An analysis of the interactions between biomass burning aerosols and deep convection during the 2011 MC3E campaign

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Outline

- Motivation and objectives
- Discussion of two case studies during MC3E
  - Synoptic pattern of biomass burning smoke transport
  - Multiplatform dataset (ground, satellite, aircraft)
  - Brief discussion of possible AIE due to smoke
- Summary/Future Work
- Questions

Motivation

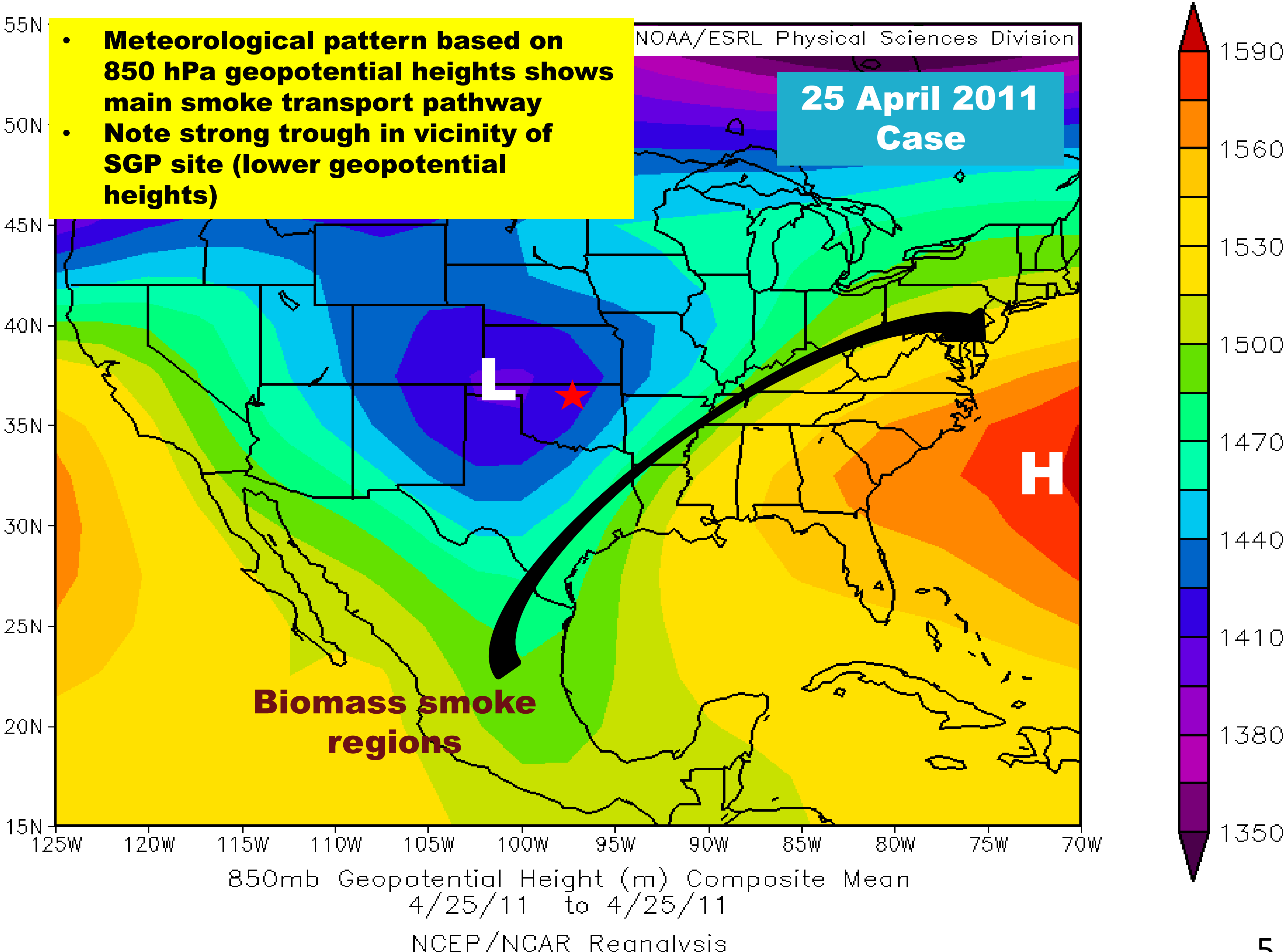
- Peppler et al., 2000
  - ARM SGP Site Observations of the Smoke Pall Associated with the 1998 Central American Fires
    - Paper did not address severe weather
- Wang et al., 2009
  - A conceptual model for the link between Central American biomass burning aerosols and severe weather over the south central United States (SGP Site)
    - Compared 1998 to 2003 wildfire seasons
    - Paper addressed link between biomass smoke from Mexico and severe storms/deep convection
- 2011 MC3E Field campaign
  - Yet another record setting wildfire year
  - Multiplatform analysis of cloud/aerosol microphysical properties and interactions over SGP Site

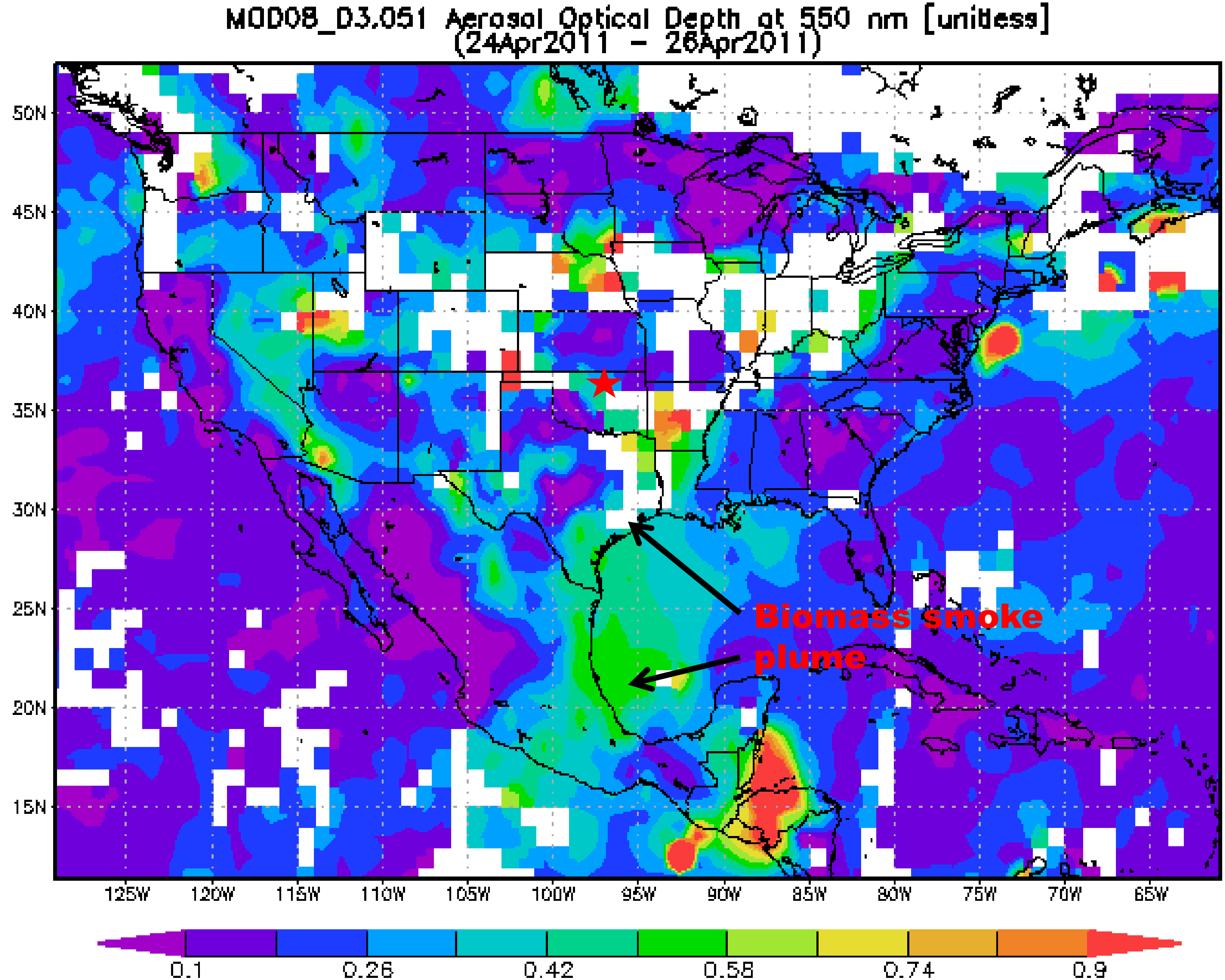
Objectives

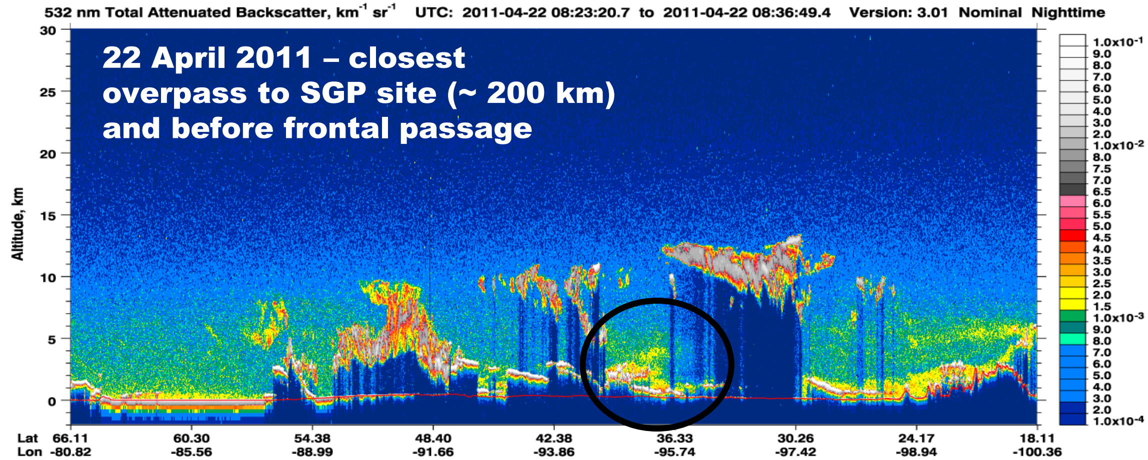
- Currently studying 2 cases
  - 25 April 2011 – Low AOD and deep convection
    - Example of "clean case" – weak aerosol/cloud interaction
  - 23 May 2011 – High AOD and discrete convection
    - Example of "polluted case" – strong aerosol/cloud interaction
- Smoke was in the vicinity of the SGP site in both cases
- Both dates associated with severe outbreaks of tornadoes and hail (e.g. Tuscaloosa and Joplin)
- What role (if any) did the smoke play in the evolution of the convective storm development?

- Meteorological pattern based on 850 hPa geopotential heights shows main smoke transport pathway
- Note strong trough in vicinity of SGP site (lower geopotential heights)

25 April 2011 Case

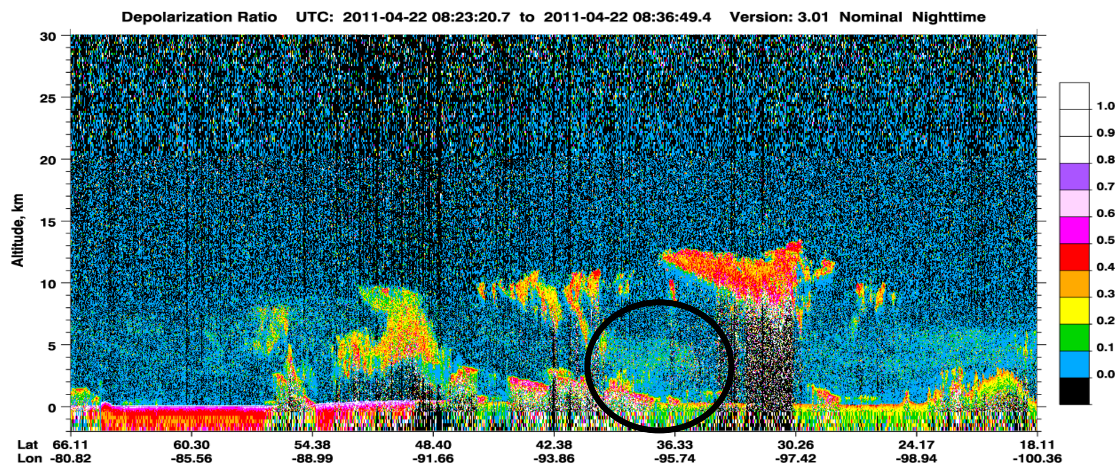



MOD08_D3.051 Aerosol Optical Depth at 550 nm [unitless]
(24Apr2011 - 26Apr2011)
50N
45N
40N
35N
30N
25N
20N
15N
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
65W
Biomass smoke plume
0.1
0.26
0.42
0.58
0.74
0.9

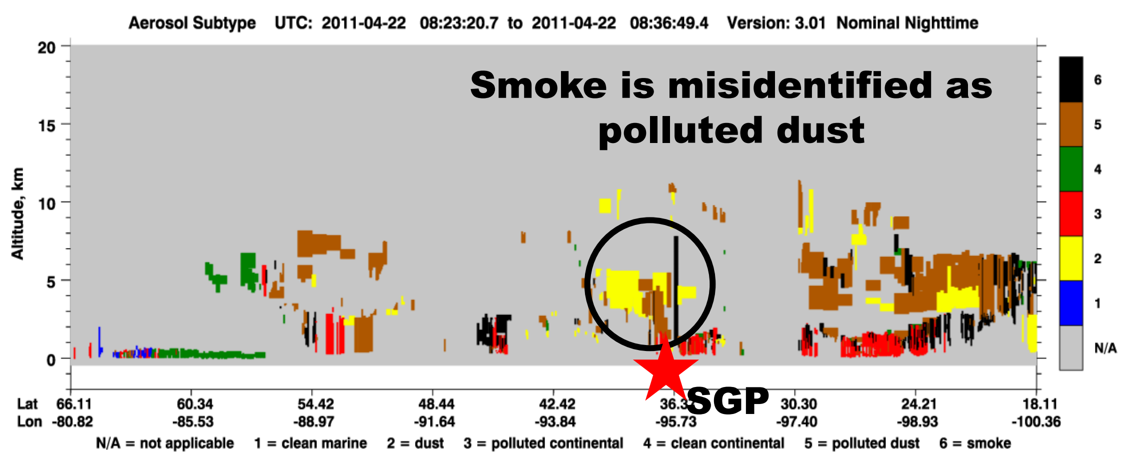


- **Aerosols (yellow and red colors) distinguished from clouds (red and grey colors)**
- **Smoke plume is mainly confined to 5km and below**

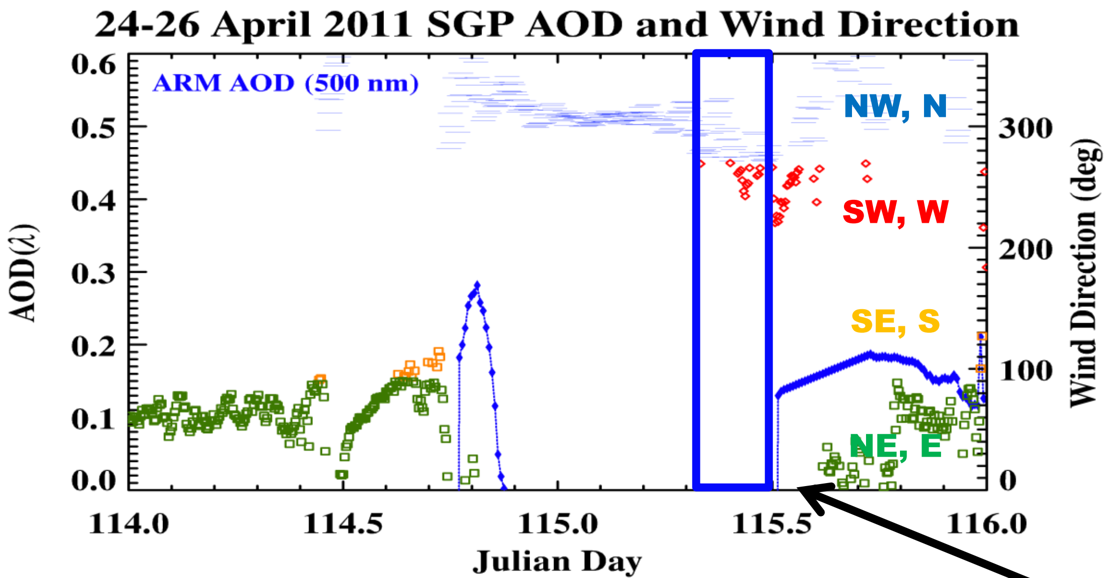
***Note elevated aerosol layer near 5km.**



- **Low depolarization denotes more spherical aged smoke particles**
- **High depolarization is reserved for cloud particles (water/ice)**

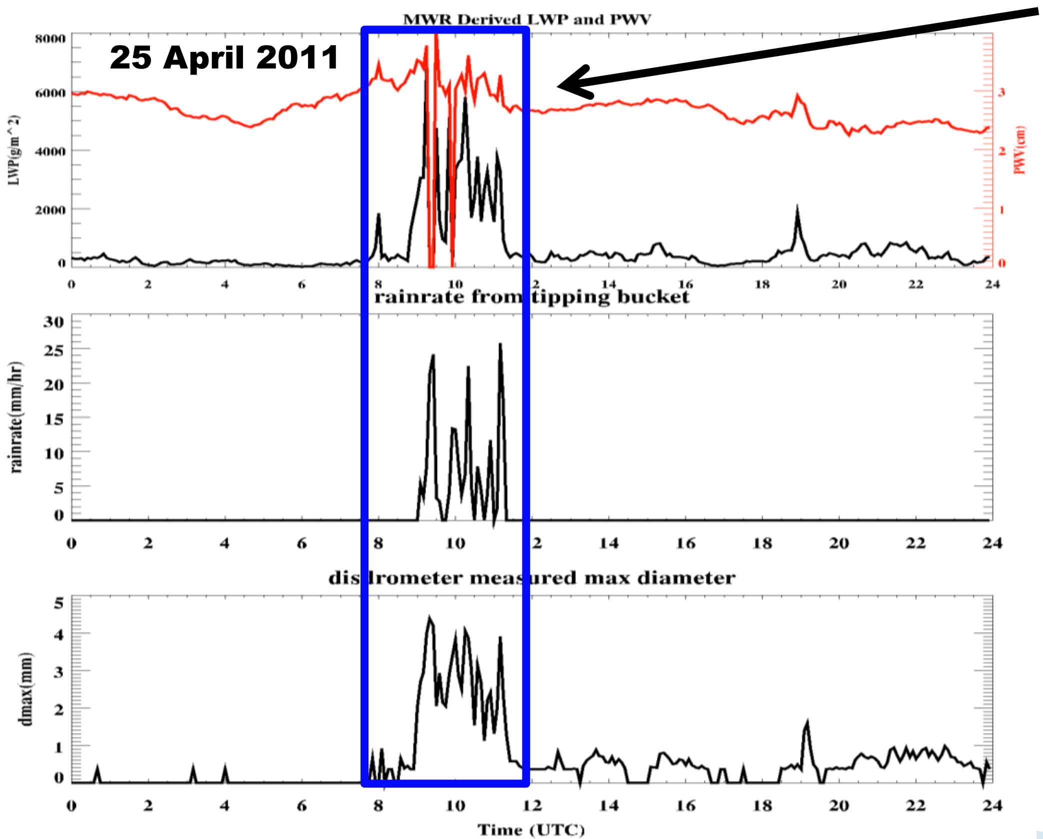


- **VFM tends to misclassify smoke as polluted dust**
- **Likely a result of smoke particle coagulation during transport**



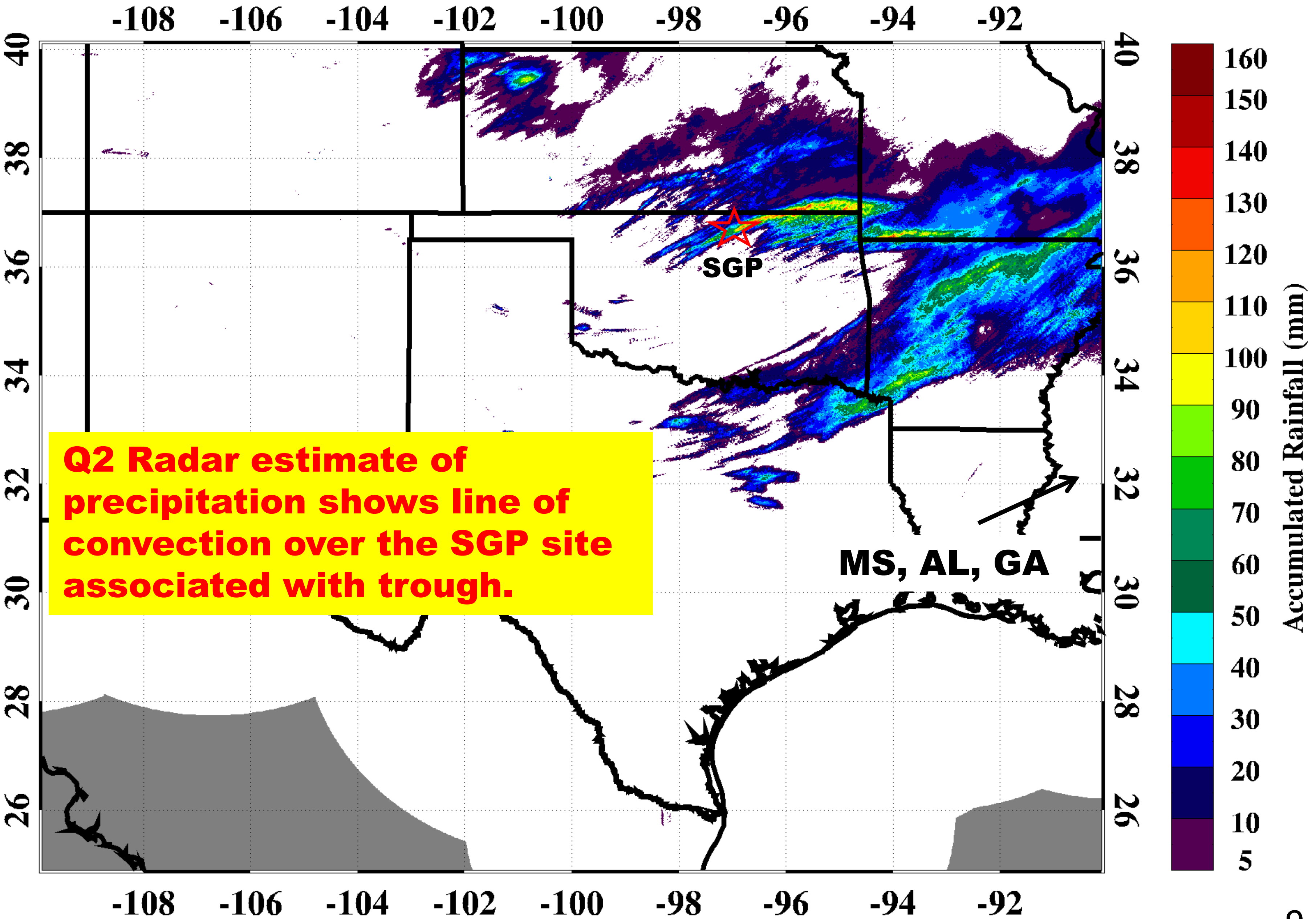
Airflow mainly from the southwesterly to westerly directions especially after the frontal passage; lower smoke aerosol loading

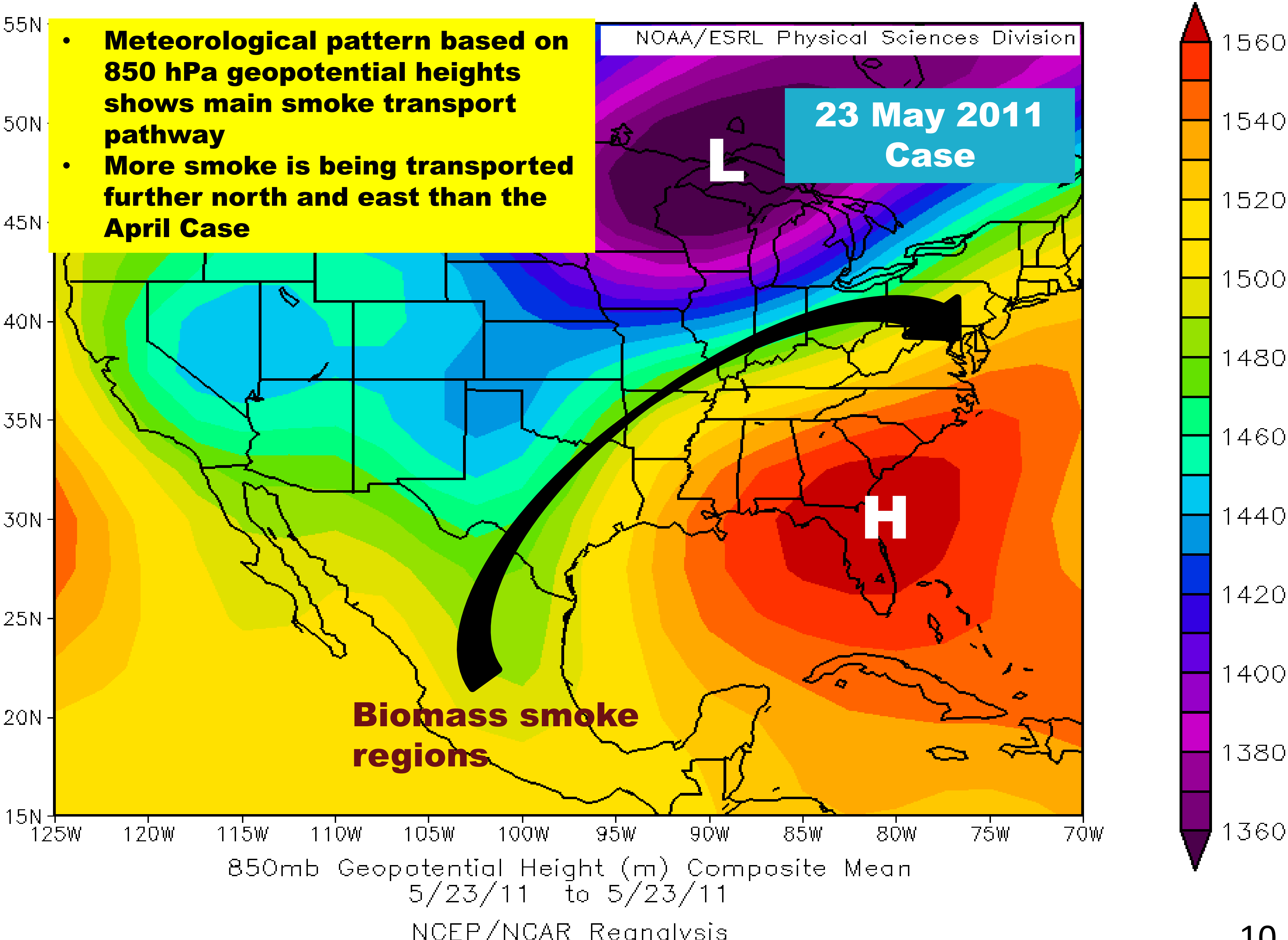
08Z – 12Z



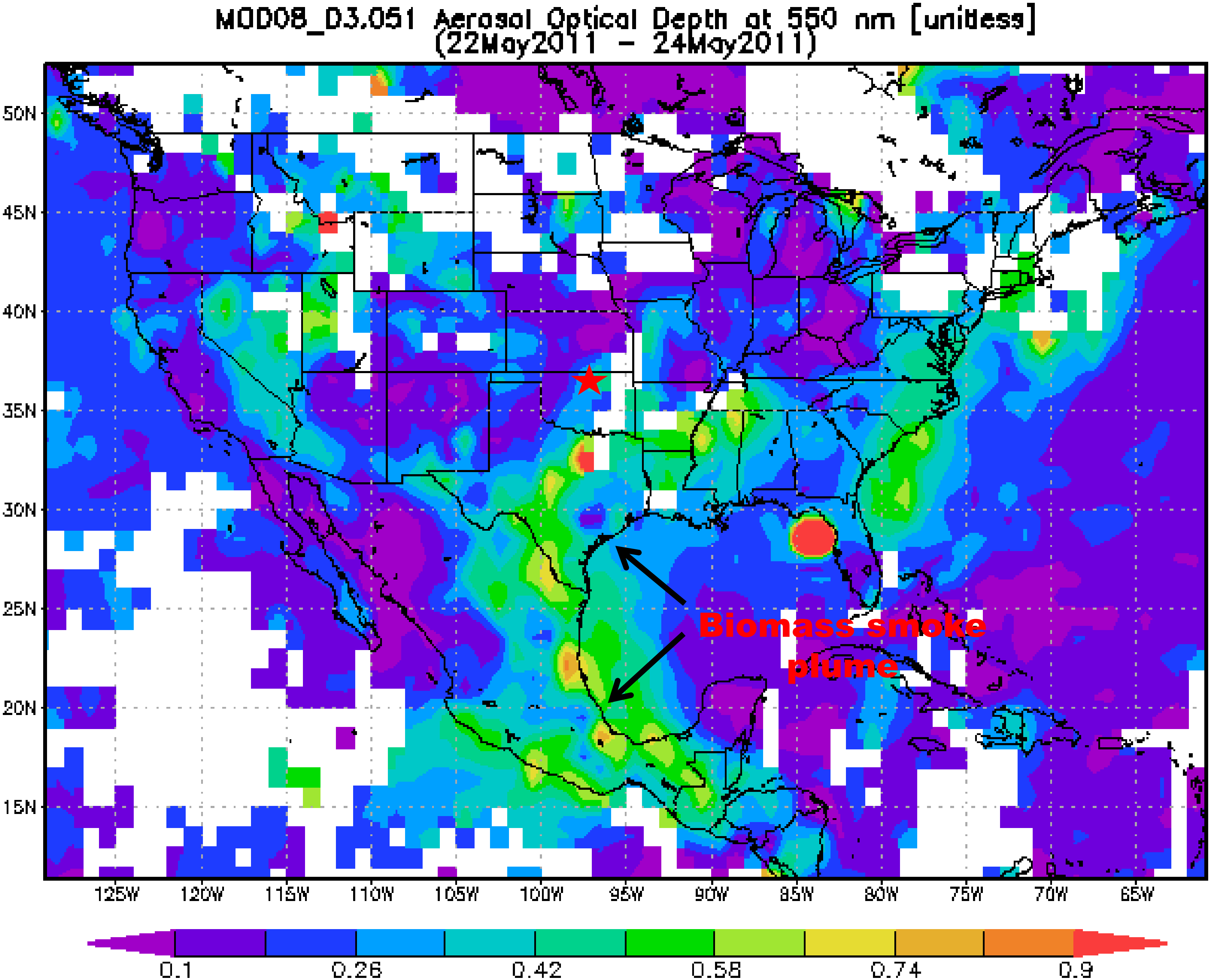
- **LWP is elevated in low AOD case (~6000 g m^{-2}) and PWV is nearly 4 cm**
- **Rain rate of nearly an inch per hour (25 mm hr^{-1}) indicates strong convection**
- **Large raindrops indicate deep convection**

Q2 Estimate 07-14UTC April 25, 2011





• Meteorological pattern based on 850 hPa geopotential heights shows main smoke transport pathway
• More smoke is being transported further north and east than the April Case
NOAA/ESRL Physical Sciences Division
23 May 2011 Case
L
H
Biomass smoke regions
55N
50N
45N
40N
35N
30N
25N
20N
15N
125W 120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W
1560
1540
1520
1500
1480
1460
1440
1420
1400
1380
1360
850mb Geopotential Height (m) Composite Mean
5/23/11 to 5/23/11
NCEP/NCAR Reanalysis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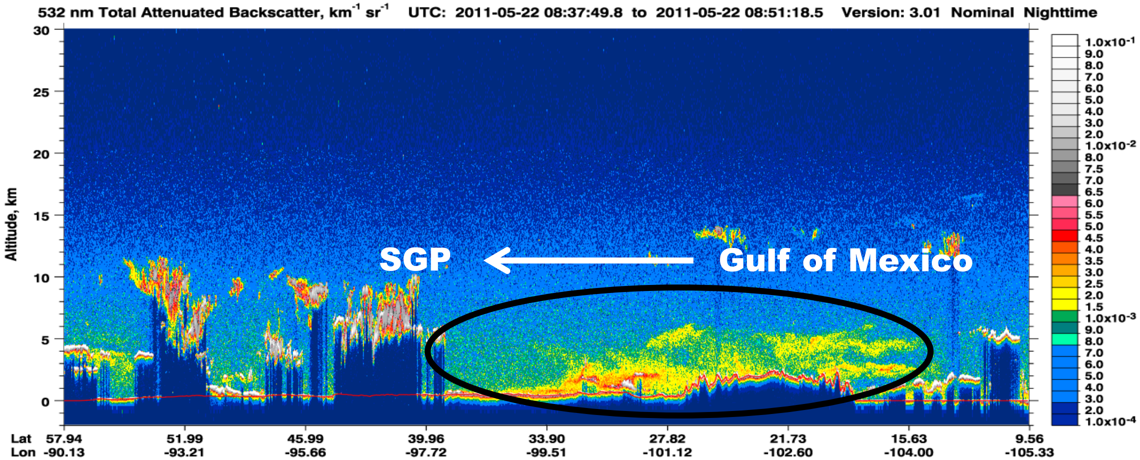
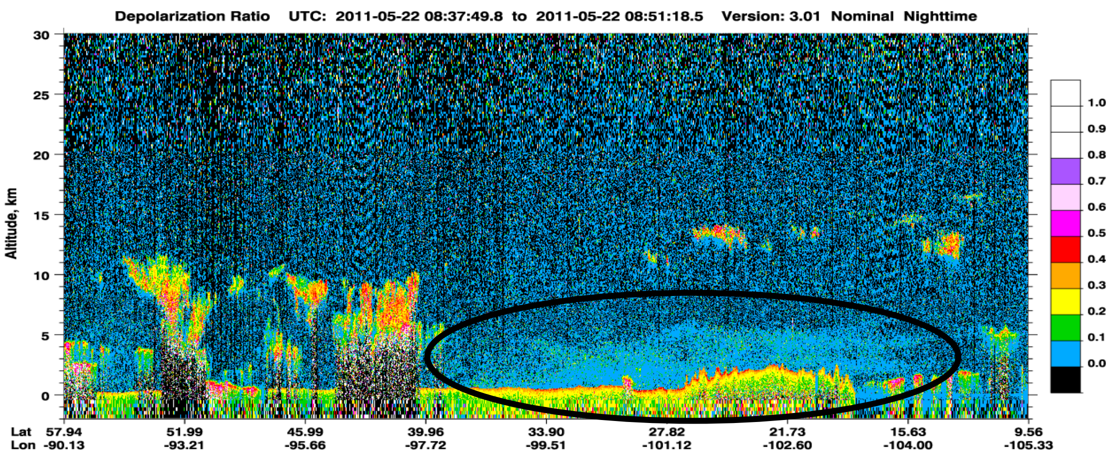
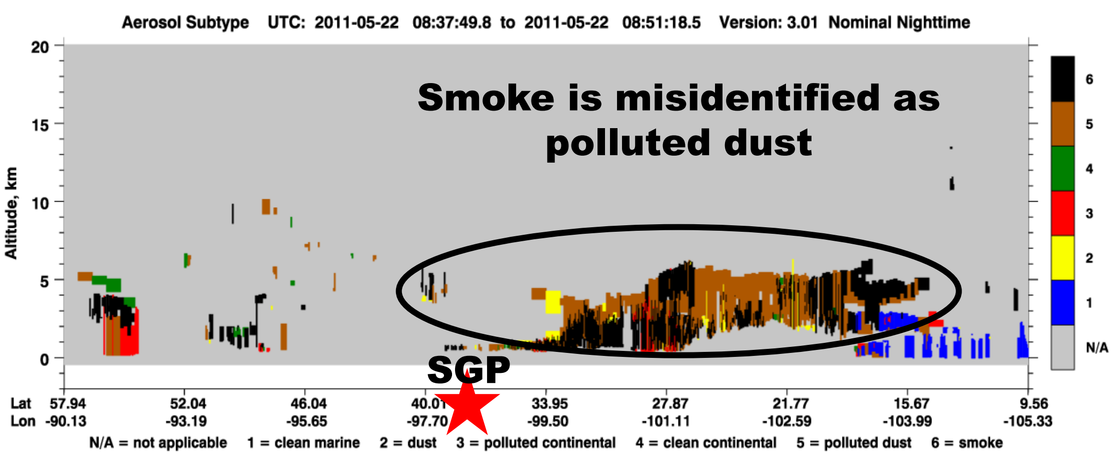


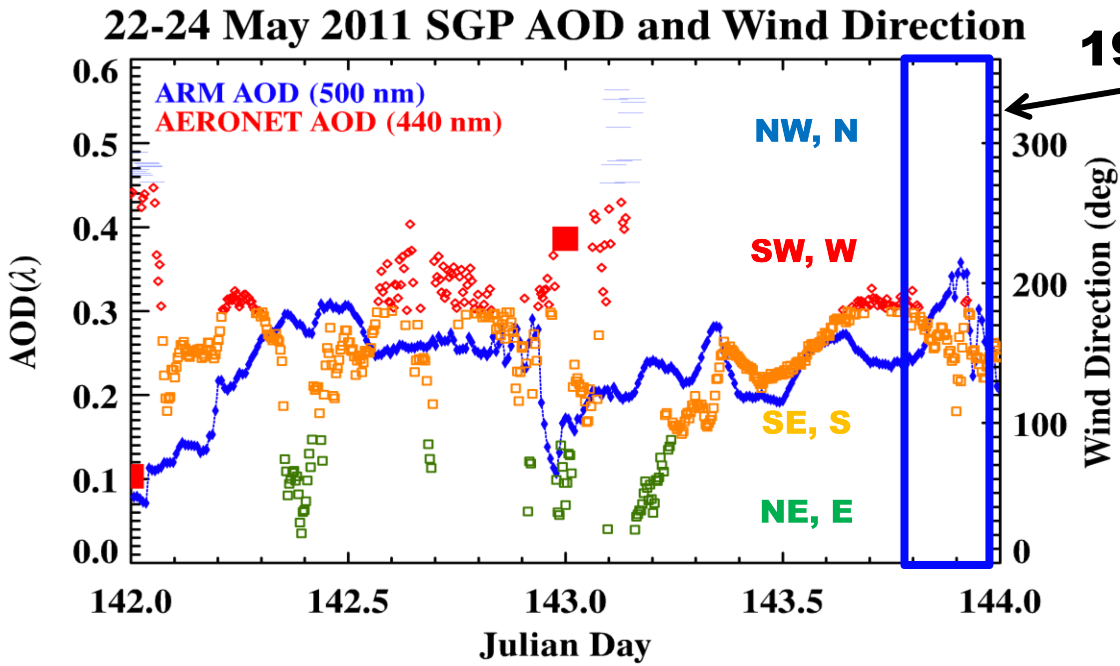
- **CALIPSO overpass follows entire swath of smoke from source region to SGP site**
- **Elevated layer of smoke (Mexico) with possible local contributions along the path**



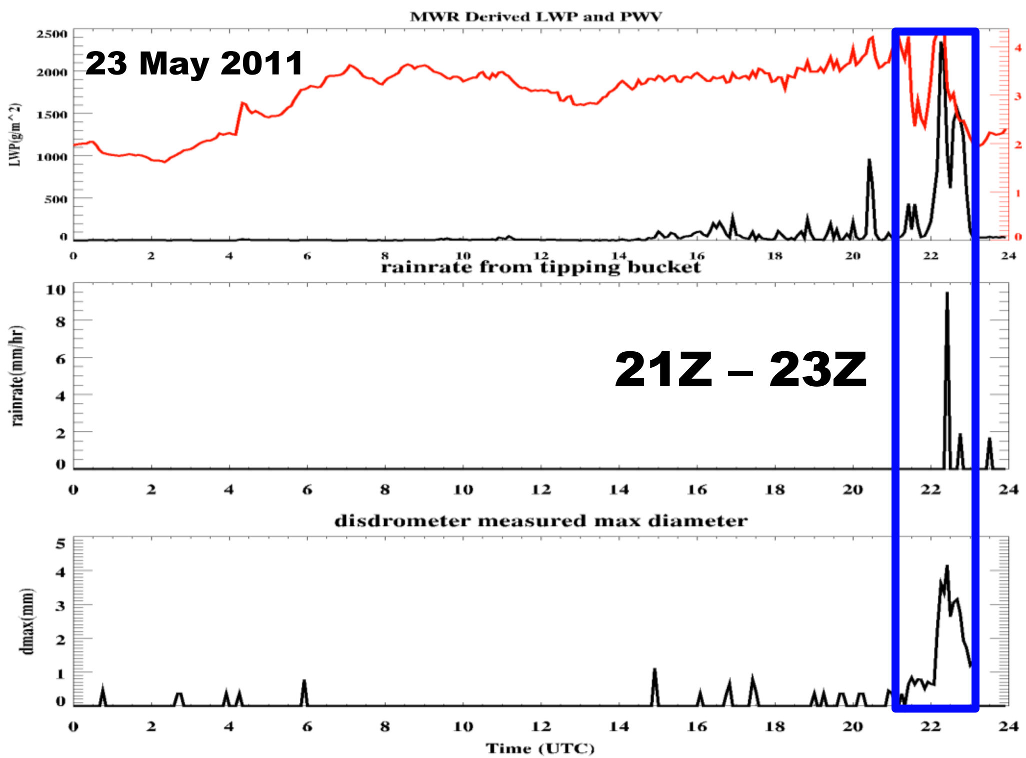
- **Smoke aerosols are more extensive in this case**
- **Later in the fire season**



- **VFM does a little better at classification but still mostly “polluted dust” and smoke**



- **Airflow mainly from southerly direction (Mexico)**
- **Increase in AOD denotes more smoke in the SGP vicinity**
- **Peak occurs around 2130Z**

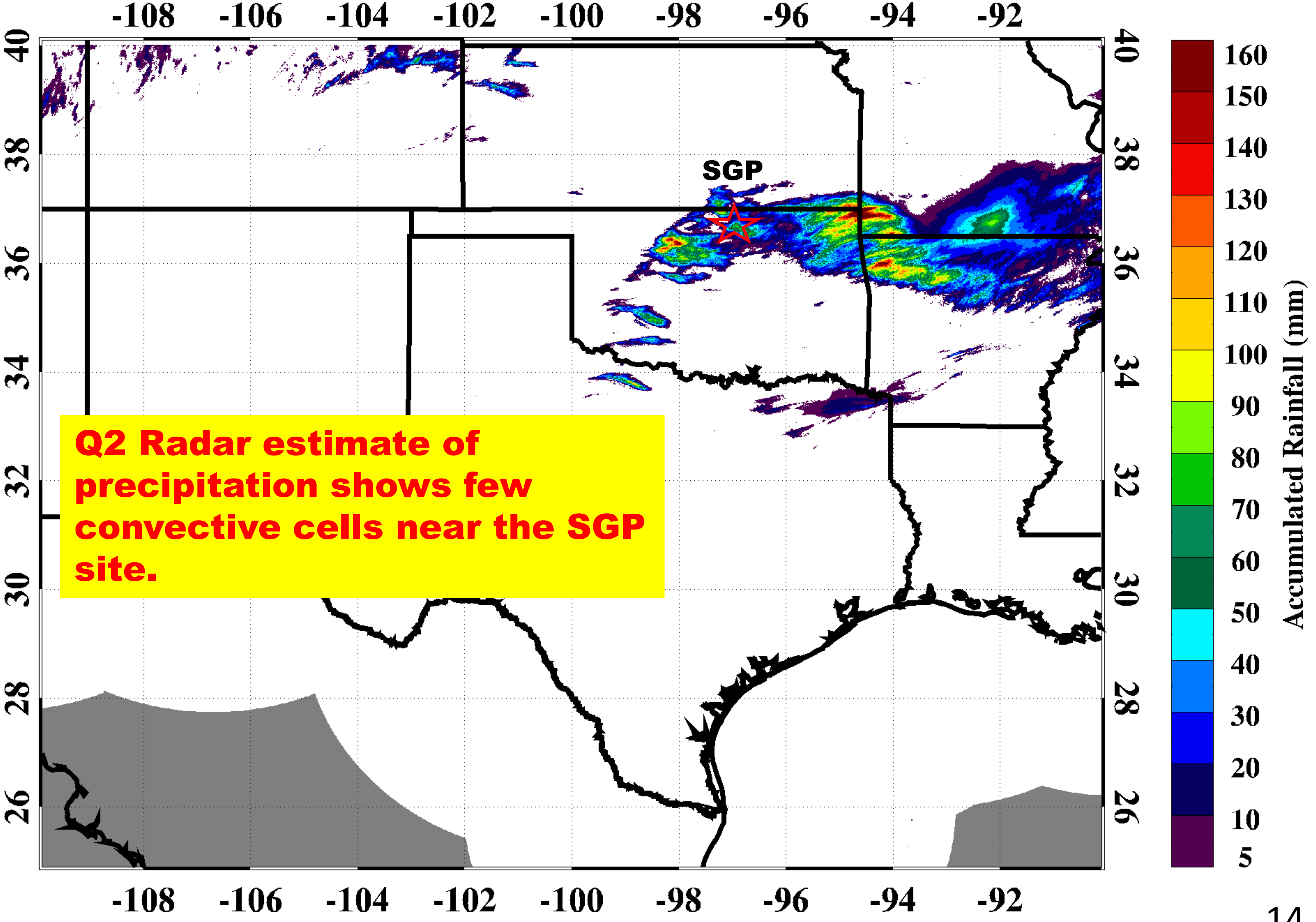


- **LWP is lower in high AOD case (~2200 g m^{-2}); PWV just over 4 cm**
- **Possible competition between aerosols and CCN for water vapor**

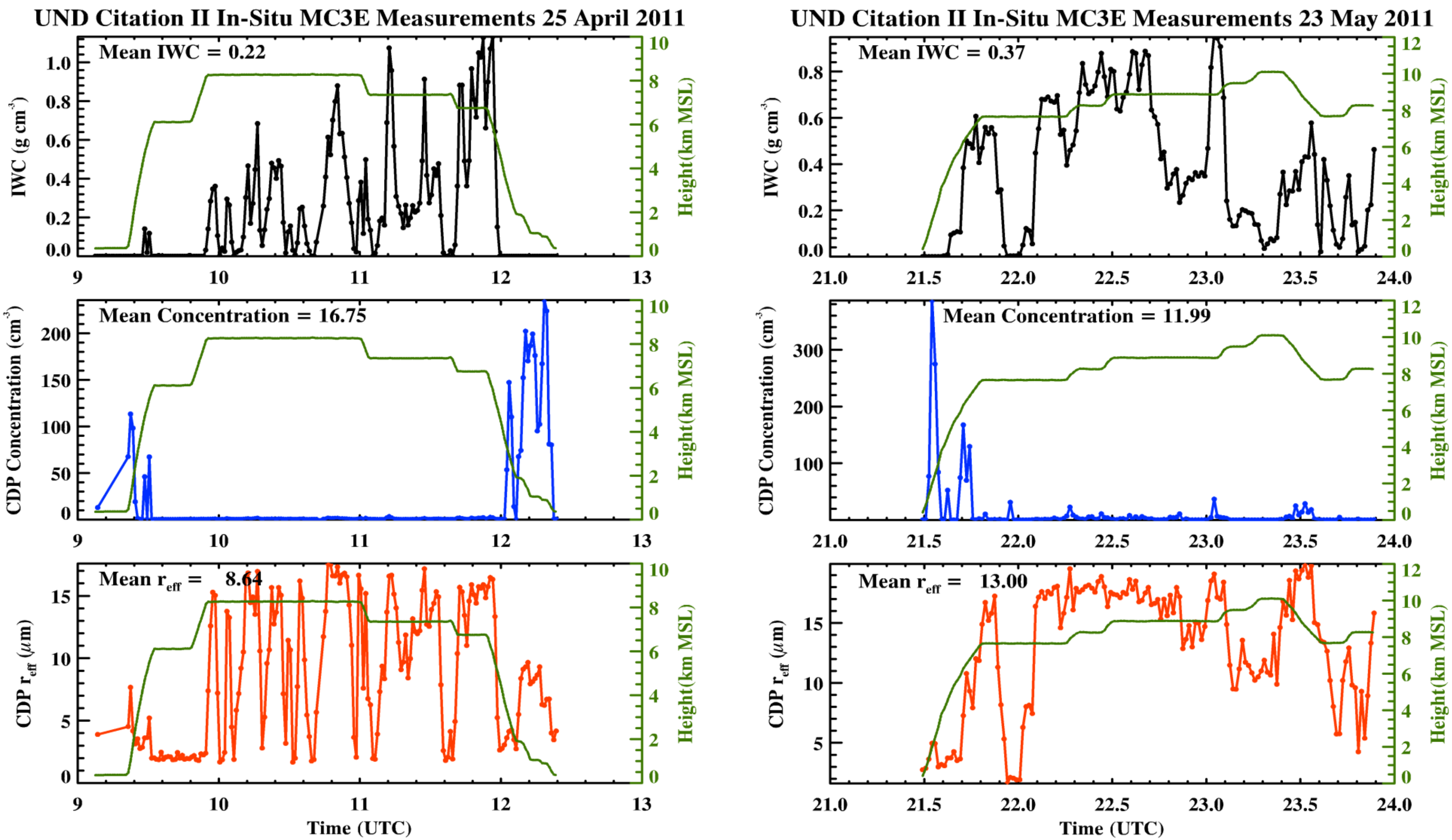
- **Rain rate of nearly half inch per hour (10 mm hr^{-1}) indicates weak or spotty convection**

- **Drops are smaller here than in Case I**
- **At peak rainfall event as well as overall average**

Q2 Estimate 19UTC May 23 through 01UTC May 24, 2011



Q2 Radar estimate of precipitation shows few convective cells near the SGP site.



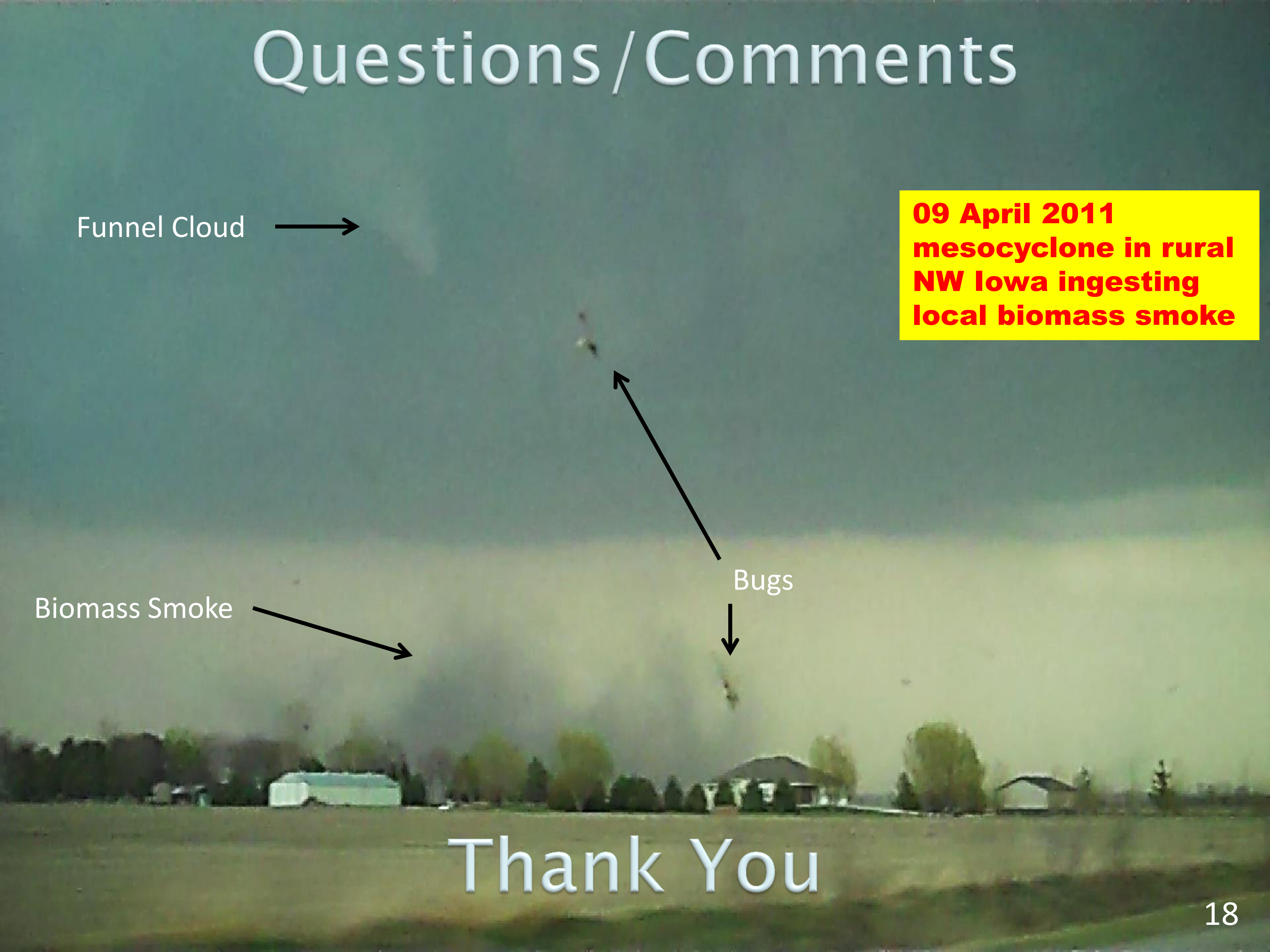
- **Peaks in IWC correspond to strong updraft regions where the UND Citation II flew over convective cores**
- **Number concentration is enhanced in 23 May case in the 0-4km level (near LCL) likely due to more aerosol loading (smoke)**
- **Effective radii larger in 23 May case due to more contribution from the cold rain process**

Summary and Future Work

- Dynamic forcing a major factor in the 25 April 2011 Case
  - However, smoke was clearly seen being transported to the Gulf Coast states at the time of the Tuscaloosa outbreak
- Smoke may have played a role in the evolution of storms in the 23 May 2011 Case
  - Decreased LWP due to aerosol/CCN competition
  - Delay of warm rain process and aerosol invigoration
- Will continue to analyze more cases during MC3E
  - 4-6 September 2012 severe weather outbreak

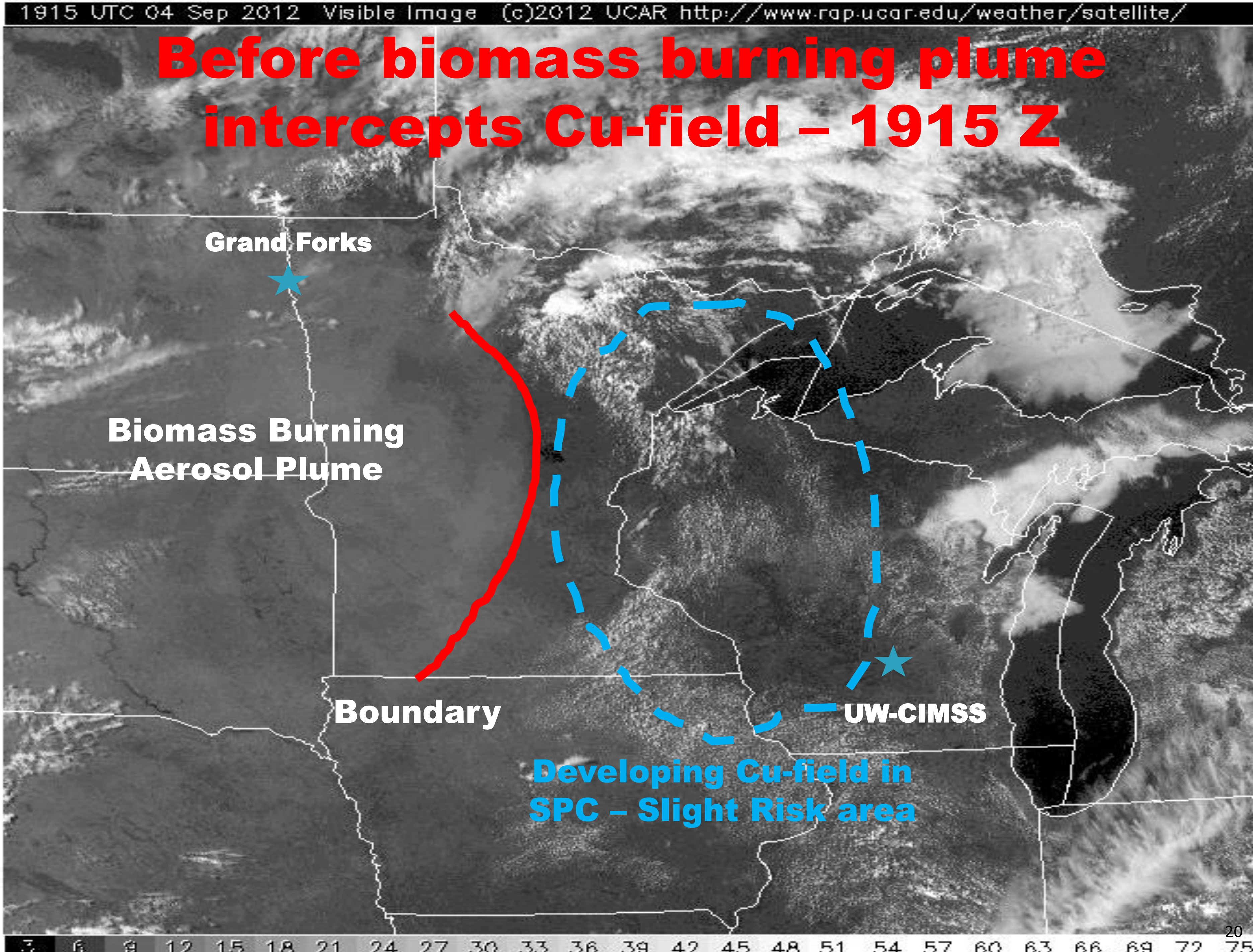
Acknowledgements

- ARM SGP Site Data
- AERONET Data – P.I. Brent Holben and staff
- CALIPSO Products – NASA Langley
- NCEP/NCAR Re-analysis – meteorological plots provided by NOAA-ESRL
  - http://www.esrl.noaa.gov/psd/data/composites/day/
- Analyses and visualizations used in this presentation were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC
- Research funded by NASA EPSCoR CAN and NASA CERES

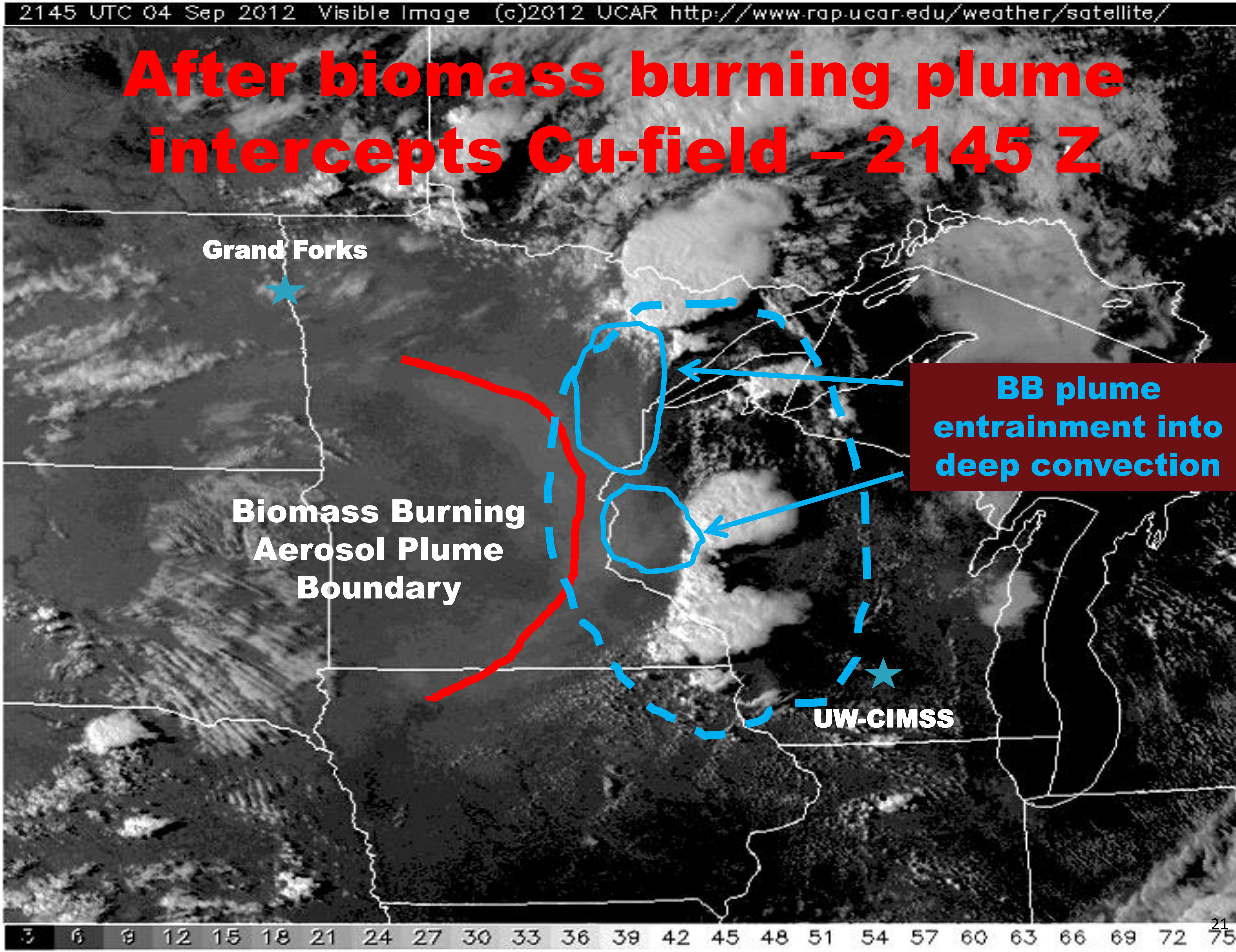

Questions/Comments
Funnel Cloud
09 April 2011 mesocyclone in rural NW Iowa ingesting local biomass smoke
Bugs
Biomass Smoke
Thank You

Extra Slides

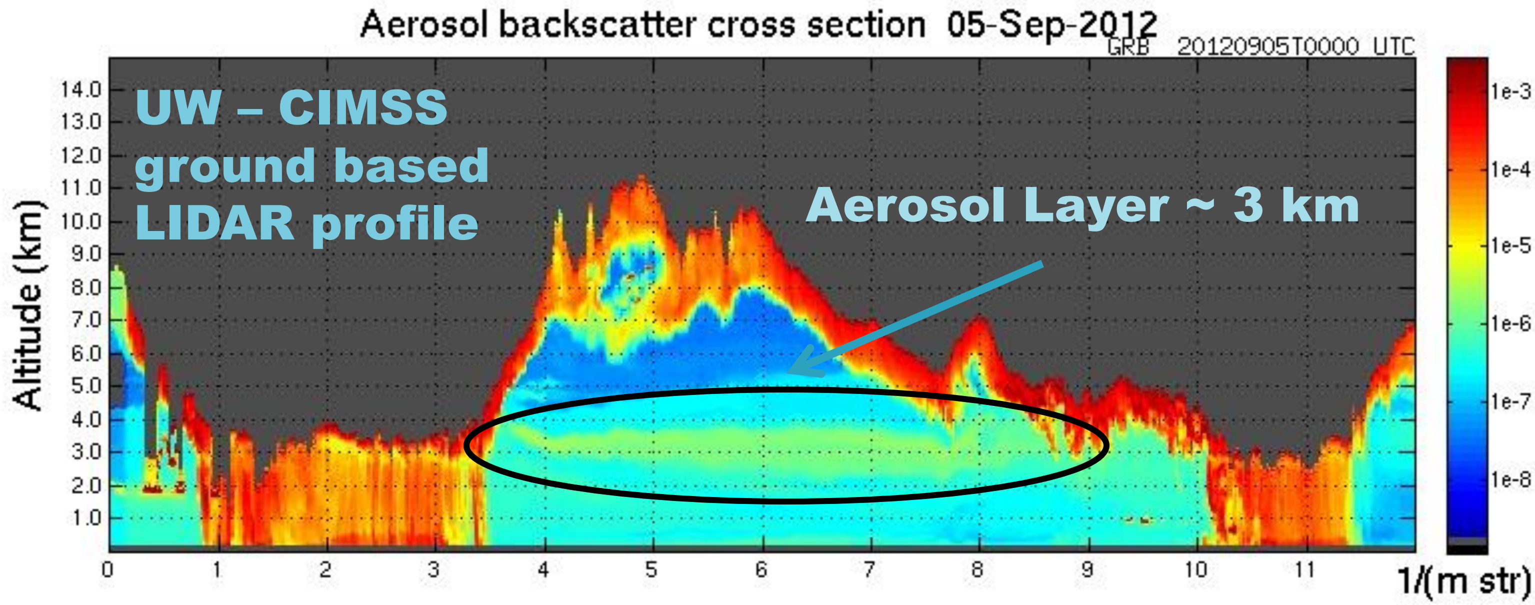
Before biomass burning plume intercepts Cu-field – 1915 Z

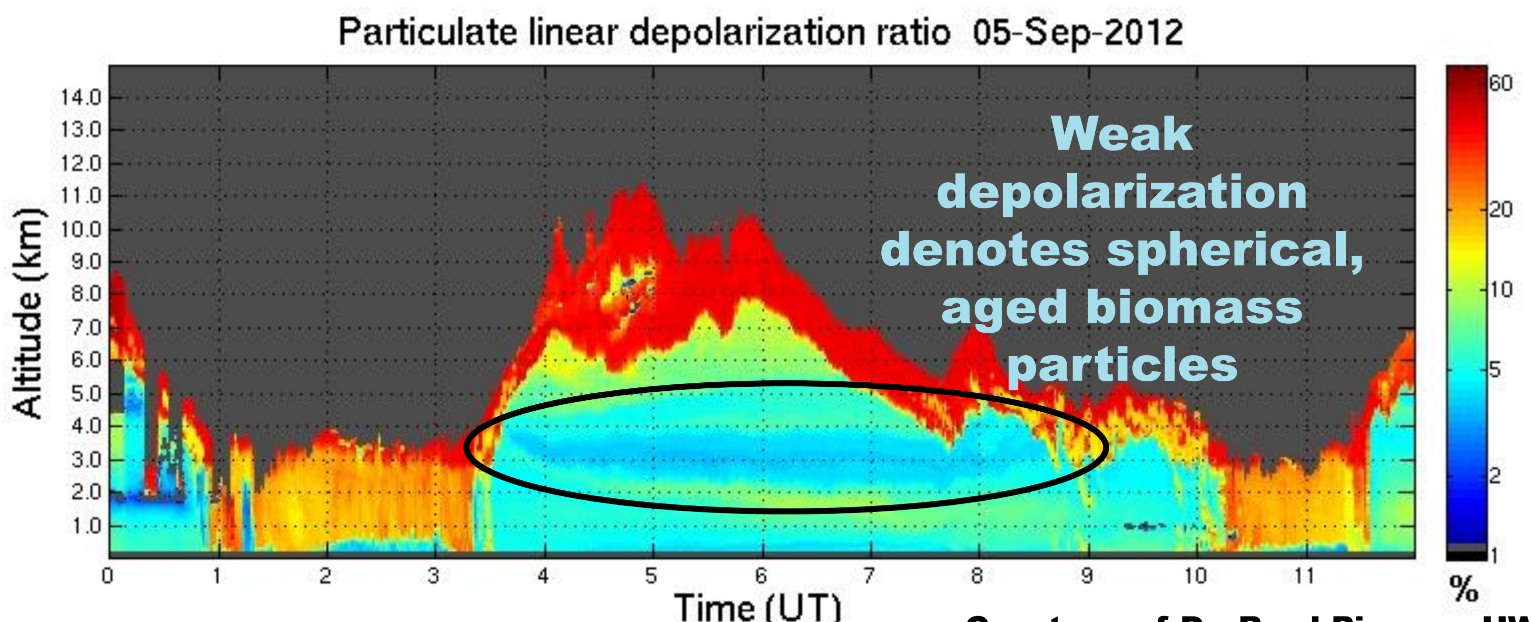


After biomass burning plume intercepts Cu-field – 2145 Z



Return





Courtesy of Dr. Brad Pierce – UW-CIMSS

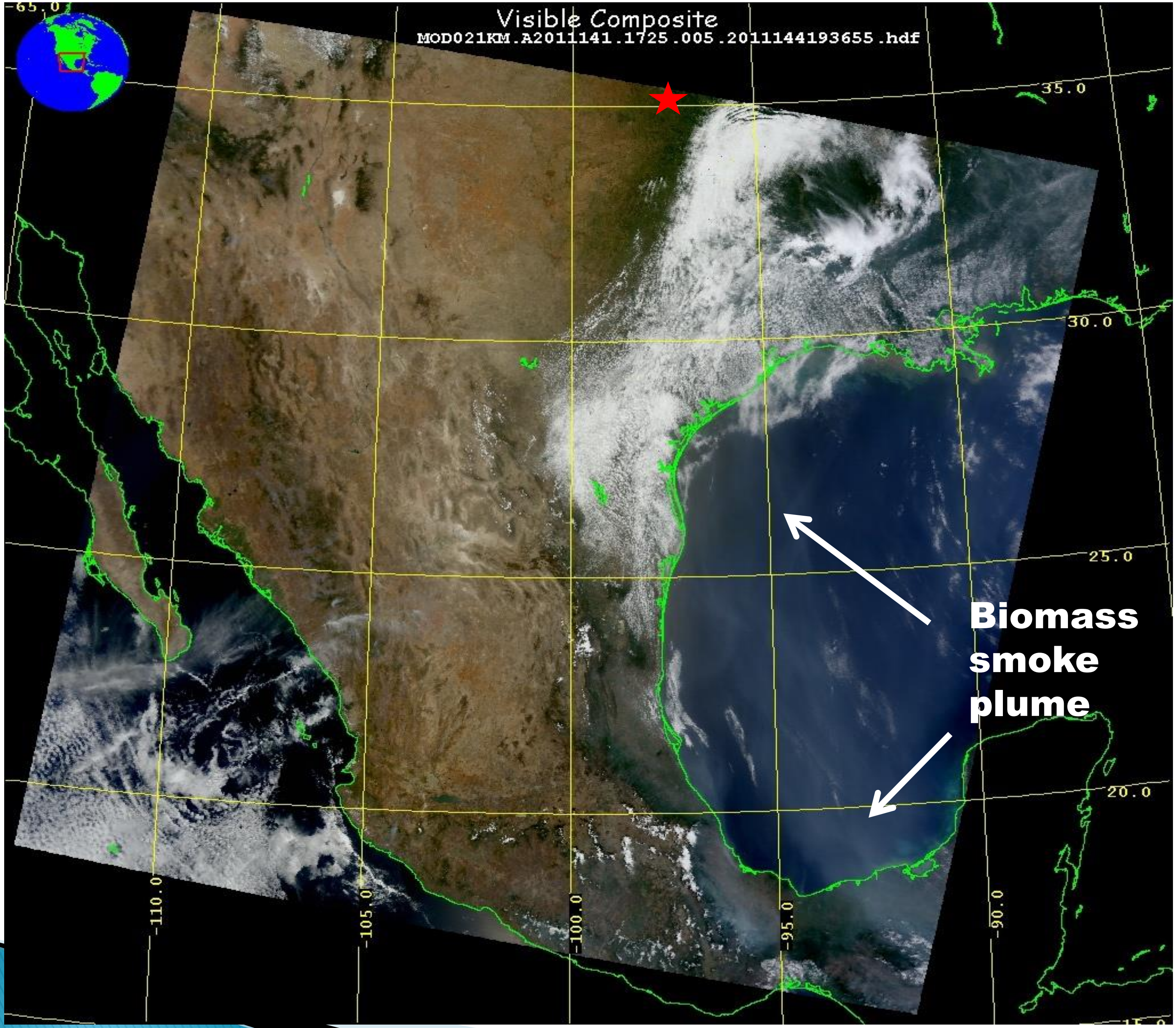

Visible Composite
MOD021KM.A2011141.1725.005.2011144193655.hdf
35.0
30.0
25.0
20.0
-110.0
-105.0
-100.0
-95.0
-90.0
Biomass smoke plume

TABLE 1. Key Observational Studies Identifying the Differences in Microphysical Properties, Cloud Characteristics, Thermodynamics, and Dynamics Associated With Clouds and Cloud Systems Developed in Dirty and Clean Environments[a]

Properties	High CCN[b] (Dirty)	Low CCN (Clean)	References (Observations)
Cloud droplet size and distribution	smaller and narrower	larger and broader	*Squires* [1958], *Radke et al.* [1989], *Ferek et al.* [2000], *Rosenfeld and Lensky* [1998], *Rosenfeld* [1999, 2000], *Rosenfeld et al.* [2001], *Rosenfeld and Woodley* [2000], *Andreae et al.* [2004], *Koren et al.* [2005], *Yuan et al.* [2008]
Warm-rain process	suppressed	enhanced	*Squires* [1958], *Radke et al.* [1989], *Albrecht* [1989], *Rosenfeld* [1999, 2000], *Rosenfeld and Woodley* [2000], *Rosenfeld and Ulbrich* [2003], *Andreae et al.* [2004], *Lin et al.* [2006], *Givati and Rosenfeld* [2004], *Li et al.* [2011a]
Cold-rain process	enhanced	suppressed	*Rosenfeld and Woodley* [2000], *Orville et al.* [2001], *Williams et al.* [2002], *Andreae et al.* [2004], *Lin et al.* [2006], *Bell et al.* [2008]
Mixed-phase region	deeper	shallower	*Rosenfeld and Lensky* [1998], *Williams et al.* [2002], *Andreae et al.* [2004], *Koren et al.* [2005, 2008, 2010a, 2010b], *Lin et al.* [2006], *Li et al.* [2011a], *Niu and Li* [2011]
Lightning	enhanced (downwind side)/ higher maximum flash	less and lower maximum flash	*Williams et al.* [2002], *Orville et al.* [2001], *Steiger et al.* [2002], *Steiger and Orville* [2003], *Yuan et al.* [2011]

[a]Updated and modified from *Tao et al.* [2007].
[b]Cloud condensation nuclei.