

Evaluation of *in situ* size-resolved composition model from the 2023 AEROMMA airborne field mission against ground-based and space-borne remote sensing aerosol optical measurements



Han N. Huynh,^{1,2} Adam T. Ahern,^{1,2} Charles A. Brock,² Ming Lyu,^{1,2} Xiaoli Shen,³ Justin Jacquot,³ Daniel J. Cziczo,³ Alison Piasecki,⁴ Ann M. Middlebrook,² Sarah Albertin,^{1,2} Glenn S. Diskin,⁶ Charles K. Gabete,⁶ John Hair,⁵ Pawan Gupta,⁷ Hai Zhang,⁸ Shobha Kondragunta,⁹ Pubu Ciren,⁸ Amy Huff,⁸ Daniel M. Murphy,² and the AEROMMA team

¹Cooperative Institute for Research in the Environmental Sciences (CIRES), CU Boulder, Colorado, USA

²NOAA Chemical Sciences Laboratory (CSL), Boulder, Colorado, USA

³Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, Indiana, USA

⁴US Geological Survey, Denver, Colorado, USA

⁵Langley Research Center, NASA, Hampton, Virginia, USA

⁶Ames Research Center, NASA, Moffett Field, California, USA

⁷Goddard Space Flight Center, NASA, Greenbelt, Maryland, USA

⁸Science and Technology Corporation at NOAA, College Park, MD, USA

⁹NOAA/NESDIS/STAR, College Park, MD, USA



16 June 2026

Aerosol data used for model construction and evaluation

Ongoing work:
TEMPO aerosol data product evaluation

AGES+

AEROMMA • GOTHAAM • EPCAPE • STAQS • CUPiDS
NEC-AQ-GHG • SCILLA • FROG-NY • NYC-METS • THE CIX

2023

★ Ground Sites:

- EPCAPE – La Jolla, CA
- NYC-METS – New York City
- FROG-NY – New York City
- THE CIX – Toronto, Canada
- Atlanta, GA
- Chicago, IL

NASA STAQS

New York City, Chicago, Toronto, Los Angeles



NSF/NCAR GOTHAAM

New York City

NSF C-130



NOAA CUPiDS

New York City



NOAA Twin Otter



NASA DC-8

NOAA AEROMMA

marine Pacific, New York City, Chicago, Toronto, Los Angeles

Toronto, Canada ★

Chicago, IL ★

New York City ★ ★

Atlanta, GA ★

La Jolla, CA ★

NPS SCILLA

coastal marine



NPS Twin Otter



Ground sites

UMD/NOAA Cessna

UMD/NOAA NEC-AQ-GHG

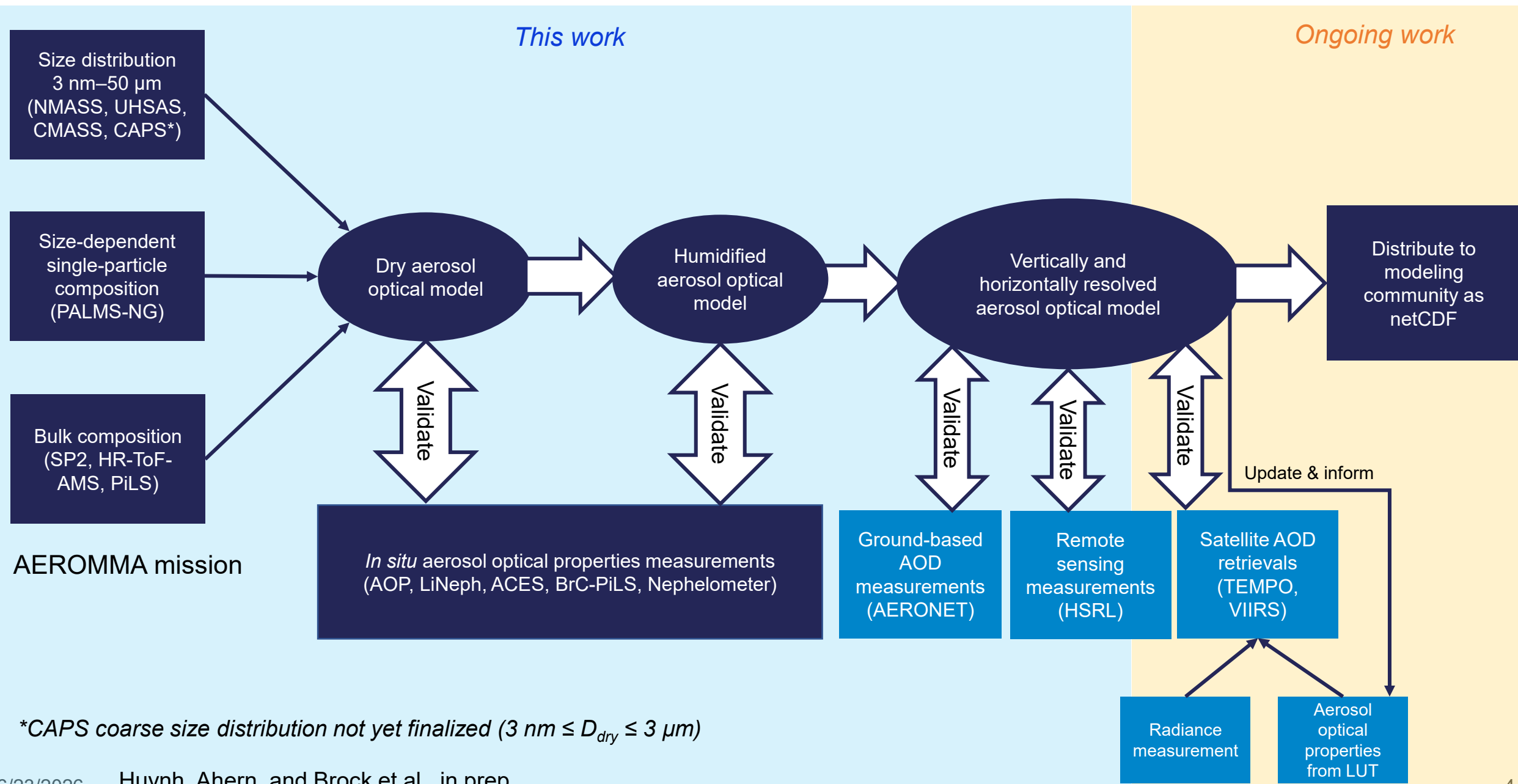
North East Corridor

modeled NO₂ | satellite observed NO₂

Summary of dataset used in this presentation

Field mission	Instrument/Dataset	Point of Contact	Affiliation
NOAA AEROMMA	AMS	A. Piasecki, S. Albertin, A. Middlebrook	CU CIRES / NOAA CSL
	AMP (NMASS, UHSAS, CMASS)	C. Brock, M. Lyu, A. Ahern, H. Huynh	CU CIRES / NOAA CSL
	AOP (CRDS-PAS)	H. Huynh, A. Ahern, C. Brock, M. Lyu	CU CIRES / NOAA CSL
	DLH	G. Diskins	NASA LaRC
	MMS	C. Gatebe	NASA ARC
	PALMS-NG	X. Shen, J. Jacquot, D. Cziczo	Purdue U.
NASA STAQS	HSRL-2	J. Hair	NASA LaRC
NASA AERONET	AERONET	P. Gupta	NASA GSFC
NASA TEMPO	AOD-ALH (v02)	S. Kondragunta, H. Zhang, Pubu Ciren, A. Huff	STC / NOAA

Aerosol optical model validation effort milestones for the AEROMMA field mission



*CAPS coarse size distribution not yet finalized ($3 \text{ nm} \leq D_{\text{dry}} \leq 3 \text{ }\mu\text{m}$)

Example of size-resolved composition mapping:

Number concentration (top) and mass concentration (bottom) of an urban plume from 2023-08-01 Chicago flight

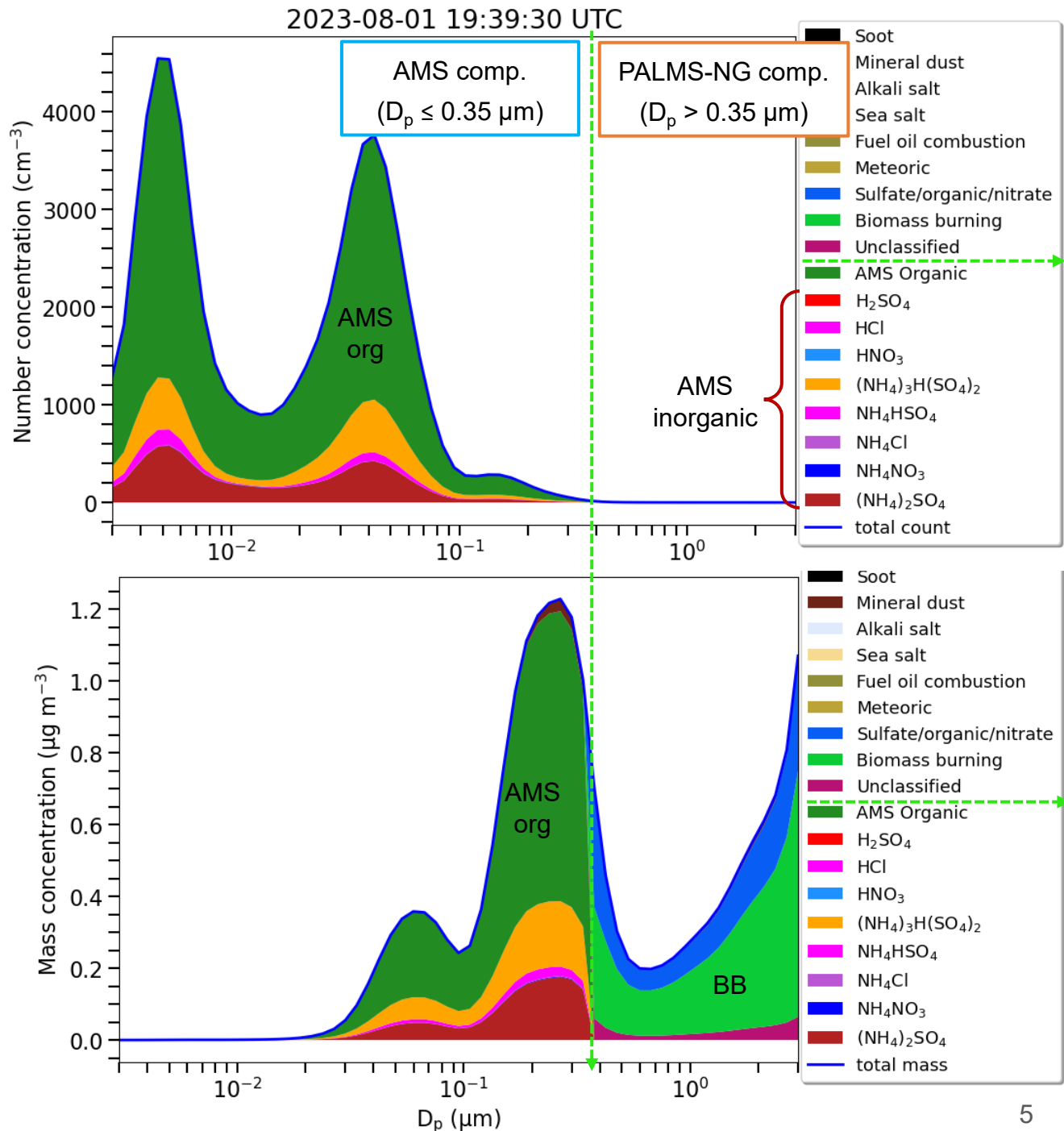
Prescribed size-resolved aerosol comp. allows us to apply particle intrinsic properties to determine optical properties (e.g., extinction)

$$\sigma_{\text{ext},i} = \int_{3 \text{ nm}}^{3 \text{ }\mu\text{m}} \frac{\pi}{4} D_p^2 \alpha_i(D_p, n_i, \lambda) N_i(D_p) d\log(D_p)$$

refractive index

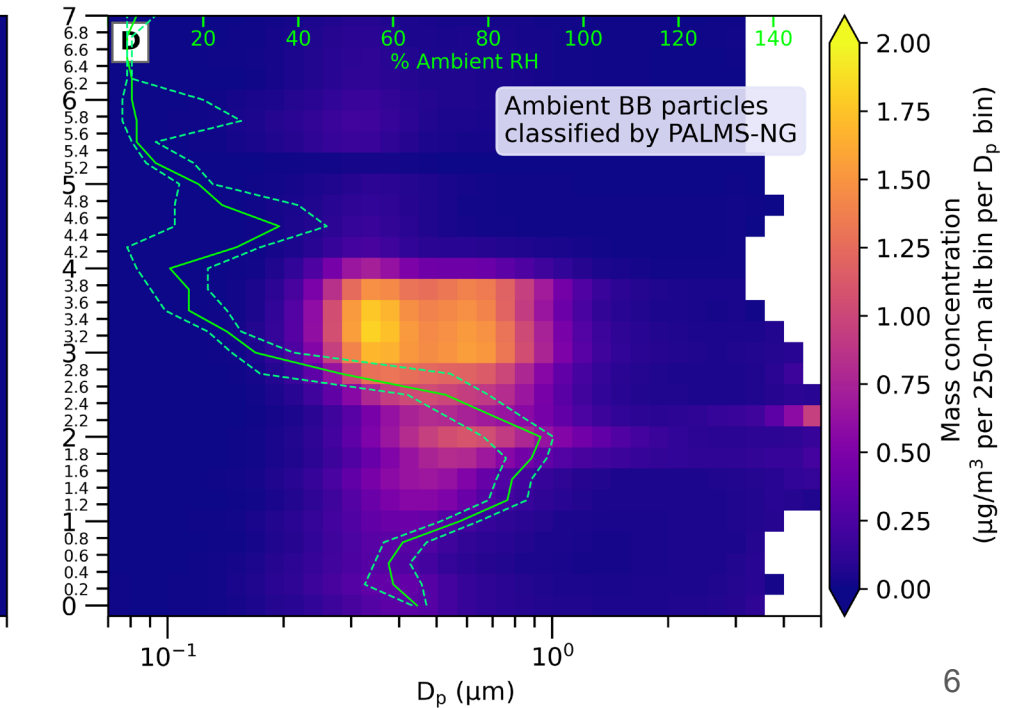
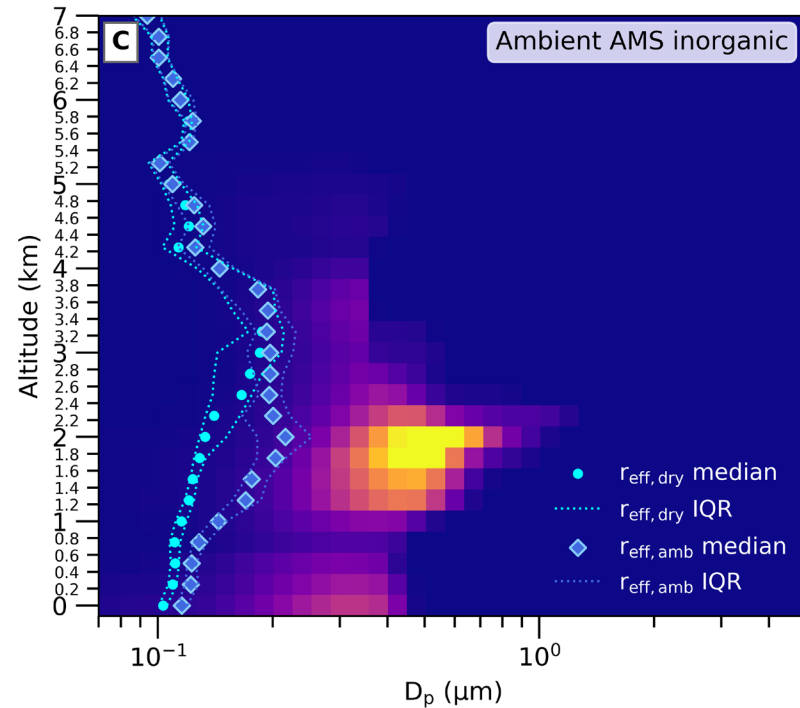
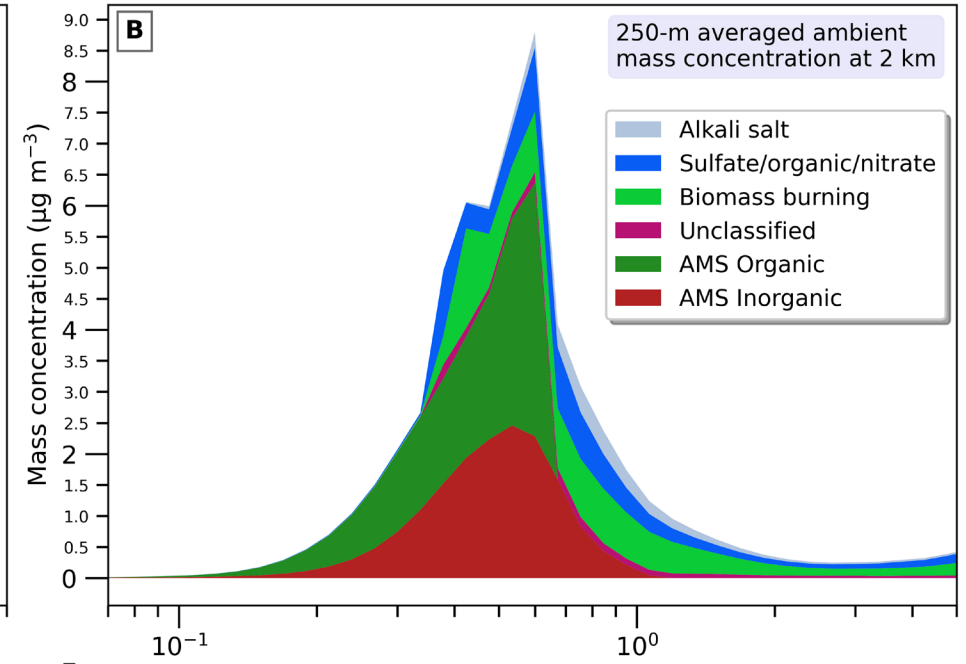
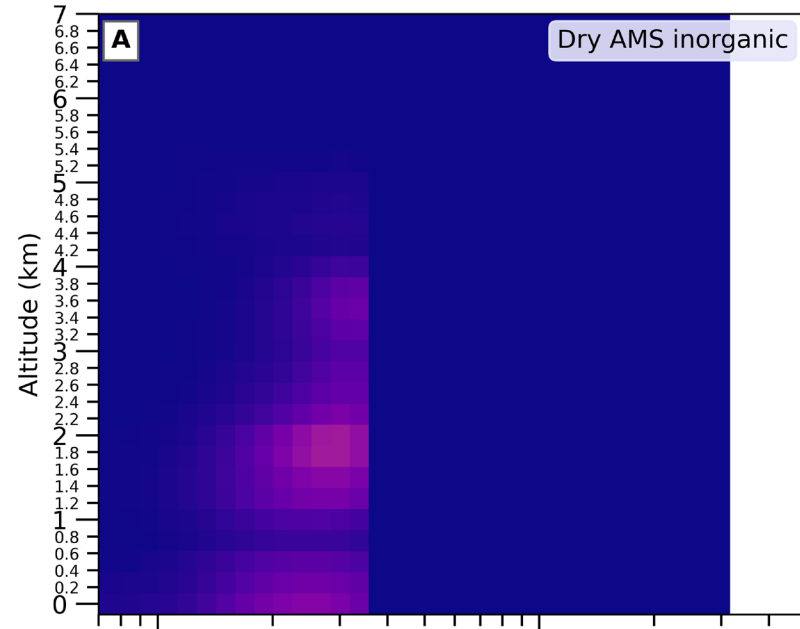
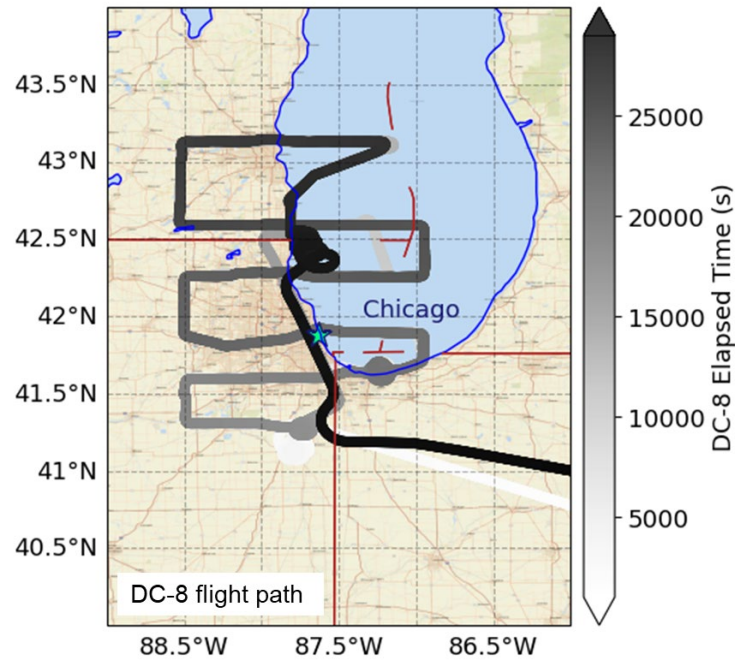
$$n_{\text{BB}}(\lambda) = 1.506 + 1.04 \times 10^9 (\lambda^{-3.8})$$

Ahern et al., JGRA (2025)



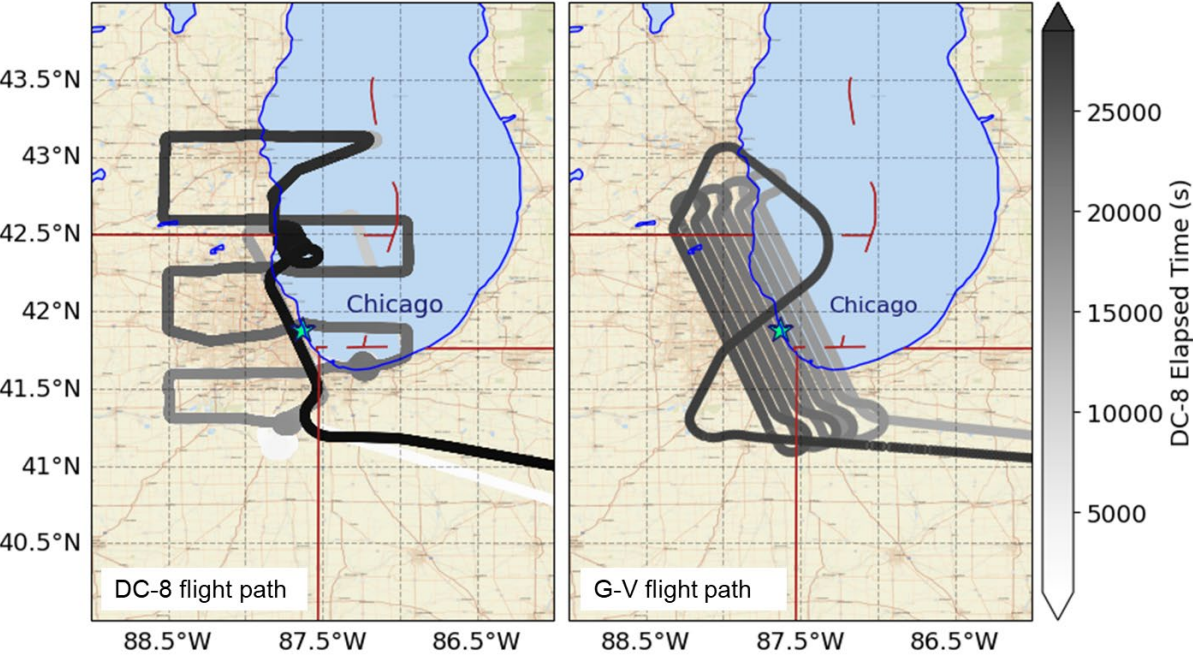
Vertically-resolved and size-dependent aerosol profiles from 2023-08-01 flight

Example of vertically-resolved and size-dependent aerosol profiles averaged for 2023-08-01 flight:

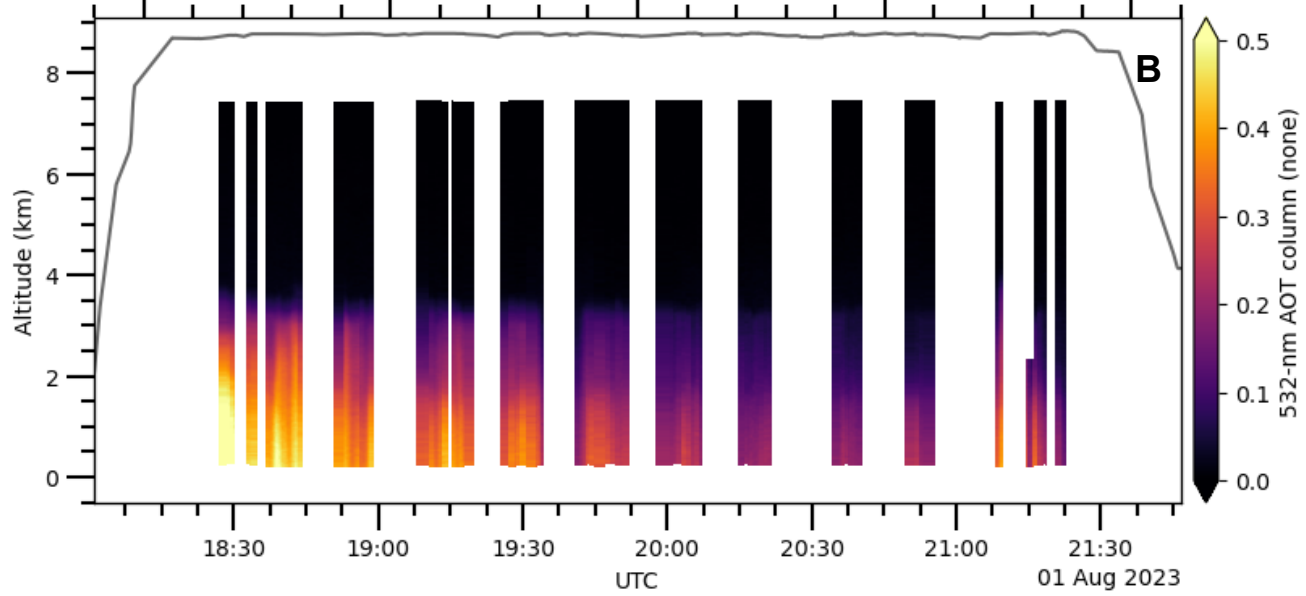
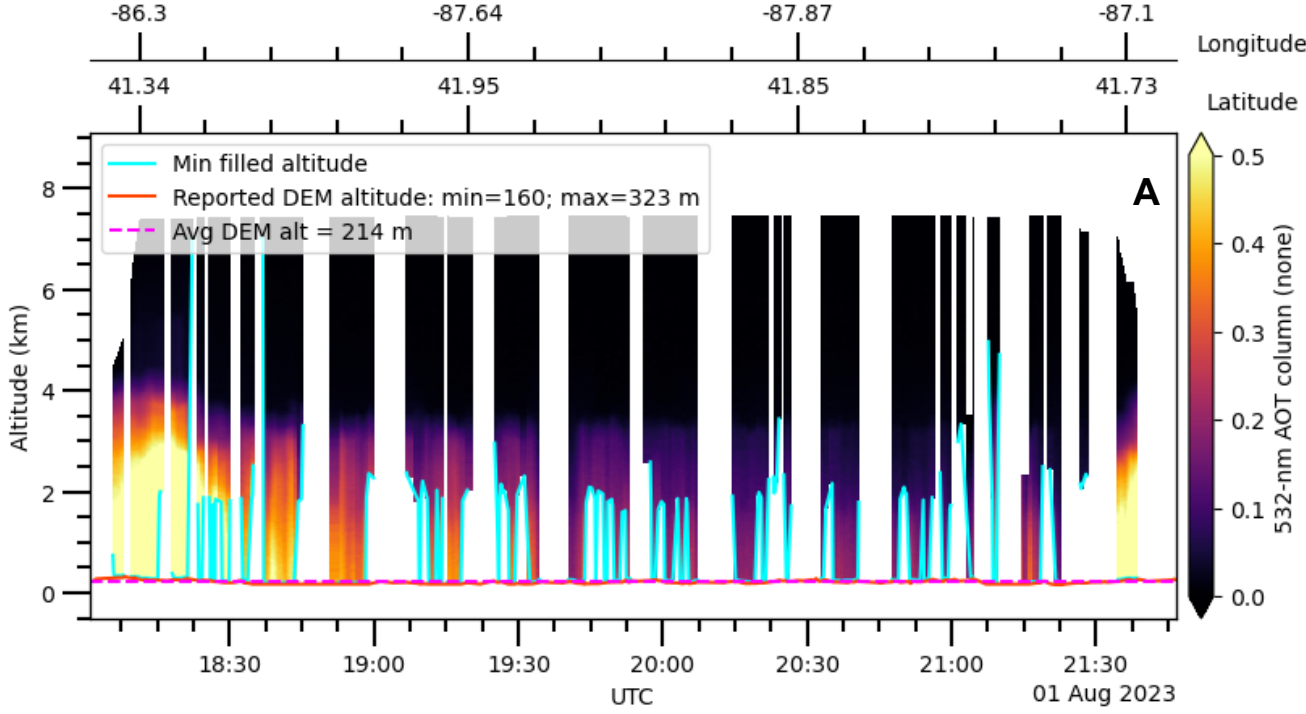


Collocation of *in situ* DC-8 aerosol measurements with remote-sensing aerosol meas.:

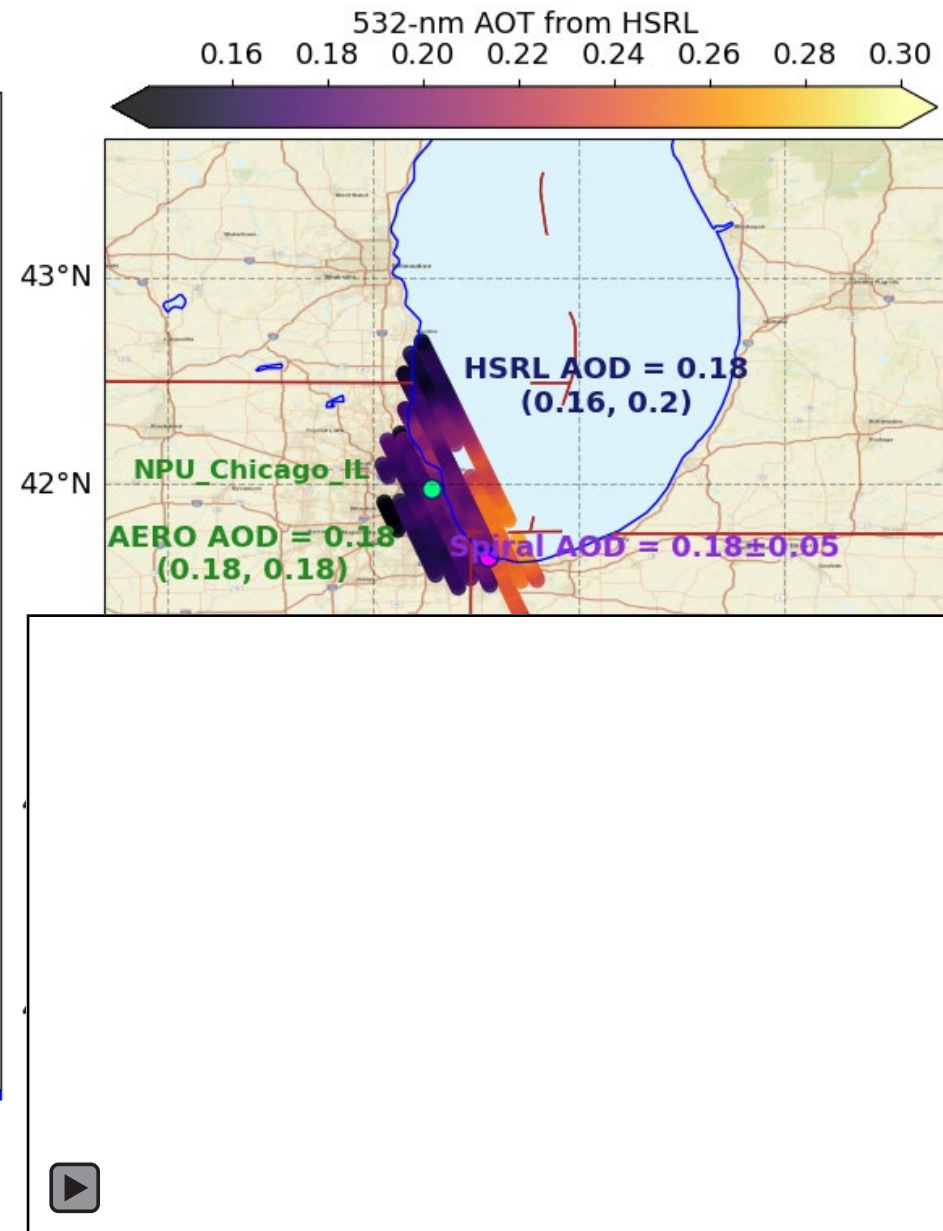
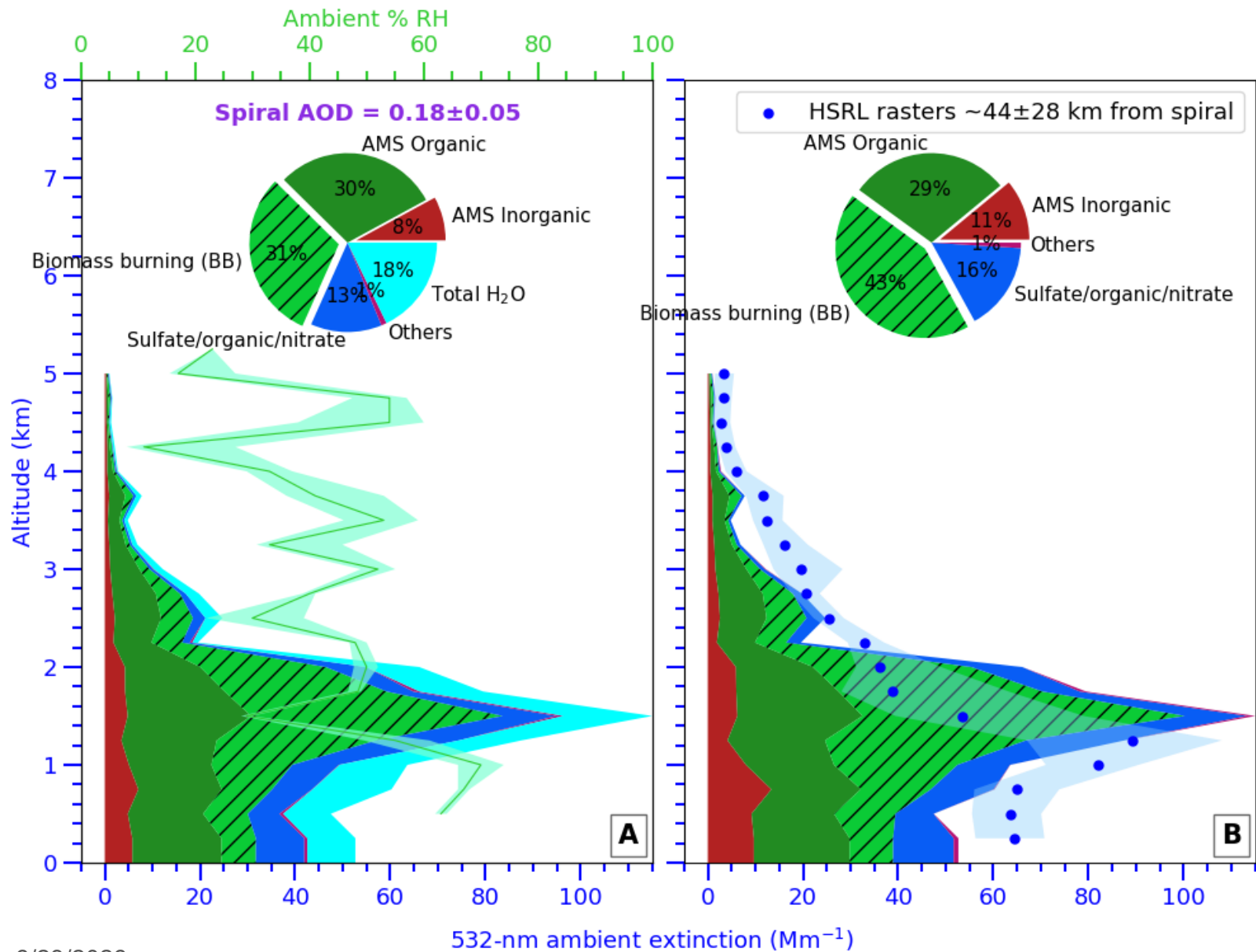
- Space-borne lidar meas. (HSRL on NASA G-V)
- Ground-based remote sensing Sun-sky radiometers meas. (AERONET)



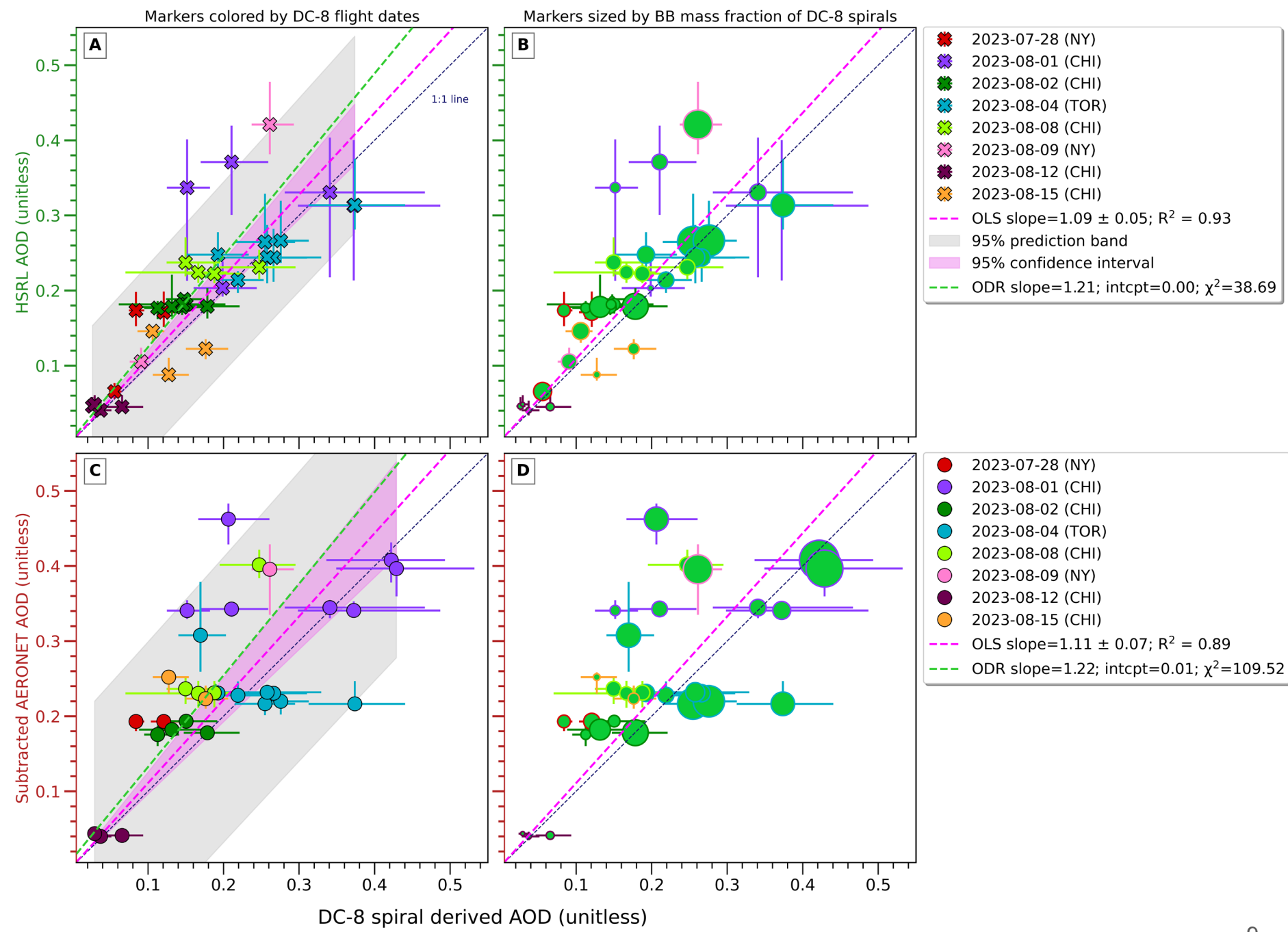
2023-08-01 flight paths superimposed on a base map from ArcGIS server REST API (<http://server.arcgisonline.com/ArcGIS>)



Example of DC-8 spiral in homogeneous atmosphere (2023-08-02): Spiral aerosol extinction profile matches HSRL retrieved profile over the same spiral area

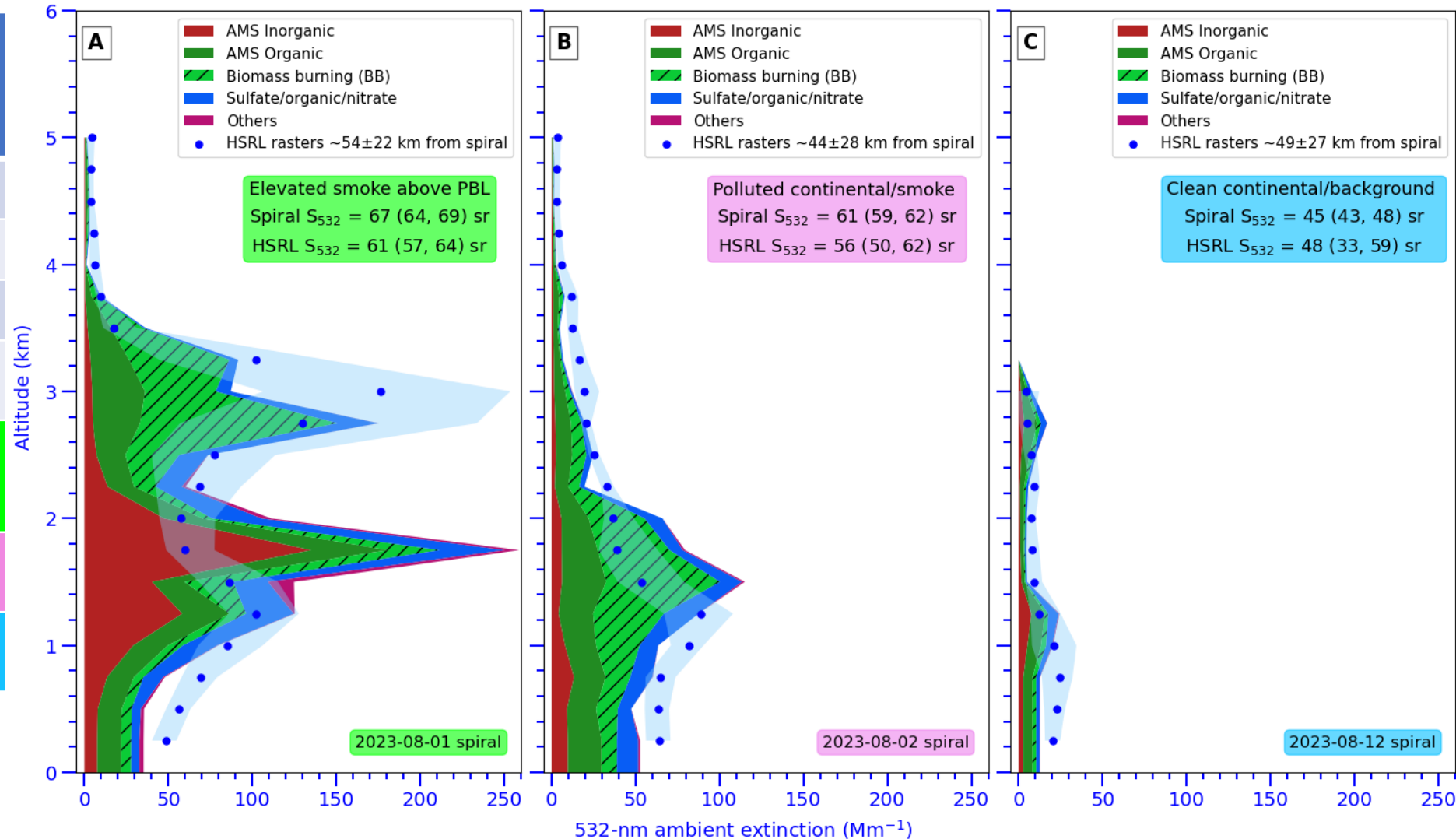


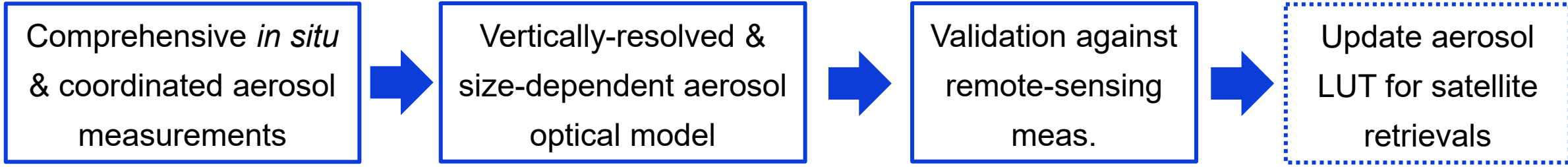
- *In situ* DC-8 AODs are on average ~20 % smaller than both AERONET and HSRL AOD retrievals
- Tighter correlation between observation-based AODs and HSRL AODs due to aircraft coordinated efforts
- AOD variation between aircraft spiral and other remote sensing meas. does not depend on BB mass fraction or any other particle type mass fraction



Vertically-resolved aerosol composition provides aerosol extinction-to-backscattering (i.e. lidar) ratio (S_a) validation for satellite retrieval algorithm for specific aerosol types (e.g., CALIOP aboard CALIPSO)

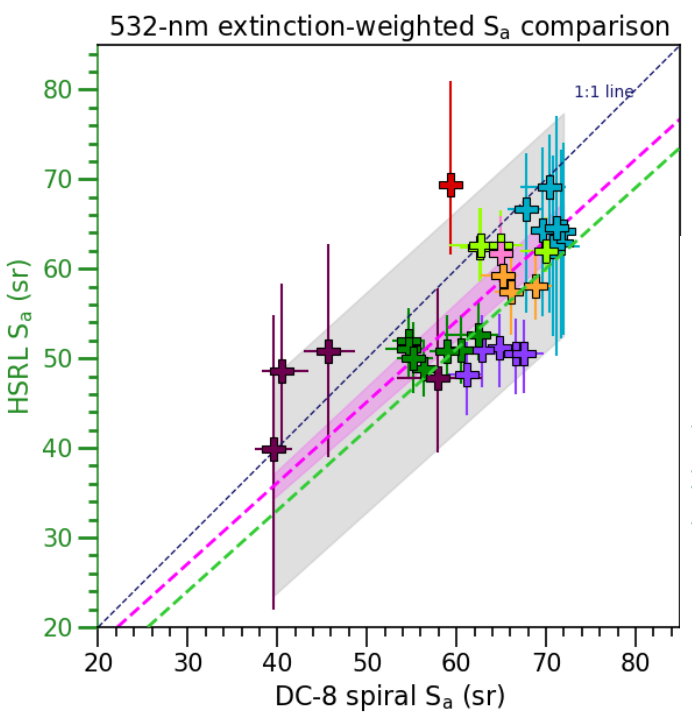
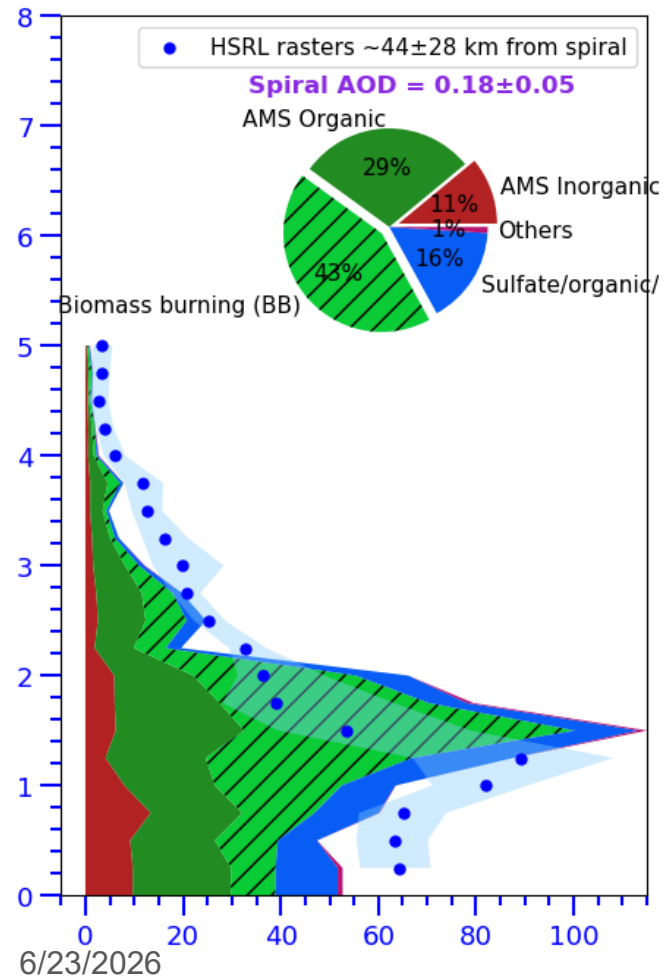
Aerosol type	CALIPSO v4 LUT S_{532} (sr) (Kim et al., AMT, 2018)
Clean marine	23 ± 5
Dusty marine	37 ± 15
Dust	44 ± 9
Polluted dust (dust + BB)	55 ± 22
Elevated Smoke (> 2.5 km – region above PBL)	70 ± 16
Polluted continental/smoke	70 ± 25
Clean continental/background	53 ± 24



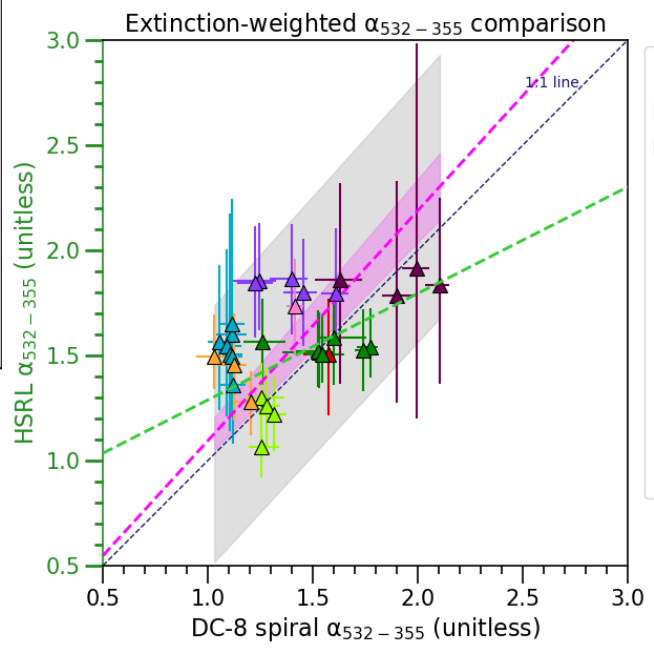


- ❖ Ambient extinction profile ($\sigma_{\text{ext,amb}}$)
- ❖ Aerosol optical depth (τ_λ)

❖ Lidar ratio (S_a)



— OLS slope = 0.90 ± 0.02 ; $R^2 = 0.99$
 — 95% prediction band
 — 95% confidence interval
 - - ODR slope = 0.90; intcpt = -3.00; $\chi^2 = 198.72$

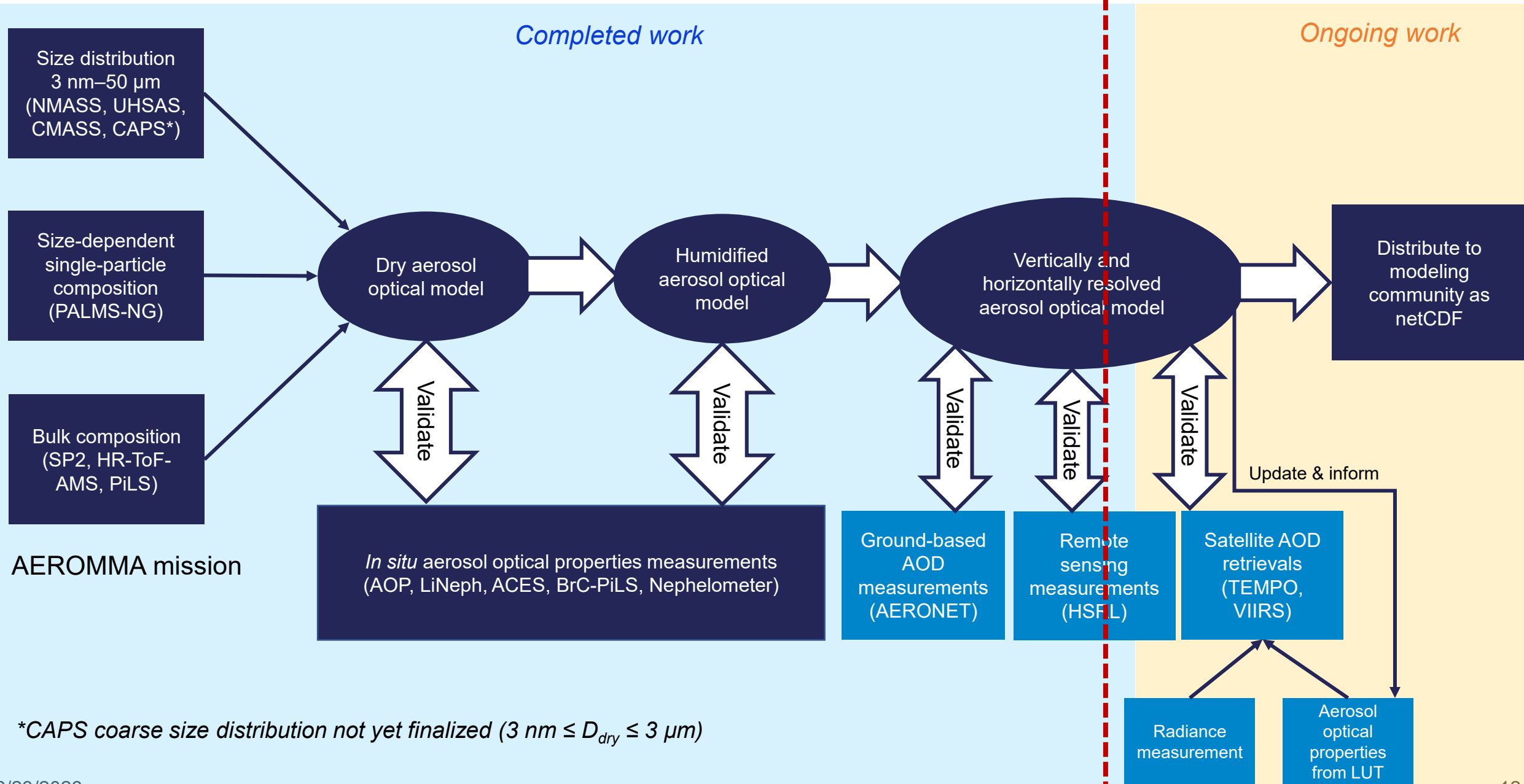


— OLS slope = 1.09 ± 0.04 ; $R^2 = 0.97$
 — 95% prediction band
 — 95% confidence interval
 - - ODR slope = 0.51; intcpt = 0.78; $\chi^2 = 257.98$

- ▲ 20230728 (NY)
- ▲ 20230801 (CHI)
- ▲ 20230802 (CHI)
- ▲ 20230804 (TOR)
- ▲ 20230808 (CHI)
- ▲ 20230809 (NY)
- ▲ 20230812 (CHI)
- ▲ 20230815 (CHI)

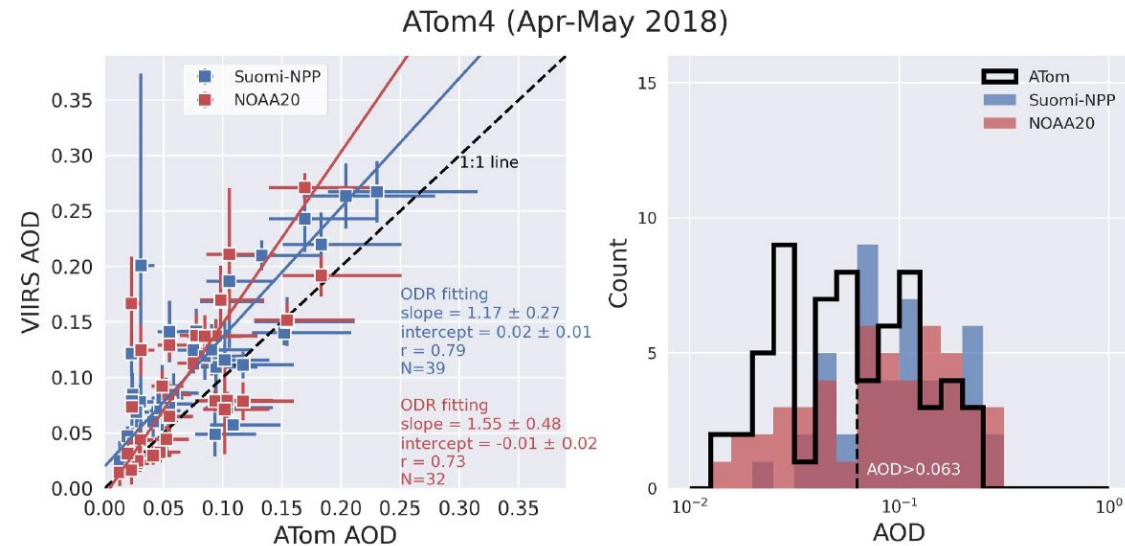
- ❖ Ångström exponent ($\alpha_{\lambda_1-\lambda_2}$)

Satellite AOD evaluation with our aerosol optical model



Previously: AOD comparison b/w *in situ* measurements and VIIRS satellite-derived values from ATom field campaign (Thompson et al., BAMS, 2022)

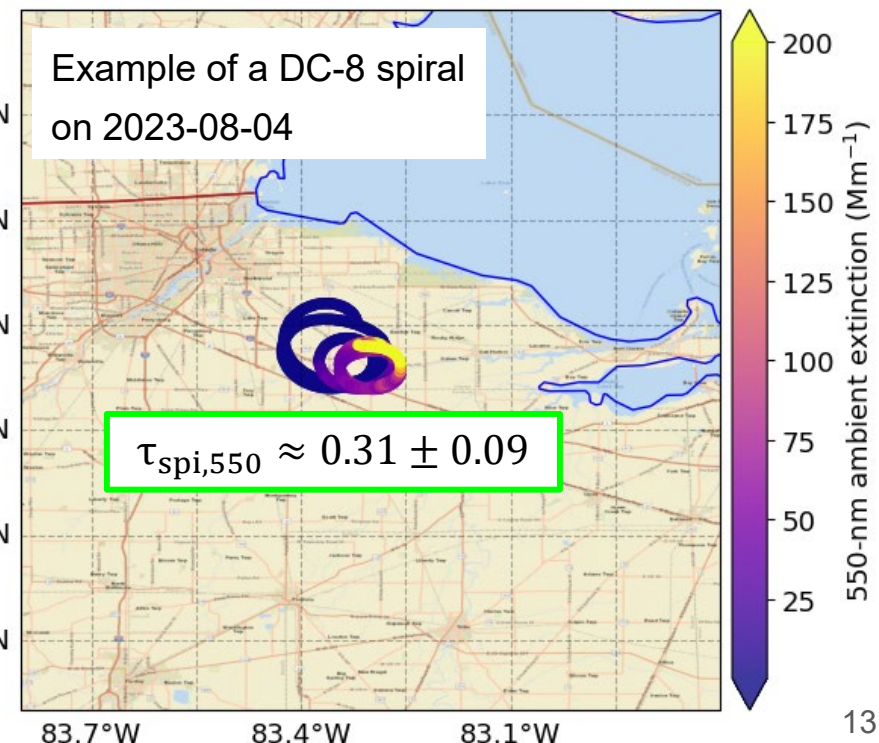
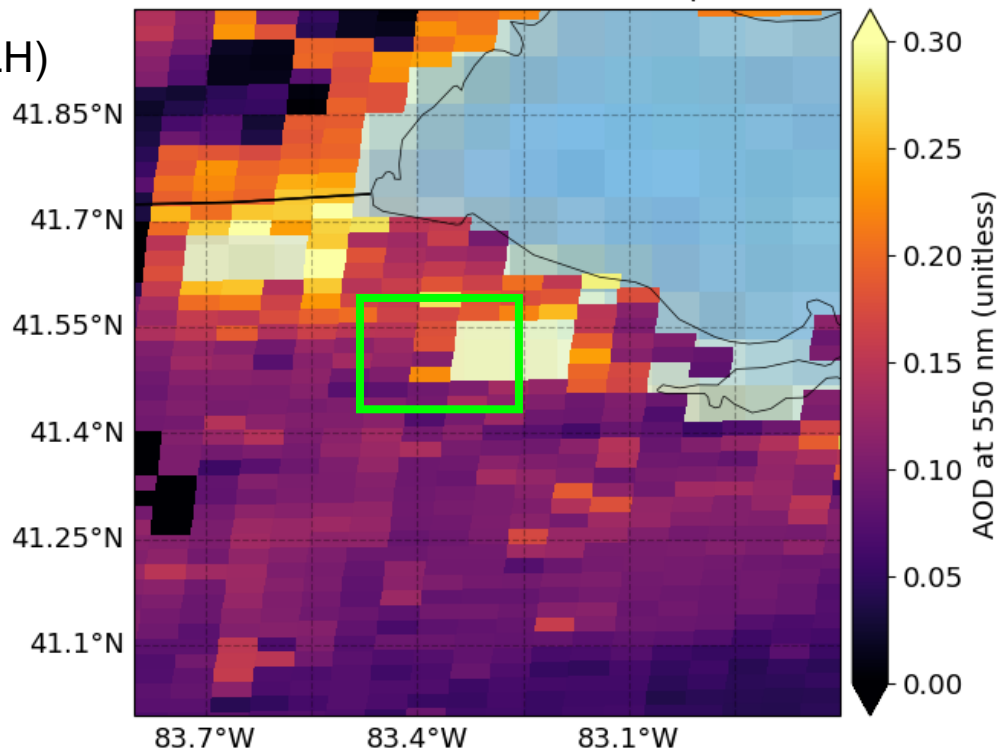
Wang and Brock et al., JGR, 2024
 Brock et al., ACP, 2021



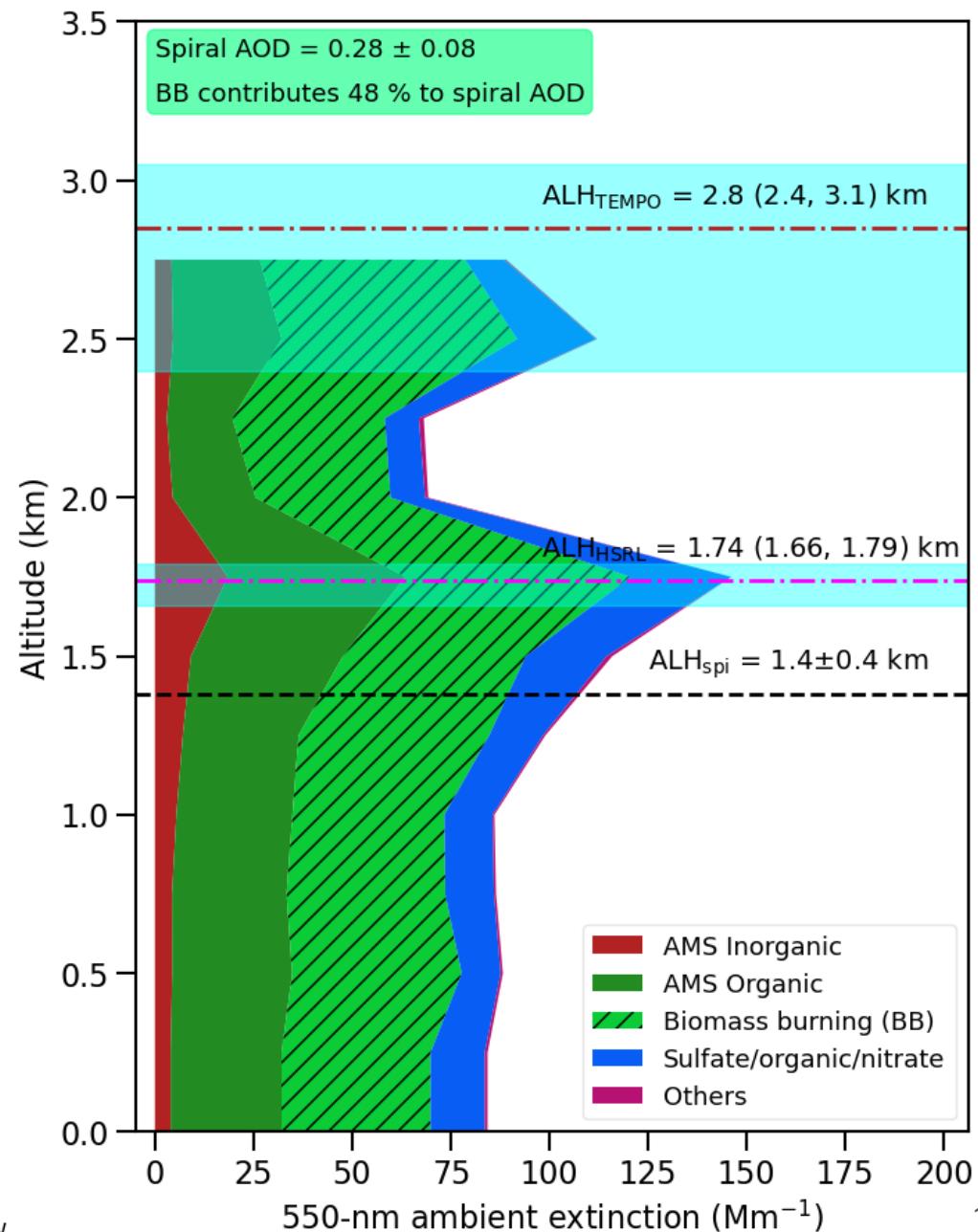
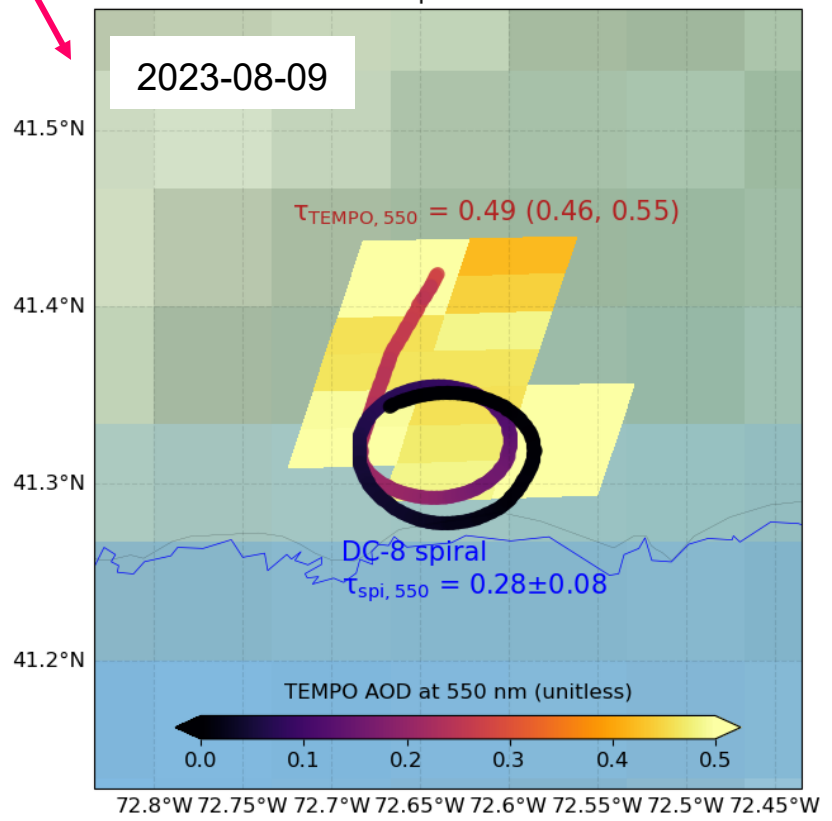
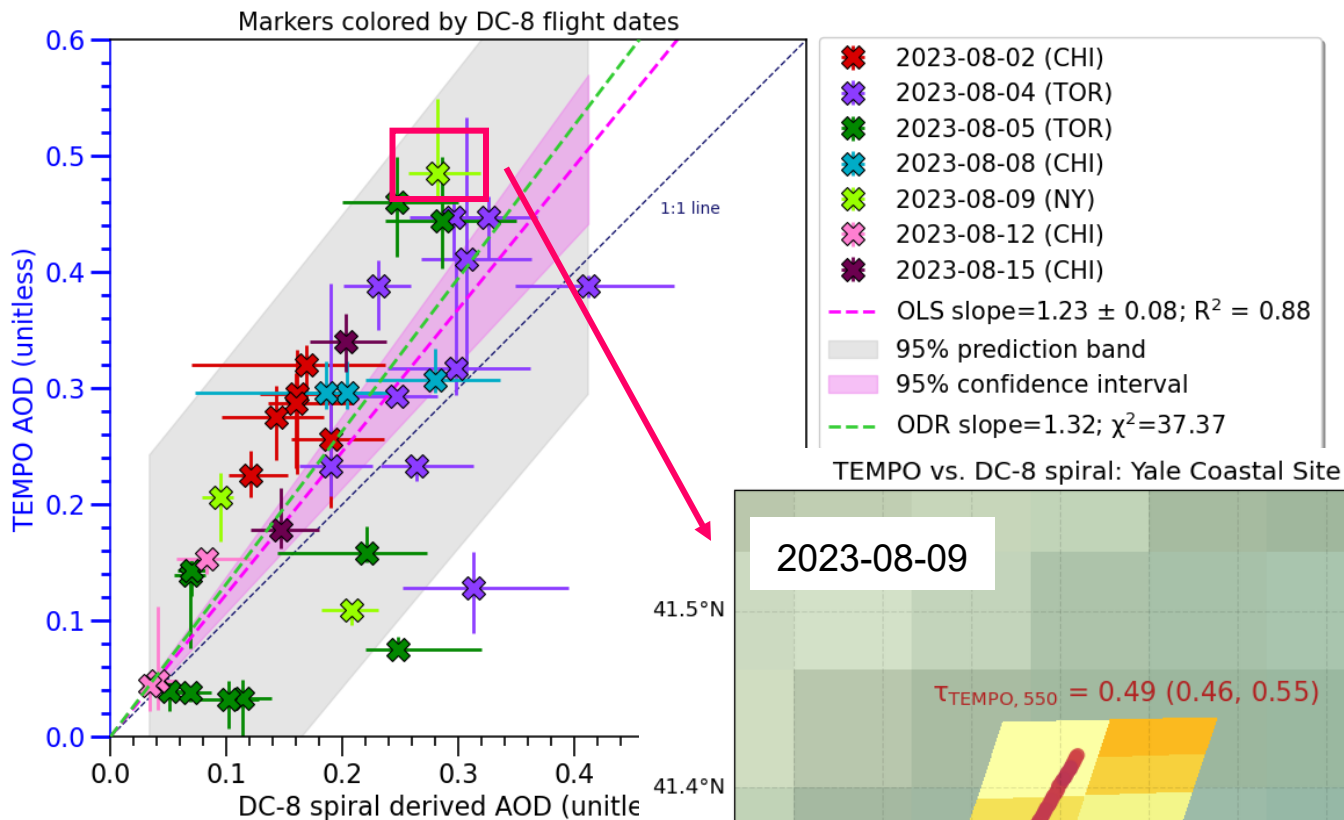
Ongoing work: Evaluation of observation-based aerosol optical model against TEMPO aerosol data products

- AOD
- Aerosol layer height (ALH)

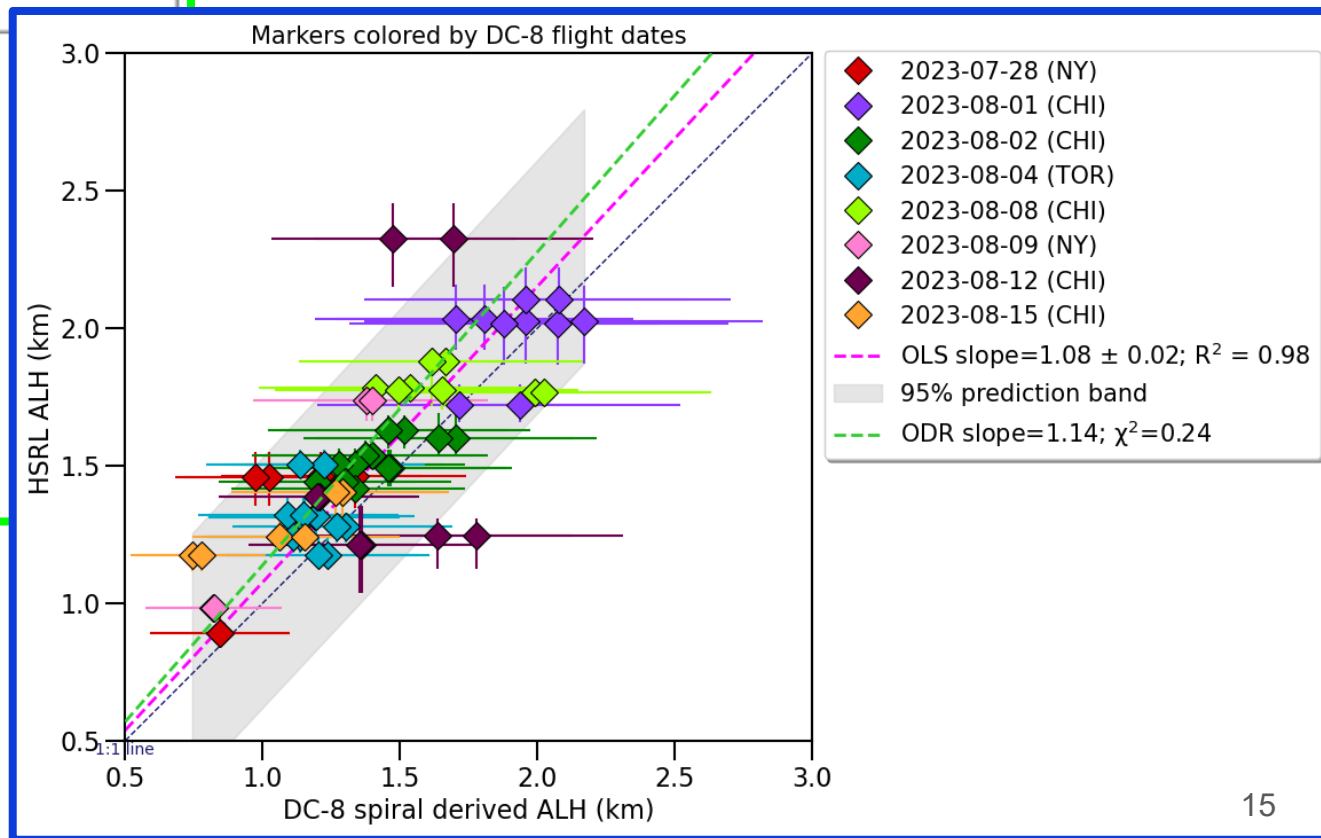
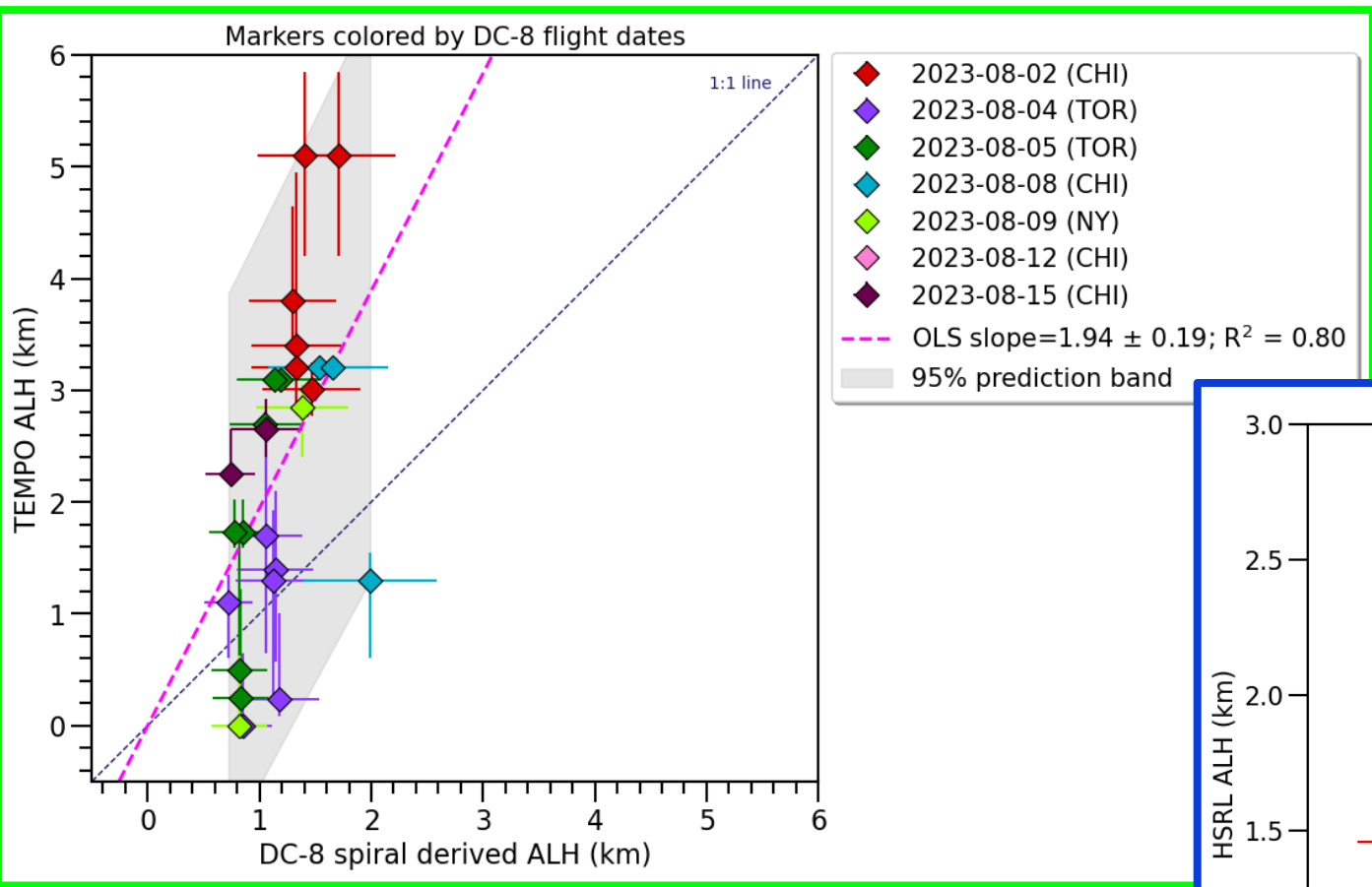
TEMPO Scans of Toronto area on 2023-08-04 (14:38:29 - 14:50:55)



ALH supplements AOD by identifying vertical location of dust, smoke, etc. in the atmosphere



TEMPO ALH on average about 2x higher than *in situ* (DC-8) compared to close agreement between DC-8 and remote-sensing (HSRL-2) ALH



Current scientific objective: Derive observation-based aerosol optical model and compare against TEMPO aerosol

LUT

Table 1. Optical Properties of the Aerosol Models Used for the V5.2 Over-Land Lookup Table^a

Model	Mode	$r_v, \mu\text{m}$	σ	$V_0, \mu\text{m}^3/\mu\text{m}^2$	Refractive Index: k
Continental	Water Solub	0.176	1.09	3.05	1.53 - 0.005i; 1
					1.53 - 0.006i; 2
					1.53 - 0.006i; 3
					1.42 - 0.01i; 4
	Dust	17.6	1.09	7.364	1.53 - 0.008i; 1
					1.53 - 0.008i; 2
					1.53 - 0.008i; 3
	Soot	0.050	0.693	0.105	1.22 - 0.009i; 4
					1.75 - 0.45i; 1
1.75 - 0.44i; 2					
1.75 - 0.43i; 3					
Moderately Absorbing/Developing	Accum	$0.0203\tau + 0.145$	$0.1365\tau + 0.374$	$0.1642 \tau^{0.775}$	1.43 - (-0.002 τ + 0.008)i
	Coarse	$0.3364\tau + 3.101$	$0.098\tau + 0.729$	$0.1482 \tau^{0.684}$	1.43 - (-0.002 τ + 0.008)i
Absorbing/Smoke	Accum	$0.0096\tau + 0.134$	$0.0794\tau + 0.383$	$0.1748 \tau^{0.891}$	1.51 - 0.02i
	Coarse	$0.9489\tau + 3.448$	$0.0409\tau + 0.743$	$0.1043 \tau^{0.682}$	1.51 - 0.02i
Nonabsorb/Urban-Ind	Accum	$0.0434\tau + 0.160$	$0.1529\tau + 0.364$	$0.1718 \tau^{0.821}$	1.42 - (-0.0015 τ + 0.007)i
	Coarse	$0.1411\tau + 3.325$	$0.1638\tau + 0.759$	$0.0934 \tau^{0.639}$	1.42 - (-0.0015 τ + 0.007)i
Spheroid/Dust	Accum	$0.1416 \tau^{-0.052}$	$0.7561 \tau^{0.148}$	$0.0871 \tau^{1.026}$	1.48 $\tau^{-0.021}$ - (0.0025 $\tau^{0.132}$)i; 1 1.48 $\tau^{-0.021}$ - 0.002i; 2 1.48 $\tau^{-0.021}$ - (0.0018 $\tau^{-0.08}$)i; 3 1.46 $\tau^{-0.040}$ - (0.0018 $\tau^{-0.30}$)i; 4
	Coarse	2.2	$0.554 \tau^{-0.052}$	$0.6786 \tau^{1.057}$	1.48 $\tau^{-0.021}$ - (0.0025 $\tau^{0.132}$)i; 1 1.48 $\tau^{-0.021}$ - 0.002i; 2 1.48 $\tau^{-0.021}$ - (0.0018 $\tau^{-0.08}$)i; 3 1.46 $\tau^{-0.040}$ - (0.0018 $\tau^{-0.30}$)i; 4

^aListed for each model are the individual lognormal modes, and the final SSA at different wavelengths. Listed for each mode are the volume modal radius r_v , standard deviation σ of the volume distribution, and total volume of the mode, V_0 . The complex refractive index is assumed for all wavelengths (1, 2, 3, and 4 for 0.47, 0.55, 0.66, and 2.1 μm , respectively), unless otherwise noted. The absorbing and moderately absorbing model parameters (r_v , σ , and k) are defined for $\tau \leq 2.0$; for $\tau > 2.0$, we assume $\tau = 2.0$. Likewise, the nonabsorbing and spheroid model parameters are defined for $\tau \leq 1.0$. V_0 (for all models) is defined for all τ .

THANK YOU! Q&A

Interested in our aerosol dataset? Available
NetCDF files for distribution!

Contact: Han Huynh (han.huynh@noaa.gov) and
Adam Ahern (adam.ahern@noaa.gov)

