
HSRL-2 observations of aerosol variability and mixing during boundary layer evolution in Houston

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⁴ *Lord Fairfax Community College, Middletown VA*

High Spectral Resolution Lidar, HSRL-2

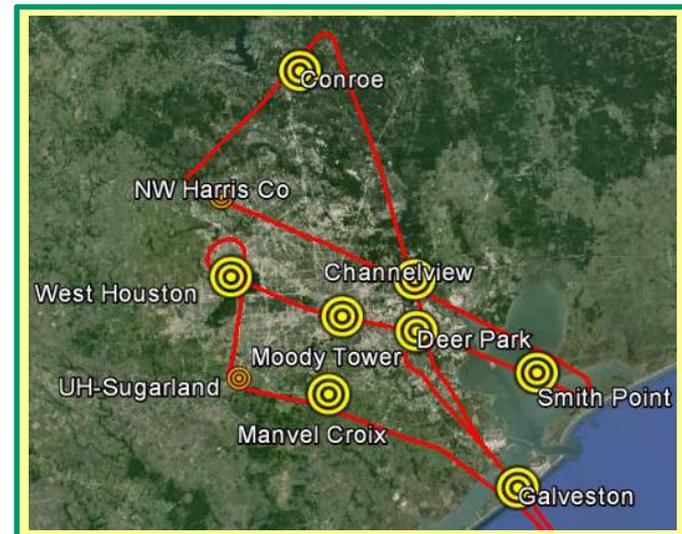


High Spectral Resolution Lidar —

- independently measures aerosol extinction and backscatter at two wavelengths
- Langley HSRL-2 is the only operational multi-wavelength airborne HSRL in the world

Uses —

- Satellite Validation
- Testbed for future space instruments and retrievals
- Overview and context during field missions
- Input to and validation of models

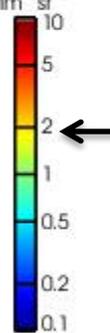
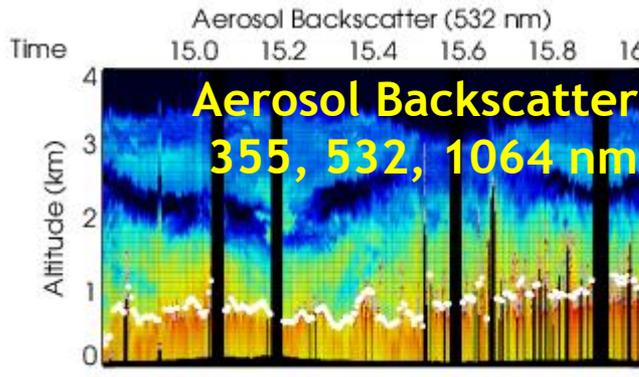


DISCOVER-AQ Houston
September 4-27, 2013
26 science flights
101 flight hours

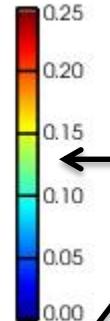
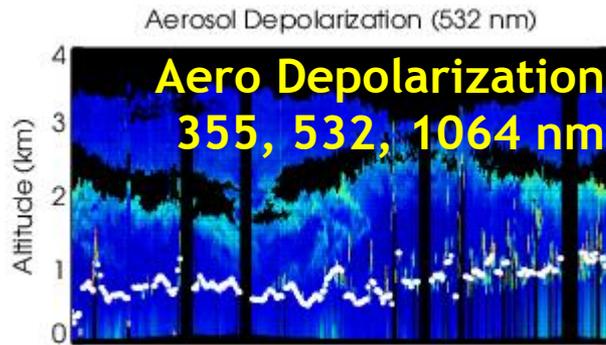
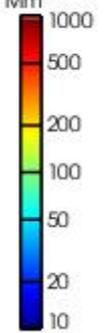
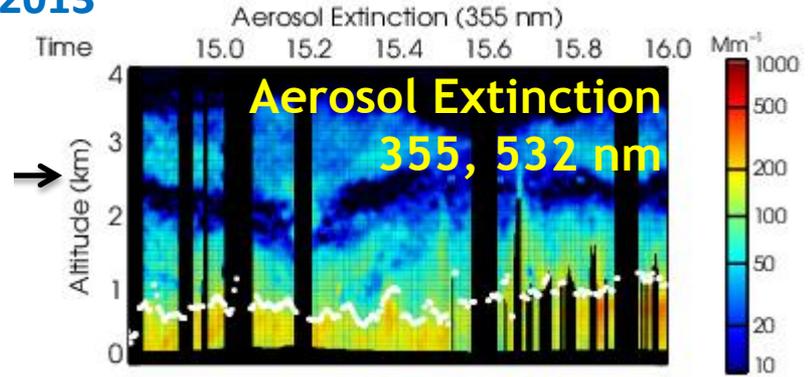
HSRL-2 measurement products



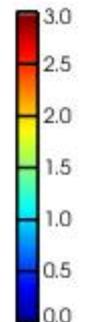
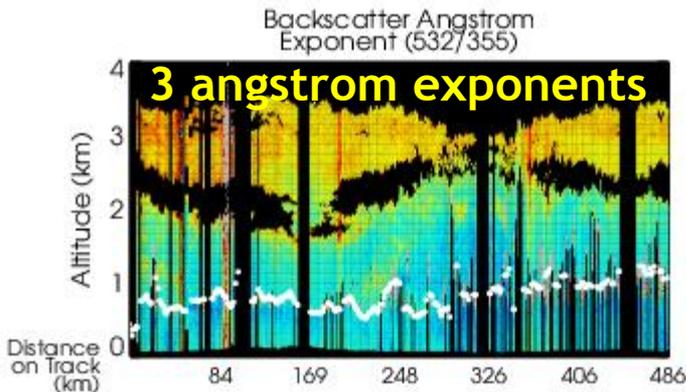
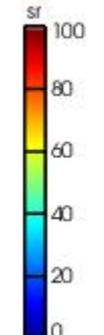
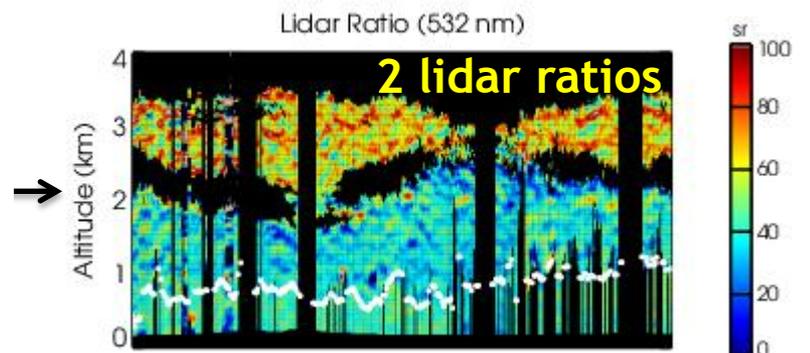
September 11, 2013



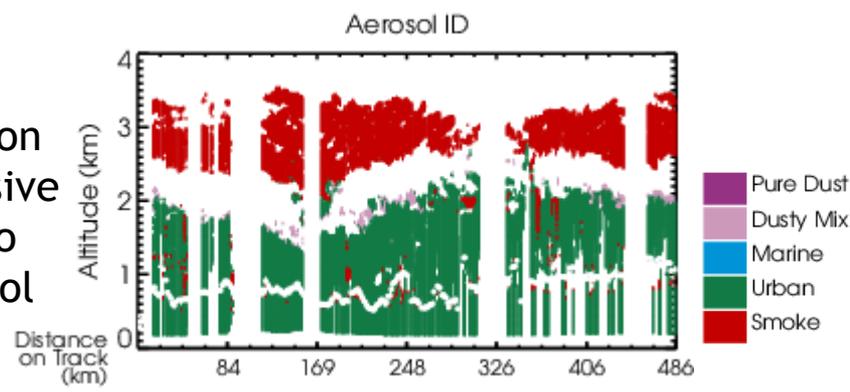
Extensive variables



Intensive variables

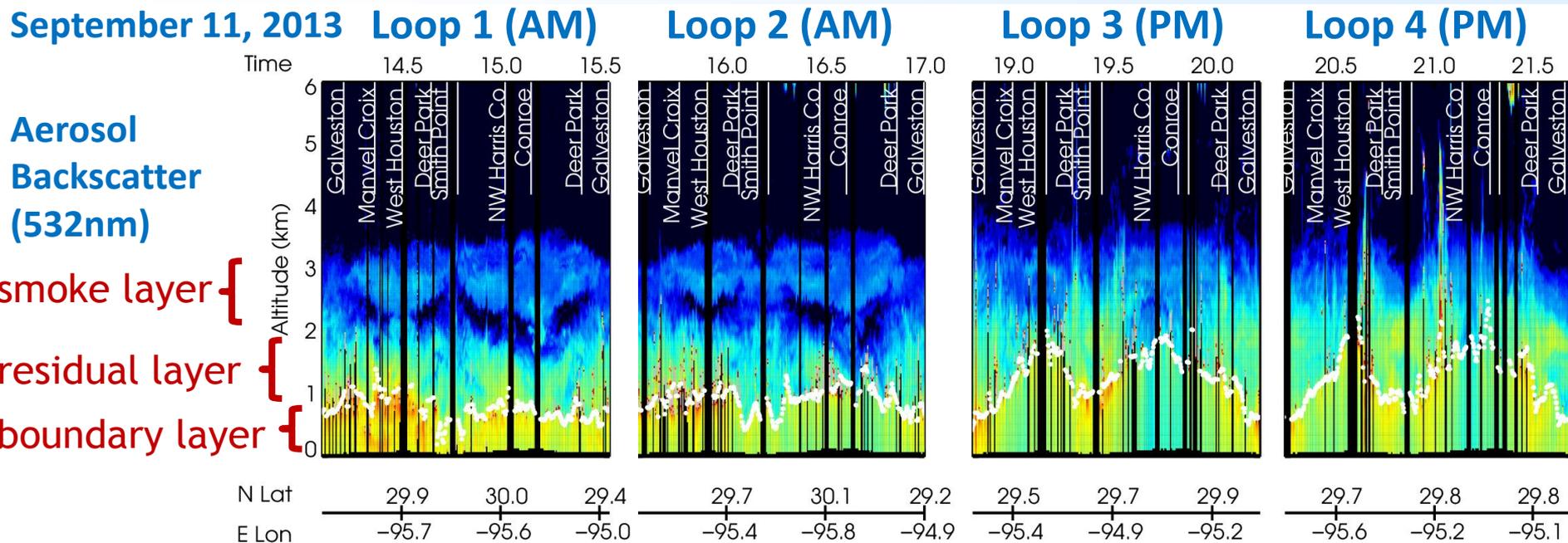


Aerosol classification uses intensive variables to infer aerosol type

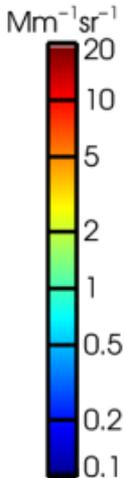


HSRL-2 observations of aerosol layers

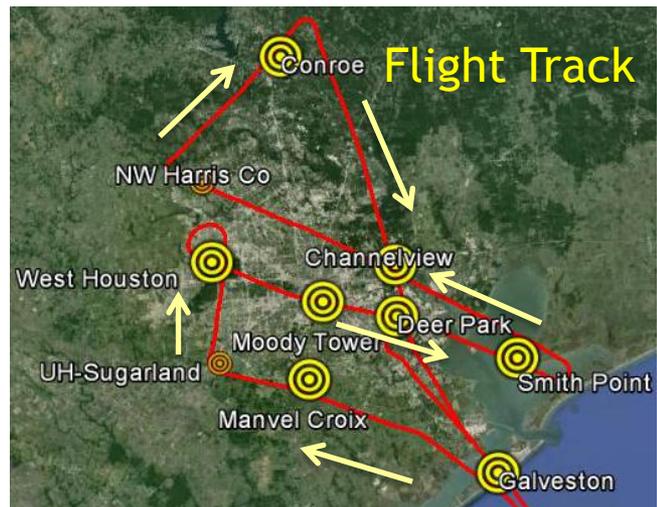
September 11, 2013, Houston TX



smoke layer {
residual layer {
boundary layer {



- HSRL-2 airborne lidar provides vertically resolved measurements of aerosol layers
- During DISCOVER-AQ, flight track thoroughly covered Houston and surrounding regions
- Loop repeated 4x per day, frequently sampling several days in a row
- This is a rare opportunity to observe diurnal and day-to-day evolution in so much detail



Smoke and Boundary Layer evolution, Sep 11-12



Sep 11, 2013

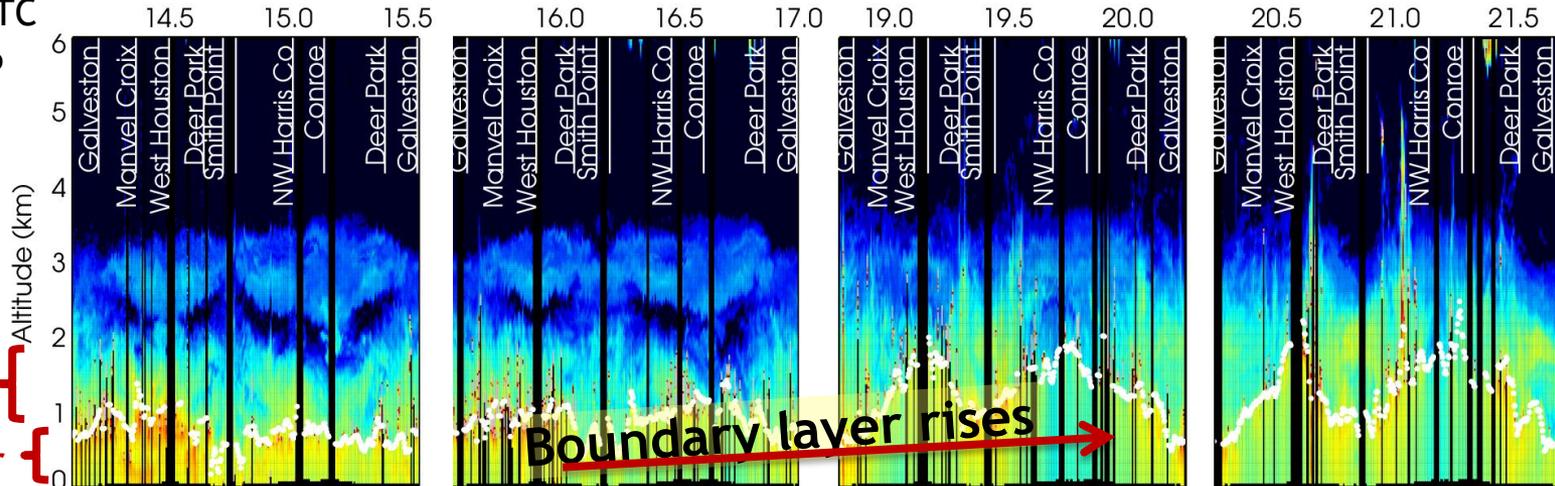
Time UTC
= LST+6

Loop 1

Loop 2

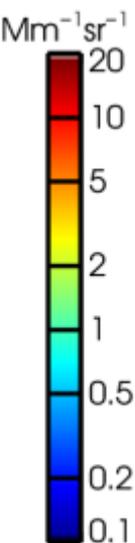
Loop 3

Loop 4



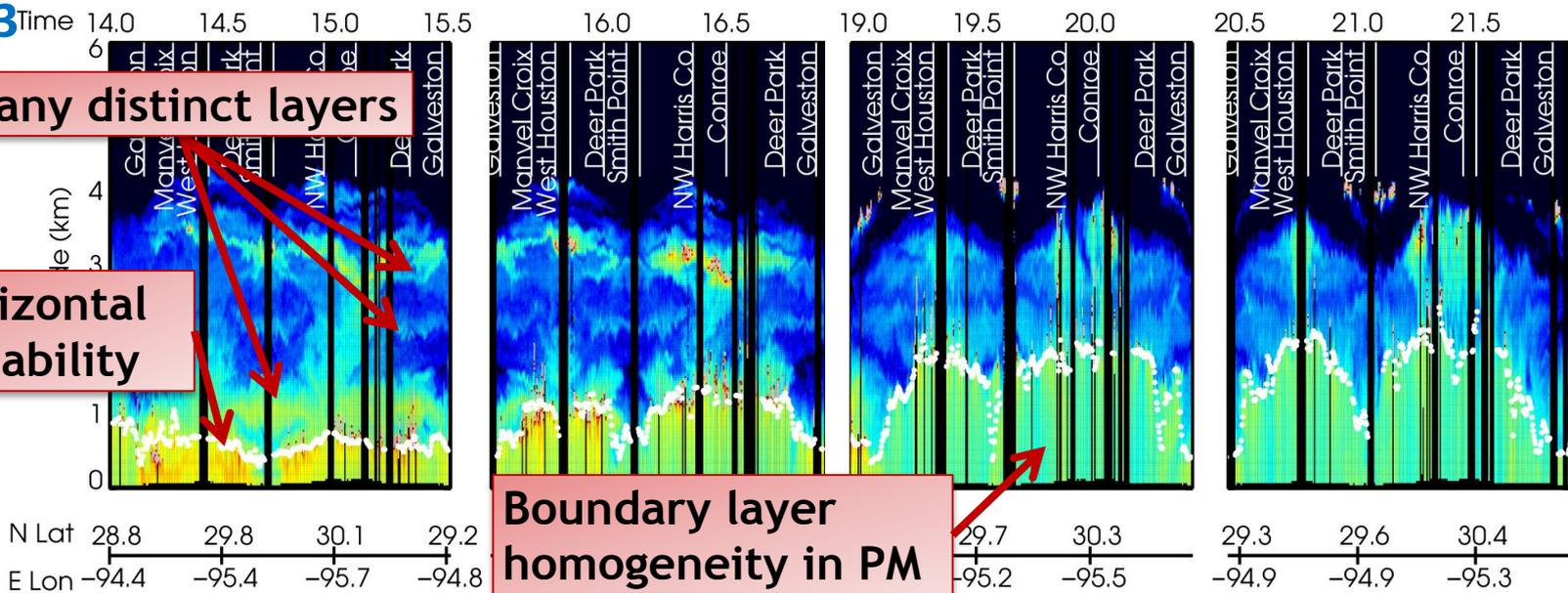
smoke layer {
residual layer {
boundary layer {

Sep 12, 2013



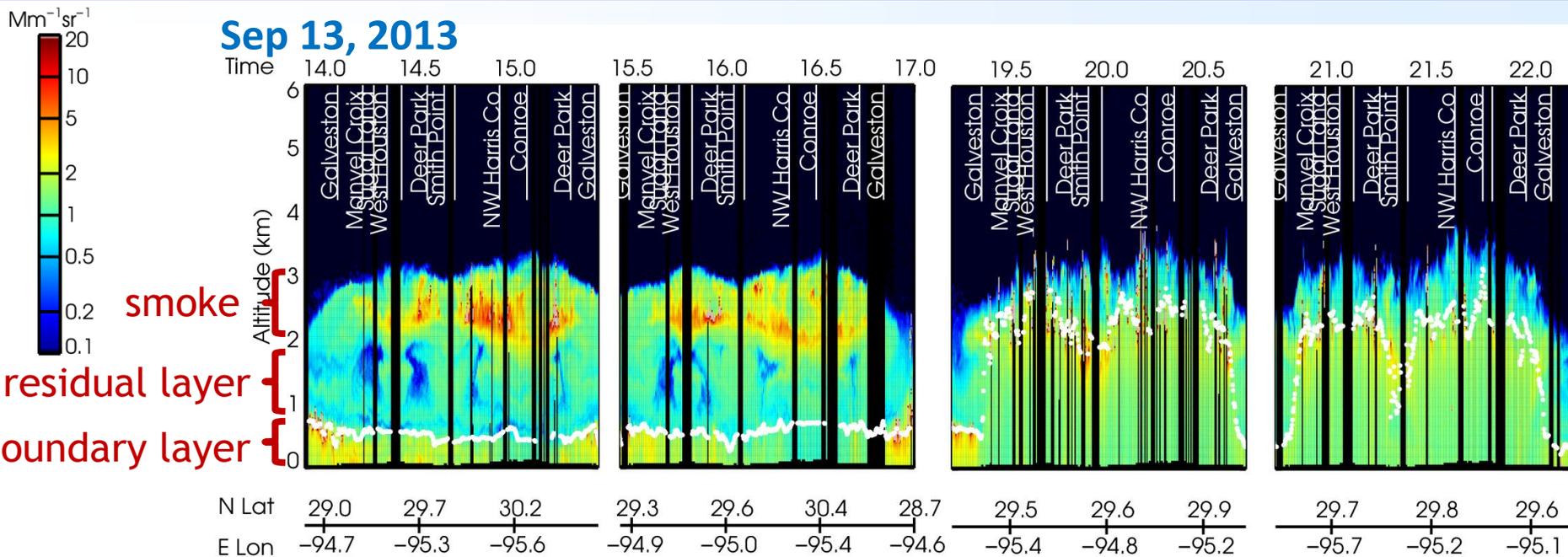
Many distinct layers

Horizontal variability

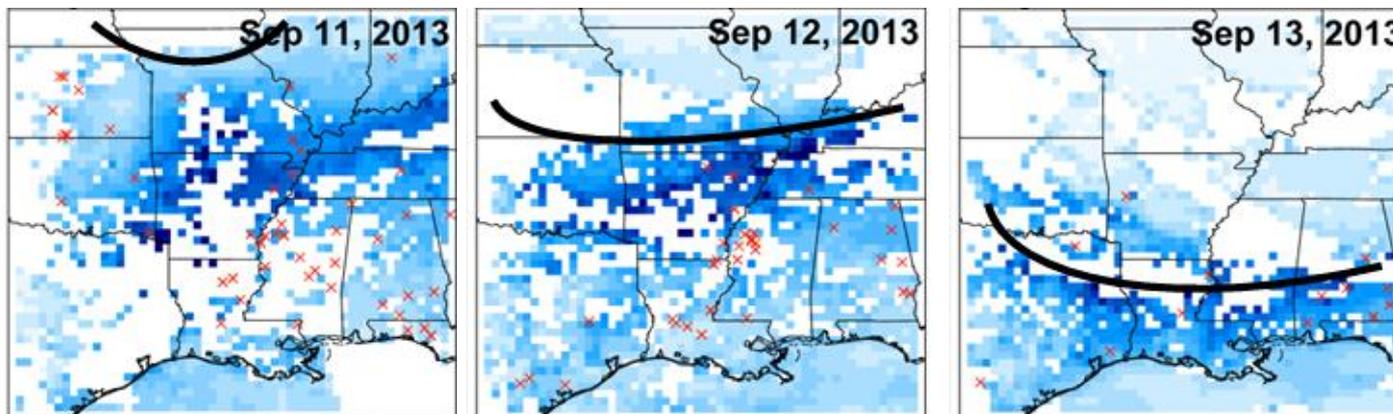


Boundary layer homogeneity in PM

continued... September 13



NPP VIIRS AOD



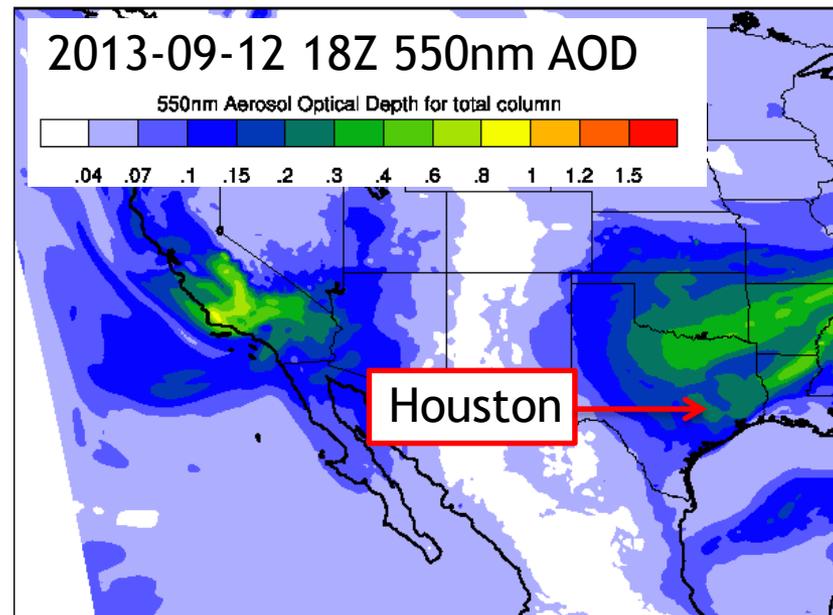
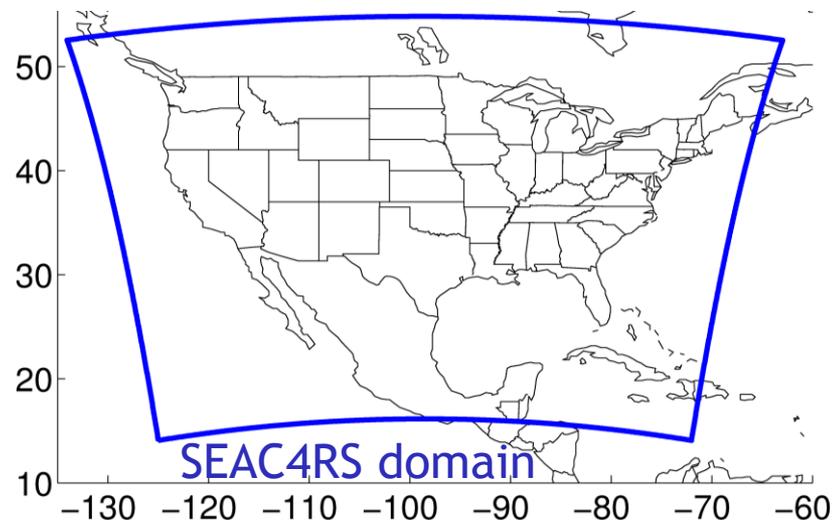
see Duncan, B. N., et al. *Atmos Environ*, 2014



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)



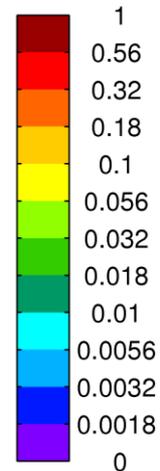
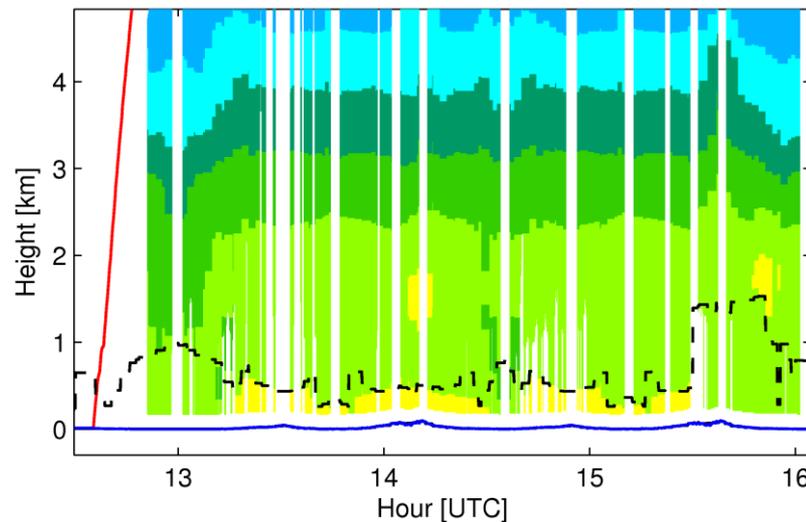
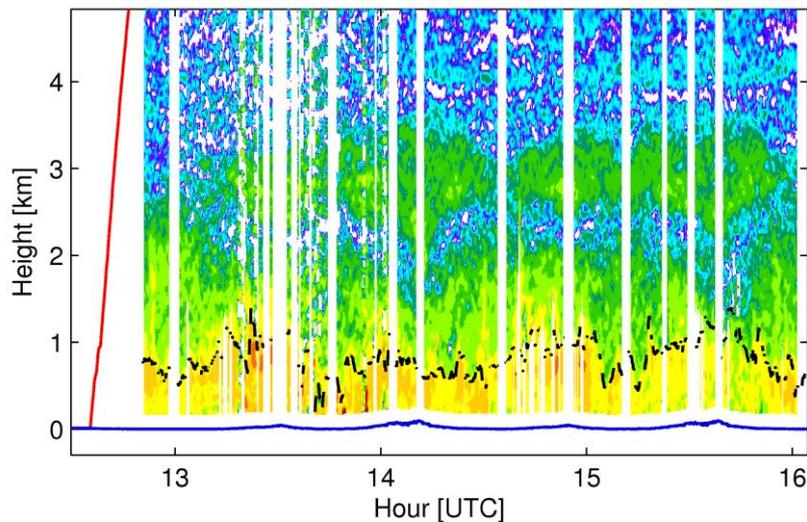
WRF-Chem vs. HSRL2 comparison 9/11



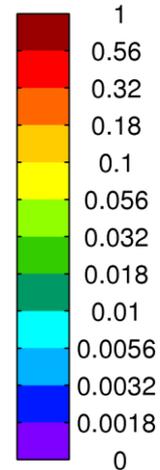
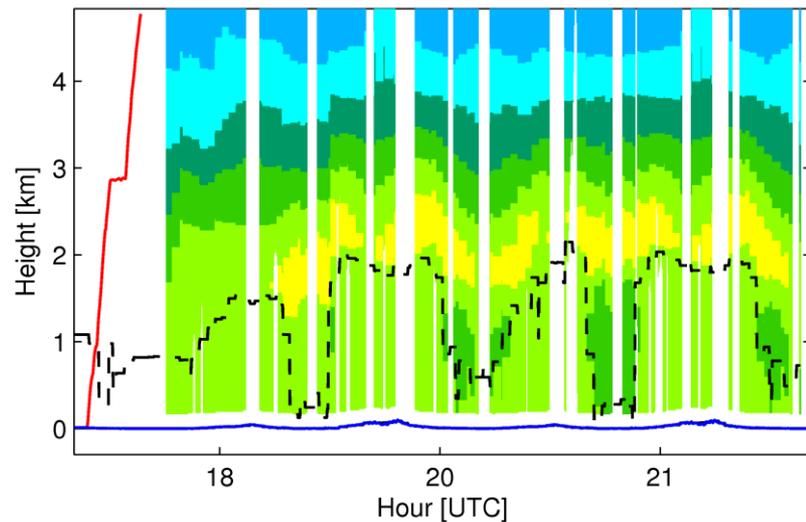
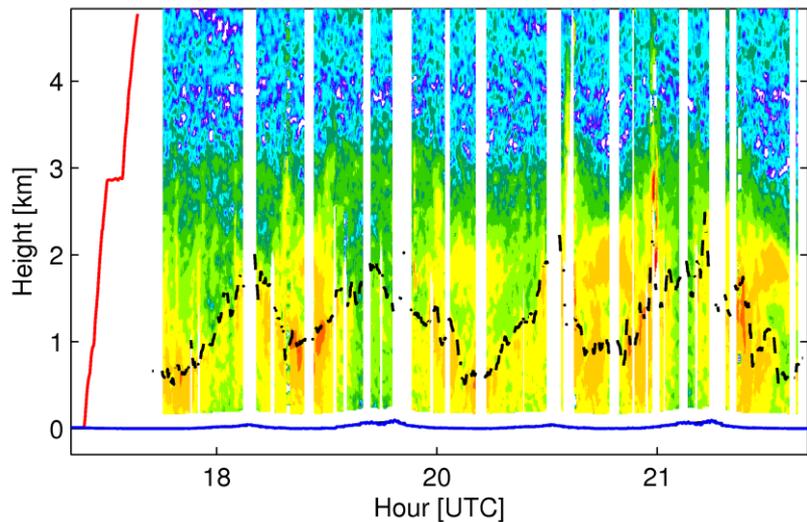
HSRL2 EXT

MODEL EXT

September 11 AM



September 11 PM



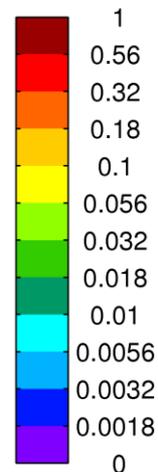
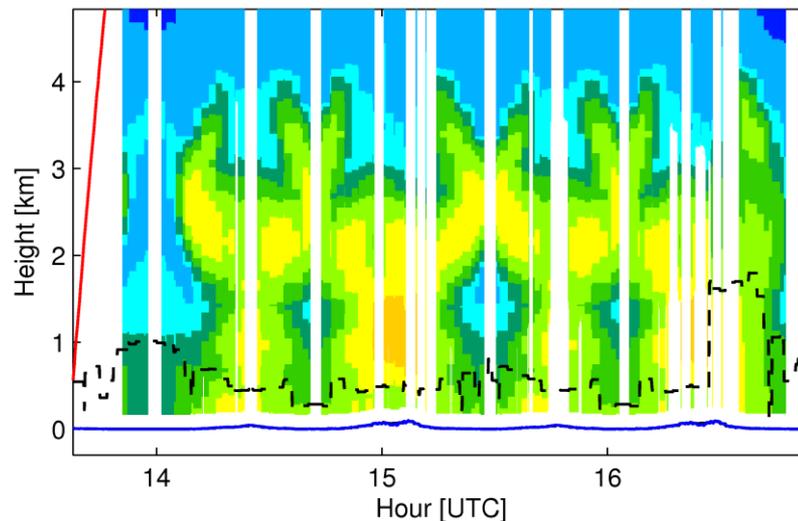
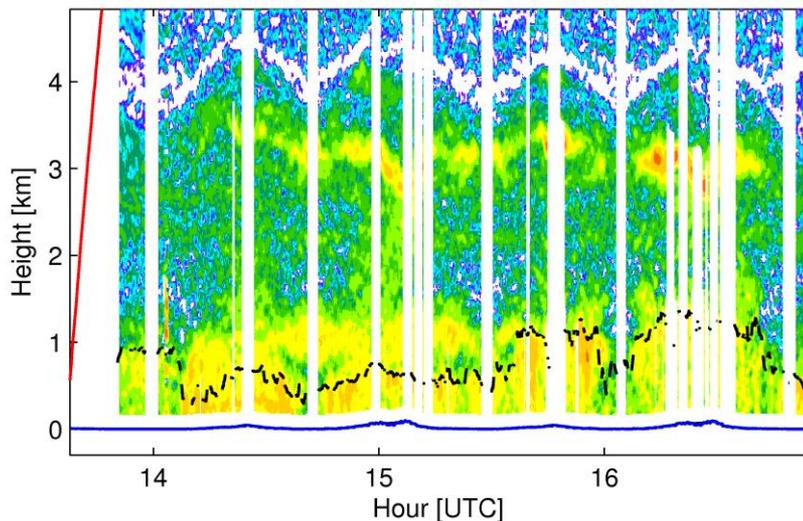
WRF-Chem vs. HSRL2 comparison 9/12



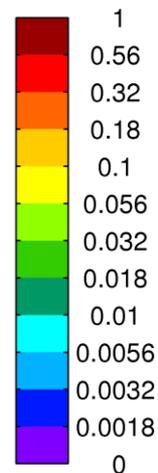
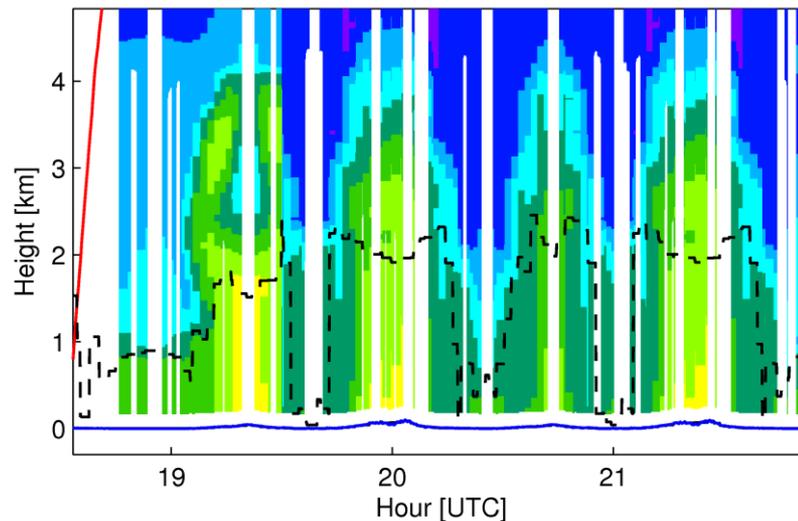
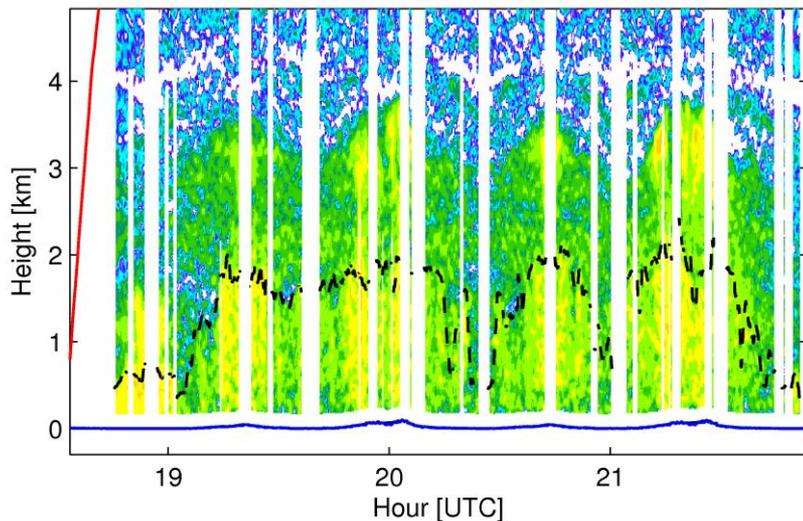
HSRL2 EXT

MODEL EXT

September 12 AM



September 12 PM

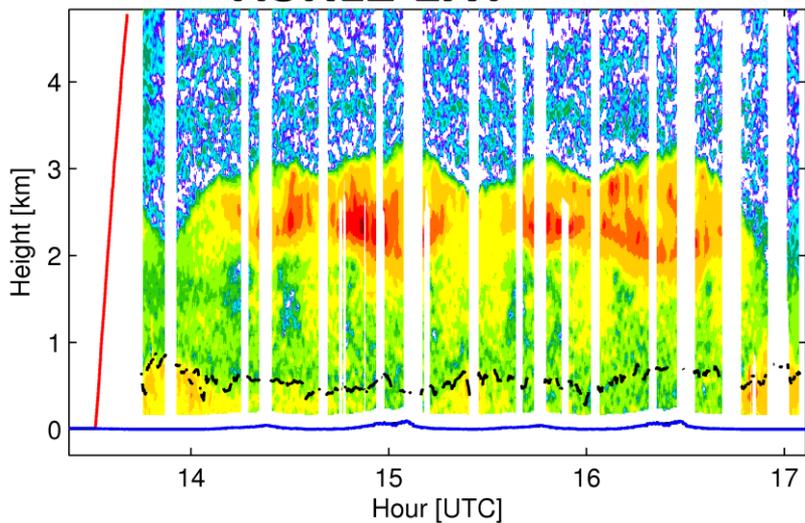


WRF-Chem vs. HSRL2 comparison 9/13

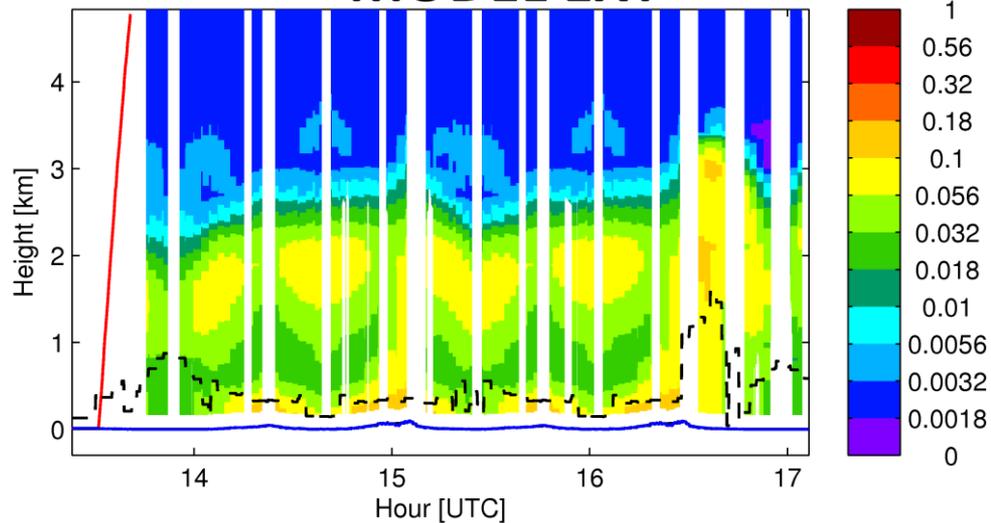


September 13 AM

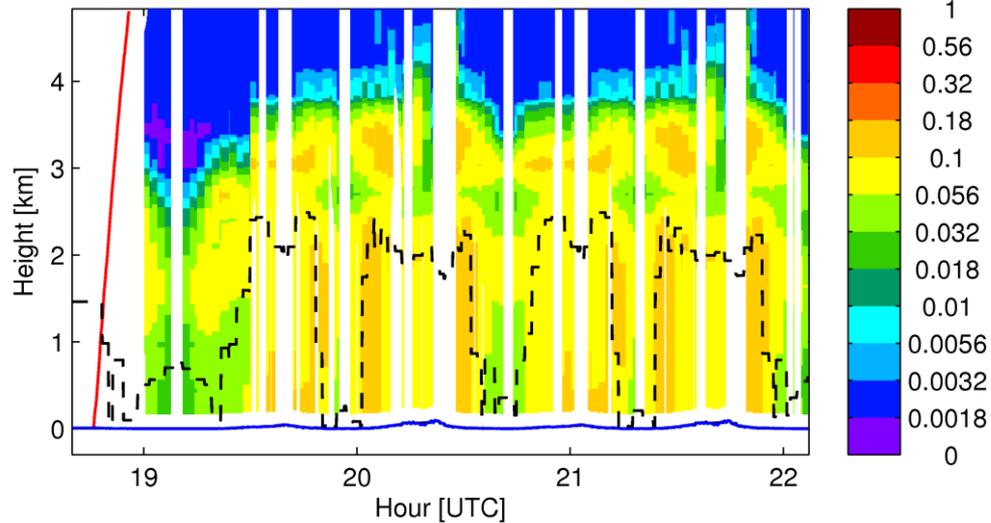
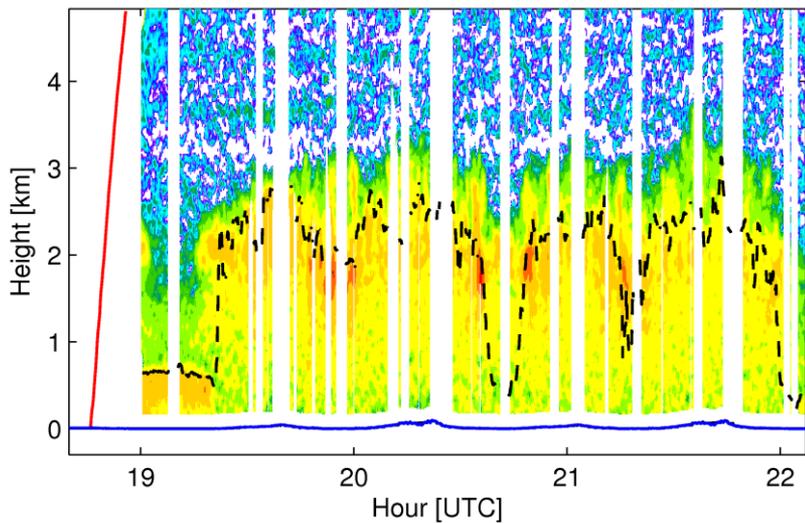
HSRL2 EXT



MODEL EXT



September 13 PM



HSRL-2 Aerosol Type Sep 11-13



Sep 11, 2013

Sep 12, 2013

Sep 13, 2013

Time 14.5 15.0 15.5

14.0 14.5 15.0 15.5

14.0 14.5 15.0

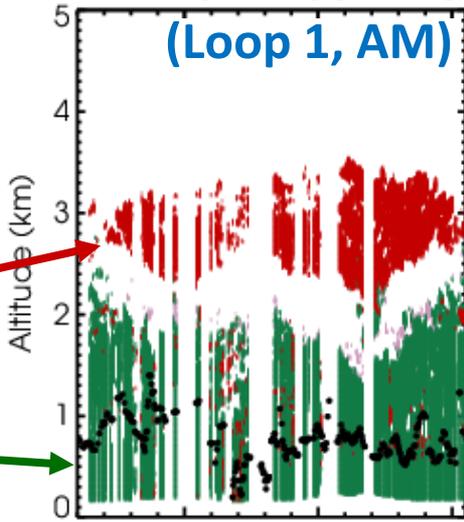
(Loop 1, AM)

(Loop 1, AM)

(Loop 1, AM)

Smoke

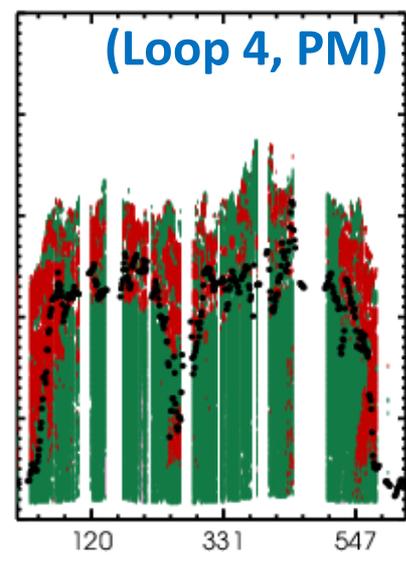
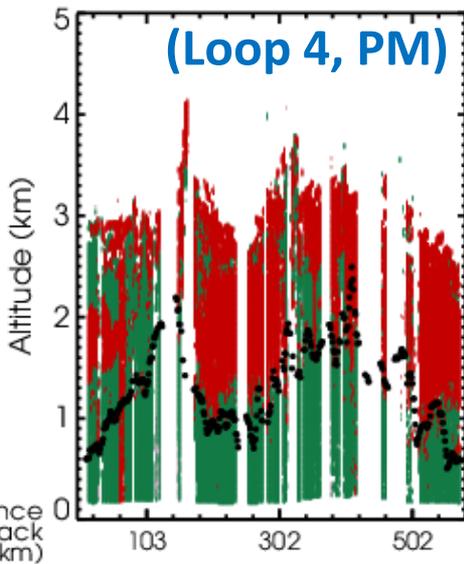
Urban



(Loop 4, PM)

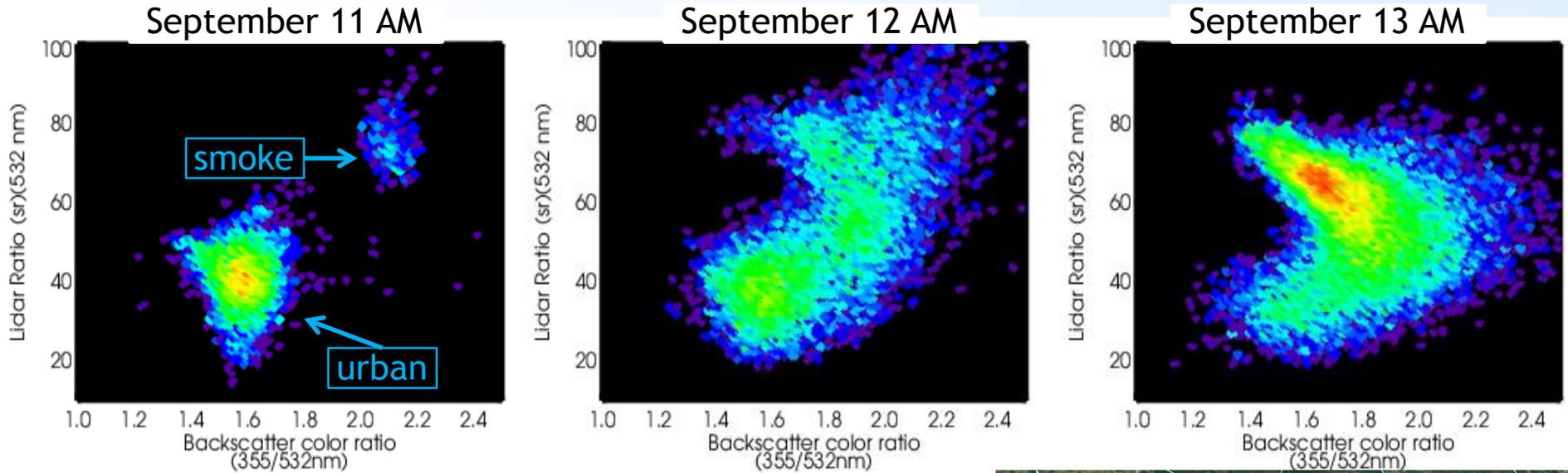
(Loop 4, PM)

(Loop 4, PM)



- Pure Dust
- Dusty Mix
- Marine
- Urban
- Smoke

Recap: HSRL-2 Intensive variables for smoke are different each day

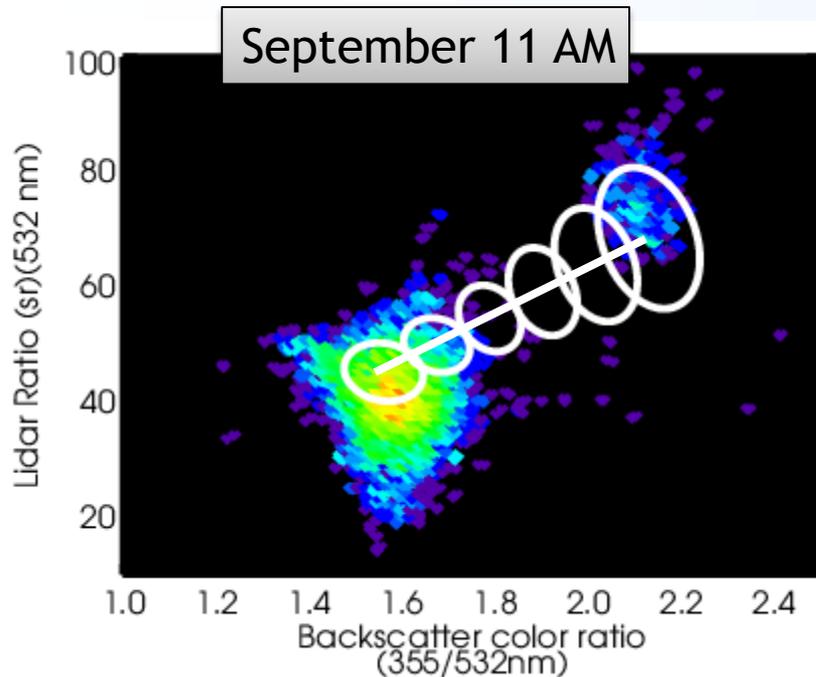


Differences in smoke intensive properties

- Reflect probable difference in refractive index, SSA
- Could be due to different sources, ages, mixing, or relative humidity

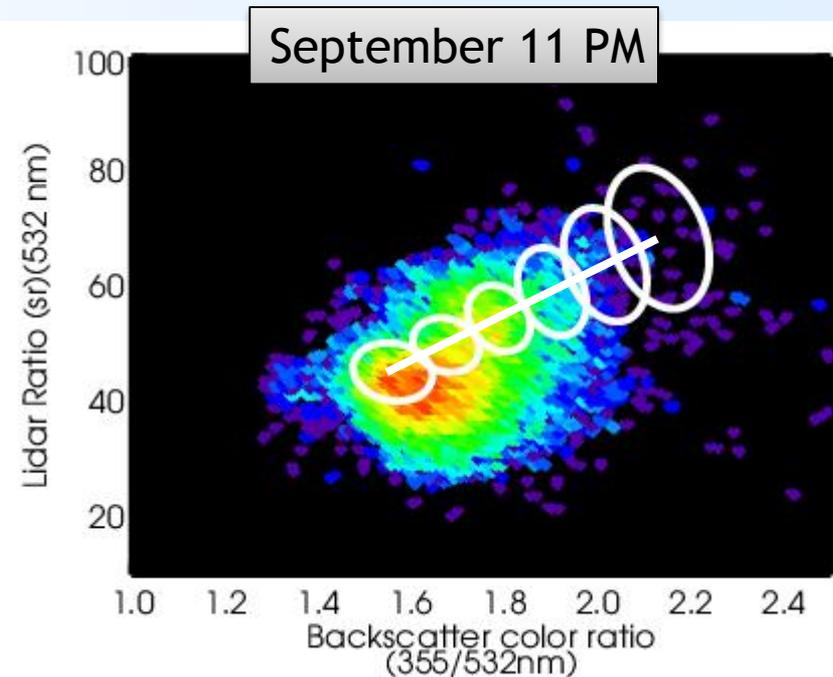


September 11 boundary layer mixing



September 11 AM

- smoke layer and boundary layer pollution well separated in aerosol properties
- Ellipses indicate data samples (multi-variate gaussians)

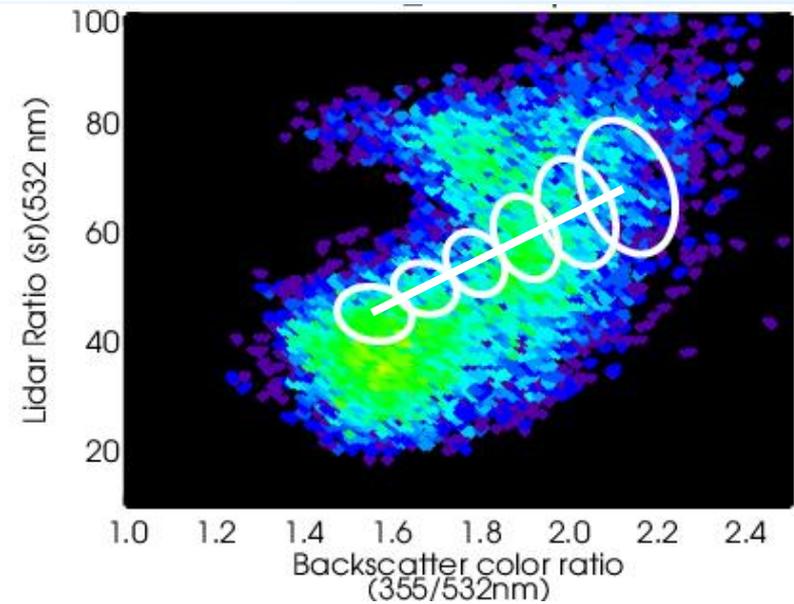
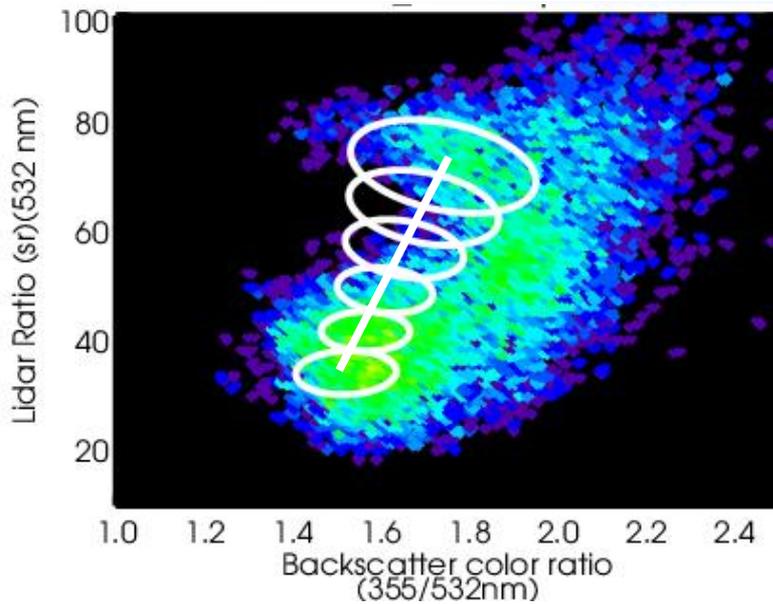


September 11 PM

- Homogeneity with no distinct layering
- Mixing line blends the two samples from the AM according to the rules of external mixing. String of ellipses is a more generalized “mixing line” that also takes data variance into account
- data moves along this line, indicating that external mixing is a reasonable explanation for the properties

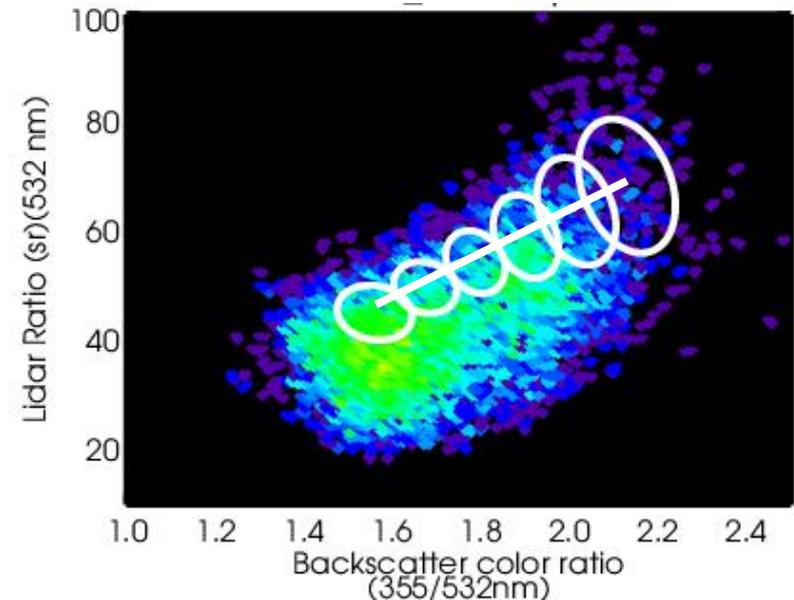
for more on lidar mixing technique, see Burton et al. AMT 2014

September 12 AM, Mixing?



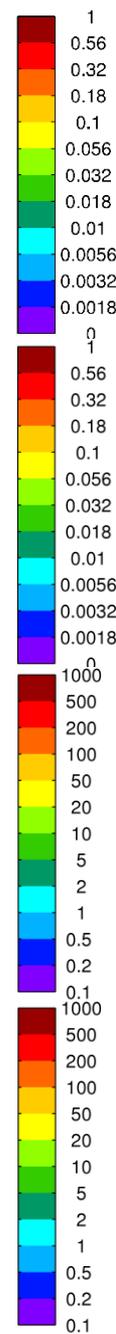
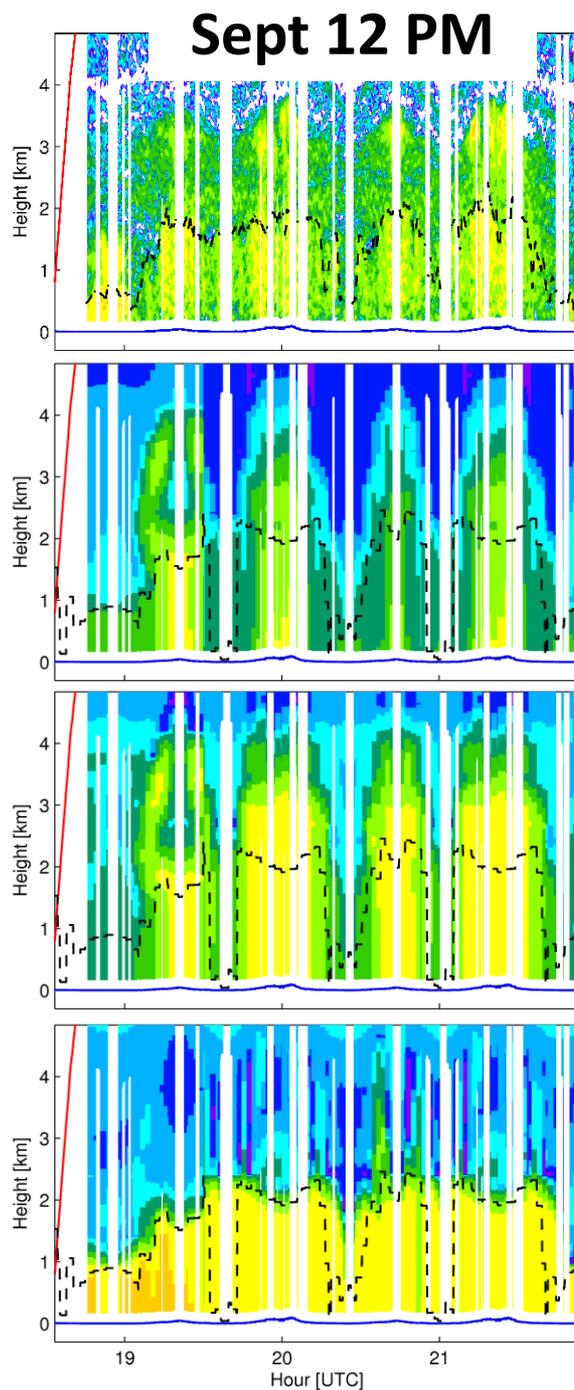
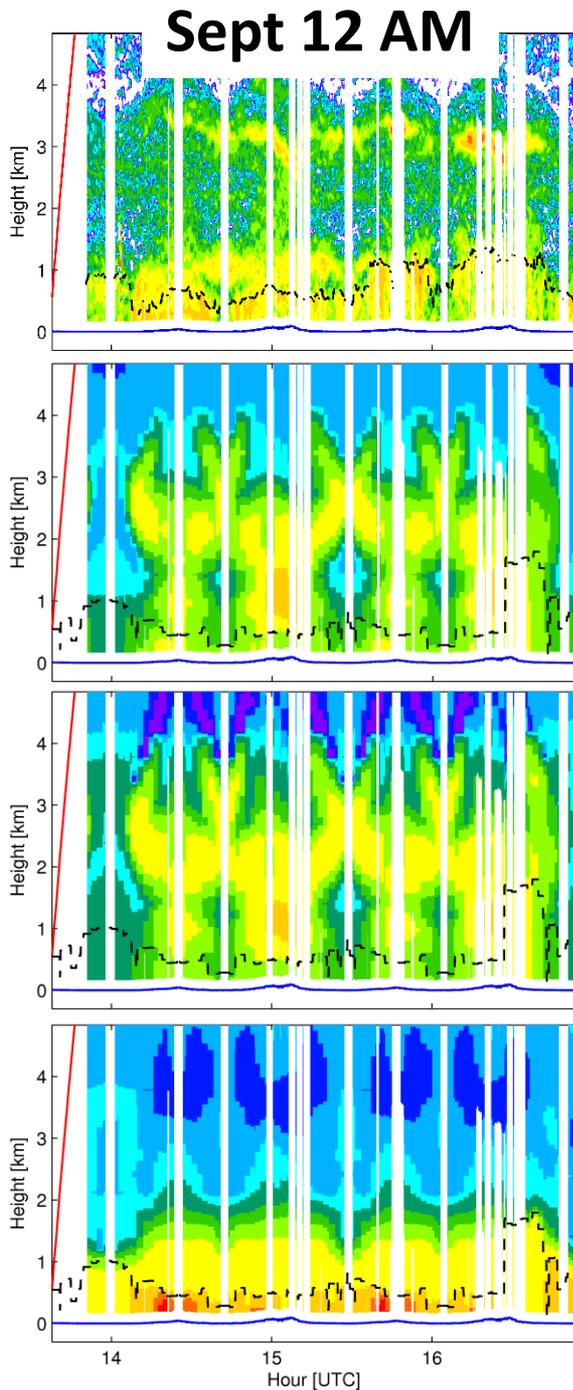
September 12 AM

- Mixing of samples from the upper and lower layers cannot explain this data
- Mixing of yesterday's samples is better, but still cannot explain apparent curvature in the data
- Separation of data into distinct layers reveals that the "curvature" is an illusion
- Only the residual layer and boundary layer fall on mixing line. The elevated layer is distinct.





MODEL CO ANTHRO
MODEL CO FIRE
MODEL EXT
HSRL2 EXT





- HSRL-2 makes horizontally and vertically resolved observations of aerosol layering and diurnal and day-to-day evolution
- HSRL-2 is the most advanced airborne lidar in operation, measuring a large set of intensive parameters that give information on aerosol type and mixing
- Subtleties in HSRL-2 intensive parameters have the potential to give a more nuanced understanding of aerosols, when combined with other information sources (models, backtrajectories, RH, in situ)
- During DISCOVER-AQ:
 - multiple transported agricultural smoke layers were observed with varying optical properties
 - Mixing of smoke into the boundary layer is observed in HSRL-2 measurements and WRF-Chem model
- HSRL-2 provides opportunity for model assessment