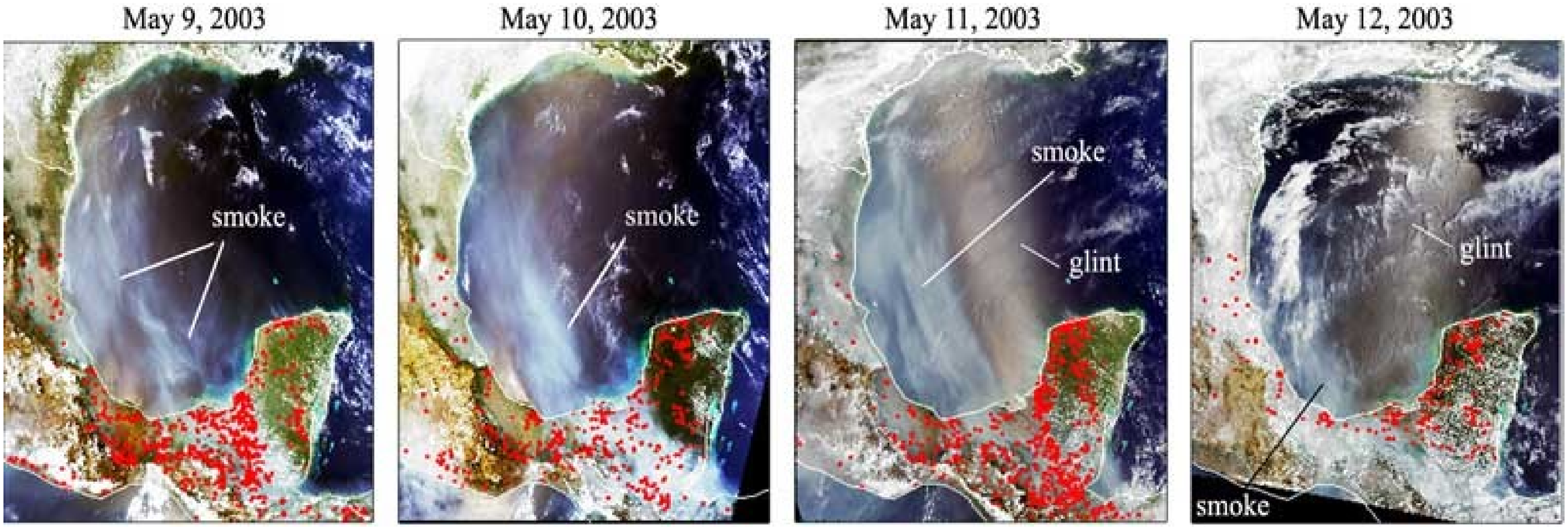
From Emission Inventory To Atmospheric Process Studies: A Case Analysis Of Central American Biomass Burning Aerosols

Jun Wang

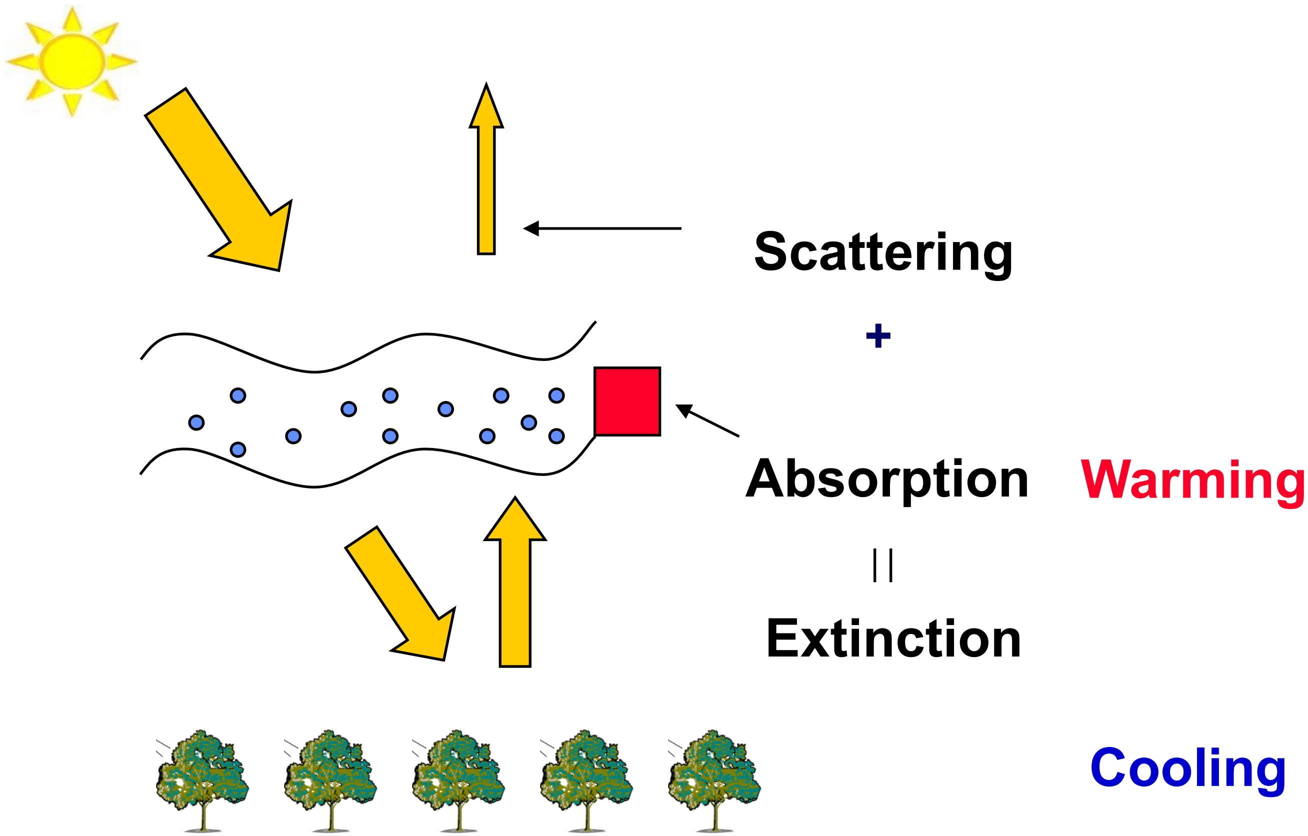
University of Nebraska – Lincoln

NCAR Junior Faculty Forum

15 July 2010



Aerosol direct radiative effect



Affects atmospheric lapse rate, atmospheric stability, surface energy budget, photosynthesis, photochemistry, …

Aerosol Indirect Effect: Interactions with Clouds & Precipitation

Aerosol

↓

Cloud condensation nuclei (CCN)

↓

Cloud droplets

↓

Precipitation

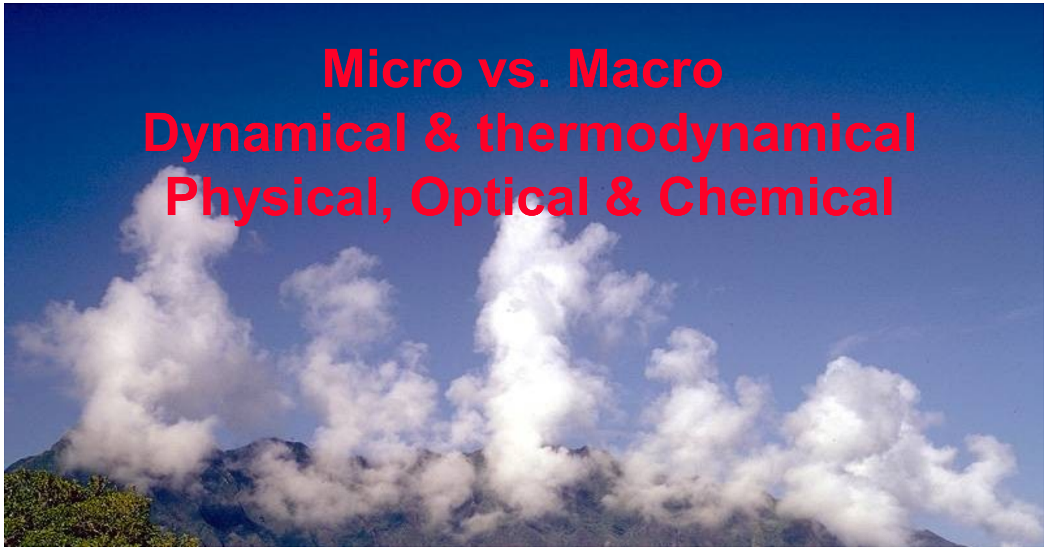
↓

Cloud life time

cloud cover

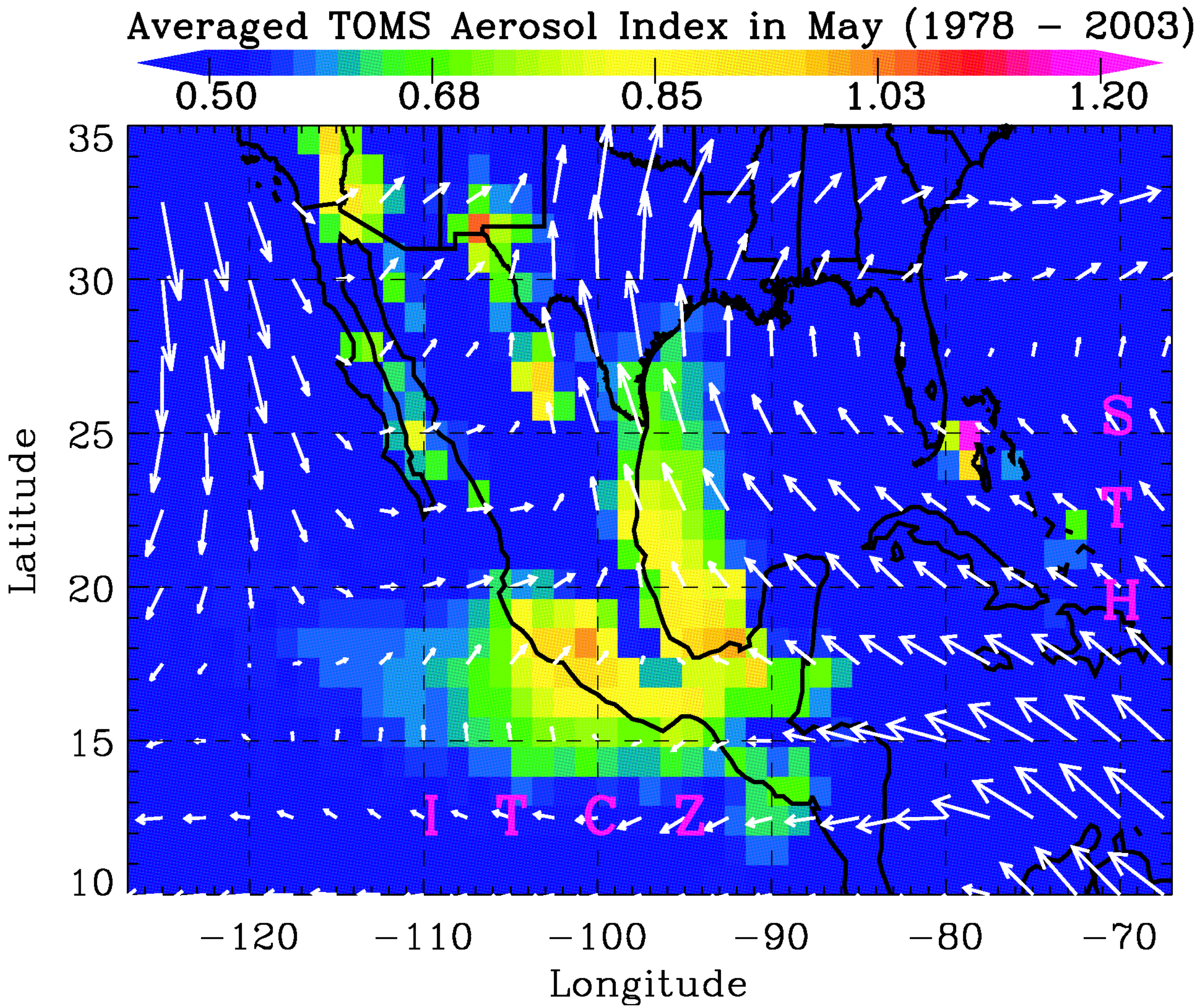
Aitken (*Nature*, 1880) :

"… the vapor must have some solid or liquid body on which to condense…, if there were no dust, there would be no fogs, no clouds, no mists, and probably no rain"



How do anthropogenic aerosols affect clouds & precipitation?

Climatology of Central American Smoke Transport

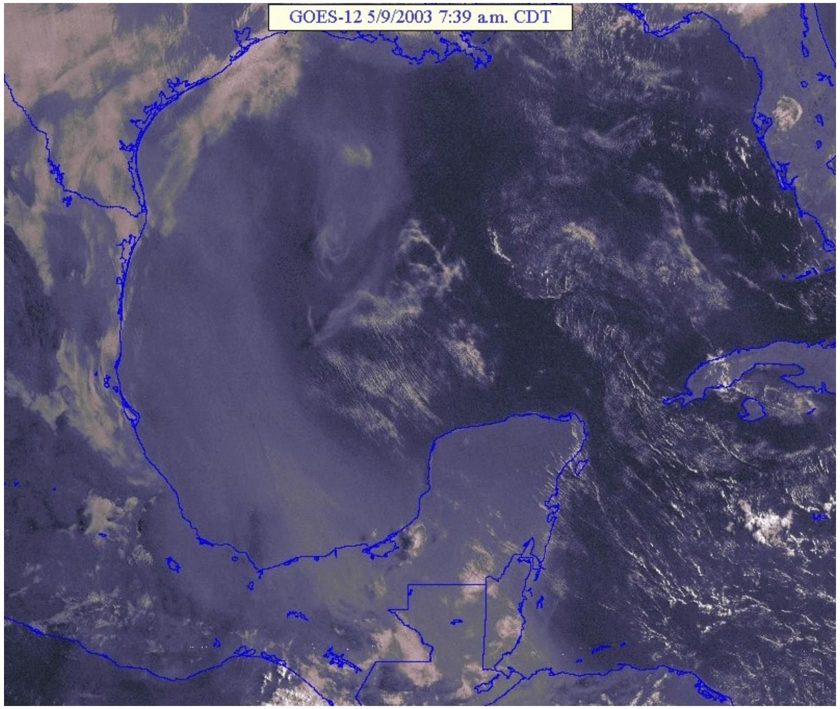


White arrows: 700mb wind

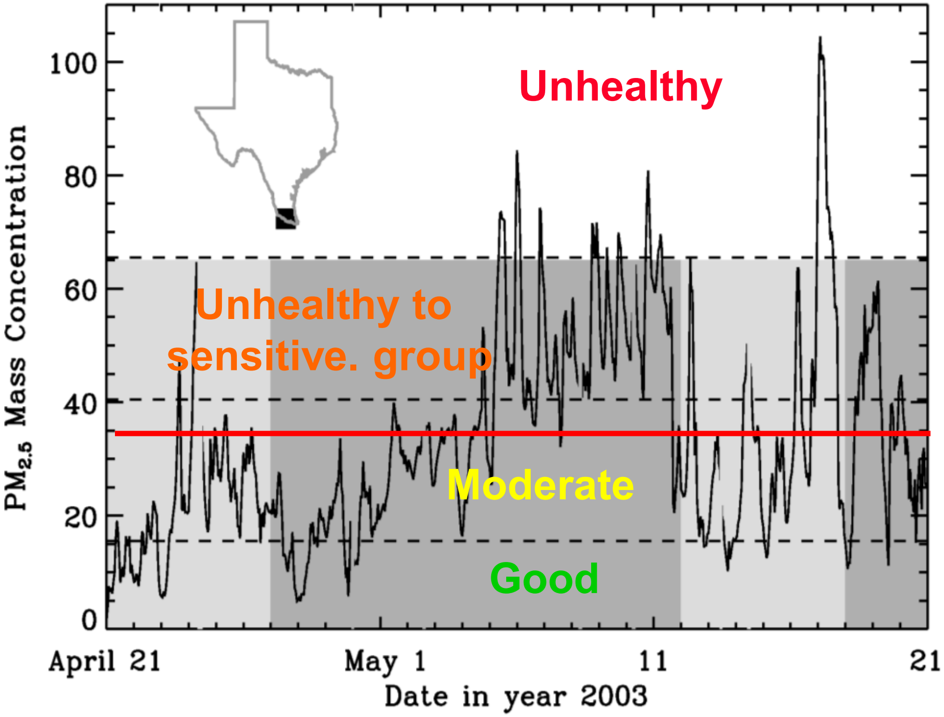
Central American biomass burning in April – May, 2003

Key question:
How does smoke from Central American fires affect the air quality and weather in southern United States?

GOES visible image, May 9, 2003



Hourly $PM_{2.5}$ (μgm^{-3}), Brownsville, TX



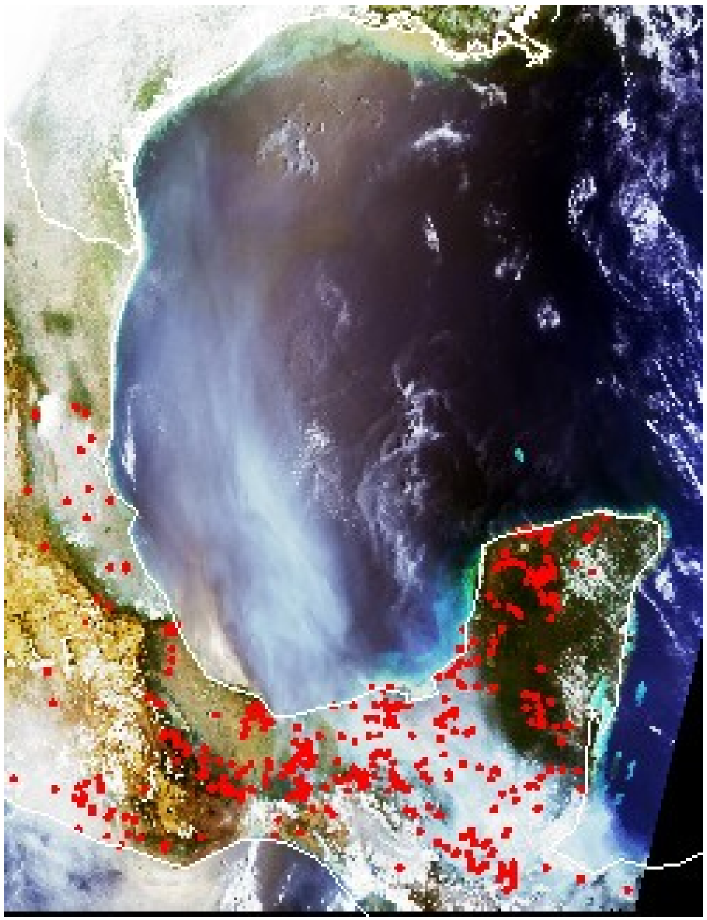
(using EPA 1997 standard)

Smoke transport in May 9 – May 12, 2003

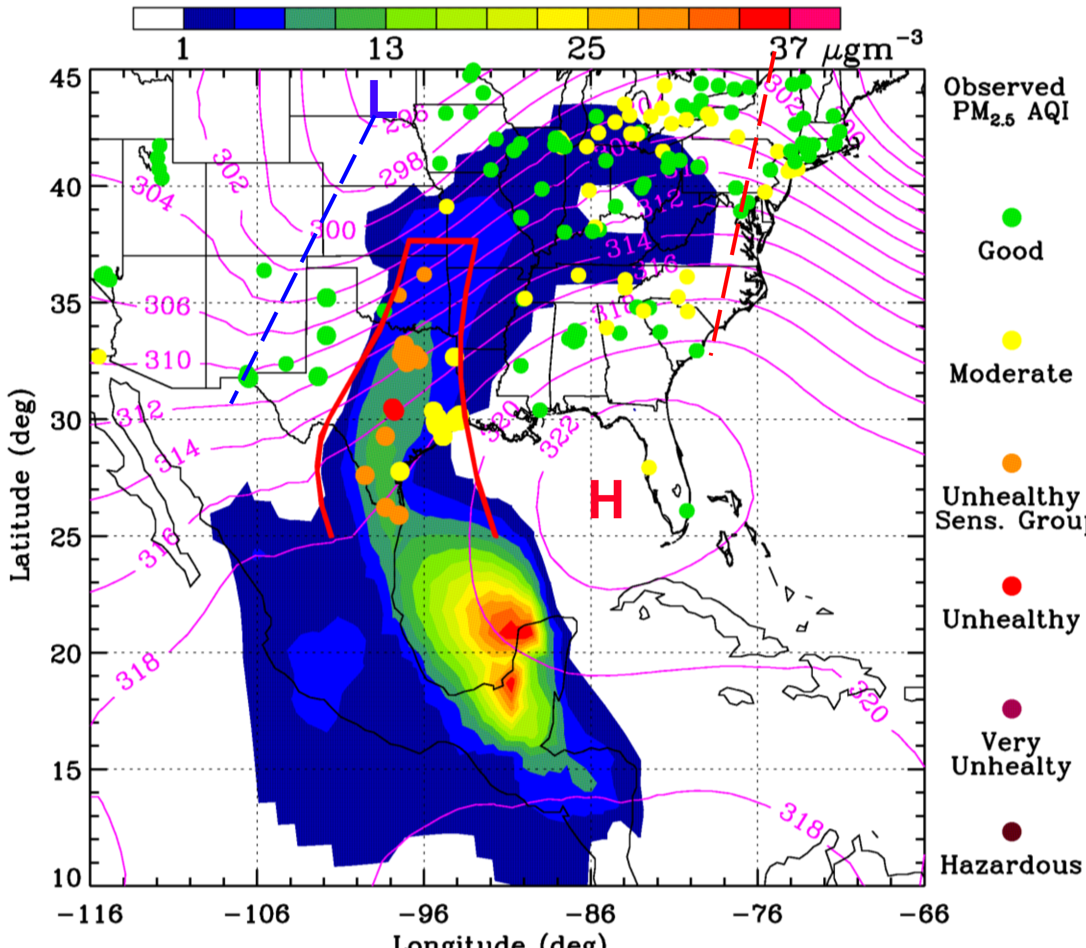
Wang et al., 2006, JGR

12:00 CDT, 10 May 2003

MODIS Observation

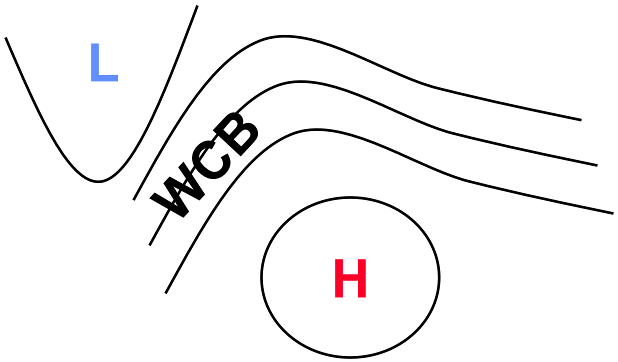


RAMS-AROMA Smoke



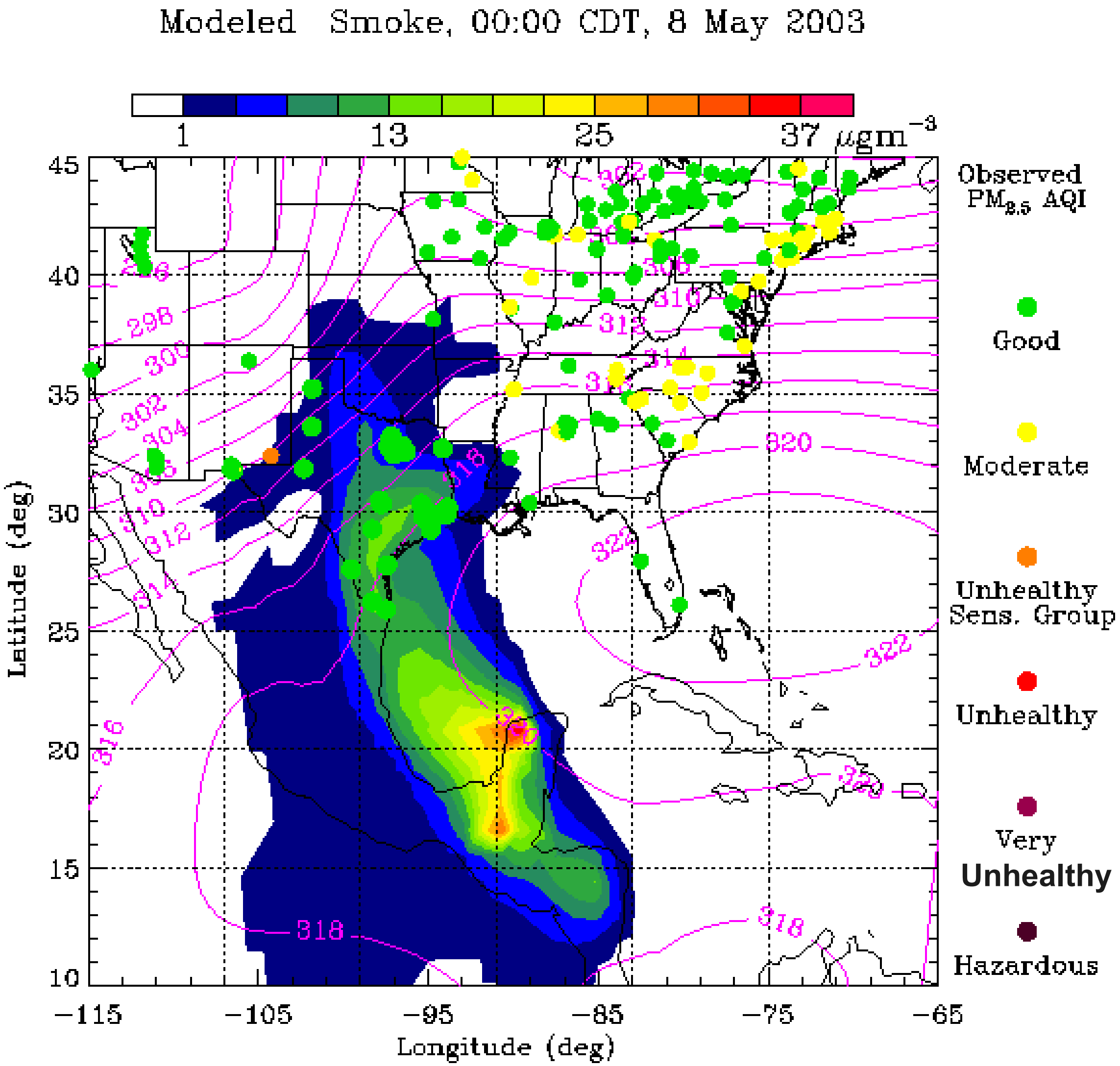
The model uses hourly smoke emission inventory based upon NRL FLAMBE.

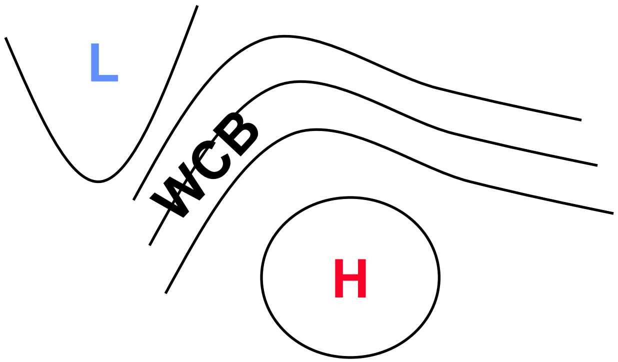
A movie of smoke transport



Warm Conveyor Belt
(WCB)

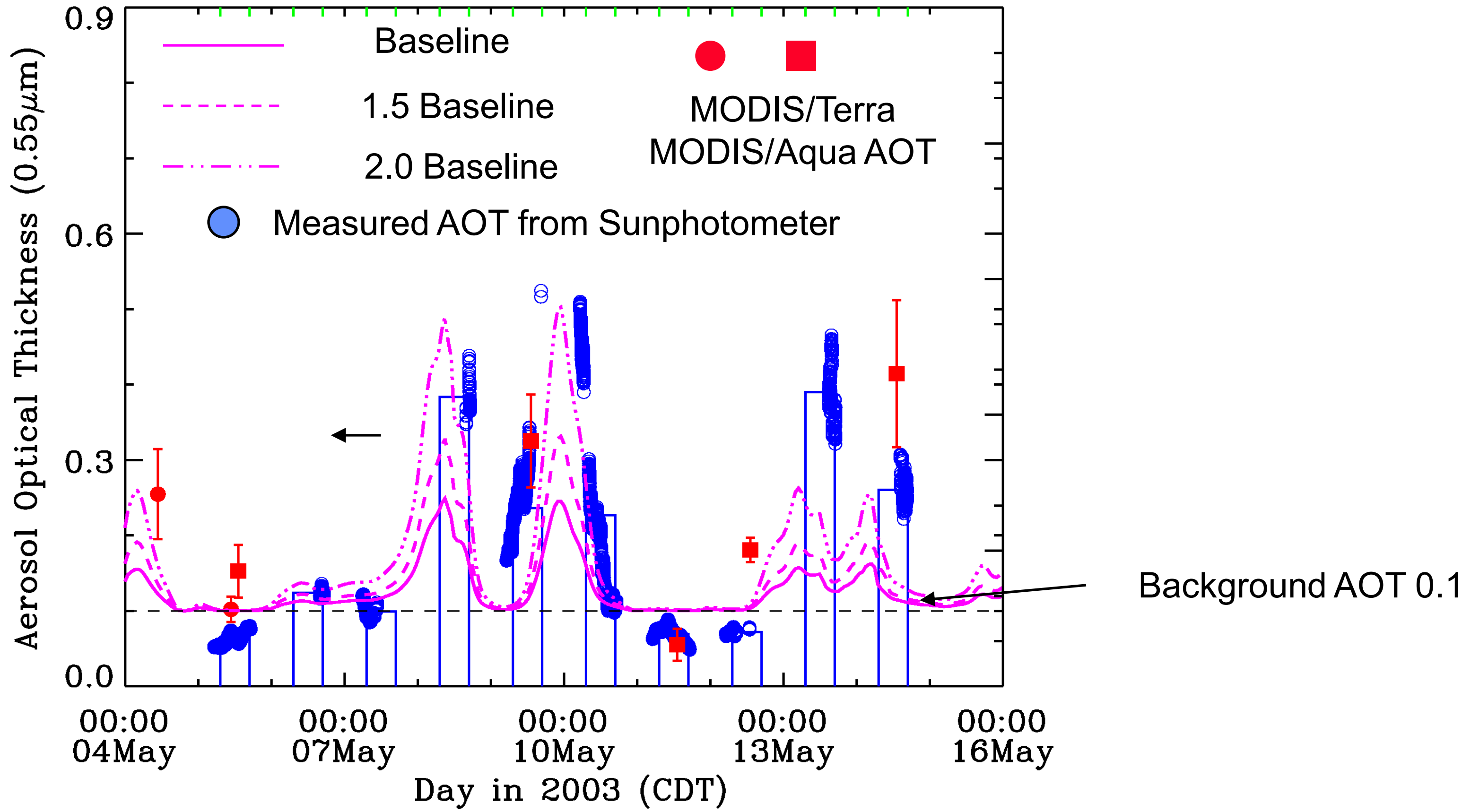
A movie of smoke transport





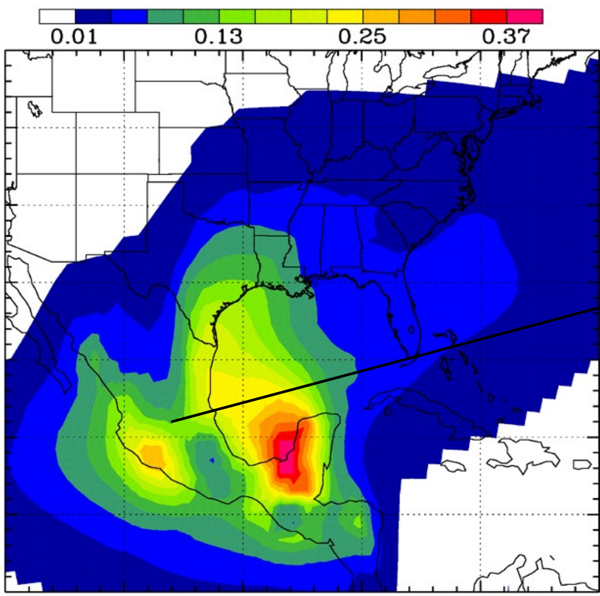
Top-down assessment of smoke emission

Comparison with AOT measured at ARM site in Oklahoma



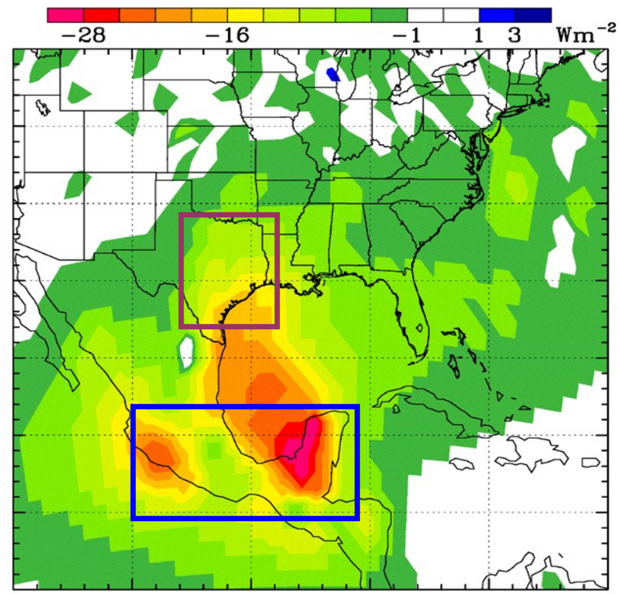
Smoke effect on the surface energy budget and temperature

smoke aerosol optical thickness



Central Plateau of Mexico

Change of downward solar irradiance (DSWI)



Summary of smoke direct radiative effect and feedback (averages over 30 days)

AOT	ΔDSWI (Wm^{-2})	ΔLTH (Wm^{-2})	ΔSEN (Wm^{-2})	ΔPBLH (m)	Δ2mT (°C)	ΔMin2mT (°C)	ΔMax2mT (°C)	ΔDRT (°C)
0.18	-22.5	-6.2	-6.2	-41.0	-0.28	-0.15	-0.46	-0.31
0.10	-15.8	-7.9	-4.7	-17.2	-0.20	-0.05	-0.31	-0.26

Yucatan

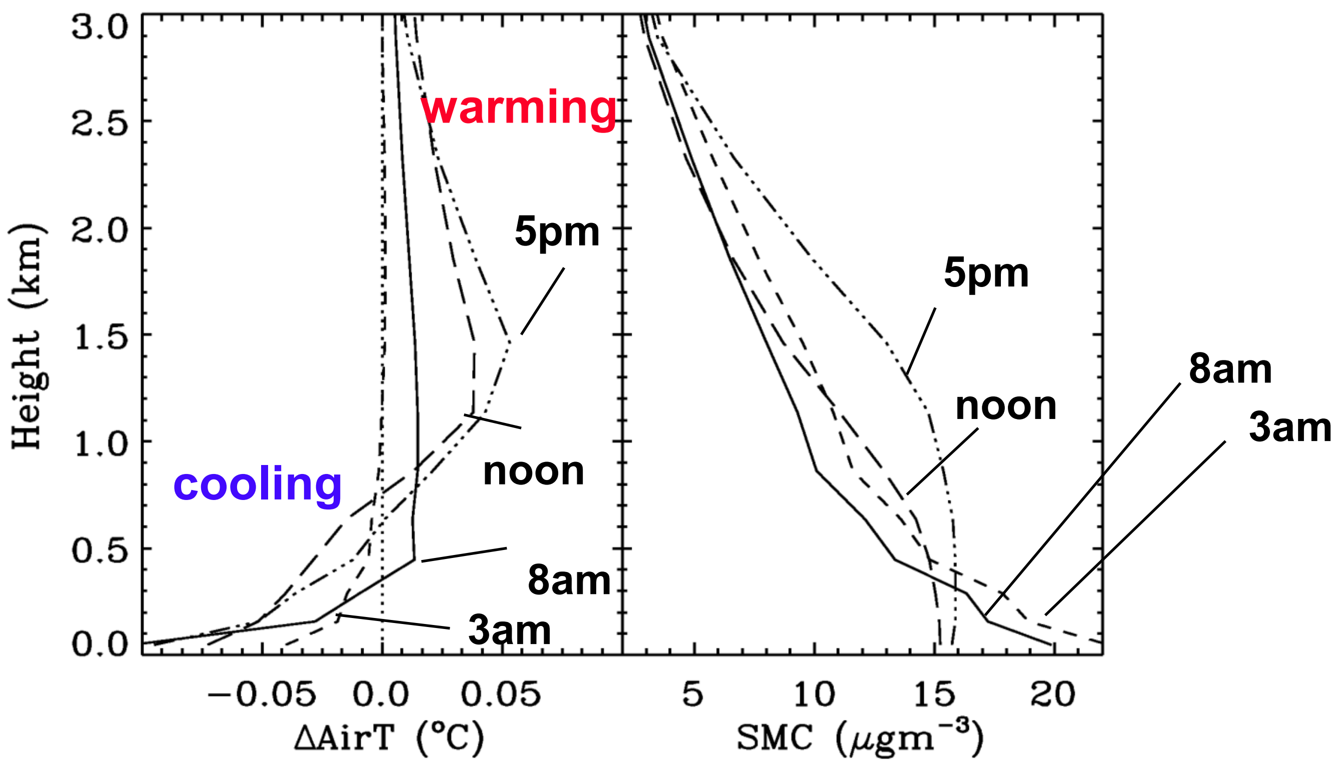
southeastern TX

Wang & Christopher, JGR, 2006

The impact of smoke vertical profile on atmospheric lapse rate

Change of air temperature ΔAirT caused by smoke radiative effect

(averages over 30 days in smoke source region)

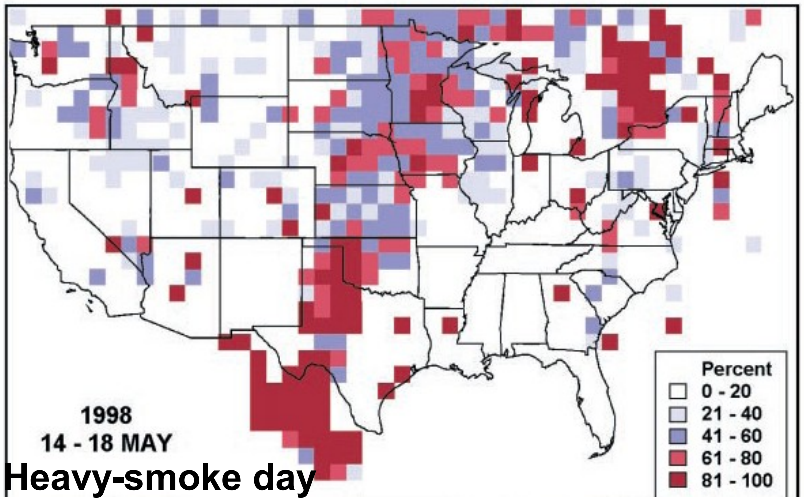


The smoke mass vertical profile and the resultant radiative warming/cooling on the atmospheric lapse rate depends on

(a) diurnal variation of boundary layer process

(b) diurnal variation of smoke emission
(max. in afternoon, smaller in morning, and zero in night)

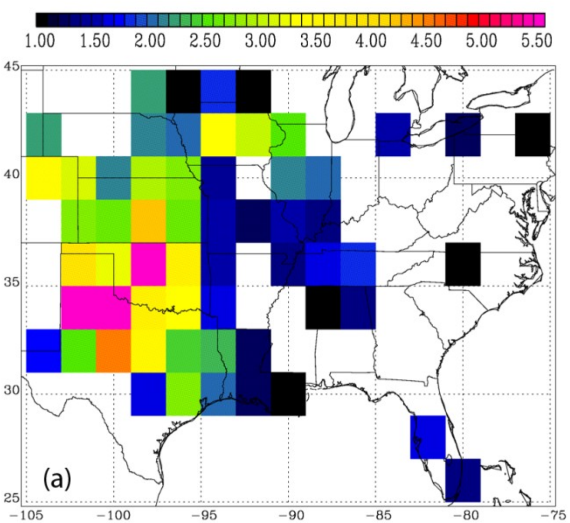
Impact of smoke particles on severe weather in U.S.



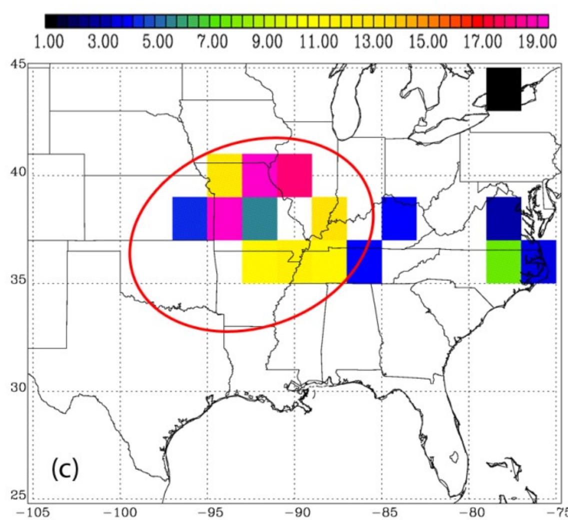
1998: lighting flashes in smoky days are enhanced by 50%. (Lyons et al., Science, 1998)

2003: 'May 2003 … 546 tornadoes, the most reported in any month for the US, exceeding the previous … by 145 …Two outbreaks … on 3–5 May and on 9–11 May, led to 25 F3–F5 tornadoes for the month'. (Levinson & Waple, 2004)

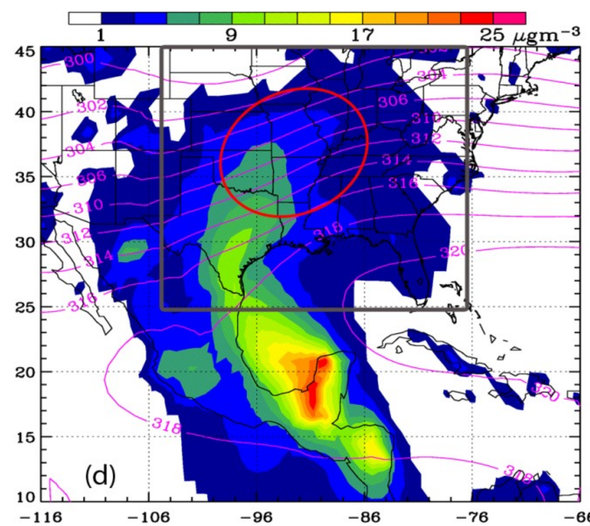
Wang et al., Env. Res. Lett., 2009.



Climatology of tornado # in May



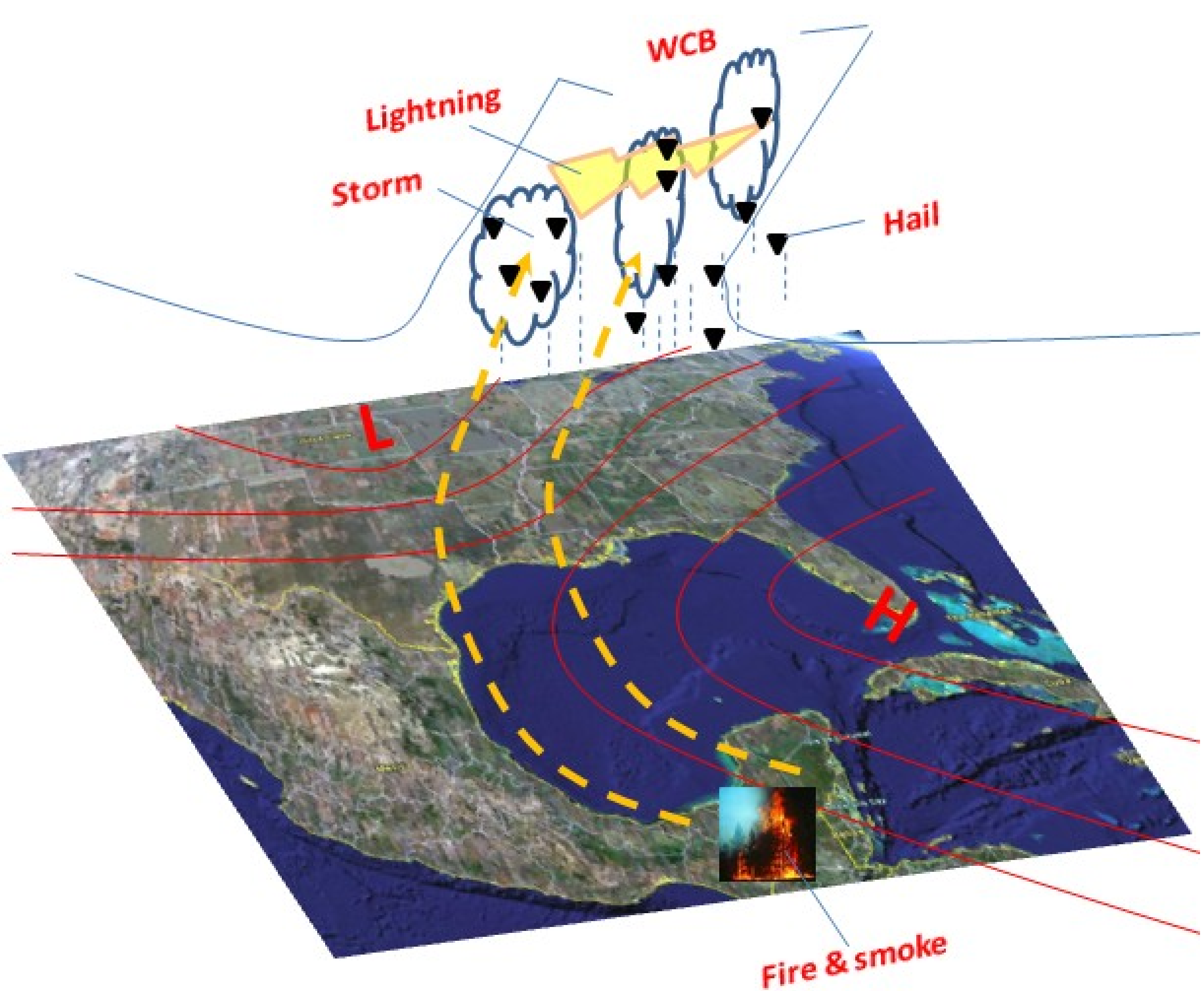
Tornado # anomaly during smoke events in May 2003

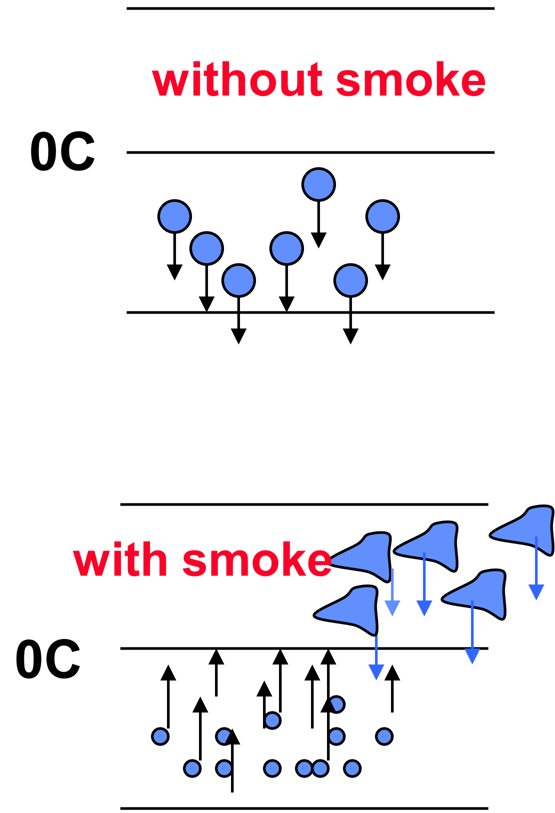


Average surface smoke mass during smoke events in May 2003

Proposed *conceptual* model

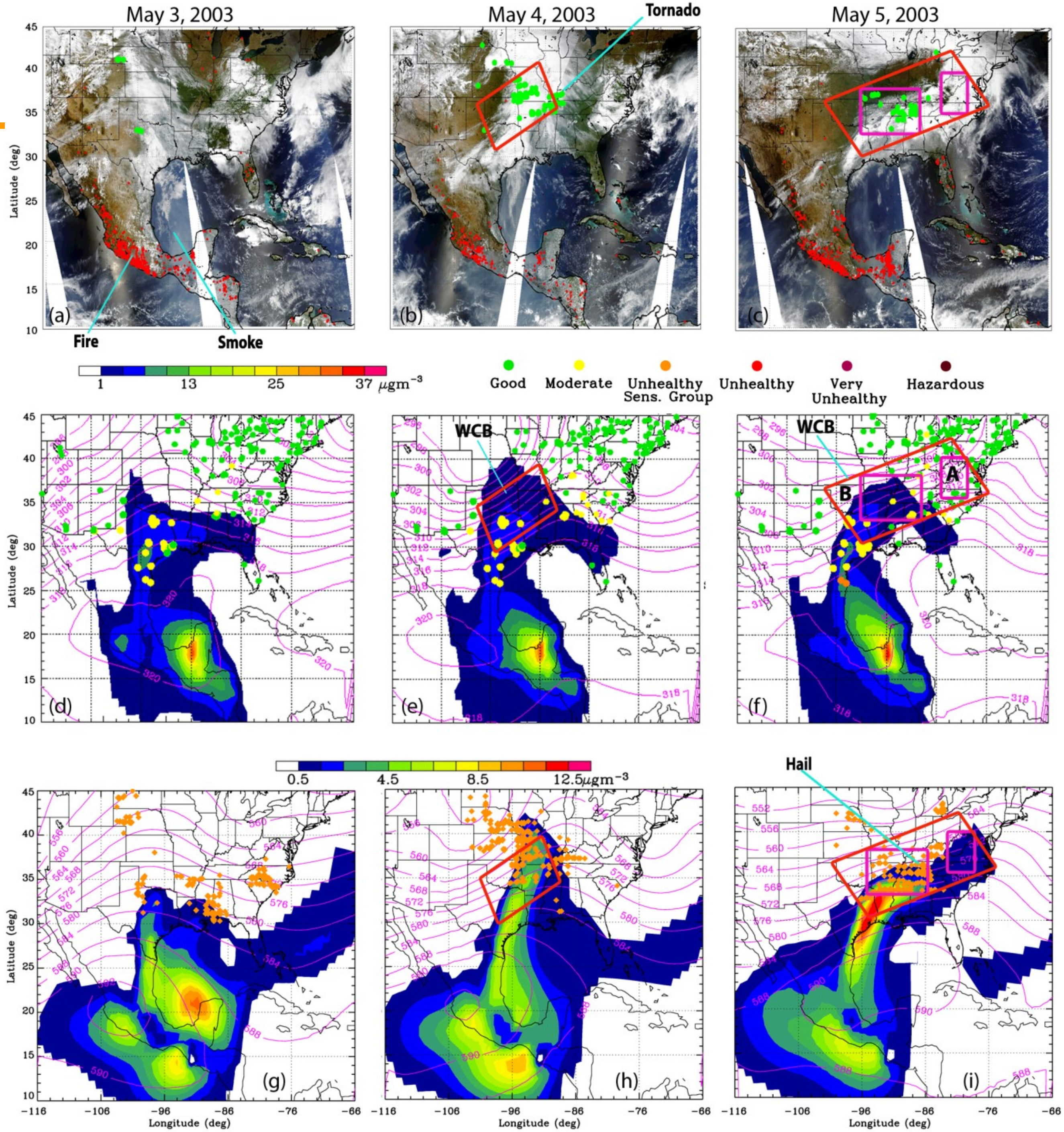
(Wang et al., 2009, Environ. Res. Lett.)





Precipitation process is delayed by the large number of small size rain droplets, which catalyzes the ice cloud formation in favorable dynamical conditions. (Rosenfeld 1999, Andreae *et al 2004 found this in tropical biomass burning regions*)

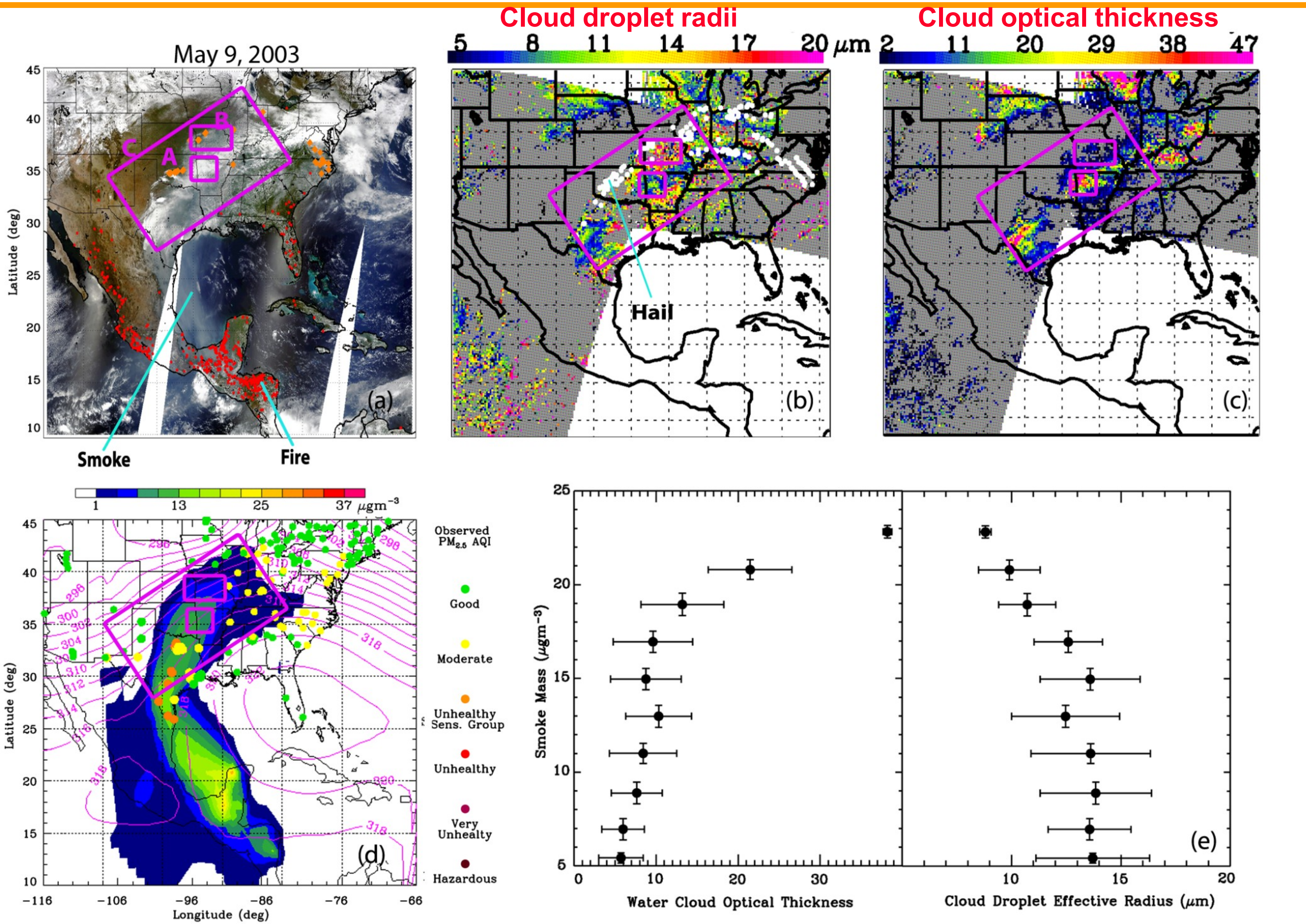
Observational support in May 3-5



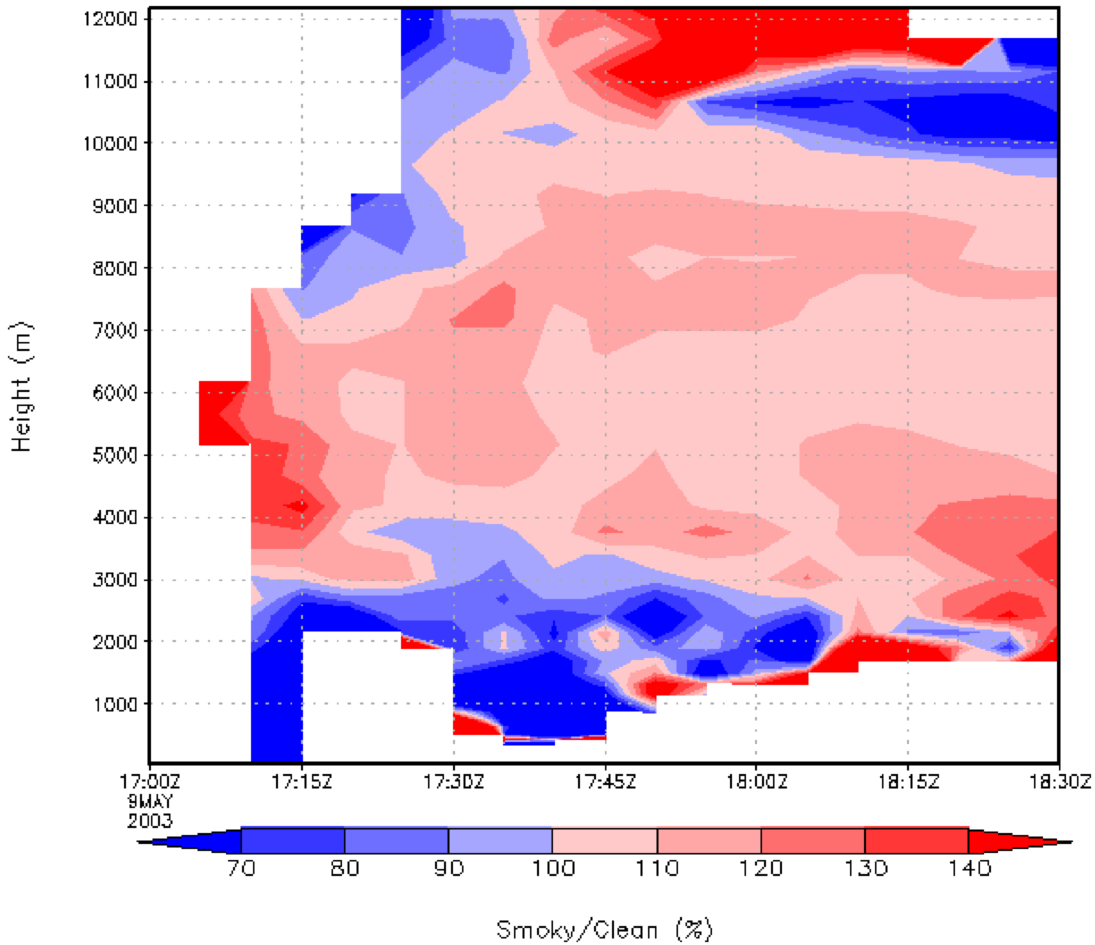
Surface smoke + 700 mb geopotential height

500 mb

Observational support: Smoke & Cloud interaction on May 9, 2003



LES Modeling Support



Contour of Ice Mixing Ratio Between Smoky and Clean Conditions (same meteorology)

Simulation with RAMS LES (S. van den Heever @ CSU)

From Emission Inventory
To Atmospheric Process Studies

1) Analyze the smoke emission inventory uncertainty specific to the transport model
2) Make sense the model outputs -- Use as much observation data (in particular, satellite data) as possible to support the model result and hypothesis
3) For cloud-aerosol interaction studies, model outputs and satellite data have to combine together to give a better picture.
4) The smoke impact on weather and climate depends on the meteorology; so far, the models are the only tool (but not necessarily reliable) tool to do the control experiment.
5) Needs inter-disciplinary collaboration