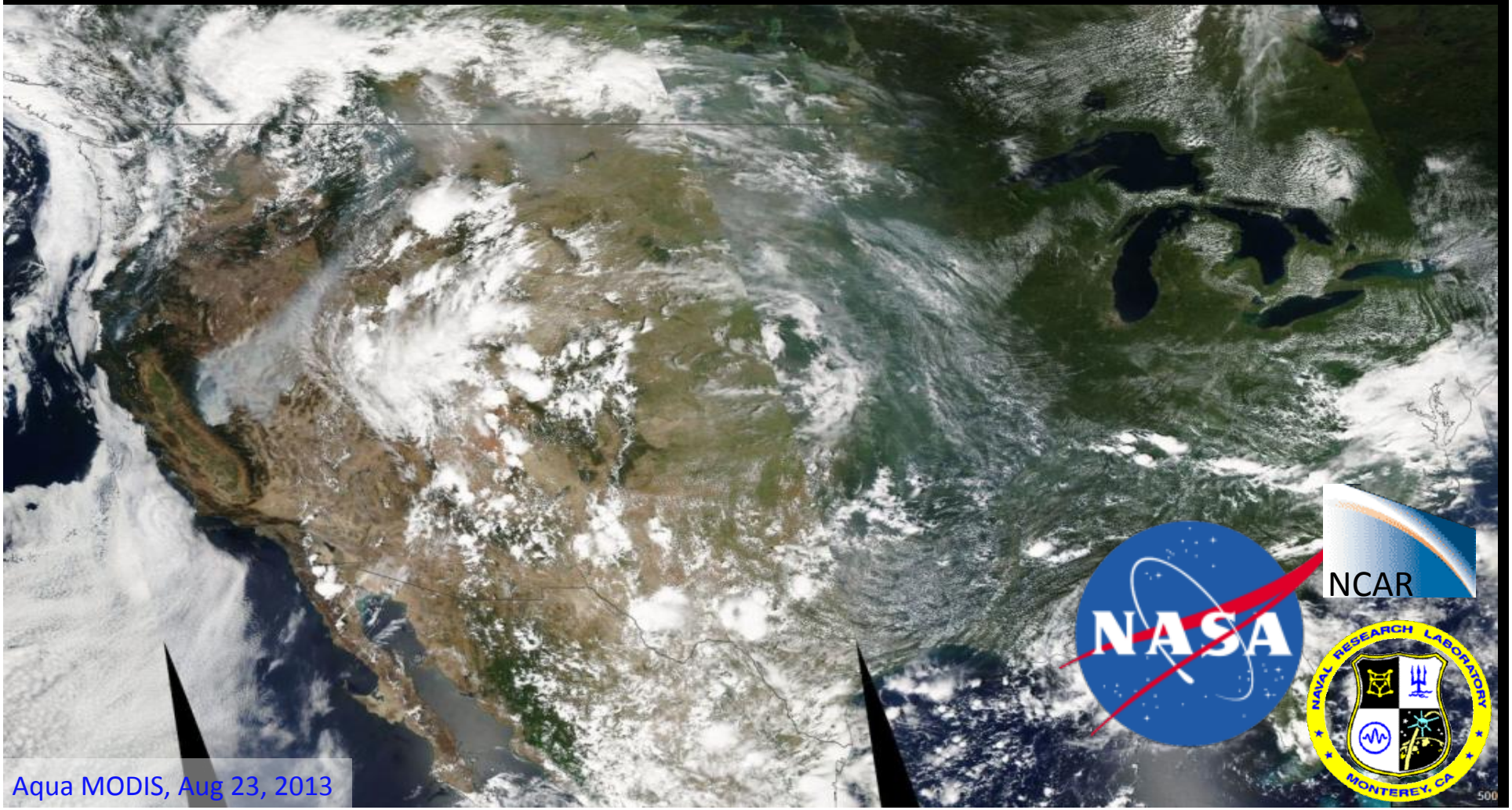
SEAC^{4}RS: Post Mission Tropospheric Aerosol, Radiation, & Remote Sensing Synopsis April 2014 http://espo.nasa.gov/missions/seac4rs/

J.S. Reid, J. Redemann, & R. Ferrare
+ much contribution from the aerosol team



Aqua MODIS, Aug 23, 2013

AR&RS Mission Synopsis
Bottom Line Up Front

- As is typical with field missions, SEAC4RS occurred in an anomalous year. AOTs are climatologically dropping in time, plus there were low AOT in their own right due to unseasonably high precipitation.
- Even so, mother nature could not have been kinder to us given the overall meteorology. We acquired in situ and remotely sensing data on most major aerosol species: sulfate and organic dominated anthropogenic pollution, biogenic background, dust, sea salt & biomass burning + smoke over cloud.
- The dozen plus AR&RS goals ranged from collection of much needed data to aid in the development of remote sensing technologies to basic research on chemistry-aerosol optical property relationships.
- Relationships between aerosol vertical properties and convection were pretty well sampled. Lidar data is spectacularly good.
- For radiation, significant amounts of much needed data were generated. But, thus far we have lots bronze and silver days rather than gold. Nevertheless, key data will allow us to start tackling the complex mixed cloud/aerosol environment. Roll out the hand analysis….
- Significant opportunity exists in linking chemistry and radiation via thermodynamics, but this is going to take some hard work.

Brief Topics

- Broad objectives and capabilities.
- Where does 2013 historically fit into typical aerosol environments?
- Specifics on what we measured and how.
- August 23rd as an example.
- Summing up/Post mortem.

SEAC^{4}RS AR&RS Aerosol Heavy Armament

- **Radiation & Remote Sensing:** Comprehensive polarimetry (AirMSPI, RPI, RSP) , imagery (eMAS), lidar (DIAL&CPL), radiation (SSFR, BBR), and sun photometry (4STAR).
- **Microphysics/Optics:** Hygroscopic dependent size (DASH-SP), scat-abs-ext (AOP, LARGE), and black carbon (HD-SP2). Plus we have phase function (PIN) and CCN (SF-CCN).
- **Chemistry:** Mass spectroscopy (TOF-AMS, PALMS), filters (SAGA).
- **Ground Network:** 15 AERONET, SSEC HSRL at UAH, SEARCH & IMPROVE networks. Plus, we had an ozonesonde network and Newchurch's DIAL at UAH.

This combination of instrumentation with the survey nature of SEAC^{4}RS not only benefits individual fields, but is the community's best opportunity to date to bridge radiation and chemistry via microphysics. SEAC^{4}RS also provides one of the few comprehensive datasets to combine aerosol, chemistry, and cloud data->we can see plumbing!

Big Topics for linking remote sensing, aerosol particles, and radiation

1. Can we generate a benchmark radiation polarimeter and lidar development data set (Dust, smoke(s), hazes, AOT>0.4; +varying land surface).
2. What physically is it the lidars are seeing in the planetary boundary layer?
3. How representative are AERONET retrievals at high and low AOTs?
4. How well do remote sensing systems represent smoke and absorption over clouds?
5. How do we connect "radiance-world" (cloud-aerosol-gas remote sensing) with "irradiance-world" (forcing/absorption), and Rem. Sens products to in-situ .
6. In heterogeneous aerosol and cloud scenes, how well do we actually represent the 3 d radiation fields by satellite and models (total irradiance, direct/diffuse)? Can we resolve 3 d radiative effect, "twilight zone" phenomenon and cloud halos?
7. Compared to the extensive surface network, how much value is there in remote sensing data in representing surface air quality?
8. How are optical properties of smoke particles changing in the far field due to the competing effects of coagulation, SOA product and evaporation/breakdown?
9. Are polarimeters capable of detecting BrC formation, and when coupled to models, monitor SOA formation?
10. Can we find a typing point in warm rain formation/suppression in the gulf?
11. To what extent do convective boundary layer processing and the radiation fields above clouds decouple aerosol chemical, thermodynamic and optical properties across the inversion?
12. How do processed aerosol particles in mid and upper level detrainment layers differ from their boundary layer counterparts?
13. What is BrC and how does it relate to particle absorption properties?

Engineering

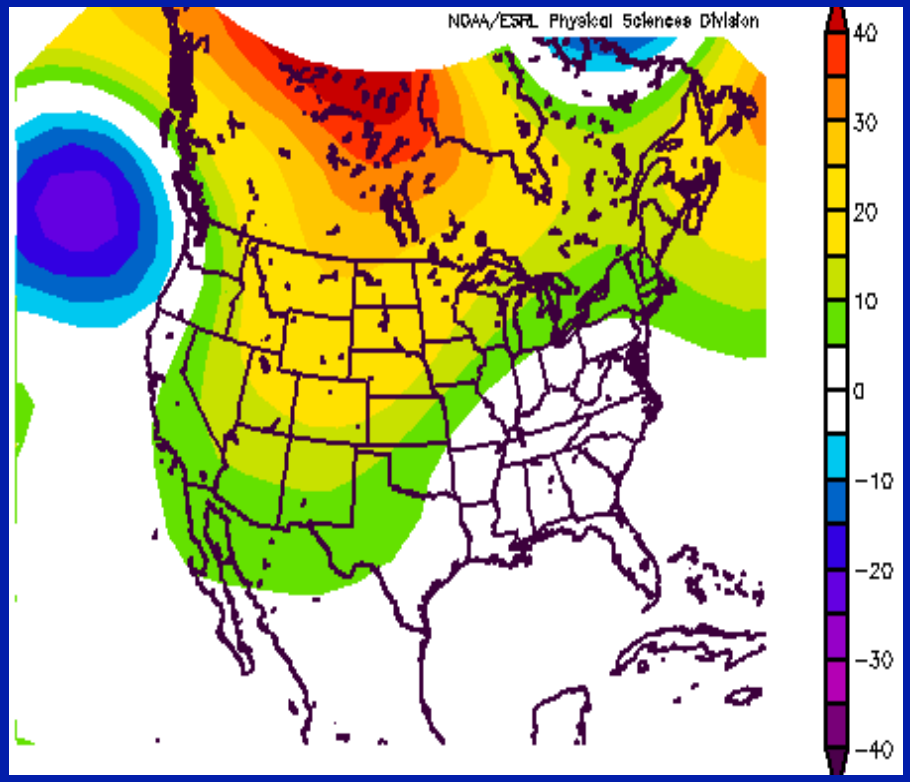
Practical Observability Predictability

Basic Research

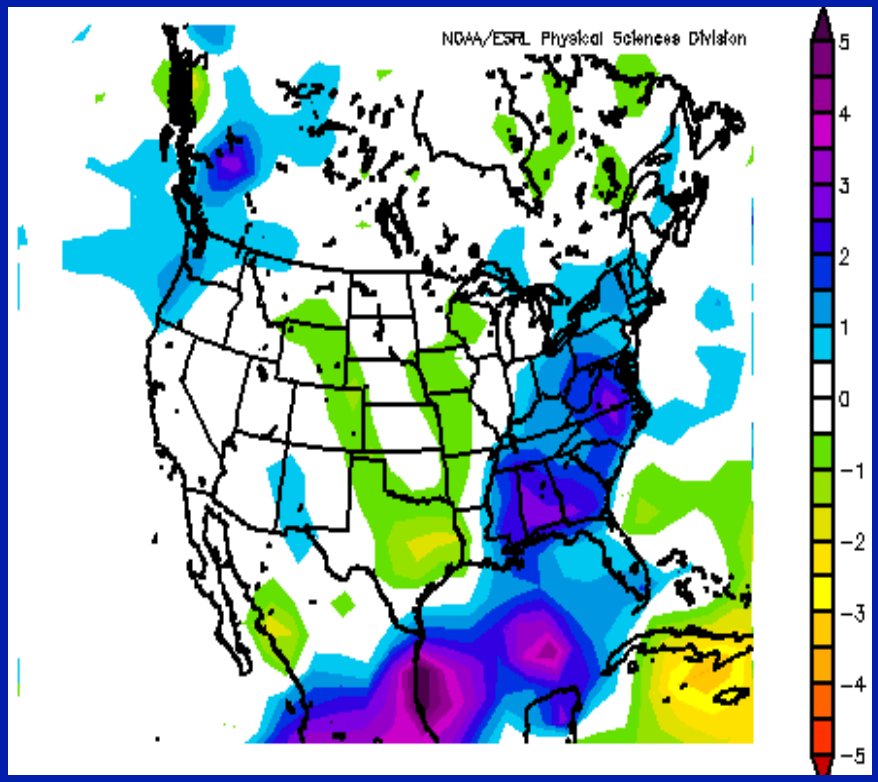
As is already clear, the 2013 news was the "Ridiculously resilient ridge" This effected everything….

2013 Jun-Sept NCEP/NCAR Reanalysis

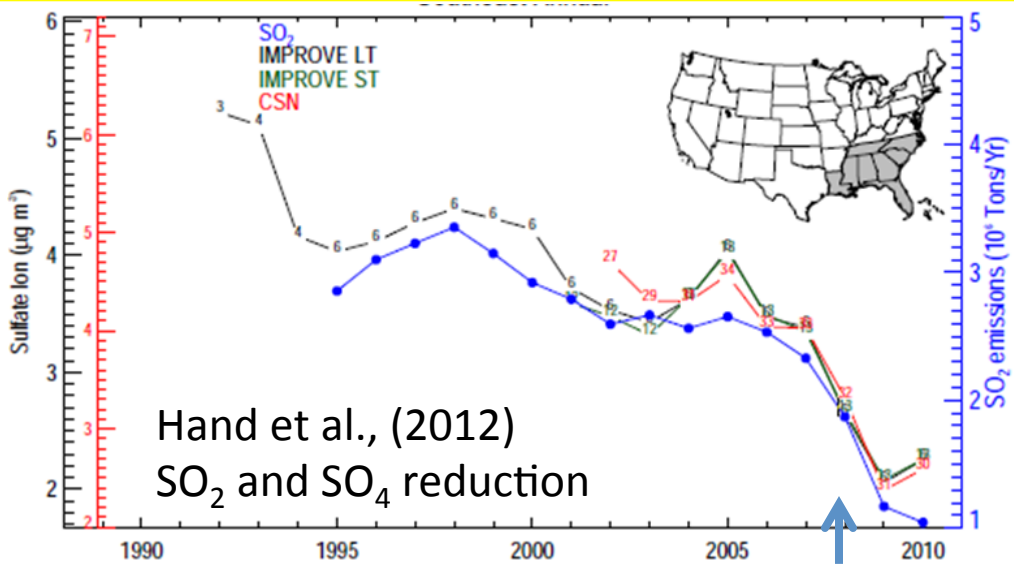
500 mb height anomaly (m)

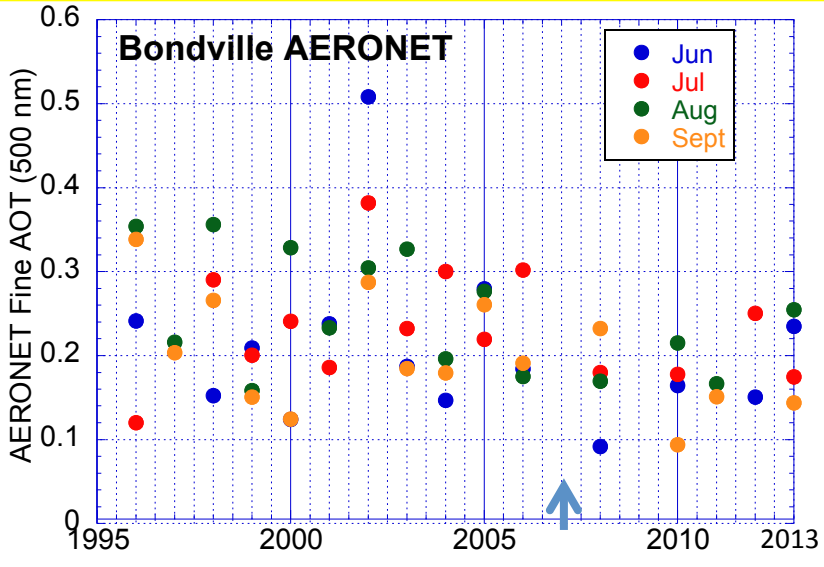


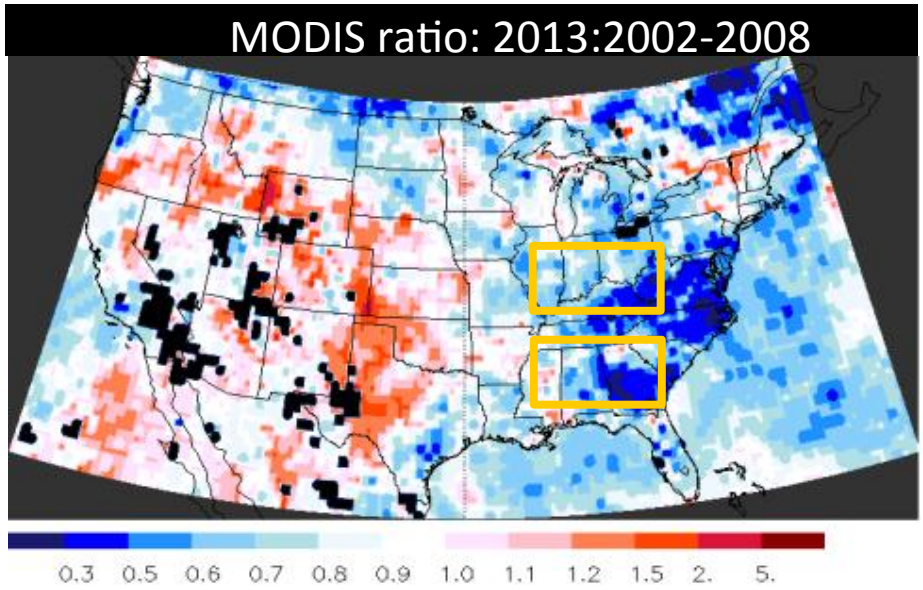
Rainrate anomaly (m)

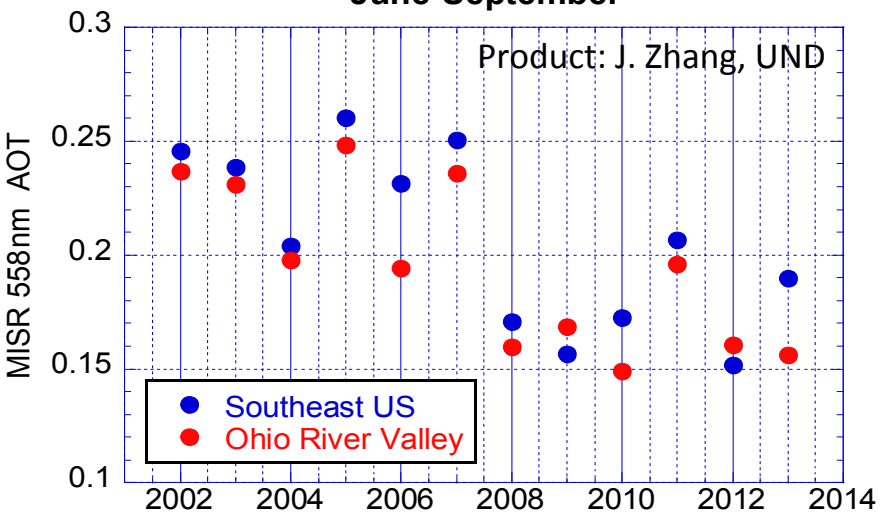


On top of the meteorological anomaly, we are in a downward trend regime for emissions and AOT. 2008 is an important year



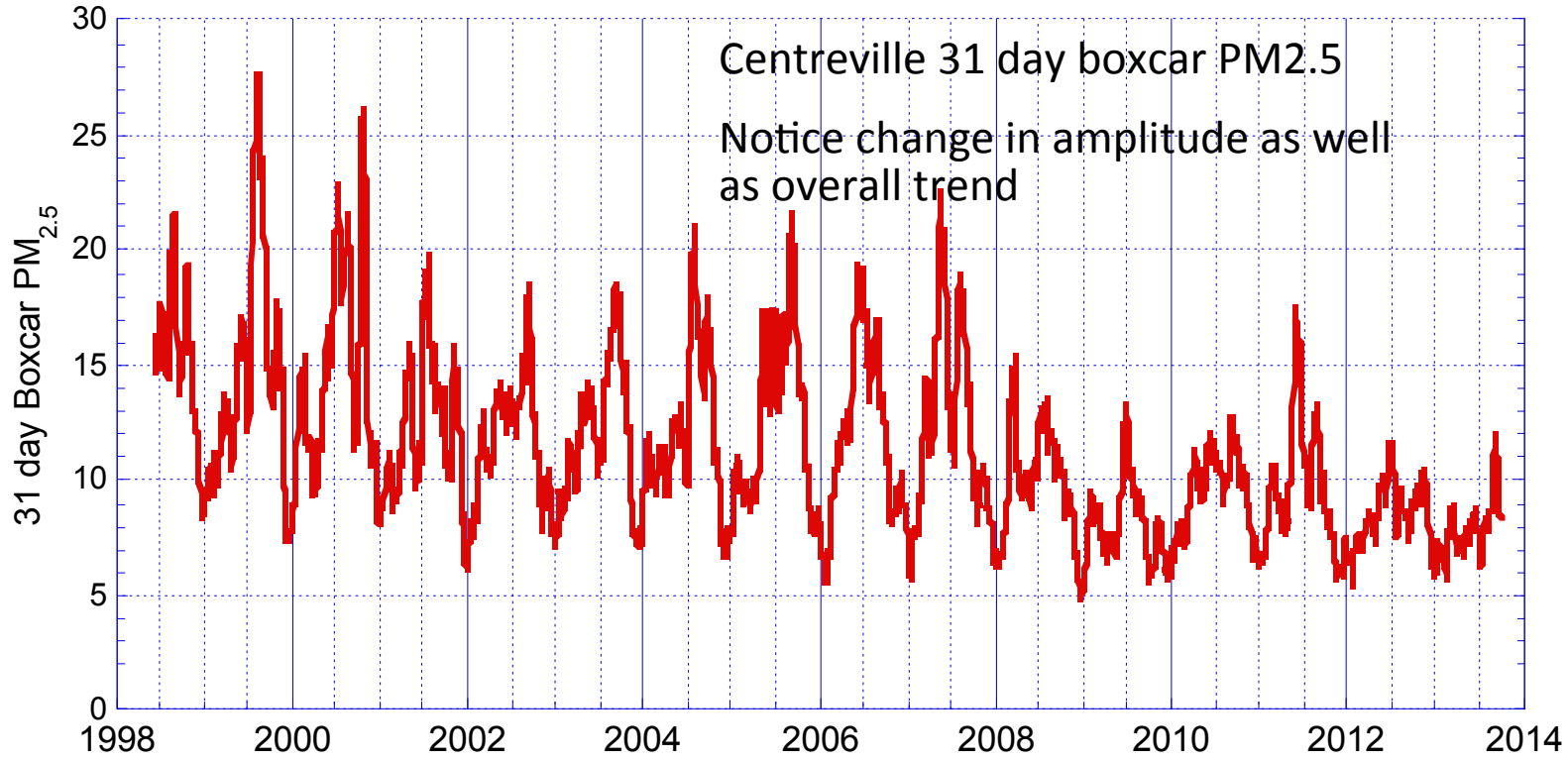






So how was 2013 in the new regime?
Surface $PM_{2.5}$ at Centreville

$PM_{2.5}$ ($\mu g\ m^{-3}$)	Jun	July	Aug	Sept
2008-2012	12.0+/-2.4	10.7+/-1.4	10.5+/1.8	9.7+/-2.0
2013	8.6	6.6	8.2	9.6

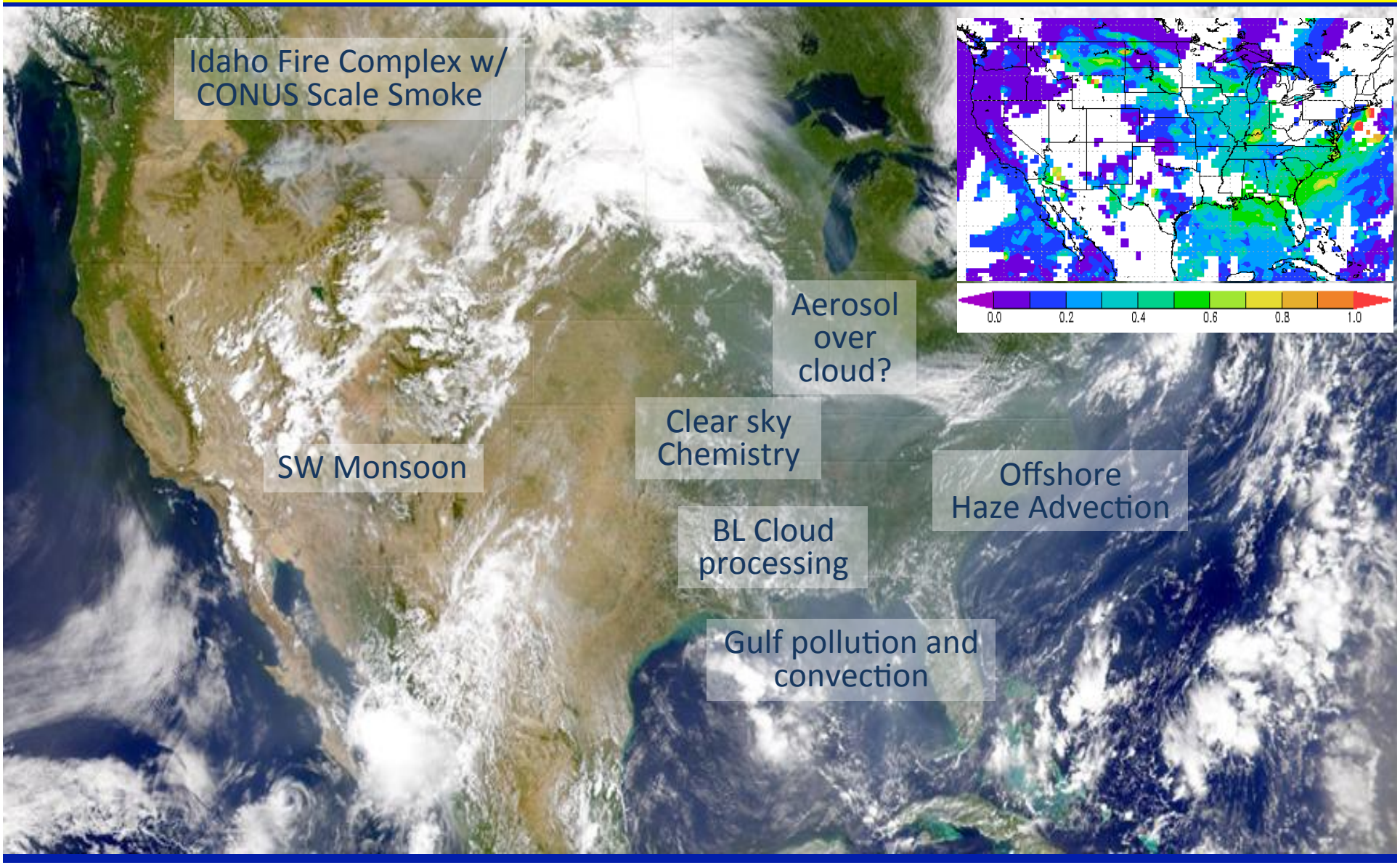


Data from E. Edgerton (SEARCH)

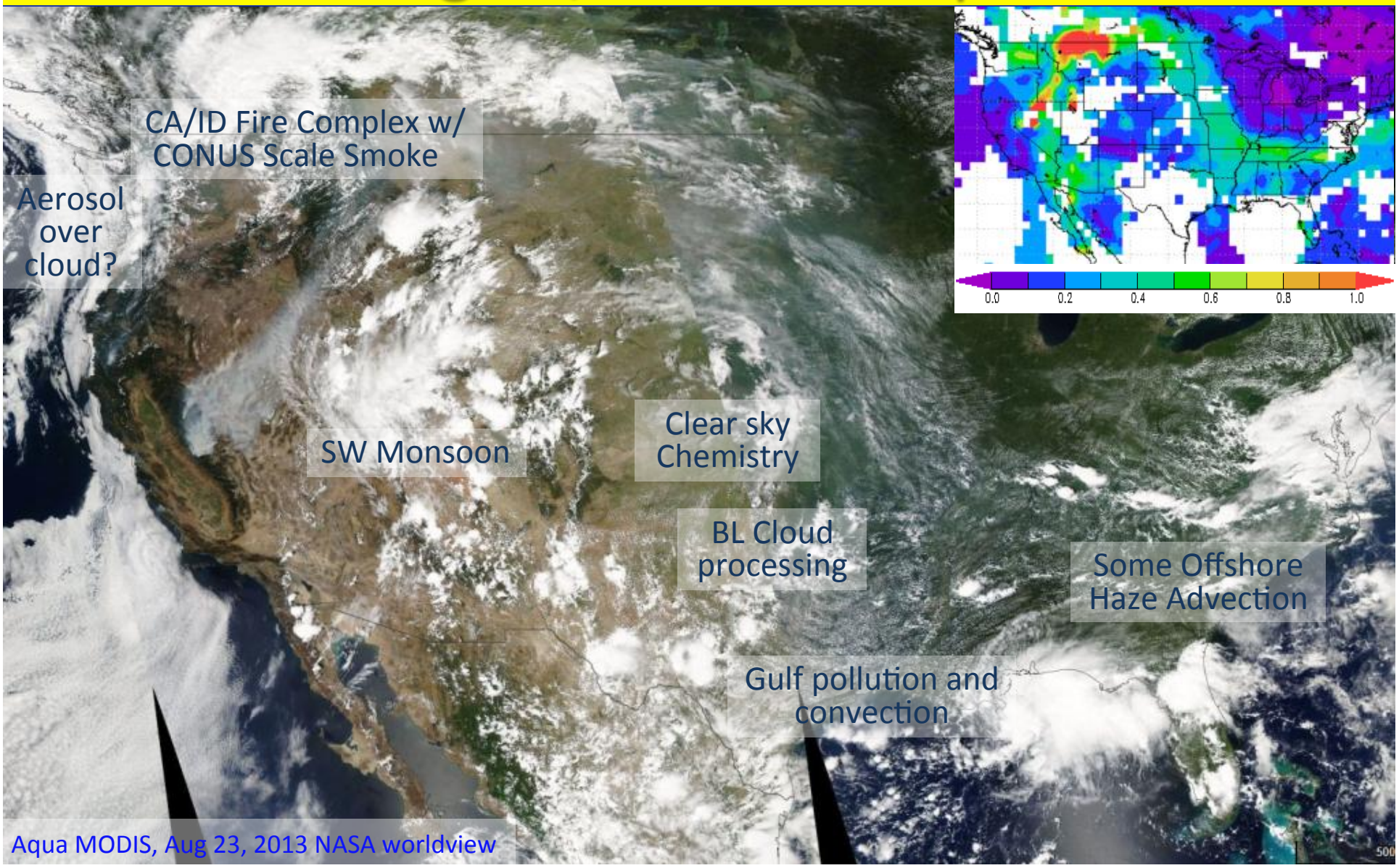
The "Perfect SEAC^{4}RS Day"

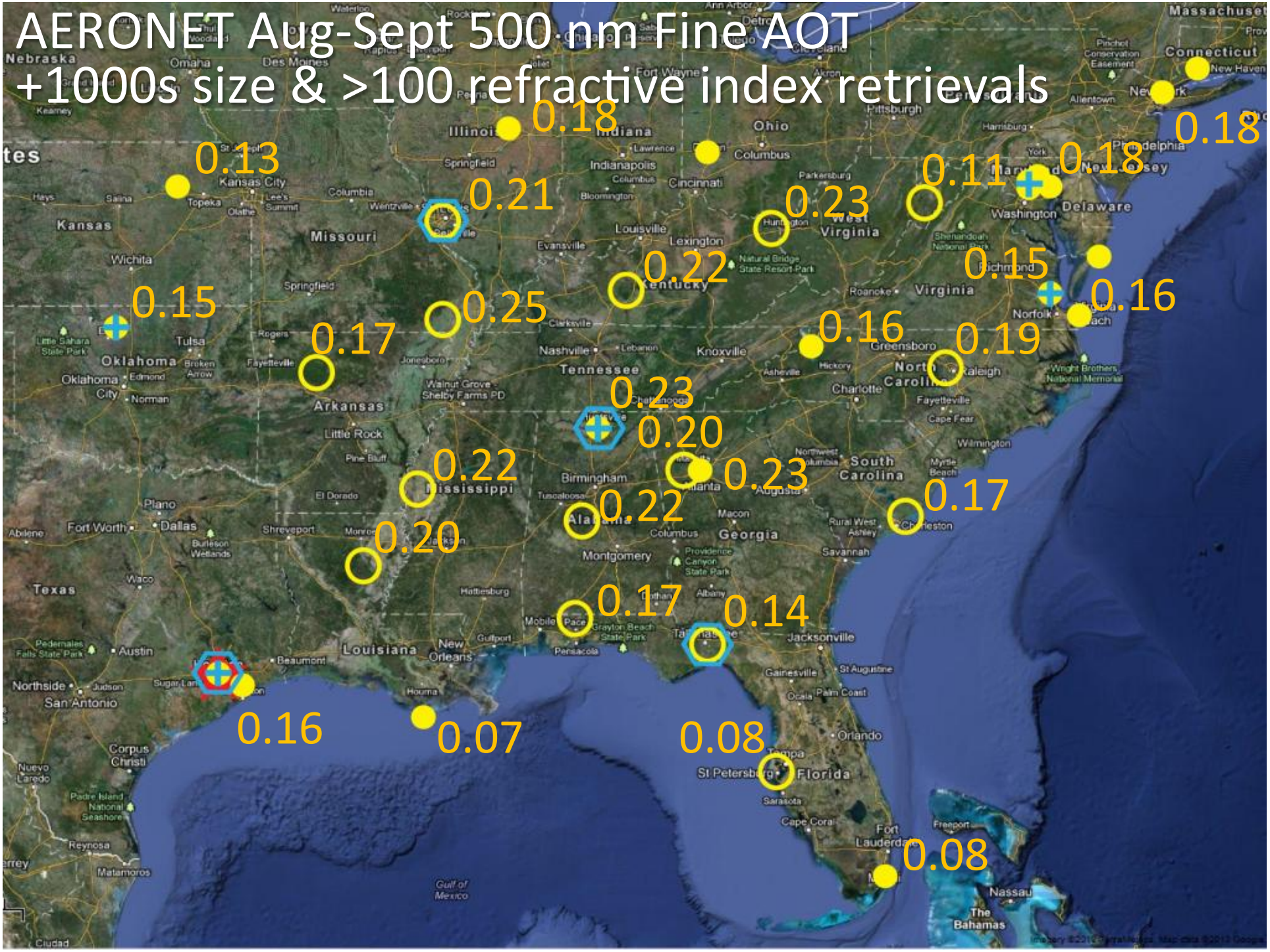
It would be nice if it happened to us, but don't count on it.

SeaWiFS, Aug 16, 2000. Norm Kuring



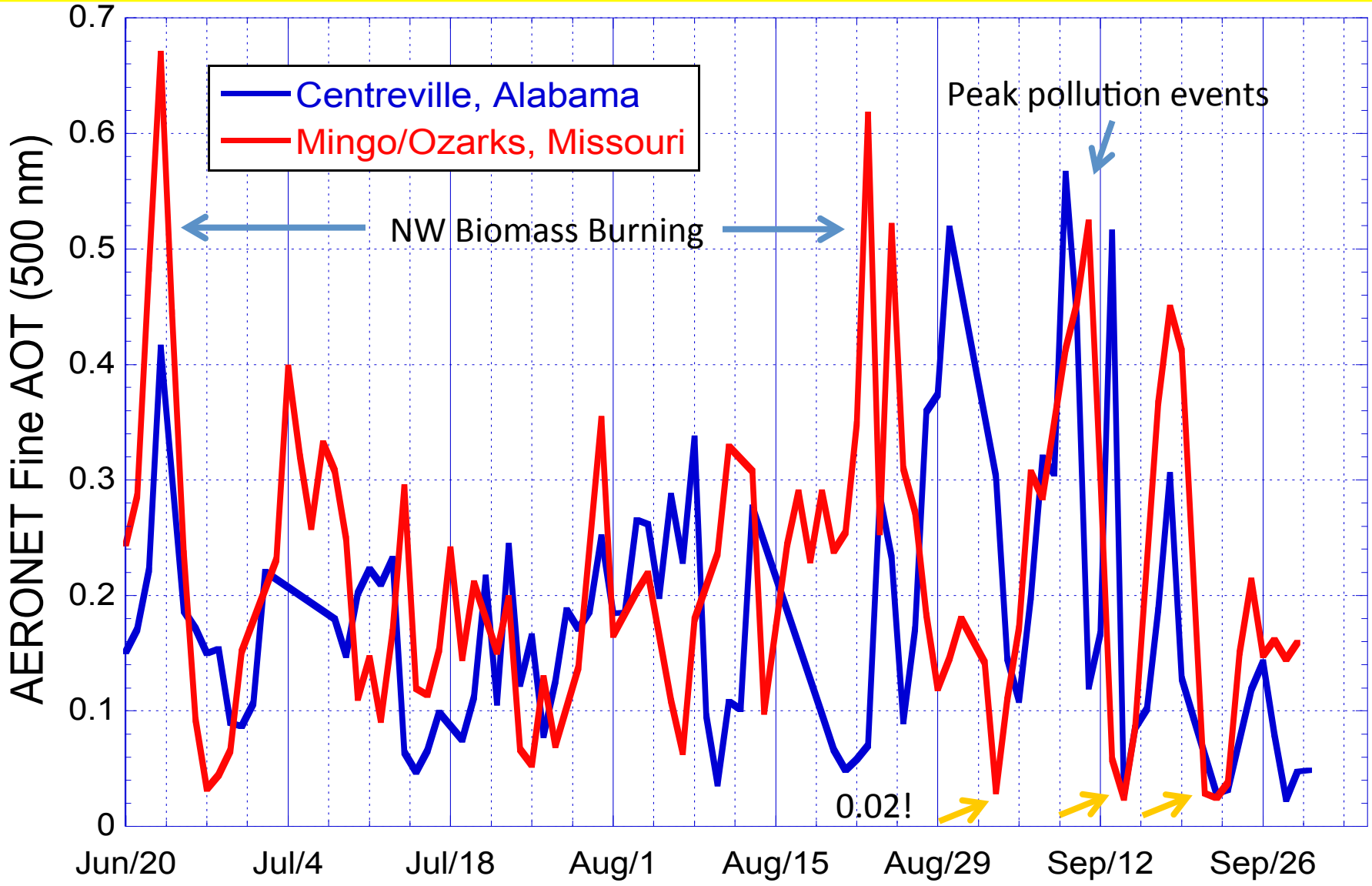
What we got:
Aug 23, 2014 example



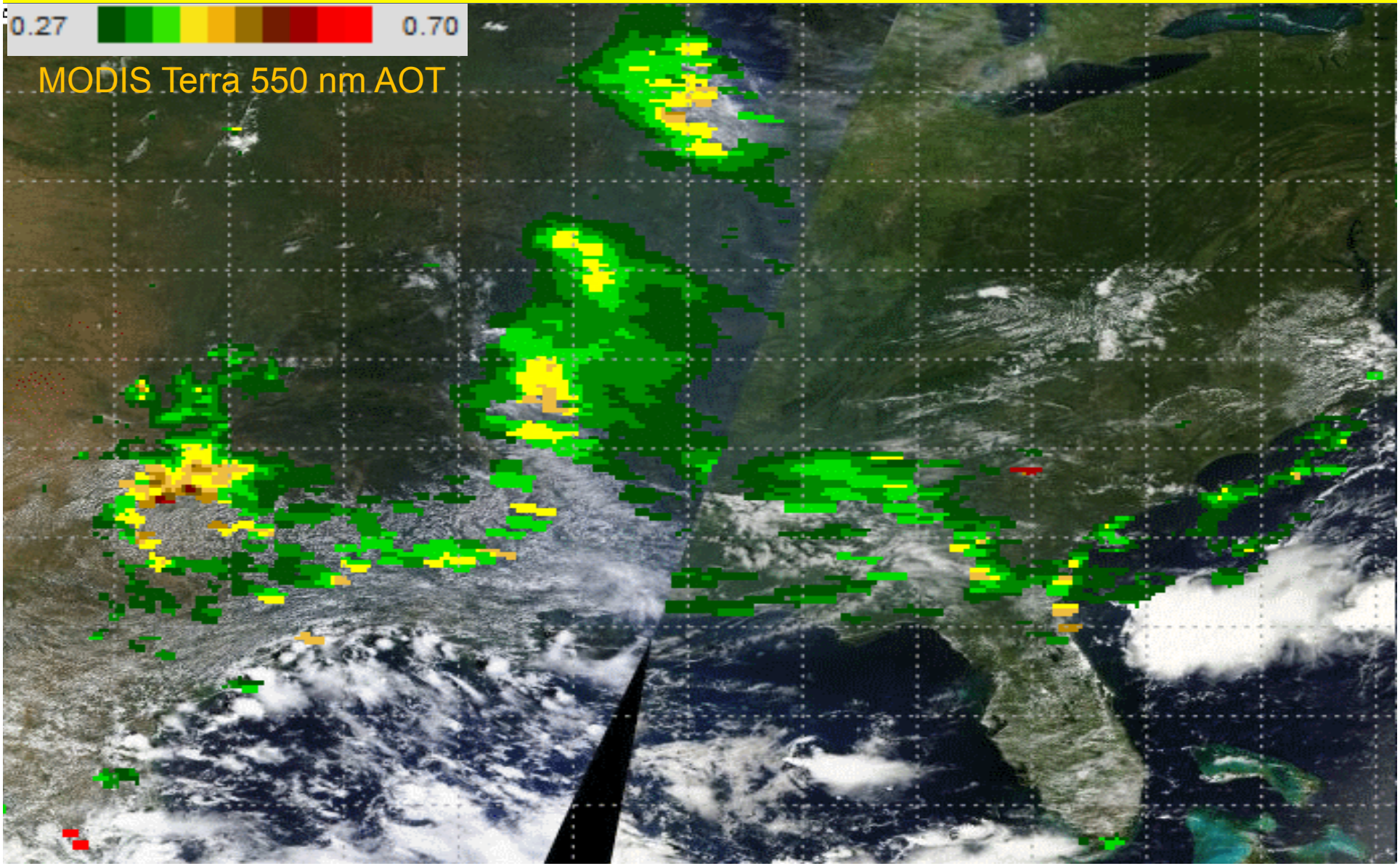

AERONET Aug-Sept 500 nm Fine AOT
+1000s size & >100 refractive index retrievals
0.18
0.13
0.21
0.23
0.11
0.18
0.18
0.22
0.15
0.15
0.25
0.16
0.16
0.17
0.19
0.23
0.20
0.22
0.23
0.17
0.22
0.20
0.17
0.14
0.16
0.07
0.08
0.08

2013 had low average AOTs, but lots of variability!

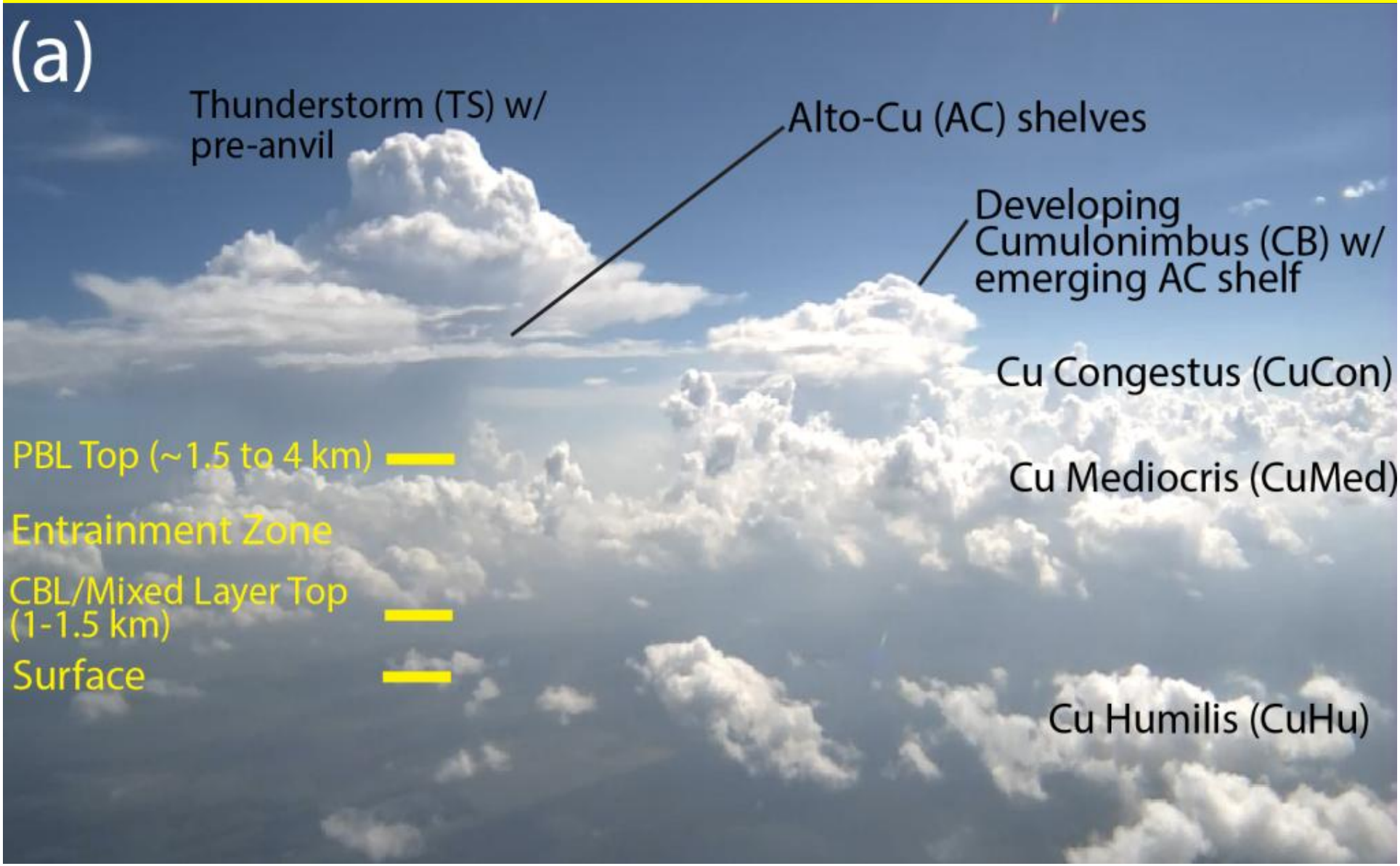
Combination of NW smoke and pollution, plus gulf coast dust (Aug 8) and smoke over west coast stratus (Aug 6)



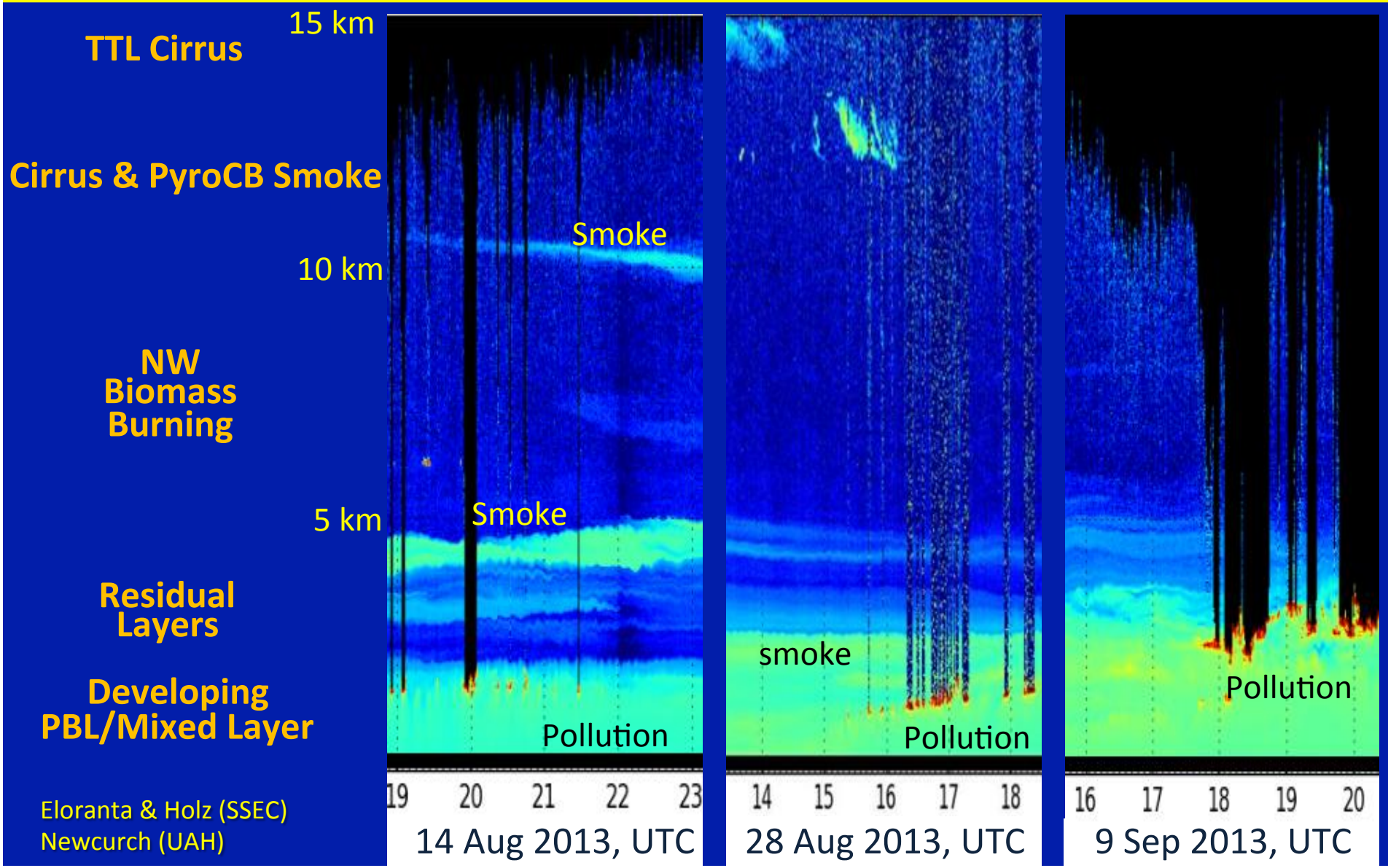
How extensive can pollution be?
Sept 6-11th event



Anatomy of the vertical
Aug 12, 2013



Anatomy of the aerosol vertical structure
Eloranta HSRL at UA Huntsville



Eloranta & Holz (SSEC)
Newcurch (UAH)

Aerosol Relevant Flight Components

Aug 6: Oregon fire & smoke over stratus

Aug 8: Houston transit-African dust

Aug 12: Training day ER2/DC8/Lear-Good aerosol-cloud and convection flight.

Aug 14: SEUS Tour #1-ER2/DC-8 stacked at Mingo. Just missed smoke.

Aug 16: NAM cross country-Smoke profile in Colorado and 4 corners plume.

Aug 19: Midwest Idaho smoke flight. Strong smoke gradients

Aug 21:SEUS Tour #2 1-ER2/DC-8/Lear stacked convection.

Aug 23: Day in the life of an Arkansas pressure cooker. Aerosol and ER2/DC-8/Lear convection dev.

Aug 26: Suitcase P1 to the Rim & Idaho fires +radiation.

Aug 27: Suitcase P2 follow Rim smoke

Aug 27b: ER2 over AERONET

Aug 30: SEUS Tour #3, 2 stacked ER2/DC8

Sep 2: ER2/DC-8/Lear Land convection day

Sep 4: ER2/DC-8 Marine convection day

Sep 6: SEUS Tour #4+NAM

Sept 9: N. Louisiana Terpines

Sep 11: SEUS Tour #5+ 2 AK convective cells

Sep 13: Gulf coast tropical convection

Sep 16: Sample across a front.

Sep 18: ER2/DC-8/Lear Petrochemical day w/ two cells + Houston plume.

Sep 21: DC8 SEUS Front sampling

Sep 23: Transit home via Ozarks.

Biomass Burning

Clouds/Convection

Dust

Regional Pollution & Biogenics

Radiation

Anatomy of flight plans:

Tensions: Coverage, vertical resolution, and convection

Ohio River Valley

Isoprene Ozarks/Mingo

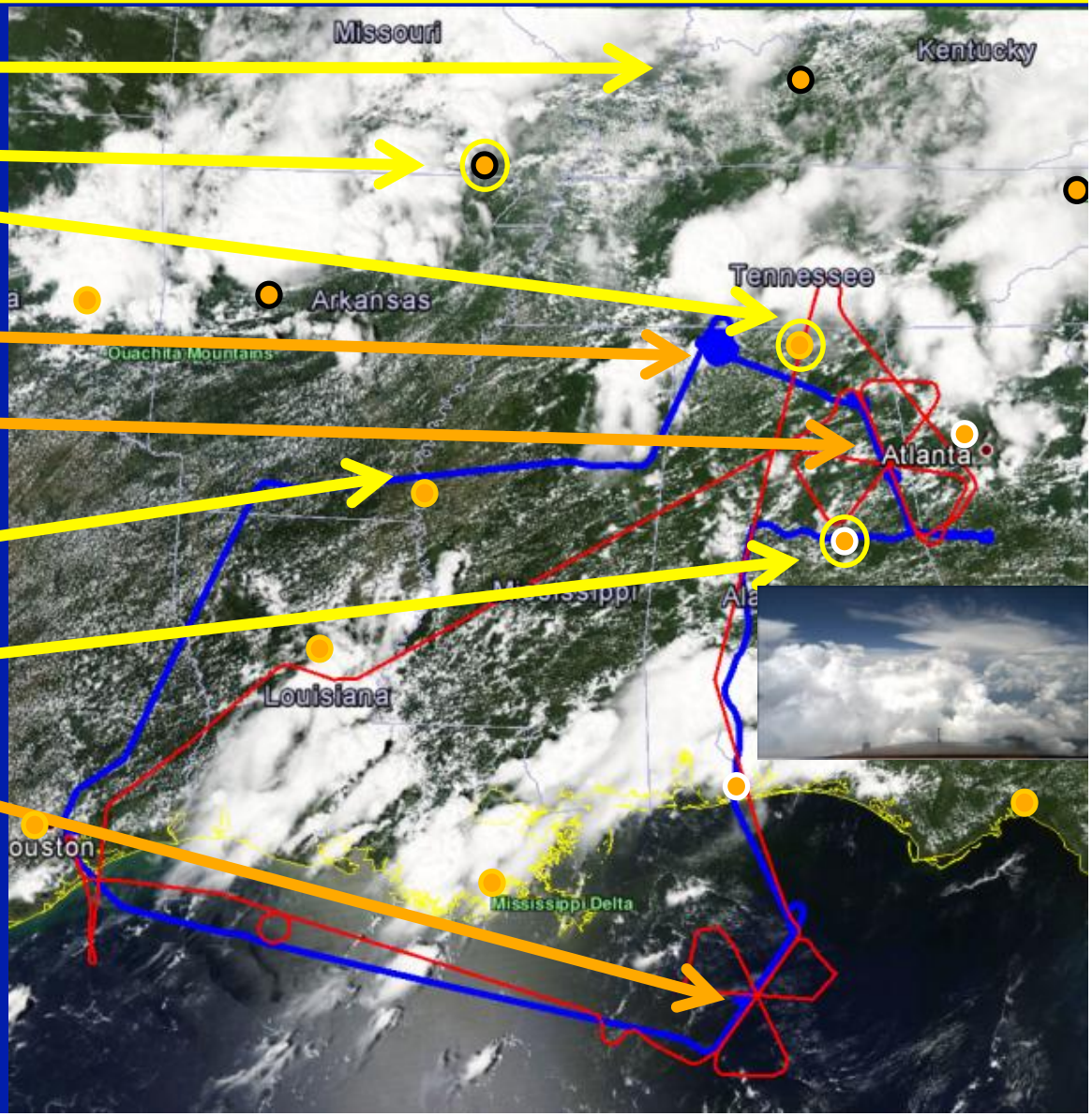
Huntsville Lidar Site

Storm Spiral
ER2 Rosette over
DC-8 Curtain wall

Terpine Emissions/
Ag Burning

Centreville

ER2 Rosette over
DC-8 Curtain wall

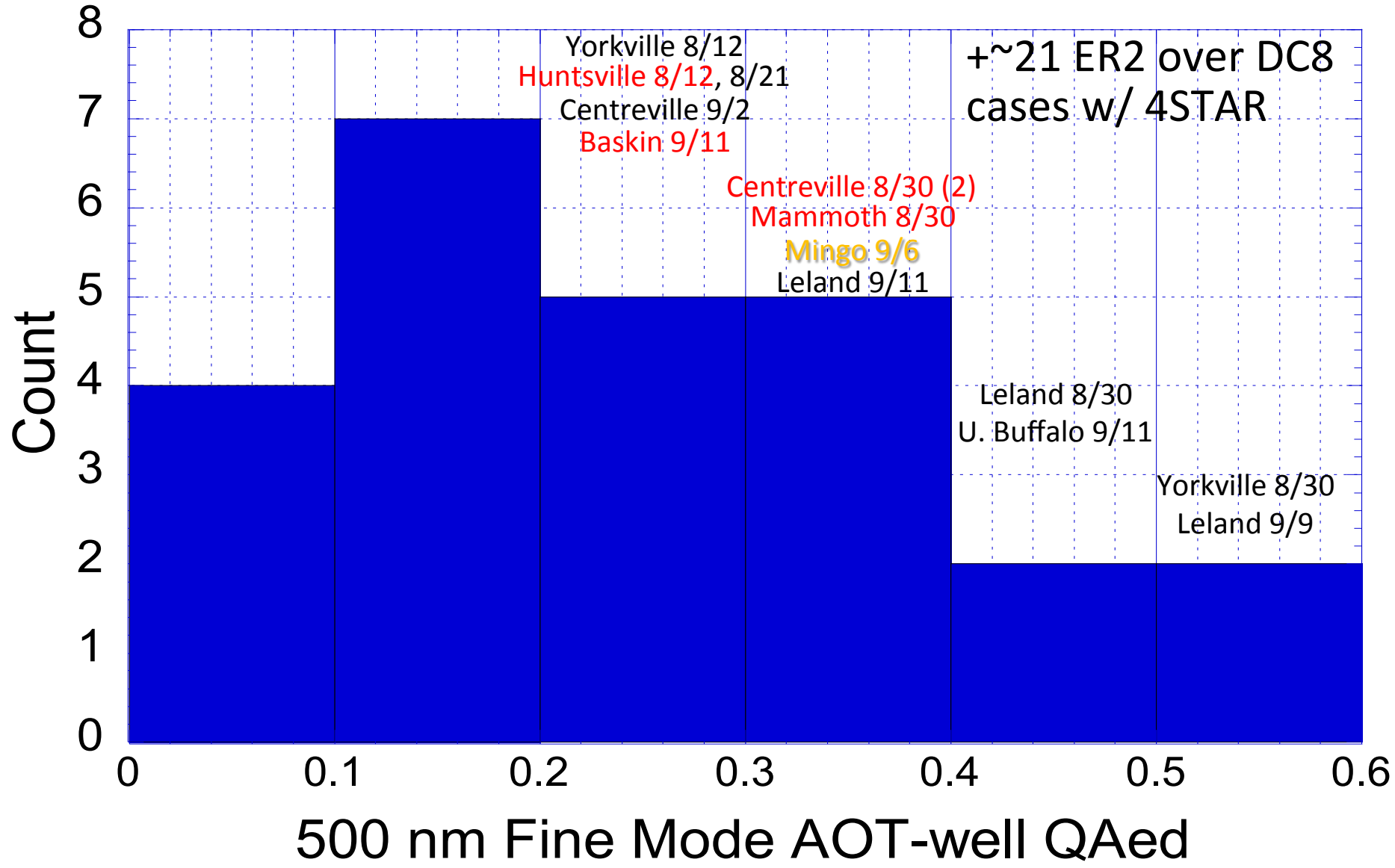


AERONET
+SEARCH • +IMPROVE

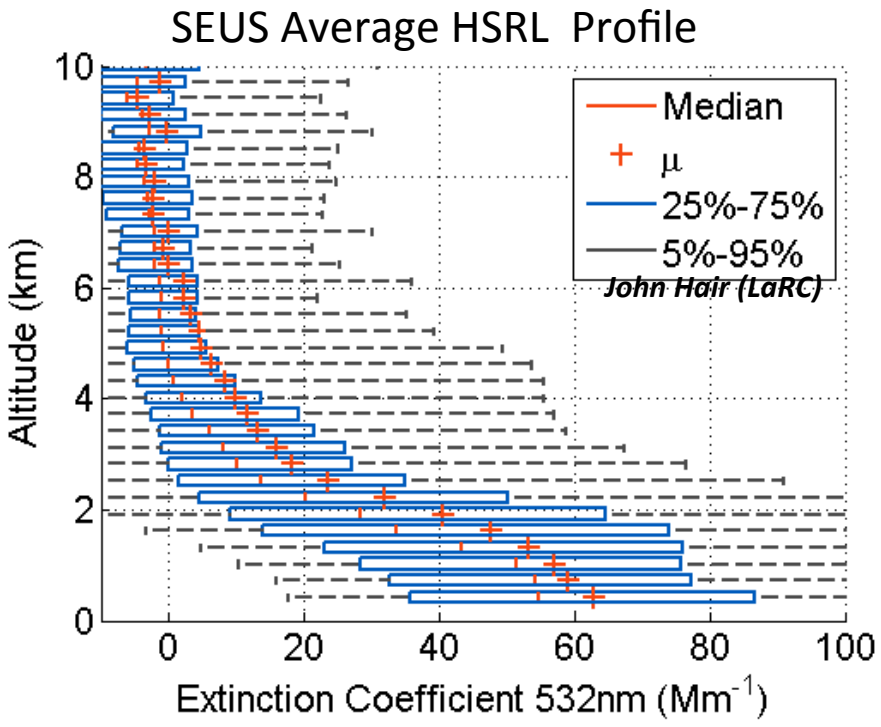
No golden DC8/ER2 days for aerosol and radiation, but lots of silver& bronze

- Aug. 6th, Smoke over clouds, although no eMAS
- Aug. 12, Training day. Good coordination, but AOT=0.03 water, 0.2 land for coincidence
- Aug. 16, That little dip in southern Colorado +19th may save us on "coincident and comprehensive" ER2 and DC8 data for high biomass burning.
- Aug 19, Midwest flight devoted to biomass burning, but sharp gradients in smoke plus enhanced DC8 fuel burn suggest we may not have maximized our opportunity. TBD.
- Aug. 23, Best coordination, PBL AOT=~0.25, but thin and variable smoke layer aloft.
- Aug. 30th, Decent coordination plus CALIOP, AOTs 0.2-0.3. Perhaps our best overall day for regional pollution.
- Sept. 9, ER2/DC8/CALIPSO coordination with 0.25 AOT, but ER2 over high haze site to the north (AOT>0.5)
- Sept. 11, Thick haze when we were working the convection (AOT>0.5?), but the ER2 and DC8 were in a cloud pattern.

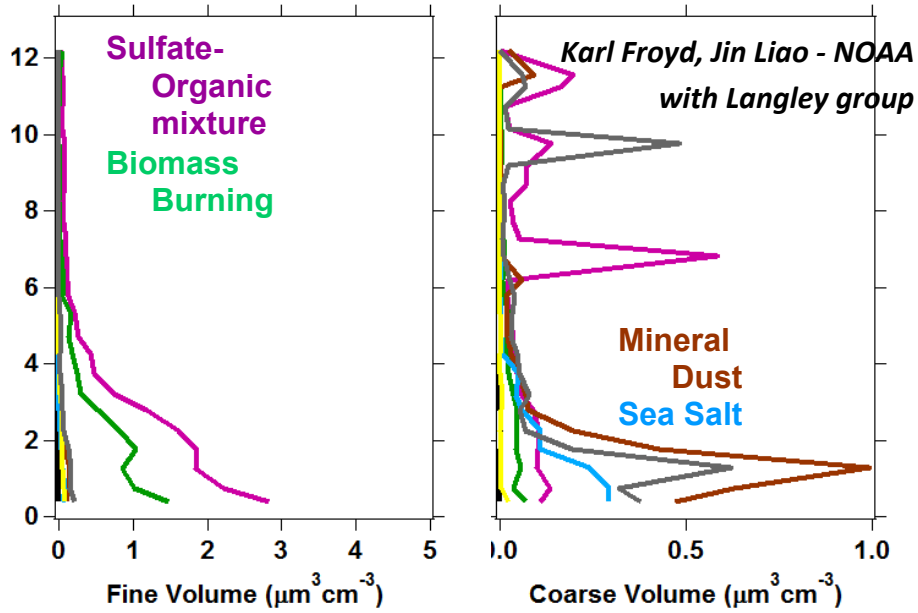
26 ER2 near AERONET cases Sampled Fine AOTs-Tentative



Southeast US SEAC⁴RS "Standard Atmosphere"



SEAC⁴RS Eastern US



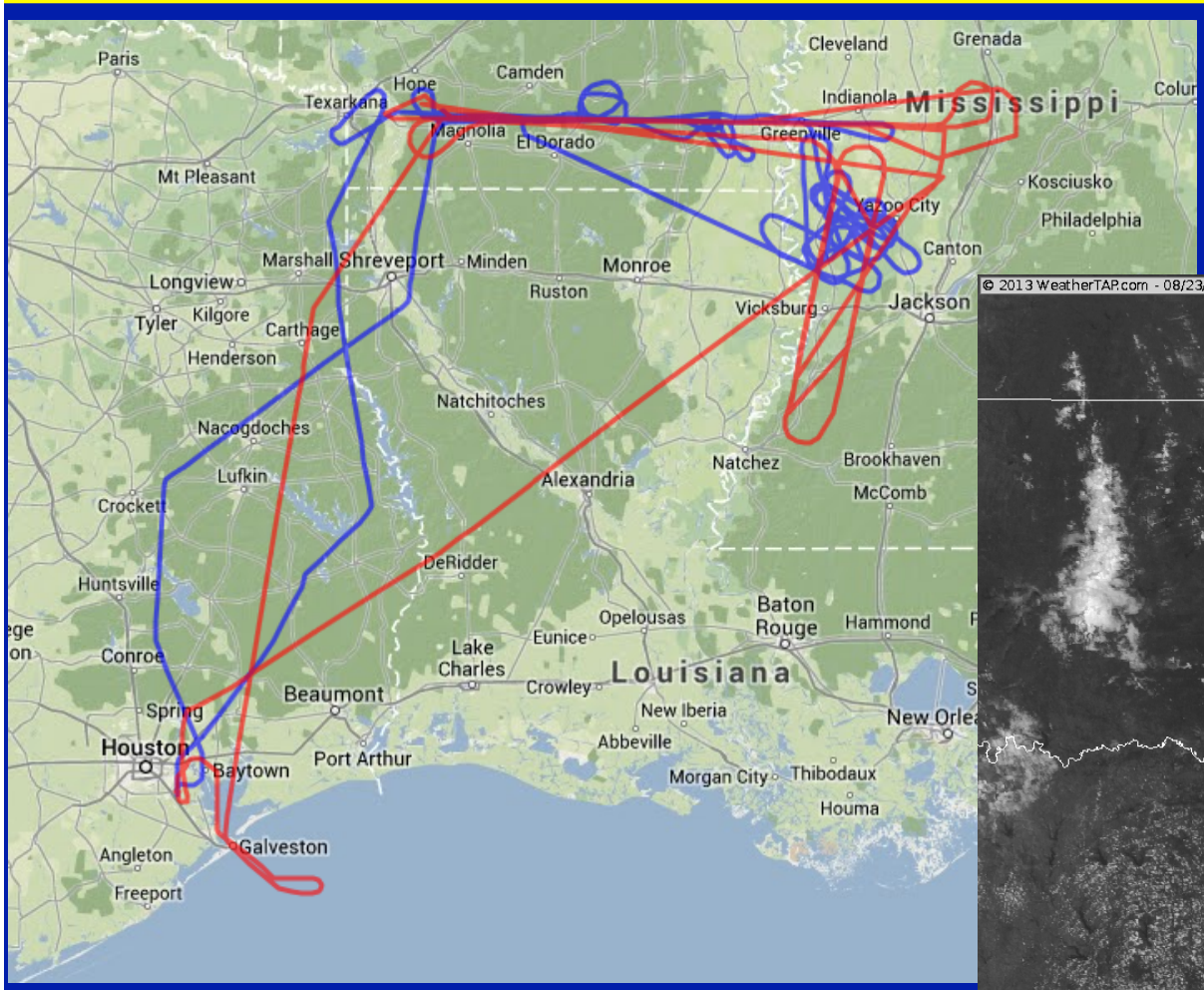
Much lower **Biomass Burning**

Low volume, mostly **Dust**.

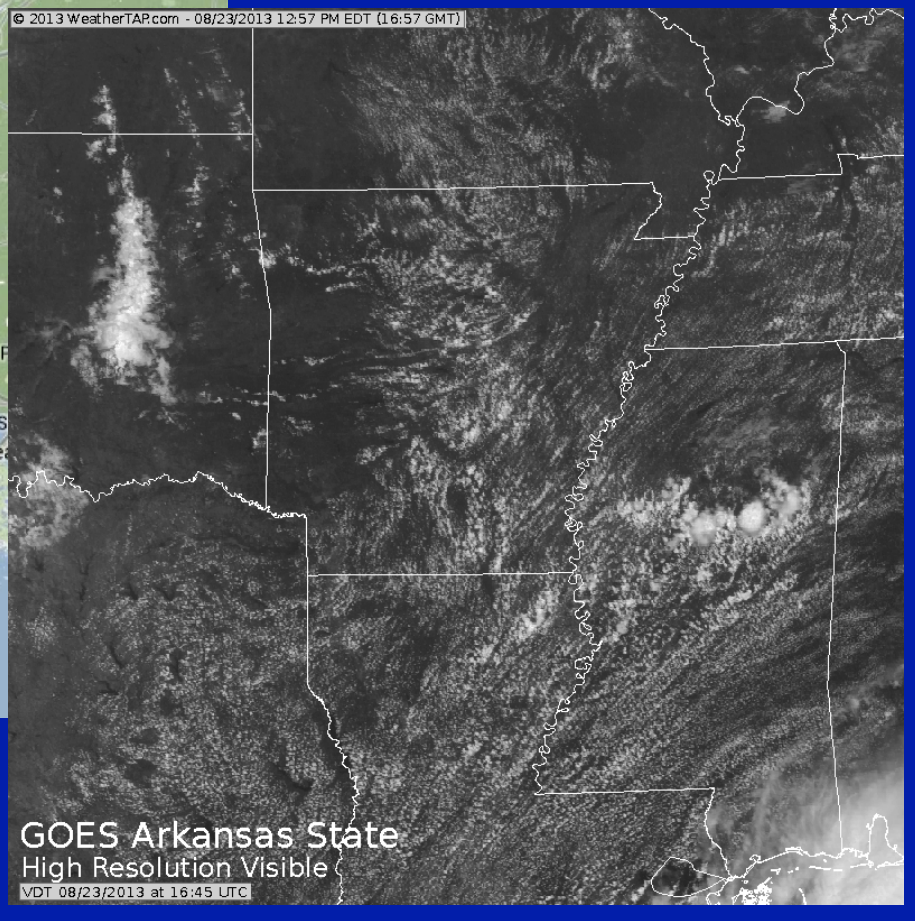
Froyd assessment

- **Lower trop fine mode vol x2-3 HIGHER than DC3**
- **Very clean UT – vol x2-3 LOWER than DC3: convection not as deep in SEAC4RS?**
- **Low dust abundance throughout mission except for Aug 9 transit flight**
- **Sampled background UT not strongly influenced by BB**

DC8-ER2 Coordination: August 23rd



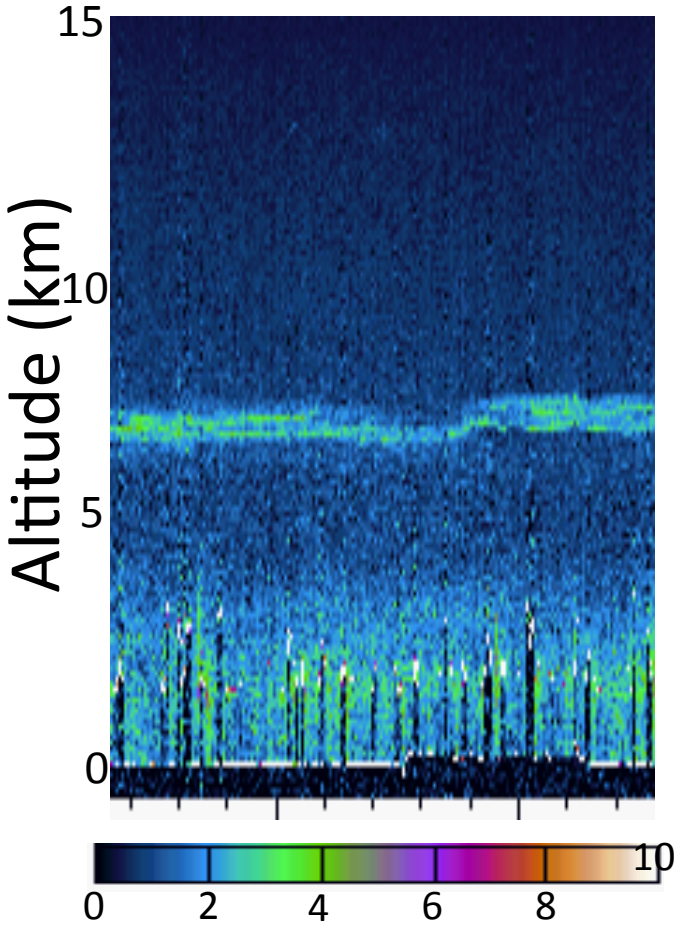
Watch biogenic region evolve
Capture gradients valley->forest
Sample regional storm w/Lear
Maximize DC8-ER2 overlap



"Day in the life of an Arkansas pressure cooker"

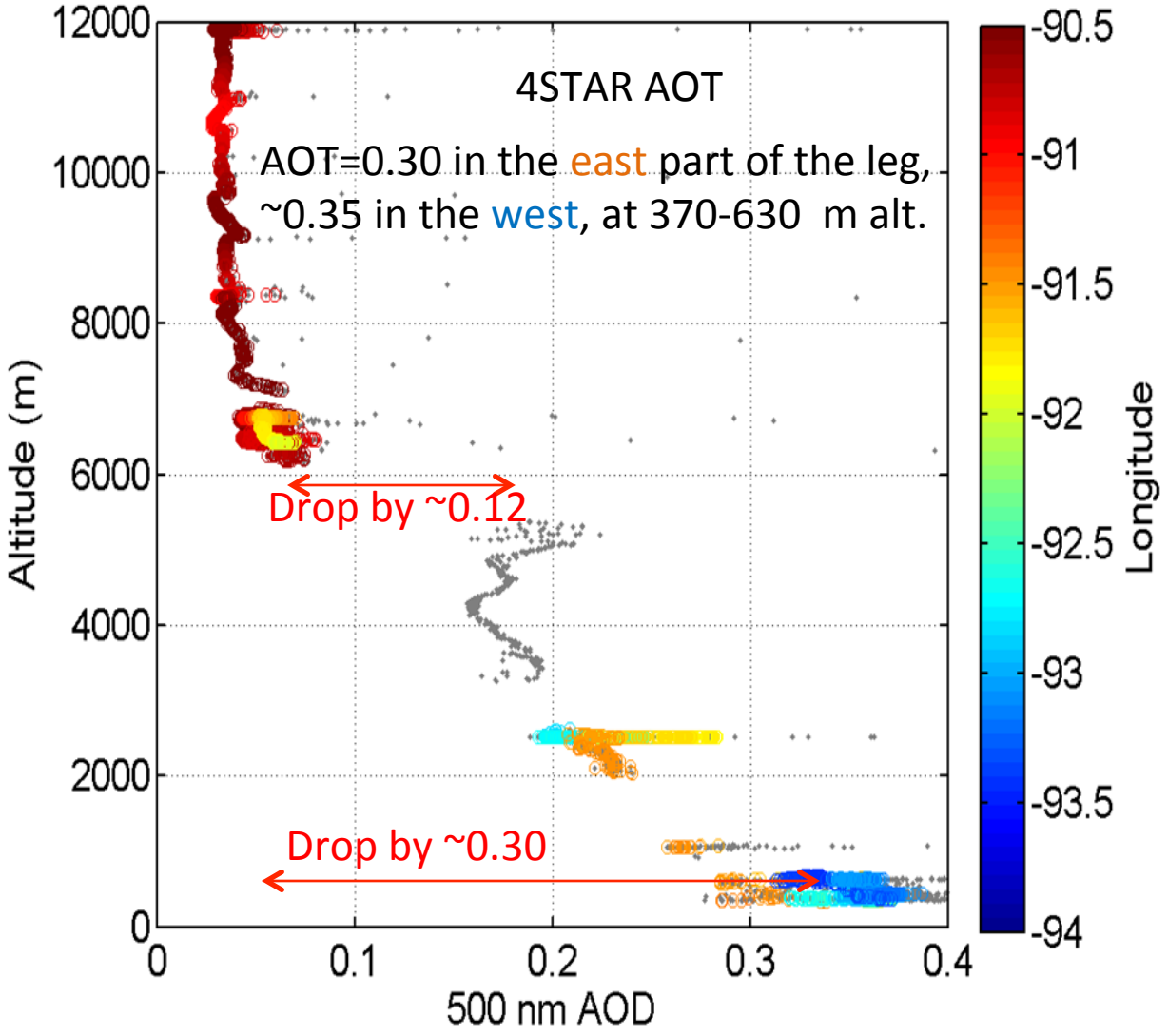
Aug 23:The vertical environment

AOT=0.22 PBL haze+0.12 smoke aloft



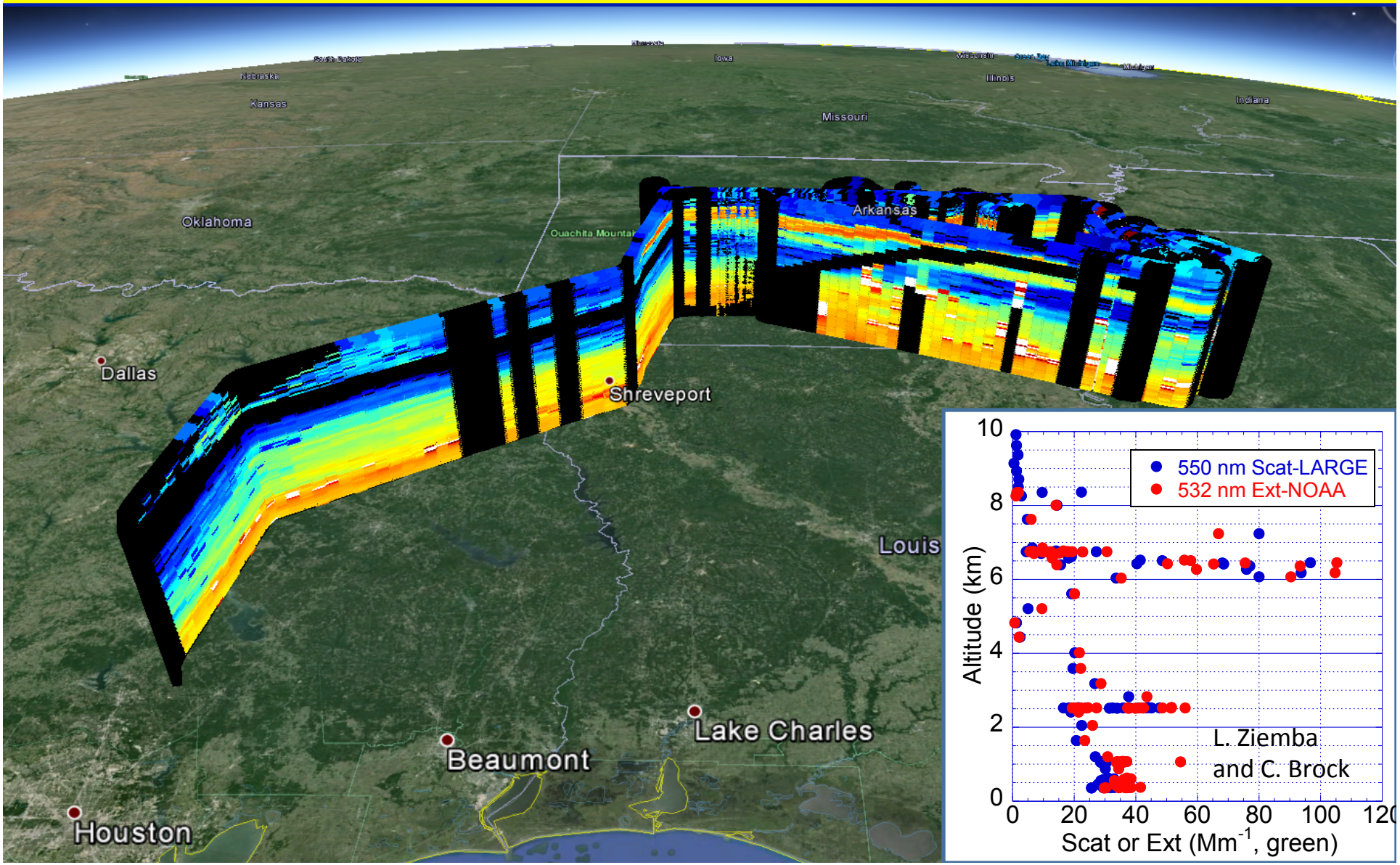
CPL Attenuated Backscatter
532 nm, 10^{-6} 1/m-sr

John York, GSFC



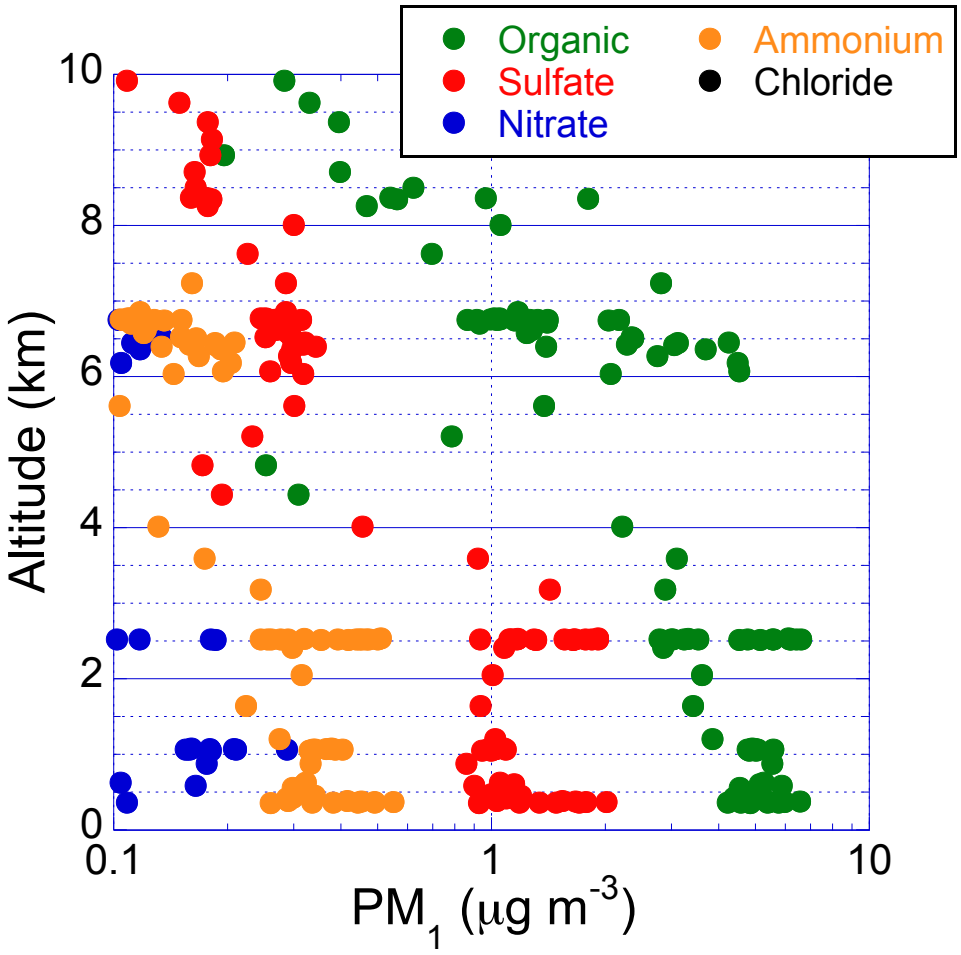
Yohei Shinozuka, Ames

Aug 23:
HSRL Perspective

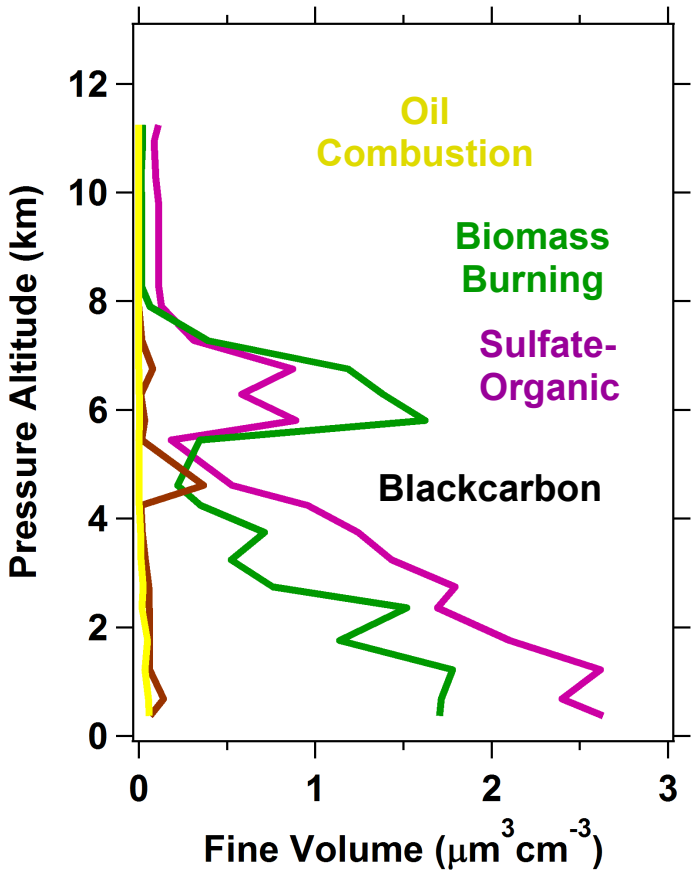


August 23rd-Chemistry

HR-ToF-AMS



NOAA PALMS

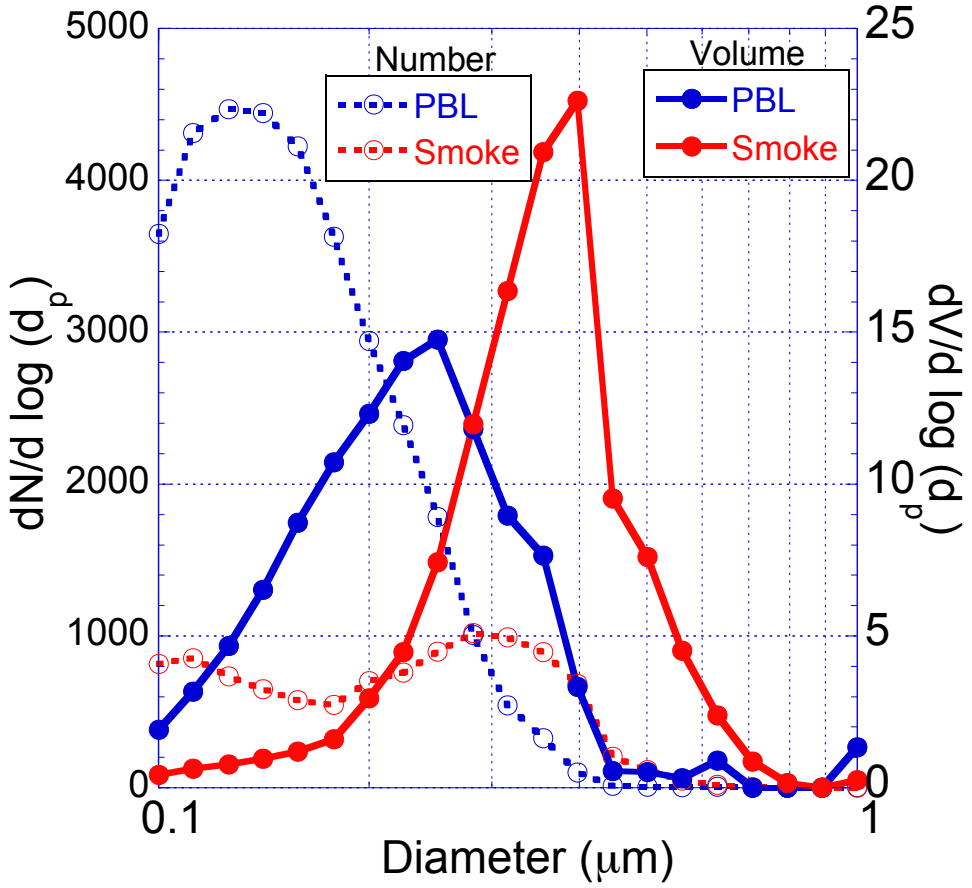


Data: Jimenez

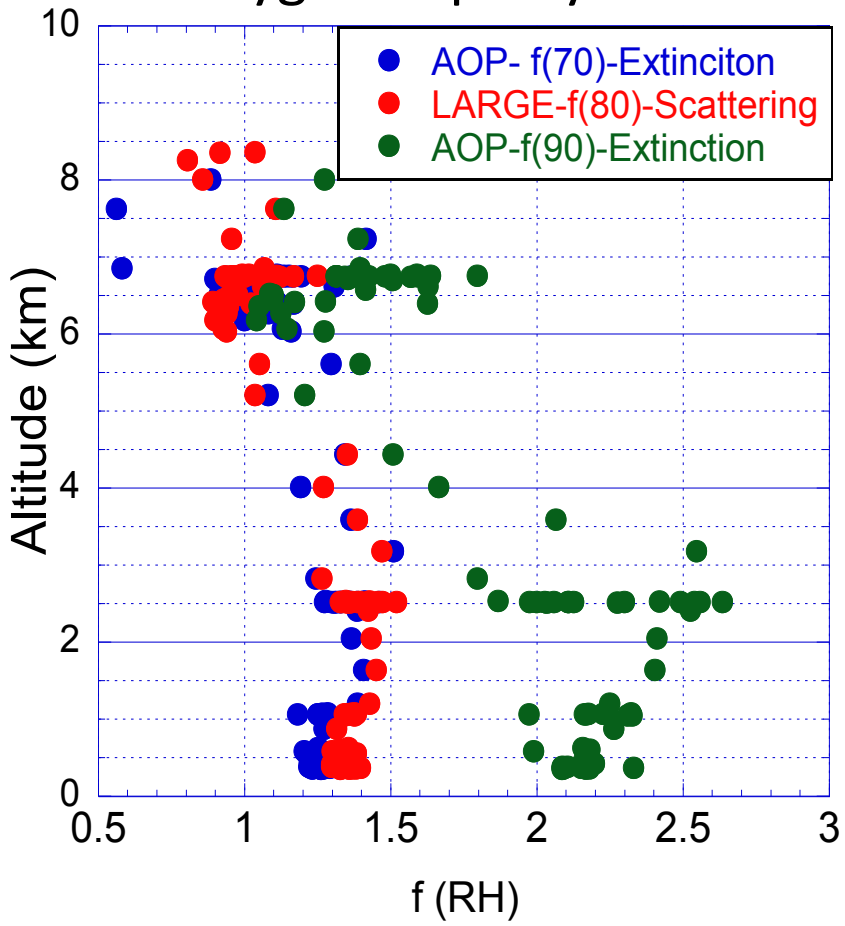
Plot: Froyd

Microphysics

Comparison of Layer Size



Extinction/Scattering Hygroscopicity



Data: LARGE/ Ziemba & AOP/Brock

Differential Aerosol Sizing and Hygroscopicity Spectrometer Probe (DASH-SP)

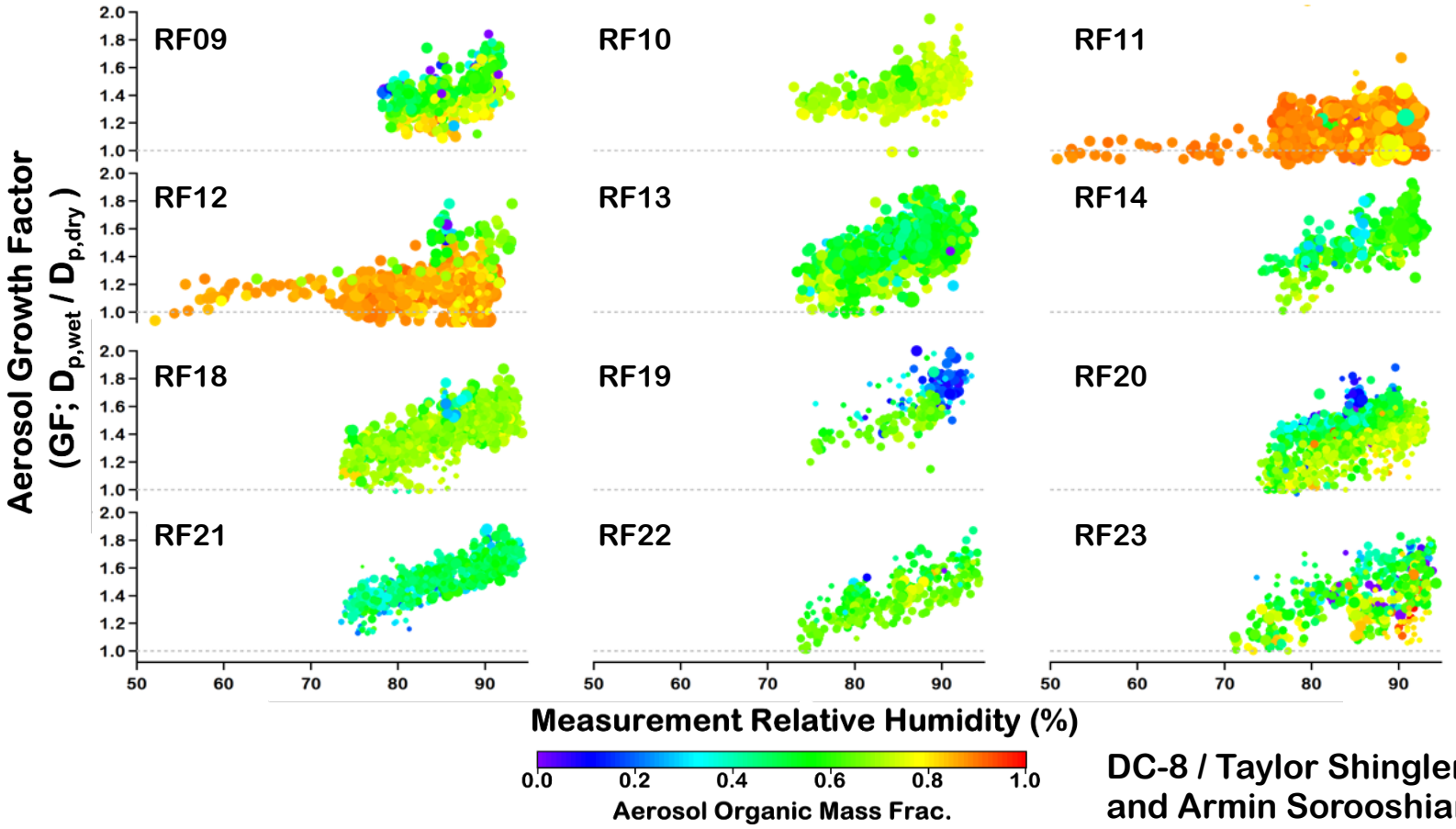
Instrument: DASH-SP
Measurement:
Monodisperse Aerosol Growth Factors

$$GF = \frac{D_{p,wet}}{D_{p,dry}}$$

Analysis of specific emission's impact on subsaturated water uptake of aerosols

(⇧⇩ = Increase/decrease in GF compared to background)

Aerosol Growth Factor vs. RH (Select Flights)



Wild Fires: ⇩
RF11
RF12

Ag Fires: ⇩
RF20
RF23

Urban: ⇧
RF19
RF20

Biogenics: ⇩
RF10
RF18

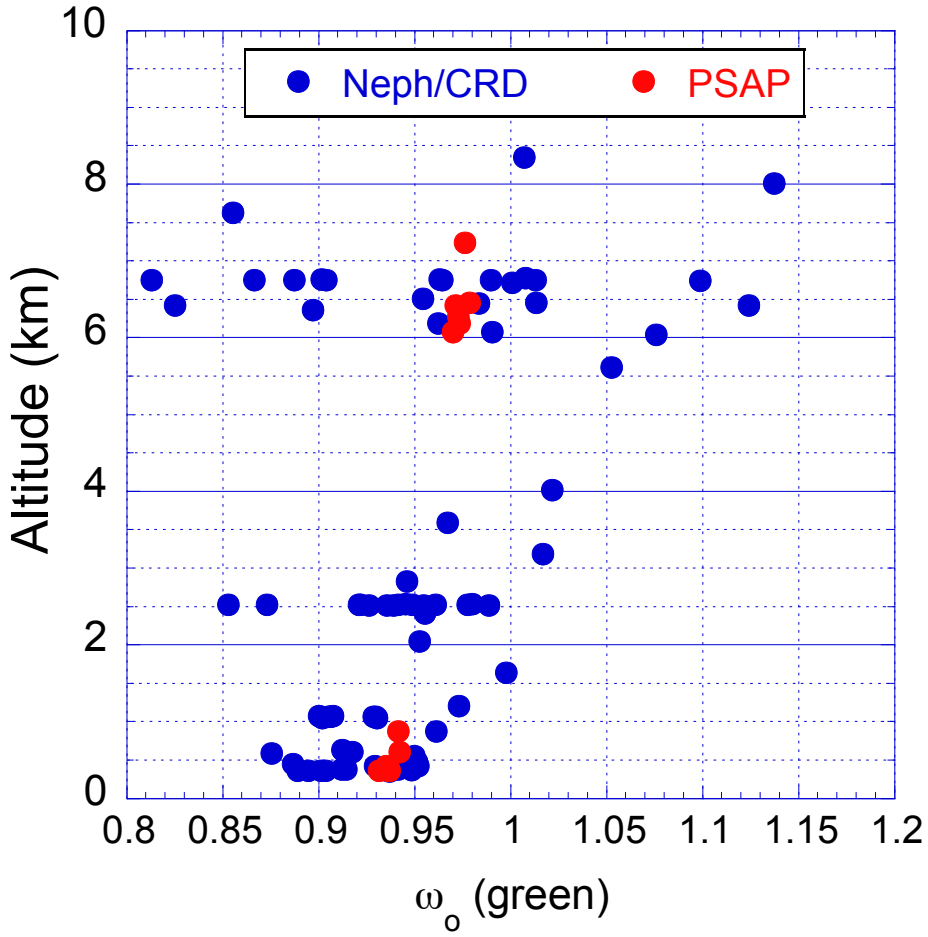
Marine: ⇧
RF19
RF21

DC-8 / Taylor Shingler, Ewan Crosbie, and Armin Sorooshian

How about absorption?

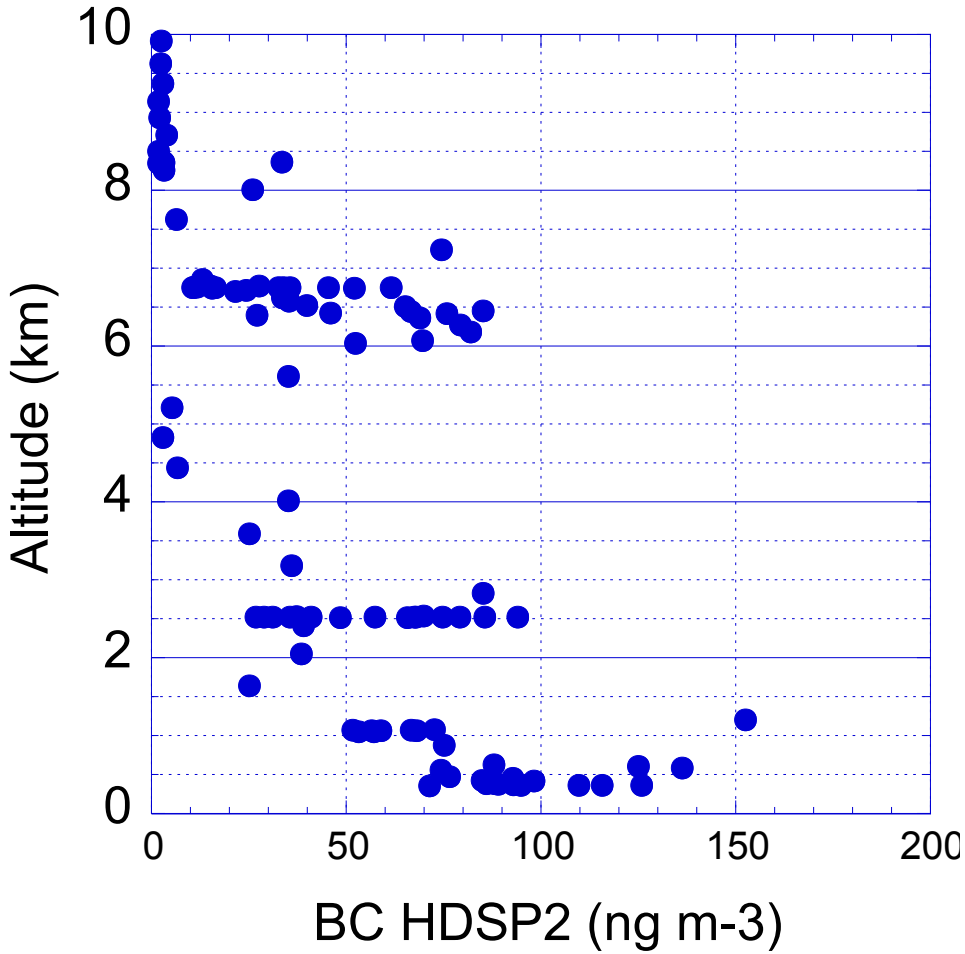
Needs lots of processing, and counter-intuitive results but is consistent between instruments

Single Scattering Albedo



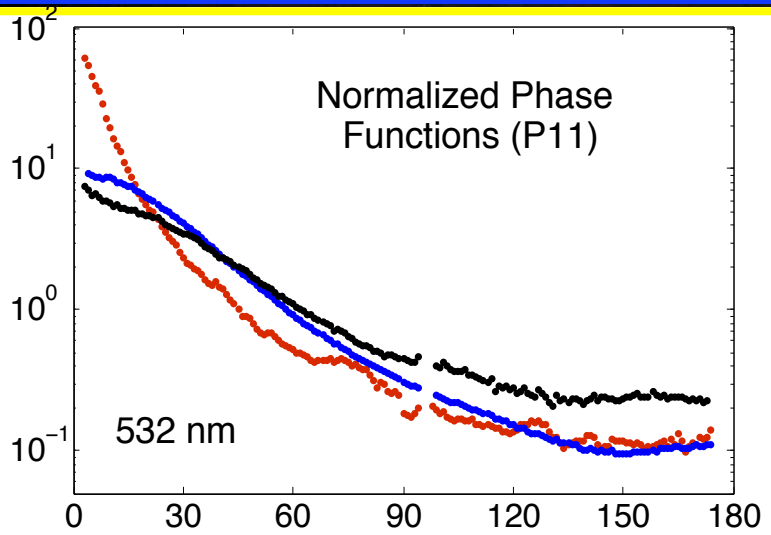
Data: LARGE/ Zembia & AOP/Brock

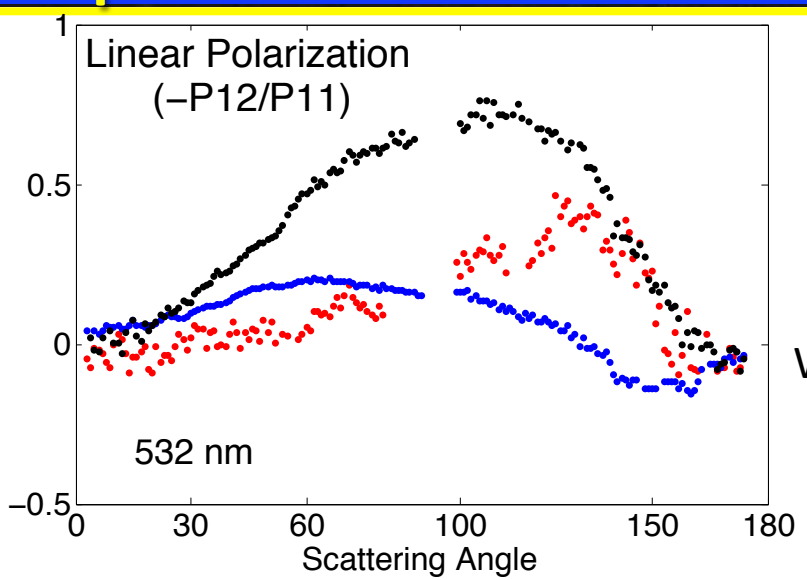
Black Carbon Concentration



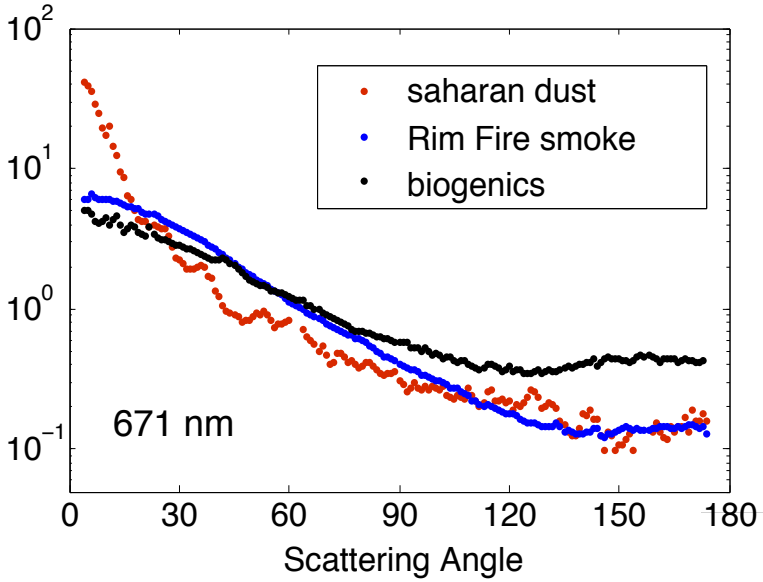
Data: Schwartz

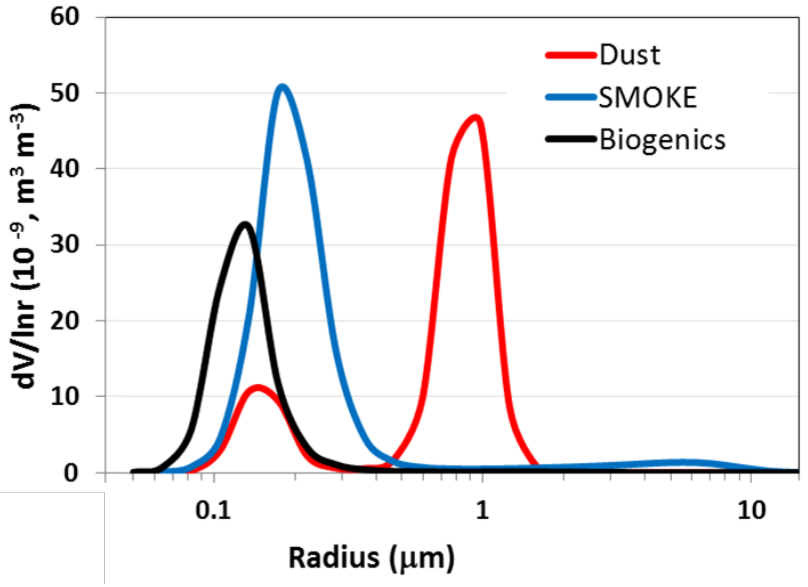
UMBC Polar Nephelometer
Now we have phase functions!





J.V. Martins
W.R. Espinosa
F.D. Orozco
L.A. Remer

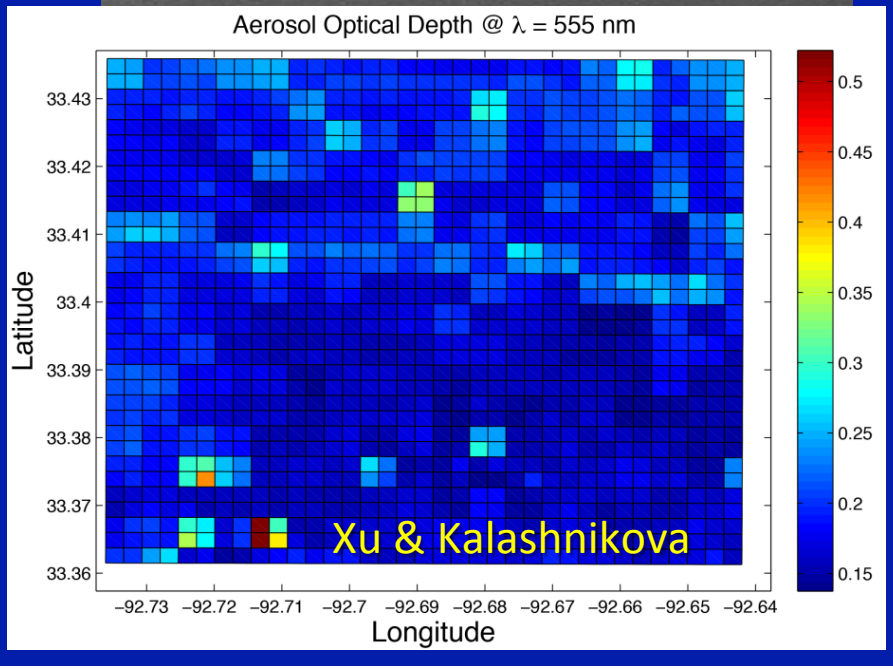




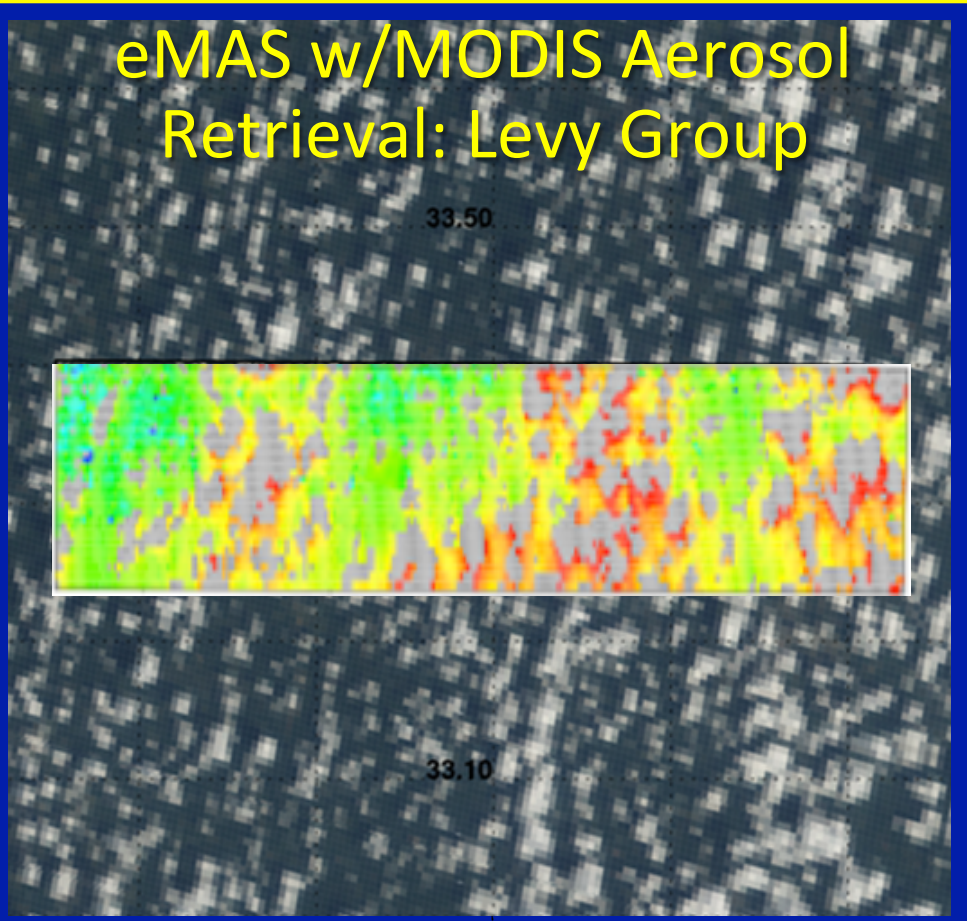
Size distributions retrieved from P11 using Dubovik retrieval

Remote Sensors.
Partly cloudy environments

AirMISPI, Spectral Loop:Garay

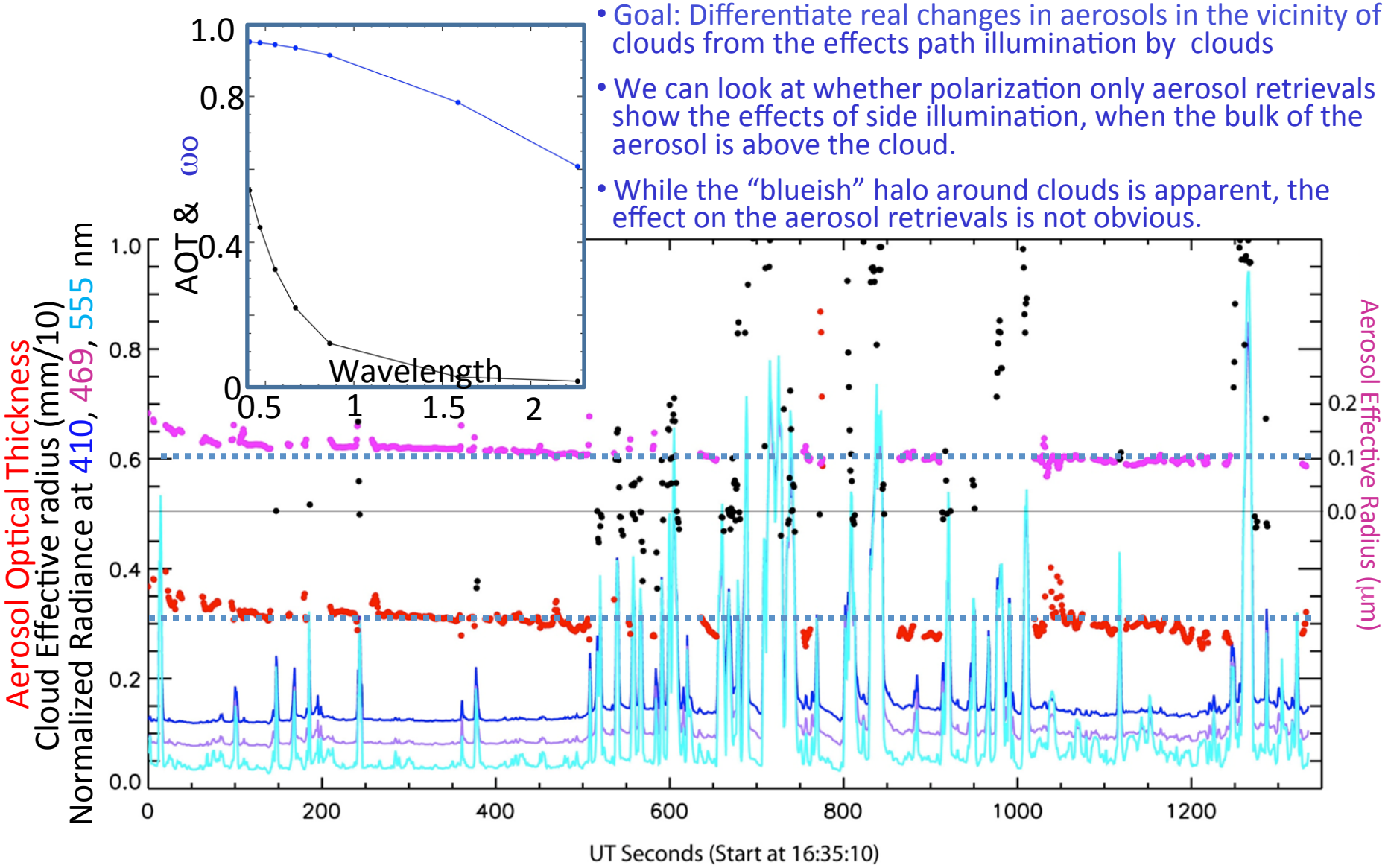


eMAS w/MODIS Aerosol Retrieval: Levy Group



Haloes and Polarimeters
RSP Case for August 23rd.

- Goal: Differentiate real changes in aerosols in the vicinity of clouds from the effects path illumination by clouds
- We can look at whether polarization only aerosol retrievals show the effects of side illumination, when the bulk of the aerosol is above the cloud.
- While the "blueish" halo around clouds is apparent, the effect on the aerosol retrievals is not obvious.



Summing Up/Post Morten

- Strategically SEAC^{4}RS was a good mission, with an excellent payload.
- Mission was conducted on the edge of an improving air quality trend, with a significant regime change starting in 2008.
- There was significant variability in AOT due to most major aerosol speciers, some of which was captured by the aircraft.
- Tactically, merging radiation and chemistry was a challenge in the field, largely to the detriment of radiation.
- We had many silver and bronze days, but it is not yet clear if we have any golden days for radiation. But, SEAC4RS nevertheless developed a benchmark dataset-particularly for mixed aerosol-cloud scenes. There will be a lot of hand analyses.
- There are a few surprises being found in the data, and there is still significant potential in using SEAC4RS as an opportunity to bridge