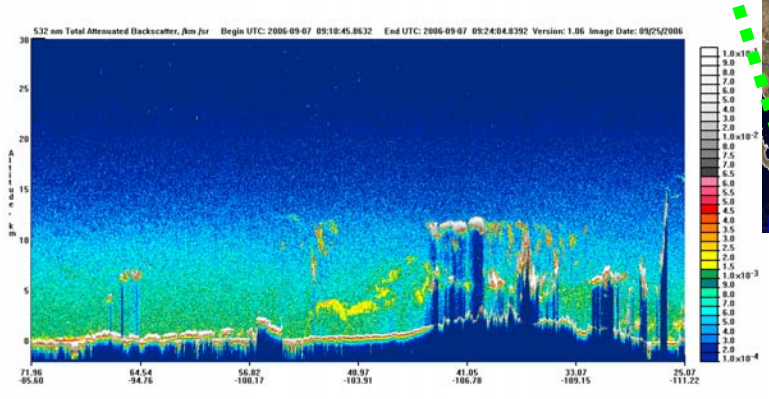
MODIS Aerosol Optical Depth (AOD): Vertically integrated aerosol loading

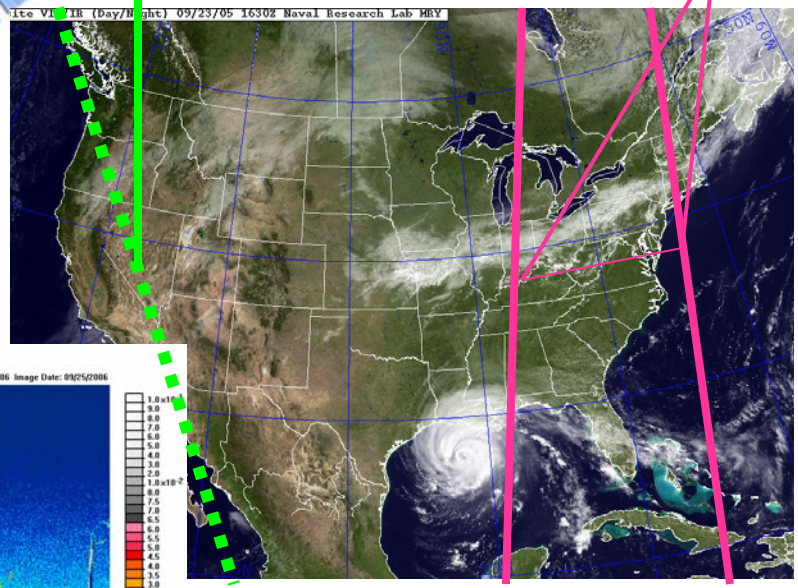


Satellite data used in Analysis:



Integrated Attenuated Backscatter (IAB): Vertically resolved aerosol loading





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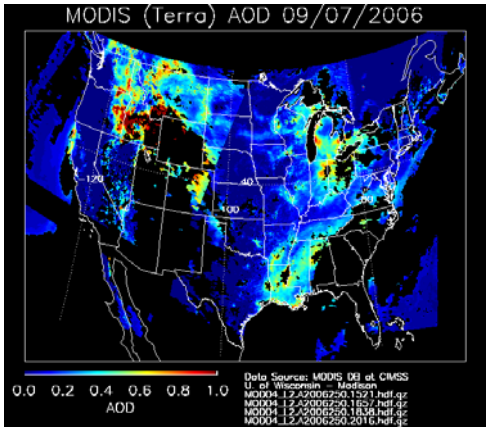
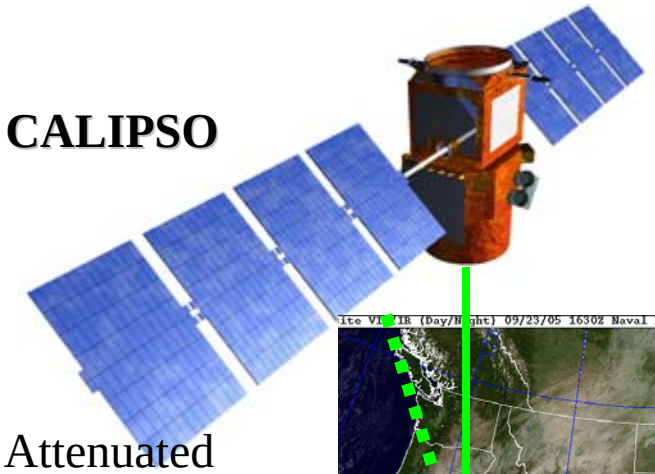
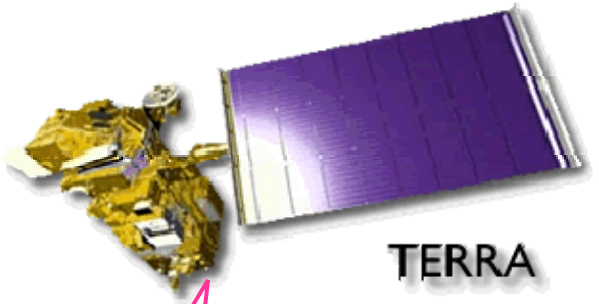


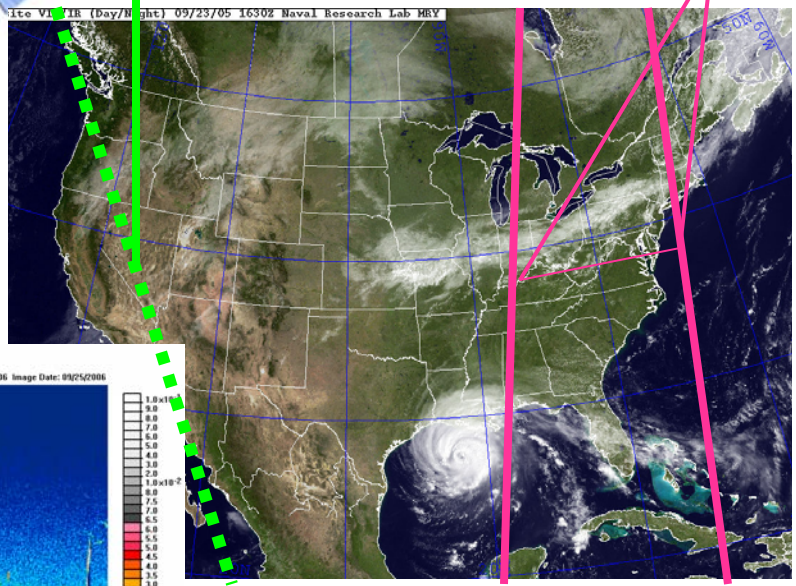
Combination of MODIS AOD and CALIPSO Backscatter provides a three-dimensional view of aerosol loading.

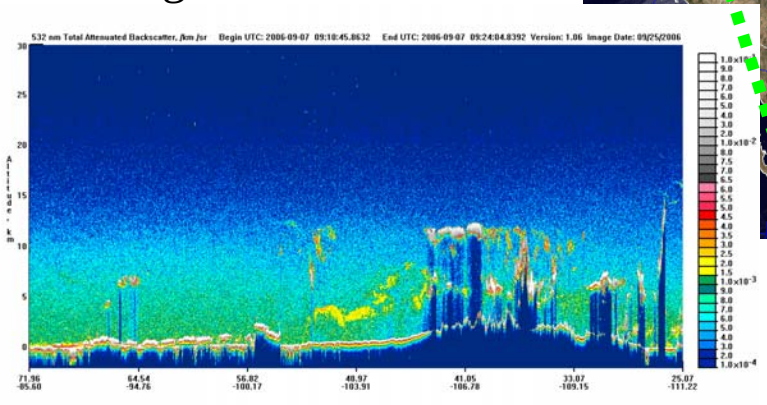
Satellite data used in Analysis:





Integrated Attenuated Backscatter (IAB): Vertically resolved aerosol loading





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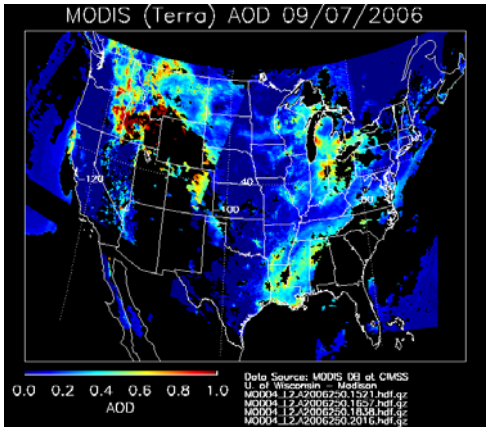
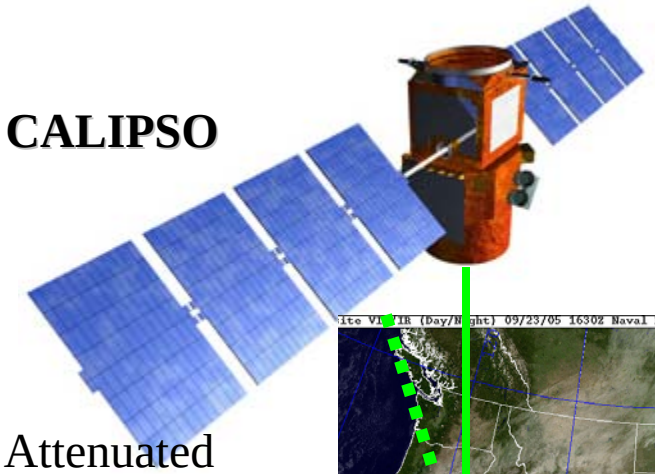
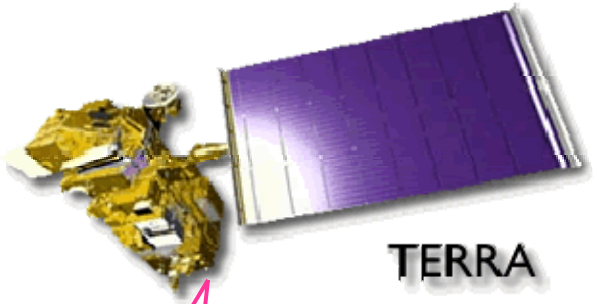


Combination of MODIS AOD and CALIPSO Backscatter provides a three-dimensional view of aerosol loading.

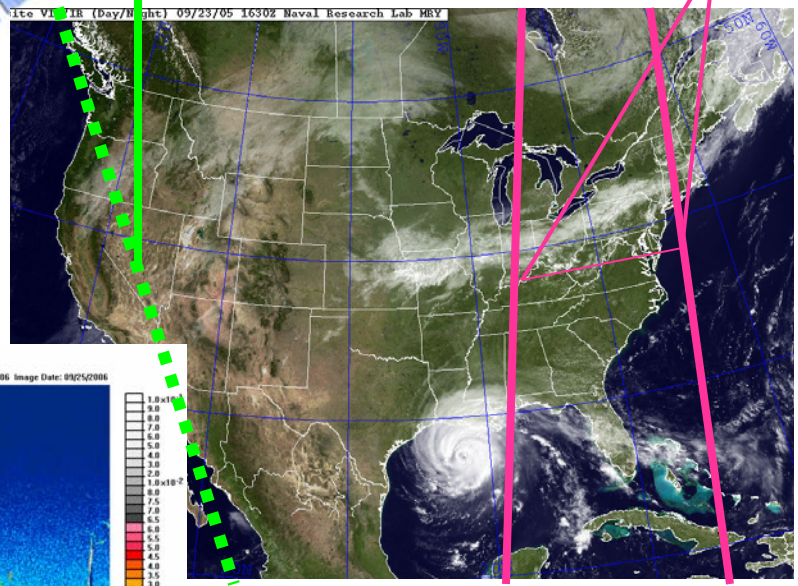
Assimilate AOD and constrain total AOD to the model

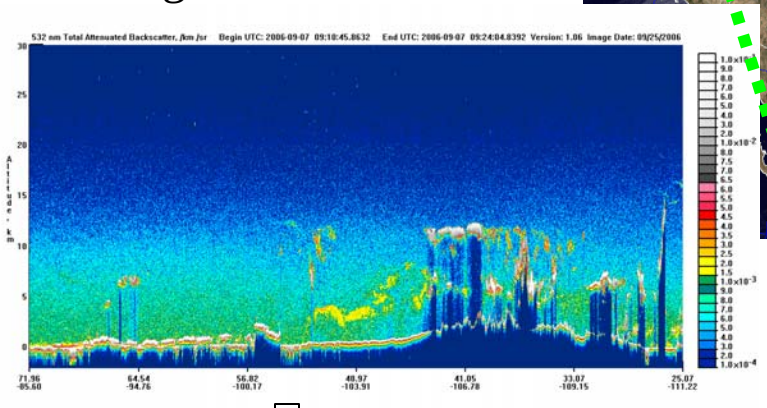
Satellite data used in Analysis:



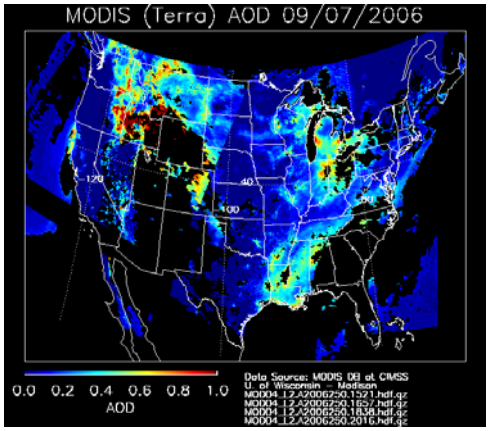


Integrated Attenuated Backscatter (IAB): Vertically resolved aerosol loading





MODIS Aerosol Optical Depth (AOD): Vertically integrated aerosol loading

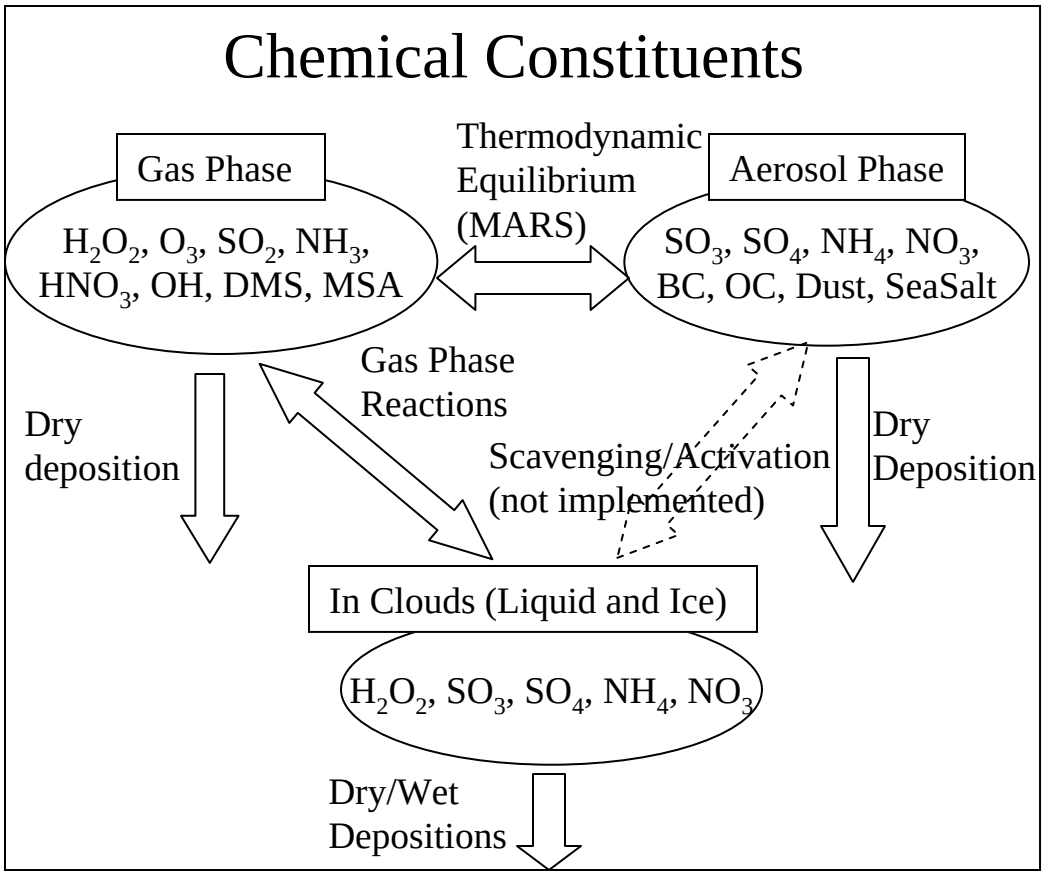


Evaluate altitude of aerosol transport

Combination of MODIS AOD and CALIPSO Backscatter provides a three-dimensional view of aerosol loading.

Assimilate AOD and constrain total AOD to the model

Modeling system used in Analysis:
Real-time Air Quality Modeling System (RAQMS)
Description of RAQMS Aerosol Modules

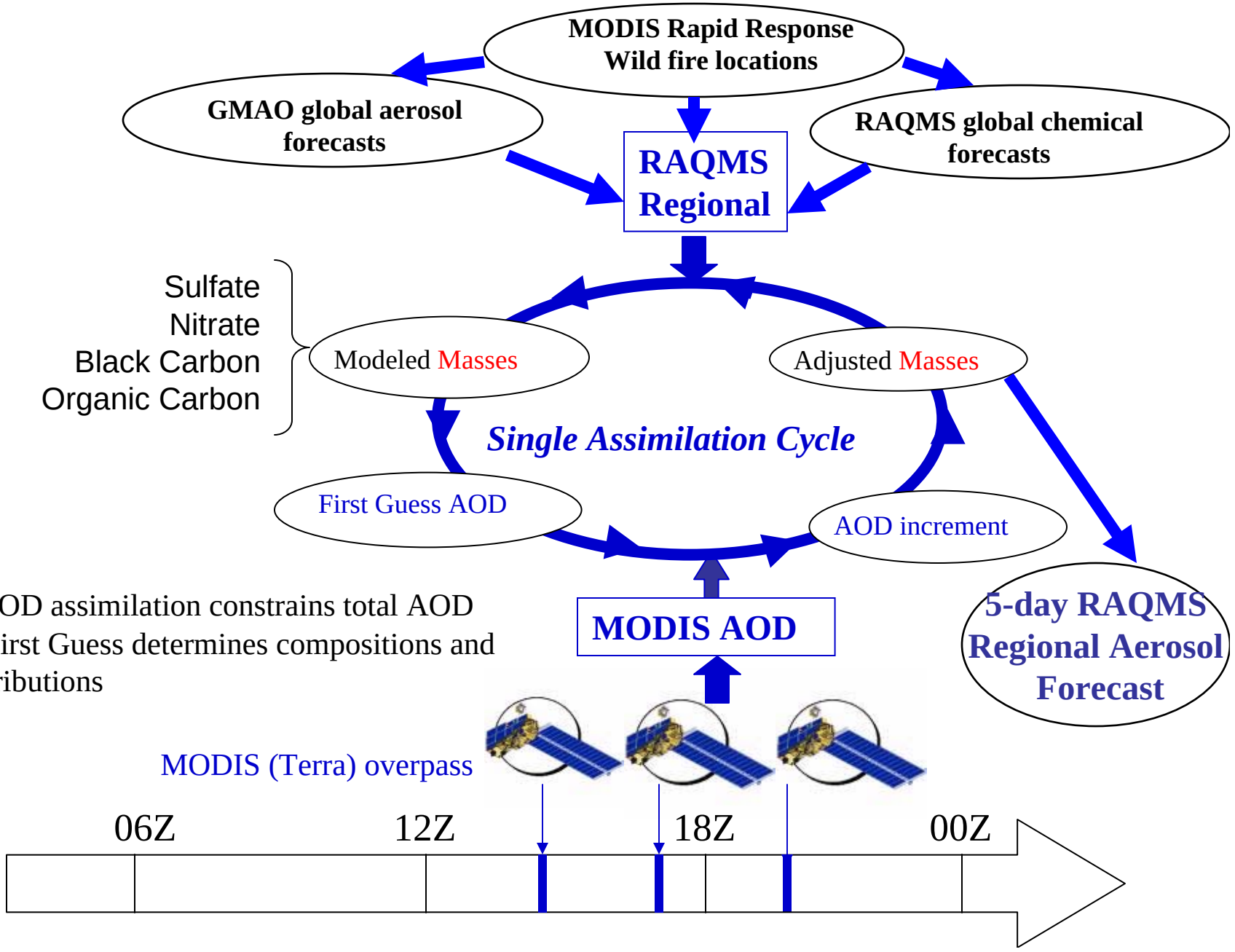


- **CONUS domain (80km×80km×0.4km)**
- **RAQMS global analyses used for chemical constraints**
- **GMAO global aerosol analysis/forecast products used for lateral boundary conditions**
- **<u>Convective transport due to fires</u> is represented based on total carbon burned with the conversion factor 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.**

<u>RAQMS Aerosol Mechanism:</u>

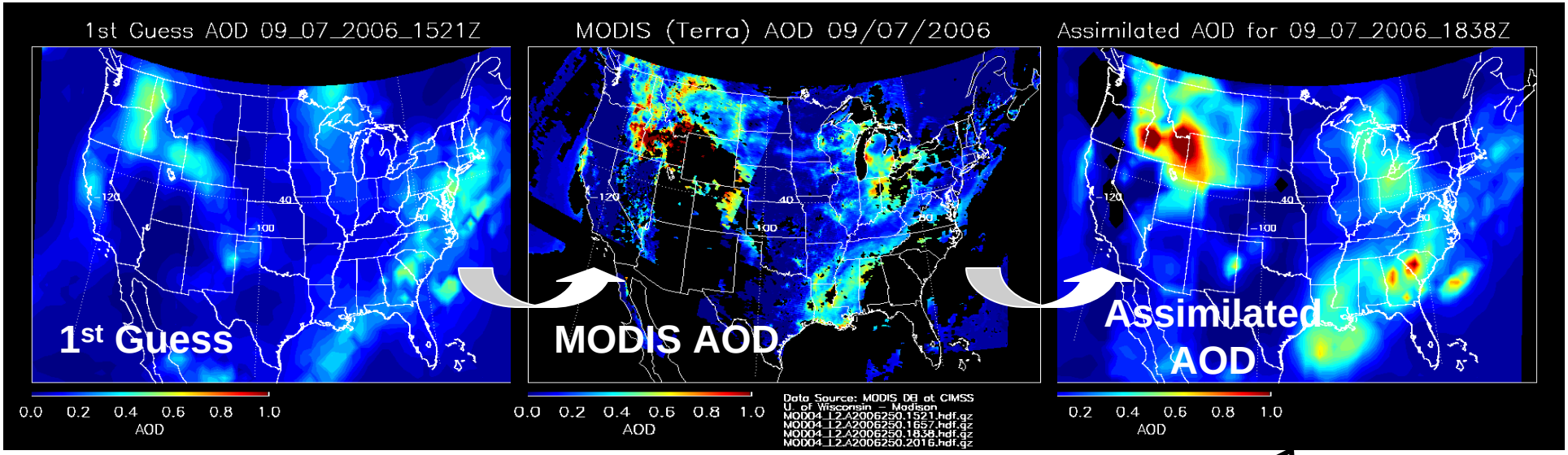
- **Sulfate [Kittaka, 2004],**
- **Dust, Sea Salt, Carbonaceous Aerosol from GOCART [provided by Mian Chin, GSFC]**
- **Nitrate and Ammonium from GEOS-CHEM [provided by Rokjin Park, Harvard]**

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



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

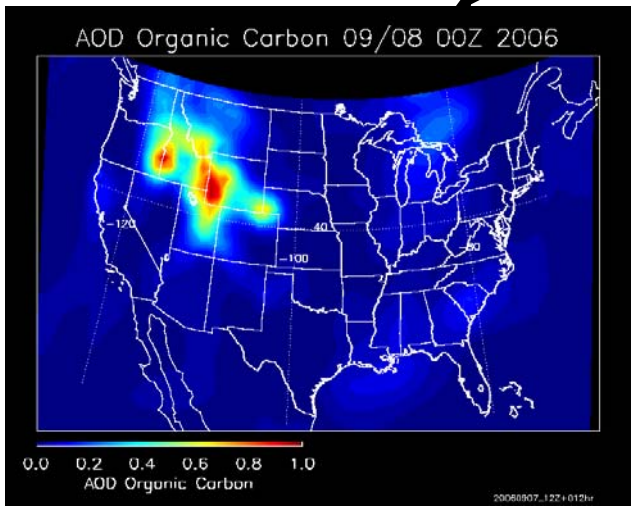
RAQMS$_{regional}$ MODIS AOD Assimilation cycle 09/07/06

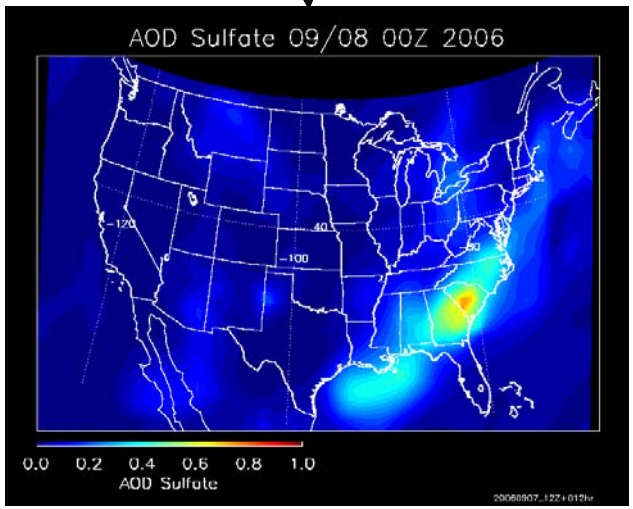


AOD assimilation improved estimate of smoke from NW biomass burning and SE sulfate aerosol distributions

Organic Carbon

Sulfate



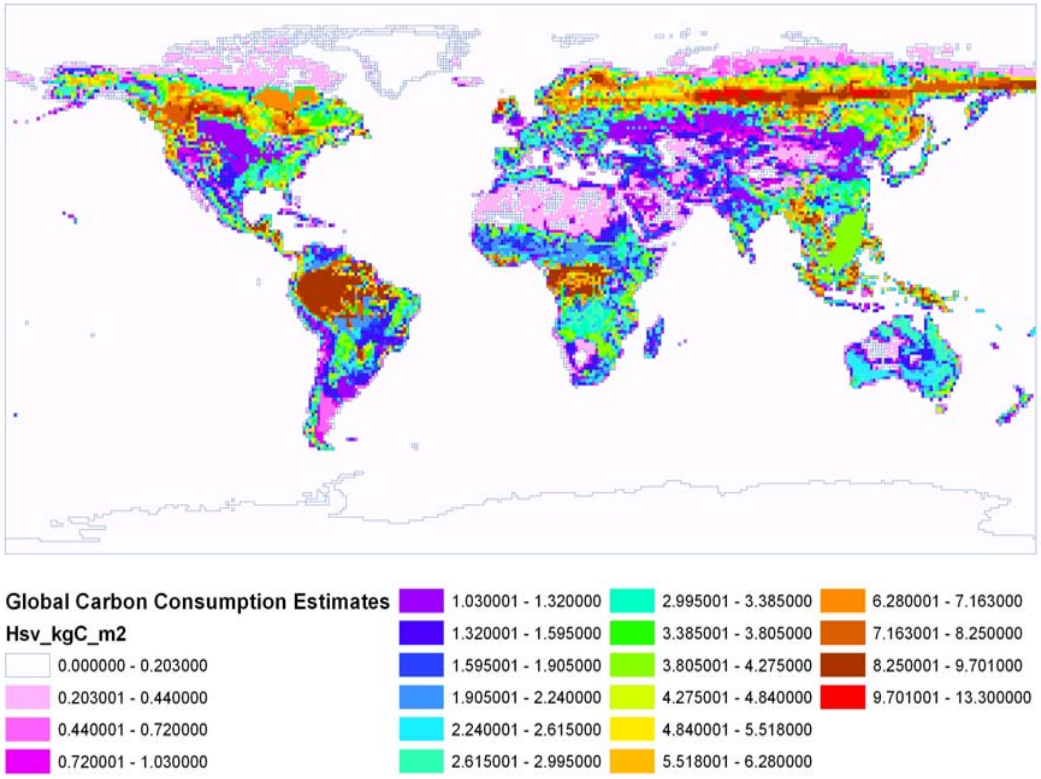


Biomass Burning Emission Estimates = (Area Burned) x (Available Fuel)

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)



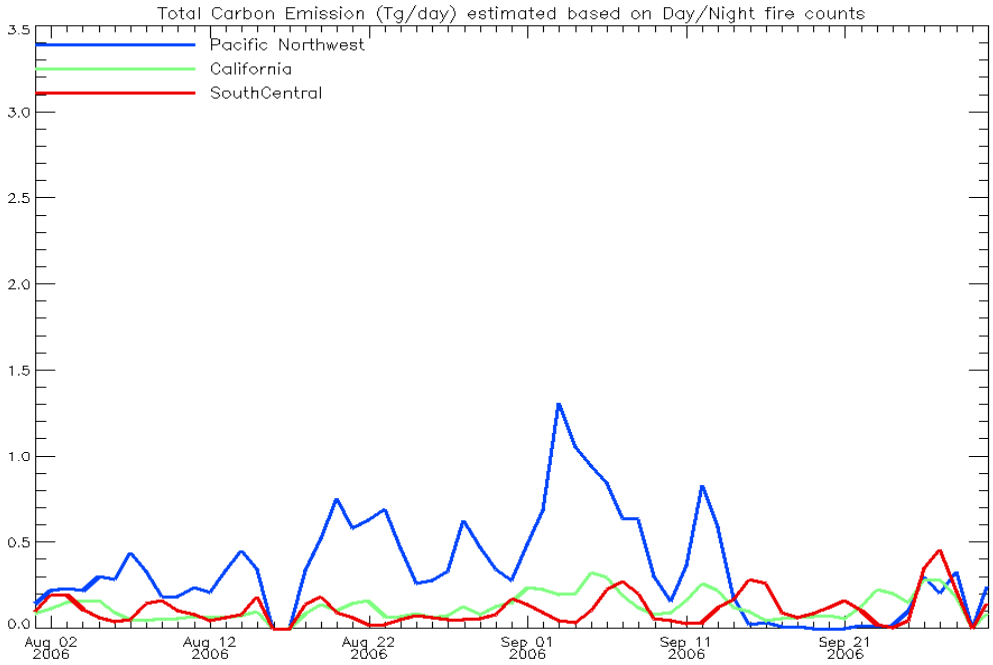
Global *high-severity* carbon consumption estimates

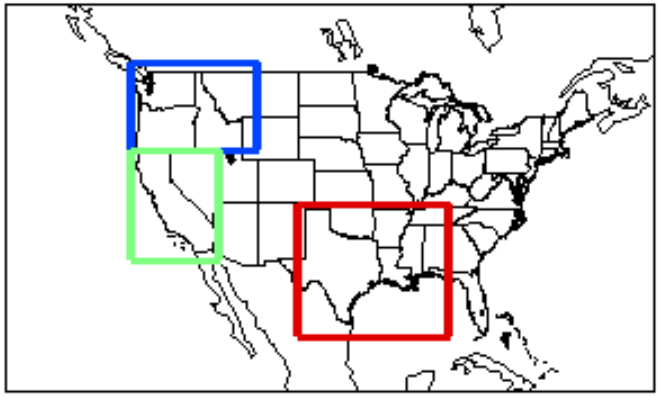
Fire Statistics

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

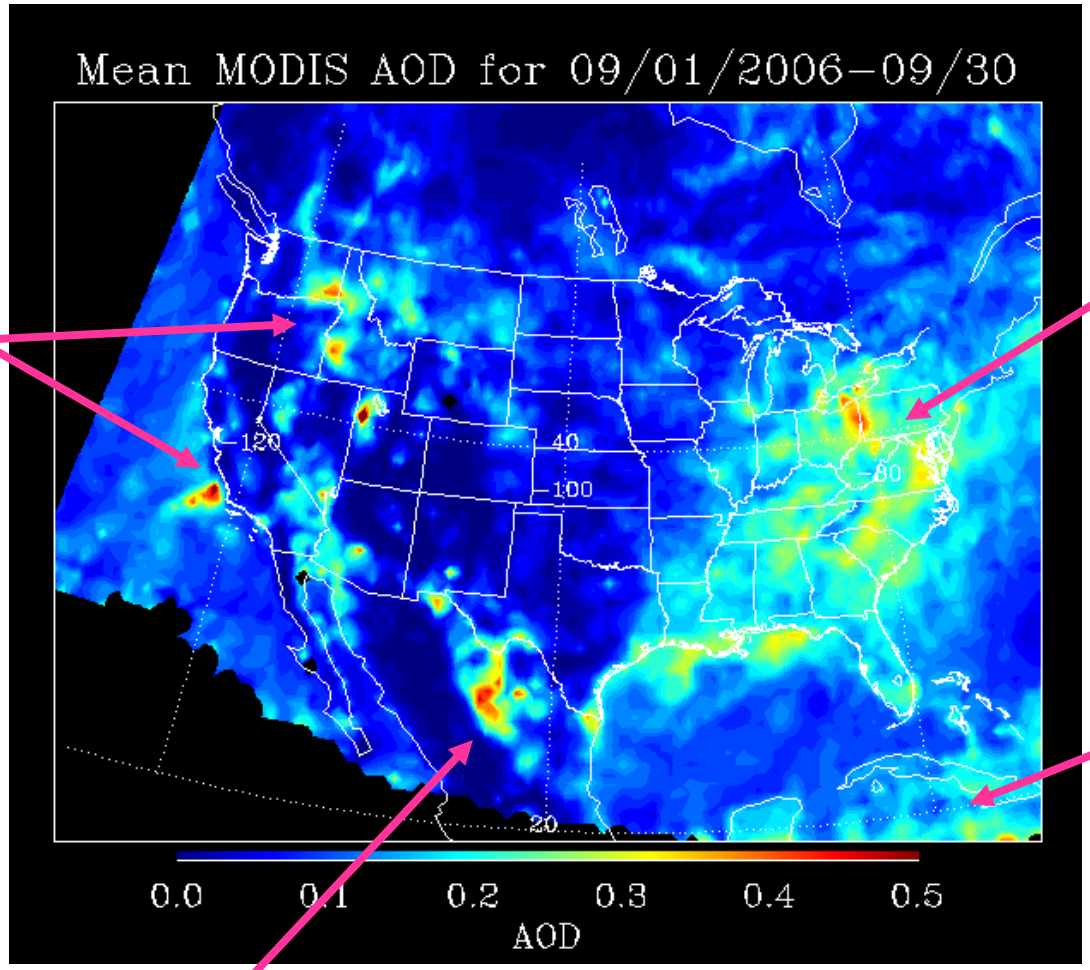
2006 (1/1/06 - 9/29/06) Fires: 83,752 Acres: 9,074,358
2005 (1/1/05 - 9/29/05) Fires: 53,175 Acres: 8,160,688
2004 (1/1/04 - 9/29/04) Fires: 60,934 Acres: 7,737,472
2003 (1/1/03 - 9/29/03) Fires: 49,180 Acres: 3,167,289
2002 (1/1/02 - 9/29/02) Fires: 67,265 Acres: 6,578,985
2001 (1/1/01 - 9/29/01) Fires: 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 where higher than the previous 6 years by 110 -280%





Continental Aerosols observed from MODIS (Terra) during Sept. 2006



Biomass emission from wild fires

Persistent sulfate pollution

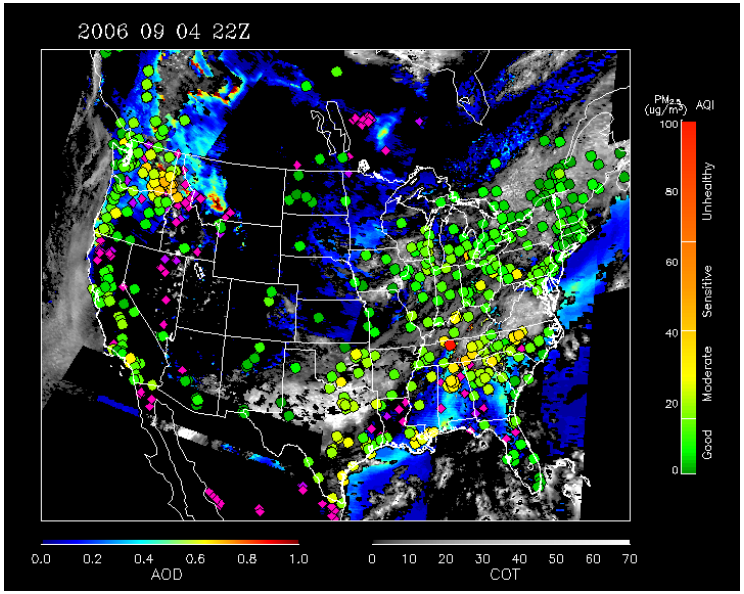
Dust from Sahara

Artifact due to high reflective surface

Pacific NW Wild fire event September 4-8

MODIS AOD/COT (contours) and AIRNow PM2.5 (circles)

9/4



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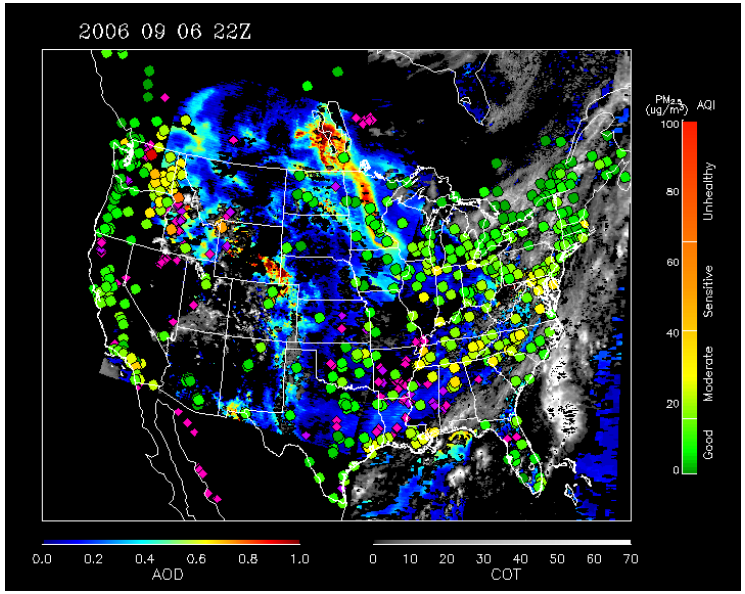

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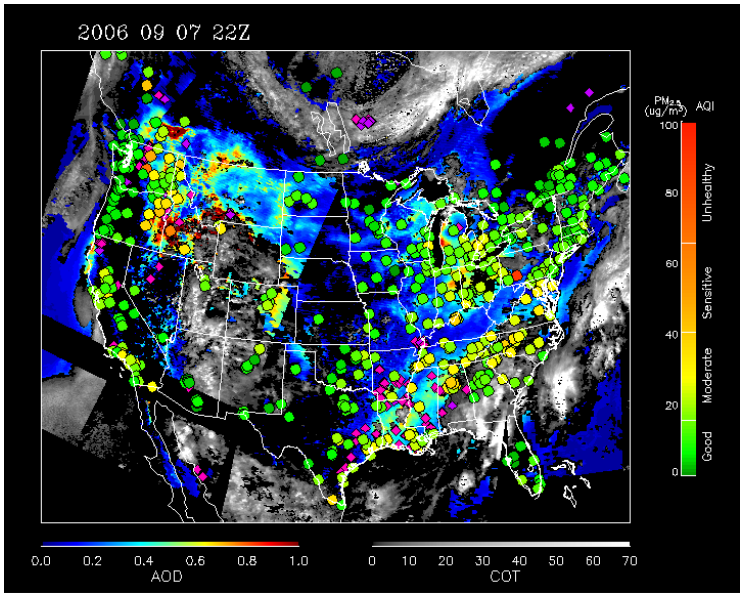

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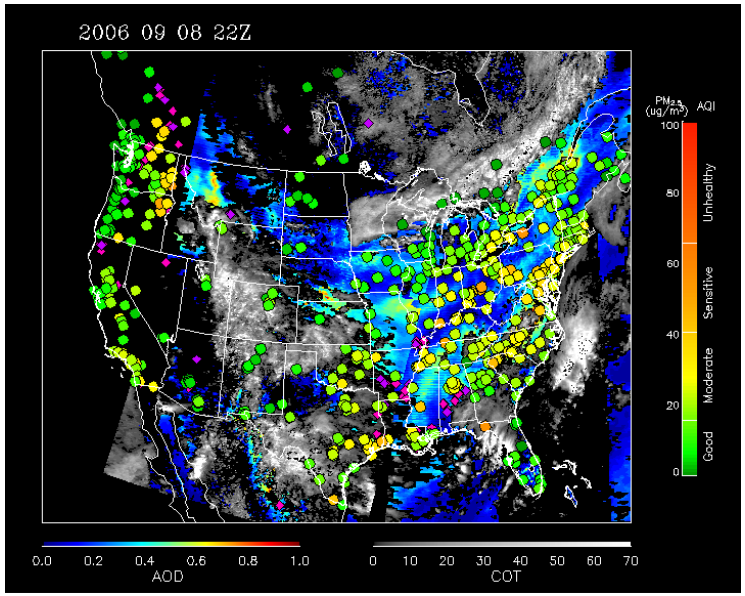
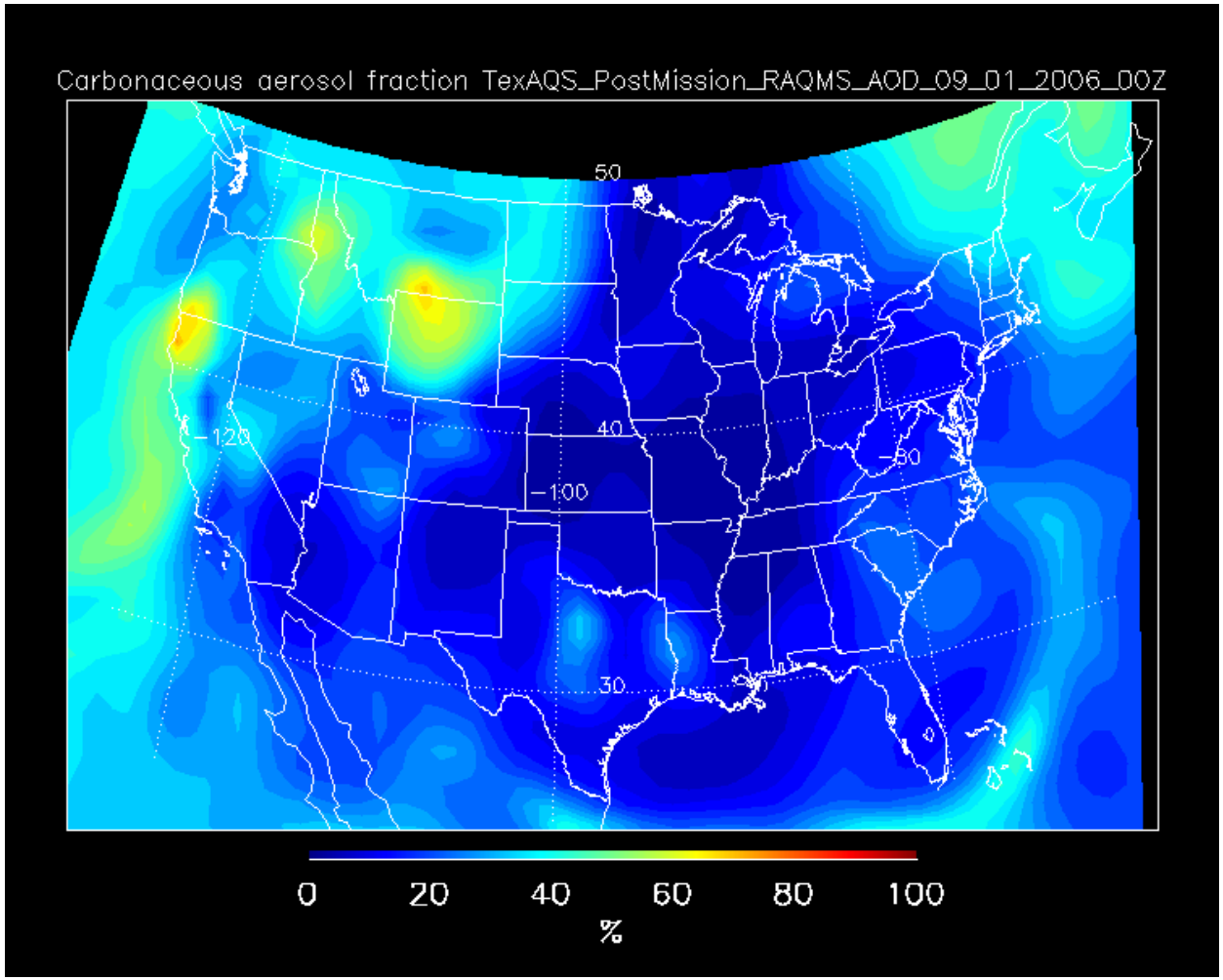


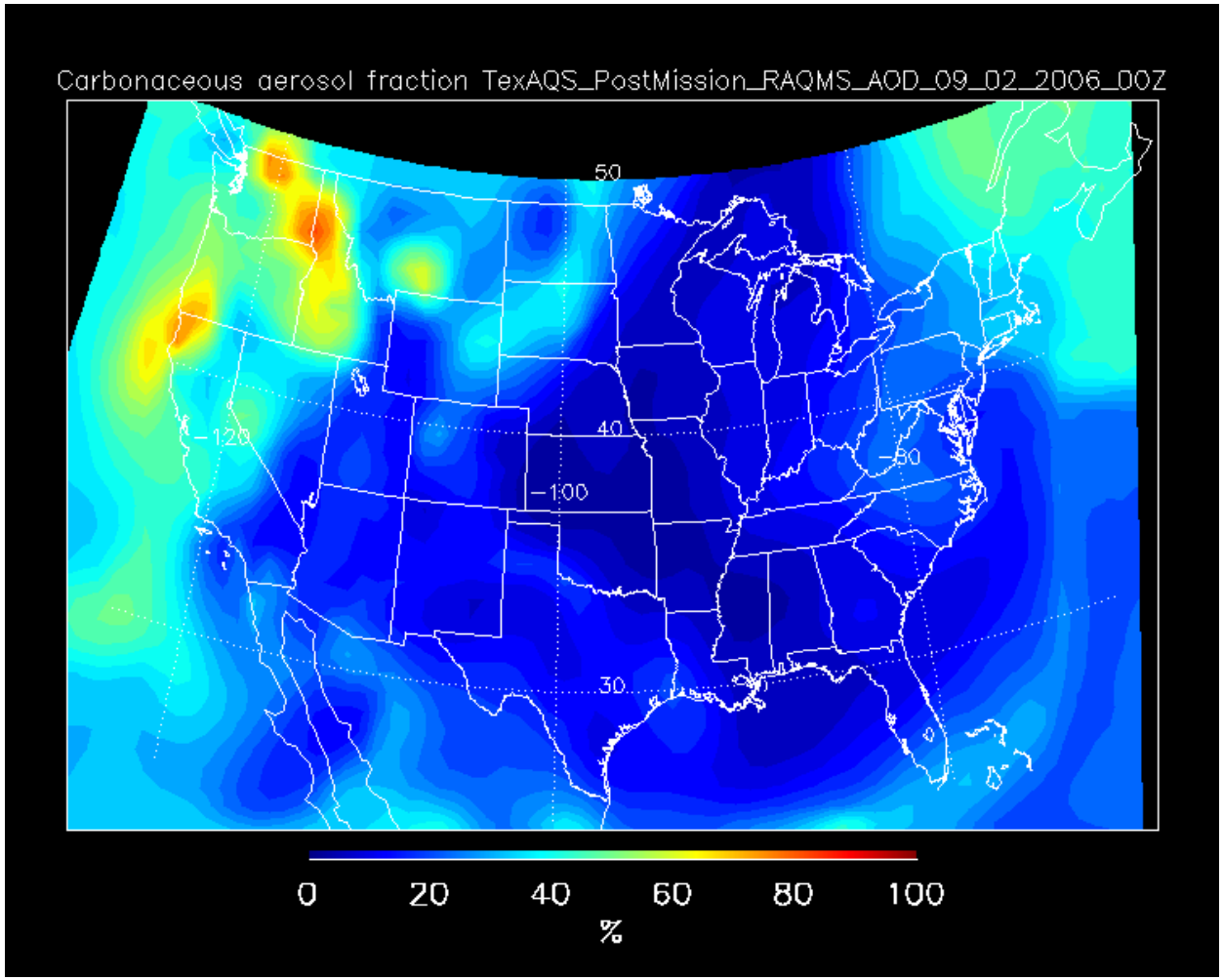
RAQMS Carbonaceous Aerosol Fraction

09/01 00Z



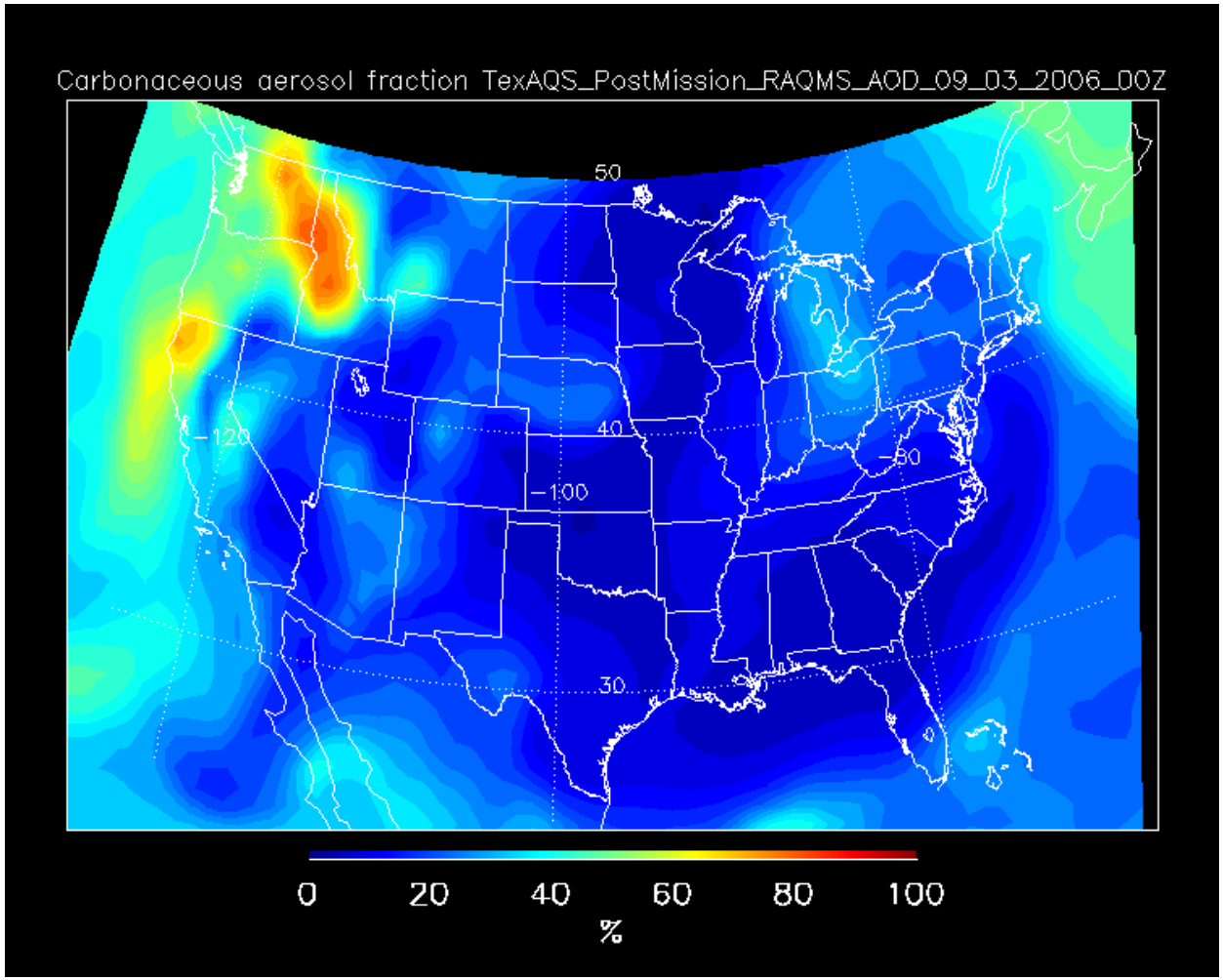
RAQMS Carbonaceous Aerosol Fraction

09/02 00Z



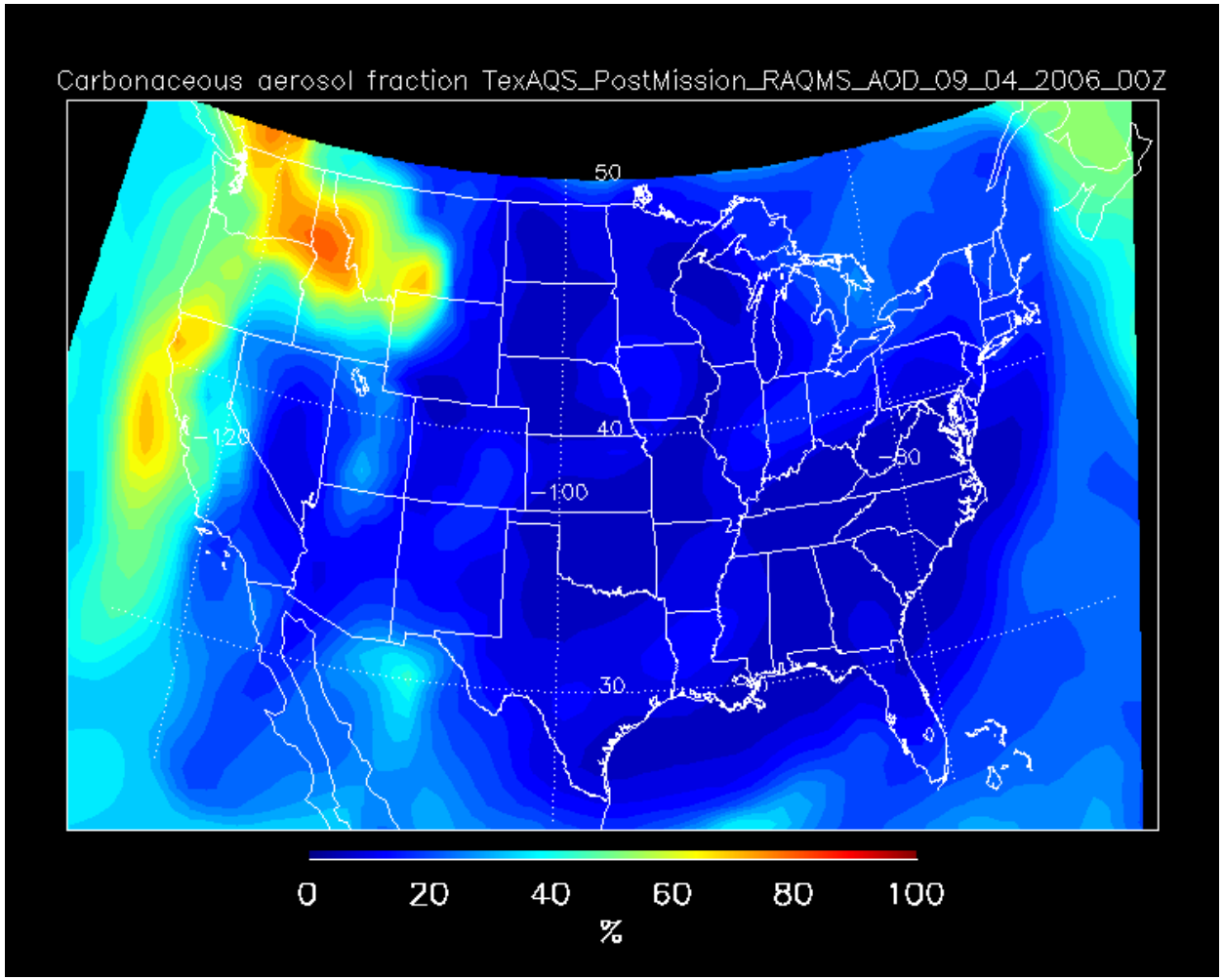
RAQMS Carbonaceous Aerosol Fraction

09/03 00Z



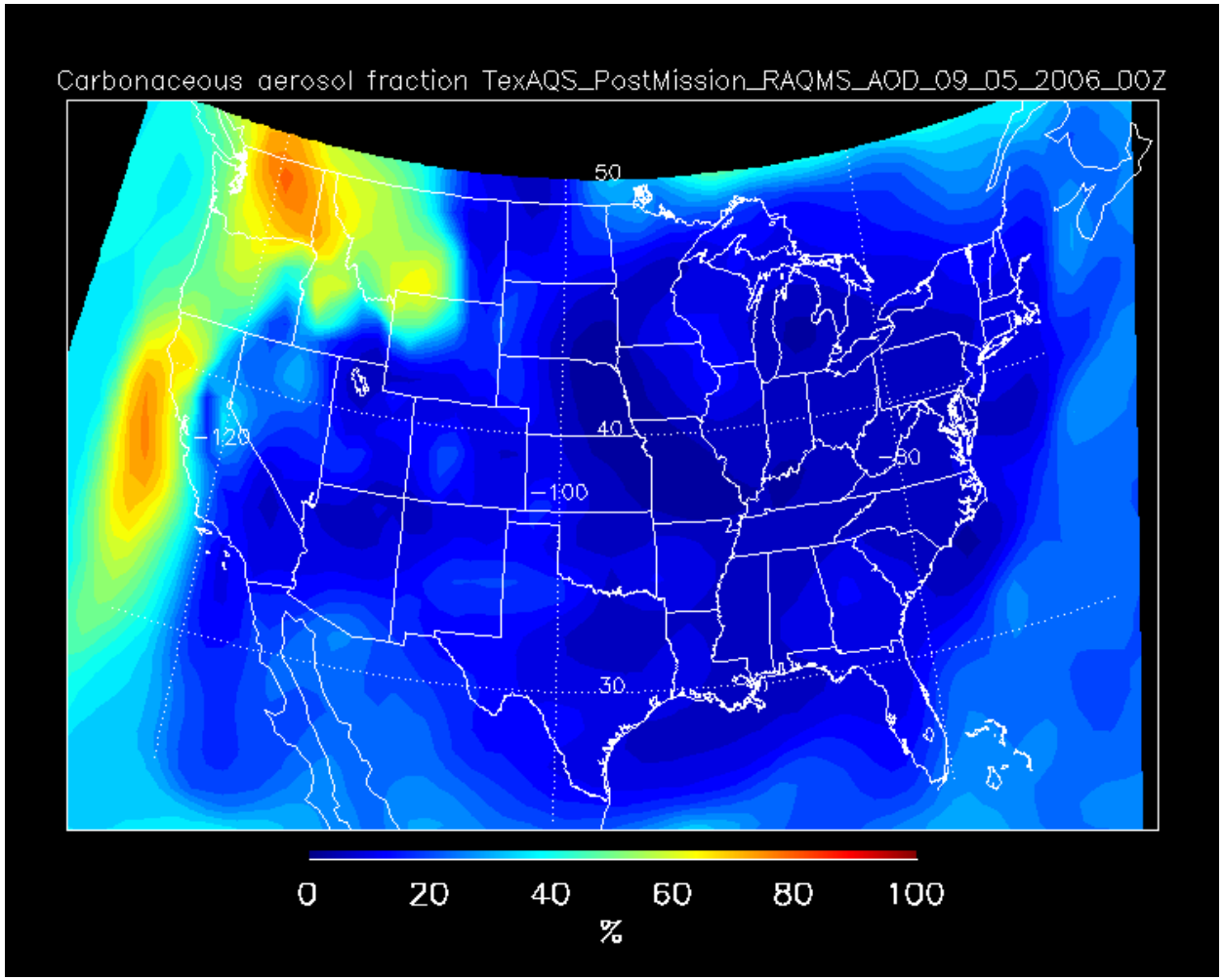
RAQMS Carbonaceous Aerosol Fraction

09/04 00Z



RAQMS Carbonaceous Aerosol Fraction

09/05 00Z



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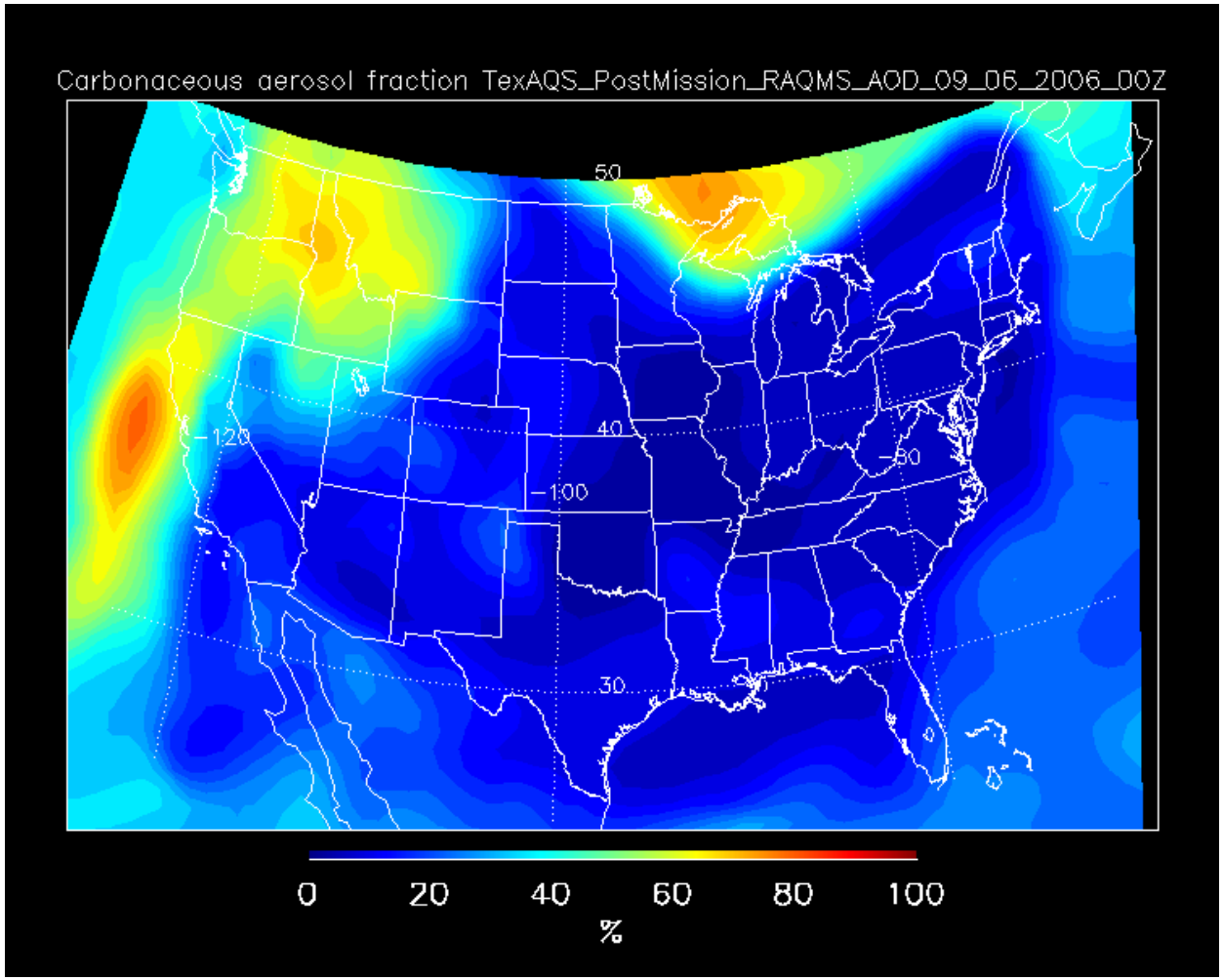
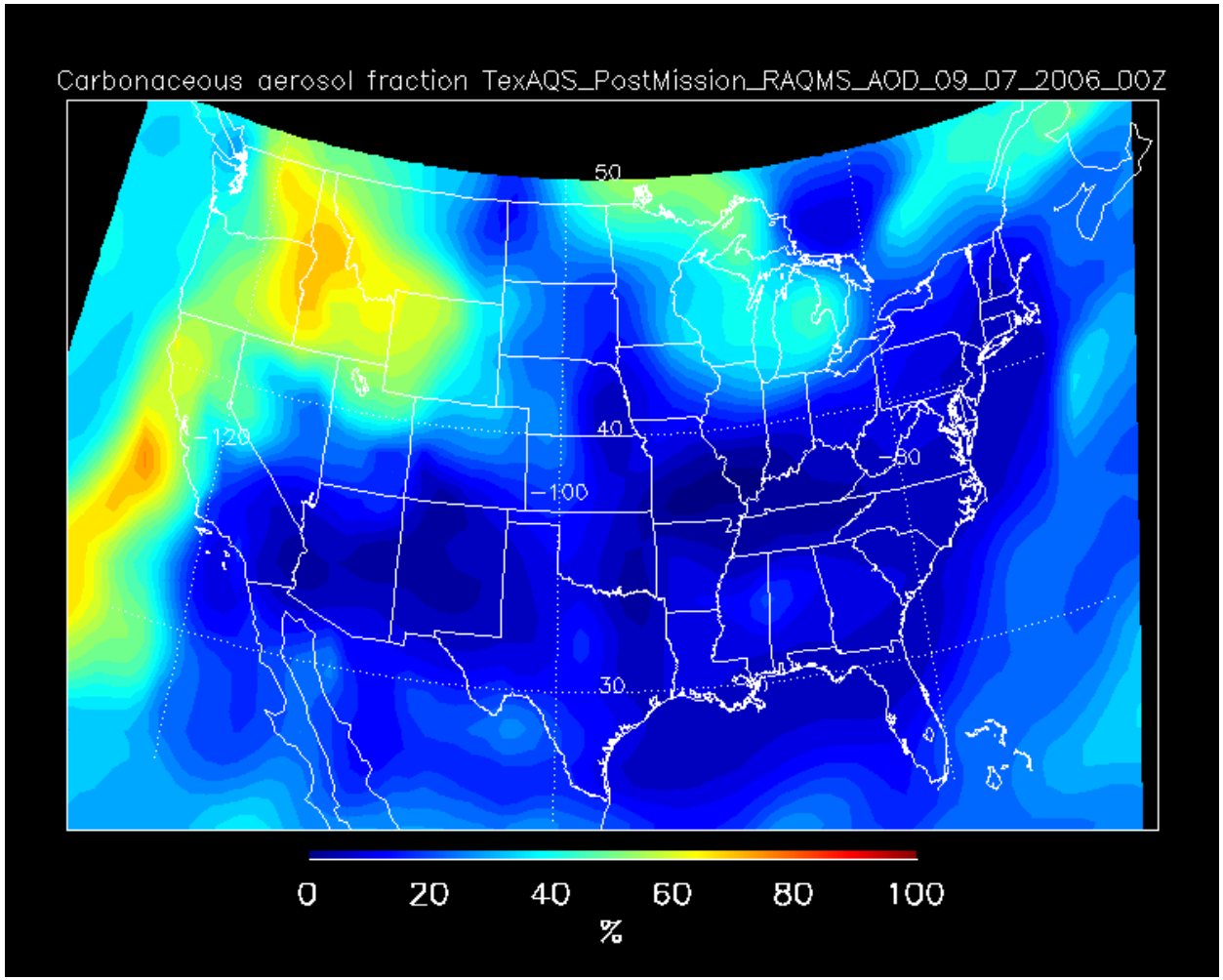
09/06 00Z



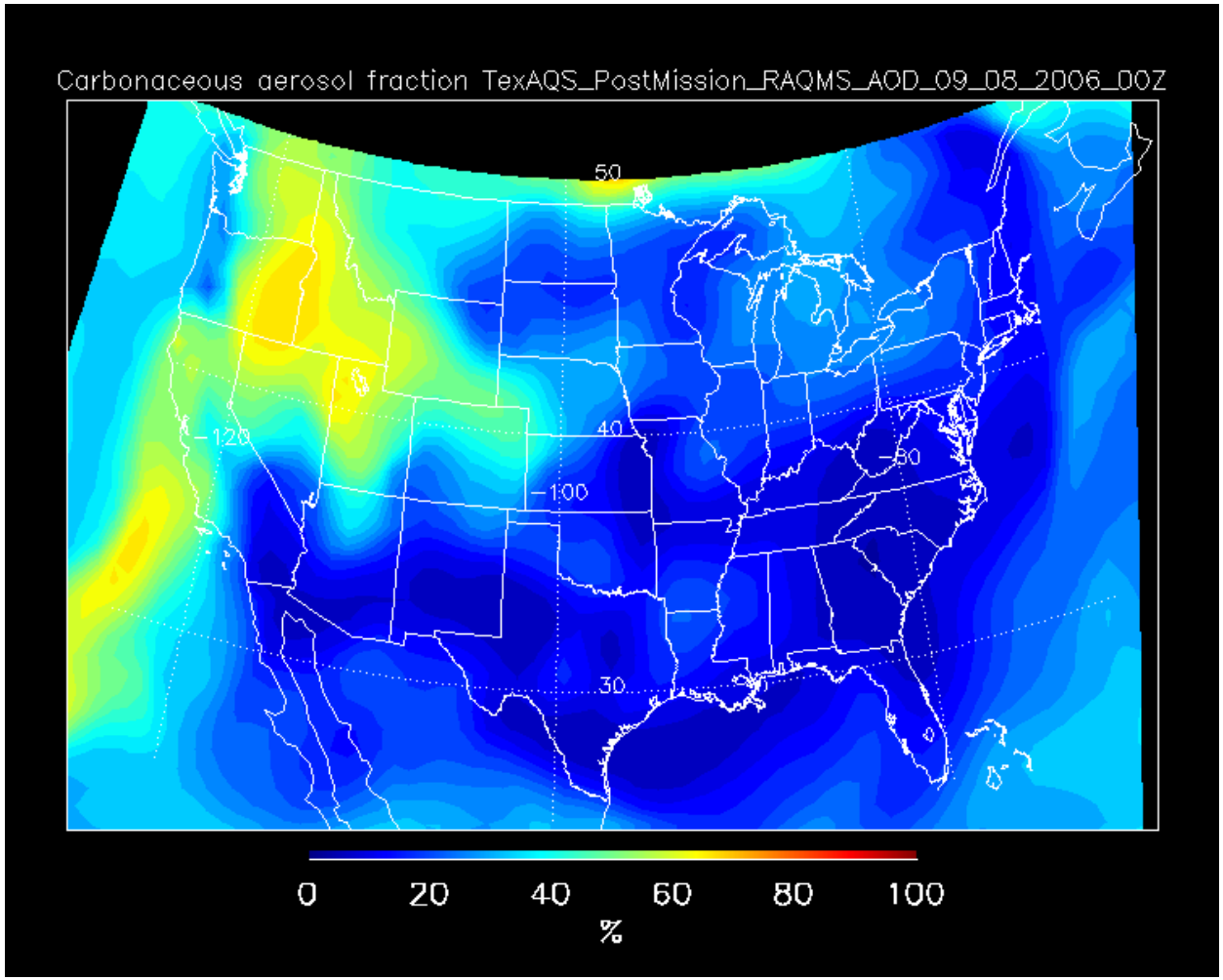
RAQMS Carbonaceous Aerosol Fraction

09/07 00Z



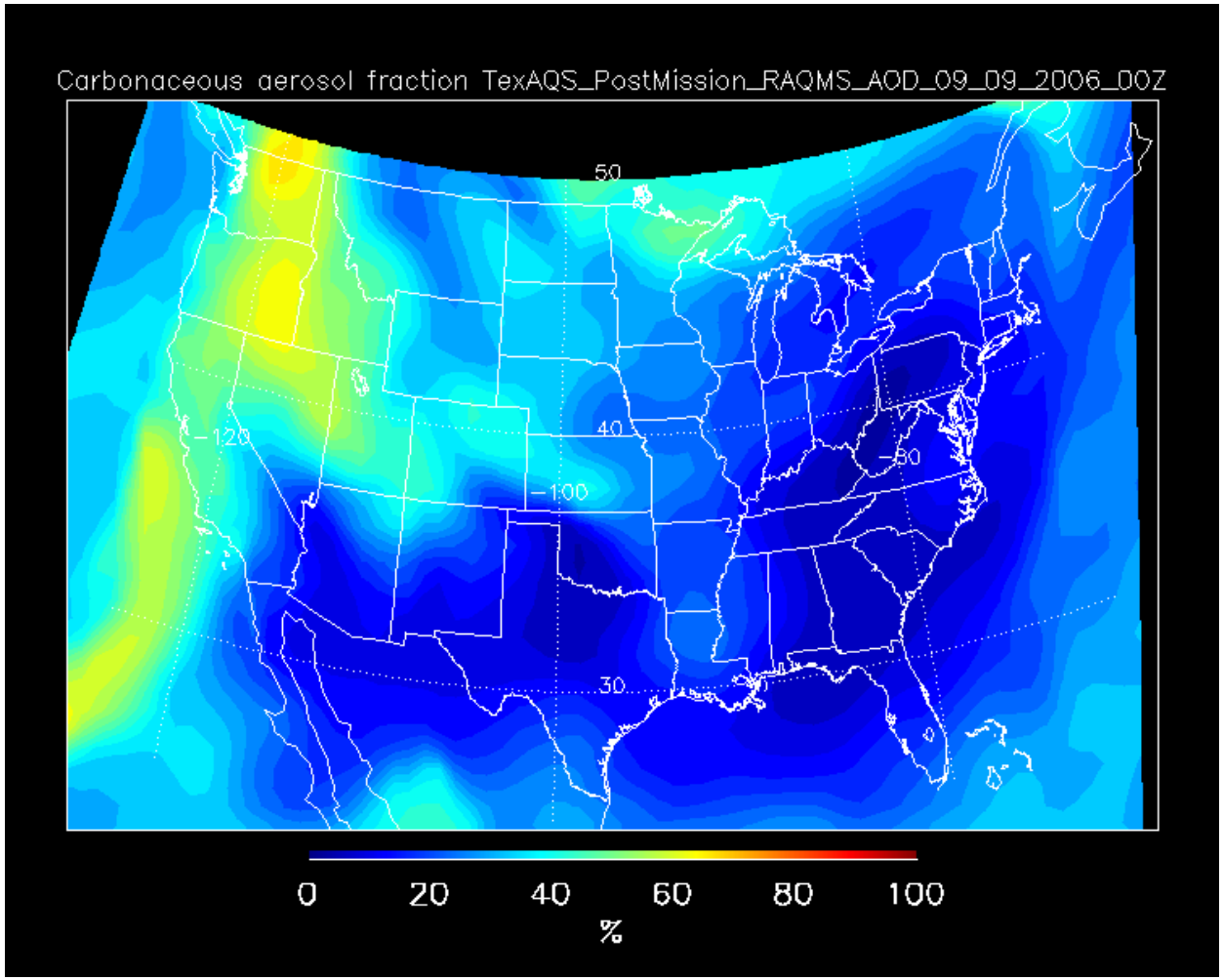
RAQMS Carbonaceous Aerosol Fraction

09/08 00Z



RAQMS Carbonaceous Aerosol Fraction

09/09 00Z



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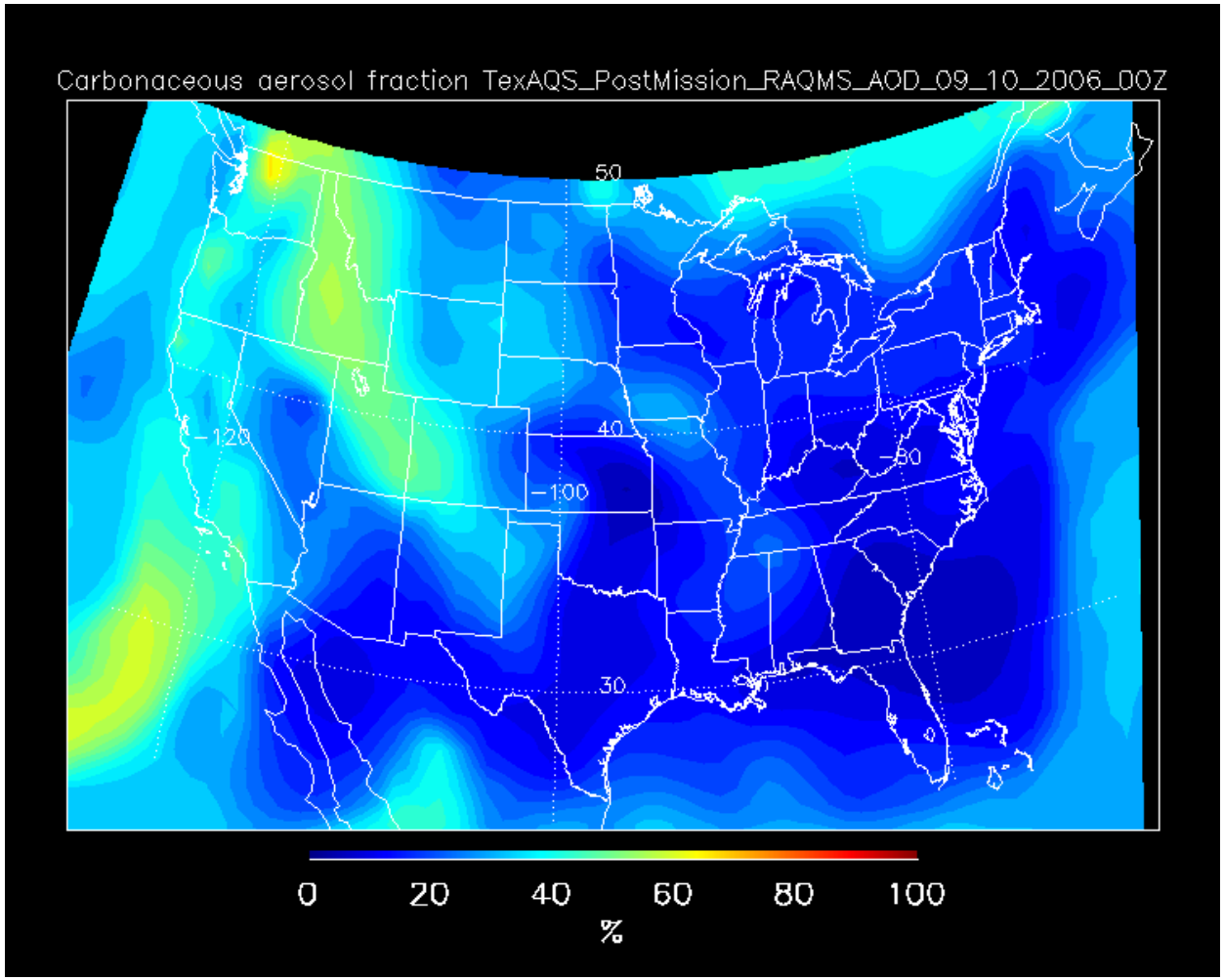

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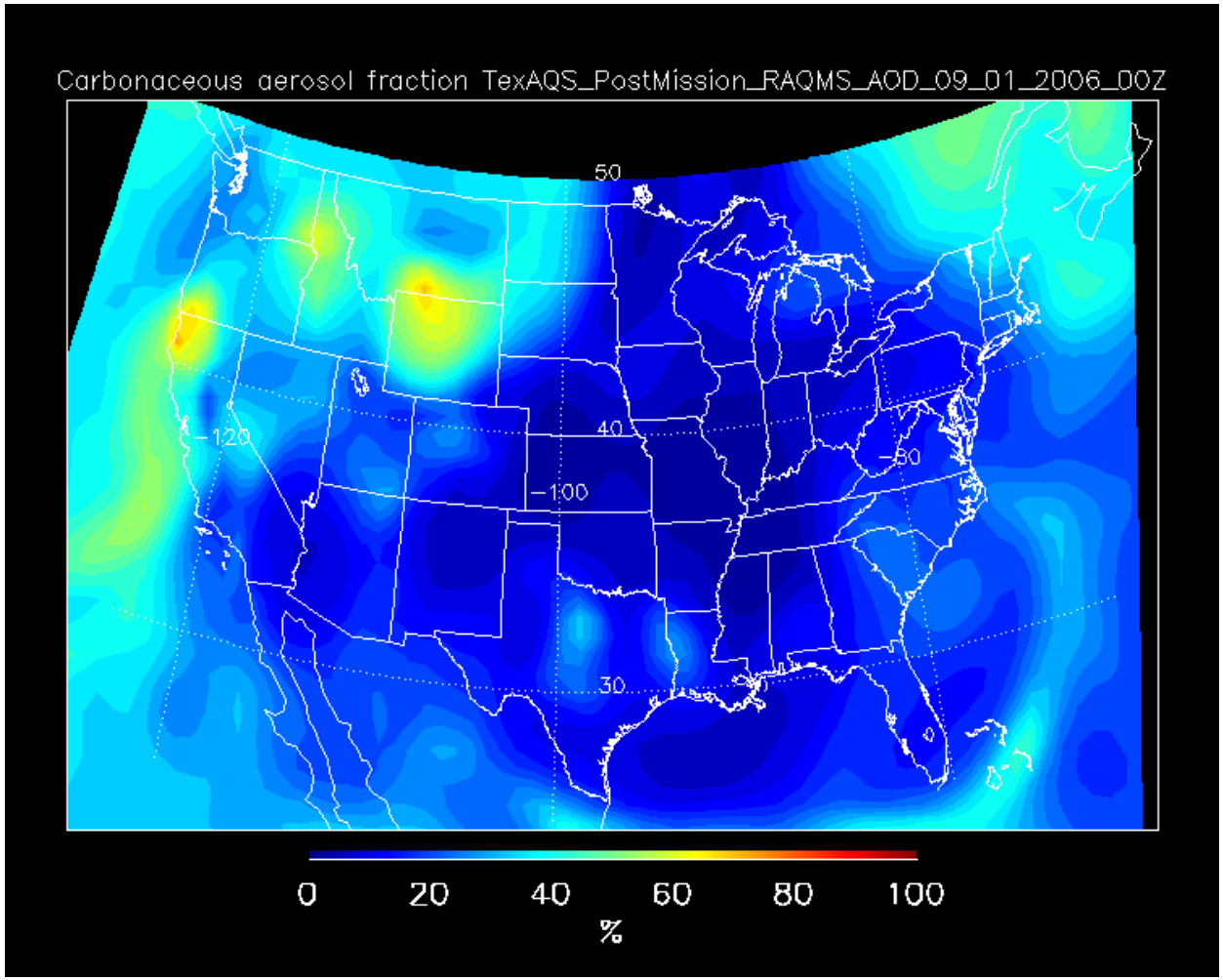
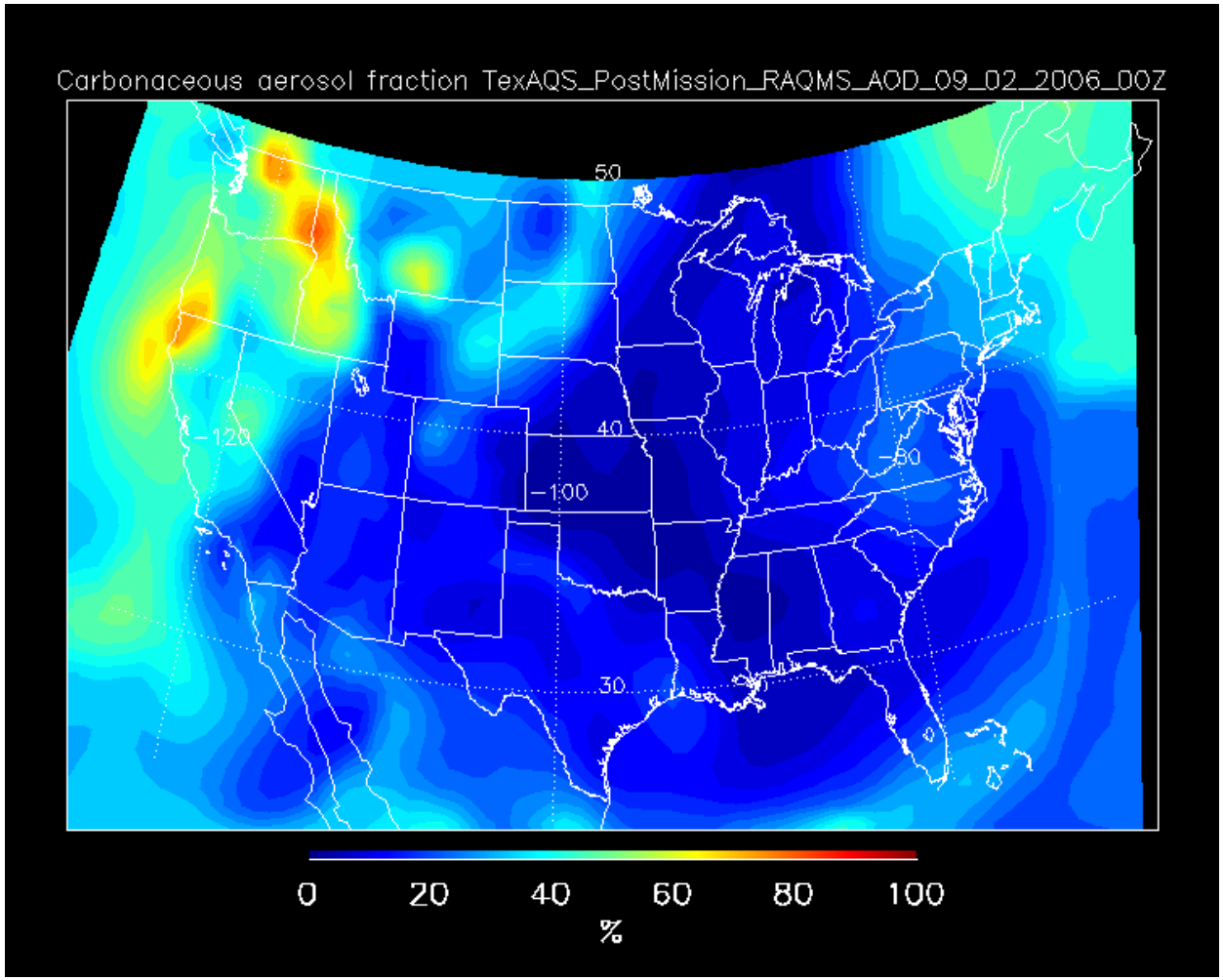
09/01 00Z



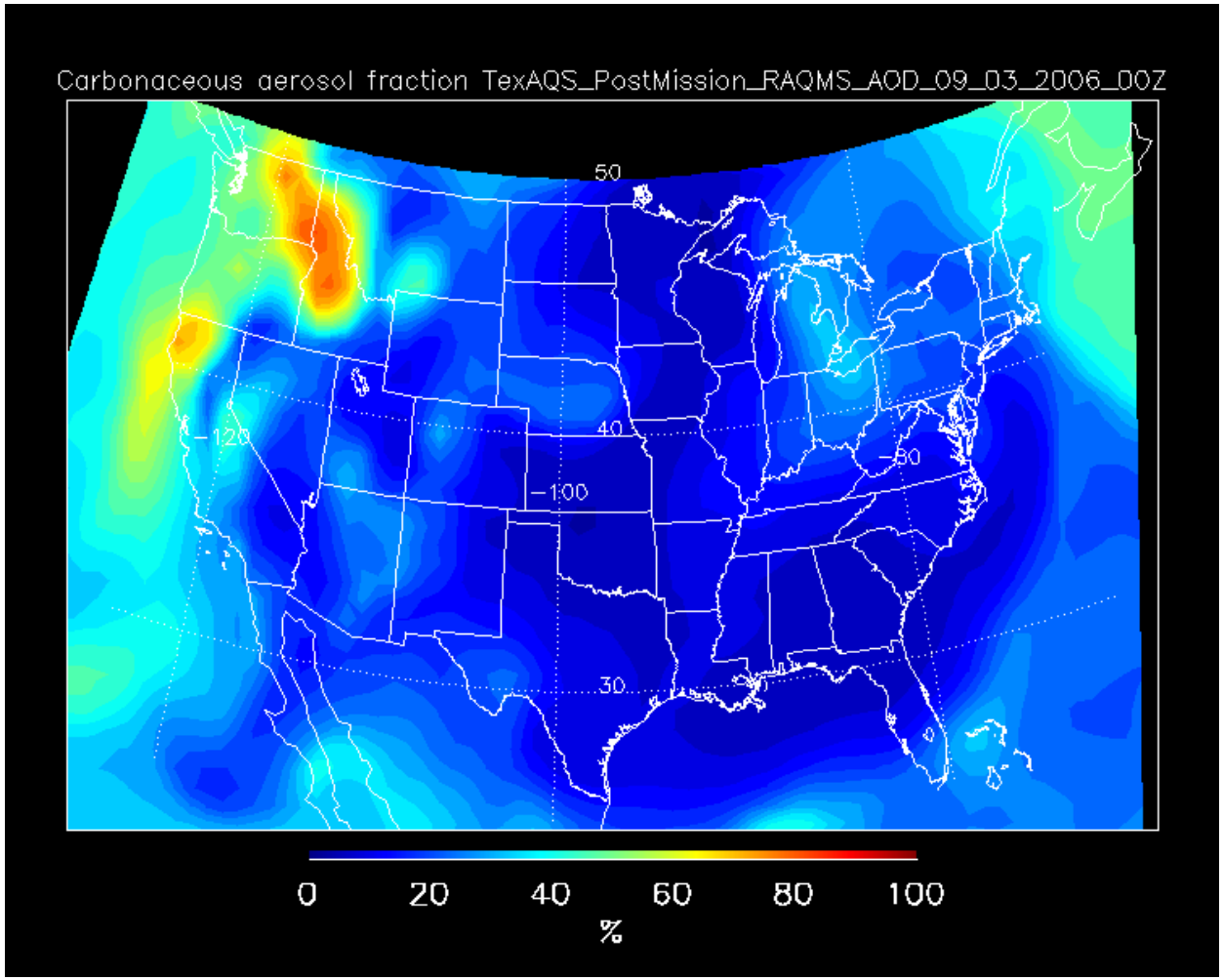
RAQMS Carbonaceous Aerosol Fraction

09/02 00Z



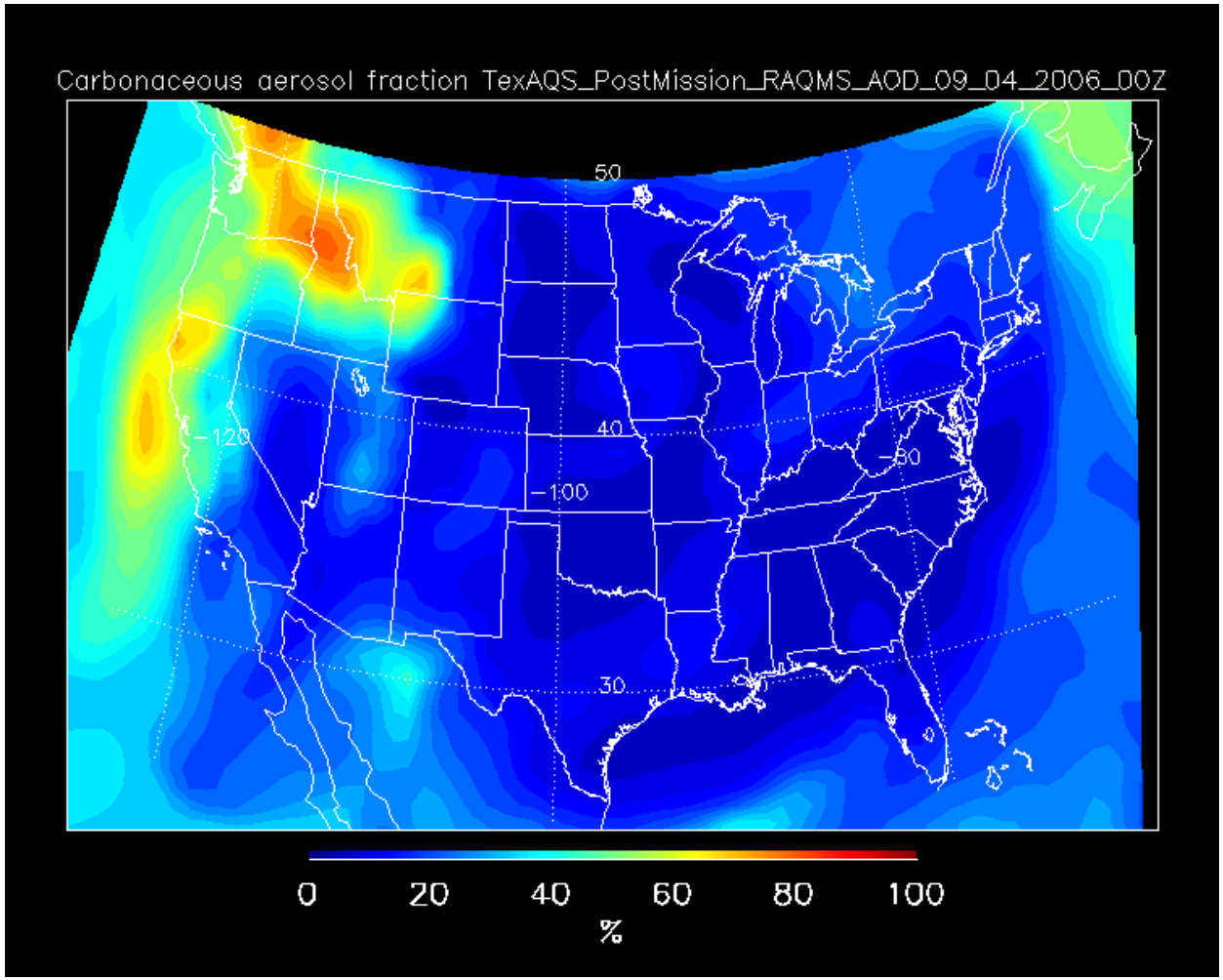
RAQMS Carbonaceous Aerosol Fraction

09/03 00Z



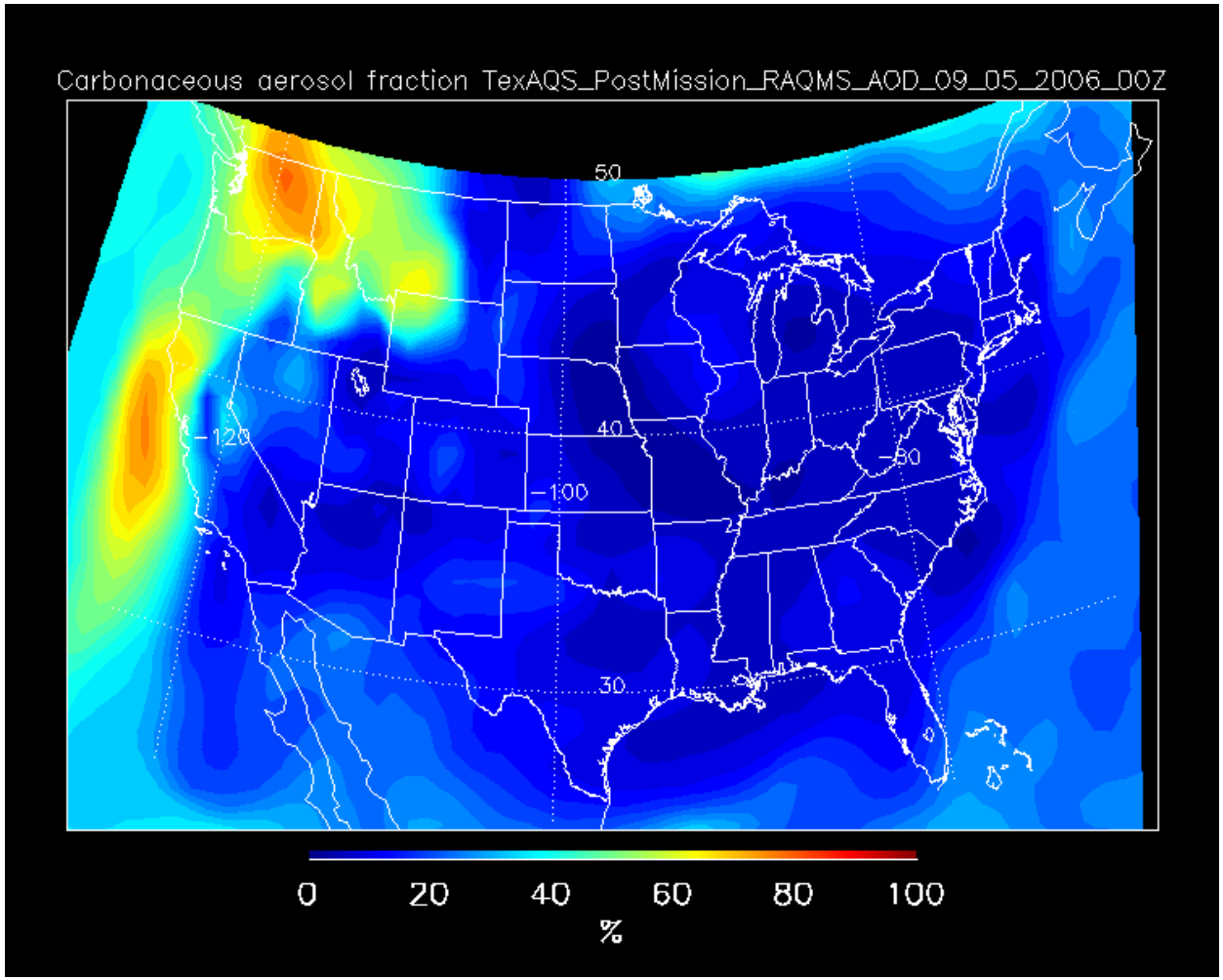
RAQMS Carbonaceous Aerosol Fraction

09/04 00Z



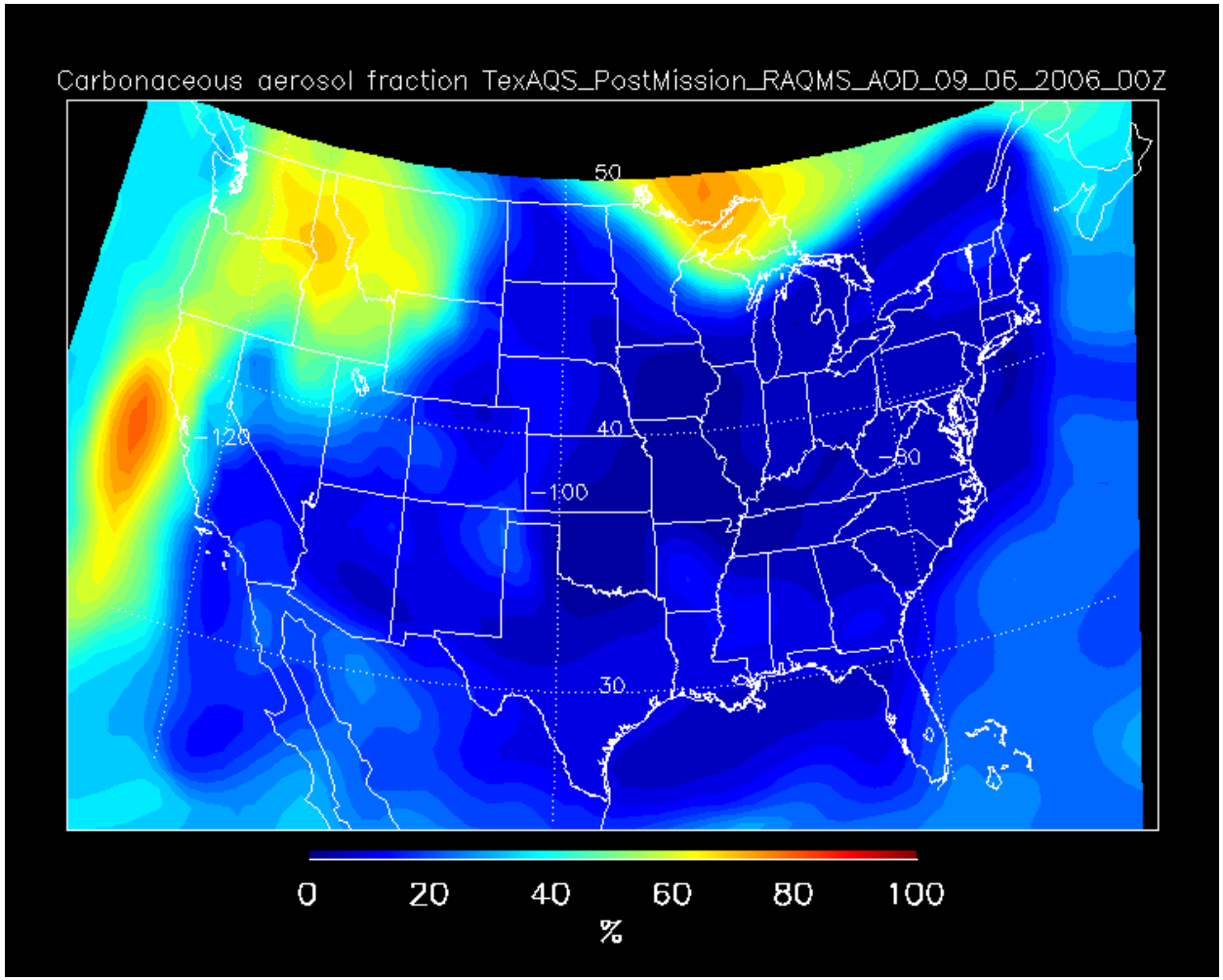
RAQMS Carbonaceous Aerosol Fraction

09/05 00Z



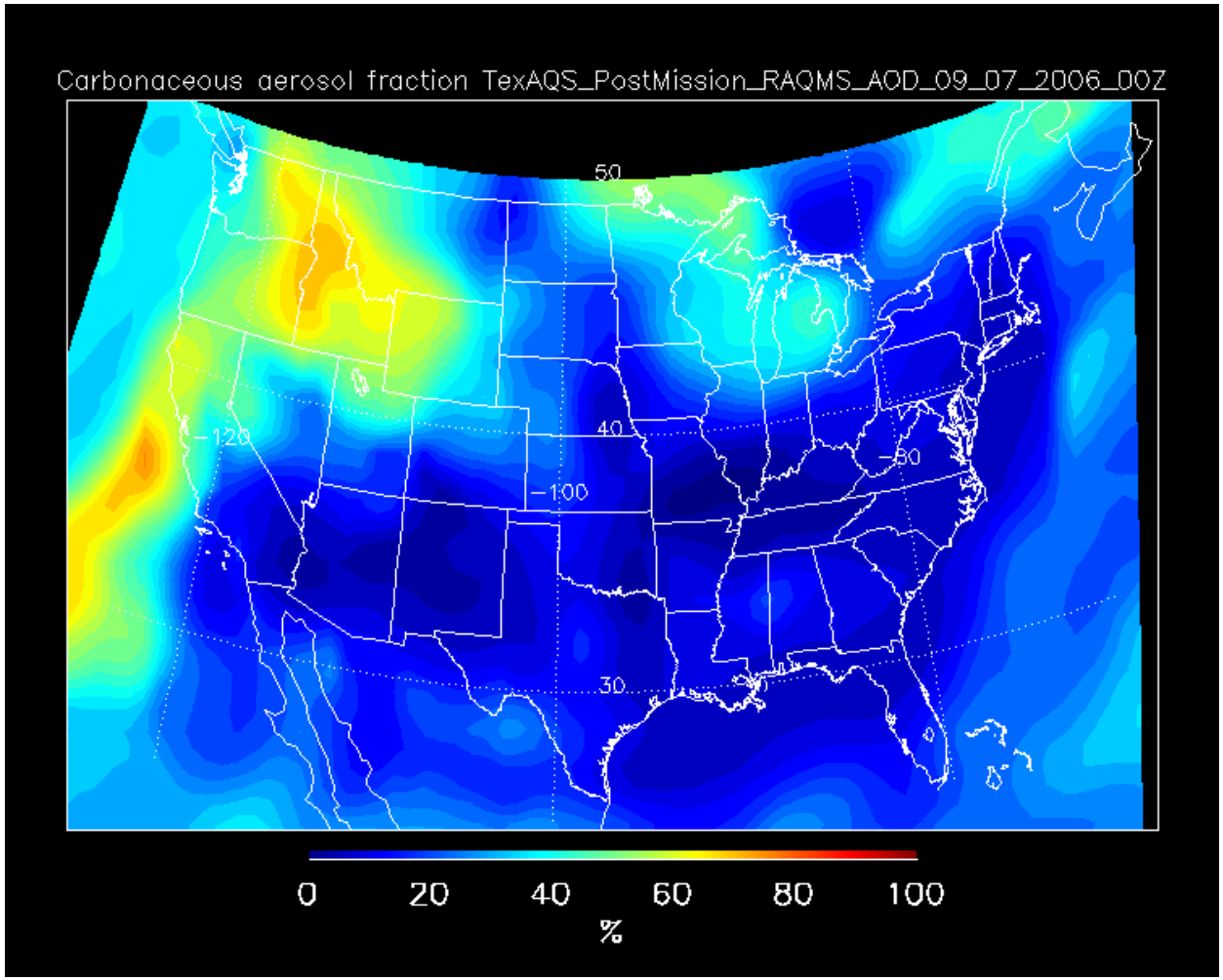
RAQMS Carbonaceous Aerosol Fraction

09/06 00Z



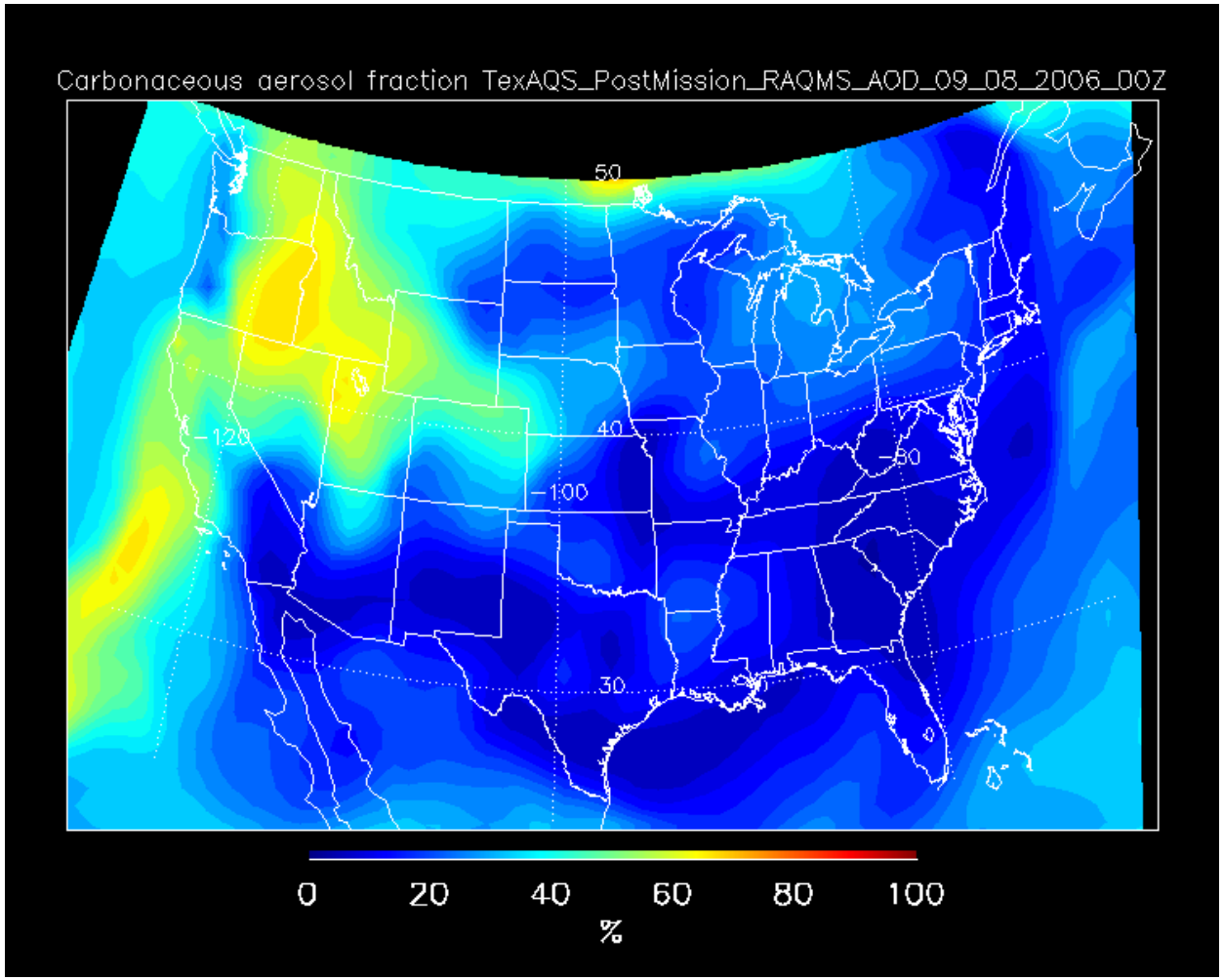
RAQMS Carbonaceous Aerosol Fraction

09/07 00Z



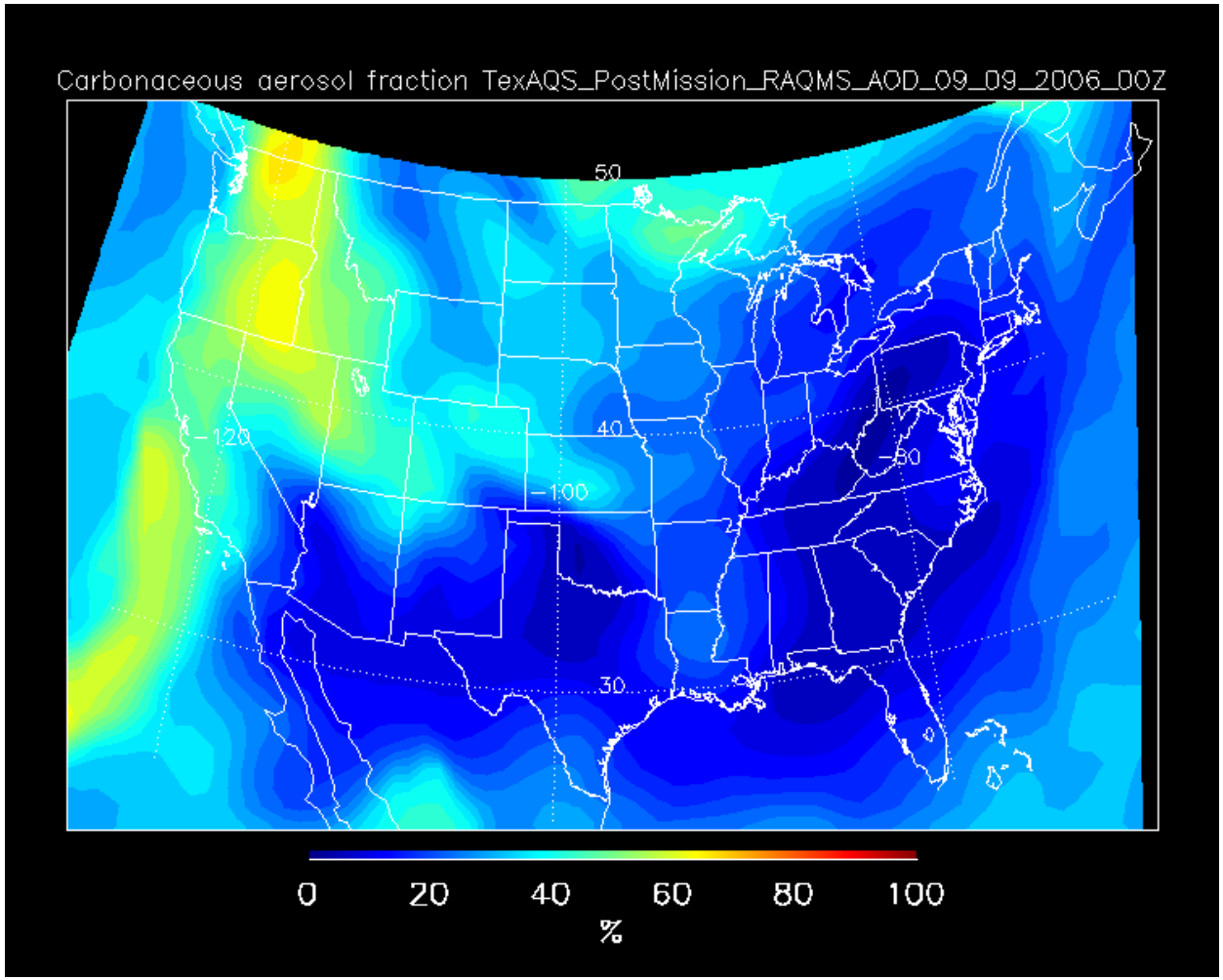
RAQMS Carbonaceous Aerosol Fraction

09/08 00Z



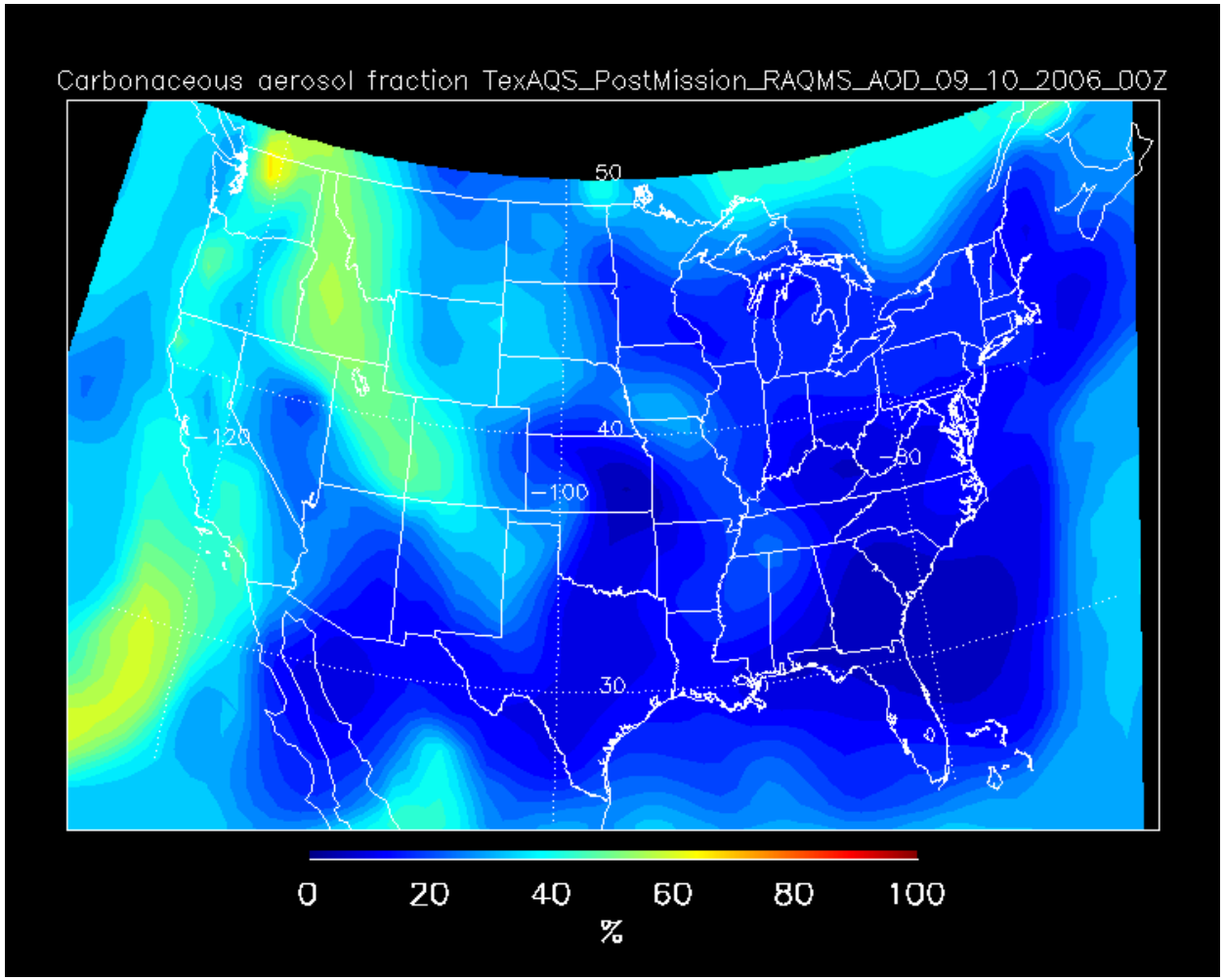
RAQMS Carbonaceous Aerosol Fraction

09/09 00Z



RAQMS Carbonaceous Aerosol Fraction

09/10 00Z

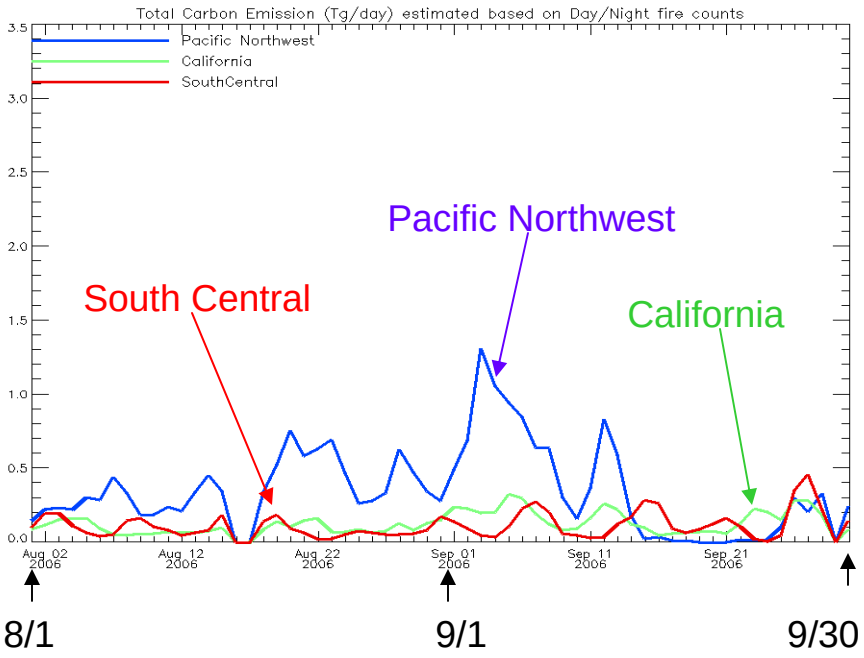


Sensitivity Studies: Wild fire emission estimates

RAQMS Total Carbon Emission Estimates (Tg/day) for Aug – Sept, 2006

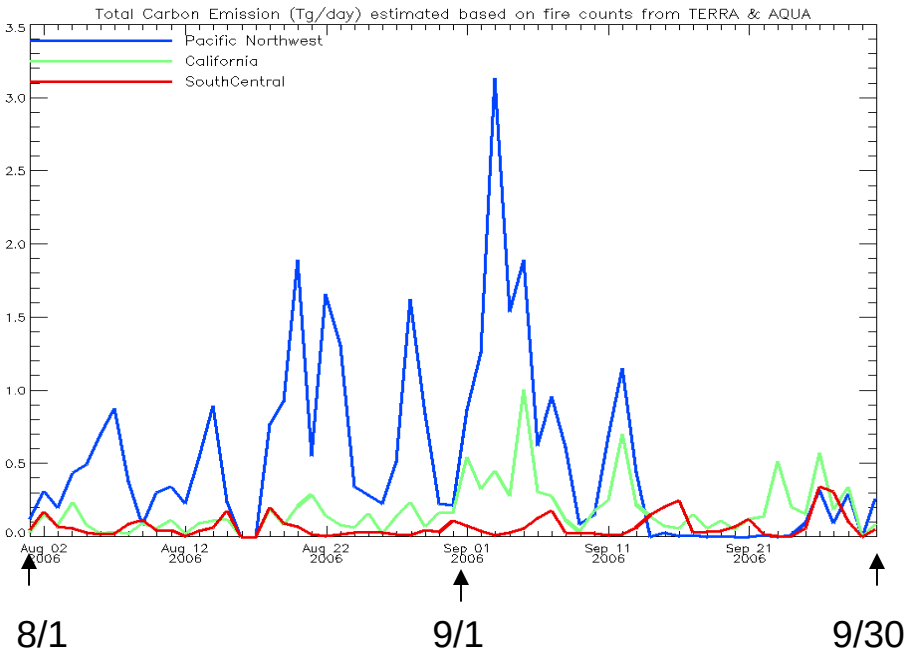
Case A:

based on MODIS fire counts with duplicated counts removed, 48hr window, day/night fire counts



Case B:

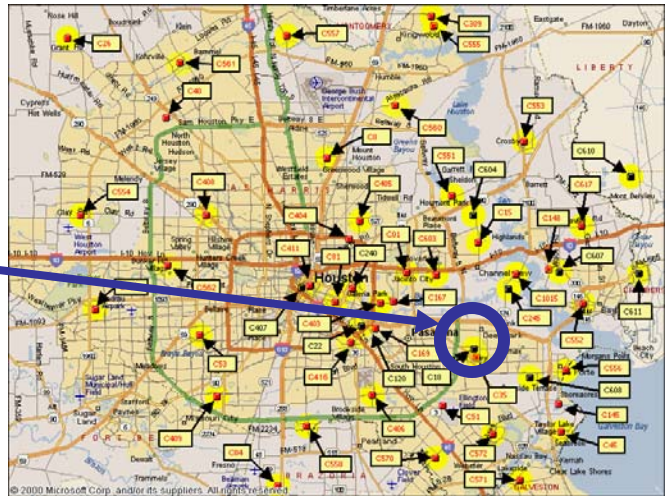
based on combined MODIS fire counts Terra +Aqua and day+night

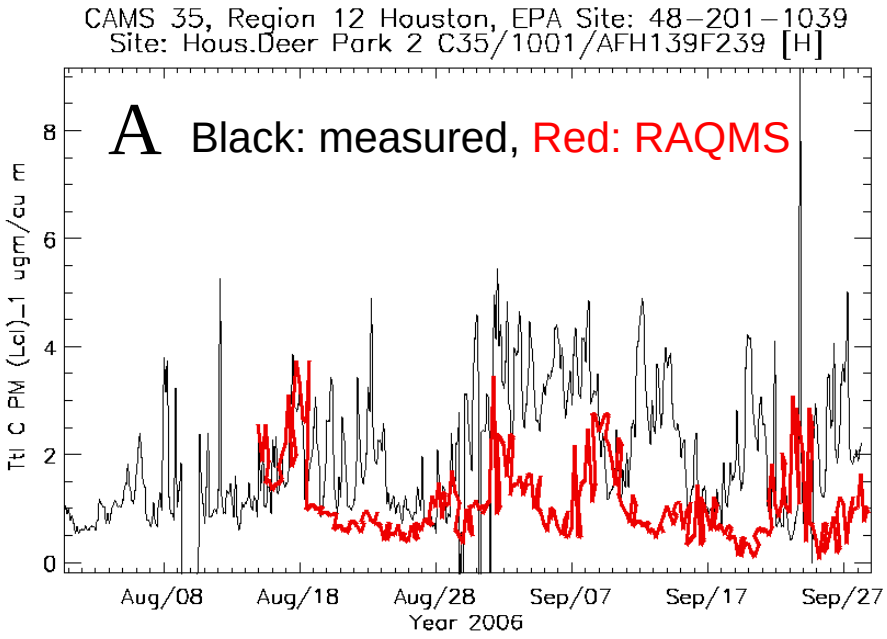


Sensitivity Studies: Results – Surface Comparisons

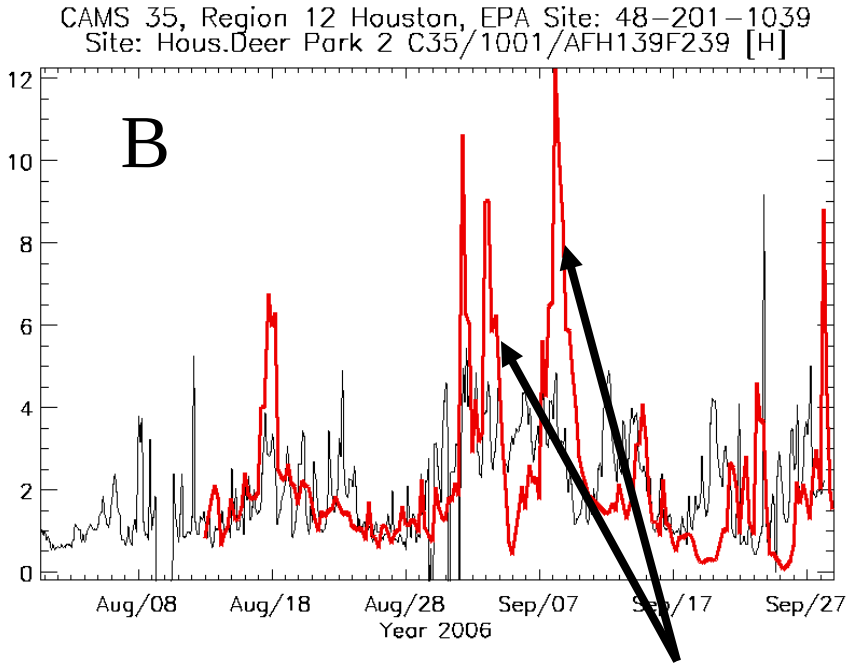
Comparisons with ground-based measurement of carbonaceous aerorol at the Deer Park site, Houston, TX

- Measurement data provided by TCEQ -





Underestimate of Carbonaceous

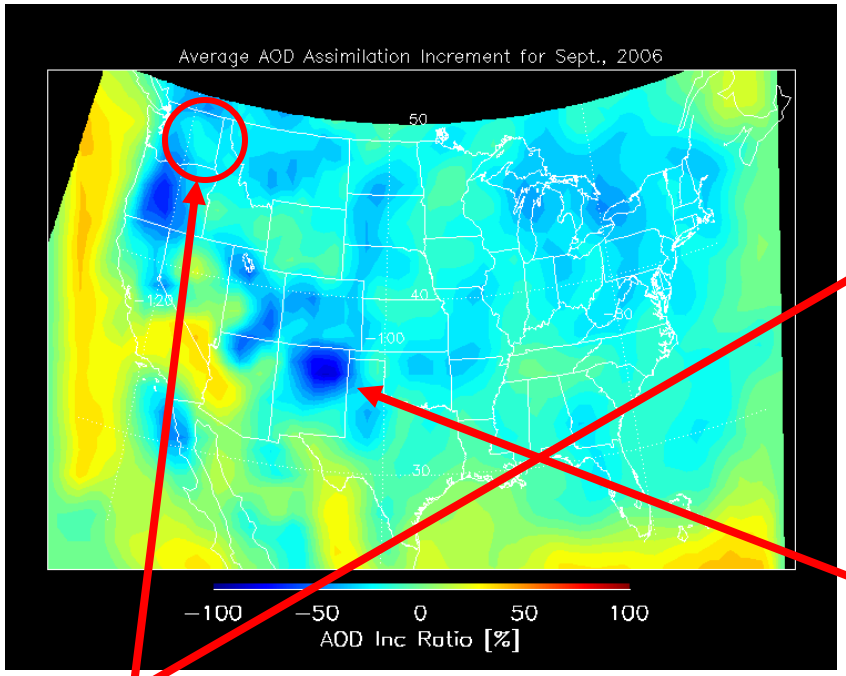


Overestimate of Carbonaceous due to overestimate of carbon emission from fires

Sensitivity Studies: Results
Average AOD Assimilation Increment for Sept., 2006

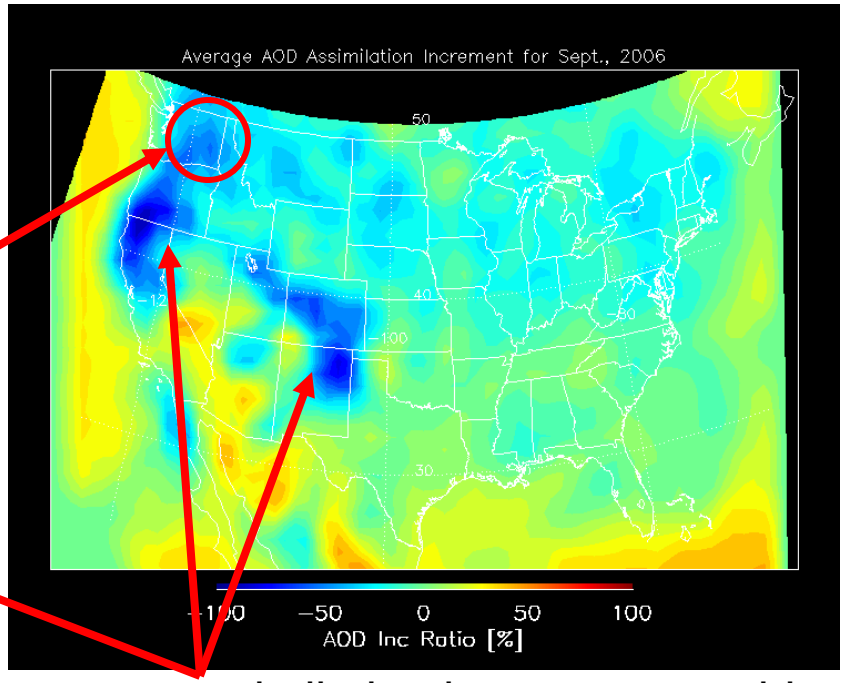
Assimilation Increment = (Observation – 1st guess)

Case A



Assimilation increment closer to zero over the source region in A than in B suggesting the emission estimate in A is better than that in B

Case B



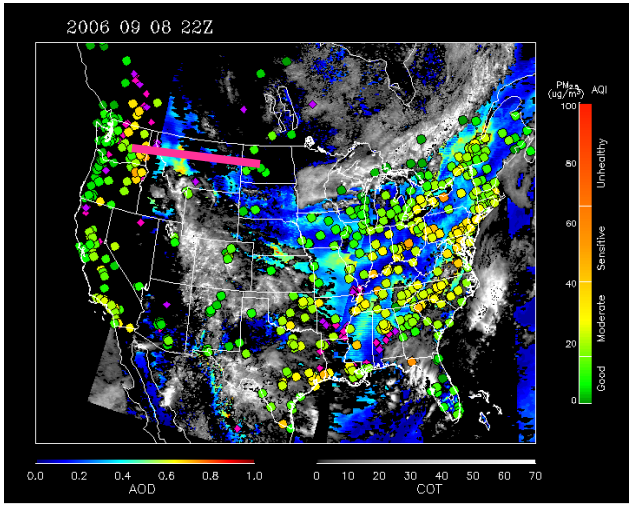
Large assimilation increment outside of the source region suggesting a problem with the aerosol transport path

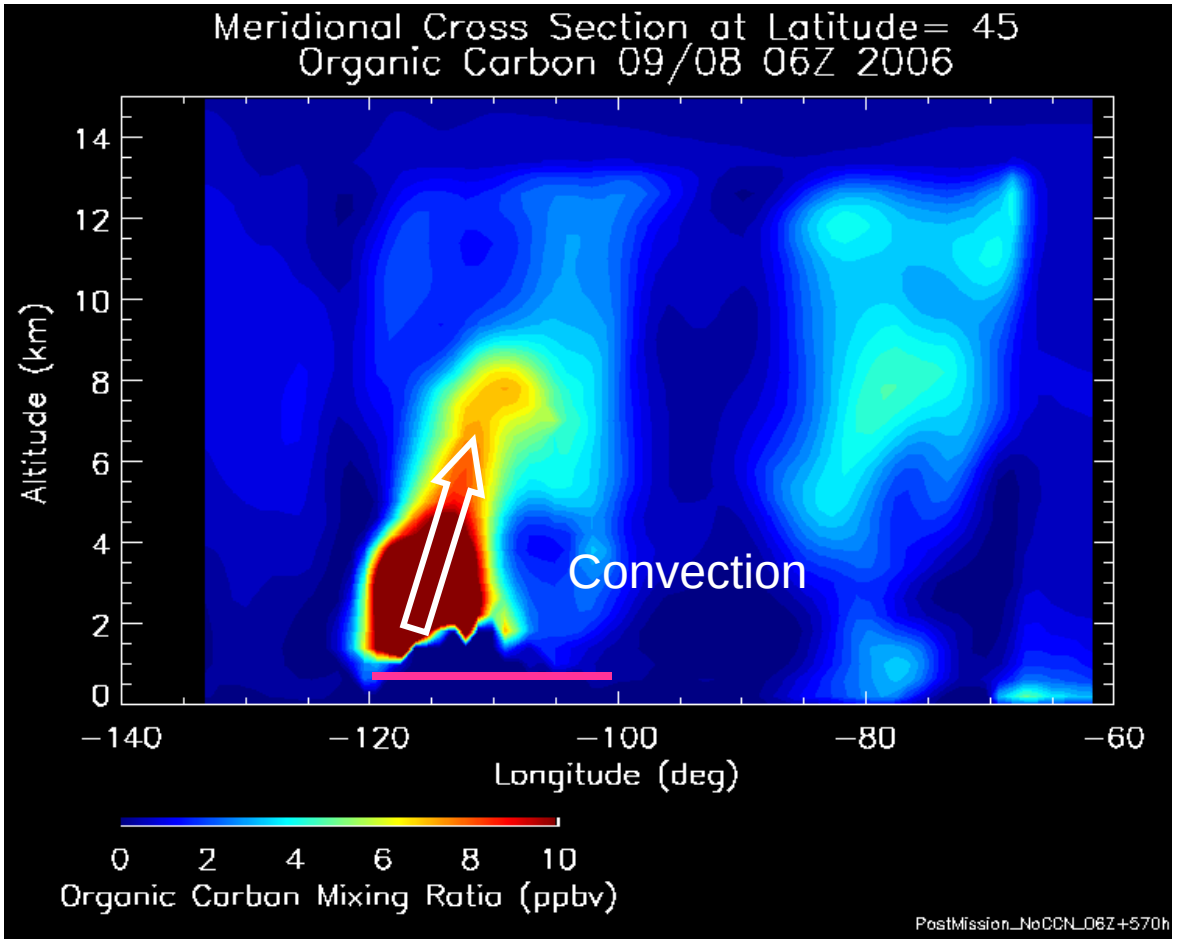
⇩

Injection Height ???

Convective transport due to fires

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.

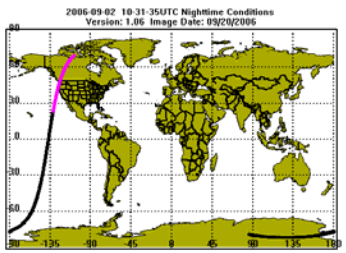


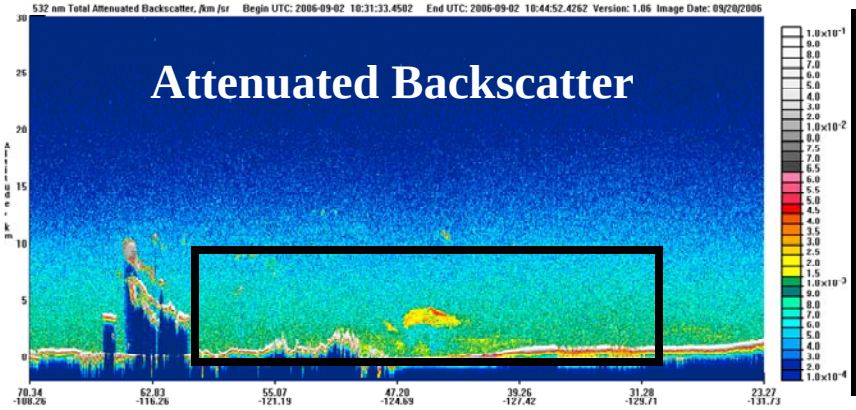


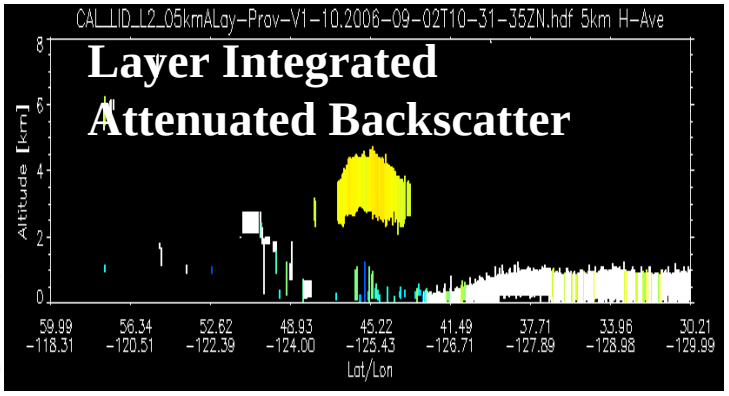
CALIPSO orbits sampling near fire location (top two) and down stream (bottom)

CALIPSO Orbit

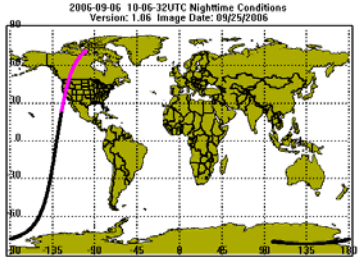
9/2

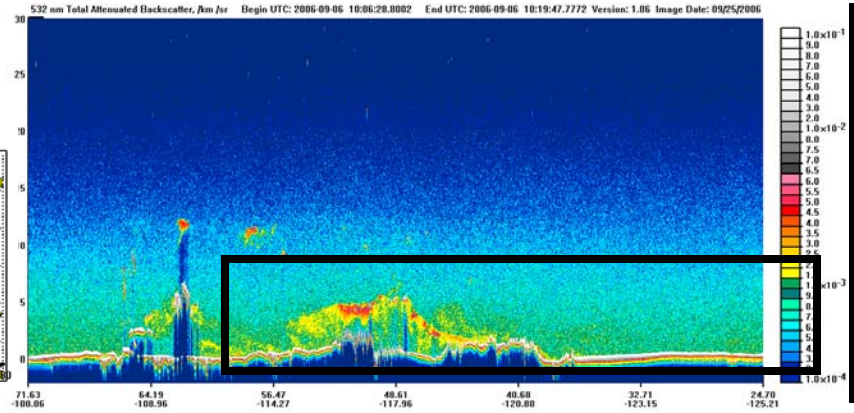


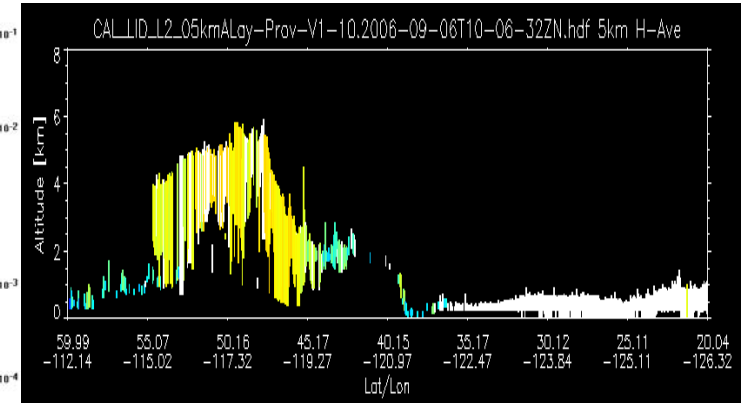




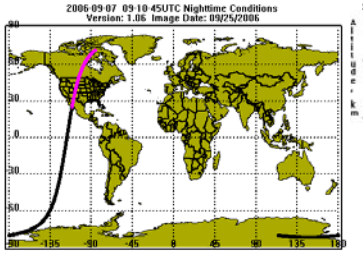
9/6

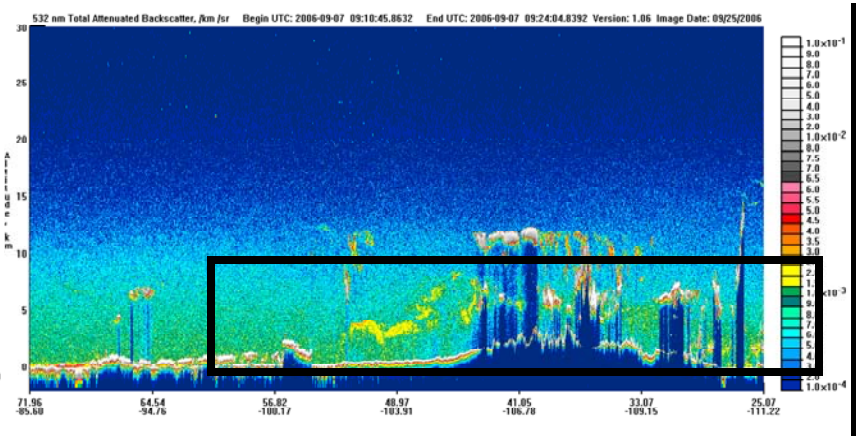


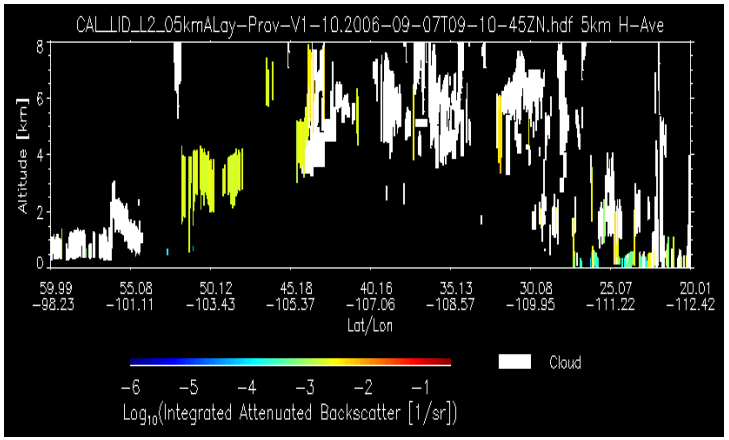




9/7



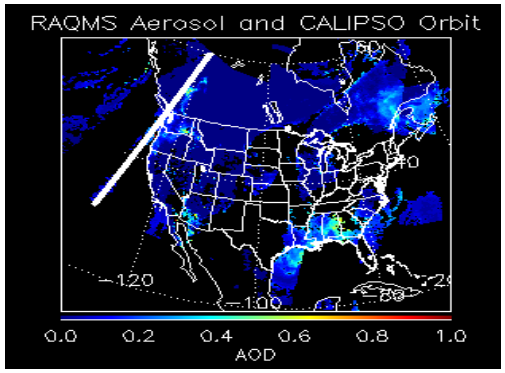




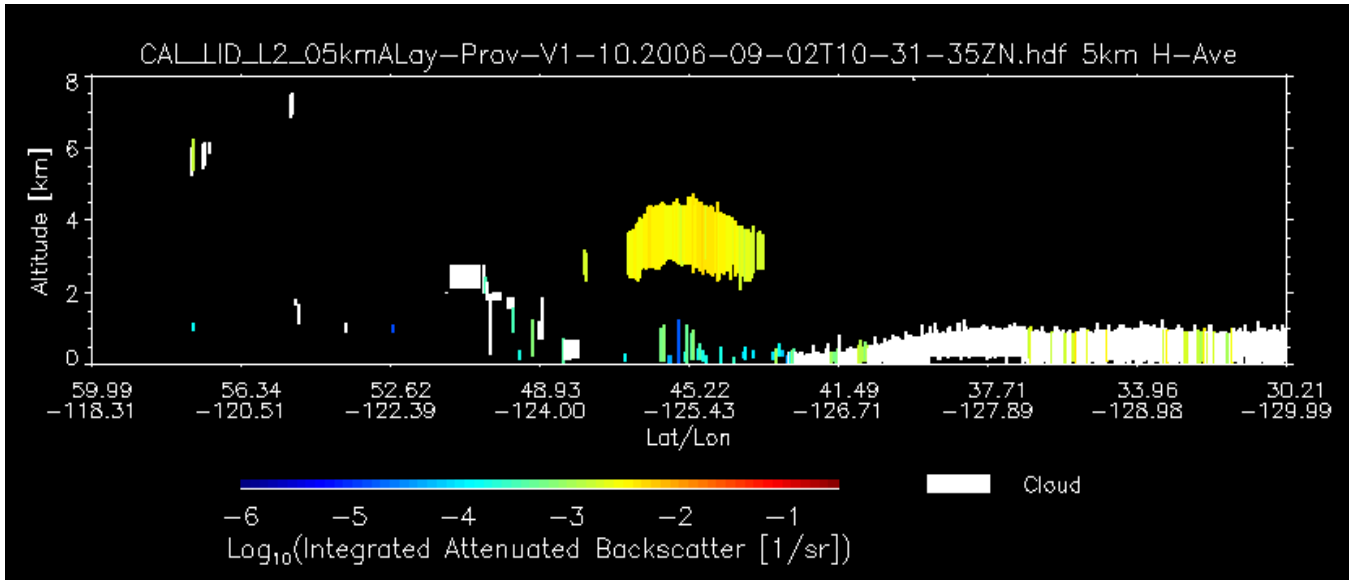
Evaluation of altitude of aerosol layer with CALIPSO data

9/2

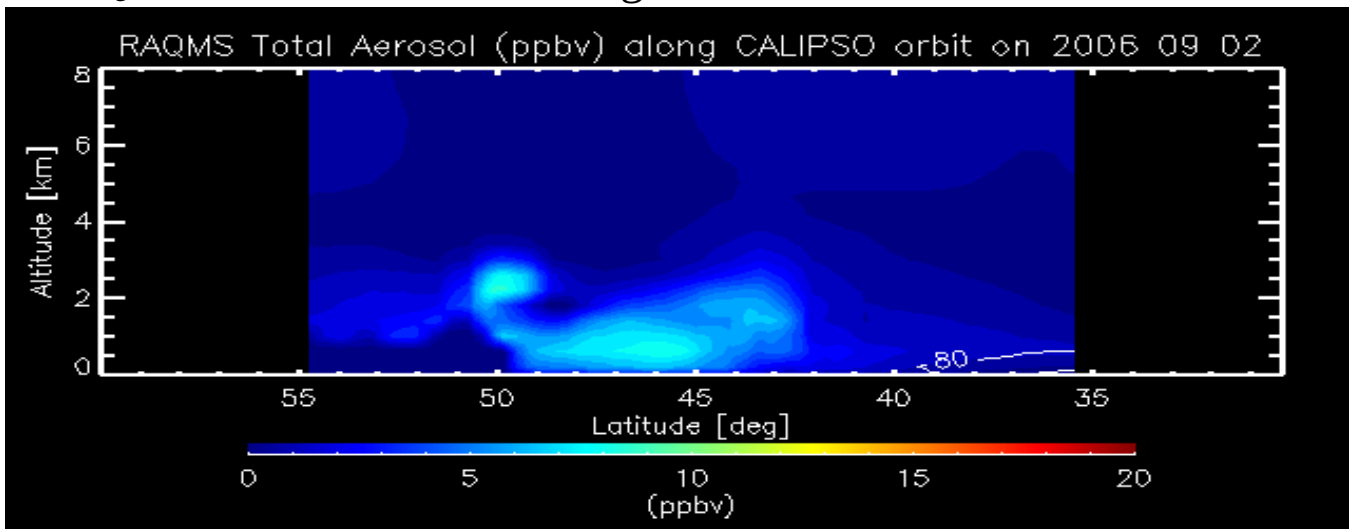
MODIS AOD



CALIPSO Integrated Attenuated Backscatter



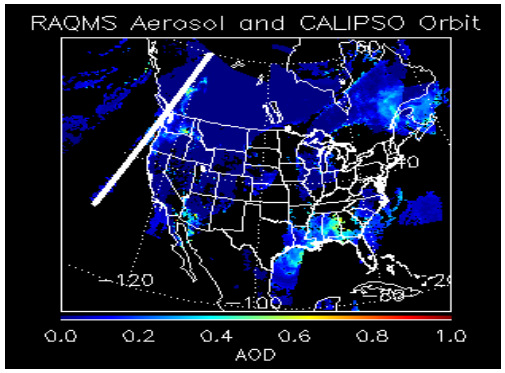
RAQMS Total Aerosol Loading



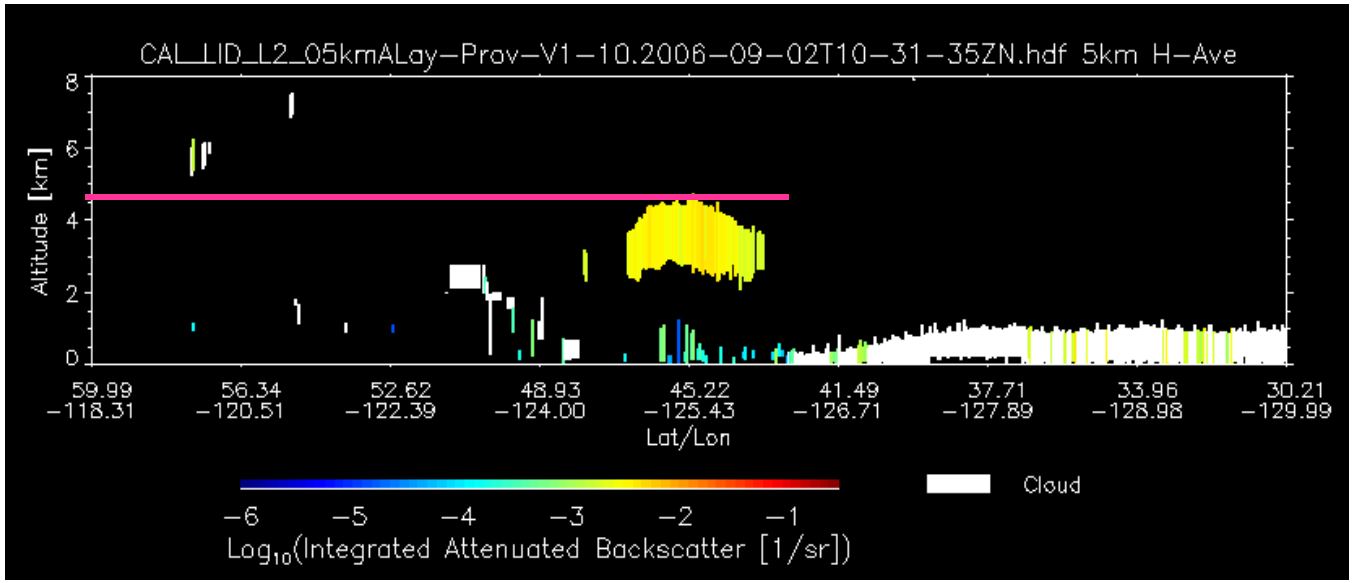
Evaluation of altitude of aerosol layer with CALIPSO data

9/2

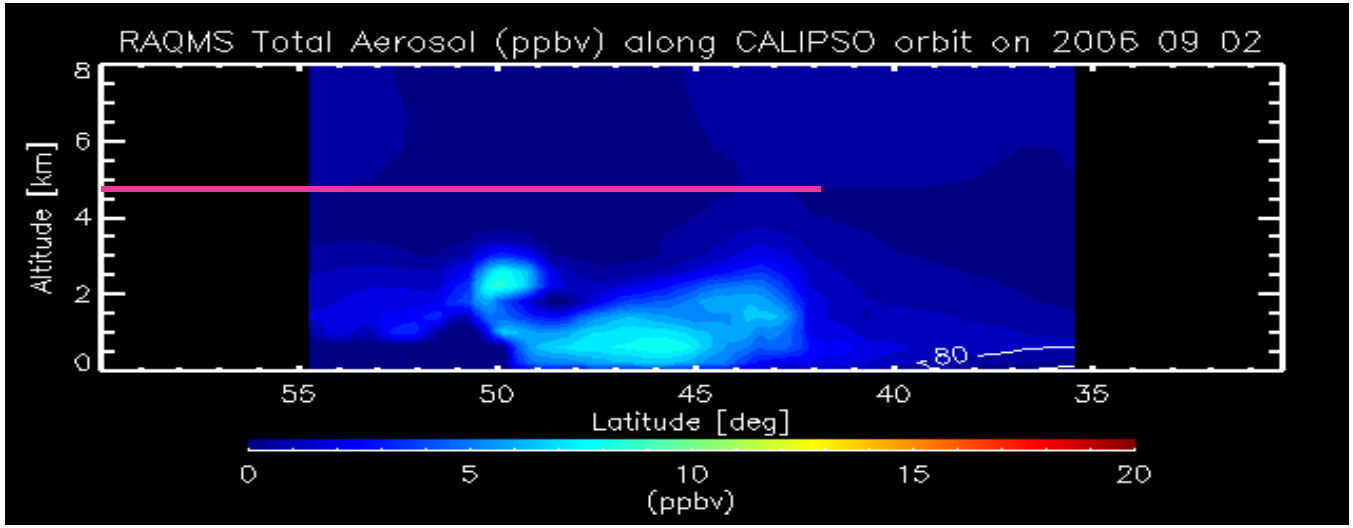
MODIS AOD



CALIPSO Integrated Attenuated Backscatter



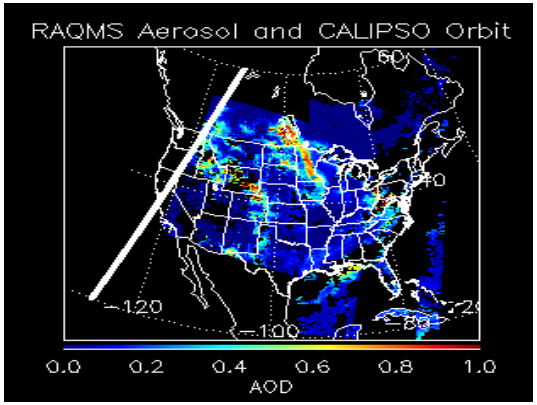
RAQMS Total Aerosol Loading



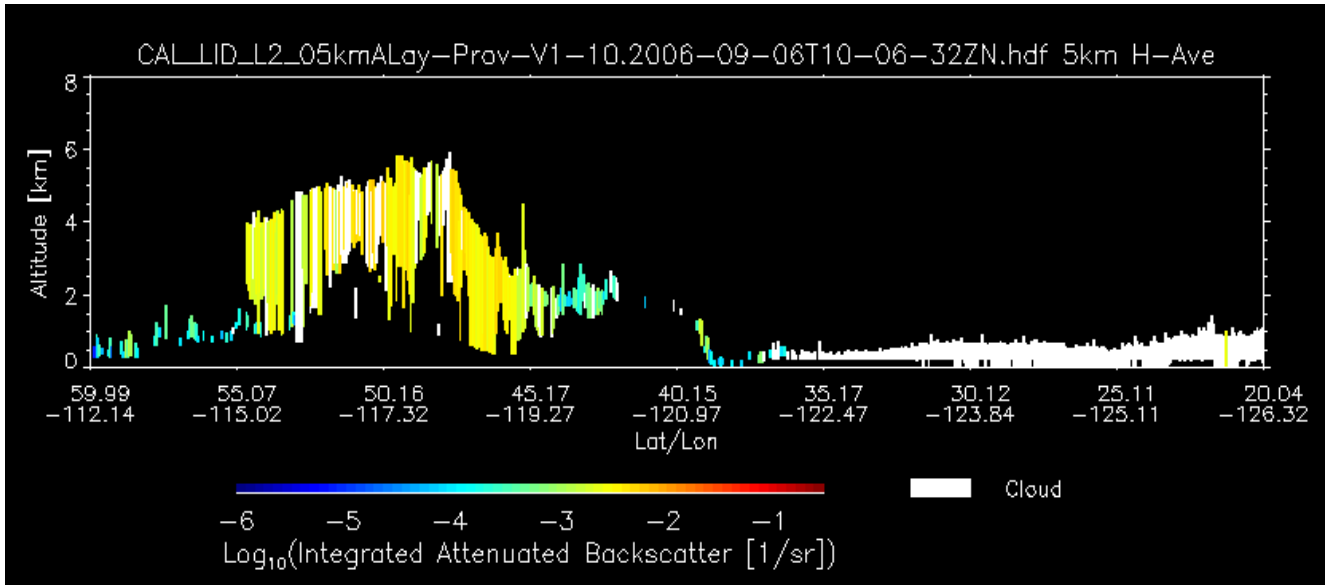
Evaluation of altitude of aerosol layer with CALIPSO data

9/6

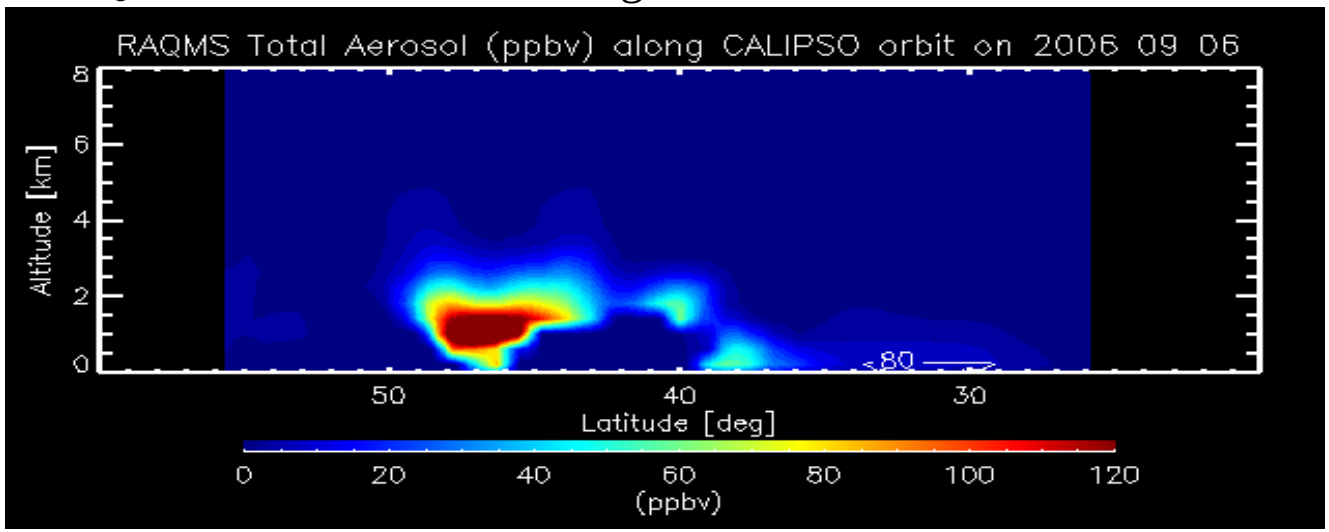
MODIS AOD



CALIPSO Integrated Attenuated Backscatter



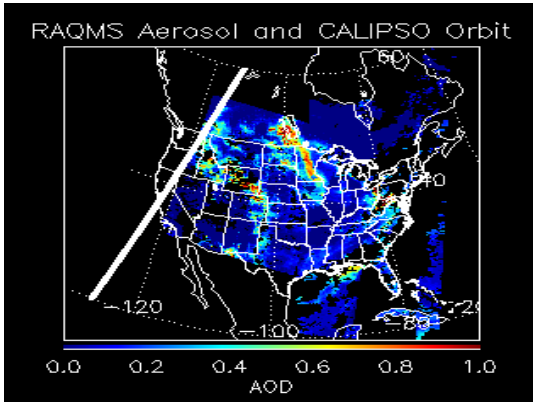
RAQMS Total Aerosol Loading



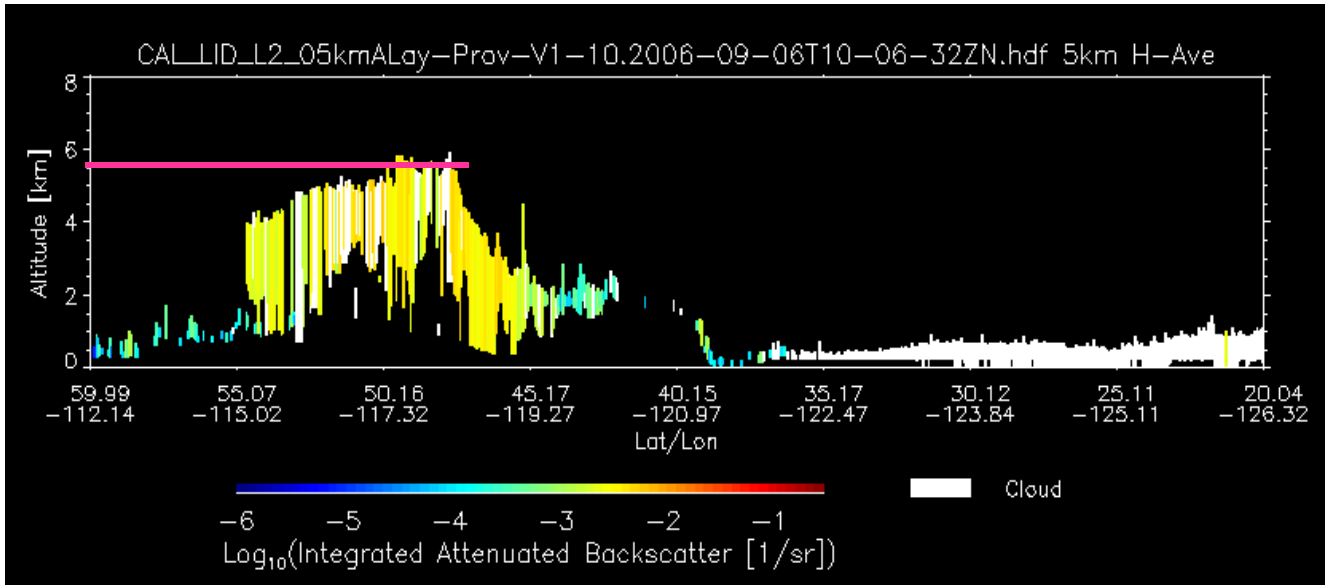
Evaluation of altitude of aerosol layer with CALIPSO data

9/6

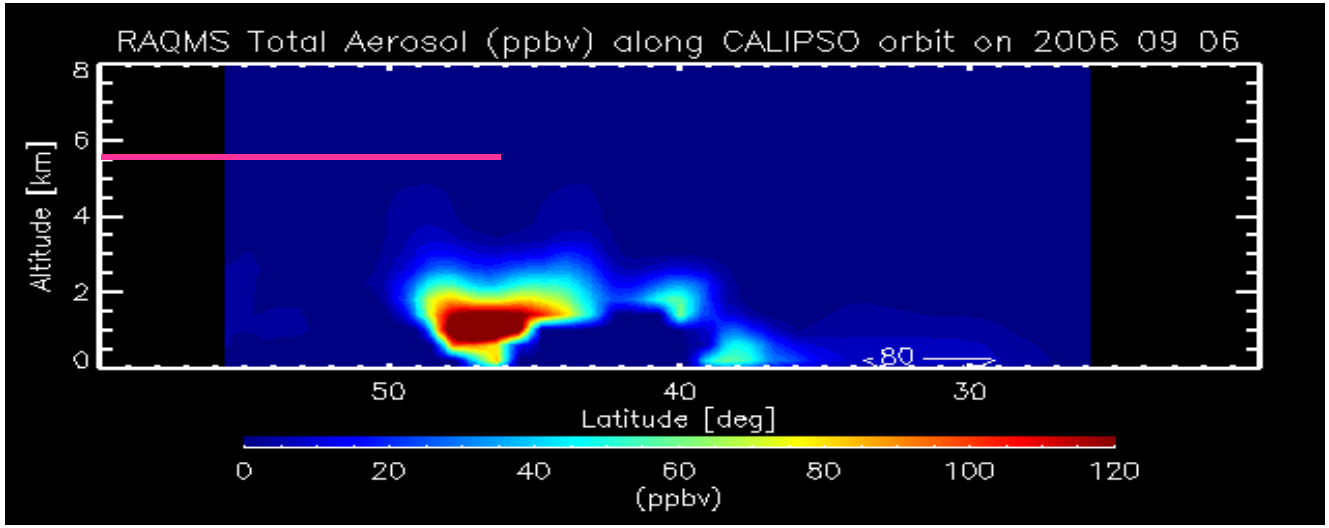
MODIS AOD



CALIPSO Integrated Attenuated Backscatter



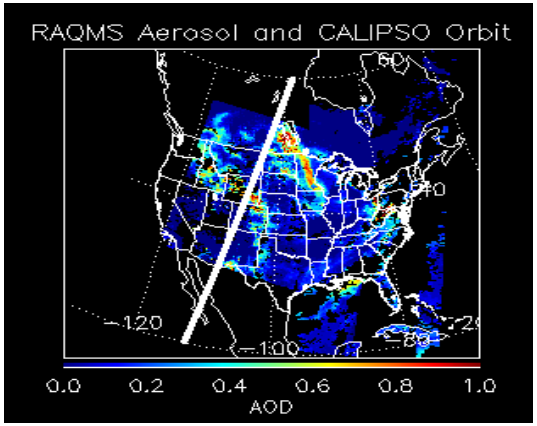
RAQMS Total Aerosol Loading



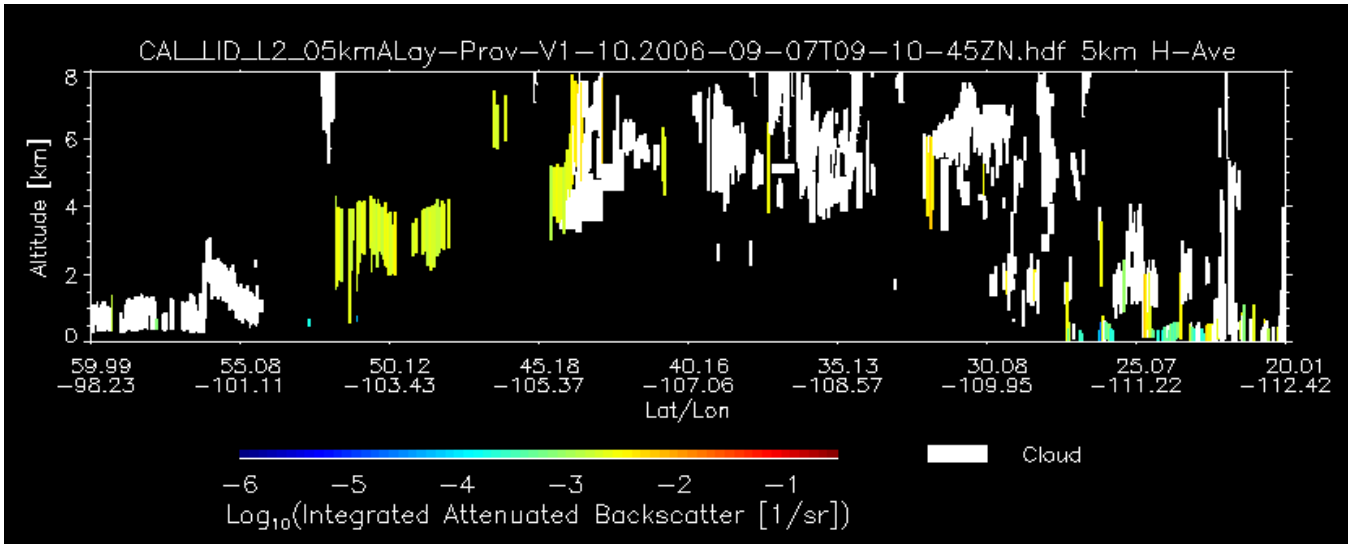
Evaluation of altitude of aerosol layer with CALIPSO data

9/7

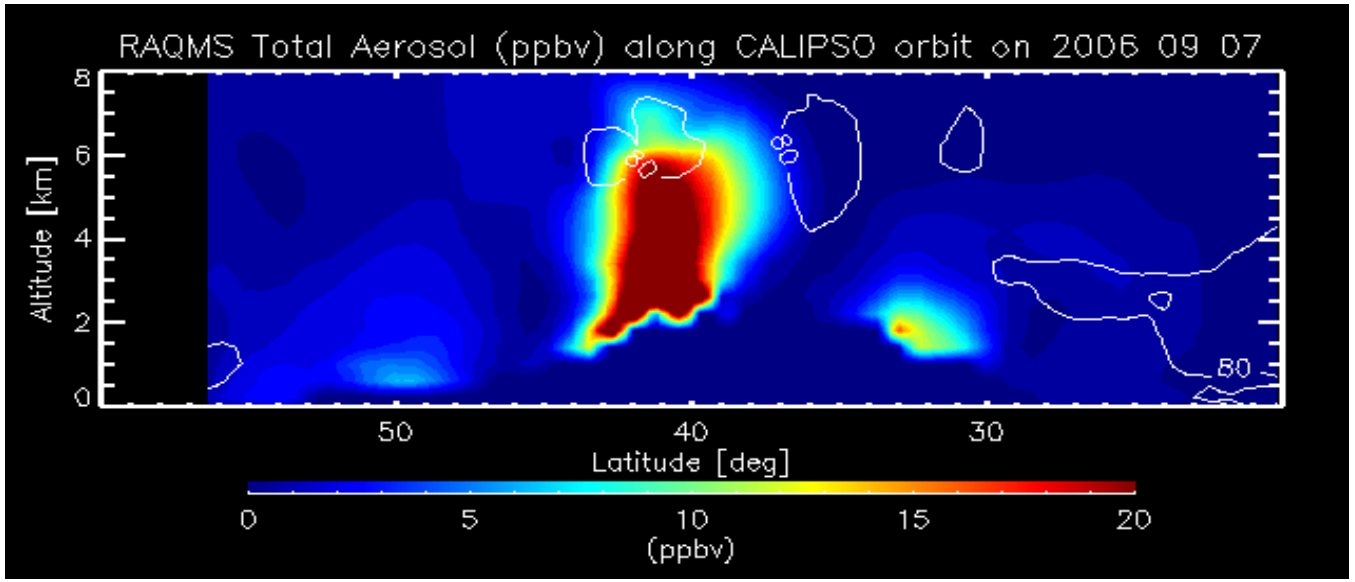
MODIS AOD



CALIPSO Integrated Attenuated Backscatter



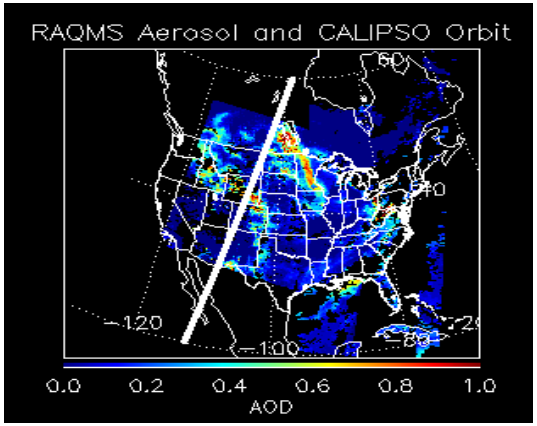
RAQMS Total Aerosol Loading



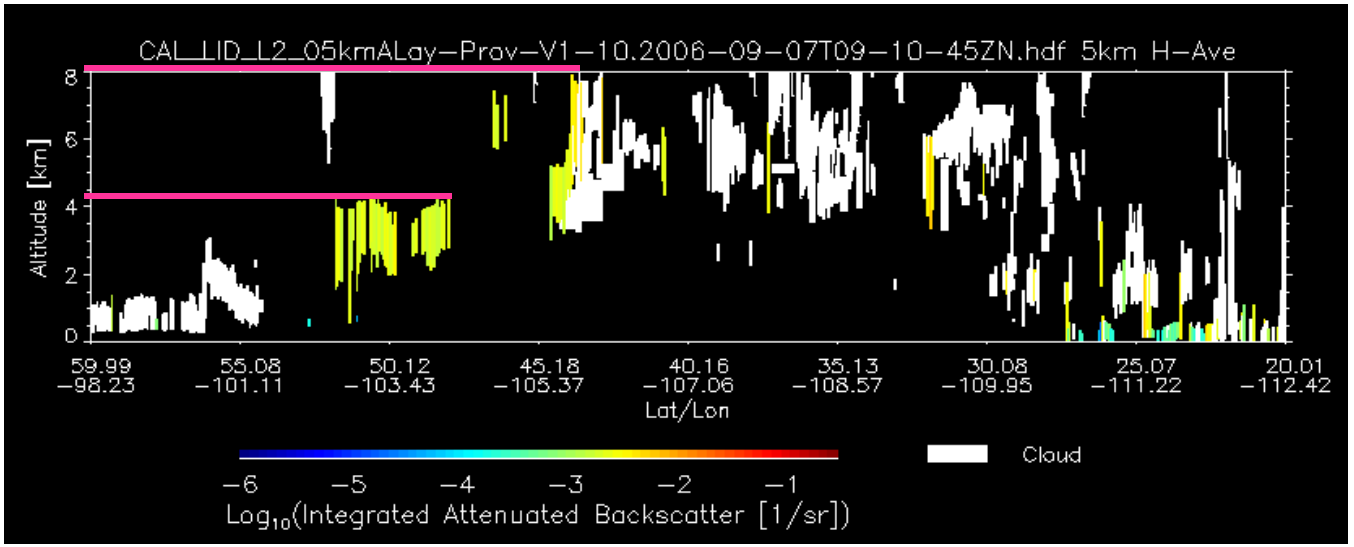
Evaluation of altitude of aerosol layer with CALIPSO data

9/7

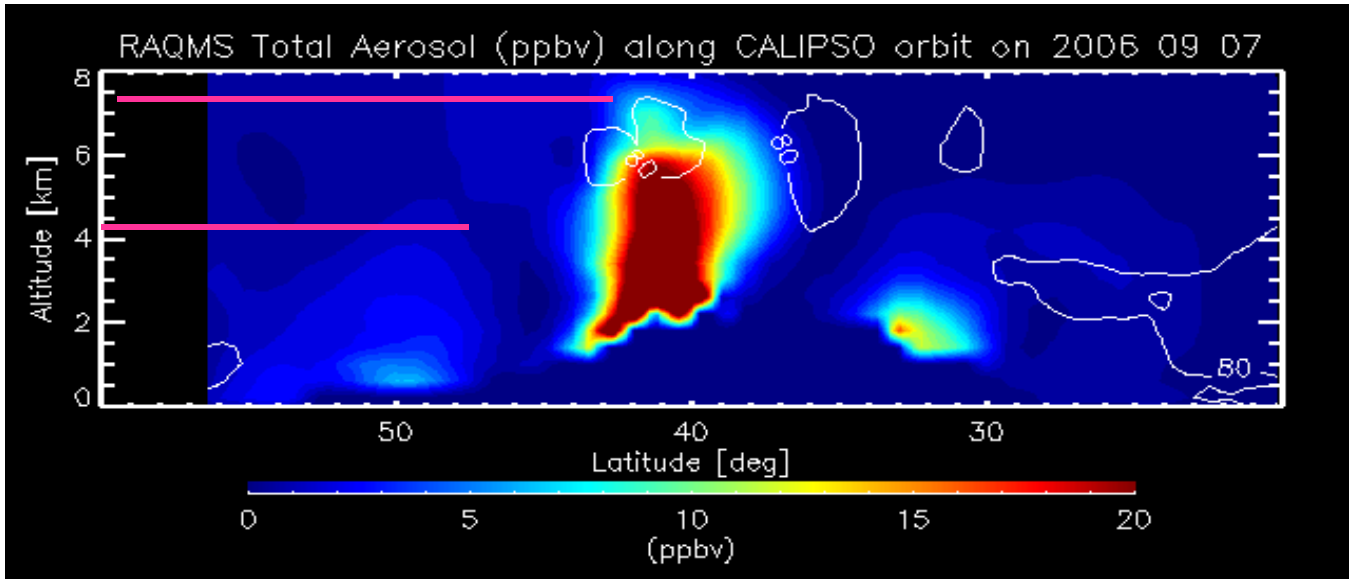
MODIS AOD



CALIPSO Integrated Attenuated Backscatter



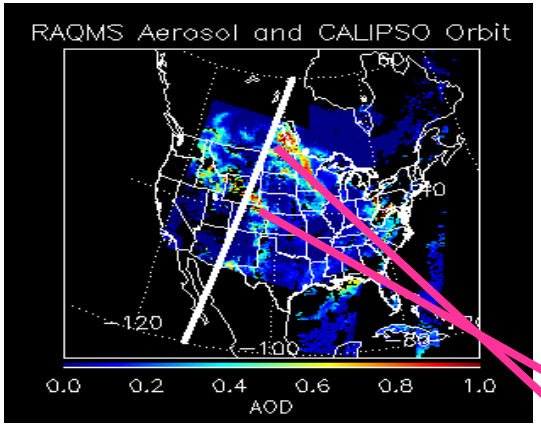
RAQMS Total Aerosol Loading



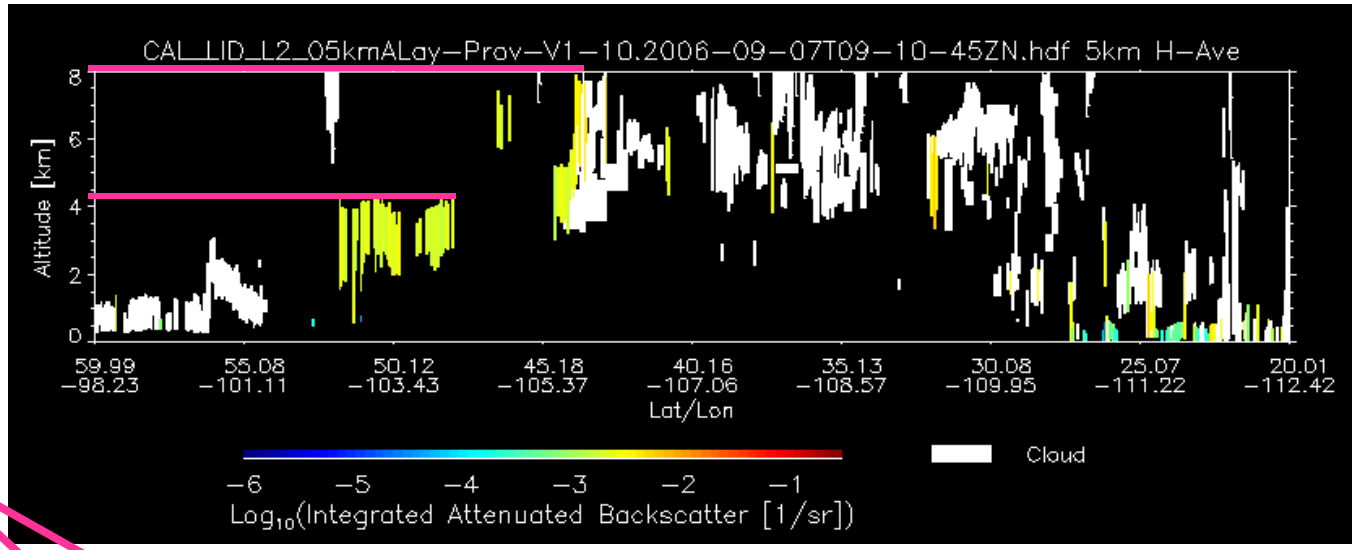
Evaluation of altitude of aerosol layer with CALIPSO data

9/7

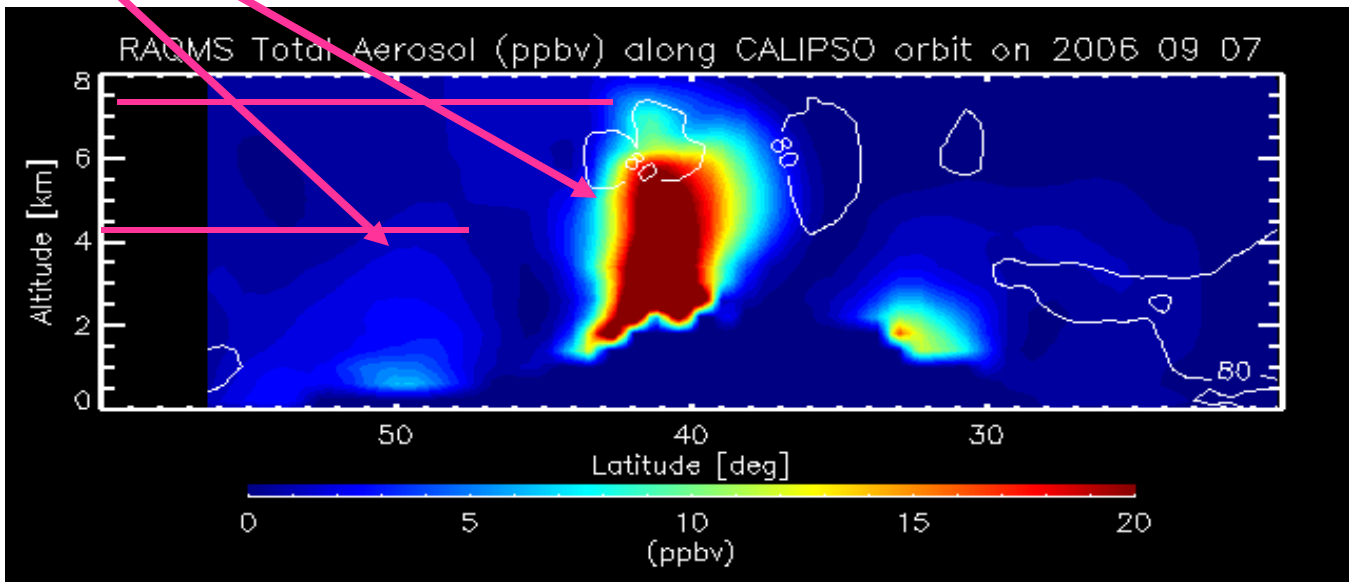
MODIS AOD



CALIPSO Integrated Attenuated Backscatter



RAQMS Total Aerosol Loading



Conclusions

• The RAQMS analysis shows smoke from the Pacific Northwest fires dominates the aerosol distribution over the Western US in early September, 2006.

• The model run with the new carbon emission estimate shows an AOD assimilation increment close to zero over the smoke source region. This indicates the improvement of the emission estimate.

• The larger AOD assimilation increment outside the source region suggests a problem with the aerosol transport pathway.

• The comparison with CALIPSO data indicates an underestimate of the height of smoke plume. This may result from an underestimate of smoke injection height.

fn.c.kittaka@larc.nasa.gov for question/comment. Thanks!