# Airborne High Spectral Resolution Lidar Measurements of Aerosol Distributions and Properties during the NASA CAMP2Ex Mission

NASA LaRC HSRL-2 Team - Rich Ferrare, Chris Hostetler, Sharon Burton, Marta Fenn, Dave Harper, Tony Cook, Amy Jo Scarino, Marian Clayton, John Hair, Joe Lee
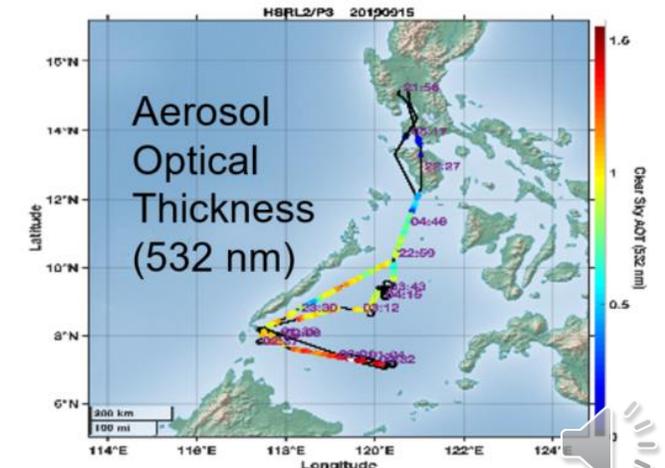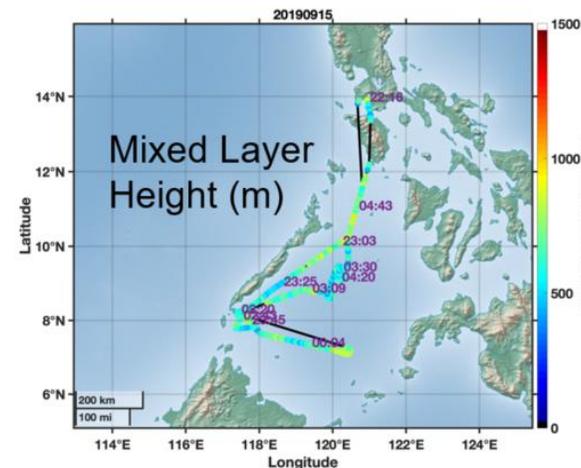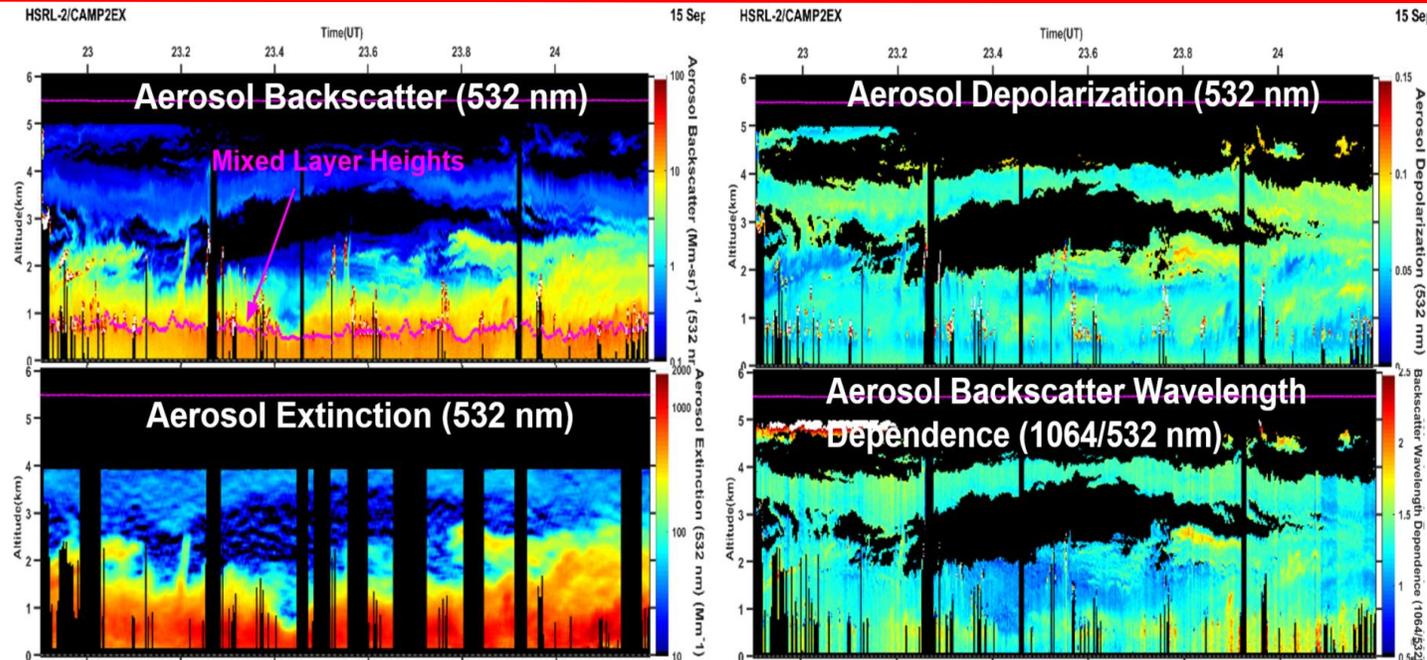
Sue van den Heever (CSU); Arlindo da Silva (GSFC); Ed Eloranta, Bob Holz (UW)

- CAMP2Ex focuses on three NASA focus areas
    1. Aerosol and cloud microphysics – how aerosol particle concentration and composition effect the optical and microphysical properties of clouds and how these effects relate to the transition from shallower to deeper convection
    2. Cloud and aerosol radiation - how spatially inhomogeneous and changing aerosol and cloud fields impact three dimensional heating rates and fluxes and how 3D effects may impact aerosol, cloud, and precipitation fields
    3. Aerosol and cloud meteorology - Determine the meteorological features that are the most influential in regulating the distribution of aerosol particles the extent to which aerosol-cloud interactions studies are impacted by co-varying meteorology.

- Experiment also conducted jointly with R/V Thompson as part of **PISTON –** Propagation of Intraseasonal Tropical Oscillations mission

- CAMP2Ex employed two aircraft
    - NASA P-3B aircraft
    - SPEC Learjet

- NASA LaRC HSRL-2 deployed on P-3B aircraft for nadir viewing measurements
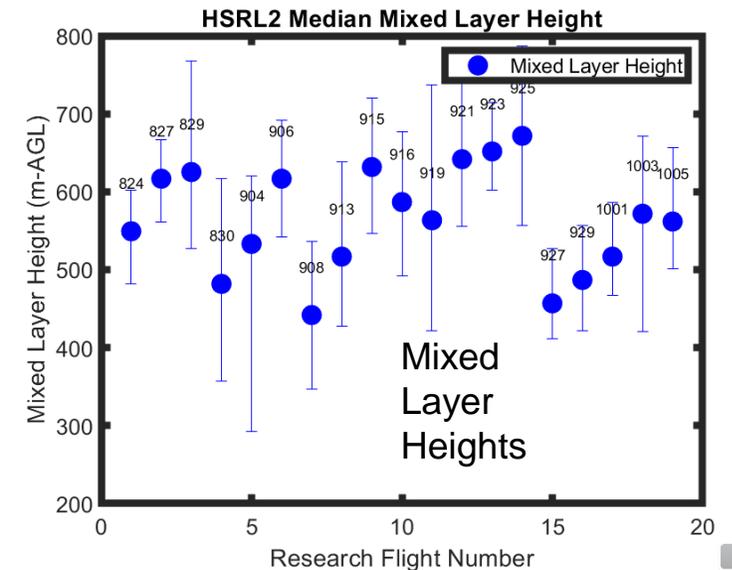
- P-3B, based at Clark Air Base, conducted 19 science flights between Aug. 24 and Oct. 5, 2019
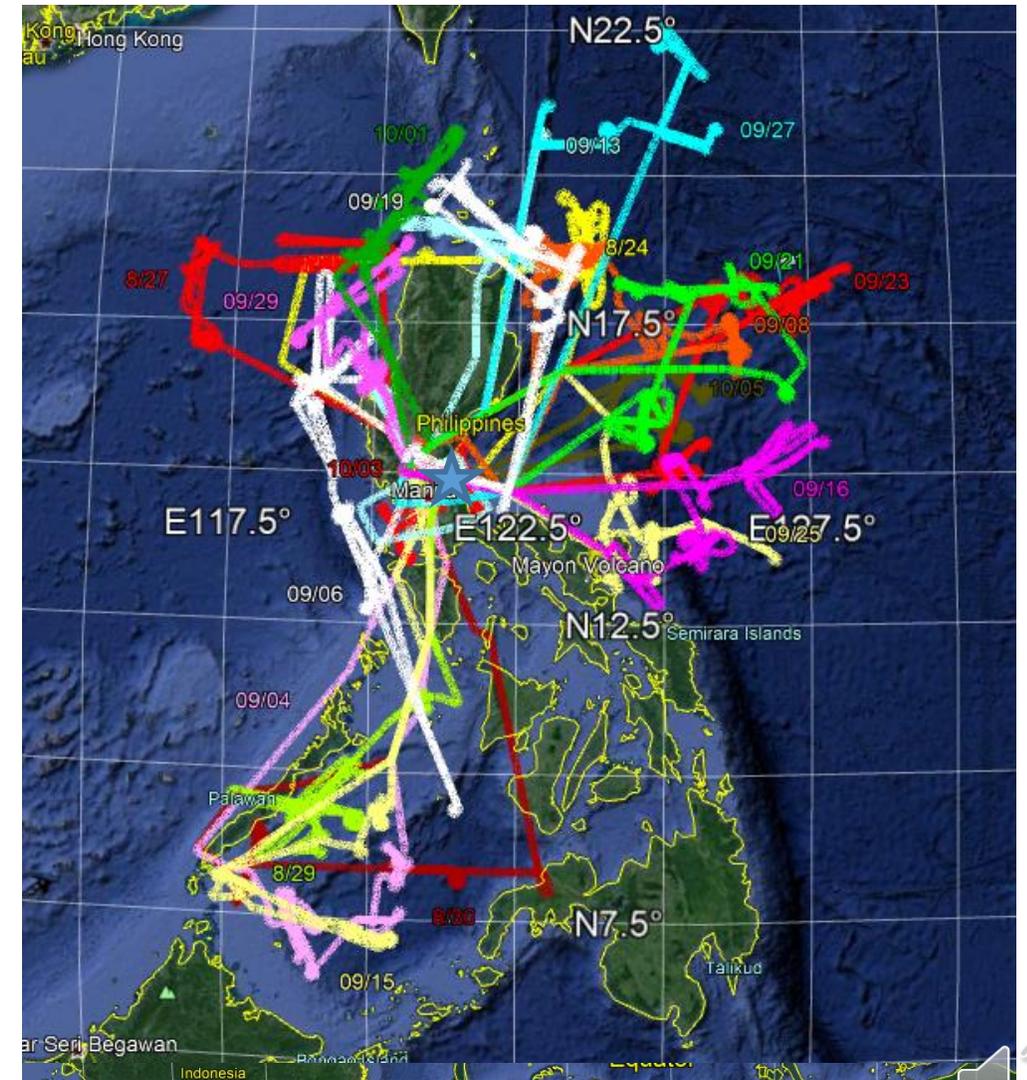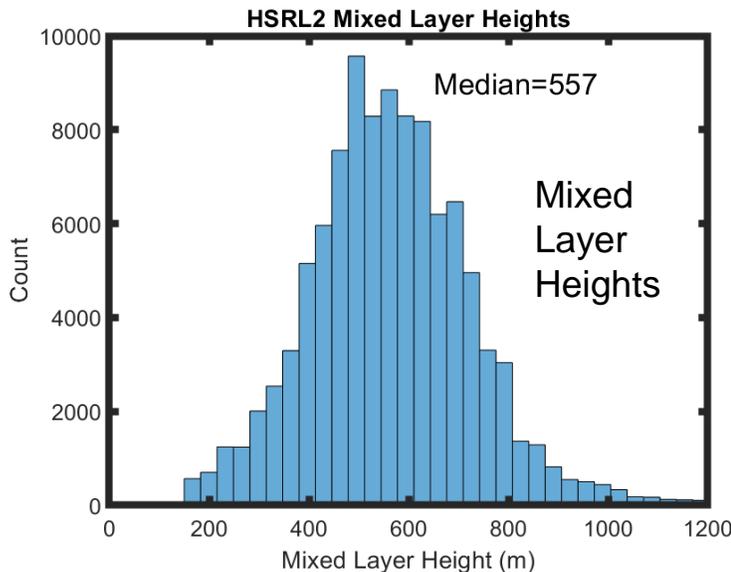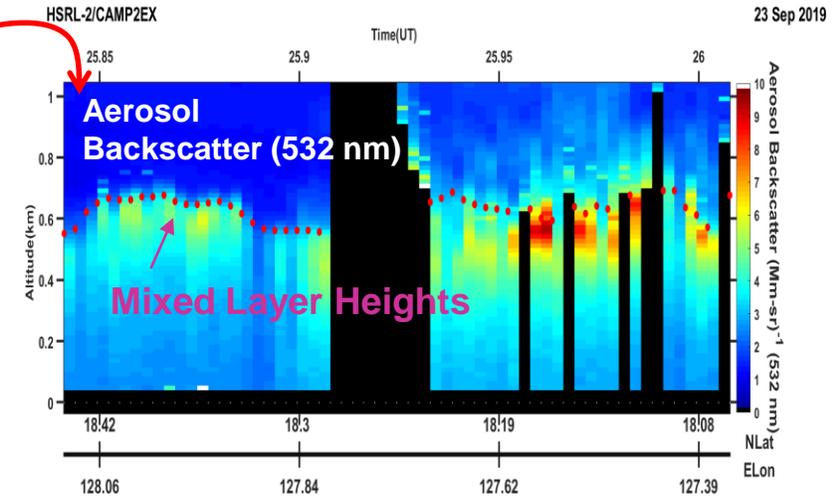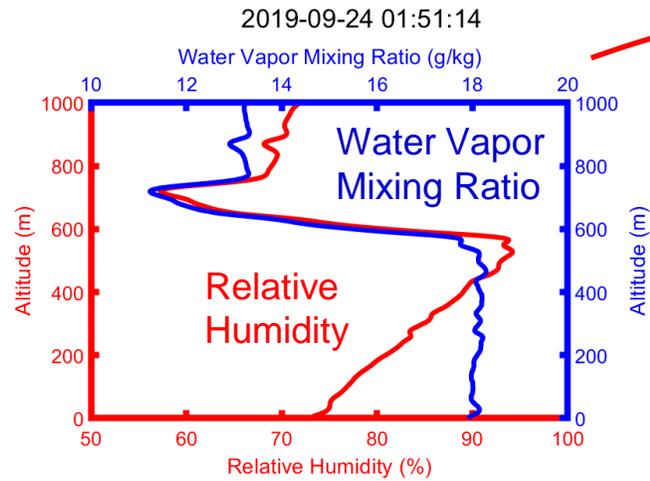
Available Data Products

- Aerosol Extensive Measurements (data(hdf5) and imagery(png) archived)
  - Particulate backscatter profiles (355, 532, 1064 nm)
  - Aerosol extinction profiles and AOT (355 and 532 nm)
- Aerosol Intensive measurements (data(hdf5) and imagery(png) archived)
  - Particle depolarization profiles (355, 532, 1064 nm)
  - Extinction-to-backscatter ratio profiles (355 and 532 nm)
  - Angstrom exponent profiles
    - Extinction: 355-532
    - Backscatter 355-532, 532-1064
- Aerosol Type (data(hdf5) and imagery(png) archived)
- Aerosol Optical Thickness (data(ICARTT) archived)
- Mixed Layer Heights (data(ICARTT) archived)
- Mean aerosol extinction and backscatter values within and above the Mixed Layer (data(ICARTT) archived)

HSRL-2 data from CAMP2Ex data at
https://www-air.larc.nasa.gov/cgi-bin/ArcView/camp2ex#HOSTETLER.CHRIS/

Mixed Layer Heights derived from HSRL2

- Mixed Layer (ML) heights derived from cloud-screened aerosol backscatter profiles

- ML heights can be a good proxy for daytime PBL heights

- Technique uses a Haar wavelet covariance transform with multiple wavelet dilations to identify sharp gradients in aerosol backscatter (adapted from Brooks, JAOT, 2003)

- Automated HSRL algorithm chooses ML from among aerosol gradients with input from manual inspection where necessary (Scarino et al., 2014, ACP)

- During CAMP2Ex, median MLH = 557 m

Dropsonde data from Sue van den Heever (CSU)

2019-09-24 01:51:14

Water Vapor Mixing Ratio

Relative Humidity

HSRL-2/CAMP2EX   23 Sep 2019

Aerosol Backscatter (532 nm)

Mixed Layer Heights

HSRL2 Mixed Layer Heights

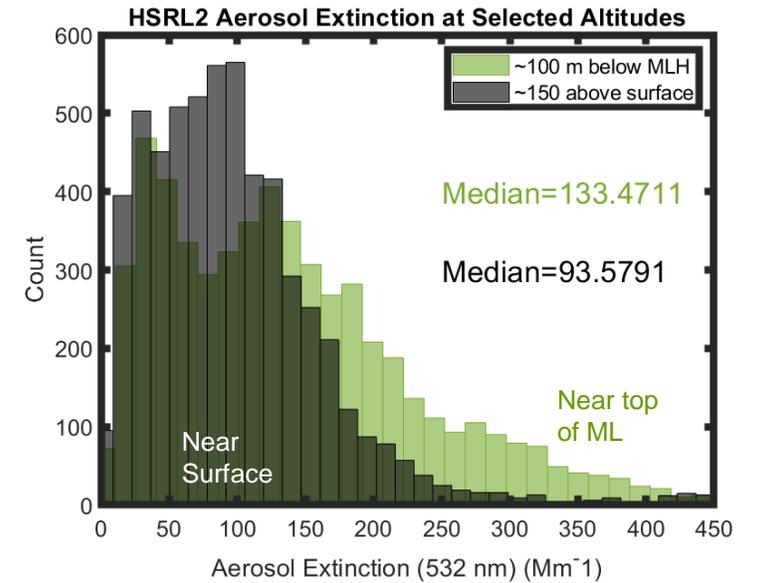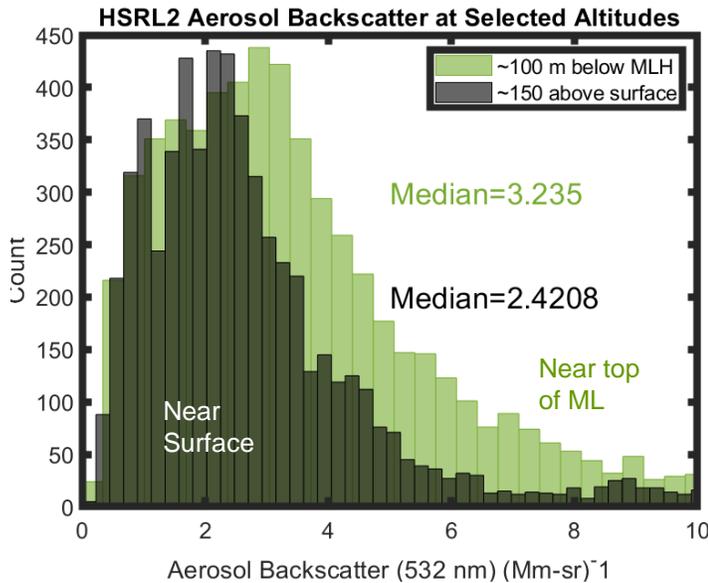Median=557

Mixed Layer Heights



HSRL2 Median Mixed Layer Height

Mixed Layer Heights

Vertical Variability of Aerosol Properties within the Mixed Layer Associated with Relative Humidity (RH)
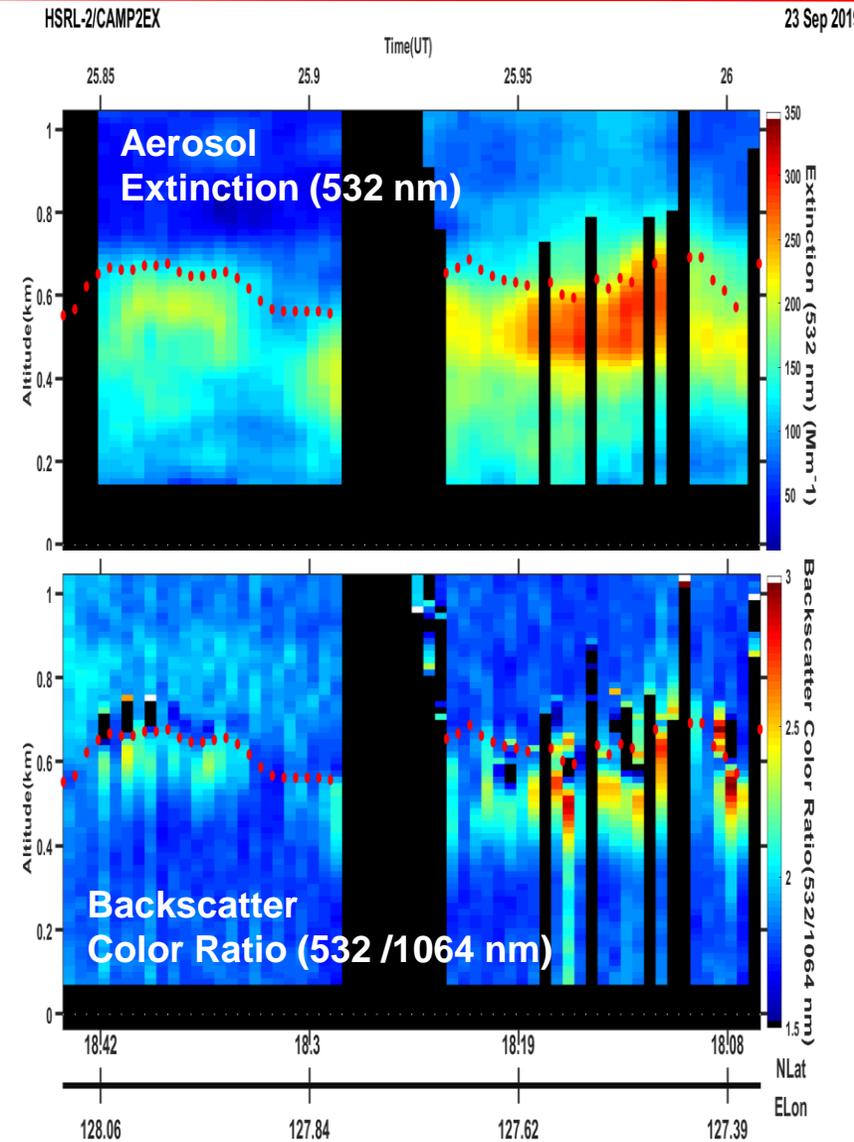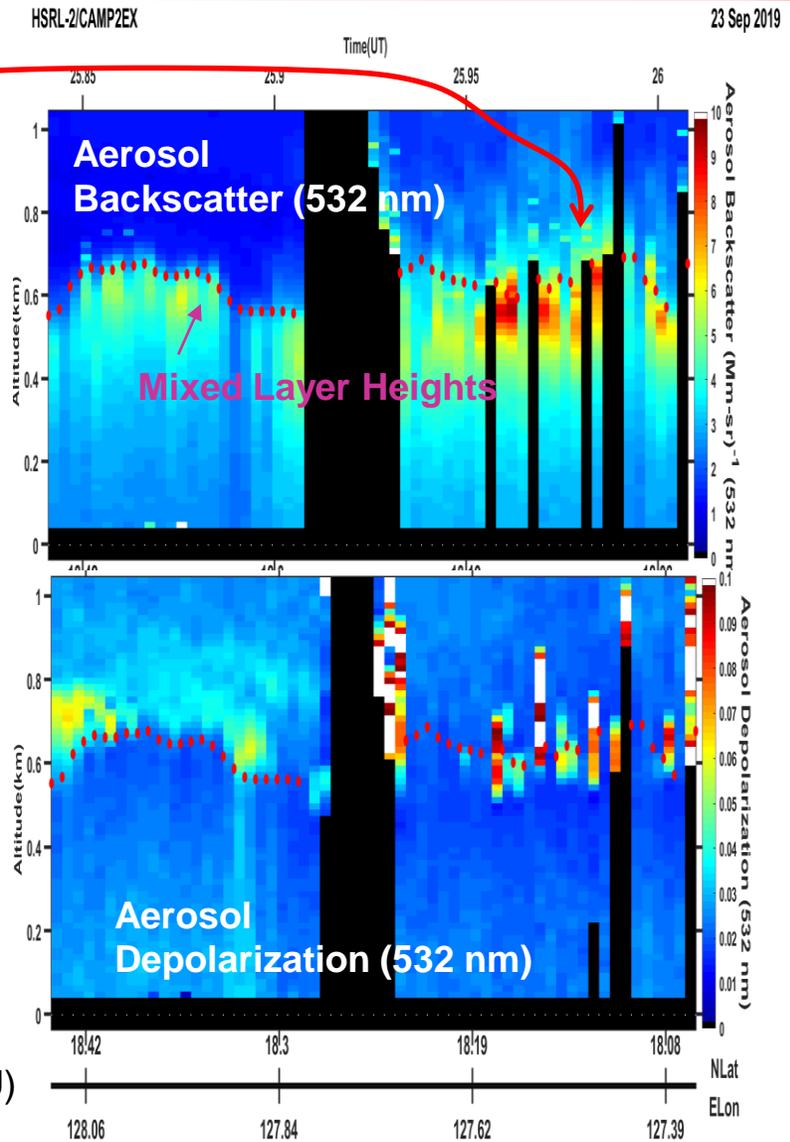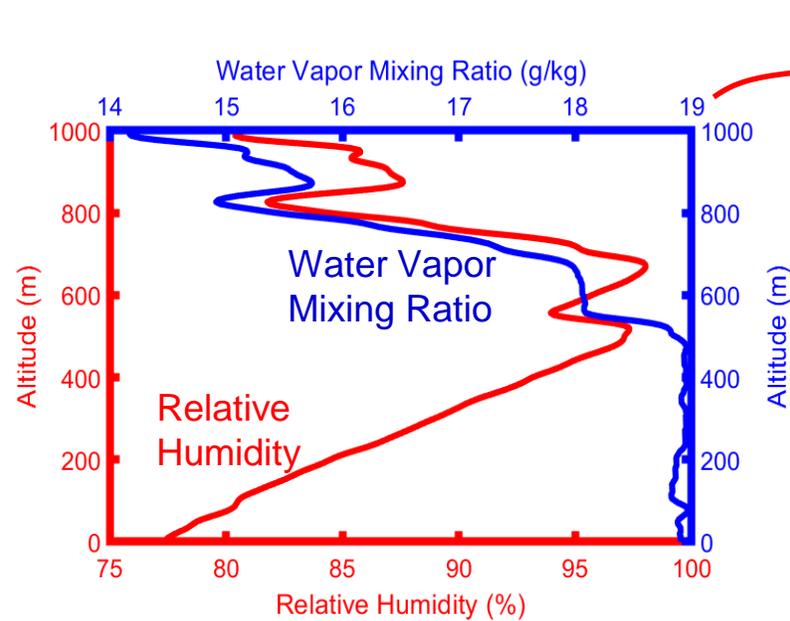
As RH increases near top of Mixed Layer, fine mode hygroscopic particles take on water

- Aerosol backscatter and extinction increase
- Particles become more spherical so particulate depolarization decreases
- Increase in fine mode particle scattering so backscatter color ratio increases
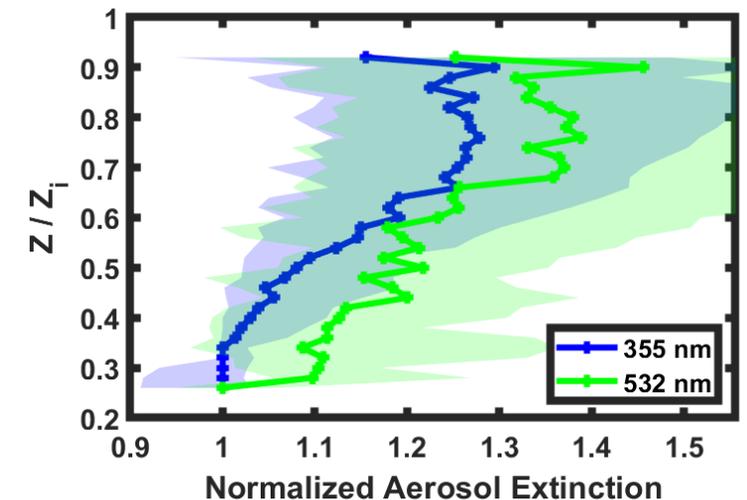
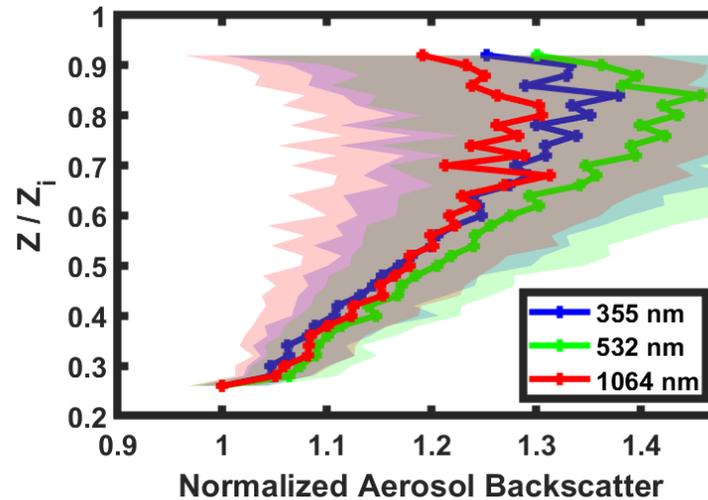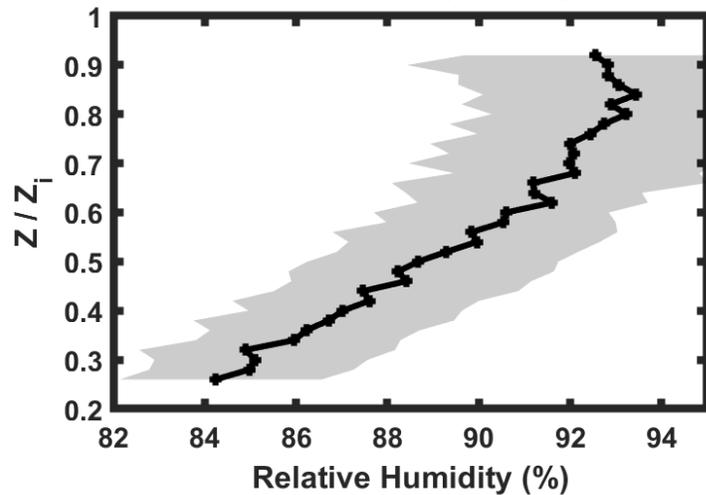Dropsonde data from Sue van den Heever (CSU)
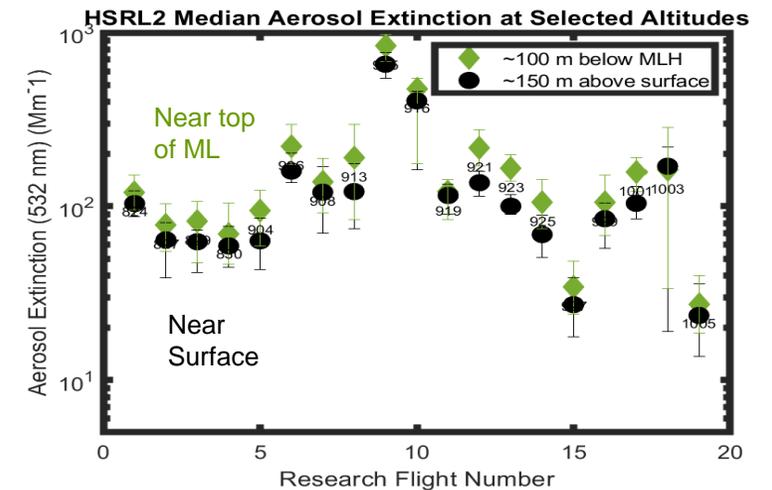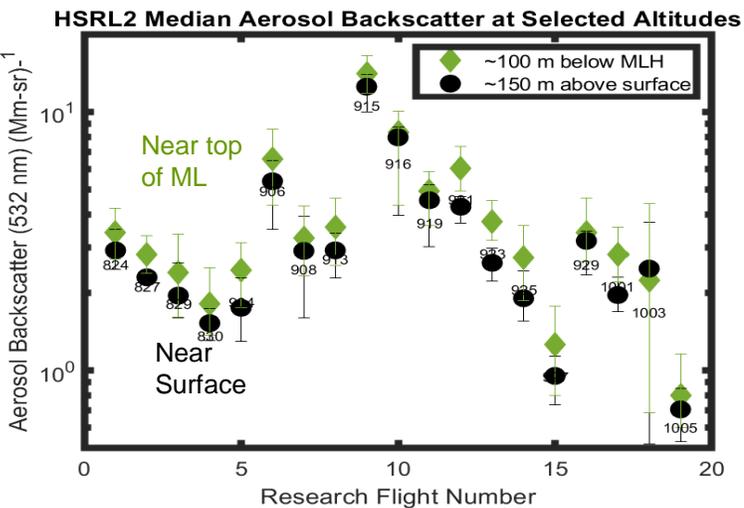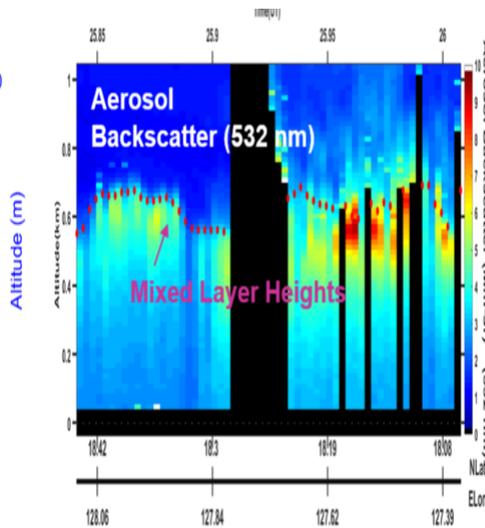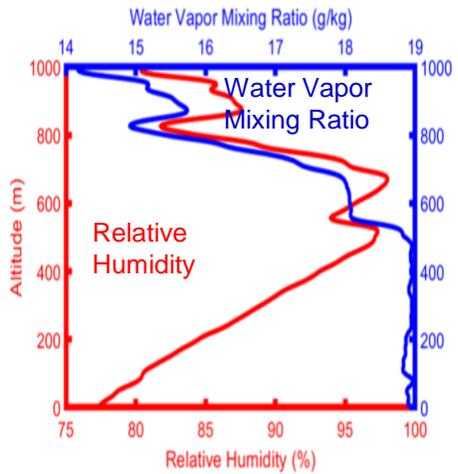
Aerosol backscatter and extinction are systematically larger during all of CAMP2Ex near the top of the Mixed Layer due to the increase in fine mode scattering and fine mode particle size associated with increased RH
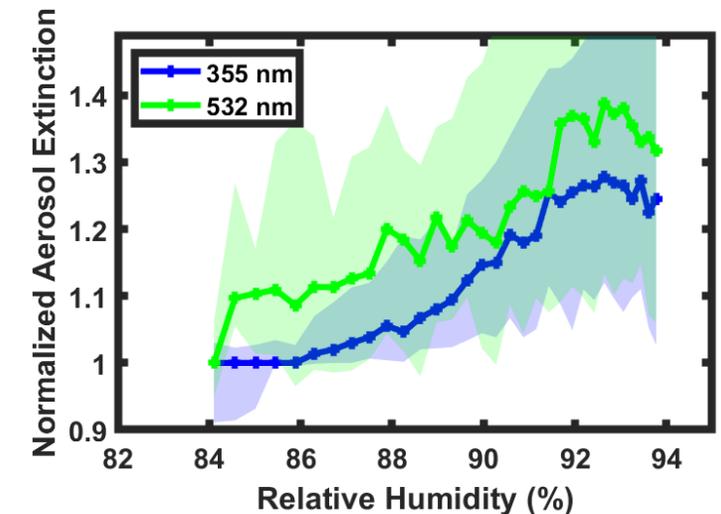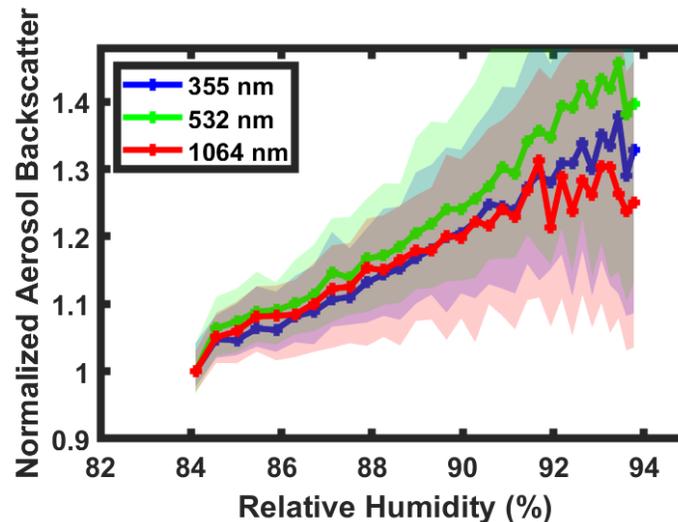
Z_i = mixed layer height

Analysis using entire CAMP2EX dataset reveals systematic increases in both backscatter and extinction with altitude within mixed layer

- RH from coincident dropsondes

- Cases selected such that water vapor mixing ratio is nearly constant in mixed layer so that vertical variability in aerosol properties is mostly likely due to RH

- Backscatter and extinction normalized to unity near surface

Median Variability of Aerosol Intensive Parameters Within the Mixed Layer

Z_i = mixed layer height
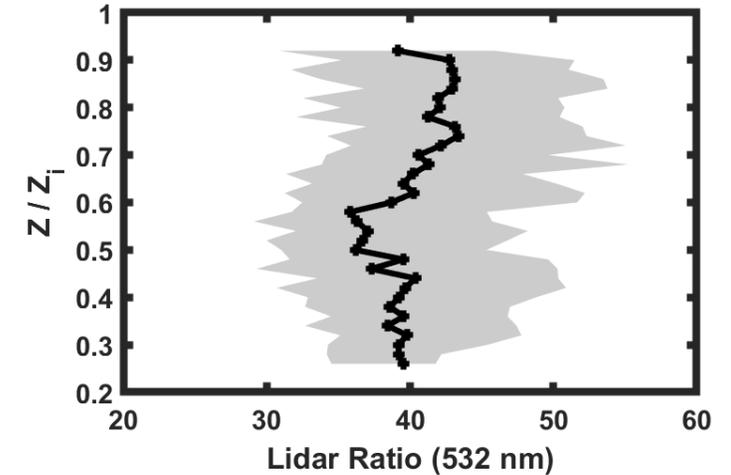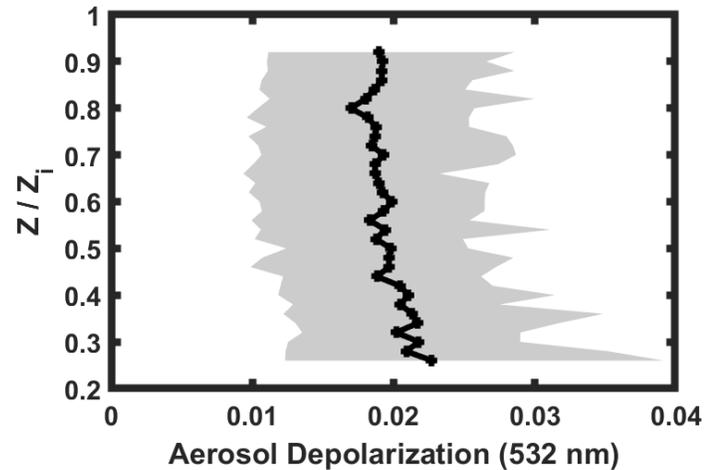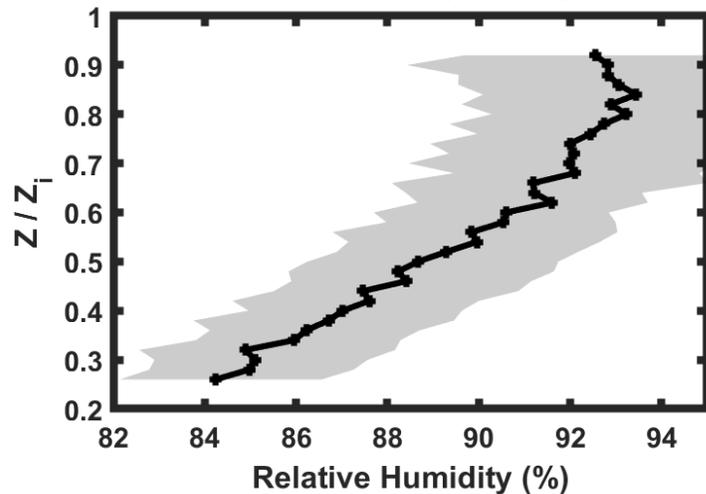
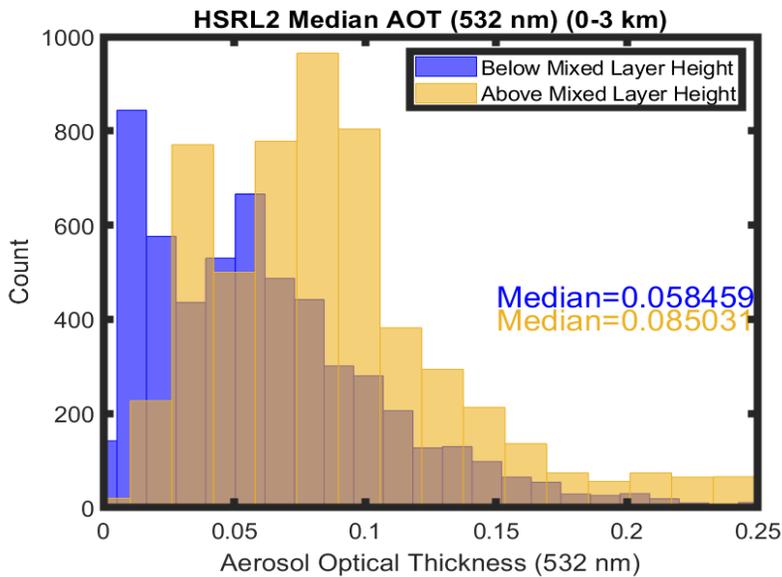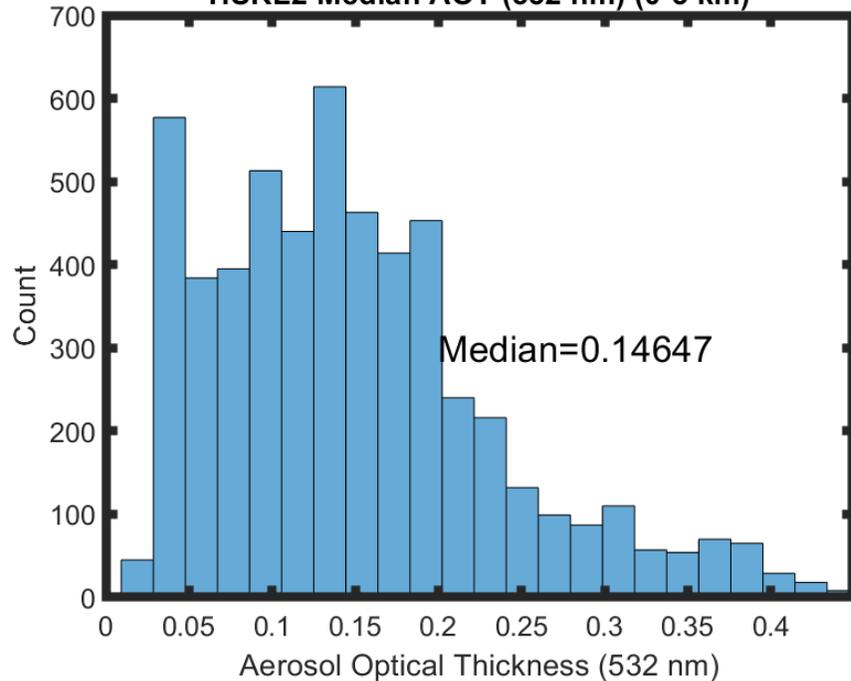Analysis using entire CAMP2EX dataset; as RH increases near the top of mixed layer:

- Slight decrease in aerosol depolarization as particles become more spherical so particulate depolarization decreases
- Increase in fine mode particle scattering so backscatter color ratio (532/1064) increases
- Slight increase in fine mode size so backscatter color ratio (355/532) decreases
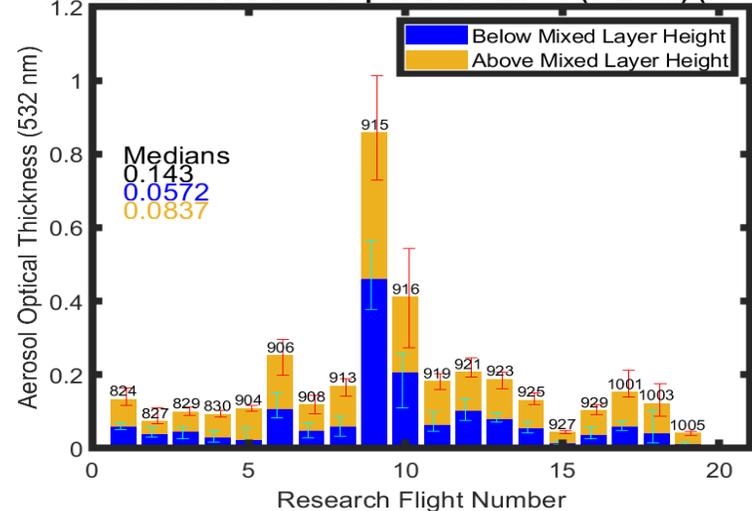- Very little change in lidar ratio
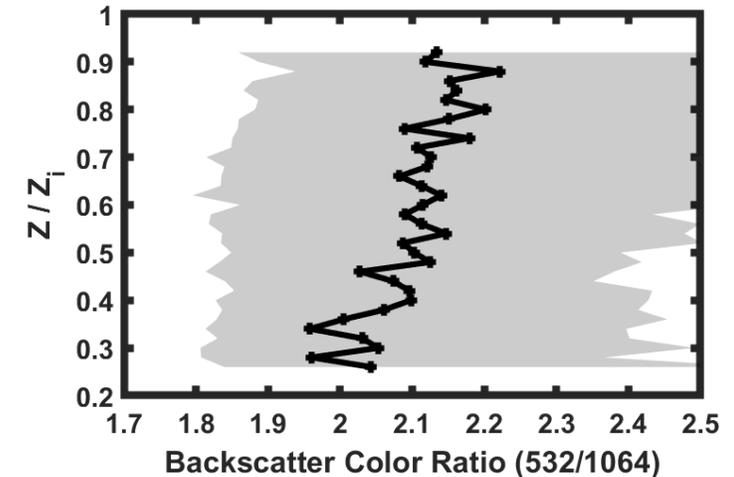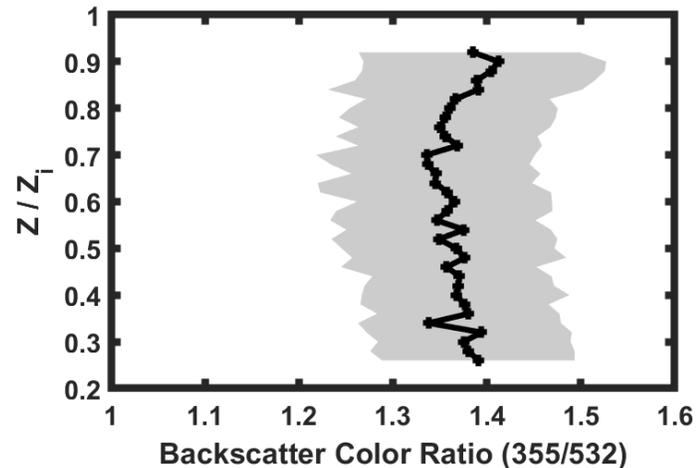
HSRL2 Measurements of Aerosol Optical Thickness (AOT) During CAMP2Ex

- Median AOT (532 nm) within the 0-3 km layer ~ 0.15
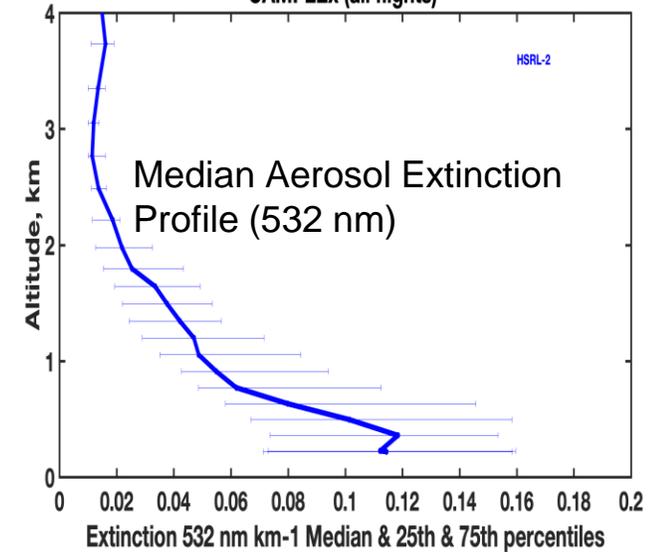- About 40% of AOT within Mixed Layer
- About 60% of AOT above Mixed Layer

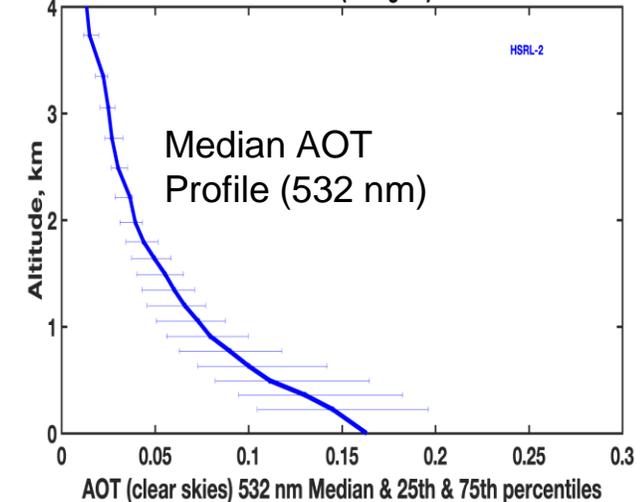

HSRL2 Median AOT (532 nm) (0-3 km)

Median=0.14647

HSRL2 Median AOT (532 nm) (0-3 km)

Below Mixed Layer Height
Above Mixed Layer Height

Median=0.058459
Median=0.085031

HSRL2 Median Aerosol Optical Thickness (532 nm) (0-3 km)

Below Mixed Layer Height
Above Mixed Layer Height

Medians
0.143
0.0572
0.0837

CAMP2Ex (all flights)

HSRL-2

Median Aerosol Extinction Profile (532 nm)

Extinction 532 nm km-1 Median & 25th & 75th percentiles

CAMP2Ex (all flights)

HSRL-2

Median AOT Profile (532 nm)

AOT (clear skies) 532 nm Median & 25th & 75th percentiles
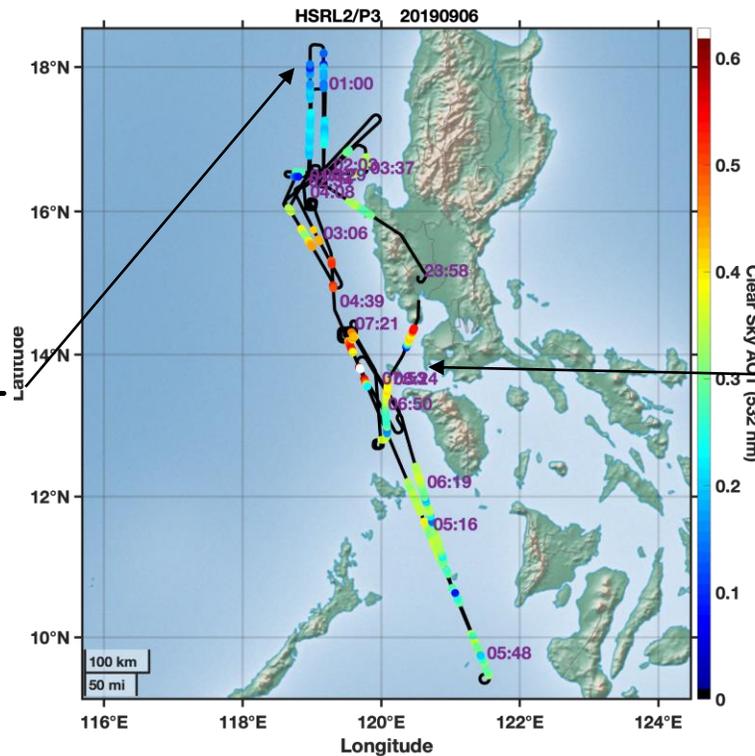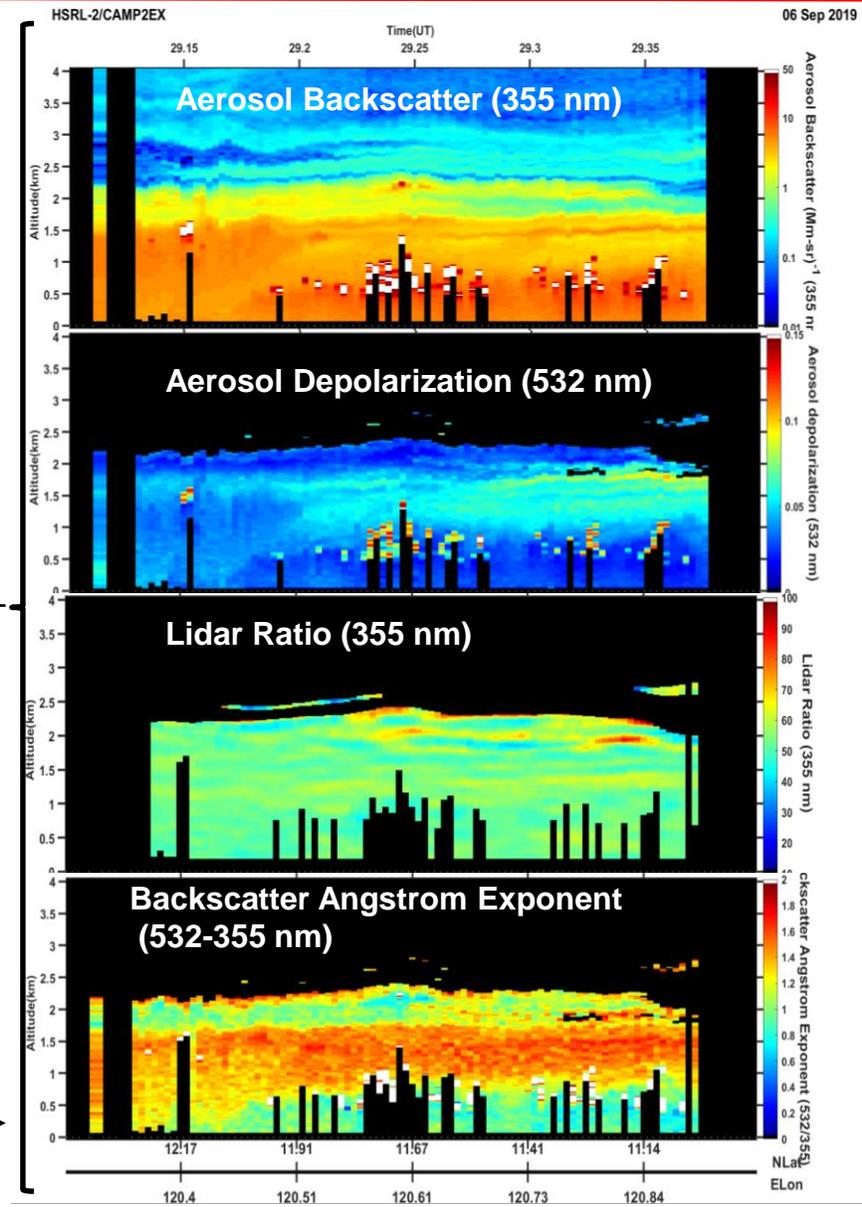
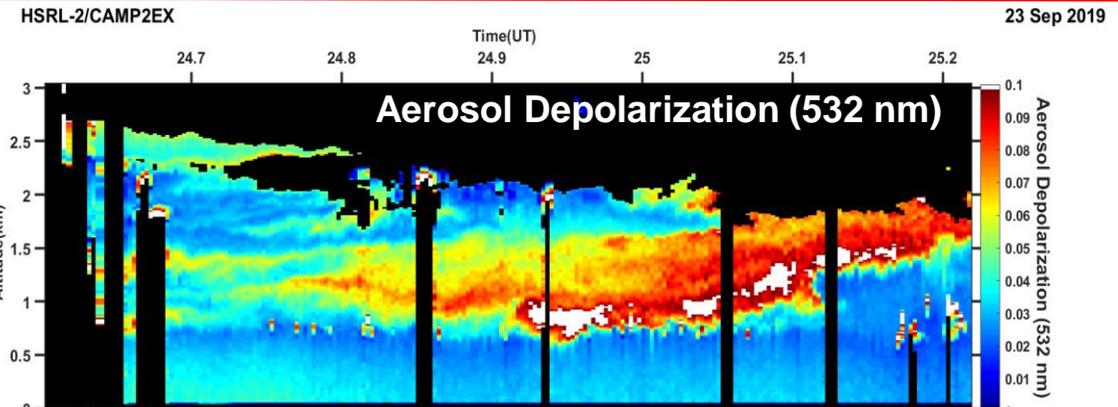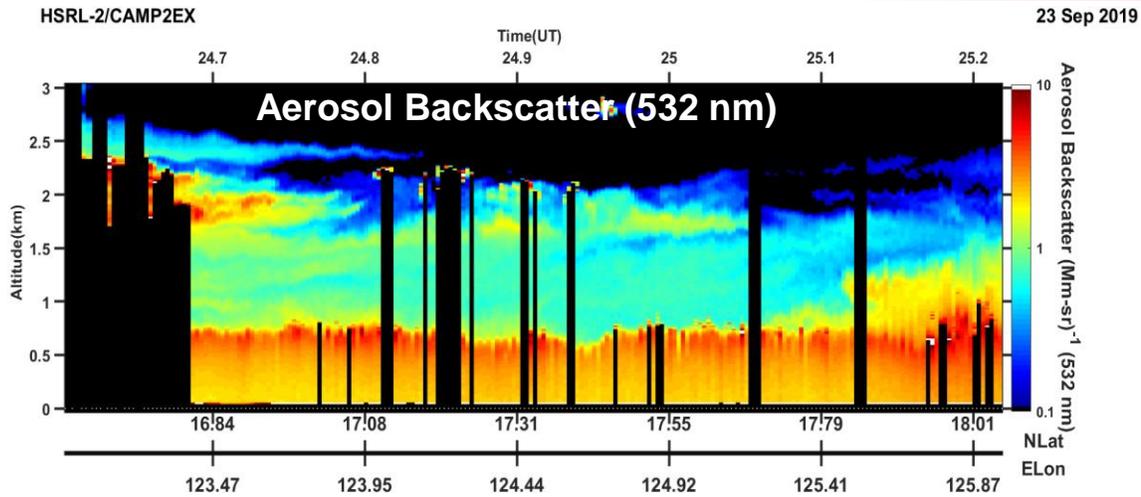# HSRL-2 Reveals Horizontal and Vertical Variability of Aerosol Properties
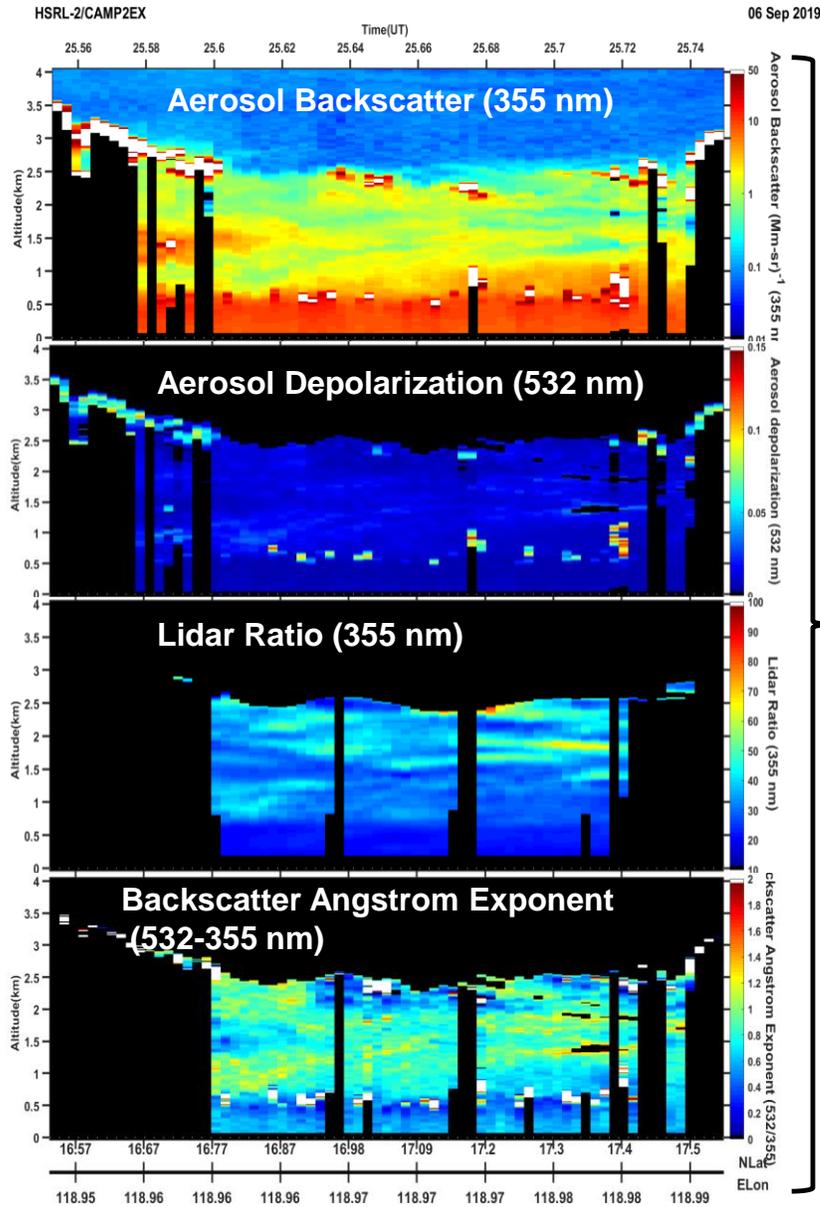
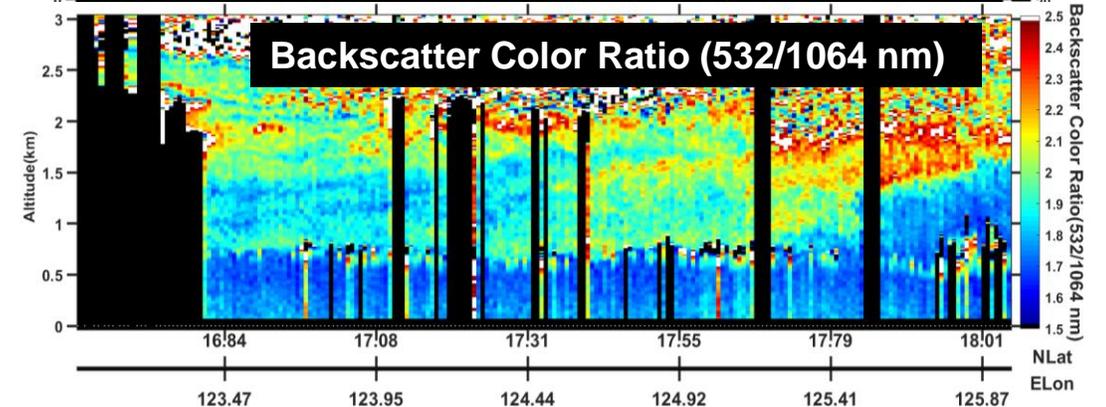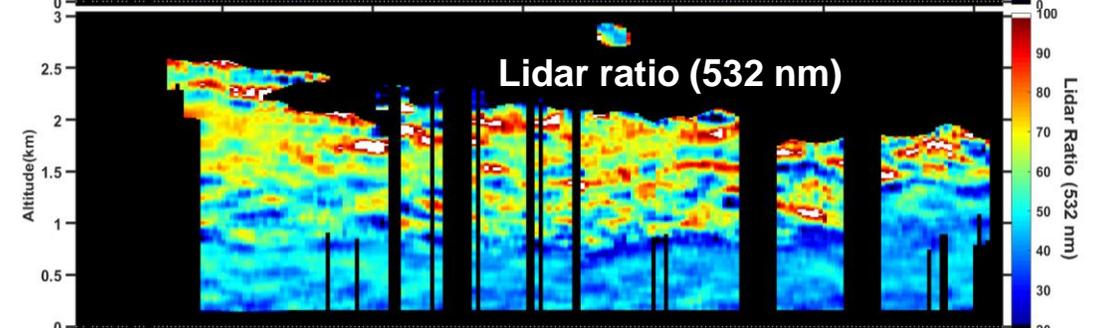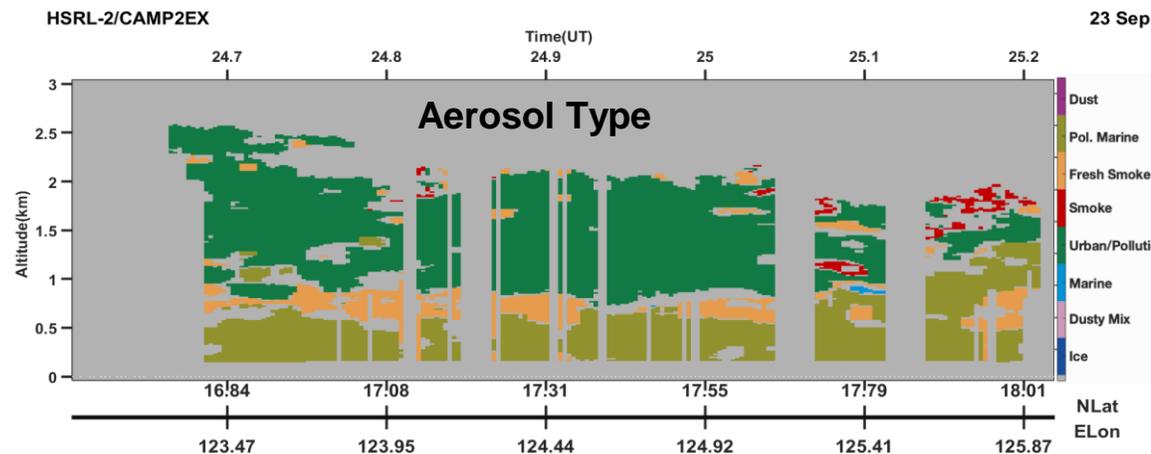WNW of Luzon – larger, maritime (sea-salt) aerosol near surface

SSW of Manila – smaller particles (pollution/smoke) near surface, small, slightly nonspherical smoke aloft

HSRL2 Measurements used to Infer Aerosol Type

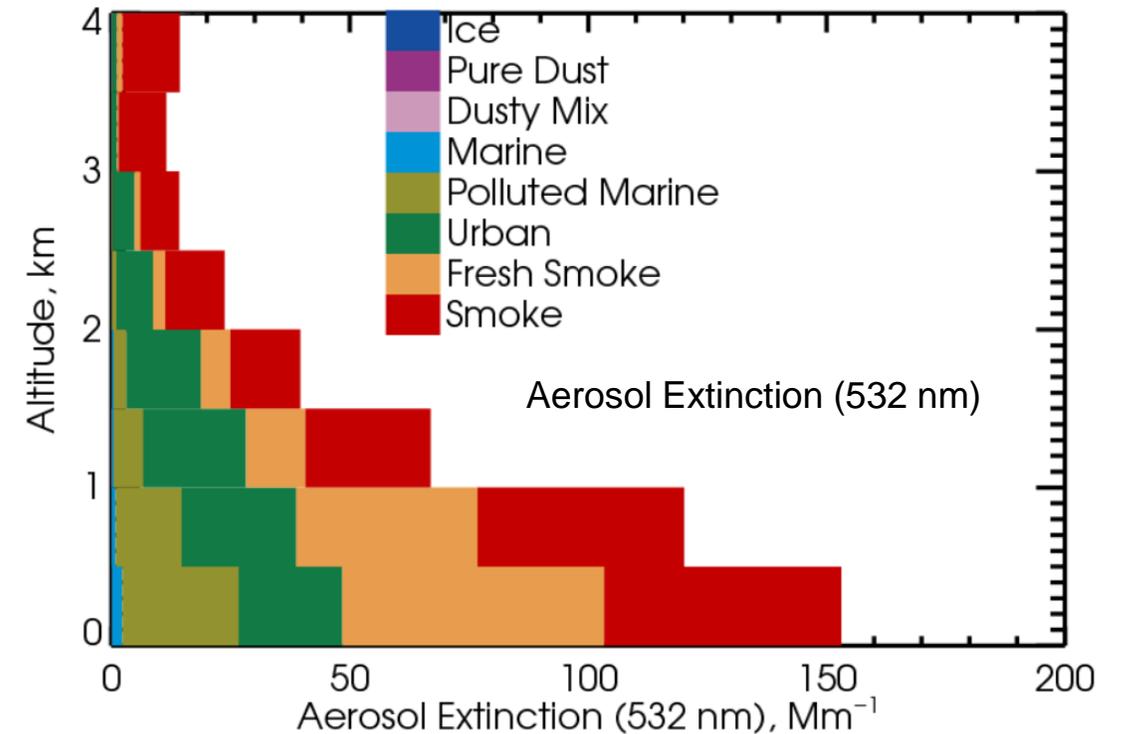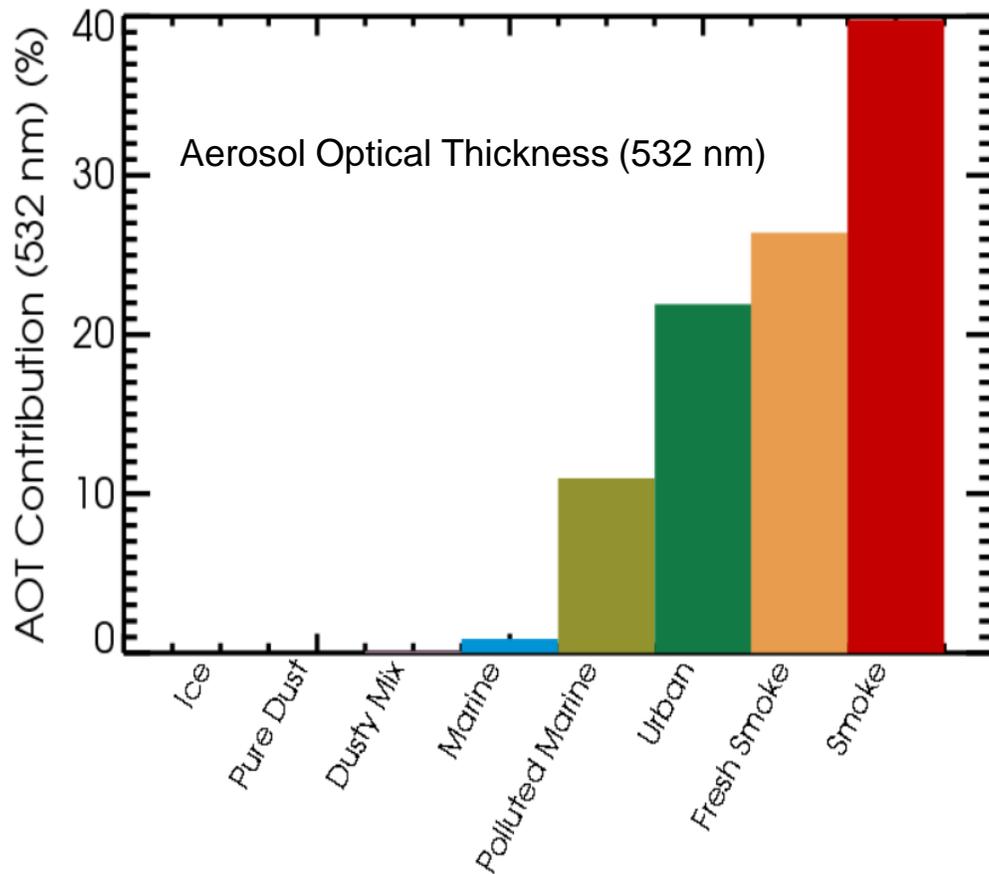Aerosol type inferred from measurements of aerosol intensive parameters (Burton et al., 2012, AMT)

AOT and Aerosol Extinction Apportioned to Aerosol Type
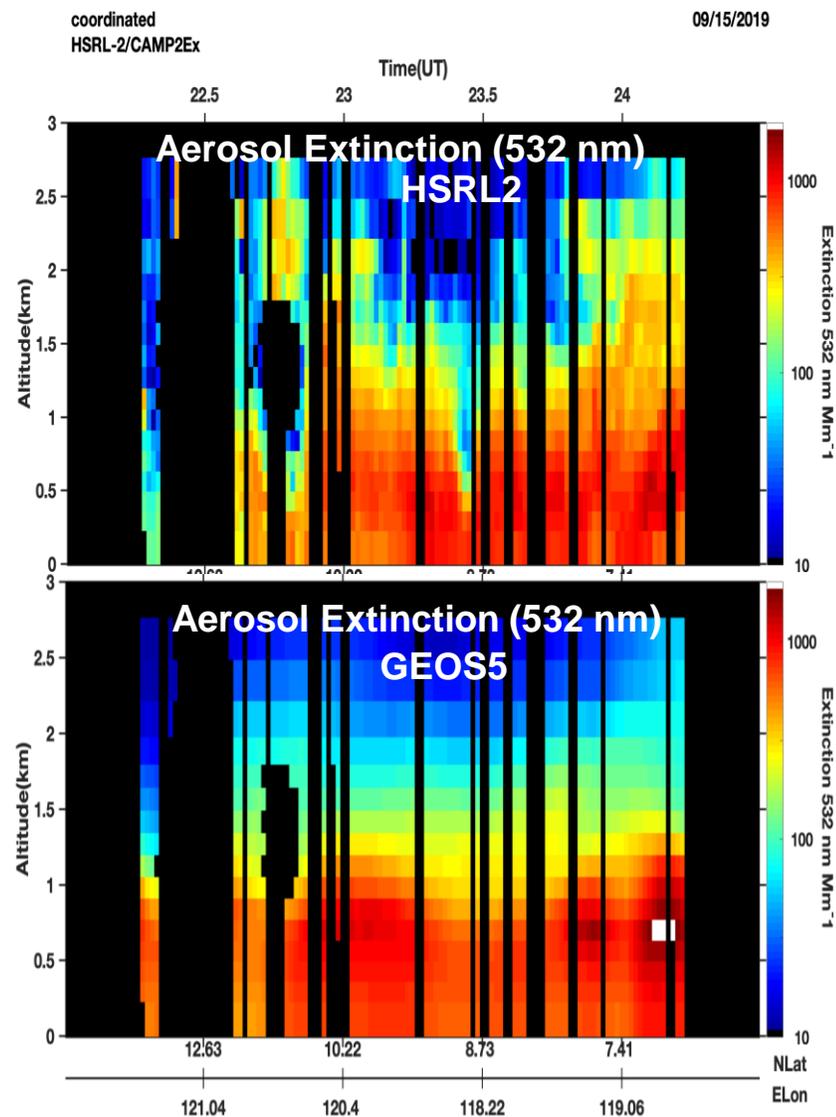
Majority of AOT and aerosol extinction classified using HSRL2 data during CAMP2Ex attributed to smoke

Example: HSRL-2/GEOS-5 Comparison of Aerosol Extensive Parameters for Sept. 15
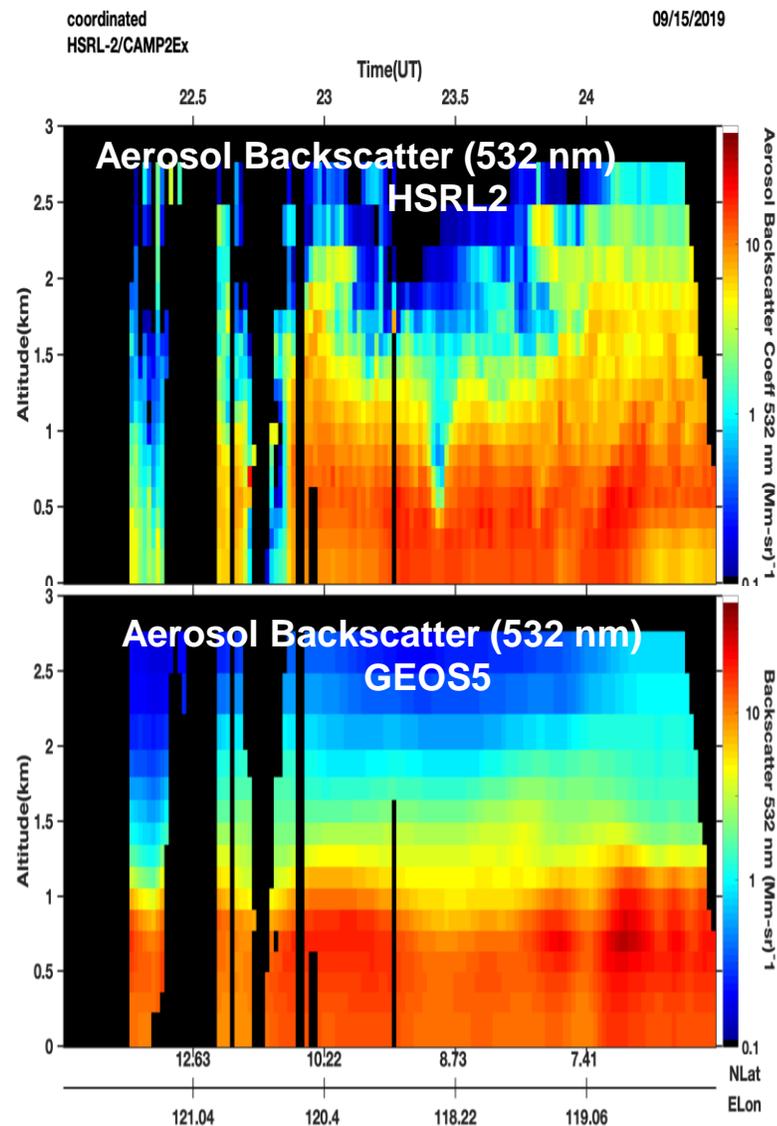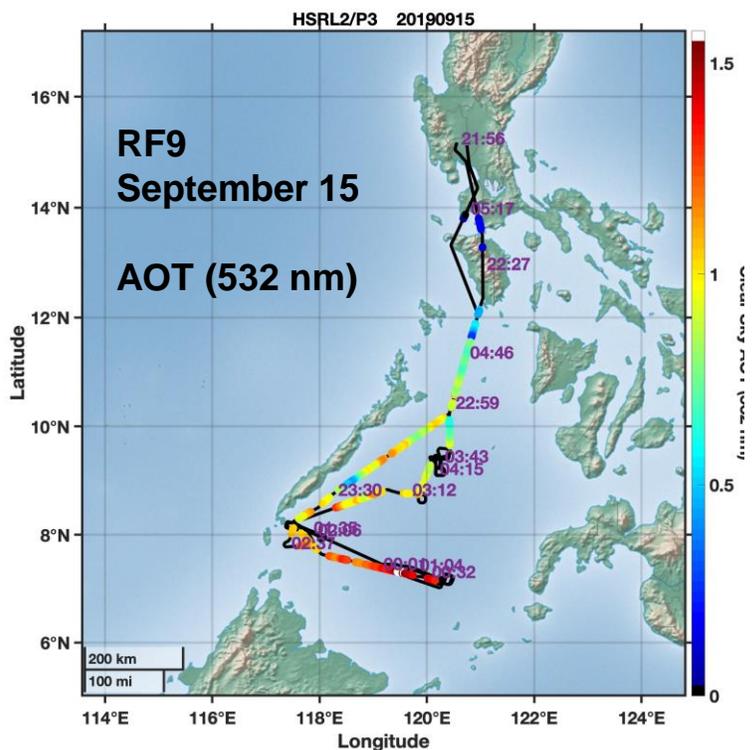
GEOS-5 Simulations provided by
Arlindo da Silva (GSFC)

Example: HSRL-2/GEOS-5 Comparison of Aerosol Intensive Parameters for Sept. 15

GEOS-5 Simulations provided by Arlindo da Silva (GSFC)

HSRL- 2/GEOS-5 Comparison of Median Aerosol Profiles for all of CAMP2Ex

Median Profiles for all of CAMP2Ex flights
HSRL-2
GEOS-5
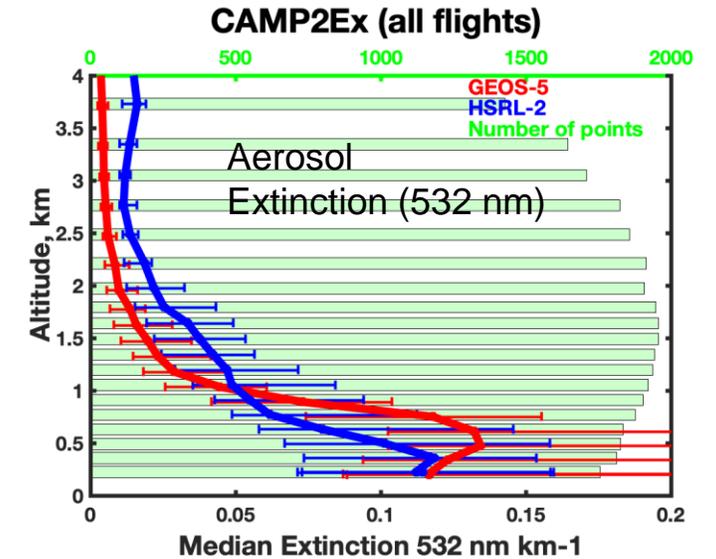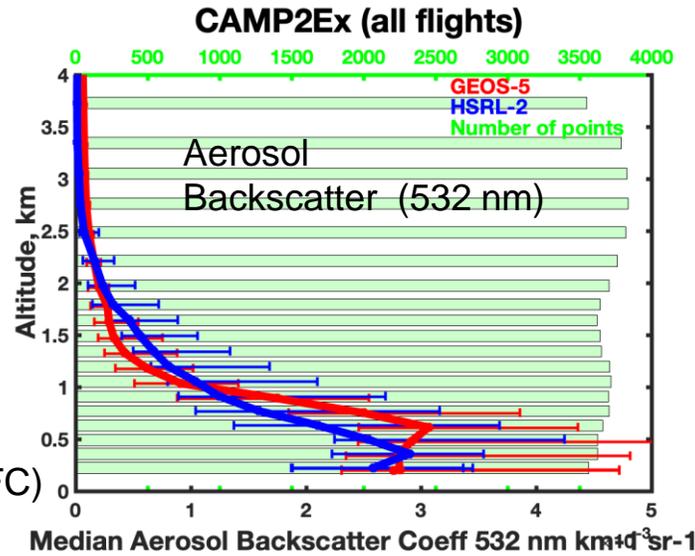
GEOS-5 Simulations provided by Arlindo da Silva (GSFC)

Cold Pool Example RF7-Sept. 8
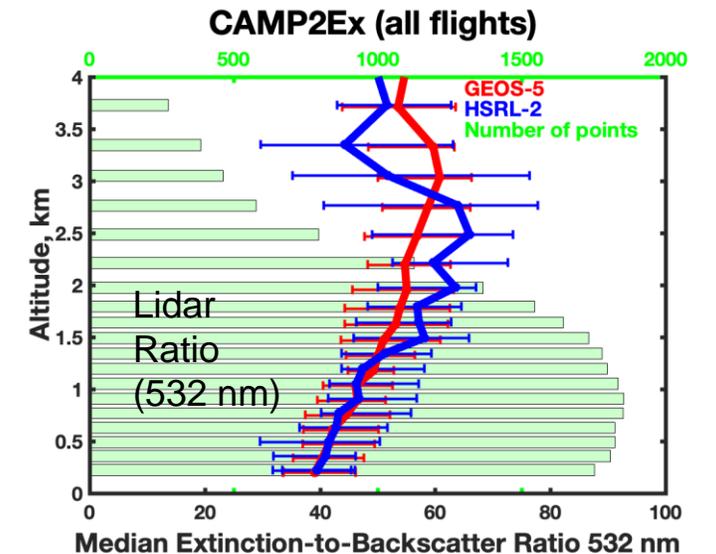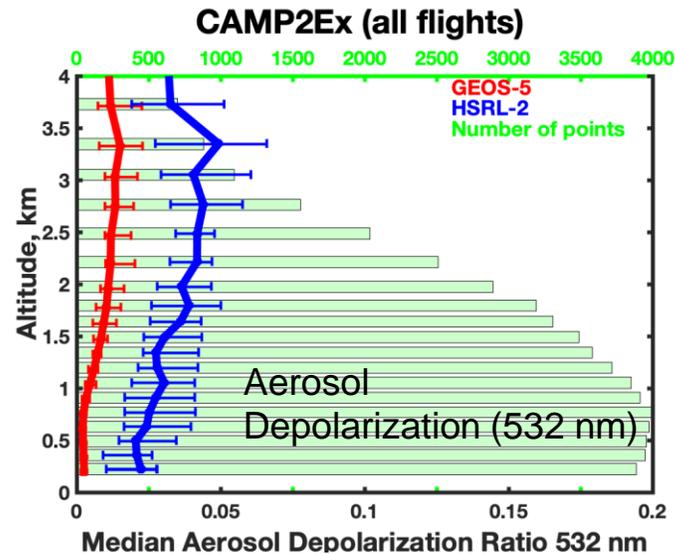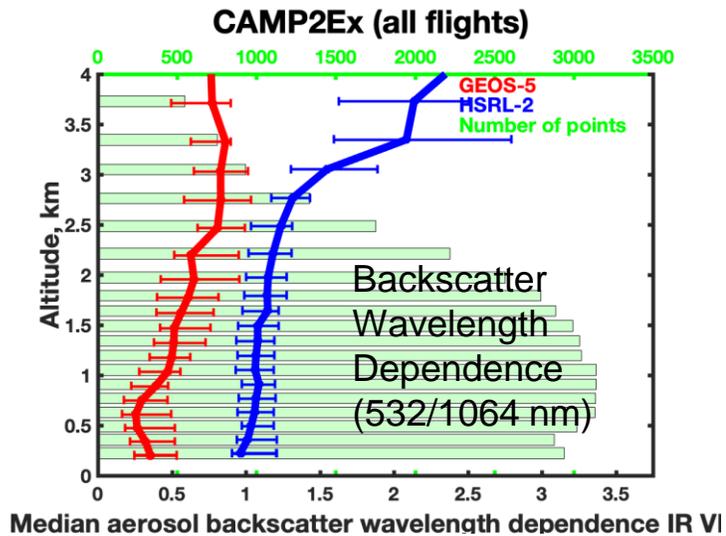
Cold air appears to force up aerosol layer and generate clouds at leading edge
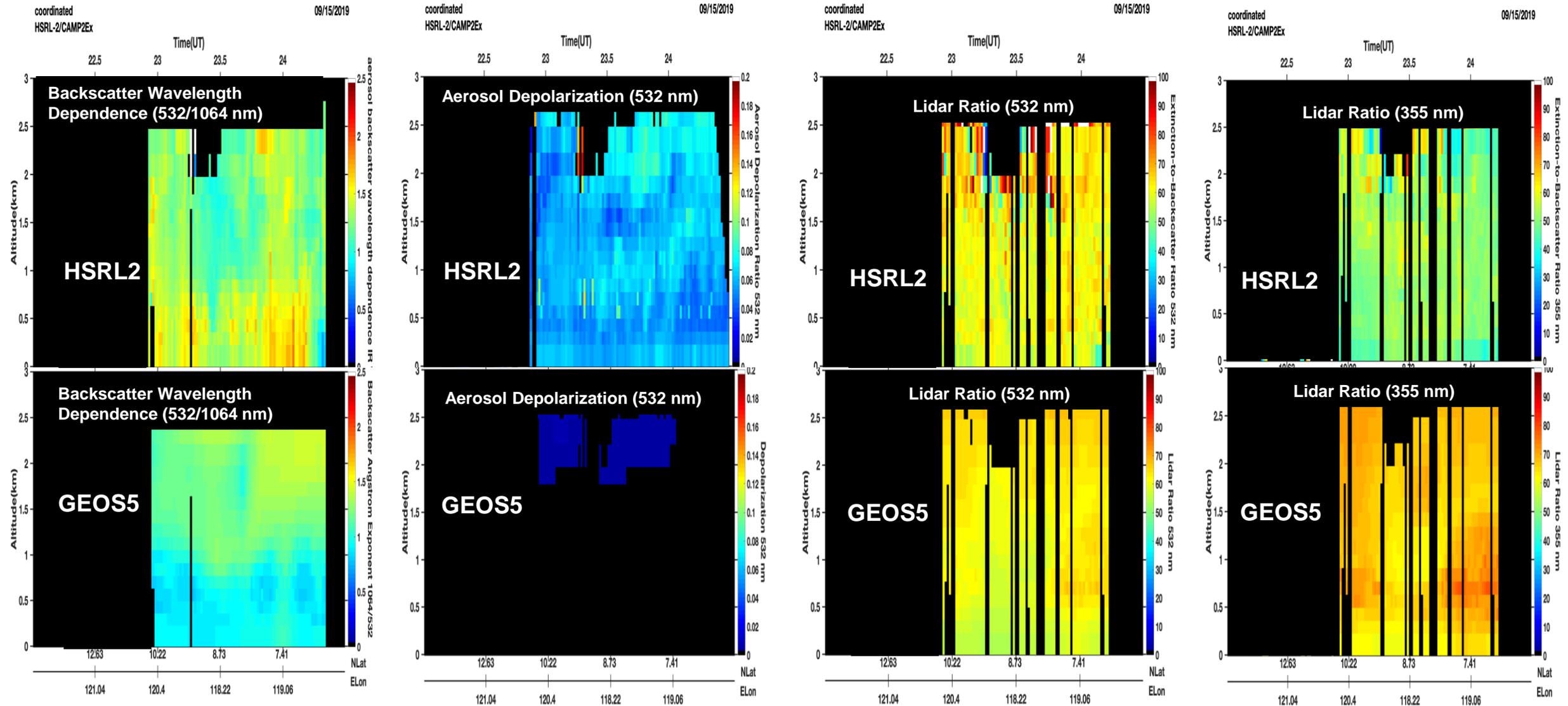
Very clean air in cold pool

SF07 2019-09-08 SF07_S06_behindcldpl_qc
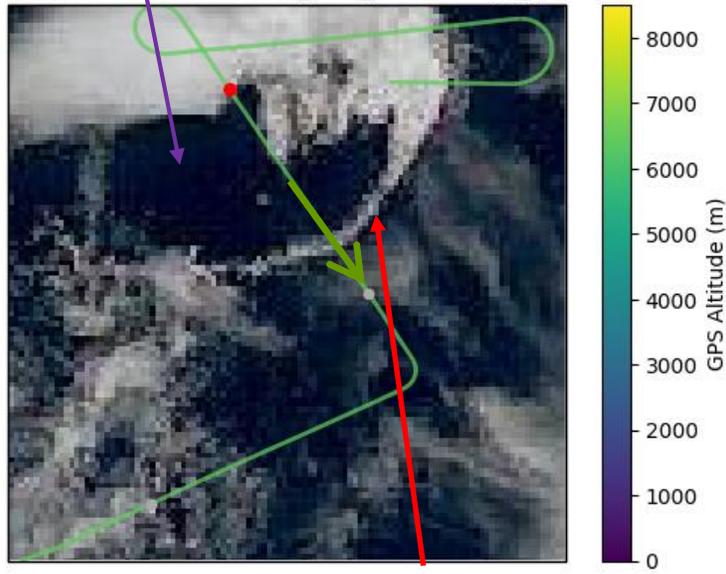
Cold air appears to force up aerosol layer and generate clouds at leading edge

Sonde 6 Cold Pool

Sonde 7 Environ

Aerosol Backscatter (532 nm)

Aerosol Extinction (532 nm)

Aerosol Depolarization (532 nm)

Aerosol Optical Thickness (532 nm)
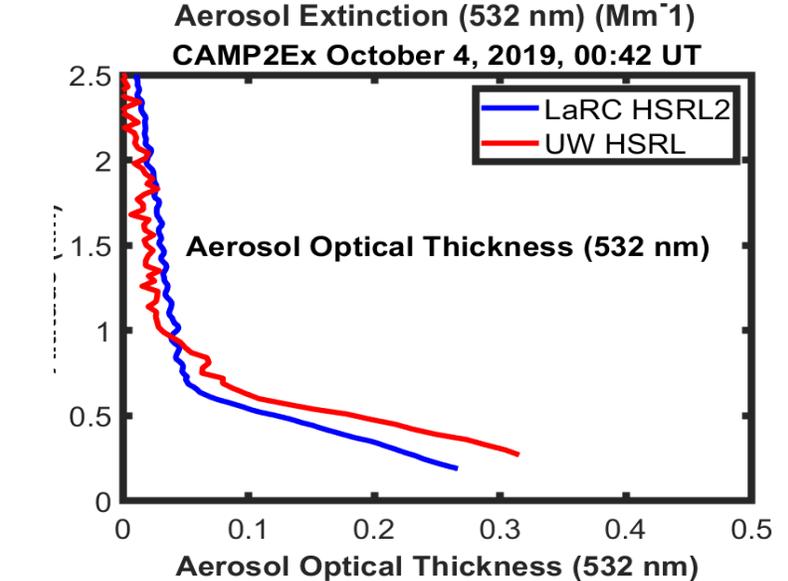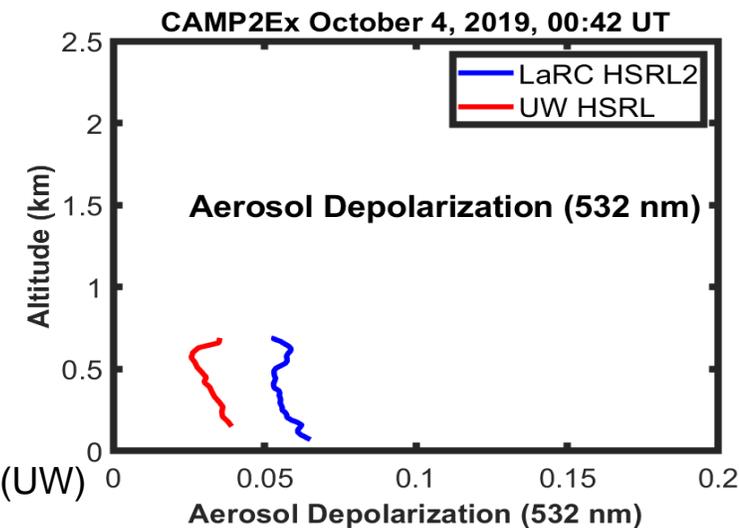
UW HSRL data provided by Ed Eloranta and Bob Holz (UW)

Summary and Future Work

- Deployed from the NASA P-3B aircraft, the NASA LaRC airborne HSRL-2 measured profiles of aerosol extensive and intensive properties during all 19 CAMP2EX science flights
  - Aerosol backscatter and depolarization (355, 532, 1064 nm)
  - Aerosol extinction and aerosol optical thickness (AOT) via HSRL technique (355, 532 nm)
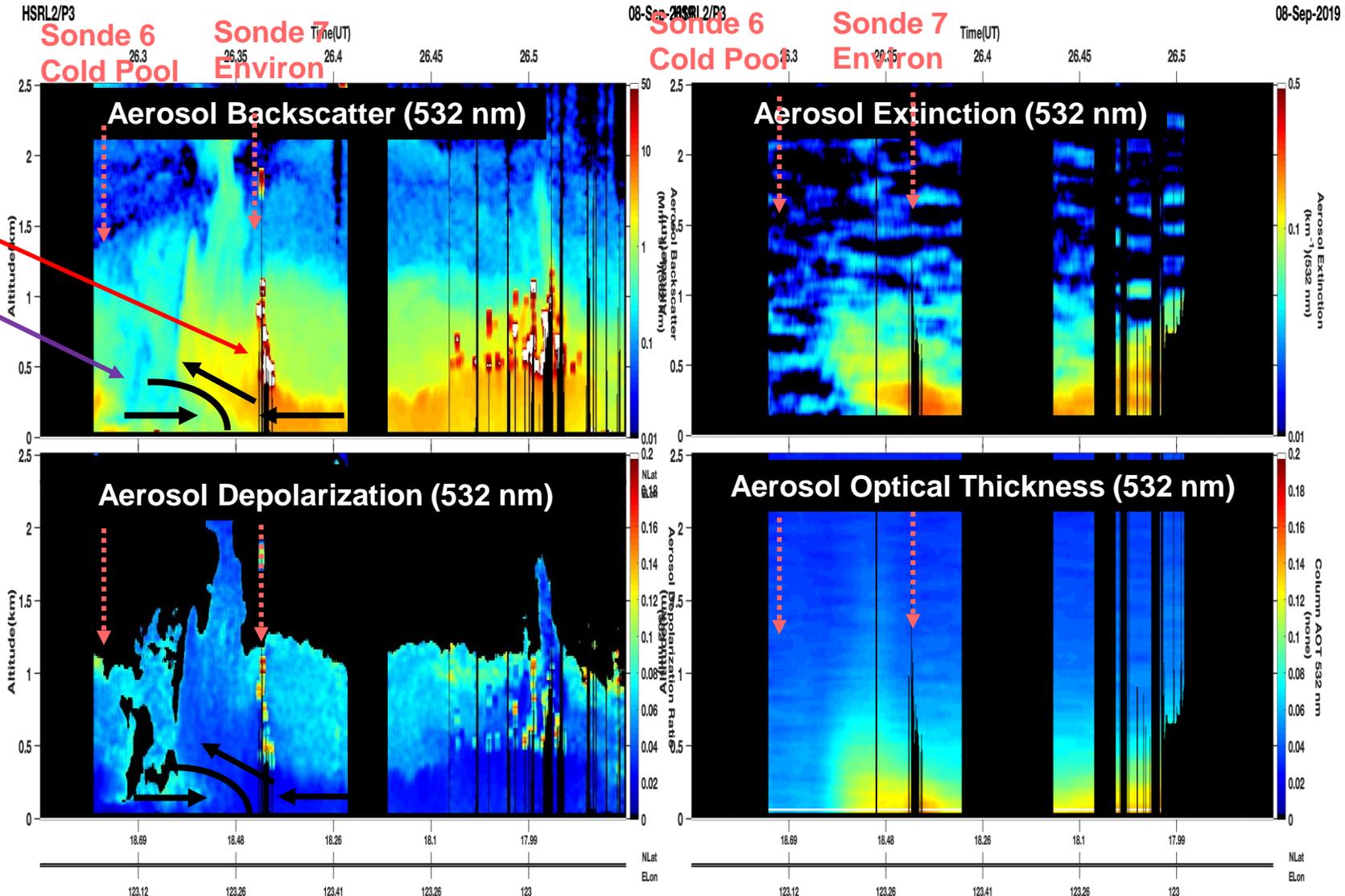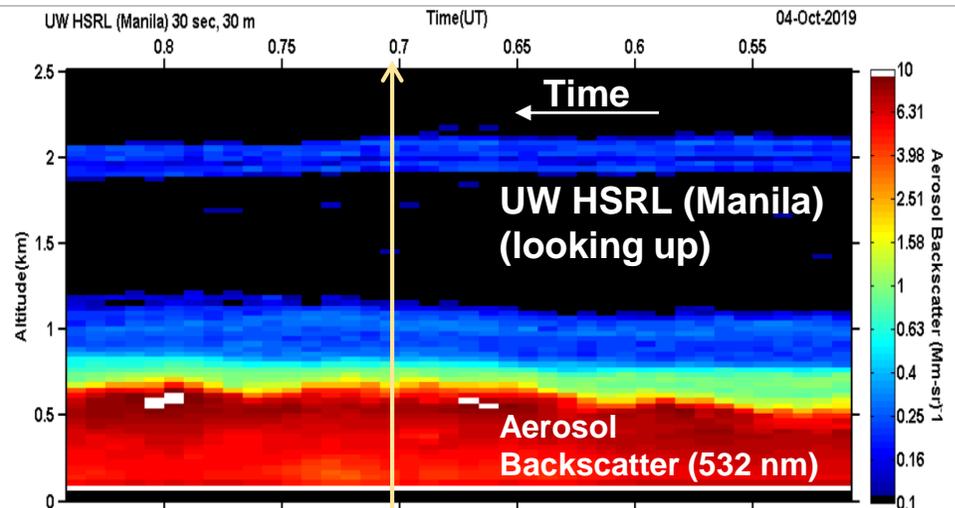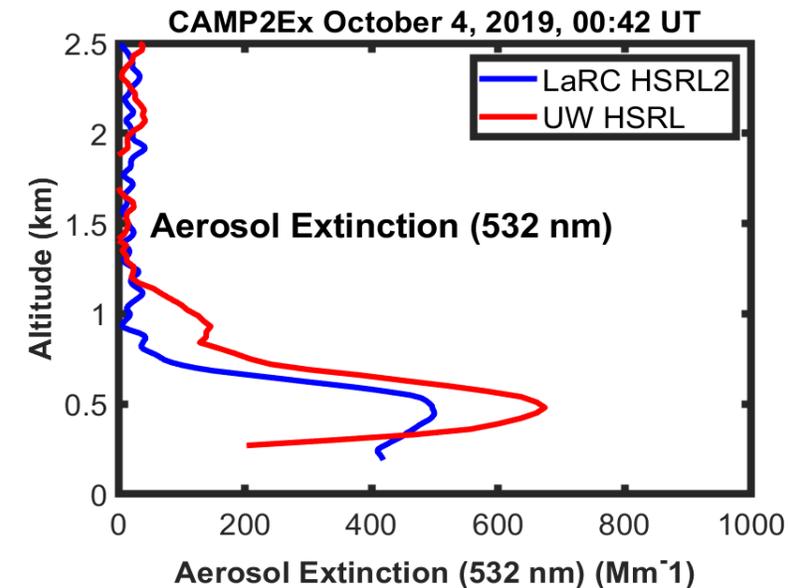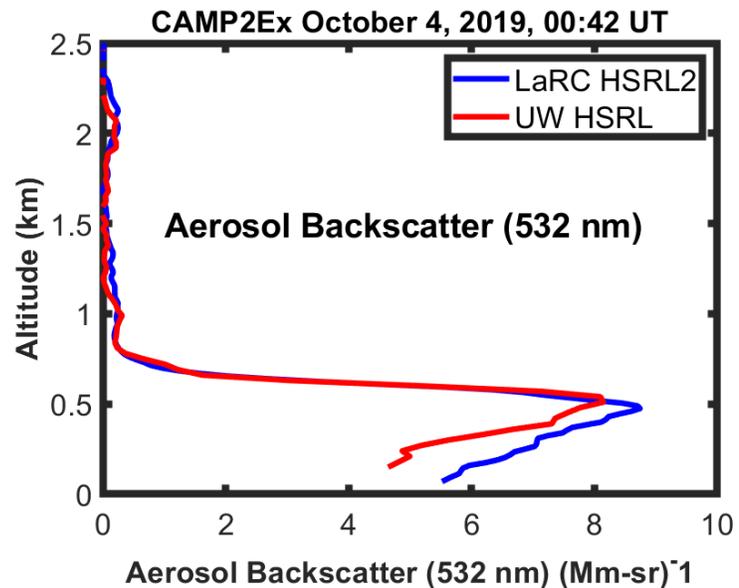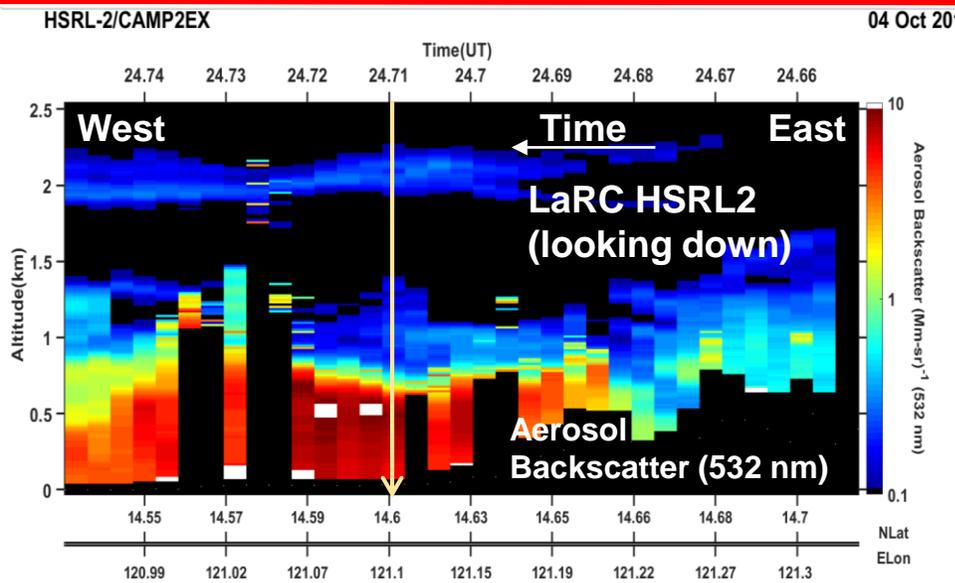 - Additional products include aerosol type and mixed layer heights
- Median mixed layer height was about 560 m
- Associated with the increase in RH near the top of the mixed layer, HSRL2 measurements reveal:
  - Aerosol backscatter and extinction are systematically larger by about 30-40% near the top of the mixed layer due to the increase in fine mode scattering and fine mode particle size associated with increased RH
  - Slight decrease in aerosol depolarization associated with particles becoming more spherical due to water uptake
- About 40% (60%) of AOT was within (above) the mixed layer
- Majority of AOT and aerosol extinction classified by HSRL2 attributed to smoke
- HSRL2 data are being used to evaluate:
  - GEOS-5 simulations of aerosol distributions and properties
  - Variability of aerosol distributions and properties associated with cold pools
- Future work to include lidar-only and combined lidar+polarimeter retrievals of aerosol physical and optical properties

Extra Slides

HSRL2 Particulate Backscatter (532 nm) (km-sr)^-1

CALIOP Total Attenuated Backscatter (532 nm) (km-sr)^-1

Underpass Flight Segment

Unusual Dropsonde – Sept. 4

SF05 S01 launched at 2019-09-04 01:31:29 Z

"Unusual dropsonde"

PWAT = 39.31 mm
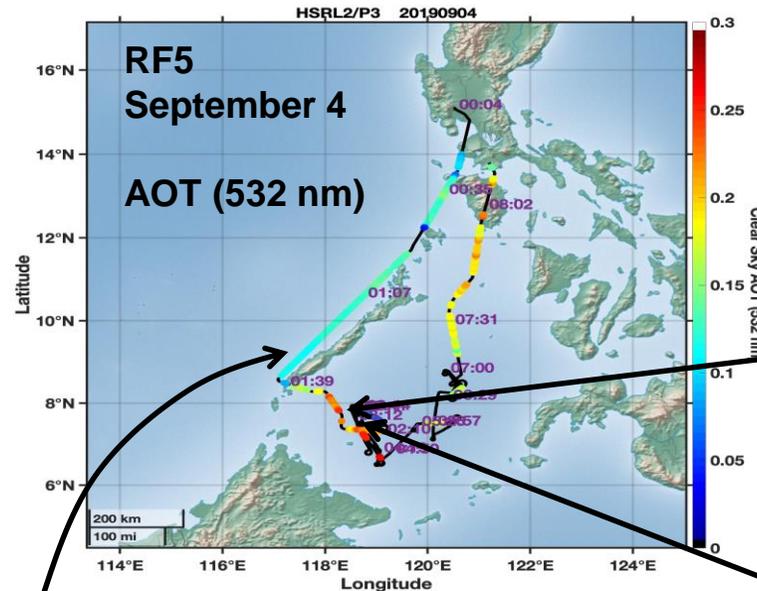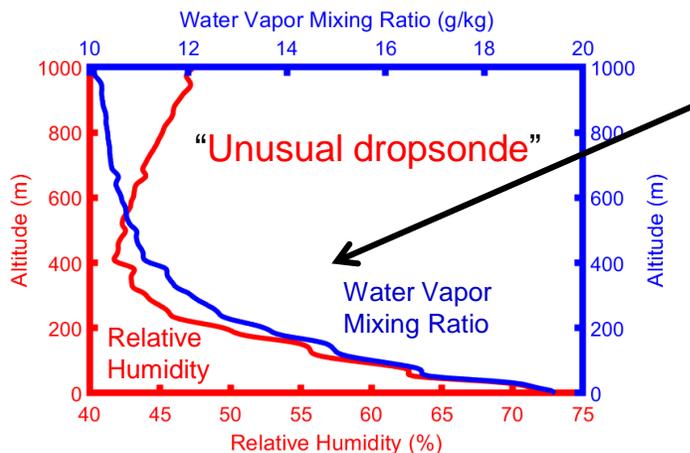LCL = 689.7 m
LFC = 1544.2 m
CIN = −105.01 J kg⁻¹
0 − 1 km SHR = 27.01 kt
0 − 3 km SHR = 24.62 kt
0 − 5 km SHR = 6.53 kt

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HSRL2/P3   20190904

RF5
September 4

AOT (532 nm)

SF05 S02 launched at 2019-09-04 02:04:09 Z

"Usual dropsonde"

PWAT = 47.15 mm
LCL = 552.1 m
LFC = 1710.7 m
CIN = −10.63 J kg⁻¹
0 − 1 km SHR = 7.07 kt
0 − 3 km SHR = 16.00 kt
0 − 5 km SHR = 9.31 kt

Colorado State University   PI: Susan C. van den Heever
sue@atmos.colostate.edu

2019-09-04 01:31:29

"Unusual dropsonde"

Water Vapor Mixing Ratio

Relative Humidity

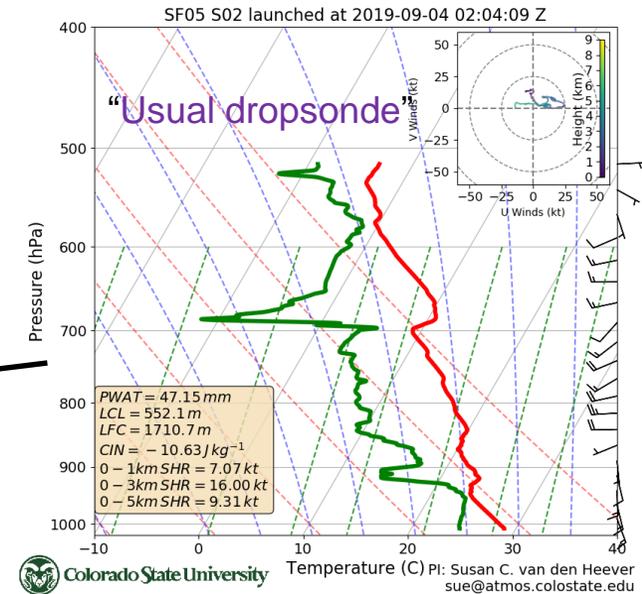2019-09-04 02:04:09

Water Vapor Mixing Ratio

"Usual dropsonde"

Relative Humidity

"Sounding 20190904_013129 (SF05) shows an unusually dry boundary layer with a minimum relative humidity of 42 % at about 500 m altitude. This is about 50% drier than the median at that altitude and 20% drier than the next driest profile. At the same time, the profile is nearly isothermal in the boundary layer, showing the warmest temperatures of the entire data set. All engineering data of the sonde indicate proper functioning of the instrument. *This profile may require more scientific attention and validation.*" (Dropsonde Data Quality Report-CAMP2Ex) (italics added)

Dropsonde data from Sue van den Heever (CSU)

Unusual Dropsonde – Sept. 4
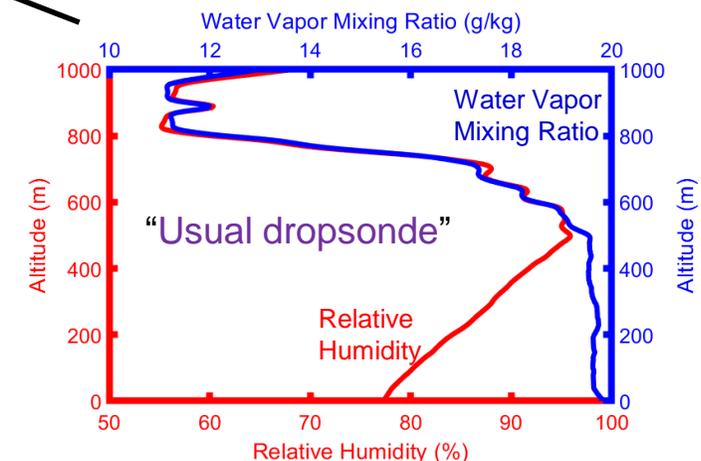
HSRL2 data also show significant differences between dropsondes released west and southeast of Palawan

Dropsonde data from Sue van den Heever (CSU)