Examining HSRL measurements of aerosol optical and microphysical properties and surface PM2.5 during the DISCOVER-AQ deployments

Richard Ferrare[1], Chris Hostetler[1], John Hair[1], Amy Jo Scarino, Sharon Burton[1], Dave Harper, Anthony Cook, Tim Berkoff, Shane Seaman, Ray Rogers, Mike Obland, Marta Fenn[2], Detlef Müller, Eduard Chemyakin, Bruce Anderson, Andreas Beyersdorf, Luke Ziemba

[1]NASA Langley Research Center, Hampton, VA USA
[2]SSAI, Hampton, VA USA
[3]NASA Goddard Space Flight Center, Greenbelt, MD USA

Airborne HSRL-2 Aerosol Measurements

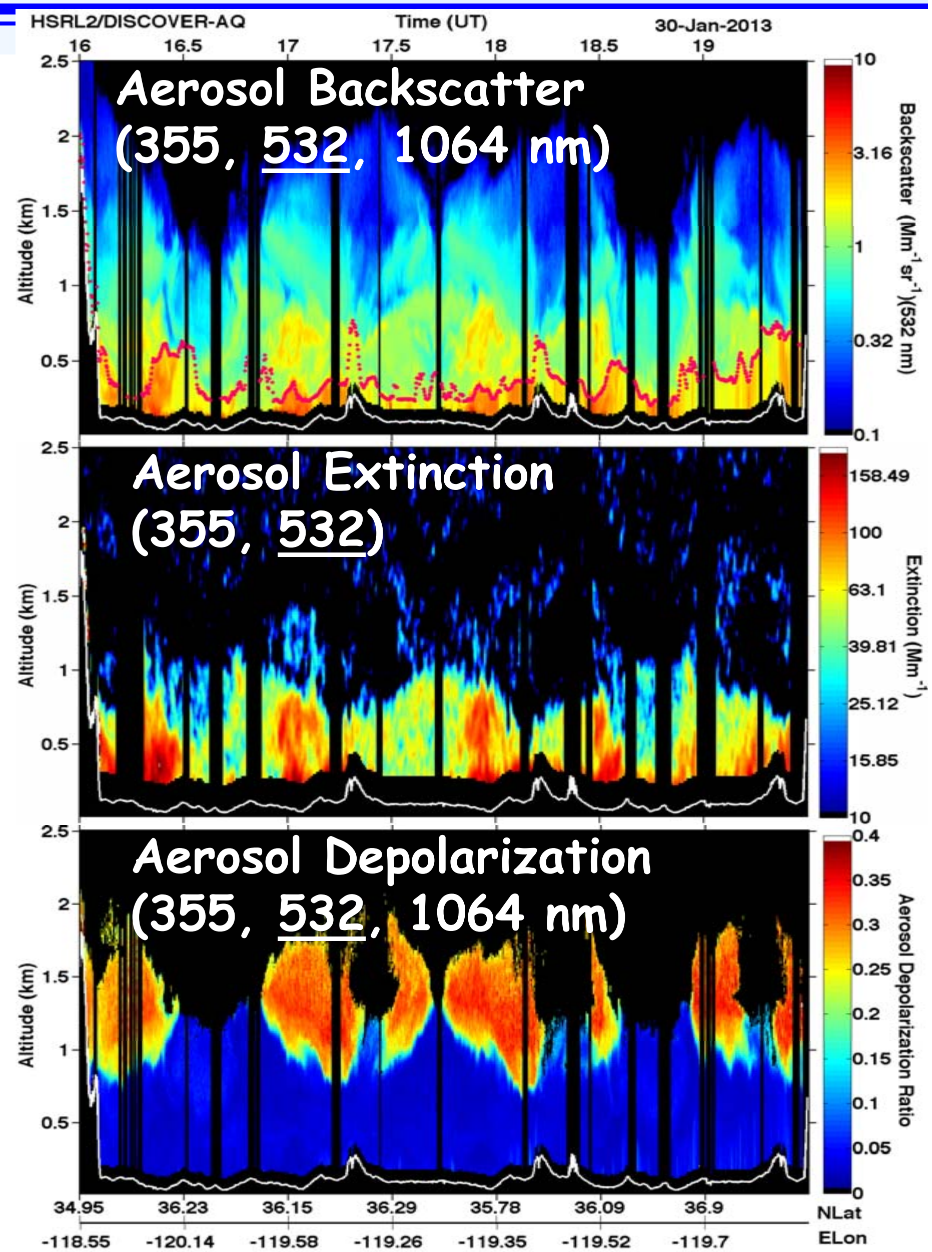
- NASA/LaRC King Air
- Flight altitude ~ 9 km
- Nadir pointing lidar

<u>HSRL Technique:</u>

- Independently measures aerosol backscatter, extinction, and optical thickness

<u>HSRL Aerosol Data Products:</u>

- Backscatter coefficient (355, 532,1064 nm)
- Depolarization (355,532,1064nm)
- Extinction Coefficient (355,532nm)
- Optical Depth (AOD) (355,532nm)
- Aerosol Typing
- Mixed Layer (ML) Heights



Estimation of $PM_{2.5}$ from AOT

$AOT = \int \alpha(z)\, dz$

$AOT \approx \overline{\alpha_H(\text{ambient RH})} \times H$

Assume: $\alpha_{SFC}(\text{ambient RH}) \sim \overline{\alpha_H(\text{ambient RH})}$

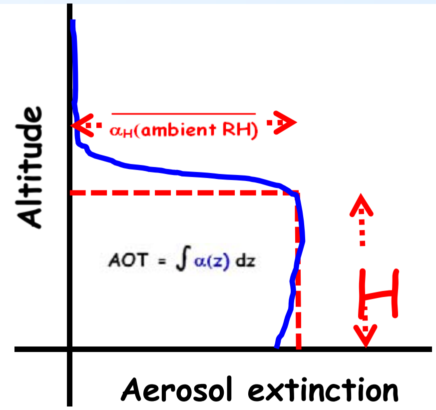
$\alpha_{SFC}(\text{ambient RH}) = f(RH) \times \alpha_{SFC}(\text{dry})$

Assume: $\alpha_{SFC}(\text{dry}) \sim b_{sca}(\text{dry})$

$b_{sca}(\text{dry}) = SSC \times PM_{2.5}$

$$AOT \approx f(RH) \times SSC \times H \times PM_{2.5}$$

Where:
- α = aerosol extinction
- b_{sca} = aerosol scattering
- SSC = specific scattering coefficient
- f(RH) = aerosol humidification factor
- H = height of aerosol layer



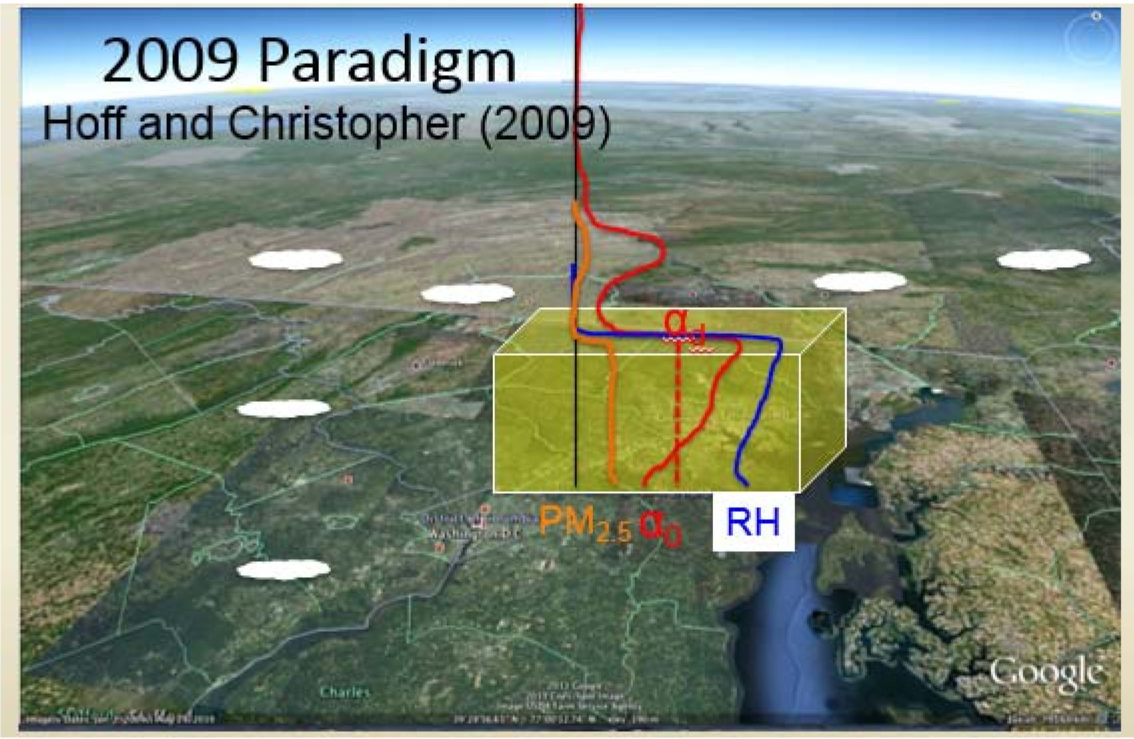
What to use for H?
PBL height (z_{PBL}) or height of maximum aerosol gradient (z_{AG})?

Can we assume that surface extinction is about the same as the mean extinction in aerosol layer?

$\alpha_{SFC}(\text{ambient RH}) \sim \overline{\alpha_H(\text{ambient RH})}$?

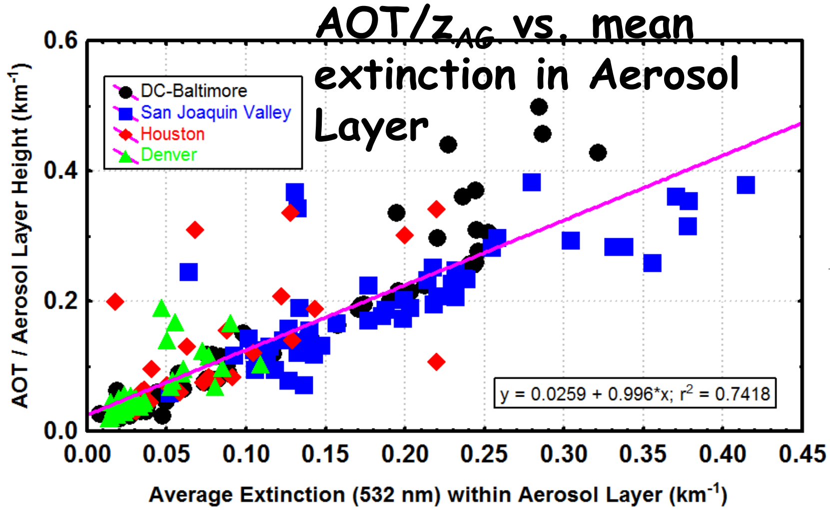
How well is surface extinction related to $PM_{2.5}$?
Can we estimate SSC?
$\alpha_{SFC}(\text{dry}) \sim SSC \times PM_{2.5}$?

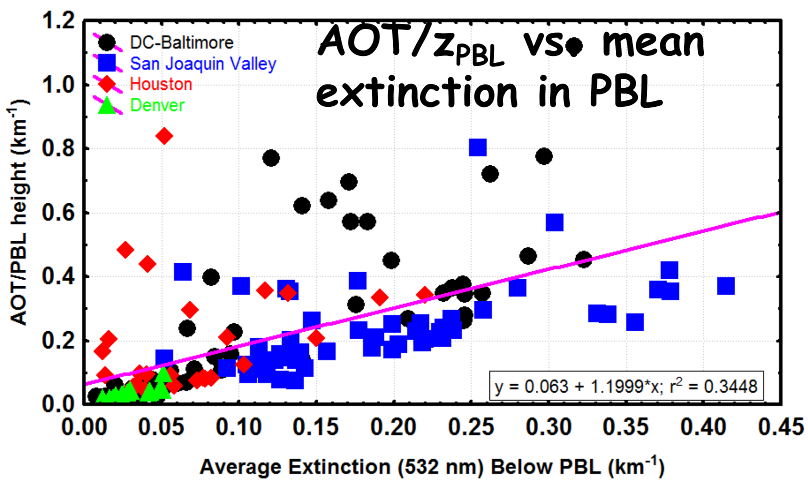
How well is AOT correlated with:
$\alpha_{SFC}(\text{ambient RH})$, $\alpha_{SFC}(\text{dry})$, $PM_{2.5}$?


2009 Paradigm
Hoff and Christopher (2009)
α_1
$PM_{2.5}$
α_0
RH
Google

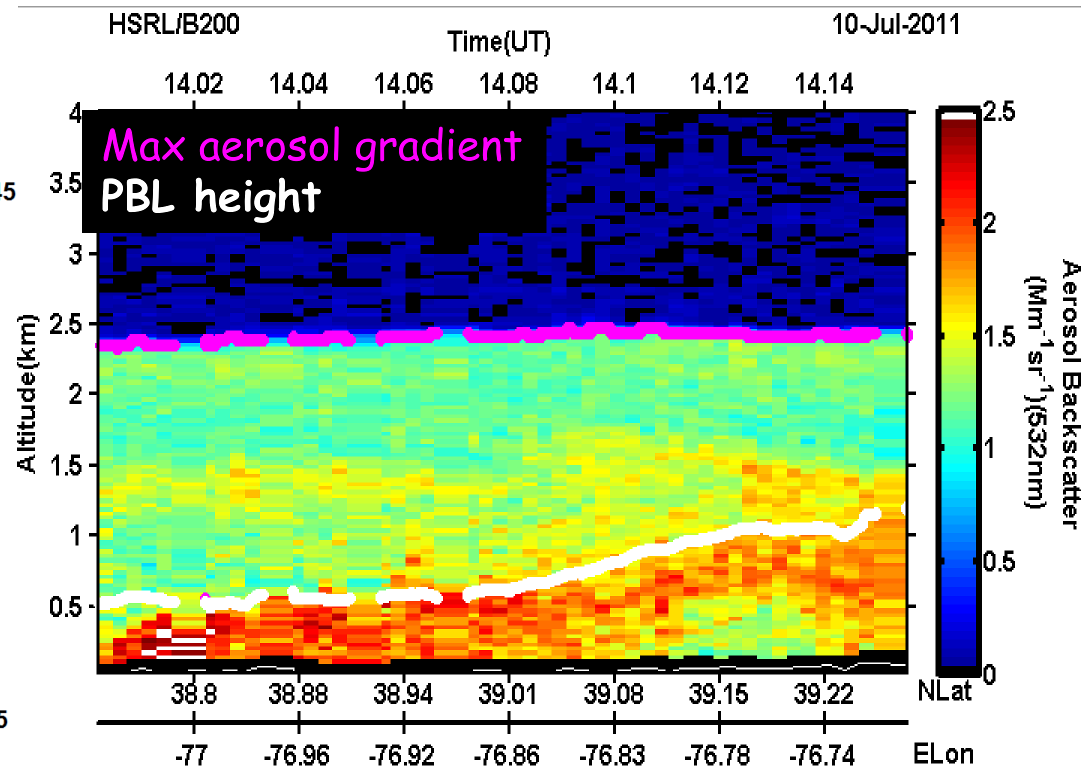
Aerosol Layer Height

We examine AOT / H vs. $\overline{\alpha_H\text{(ambient RH)}}$
Where H = z_{PBL} and H = z_{AG}





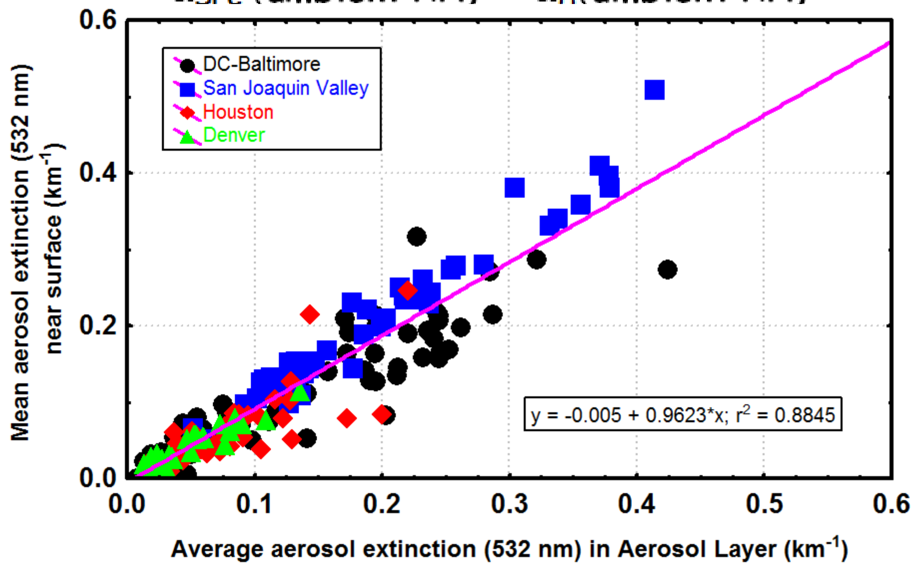
- We investigate the impact of layer height by examining the correlation between AOT and mean extinction within PBL and aerosol layer
- Height of the maximum aerosol gradient (which we call aerosol layer height) is a better measure of scale height than PBL height

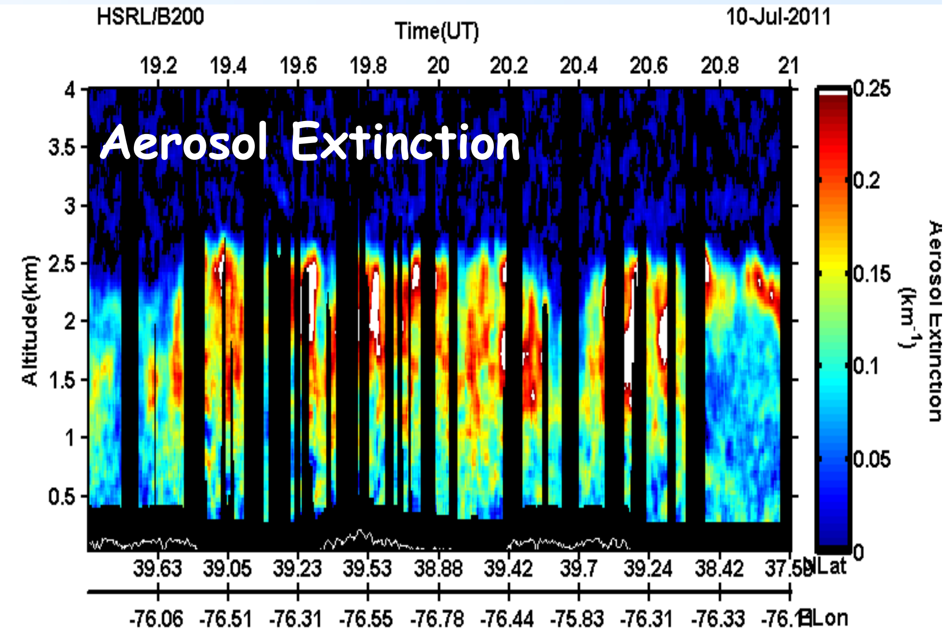


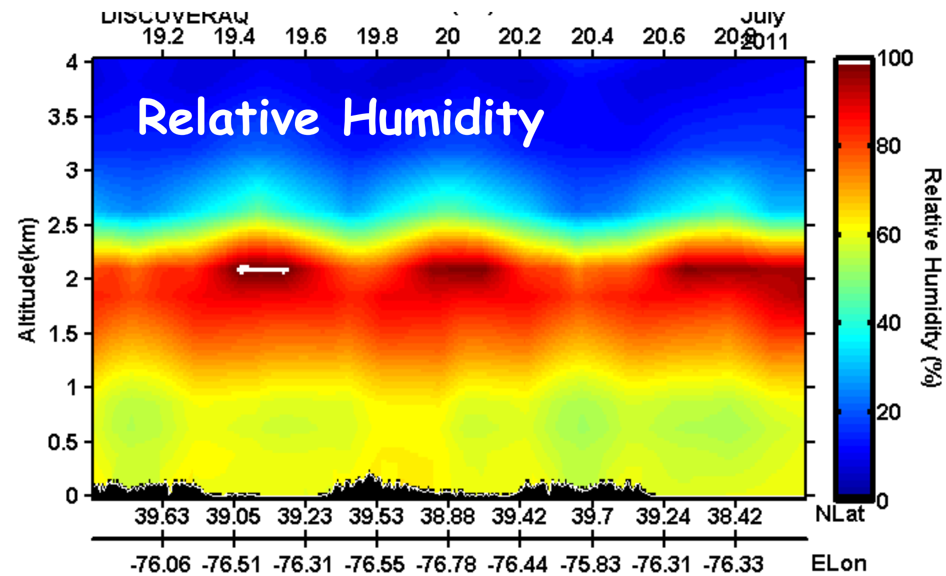
Relationship between mean layer extinction and surface extinction

We examine

α_{SFC} (ambient RH) ~ α_H(ambient RH)



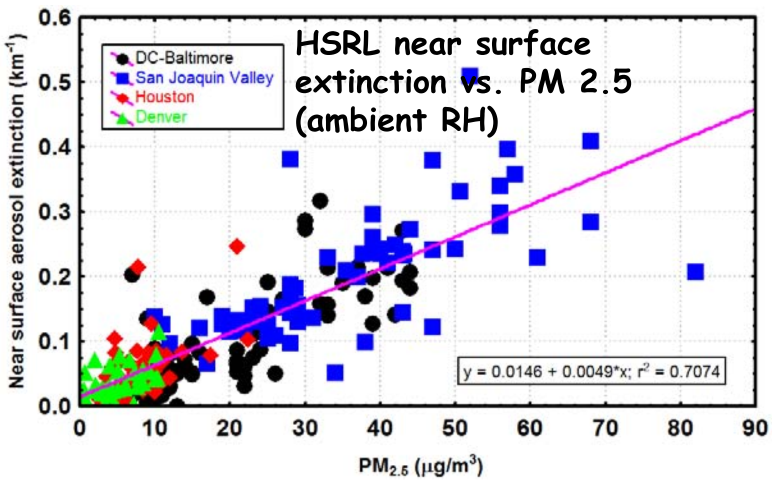


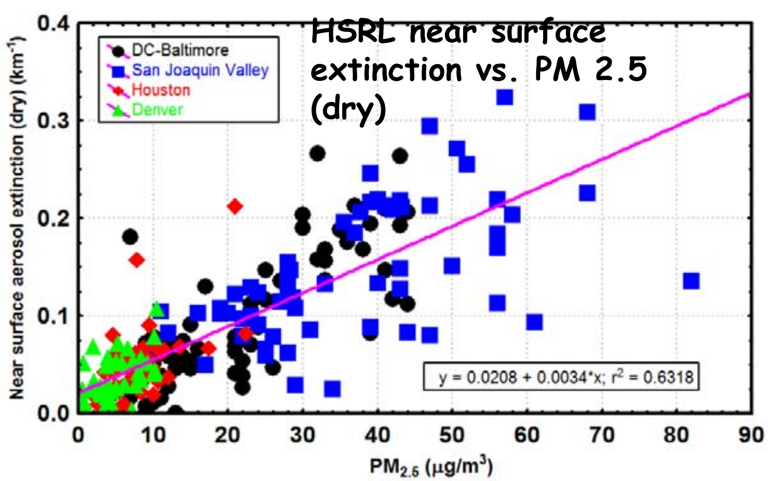


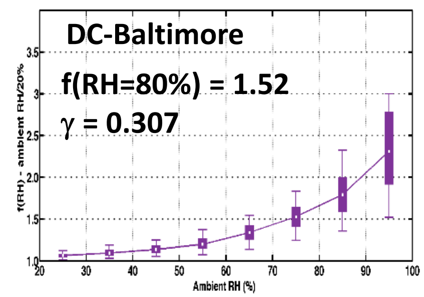
- Surface extinction is well correlated with mean aerosol extinction in the layer
- Surface extinction is slightly lower than mean extinction in the layer in DC-Balt
  - HSRL data sometimes show increase in extinction with height in aerosol layer
  - This increase likely associated with higher RH near the top of the layer
- Surface extinction slightly higher than mean extinction in San Joaquin Valley due to higher RH near surface in some cases

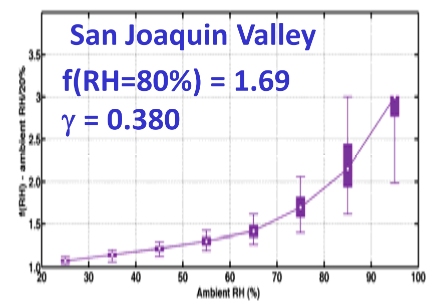
Correlation between near-surface extinction and surface $PM_{2.5}$ concentrations

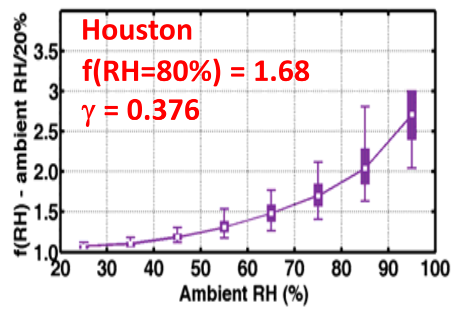
- **HSRL measurements of extinction near the surface were correlated with hourly surface $PM_{2.5}$ data**
- **Correlations performed using extinction at ambient RH as well as dry (RH=20%) extinction estimated using average humidification factors obtained from P3 in situ data**

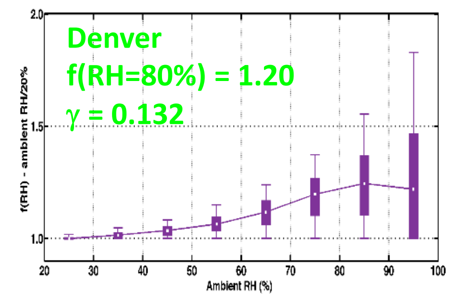












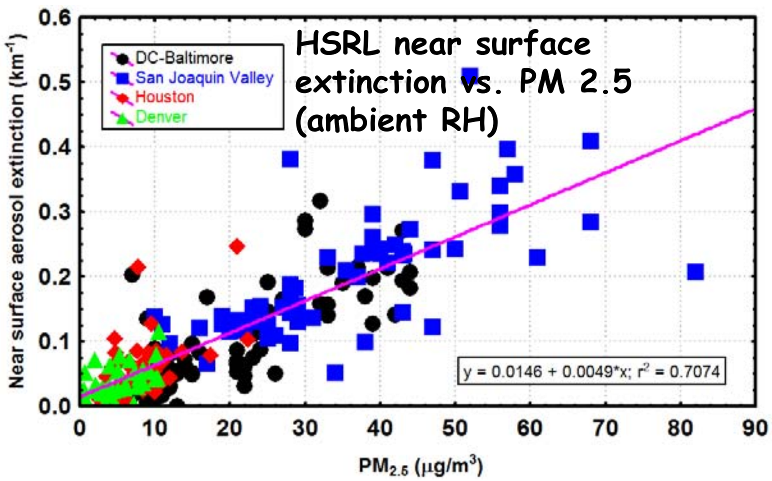
Using equations from Ziemba et al. (2013):

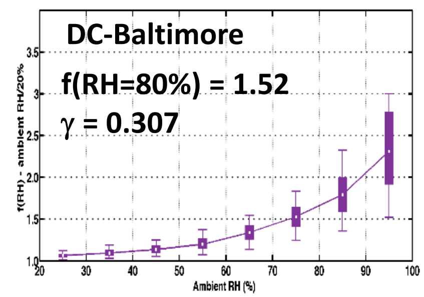
$$f(RH) = \frac{\sigma_{scat,wet}}{\sigma_{scat,dry}} \quad (1)$$

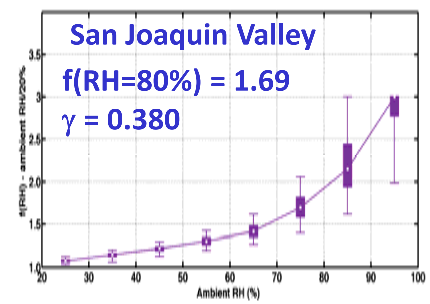
$$\sigma_{scat,amb} = \sigma_{scat,dry}\left[\frac{1-\frac{RH_{amb}}{100}}{1-\frac{RH_{dry}}{100}}\right]^{(-\gamma)}, \gamma = \frac{\ln\left[\frac{\sigma_{scat,wet}}{\sigma_{scat,dry}}\right]}{\ln\left[\frac{100-RH_{dry}}{100-RH_{wet}}\right]} \quad (2)$$

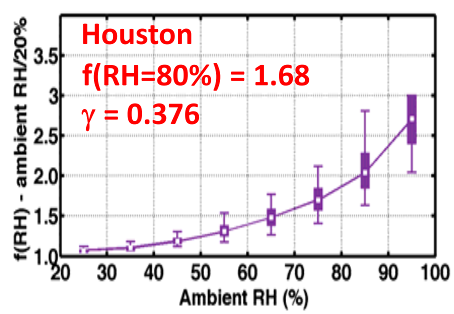
Correlation between near-surface extinction and surface $PM_{2.5}$ concentrations

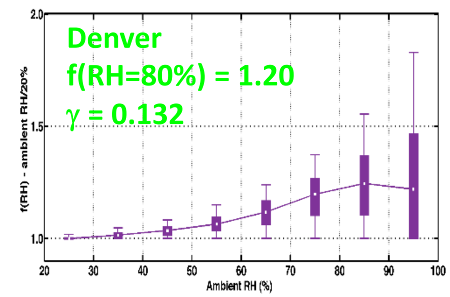
- HSRL measurements of extinction near the surface were correlated with hourly surface $PM_{2.5}$ data
- $PM_{2.5}$ correlated well with both ambient and dry aerosol extinction

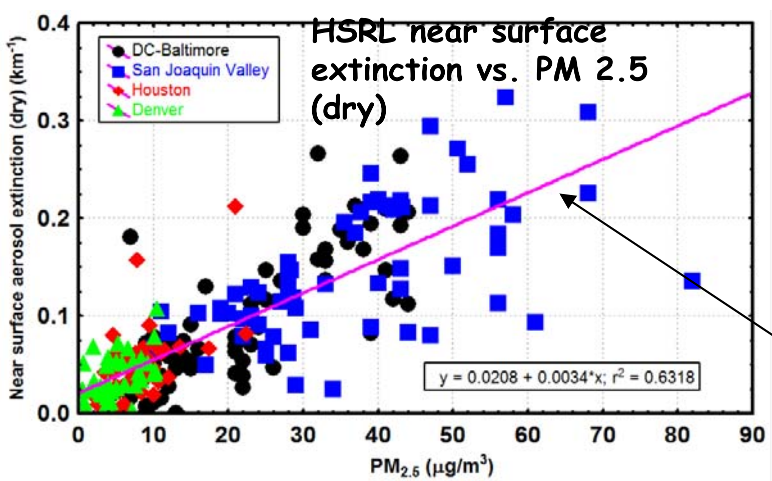












Using

α(dry) ≈ SSC * $PM_{2.5}$

α(ambient RH)/f(RH) ≈ SSC * $PM_{2.5}$

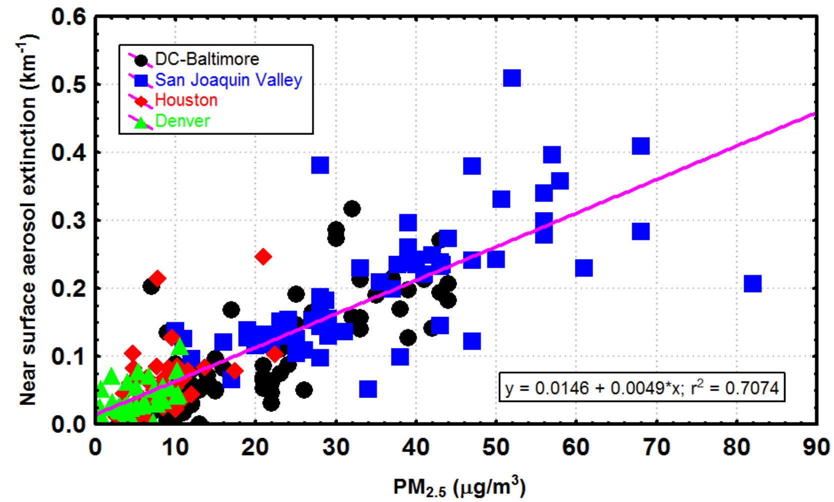
Used average f(RH) correction derived from P3

Slope = 3.4 m/g Specific scattering coefficient (SSC)

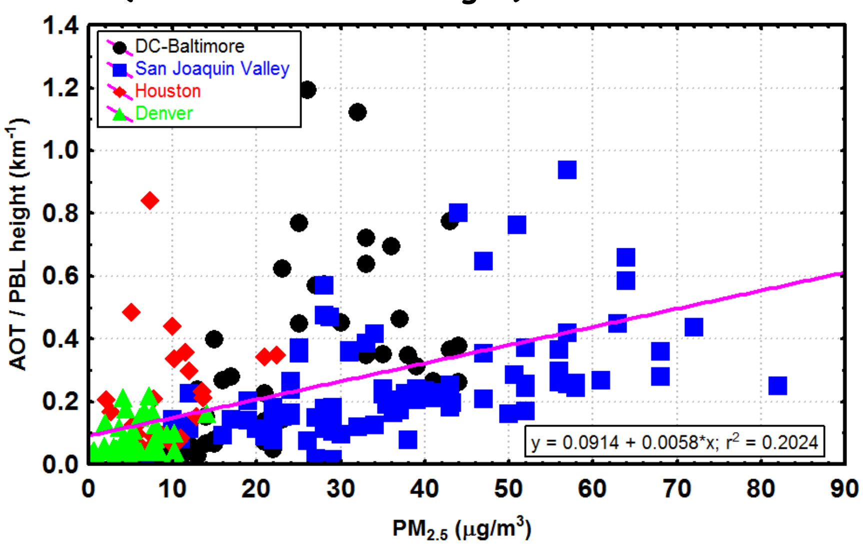
Correlation between HSRL AOT and $PM_{2.5}$

- In some cases, surface $PM_{2.5}$ can be inferred from measurements of AOT and height of the aerosol layer
- However, HSRL data show PM2.5 is better correlated with near surface extinction than AOT scaled by aerosol layer or PBL heights
- Correlations may improve with:
  - higher temporal resolution surface $PM_{2.5}$ data
  - use of individual f(RH, z) measurements rather than an average f(RH)

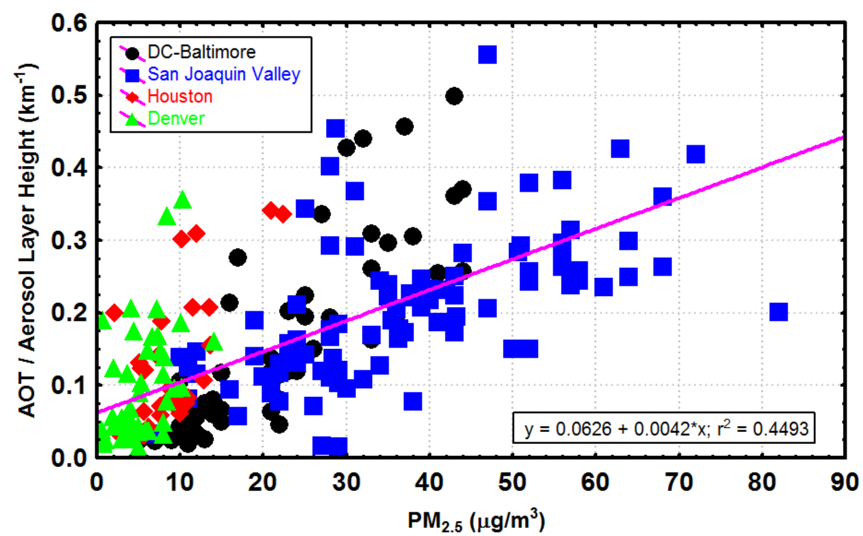
HSRL near-surface extinction (ambient RH) vs. PM 2.5



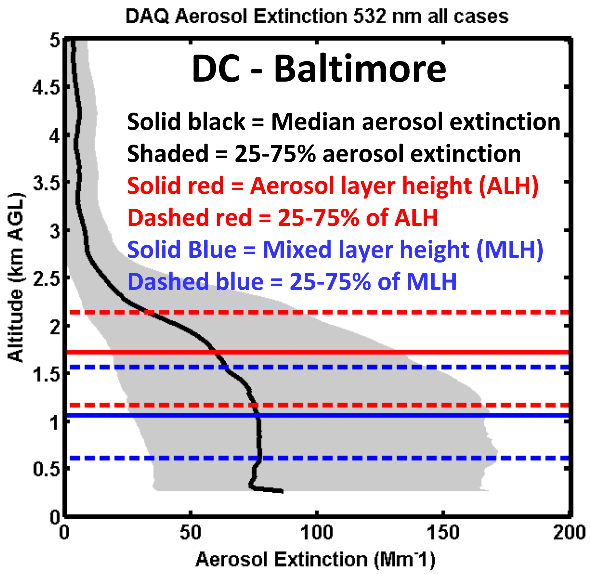
(HSRL AOT / PBL height) vs. PM 2.5

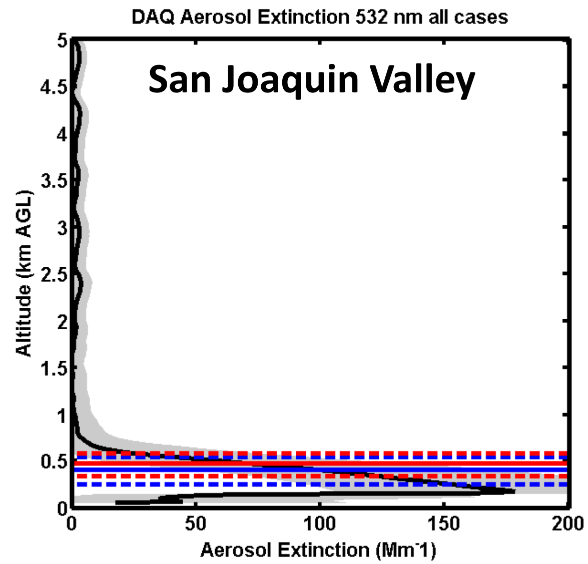


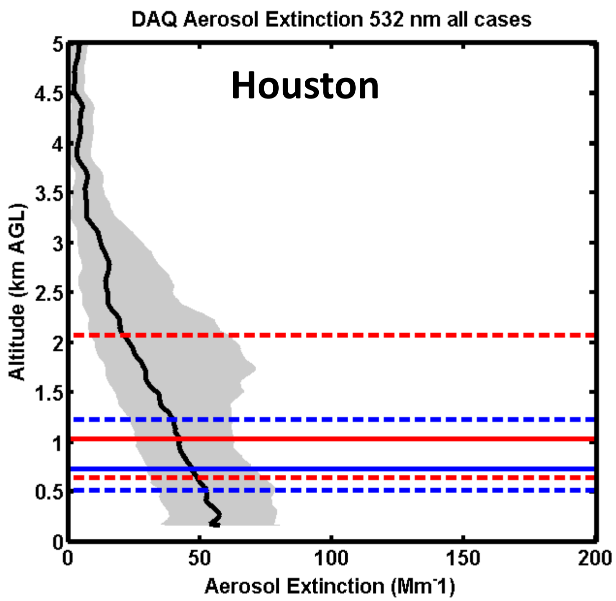
(HSRL AOT / aerosol layer height) vs. PM 2.5

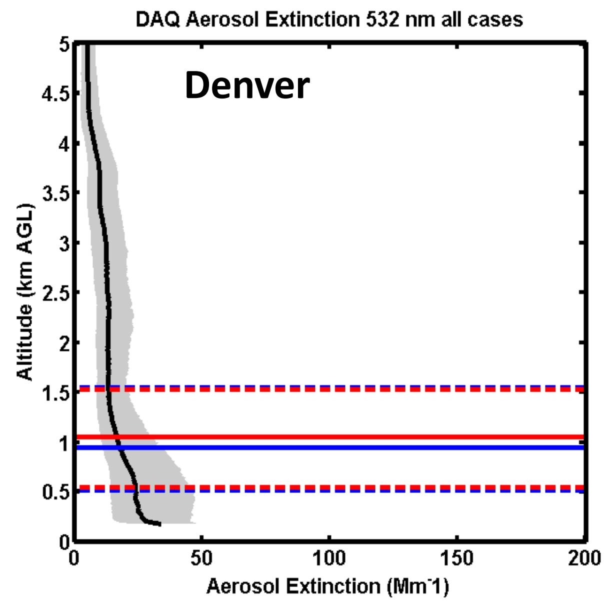


Median Aerosol Extinction Profiles



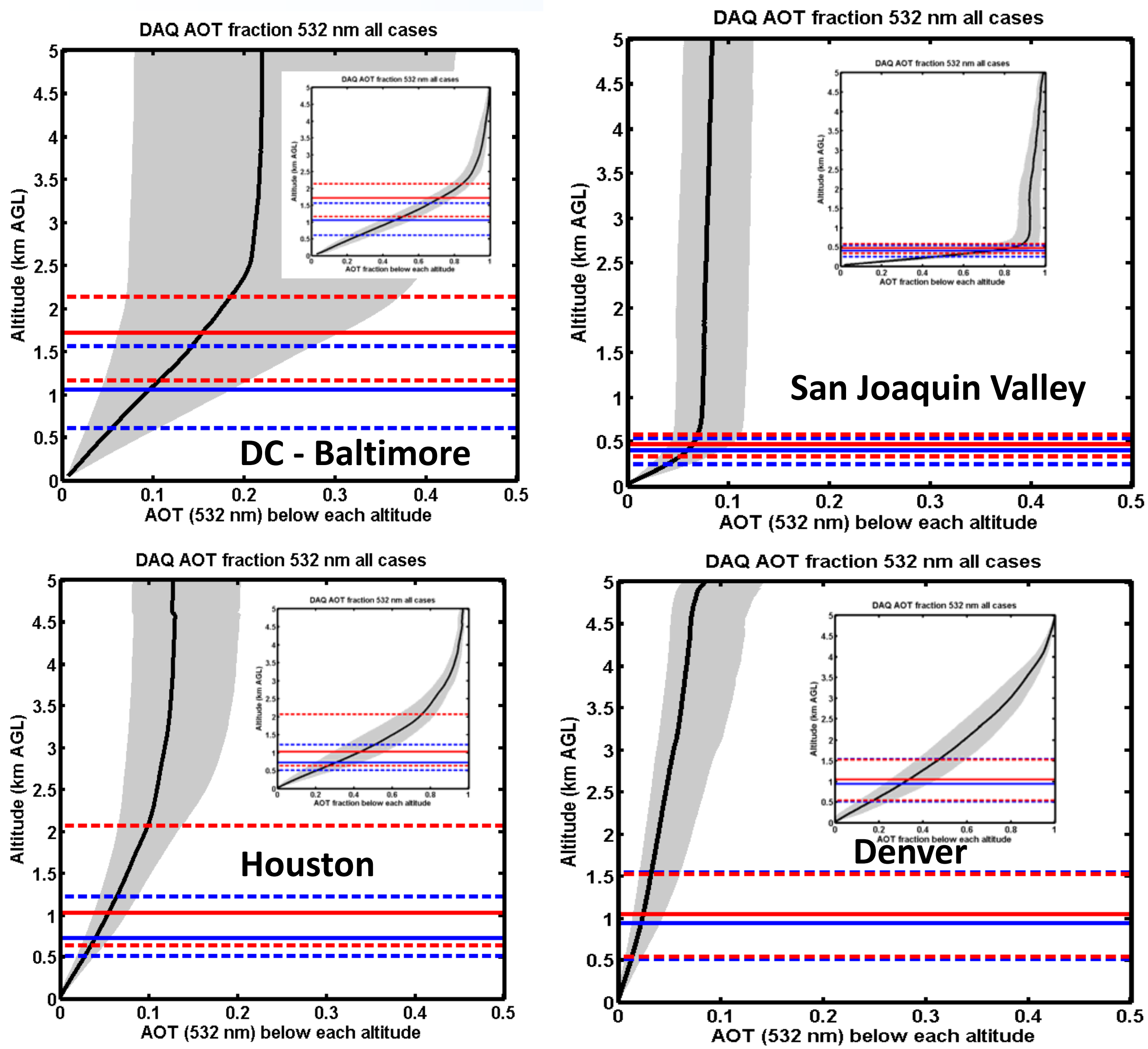






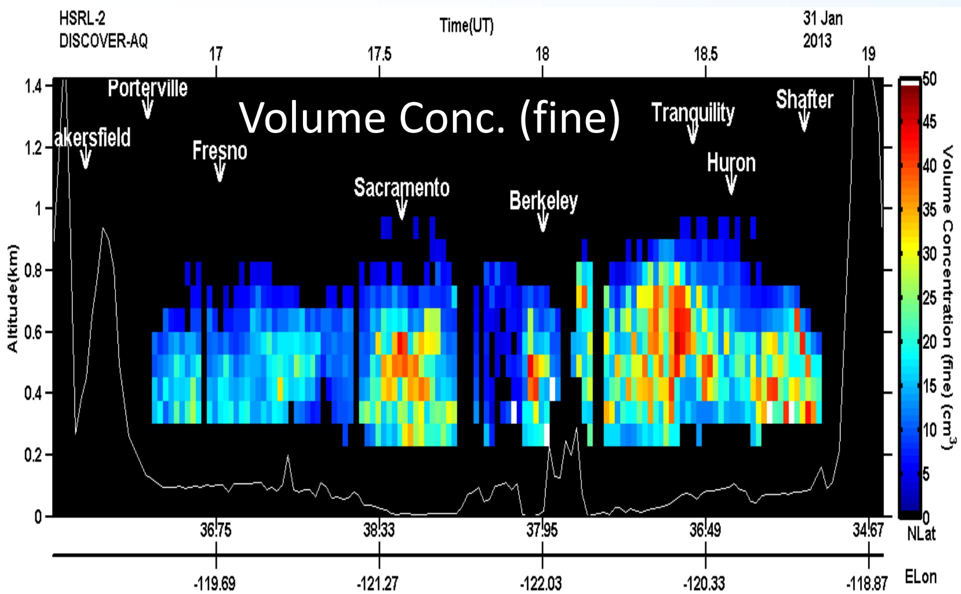
- DC-Baltimore had wide range of aerosol extinction values throughout lowest two kilometers
- San Joaquin Valley was unusual in that aerosols were confined to shallow layer near surface
- Highest aerosol extinction values found in San Joaquin Valley
- Median mixed layer heights for DC-Balt, Houston, Denver were around 1 km ± 0.5 km
- Mixed layer heights in San Joaquin Valley were generally at or below 0.5 km

Median Aerosol Optical Thickness Profiles

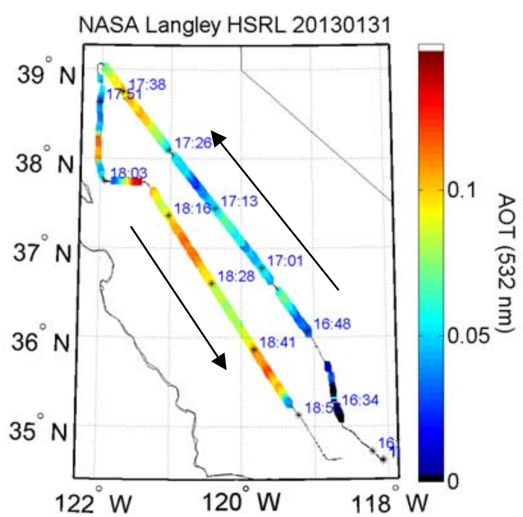


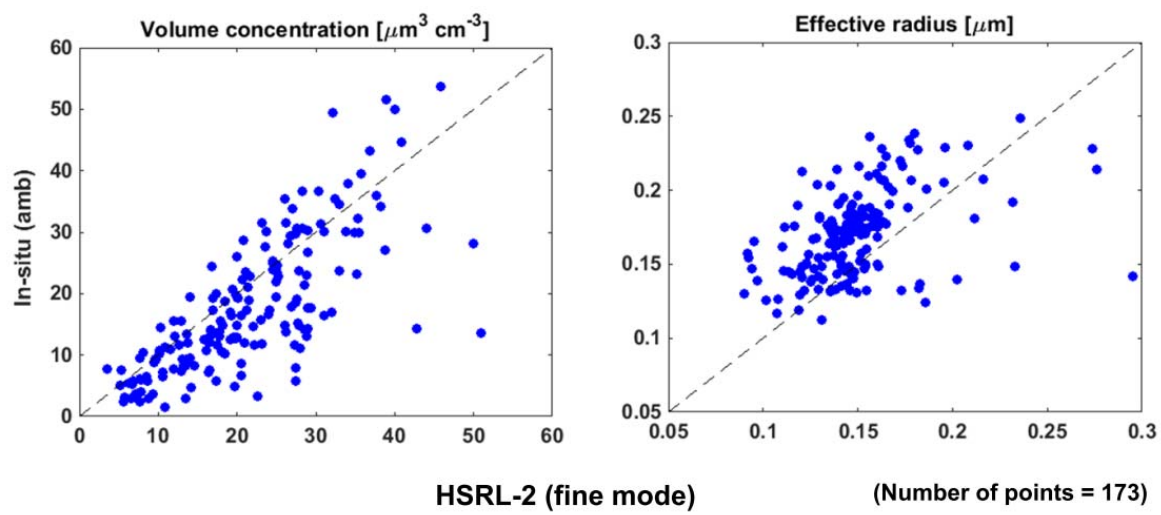
- DC-Baltimore had largest median column AOT values
- Median AOT values in the later three campaign were comparable
- With exception of San Joaquin Valley, median profiles show that about only about 20-65% of AOT was within mixed layer; much of AOT was above mixed layer
- In San Joaquin Valley, most (>80%) of AOT was within mixed layer

HSRL-2 Multiwavelength Aerosol Retrievals

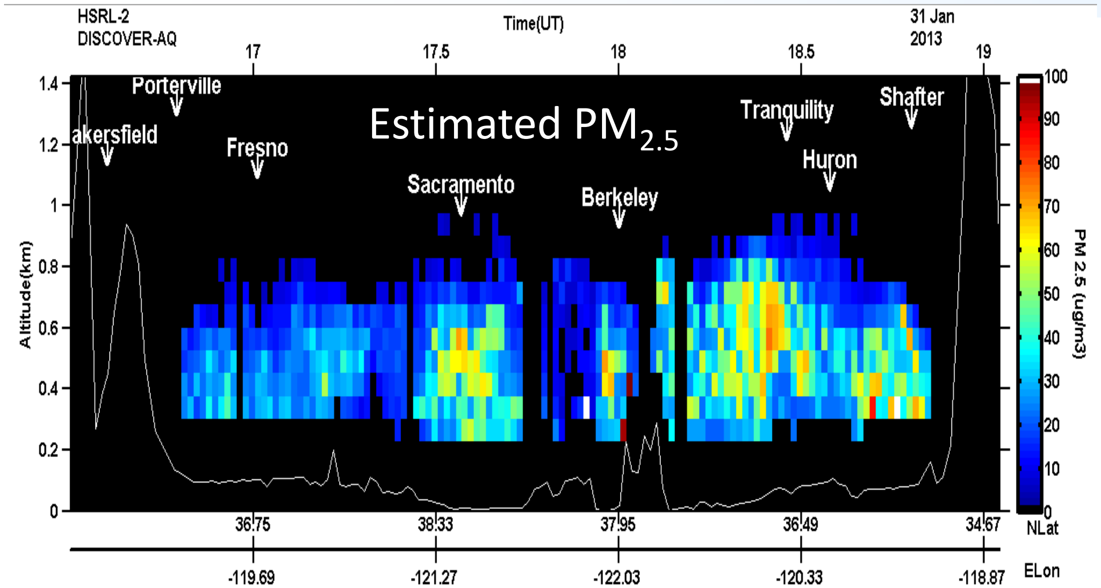


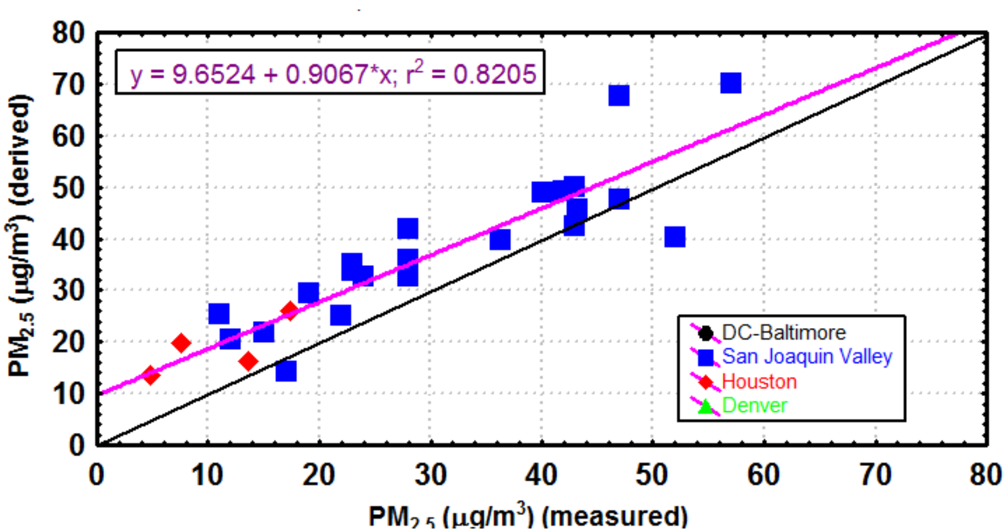
- HSRL-2 multiwavelength measurements of aerosol backscatter and extinction were used to retrieve fine mode aerosol volume concentration and effective radius (e.g. Müller et al., 2014) (see poster by Sawamura et al. for evaluation of these retrievals)
- In this example, these results show changes in particle size and concentration in SJV
- Sawamura et al. poster shows the retrievals compare reasonably well with corresponding values derived from P-3 in situ data





HSRL-2 Retrieval of $PM_{2.5}$

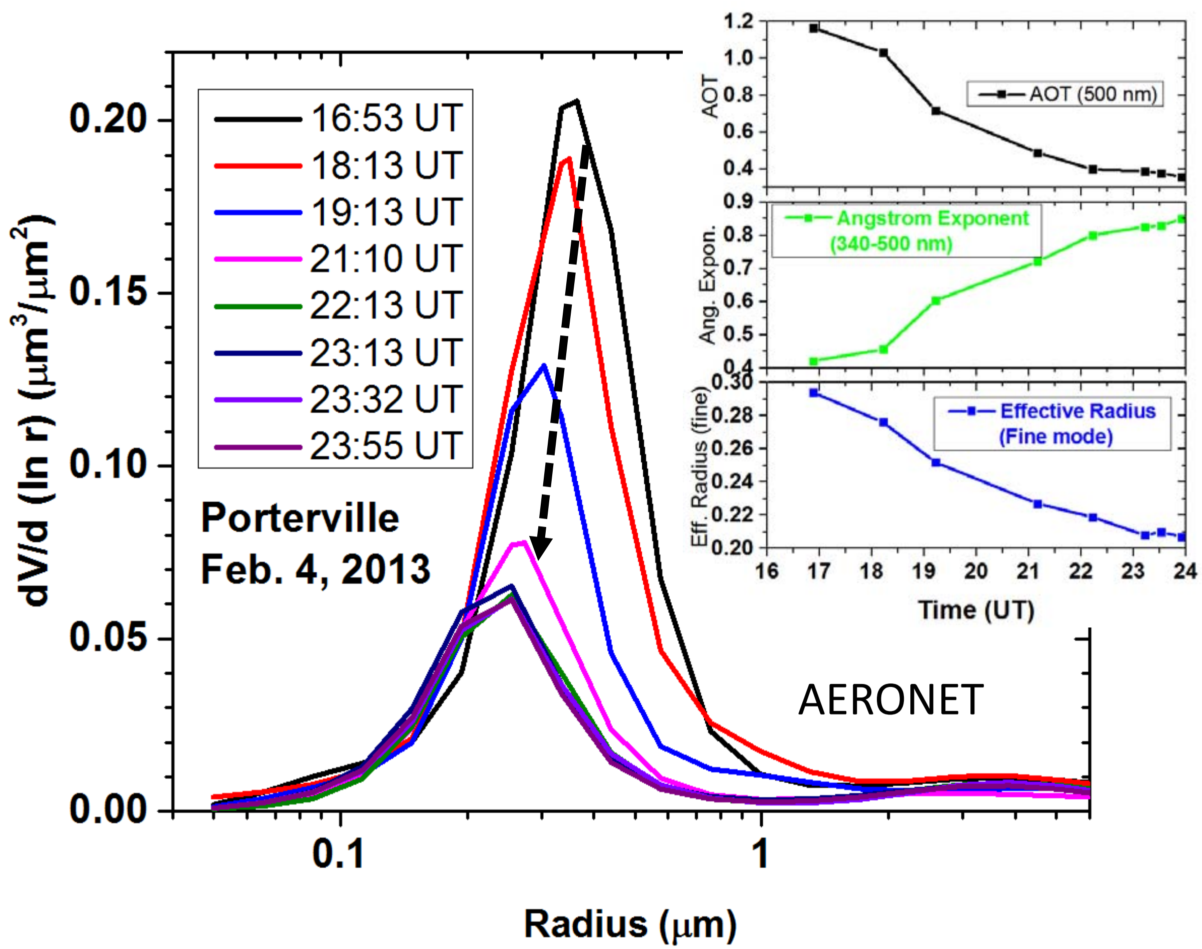


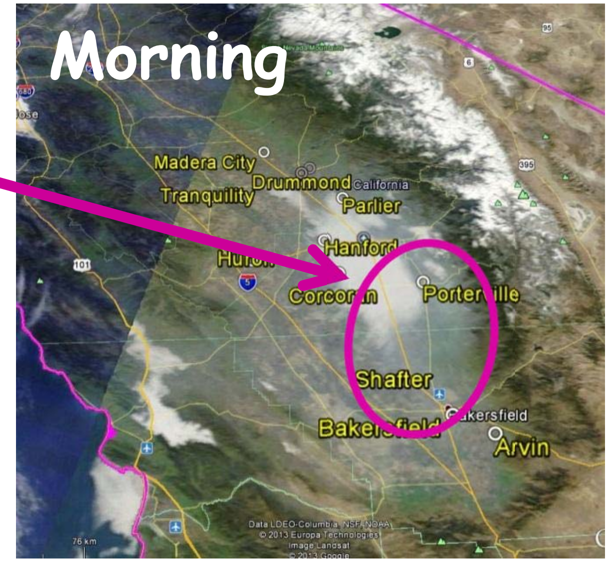


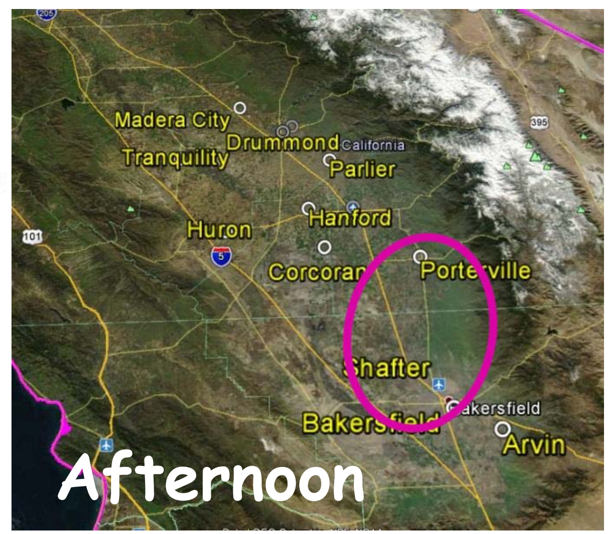
- HSRL-2 multiwavelength retrievals of fine mode volume concentration were used, along with an assumed particle density of 1.65 g/cm^3, to derive $PM_{2.5}$ concentrations
- The derived concentrations vary spatially and vertically throughout the SJV
- $PM_{2.5}$ concentrations derived near the surface compare reasonably well with hourly values measured near the surface

Decrease in fine mode particle size due to decrease in RH

- In his Fall 2013 AGU presentation, Tom Eck noted the decrease in AOT and fine mode size over the southern portion of DRAGON on Feb. 4
- This decrease occurred as fog processed and/or humidified aerosols transitioned to dried aerosol

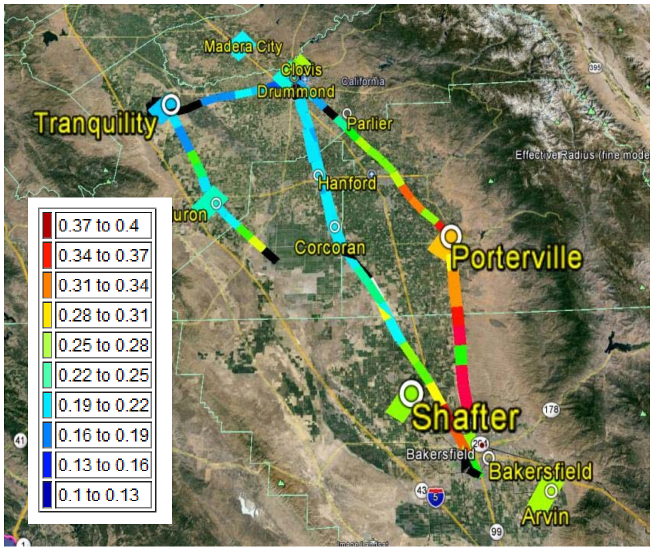




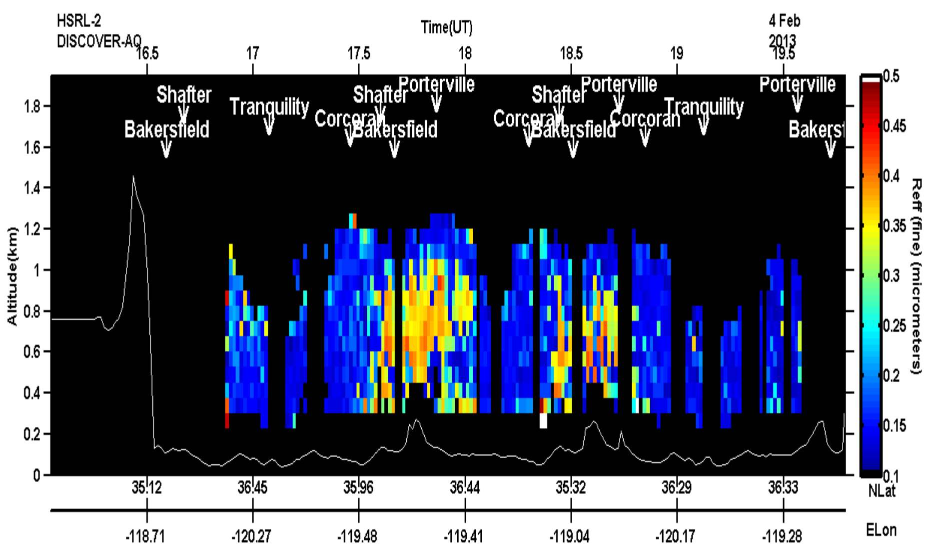


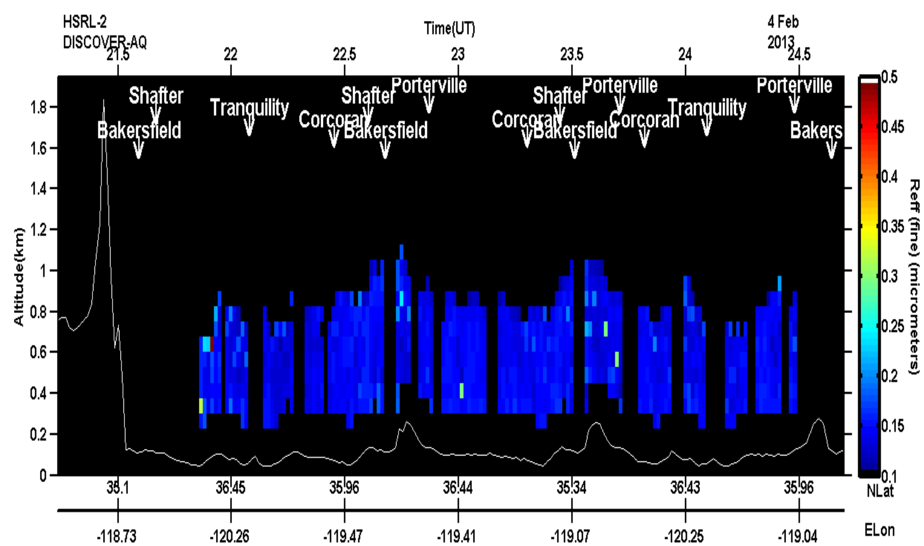
Temporal and spatial variability in column average particle size

Column Average Reff (fine)

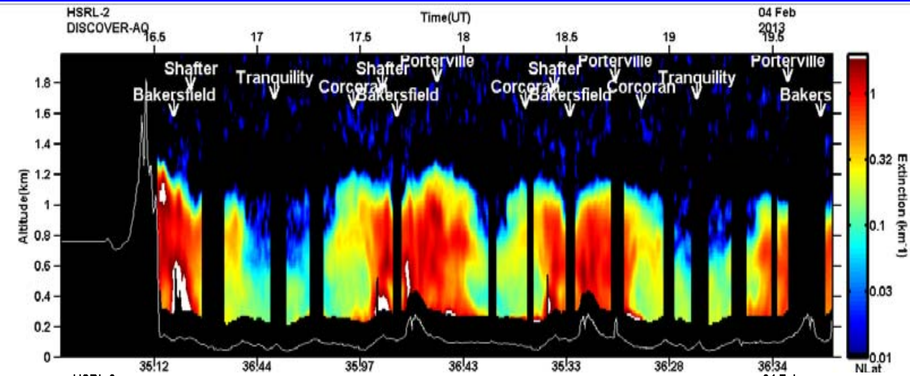


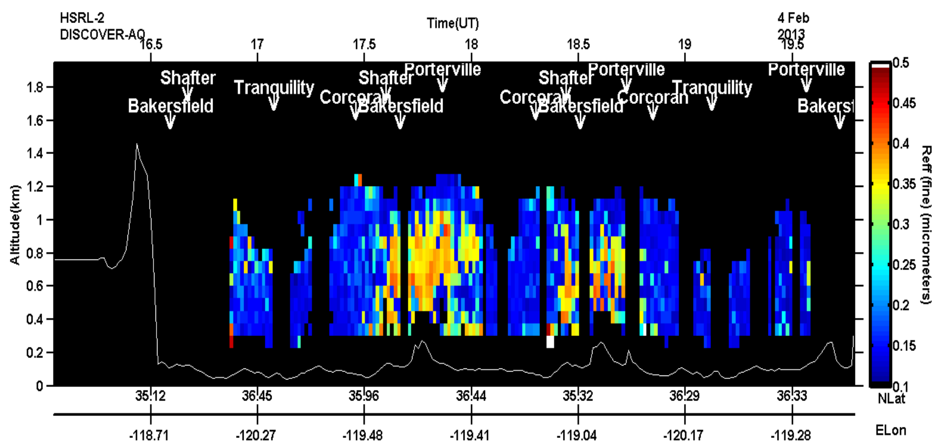
- Highest RH occurred over the southeastern portion (Porterville, Shafter) and this RH decreased with time
- Consequently, fine mode particle size was largest the southeastern portion and decreased with time
- Both HSRL-2 and AERONET found:
  - Decrease in fine mode effective radius associated with decrease in RH over the southeastern portion
  - No change in particle size over the northwestern portion where RH was lower

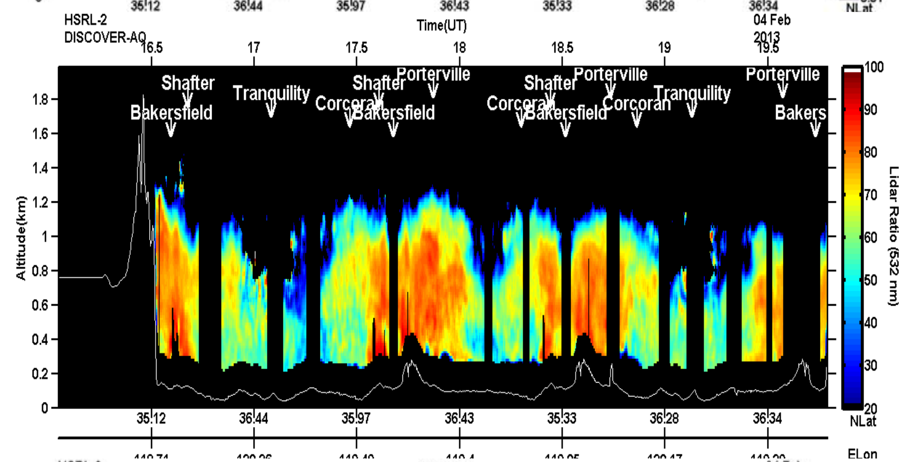


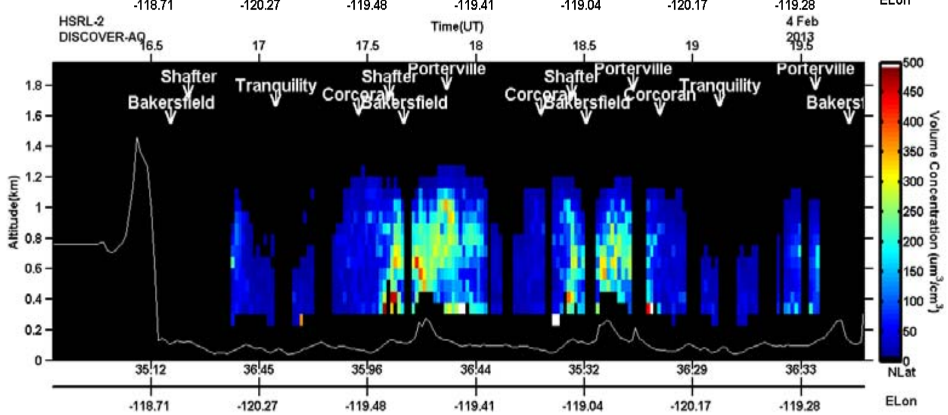


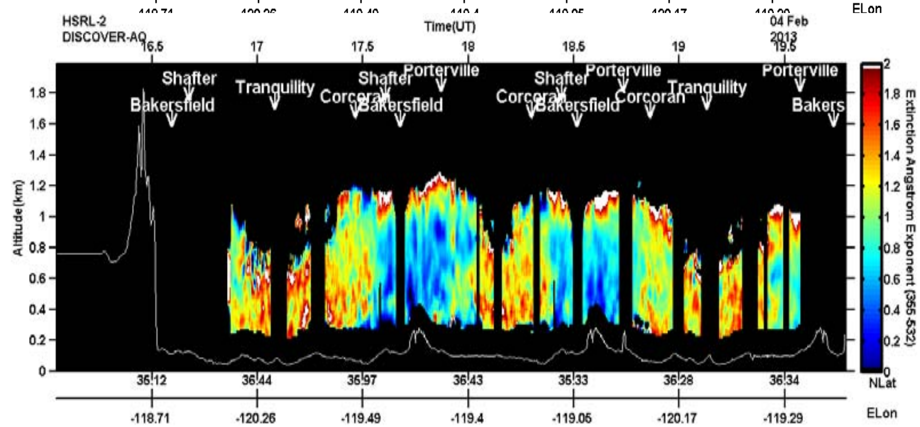
- Volume concentration, extinction, and lidar ratio also increased with high RH
- Extinction Angstrom exponent (355-532) decreased with RH as fine mode particle size increased



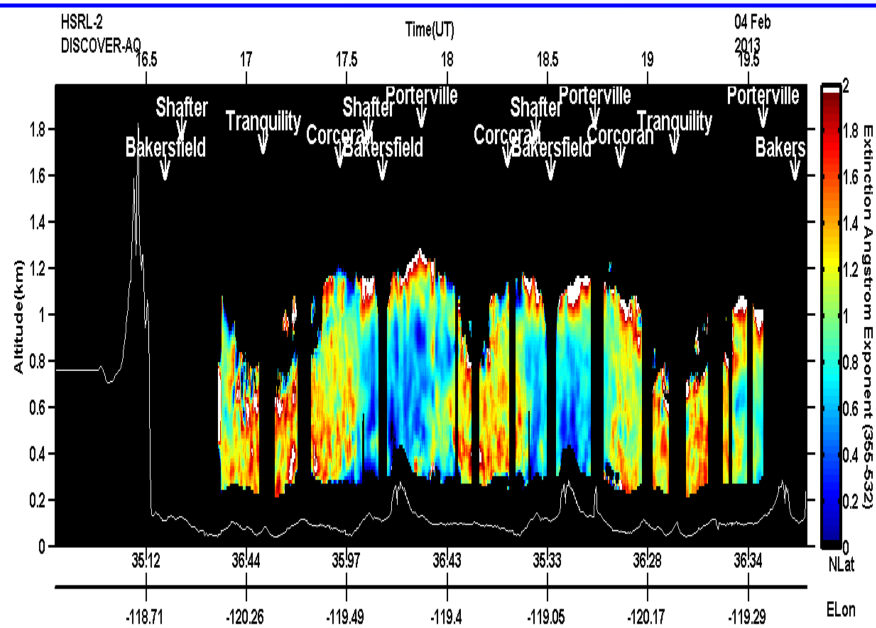


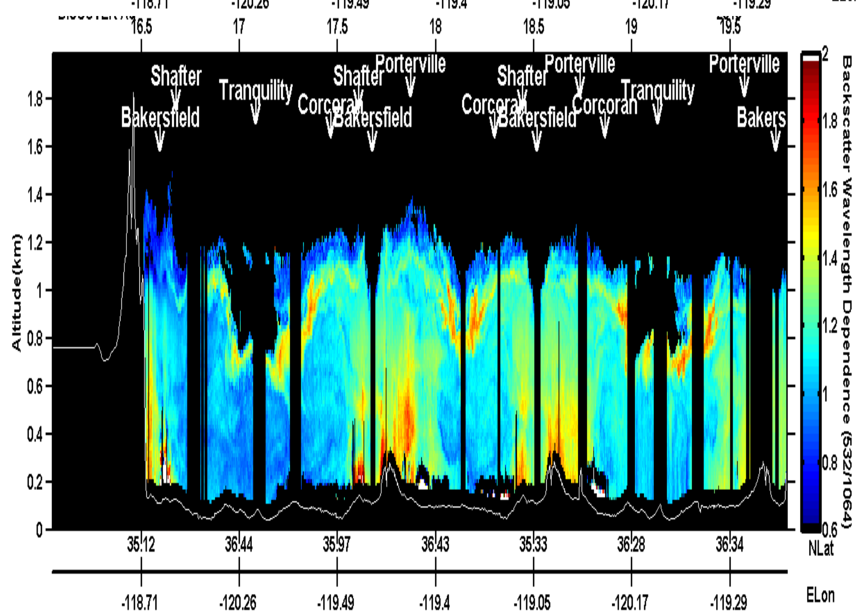


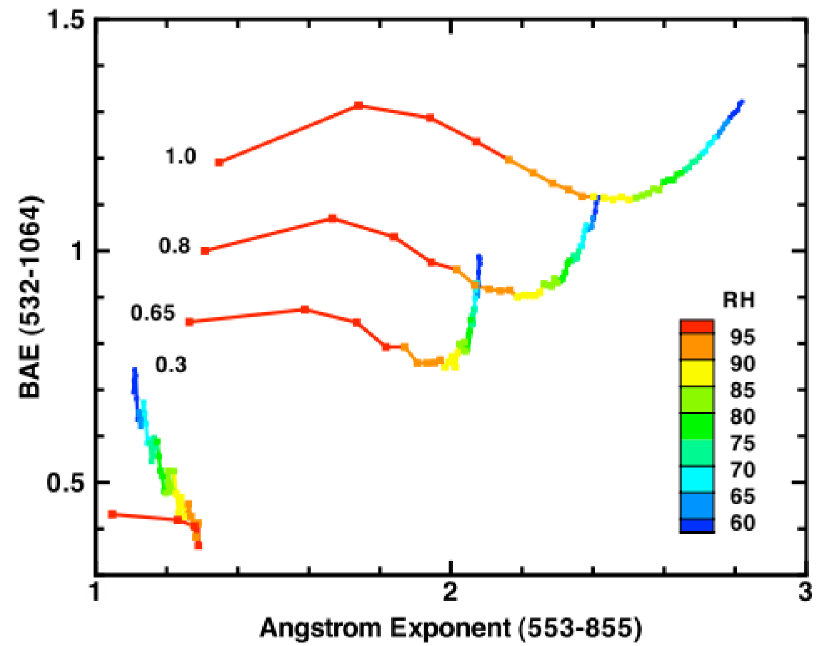


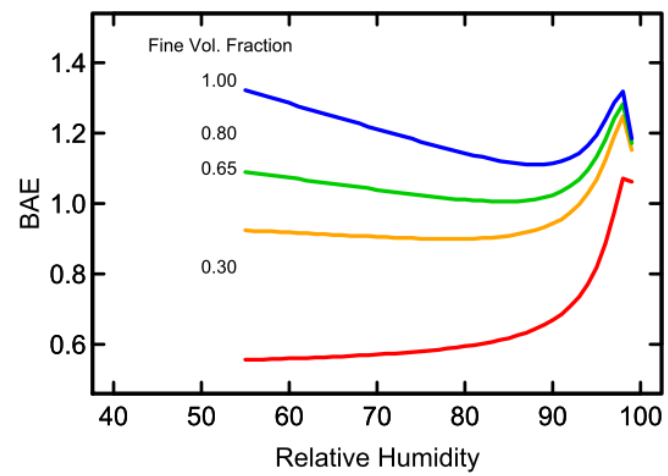


Extinction and Backscatter Angstrom exponents behave different as RH increases



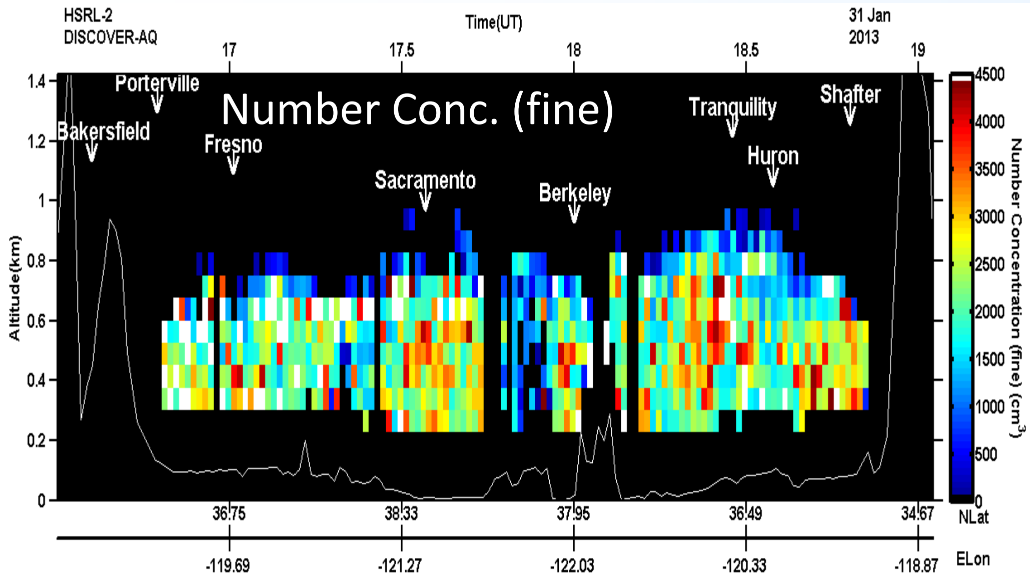


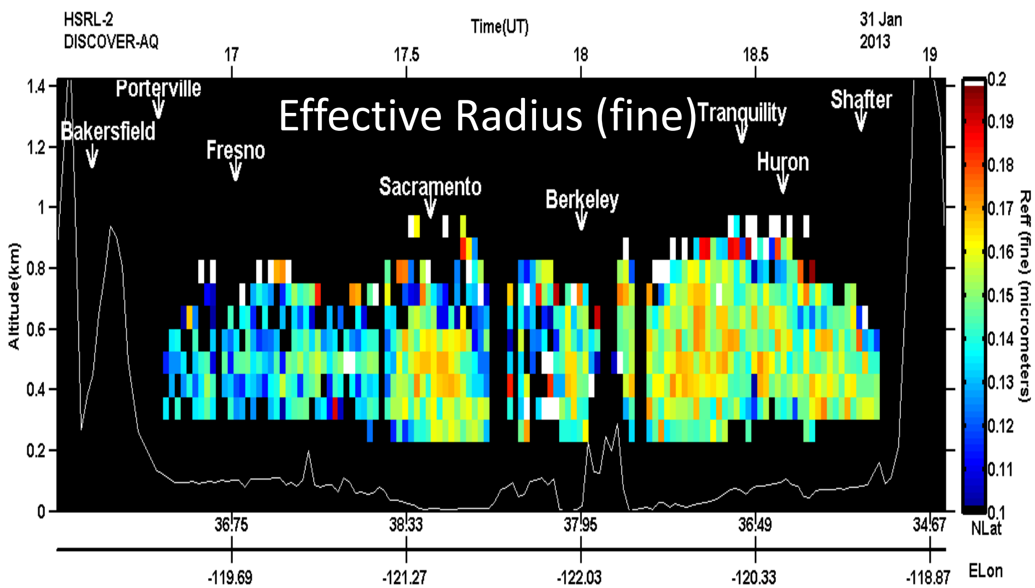




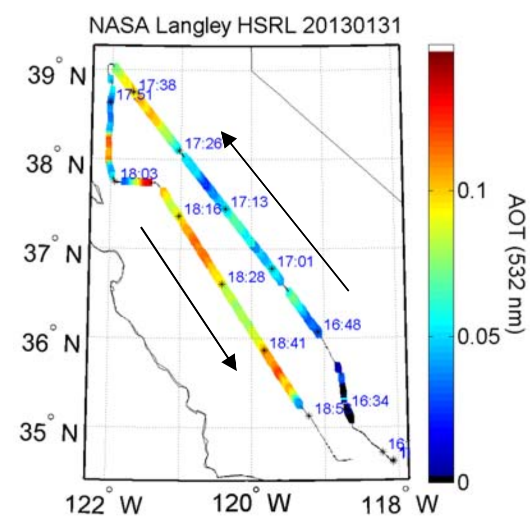
- Extra slides

HSRL-2 Aerosol Retrievals

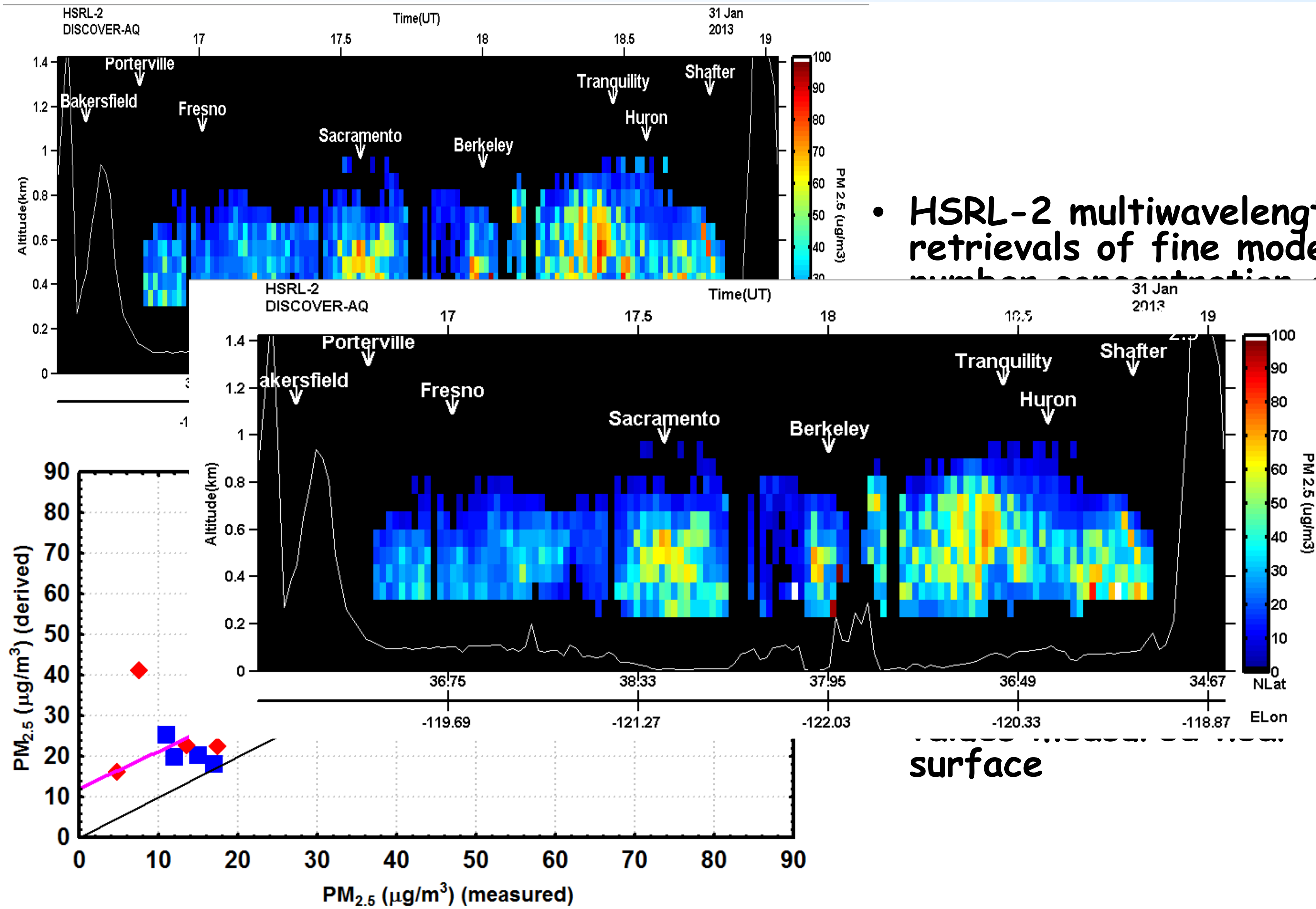




- HSRL-2 multiwavelength measurements of aerosol backscatter and extinction were used to retrieve aerosol concentration and effective radius (e.g. Müller et al., 2014) (see poster by Sawamura et al. for evaluation of these retrievals)
- In this example, these results show changes in particle size and concentration in SJV

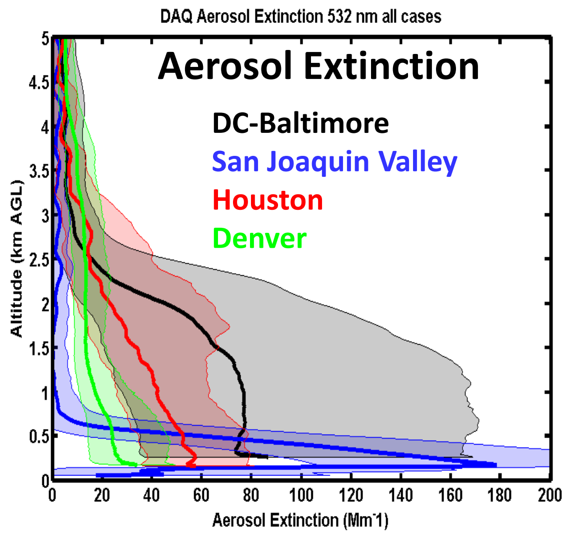


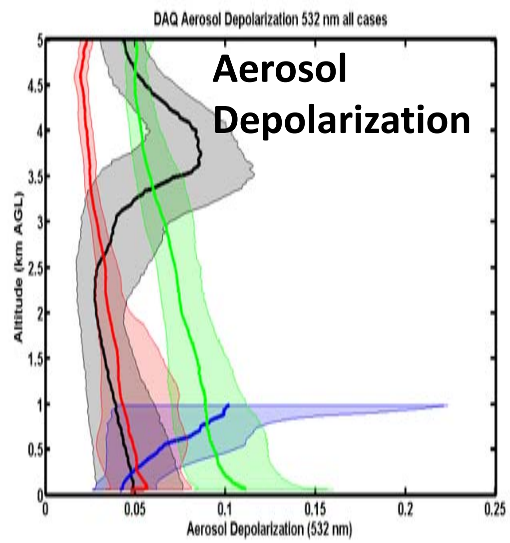
HSRL-2 Retrieval of $PM_{2.5}$



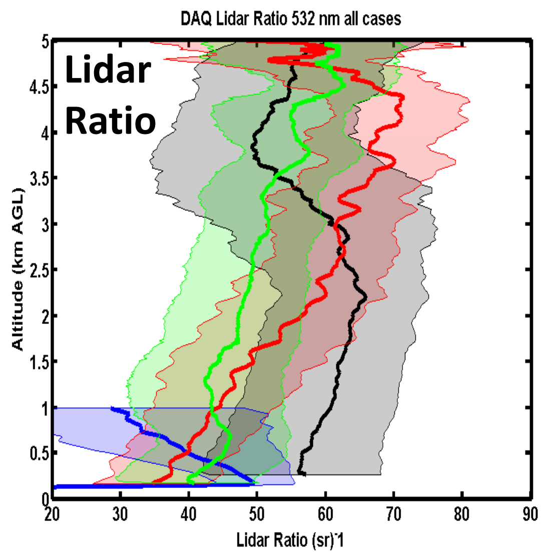
- HSRL-2 multiwavelength retrievals of fine mode number concentration and … used, … /cm³, … ions … cally … erived … are … urly … the … surface

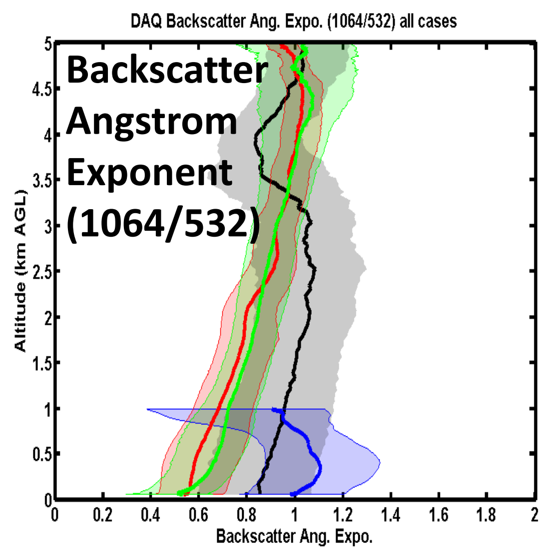
Median vertical variability of aerosol optical properties during DAQ missions

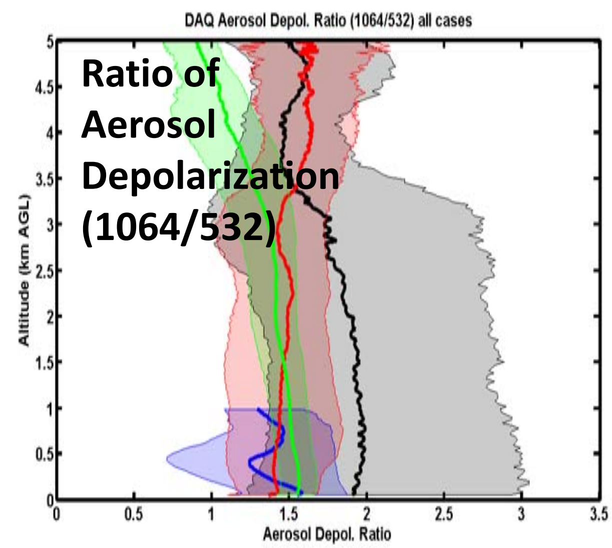


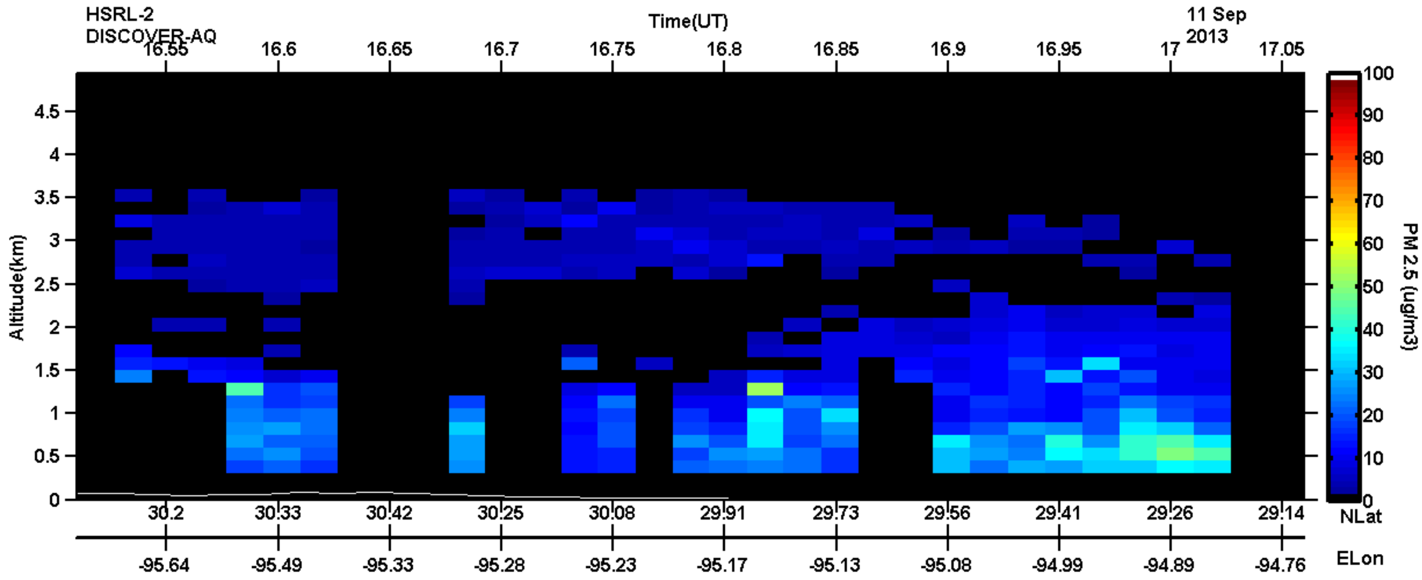


Increase in lidar ratio and backscatter Angstrom exponent during MD, TX, CO campaigns suggest smaller particles aloft – perhaps smoke








HSRL-2
DISCOVER-AQ
Time(UT)
11 Sep 2013
16.55
16.6
16.65
16.7
16.75
16.8
16.85
16.9
16.95
17
17.05
Altitude(km)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
30.2
30.33
30.42
30.25
30.08
29.91
29.73
29.56
29.41
29.26
29.14
NLat
-95.64
-95.49
-95.33
-95.28
-95.23
-95.17
-95.13
-95.08
-94.99
-94.89
-94.76
ELon
PM 2.5 (ug/m3)
100
90
80
70
60
50
40
30
20
10
0

Estimation of $PM_{2.5}$ from AOT: Questions addressed using HSRL data

What to use for H?
PBL height (z_{PBL}) or height of maximum aerosol gradient (z_{AG})?

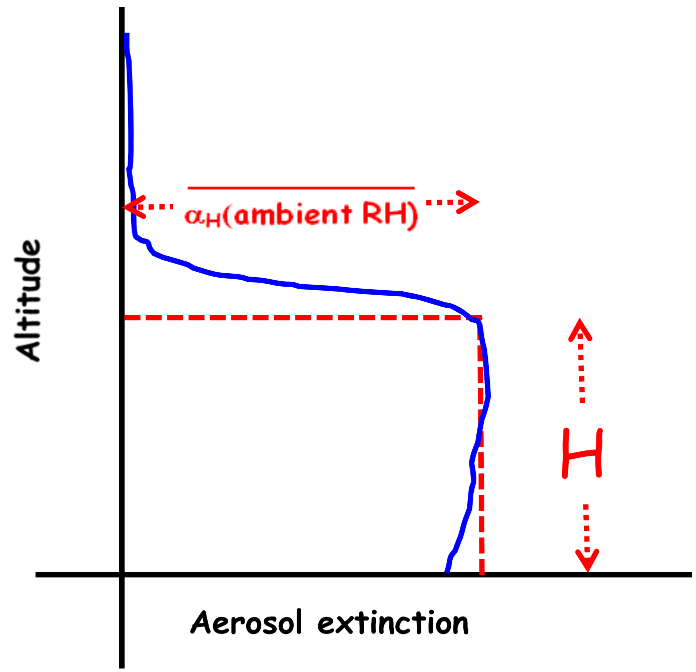
Can we assume that surface extinction is about the same as the mean extinction in aerosol layer?

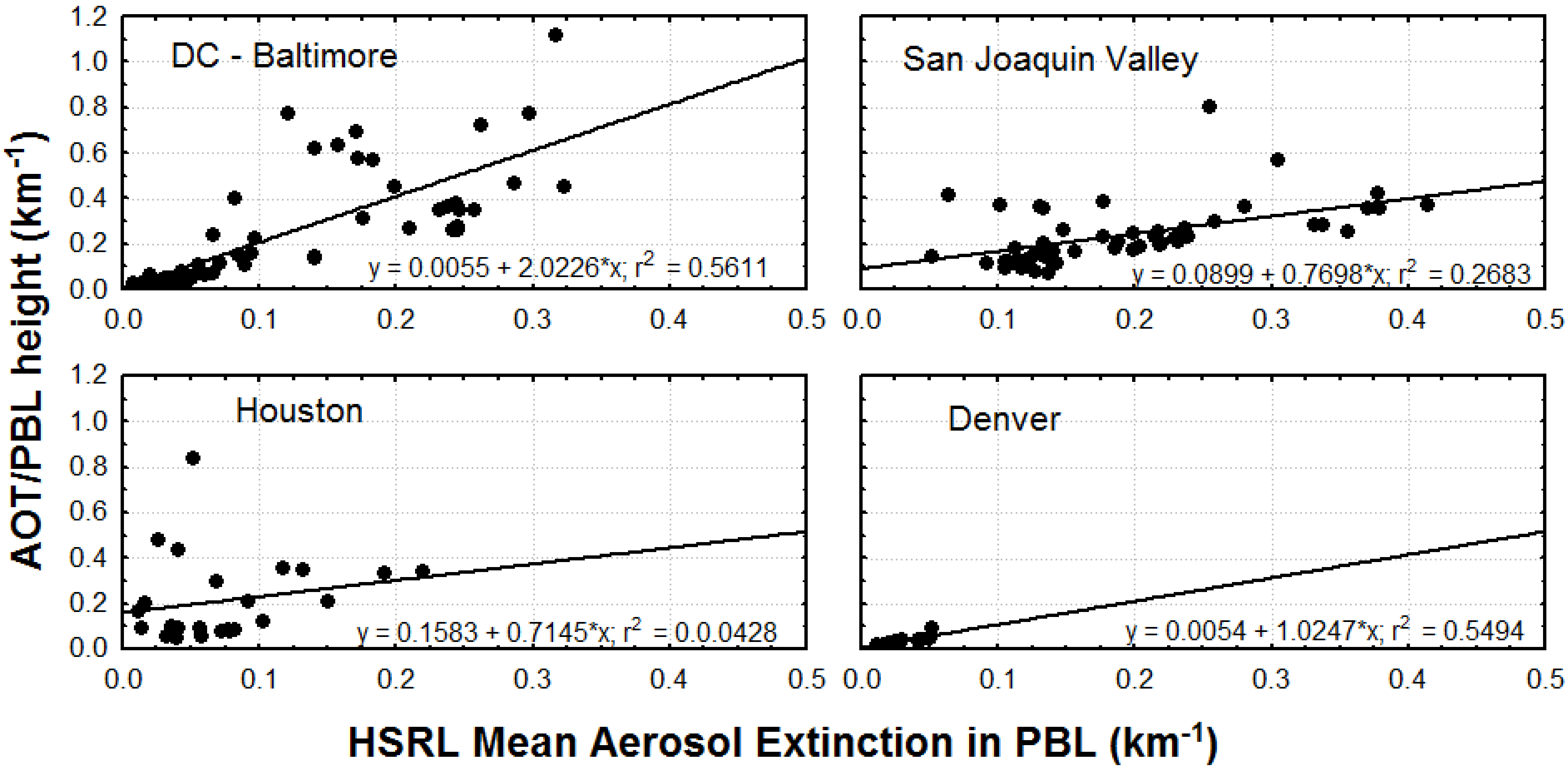
α_{SFC} (ambient RH) ~ $\overline{\alpha_H\text{(ambient RH)}}$?

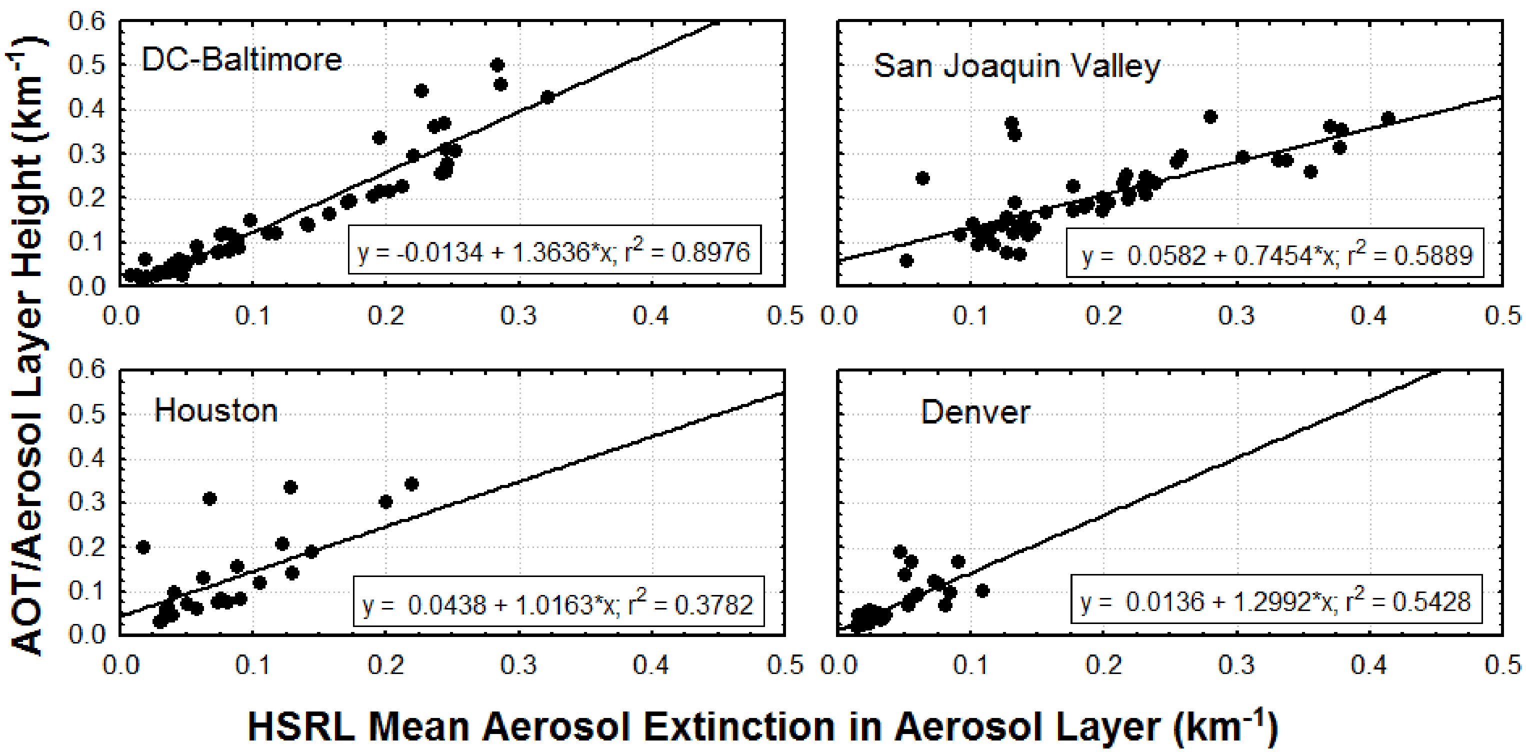
How well is surface extinction related to $PM_{2.5}$?
Can we estimate SSC?
α_{SFC} (dry) ~ SSC x $PM_{2.5}$?

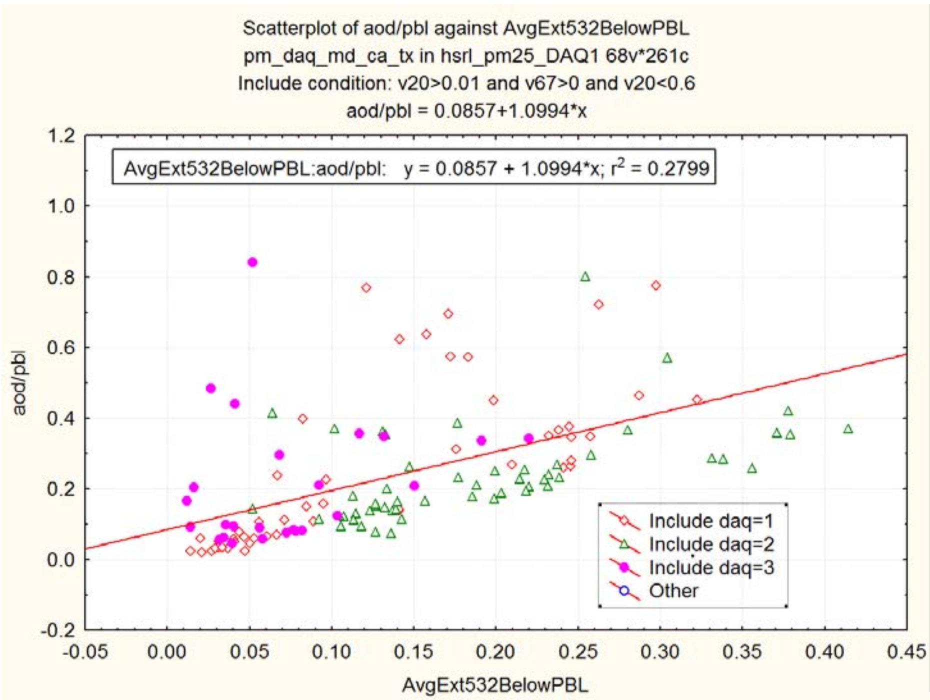
How well is AOT correlated with:
α_{SFC} (ambient RH), α_{SFC} (dry) , $PM_{2.5}$?

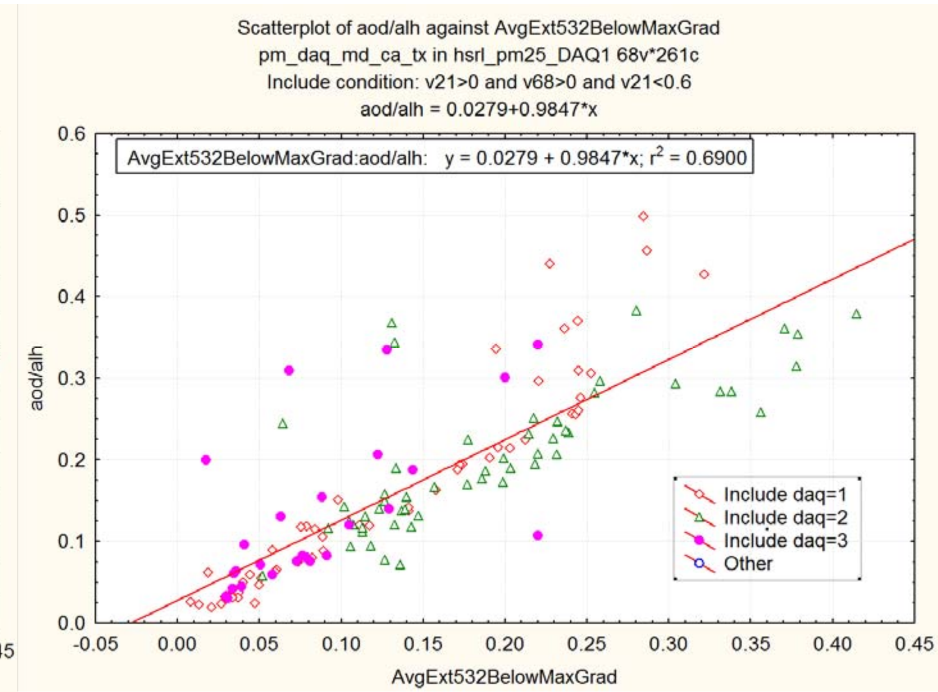
$$AOT = \int \alpha(z)\, dz$$




DC - Baltimore
y = 0.0055 + 2.0226*x; r2 = 0.5611
San Joaquin Valley
y = 0.0899 + 0.7698*x; r2 = 0.2683
Houston
y = 0.1583 + 0.7145*x; r2 = 0.0.0428
Denver
y = 0.0054 + 1.0247*x; r2 = 0.5494
AOT/PBL height (km-1)
HSRL Mean Aerosol Extinction in PBL (km-1)


DC-Baltimore
y = -0.0134 + 1.3636*x; r2 = 0.8976
San Joaquin Valley
y = 0.0582 + 0.7454*x; r2 = 0.5889
Houston
y = 0.0438 + 1.0163*x; r2 = 0.3782
Denver
y = 0.0136 + 1.2992*x; r2 = 0.5428
AOT/Aerosol Layer Height (km-1)
HSRL Mean Aerosol Extinction in Aerosol Layer (km-1)
0.0
0.1
0.2
0.3
0.4
0.5
0.6

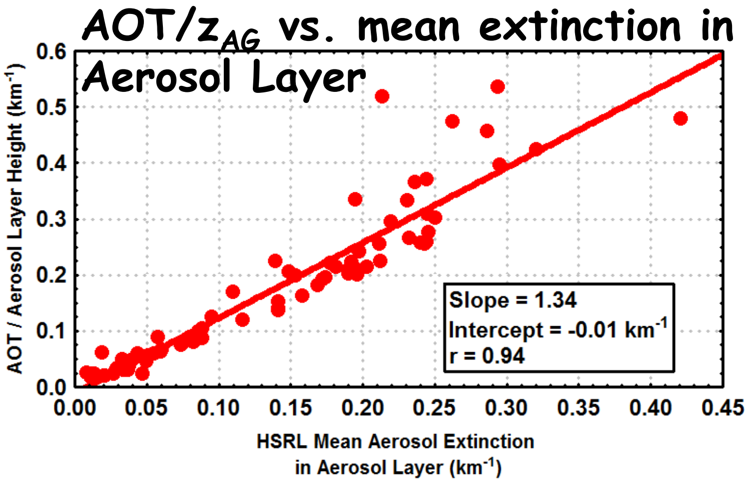

Scatterplot of aod/pbl against AvgExt532BelowPBL
pm_daq_md_ca_tx in hsrl_pm25_DAQ1 68v*261c
Include condition: v20>0.01 and v67>0 and v20<0.6
aod/pbl = 0.0857+1.0994*x
AvgExt532BelowPBL:aod/pbl: y = 0.0857 + 1.0994*x; r2 = 0.2799
Include daq=1
Include daq=2
Include daq=3
Other
aod/pbl
AvgExt532BelowPBL

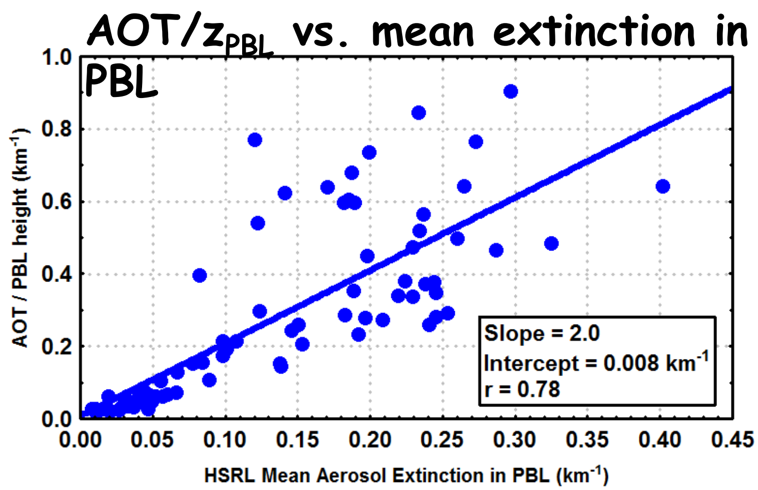

Scatterplot of aod/alh against AvgExt532BelowMaxGrad
pm_daq_md_ca_tx in hsrl_pm25_DAQ1 68v*261c
Include condition: v21>0 and v68>0 and v21<0.6
aod/alh = 0.0279+0.9847*x
AvgExt532BelowMaxGrad:aod/alh: y = 0.0279 + 0.9847*x; r2 = 0.6900
Include daq=1
Include daq=2
Include daq=3
Other
aod/alh
AvgExt532BelowMaxGrad

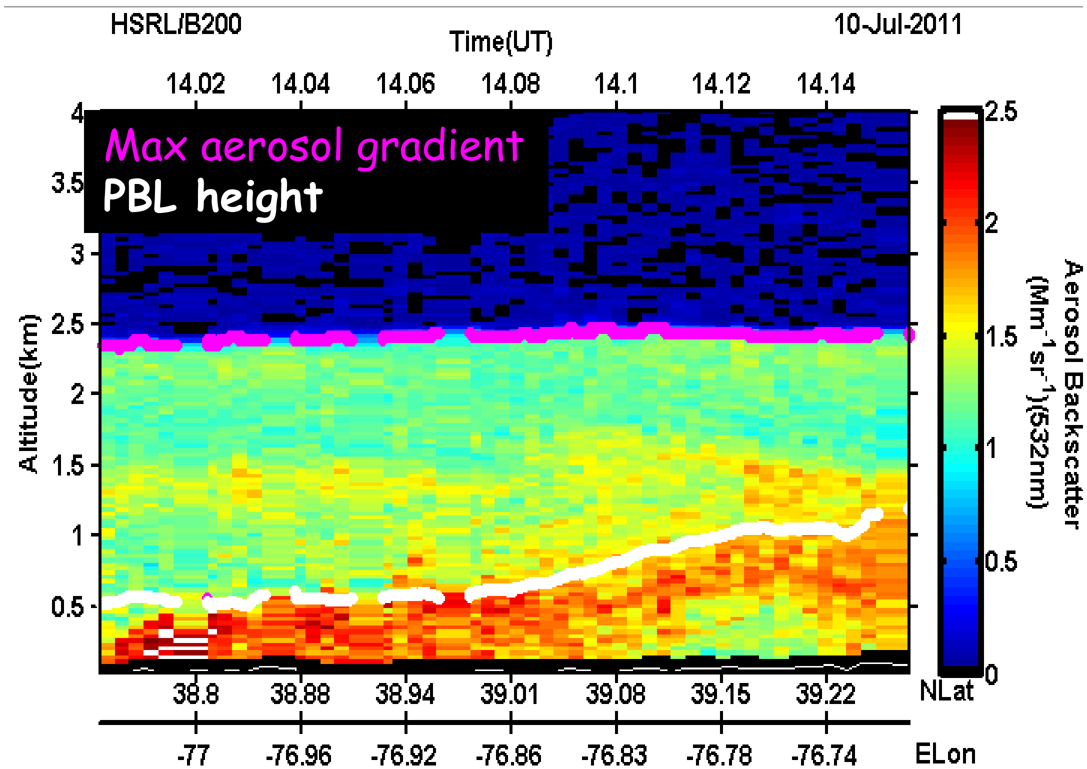
Aerosol Layer Height

We examine AOT / H vs. α_H(ambient RH)
Where H = z_{PBL} and H = z_{AG}

- We investigate the impact of layer height by examining the correlation between AOT and mean extinction within PBL and aerosol layer
- Height of the maximum aerosol gradient (aka aerosol layer) is a better measure of scale height than PBL height (but not the best)



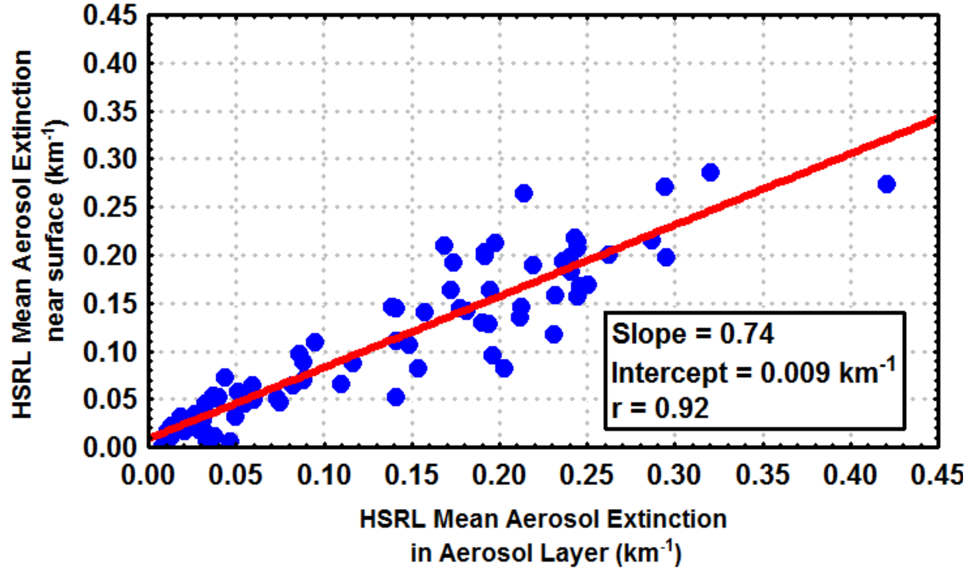


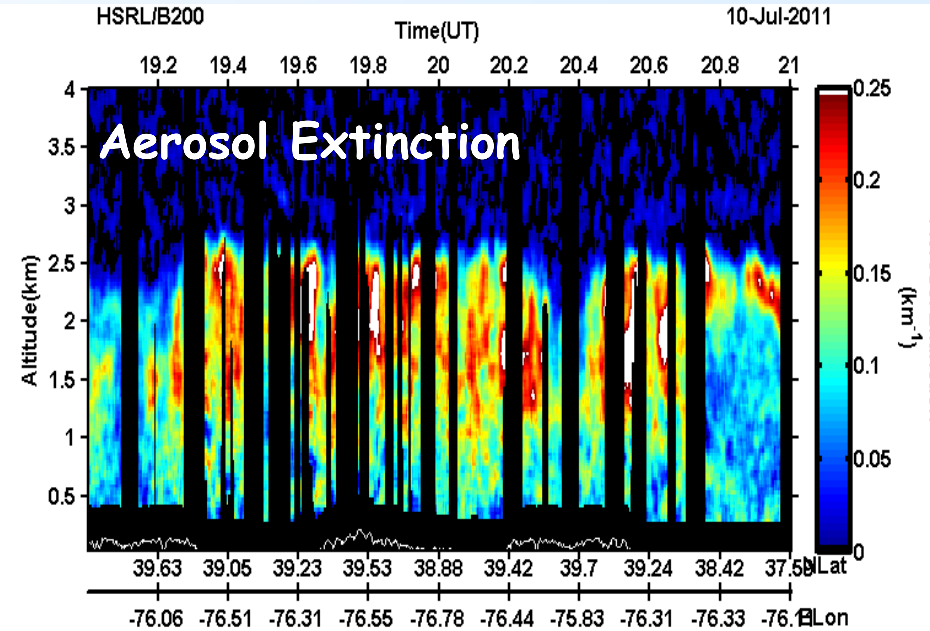


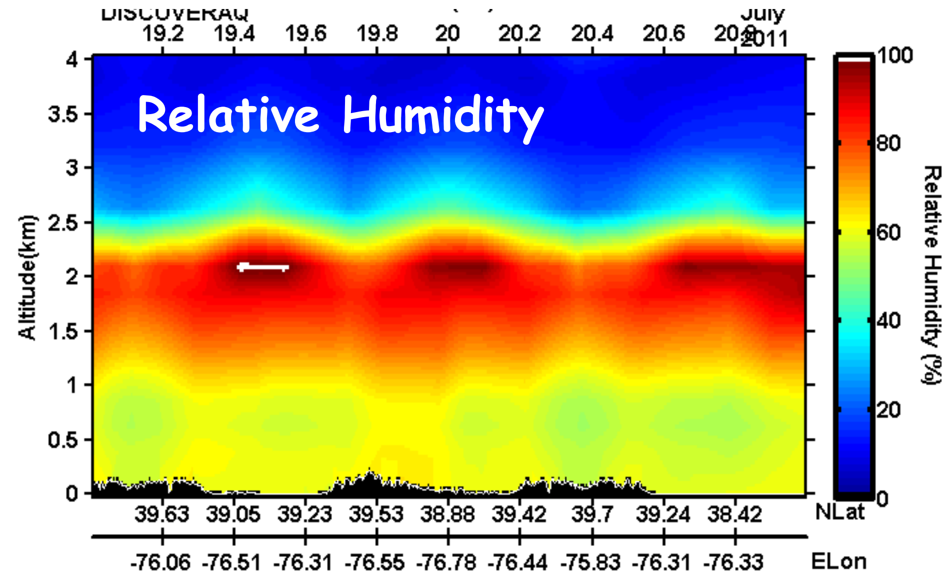
Relationship between mean layer extinction and surface extinction

We examine

α_{SFC} (ambient RH) ~ $\overline{\alpha_H\text{(ambient RH)}}$



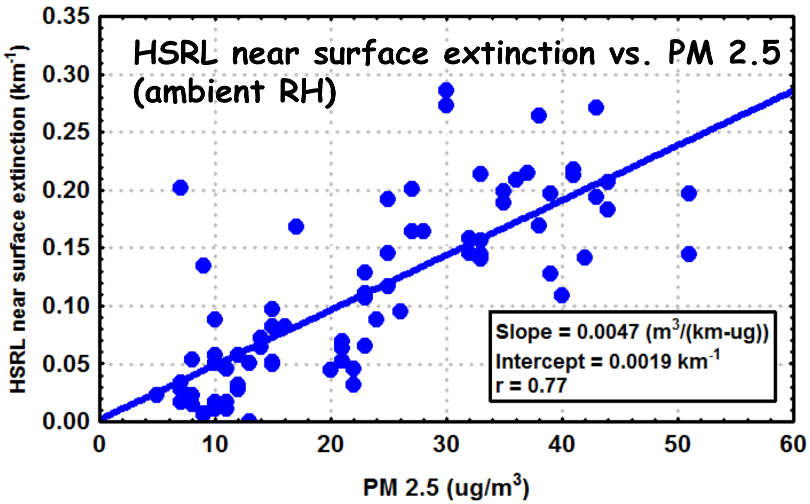


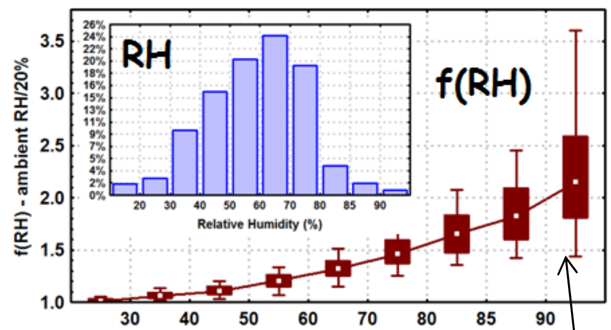


- Surface extinction is well correlated with mean aerosol extinction in the layer
- Surface extinction is generally lower than mean extinction in the layer
  - HSRL data often show increase in extinction with height in aerosol layer
  - This increase likely associated with higher RH near the top of the layer

Correlation between near-surface extinction and surface $PM_{2.5}$ concentrations

- HSRL measurements of extinction near the surface were correlated with hourly surface $PM_{2.5}$ data from four stations (Beltsville, Fairhill, Edgewood, UMBC)
- *Average humidification factor was obtained from P3 in situ data*
- Correlations would likely improve with higher temporal resolution surface $PM_{2.5}$ data



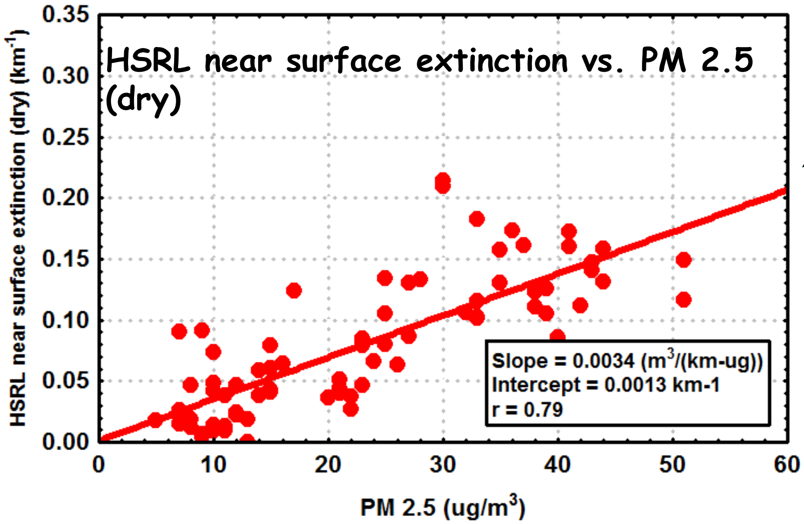


We examine

$\alpha_{SFC}(dry) \approx SSC * PM_{2.5}$

$\alpha_{SFC}(ambient\ RH)/f(RH) \approx SSC * PM_{2.5}$

Used average f(RH) correction derived from P3



Slope = ~ 3.4 m^2/g

(recall from Hoff et al. Nov. 3 presentation

SSC from surface BAM = 3.2 ± 1.3 m^2/g)

where:

α = aerosol extinction

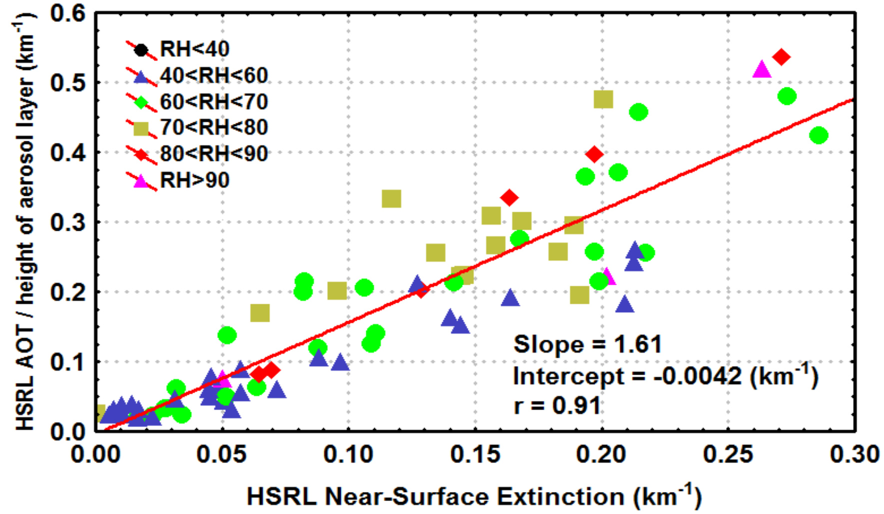
SSC = specific scattering coefficient

f(RH) = humidification factor

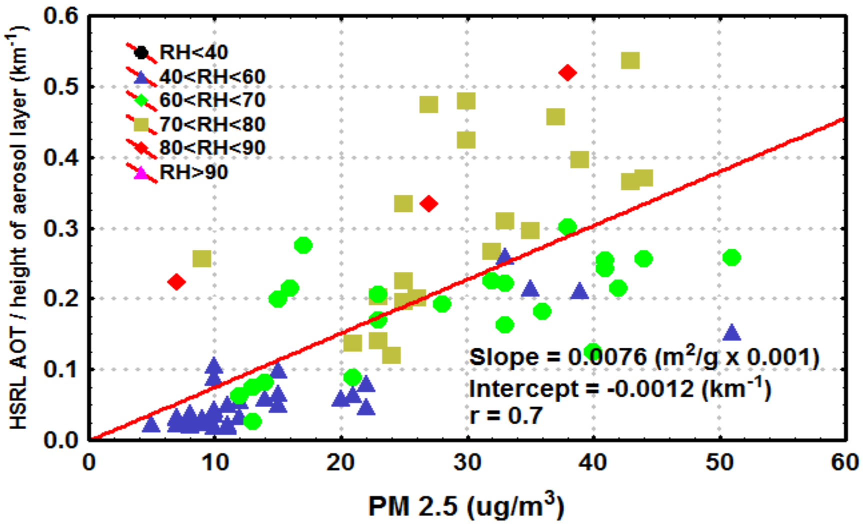
Correlation between HSRL AOT and $PM_{2.5}$

- Surface $PM_{2.5}$ can be inferred from measurements of AOT and height of the aerosol layer
- Highest correlation between HSRL AOT scaled by height of aerosol layer and HSRL near-surface extinction
- Correlations would likely improve with:
  - higher temporal resolution surface $PM_{2.5}$ data
  - use of individual f(RH, z) measurements rather than an average f(RH)

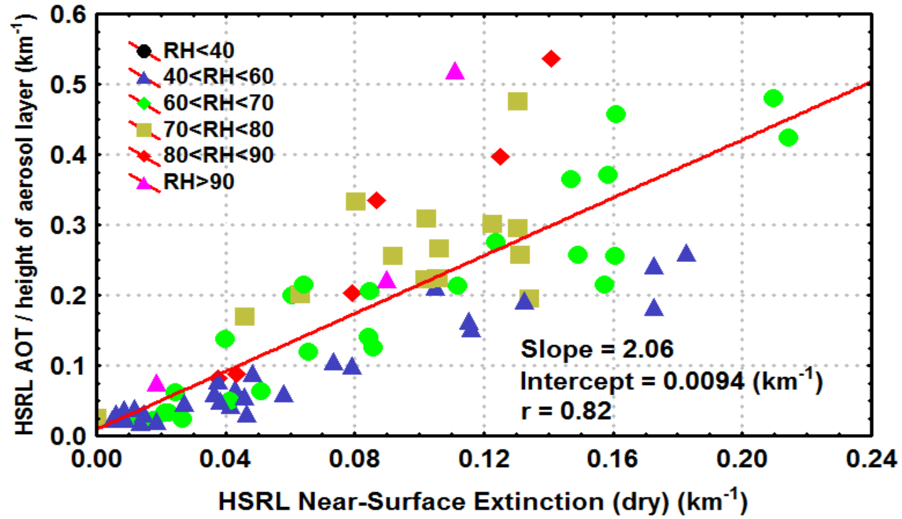
(HSRL AOT / aerosol layer height) vs.
HSRL near-surface extinction (ambient RH)



(HSRL AOT / aerosol layer height) vs. PM 2.5



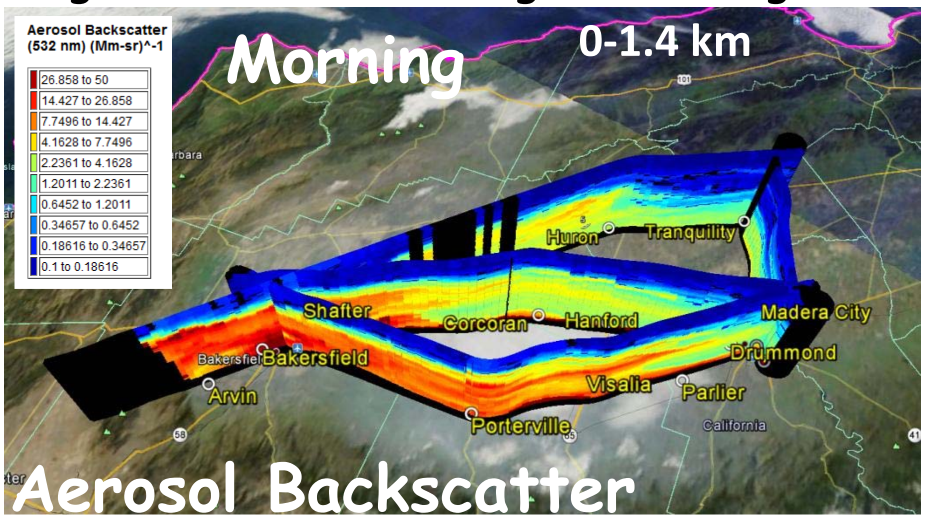
(HSRL AOT / aerosol layer height) vs.
HSRL near-surface extinction (dry)

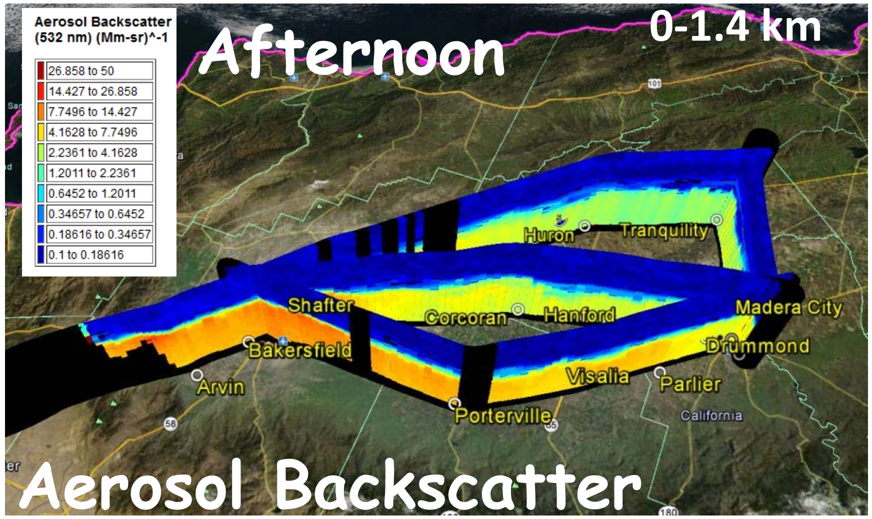


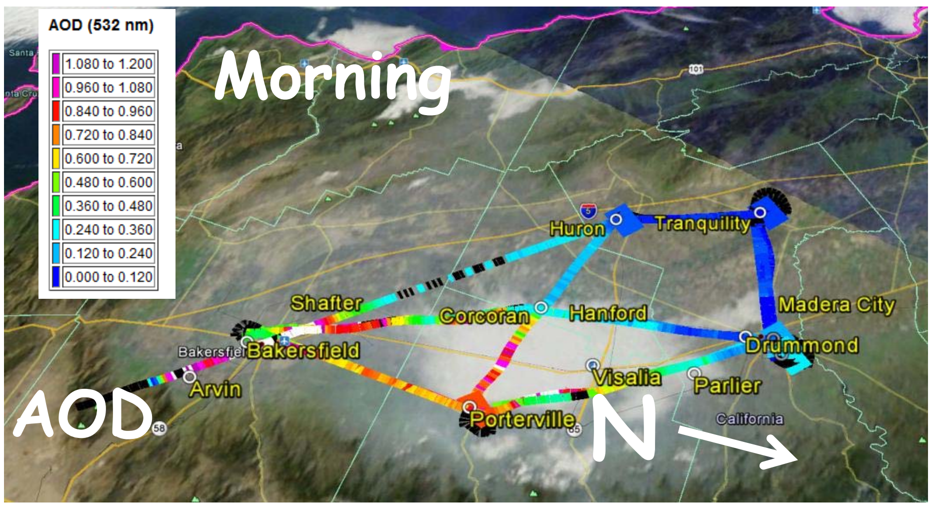
Impact of High Relative Humidity
Feb. 4, 2013

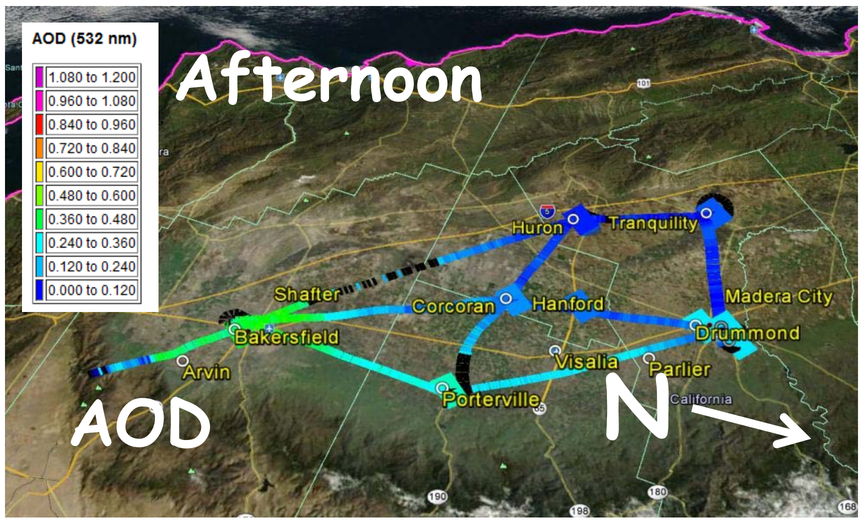
February 4 – Morning and Afternoon

- Aerosols more stratified during the morning
- Over southeastern portion (Porterville, Bakersfield) AOT 2 to 3 times higher in the morning than during the afternoon due to higher RH
- Higher AOT values along eastern leg









High RH affects ability to infer $PM_{2.5}$ from AOT

$AOT = \int \alpha(z)\, dz$

$AOT \approx \overline{\alpha_H(\text{ambient RH})} \times H$

Assume: $\alpha_{SFC}(\text{ambient RH}) \sim \overline{\alpha_H(\text{ambient RH})}$

$\alpha_{SFC}(\text{ambient RH}) = f(RH) \times \alpha_{SFC}(\text{dry})$

Assume: $\alpha_{SFC}(\text{dry}) \sim b_{sca}(\text{dry})$

$b_{sca}(\text{dry}) = SSC \times PM_{2.5}$

$$AOT \approx \boxed{f(RH)} \times SSC \times H \times PM_{2.5}$$

Where:

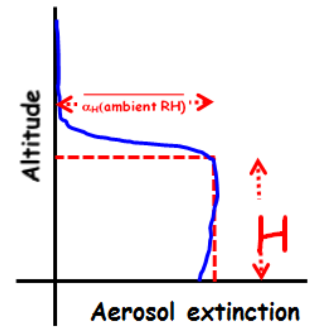
α = aerosol extinction

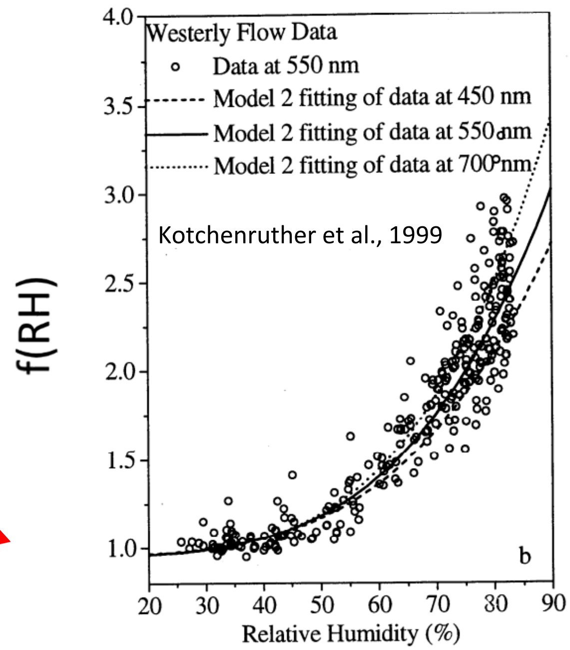
b_{sca} = aerosol scattering

SSC = specific scattering coefficient

f(RH) = aerosol humidification factor

H = height of aerosol layer

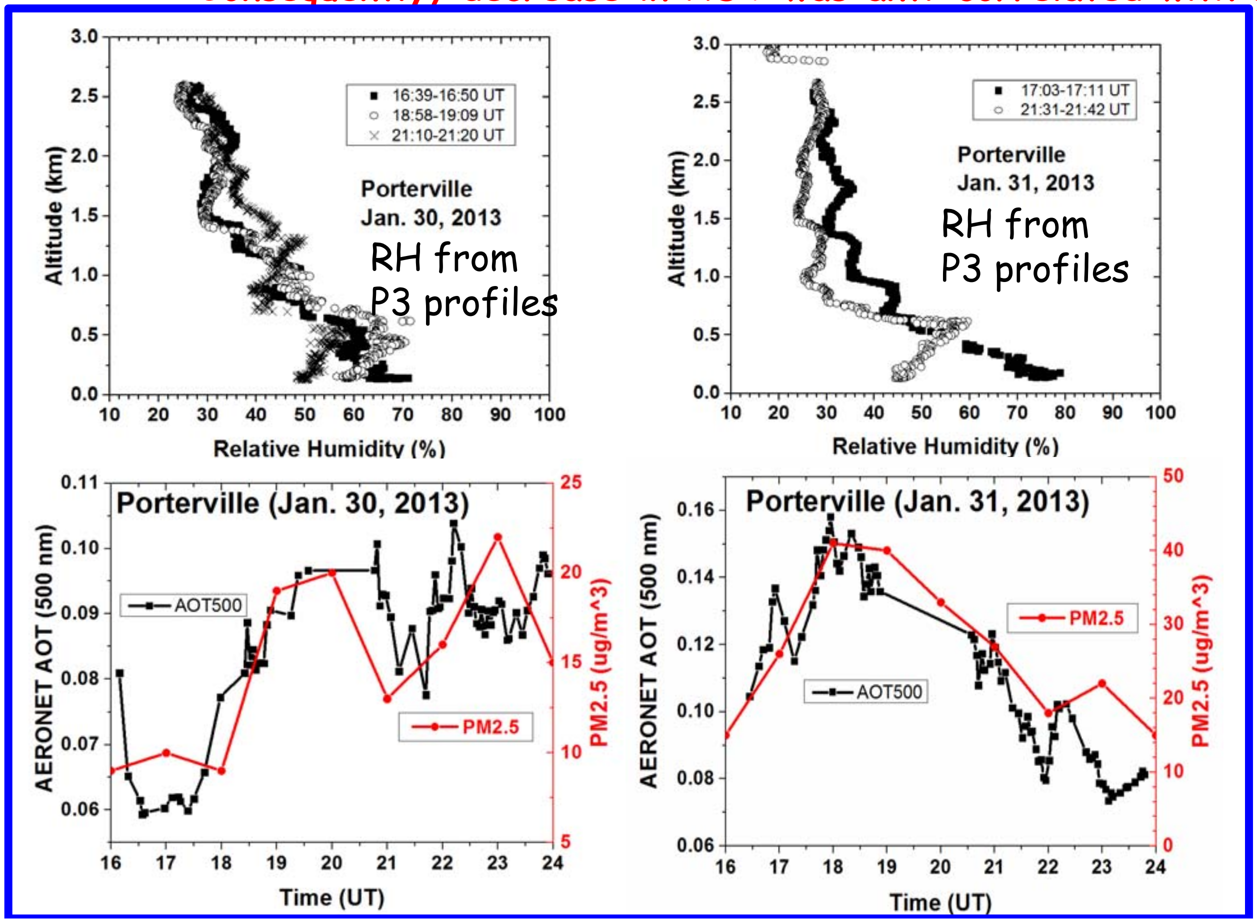


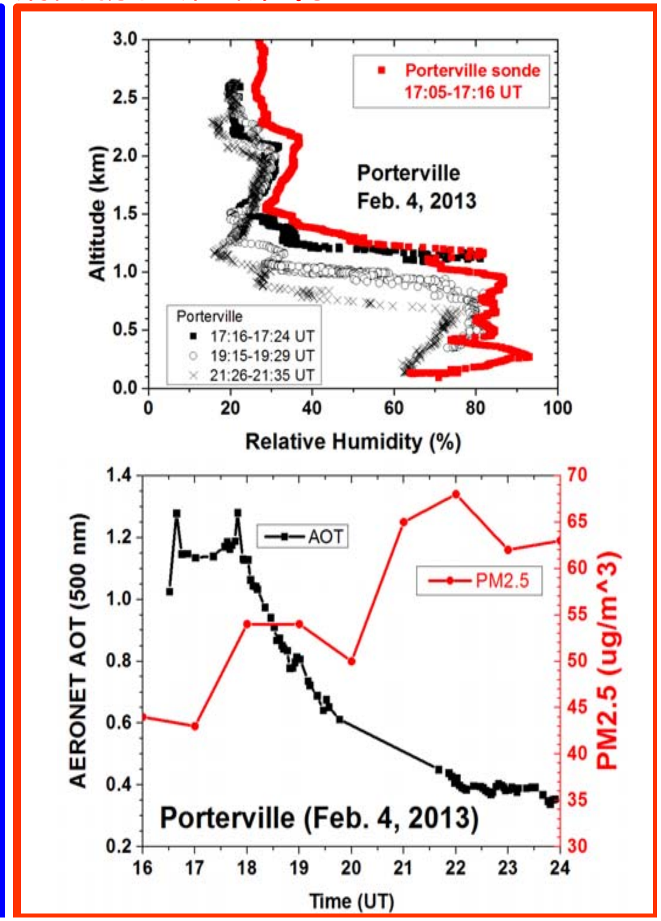


Aerosol humidification can impact ability to infer PM2.5 from AOT

Large decrease in RH over Porterville decreases correlation between $PM_{2.5}$ and AOT

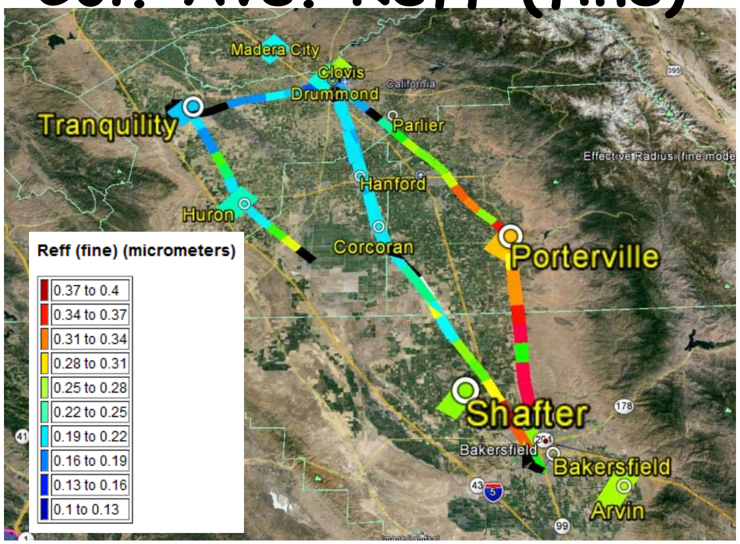
- On Jan. 30 and 31
  - RH was generally below 70% so that f(RH) was relatively low and constant
  - Good correlation between AOT and PM2.5
- On Feb. 4
  - High (>80-90%) RH in the morning
  - Large decrease in RH led to large decrease in f(RH) and AOT
  - Consequently, decrease in AOT was anti-correlated with increase in PM2.5



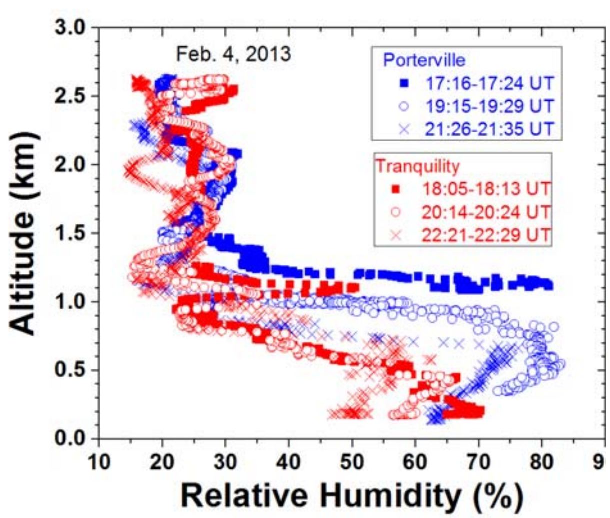


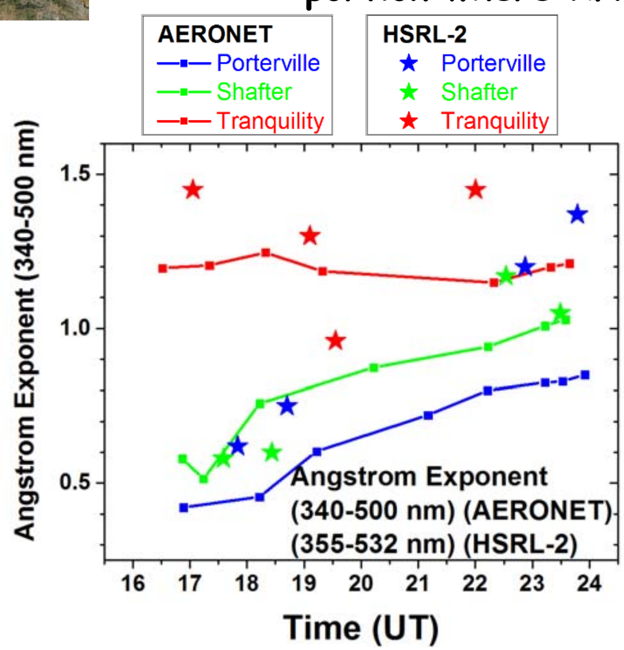
Temporal and spatial variability in column average particle size

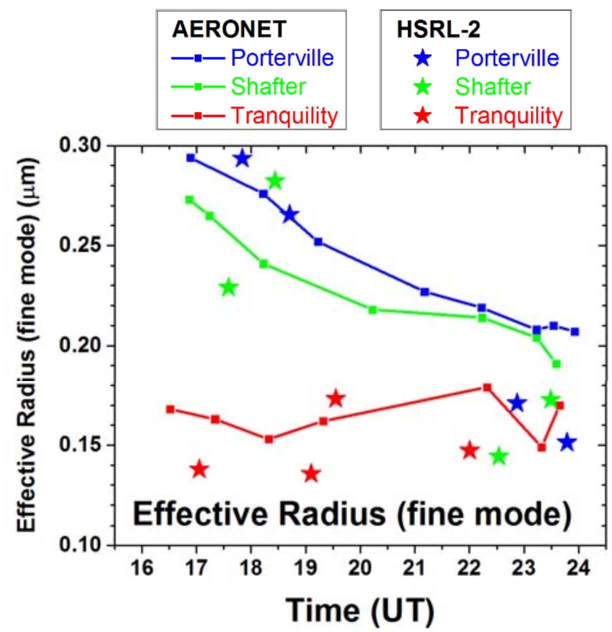
Col. Ave. Reff (fine)



- Large changes in RH occurred over the southeastern portion (Porterville, Shafter)
- Little or no change in RH over the northwestern portion (Tranquility)
- Consequently, changes in fine mode particle size were found over the southeastern portion
- Both HSRL-2 and AERONET found:
  - Increase in column aerosol extinction Angström exponent and decrease in fine mode effective radius associated with the decrease in RH over the southeastern portion
  - No change in particle size over the northwestern portion where RH was lower

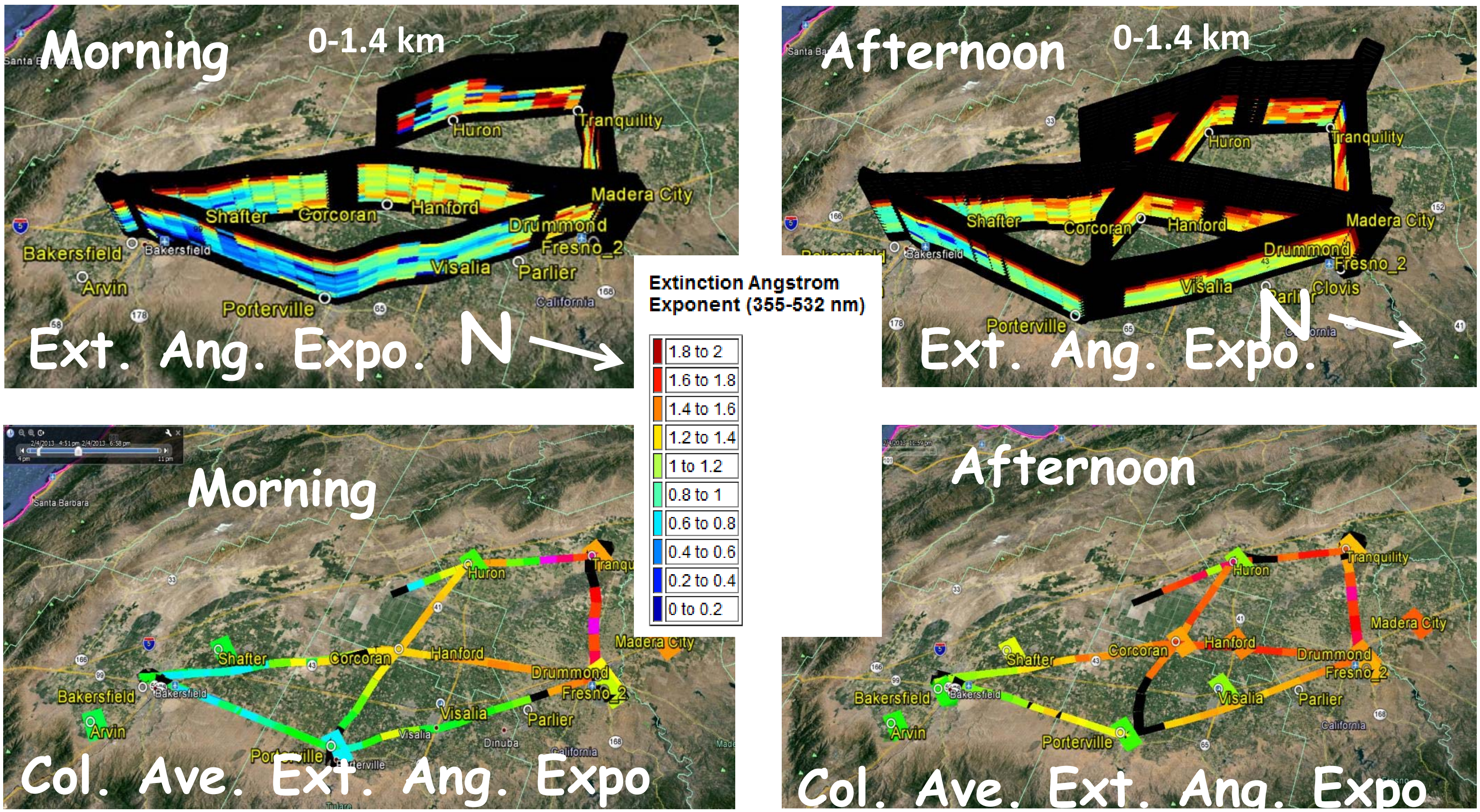






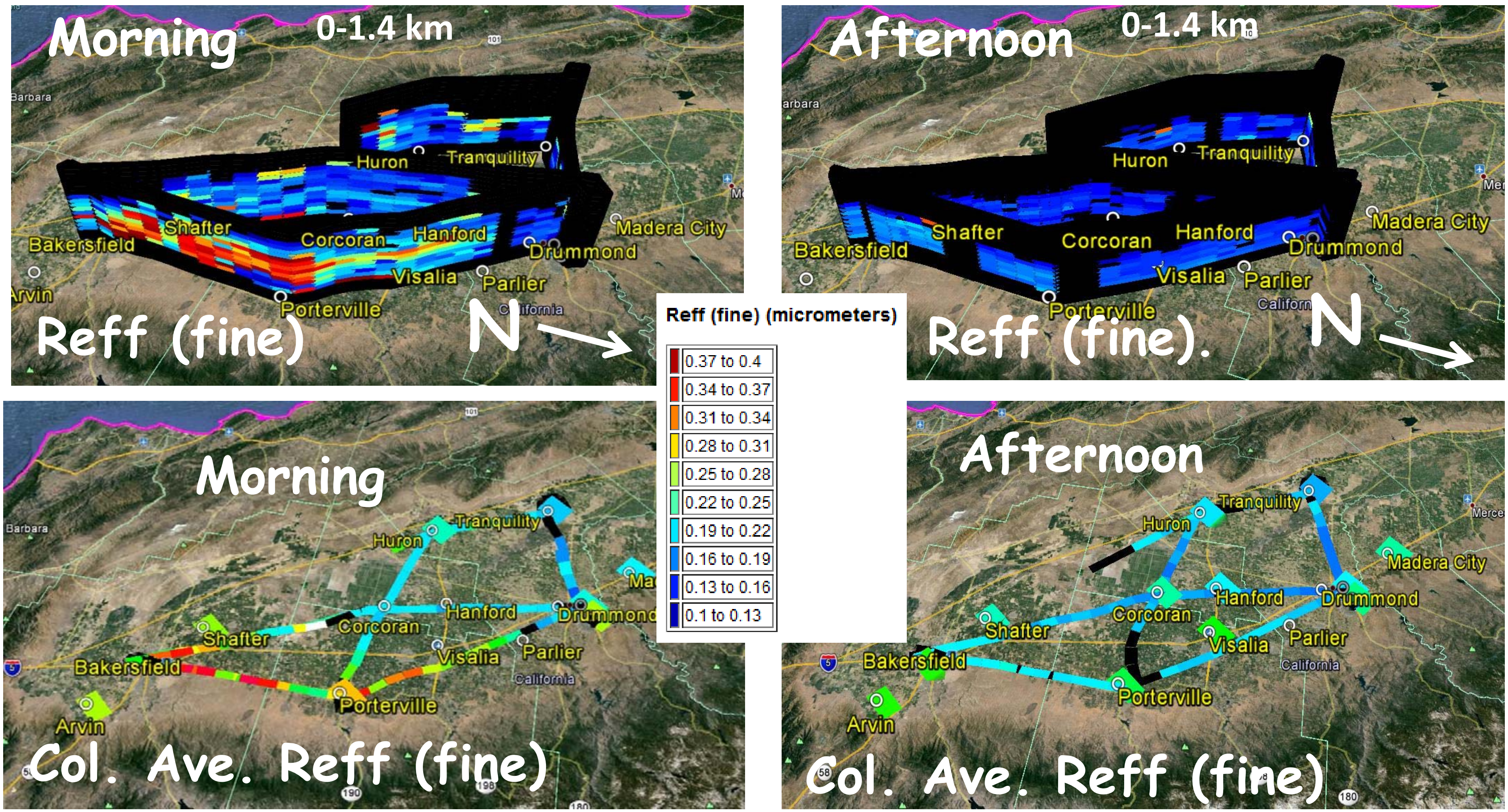
HSRL-2 reveals temporal, horizontal, and vertical variability in extinction Angström exponent

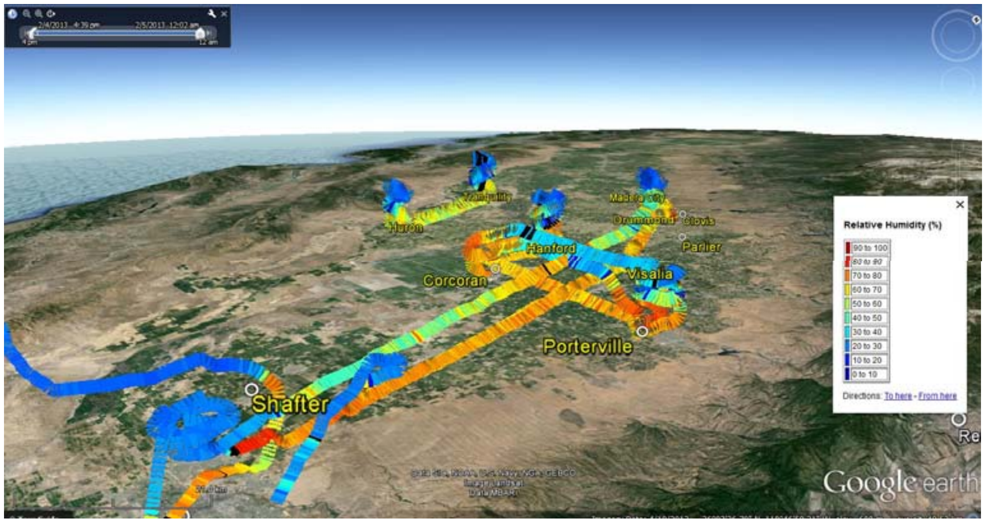
- Morning – Low extinction Angstrom exponent over southeastern portion (Porterville, Bakersfield)
- Afternoon – Increase in extinction Ansgtröm exponent over southeast as RH decreased
- Northwestern portion (Tranquility) – consistently high values of extinction Angström exponent associated with lower RH



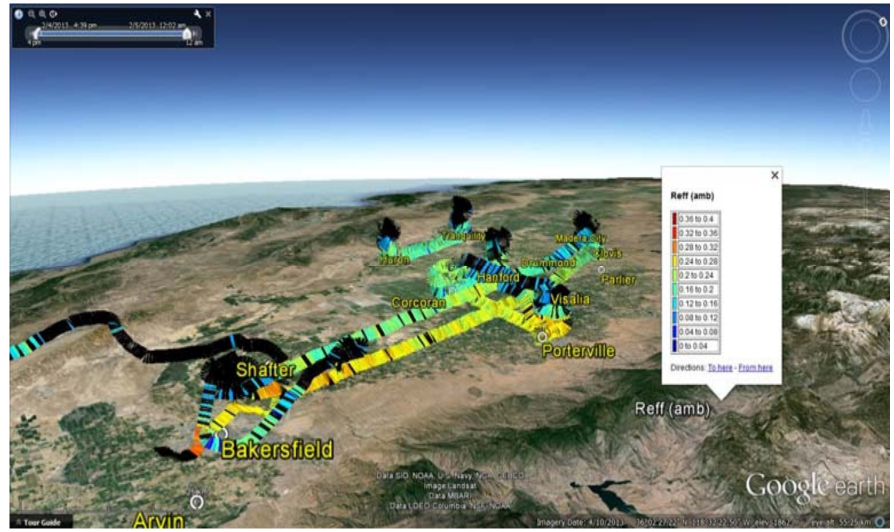
HSRL-2 reveals temporal, horizontal, and vertical variability in fine mode effective radius

- Morning – Larger fine mode aerosols over southeastern portion (Porterville, Bakersfield)
- Afternoon – Decrease in fine mode particle size over southeast as RH decreased
- Northwestern portion (Tranquility) – consistently smaller fine mode particles associated with lower RH

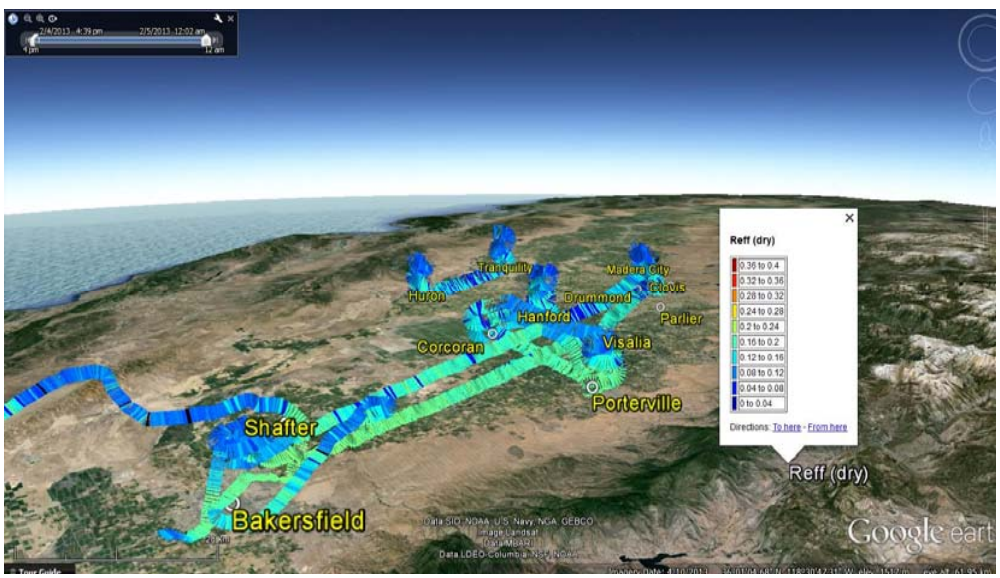




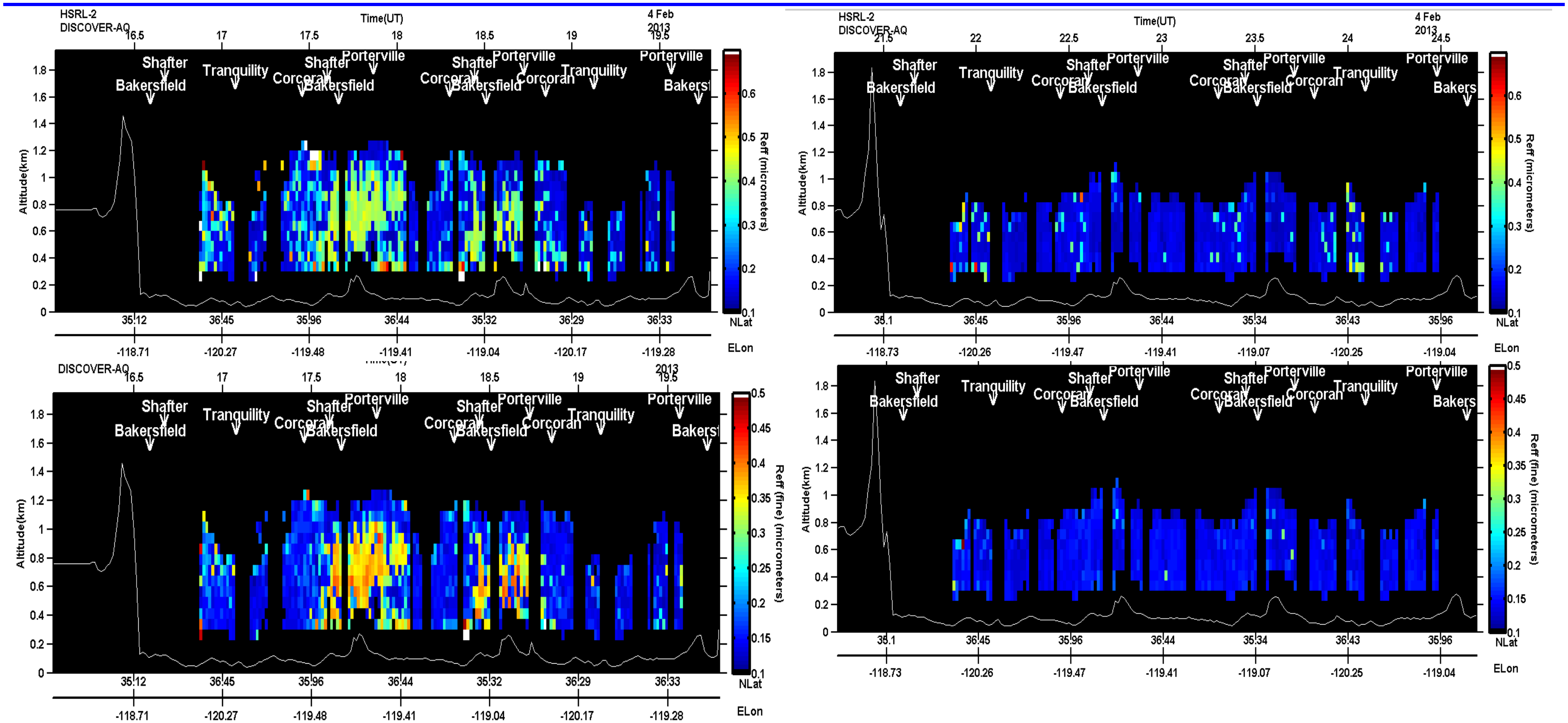
Relative Humidity (%)
90 to 100
80 to 90
70 to 80
60 to 70
50 to 60
40 to 50
30 to 40
20 to 30
10 to 20
0 to 10
Directions: To here - From here
Huron
Tranquility
Madera City
Drummond
Clovis
Parlier
Hanford
Corcoran
Visalia
Porterville
Shafter
Google earth

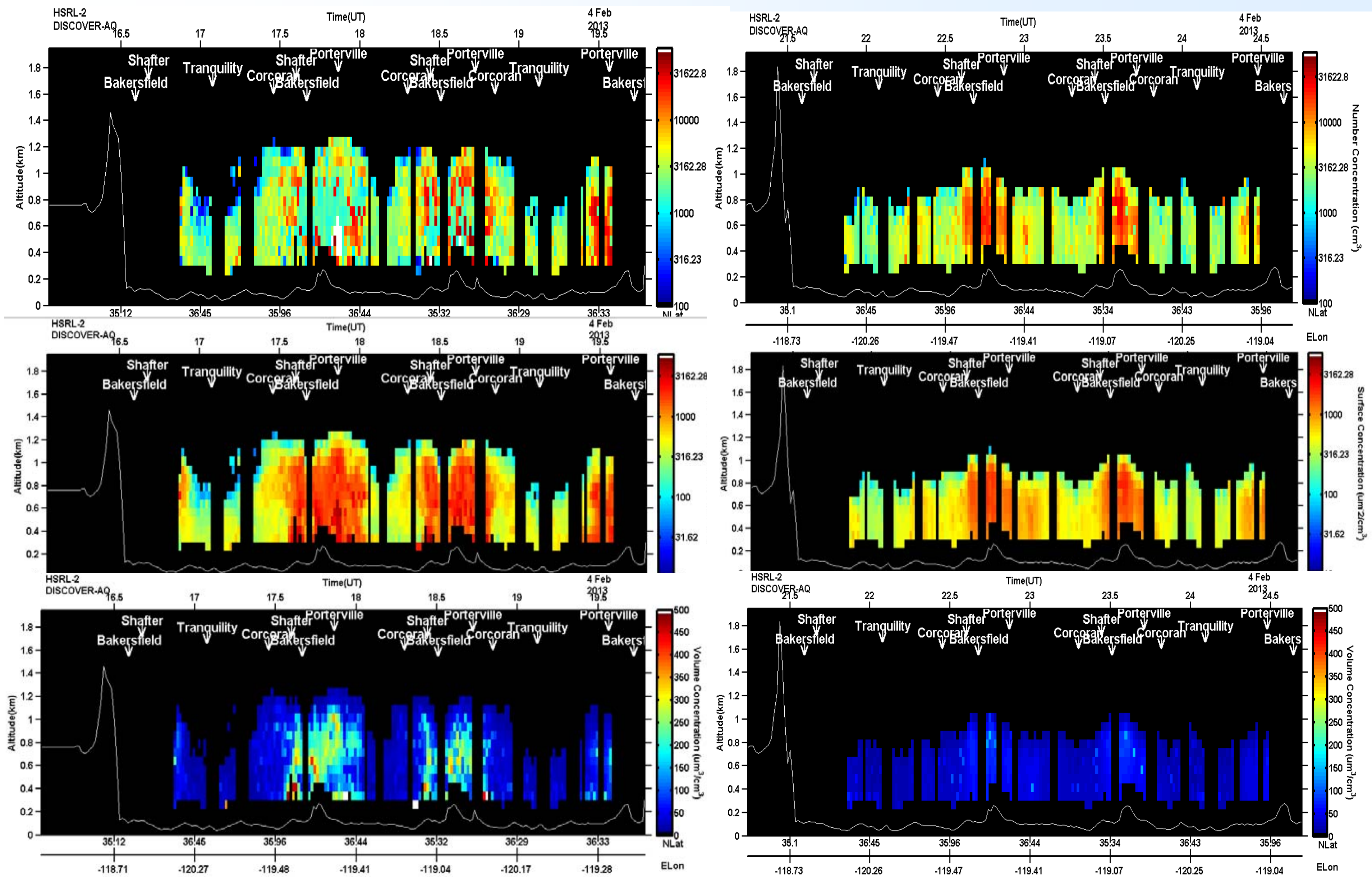


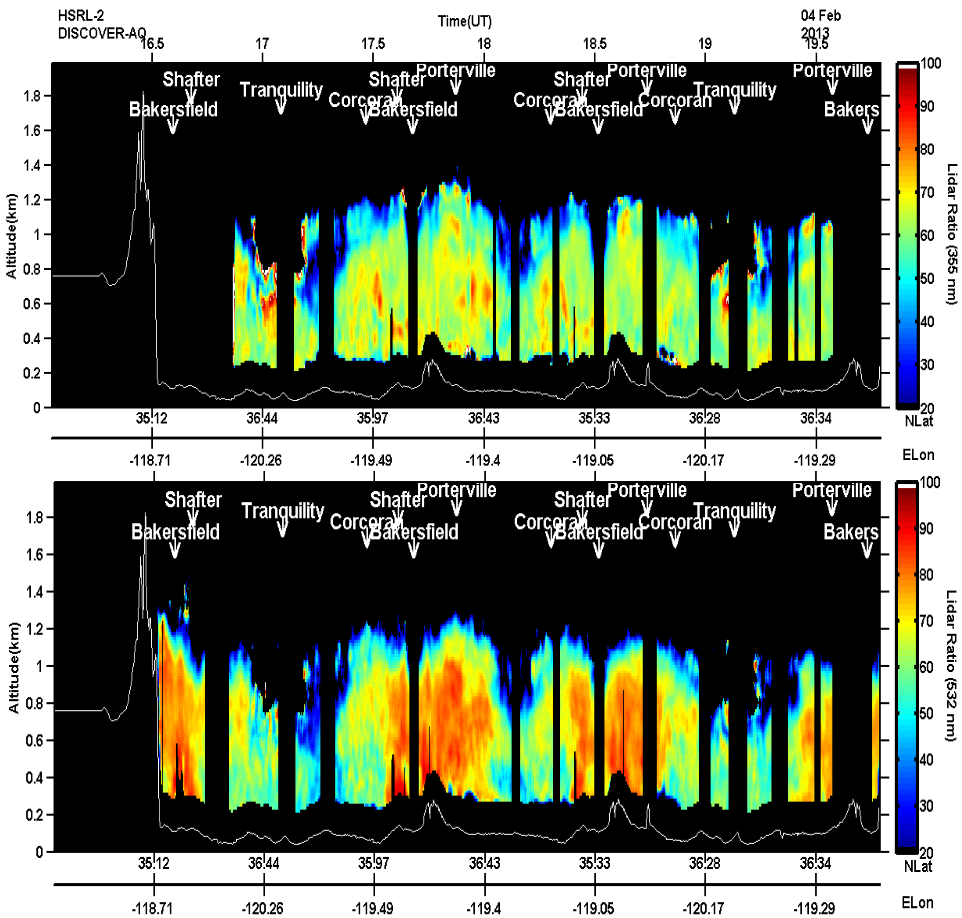
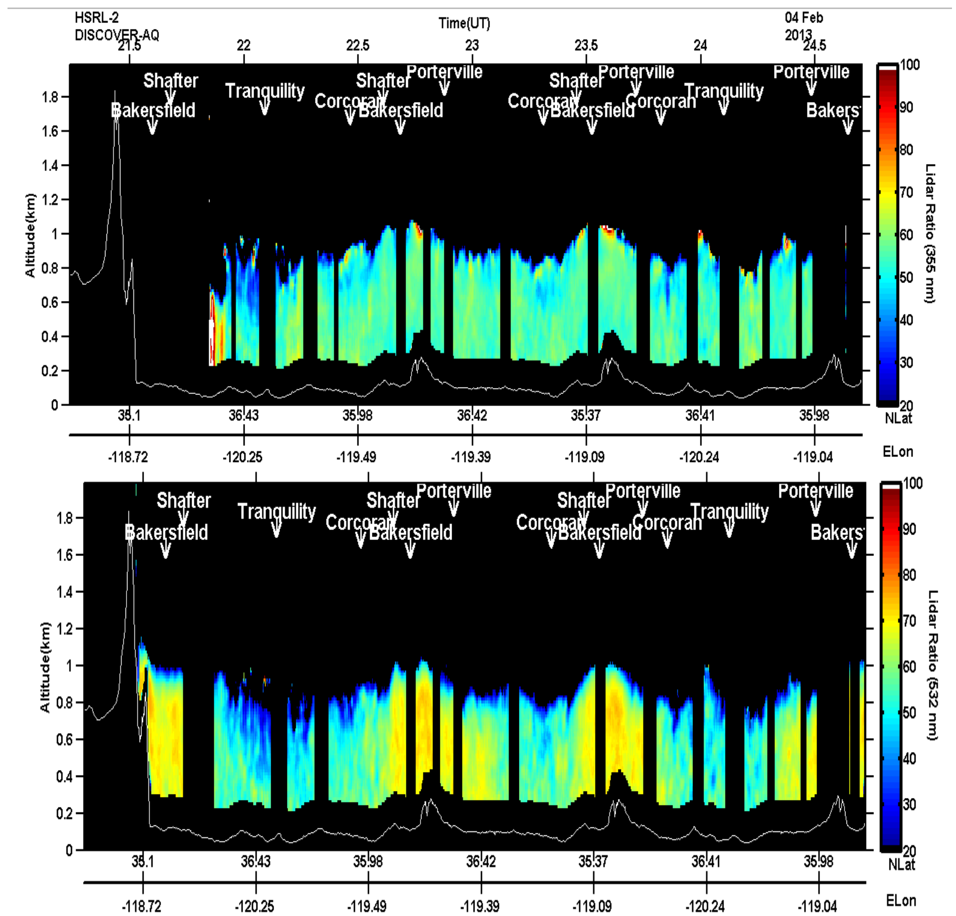
Reff (amb)
0.36 to 0.4
0.32 to 0.36
0.28 to 0.32
0.24 to 0.28
0.2 to 0.24
0.16 to 0.2
0.12 to 0.16
0.08 to 0.12
0.04 to 0.08
0 to 0.04
Directions: To here - From here
Reff (amb)
Huron
Tranquility
Madera City
Drummond
Clovis
Parlier
Hanford
Corcoran
Visalia
Porterville
Shafter
Bakersfield
Arvin
Google earth

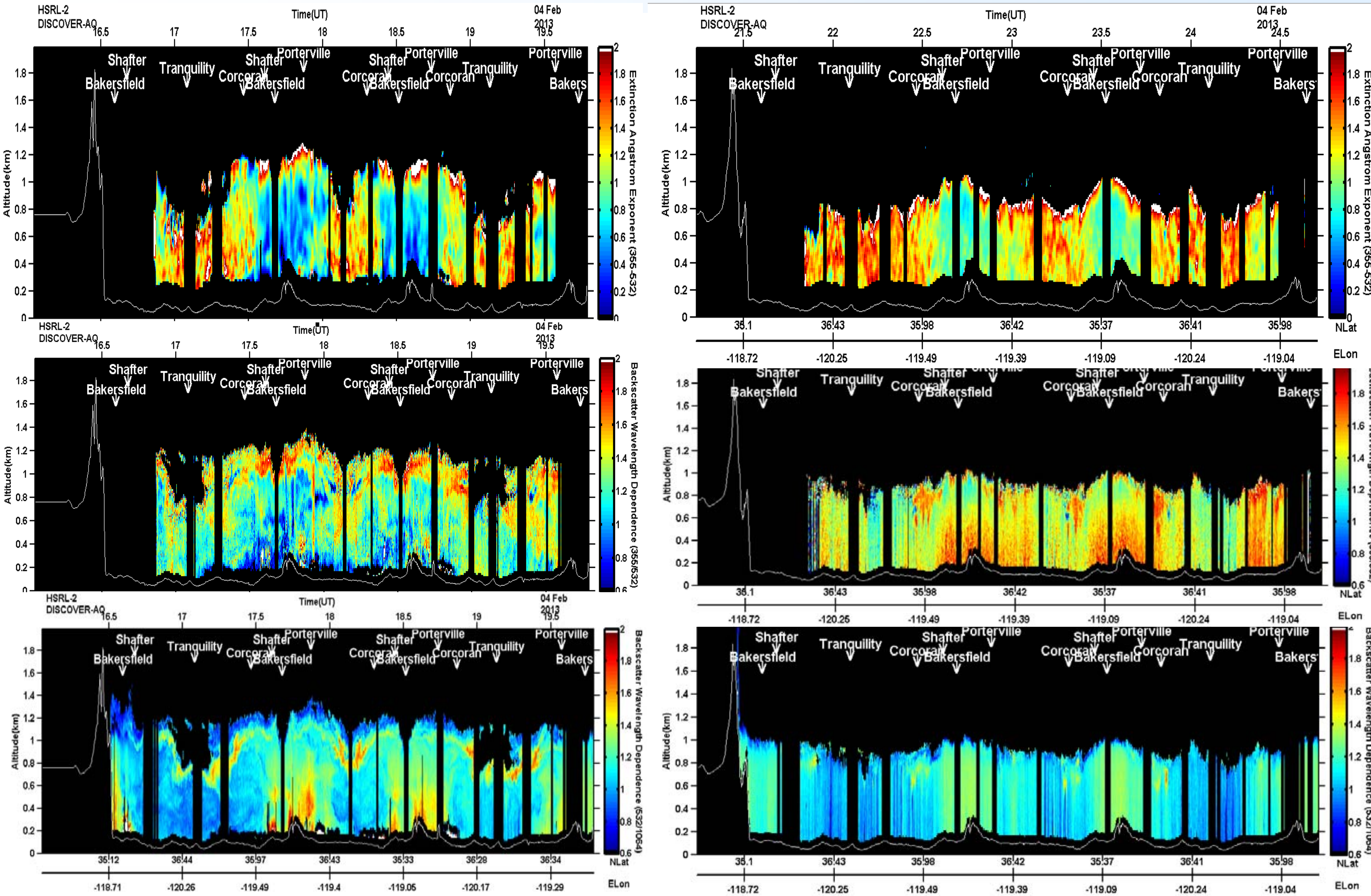


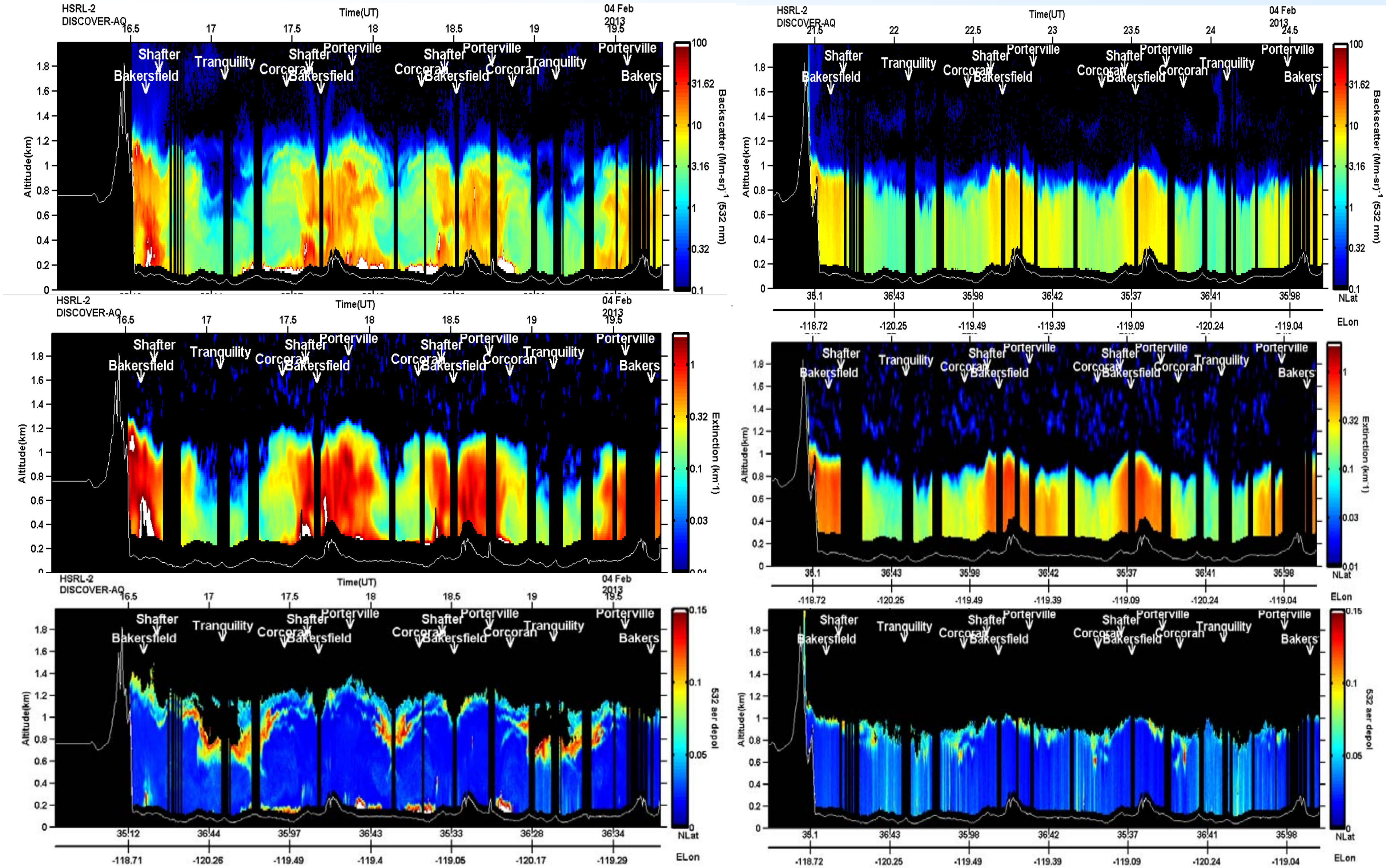
Reff (dry)
0.36 to 0.4
0.32 to 0.36
0.28 to 0.32
0.24 to 0.28
0.2 to 0.24
0.16 to 0.2
0.12 to 0.16
0.08 to 0.12
0.04 to 0.08
0 to 0.04
Directions: To here - From here
Reff (dry)
Huron
Tranquility
Madera City
Drummond
Clovis
Parlier
Hanford
Corcoran
Visalia
Porterville
Shafter
Bakersfield

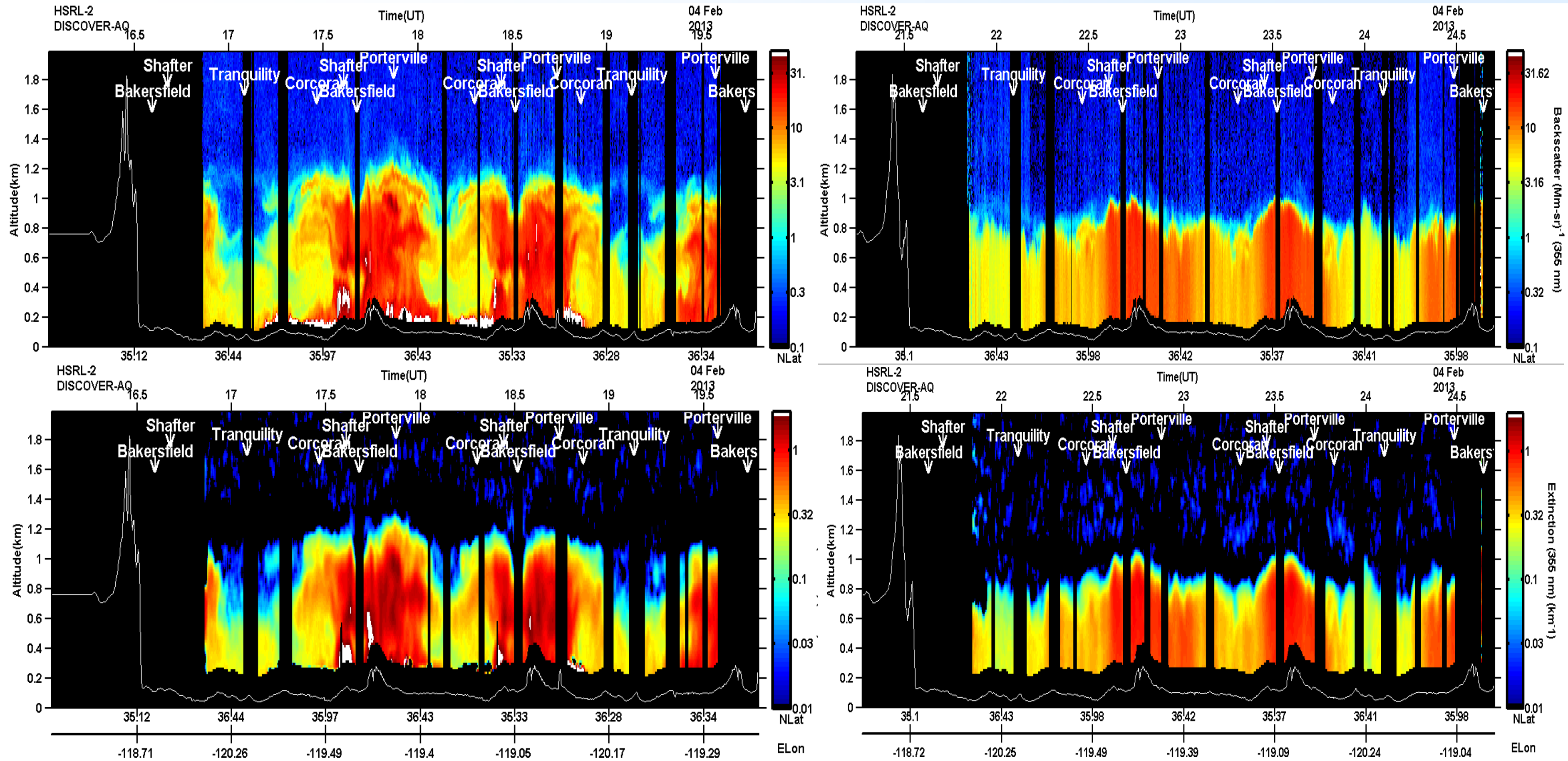

HSRL-2
DISCOVER-AQ
Time(UT)
4 Feb 2013
Shafter
Bakersfield
Tranquility
Corcoran
Porterville
Altitude(km)
Reff (micrometers)
Reff (fine) (micrometers)
NLat
ELon


HSRL-2
DISCOVER-AQ
Time(UT)
4 Feb 2013
16.5
17
17.5
18
18.5
19
19.5
21.5
22
22.5
23
23.5
24
24.5
Shafter
Tranquility
Porterville
Corcoran
Bakersfield
Altitude(km)
Number Concentration (cm^{-3})
31622.8
10000
3162.28
1000
316.23
100
Surface Concentration (um^2/cm^3)
31.62
Volume Concentration (um^3/cm^3)
500
450
400
350
300
250
200
150
50
0
NLat
35.12
36.45
35.96
36.44
35.32
36.29
36.33
35.1
35.34
36.43
ELon
-118.71
-120.27
-119.48
-119.41
-119.04
-120.17
-119.28
-118.73
-120.26
-119.47
-119.07
-120.25


HSRL-2
DISCOVER-AQ
Time(UT)
04 Feb 2013
16.5
17
17.5
18
18.5
19
19.5
Shafter
Tranquility
Porterville
Corcoran
Bakersfield
Altitude(km)
Lidar Ratio (355 nm)
Lidar Ratio (532 nm)
35.12
36.44
35.97
36.43
35.33
36.28
36.34
NLat
-118.71
-120.26
-119.49
-119.4
-119.05
-120.17
-119.29
ELon

HSRL-2
DISCOVER-AQ
Time(UT)
04 Feb 2013
21.5
22
22.5
23
23.5
24
24.5
Shafter
Tranquility
Porterville
Corcoran
Bakersfield
Altitude(km)
Lidar Ratio (355 nm)
Lidar Ratio (532 nm)
35.1
36.43
35.98
36.42
35.37
36.41
35.98
NLat
-118.72
-120.25
-119.49
-119.39
-119.09
-120.24
-119.04
ELon


HSRL-2
DISCOVER-AQ
Time(UT)
04 Feb 2013
16.5
17
17.5
18
18.5
19
19.5
21.5
22
22.5
23
23.5
24
24.5
Shafter
Tranquility
Porterville
Corcoran
Bakersfield
Altitude(km)
Extinction Angstrom Exponent (355-532)
Backscatter Wavelength Dependence (355/532)
Backscatter Wavelength Dependence (532/1064)
NLat
ELon
35.1
36.43
35.98
36.42
35.37
36.41
-118.72
-120.25
-119.49
-119.39
-119.09
-120.24
-119.04
35.12
36.44
35.97
36.43
35.33
36.28
36.34
-118.71
-120.26
-119.4
-119.05
-120.17
-119.29


HSRL-2
DISCOVER-AQ
Time(UT)
04 Feb 2013
16.5
17
17.5
18
18.5
19
19.5
21.5
22
22.5
23
23.5
24
24.5
Shafter
Bakersfield
Tranquility
Corcoran
Porterville
Bakers
Altitude(km)
Backscatter (Mm-sr)^-1 (532 nm)
Extinction (km^-1)
532 aer depol
100
31.62
10
3.16
1
0.32
0.1
0.03
0.01
0.15
0.05
NLat
ELon
35.12
36.44
35.97
36.43
35.33
36.28
36.34
-118.71
-120.26
-119.49
-119.4
-119.05
-120.17
-119.29
35.1
36.43
35.98
36.42
35.37
36.41
-118.72
-120.25
-119.39
-119.09
-120.24
-119.04



HSRL-2
DISCOVER-AQ
Time(UT)
04 Feb 2013
16.5
17
17.5
18
18.5
19
19.5
Shafter
Bakersfield
Tranquility
Corcoran
Porterville
Altitude(km)
35.12
36.44
35.97
36.43
35.33
36.28
36.34
NLat
31.62
10
3.16
1
0.32
0.1
Backscatter (Mm-sr)^-1 (355 nm)
21.5
22
22.5
23
23.5
24
24.5
35.1
36.43
35.98
36.42
35.37
36.41
35.98
0.03
0.01
Extinction (355 nm) (km^-1)
-118.71
-120.26
-119.49
-119.4
-119.05
-120.17
-119.29
-118.72
-120.25
-119.39
-119.09
-120.24
-119.04
ELon