Methods to Quantify Aerosol Absorption That Could Cause Laser Thermal Blooming

13 October 2021

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Optica's Laser Systems Technical Group

Overview

Abstract: This webinar outlines a simple, low-cost method to rapidly quantify aerosol and molecular absorption and scattering effects at any laser wavelength using only measurements of temperature, pressure, humidity, and aerosol number concentration.

Webinar Objectives

1. Describe how absorption due to molecules and aerosols can cause laser thermal blooming
   - Off-axis laser scattering affected by aerosol absorption
   - Thermal blooming may be an on-axis method to quantify aerosol absorption

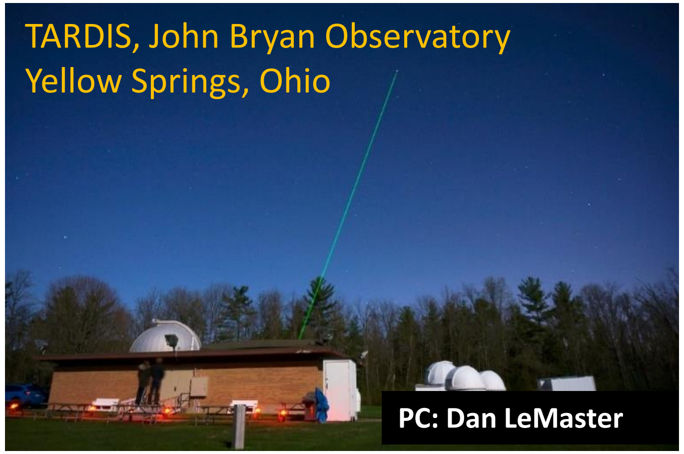
2. Describe AFIT CDE's initial testing of NOAA's Continuous Light Absorption Photometer (CLAP) as it prepares to join the NOAA Federated Aerosol Network (NFAN)
   - Comparisons to Magee Scientific Black Carbon Aethalometer
   - Importance of quantifying aerosol scattering in aerosol absorption measurement

3. Demonstrate that calculations from total aerosol number concentration assuming a single mode lognormal size distribution can provide reasonable aerosol absorption estimates of CLAP measurements

4. Describe the need to better characterize aerosol absorption for climate change assessments

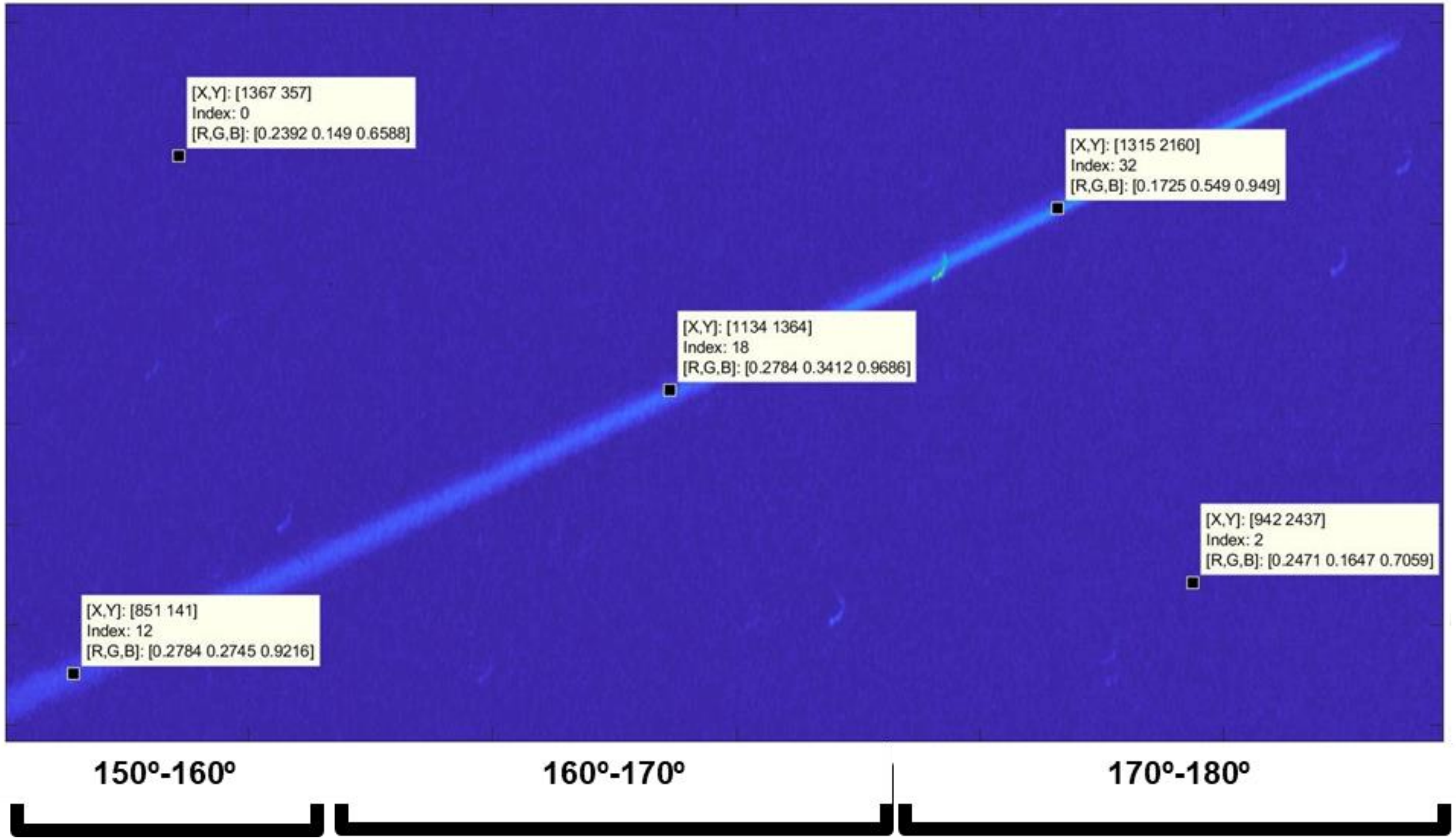
Aerosol Absorption from Off-Axis Backscattering

Rayleigh Beacon Laser Pulses



Laser Images

- Image of the upper portion of the beam. Pixel index and location are plotted to show the increase in brightness values along the length of the beam.
- This shows an increase in scattered irradiance at larger phase angles.



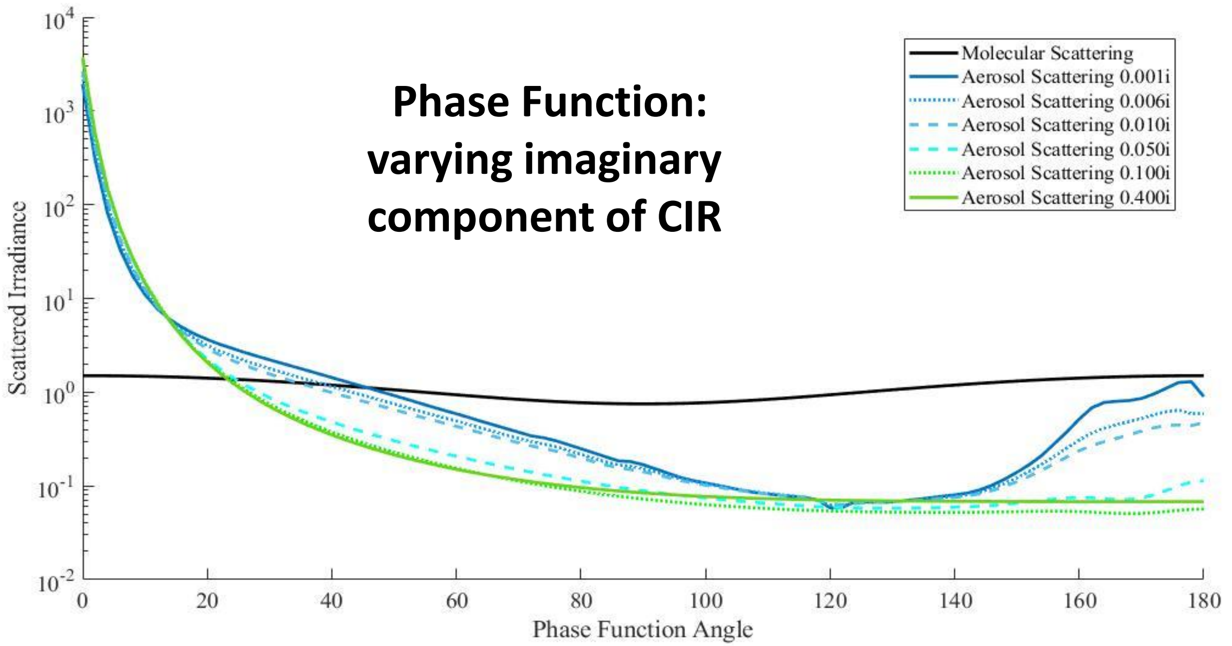
Grossnickle, J. C., "Determining Bulk Aerosol Absorption from Off Axis Backscattering using Rayleigh Beacon Laser Pulses" (2020). *Theses and Dissertations*. 3597. https://scholar.afit.edu/etd/3597

Aerosol Absorption from Off-Axis Backscattering

Rayleigh Beacon Laser Pulses

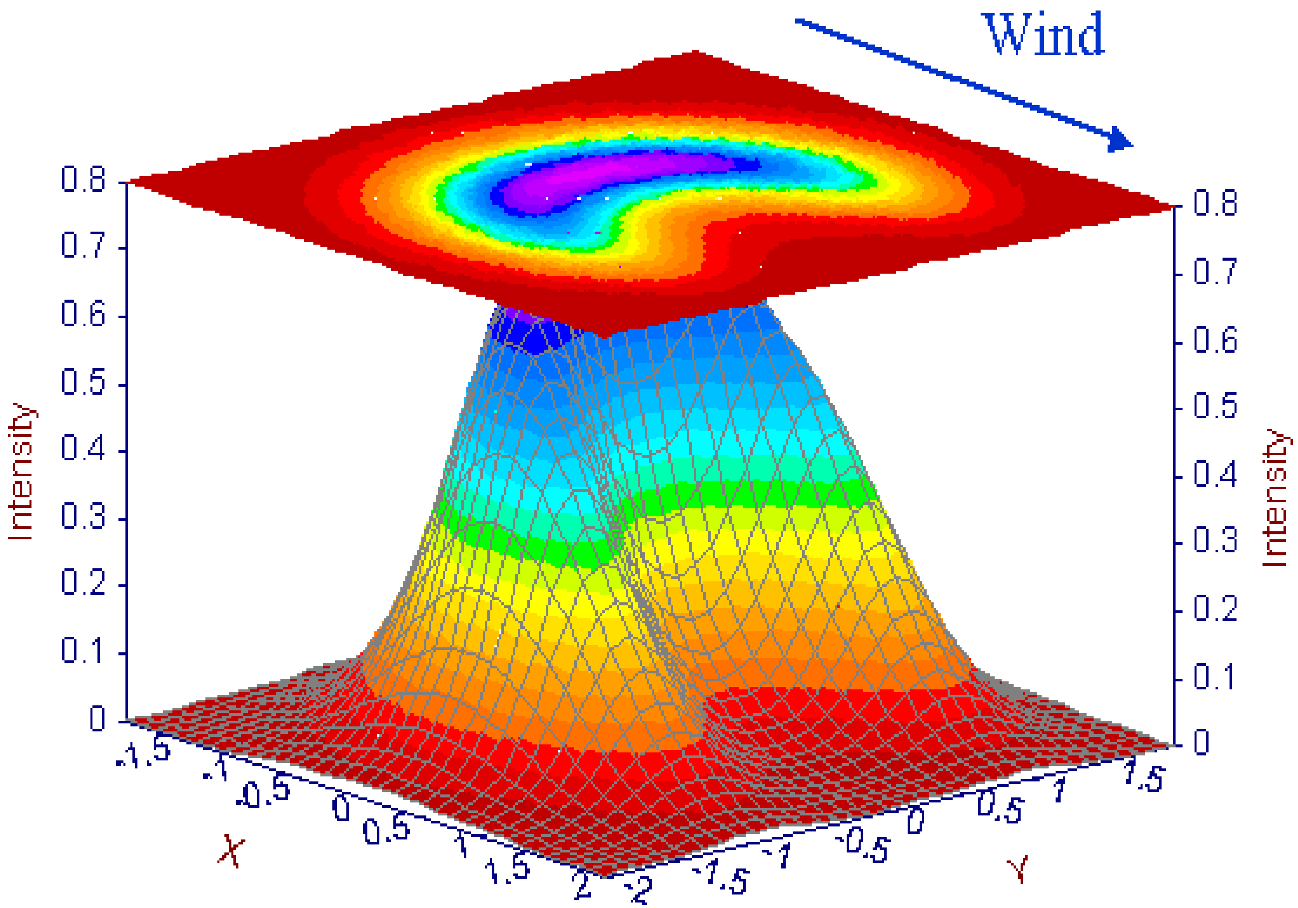
- Multiple LEEDR-derived predicted phase function profiles. The black solid line represents molecular (Rayleigh) scattering, while the blue and green lines are the different aerosol scattering (Mie) phase functions resulting from various imaginary index values
- To capture full spectrum of common imaginary index values seen in local aerosol components the following values are used: 0.001i, 0.006i (GADS), 0.010i, 0.050i, 0.100i, 0.400i (soot).

- Varying absorption properties (CIR) changes the shape of the phase function, notably at backward phase angles.
- Backscattered portion of scattering phase function offers the most information about aerosol absorption properties for off-axis laser energy analysis
    - Laser images show additional brightness as approach 170-180 scattering angles
    - Backscattered imagery suggests bulk aerosol absorption values no greater than 0.05 at 527 nm



Grossnickle, J. C., "Determining Bulk Aerosol Absorption from Off Axis Backscattering using Rayleigh Beacon Laser Pulses" (2020). *Theses and Dissertations*. 3597. https://scholar.afit.edu/etd/3597

Absorption & Thermal Blooming



Thermal Blooming: The effect that characterizes an intense laser beam that is passed through an absorbing medium, causing the absorbed energy to produce density changes that can alter the intensity distribution of the beam and shift it away from the intended direction of propagation. Thermal blooming is an effect associated with heating the atmosphere.

Thermal blooming produces an intensity pattern with a crescent shape, turned into the wind direction.

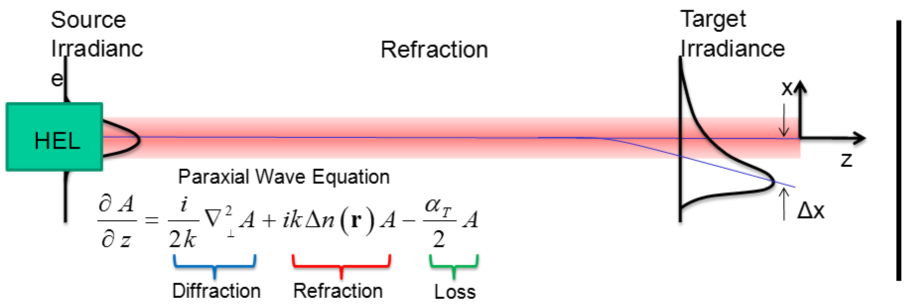
Perram, G.P., S.J. Cusumano, R.L. Hengehold, and S.T. Fiorino, 2010: *An Introduction to Laser Weapon Systems*. Directed Energy Professional Society. 463 pp.

Absorption & Thermal Blooming

Thermal Blooming Distortion Number, N_D

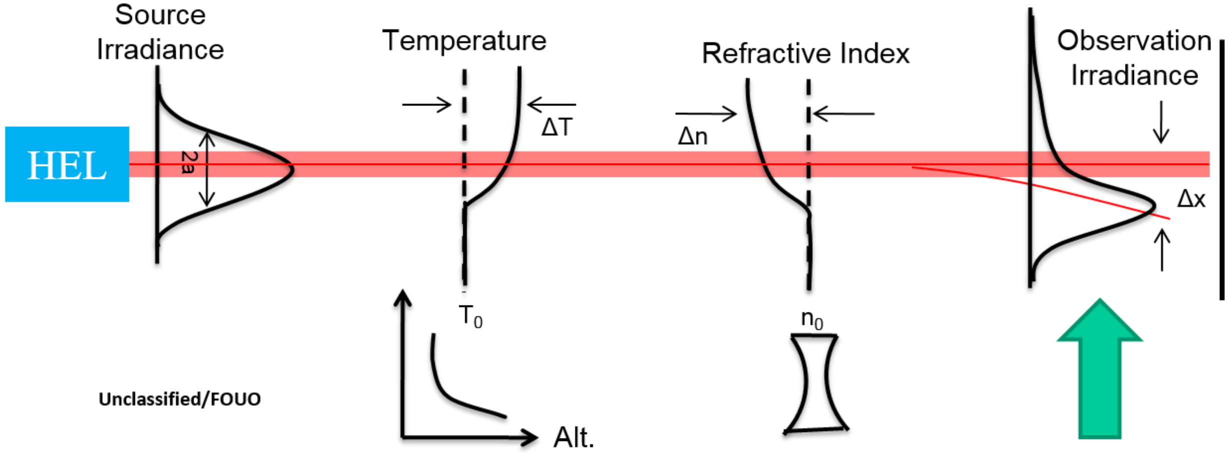
Thermal Blooming due to smoke

$$N_D = -\frac{4\sqrt{2}kP}{\rho_0 C_p}\int_{path}\frac{\alpha(z)T(z)n_T(z)}{V_{wind}(z)D(z)}dz$$



Courtesy
Wick & Lloyd

$\alpha(z)$= absorption coefficient
V_{wind} = effective wind speed
P = laser power
z = propagation distance
$k = 2\pi/\lambda$
D(z) = beam diameter
D = primary aperture diameter
ρ_o = 1.2 kg m^{-3}
C_p = 1005 J kg^{-1} K^{-1}
T(z) = transmission at range z
n_T (z) = thermal refractive gradient
R = total slant range



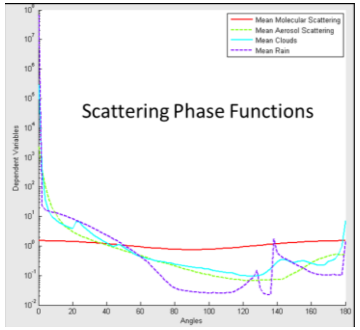
Unclassified/FOUO

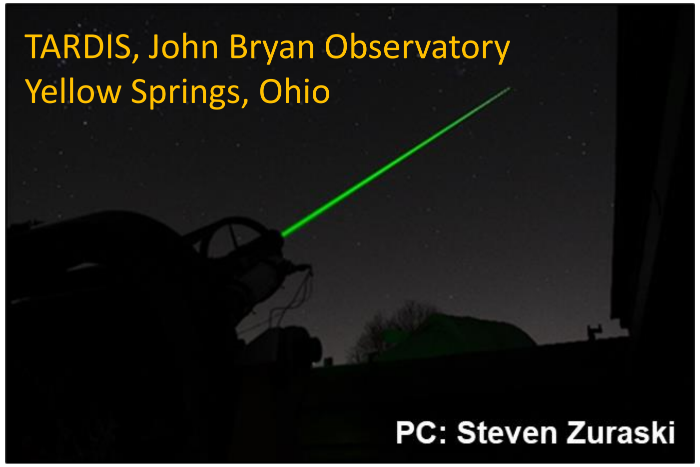
Thermal Blooming is a significant problem when $N_D > 25$

Current Research– Aerosol Absorption via Off-Axis Measurements and Thermal Blooming

Laser energy measurements using a side telescope and ultrafast laser to separate absorption from scattering (off-axis measurements)

- John Bryan Observatory is the laboratory
- Phase function shapes elucidate bulk aerosol absorption properties
- Implication: thermal blooming impacts on HEL spot displacement and distortion

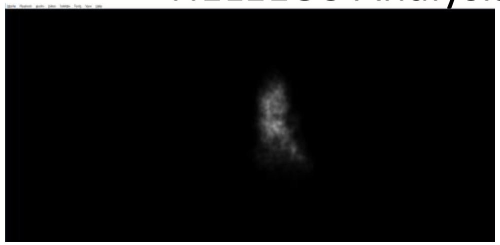




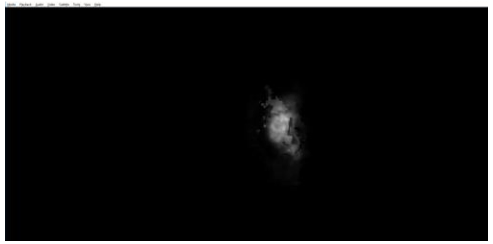
Deducing the amount of absorption from thermal blooming distortion and displacement

- AFIT 2.5 kW HEL Laboratory
- The amount of thermal blooming displacement and distortion is directly tied to absorption along the path
- Modeling allows quantification of molecular absorption component, remainder is aerosol absorption

HELEEOS Analysis of UK Trial Data



10-06-17, 10:06:13



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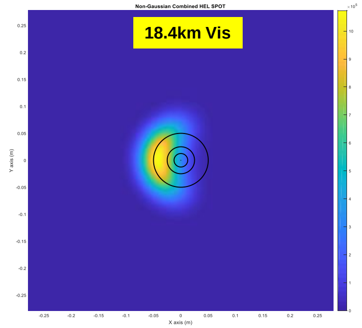
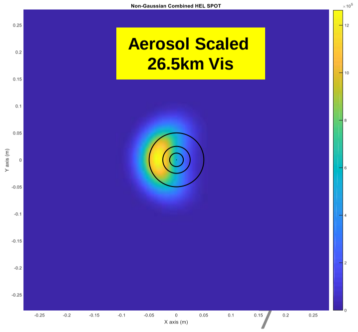
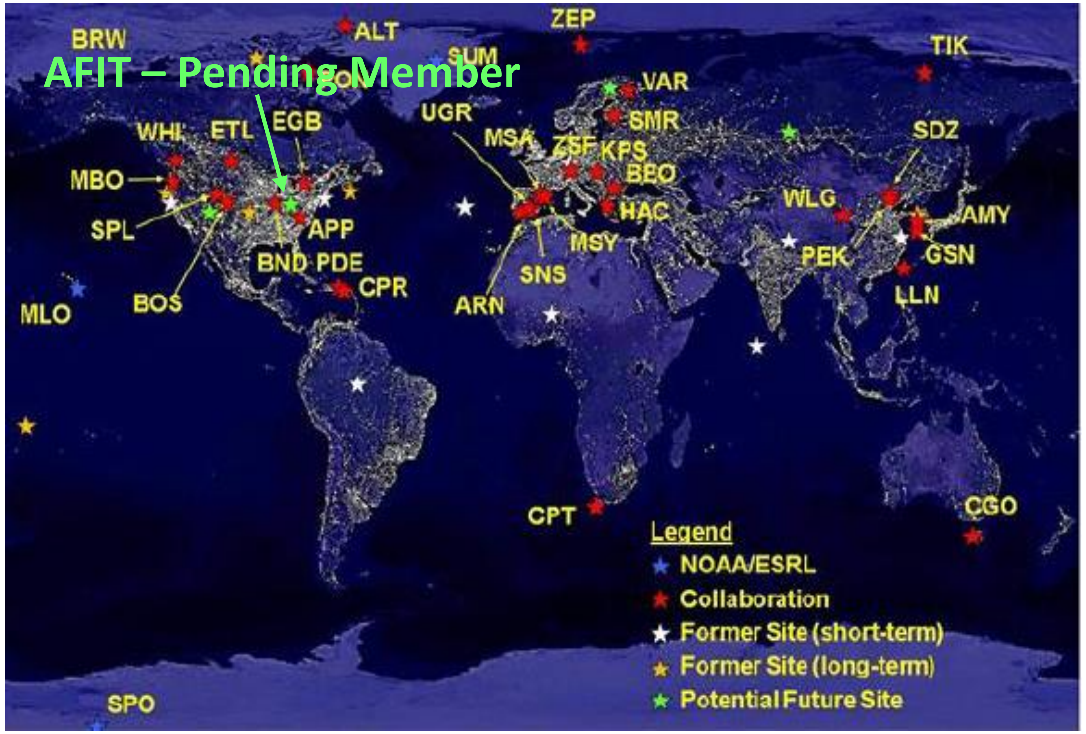




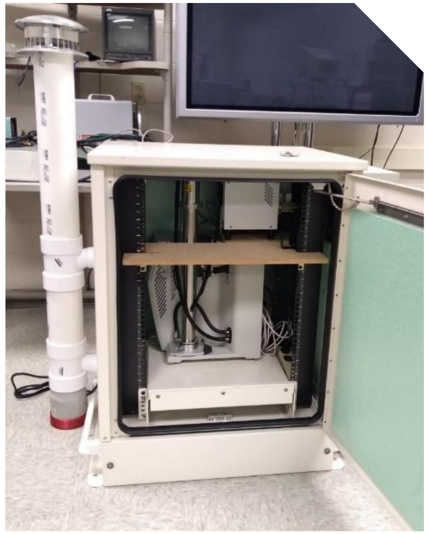
Neither method requires the production and/or control of the aerosol distribution. All that is required is the aerosol distribution be measured at the time of the test.

AFIT Aerosol Measurement Campaign

NOAA's Federal Aerosol Network (FAN)



Aerosol stack for main aerosol inlet (representative FAN config)



MEMORANDUM OF AGREEMENT

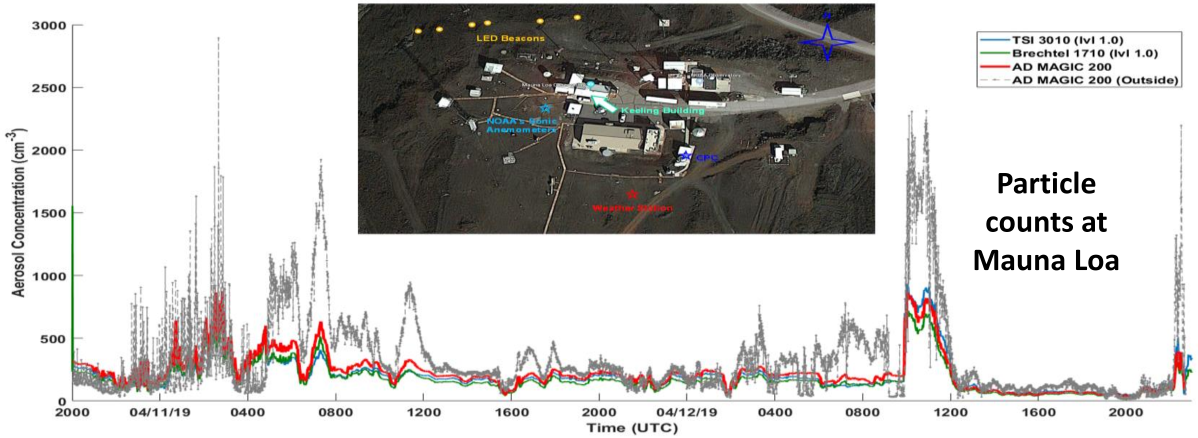
ESTABLISHING A COLLABORATION BETWEEN THE

Global Monitoring Division (GMD)
Earth System Research Laboratory (ESRL)
Office of Oceanic and Atmospheric Research (OAR)
National Oceanic and Atmospheric Administration (NOAA)
United States Department of Commerce (DOC)

And,

Air Force Institute of Technology (AFIT)
Air University (AU)
Air Education and Training Command (AETC)
United States Department of the United States Air Force (USAF)

Agreement No: GMD-AFIT-2019



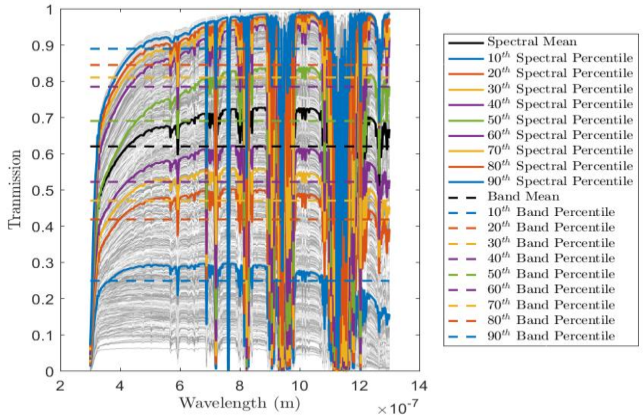
Andrews, E., P.J. Sheridan, J. , et al., 2019: "Overview of the NOAA/ESRL Federated Aerosol Network," Bull. Amer. Meteor. Soc., 100, 123-135, https://doi.org/10.1175/BAMS-D-17-0175.1.

LEEDR

Laser Environmental Effects Definition and Reference

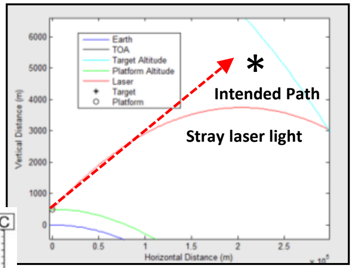
573 ExPERT (land) locations represented in LEEDR

Worldwide climatology for diffuse cloud transmission



V&V'd Atmospheric Effects and Radiative Transfer Code for HEL

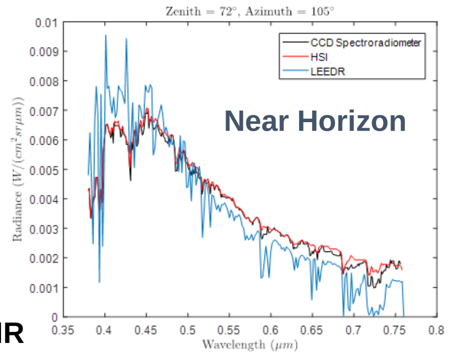
Light Refraction: Path Bending

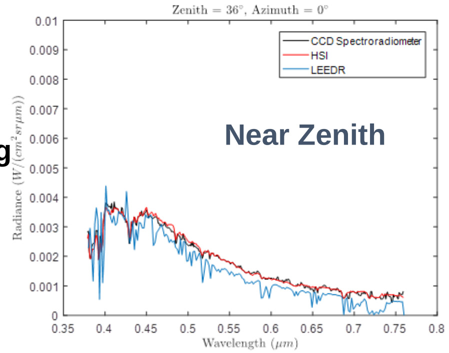


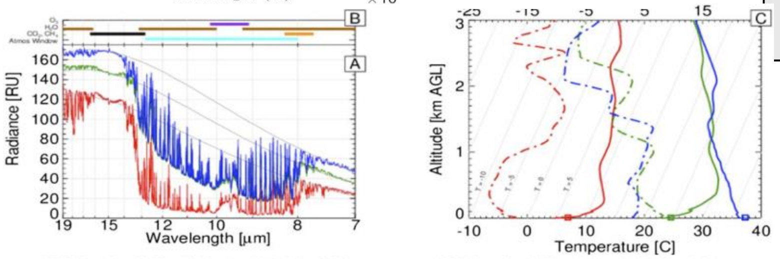
Creates physically realizable horizontal / vertical profiles of meteorological and weather event data and associated radiative effects (e.g. optical extinction, path radiance):

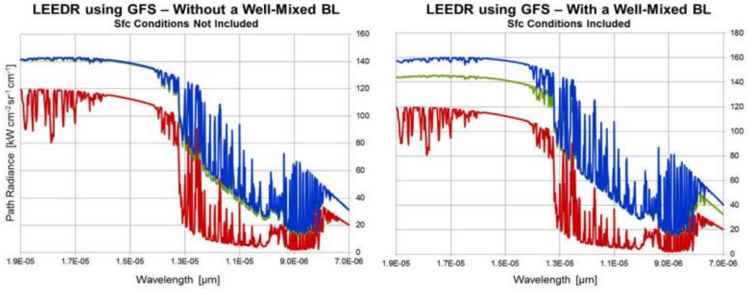
- **Aerosol and surface observation (i.e. T, P, RH) climatology at 573 ExPERT and 1° x 1° oceanic grid locations**
- **Numerical weather forecast, re-analysis data**
- **Profiles optical turbulence (i.e. C_n^2)**
- **Accounts for light-refraction and single/multi-scatter**
- **Includes sun-moon calculator**

UV/VIS/NIR Path Radiance with Multiple Scattering







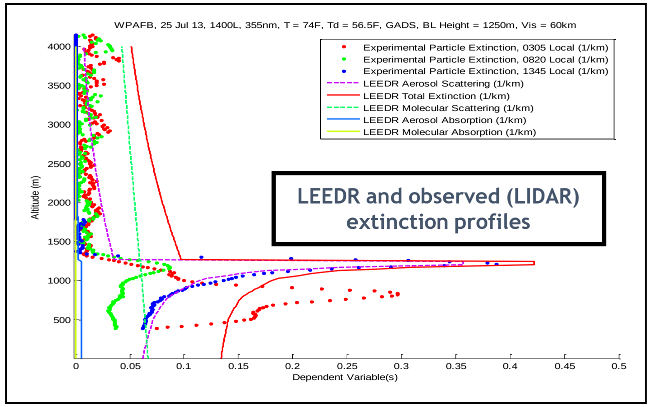


LWIR Path Radiance

Red: 7 Nov 2012 at 1125Z

Green: 27 June 2013 at 1132Z

Blue: 27 June 2013 at 1731Z



Boundary Layer - Aerosol Extinction Increasing with Height

A tool for Applied Physics, Nuclear Physics, Atmospheric Physics, Remote Sensing, & DE

Burley, J.L., S.T. Fiorino, B. Elmore, and J. Schmidt, 2017: "A Fast Calculating Two-Stream-Like Multiple Scattering Algorithm that Captures Azimuthal and Elevation Variations" J. Appl. Meteor. Climatol. 56:11, pp. 3049-3063. DOI:10.1175/JAMC-D-17-0044.1.

Fiorino, S.T., R. M. Randall, M. F. Via, and J. L. Burley, 2014: Validation of a UV-to-RF high-spectral-resolution atmospheric boundary layer characterization tool. J. Appl. Meteor. Climatol., 53, 136–156.

LEEDR's Exceptionally Complete Aerosol Optical Properties Database

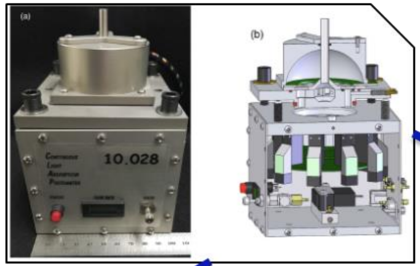
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	lambda(microns)	insoluble	mineral(acc)(desert dust)	mineral(coa)(desert dust)	mineral(nuc)(desert dust)	mineral(transported)(desert dust)	sea salt(acc)	sea salt(coa)	soot	sulfate droplets	water-soluble	MODTRAN	MODTRAN	MODTRAN	MODTRAN	
2	0.25	1.53-0.03i	1.53-0.03i	1.53-0.03i	1.53-0.03i	1.53-0.03i	1.51-5e-06i	1.51-5e-06i	1.62-0.45i	1.484-1e-08i	1.53-0.03i	1.53-0.0	1.53-0.0	1.5693-0	1.5693-0	
3	0.3	1.53-0.008i	1.53-0.025i	1.53-0.025i	1.53-0.025i	1.53-0.025i	1.51-2e-06i	1.51-2e-06i	1.74-0.47i	1.469-1e-08i	1.53-0.008i	1.53-0.0	1.53-0.0	1.572-0.	1.572-0.	
4	0.35	1.53-0.008i	1.53-0.017i	1.53-0.017i	1.53-0.017i	1.53-0.017i	1.51-3.24e-07i	1.51-3.24e-07i	1.75-0.465i	1.452-1e-08i	1.53-0.005i	1.53-0.0	1.53-0.0	1.574-0.	1.574-0.	
5	0.4	1.53-0.008i	1.53-0.013i	1.53-0.013i	1.53-0.013i	1.53-0.013i	1.5-3e-08i	1.5-3e-08i	1.75-0.46i	1.44-1e-08i	1.53-0.005i	1.53-0.0	1.53-0.0	1.574-0.	1.574-0.	
6	0.45	1.53-0.008i	1.53-0.0085i	1.53-0.0085i	1.53-0.0085i	1.53-0.0085i	1.5-2.43e-08i	1.5-2.43e-08i	1.75-0.455i	1.432-1e-08i	1.53-0.005i	1.53-0.0	1.53-0.0	1.574-0.	1.574-0.	
7	0.5	1.53-0.008i	1.53-0.0078i	1.53-0.0078i	1.53-0.0078i	1.53-0.0078i	1.5-1.55e-08i	1.5-1.55e-08i	1.75-0.45i	1.431-1e-08i	1.53-0.005i	1.53-0.0	1.53-0.0	1.574-0.	1.574-0.	
8	0.55	1.53-0.008i	1.53-0.0055i	1.53-0.0055i	1.53-0.0055i	1.53-0.0055i	1.5-1e-08i	1.5-1e-08i	1.75-0.44i	1.43-1e-08i	1.53-0.006i	1.53-0.0	1.53-0.0	1.574-0.	1.574-0.	
9	0.6	1.53-0.008i	1.53-0.0045i	1.53-0.0045i	1.53-0.0045i	1.53-0.0045i	1.49-1.6e-08i	1.49-1.6e-08i	1.75-0.435i	1.429-1.47e-08i	1.53-0.006i	1.53-0.0	1.53-0.0	1.574-0.	1.574-0.	
10	0.65	1.53-0.008i	1.53-0.0045i	1.53-0.0045i	1.53-0.0045i	1.53-0.0045i	1.49-4.24e-08i	1.49-4.24e-08i	1.75-0.435i	1.429-1.67e-08i	1.53-0.007i	1.5292-0	1.5292-0	1.5734-0	1.5734-0	
11	0.7	1.53-0.008i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.49-2e-07i	1.49-2e-07i	1.75-0.43i	1.428-2.05e-08i	1.53-0.007i	1.527-0.	1.527-0.	1.5716-0	1.5716-0	
12	0.75	1.53-0.008i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.49-1.08e-06i	1.49-1.08e-06i	1.75-0.43i	1.427-7.17e-08i	1.53-0.0085i	1.5248-0	1.5248-0	1.5699-0	1.5699-0	
13	0.8	1.52-0.008i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.48-1.95e-06i	1.48-1.95e-06i	1.75-0.43i	1.426-8.63e-08i	1.52-0.01i	1.5226-0	1.5226-0	1.5681-0	1.5681-0	
14	0.85	1.52-0.008i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.48-2.2175e-05i	1.48-2.2175e-05i	1.75-0.4325i	1.4255-1.7065e-07i	1.52-0.0115i	1.5204-0	1.5204-0	1.5664-0	1.5664-0	
15	0.9	1.52-0.008i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.48-4.24e-05i	1.48-4.24e-05i	1.75-0.435i	1.425-2.55e-07i	1.52-0.013i	1.52-0.0	1.52-0.0	1.566-0.	1.566-0.	
16	0.95	1.52-0.008i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.475-9.17e-05i	1.475-9.17e-05i	1.755-0.4375i	1.4235-8.925e-07i	1.52-0.01425i	1.52-0.0	1.52-0.0	1.566-0.	1.566-0.	
17	1	1.52-0.008i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.53-0.004i	1.47-0.000141i	1.47-0.000141i	1.76-0.44i	1.422-1.53e-06i	1.52-0.0155i	1.52-0.0	1.52-0.0	1.566-0.	1.566-0.	
18	1.05	1.508-0.008i	1.53-0.0042i	1.53-0.0042i	1.53-0.0042i	1.53-0.0042i	1.47-0.0001844i	1.47-0.0001844i	1.76-0.442i	1.4202-2.612e-06i	1.518-0.0162i	1.52-0.0	1.52-0.0	1.566-0.	1.566-0.	
19	1.1	1.496-0.008i	1.53-0.0044i	1.53-0.0044i	1.53-0.0044i	1.53-0.0044i	1.47-0.0002278i	1.47-0.0002278i	1.76-0.444i	1.4184-3.694e-06i	1.516-0.0169i	1.5158-0	1.5158-0	1.563-0.	1.563-0.	
20	1.15	1.484-0.008i	1.53-0.0046i	1.53-0.0046i	1.53-0.0046i	1.53-0.0046i	1.47-0.0002712i	1.47-0.0002712i	1.76-0.446i	1.4166-4.776e-06i	1.514-0.0176i	1.5106-0	1.5106-0	1.5593-0	1.5593-0	
21	1.2	1.472-0.008i	1.53-0.0048i	1.53-0.0048i	1.53-0.0048i	1.53-0.0048i	1.47-0.0003146i	1.47-0.0003146i	1.76-0.448i	1.4148-5.858e-06i	1.512-0.0183i	1.5054-0	1.5054-0	1.5555-0	1.5555-0	
22	1.25	1.46-0.008i	1.53-0.005i	1.53-0.005i	1.53-0.005i	1.53-0.005i	1.47-0.000358i	1.47-0.000358i	1.76-0.45i	1.413-6.94e-06i	1.51-0.019i	1.5002-0	1.5002-0	1.5518-0	1.5518-0	
23	1.3	1.45-0.008i	1.53-0.00514i	1.53-0.00514i	1.53-0.00514i	1.53-0.00514i	1.468-0.0004004i	1.468-0.0004004i	1.762-0.452i	1.411-2.9552e-05i	1.51-0.0197i	1.495-0.	1.495-0.	1.548-0.	1.548-0.	
24	1.35	1.44-0.008i	1.53-0.00528i	1.53-0.00528i	1.53-0.00528i	1.53-0.00528i	1.466-0.0004428i	1.466-0.0004428i	1.764-0.454i	1.409-5.2164e-05i	1.51-0.0204i	1.4912-0	1.4912-0	1.5455-0	1.5455-0	
25	1.4	1.43-0.008i	1.53-0.00542i	1.53-0.00542i	1.53-0.00542i	1.53-0.00542i	1.464-0.0004852i	1.464-0.0004852i	1.766-0.456i	1.407-7.4776e-05i	1.51-0.0211i	1.4874-0	1.4874-0	1.5429-0	1.5429-0	
26	1.45	1.42-0.008i	1.53-0.00556i	1.53-0.00556i	1.53-0.00556i	1.53-0.00556i	1.462-0.0005276i	1.462-0.0005276i	1.768-0.458i	1.405-9.7388e-05i	1.51-0.0218i	1.4836-0	1.4836-0	1.5404-0	1.5404-0	
27	1.5	1.41-0.008i	1.53-0.0057i	1.53-0.0057i	1.53-0.0057i	1.53-0.0057i	1.46-0.00057i	1.46-0.00057i	1.77-0.46i	1.403-0.00012i	1.51-0.0225i	1.4797-0	1.4797-0	1.5378-0	1.5378-0	
28	1.55	1.396-0.008i	1.53-0.00584i	1.53-0.00584i	1.53-0.00584i	1.53-0.00584i	1.458-0.0006084i	1.458-0.0006084i	1.774-0.464i	1.4012-0.0001792i	1.502-0.0215i	1.474-0.	1.474-0.	1.5338-0	1.5338-0	
29	1.6	1.382-0.008i	1.53-0.00598i	1.53-0.00598i	1.53-0.00598i	1.53-0.00598i	1.456-0.0006468i	1.456-0.0006468i	1.778-0.468i	1.3994-0.0002384i	1.494-0.0205i	1.4634-0	1.4634-0	1.5261-0	1.5261-0	
30	1.65	1.368-0.008i	1.53-0.00612i	1.53-0.00612i	1.53-0.00612i	1.53-0.00612i	1.454-0.0006852i	1.454-0.0006852i	1.782-0.472i	1.3976-0.0002976i	1.486-0.0195i	1.4528-0	1.4528-0	1.5183-0	1.5183-0	
31	1.7	1.354-0.008i	1.53-0.00626i	1.53-0.00626i	1.53-0.00626i	1.53-0.00626i	1.452-0.0007236i	1.452-0.0007236i	1.786-0.476i	1.3958-0.0003568i	1.478-0.0185i	1.4422-0	1.4422-0	1.5105-0	1.5105-0	
32	1.75	1.34-0.008i	1.53-0.0064i	1.53-0.0064i	1.53-0.0064i	1.53-0.0064i	1.45-0.000762i	1.45-0.000762i	1.79-0.48i	1.394-0.000416i	1.47-0.0175i	1.4316-0	1.4316-0	1.5028-0	1.5028-0	
33	1.8	1.3383-0.008075	1.5293-0.00654i	1.5293-0.00654i	1.5293-0.00654i	1.5293-0.00654i	1.4505-0.00077795i	1.4505-0.00077795i	1.7928-0.48225i	1.3941-0.0036806i	1.4695-0.017163i	1.421-0.	1.421-0.	1.495-0.	1.495-0.	
34	1.85	1.3365-0.00815i	1.5285-0.00668i	1.5285-0.00668i	1.5285-0.00668i	1.5285-0.00668i	1.451-0.0007939i	1.451-0.0007939i	1.7955-0.4845i	1.3941-0.0069452i	1.4691-0.016825i	1.4087-0	1.4087-0	1.4858-0	1.4858-0	
35	1.9	1.3348-0.008225	1.5277-0.00682i	1.5277-0.00682i	1.5277-0.00682i	1.5277-0.00682i	1.4515-0.00080985i	1.4515-0.00080985i	1.7983-0.48675i	1.3942-0.01021i	1.4687-0.016488i	1.3965-0	1.3965-0	1.4765-0	1.4765-0	
36	1.95	1.333-0.0083i	1.527-0.00696i	1.527-0.00696i	1.527-0.00696i	1.527-0.00696i	1.452-0.0008258i	1.452-0.0008258i	1.801-0.489i	1.3942-0.013474i	1.4682-0.01615i	1.3843-0	1.3843-0	1.4672-0	1.4672-0	
299	1000	2.1-0.6i	2.34-0.7i	2.34-0.7i	2.34-0.7i	2.34-0.7i	1.74-1i	1.74-1i	2.69-1i	1.89-0.22i	1.86-0.5i	1.932-0.	1.932-0.	2.084-0.	2.084-0.	
300	1500	2.1-0.6i	2.34-0.7i	2.34-0.7i	2.34-0.7i	2.34-0.7i	1.74-1i	1.74-1i	2.69-1i	1.89-0.22i	1.86-0.5i	1.932-0.	1.932-0.	2.084-0.	2.084-0.	
301	3000	2.1-0.6i	2.34-0.7i	2.34-0.7i	2.34-0.7i	2.34-0.7i	1.74-1i	1.74-1i	2.69-1i	1.89-0.22i	1.86-0.5i	1.932-0.	1.932-0.	2.084-0.	2.084-0.	
302	8600000	2.1-0.6i	2.34-0.7i	2.34-0.7i	2.34-0.7i	2.34-0.7i	1.74-1i	1.74-1i	2.69-1i	1.89-0.22i	1.86-0.5i	1.932-0.	1.932-0.	2.084-0.	2.084-0.	
	10.6	1.62-0.12i	1.91-0.25i	1.91-0.25i	1.91-0.25i	1.91-0.25i	1.5-0.014i	1.5-0.014i	2.22-0.73i	1.72-0.34i	1.76-0.07i	1.7174-0	1.7174-0	1.8176-0	1.8176-0	1.4978-0

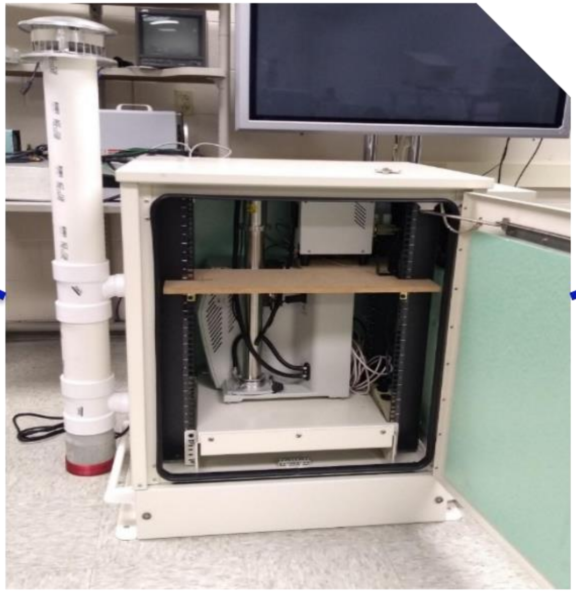
Sheet1

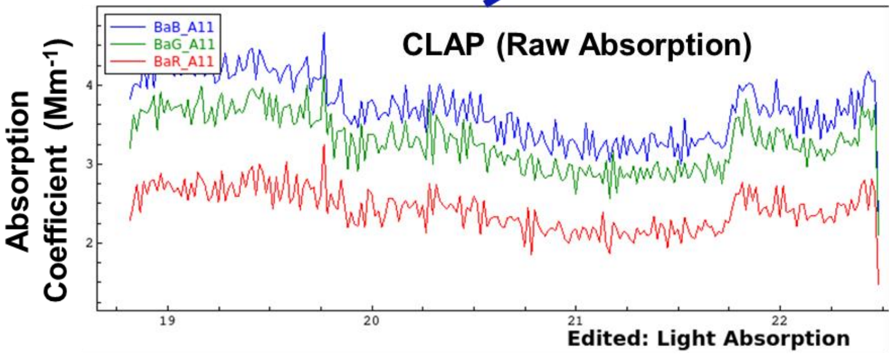
Köpke, P., M. Hess, I. Schult, and E. P. Shettle, 1997: Global aerosol data set. MPI Meteorologie Rep. 243, 44 pp.

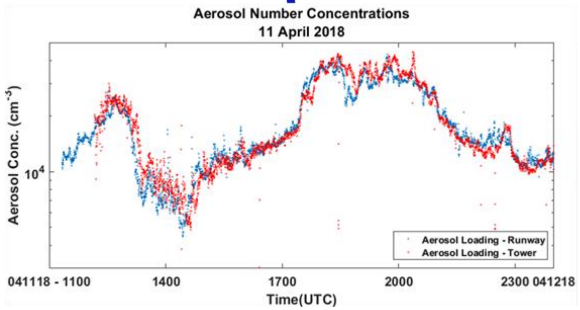
Initial FAN: In-situ 3-color Aerosol Absorption
CLAP + Aerosol Size Spectroscopy

- Aerosol characterization data (particle counts, size distributions, raw absorption) collected at JBO using:
  - MAGIC200 Condensation Particle Counter (CPC)
  - Scanning Mobility particle Sizer (SMPS)
  - Continuous Light Absorption Photometer (CLAP)





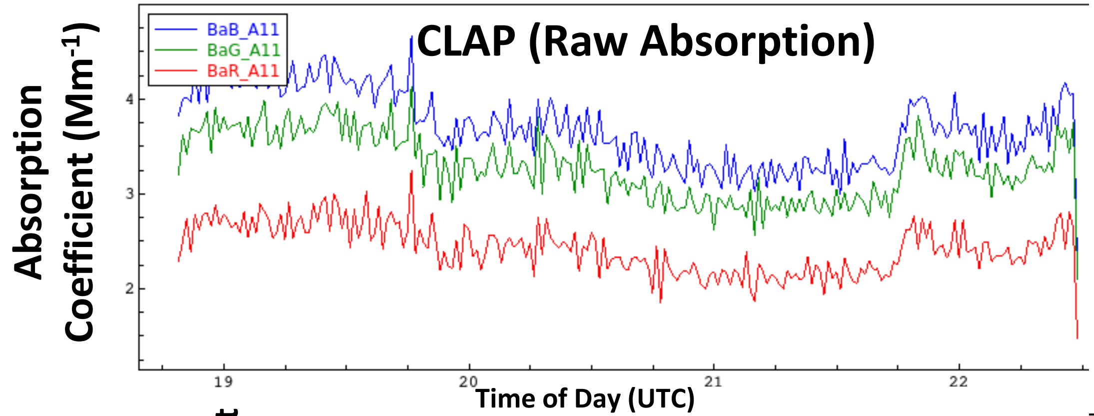




Raw absorption data collection was made possible by the NOAA Global Monitoring Division, specifically Patrick Sheridan and Betsy Andrews for providing the CLAP device.

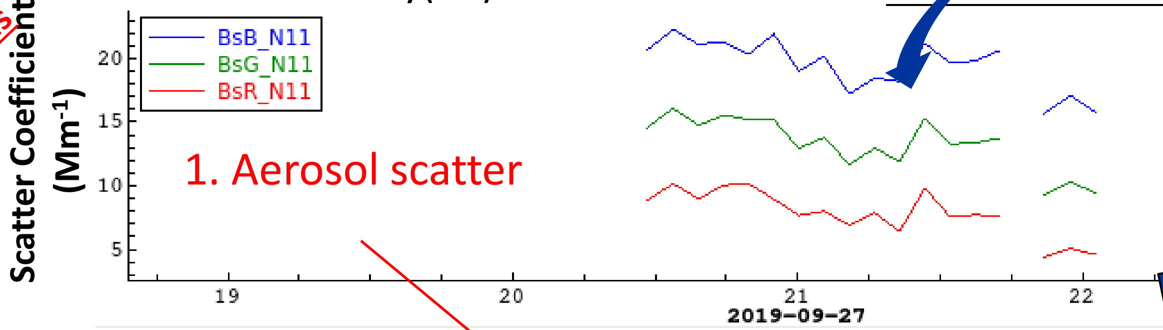
Ogren, J.A., J. Wendell, E. Andrews, and P.J. Sheridan, 2017: "Continuous light absorption photometer for long-term studies," Atm Meas.Tech.

In-situ 3-color Aerosol Absorption Measurement: CLAP with filter and aerosol scatter corrections



Size Sampled: 15nm – 898nm

Light Scattering

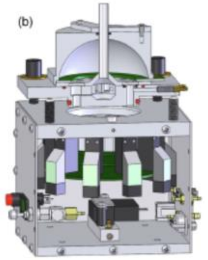


TSI Scanning Mobility Particle Sizer Spectrometer

Size Sampled: 9.7nm – 453nm

CLAP Extinction Corrections

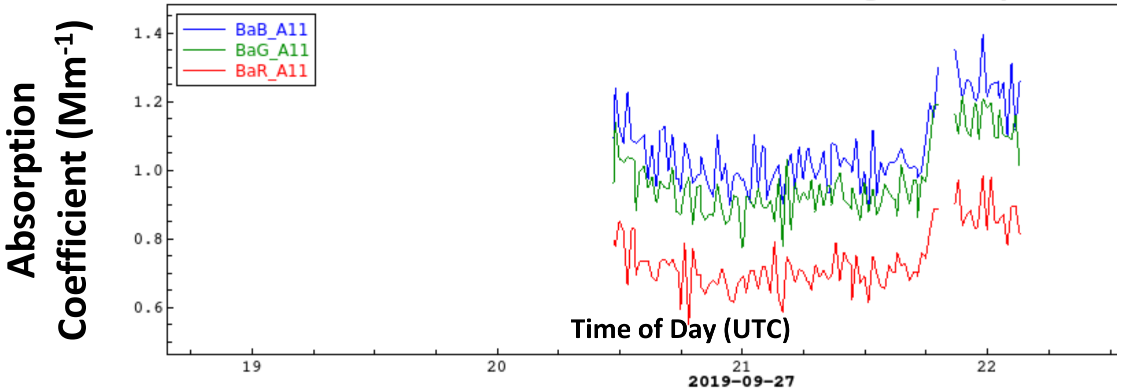
1. Aerosol scatter



2. Filter loading correction

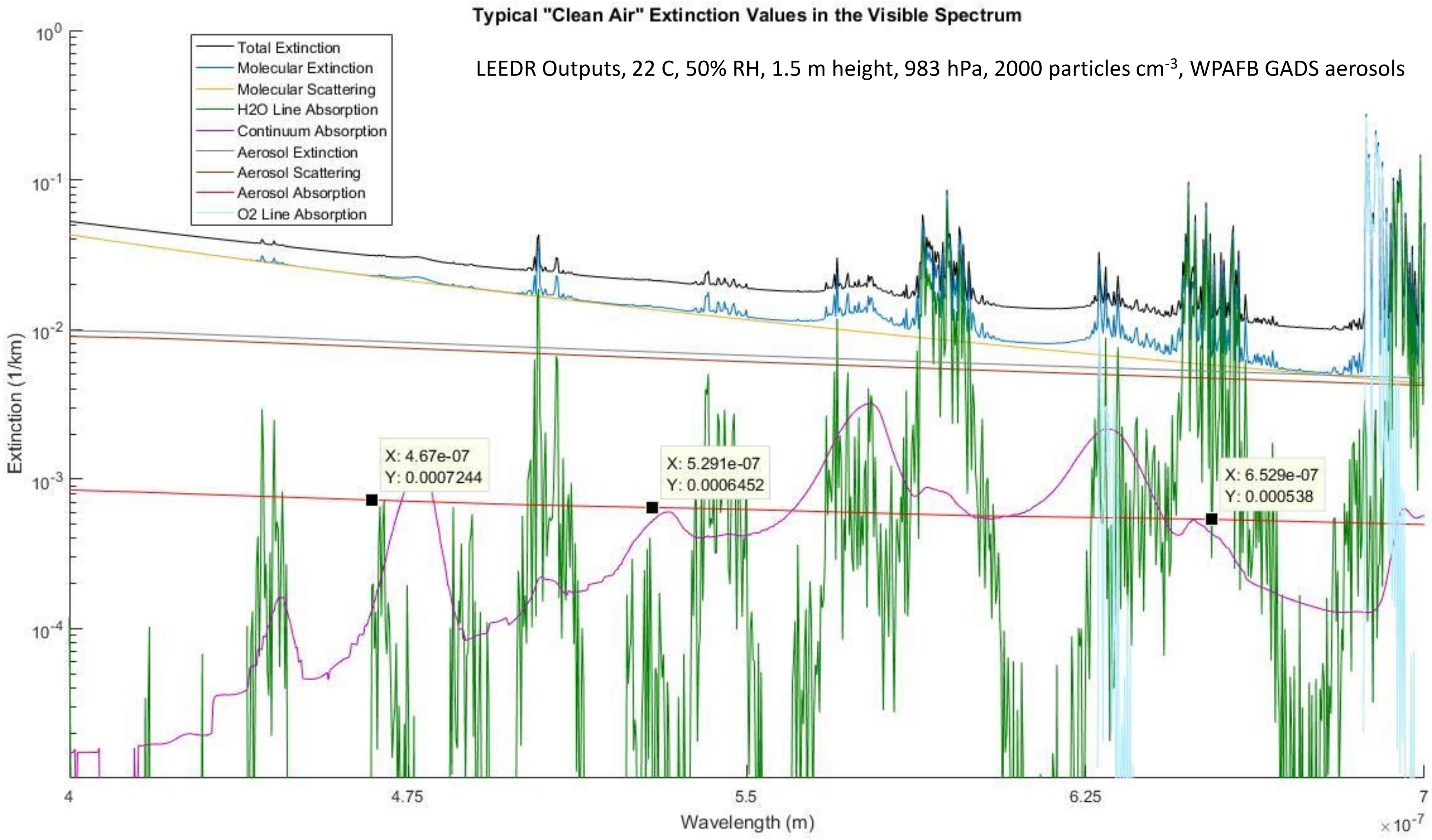
3. Filter multiple scattering correction

CLAP-Derived Aerosol Absorption



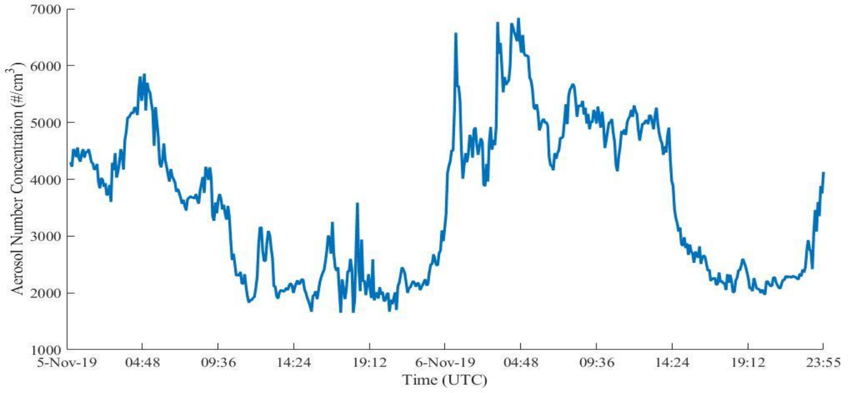
Improving Aerosol & Molecular Absorption Data in LEEDR:

Implementing NOAA's Continuous Light Absorption Photometer (CLAP) Measurements

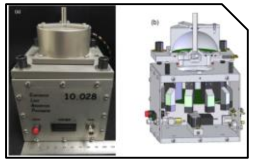


Methodology to compare CLAP Aerosol Absorption to LEEDR calculations with number concentration

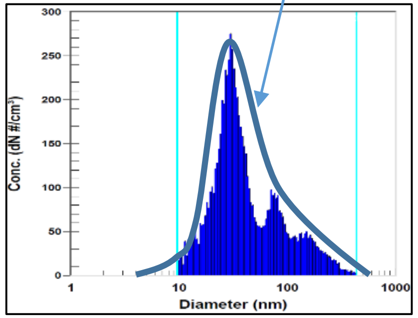
Bottom line: Use a laser transmissometer to get accurate transmission at a single wavelength. Use a weather station (T, P, H) and LEEDR + CPC to get extinction (scattering + absorption) at any λ.

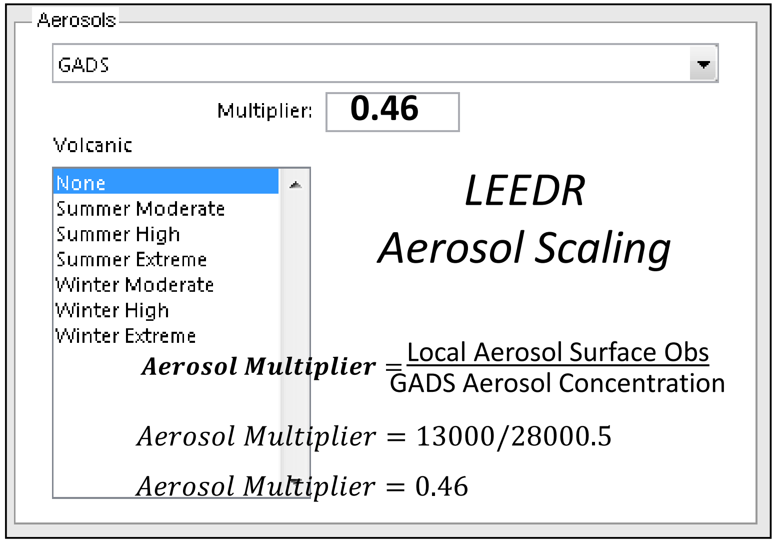


- Aerosol Measurements
  - MAGIC200 Condensation Particle Counter
  - Scanning Mobility Particle Sizer
  - Continuous Light Absorption Photometer (CLAP)



LEEDR Assumption





LEEDR Aerosol Scaling

$$\textbf{\textit{Aerosol Multiplier}} = \frac{\text{Local Aerosol Surface Obs}}{\text{GADS Aerosol Concentration}}$$

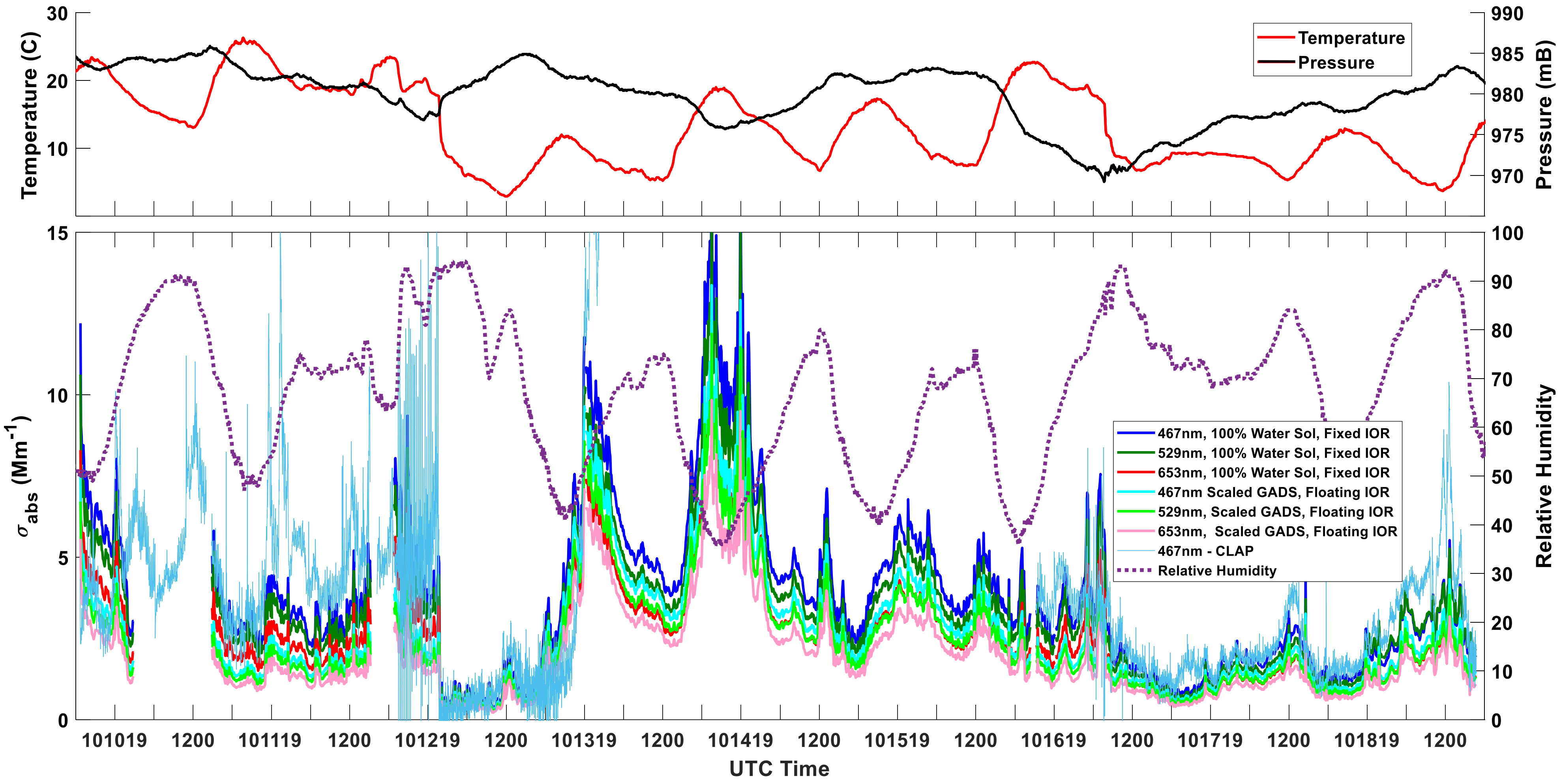
$$Aerosol\ Multiplier = 13000/28000.5$$

$$Aerosol\ Multiplier = 0.46$$

- LEEDR + Micro-met surface obs (aerosol number concentrations, temperature, dew point, and pressure)
  - GADS constituent defined as $(NH4)_2SO4$ + absorber with constant index of refraction = 1.53 – 0.010i
  - Varied local aerosol mix (relative proportion of Water Soluble, Soot, etc)

SEASON	INSOLUBLE (cm^{-1})	SOOT (cm^{-1})	WATER-SOLUBLE (cm^{-1})	TOTAL # CONCENTRATION
Winter	0.5	15,000	11,000	26,000.5
Summer	0.5	15,000	13,200	28,000.5

Initial FAN: In-situ 3-color Aerosol Absorption
CLAP + Aerosol Size Spectroscopy

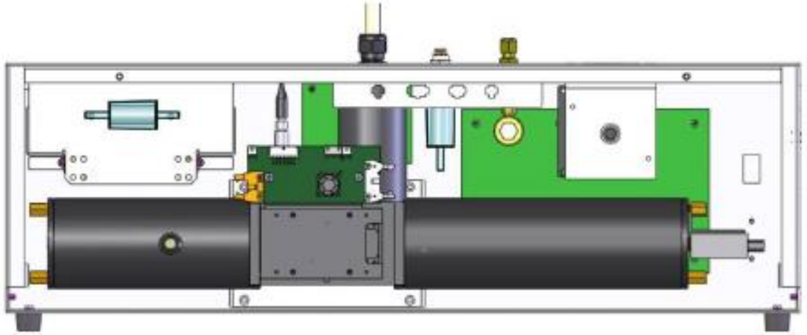


Aerosol absorption as inferred by corrected CLAP extinction measurement, TSI SMPS, and LEEDR. The LEEDR profiles were calculated using the SMPS-measured, aggregate aerosol number concentration to scale a.) a single component, GADS water soluble aerosol with optical properties of 1.53-0.01*i*; or b.) a local GADS aerosol mix with bulk optical properties modulated by ambient relative humidity. While the ambient relative humidity is profiled in the lower portion of the figure, the diurnal surface pressure and temperature are shown in the top portion of the figure.

Integration of new aerosol instrumentation

American Ecotech Nephalometer

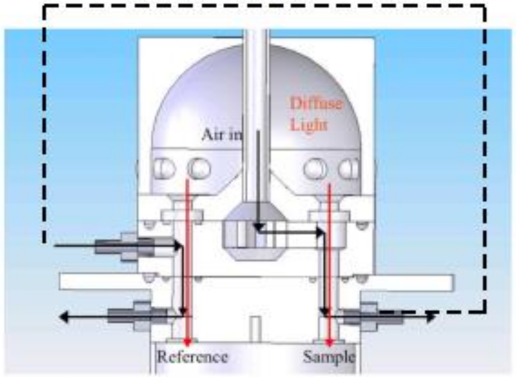
(Aerosol Optical Scatter)



λ = 450, 525, 635nm

NOAA Continuous Light Absorption Photometer

(Aerosol Absorption)



CAD cutaway of CLAP

The primary advantages of the CLAP, compared to the PSAP, are that it is one-tenth the size, can sample for roughly eight times as long before the operator needs to change the filter, and is temperature-stabilized to reduce sensitivity to changes in room temperature. In addition, the computer software running on the internal microprocessor is completely open on the CLAP. These features make the CLAP much better suited for long-term monitoring applications, and currently NOAA-built CLAPs are deployed at 23 stations around the globe.

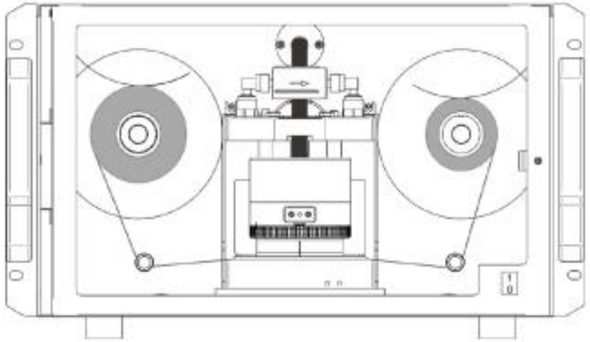
Exposed CLAP filter

Open CLAP

λ = 467, 529, 653nm

Magee Scientific Aethalometer

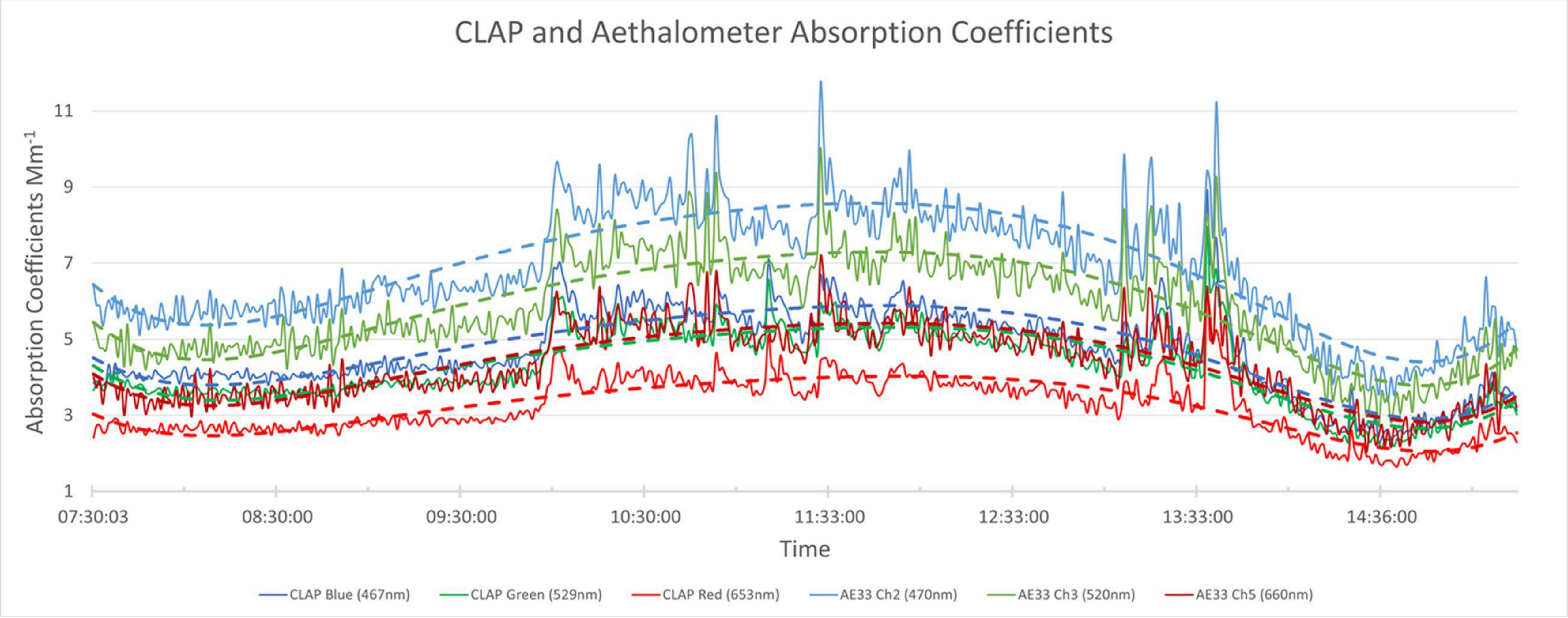
(BC Monitor)



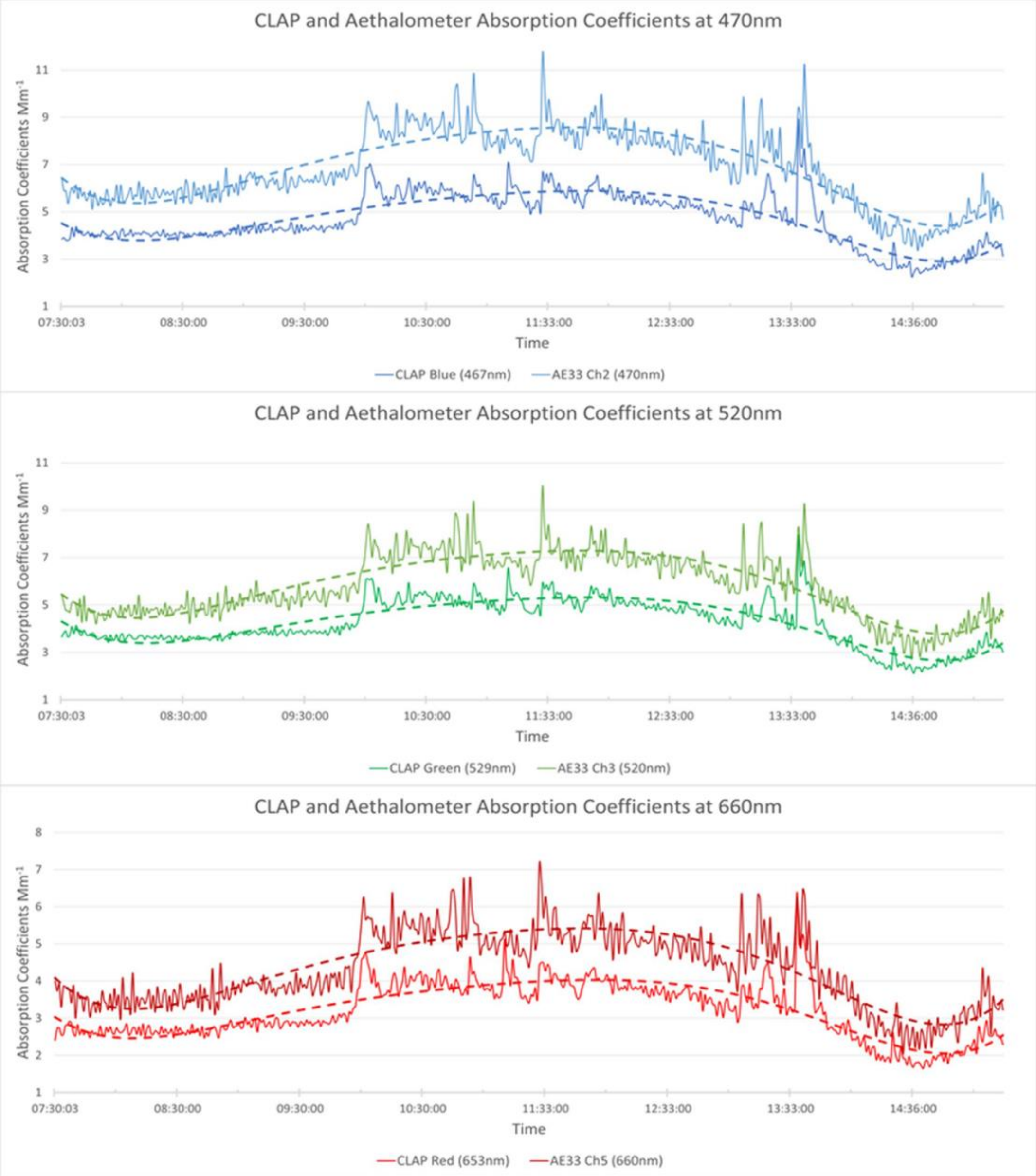
λ = 370, 470, 520, 590, 660, 880, 950nm

A Comparison of NOAA CLAP and Magee Scientific Black Carbon Aethalometer Absorption Coefficients

Jack Bajcz[1,2,3], Dr. Kevin J. Keefer[1,2], Dr. Steven T. Fiorino[1]
[1]AFIT -Center for Directed Energy, [2]Applied Research Solutions (ARS), [3]Michigan State University



A Comparison of NOAA CLAP and Magee Scientific Black Carbon Aethalometer Absorption Coefficients

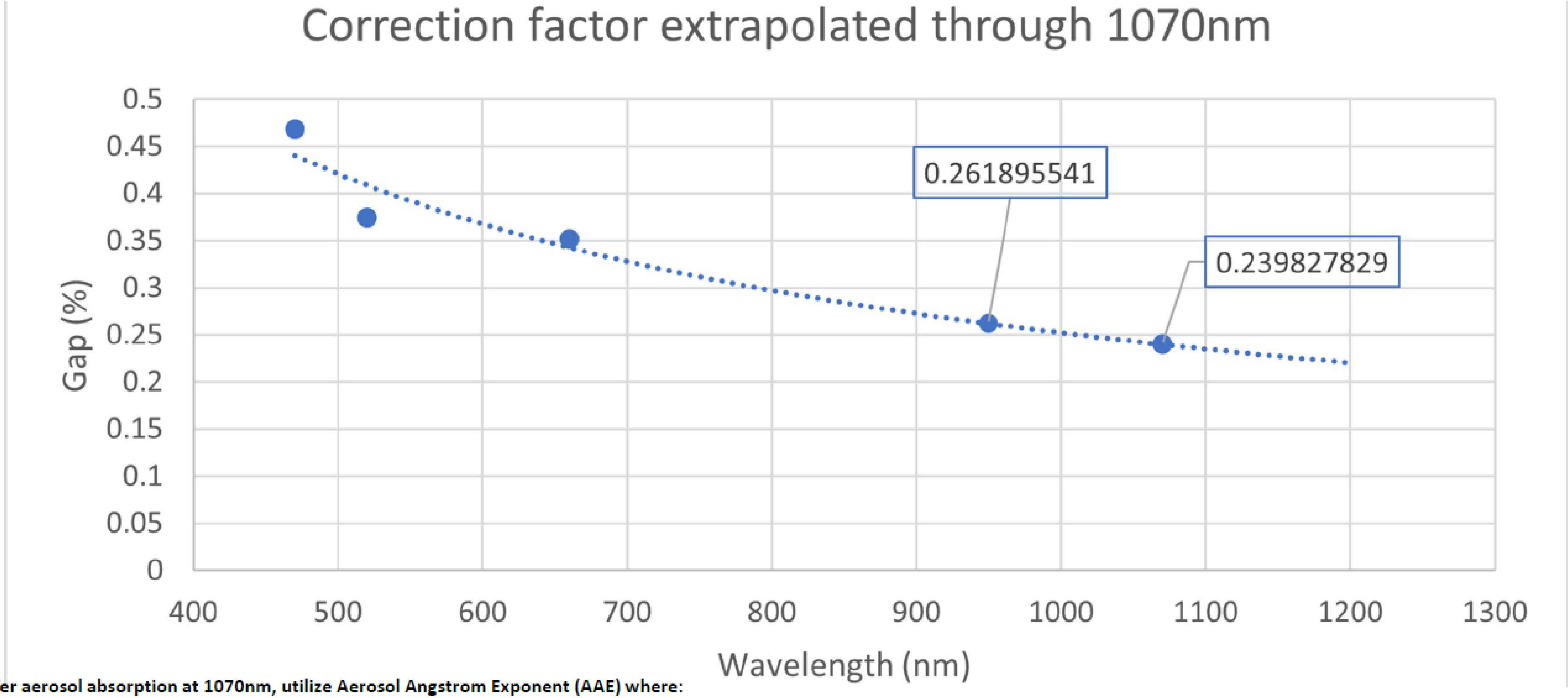


Average gap: 47%
Pearson Coefficient: 0.9325

Average gap: 37%
Pearson Coefficient: 0.9223

Average gap: 35%
Pearson Coefficient: 0.9078

A Comparison of NOAA CLAP and Magee Scientific Black Carbon Aethalometer Absorption Coefficients



To infer aerosol absorption at 1070nm, utilize Aerosol Angstrom Exponent (AAE) where:

$C_{abs(1.07)} = C_{abs(.950)} * 1.070^{-AAE}$

$AAE = -\ln(C_{abs(.880)}/C_{abs(.950)})/\ln(0.880/0.950)$

A Comparison of NOAA CLAP and Magee Scientific Black Carbon Aethalometer Absorption Coefficients

Jack Bajcz[1,2,3], Dr. Kevin J. Keefer[1,2], Dr. Steven T. Fiorino[1]
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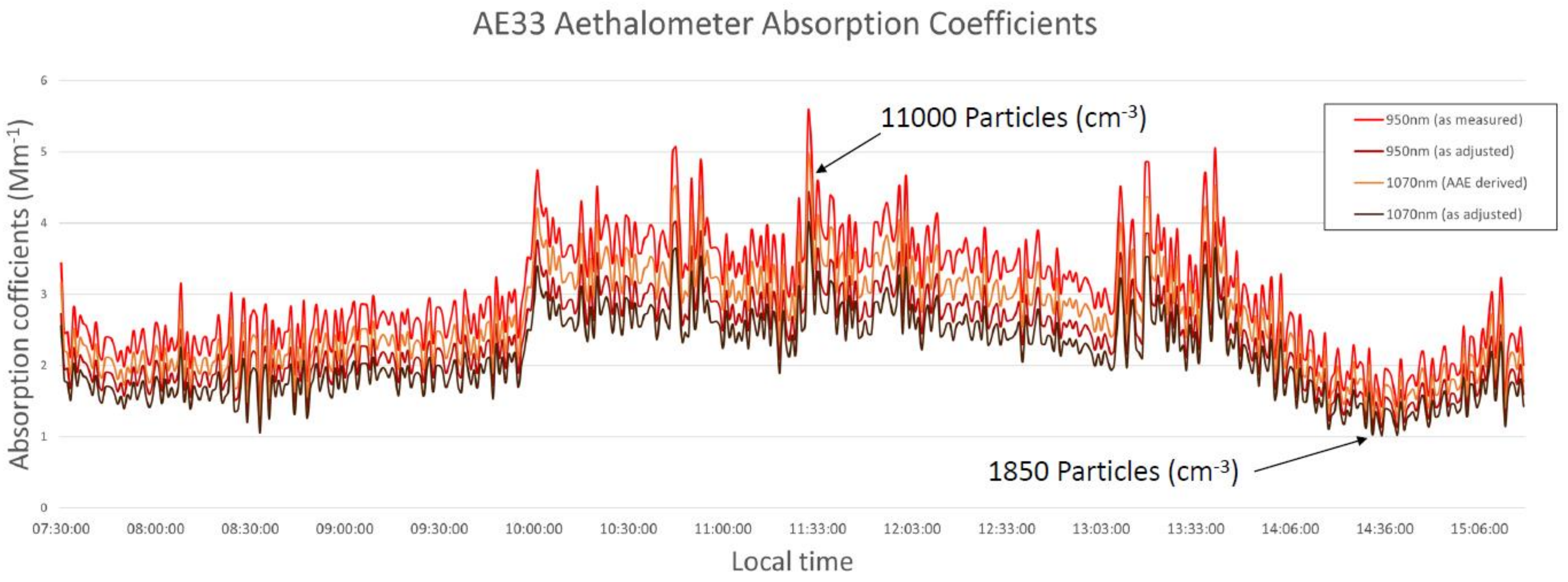
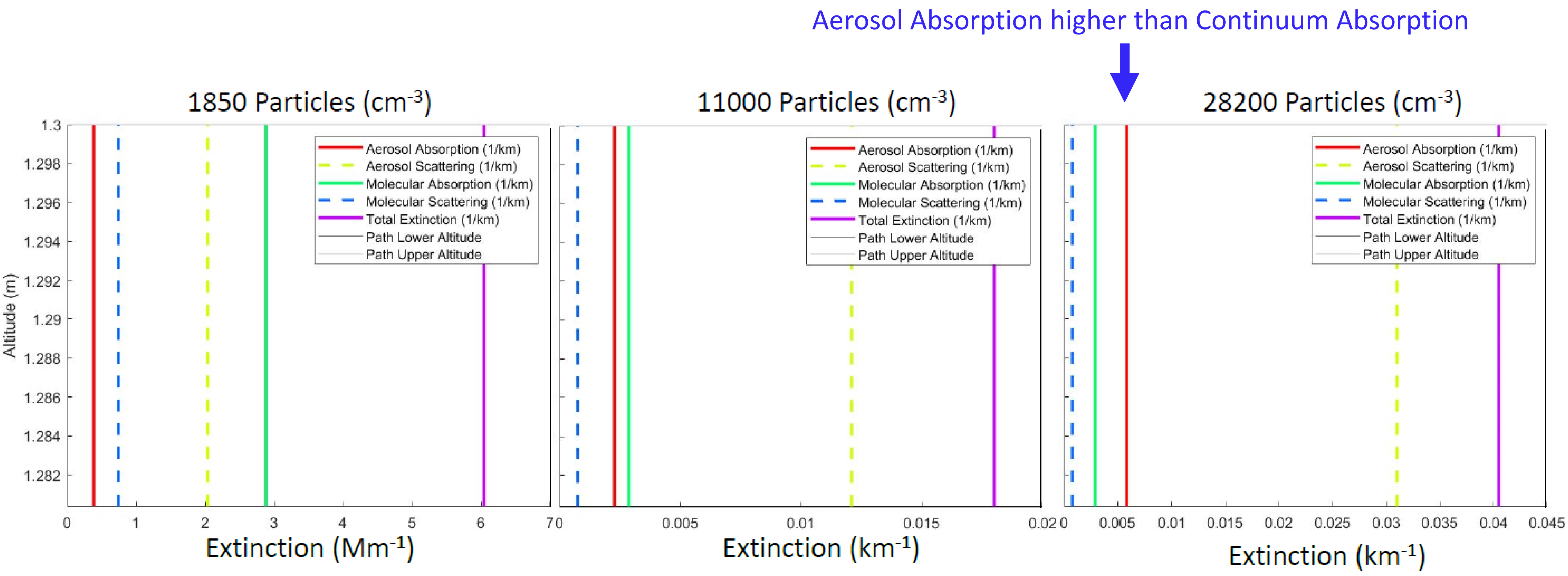


A Comparison of NOAA CLAP and Magee Scientific Black Carbon Aethalometer Absorption Coefficients

LEEDR Extinction Assessments at various particle loadings at 1.07µm



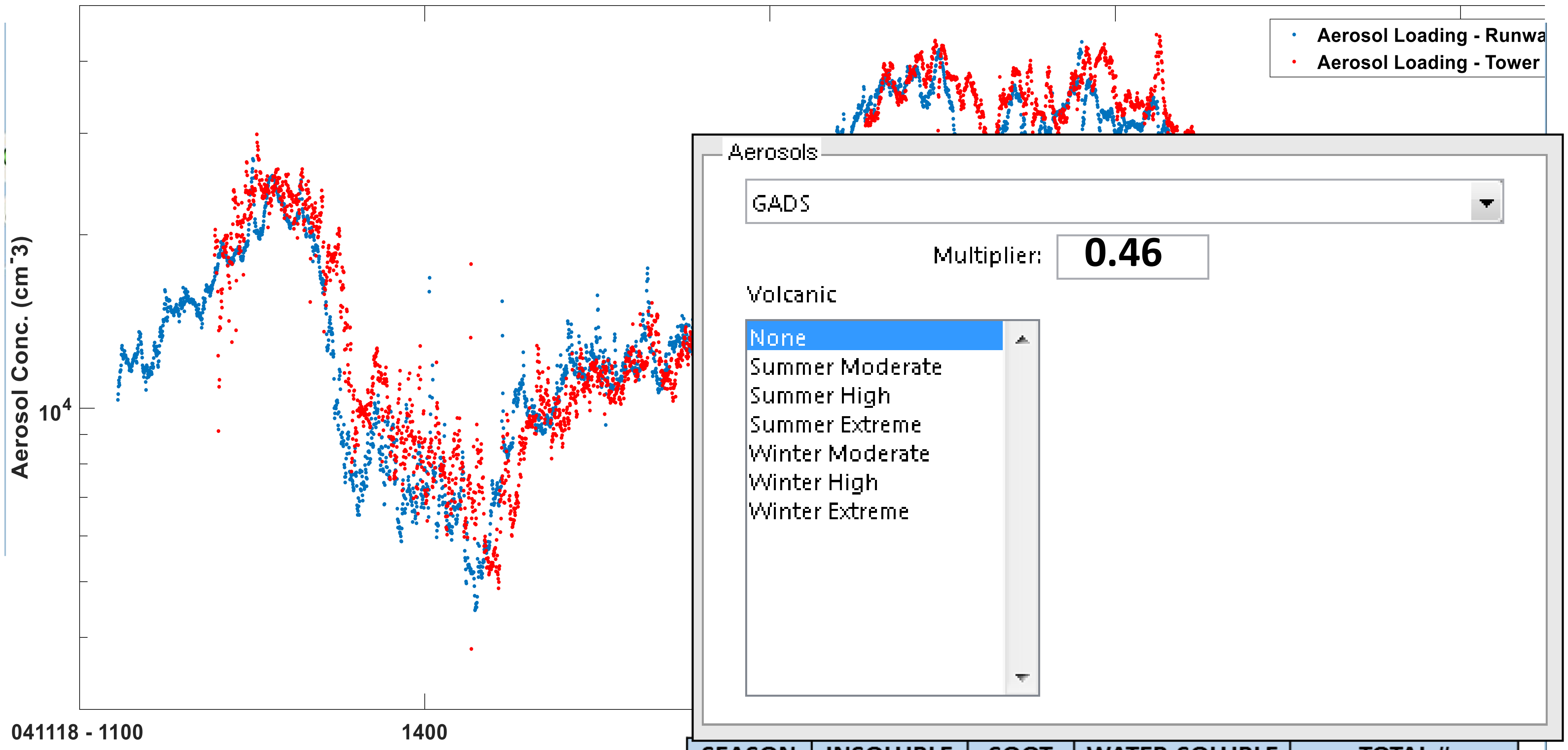
P = 984 hPa; T = 24°C; RH = 58%

Large Particles or Small?

A full size spectrum is need for visibility assessment

Aerosol Devices
MAGIC 210

CPC = 5nm – 2.5um



SEASON	INSOLUBLE (cm^{-1})	SOOT (cm^{-1})	WATER-SOLUBLE (cm^{-1})	TOTAL # CONCENTRATION
Winter	0.5	15,000	11,000	26,000.5
Summer	0.5	15,000	13,200	28,000.5

Large Particles or Small?

A full size spectrum is needed for visibility assessment

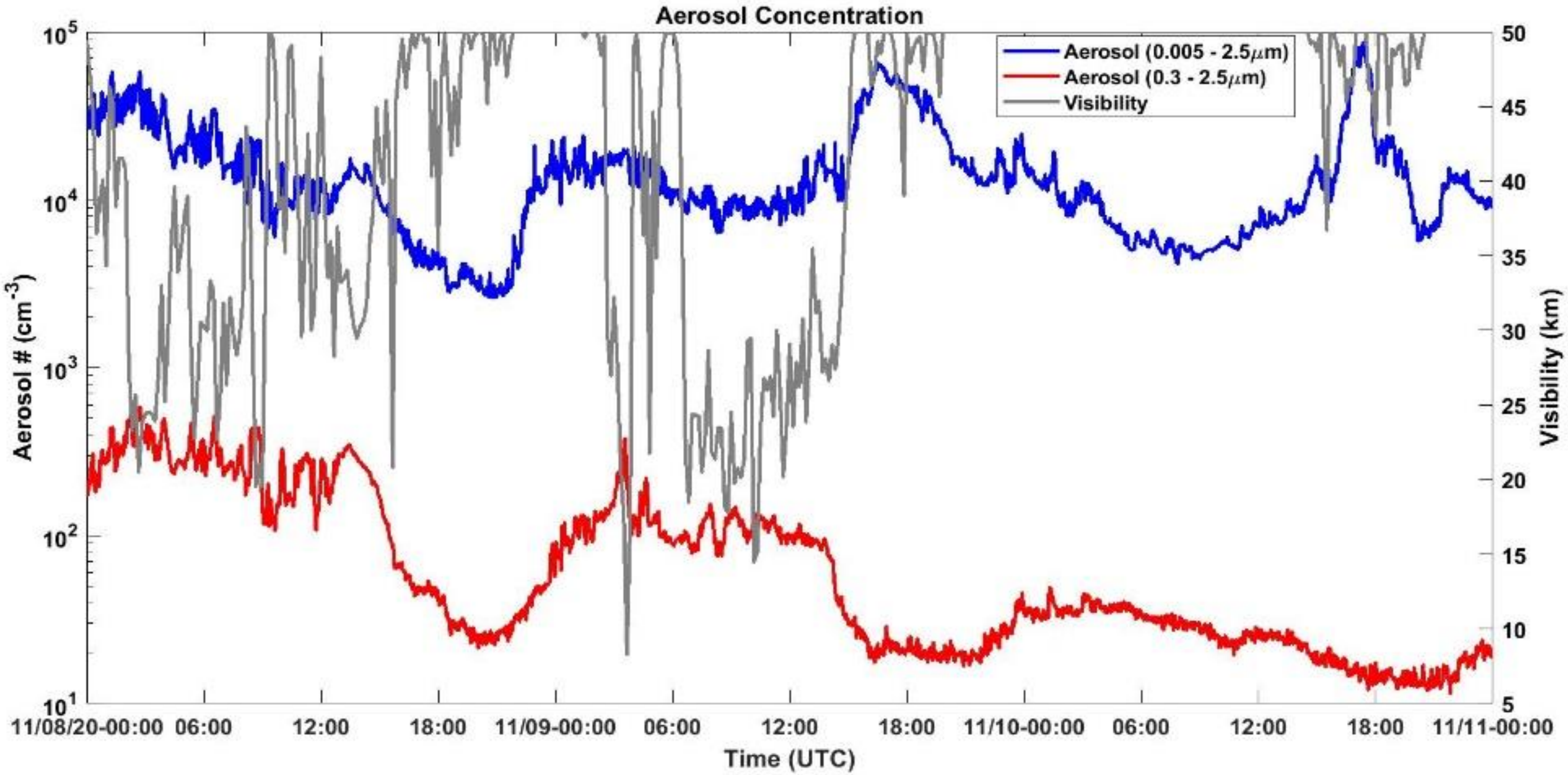
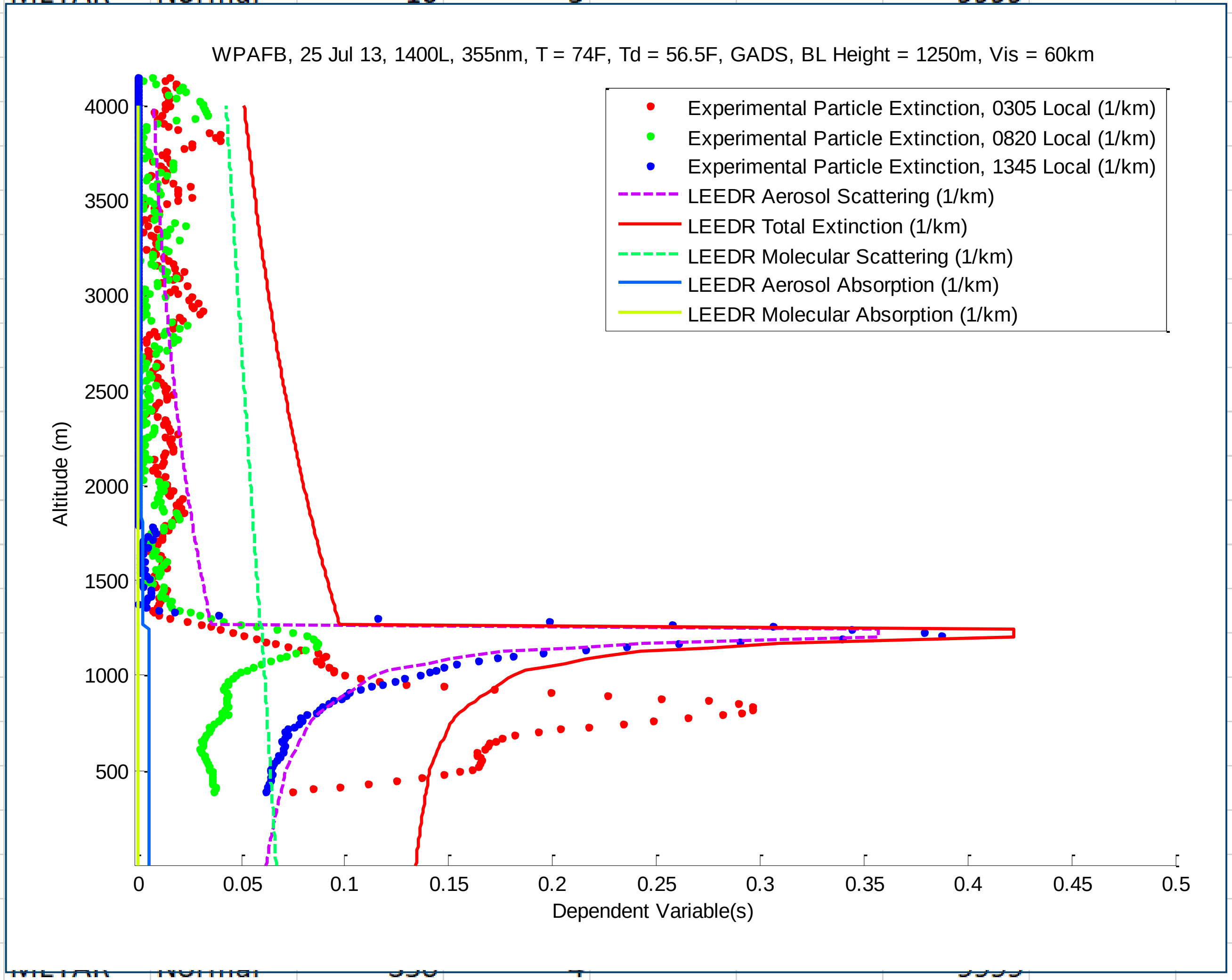


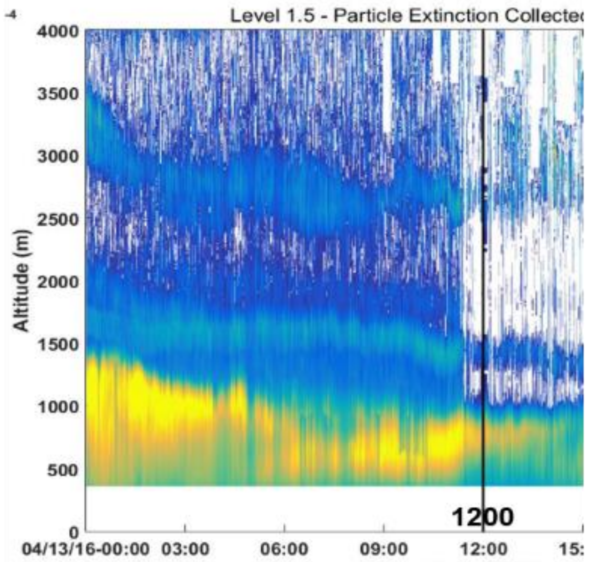
Fig. 2. Tranmissometer visibility and $PM_{2.5}$ number concentrations measured in two different size ranges at WPAFB OH Nov 2020.

Atmospheric Extinction – Quantifiable with or without Haze

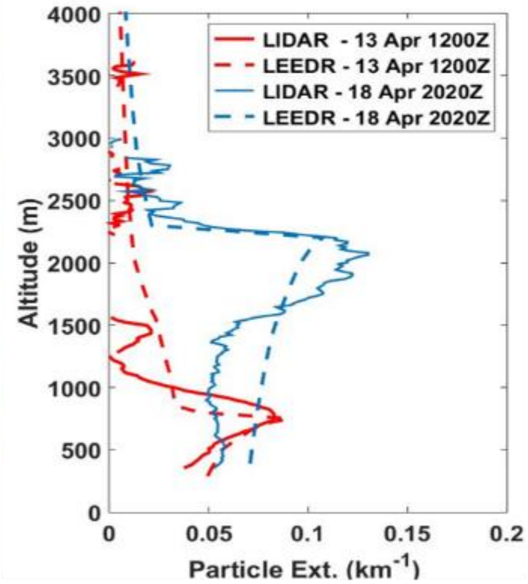
Platform Id	Date	Time (UTC	Report Typ	Wind Con	Wind Dire	Wind Spee	Wind Gust	Peak Winc	Visibility (I	Weather	Air Temp (	Dew Point	Altimeter	SLP (Millib
KFFO	7/25/2013	23:55	METAR	Normal	10	5			9999		23	13	30.08	
KFFO	7/25/2013	22:55									24.1	12.4	30.08	1018.3
KFFO	7/25/2013	21:55									24.6	12.7	30.08	1018.3
KFFO	7/25/2013	20:58									24.5	12.5	30.08	1018.6
KFFO	7/25/2013	19:58									24.4	12.4	30.09	1018.9
KFFO	7/25/2013	18:58									23.6	12.3	30.09	1018.9
KFFO	7/25/2013	17:58									23	12.5	30.09	1018.9
KFFO	7/25/2013	16:58									22.1	12.3	30.1	1019.3
KFFO	7/25/2013	15:58									21.3	11.8	30.1	1019.3
KFFO	7/25/2013	14:58									20.3	11.3	30.09	1018.9
KFFO	7/25/2013	13:58									18.5	11.8	30.09	1018.9
KFFO	7/25/2013	12:58									16.3	12.2	30.09	1019
KFFO	7/25/2013	11:58									13.8	11.7	30.08	1018.6
KFFO	7/25/2013	10:58									12.9	11.3	30.06	1018
KFFO	7/25/2013	9:58									12.8	11.2	30.04	1017.3
KFFO	7/25/2013	8:58									13.3	11.6	30.04	1017.2
KFFO	7/25/2013	7:58									13.1	11.6	30.04	1017.3
KFFO	7/25/2013	6:58									14.6	11.8	30.04	1017.2
KFFO	7/25/2013	5:58									13.8	11.7	30.03	1016.9
KFFO	7/25/2013	4:58									15.1	12.4	30.04	1017.2
KFFO	7/25/2013	3:58									15.7	12.4	30.03	1016.9
KFFO	7/25/2013	2:58									17	12.8	30.02	1016.6
KFFO	7/25/2013	1:58	METAR	Normal		4			9999		17.5	12.9	30.01	1016.2
KFFO	7/25/2013	0:58	METAR	Normal	20	8			9999		19.6	13	29.99	1015.5

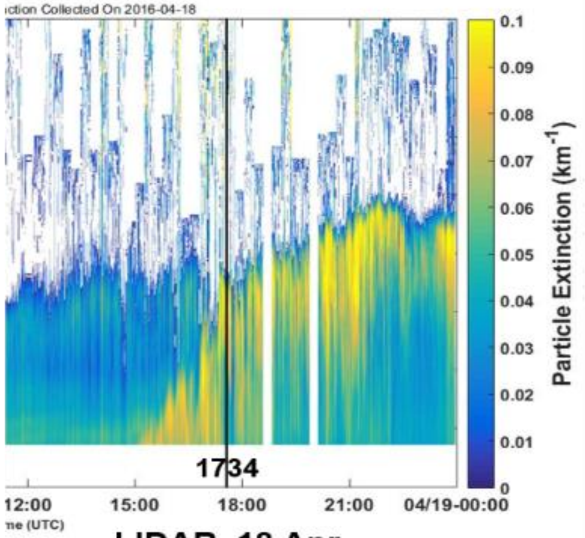


Atmospheric Extinction / Haze



LIDAR, 13 Apr 1200Z



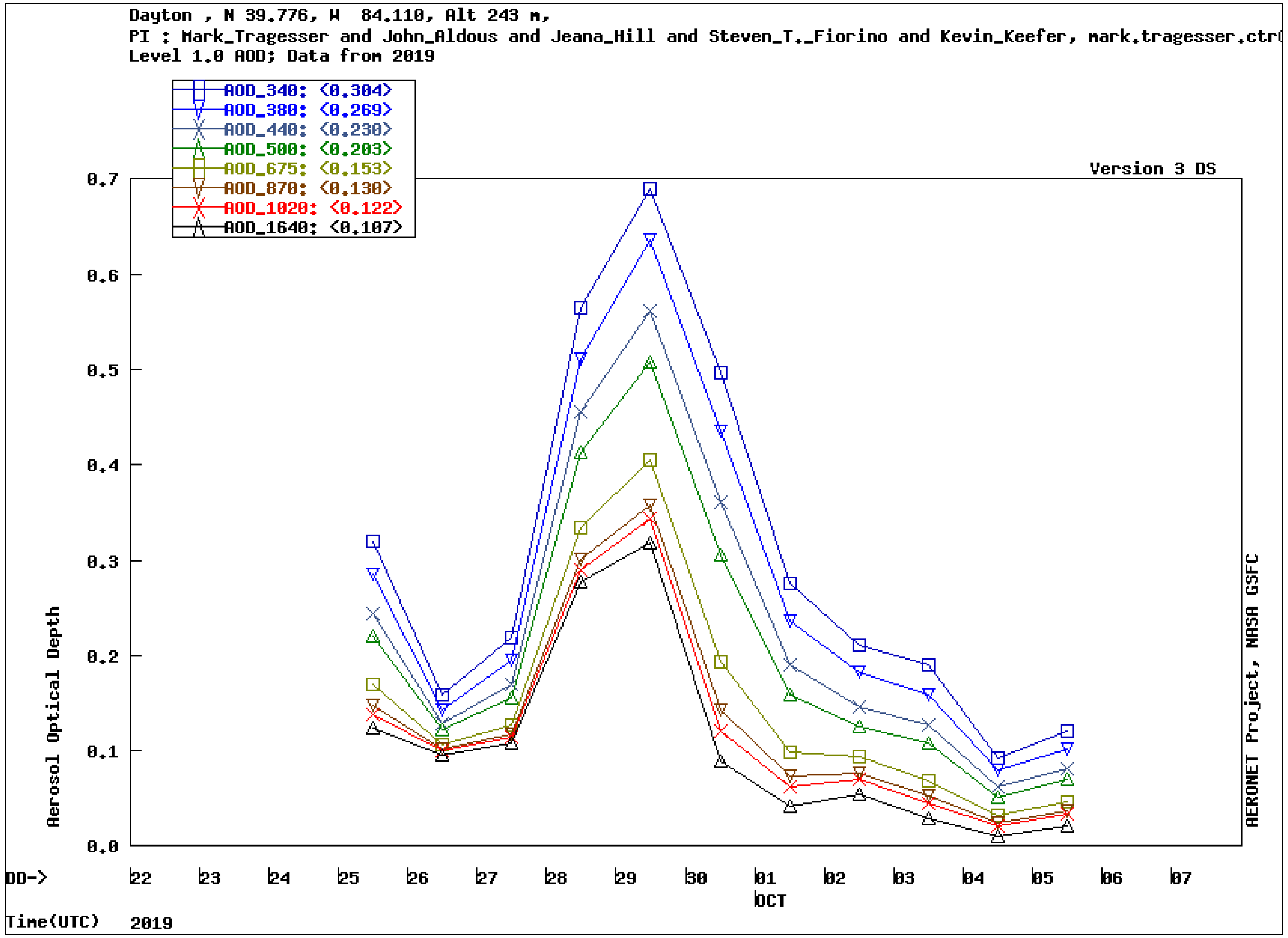


LIDAR, 18 Apr 1734Z

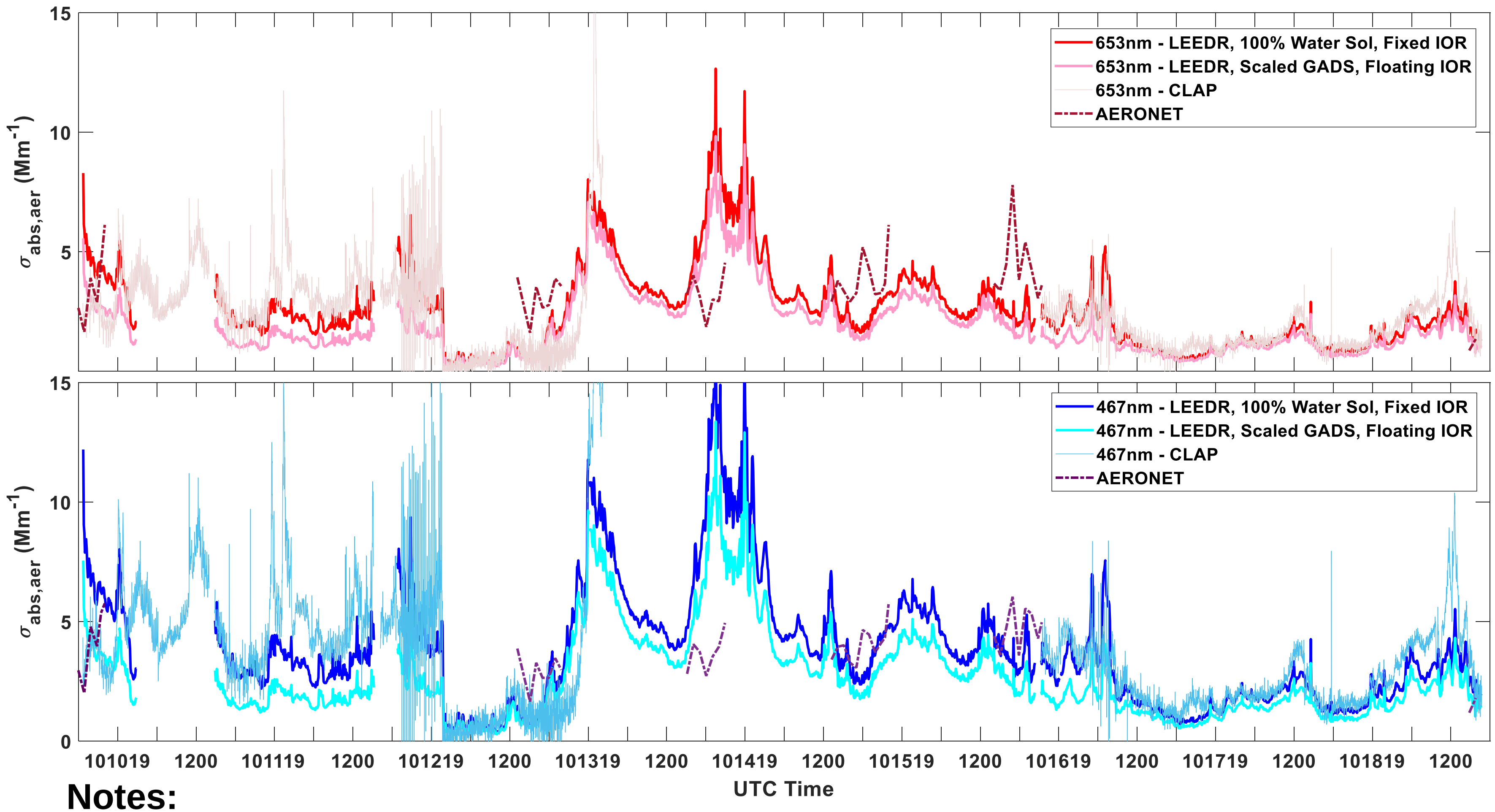
Sky and visibility conditions as seen from AFIT were collected in conjunction with surface aerosol concentrations, LIDAR, and AERONET (Dayton OH site) data over at five-day period. An increase in haze from 13 April to 18 April 2017 is evident in the visible imagery. A peak in LIDAR particle extinction is noted at 750m and 2000m on 13 and 18 April, respectively. Scaling surface aerosol loading within LEEDR using CPC measurements resulted in a very realistic, height resolved aerosol extinction profile, which closely matched the LIDAR measurement. These height-resolved aerosol extinction profiles are not retrievable using AERONET data.

Aerosol Absorption from AERONET?

- AFIT's NASA AERONET sun-lunar photometer NASA-certified on 1 Oct 2019



Derived Surface Aerosol Absorption: CLAP and CPC + LEEDR and Sun Photometer



Notes:

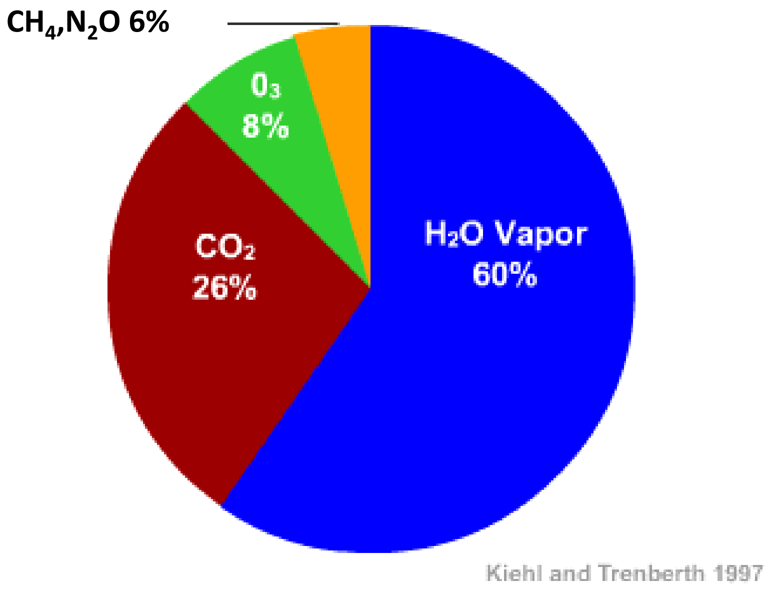
1. AERONET Data based on adjusted AERONET absorbing AOD measurements at 440nm and 675nm

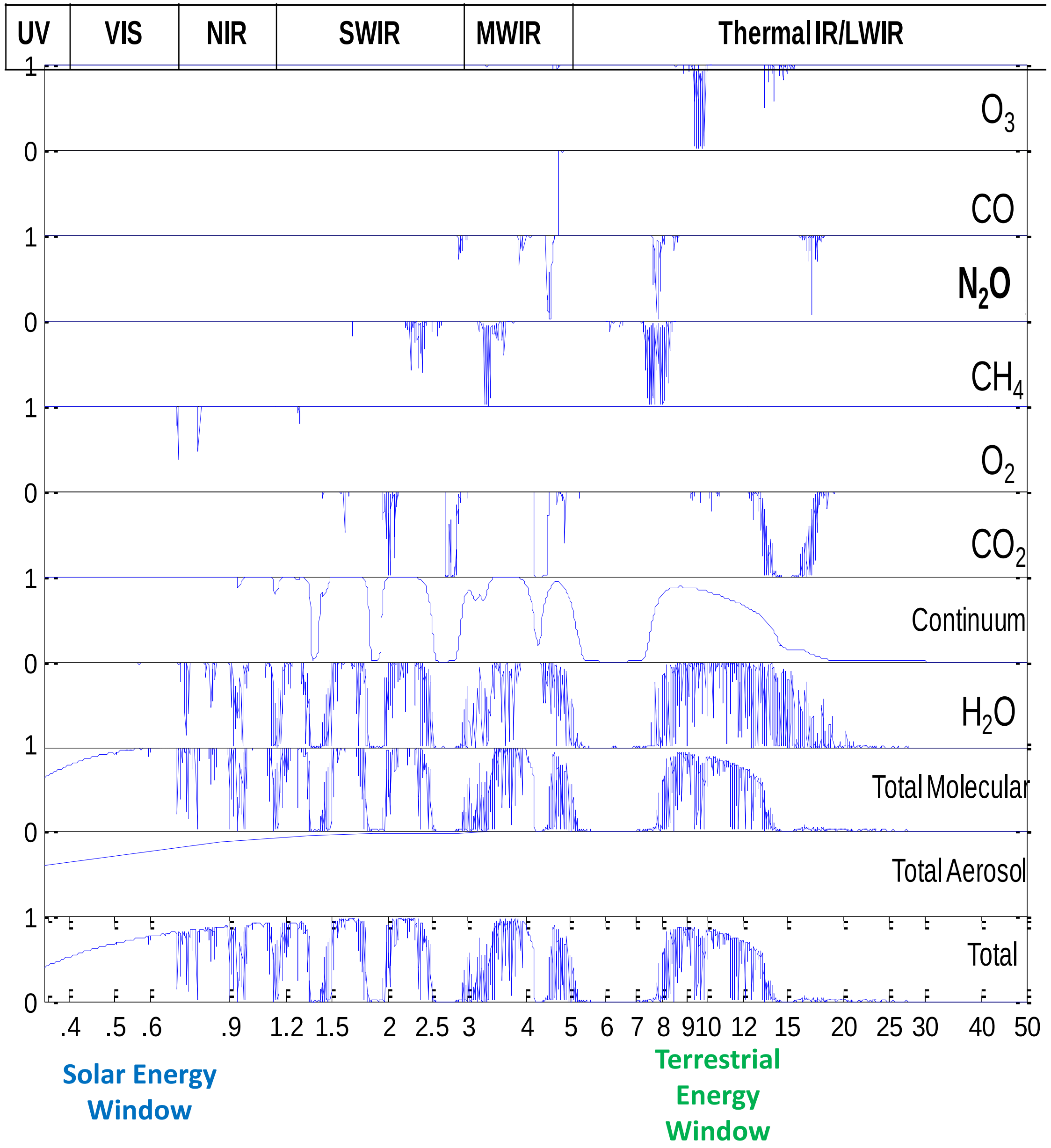
Aerosols and the Greenhouse Gasses

The main components in the natural greenhouse effect:

- Water vapor - 60%
- Carbon dioxide - 26%
- Ozone - 8%
- Methane/nitrous oxide/other trace gases - 6%

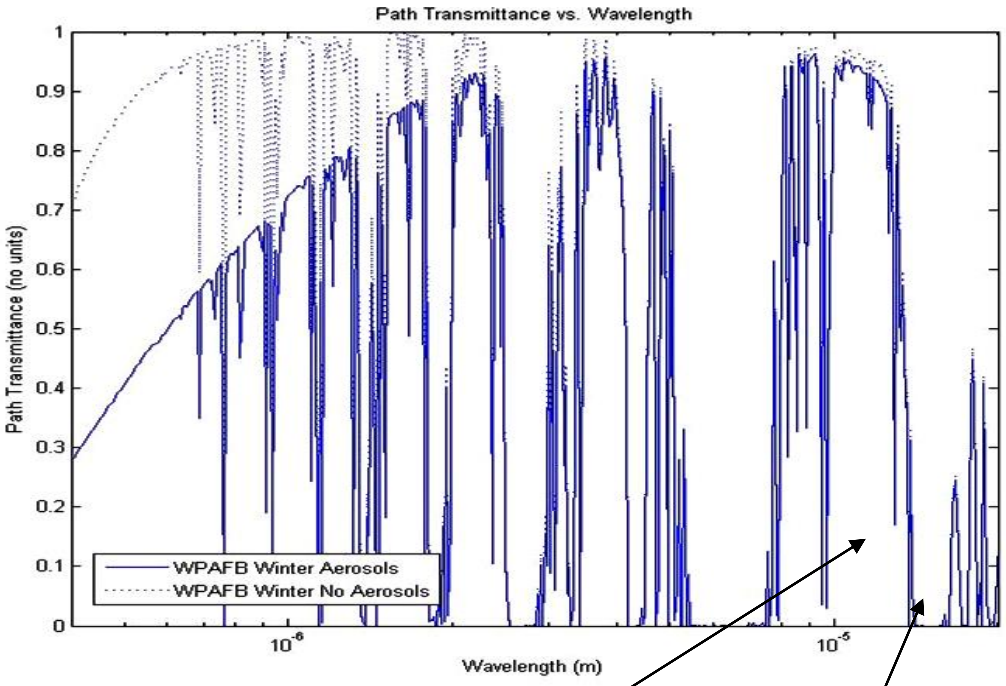
Clouds create a greenhouse effect, as well as a cooling effect due to reflection.





Aerosol Extinction is spectrally modulated by RH and Water Vapor

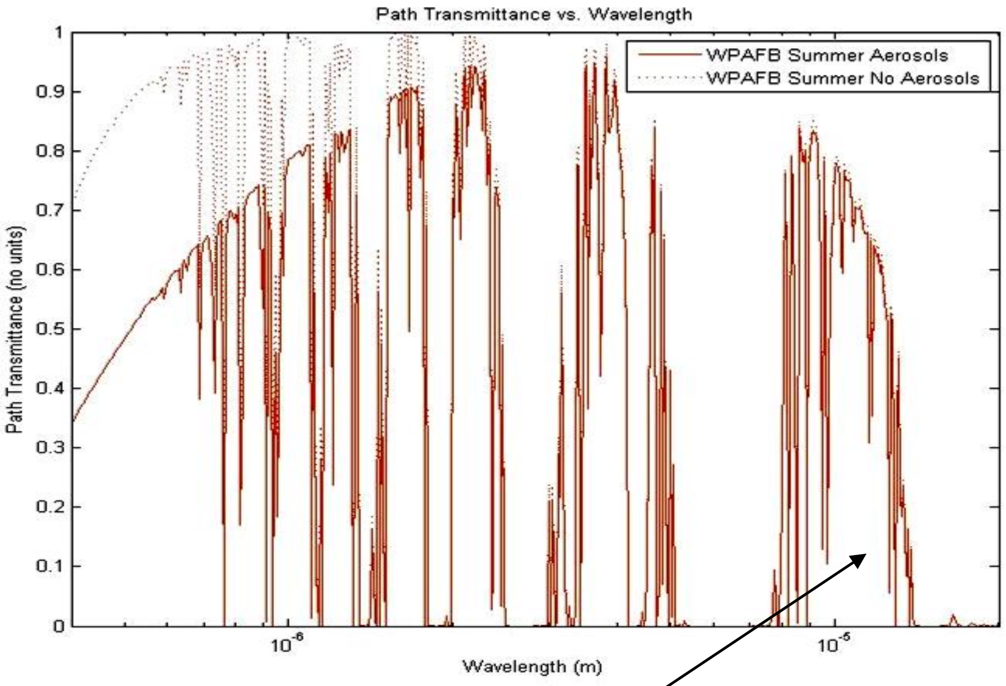
Winter, Lower Temps, Less Humidity



Atmospheric Window

CO_2 Absorption

Summer, Higher Temps, More Humidity



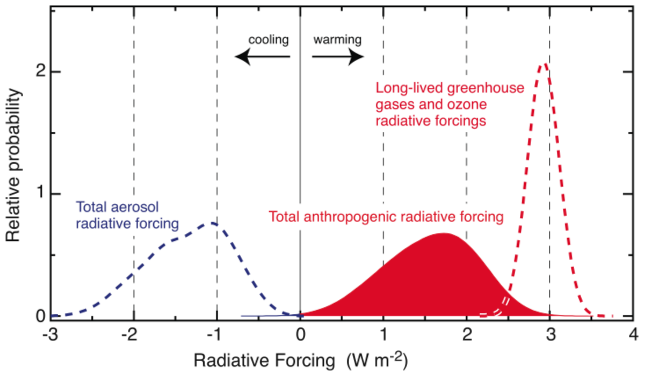
Atmospheric Window

Where's the CO_2 Absorption?

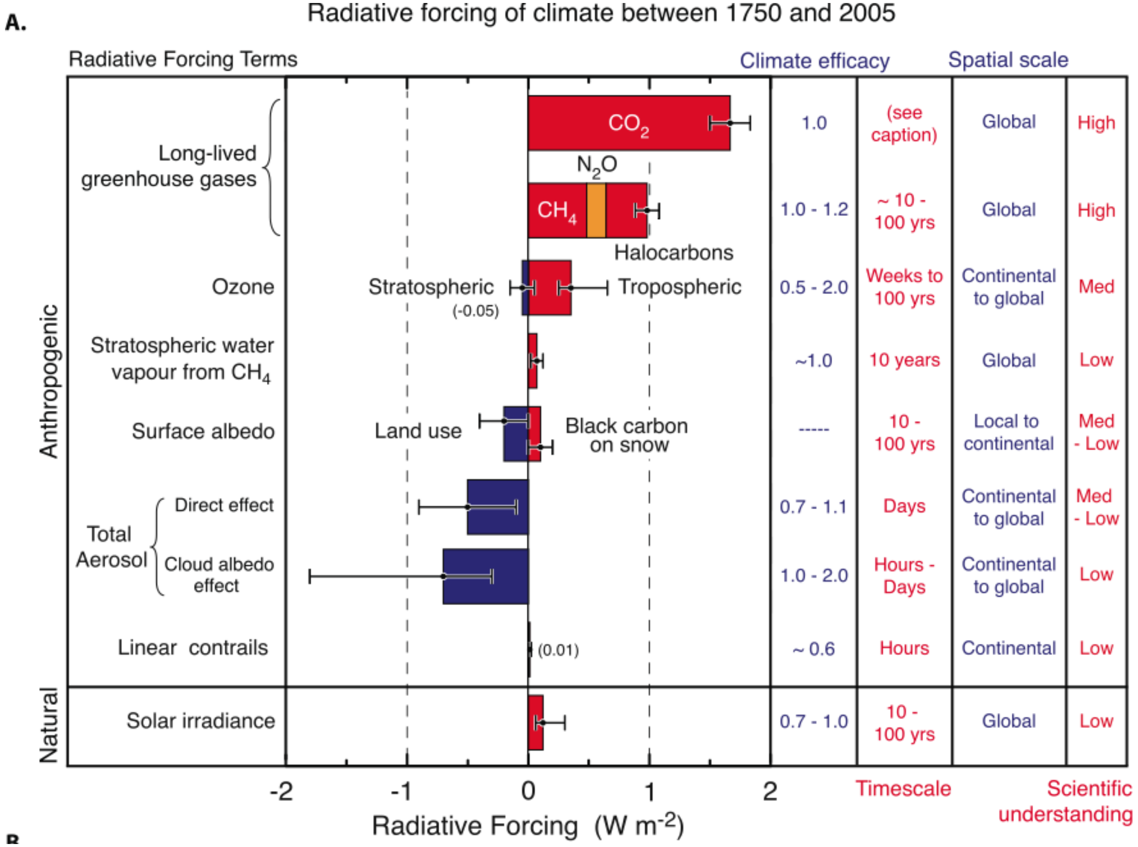
Takeaways: Water vapor closes the atmospheric window; the CO_2 changes are radiatively masked; aerosols are important UV-NIR, not much in LWIR; winter RH is higher than summer, but more H_2O in summer. **Aerosol absorption uncertain in the LWIR.**

Zenith Atmospheric Transmission With H_2O, Aerosol & Seasonal Effects at WPAFB

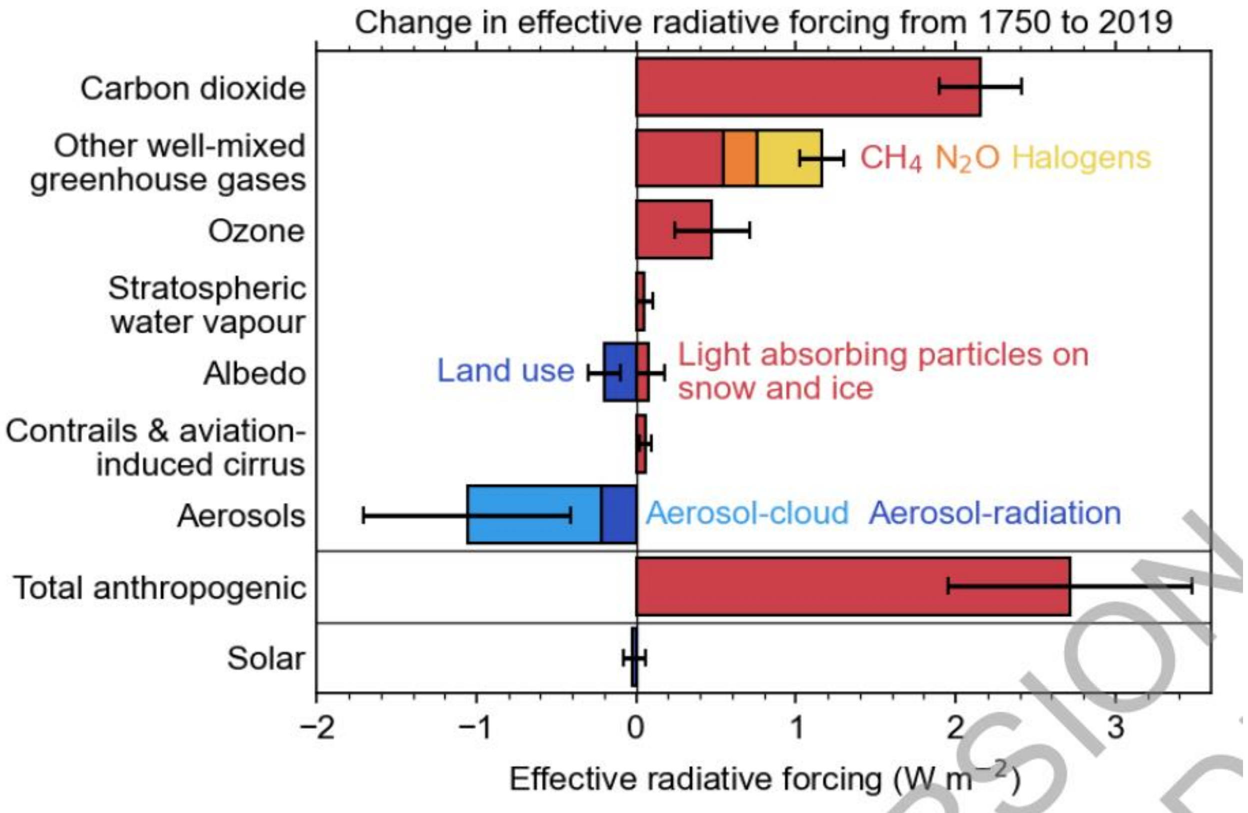
Aerosol Extinction a Big Uncertainty for Climate Change



IPCC (2007)
Forcing Summary

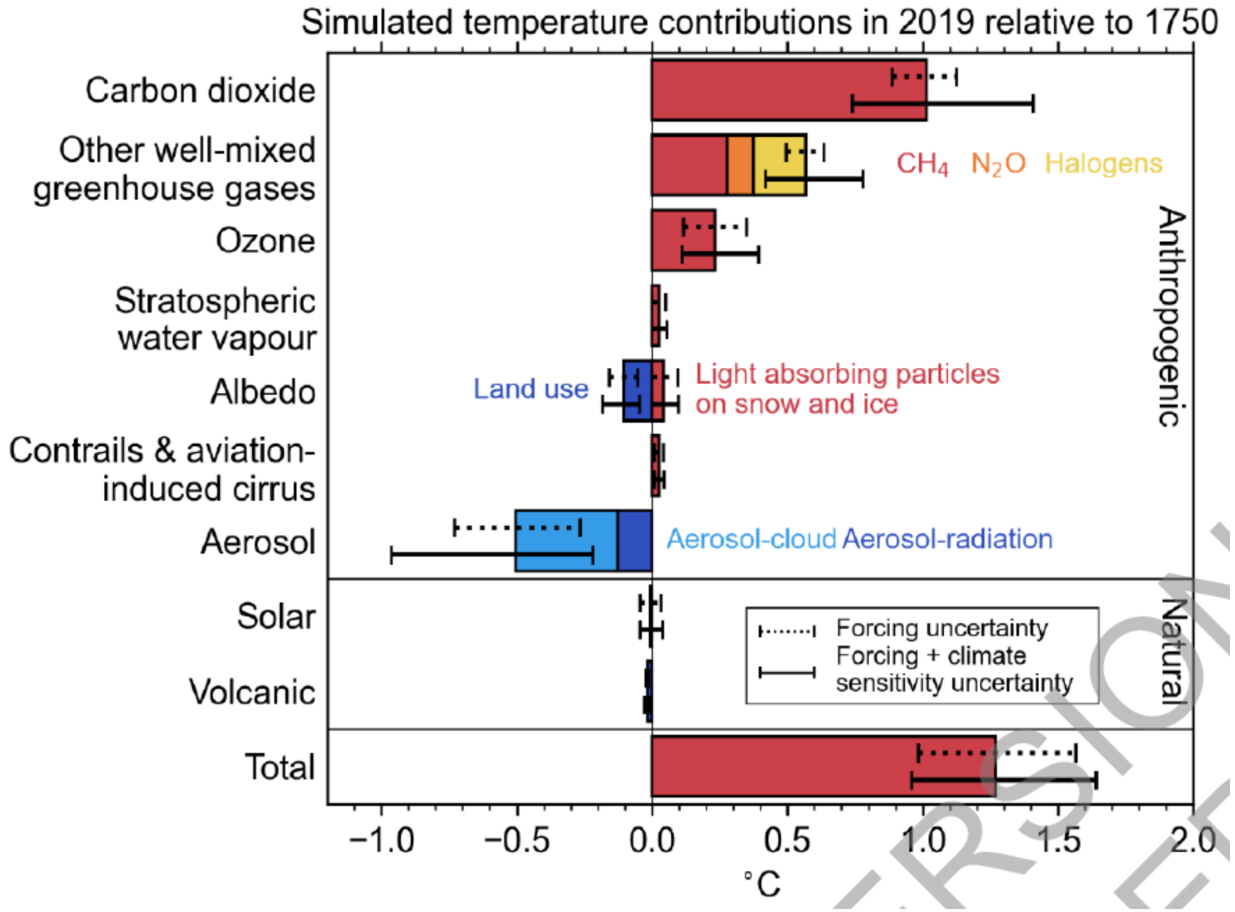


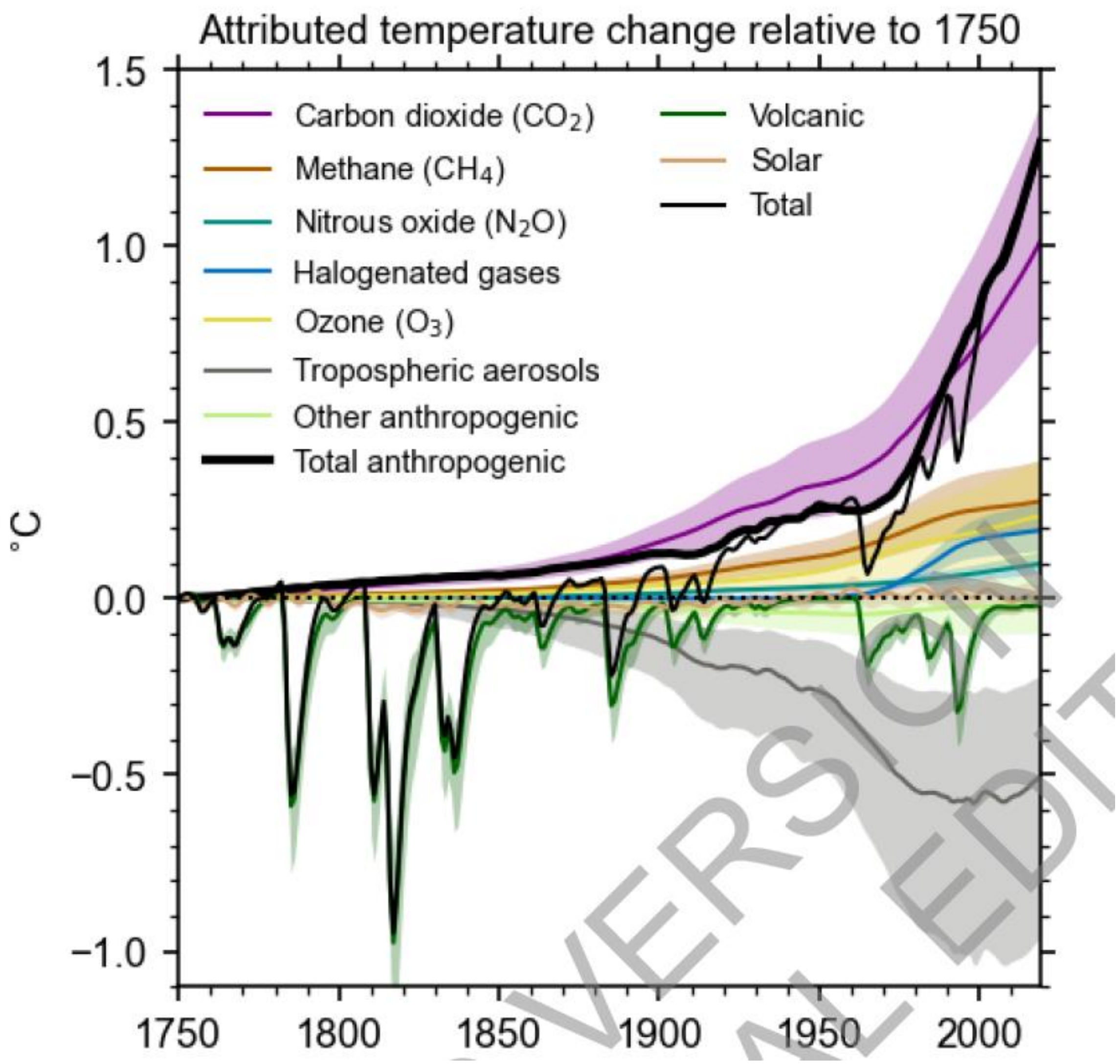
IPCC (2021, Draft)
Forcing Summary



Aerosol Extinction a Big Uncertainty for Climate Change

IPCC (2021, Draft) Temperature Change Summary





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Summary

Abstract: This webinar outlines a simple, low-cost method to rapidly quantify aerosol and molecular absorption and scattering effects at any laser wavelength using only measurements of temperature, pressure, humidity, and aerosol number concentration.

Webinar Objectives

1. Describe how absorption due to molecules and aerosols can cause laser thermal blooming
   - Off-axis laser scattering affected by aerosol absorption
   - Thermal blooming may be an on-axis method to quantify aerosol absorption

2. Describe AFIT CDE's initial testing of NOAA's Continuous Light Absorption Photometer (CLAP) as it prepares to join the NOAA Federated Aerosol Network (NFAN)
   - Comparisons to Magee Scientific Black Carbon Aethalometer
   - Importance of quantifying aerosol scattering in aerosol absorption measurement

3. Demonstrate that calculations from total aerosol number concentration assuming a single mode lognormal size distribution can provide reasonable aerosol absorption estimates of CLAP measurements

4. Describe the need to better characterize aerosol absorption for climate change assessments