HSRL-2 observations of aerosol variability during an aerosol build-up event in Houston and comparisons with WRF-Chem

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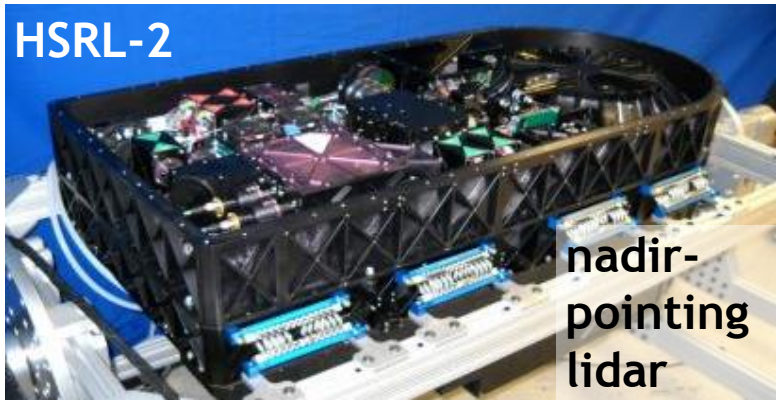
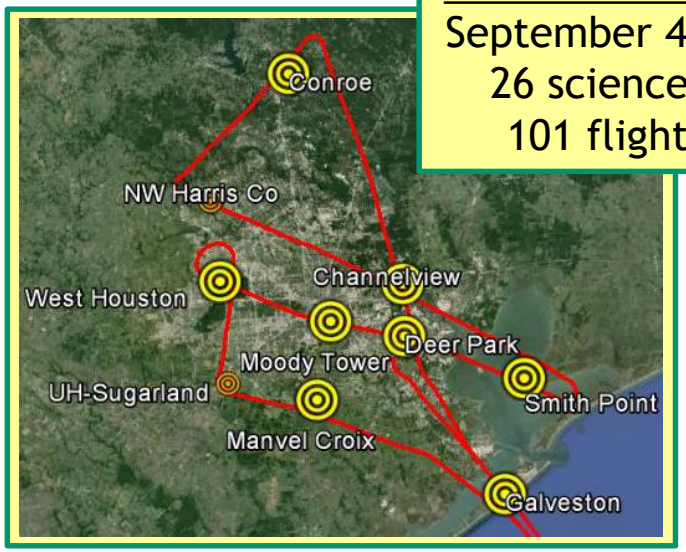
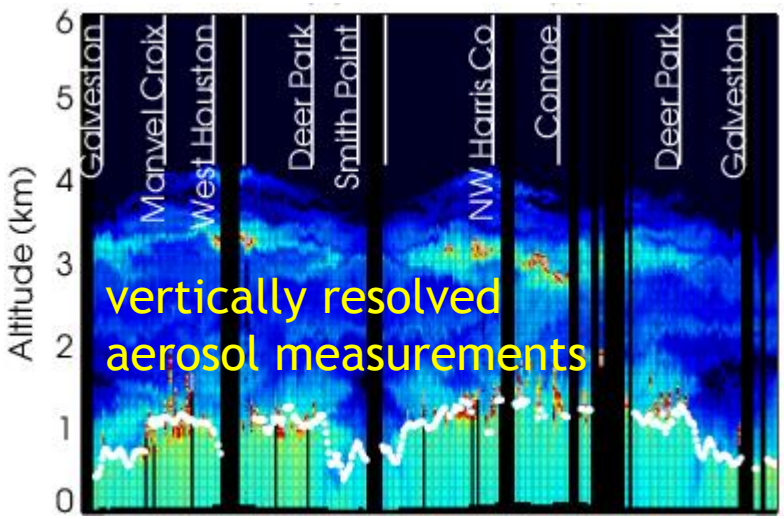
[4]Science Systems and Applications, Inc., Hampton VA
[5]Lord Fairfax Community College, Middletown VA

High Spectral Resolution Lidar, HSRL-2



DISCOVER-AQ Houston
September 4-27, 2013
26 science flights
101 flight hours

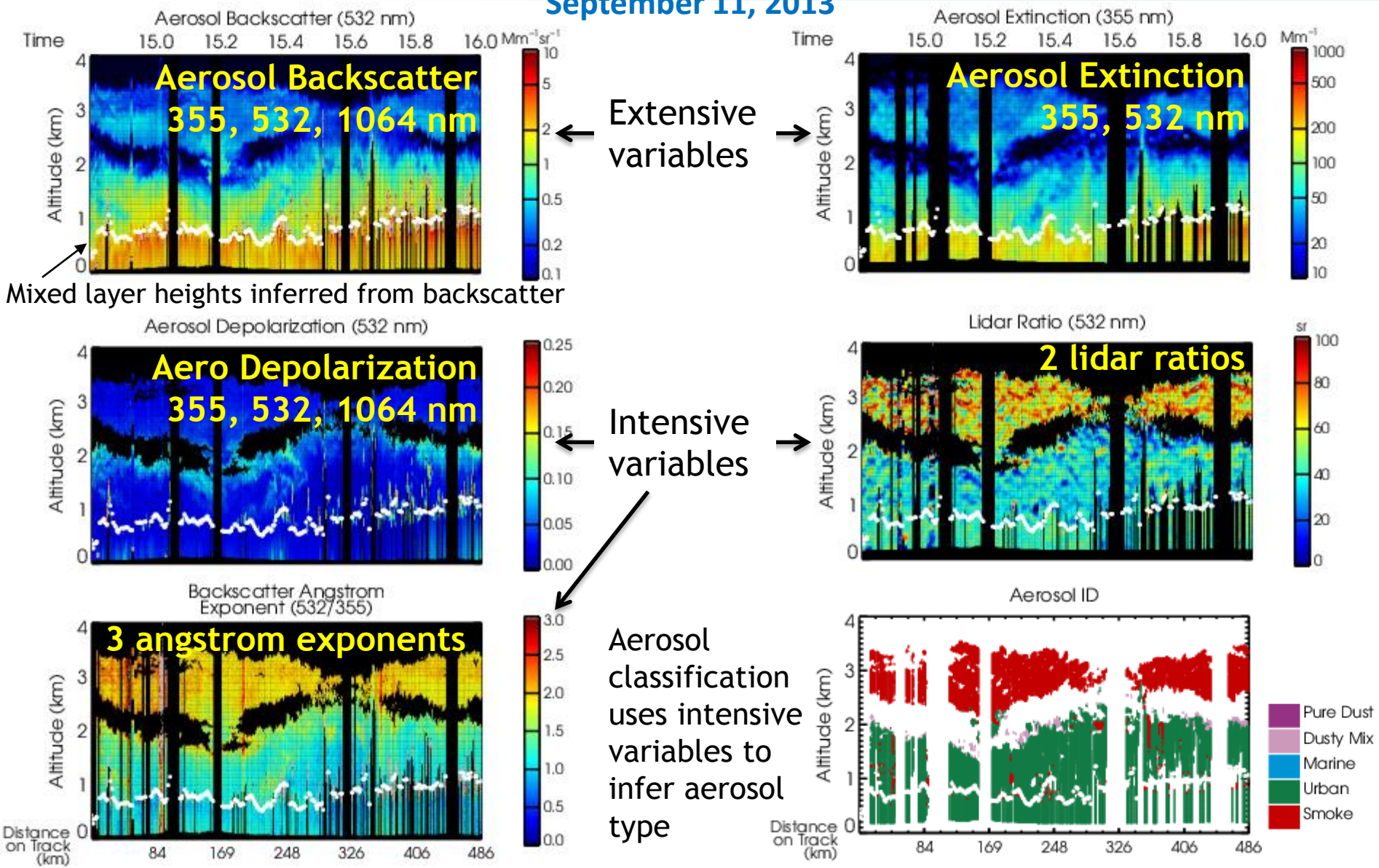




High Spectral Resolution Lidar 2 —

- measures profiles of aerosol optical properties at 3 wavelengths
- Flew on DAQ California, Houston, and Colorado

HSRL-2 measurement products

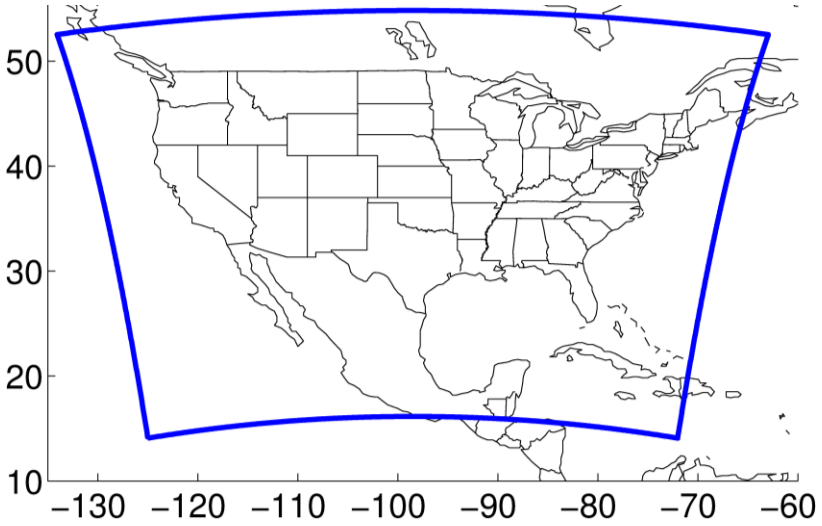


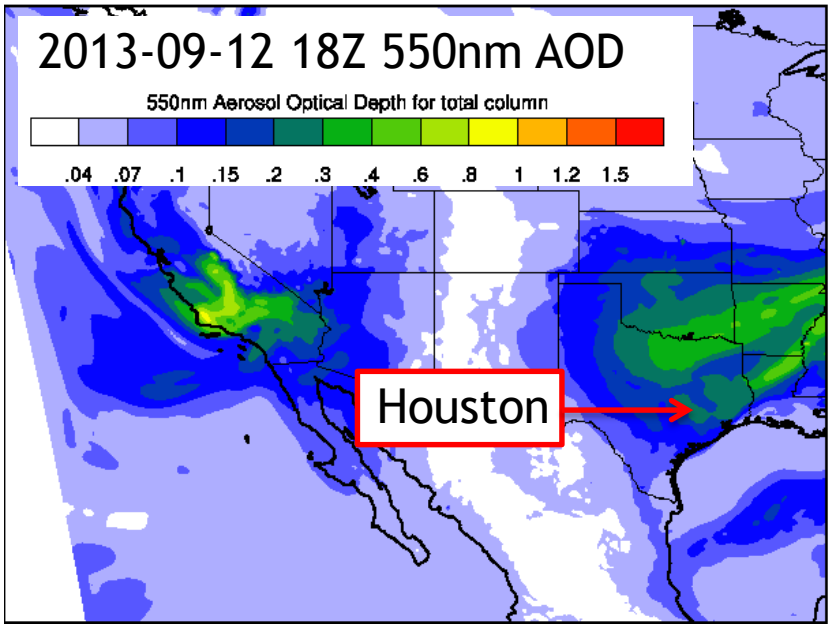
WRF-Chem Forecasting

WRF-Chem model run performed by Pablo Saide, U. Iowa, for the SEAC4RS campaign, to provide guidance for flight planning and evaluate model in near-real time

Domain includes the DISCOVER-AQ Houston campaign as well

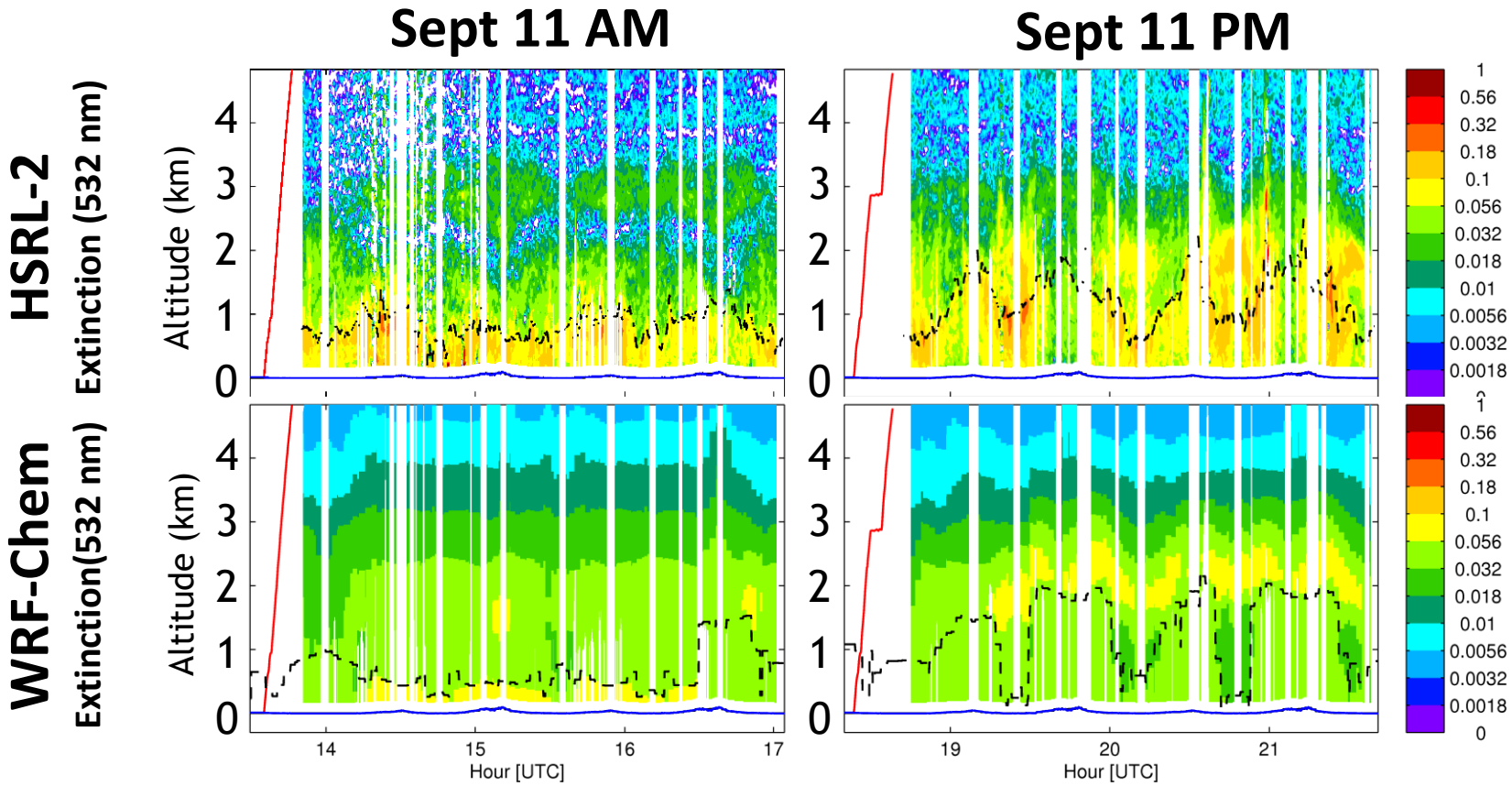
- WRF-Chem v3.5 CBMZ, 4bin MOSAIC, 12km dx, 52 vertical lvls, and WRF-tracer for emission regions/sectors
- Emissions: anthropogenic, biomass burning (FINN, QFED2) with plume-rise, MEGAN biogenics, dust & sea-salt. MACC boundary conditions
- AOD assimilation (NRL product) every 3 hours, 1 cycle a day (Saide et al., ACP 2013)



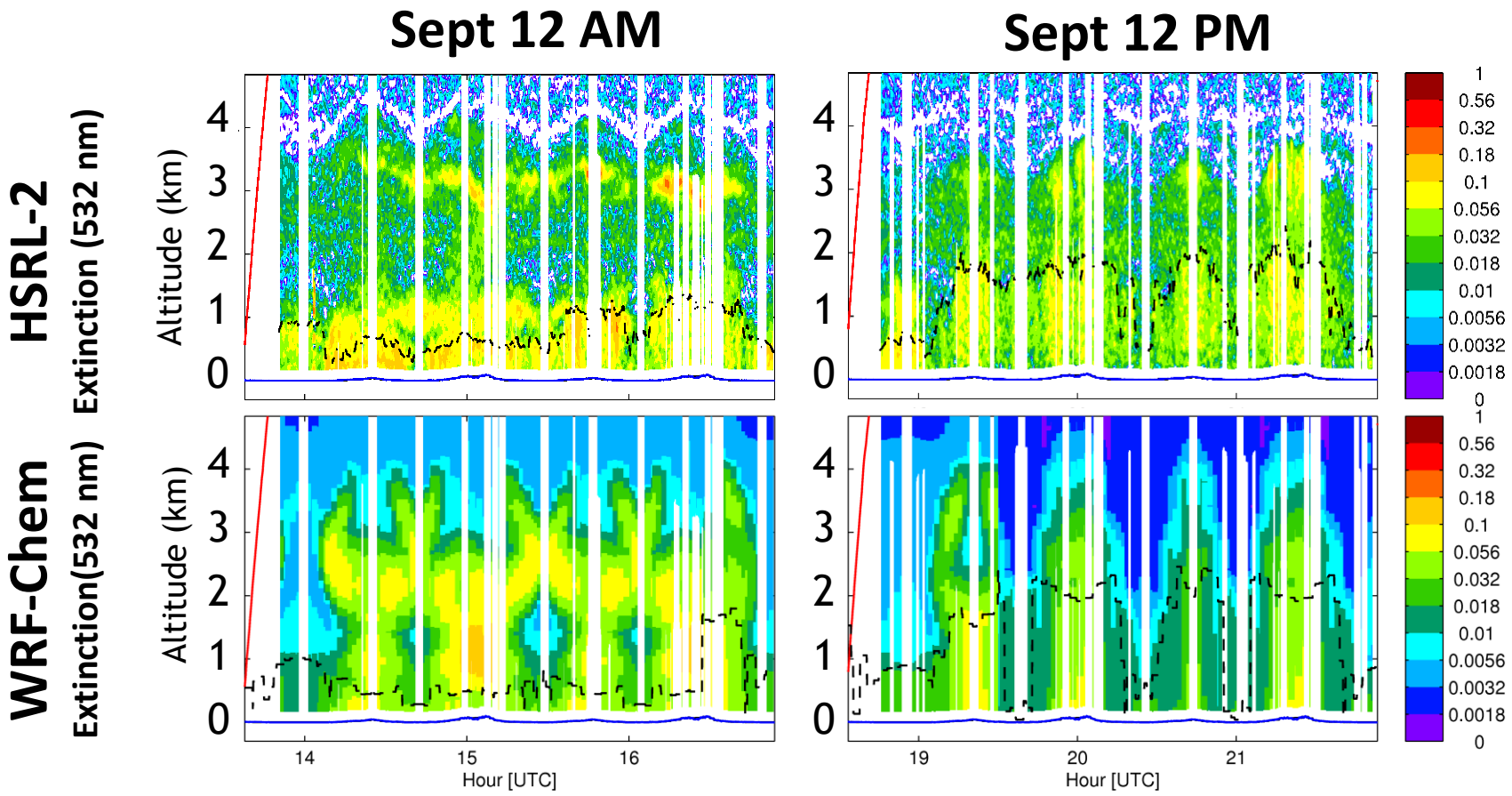


Day by day extinction comparison

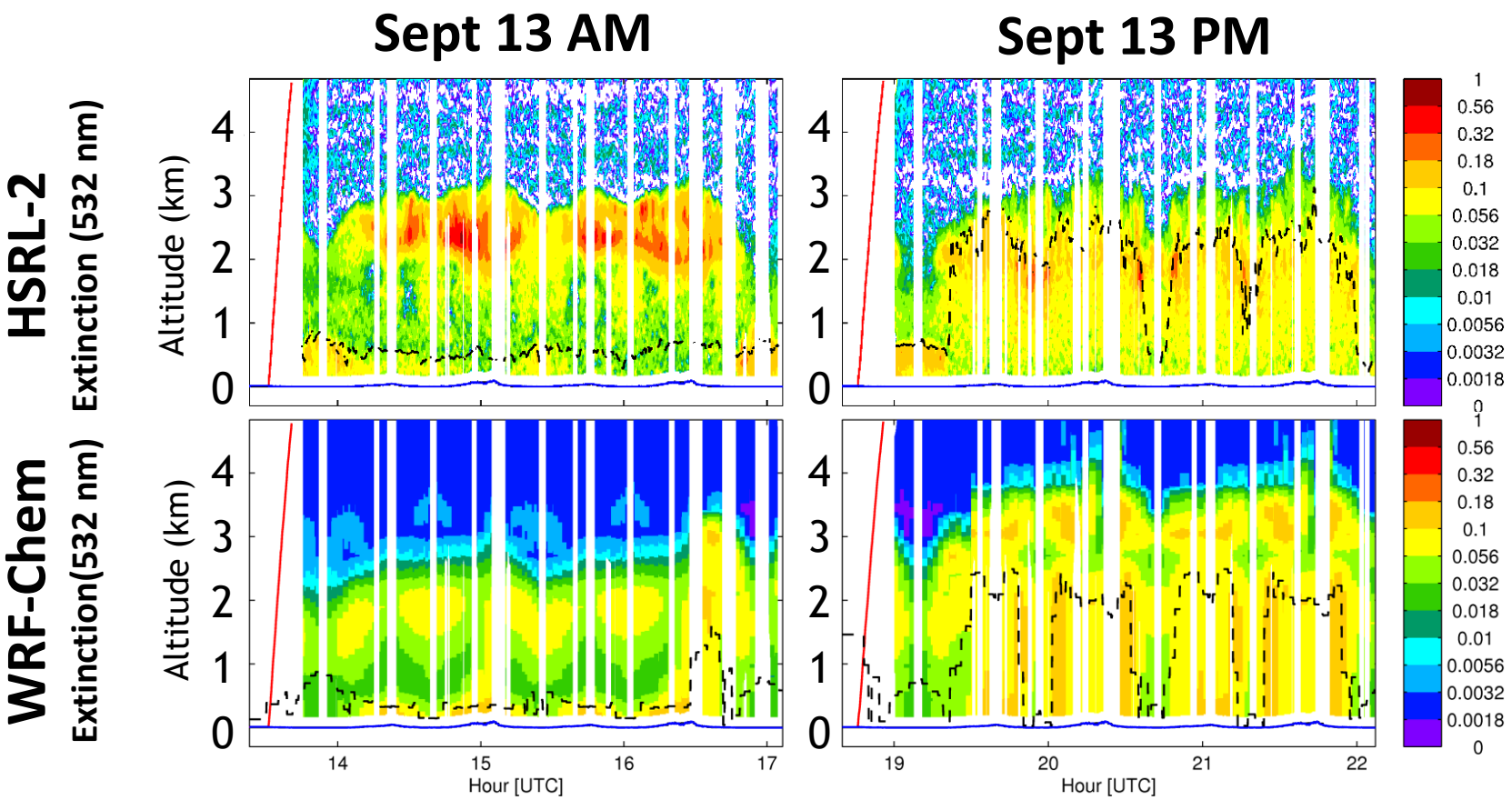
Extinction comparison, lidar vs. model



Extinction comparison, lidar vs. model

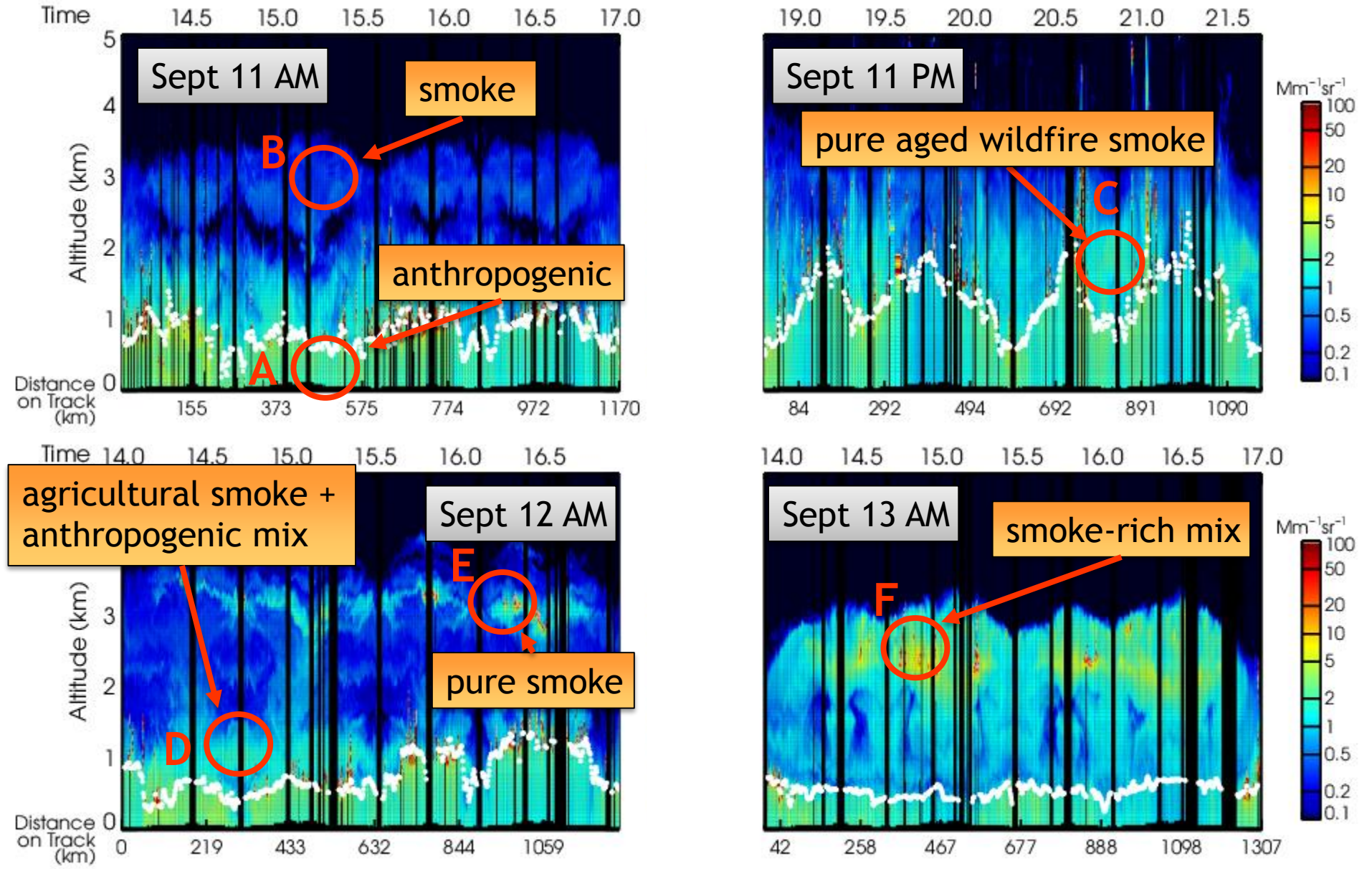


Extinction comparison, lidar vs. model



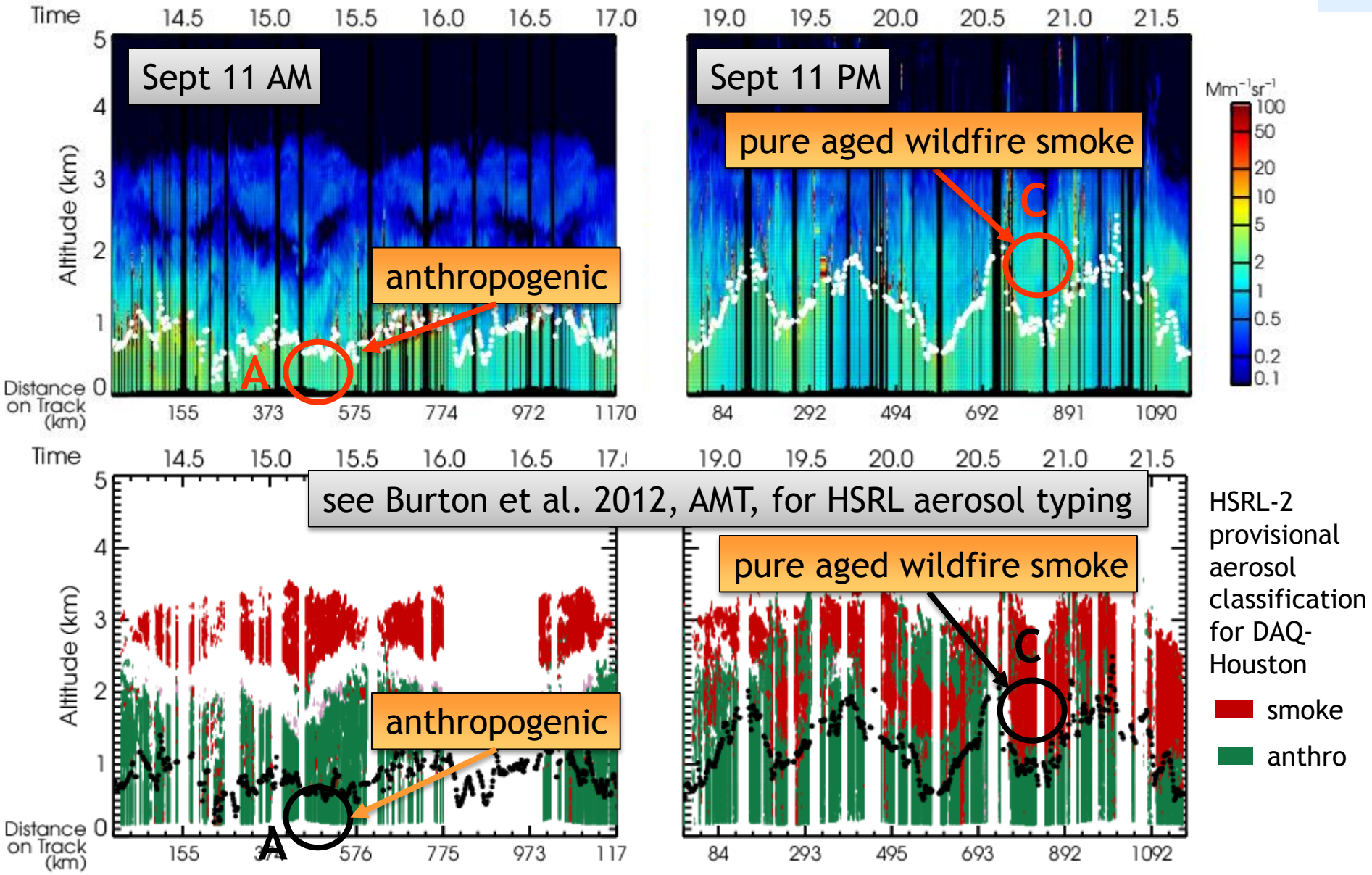
Insights about aerosol source & type

Aerosol source and type, 6 example layers



Anthropogenic vs. Smoke
A vs. C

Anthropogenic vs. Smoke: A vs. C



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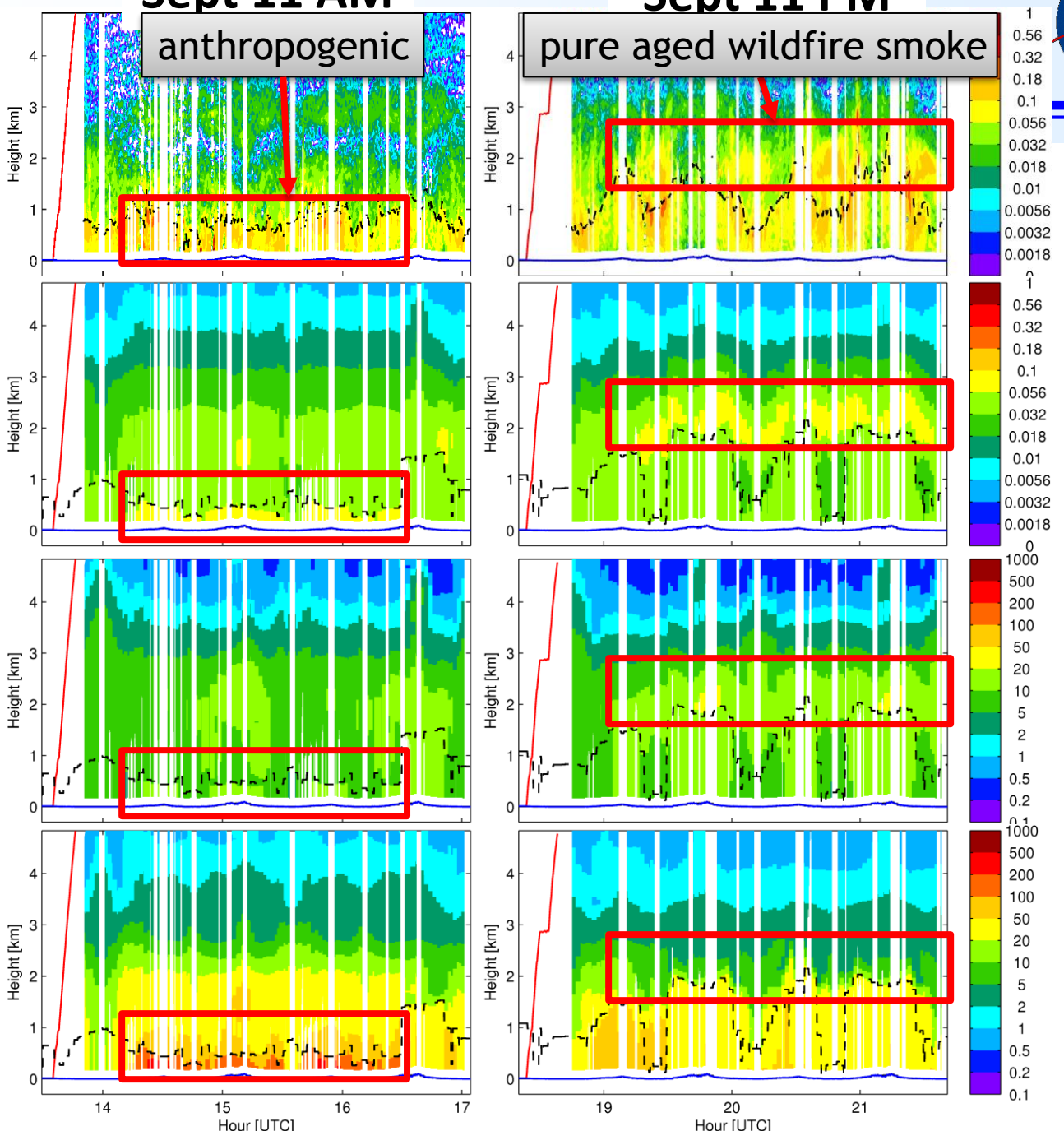
NASA

WRF-Chem Tracers



WRF-Chem Backtrajectories

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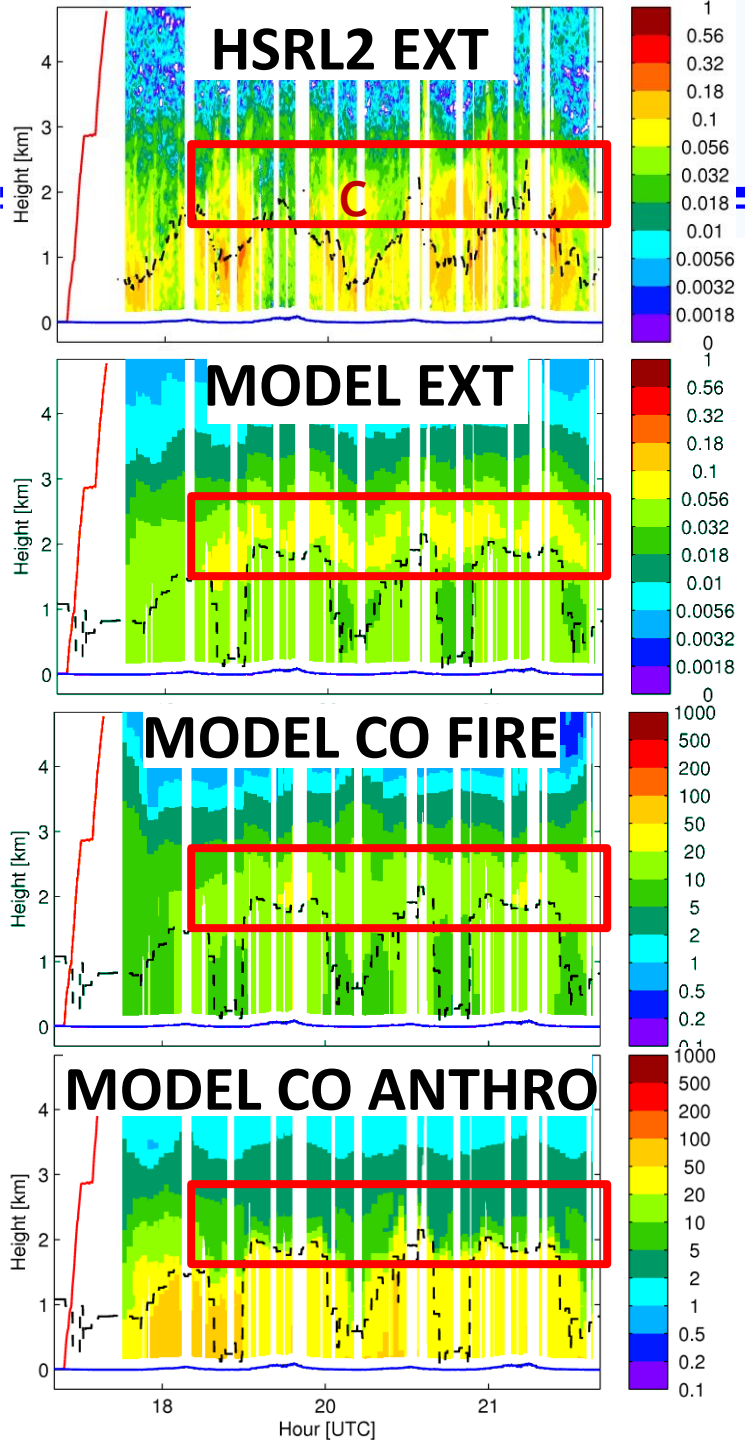
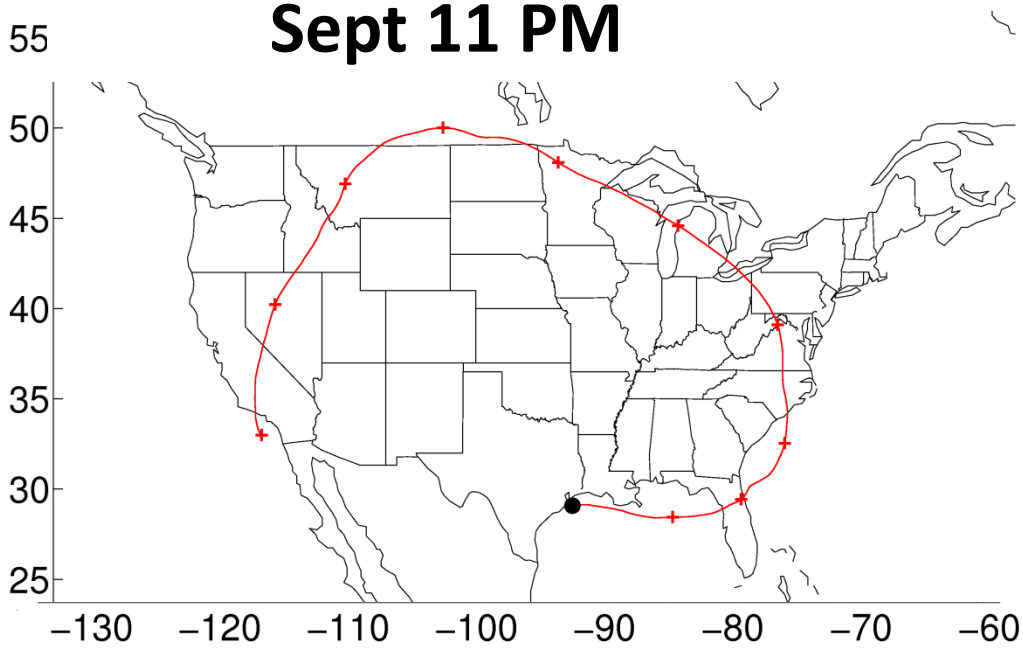
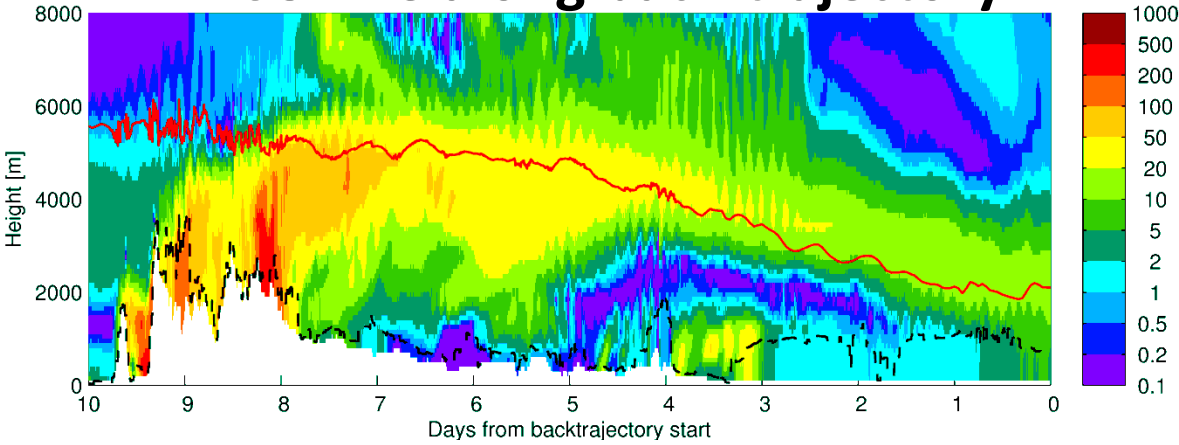


Sept 11 PM

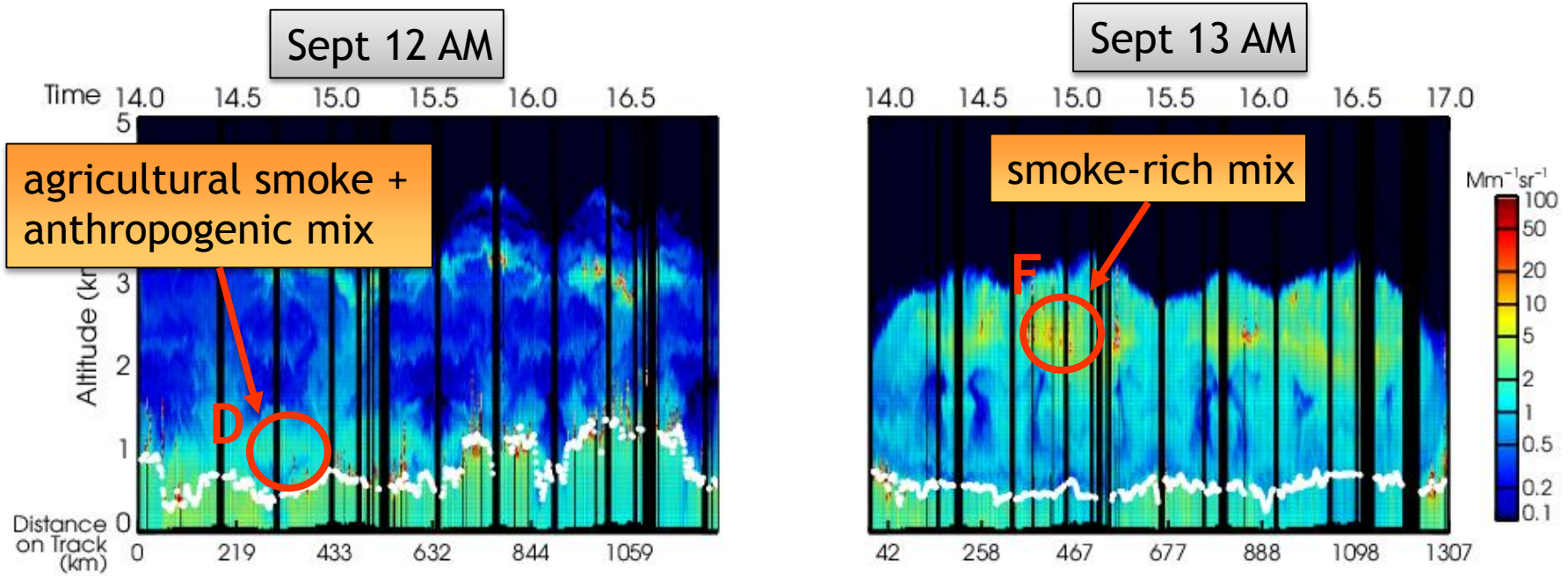


CO Fire along back-trajectory



Mixtures of Agriculture Smoke and Anthropogenic
D vs. F

Mixtures of Agriculture Smoke and Anthropogenic: D vs. F



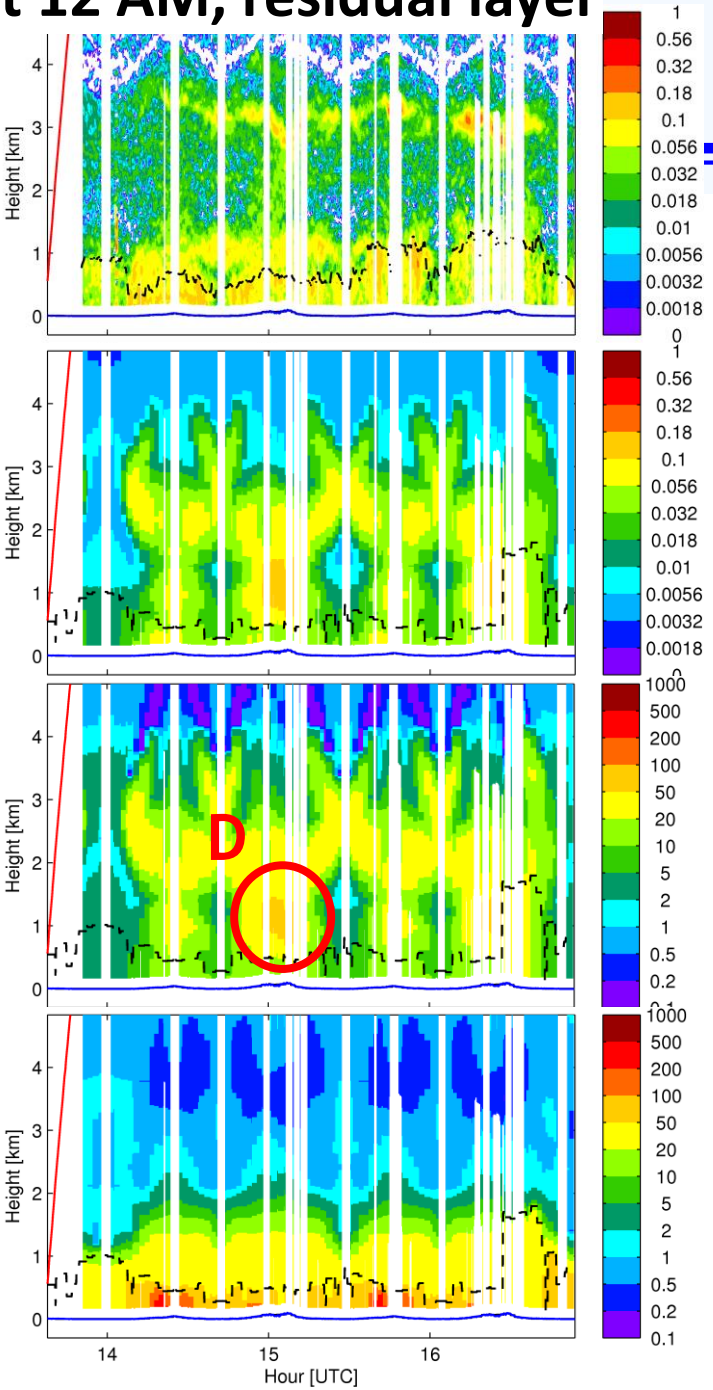
Sept 12 AM, residual layer

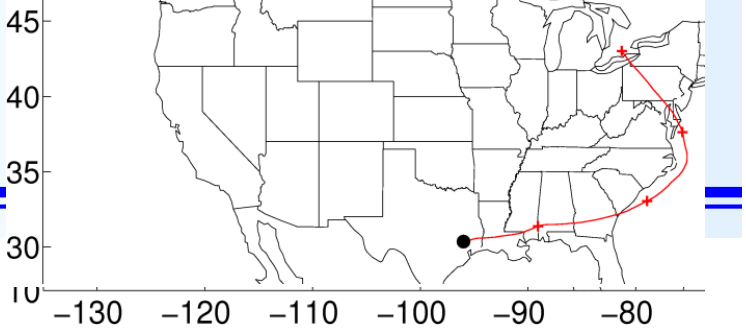
HSRL2 EXT

MODEL EXT

MODEL CO FIRE

MODEL CO ANTHRO





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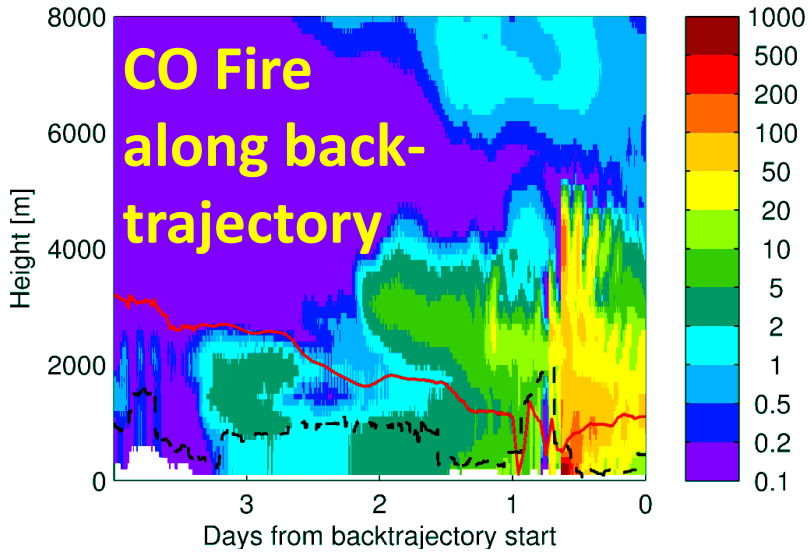

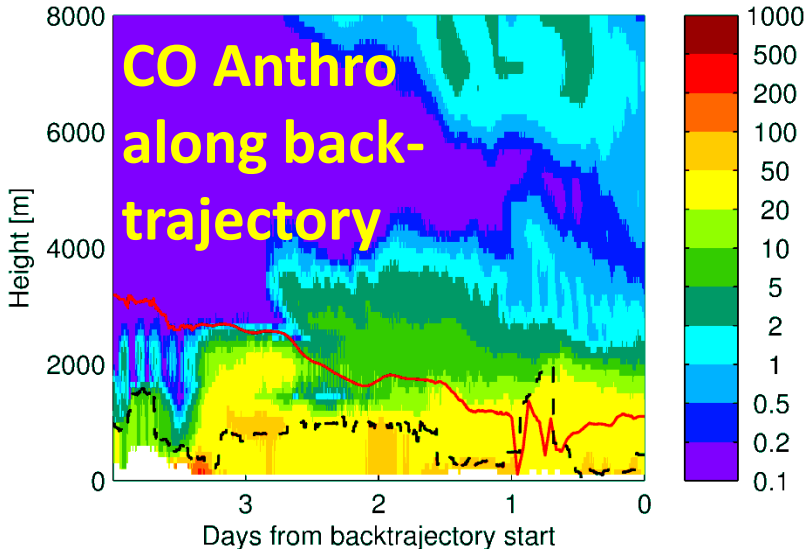

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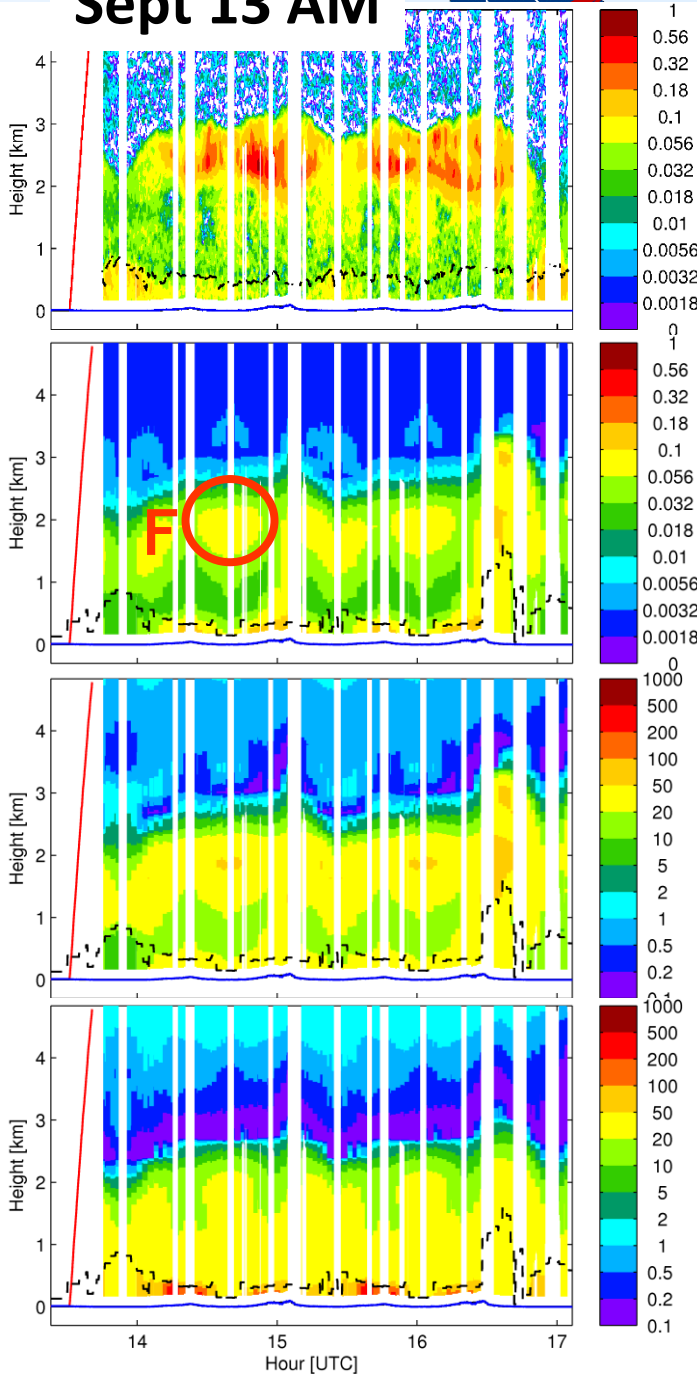
Sept 13 AM

HSRL2 EXT

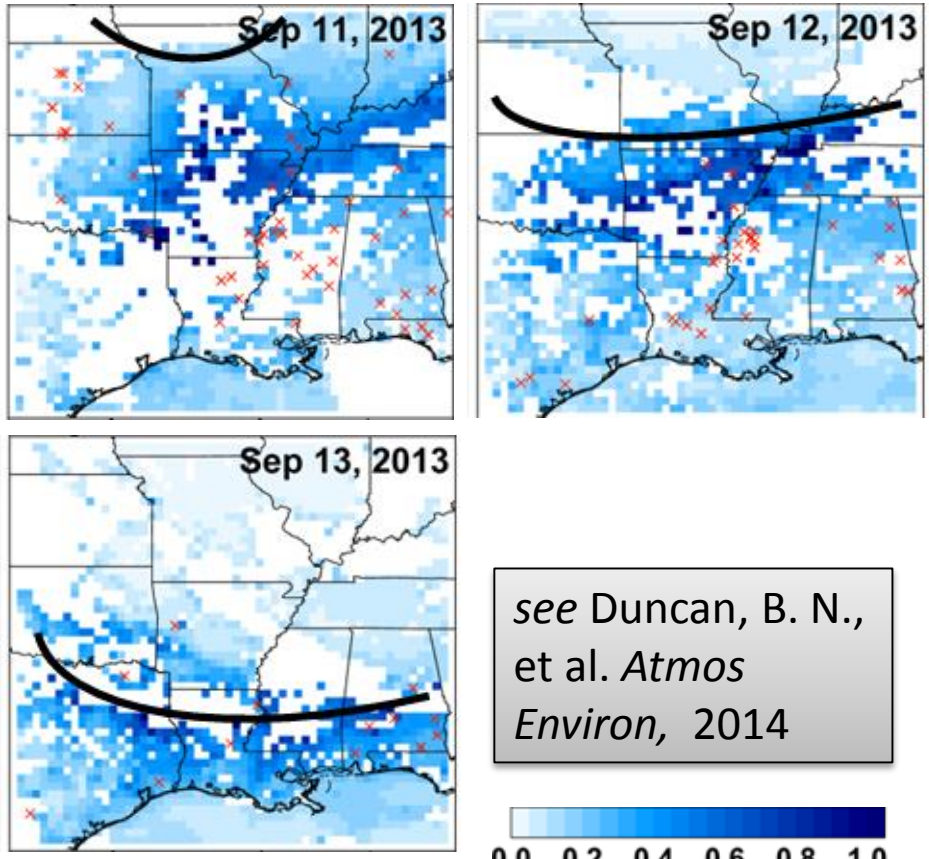
MODEL EXT

MODEL CO FIRE

MODEL CO ANTHRO

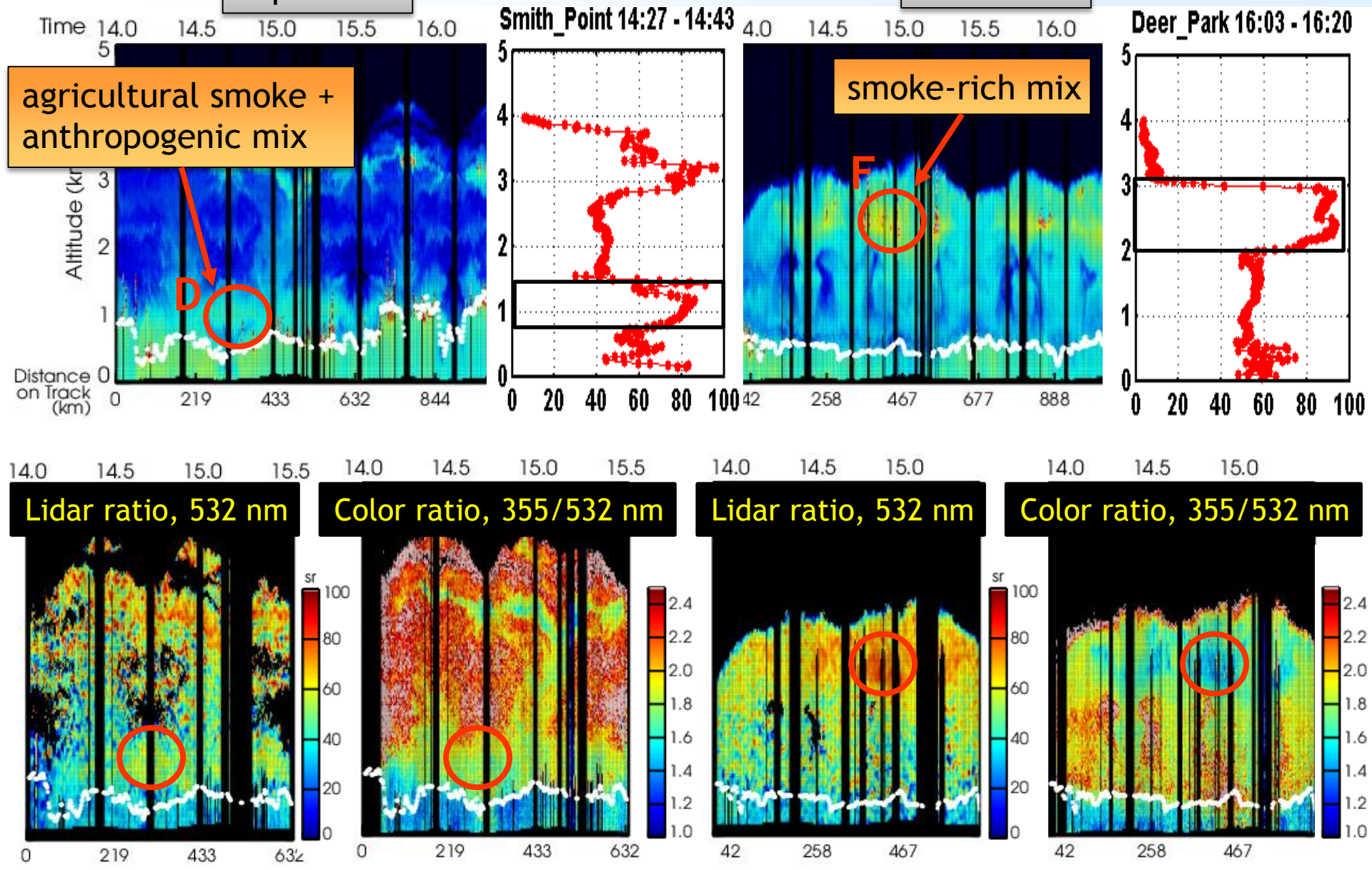


NPP VIIRS AOD



see Duncan, B. N., et al. *Atmos Environ,* 2014

HSRL-2 Intensive Properties



Effect of Relative Humidity on lidar intensive properties: setup and assumptions

- Diameter-independent growth factor:

$$D_{amb} = g * D_{dry}$$

the entire size distribution simply shifts to larger diameters as the particles grows.

- Correction is applied to both real and imaginary parts of refractive index following:

$$m_{amb} = \frac{m_{dry} + m_{H2O}(g^3 - 1)}{g^3}$$

- Growth factor function of RH from Petters and Kreidenweis (2007):

$$g = \left(1 + \kappa \frac{RH}{100\% - RH}\right)^{\frac{1}{3}}$$

where κ is the effective hygroscopicity parameter which captures all solute properties.

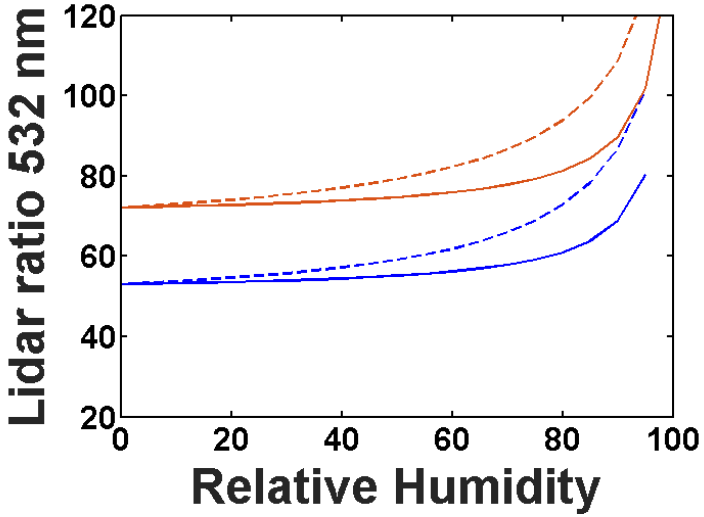
Less hygroscopic ← $0 \leq \kappa \leq 1$ → More hygroscopic

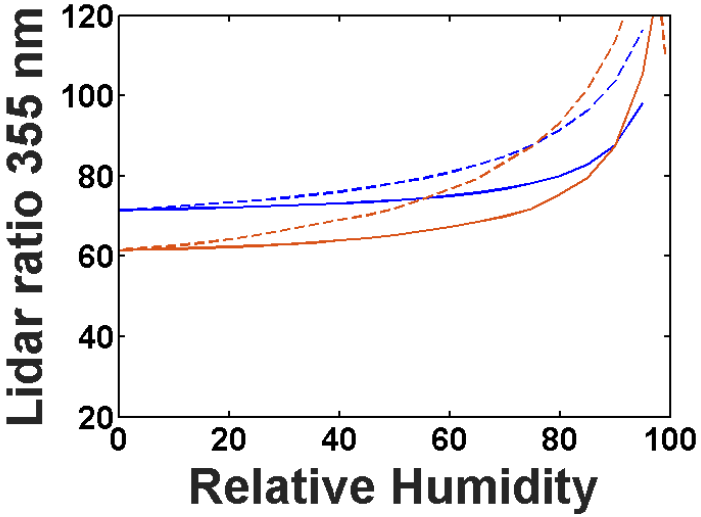
Continental aerosols: $\kappa = 0.27 \pm 0.21$

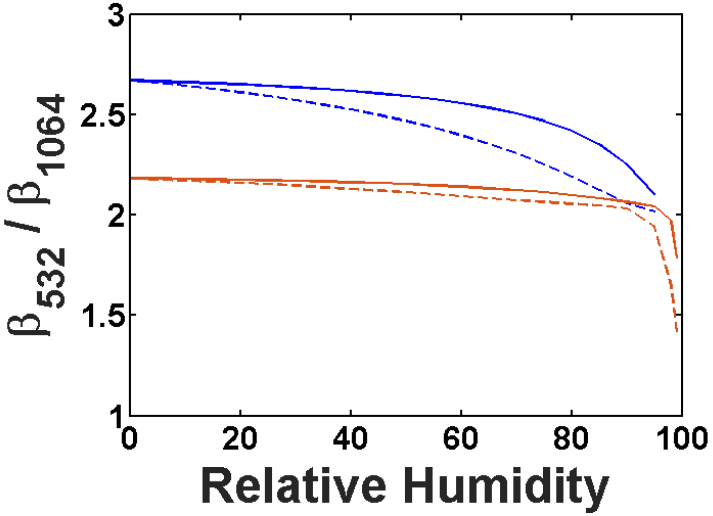
Clean marine aerosols: $\kappa = 0.72 \pm 0.24$ (Pringle et al., 2010, ACP)

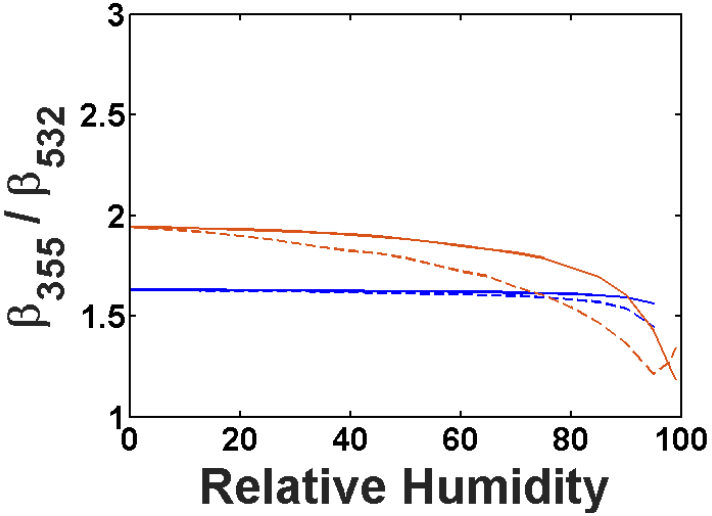
Agricultural smoke: $\kappa = 0.2$ (Rose et al., 2010, ACP)

Lidar intensive properties: effect of Relative Humidity







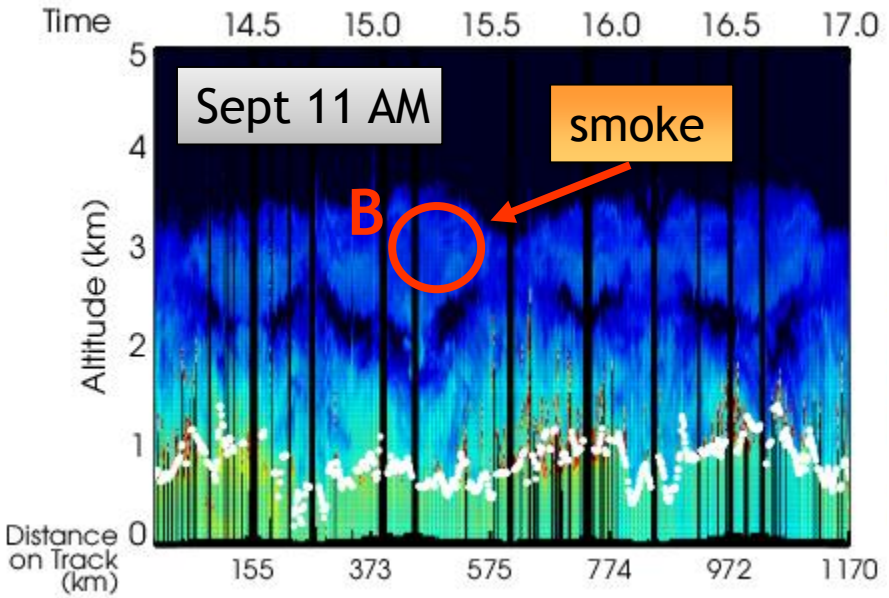


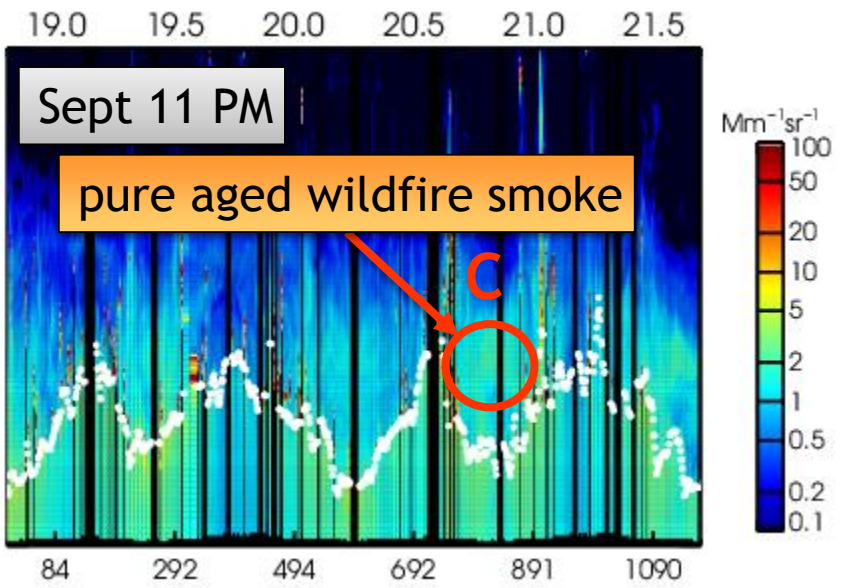
κ=0.1
κ=0.3

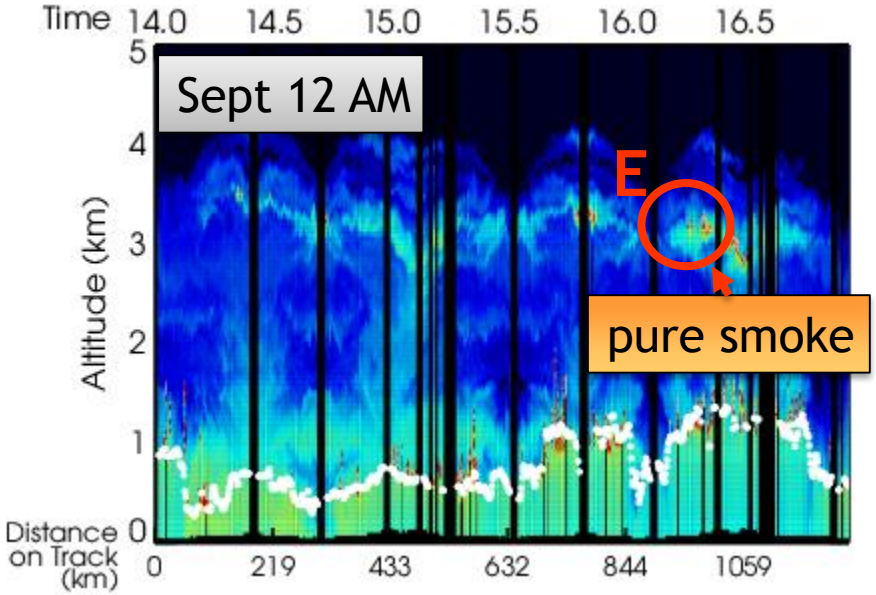
r_{eff}=0.11um, mR=1.45, mI=0.005
r_{eff}=0.16um, mR=1.51, mI=0.01

Pure Smoke
B,C,E

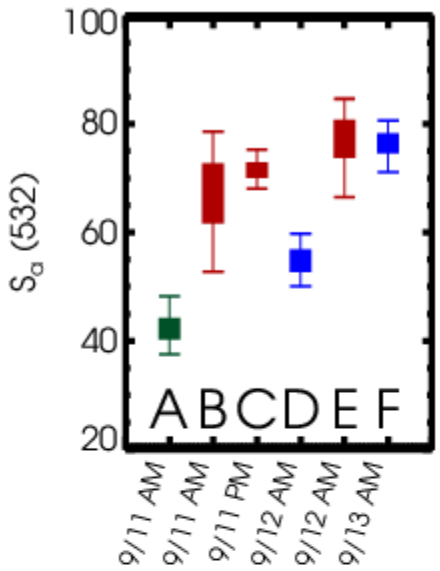
Pure Smoke: B,C,E

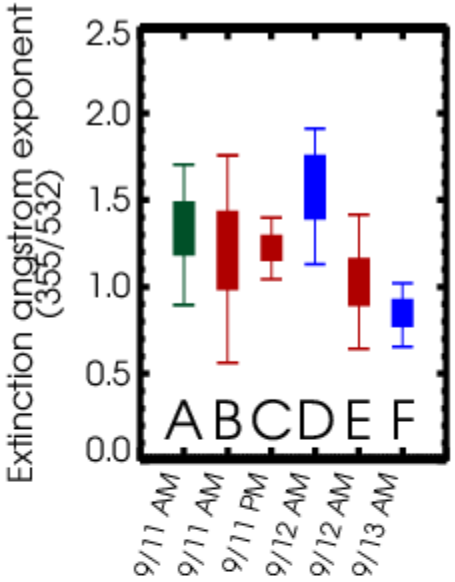


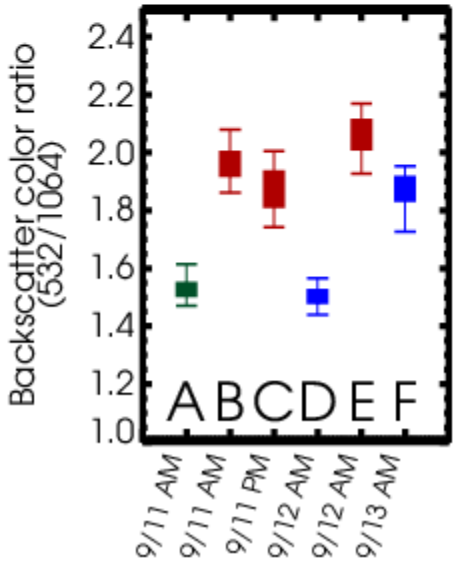


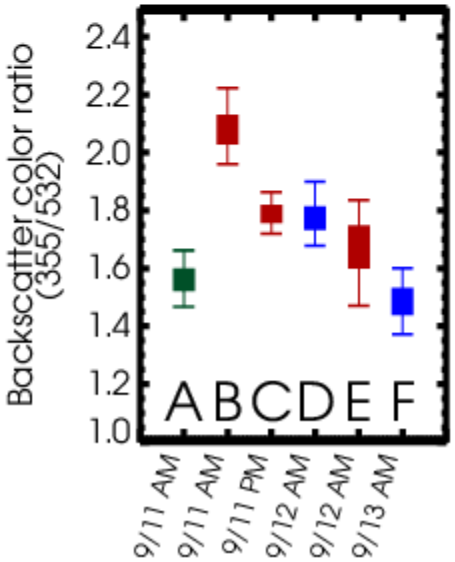


Lidar intensive properties for 6 aerosol samples









- Lidar intensive variables vary both within and between types
- Extinction angstrom exponent varies monotonically with size but is noisy
- Lidar ratio related to absorption, but also varies with particle size, as much as angstrom exponent does
- Backscatter color ratios have complicated dependence on size and complex refractive index

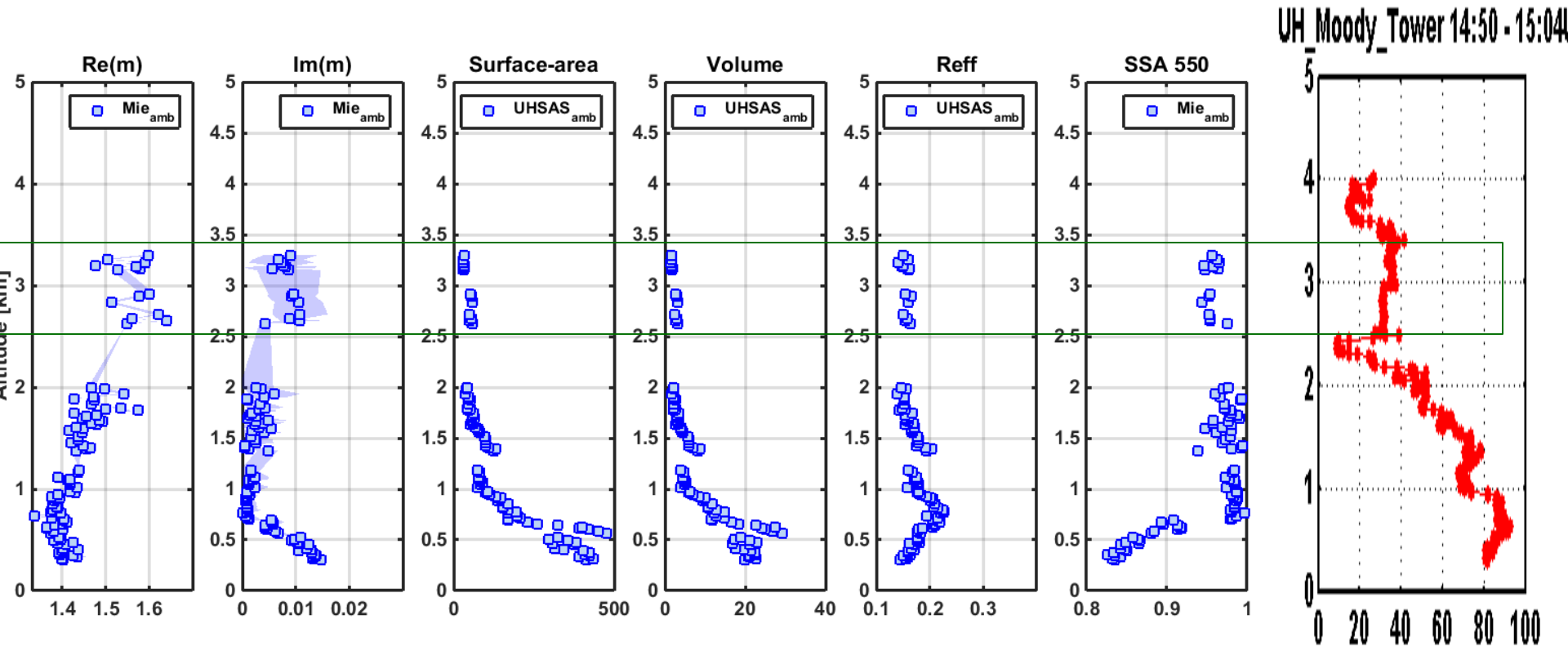
Variations within a type due to

- mixing
- humidification
- composition differences due to different sources (for smoke: e.g. wildfire vs. agricultural)
- aging & processing, etc.
- ???

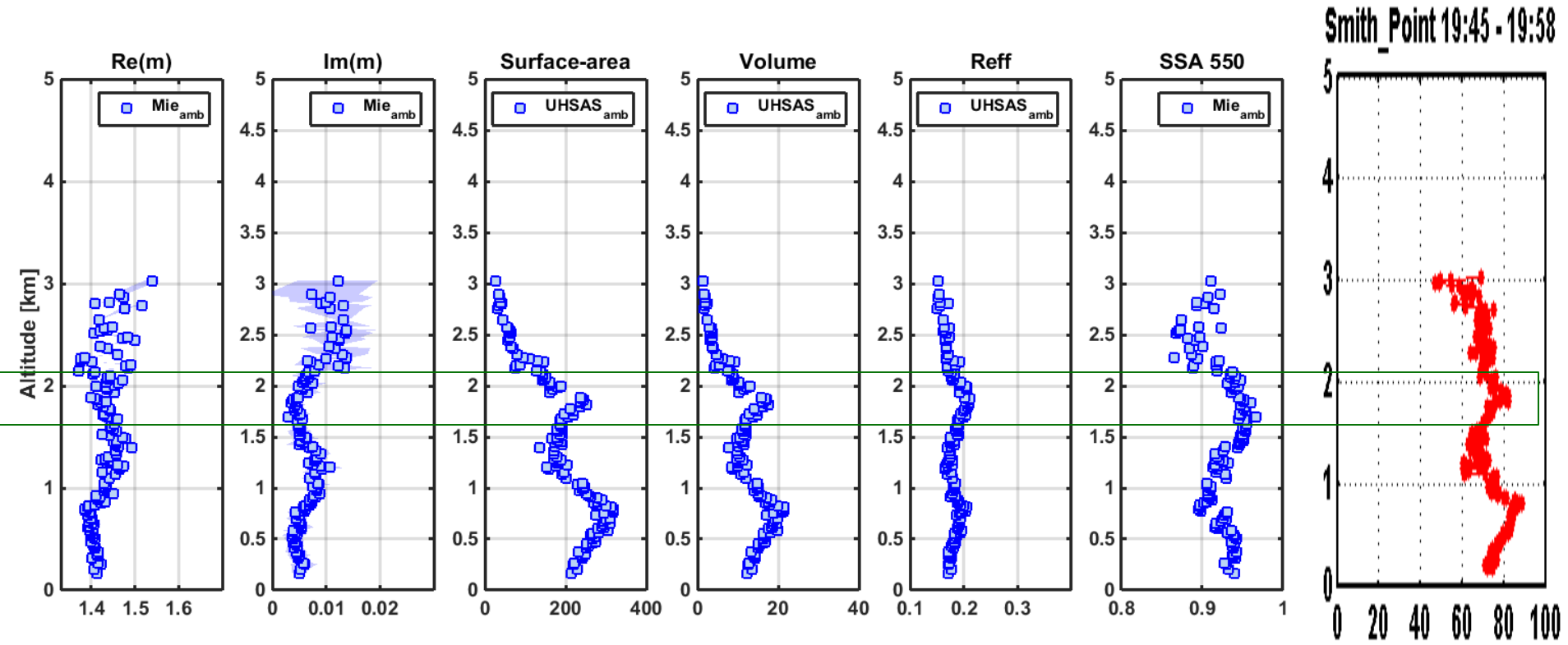
Summary

- HSRL-2 makes horizontally and vertically resolved observations of aerosol layering and diurnal and day-to-day evolution
- High information content in HSRL-2 observations provides the opportunity for model assessment
- HSRL-2 measures a large set of intensive parameters that give information on aerosol type
- Subtleties in HSRL-2 intensive parameters have the potential to give a more nuanced understanding of aerosols
- WRF-Chem model gives context on aerosol sources and transport that helps with interpretation of lidar data
- DISCOVER-AQ Houston case study
  - characterized by large variability in aerosol properties, vertically, temporally and in observed optical properties.
  - included local anthropogenic pollution plus relatively fresh agricultural smoke and aged transported wildfire smoke

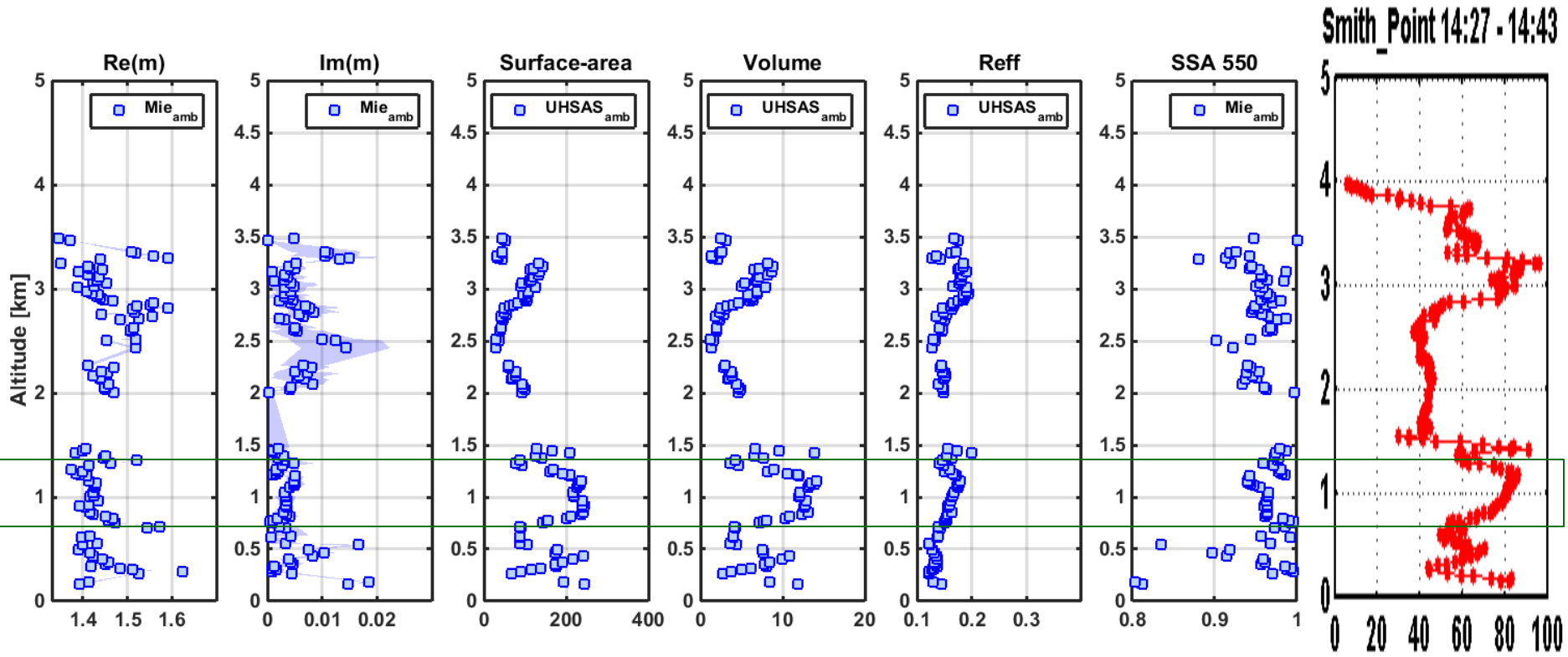
EXTRA: WHAT DOES IN SITU SAY?



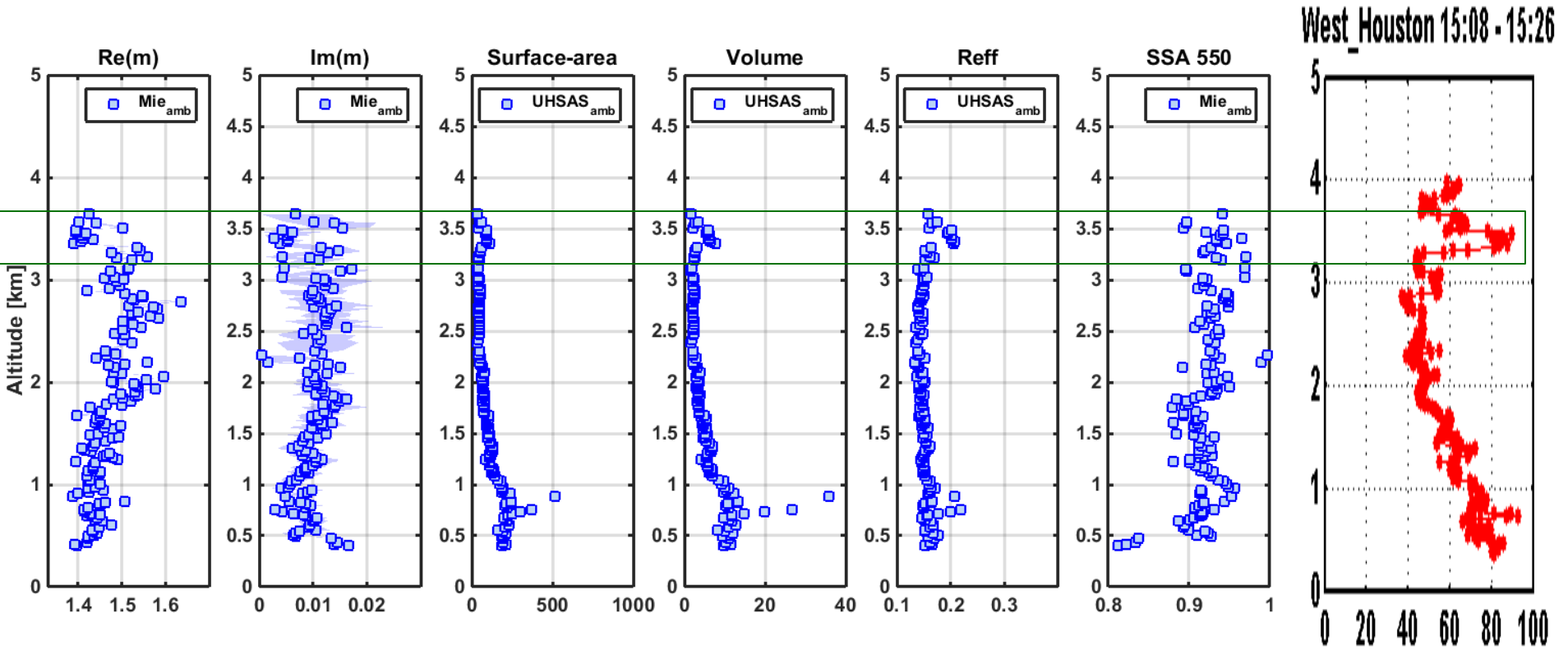
B: UH Moody Tower, 20130911, 14.84-15.07



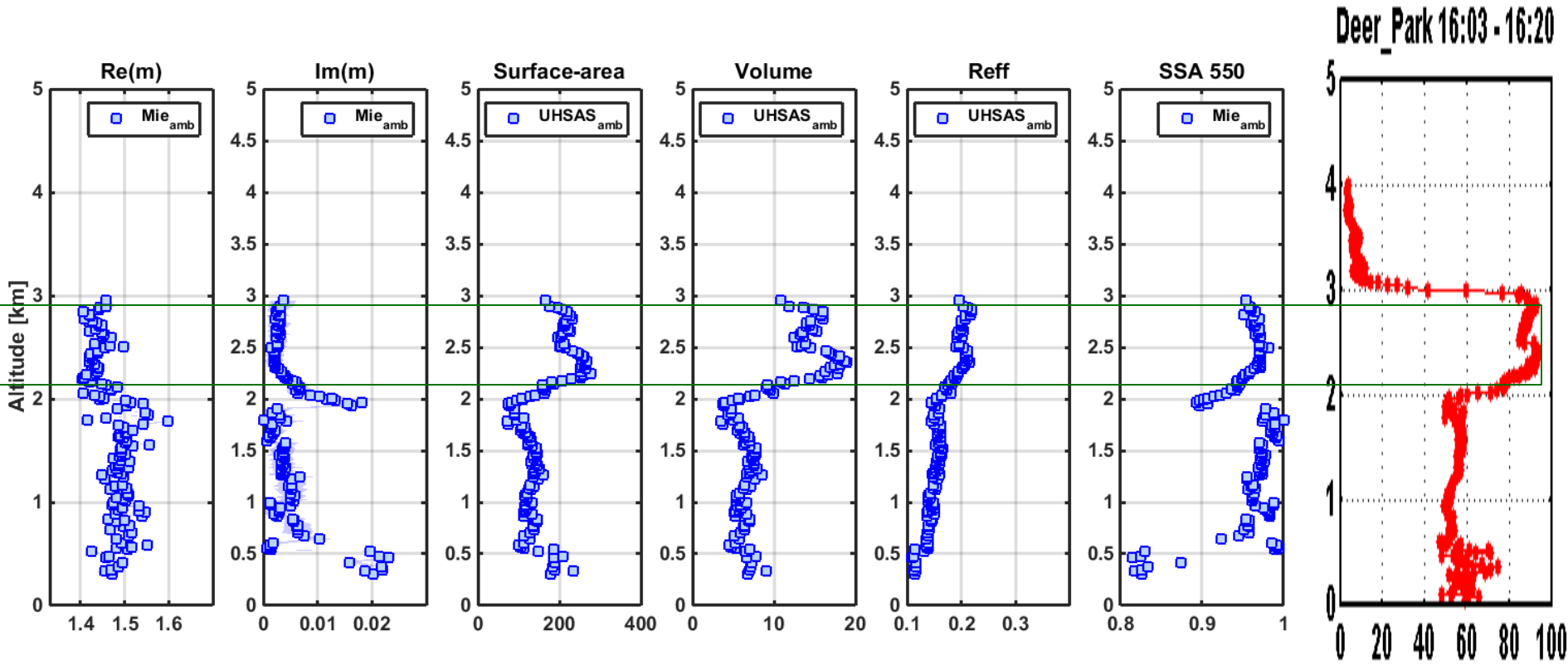
C: Smith Point, 20130911, 19.75-19.97



D: Smith Point, 20130912, 14.45-14.71

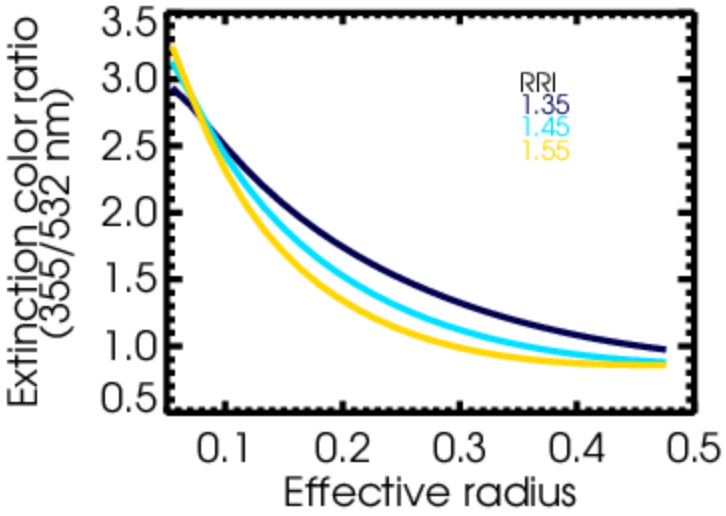


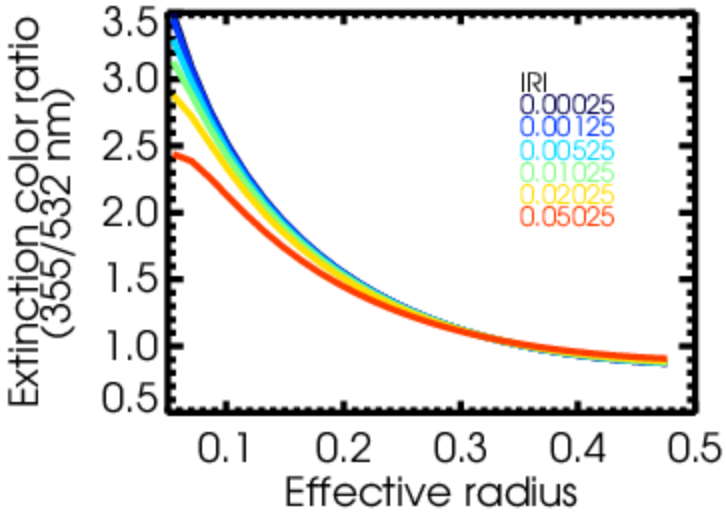
E: West Houston, 20130912, 15.14-15.43

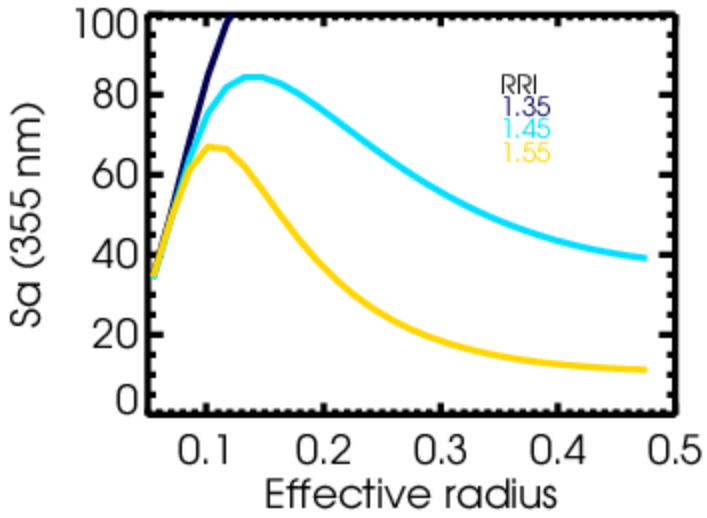


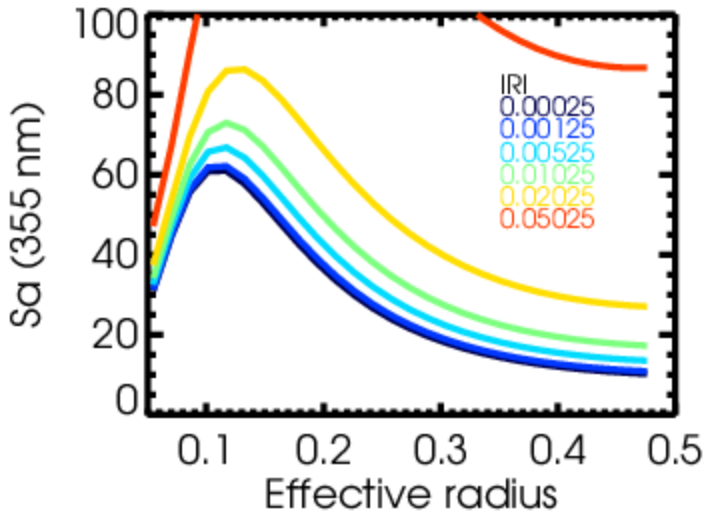
F: Deer Park, 20130913, 16.05-16.33

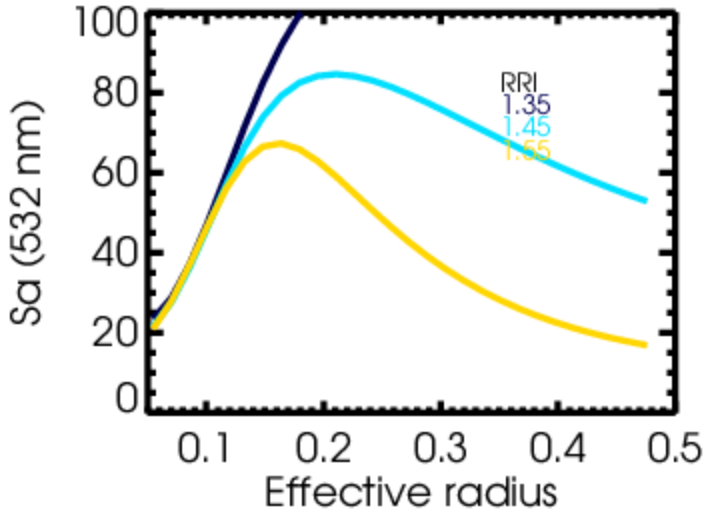
DISCUSSION OF VARIABILITY OF INTENSIVE PARAMETERS OF SMOKE

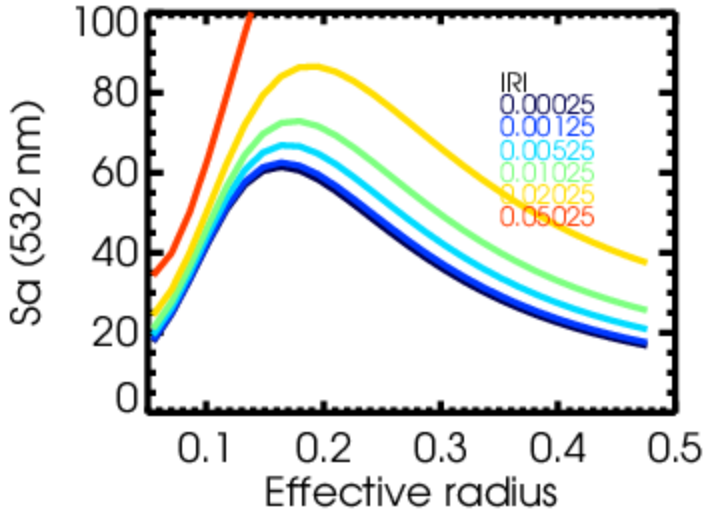

Extinction color ratio
(355/532 nm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
0.2
0.3
0.4
0.5
Effective radius
RRI
1.35
1.45
1.55

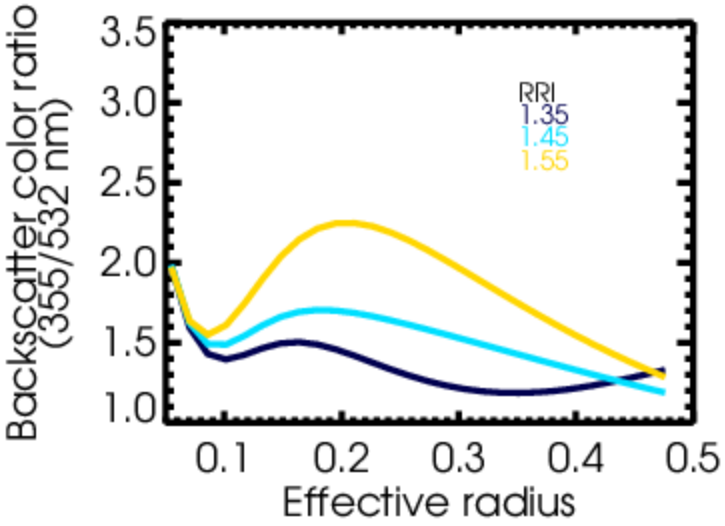

Extinction color ratio
(355/532 nm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
0.2
0.3
0.4
0.5
Effective radius
IRI
0.00025
0.00125
0.00525
0.01025
0.02025
0.05025

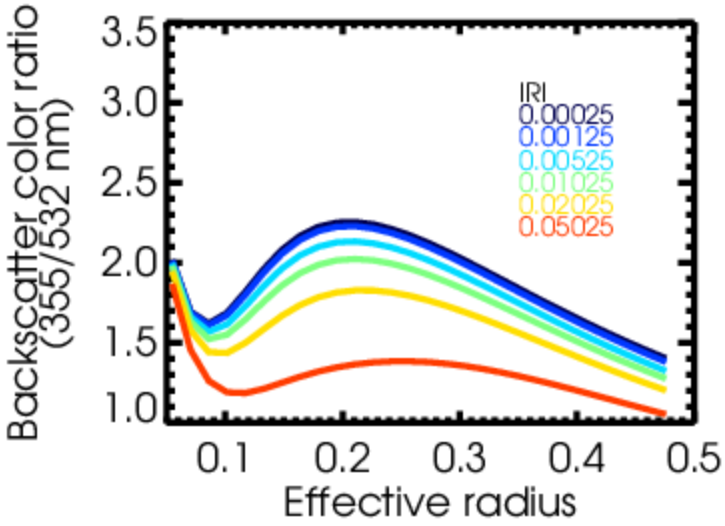

Sa (355 nm)
Effective radius
RRI
1.35
1.45
1.55

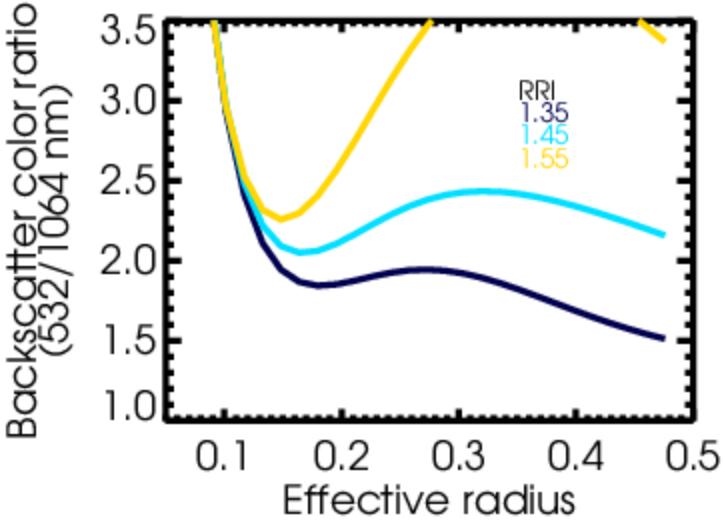

Sa (355 nm)
Effective radius
IRI
0.00025
0.00125
0.00525
0.01025
0.02025
0.05025

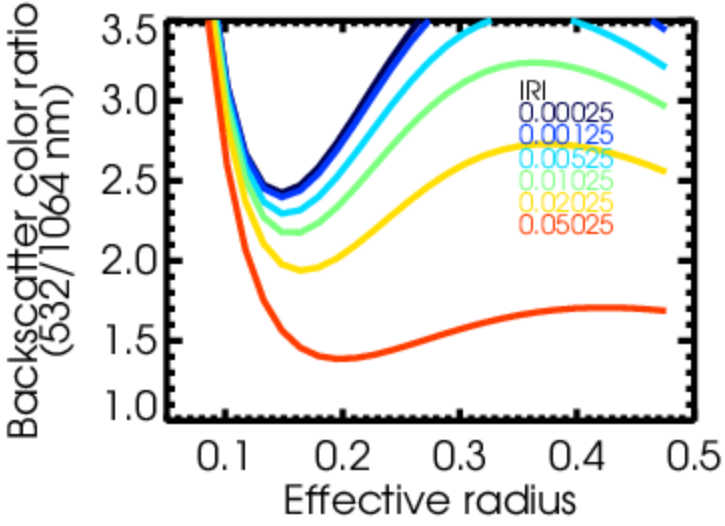

Sa (532 nm)
Effective radius
RRI
1.35
1.45
1.55

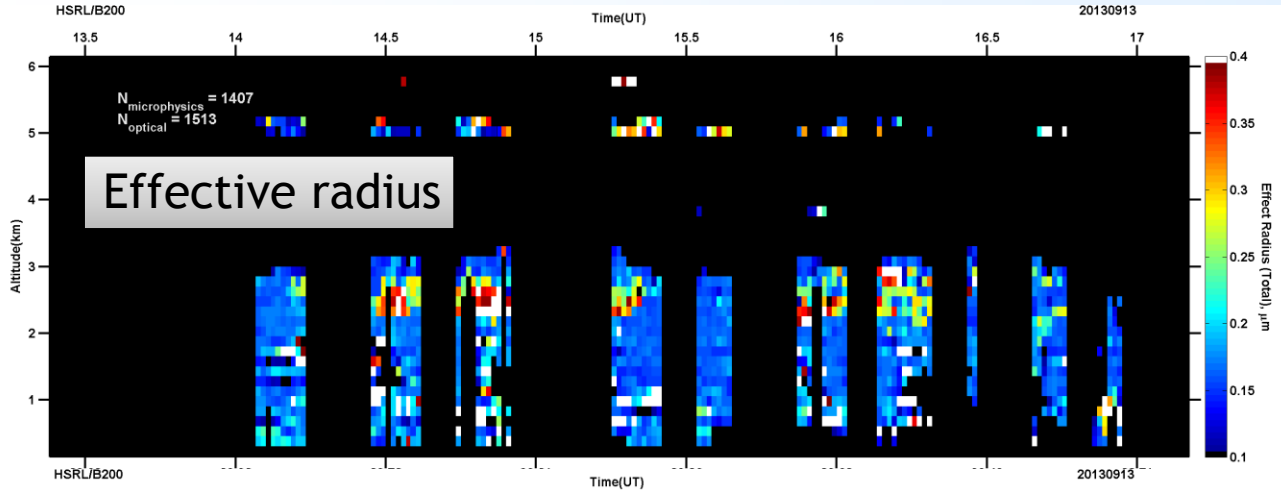

Sa (532 nm)
Effective radius
IRI
0.00025
0.00125
0.00525
0.01025
0.02025
0.05025

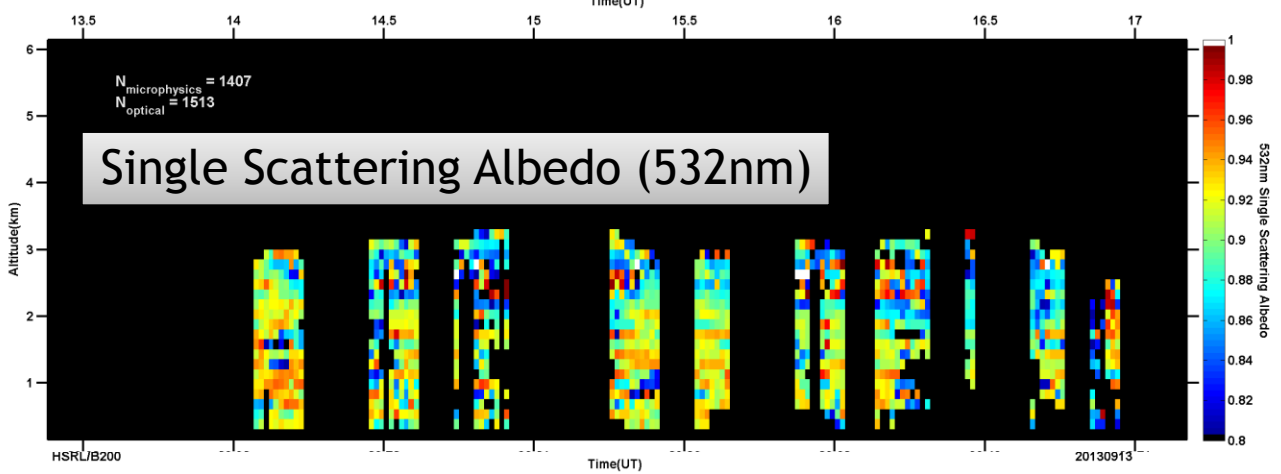

Backscatter color ratio (355/532 nm)
3.5
3.0
2.5
2.0
1.5
1.0
RRI
1.35
1.45
1.55
0.1
0.2
0.3
0.4
0.5
Effective radius

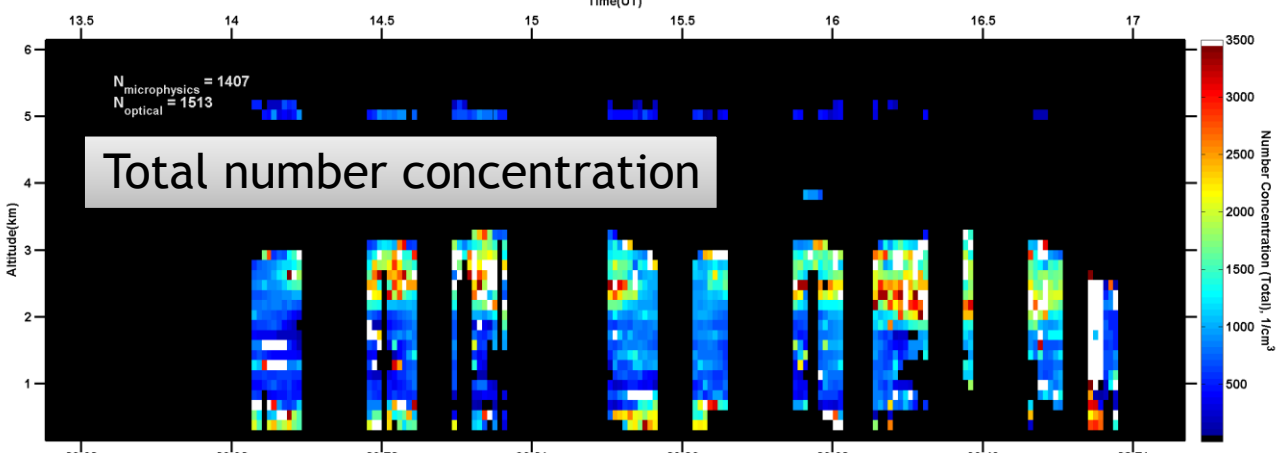

Backscatter color ratio (355/532 nm)
3.5
3.0
2.5
2.0
1.5
1.0
IRI
0.00025
0.00125
0.00525
0.01025
0.02025
0.05025
0.1
0.2
0.3
0.4
0.5
Effective radius


Backscatter color ratio (532/1064 nm)
3.5
3.0
2.5
2.0
1.5
1.0
RRI
1.35
1.45
1.55
0.1
0.2
0.3
0.4
0.5
Effective radius


Backscatter color ratio (532/1064 nm)
3.5
3.0
2.5
2.0
1.5
1.0
IRI
0.00025
0.00125
0.00525
0.01025
0.02025
0.05025
0.1
0.2
0.3
0.4
0.5
Effective radius


HSRL/B200
Time(UT)
20130913
13.5
14
14.5
15
15.5
16
16.5
17
$N_{microphysics}$ = 1407
$N_{optical}$ = 1513
Effective radius
Altitude(km)
Effect Radius (Total), μm
0.4
0.35
0.3
0.25
0.2
0.15
0.1


HSRL/B200
Time(UT)
20130913
13.5
14
14.5
15
15.5
16
16.5
17
$N_{microphysics}$ = 1407
$N_{optical}$ = 1513
Single Scattering Albedo (532nm)
Altitude(km)
532nm Single Scattering Albedo
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8


HSRL/B200
Time(UT)
20130913
13.5
14
14.5
15
15.5
16
16.5
17
$N_{microphysics}$ = 1407
$N_{optical}$ = 1513
Total number concentration
Altitude(km)
Number Concentration (Total), 1/cm^3
3500
3000
2500
2000
1500
1000
500