A33M-2719

Aerosol Hygroscopic Effects Measured by the Airborne High Spectral Resolution Lidar-2

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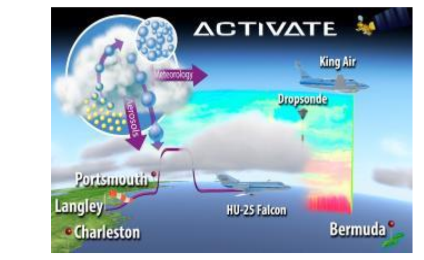


Motivation

1) Water uptake by aerosols impacts aerosol physical characteristics (size, shape, composition) which in turn affect aerosol optical properties (e.g. scattering, extinction, depolarization)
2) Changes in these aerosol characteristics impact their: 1) radiative effects, 2) ability to act as Cloud Condensation Nuclei and Ice Nuclei, 3) role in aqueous chemistry
3) There is large diversity in the magnitude of aerosol humidification in models (e.g. Burgos et al., 2020)
4) Recent evidence shows that some models have too large an increase in aerosol extinction with relative humidity (RH) (Collow et al., 2022)

➢ **We show how airborne High Spectral Resolution Lidar-2 (HSRL-2) measurements can be used to quantify the increase in aerosol backscatter and extinction with relative humidity and compare these lidar-derived humidification factors to those derived from airborne in situ measurements.**

Data

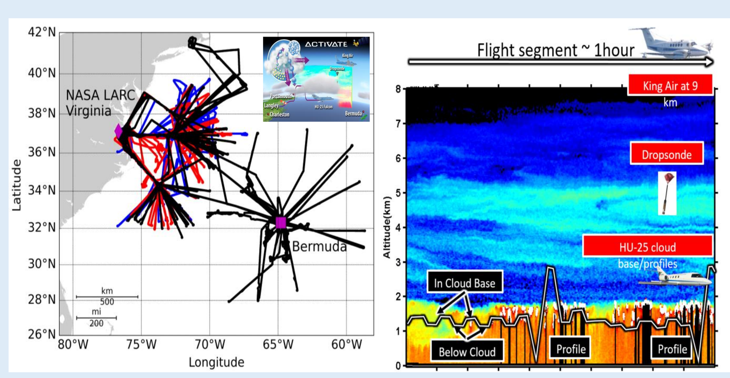
This study uses NASA Langley Research Center (LaRC) HSRL-2 and dropsonde data from the NASA CAMP2Ex and ACTIVATE Missions

1) NASA CAMP2Ex (Aug-Oct 2019) (Philippines)

- CAMP2Ex addresses aerosol and cloud microphysics
- 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
- Dropsondes deployed from P-3B aircraft
- In situ instruments also deployed on P-3B to measure BL clouds and aerosols
- Data available from https://doi.org/10.5067/Suborbital/CAMP2EX2018/DATA001

2) NASA EVS-3 ACTIVATE (Feb-Mar, Aug-Sep 2020; Jan-Jun, Dec 2021; Jan-Jun 2022) (western North Atlantic Ocean)

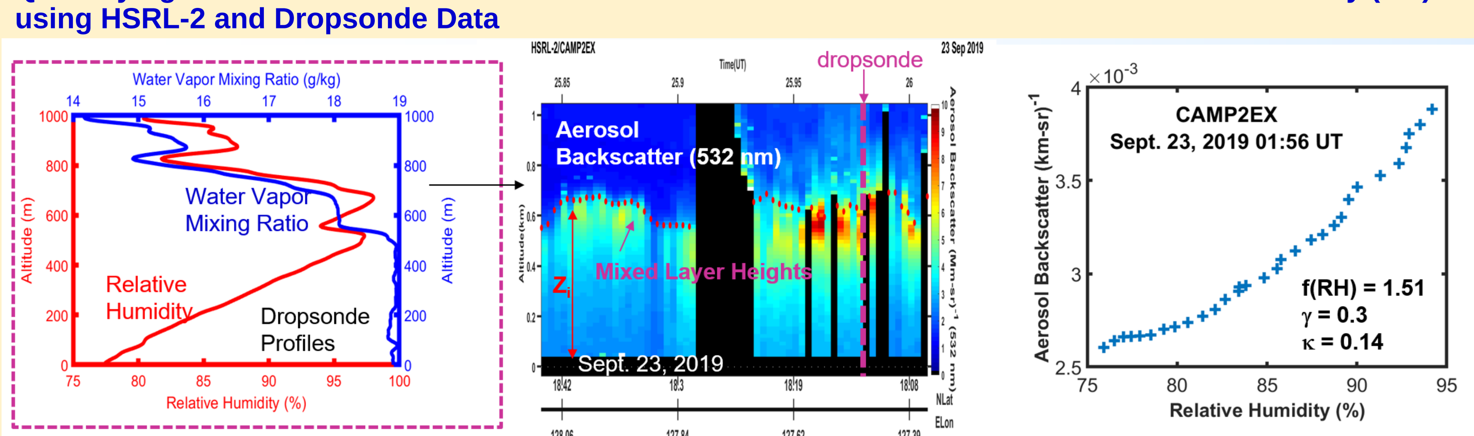
- Focus on marine boundary layer (MBL) clouds off the US Mid-Atlantic Coast
- NASA LaRC HSRL-2 deployed on LaRC King Air aircraft for nadir viewing, Dropsondes deployed from LaRC King Air aircraft
- In situ instruments deployed on NASA LaRC HU-25 Falcon aircraft to simultaneously measure BL clouds and aerosols below King Air
- Data available from https://doi.org/10.5067/SUBORBITAL/ACTIVATE/DATA001



HSRL-2, dropsonde, and in situ data acquired during 162 joint King Air and Falcon flights

Methodology

Quantifying the Aerosol Humidification Factors Associated with the Increase in Relative Humidity (RH) using HSRL-2 and Dropsonde Data

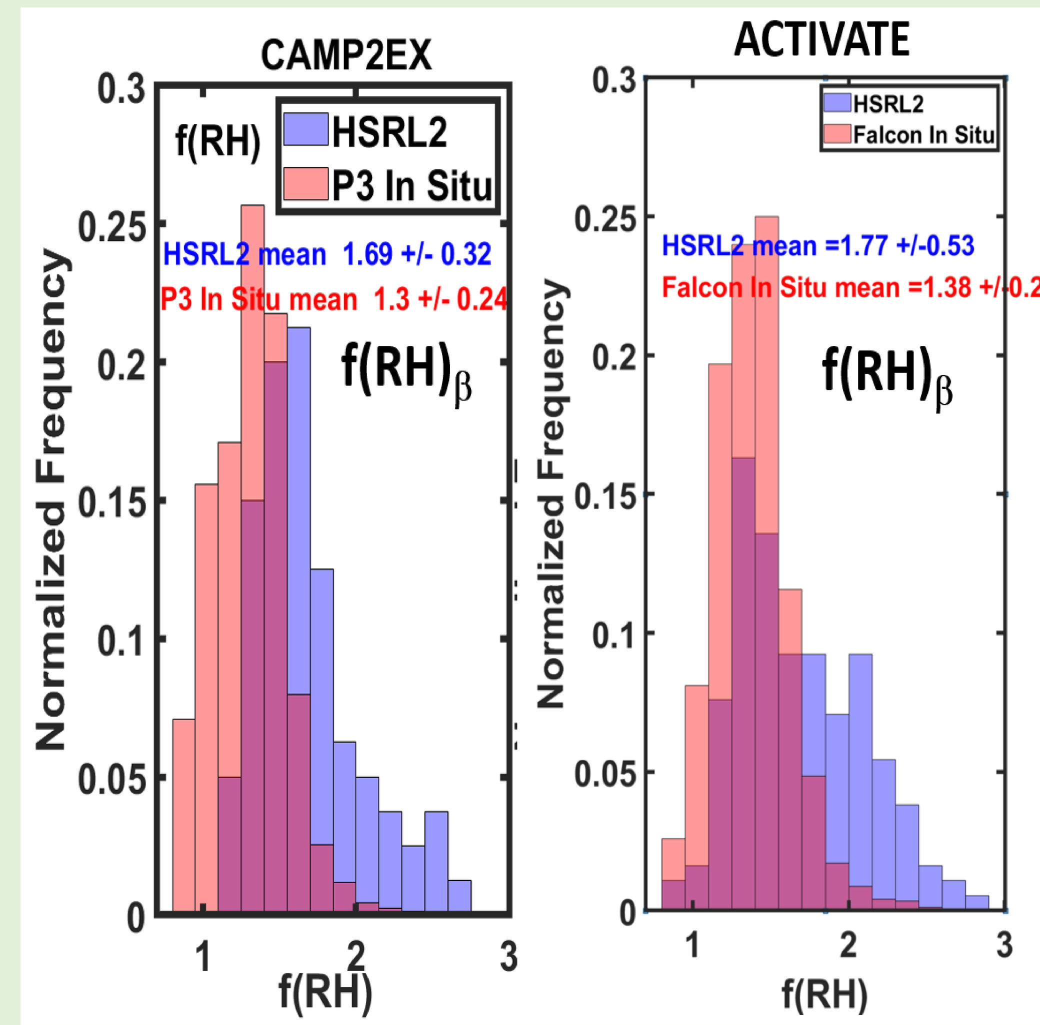


- Aerosol backscatter (355,532,1064 nm) and extinction (355,532 nm) profiles from HSRL-2; coincident RH profiles from dropsondes
- Mixed Layer Height (Z_i) derived from HSRL-2 aerosol backscatter profiles
- As RH increases with height within Mixed Layer, hygroscopic particles take on water, so aerosol backscatter and extinction increase.
- To quantify this increase, we compute aerosol humidification factor f(RH), gamma (γ), kappa (κ) within the mixed layer (i.e. Z/Z_i <1)
- Restrict cases to nearly constant water vapor mixing ratio so aerosol properties vary with RH and not due to changes in aerosol concentration or aerosol type
- Values in the comparisons are for f(RH=80%/RH=20%)

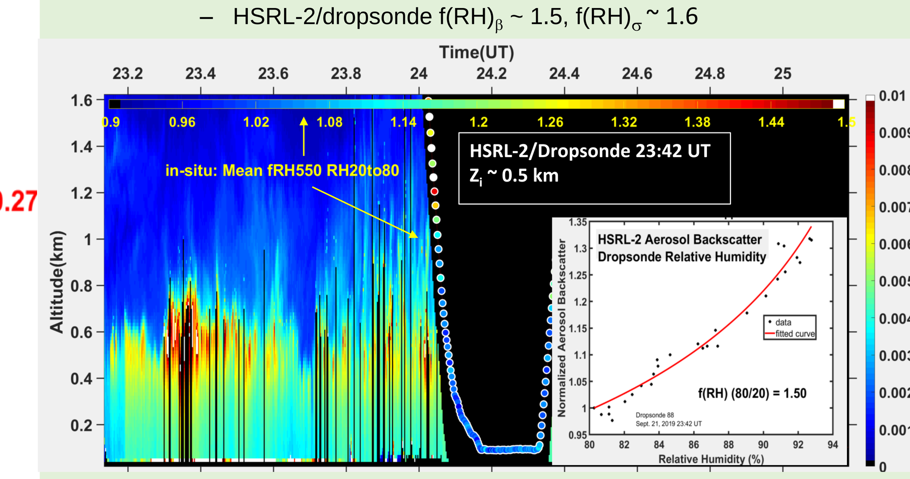
$$f(RH) = \frac{\beta(RH)}{\beta(RH_O)} = \left[\frac{(100-RH_O)}{(100-RH)}\right]^{\gamma} \cong 1 + \kappa\left[\frac{RH}{100-RH}\right]$$

$f(RH), \gamma$ computed for aerosol backscatter (β) and aerosol extinction (σ)

Results



- Example from CAMP2Ex Sept. 21, 2019 flight
  - In situ f(RH) ~ 1.0-1.1
  - HSRL-2/dropsonde $f(RH)_\beta$ ~ 1.5, $f(RH)_\sigma$ ~ 1.6



- Average f(RH=80%/RH=20%) (532 nm) derived from HSRL-2 and dropsonde data was about 1.7 for backscatter, and 1.8-2 for extinction during CAMP2Ex and ACTIVATE
- These values were higher than the corresponding values from airborne in situ measurements during both CAMP2Ex and ACTIVATE (1.30-1.39)
- Higher f(RH) values from HSRL-2 & dropsonde are likely because lidar observes both fine and coarse (sea salt) aerosol in contrast to airborne in situ measurements of only fine mode aerosol

f(RH) derived from HSRL-2 data tends to increase with increasing coarse mode

Ratio of in situ aerosol extinction to HSRL-2 aerosol extinction tends to decrease with increasing coarse mode

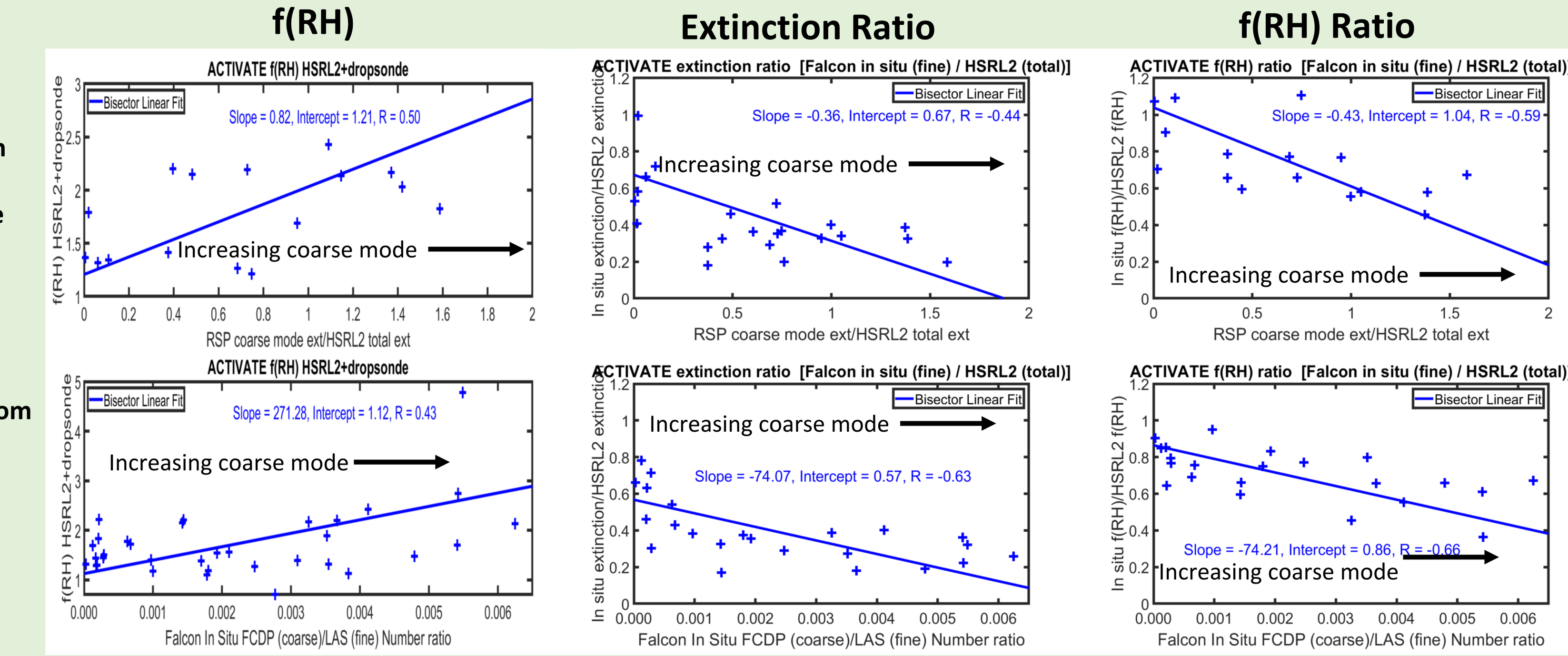
Ratio of in situ f(RH) to HSRL-2 f(RH) tends to decrease with increasing coarse mode

ACTIVATE

f(RH) | **Extinction Ratio** | **f(RH) Ratio**

Coarse mode extinction estimated from Research Scanning Polarimeter (RSP) retrievals of coarse mode aerosol optical depth (AOD)

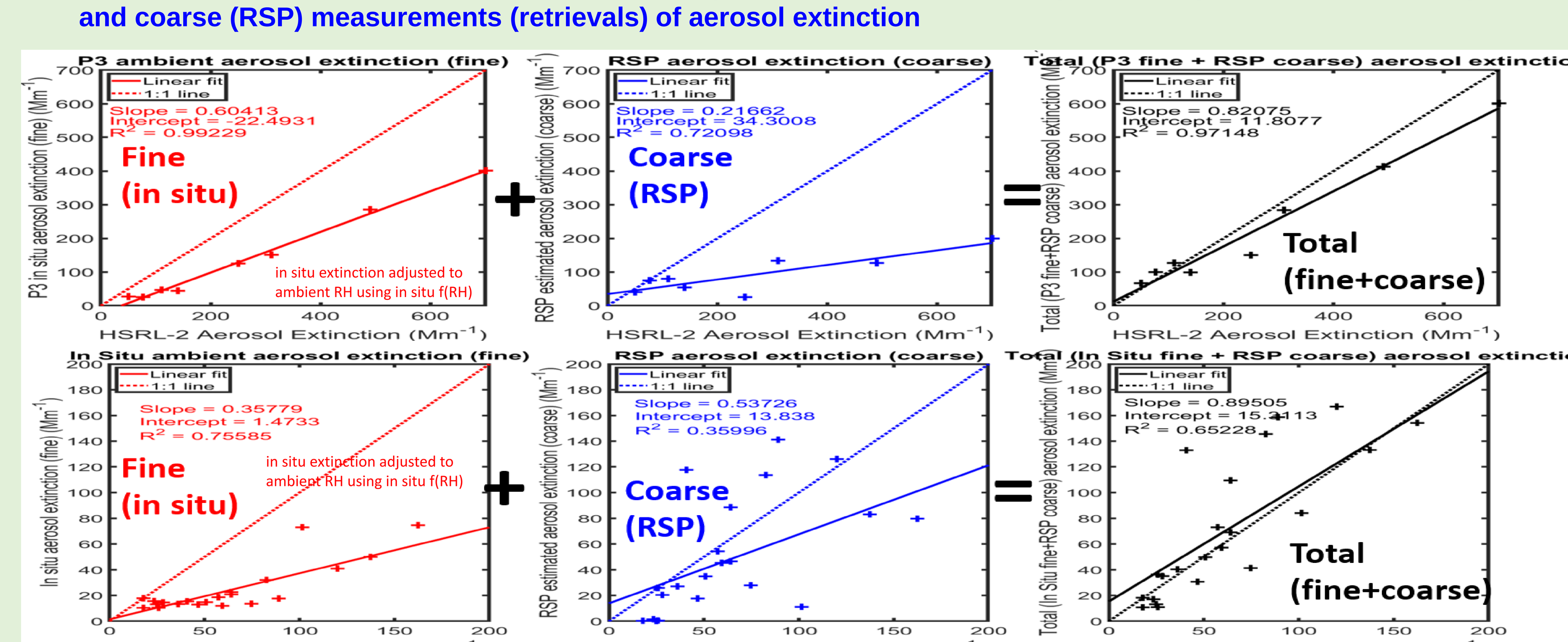
Coarse mode fraction from airborne in situ size measurements (FCDP number/ LAS fine mode number)



HSRL-2 measurements of aerosol extinction compare best with sum of fine (in situ - adjusted to ambient RH) and coarse (RSP) measurements (retrievals) of aerosol extinction

CAMP2Ex

ACTIVATE

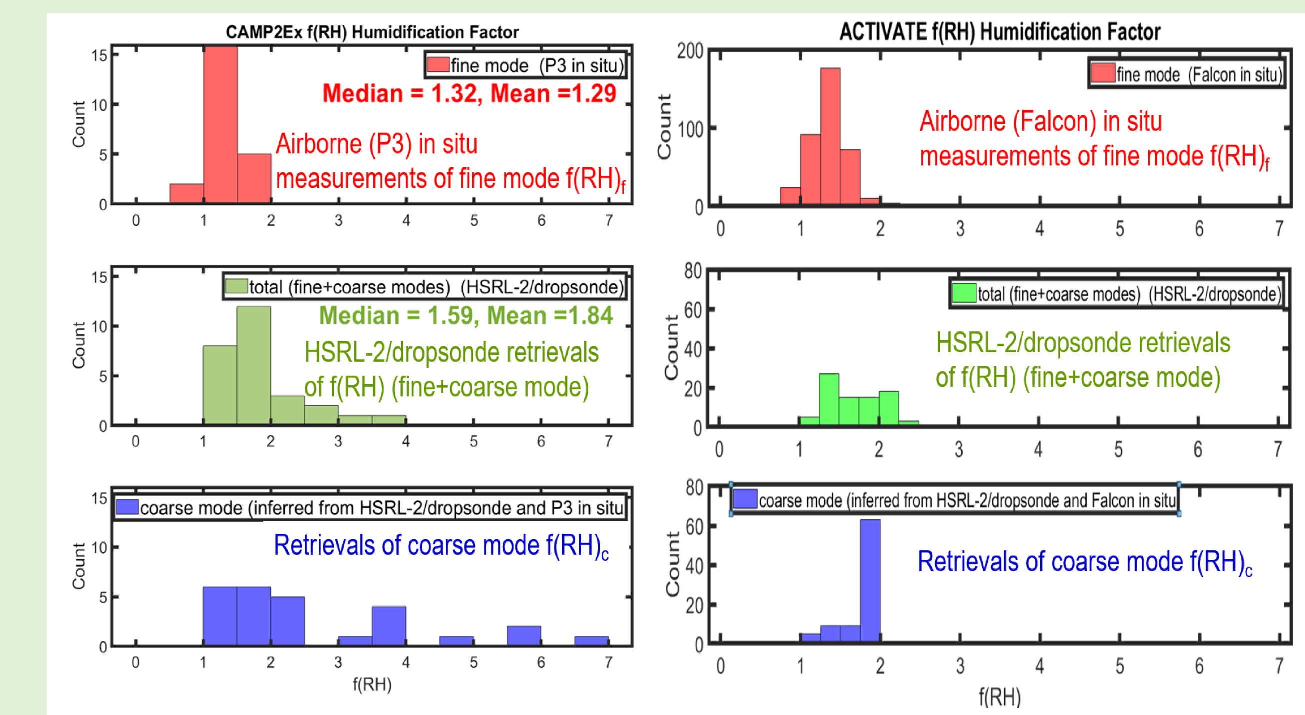


Results

Inferring f(RH) for coarse mode aerosol (sea salt)

- We infer coarse mode humidification factors based on aerosol humidification factors [f(RH)] derived from HSRL-2 and dropsonde measurements and airborne in situ measurements
- Assumptions:
  - Coarse mode aerosol is comprised of sea salt and is entirely within PBL
  - In situ measurements of f(RH) correspond to only fine mode
- Coarse mode aerosol extinction is estimated from Research Scanning Polarimeter (RSP) retrievals of coarse mode aerosol optical depth (AOD) and HSRL-2 retrievals of PBL height
- Fine mode aerosol extinction is derived from HSRL-2 measurements of total aerosol extinction and estimates of coarse mode aerosol extinction
- Coarse mode $f(RH)_c$ is derived from the change in aerosol extinction with RH measured by HSRL-2, in situ measurements of fine mode $f(RH)_f$ and estimates of fine and coarse mode aerosol extinction

➢ Mean values of coarse mode $f(RH)_c$ are around 2 and are consistent with values from literature (e.g. Titos et al., 2016)



Key Findings

- Average humidification factors [f(RH)] derived from HSRL-2 & dropsonde data were about 30% higher than f(RH) values derived from airborne in situ nephelometer measurements of aerosol scattering
  - (Aerosol Backscatter) $f(RH=80\%/RH=20\%)_\beta$ (532 nm) was about 1.7 (HSRL-2+dropsonde)
  - (Aerosol Extinction) $f(RH=80\%/RH=20\%)_\alpha$ (532 nm) was about 2.0 (HSRL-2+dropsonde)
  - (Aerosol Scattering) f(RH=80%/RH=20%) (550 nm) was about 1.35 (airborne in situ nephelometer)
- Aerosol extinction values measured by HSRL-2 were also higher than aerosol extinction values derived from airborne in situ measurements of aerosol scattering (adjusted to ambient RH) and absorption
- Higher f(RH) and aerosol extinction values derived from HSRL-2 are likely because the lidar observes both fine and coarse mode aerosol in contrast to airborne in situ measurements of predominantly fine mode aerosol
- Aerosol Extinction/Backscatter Ratio ("lidar ratio") increases 5-30% with RH, depending on RH range
- Average f(RH) similar at both 355 nm and 532 nm
- In situ and RSP retrievals indicate that the ratios of [in situ aerosol extinction/HSRL-2 aerosol extinction] and [in situ f(RH)/HSRL-2 f(RH)] decrease with increasing coarse mode aerosol
- Estimates of coarse mode (sea salt) f(RH) are around 2-3 based on f(RH) derived from HSRL-2 and in situ measurements and coarse mode aerosol extinction derived from RSP retrievals of coarse mode AOD.

References

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