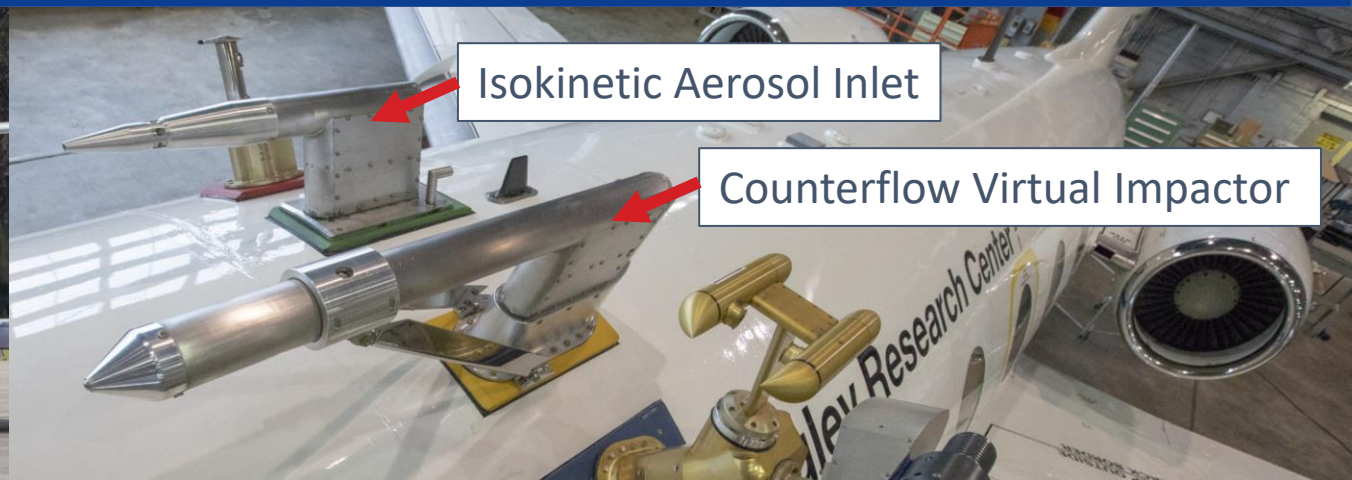
Langley Aerosol Research Group (LARGE)
Science Directorate
NASA Langley Research Center
Hampton, VA, USA

https://science-data.larc.nasa.gov/large/

Richard H. Moore (richard.h.moore@nasa.gov)
Luke D. Ziemba (luke.ziemba@nasa.gov)
Eddie Winstead, Ewan Crosbie, Claire Robinson, Michael Shook
Joe Schlosser, HSRL team

Observations of Absorbing Aerosol over Bermuda

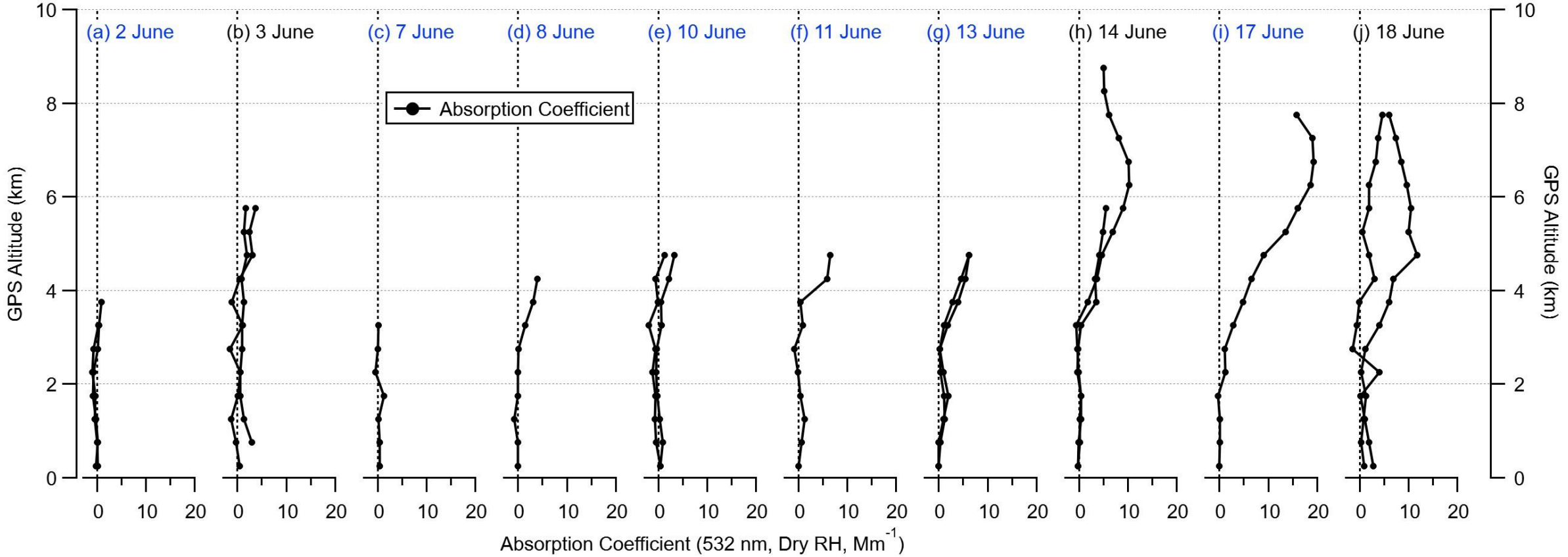
STM-2023



Motivation: Absorption Profiles during ACTIVATE-Bermuda

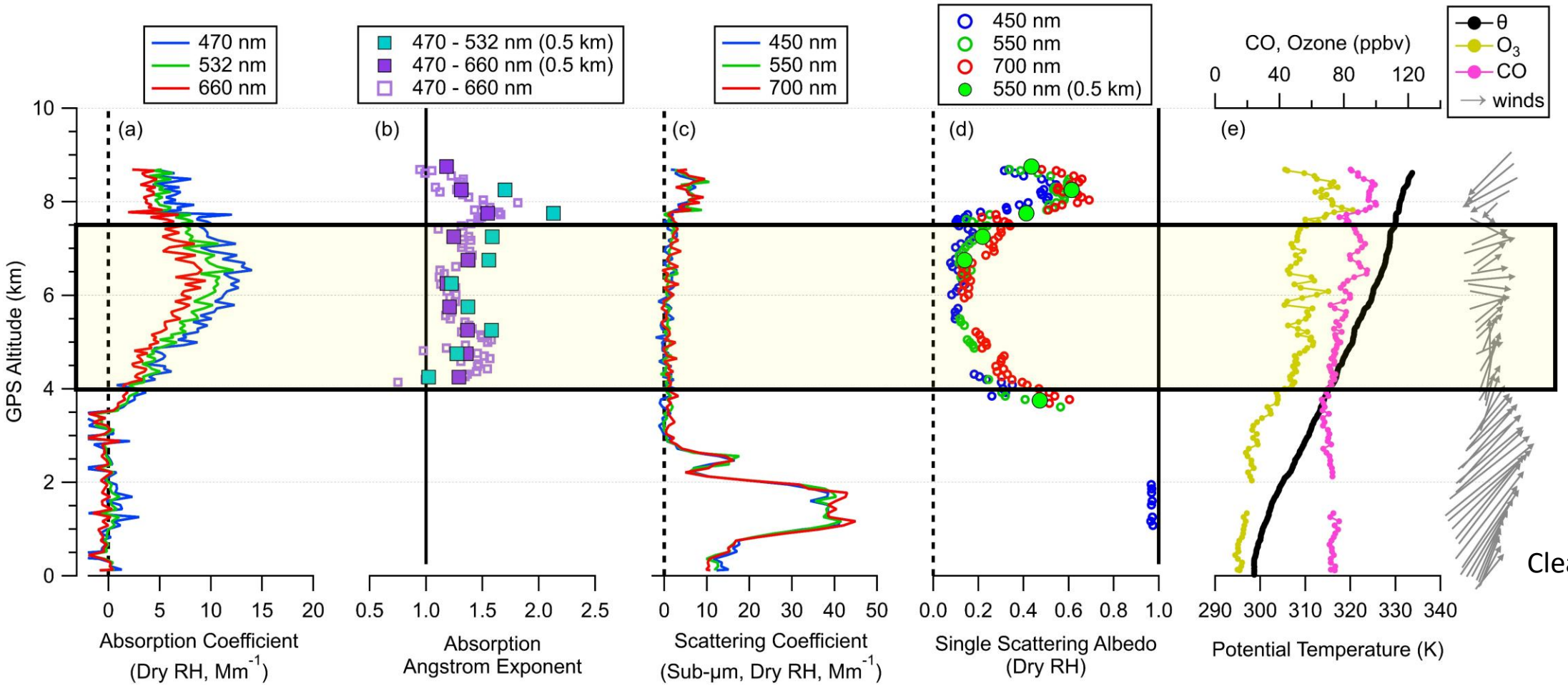
Blue Dates = Tudor Hill Spirals

Measurements = Particle Soot Absorption Photometer (PSAP)



Showing all profiles if altitude > 3.0km
Data from 10-s online merge files

Motivation: Optical Properties for 14 June 2023 Profile



Absorbing Aerosol Layer

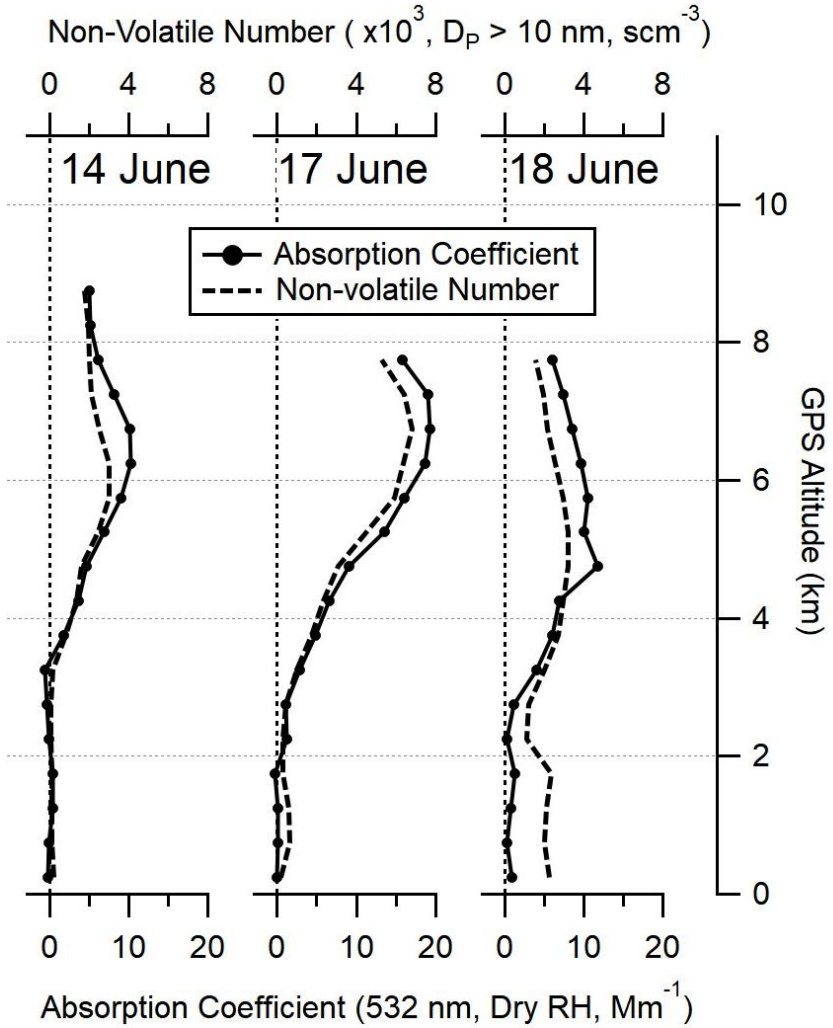
Scattering Aloft

Clean Shallow MBL

Absorbing Aerosol: 3 Cases

	14 June 16:05:15	17 June 16:20:35	18 June 14:09:05
GPS Altitude (km)	4.0 – 8.7	4.0 – 8.0	4.5 – 8.0
CN_{10nm} (scm^{-3})	3436 (919)	7579 (2242)	4292 (377)
$CN_{10nm-nv}$ (scm^{-3})	3006 (850)	7029 (2115)	3294 (878)
CN_{3nm} (scm^{-3})	5675 (1530)	12047 (3862)	7489 (679)
Abs (532nm, Mm^{-1})	7.2 (2.7)	15.0 (4.6)	8.9 (2.1)
Scat (550nm, Mm^{-1})	1.0 (0.8)	10.1 (18.5)	1.5 (1.1)
CO (ppbv)	79.7 (7)	93.4 (10.4)	82.7 (6.3)
Ozone (ppbv)	52.5 (5.7)	74.9 (12.7)	41.9 (16.4)

Average Value (standard deviation)

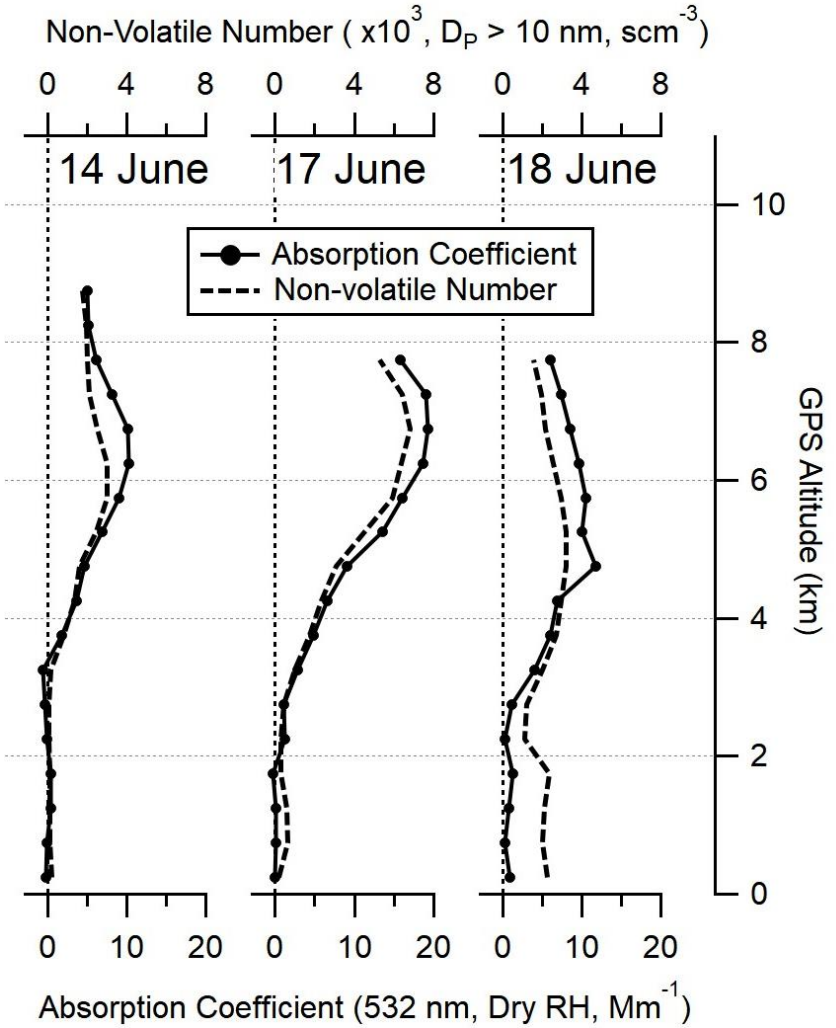


- $CN_{10nm-nv}$ is heated to 350°C → **BC**, dust, or sea-salt
- Size-dependent loss is applied to $CN_{10nm-nv}$
- High non-volatile fraction suggests that most particles contain a BC 'core'
  - SSA very low for each case
    - CO is not particularly elevated

Absorbing Aerosol: 3 Cases

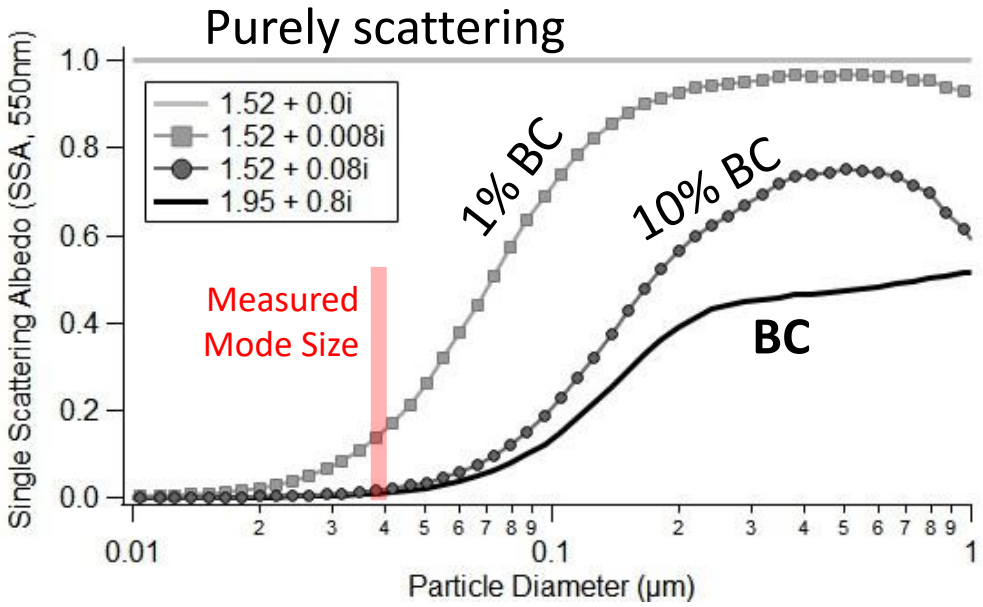
	14 June 16:05:15	17 June 16:20:35	18 June 14:09:05
GPS Altitude (km)	4.0 – 8.7	4.0 – 8.0	4.5 – 8.0
Non-vol Fraction:	87%	93%	77%
CN_{3nm} (scm^{-3})	5675 (1530)	12047 (3862)	7489 (679)
SSA (550nm):	0.11	0.38	0.13
CO (ppbv)	79.7 (7)	93.4 (10.4)	82.7 (6.3)
Ozone (ppbv)	52.5 (5.7)	74.9 (12.7)	41.9 (16.4)

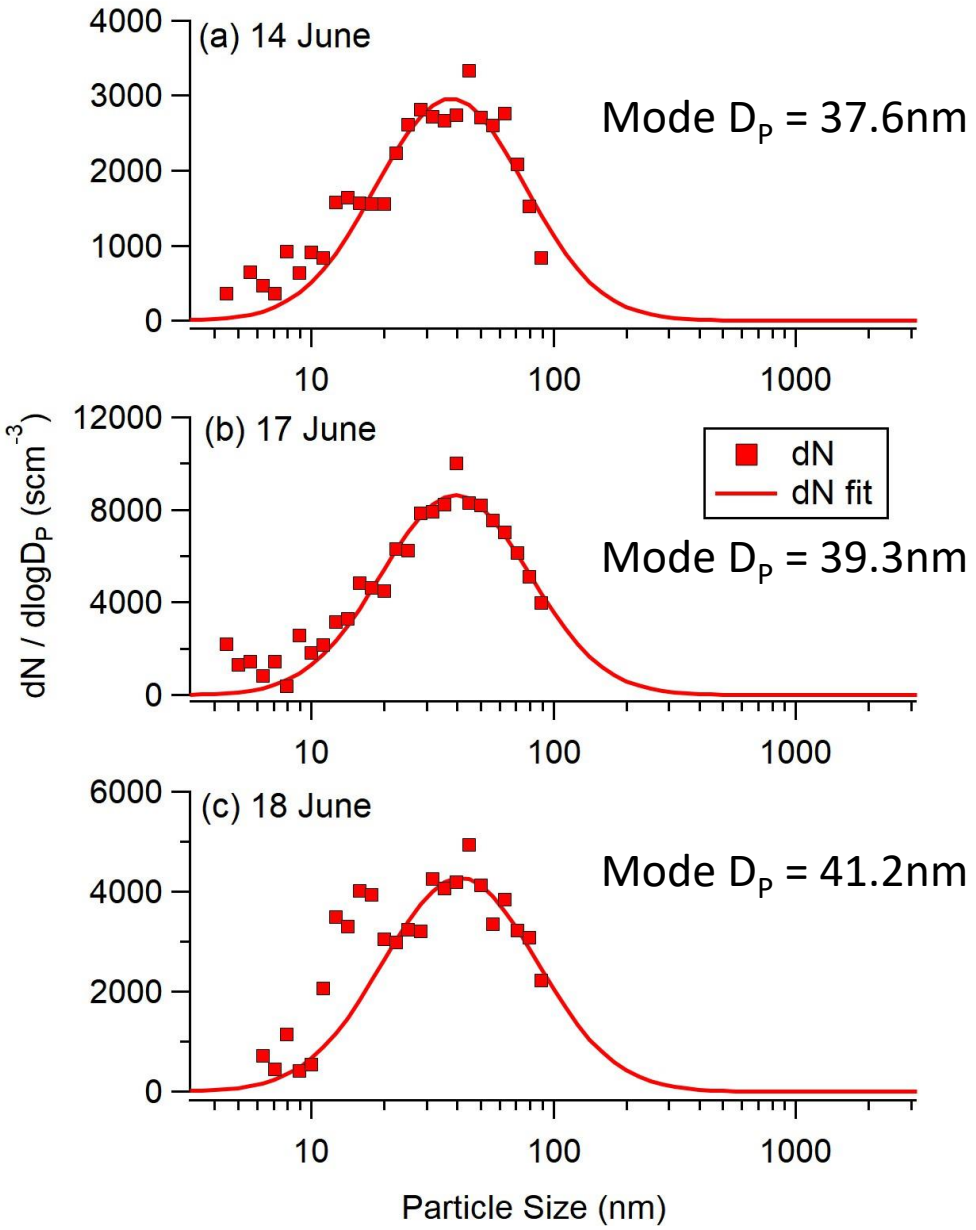
Average Value (standard deviation)



- $CN_{10nm-nv}$ is heated to 350°C → **BC**, dust, or sea-salt
- Size-dependent loss is applied to $CN_{10nm-nv}$
- High non-volatile fraction suggests that most particles contain a BC 'core'
  - CO is not particularly elevated

Mie Theory: Are Low SSA Values Possible?





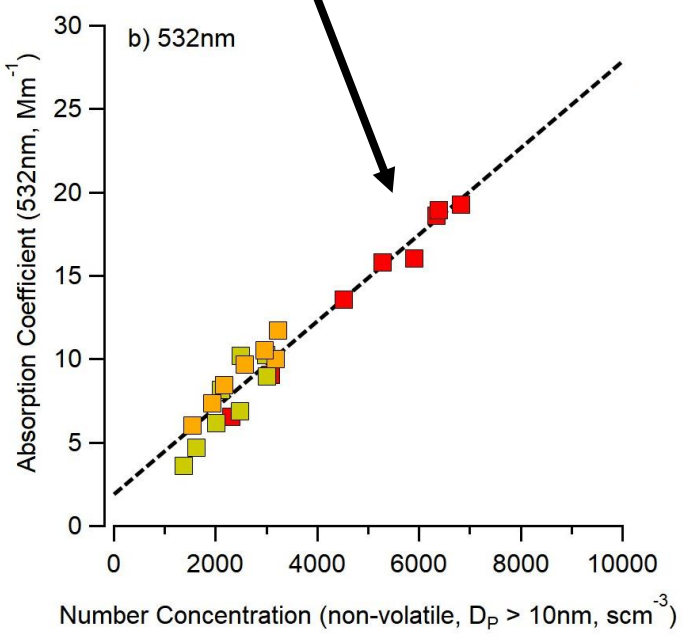
- Mie simulations from "MiePlot" for 4 cases with monodisperse particle sizes

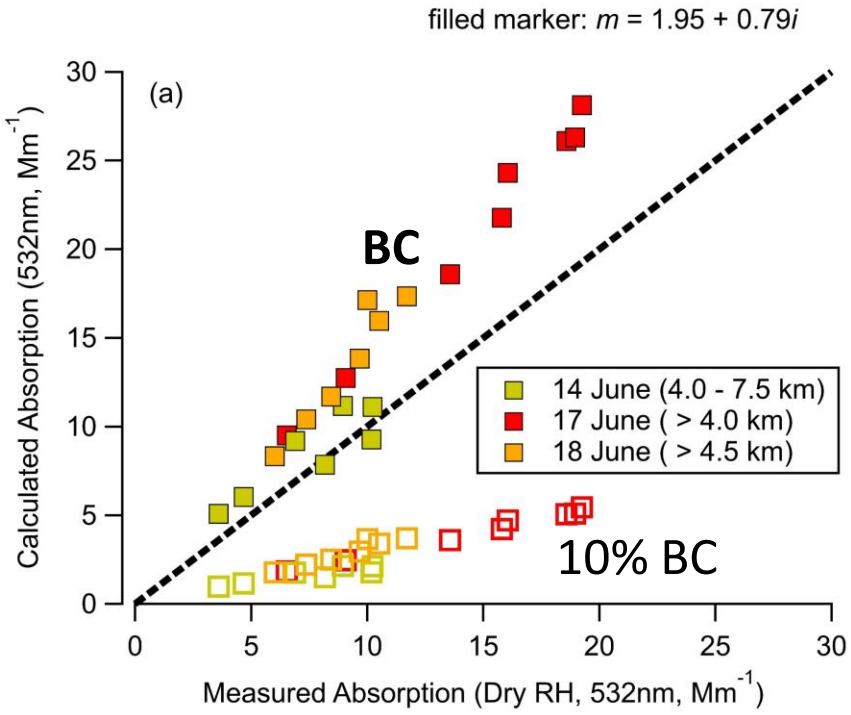
- Average SMPS size distributions are shown for each case → 40nm mode
  - **Small particle size qualitatively supports the observed low SSA values**

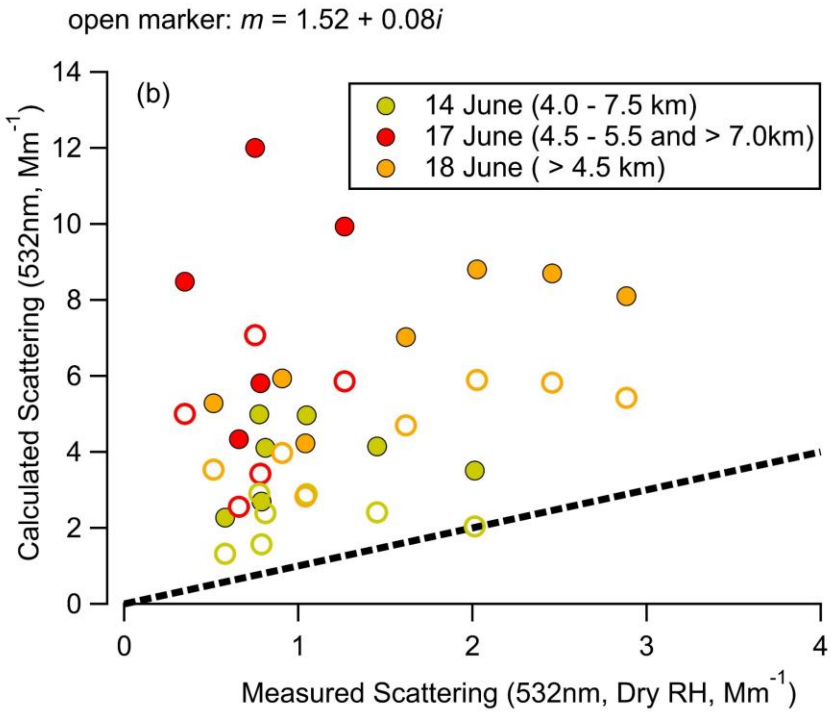
** Volume mixing based on Schuster et al. (2005)

Mie Theory Closure using Measured Size Distribution

- With good linear correlation, distributions were simply scaled using non-volatile number at each 0.5km altitude



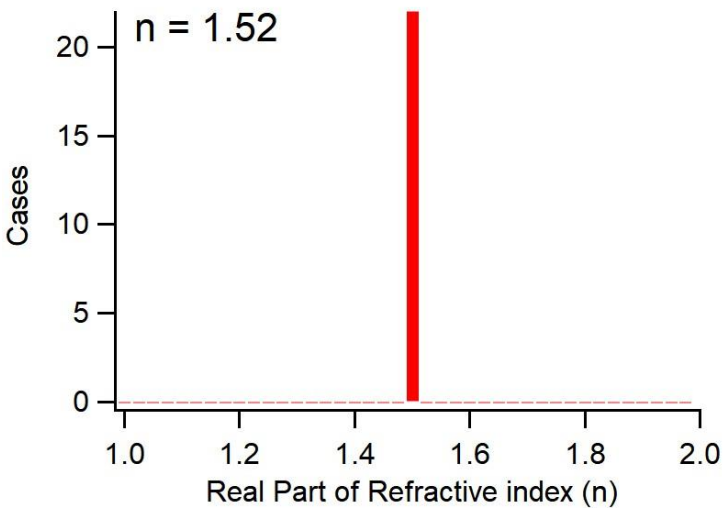


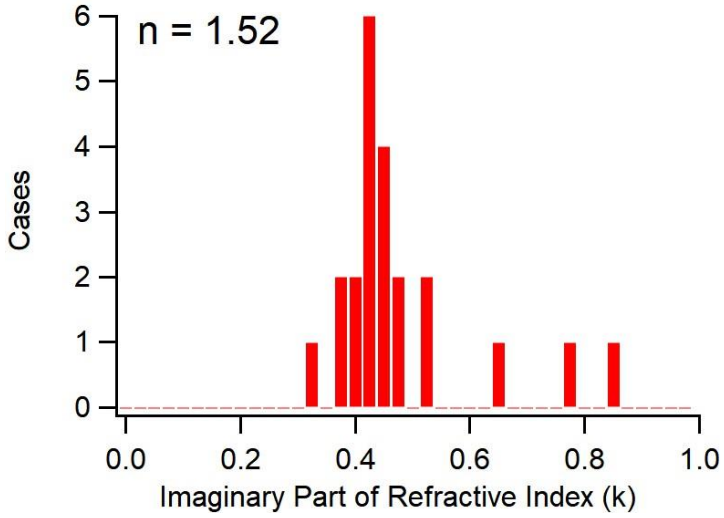


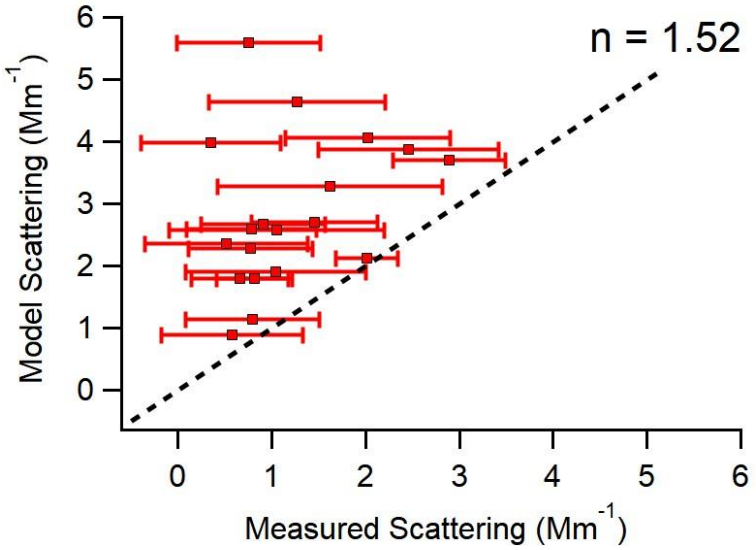
- Mie Theory to calculate absorption coefficient for BC and 10%-BC cases

- Reasonable agreement for absorption suggests slightly coated BC
- Measured scattering is too low and uncorrelated

Mie Theory Closure: PyMieScatt Results



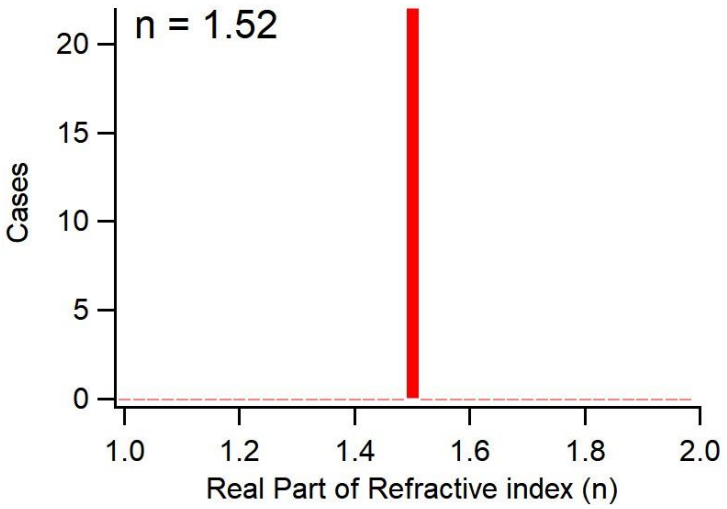


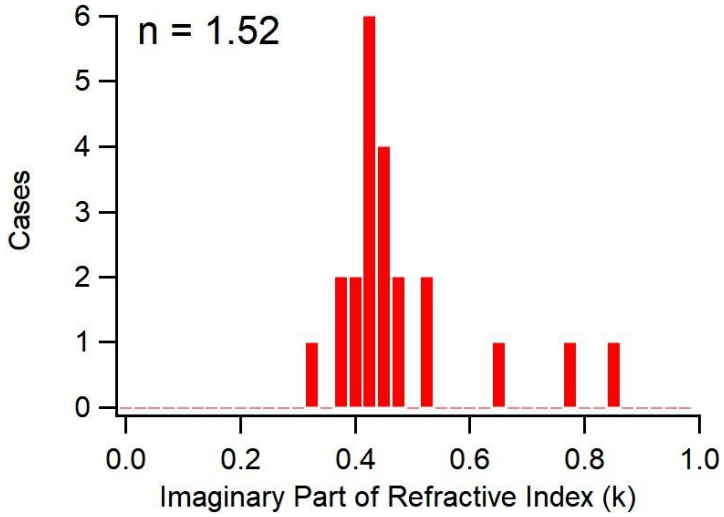


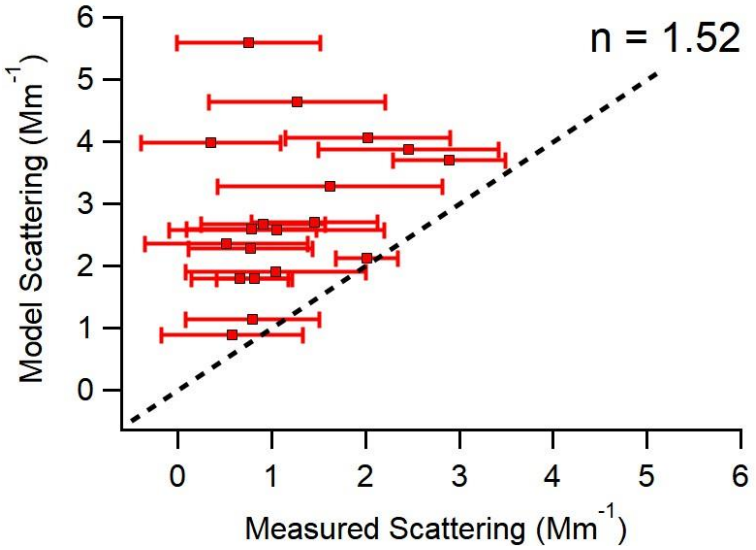
- PyMieScatt Mie Code using the same datapoints
- Reverse Mie calculations (ContourIntersection_SD):
  - SD_{meas} + Abs_{meas} + $Scat_{meas}$ → n + k

➢ Results consistent with MiePlot
➢ k ~ 0.33 - 0.54
➢ Scattering still overpredicted.

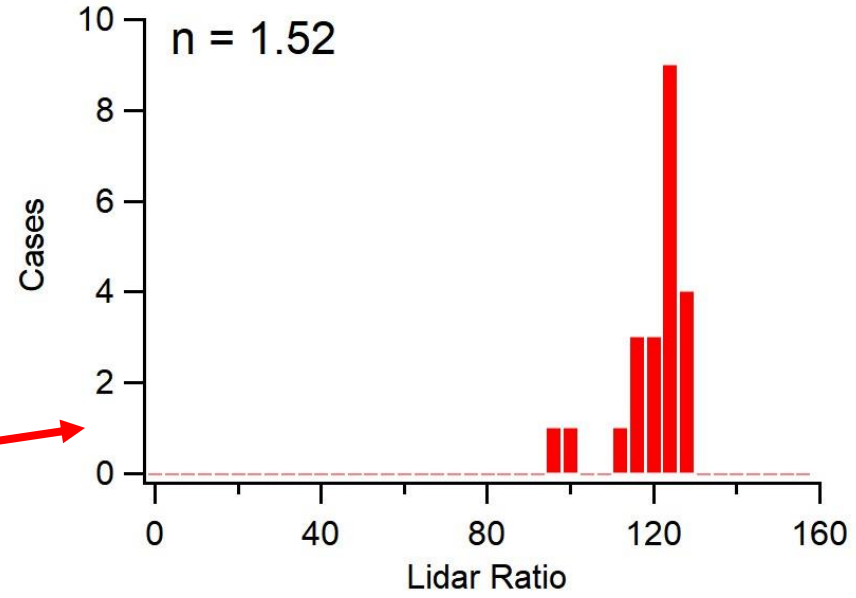
Mie Theory Closure: PyMieScat Results



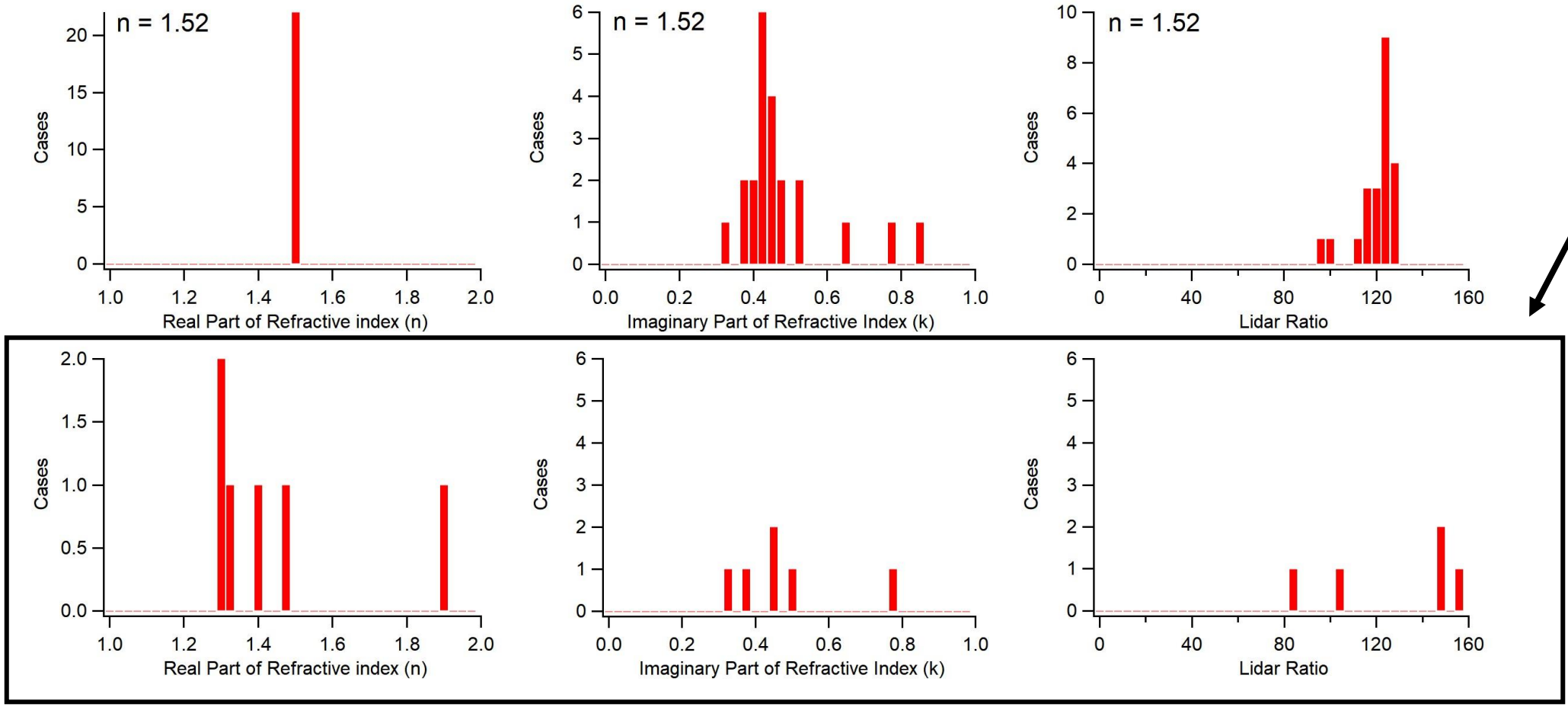




- Calculate Phase function (SF_SD):
  - SD_{meas} + $n_{1.52}$ + k_{calc} → phase function
- Normalize phase function
- Calculate backscatter:
  - $b_{180} = [p_{180} * Scat_{calc}] / 4\pi$
- Calculate Lidar Ratio:
  - $S = [Scat_{calc} + Abs_{meas}] / b_{180}$



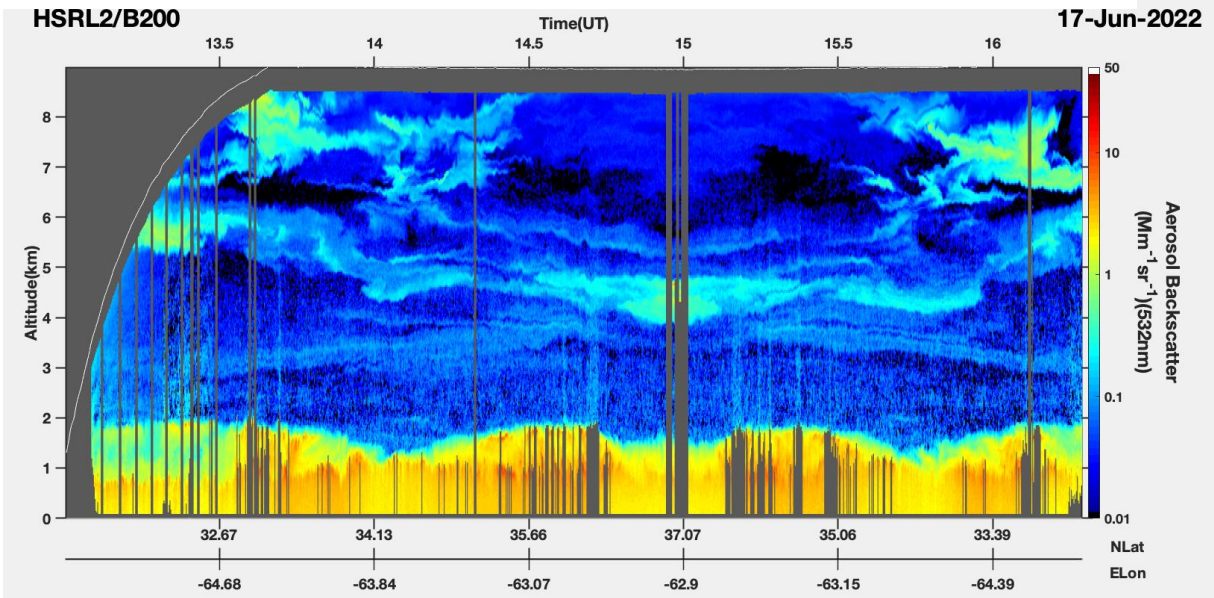
Mie Theory Closure: PyMieScat Results

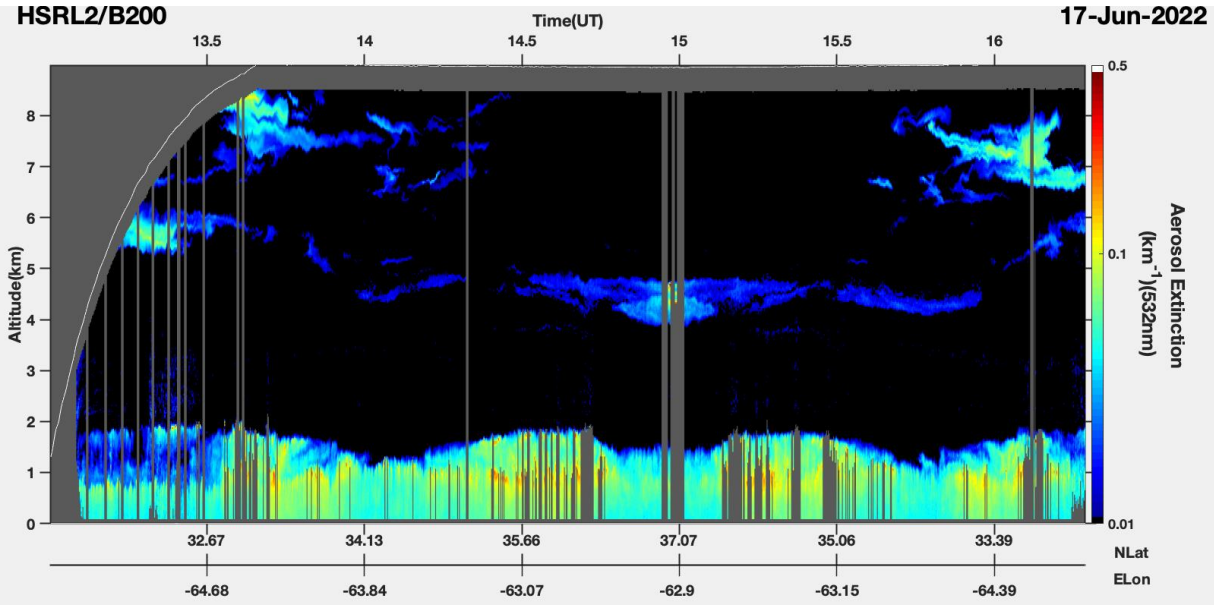


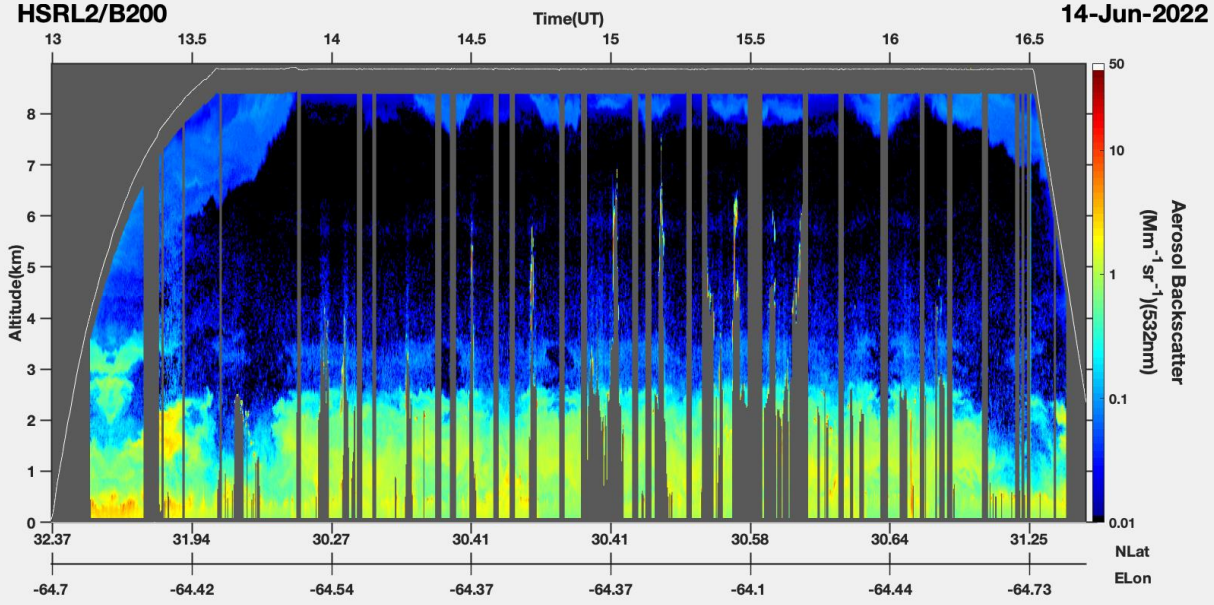
- Also ran reverse Mie calculations unconstrained
- 73% of cases did not converge on a valid solution

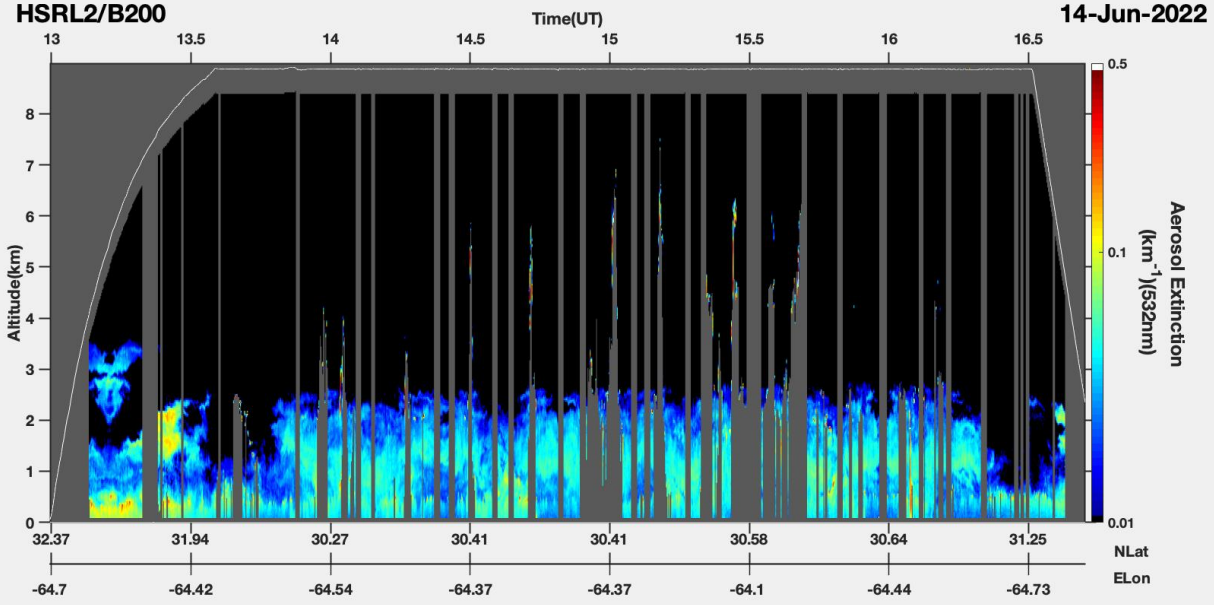
- k values similar to [n=1.52] case, suggesting insensitivity to real part (n)
- Retrieved n values are low: 1.31-1.48
- Lidar ratios still high

Absorbing Aerosol: Remote Sensing Perspective

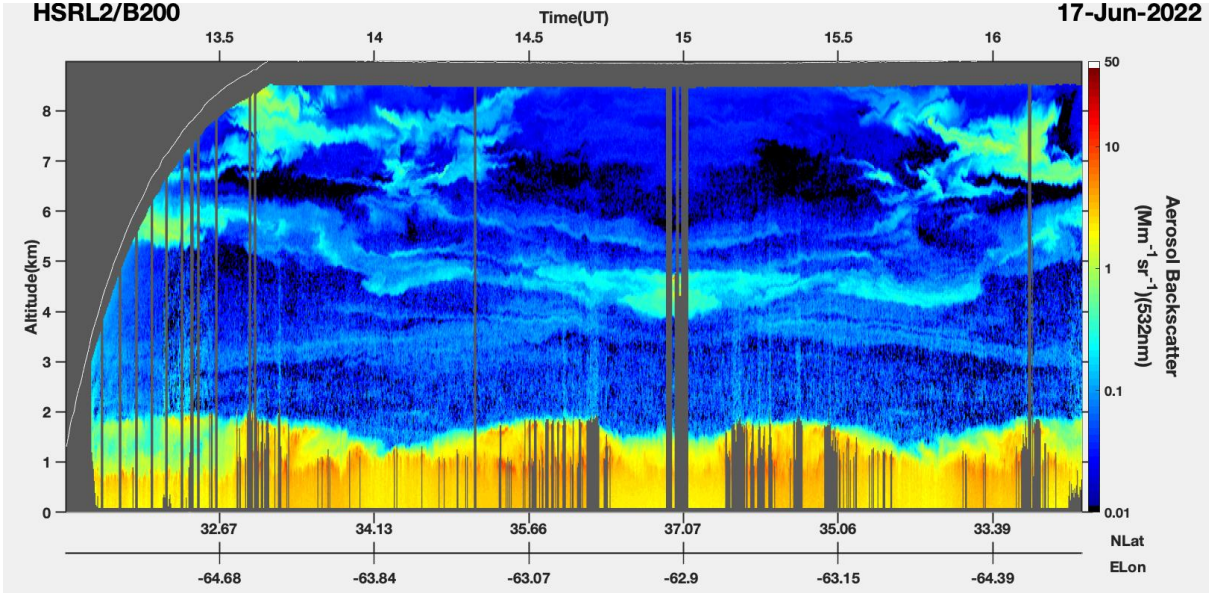


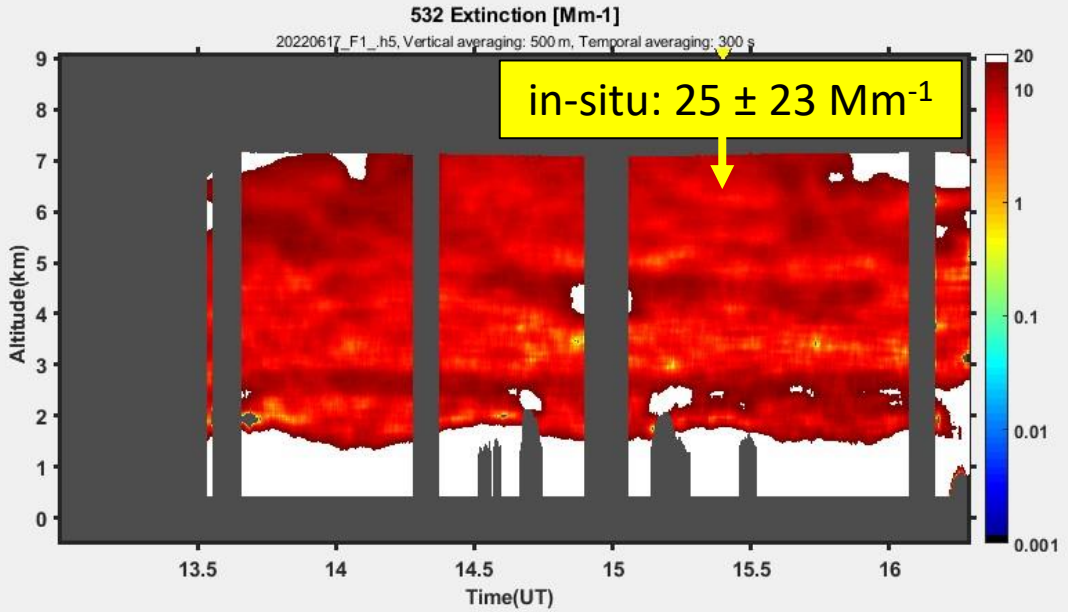


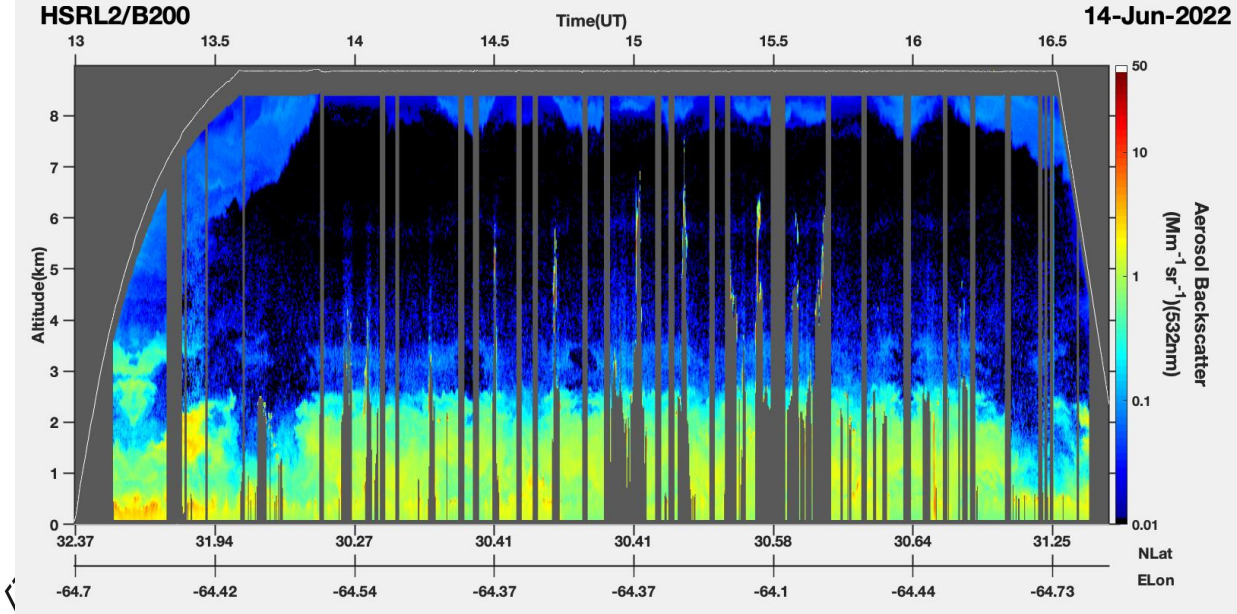


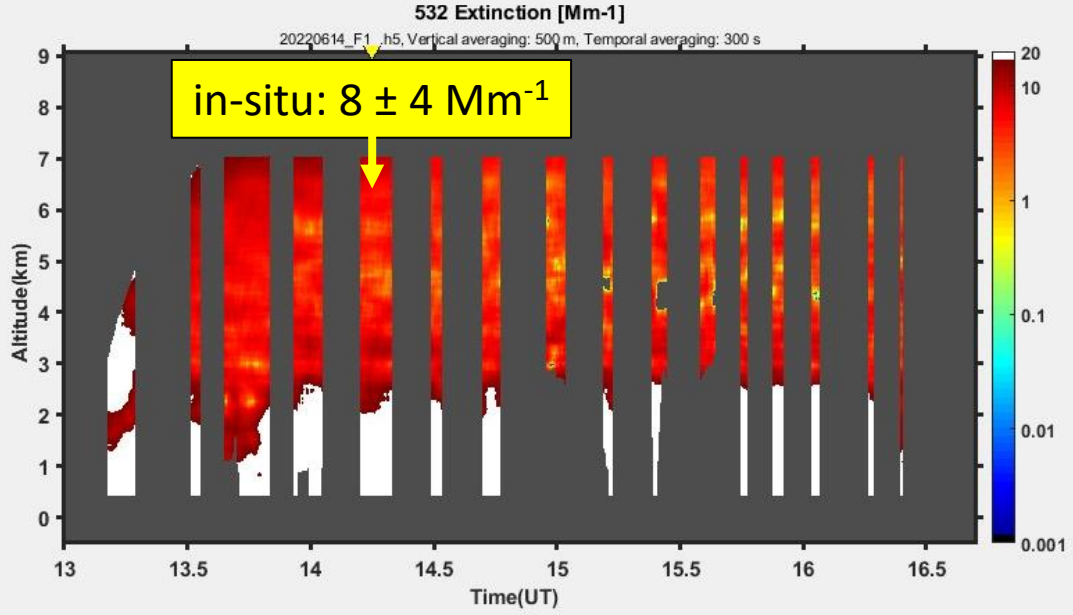


Absorbing Aerosol: Remote Sensing Perspective

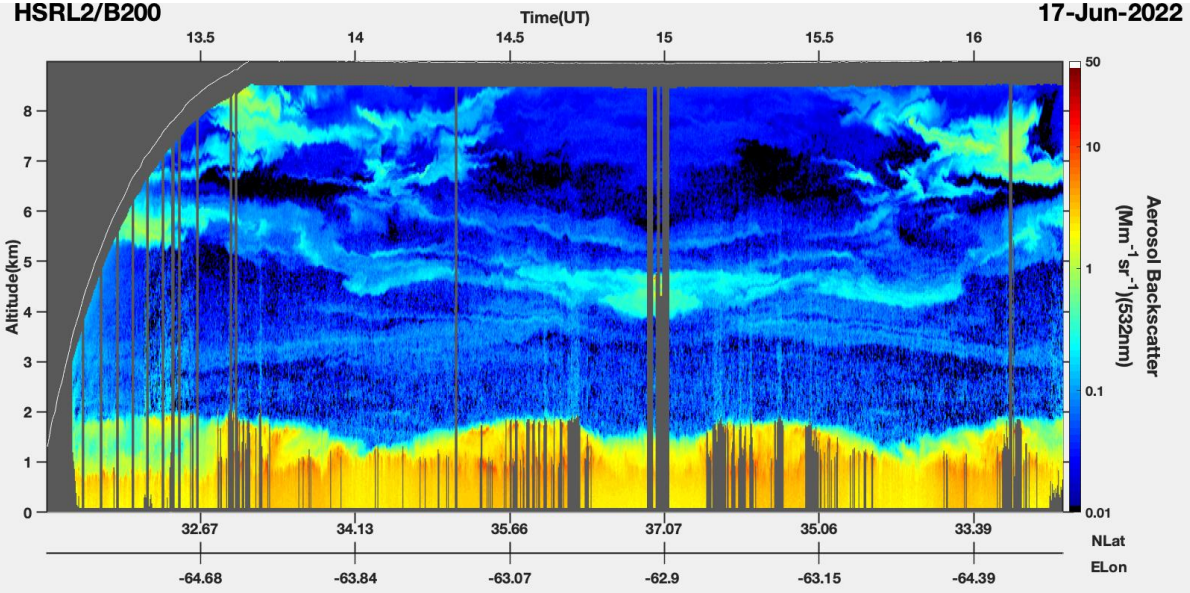


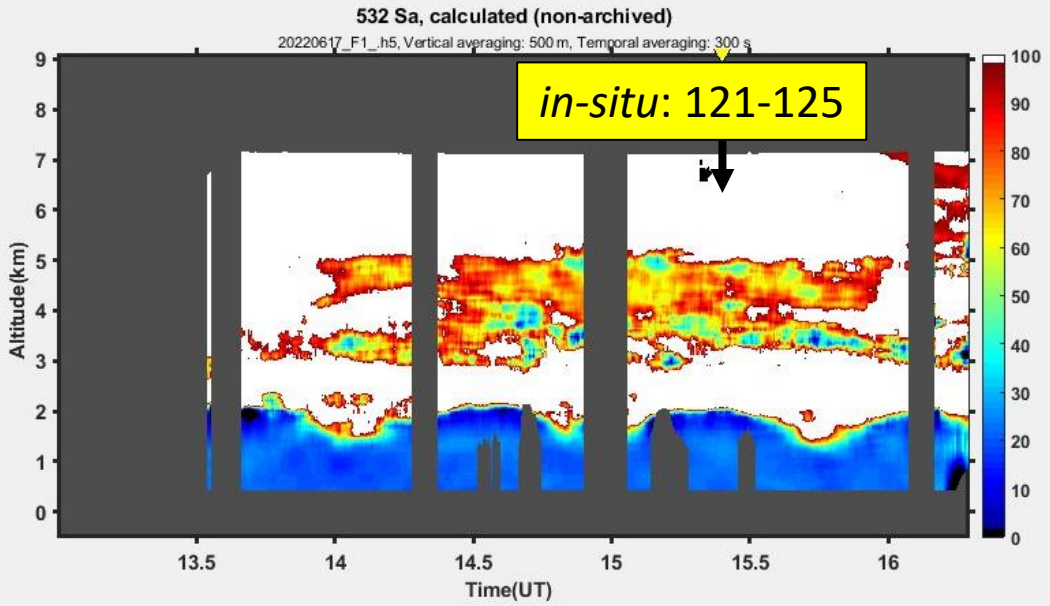


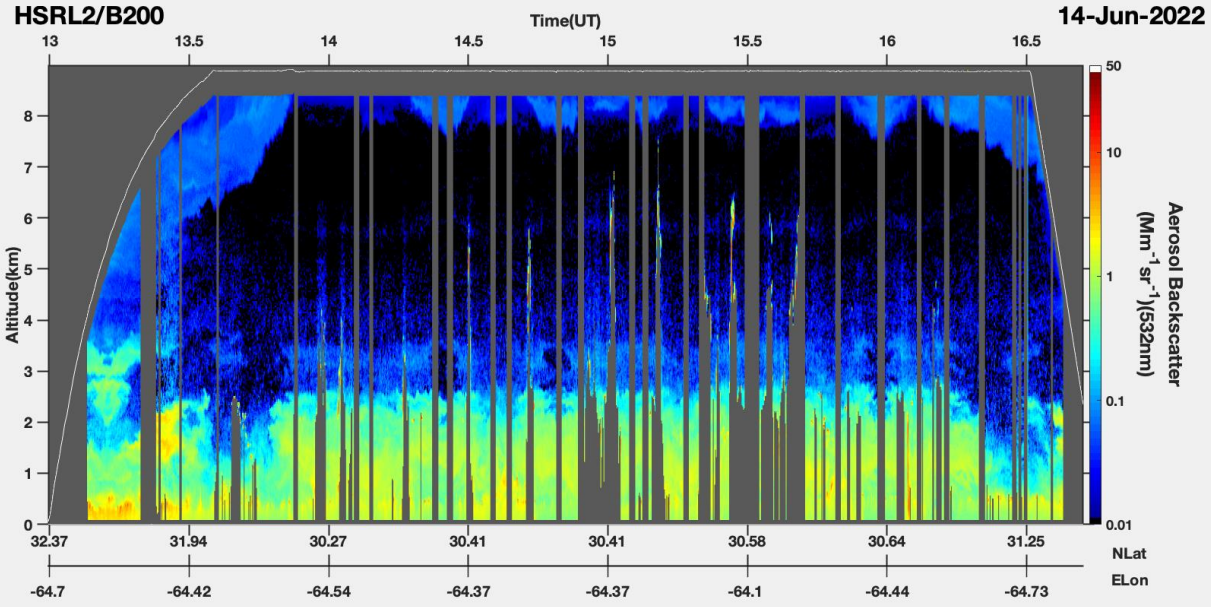


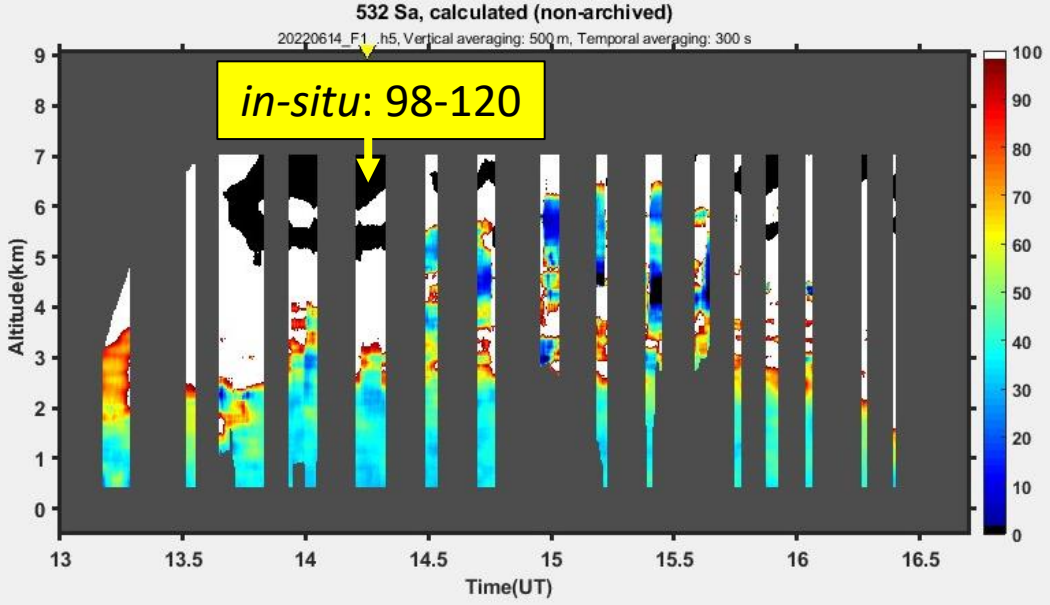


Absorbing Aerosol: Remote Sensing Perspective

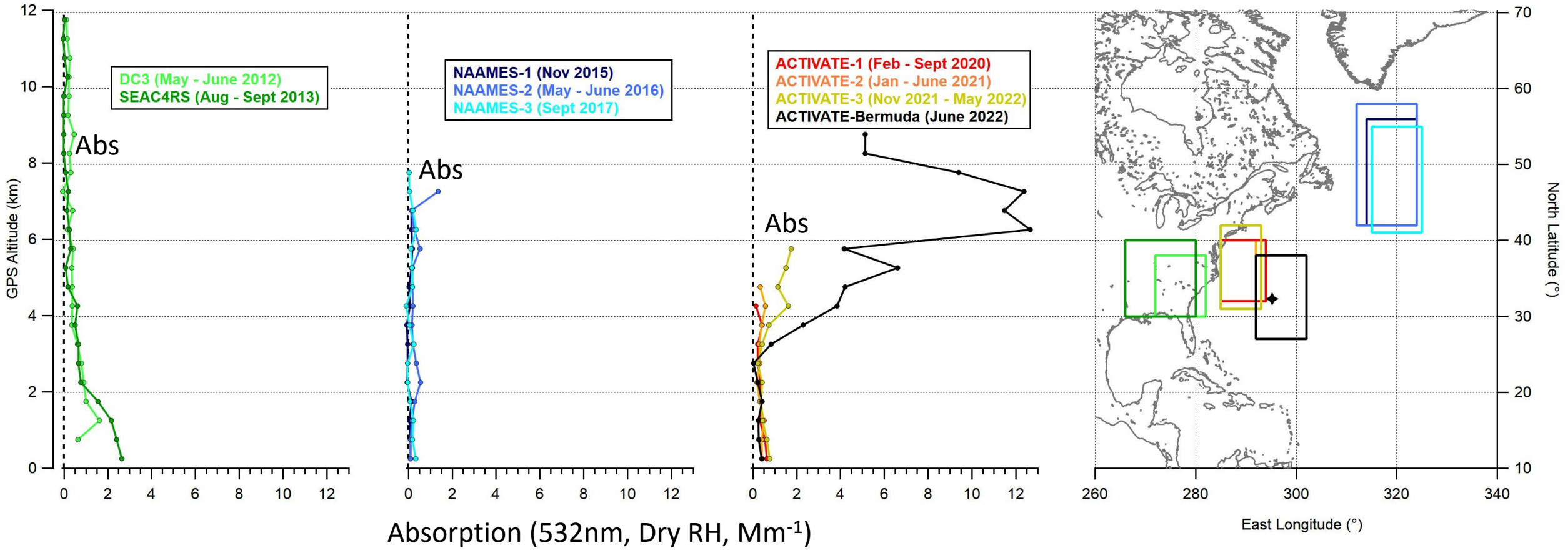




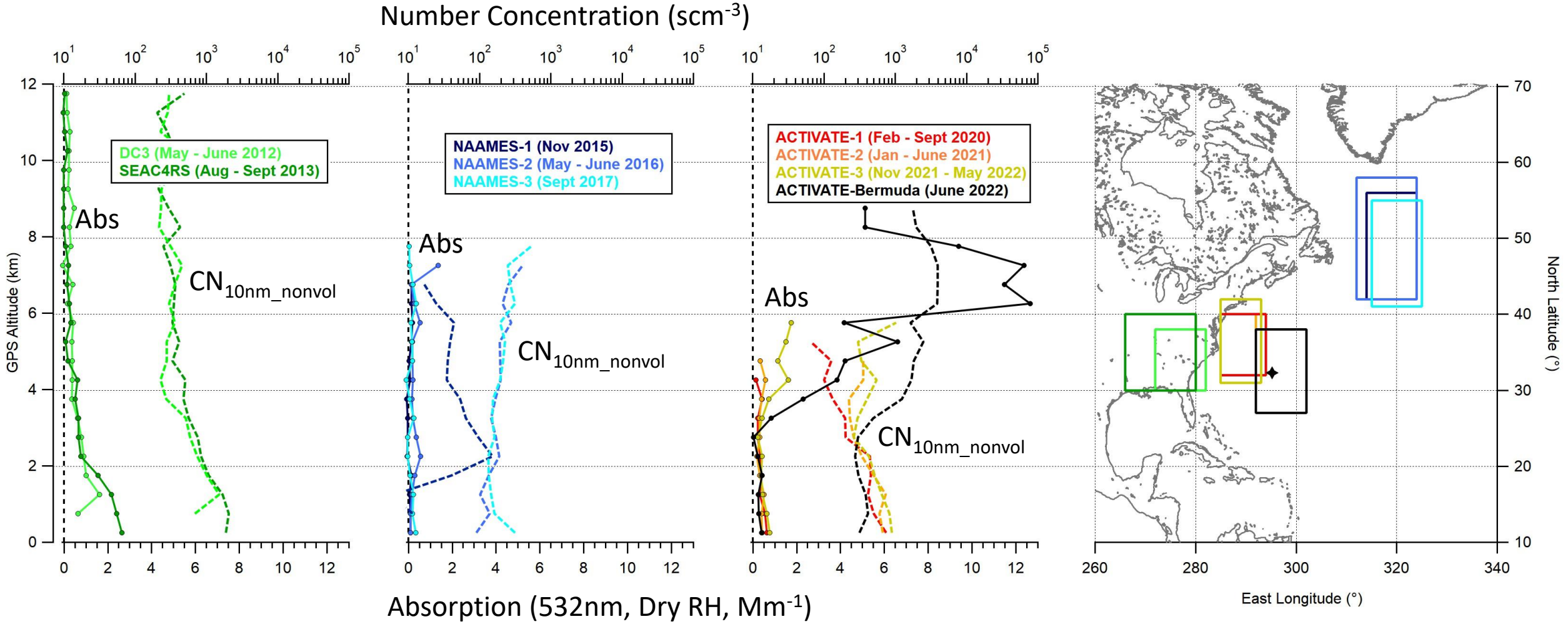




All Campaigns: Average Absorption (532nm)



All Campaigns: Absorption and $CN_{10nm\text{-}nonvol}$

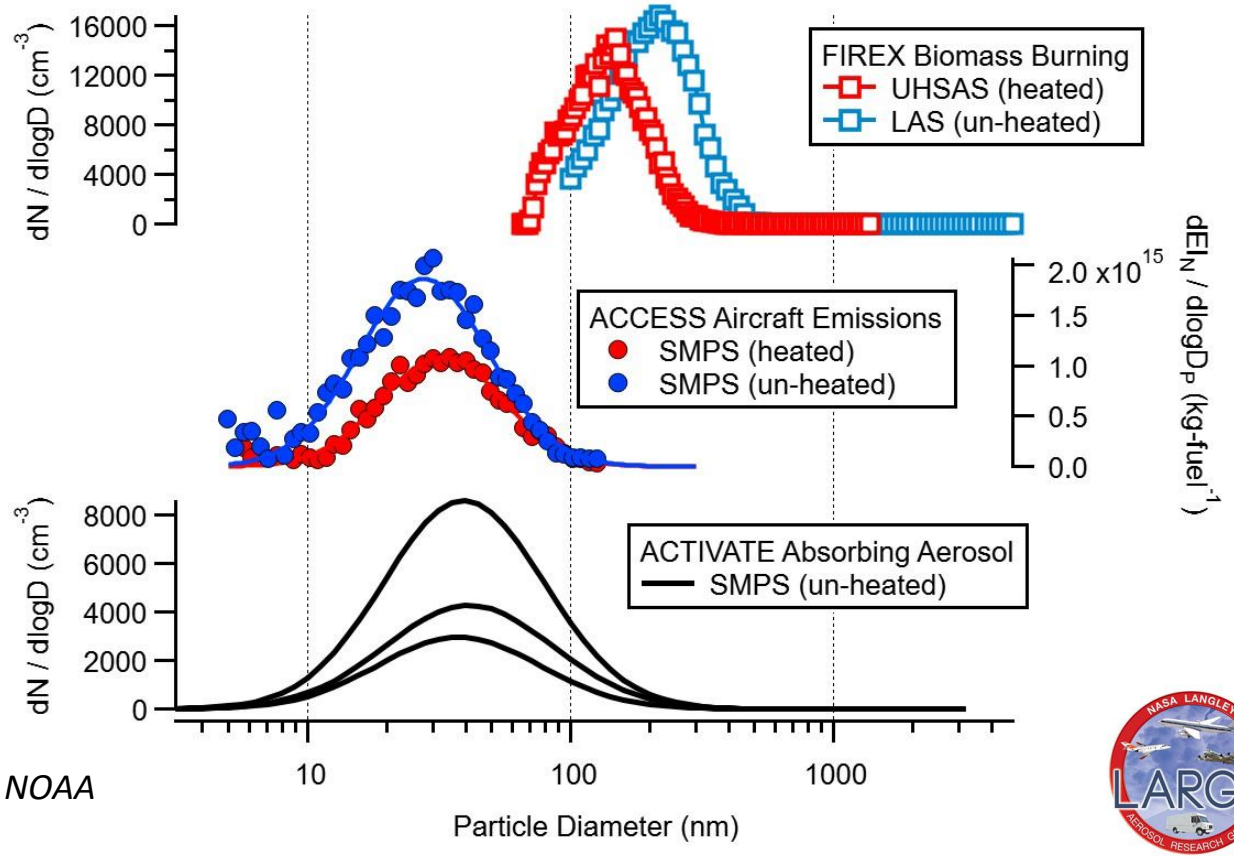


Absorbing Aerosol: Conclusions

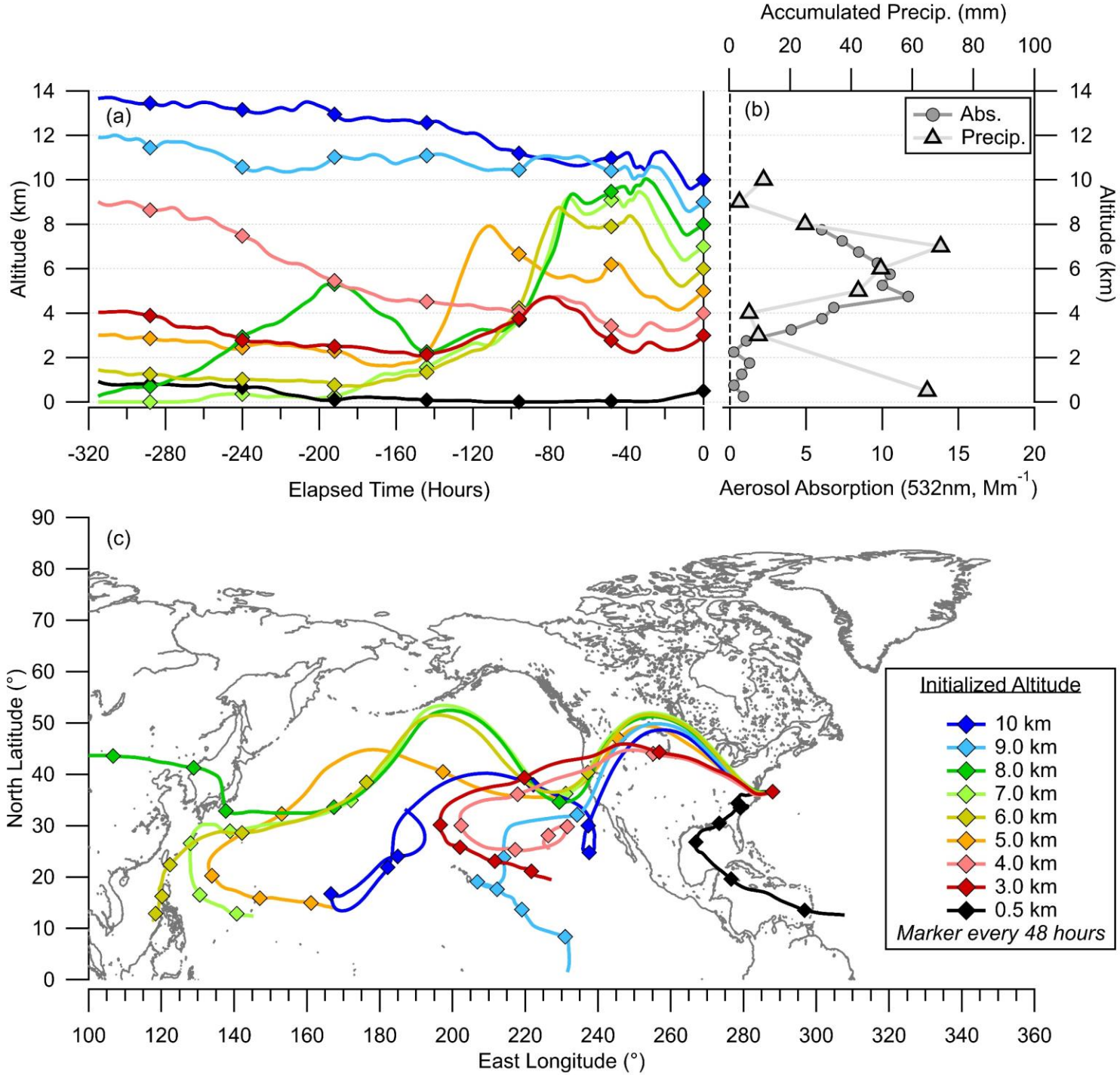
1. Mie Theory simulations were able to reproduce observations using small, mostly-BC particles
   ** Measurements are self-consistent
   - Why is scattering still too low?
   - Treatment of BC shape (Schlosser)
2. HSRL sees clean conditions for event days, more quantitative analysis is necessary (especially lidar ratio)
3. Absorption events are not obvious in past datasets
   - PSAP measurements may not be sensitive enough

How do we explain the amount and extent of this absorbing aerosol?

- Biomass burning smoke?
- Commercial Aircraft Emissions?



FIREX data: LAS = NASA, UHSAS = NOAA
ACCESS data: Moore et al. (2017)


Accumulated Precip. (mm)
0 20 40 60 80 100
(a)
(b)
Abs.
Precip.
Altitude (km)
0 2 4 6 8 10 12 14
-320 -280 -240 -200 -160 -120 -80 -40 0
Elapsed Time (Hours)
0 5 10 15 20
Aerosol Absorption (532nm, Mm-1)
(c)
North Latitude (°)
0 10 20 30 40 50 60 70 80 90
100 120 140 160 180 200 220 240 260 280 300 320 340 360
East Longitude (°)
Initialized Altitude
10 km
9.0 km
8.0 km
7.0 km
6.0 km
5.0 km
4.0 km
3.0 km
0.5 km
Marker every 48 hours