Mesoscale Modeling of Dust and Smoke Transport: How Geostationary Satellite Can Help?

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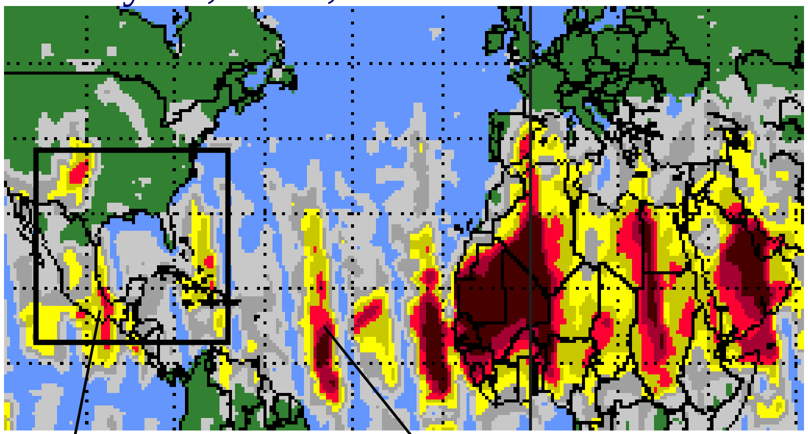
May 04, 2003, TOMS aerosol index



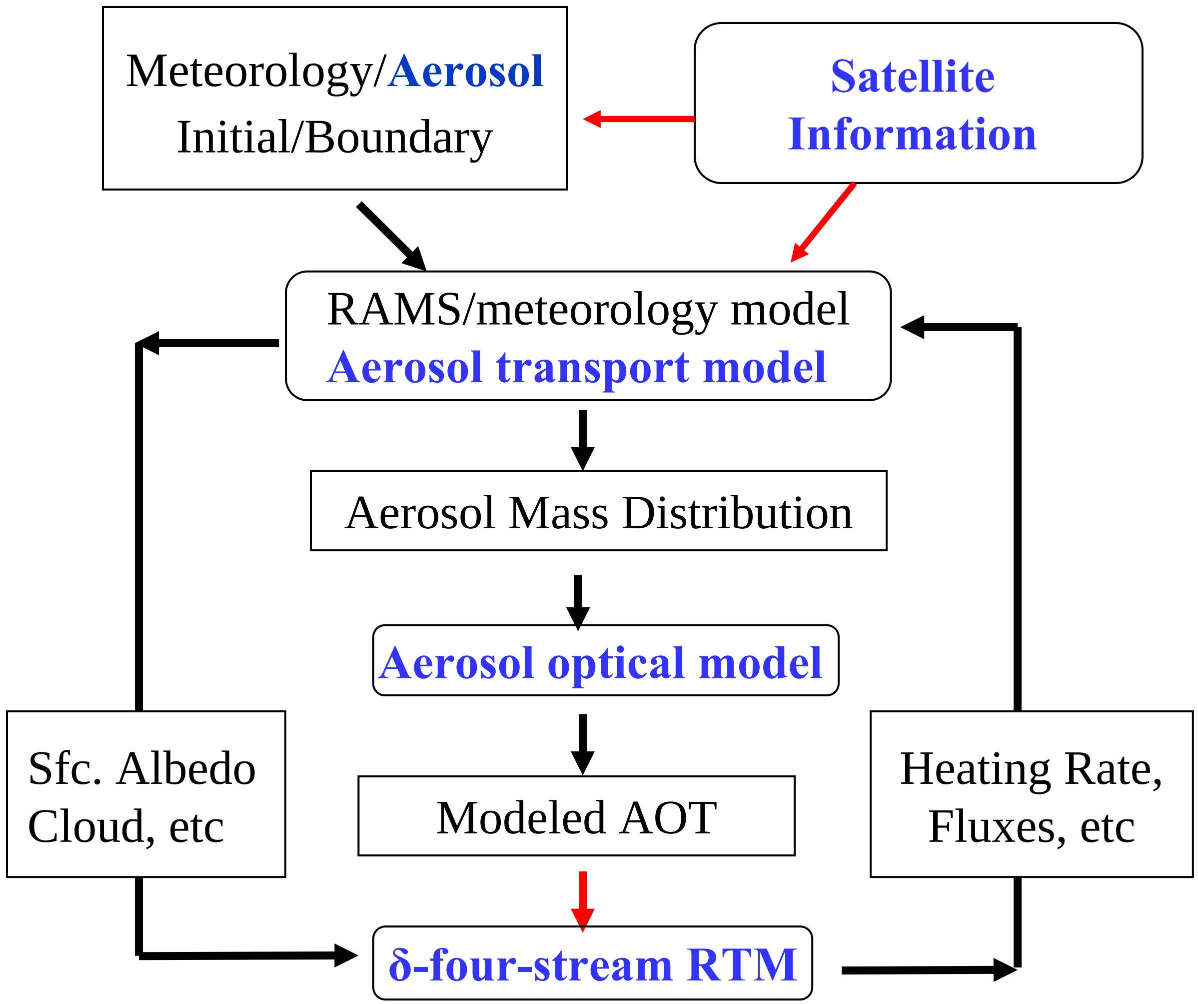
Community Workshop on Air Quality Remote Sensing From Space:

Defining An Optimum Observing Strategy

Boulder, CO, Feb 22, 2006

Model Used: RAMS-AROMA

RAMS – Assimilation and Radiation Online Modeling of Aerosols (AROMA)



Online aerosol radiative feedbacks on surface energy budget and PBL process.

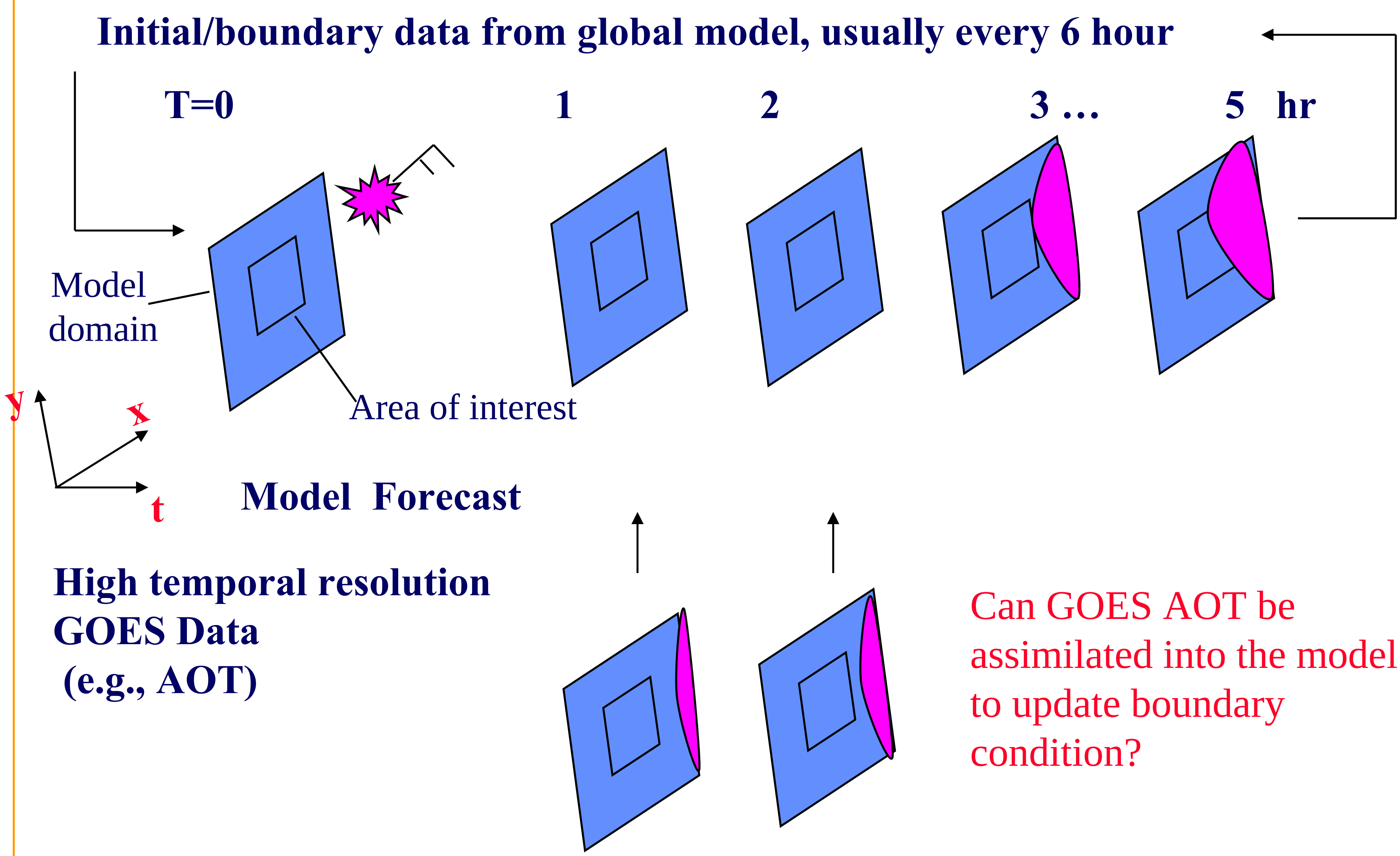
Are the feedbacks important to be considered in the air quality forecast model?

Wang et al., JGR, 2004

Wang et al., JGR, 2006, in press

Wang & Christopher, JGR, 2006, in press

Using GOES for simulation of dust transport



Assimilation of GOES AOT in PRIDE

$\tau_{t+1} = \tau_t + \partial\tau / \partial t * \Delta t$

Modeled tendency

GOES-based Tendency

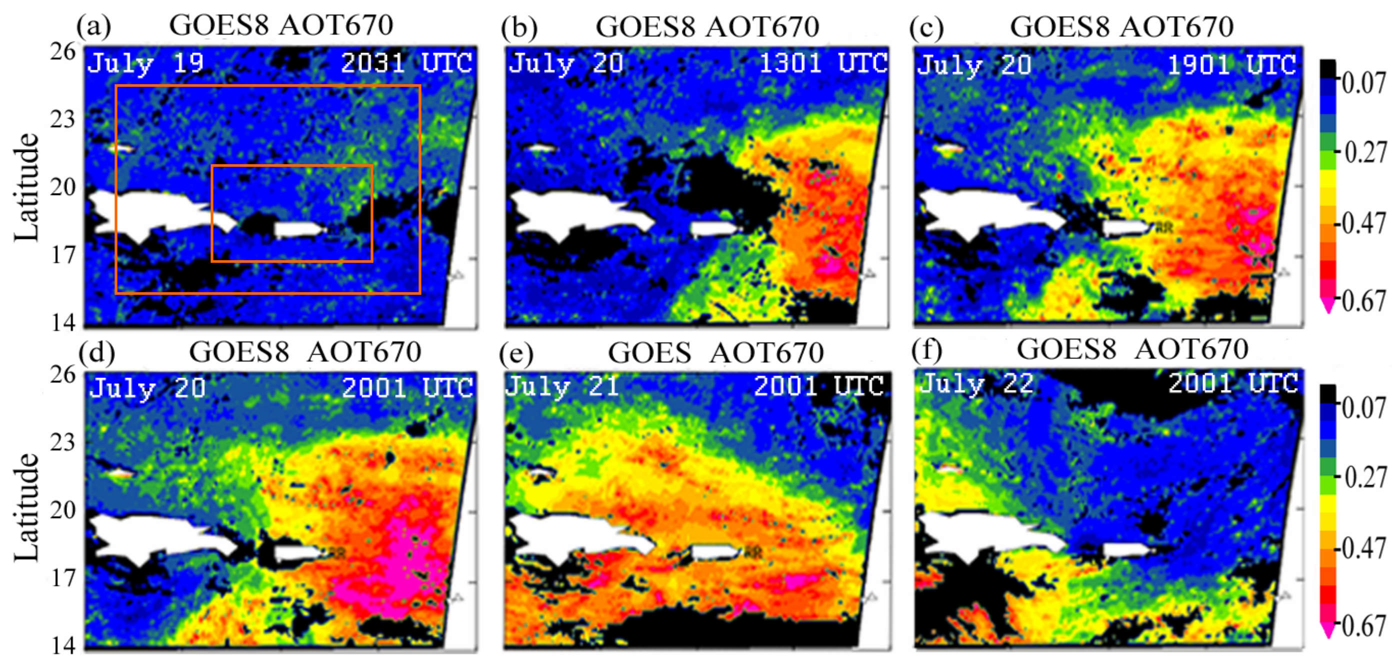
$$\left[\frac{\partial \tau'_{\mathrm{mod}}}{\partial t}\right]_t = (1-\varepsilon)\left[\frac{\partial \tau_{\mathrm{mod}}}{\partial t}\right]_t + \varepsilon\,\frac{\left[\tau_{\mathrm{GOES}}\right]_{t+1} - \left[\tau_{\mathrm{mod}}\right]_t}{\delta \times \Delta t}$$

Confidence factor

2D Weighting factor

1	**1**	**1**
	e^{-1}	**1**
e^{-2}		**1**

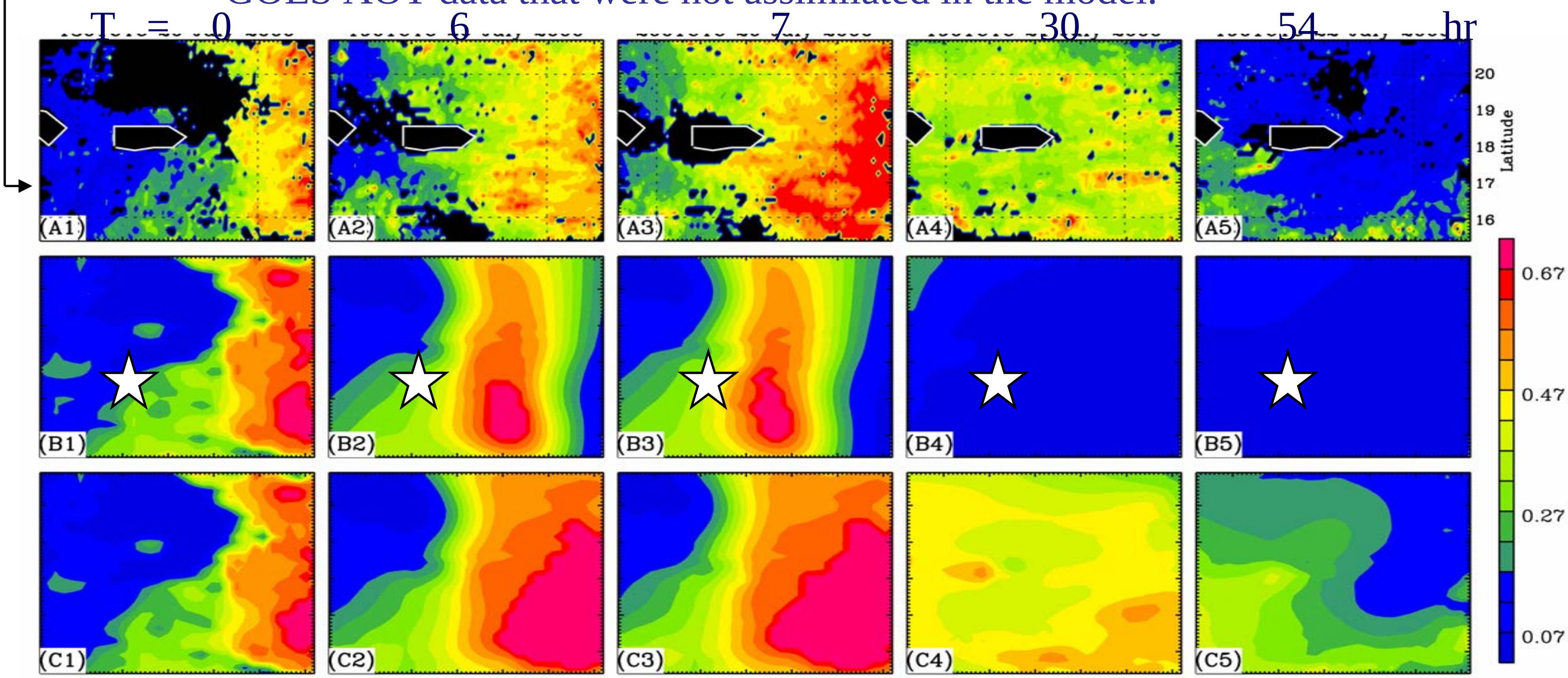
Wang et al., JGR, 2004



GOES AOT retrieval during Puerto Rico Dust Experiment (PRIDE), July 2000.
Wang et al., JGR, 2003; GRL, 2004; *Christopher, Wang et al.*, JGR, 2003.

Simulation Results W/O Nudging

GOES AOT data that were not assimilated in the model.

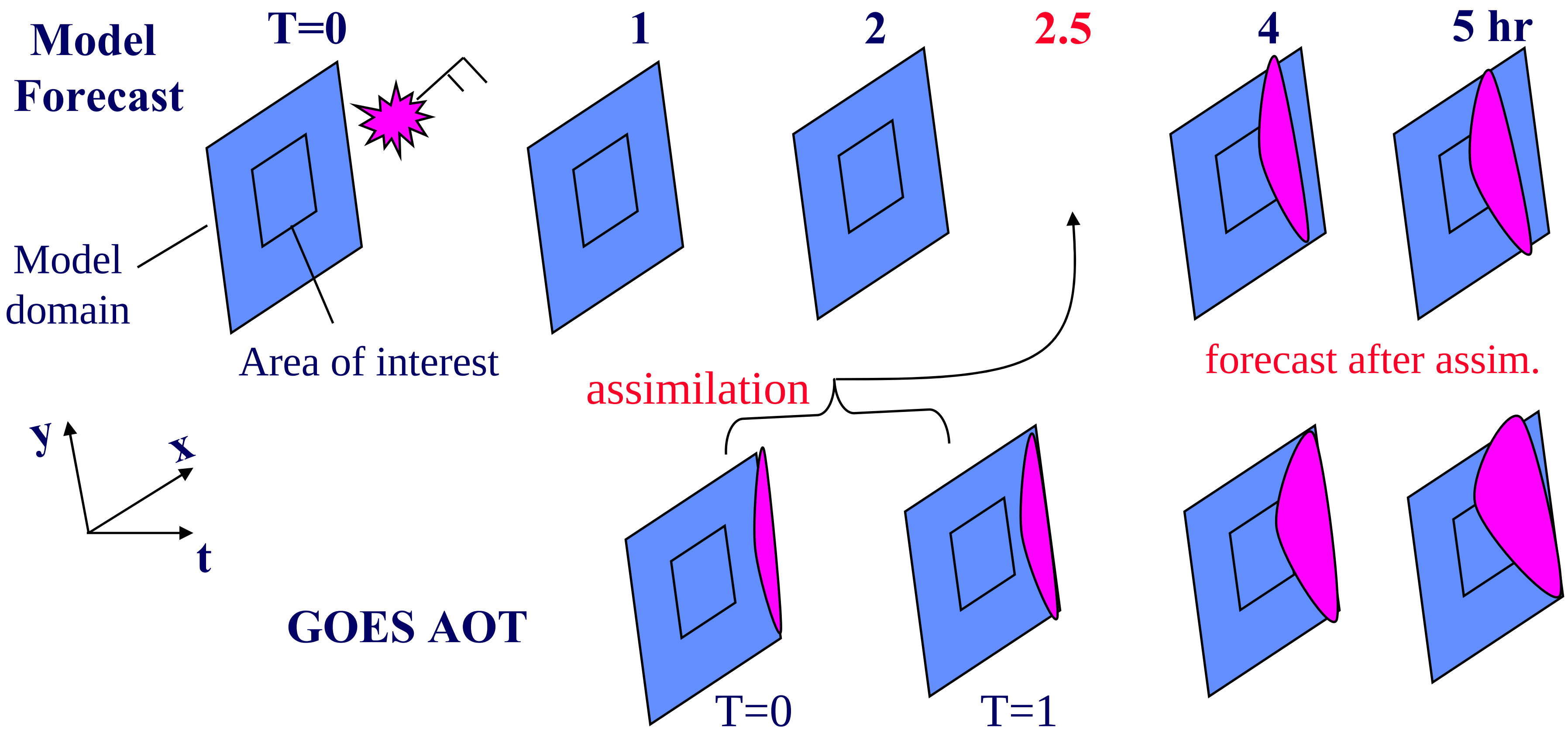


(B) AOT Simulated without nudging (C) AOT simulated with nudging

- The results show that GOES AOT provides an useful constraint for the boundary condition.
- Prediction in the area of interest mainly depends on boundary condition in previous time steps.

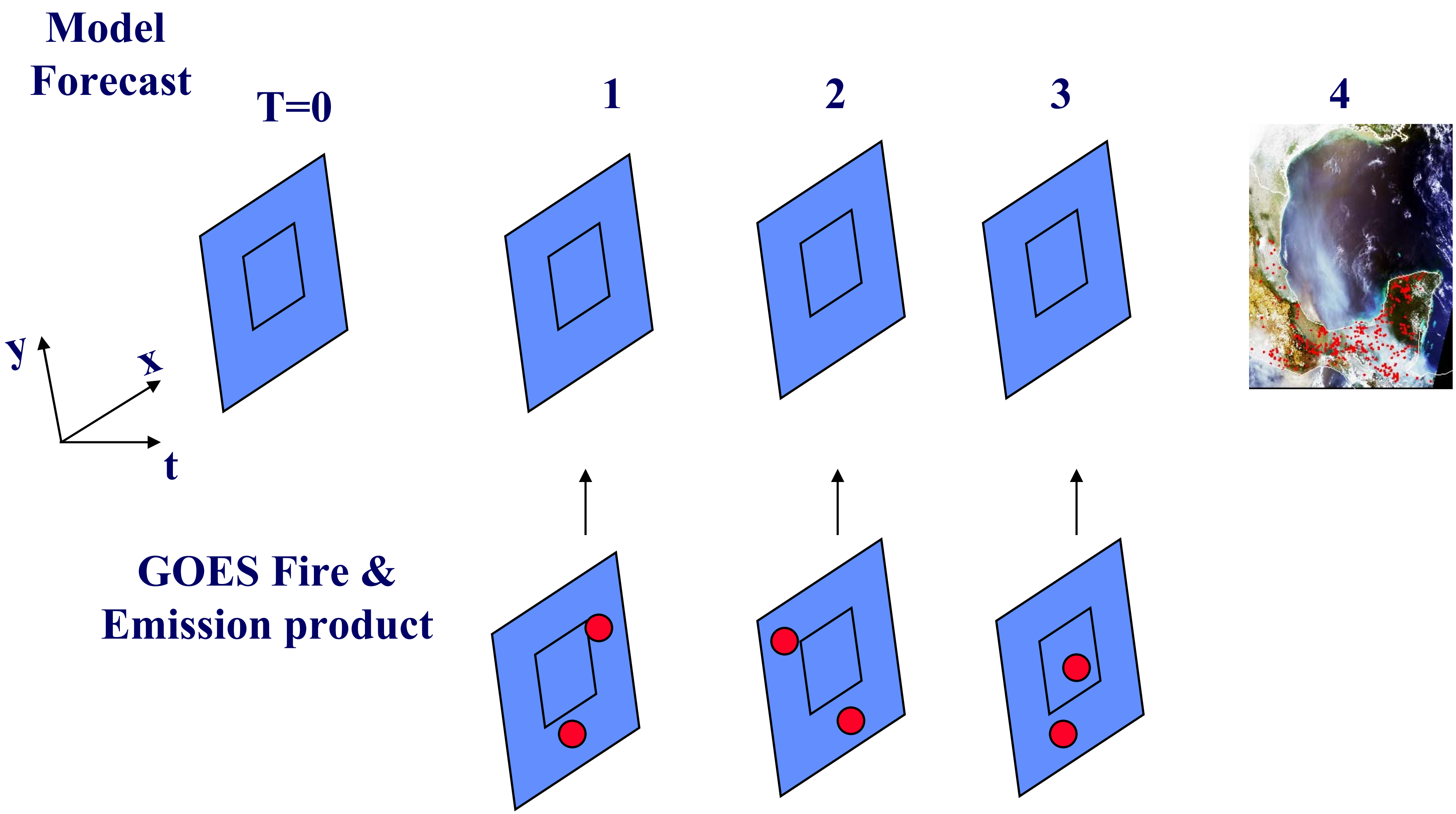
Wang et al., JGR, 2004

A Practical Perspective & Limitations



- The distance between the model boundary and the area of interest makes the short-term forecast in this area relies on the boundary condition at earlier time steps, which provides a time window for the assimilation.
- The assimilation doesn't work in cloudy condition, it should combine with global CTMs (chemical composition and vertical distribution)

Using GOES for simulation of smoke transport

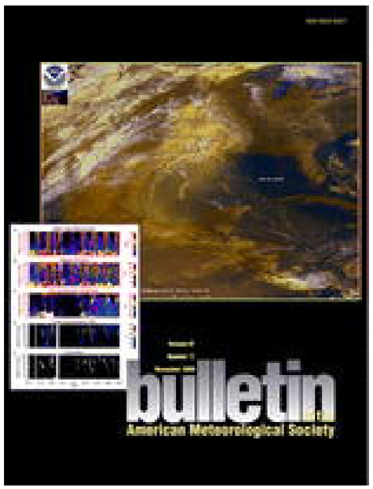


The smoke emission inventory derived from the GOES fire products with high spatial/temporal resolution are valuable for the short-term air quality forecast.

"Mexican, Central American fires smoke up U.S. states"

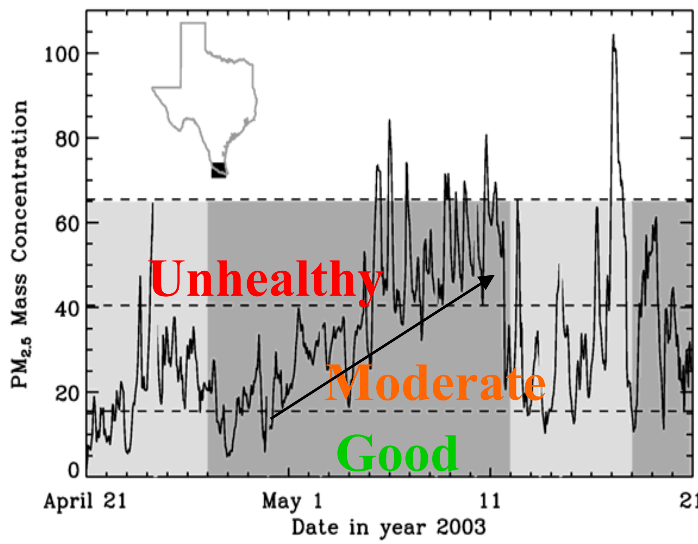
-CNN, May 13, 1998, AUSTIN, Texas (AP)

CNN: "-- Smoke from fires in Mexico … is drifting across much of the U.S. Southeast, prompting Texas officials to issue a health warning to residents throughout much of south Texas…"

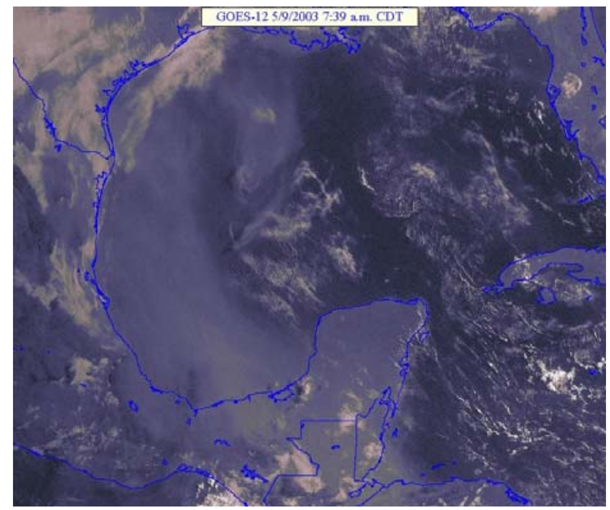


Peppler et al., *2000*

Hourly PM2.5 (μgm^{-3})
Southern TX, 2003



GOES visible, May 9, 2003

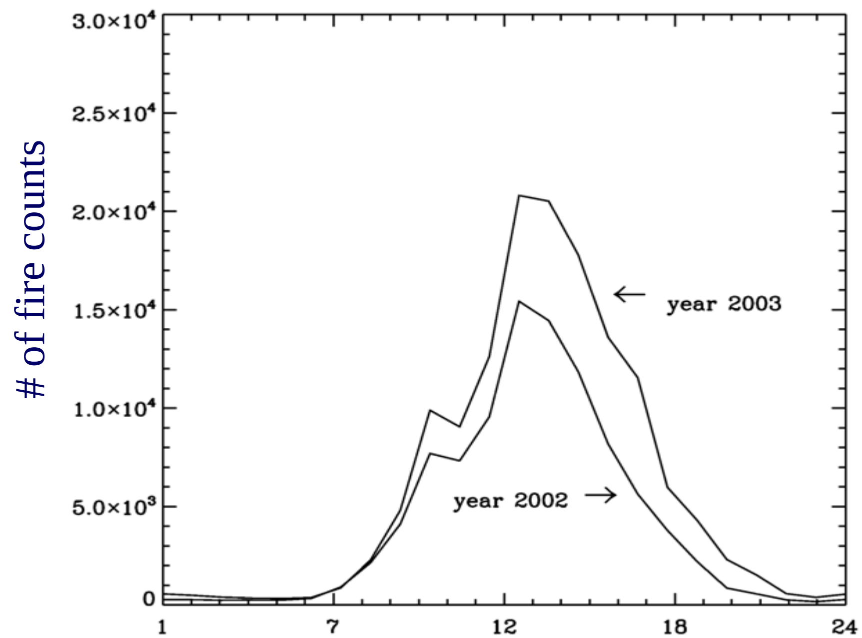


Texas Commission on Environmental Quality: "… In 2003, the dry season was unusually dry, causing many of the fires to burn out of control. In Texas, the smoke levels measured during the 2003 smoke season were the highest for any smoke season since 1998."

Hourly Smoke Emission

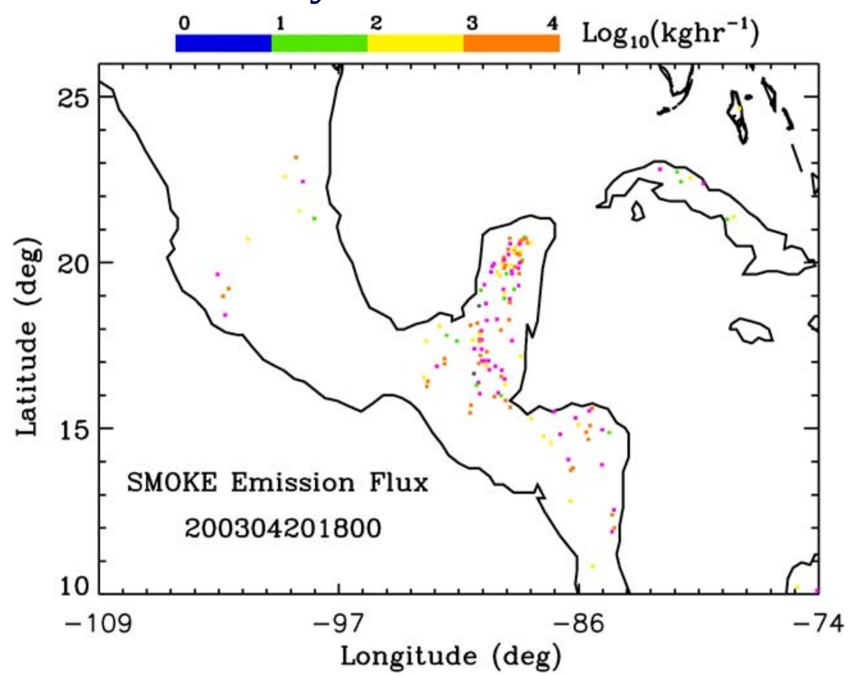
- Fires in Central America are mainly ignited by farmers for agriculture. They usually exhibit a diurnal variation with peak in noon.
- Fire Locating and Modeling of Burning Emissions **(**FLAMBE) geostationary database**.** (*Reid et al*., GRL, 2005). Based on GOES WF-ABBA fire products (*Prins et al*., 1998)

Diurnal variation of fire counts in May
(From GOES ABBA fire product)



Local Hour

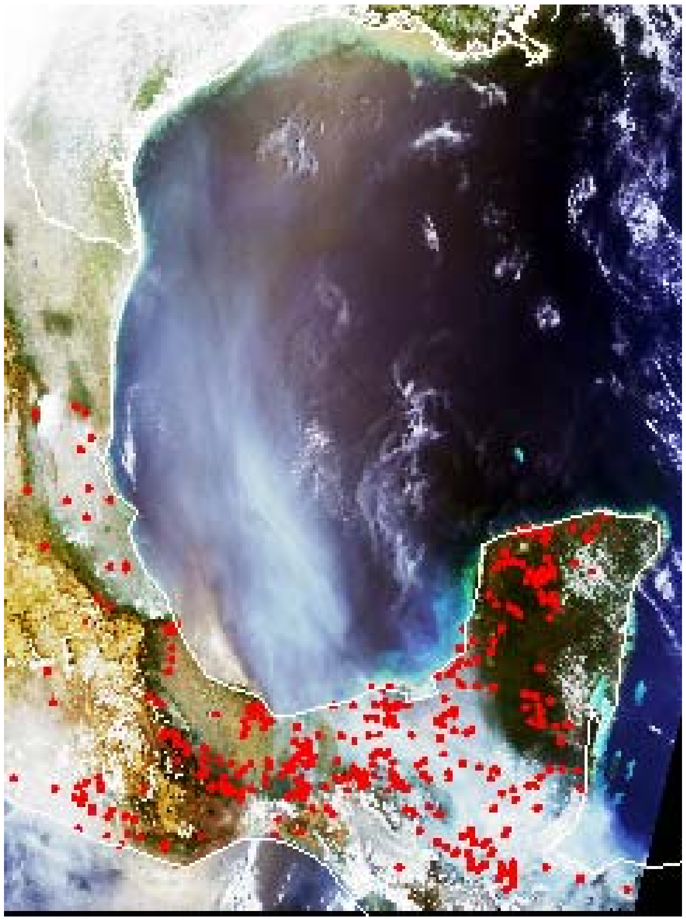
Hourly Smoke Emission



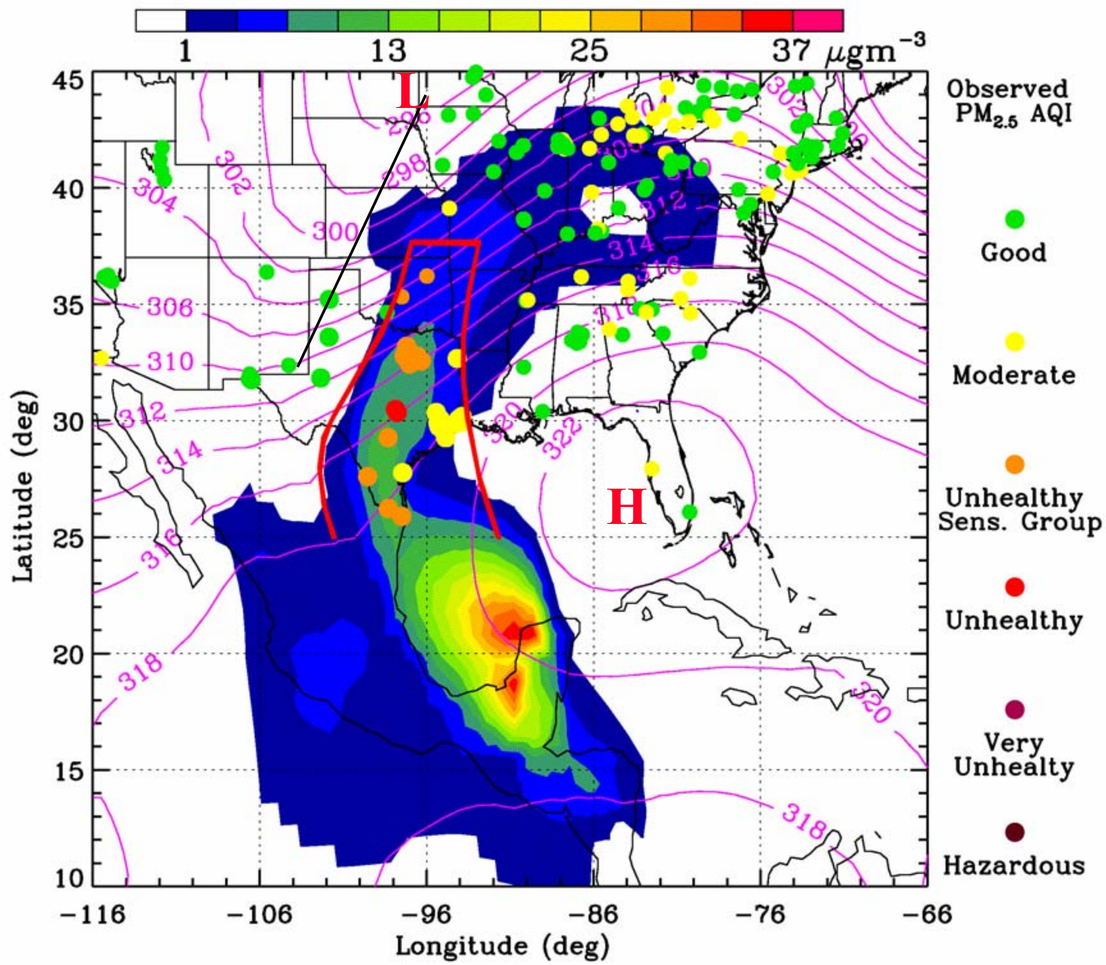
RAMS-AROMA Simulation vs. Observation

12:00 CDT, 10 May 2003

MODIS



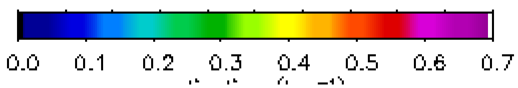
RAMS/AROMA Smoke



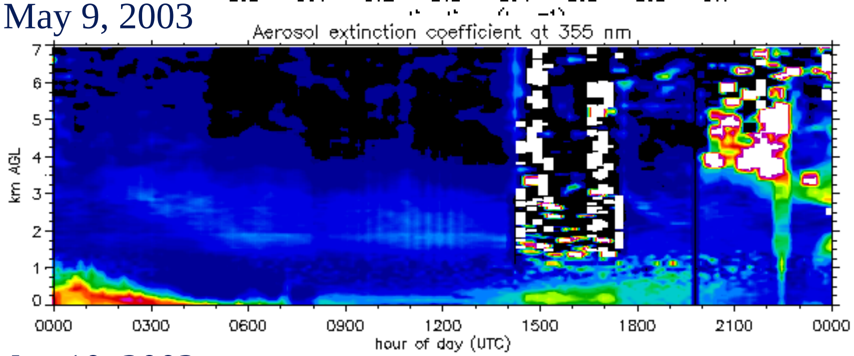
Wang et al., JGR, 2006, in press

RAMS-AROMA Smoke Profile ~ Lidar Aerosol Profile

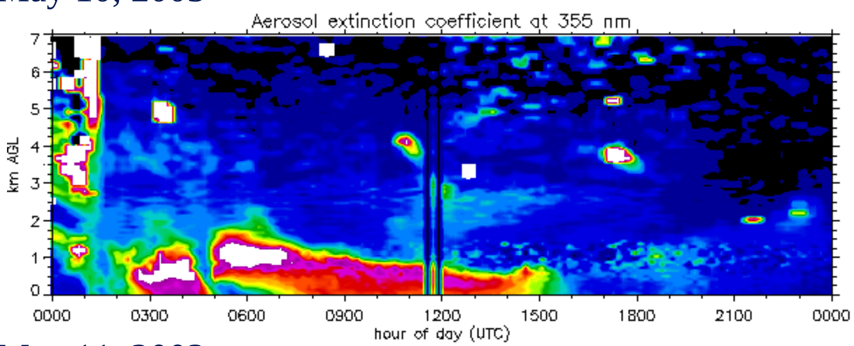
Raman Lidar Extinction Coeff. (km^{-1})



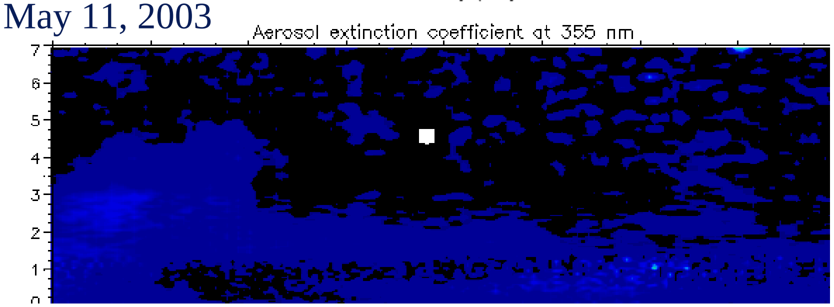
May 9, 2003



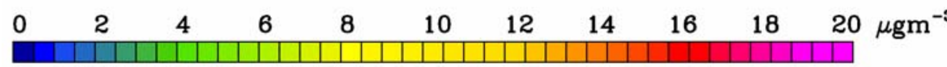
May 10, 2003

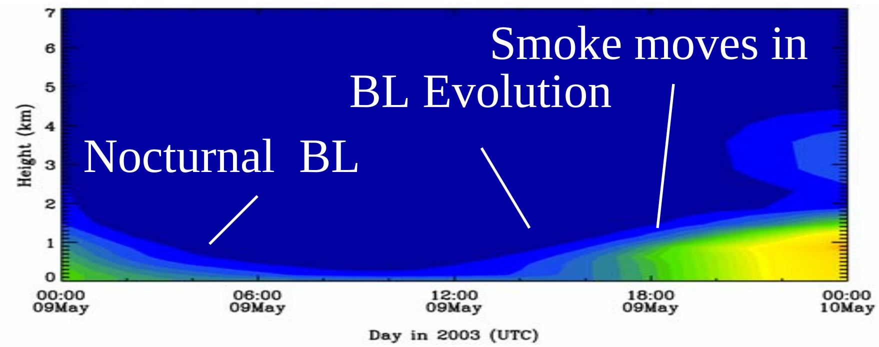


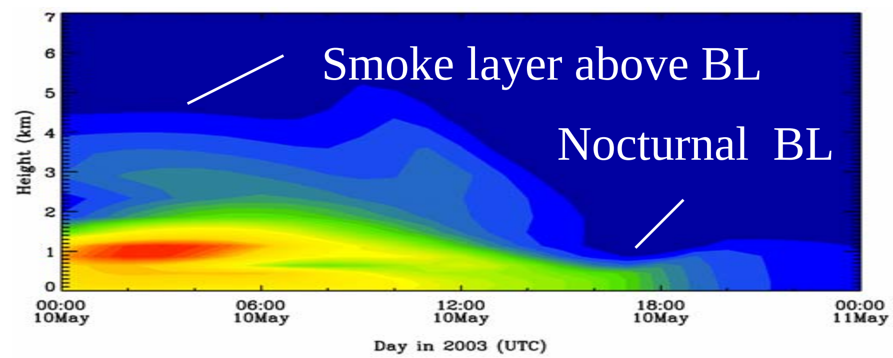
May 11, 2003

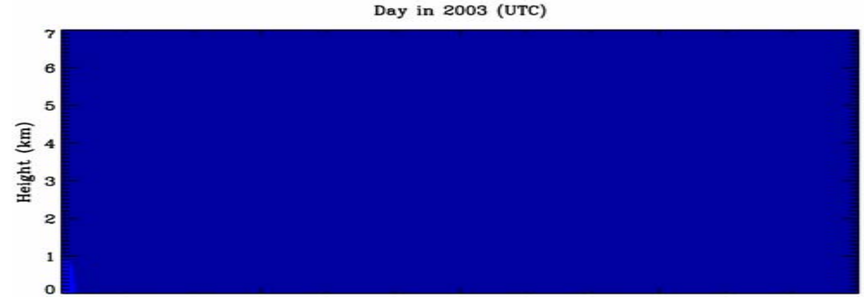


RAMS-AROMA Smoke Mass Concentration

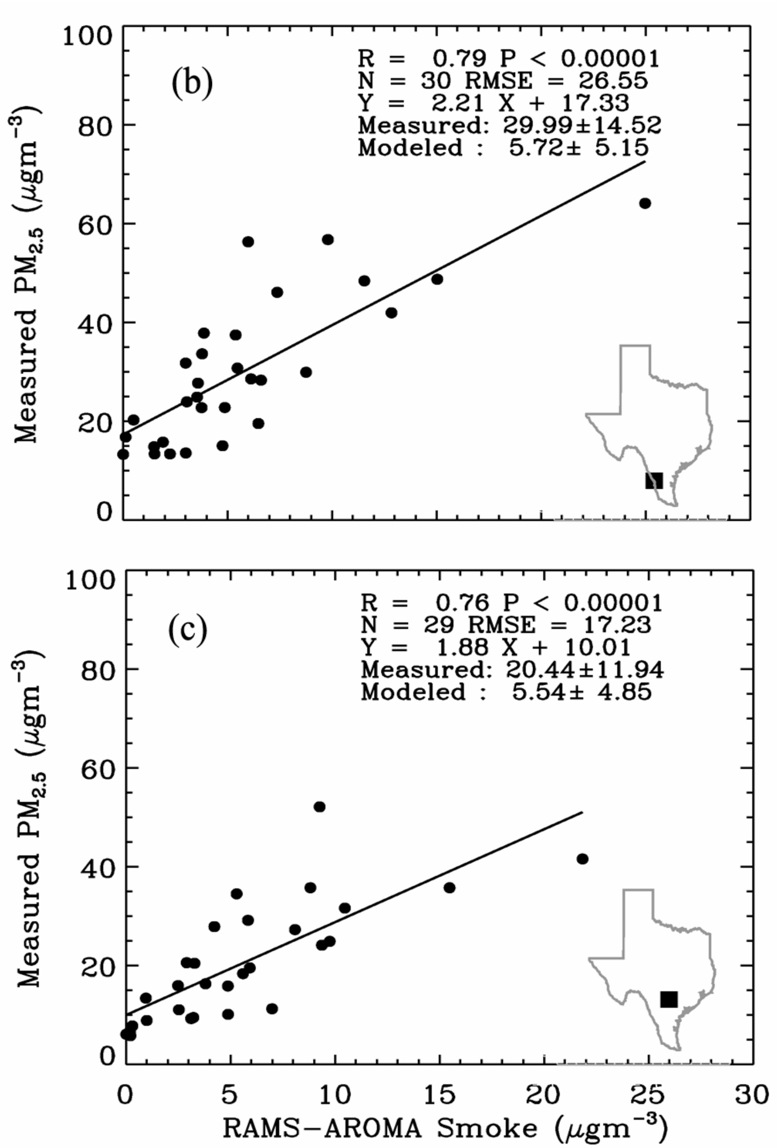


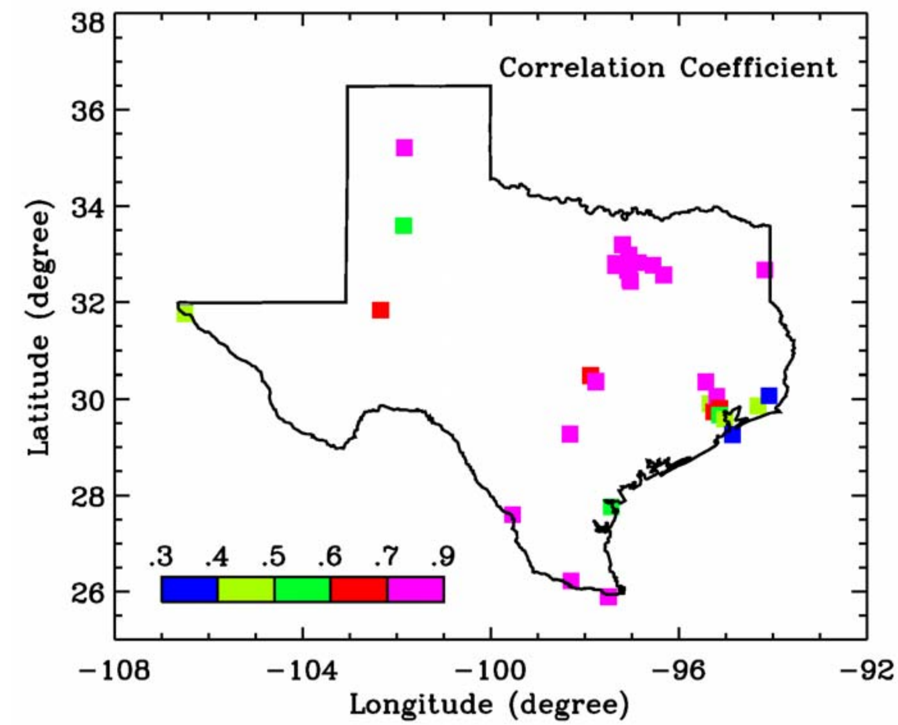






RAMS-AROMA Smoke vs. Measured $PM_{2.5}$

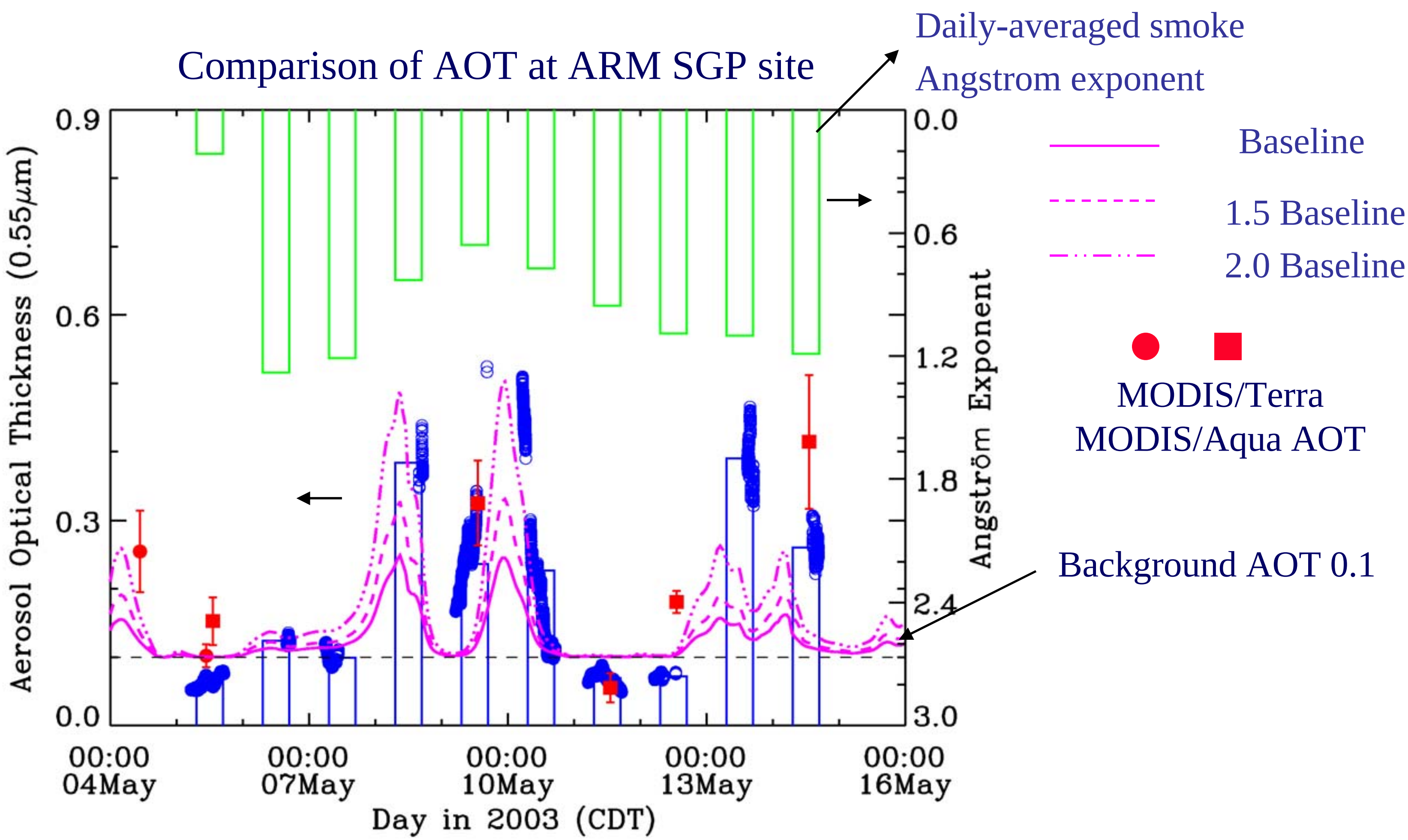




Correlations between daily PM2.5 and modeled smoke mass in 30 days.

The model is able to capture the fluctuation of daily PM2.5 concentration at most stations,
even the background aerosols are not included in the model.

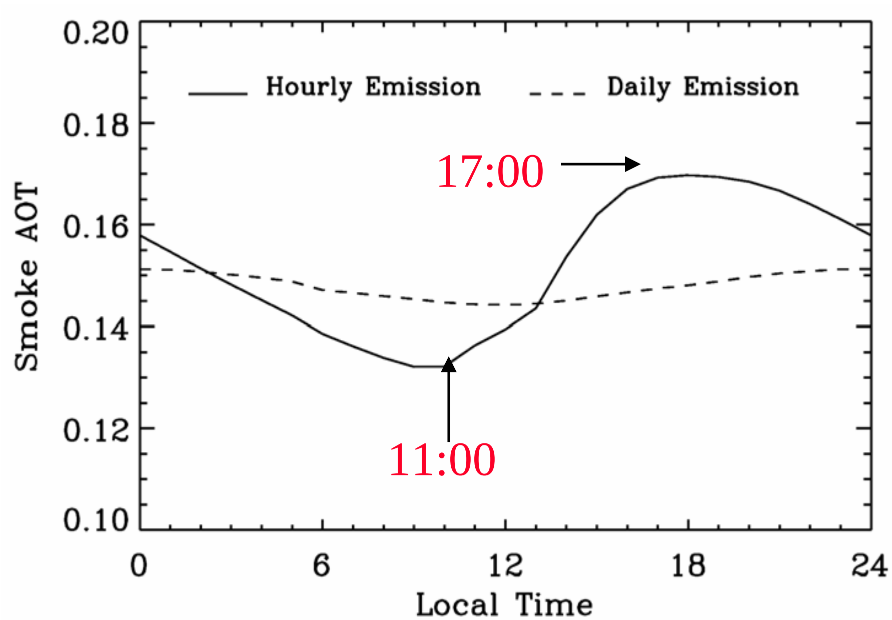
Top-down Assessment of Emission Strength



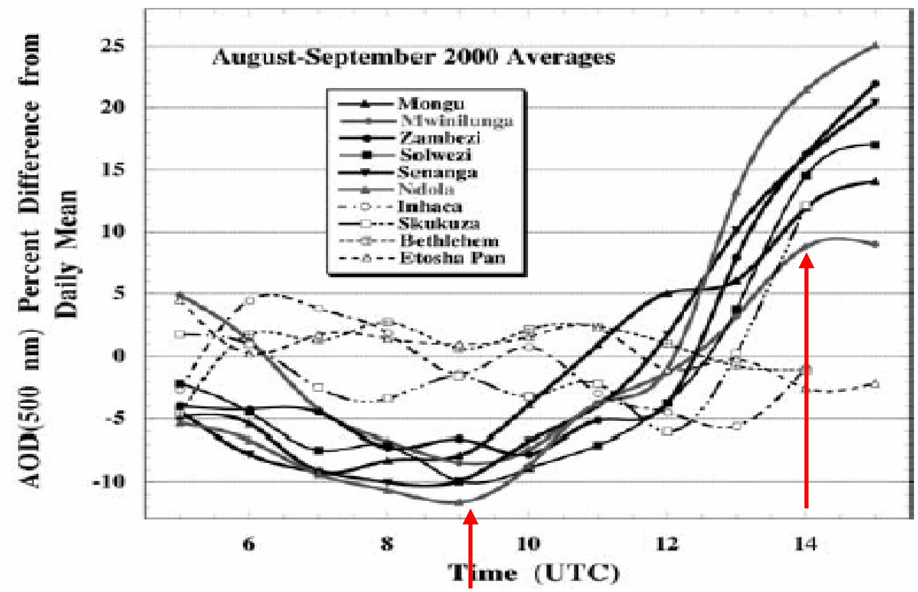
Our best estimate of smoke emission during the (30day) study time period is 1.3Tg in total (Wang et al., 2006). Preliminary estimate shows that about 55% was transported to US.

Impact of Emission Diurnal Variation

RAMS-AROMA Smoke AOT
30d avg, Yucatan Peninsula.



Diurnal variation of smoke AOT
by Sun photometer in SAFARI

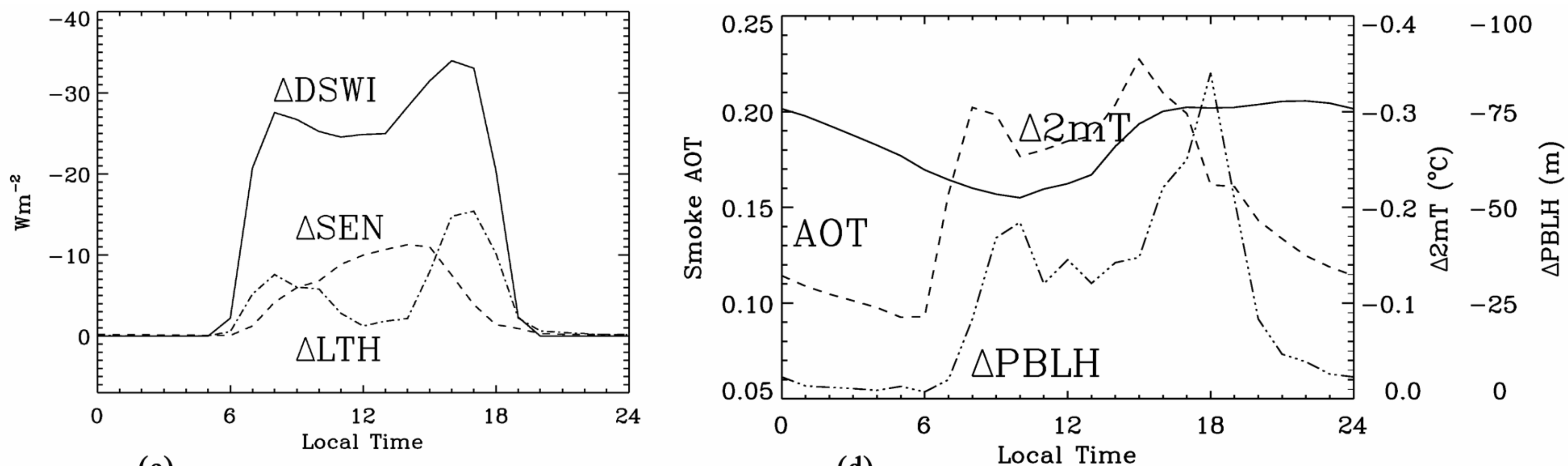


Min. @ 11:00 LT, Max. 17:00LT.
Eck et al, JGR, 2003.

Because the biomass burning peaks at local noon ,the smoke loading is accumulated in the later afternoon. Using hourly emission can simulate the diurnal pattern of smoke AOT in the source region, however, daily emission can not.

Smoke Effect on Surface Energy Budget & PBLH

30 Day averages in smoke source



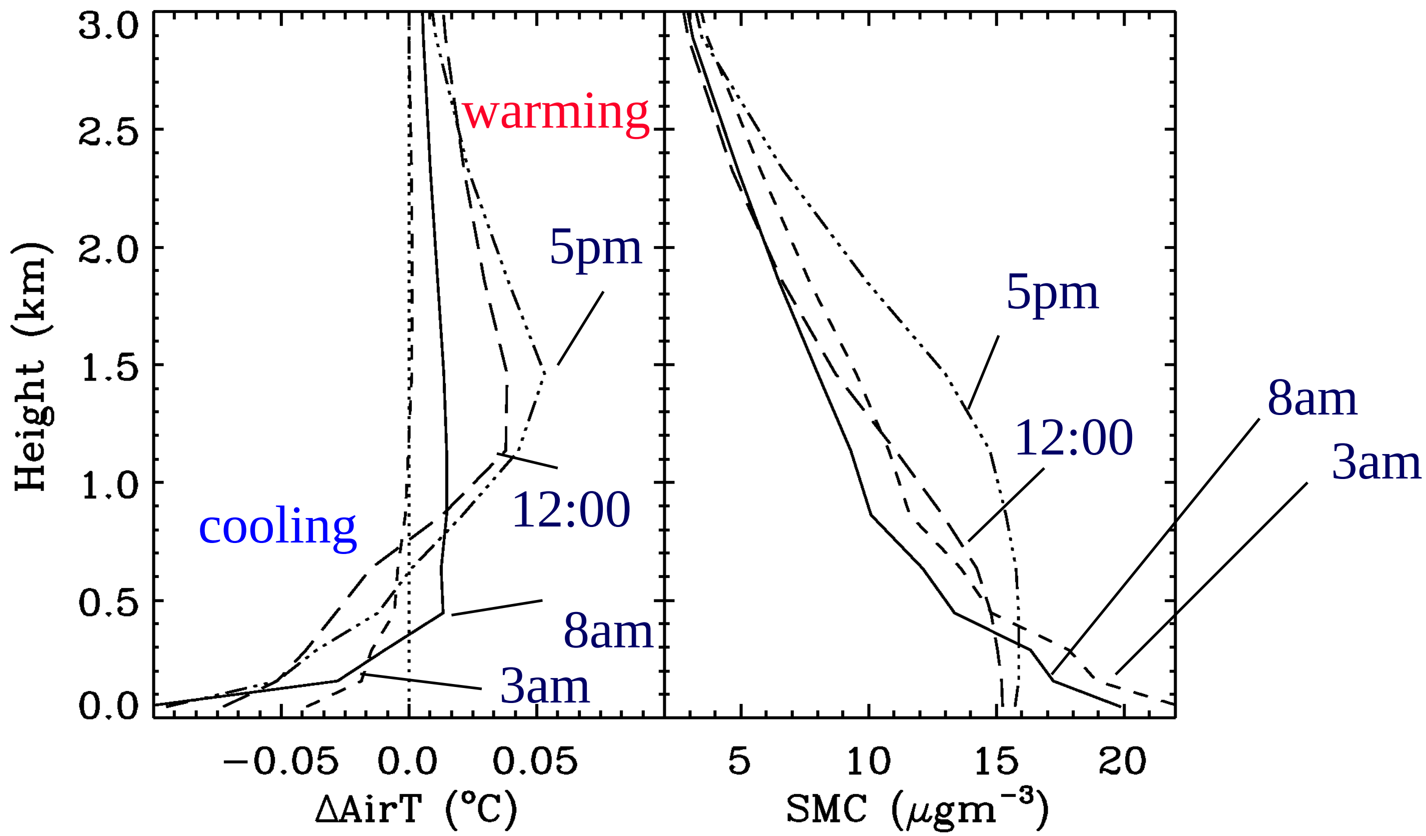
Reduce the diurnal range of temperature (DRT)

	ΔMin2mT (°C)	ΔMax2mT (°C)	DRT (°C)
Source Region	–0.15	–0.46	–0.31
Downwind Region	–0.05	–0.31	–0.26

Wang and Christopher, JGR, 2006, in press

Smoke Radiative Impact On Temperature Lapse Rate

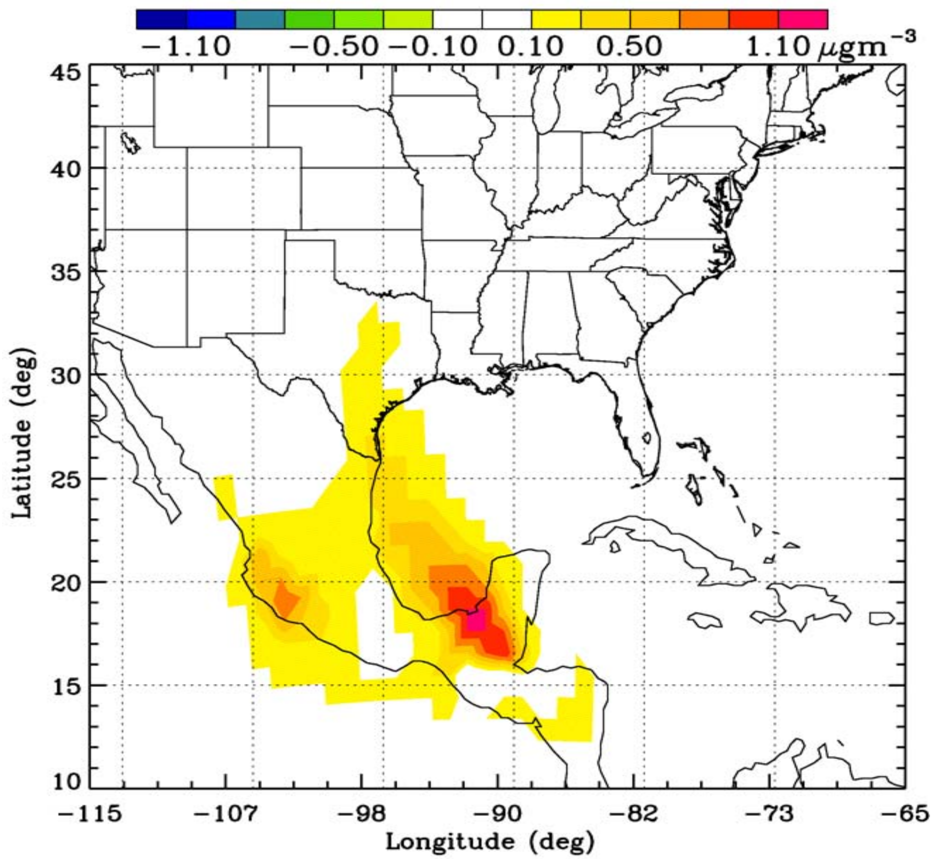
30d averages of air temperature changes
due to smoke radiative effect in smoke source region



Smoke heats the upper BL and cools lower BL and surface, increasing the atmospheric stability. The magnitude and the location of warming/cooling depend on the smoke mass vertical profile that is amenable to the diurnal variation of smoke as well as the PBL evolution.

Smoke self-trapping "feedbacks"

The difference of smoke concentration near the surface with and without smoke radative effects (30 days average)



Smoke decreases DWSI

Decrease the TKE

More smoke particles are trapped in lower PBL

Proposed by *Robock*, 1988, *Science*.

This study is able to verify and consider the smoke direct radative feedback in modeling of aerosols.

Summary & Outlook

- The high temporal resolution AOT and fire emission estimate from GOES are helpful for the meso-scale air quality modeling in following aspects:
  - Aerosol initial and boundary conditions in the model;
  - Smoke source function, unique for short-term air quality forecast;
  - Better representation of radiative process in meteorology model.

- Outlook
  - Study the smoke effect on cloud and precipitation over the SEUS. (MISR, MODIS, and OMI aerosol and cloud retrievals would be helpful).
  - MILAGRO & Nesting with GEOS-CHEM to understand smoke aging and aerosol formation process. (integration with ground-based and sub-orbital measurement)
  - CALIPSO, smoke injection profile and boundary layer processes
  - GOES-R, reliable AOT product over land

Acknowledgement

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