CLOUD-AEROSOL INTERACTIONS: RETRIEVING AEROSOL ÅNGSTRÖM EXPONENTS FROM CALIPSO MEASUREMENTS OF OPAQUE WATER CLOUDS

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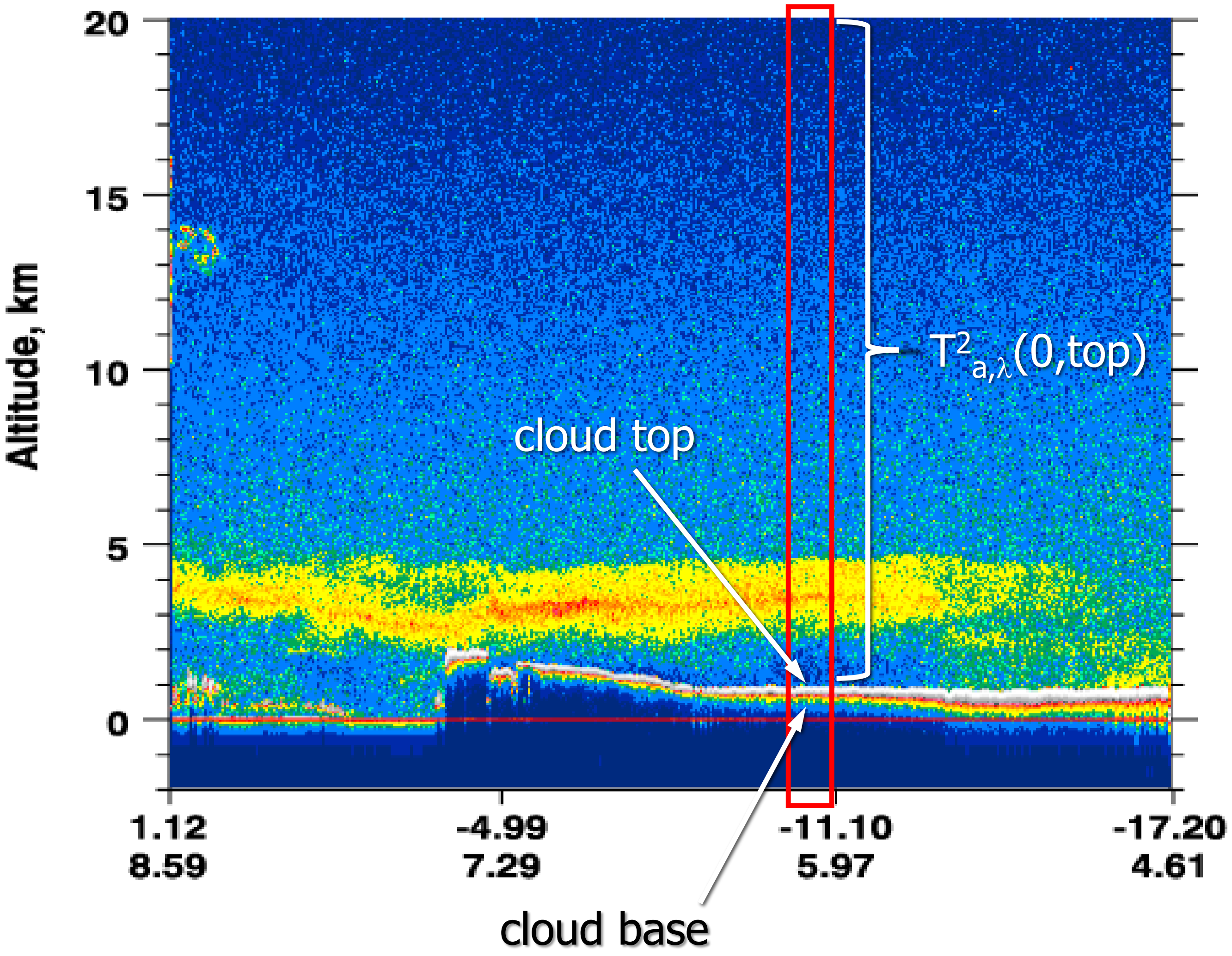
Hu et al., 2007: Retrieving Optical Depths and Lidar Ratios for Transparent Layers Above Opaque Water Clouds



cloud integrated attenuated backscatter

$$\gamma'_{c,\lambda} = T^2_{a,\lambda}(0,\text{CloudTop}) \int_{\text{CloudTop}}^{\text{CloudBase}} B_\lambda(z)\,dz$$

$$= T^2_{a,\lambda}(0,\text{CloudTop}) \left(\frac{1}{2\,\eta\, S_c} \right)$$

Platt 1973

multiple scattering factor computed from measured in-cloud volume depolarization

$$\eta_{c,532} = \left(\frac{1-\delta_{v,532}}{1+\delta_{v,532}} \right)^2$$

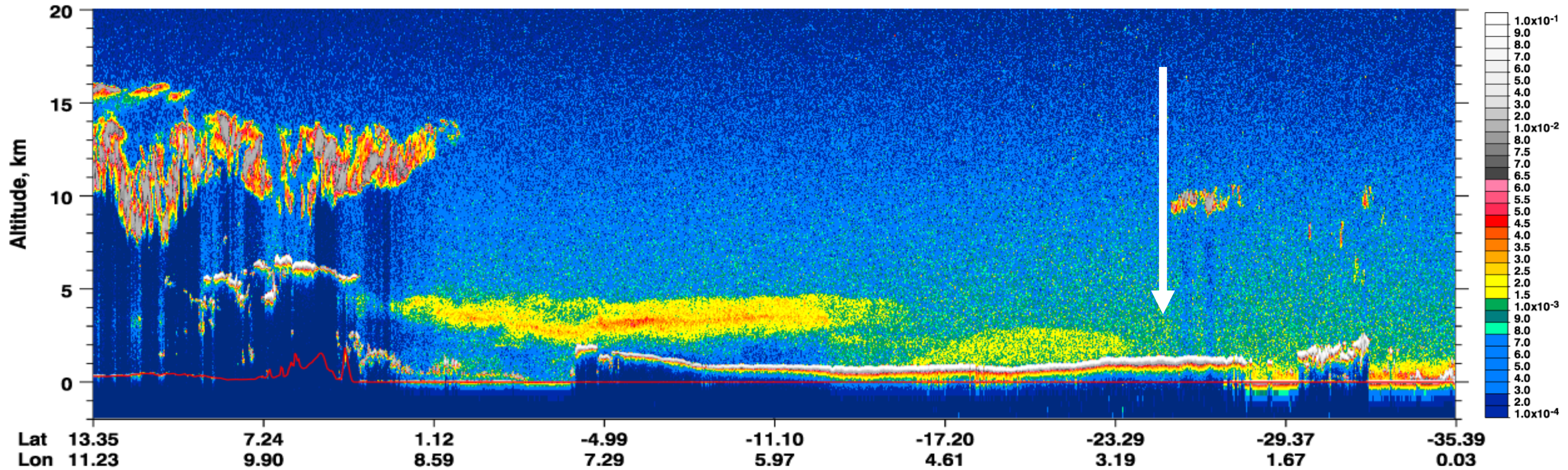
above-cloud optical depth retrieved using a (known!) water cloud lidar ratio, S_c

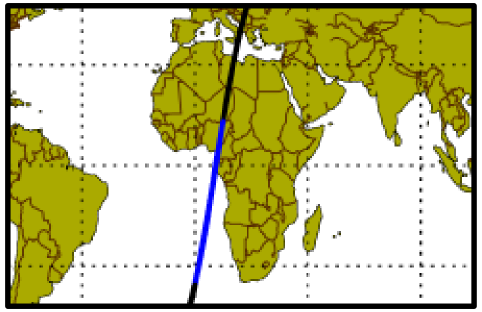
$$\tau_{a,532} = -\frac{1}{2} \ln\left(2\,S_c\,\gamma'_{c,532}\,\eta_{c,532} \right)$$

$$= -\frac{1}{2} \ln\left(2\,S_c\,\gamma'_{c,532} \left(\frac{1-\delta_{v,532}}{1+\delta_{v,532}} \right)^2 \right)$$

1064 nm Data Provides Additional Info

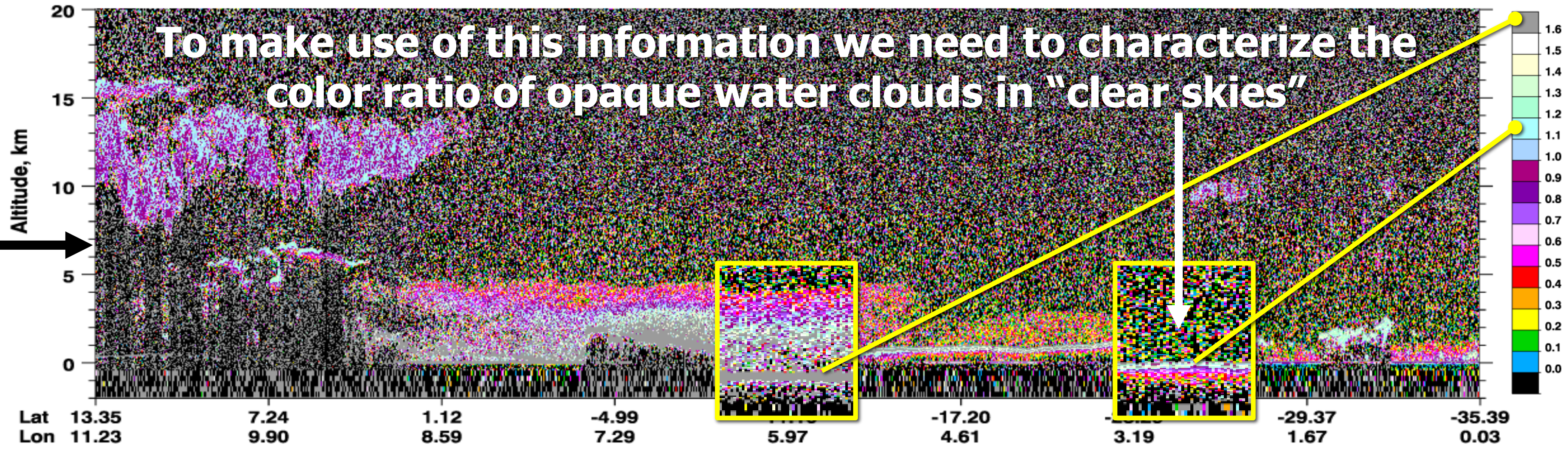
532 nm Total Attenuated Backscatter, km^{-1} sr^{-1} UTC: 2008-08-04 01:08:15.3 to 2008-08-04 01:21:44.0 Version: 3.01 Nominal Nighttime





Attenuated Color Ratio, 1064nm/532nm UTC: 2008-08-04 01:08:15.3 to 2008-08-04 01:21:44.0 Version: 3.01 Nominal Nighttime

$$\chi'(z) = \beta'_{1064}(z) \Big/ \beta'_{532}(z)$$



Layer-Integrated Attenuated Backscatter Color Ratio

$$\chi'_{\text{aerosol above}} = \frac{T^2_{a,1064}(0,\text{top}) \int_{\text{top}}^{\text{base}} B_{1064}(z)\,dz}{T^2_{a,532}(0,\text{top}) \int_{\text{top}}^{\text{base}} B_{532}(z)\,dz} = \frac{T^2_{a,1064}(0,\text{top})}{T^2_{a,532}(0,\text{top})}\chi'_{\text{clear}}$$

measured

retrieved

"characterized"

ONE EQUATION, ONE UNKNOWN

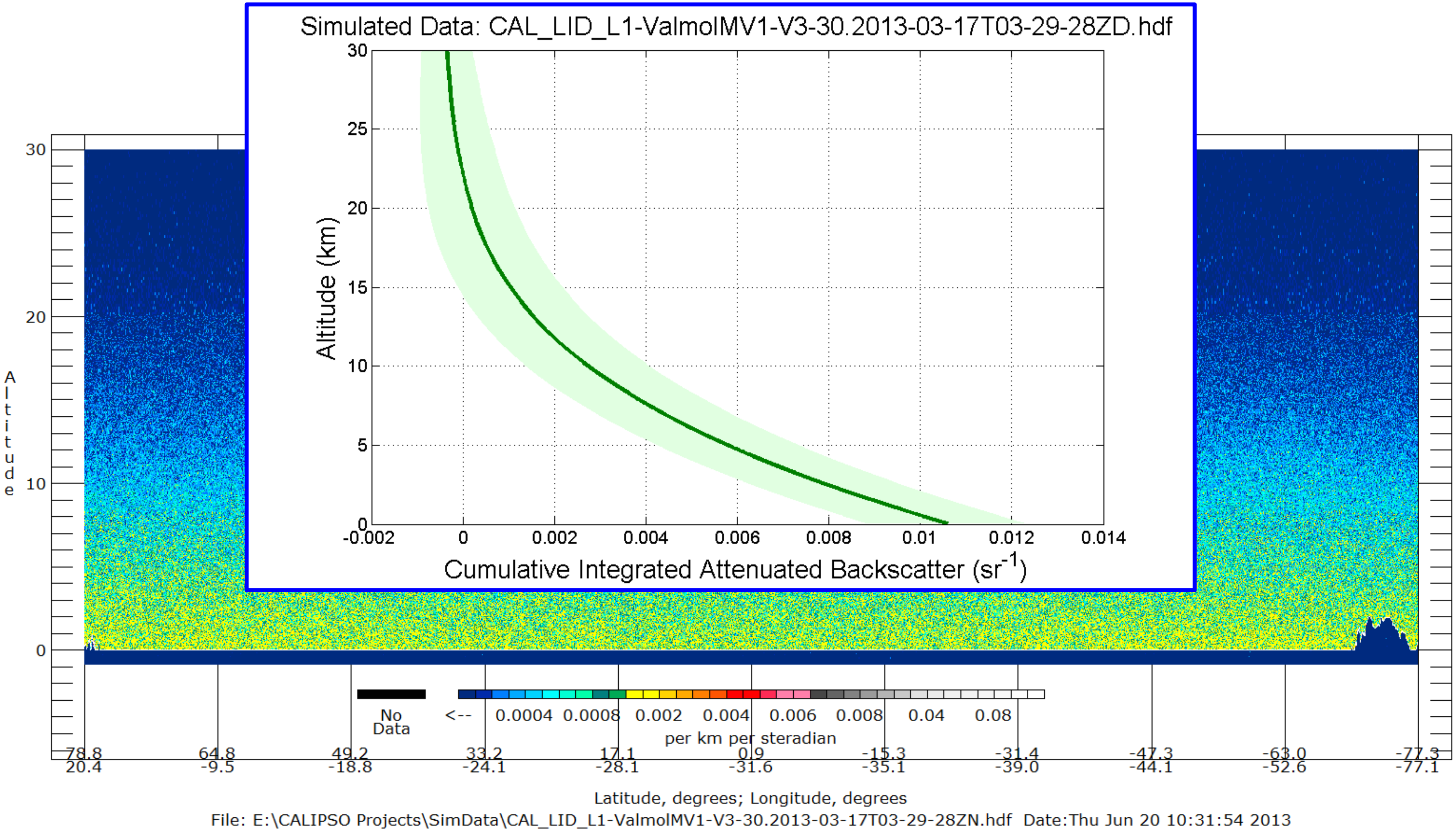
$$T^2_{a,1064}(0,\text{top}) = T^2_{a,532}(0,\text{top})\frac{\chi'_{\text{aerosol above}}}{\chi'_{\text{clear}}}$$

$$\tau_{1064} = -0.5\,\ln\left(T^2_{a,532}(0,\text{top})\frac{\chi'_{\text{aerosol above}}}{\chi'_{\text{clear}}}\right)$$

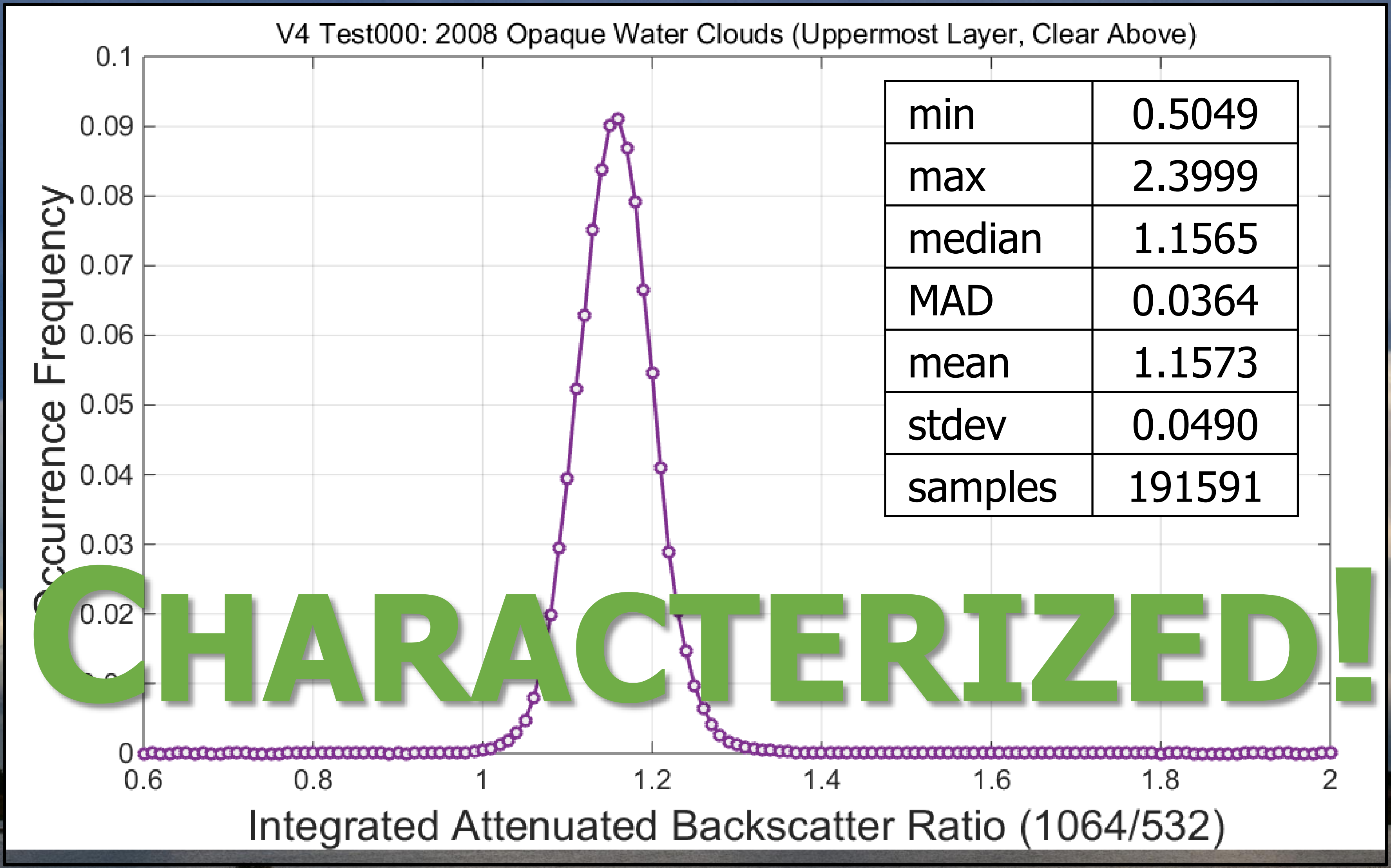
Aerosol Ångström Exponent

$$\alpha = -\frac{\log\left(\tau_{1064}/\tau_{532}\right)}{\log\left(1064/532\right)}$$

When Do We Have "Clear Air" Above?



WATER CLOUD COLOR RATIOS MEASURED BY CALIOP



min	0.5049
max	2.3999
median	1.1565
MAD	0.0364
mean	1.1573
stdev	0.0490
samples	191591

LIU ET AL., 2015: EVALUATION OF CALIOP 532 nm AOD OVER OPAQUE WATER CLOUDS

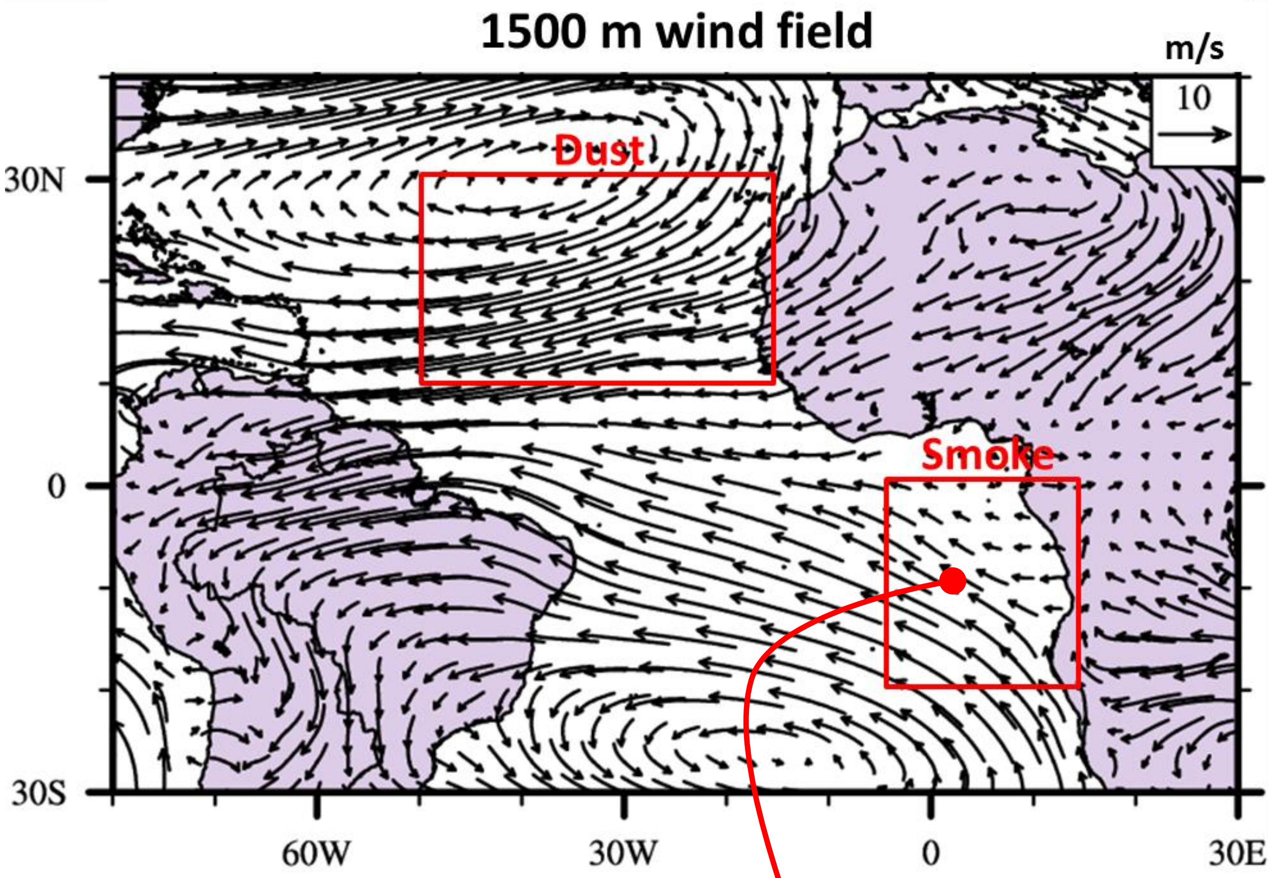


Figure 1: Spatial domains analyzed (red boxes) and wind fields (arrows) from ECMWF data for July and August from 2007 to 2012. The northern region (10°N-30°N, 50°W-15°W) is along the Saharan dust transport pathway over the tropical North Atlantic, while **the southern region (20°S-0°, 5°W-15°E) is along the smoke transport pathway over the tropical South Atlantic.**

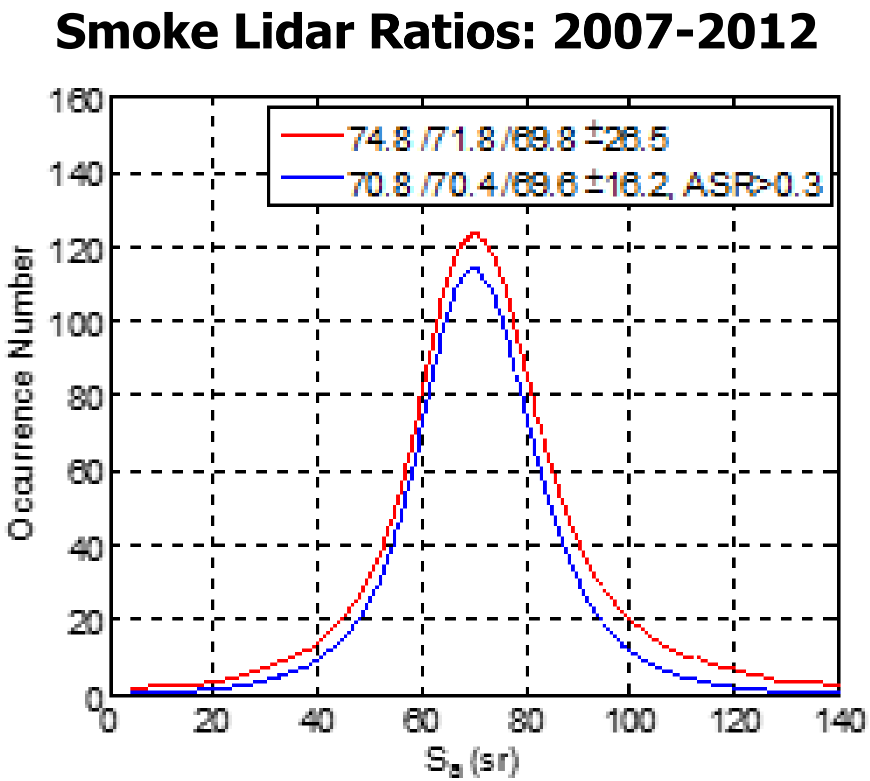
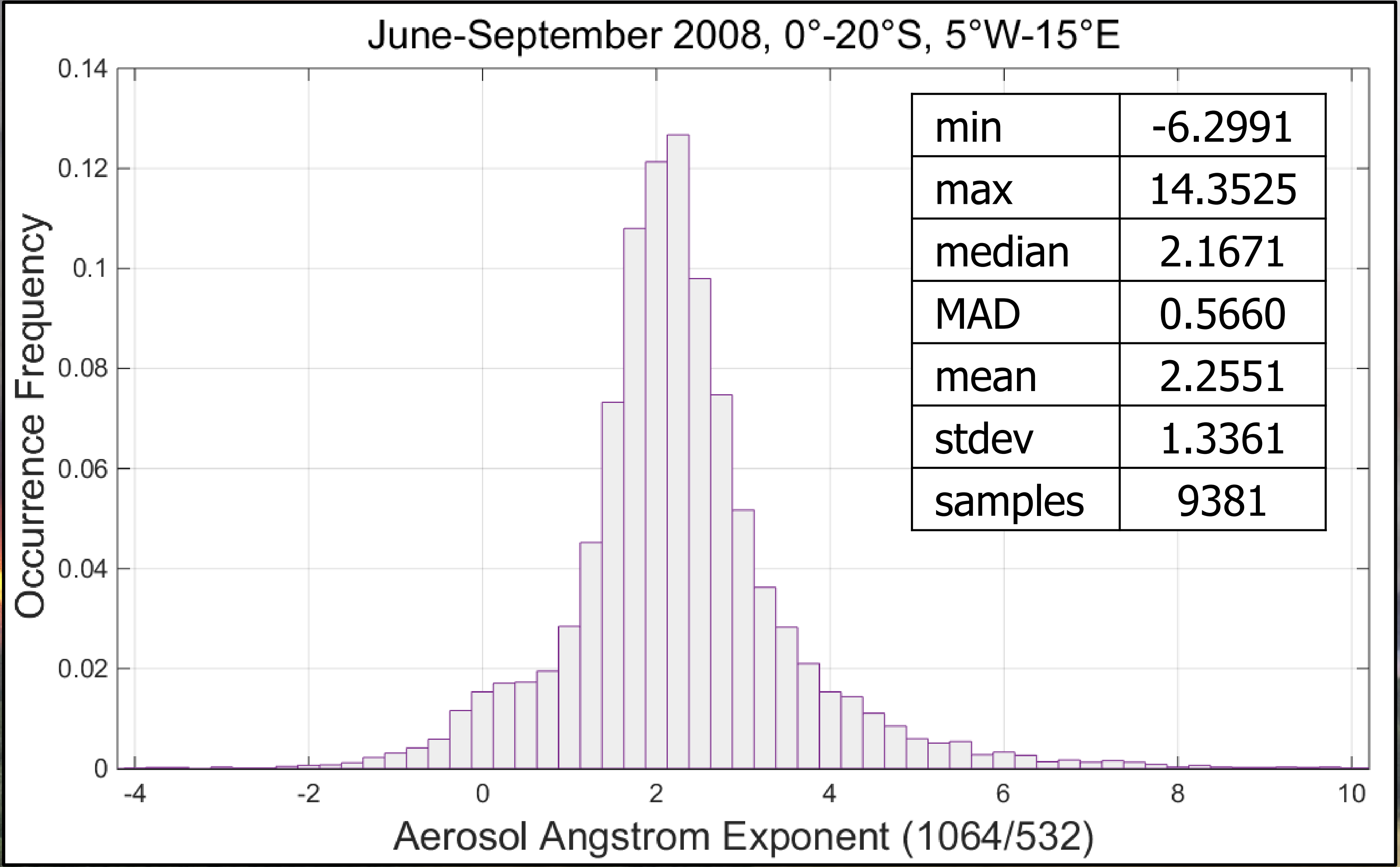


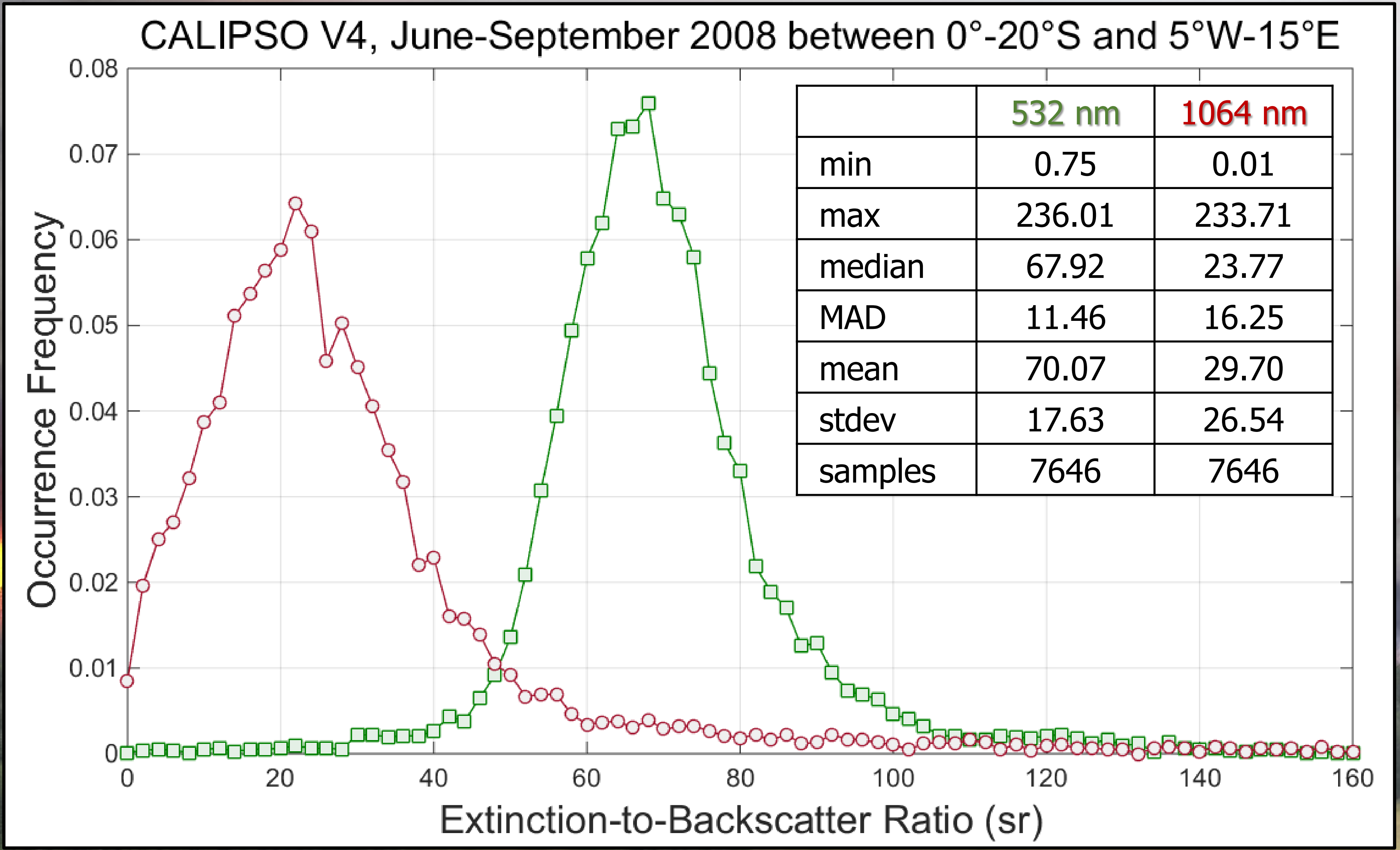
Figure 10(c): The red curve show result for all data, while the blue curve includes only data with mean scattering ratios above 0.2. The numbers in the legends of are mean/median/mode ± standard deviation.

CALIOP ÅNGSTRÖM EXPONENTS FOR SMOKE



min	-6.2991
max	14.3525
median	2.1671
MAD	0.5660
mean	2.2551
stdev	1.3361
samples	9381

CALIOP Lidar Ratios for Smoke



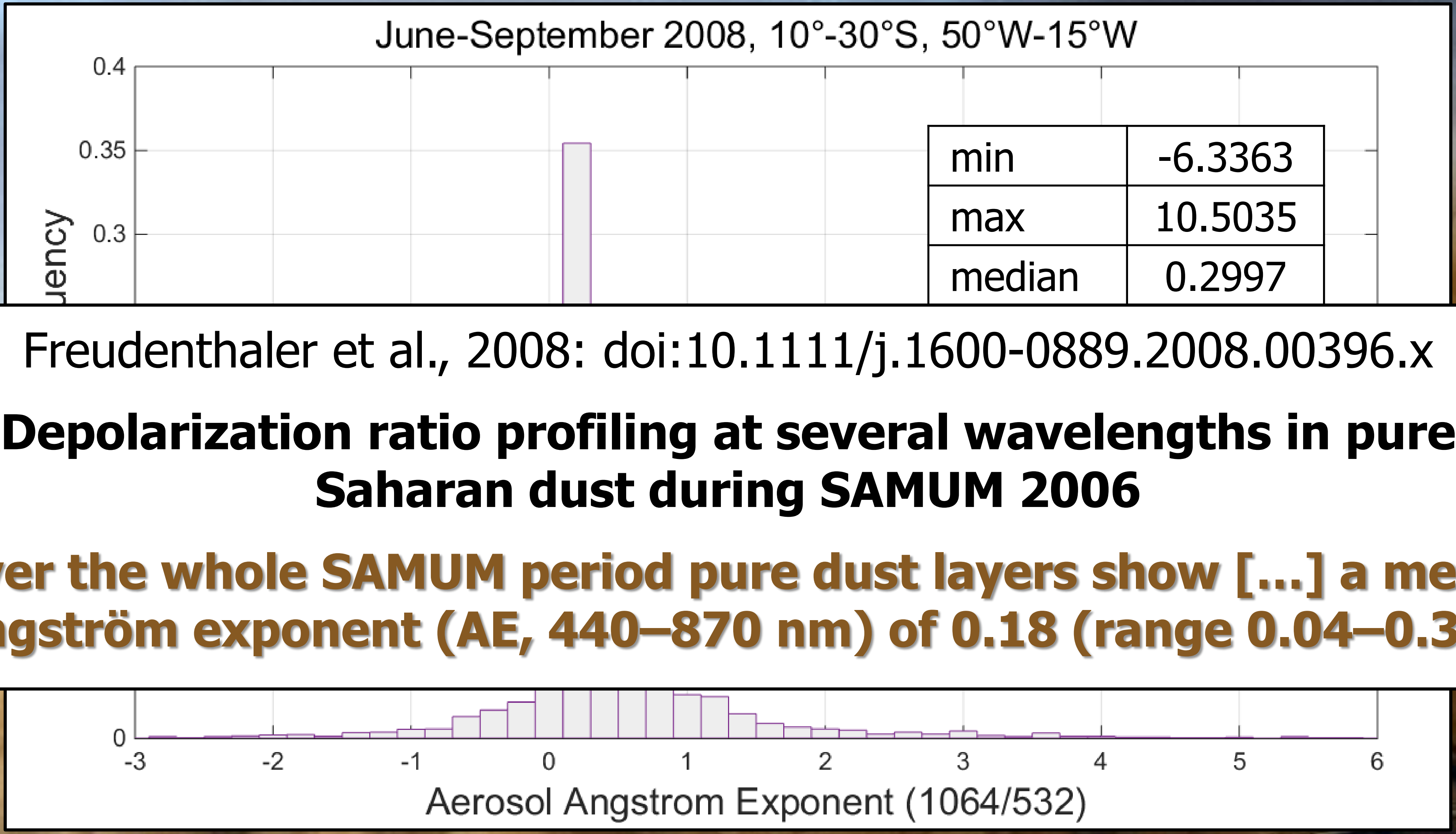
	532 nm	1064 nm
min	0.75	0.01
max	236.01	233.71
median	67.92	23.77
MAD	11.46	16.25
mean	70.07	29.70
stdev	17.63	26.54
samples	7646	7646

Table 6. Fine-mode lidar ratios S_λ for the optical models developed for each AERONET site. Data in parentheses are for $\tau_{f,550} = 0.5$.

Site	S_{355}	S_{532}	S_{1064}
Alta Floresta	$86.6–3.50\tau_{f,550}$ (84.9)	$69.1+2.63\tau_{f,550}$ (70.4)	$23.3+4.57\tau_{f,550}$ (25.6)
Bonanza Creek	$52.5–5.90\tau_{f,550}$ (49.6)	$59.3–4.65\tau_{f,550}$ (57.0)	$37.2+4.91\tau_{f,550}$ (39.7)
Cuiaba	$96.0–2.51\tau_{f,550}$ (94.8)	$67.3+7.09\tau_{f,550}$ (70.9)	$21.8+6.43\tau_{f,550}$ (25.0)
Jabiru	[illegible]	$73.8+2.39\tau_{f,550}$ (75.0)	$23.5+4.98\tau_{f,550}$ (26.0)
Mongu	[illegible]	$72.0+6.86\tau_{f,550}$ (75.4)	$24.8+4.89\tau_{f,550}$ (27.3)
Moscow	[illegible]	$66.6–0.573\tau_{f,550}$ (66.3)	$32.9+6.92\tau_{f,550}$ (36.3)
Mukdahan	[illegible]	$77.5+3.83\tau_{f,550}$ (79.4)	$30.6+8.65\tau_{f,550}$ (35.0)
Skukuza	[illegible]	$69.6+3.88\tau_{f,550}$ (71.6)	$22.2+4.06\tau_{f,550}$ (24.3)
Tomsk 22	[illegible]	$67.3+1.24\tau_{f,550}$ (67.9)	$31.6+6.25\tau_{f,550}$ (34.7)
Yakutsk	$66.6–6.04\tau_{f,550}$ (63.6)	$66.6–2.90\tau_{f,550}$ (65.1)	$29.9+5.80\tau_{f,550}$ (32.8)

www.atmos-chem-phys.net/14/11493/2014/ Atmos. Chem. Phys., 14, 11493–11523, 2014

CALIOP Ångström Exponents for Dust



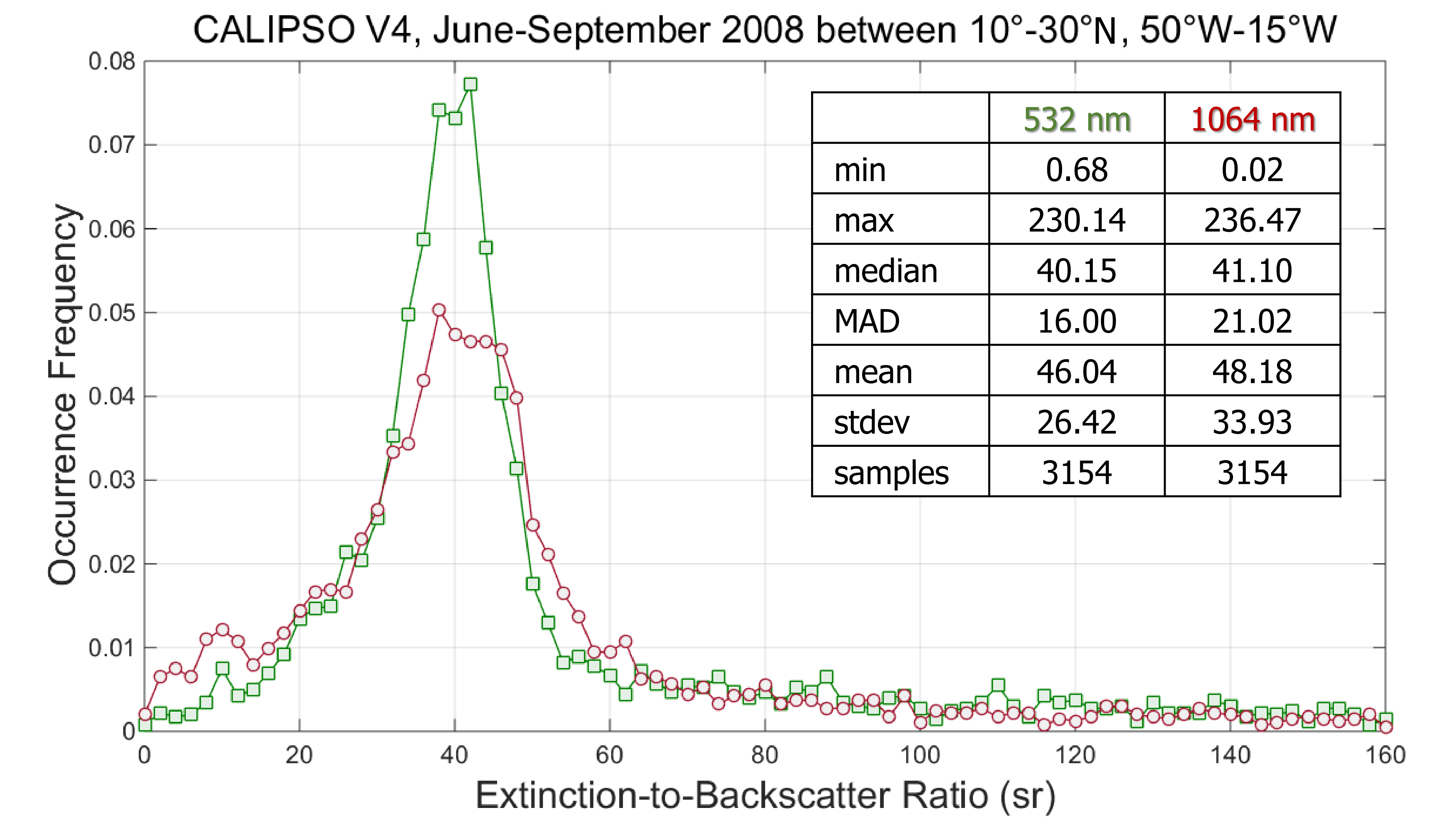
min	-6.3363
max	10.5035
median	0.2997

Freudenthaler et al., 2008: doi:10.1111/j.1600-0889.2008.00396.x

Depolarization ratio profiling at several wavelengths in pure Saharan dust during SAMUM 2006

Over the whole SAMUM period pure dust layers show [...] a mean Ångström exponent (AE, 440–870 nm) of 0.18 (range 0.04–0.34)

CALIOP Lidar Ratios for Dust

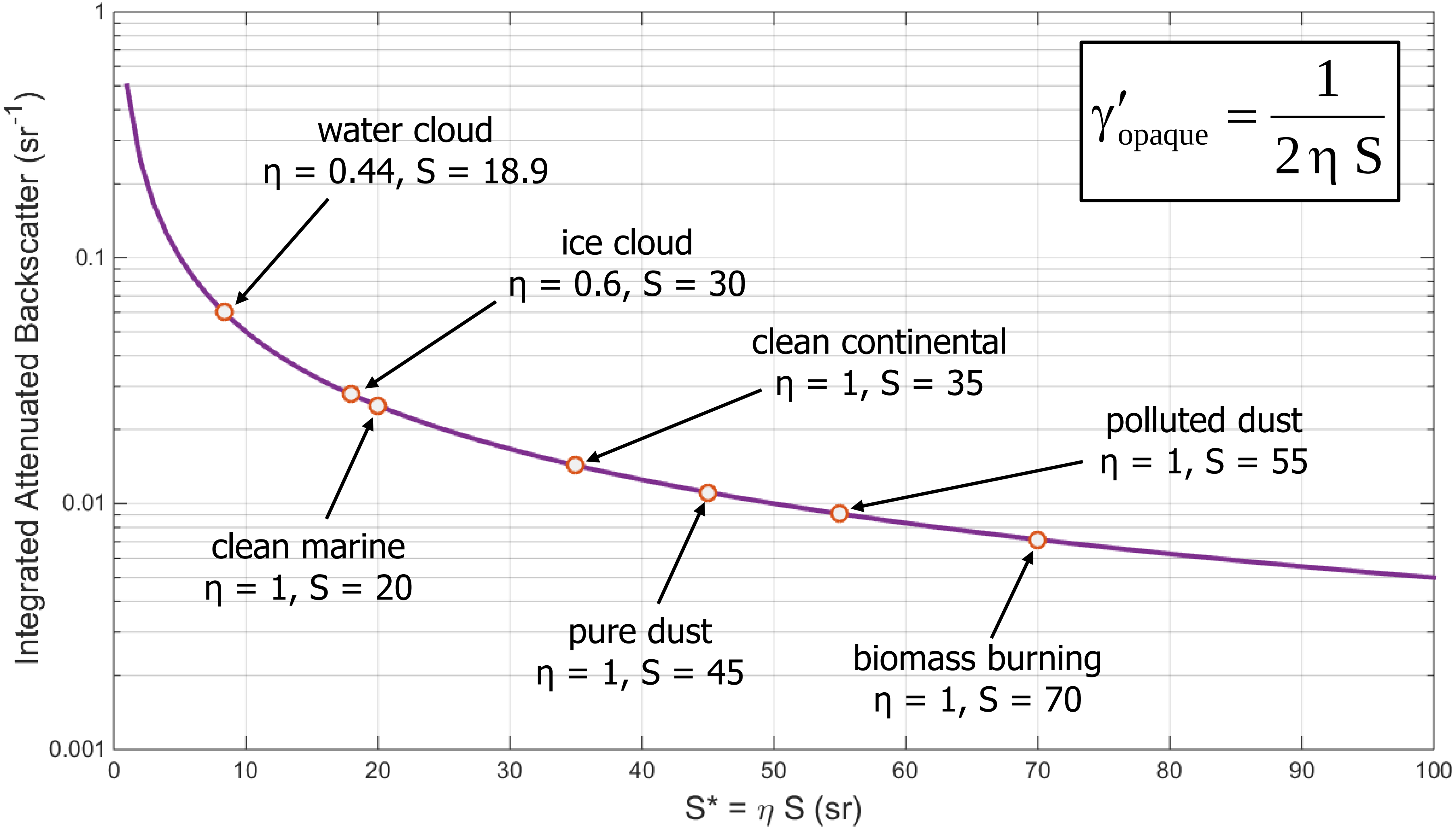


	532 nm	1064 nm
min	0.68	0.02
max	230.14	236.47
median	40.15	41.10
MAD	16.00	21.02
mean	46.04	48.18
stdev	26.42	33.93
samples	3154	3154


thanks for listening

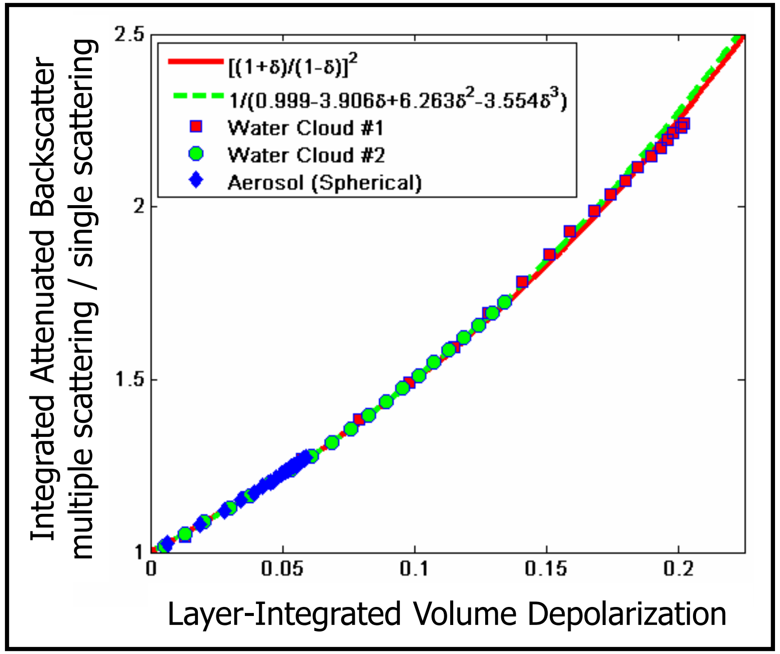
BACKUP SLIDES?

Integrated Attenuated Backscatter as a Function of Effective Lidar Ratio



$$\gamma'_{opaque} = \frac{1}{2\eta S}$$

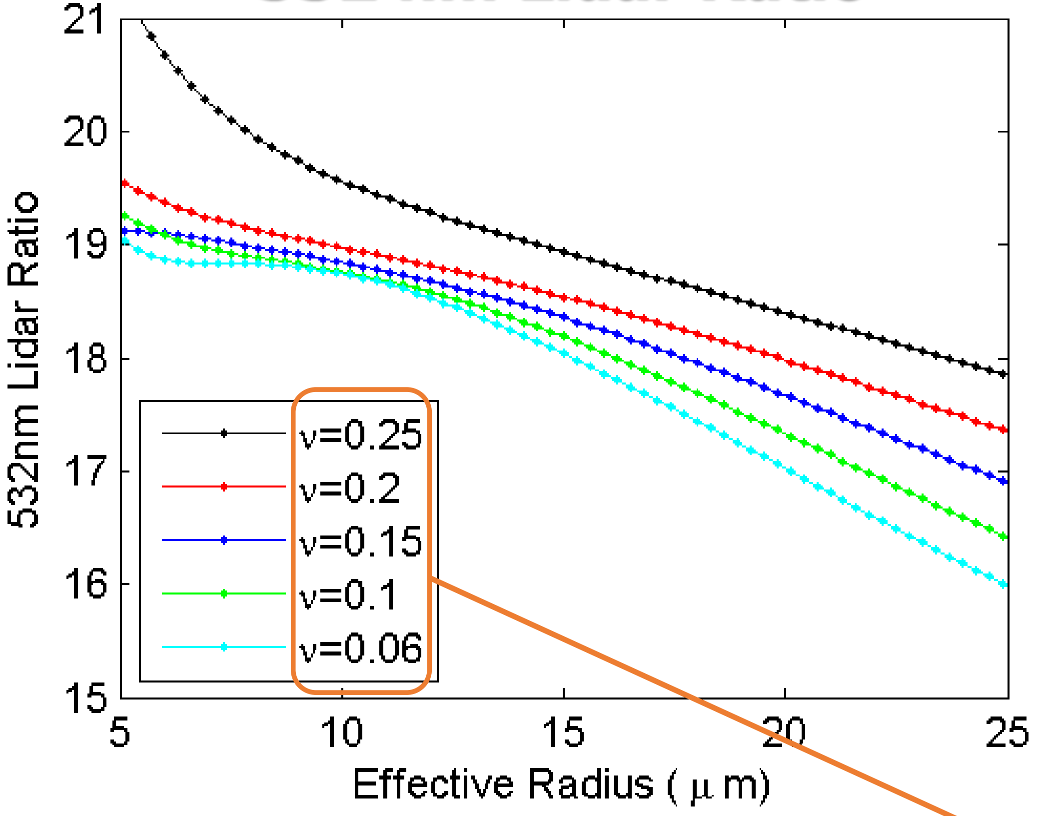
Hu et al., 2007: Retrieving Optical Depths and Lidar Ratios for Transparent Layers Above Opaque Water Clouds



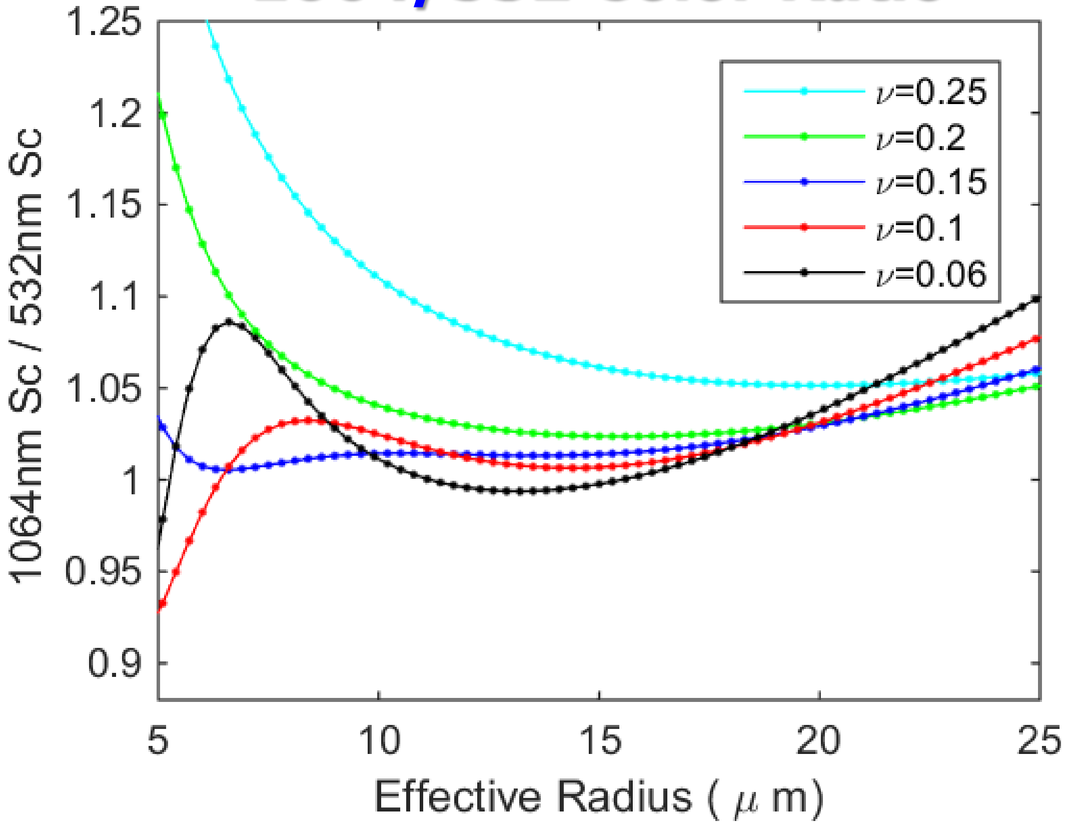
Liu et al., 2015: "S_c is found to vary insignificantly for a wide variety of water clouds, having a mean value of 18.9 sr and a standard deviation of 0.25 sr over ocean and 0.47 sr over land."

Theoretical Calculations of Water Cloud Color Ratios (Single Scattering Only!)

532 nm Lidar Ratio



1064/532 Color Ratio



variance of droplet size distribution

Siberian Smoke Over North America