Comparison of Remote Sensor and In-Situ Aerosol Properties

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ACTIVATE Science Team Meeting, 11/15/23

Overview

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Science question

How do we compare ambient aerosol measurements (King Air) with in-situ measurements (Falcon)?

Method

Step 1: Retrieve dry imaginary refractive index (IRI)

- Spectral dry scattering and absorption coefficients (C)
- Dry aerosol size resolved number concentration (n^{o}) of particles with diameters from 3 to 3162 nm

Step 2: Retrieve hygroscopicity (κ)

- Ambient scattering coefficients
- Ambient relative humidity (RH)

Step 3: Cloud filtering and calculation of total ambient aerosol properties

- Ambient aerosol n^{o} of particles with diameters from 2 to 50 µm

Step 4: Collocation of remote sensors and in-situ data

Step 1: Retrieve dry imaginary refractive index (IRI)

$$\mathrm{CRI} = \mathrm{RRI} \pm \mathrm{IRI} * i$$

RRI: 1.55
IRI: <0.0001,0.001:0.001,0.04>

Measured dry scattering and absorption C

Measured Dry n^{o}

Calculated scattering and absorption C (MOPSMAP)

$$\zeta_{\mathrm{sca}} = \left|\frac{C_{\mathrm{calc}} - C_{\mathrm{meas}}}{C_{\mathrm{meas}}}\right|_{450,550,700}^{\mathrm{sca}} \times 100\%$$

$$\zeta_{\mathrm{abs}} = |C_{\mathrm{calc}} - C_{\mathrm{meas}}|_{470,532,660}^{\mathrm{abs}}$$

$\overline{\mathrm{IRI}}$ = mean(**IRI**), For all **IRI** where ζ_{sca} < 20% and ζ_{abs} < 1 Mm^{-1} in all three wavelengths

Step 2: Retrieve hygroscopicity (κ)

$$\left(\frac{\text{Ambient Diameter}}{\text{Dry Diameter}}\right)^3 = \left(\frac{D_{amb}}{D_{dry}}\right)^3 = g^3 = 1 + \kappa * \frac{RH}{100 - RH}$$

$\boldsymbol{\kappa}$: <0.01:0.01:1.40>
$\overline{\mathbf{IRI}}$

Measured ambient scattering C

Measured Dry
n^{o}
Ambient RH

Calculated scattering C (MOPSMAP)

$$\zeta_{\text{sca}} = \left|\frac{C_{\text{calc}} - C_{\text{meas}}}{C_{\text{meas}}}\right|_{550}^{\text{sca}} \times 100\%$$

$\overline{\boldsymbol{\kappa}}$ = $\boldsymbol{\kappa}$, for smallest $\boldsymbol{\kappa}$ where $\zeta_{\text{sca}} < 1\%$

Internal Closure

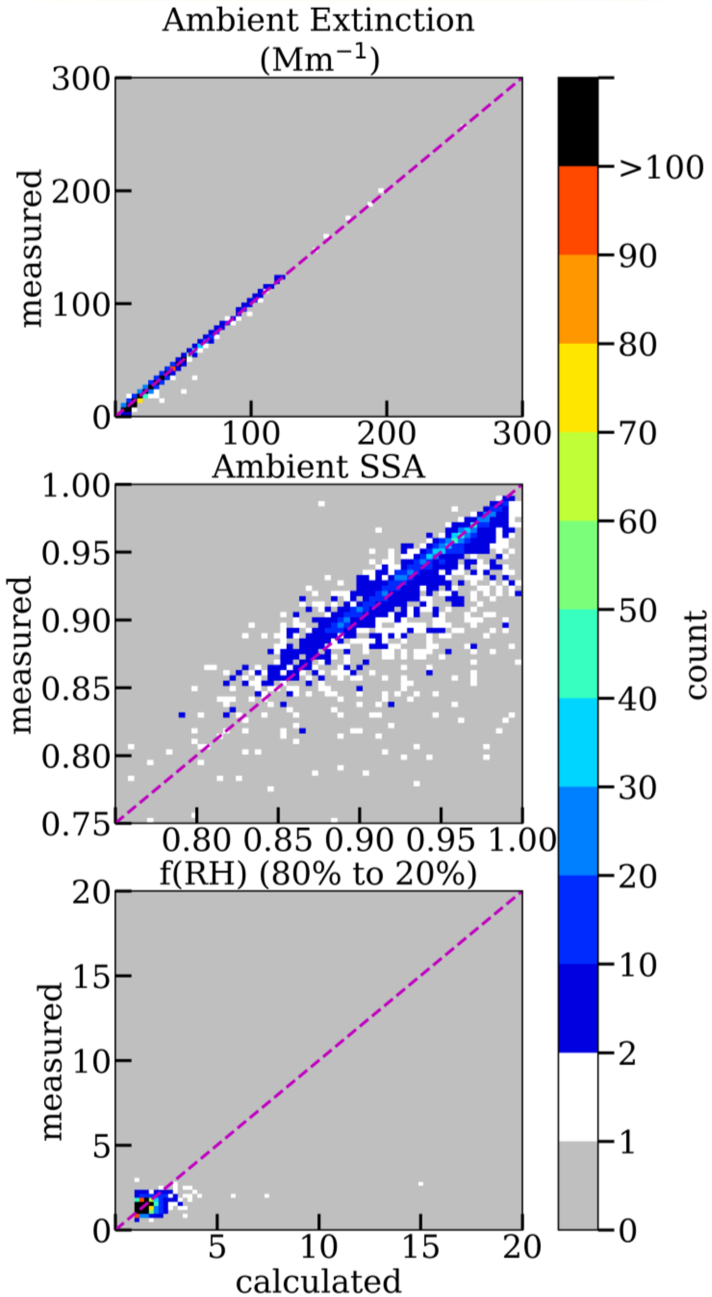
- Ambient extinction at 532 nm agrees to within 0.5%
- Ambient SSA at 532 nm agrees to within 3%
- f(RH) agrees to within 4%

Normalized-range mean absolute deviation (NMAD)

$$\sum_{j=1}^{n} \frac{|Y_j - X_j|}{n} \cdot \frac{100\%}{\max(X) - \min(X)}$$

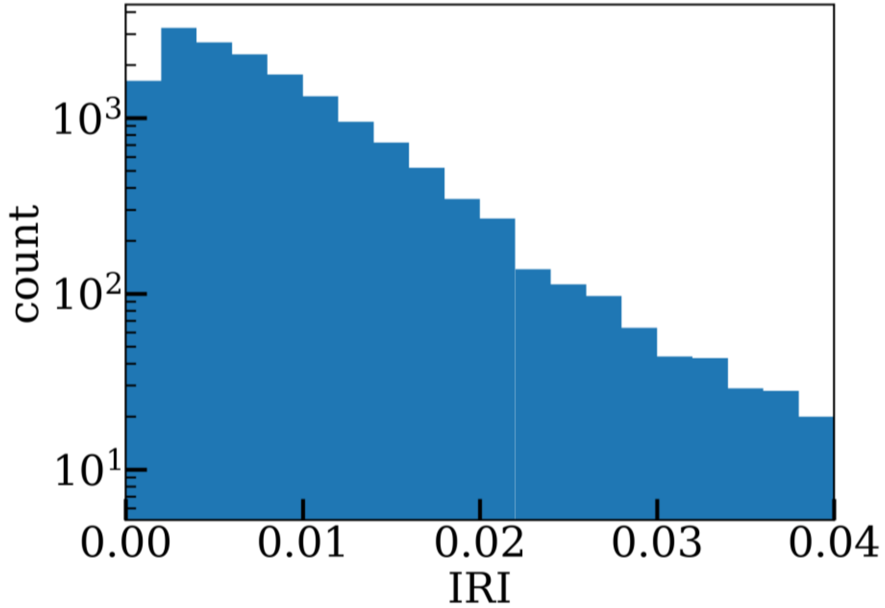
where Y_j is set of calculated data, X_j is set of measurement data, and n is the total number of points.

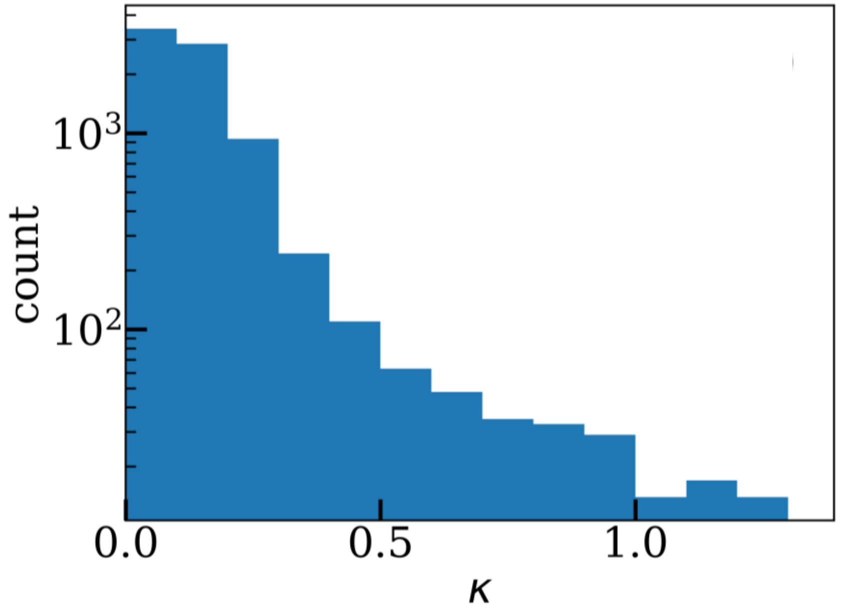
	Extinction	SSA	f(RH)
NMAD (%)	0.1	2.4	1.8



IRI and Kappa

- Most data have low-absorption and generally low hygroscopicity





Synthetic Closure

- Synthetic data are generated by randomly selecting values for IRI, *κ*, and the size distribution.
  - RRI is fixed to 1.55.
  - IRI is randomly selected from 0.0001 to 0.040
  - *κ* is randomly selected from 0.01 to 1.40
  - Size distribution is randomly selected from a normal distribution around the mean of the ACTIVATE size distributions.
- Accuracy (systematic uncertainty) and precision (random uncertainty) are 1 standard deviation assuming a normal distribution.
- After synthetic data are generated, the precision offset is applied followed by the accuracy offset.
  - Offsets are applied uniformly to each instrument’s measurements.

Synthetic Closure

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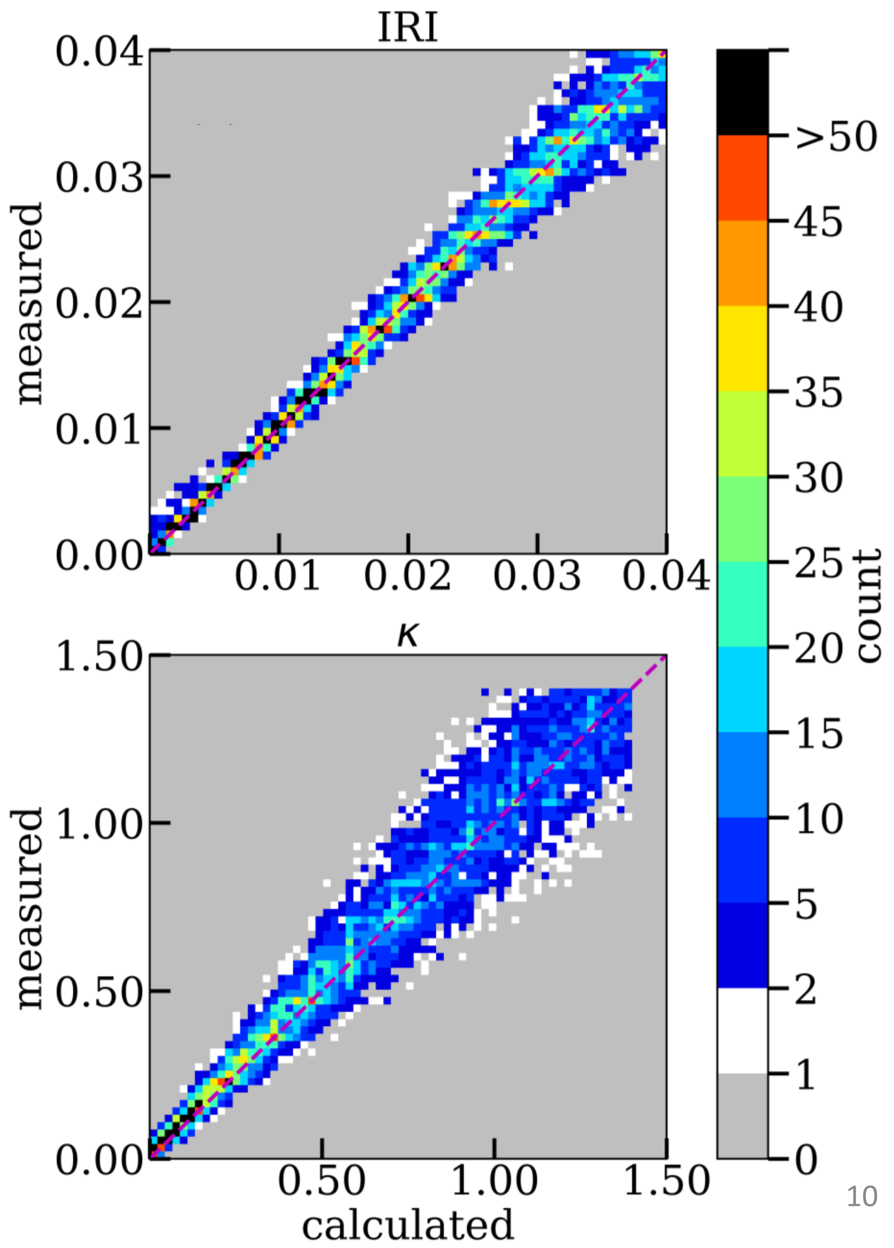
Instrument	Measurement	Resolution (s)	Systematic	Random
Tricolor Particle Soot Absorption Photometer (PSAP)	Dry Absorption Coefficients at 470, 532, and 660 nm	1	15%	1 Mm^{-1}
Nephelometers	Dry Scattering Coefficients at 450, 550, and 700 nm Ambient Scattering Coefficient at 550 nm	1	20%	2 Mm^{-1}
Scanning Mobility Particle Sizer (SMPS)	Size resolved number concentration for particles with diameters between 3 and 94 nm	45	20%	-
Laser Aerosol Spectrometer (LAS)	Size resolved number concentration for particles with diameters between 94 and 3162 nm	1	20%	-

Synthetic Closure

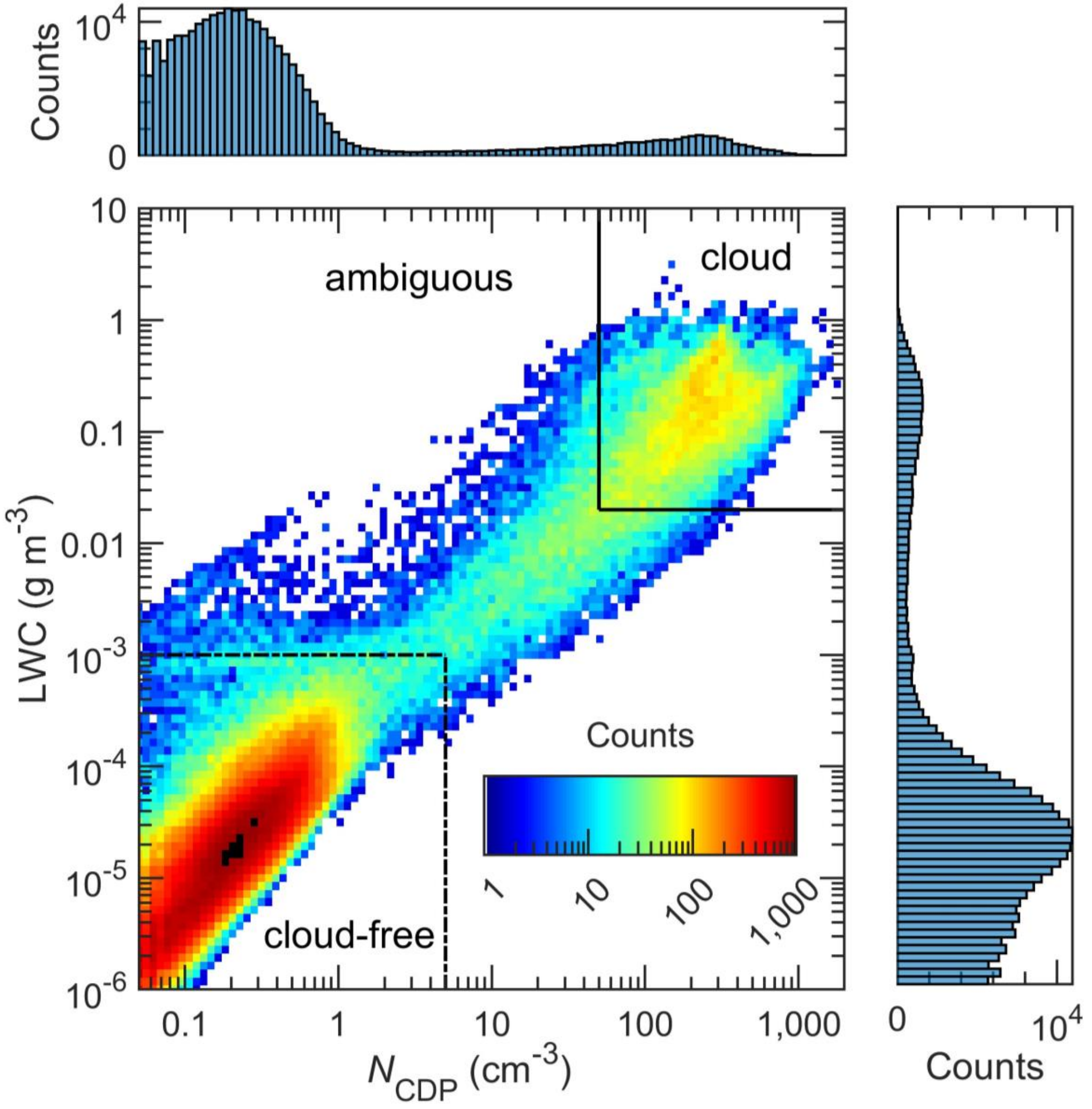
- From Monte Carlo simulations, retrieved IRI and κ have expected NMAD of 9.6% and 8%, respectively.
- Out of 10,000 simulations, 37% had successful IRI retrievals and 34% had successful retrievals of both IRI and κ.

	IRI	κ
NMAD (%)	9.6	8.0



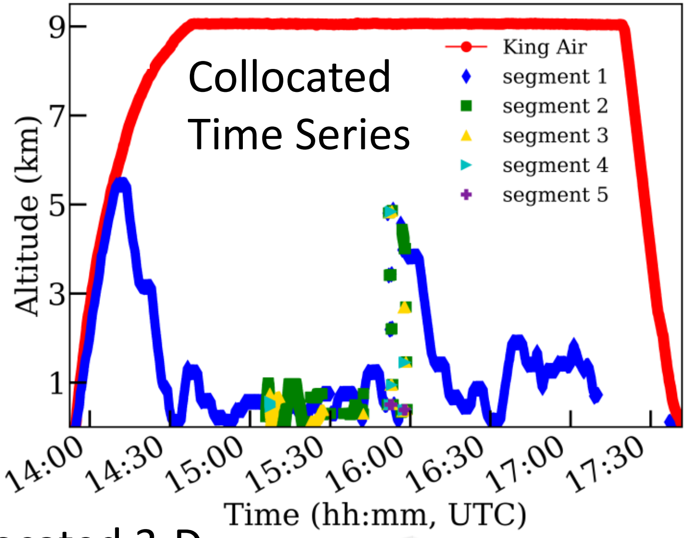
In-Situ Cloud Filtering

- Total ambient aerosol calculations require probe measurements of coarse aerosol.
  - Cloud Droplet Probe (CDP)
- All ambiguous and cloud data filtered out using the liquid water content (LWC) and CDP droplet number concentration (N_{CDP}) upper limits of 0.001 g m^{-3} and 5 cm^{-3}, respectively (Schlosser et al., 2022).
- Additionally, the counterflow virtual impactor (CVI) inlet flag was used to ensure no cloud contamination.

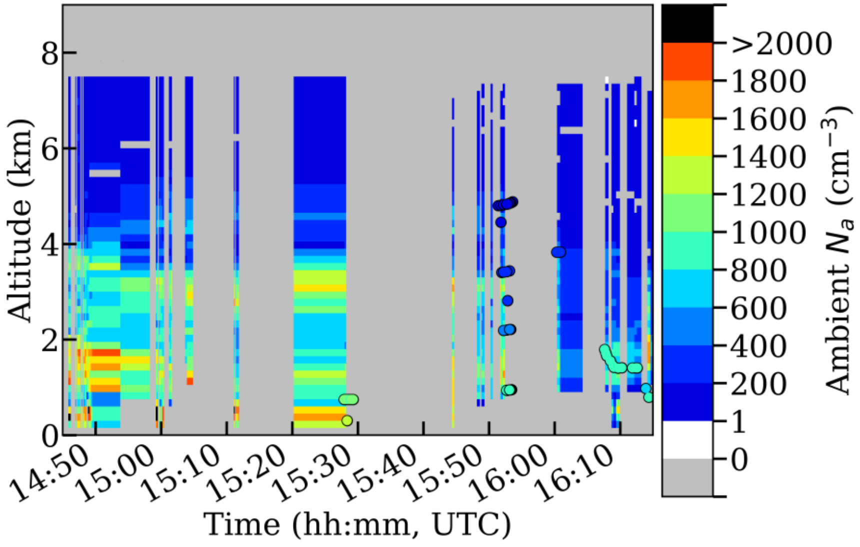


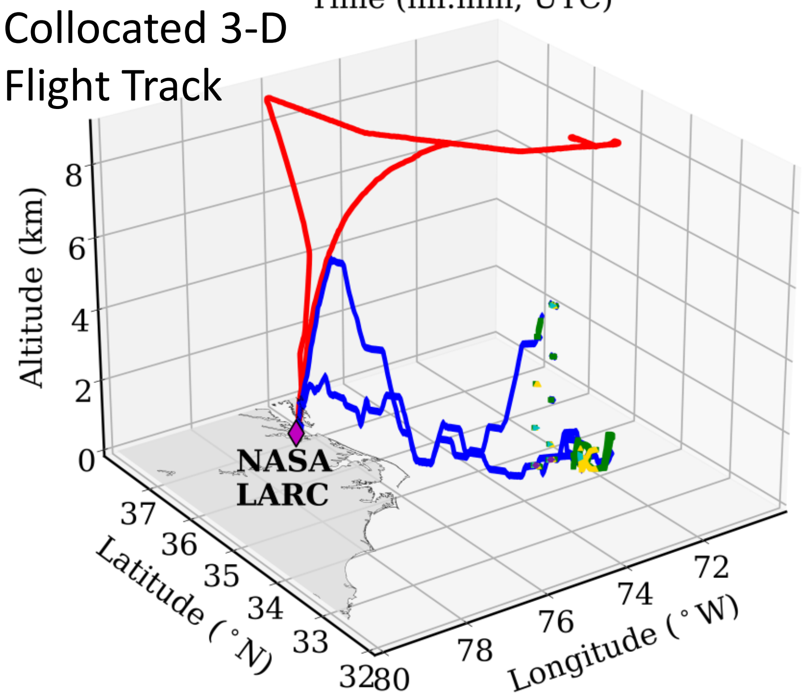
Schlosser, J. S., and Coauthors, 2022: Polarimeter + lidar–derived aerosol particle number concentration. Frontiers in Remote Sensing, 3, https://doi.org/10.3389/frsen.2022.885332.

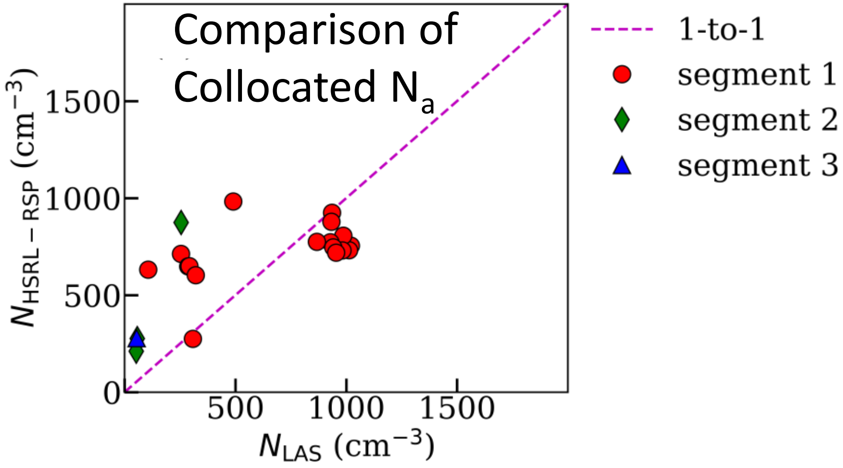
- RSP/HSRL-2 data are collocated using the collocation method developed and demonstrated in Schlosser et al., 2023.
- 73.0% of the valid time segments are within 5 minutes and 6 km.
- Maximum 6 min-15 km spatiotemporal threshold applied for the King Air and the Falcon separation.



Collocated Time Series Colored by Aerosol Number Concentration

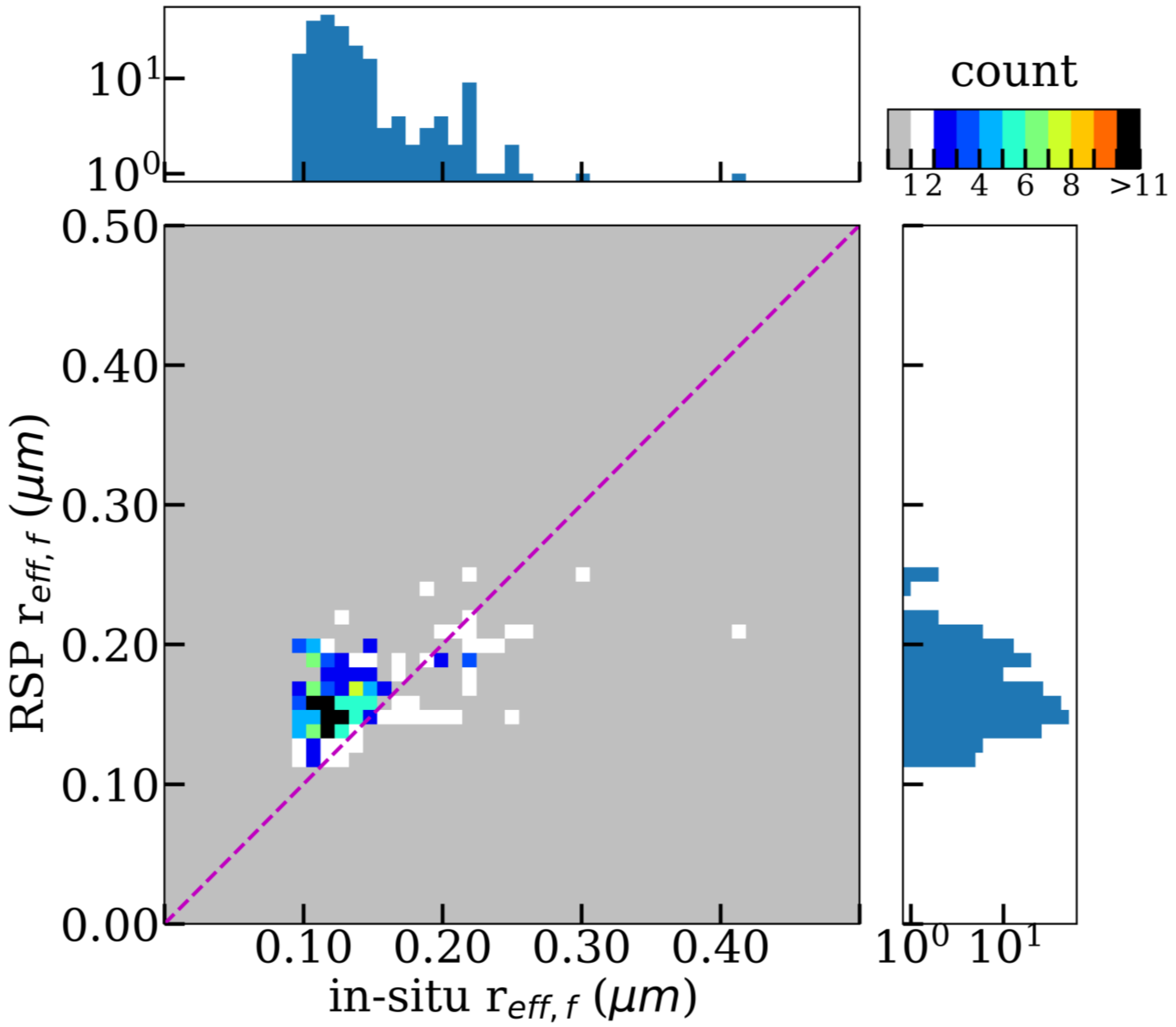




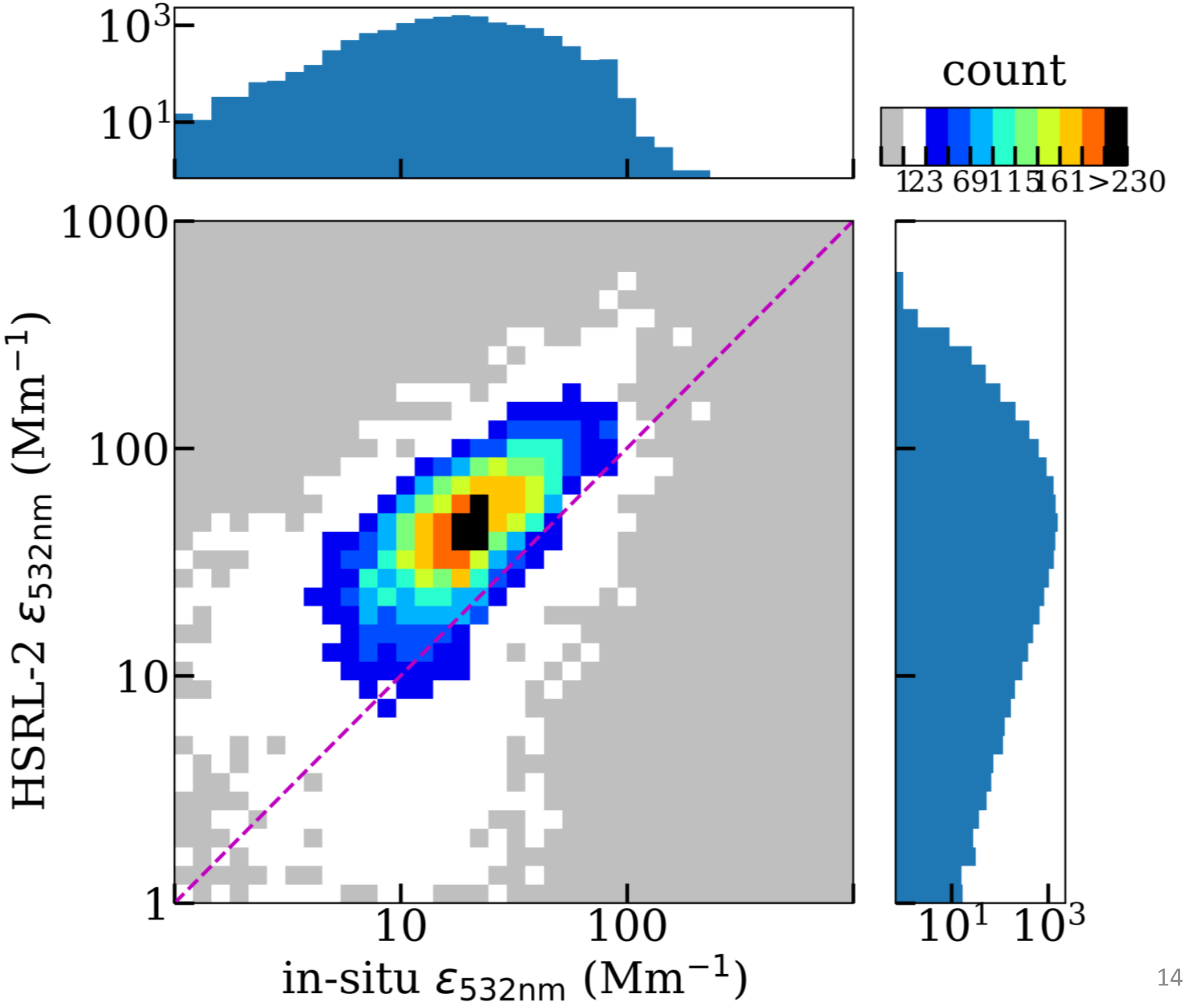


Schlosser, J. S., and Coauthors, (TBD): Maximizing the volume of collocated data from two coordinated suborbital platforms, submitted to Journal of Atmospheric and Oceanic Technology

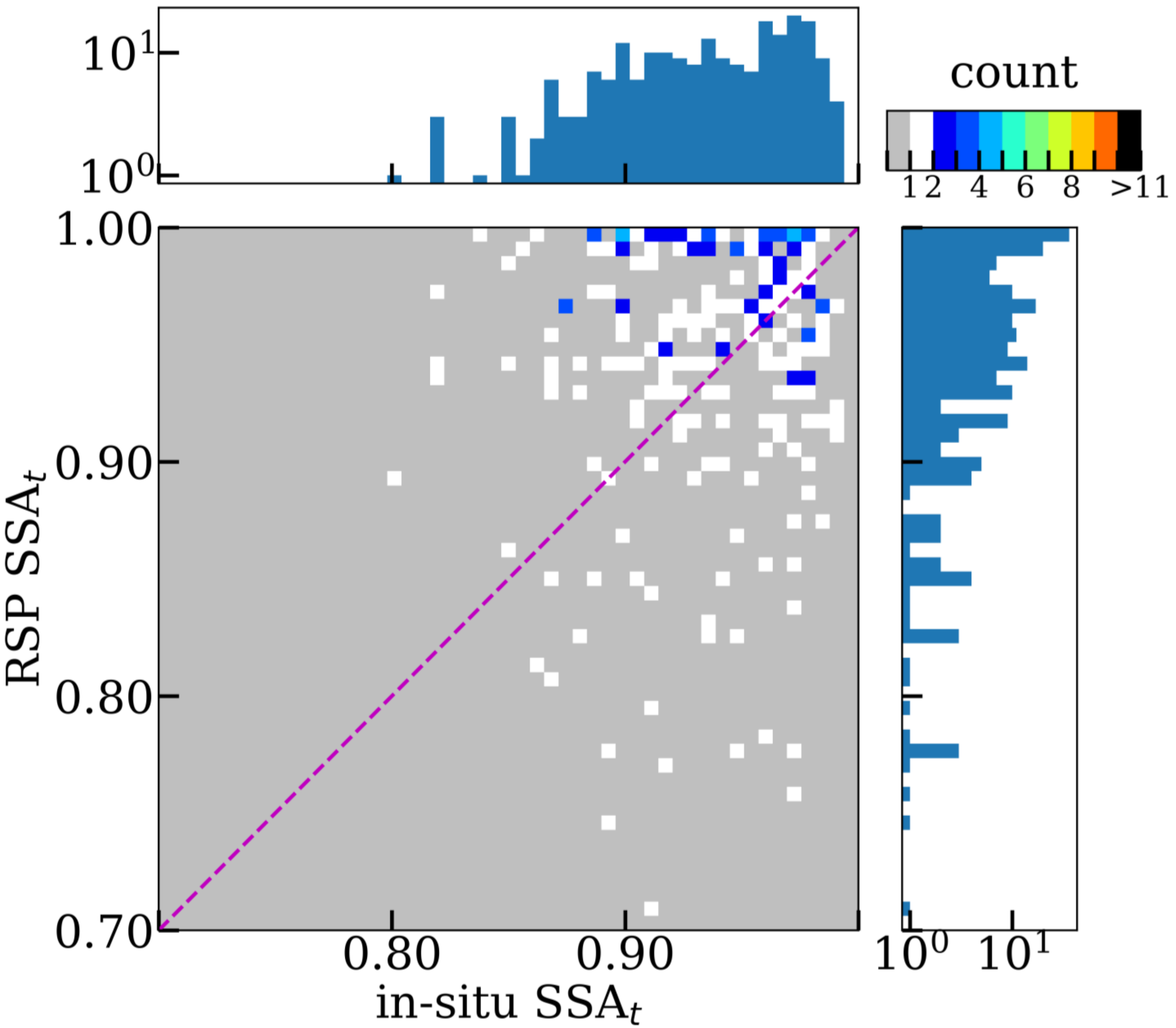
- RSP-derived vs. in-situ-derived fine-mode effective radius ($r_{eff,f}$)
- NMAD: 16%
- Count: 133
- RSP Resolution: Number of RSP scans × scan duration = 5 scans × $\left(\frac{60 \text{ seconds}}{72 \text{ scans}}\right) \cong 4.167$ seconds
- Remove data where normalized cost function > 0.15 and where ambient particle diameter > 1.5 um
- Collocated to nearest level leg and vertical profile



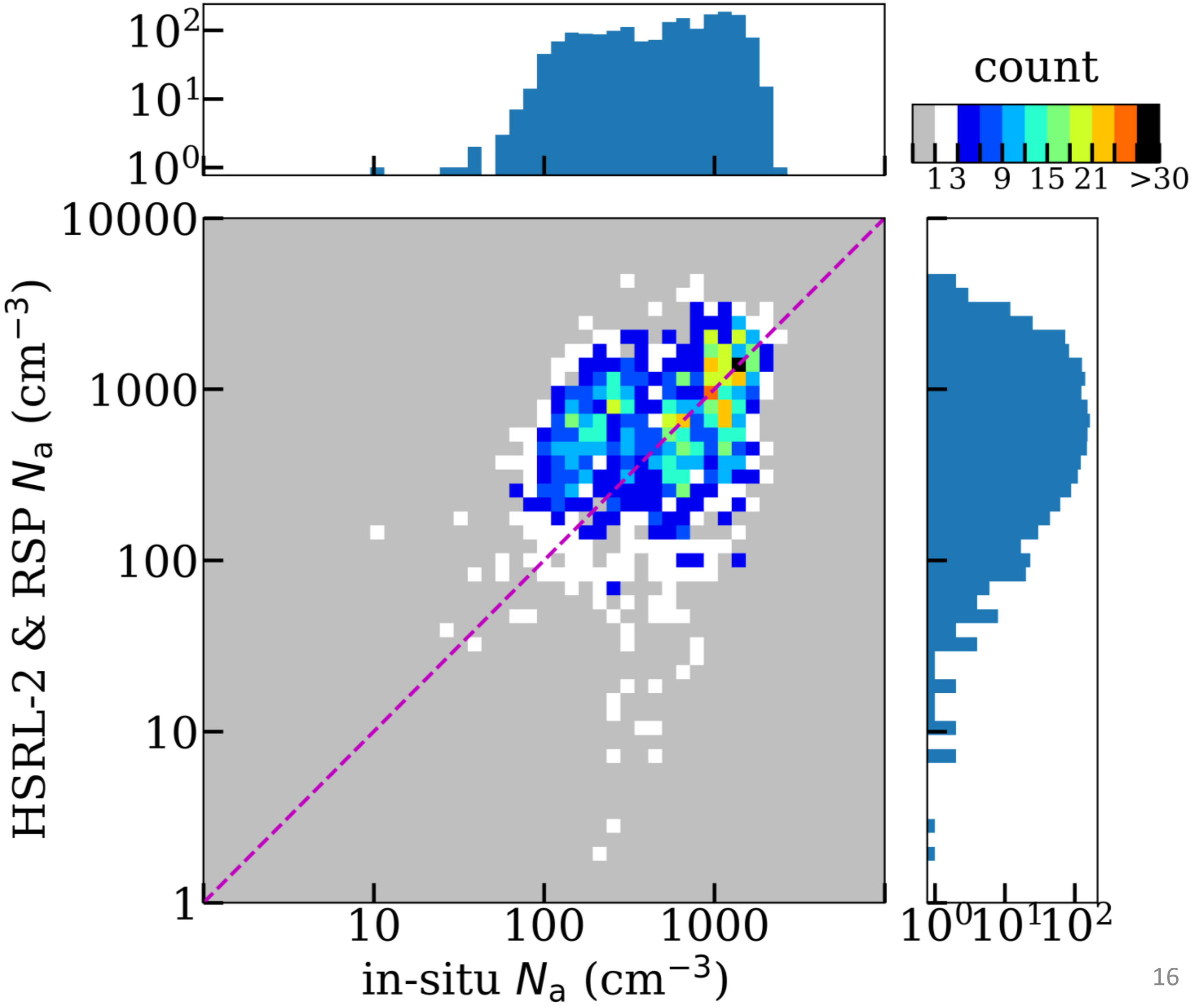
- HSRL-2-derived vs. in-situ derived extinction coefficient at 532 nm (ε_{532nm})
- NMAD: 4.5%
- Count: 14,153
- R: 0.59
- p-value: $<10^{-4}$
- Resolution: 10 seconds x 175 m



- RSP-derived vs. in-situ-derived fine-mode effective single scattering albedo (SSA_t) at 555 nm
- NMAD: 24%
- Count: 133



- HSRL-2- & RSP-derived vs. in-situ derived aerosol number concentration (N_a) of particles with ambient diameters greater than 90 nm
- NMAD: 8.5%
- Count: 1151
- R: 0.12
- p-value: $<10^{-4}$
- Filtered according to Schlosser et al., 2022




Questions?