The University of Iowa

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

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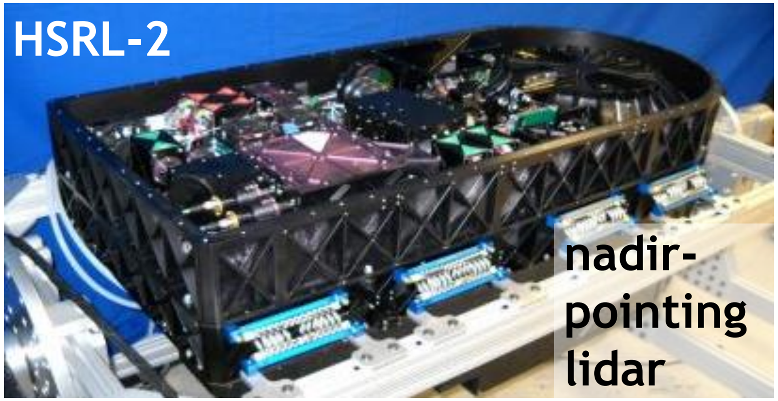
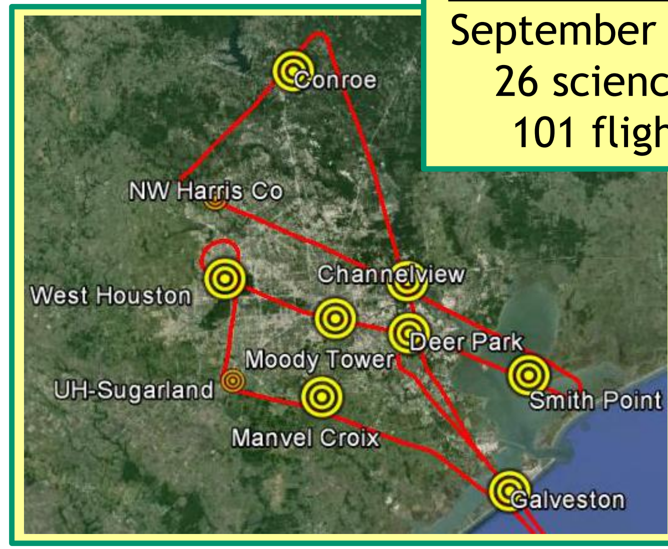
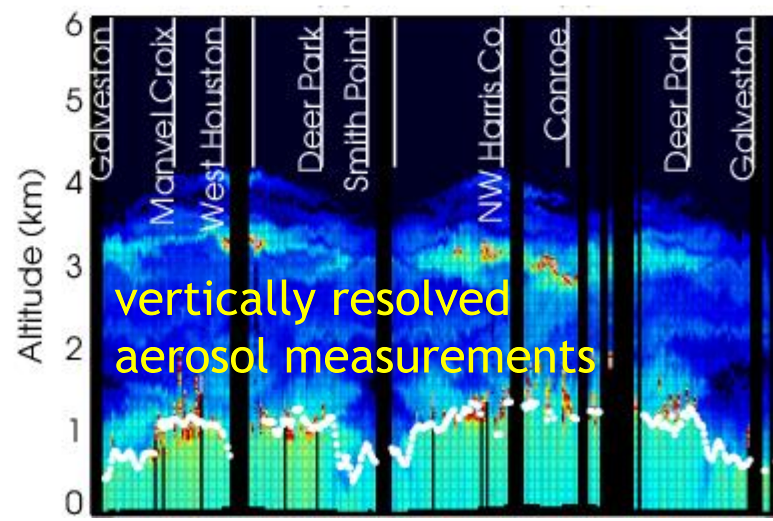
# High Spectral Resolution Lidar, HSRL-2





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

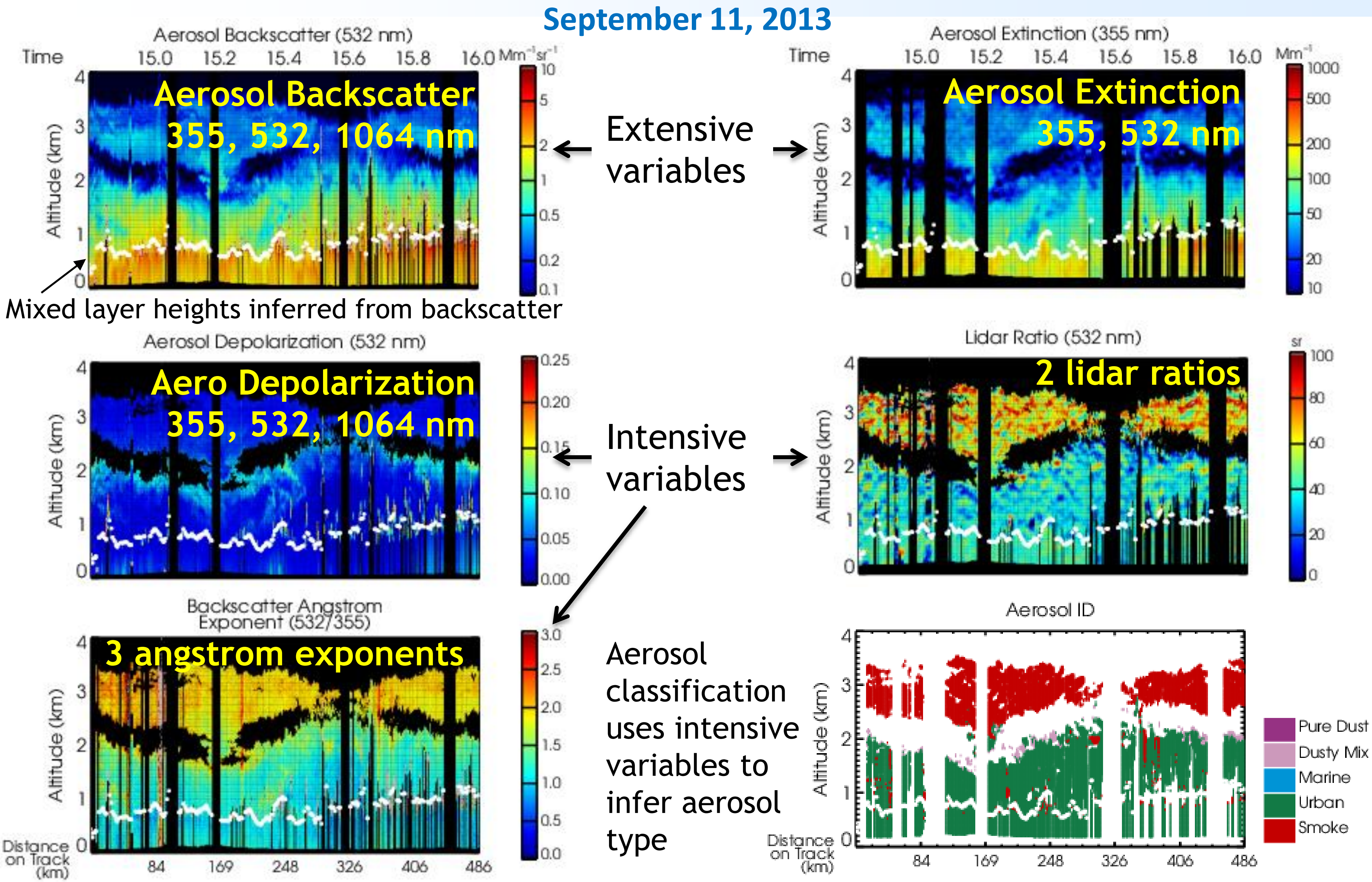



High Spectral Resolution Lidar 2 –

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

# HSRL-2 measurement products

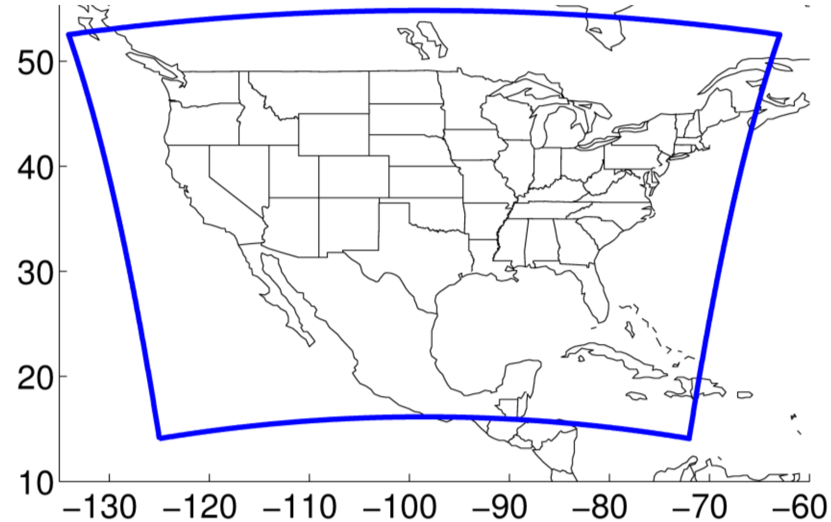


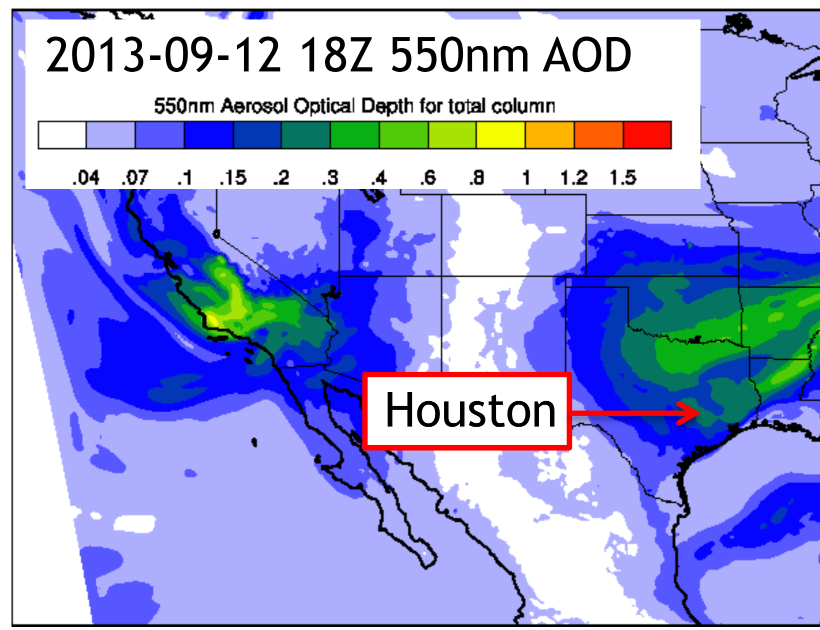
# WRF-Chem Forecasting

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

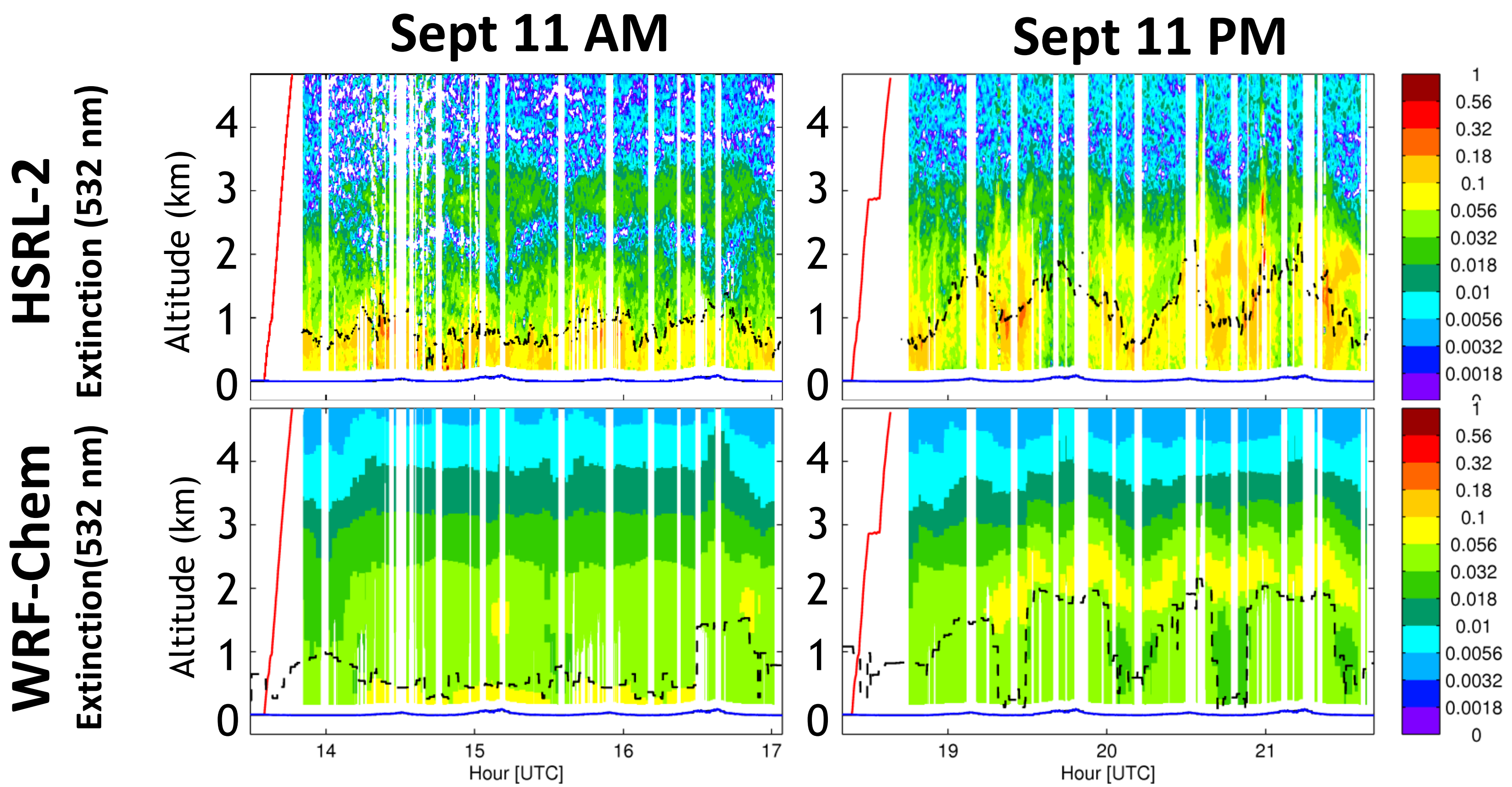
- WRF-Chem v3.5 CBMZ, 4bin MOSAIC, 12km dx, 52 vertical lvls, and WRF-tracer for emission regions/sectors
- Emissions: anthropogenic, biomass burning (FINN, QFED2) with plume-rise, MEGAN biogenics, dust & sea-salt. MACC boundary conditions
- AOD assimilation (NRL product) every 3 hours, 1 cycle a day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



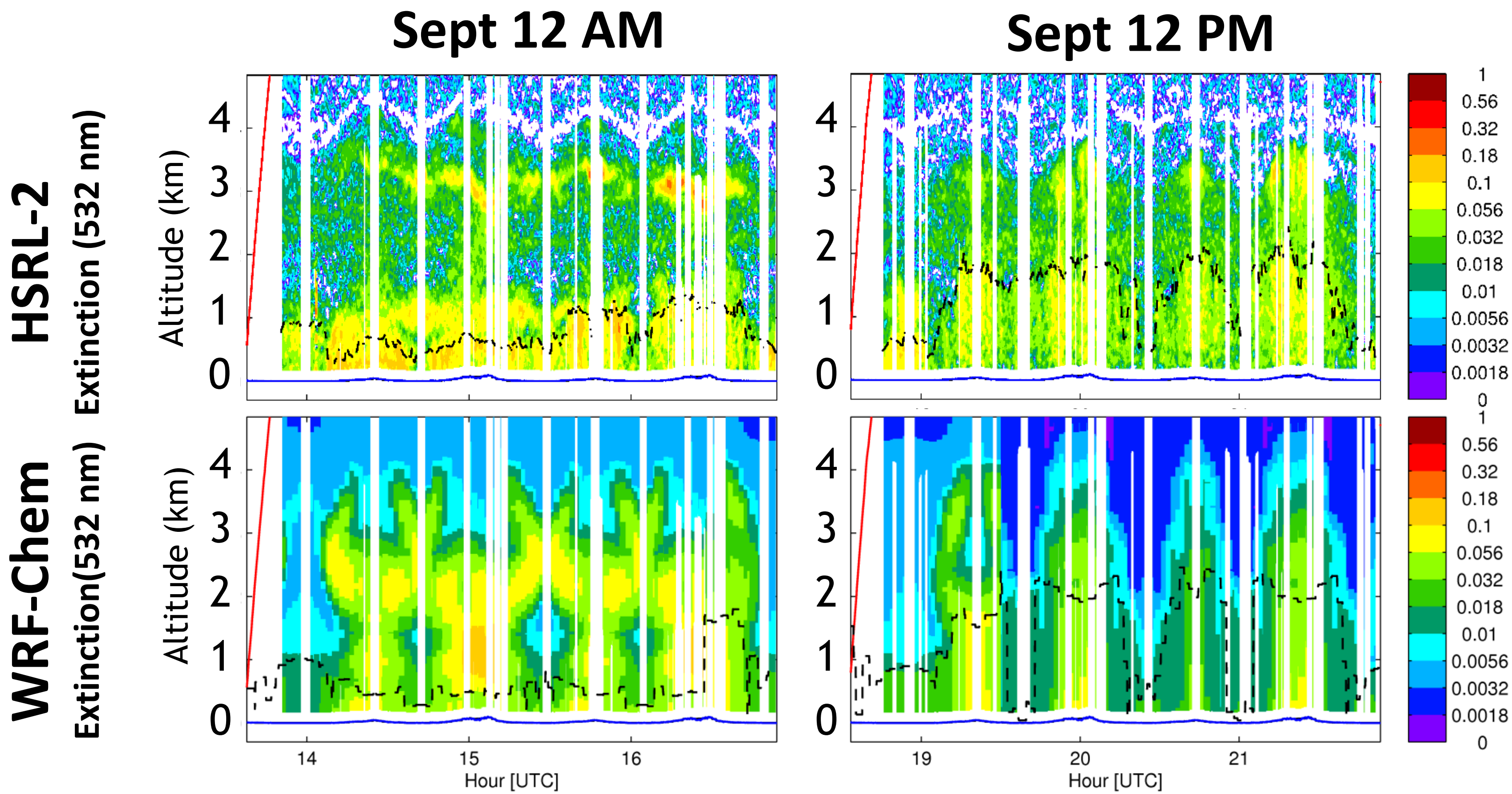



# Day by day extinction comparison

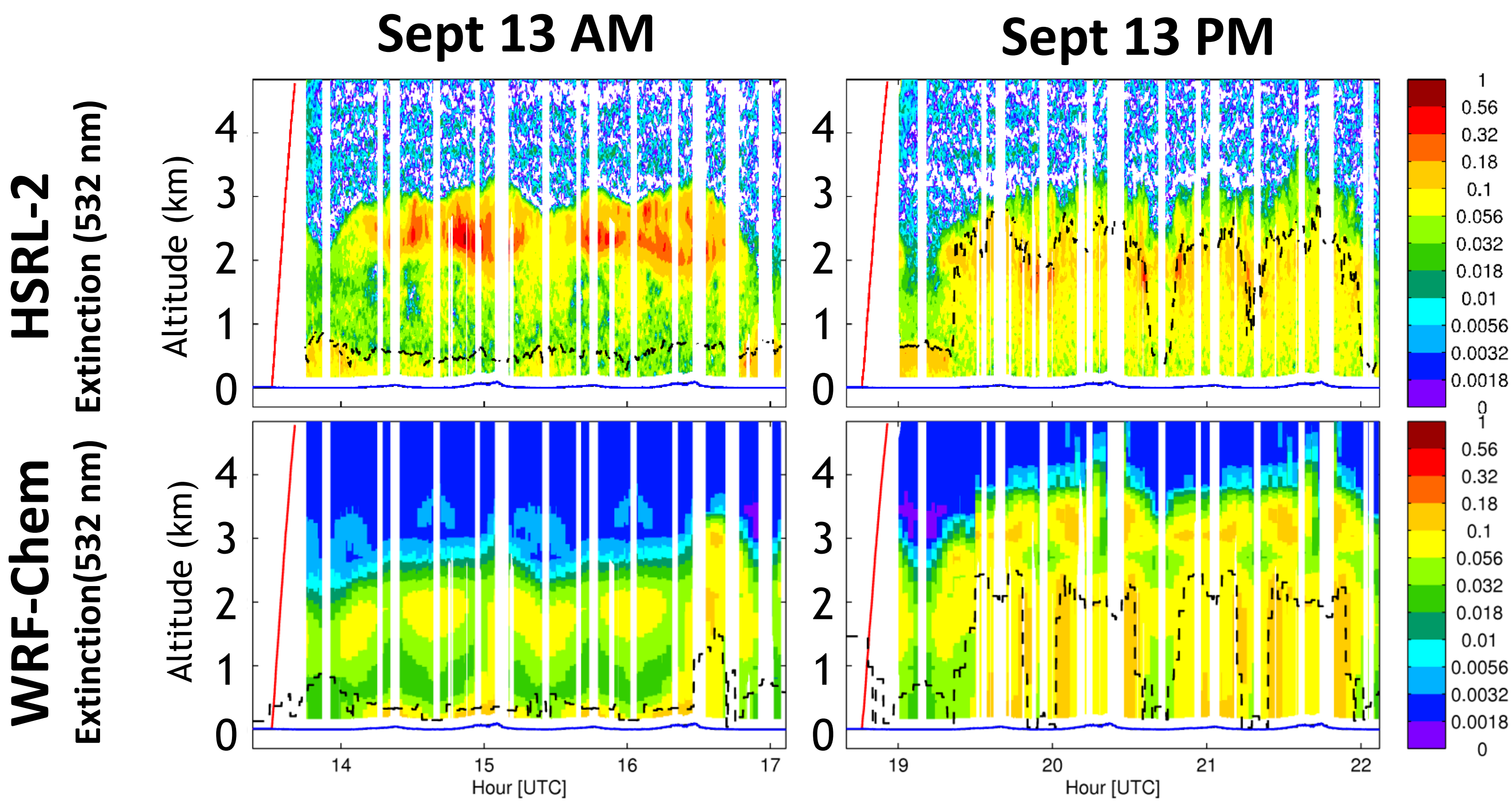
# Extinction comparison, lidar vs. model



# Extinction comparison, lidar vs. model

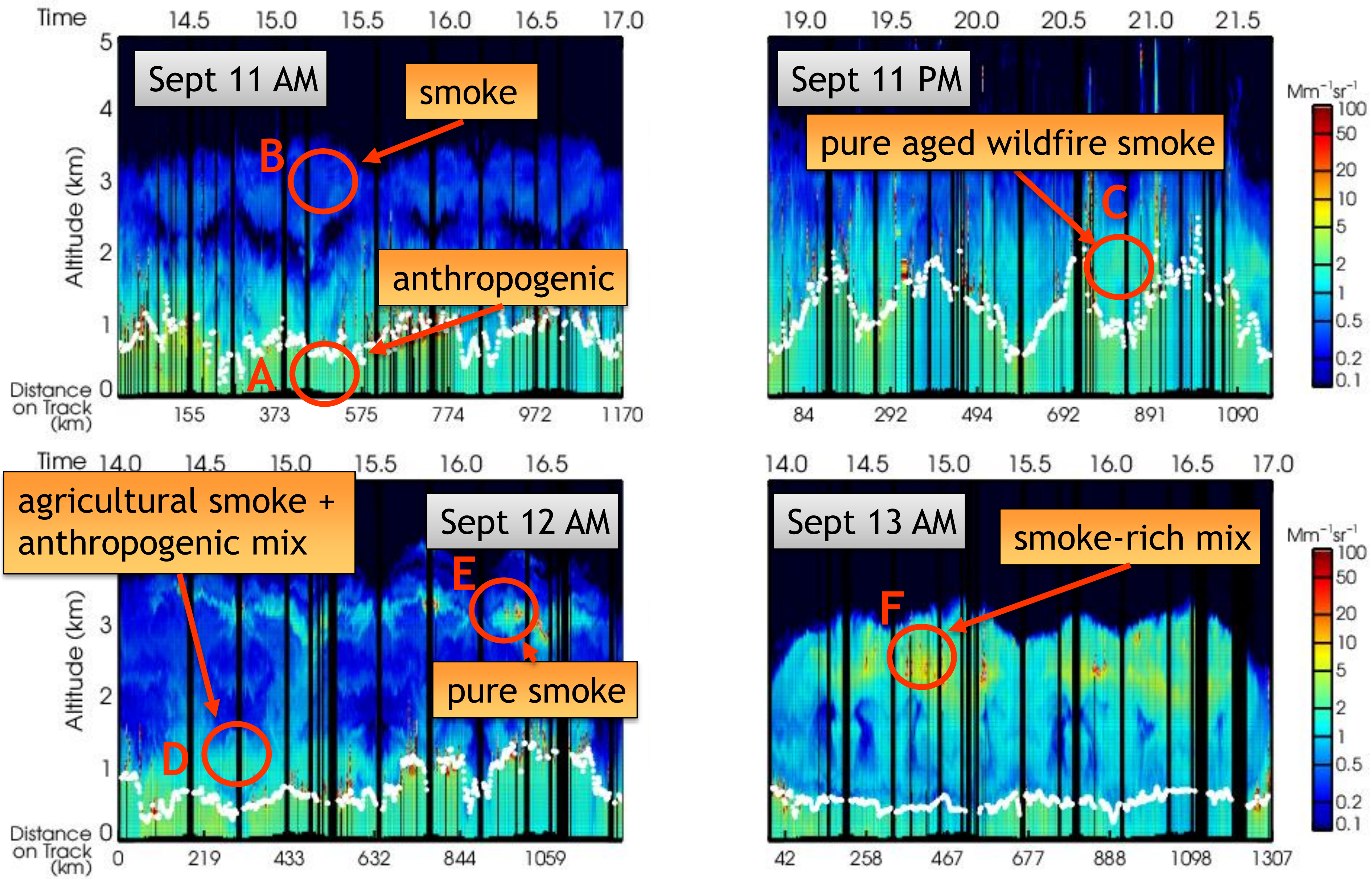


# Extinction comparison, lidar vs. model



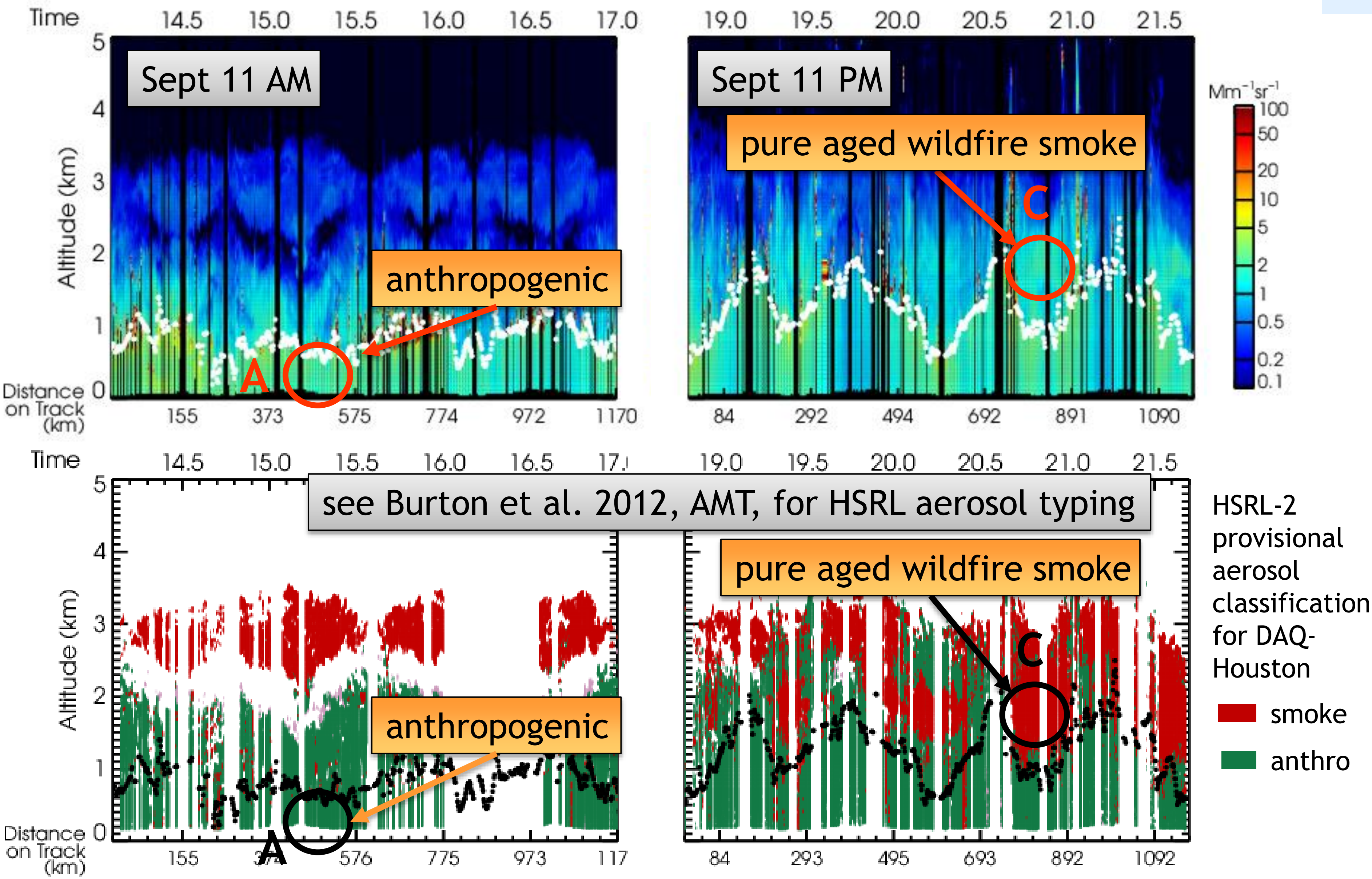
# Insights about aerosol source & type

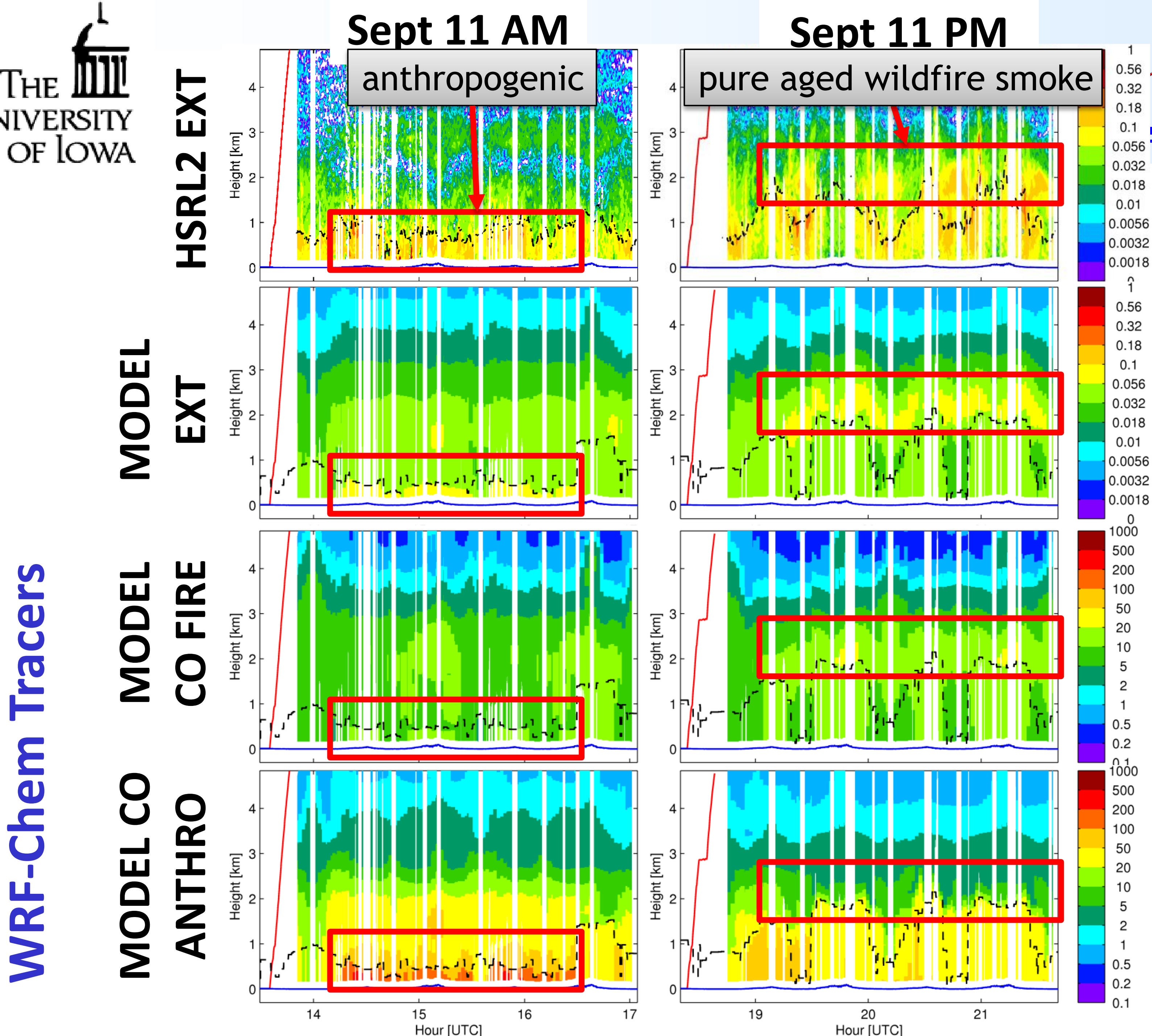
# Aerosol source and type, 6 example layers



# Anthropogenic vs. Smoke
# A vs. C

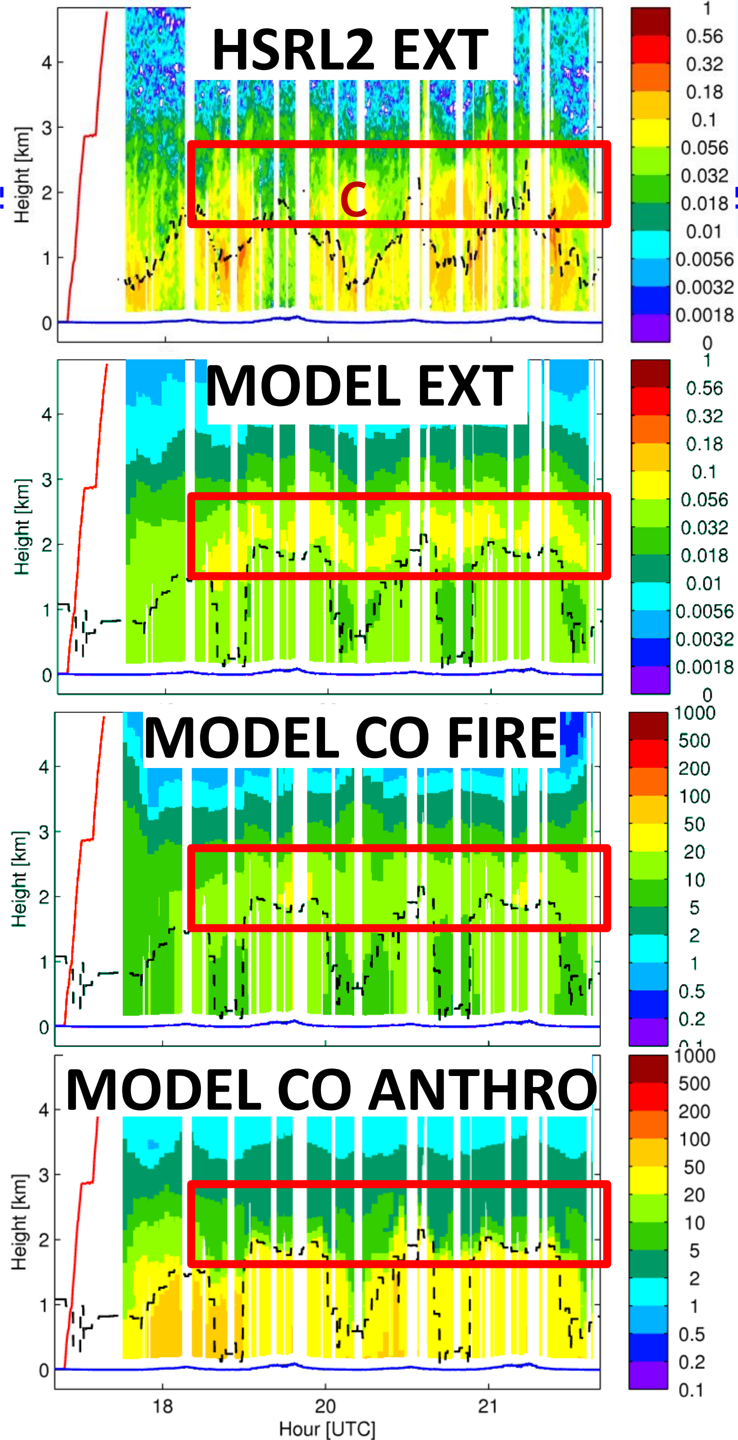
# Anthropogenic vs. Smoke: A vs. C



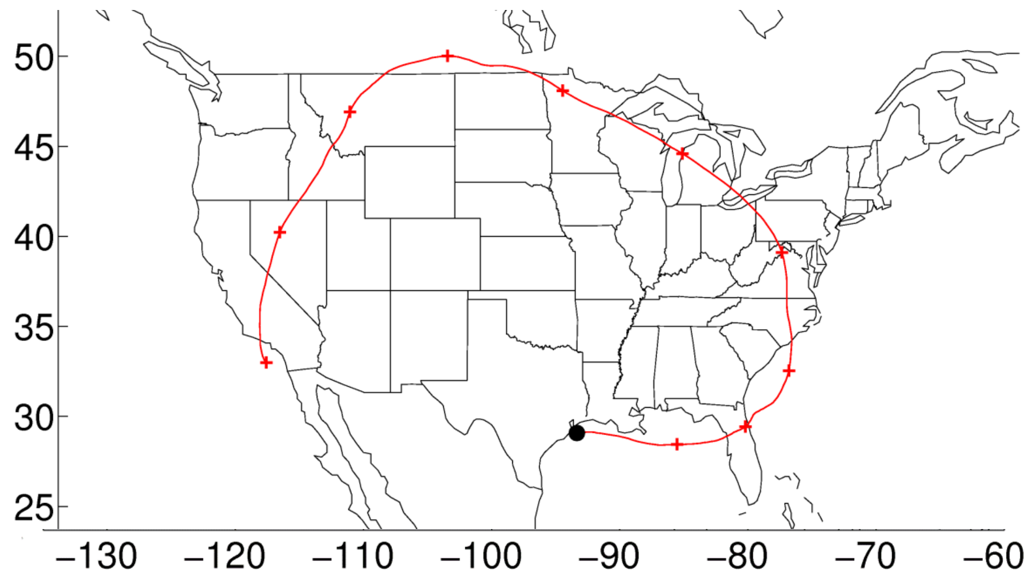


Sept 11 AM
Sept 11 PM
anthropogenic
pure aged wildfire smoke
HSRL2 EXT
MODEL EXT
MODEL CO FIRE
MODEL CO ANTHRO
WRF-Chem Tracers
Height [km]
Hour [UTC]
14
15
16
17
19
20
21
0
1
2
3
4
1
0.56
0.32
0.18
0.1
0.056
0.032
0.018
0.01
0.0056
0.0032
0.0018
0
1000
500
200
100
50
20
10
5
2
1
0.5
0.2
0.1

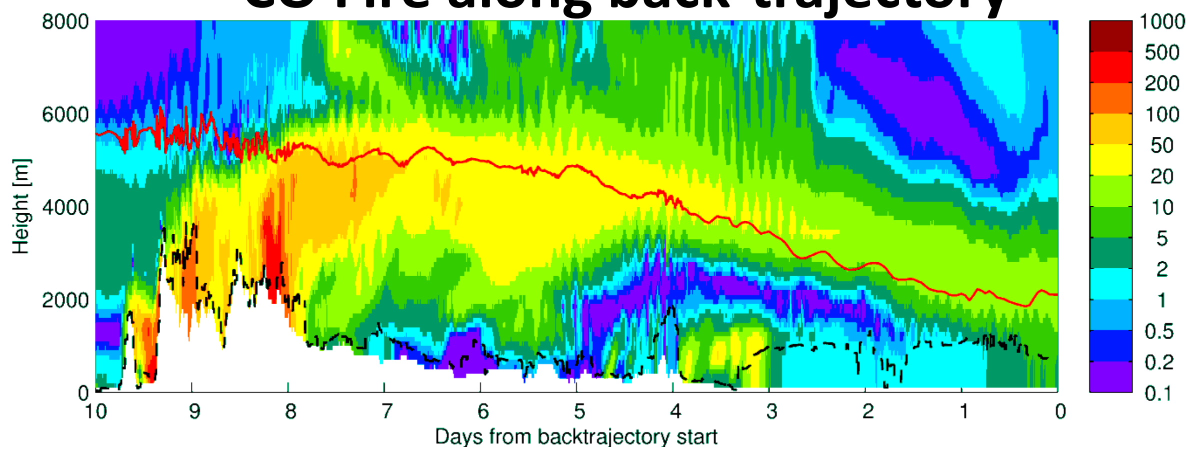
# WRF-Chem Backtrajectories




## Sept 11 PM

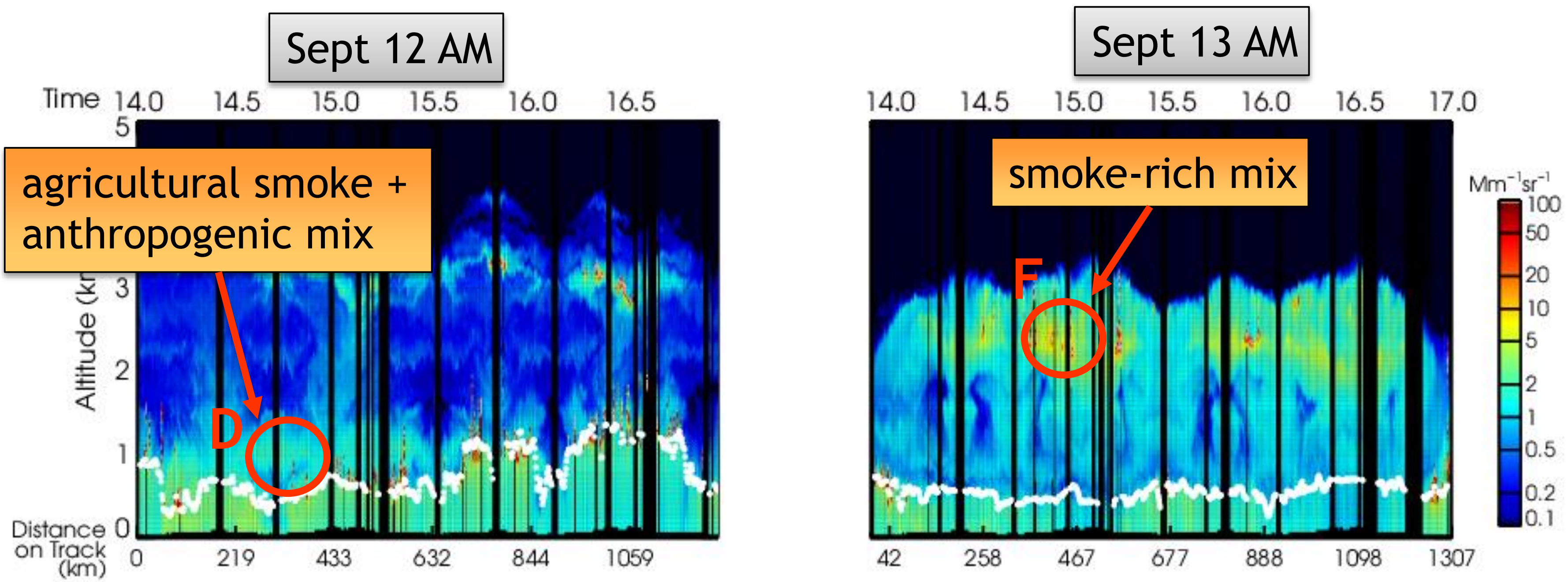



## CO Fire along back-trajectory

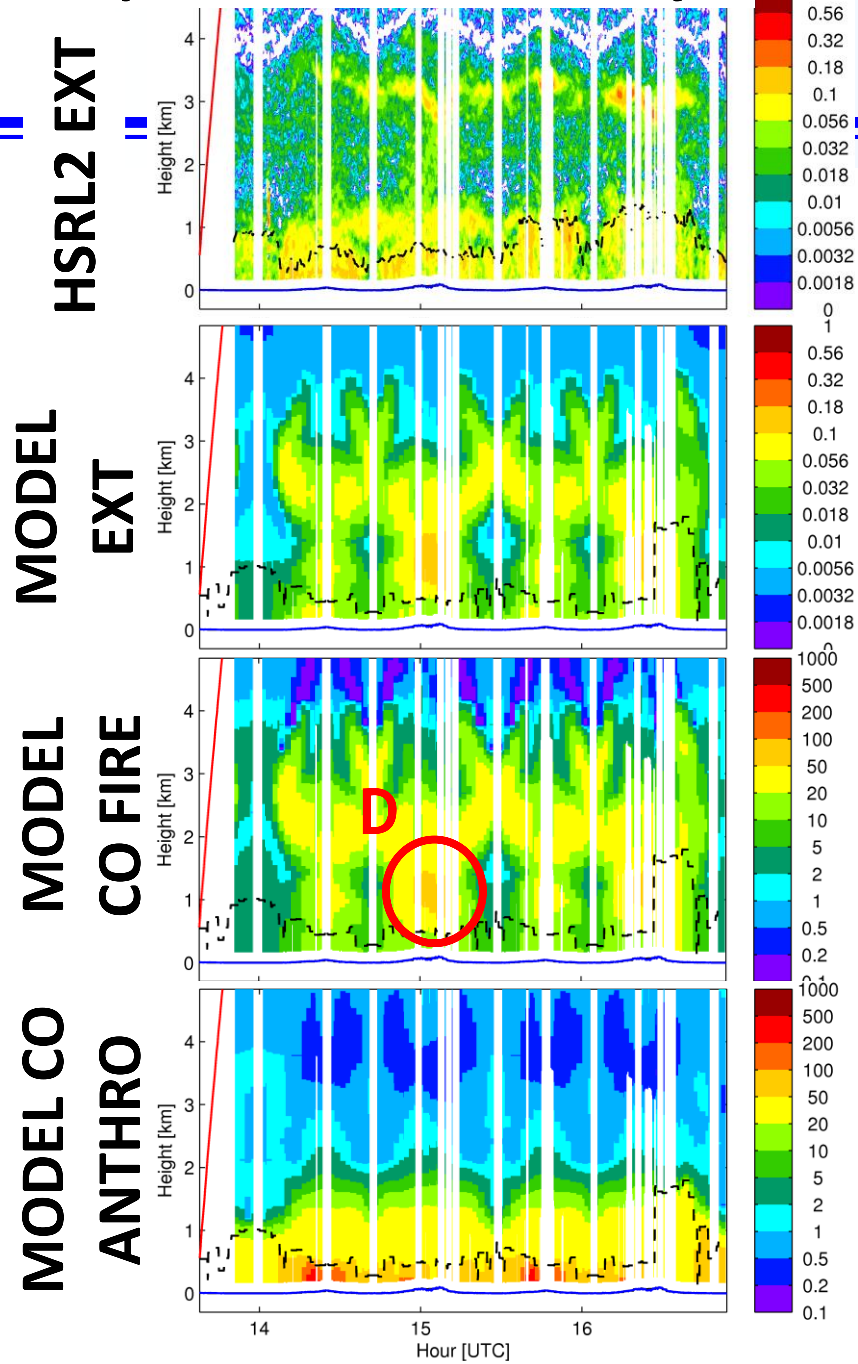


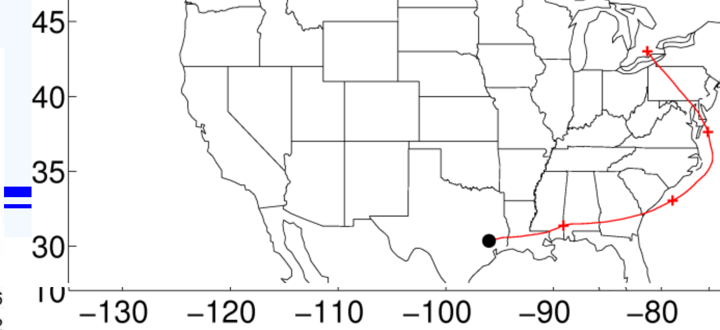
# Mixtures of Agriculture Smoke and Anthropogenic
# D vs. F

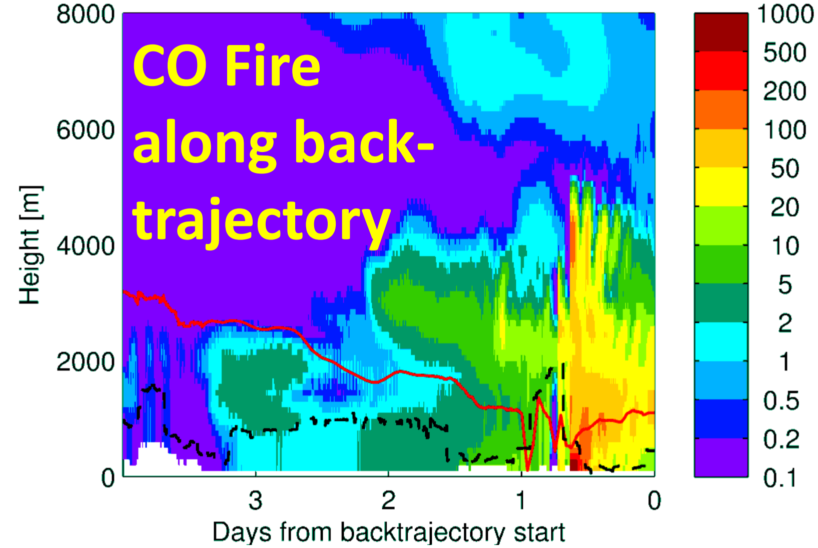
# Mixtures of Agriculture Smoke and Anthropogenic: D vs. F

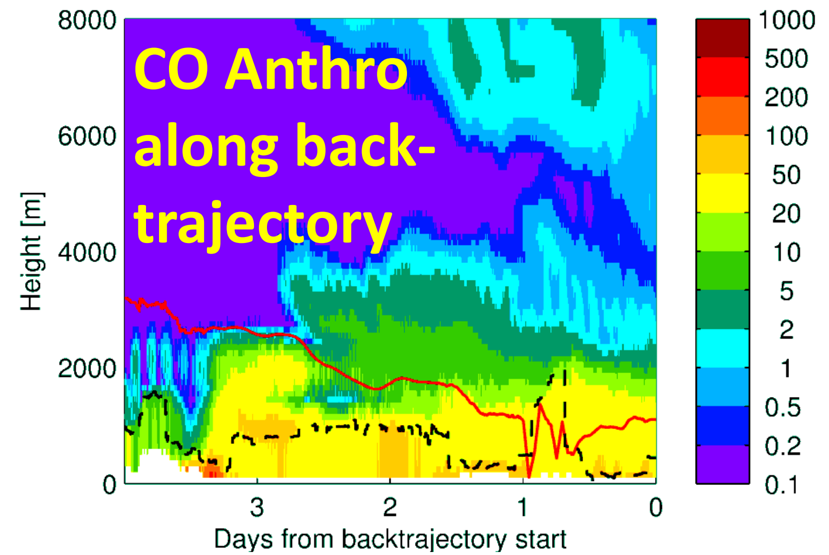


# Sept 12 AM, residual layer



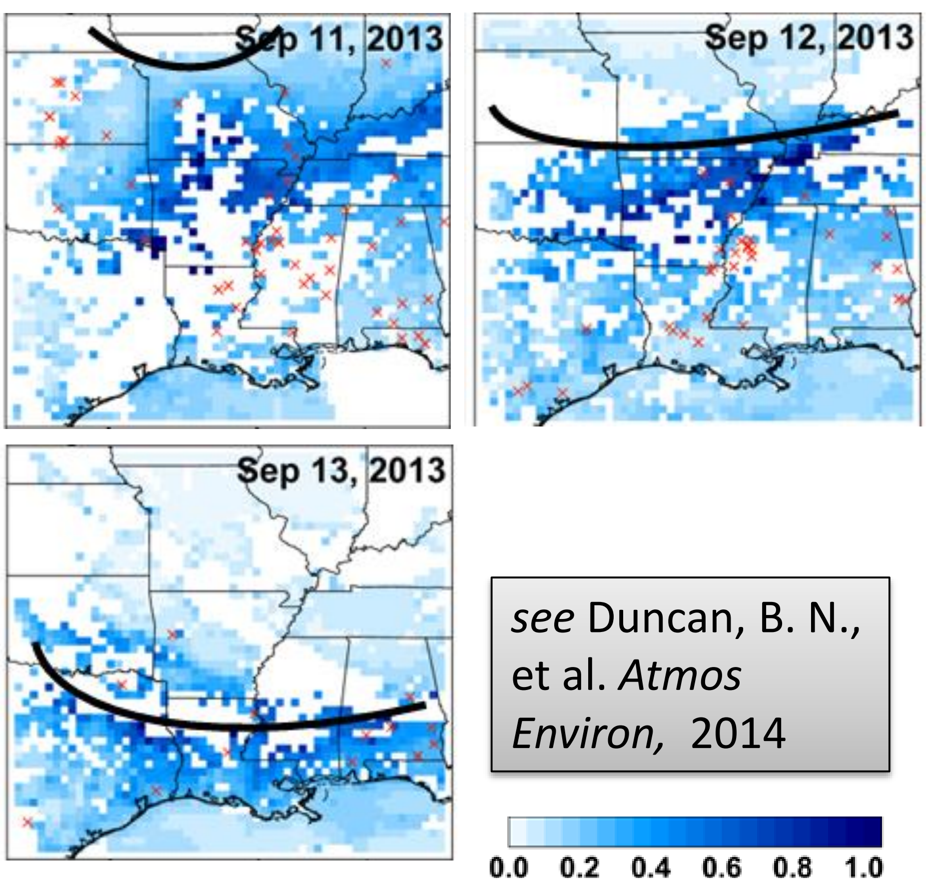





# Sept 13 AM

## NPP VIIRS AOD



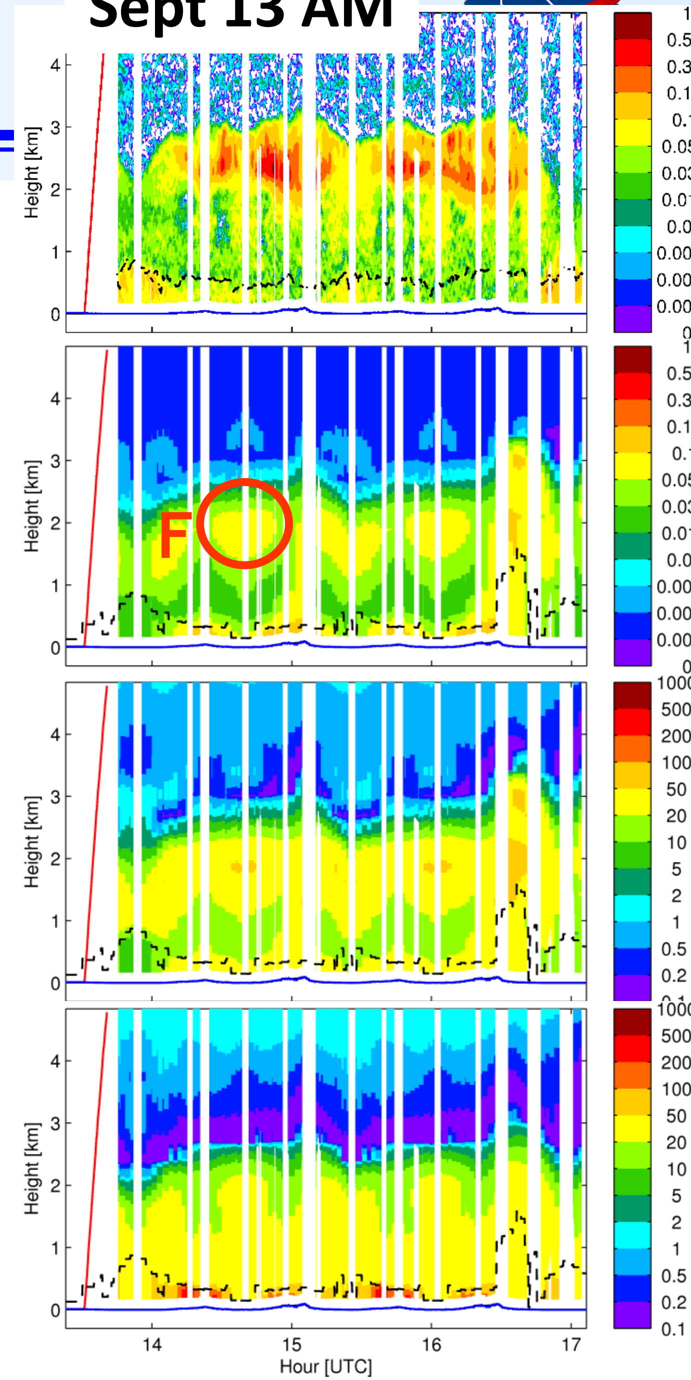

*see* Duncan, B. N., et al. *Atmos Environ,* 2014

HSRL2 EXT

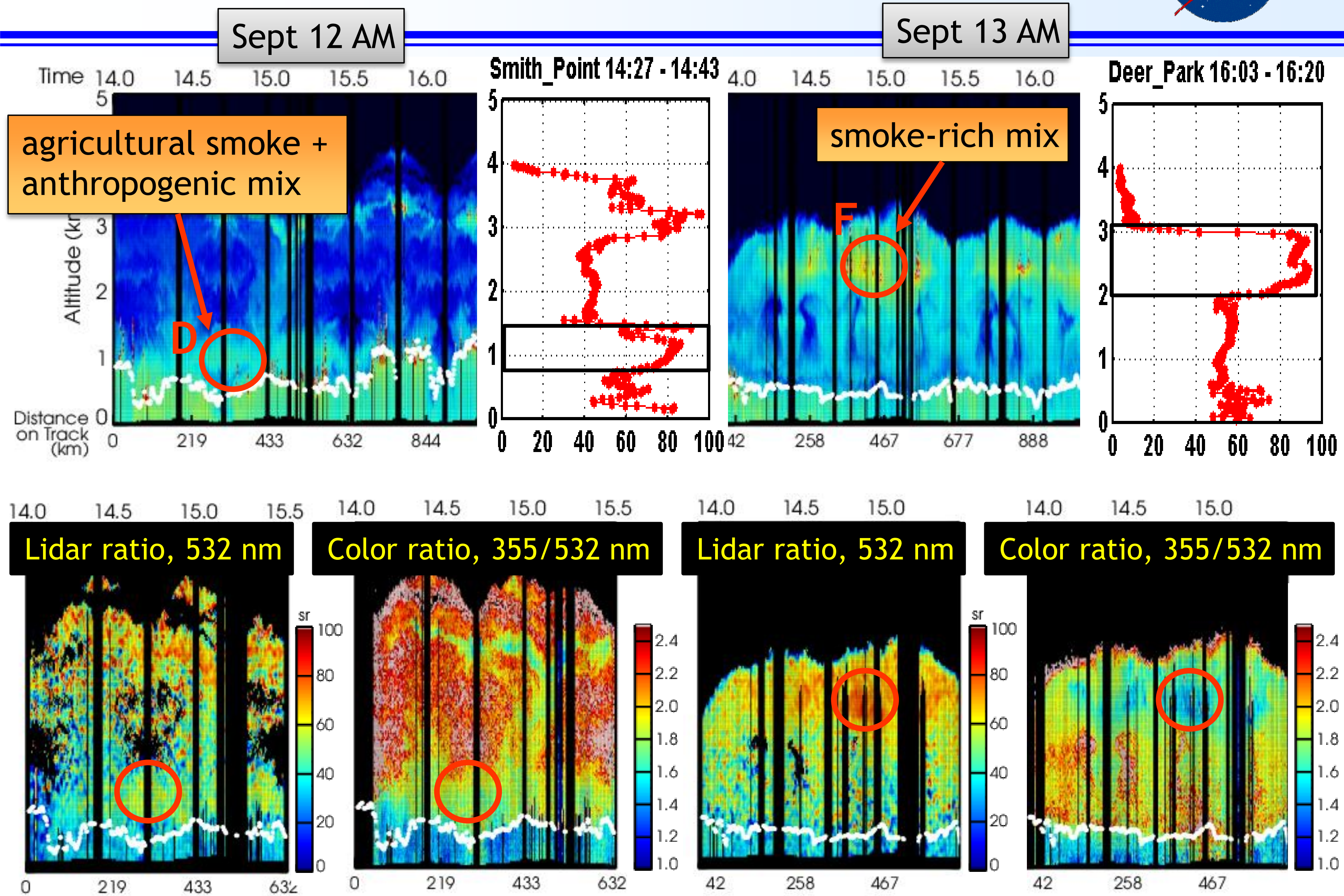
MODEL EXT

MODEL CO FIRE

MODEL CO ANTHRO



# 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 $\kappa$ is the effective hygroscopicity parameter which captures all solute properties.

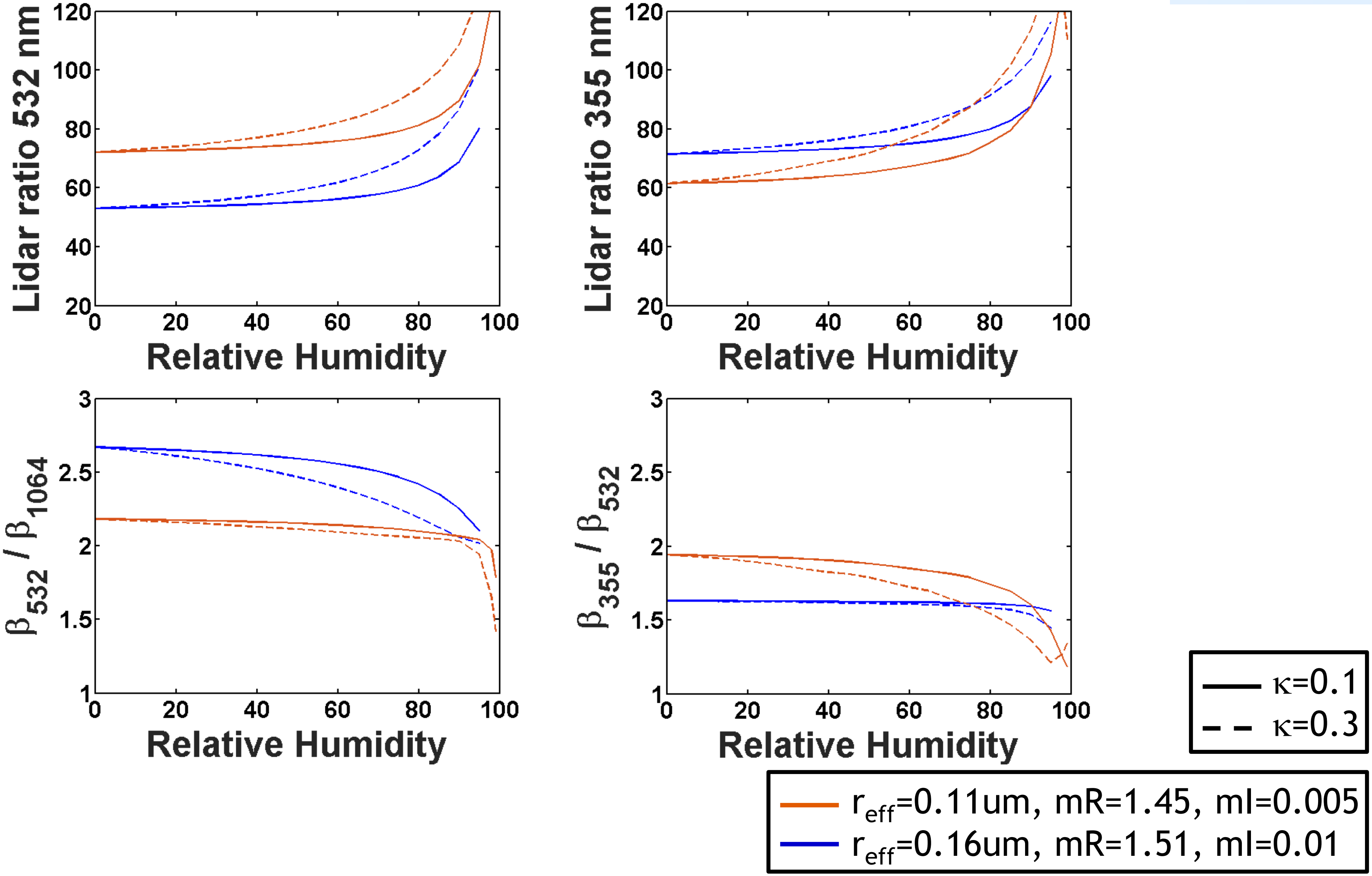
| Less hygroscopic ← $0 \leq \kappa \leq 1$ → More hygroscopic |
|---|

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

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

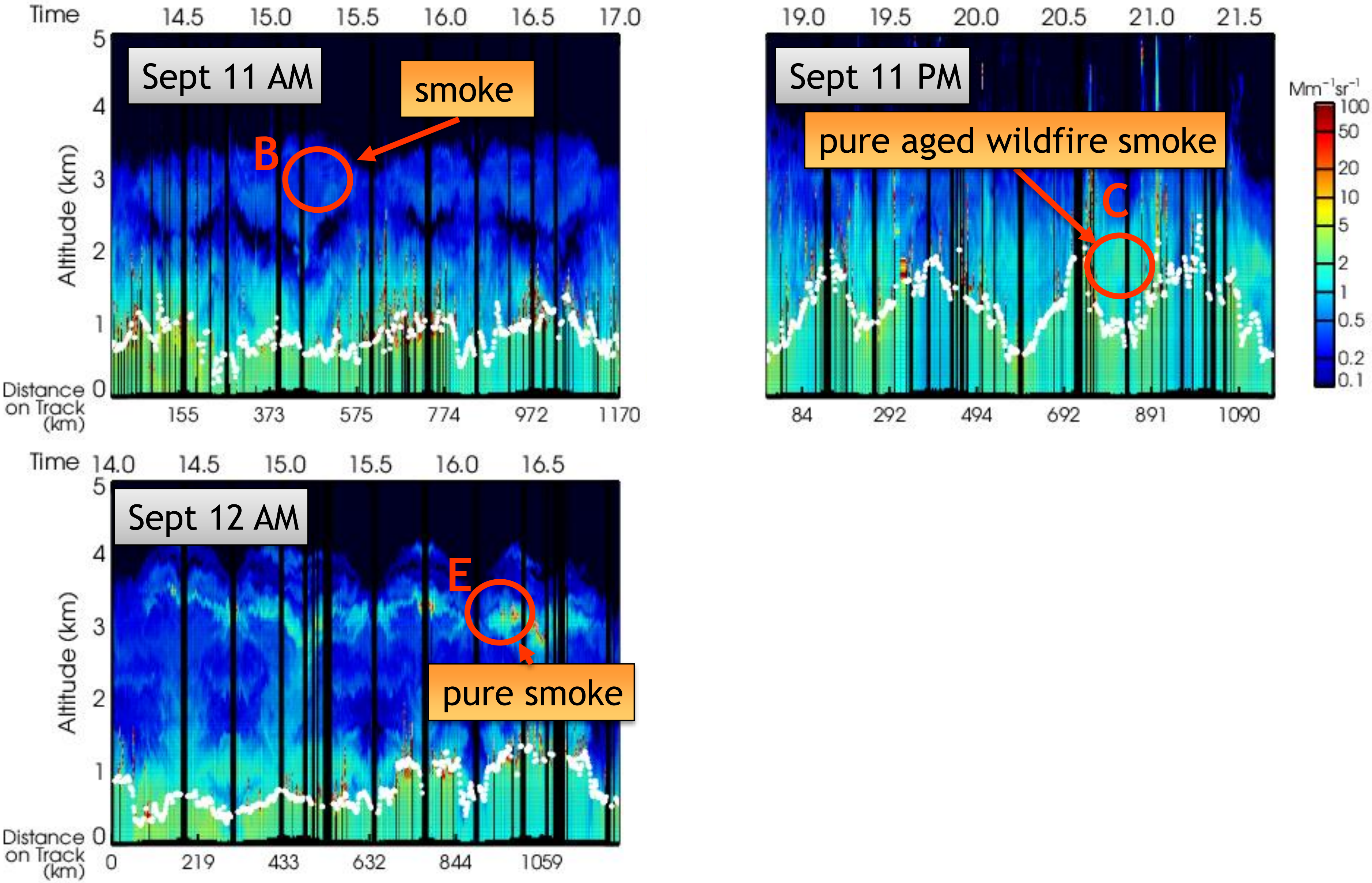
Agricultural smoke: $\kappa = 0.2$ (Rose et al., 2010, ACP)

# Lidar intensive properties: effect of Relative Humidity

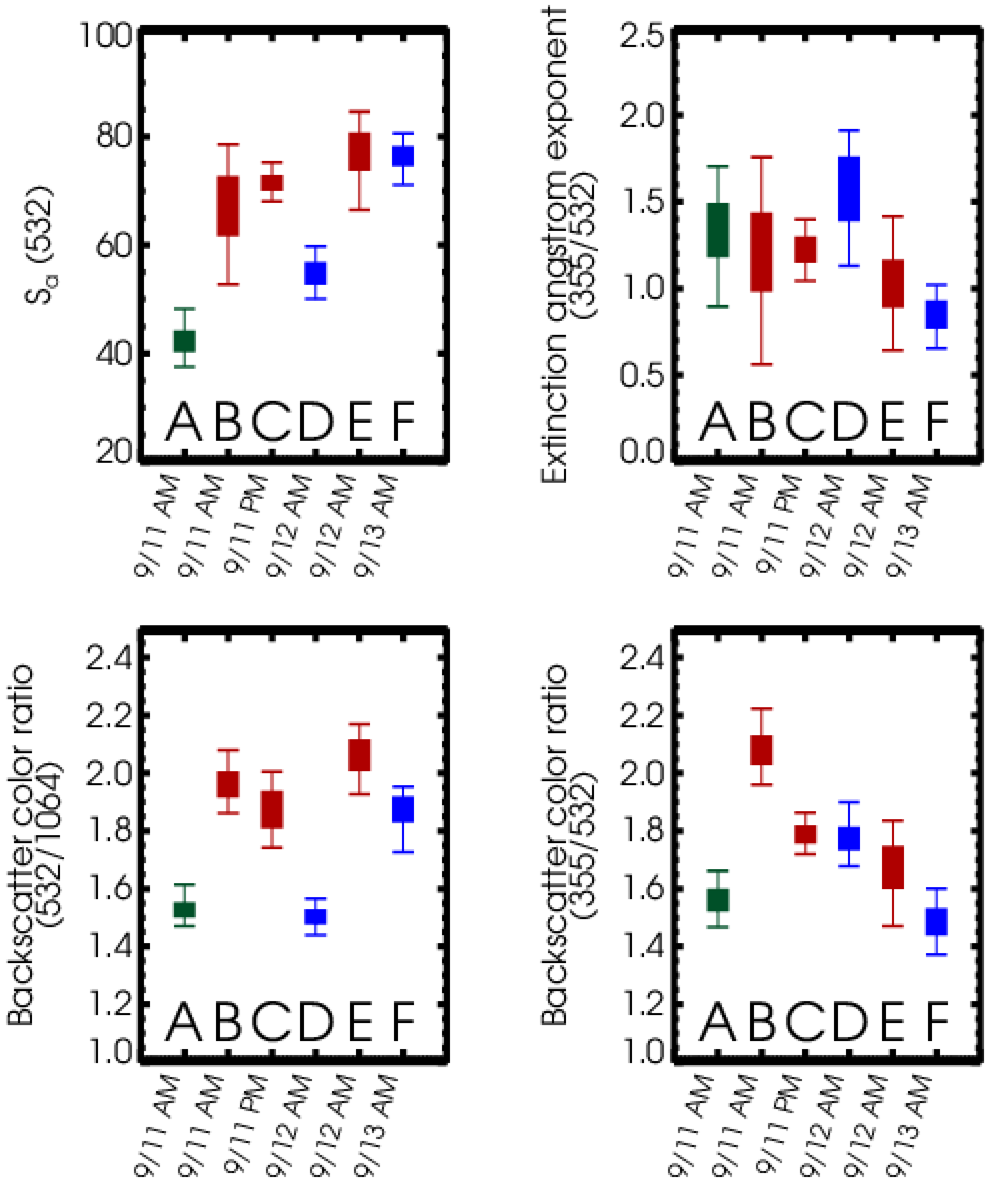


# Pure Smoke
# B,C,E

# Pure Smoke: B,C,E



# Lidar intensive properties for 6 aerosol samples



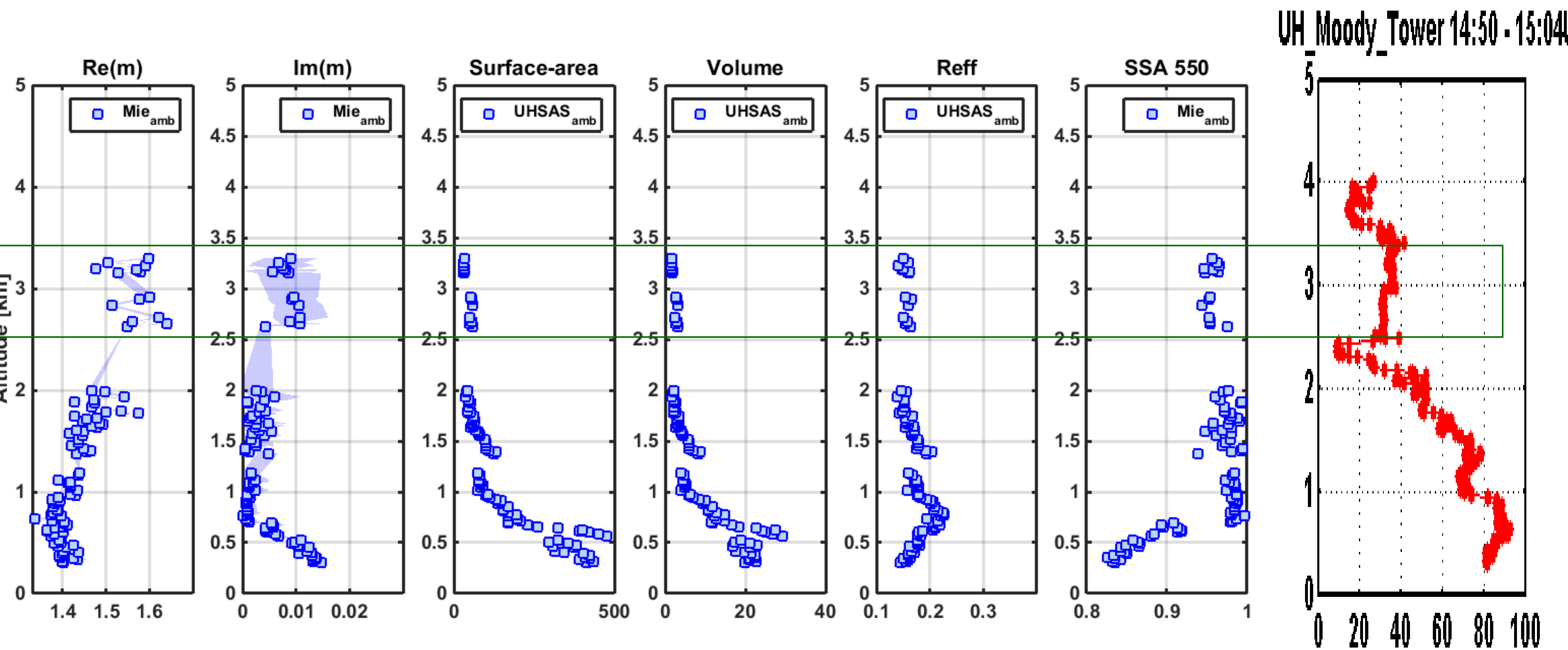

- Lidar intensive variables vary both within and between types
- Extinction angstrom exponent varies monotonically with size but is noisy
- Lidar ratio related to absorption, but also varies with particle size, as much as angstrom exponent does
- Backscatter color ratios have complicated dependence on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

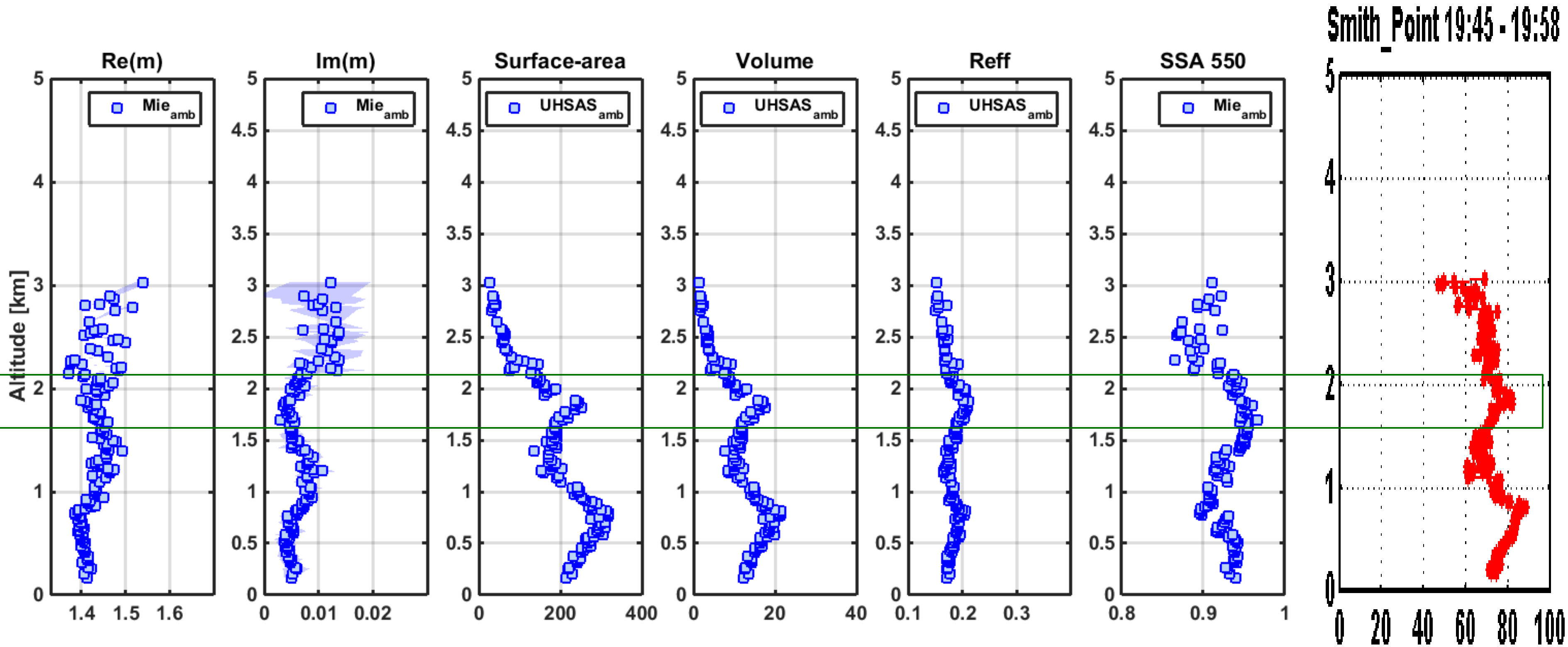
# Summary

- 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

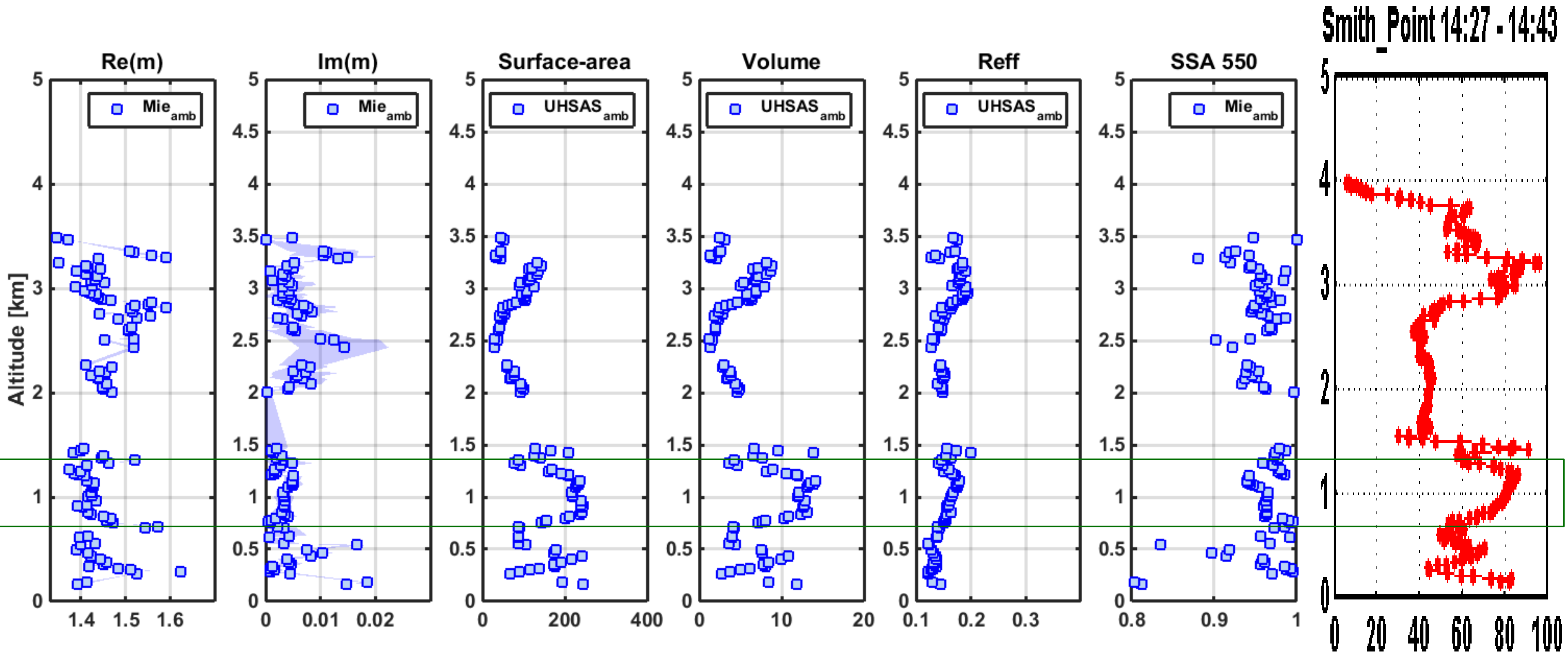
# EXTRA: WHAT DOES IN SITU SAY?



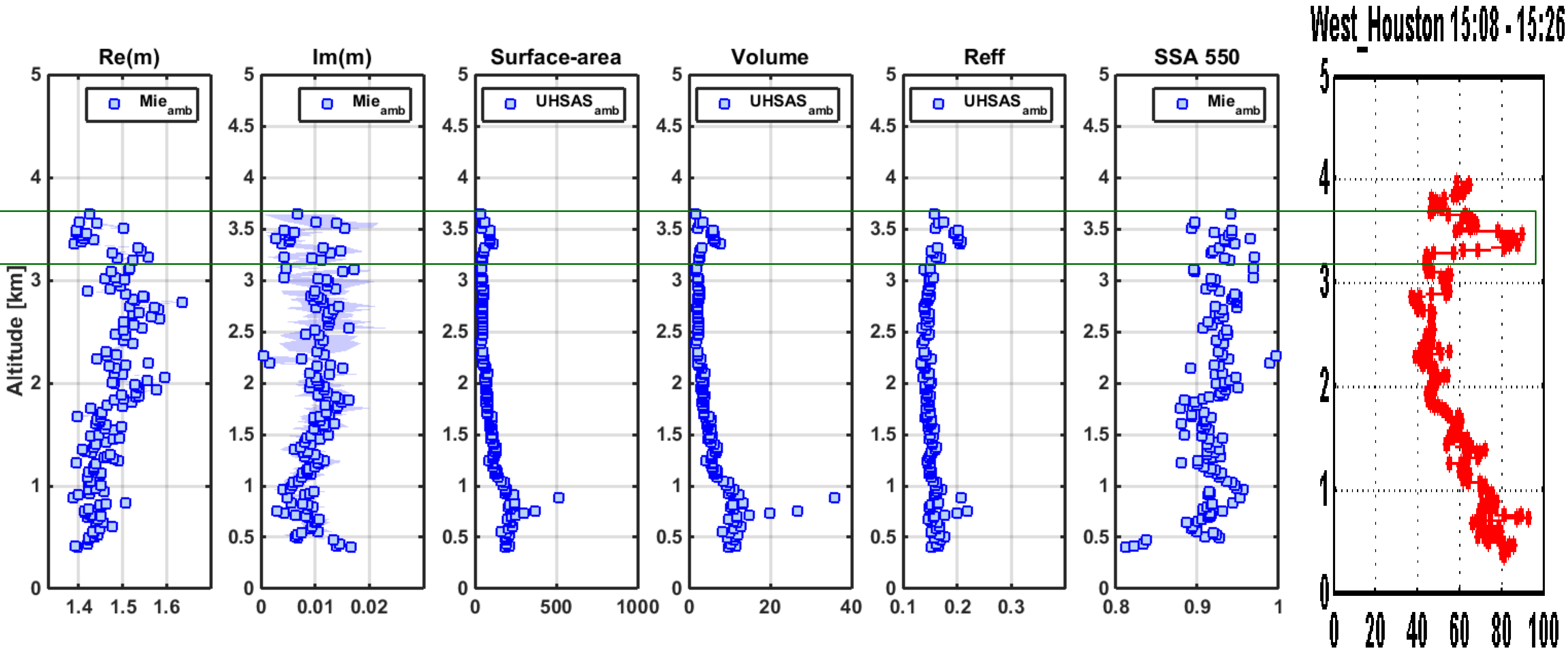

B: UH Moody Tower, 20130911, 14.84-15.07



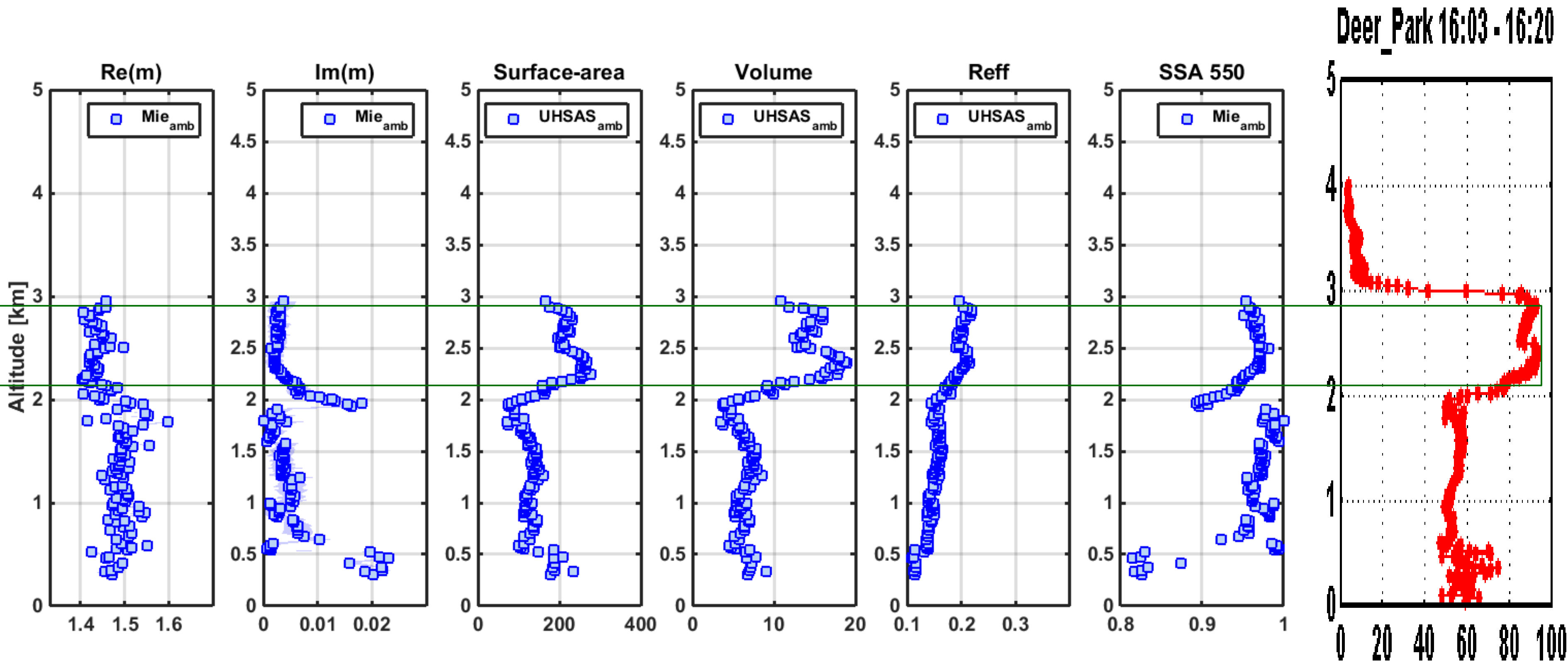

C: Smith Point, 20130911, 19.75-19.97




D: Smith Point, 20130912, 14.45-14.71

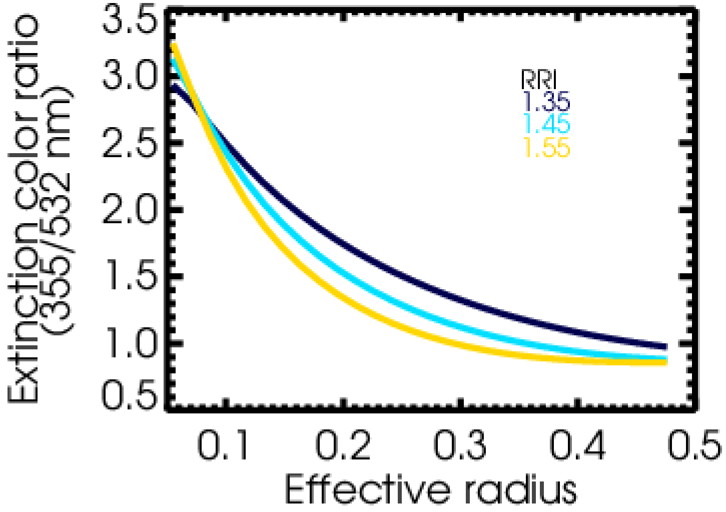



E: West Houston, 20130912, 15.14-15.43

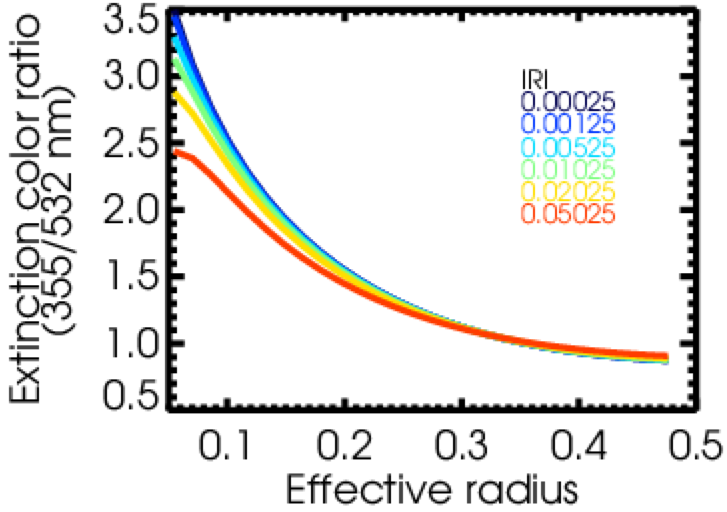



F: Deer Park, 20130913, 16.05-16.33

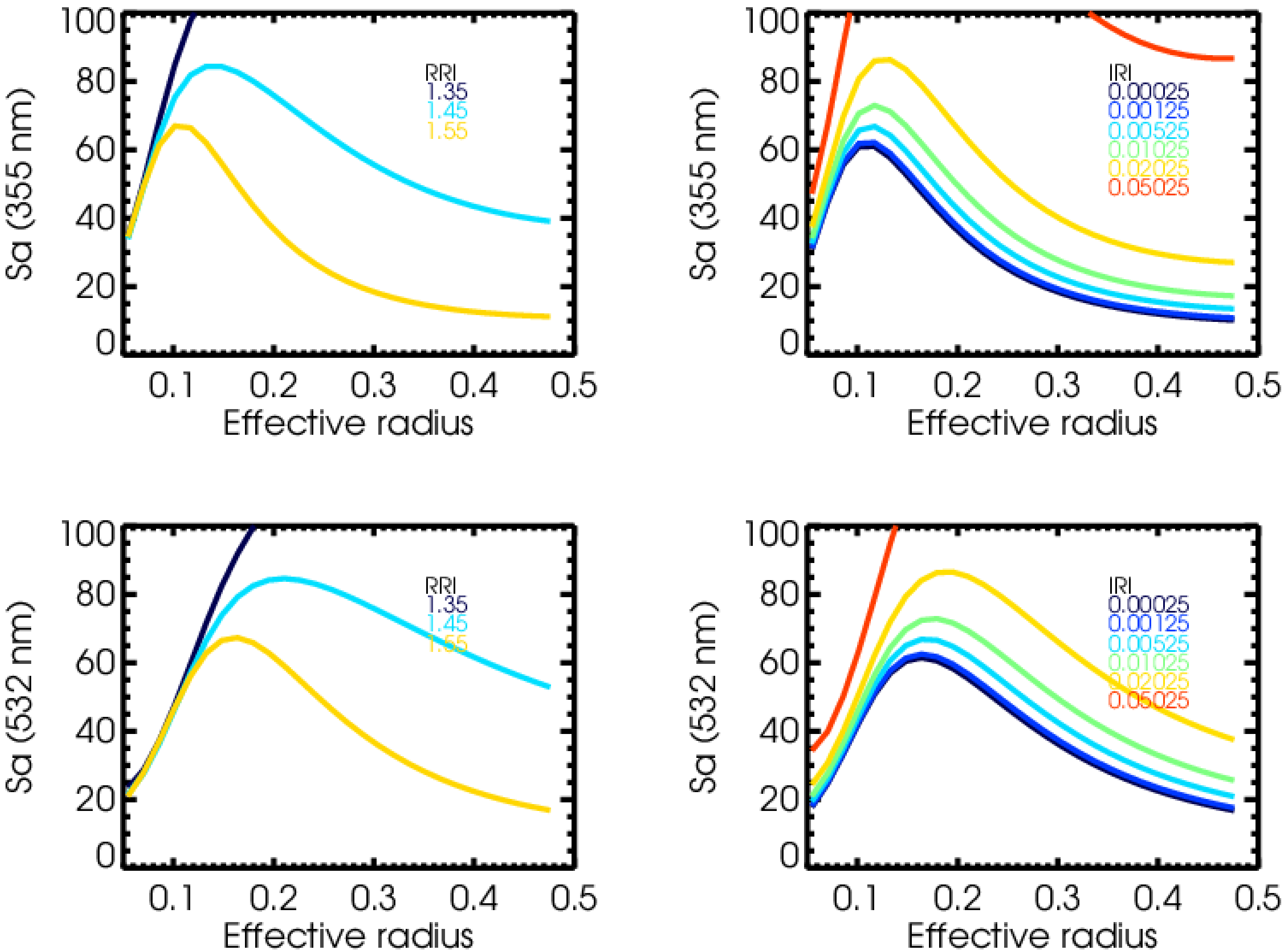
# DISCUSSION OF VARIABILITY OF INTENSIVE PARAMETERS OF SMOKE



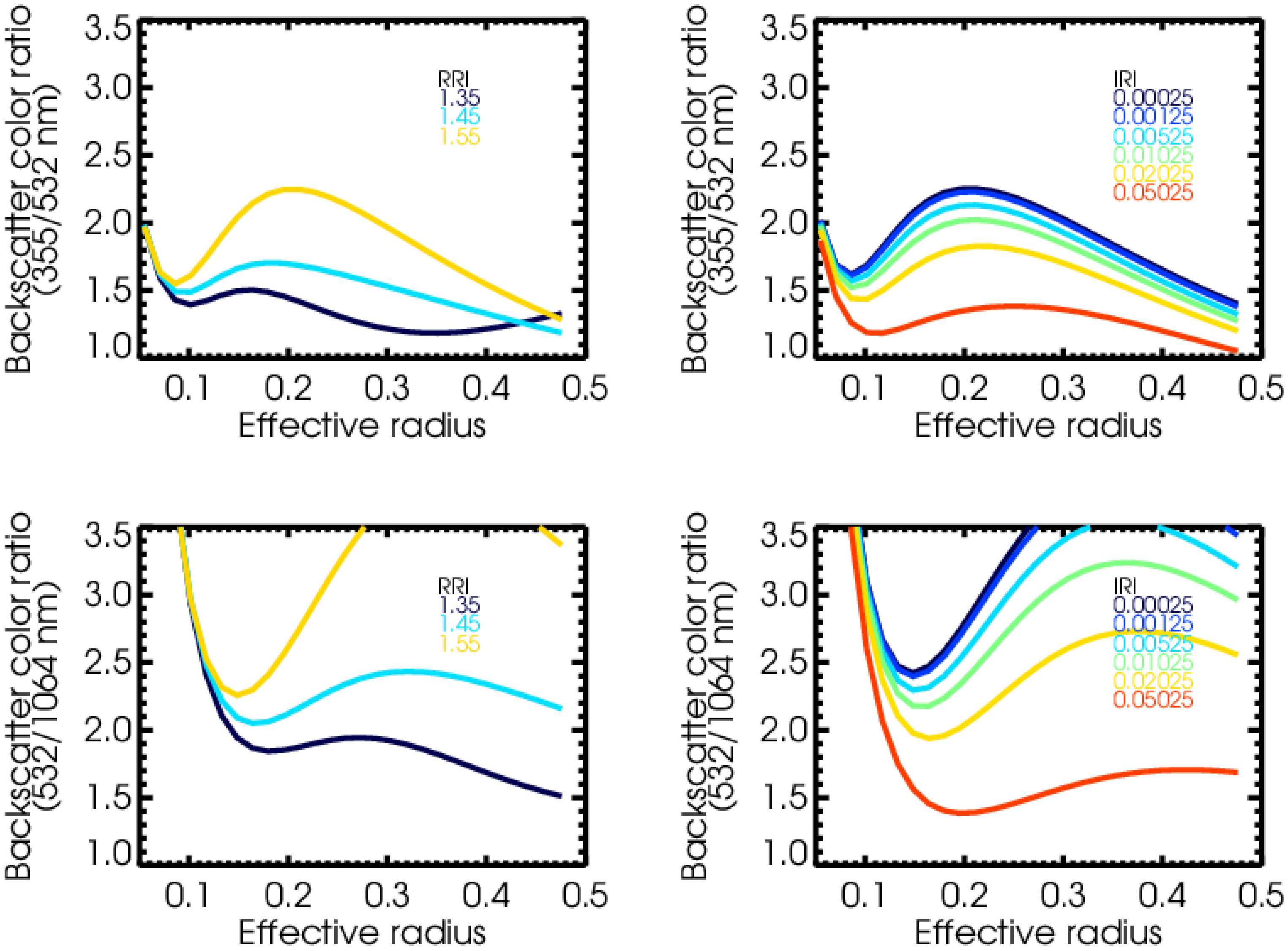
Extinction color ratio (355/532 nm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
0.2
0.3
0.4
0.5
Effective radius
RRI
1.35
1.45
1.55

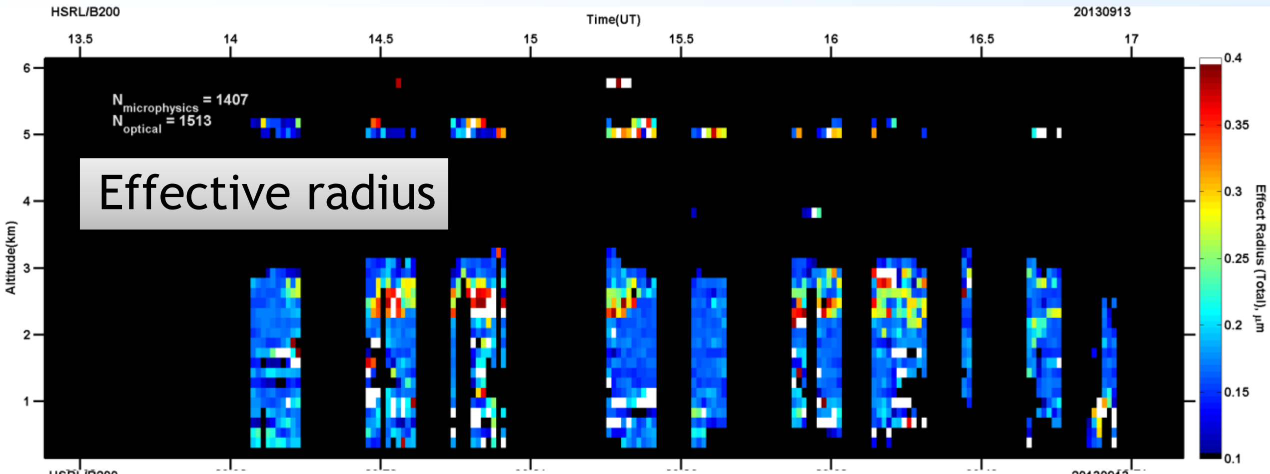
Extinction color ratio (355/532 nm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
0.2
0.3
0.4
0.5
Effective radius
IRI
0.00025
0.00125
0.00525
0.01025
0.02025
0.05025

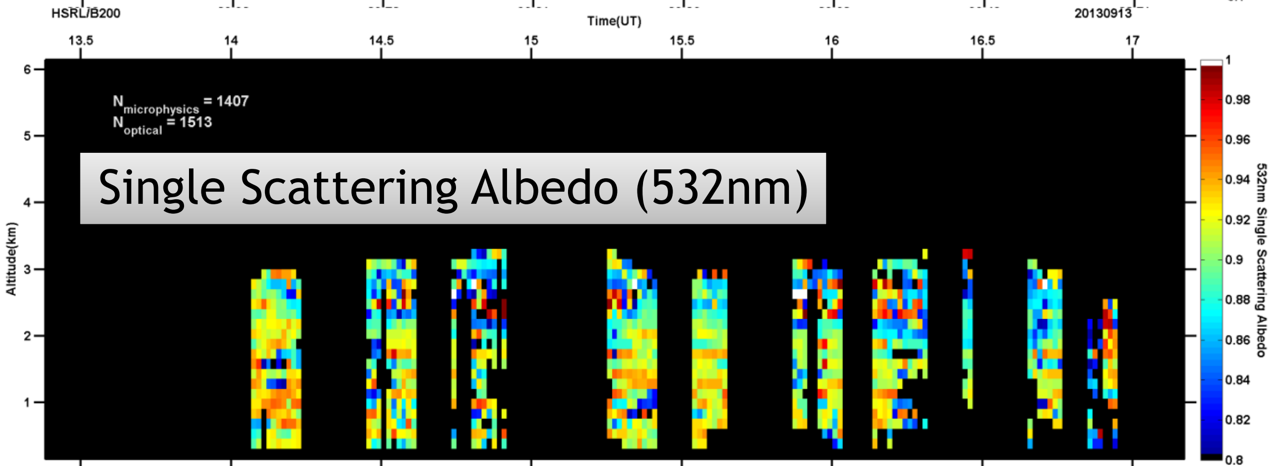


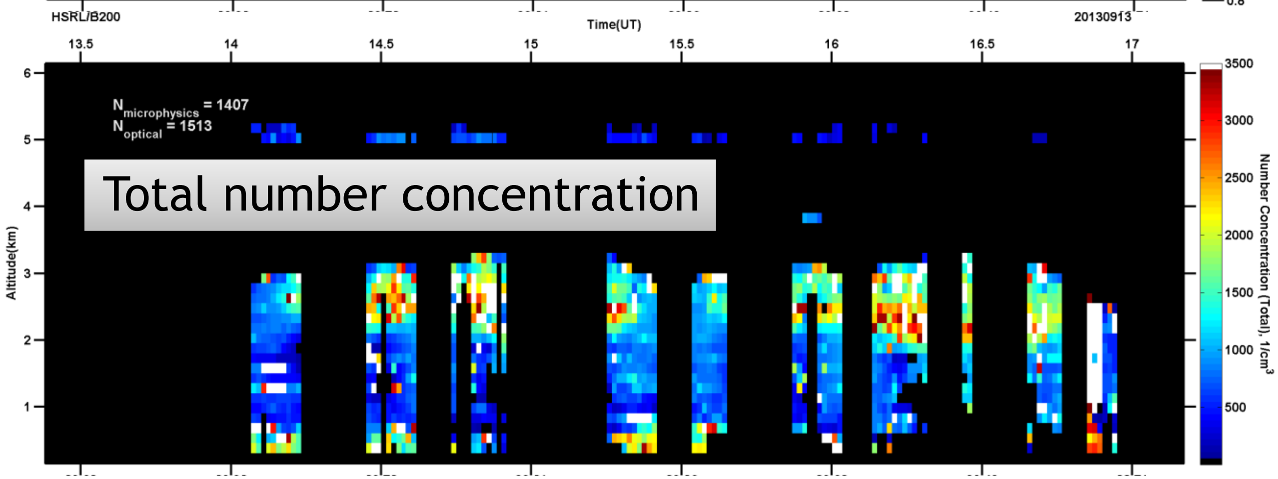
Sa (355 nm)
Effective radius
RRI
1.35
1.45
1.55
Sa (355 nm)
Effective radius
IRI
0.00025
0.00125
0.00525
0.01025
0.02025
0.05025
Sa (532 nm)
Effective radius
RRI
1.35
1.45
1.55
Sa (532 nm)
Effective radius
IRI
0.00025
0.00125
0.00525
0.01025
0.02025
0.05025



Backscatter color ratio (355/532 nm)
RRI
1.35
1.45
1.55
IRI
0.00025
0.00125
0.00525
0.01025
0.02025
0.05025
Backscatter color ratio (532/1064 nm)
Effective radius
3.5
3.0
2.5
2.0
1.5
1.0
0.1
0.2
0.3
0.4
0.5


HSRL/B200
Time(UT)
20130913
13.5 14 14.5 15 15.5 16 16.5 17
Altitude(km)
$N_{microphysics}$ = 1407
$N_{optical}$ = 1513
Effective radius
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
Altitude(km)
$N_{microphysics}$ = 1407
$N_{optical}$ = 1513
Single Scattering Albedo (532nm)
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
Altitude(km)
$N_{microphysics}$ = 1407
$N_{optical}$ = 1513
Total number concentration
Number Concentration (Total), 1/cm$^3$
3500 3000 2500 2000 1500 1000 500