

Retrieval of ambient aerosol properties from In-situ data

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Objective and Significance

- The objective of the in-situ aerosol retrieval algorithm (ISARA) is to derive ambient aerosol optical and microphysical products from a suite of direct (i.e., in-situ) measurements
- In particular, the algorithm produces ambient aerosol size and complex refractive index, for both fine-mode and coarse-mode aerosol size distributions
- The ISARA aerosol products can be directly compared to polarimeter aerosol products and to high spectral resolution lidar aerosol measurements
- The ISARA aerosol products can also provide insight into aerosol behavior in complicated atmospheric environments and near clouds

Methods Summary

Step 1: Retrieve dry complex refractive index (CRI)

- Spectral dry scattering and absorption coefficients
- Dry aerosol size resolved number concentration

Step 2: Retrieve hygroscopicity (κ)

- Hygroscopic growth function ($f(\text{RH})$)

Step 4: Calculate ambient aerosol properties

Step 3: Collocation (Schlosser et al., 2024)

Note: All aerosol properties calculated with the Modeled optical properties of ensembles of aerosol particles (MOPSMAP) package

- Schlosser, J. S., and Coauthors, 2024: Maximizing the Volume of Collocated Data from Two Coordinated Suborbital Platforms. *J. Atmos. Oceanic Technol.*, 41, 189–201, <https://doi.org/10.1175/JTECH-D-23-0001.1>.
- Gasteiger, J. and Wiegner, M.: MOPSMAP v1.0: a versatile tool for the modeling of aerosol optical properties, *Geosci. Model Dev.*, 11, 2739–2762, <https://doi.org/10.5194/gmd-11-2739-2018>, 2018.

In-situ Measurements Summary

- ❖ Dry aerosol particle size resolved number concentrations
 - DMT UHSAS (particle diameters from 0.06 to 0.1 μm)
 - TSI-3321 APS (particle diameters from 0.1 to 5 μm)
- ❖ Dry aerosol particle scattering coefficient at 450, 550, 700 nm wavelengths
 - TSI Scatter Nephelometer
- ❖ Dry aerosol particle absorption coefficient at 467, 530 and 660 nm wavelengths
 - PSAP
- ❖ Hygroscopic growth function
 - TSI Scatter Nephelometer
- ❖ Ambient relative humidity (RH)
 - DLH

Additional Analyses and Measurements

- Inlet efficiency and cut-off based on LARGE/CIRPAS analysis
- Real refractive index (RRI) constrained by LI-Nephelometer

Algorithm

Step 1: Retrieve dry complex refractive index (CRI)

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

RRI: 1.55

IRI: <0.0001,0.001:0.001:0.04>

Measured dry scattering and absorption coefficient (C_{dry})

Measured dry size distribution

Compute scattering and absorption coefficient (C_{calc})

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

450,550,700

$$\zeta_{\text{abs}} = \left| C_{\text{calc}} - C_{\text{dry}} \right|_{\text{abs}}$$

470,532,660

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

Algorithm

Step 2: Retrieve hygroscopicity (κ)

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

κ : <0.01:0.01:1.40>
CRI

Humidified scattering coefficient
($C_{\text{wet}} = C_{\text{dry}} * f(\text{RH})$)

Measured dry
size distribution
Ambient RH

Compute
scattering
coefficient (C_{calc})

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

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

ISARA products

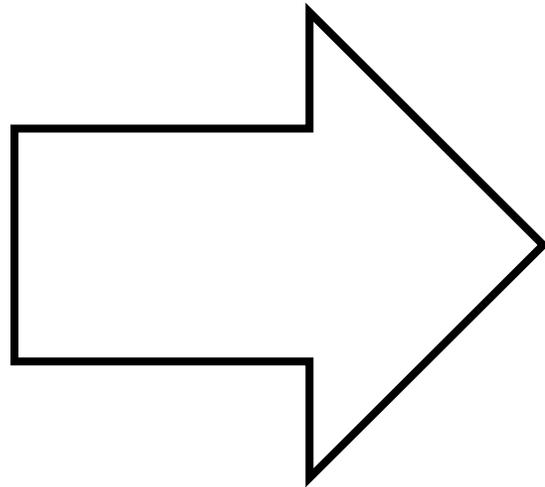
Inputs

κ

CRI

Total n°

D_{dry}



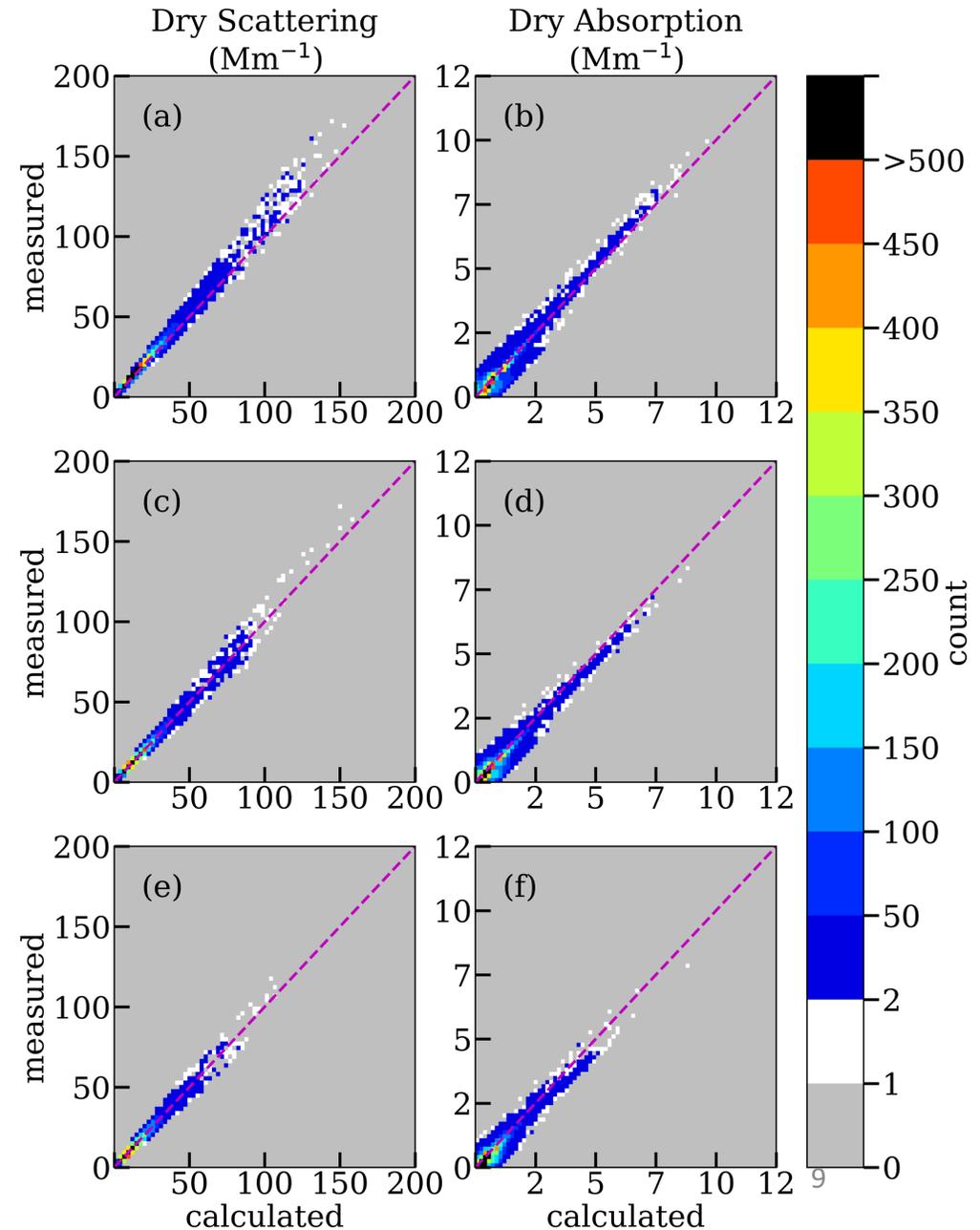
Ambient aerosol

properties:

- Total and size-resolved number, surface and volume concentration
- Spectral extinction coefficient and cross section
- Spectral single scattering albedo

Internal Closure (Dry)

- All results from ACTIVATE
- Scattering coefficients agree to within 1%
- Absorption coefficients agree to within 5%



	Scattering			Absorption		
Wavelength (nm)	450	550	700	470	532	660
NMAD (%)	0.7	0.6	0.8	2.7	2.7	3.0

Internal Closure (Dry)

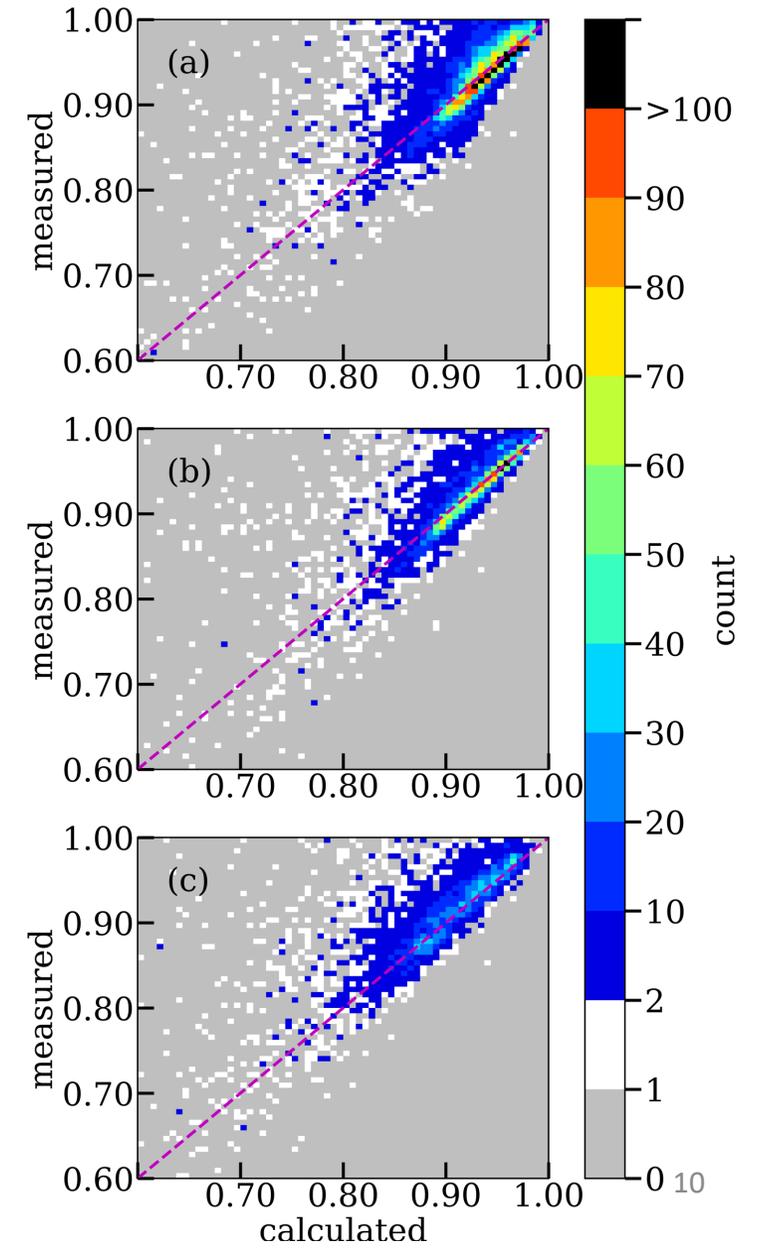
Single scattering albedo (SSA) to within 5%.

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.

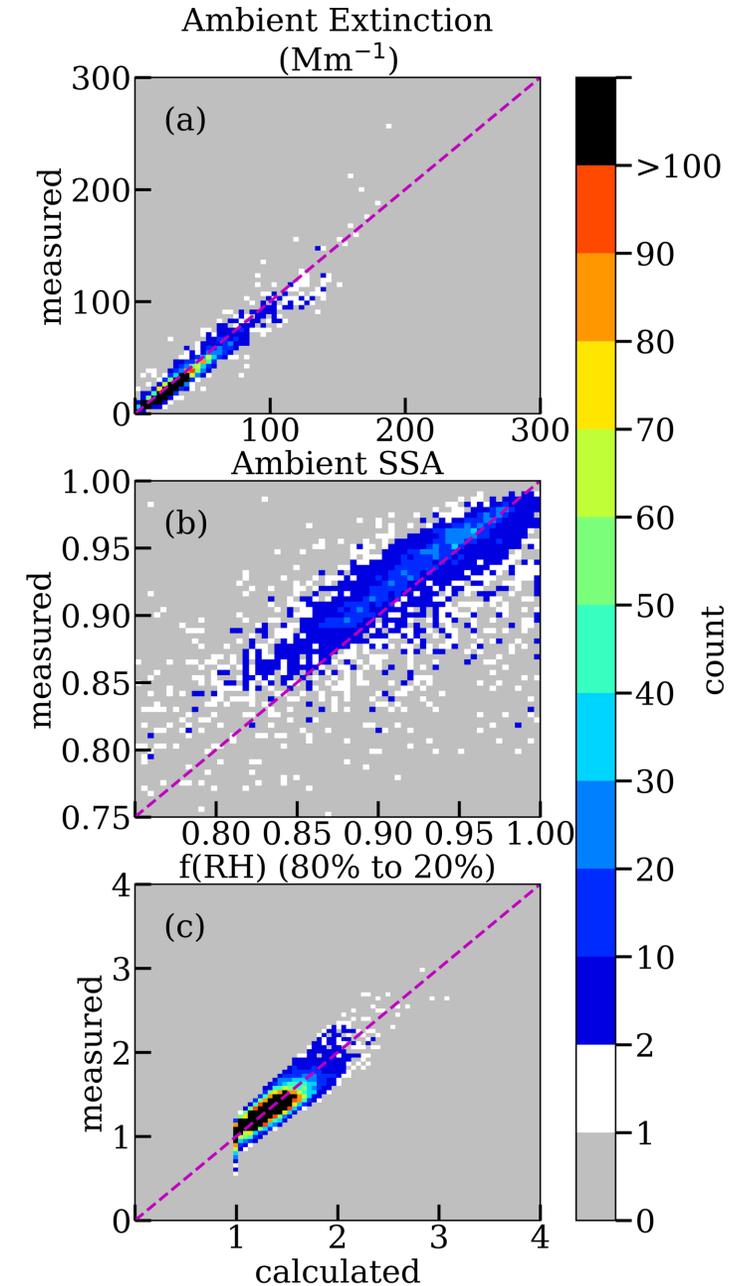
	SSA		
Wavelength (nm)	450	550	700
NMAD (%)	5.0	3.9	4.7



Internal Closure (Ambient)

- Ambient extinction at 532 nm agrees to within 0.5%
- Ambient SSA at 532 nm agrees to within 7%
- $f(\text{RH})$ agrees to within 7%

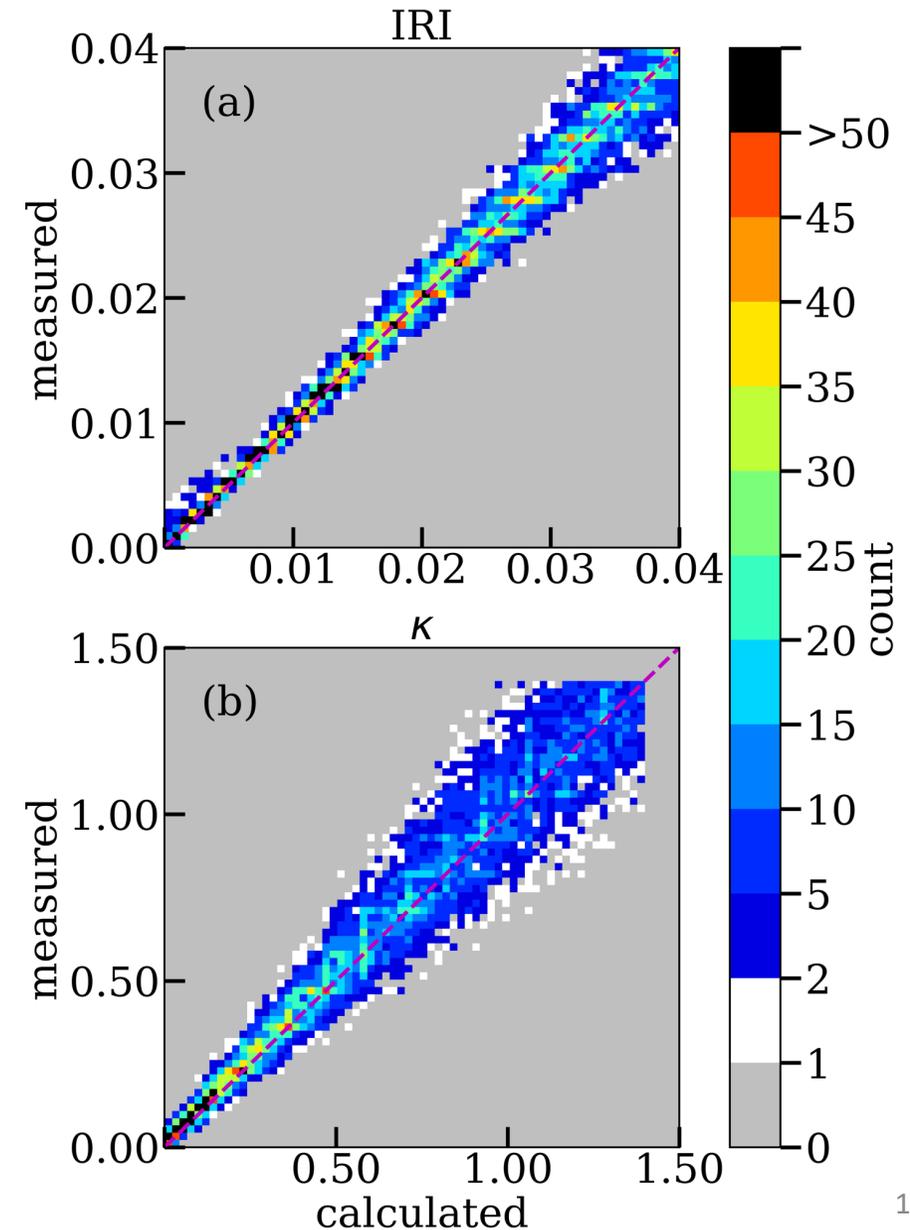
	Extinction	SSA	$f(\text{RH})$
NMAD (%)	0.3	6.9	6.4



Synthetic Closure

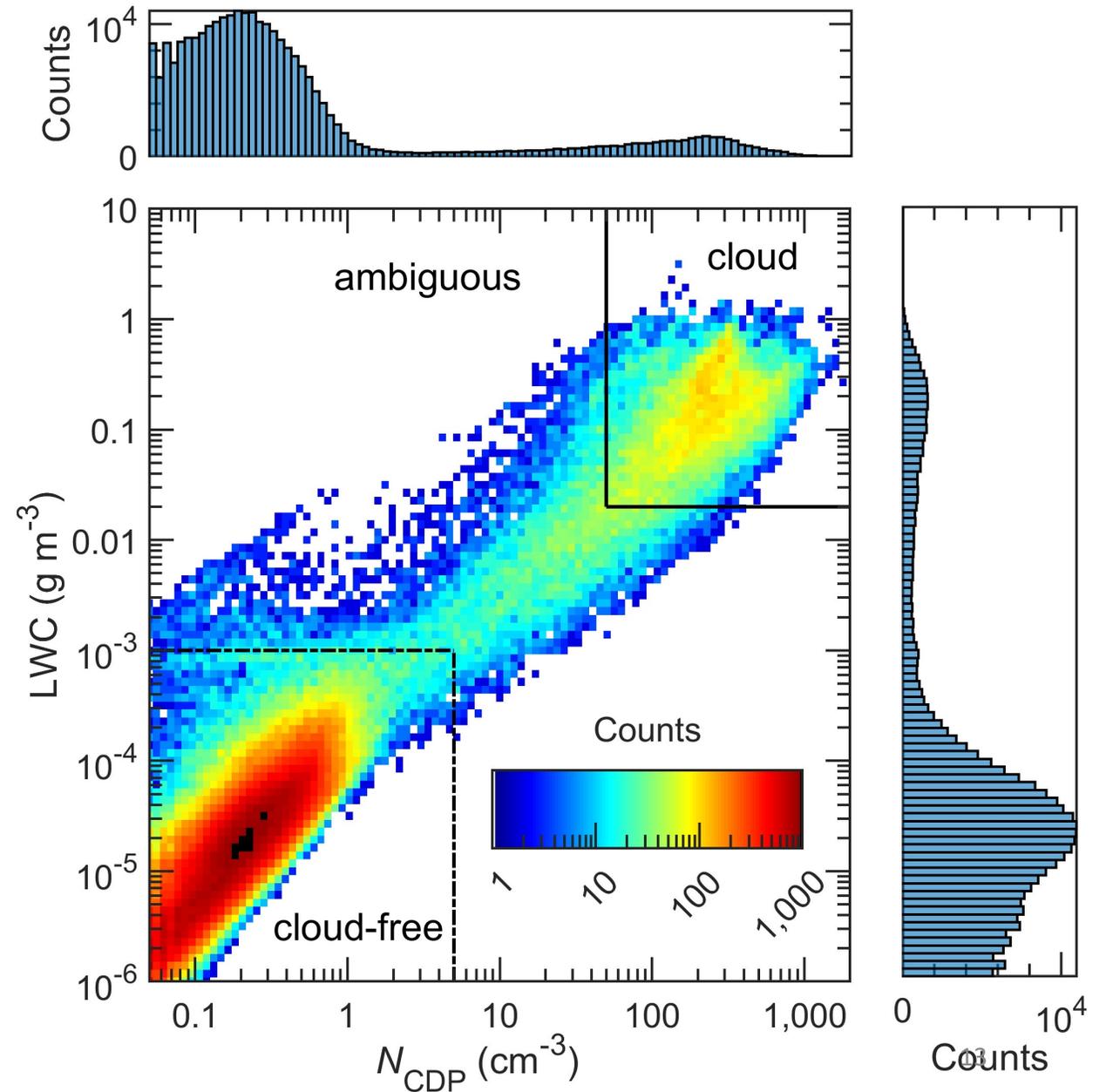
- From Monte Carlo simulations, retrieved IRI and κ have expected NMAD of 9.6% and 8%, respectively.
- Out of 10,000 simulations, 37% had successful IRI retrievals and 34% had successful retrievals of both IRI and κ .

	IRI	K
NMAD (%)	5.5	4.8



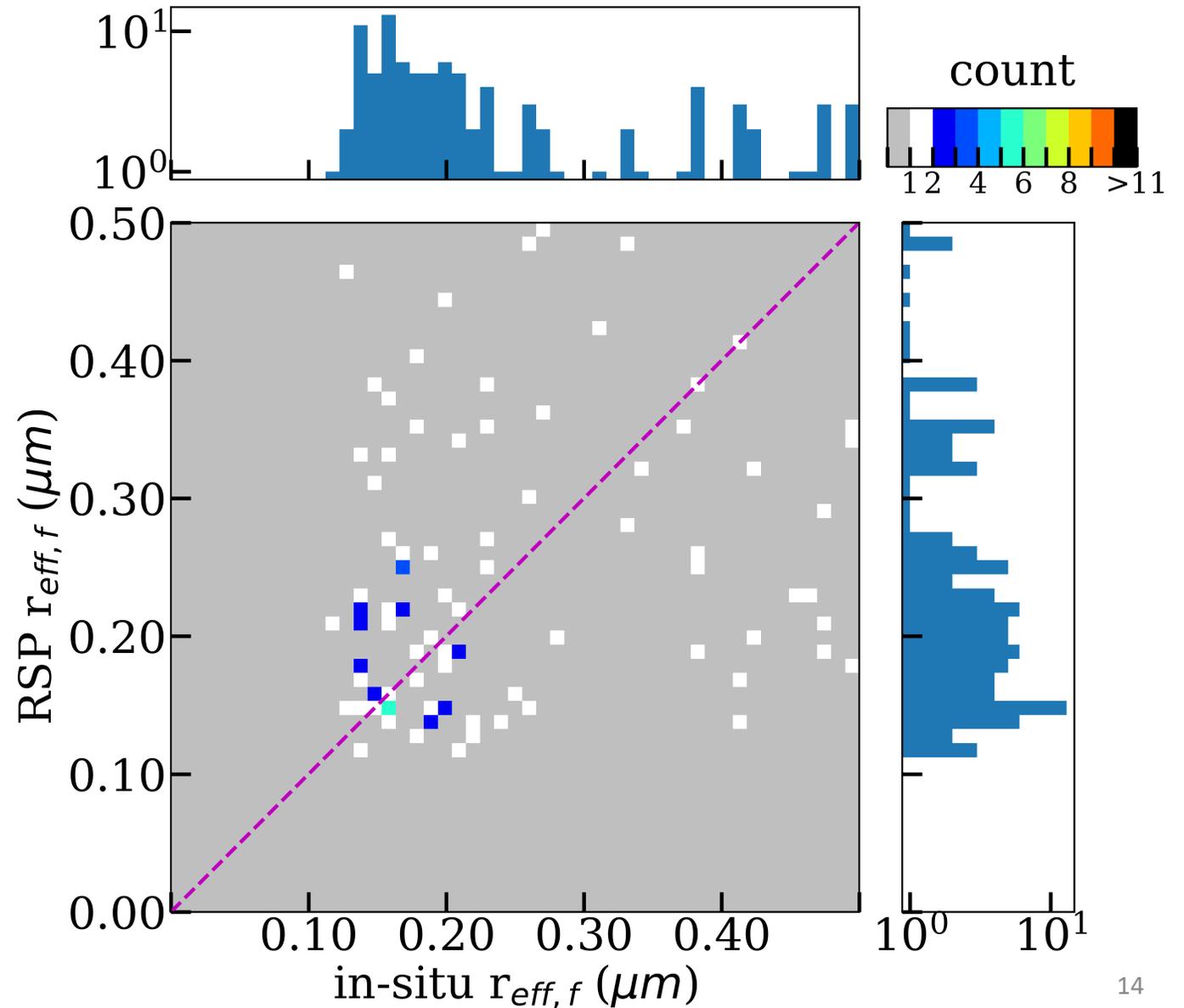
External Closure

- Final ambient aerosol calculations require probe measurements of coarse aerosol
 - Cloud Droplet Probe (CDP)
- RSP/HSRL-2 data are collocated using the collocation method developed and demonstrated in Schlosser et al., 2024



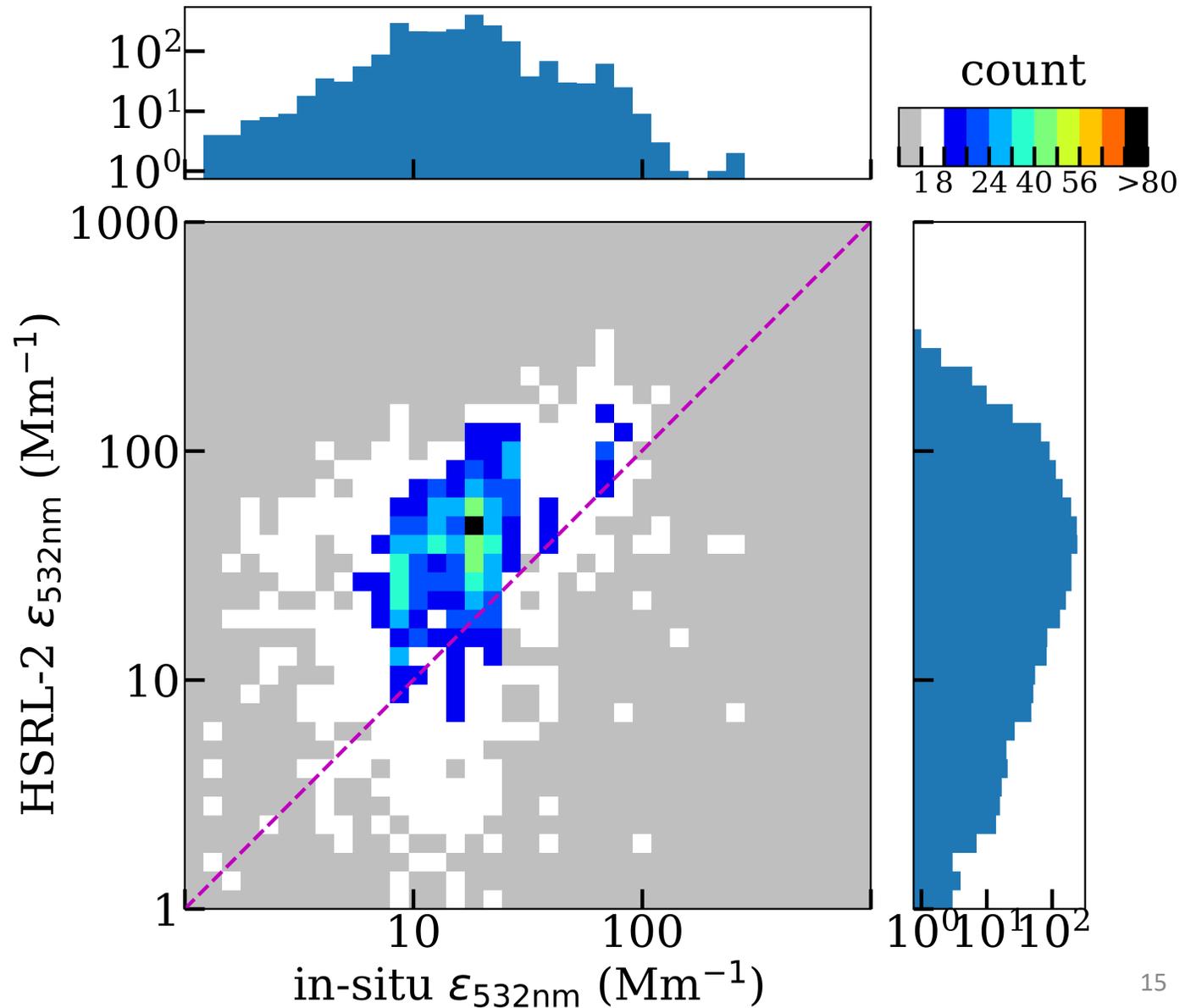
External Closure

- RSP-derived vs. in-situ-derived fine-mode effective radius ($r_{\text{eff},f}$)
- NMAD: 20.2%
- Count: 104
- Resolution: Number of RSP scans \times scan duration = 5 scans \times $\left(\frac{60 \text{ seconds}}{72 \text{ scans}}\right) \cong 4.167 \text{ seconds}$
- Remove data where normalized cost function > 0.05



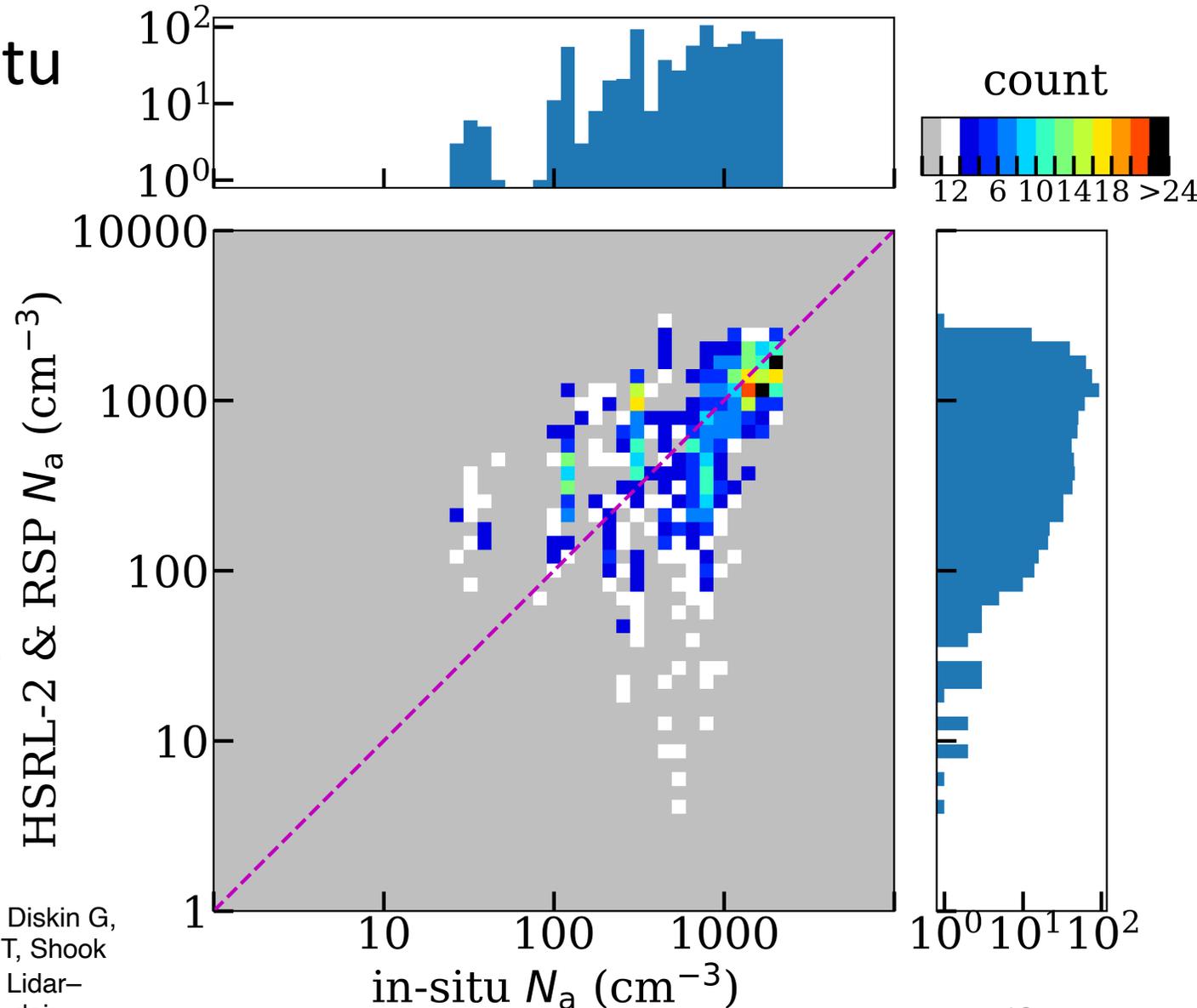
External Closure

- HSRL-2-derived vs. in-situ derived extinction coefficient at 532 nm ($\epsilon_{532\text{nm}}$)
- NMAD: 9.3%
- Count: 2,306
- R: 0.49
- p-value: $<10^{-4}$
- Resolution: 10 seconds x 175 m



External Closure

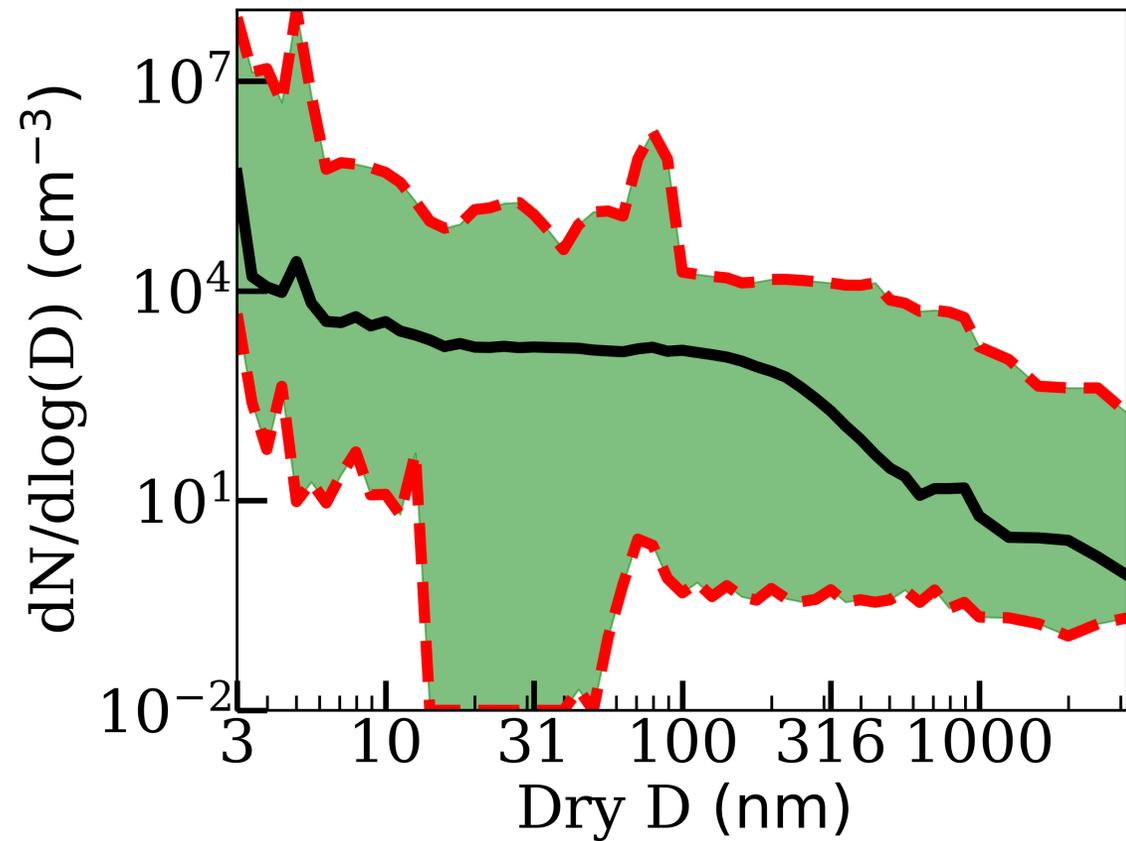
- HSRL-2- & RSP-derived vs. in-situ derived aerosol number concentration (N_a)
- NMAD: 12%
- Count: 804
- R: 0.67
- p-value: $<10^{-4}$
- Filtered according to Schlosser et al., 2022



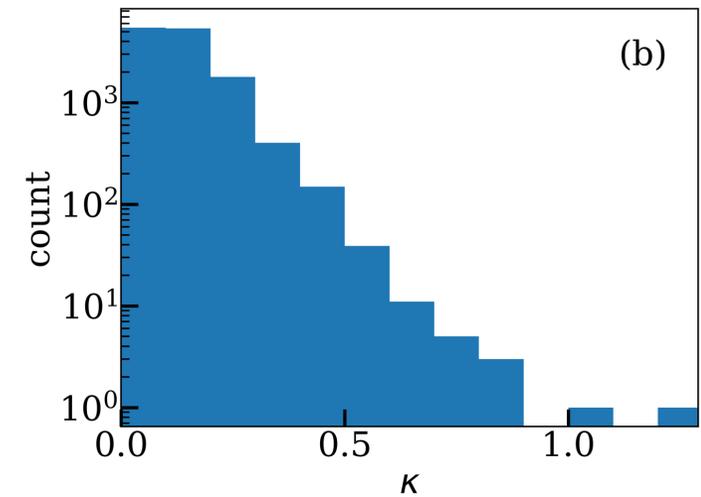
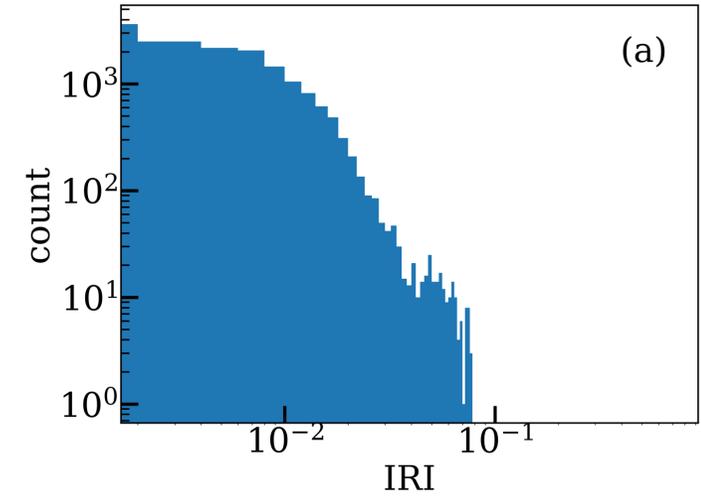
An aerial photograph of a coastline. The left side shows a rugged, brownish coastline with cliffs and a road. The right side shows a vast expanse of blue water under a cloudy sky. A semi-transparent grey rectangular box is centered in the lower half of the image, containing the word "Questions?" in a large, black, sans-serif font.

Questions?

- There is a small coarse mode present in low number concentrations but even for ACTIVATE 2020, this is not common.



- Retrieved IRI and hygroscopicity (κ) follow expected trends.
- Low-absorption and generally low hygroscopicity.

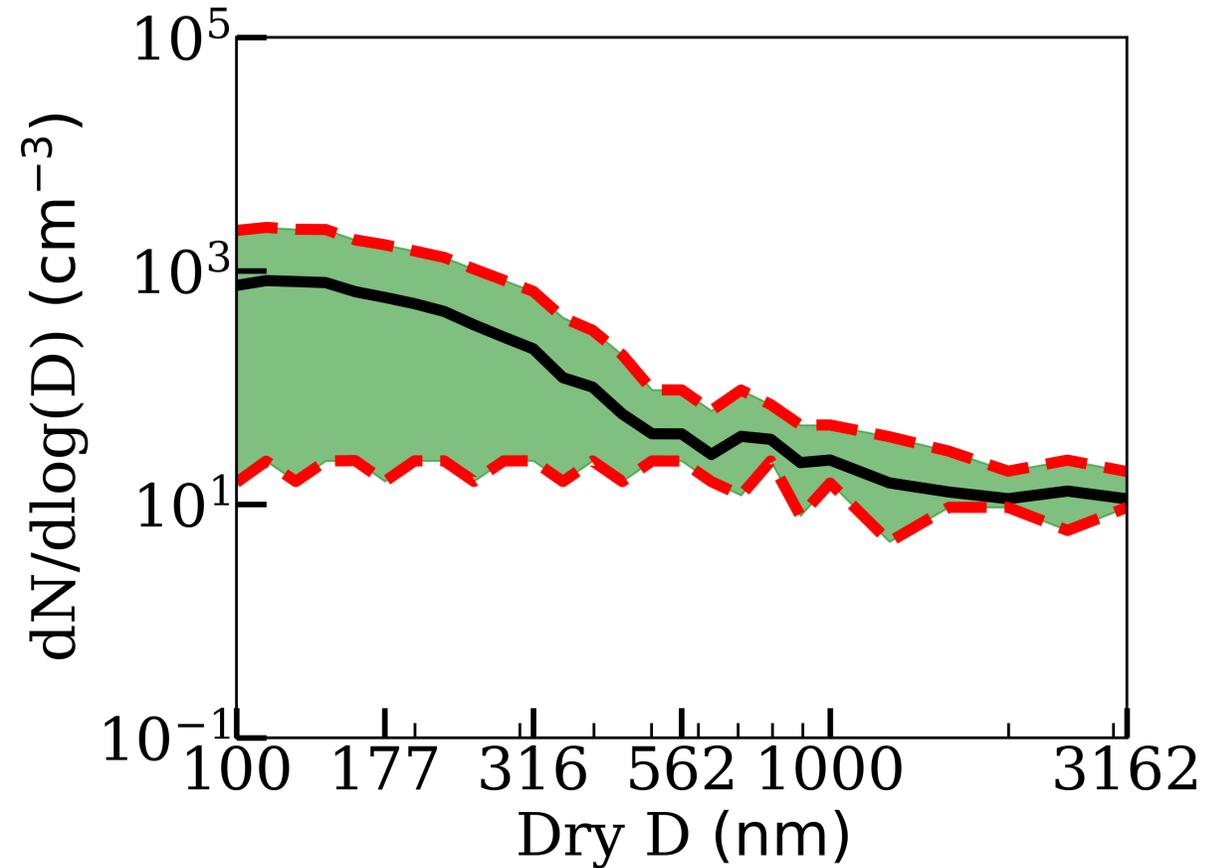


- Synthetic data are generated by randomly selecting values for IRI, κ , and the size distribution.
 - RRI is fixed to 1.55.
 - IRI: 0.0001 to 0.04
 - κ : 0.01 to 1.40
 - SD: randomly select from 0, 10, 25, 50, 75, 90, and 100 percentile of ACTIVATE size distributions.
- Accuracy (systematic uncertainty) 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.

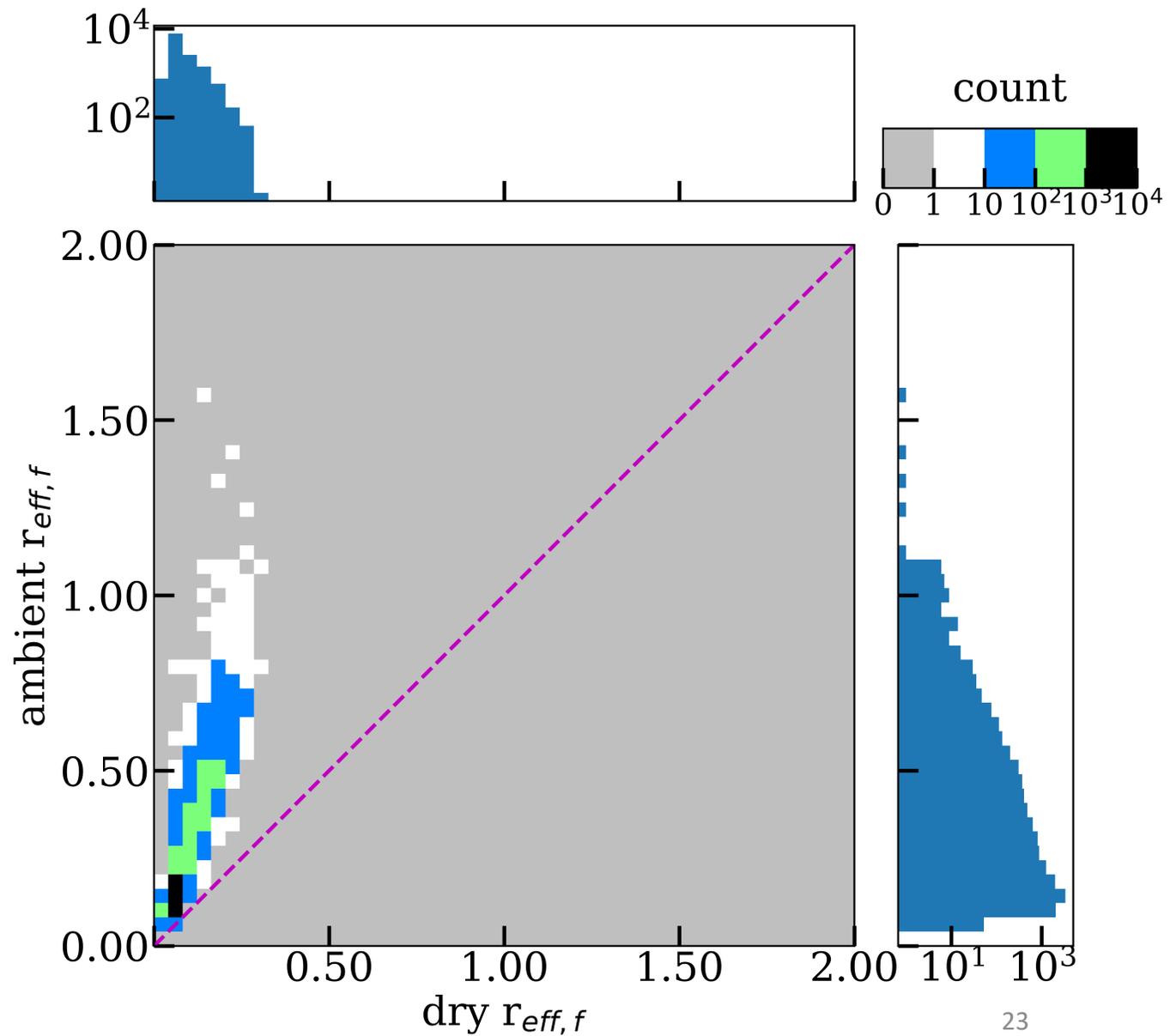
- After synthetic data are generated, the precision offset is applied followed by the accuracy offset.
 - Offsets are applied uniformly to each instrument's measurements.

Instrument	Measurement	Systematic	Random
PSAP	Dry Absorption Coefficients at 470, 532, and 660 nm	15%	1 Mm ⁻¹
Nephelometers	Dry Scattering Coefficients at 450, 550, and 700 nm Ambient Scattering Coefficient at 550 nm	20%	2 Mm ⁻¹
LAS	Size resolved number concentration	20%	-

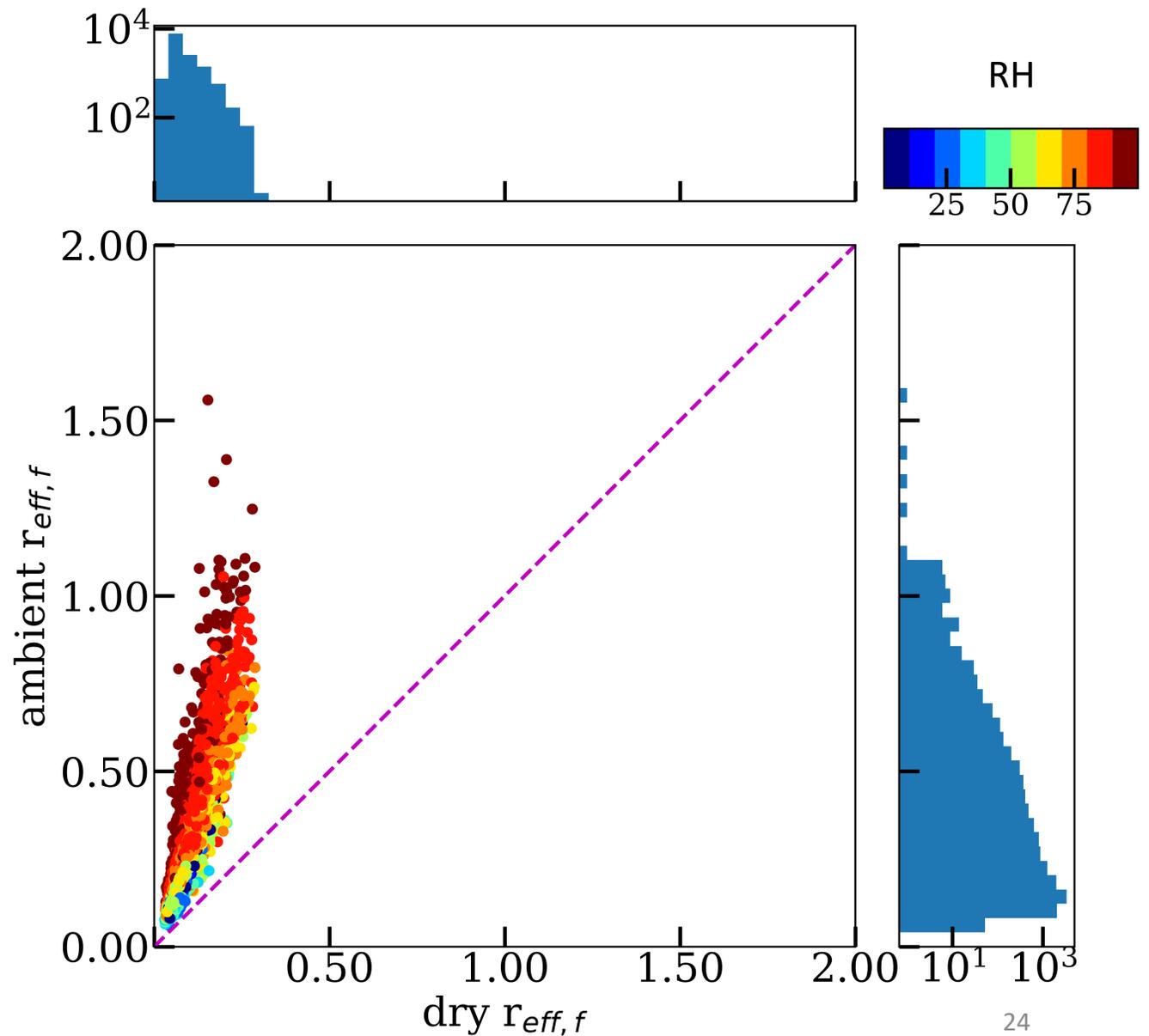
- There is a small coarse mode present in low number concentrations but even for ACTIVATE 2020, this is not common.



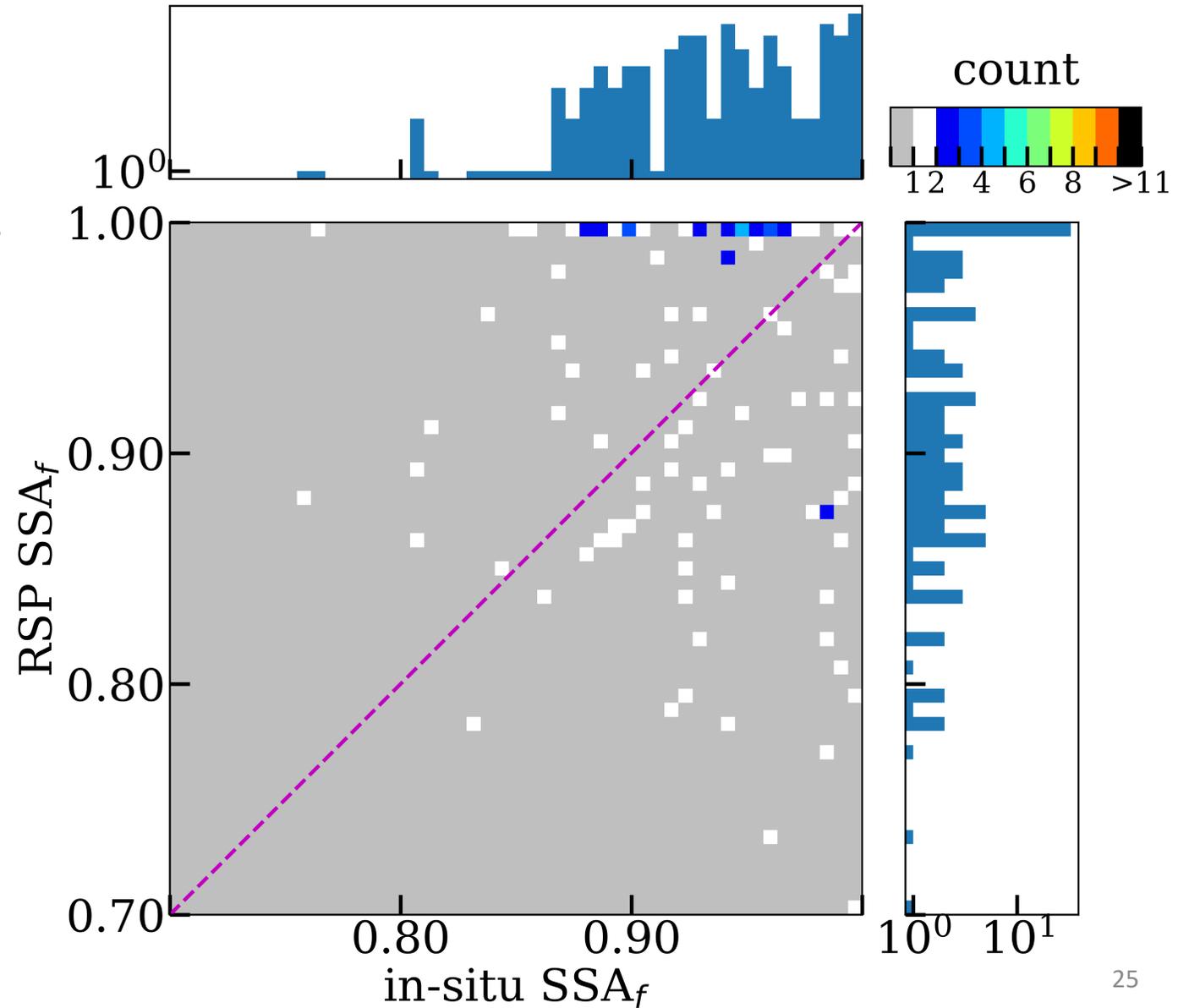
- Ambient vs. dry measured $r_{eff,f}$
- NMAD: 7%
- Count: 13,262
- R: 0.92
- p-value: $<10^{-4}$
- 95th percentile in dry $r_{eff,f}$: 0.17 μm .
- Resolution: 1 second



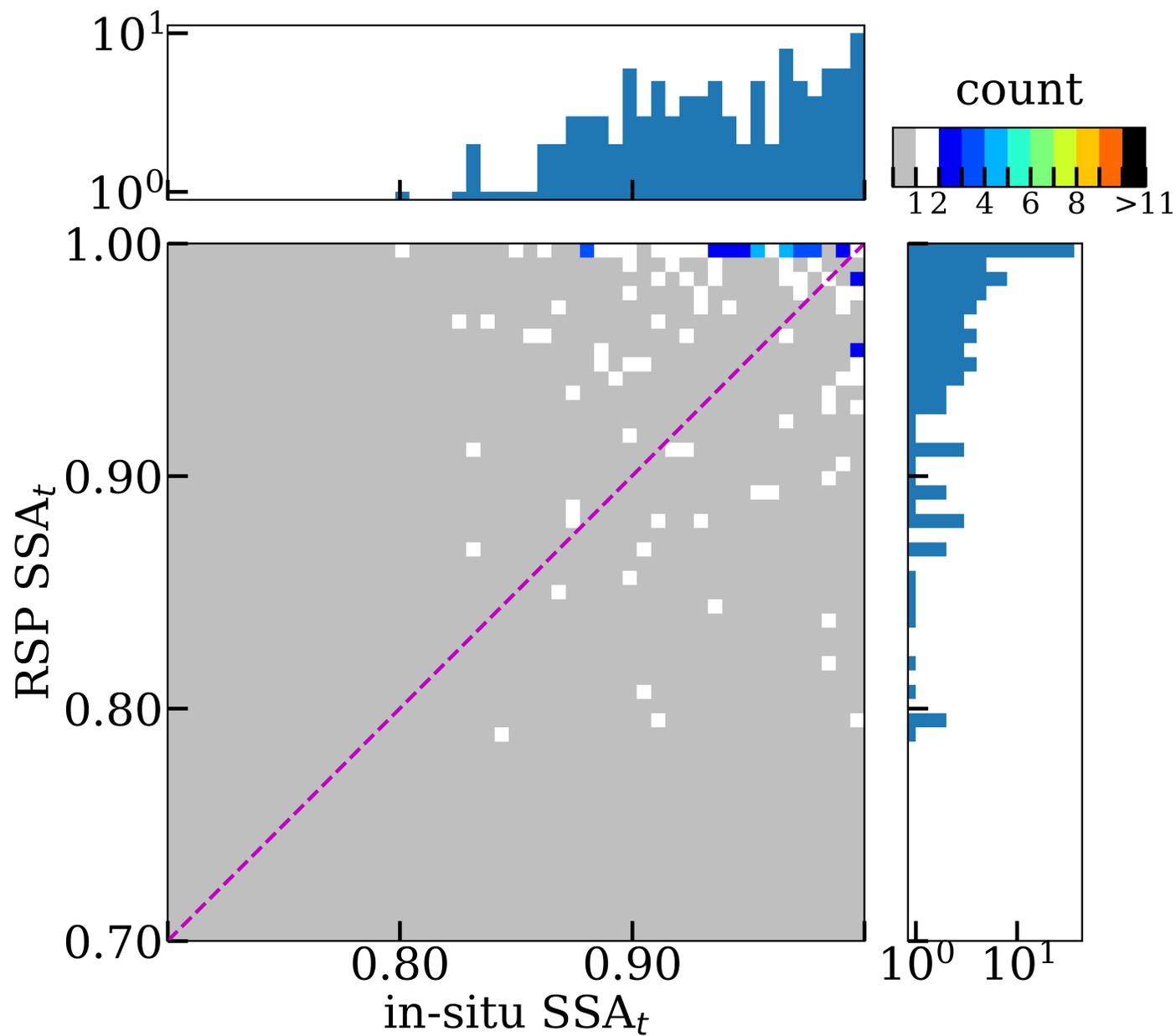
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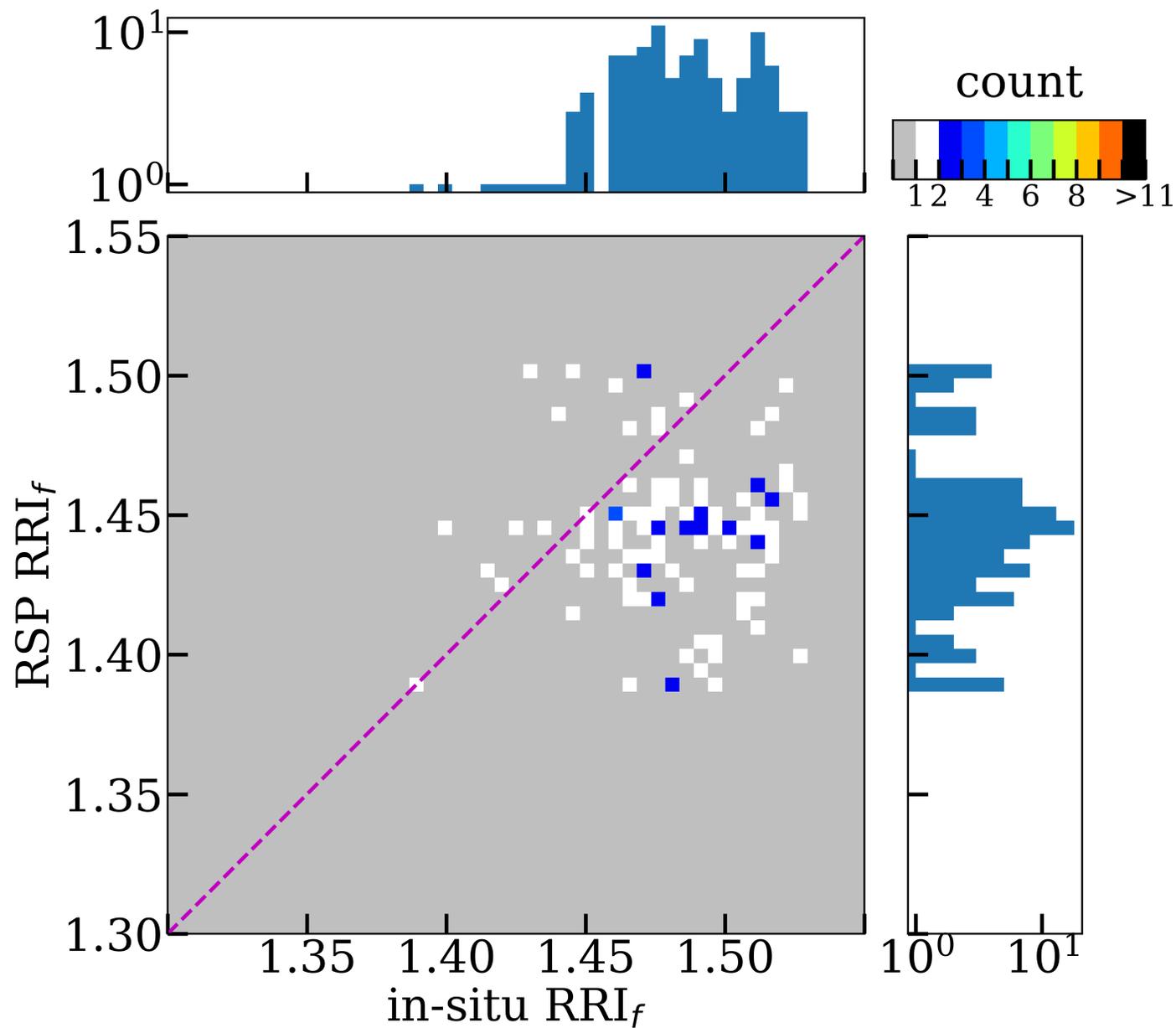
- RSP-derived vs. in-situ-derived fine-mode effective single scattering albedo (SSA_f) at 555 nm
- NMAD: 30%
- R: 0.019
- Count: 104



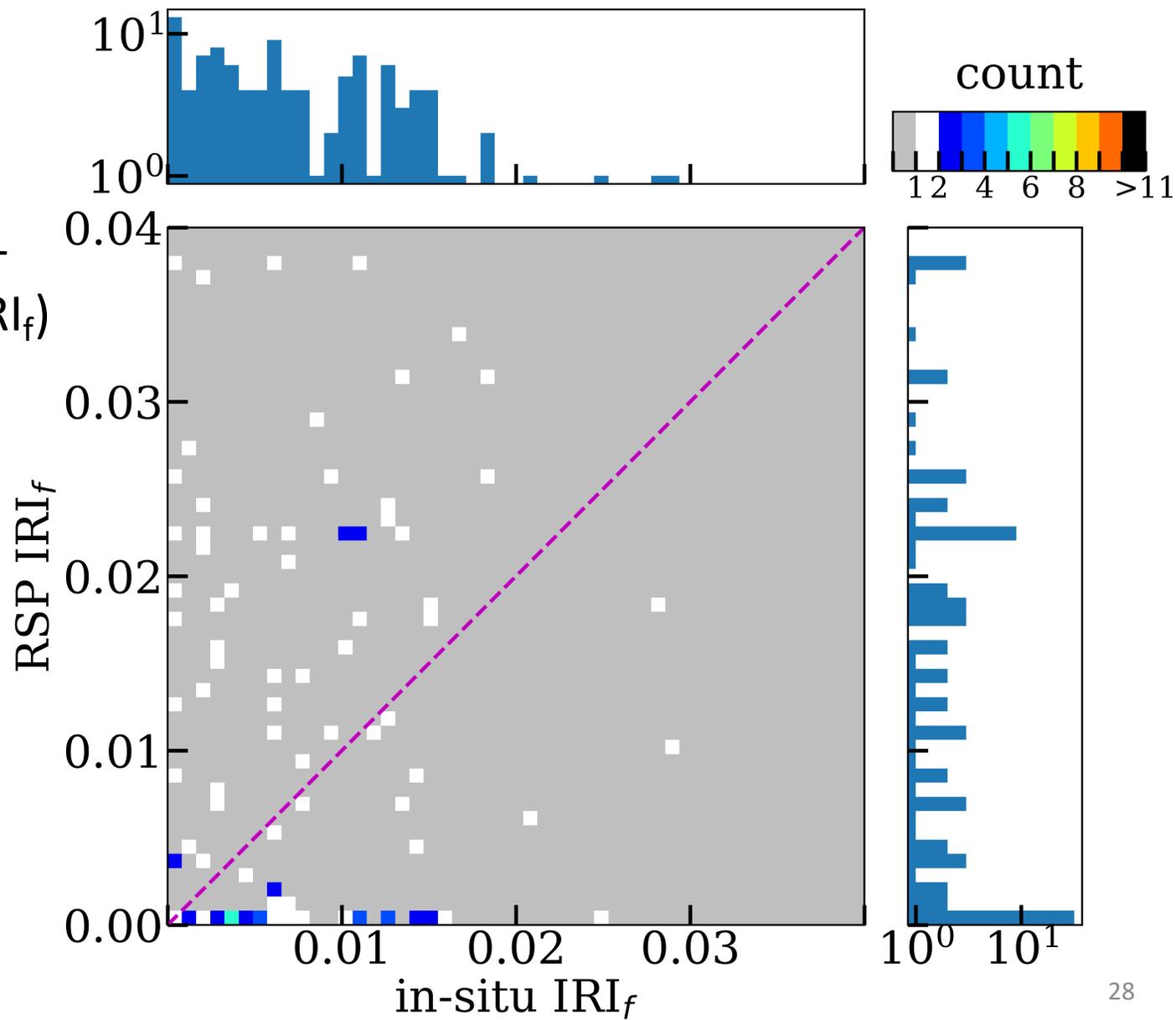
- RSP-derived vs. in-situ-derived τ_c effective single scattering albedo (SSA_t) at 555 nm
- NMAD: 26.9%
- R: -0.06
- Count: 104



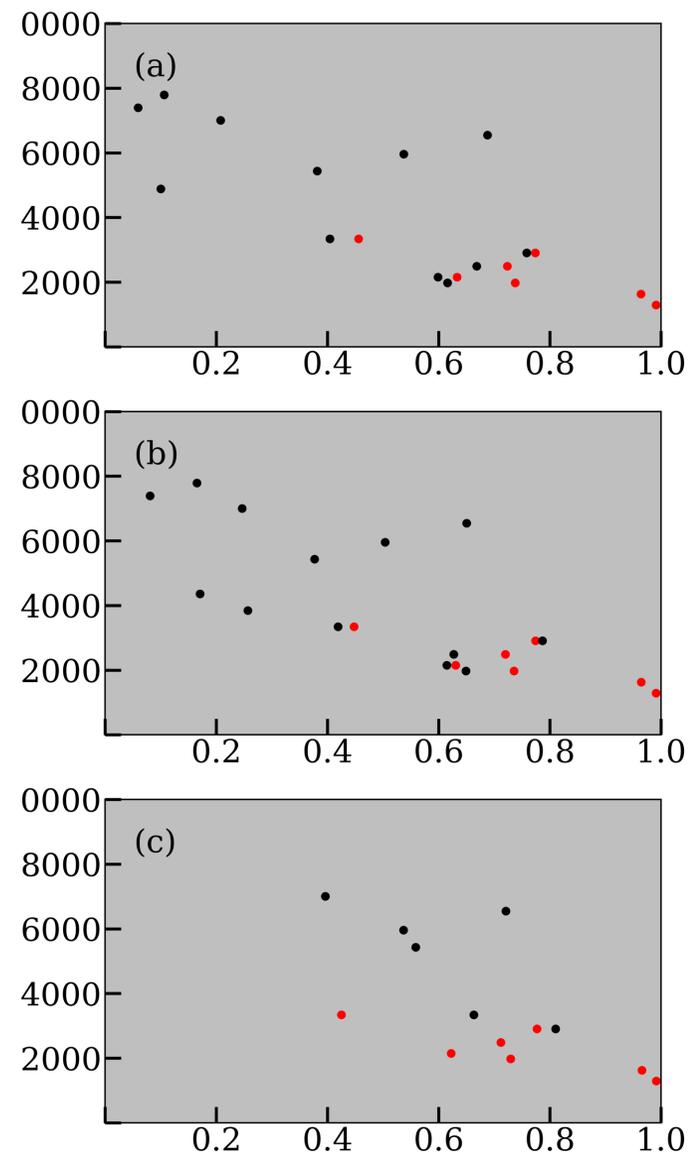
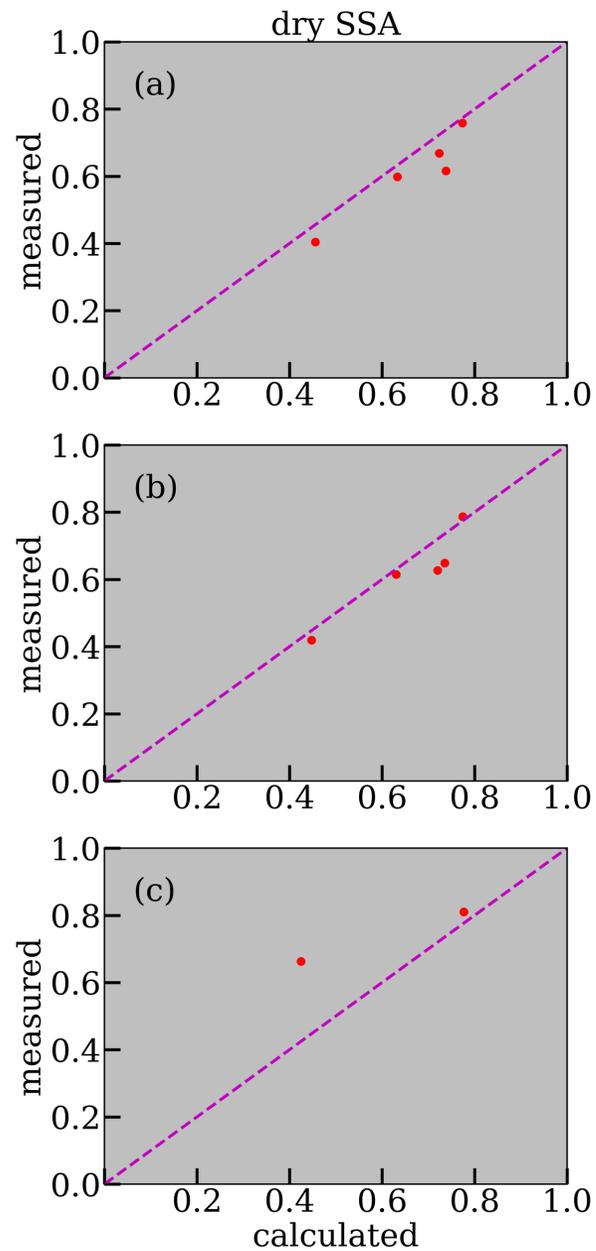
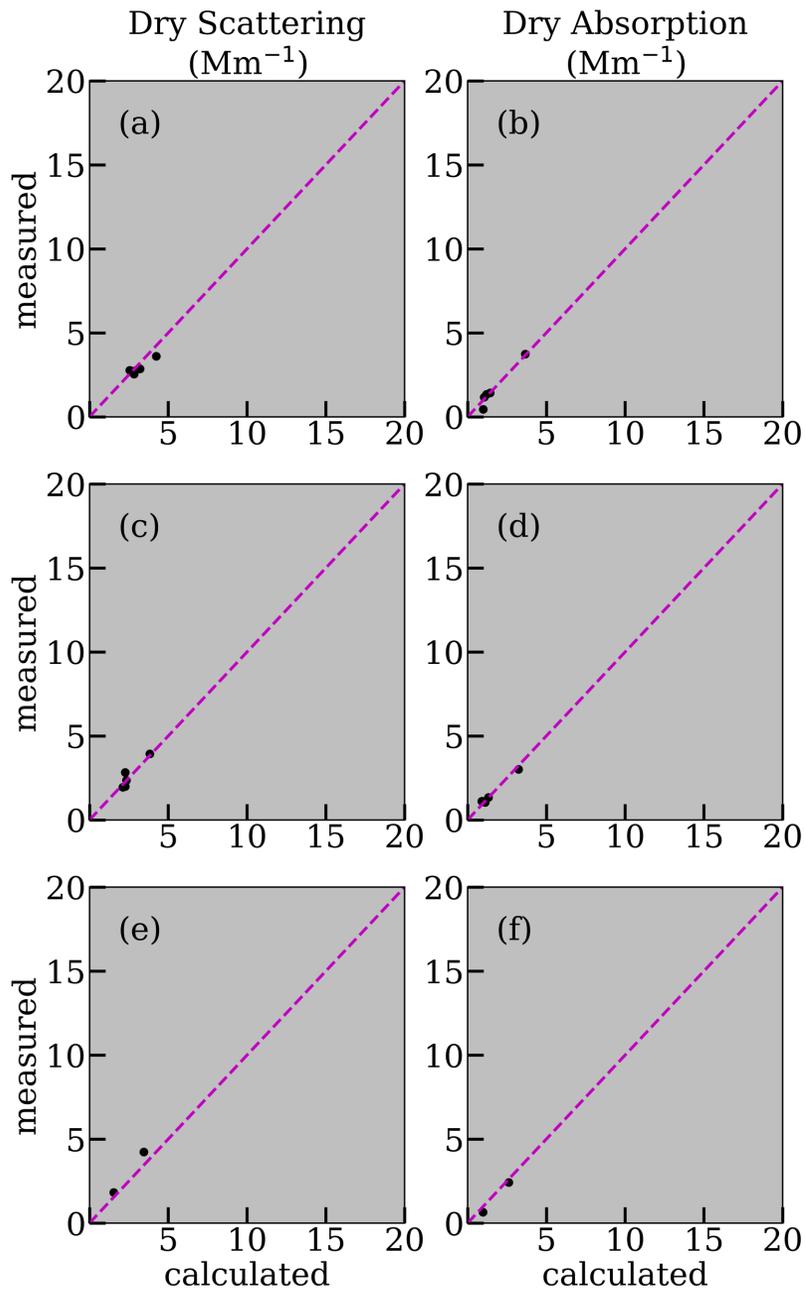
- RSP-derived vs. in-situ-derived fine-mode real refractive index (RRI_f) at 555 nm
- NMAD: 33%
- R: 0.02
- Count: 104



- RSP-derived vs. in-situ-derived fine-mode imaginary refractive index (IRI_f) at 555 nm
- NMAD: 27.5%
- R: 0.12
- Count: 104



6/17/22



6/18/22

