AERONET: 1 to 600 in 25 yrs

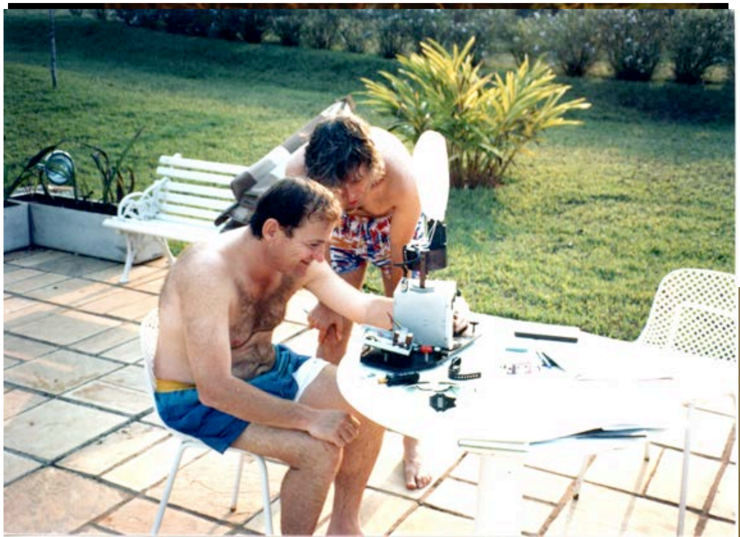
Brent’s Flawed Recollections

Brief History

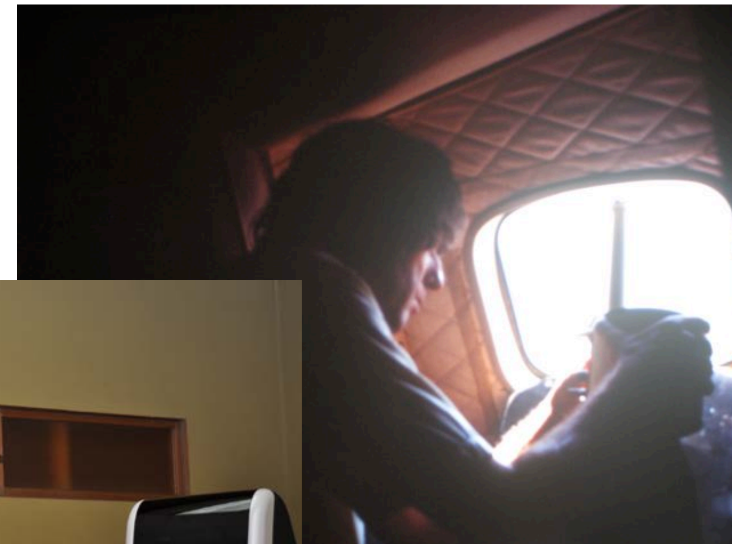
People, Evolution & Milestones

The Plan

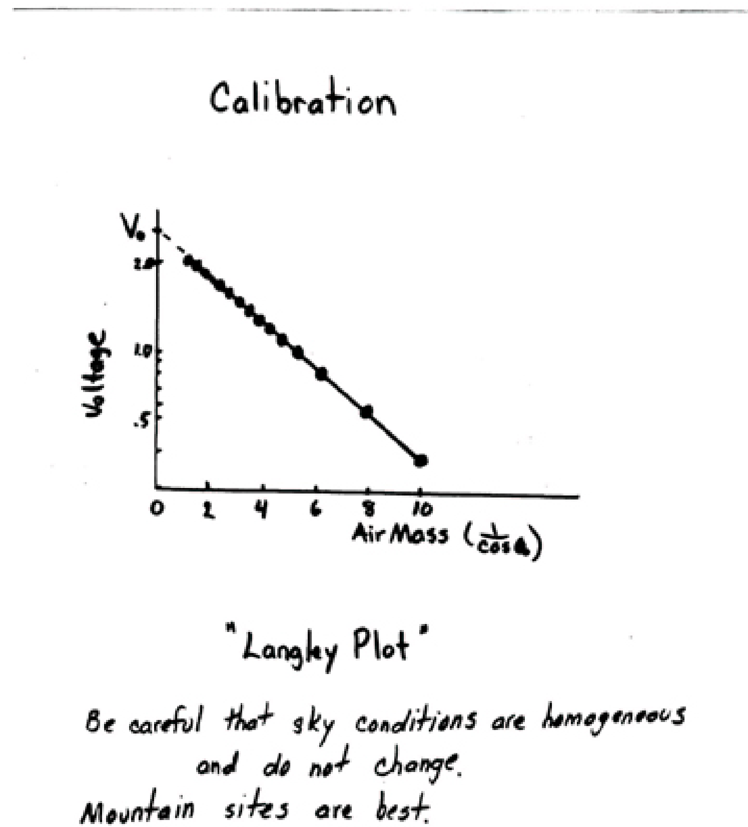
Tanre/Nakajima/ Kaufman/Holben/Smoke



1988 - 1992

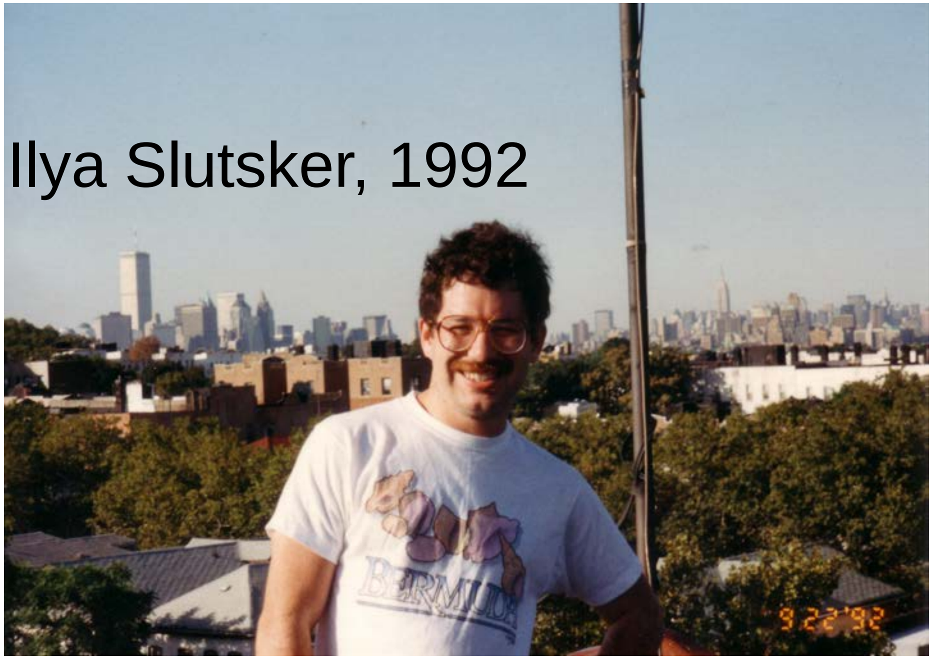


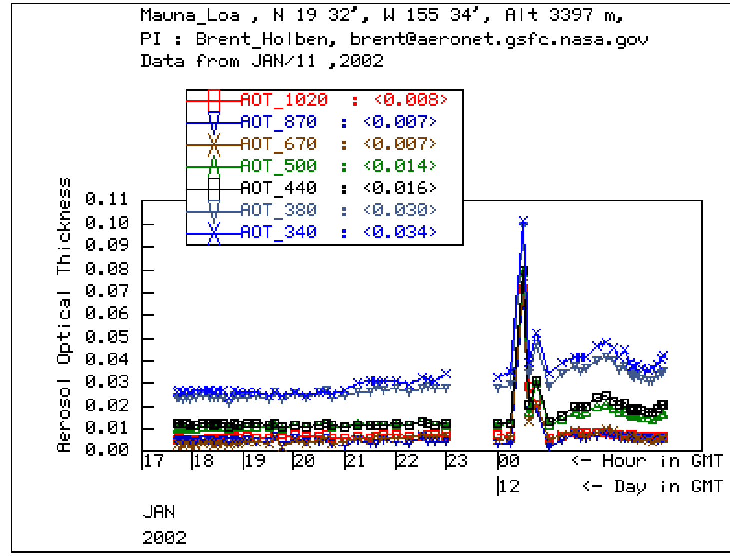
AERONET’s First Light (1993)



The interactive computer era

Ilya Slutsker, 1992





Demonstrat

EOS MODIS Validation/atmospheric correction (1995)-King: Kaufman, Justice, Esaias

$ $ $

People and Campaigns and Instruments

- Nadir Abuhassen-Engineer
- Alexander Smirnov-Sun Photometry
- Oleg Dubovik-RT Inversion
- Boreas-Markham
- LBA-Schafer
- TARFOX, INDOEX, Zibbie, Safari, BASE-B
- 100 instruments by 1998

Holben et al., 1998

- Imposed Network Standardization
  - Calibration
  - Measurements
  - Processing
  - Distribution
- Near real time Acquisition-transparency of data (the good and bad)
- Federated with global partners
- AOT➔Size Distribution,ref Index
- Citations: 5316

AERONET Milestones: Eck et al., 1999

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 104, NO. D24, PAGES 31,333–31,349, DECEMBER 27, 1999

Wavelength dependence of the optical depth of biomass burning, urban, and desert dust aerosols

T. F. Eck,[1] B. N. Holben,[2] J. S. Reid,[3] O. Dubovik,[4] A. Smirnov,[4] N. T. O'Neill,[5] I. Slutsker,[4] and S. Kinne[6]

Abstract. The Angstrom wavelength exponent α, which is the slope of the logarithm of aerosol optical depth (τ_a) versus the logarithm of wavelength (λ), is commonly used to characterize the wavelength dependence of τ_a and to provide some basic information on the aerosol size distribution. This parameter is frequently computed from the spectral measurements of both ground-based sunphotometers and from satellite and aircraft remote sensing retrievals. However, spectral variation of α is typically not considered in the analysis and comparison of values from different techniques. We analyze the spectral measurements of τ_a from 340 to 1020 nm obtained from ground-based Aerosol Robotic Network radiometers located in various locations where either biomass burning, urban, or desert dust aerosols are prevalent. Aerosol size distribution retrievals obtained from combined solar extinction and sky radiance measurements are also utilized in the analysis. These data show that there is significant curvature in the ln τ_a versus ln λ relationship for aerosol size distributions dominated by accumulation mode aerosols (biomass burning and urban). Mie theory calculations of α for biomass burning smoke (for a case of aged smoke at high optical depth) agree well with observations, confirming that large spectral variations in α are due to the dominance of accumulation mode aerosols. A second order polynomial fit to the ln τ_a versus ln λ data provides excellent agreement with differences in τ_a of the order of the uncertainty in the measurements (~0.01-0.02). The significant curvature in ln τ_a versus ln λ for high optical depth accumulation mode dominated aerosols results in α values differing by a factor of 3-5 from 340 to 870 nm. We characterize the curvature in ln τ_a versus ln λ by the second derivative α' and suggest that this parameter be utilized in conjunction with α to characterize the spectral dependence of τ_a. The second derivative of ln τ_a versus ln λ gives an indication of the relative influence of accumulation mode versus coarse mode particles on optical properties.

1. Introduction

Variability in the size distribution of atmospheric aerosols results in part from variability in the processes that initially form the aerosols such as biomass burning [*Reid and Hobbs*, 1998; *Remer et al.*, 1998], combustion of fossil fuels from urban/industrial processes [*Remer and Kaufman*, 1998], oceanic wave action producing sea salt aerosol [*Hoppel et al.*, 1990], plants producing biogenic aerosols [*Kavouras et al.*, 1998; *Artaxo et al.*, 1988], volcanic eruptions [*Russell et al.*, 1993] and airborne soil particles [*d'Almeida*, 1987]. In addition, once these aerosols have been formed there are often dynamic processes that may result in evolution of the size distribution in time. For example, in the case of biomass burning aerosols, *Reid et al.* [1998] show that aging of the aerosols results in changes in aerosol size distribution related to coagulation, condensation, and gas-to-particle conversion processes. Similarly *Remer and Kaufman* [1998] have observed variability in the size distributions of urban/industrial aerosols which are likely due to particle growth at high relative humidity and aerosol interactions with clouds.

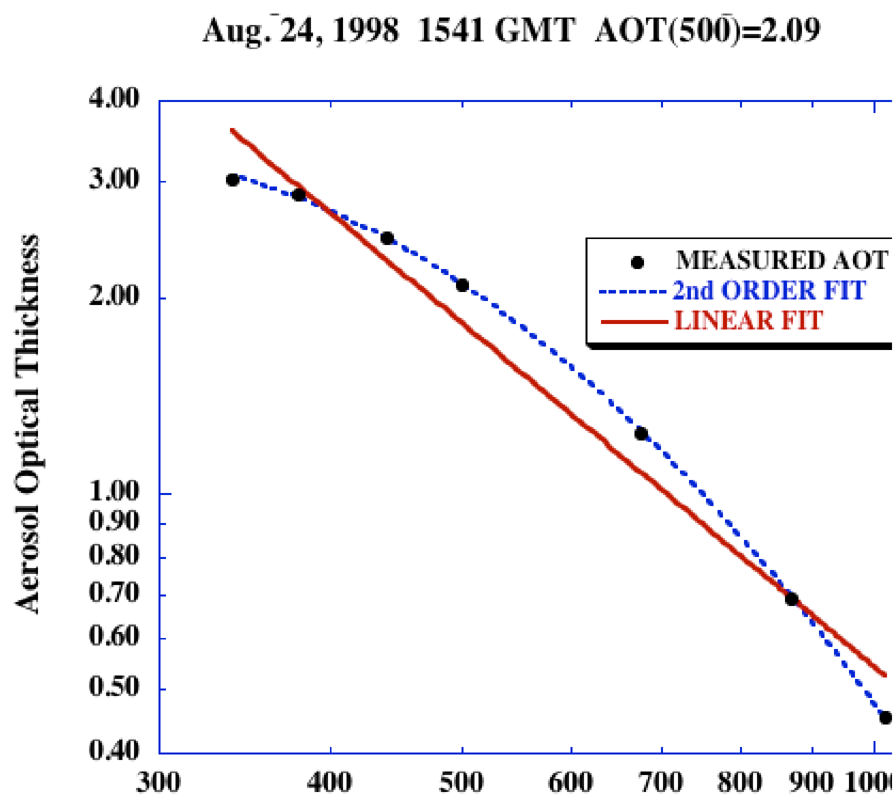
These variations in size distribution of various aerosol types strongly influence the radiative properties of the aerosols such as the scattering phase function, single scattering albedo, and spectral variation of aerosol optical thickness. The characterization of the spectral dependence of aerosol optical thickness τ_a in the atmosphere is important for modeling of the radiative effects of aerosols on the atmosphere/surface system, retrieval of aerosol parameters from satellite remote sensing, correction for aerosol effects in remote sensing of the Earth's surface, and assistance in identification of aerosol source regions and aerosol evolution in time. Many studies of aerosol optical thickness and its spectral dependence rely on the Angstrom wavelength exponent α to quantify this spectral dependence. *Angstrom's* [1929] empirical expression is given as

$$\tau_a = \beta\lambda^{-\alpha} \quad (1)$$

where λ is the wavelength in microns of the corresponding τ_a

[1]Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland
[2]Biospheric Sciences Branch, NASA Goddard Space Flight Center, Greenbelt, Maryland
[3]Tropospheric Branch, Space and Naval Warfare Systems Center, San Diego, California.
[4]Science Systems Applications, Inc., NASA Goddard Space Flight Center, Greenbelt, Maryland
[5]Centre d'Applications et de Recherches en Teledetetection, Universite de Sherbrooke, Quebec; currently on leave at NASA Goddard Space Flight Center, Greenbelt, Maryland
[6]University of Maryland, Baltimore, Maryland and NASA Goddard Space Flight Center, Greenbelt, Maryland

Paper number 1999JD900923.
0148-0227/99/1999JD900923$09.00



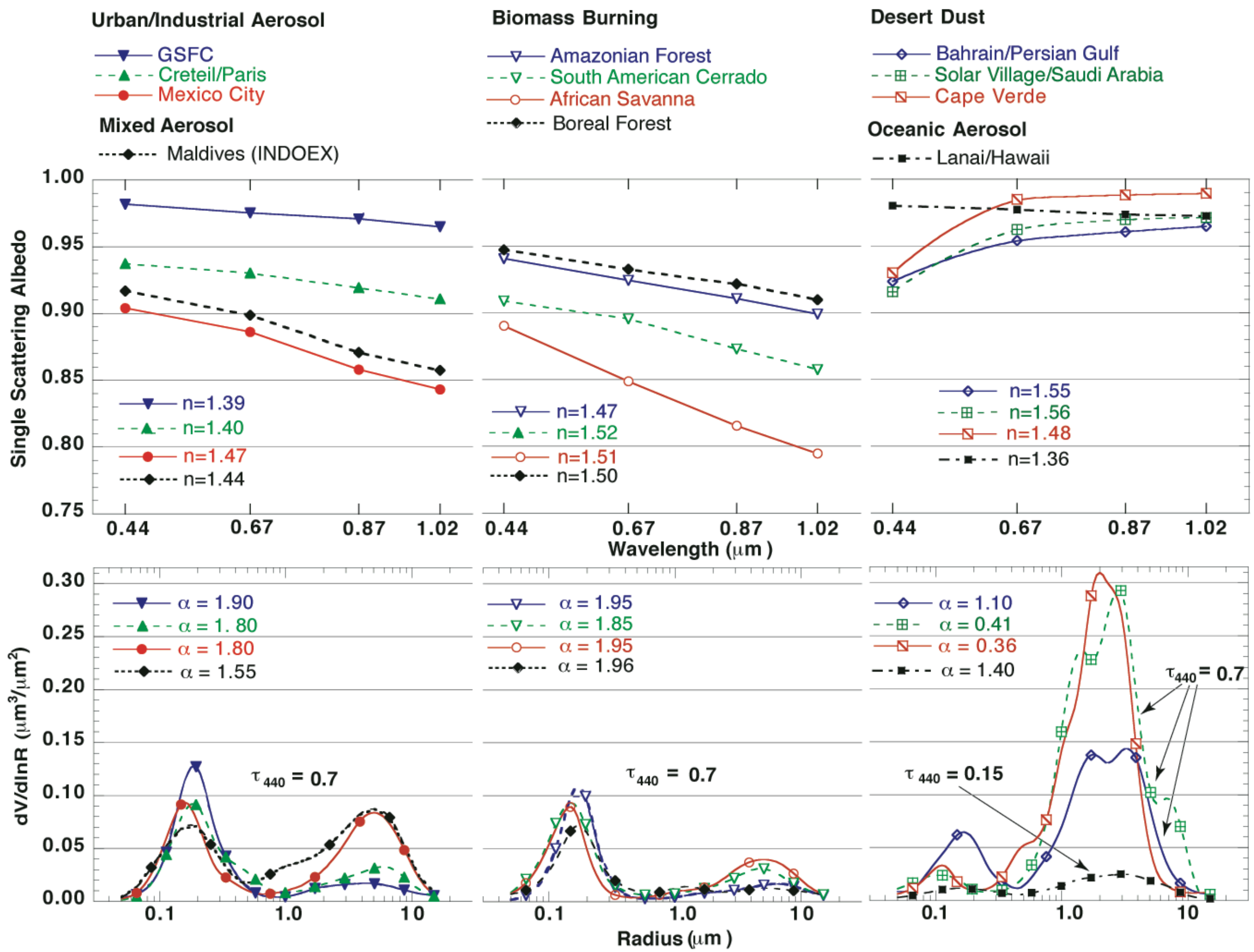
1462 Citations

AERONET Milestones: Smirnov et al., 2000 Dubovik and King 2000

- Standardized cld screening and QA, Smirnov
- Accuracy/Sensitivity assessment of inversion products, Dubovik
- Smirnov, 1168 citations
- Dubovik, 1367 citations

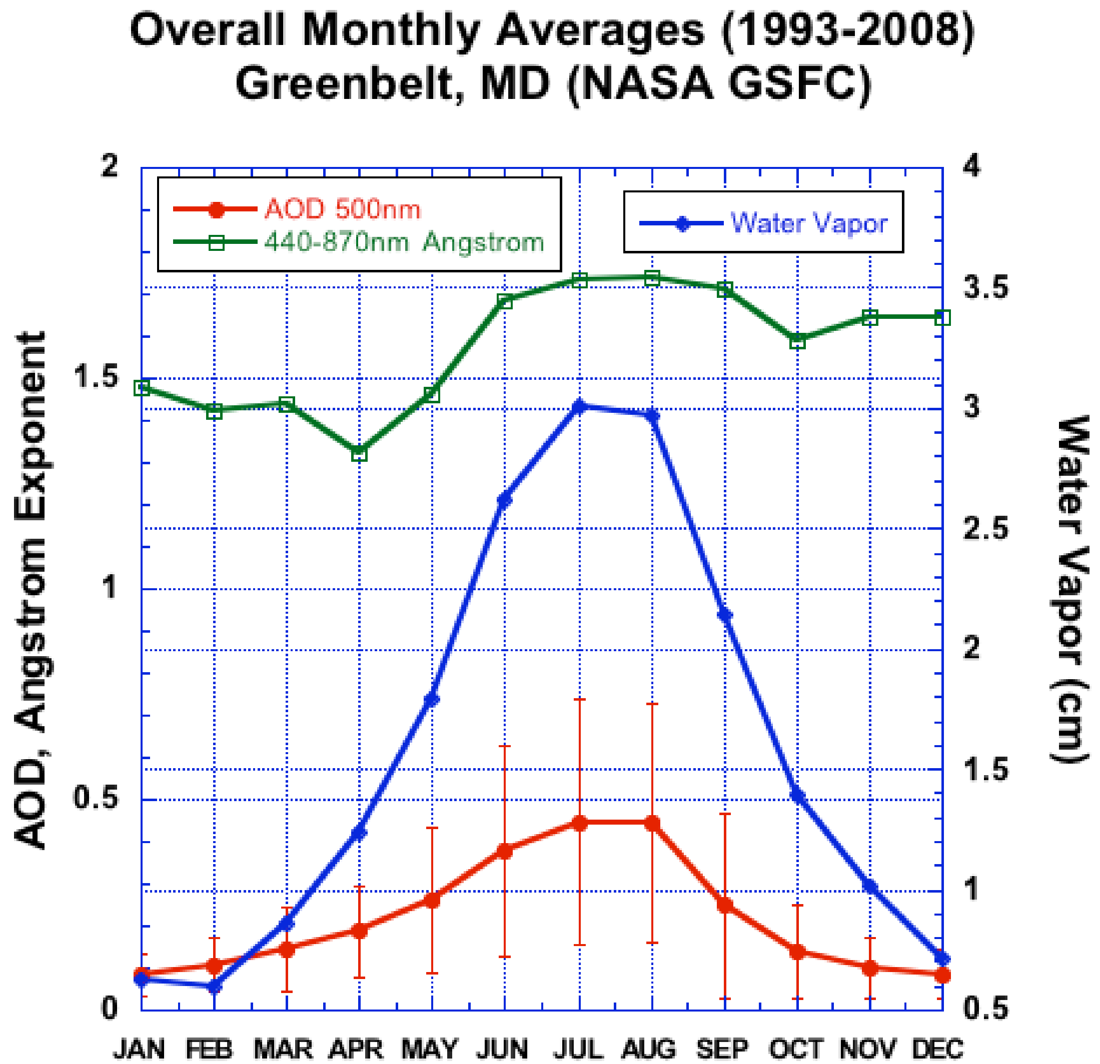
AERONET Milestones: Dubovik & King 2000; Dubovik et al., 2002

2283 citations



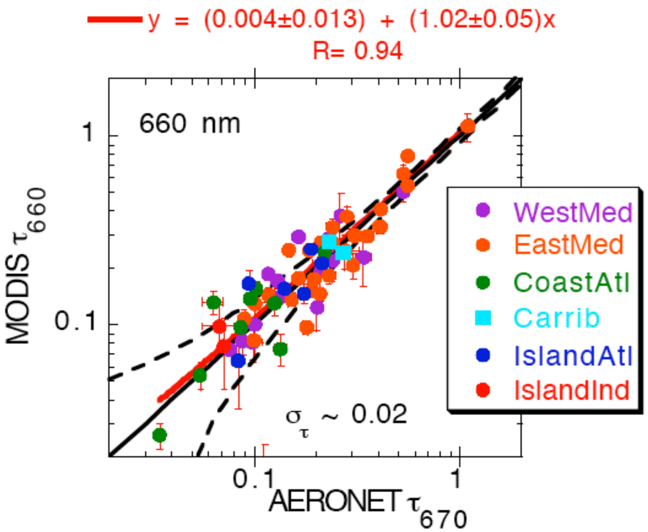
AERONET Milestones: Holben et al., 2001

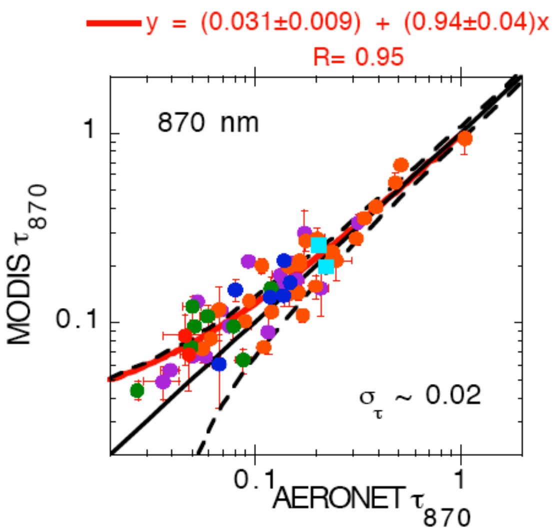
1577 citations



The flood gates opened

- Regional studies
- Field campaigns
- Model comparisons
- Satellite comparisons
- And complimentary data sets





Remer et al. (2005); 2361 Citations

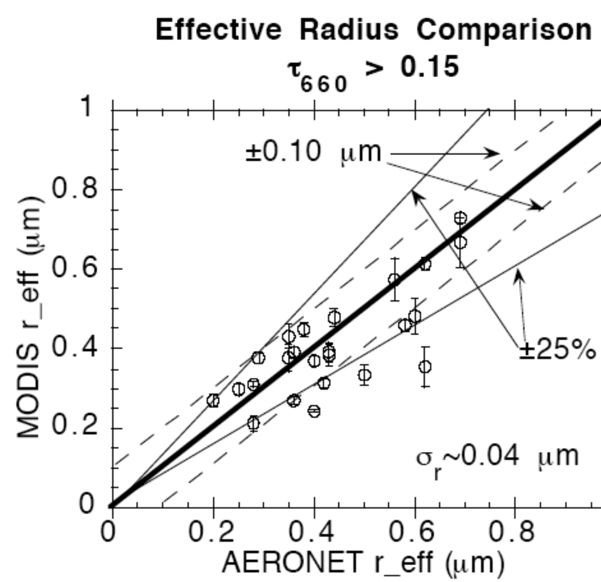
First ever MODIS validation using AERONET data.

These are for the over ocean product.

After 2 months, 64 collocated AOD data points and 25 collocated inversions when AOD > 0.15.

Data collection during the period Aug 21, 2000 to roughly Oct 20, 2000.

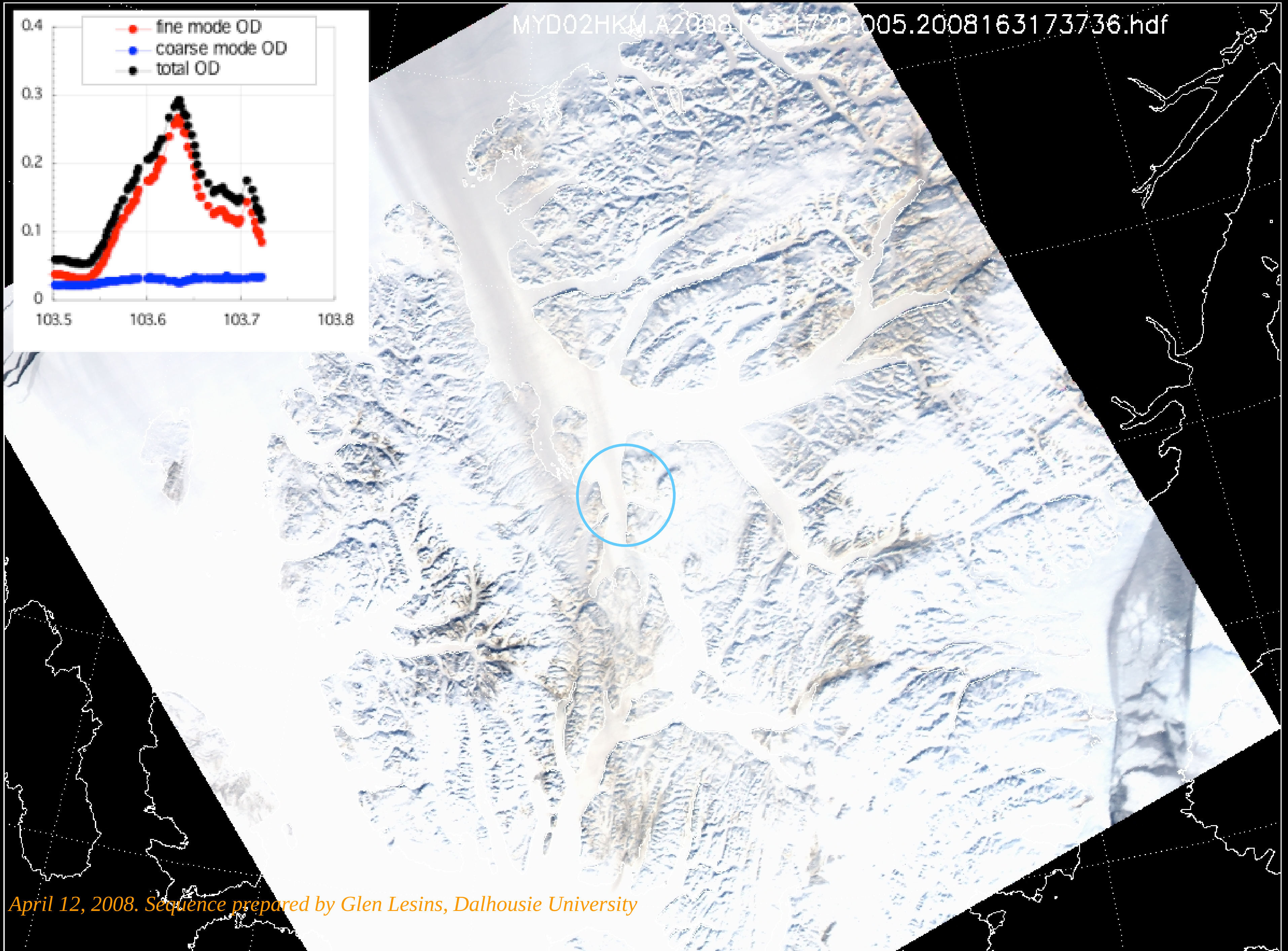
8 months after MODIS 'first light', we had validation!



Program Evolution

- O’Neill Factor
- AERONET-OC
- Maritime Aerosol Network
- SolRad-NET
- Spectral Polarization
- Data Access

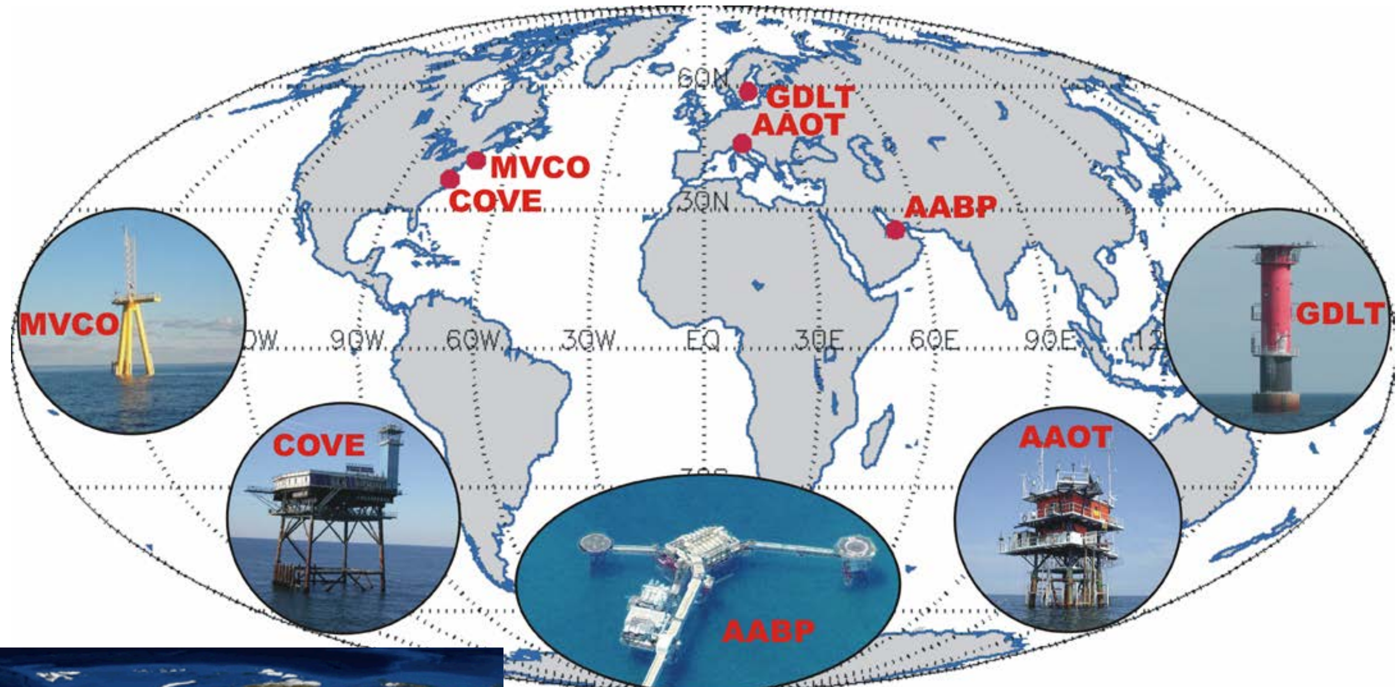
Norm, Sasha & Tom. San Fran AGU, Dec. 07 AGU. Discussing SDA



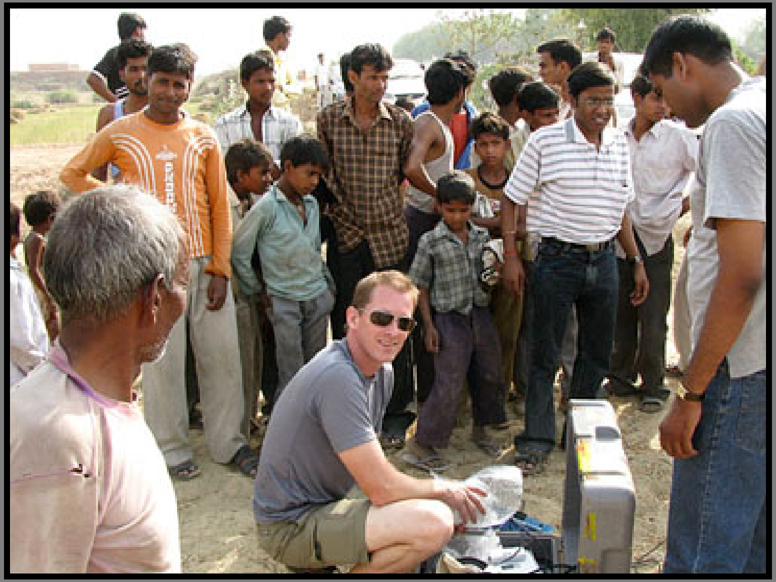
April 12, 2008. Sequence prepared by Glen Lesins, Dalhousie University

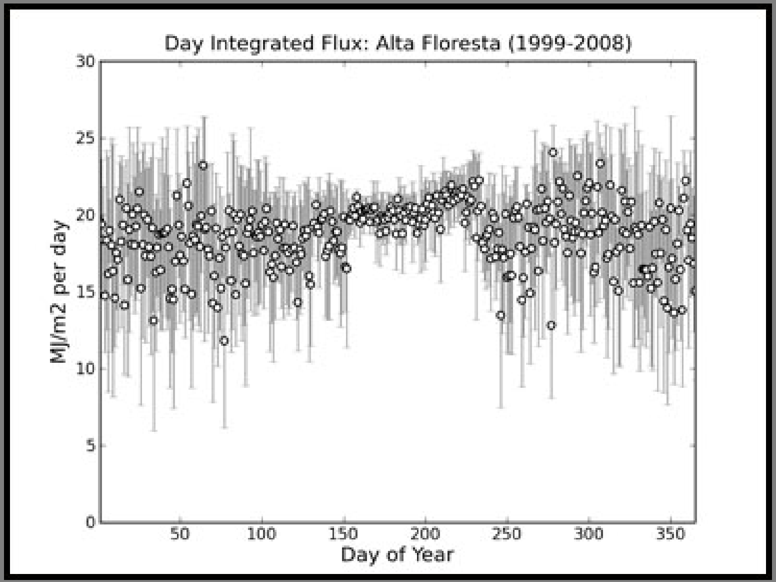
G. Zibordi/JRC & S. Hooker/GSFC

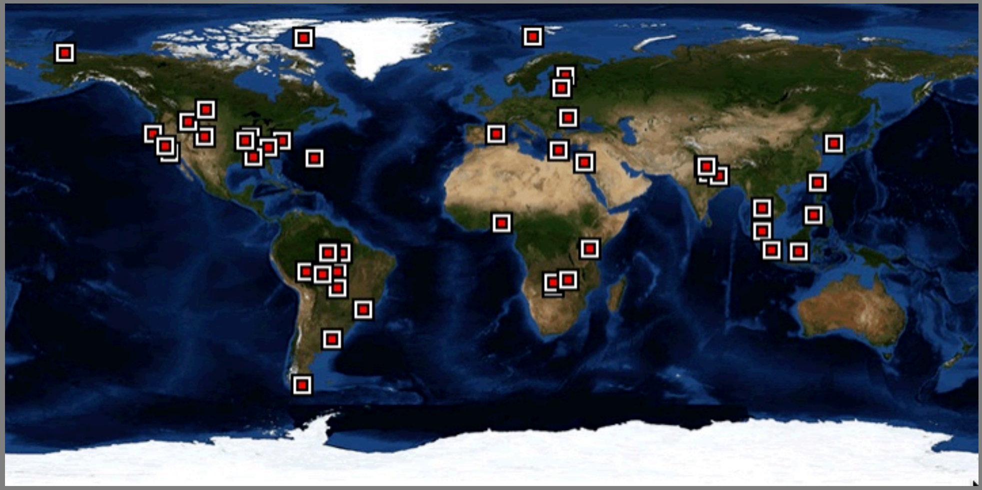
AERONET – Ocean Color (AERONET-OC): an integrated network, part of the Aerosol Robotic Network (AERONET), supporting ocean color validation with highly consistent time-series of standardized $L_{WN}(\lambda)$.



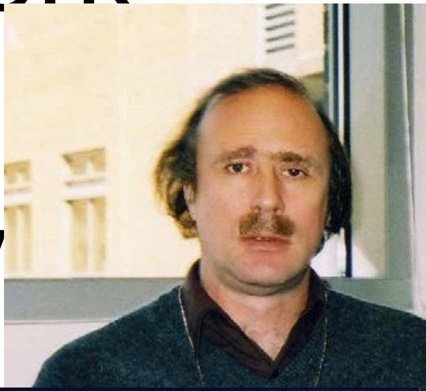
SolRad-NET-Joel Schafer 1992-present

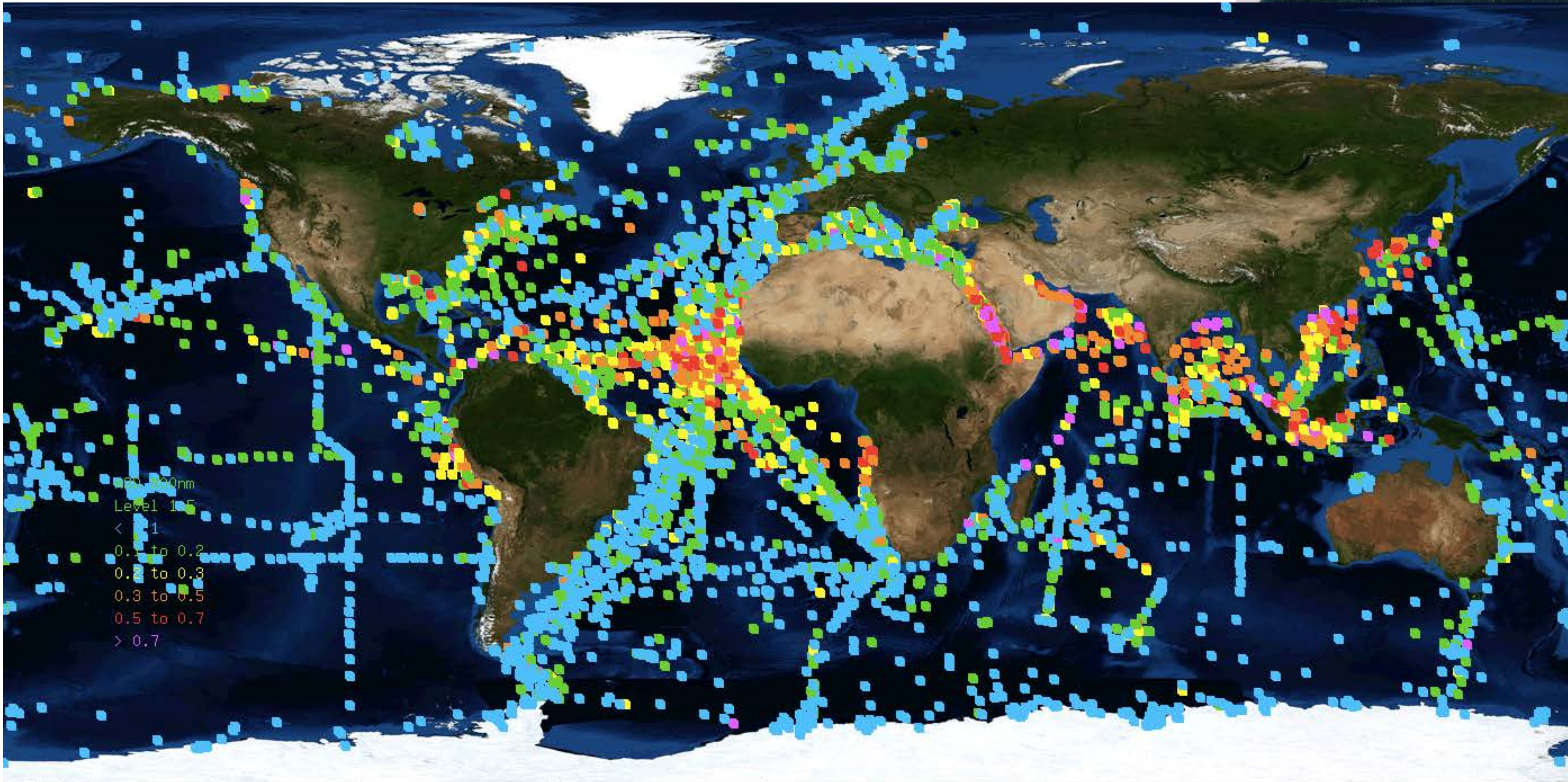




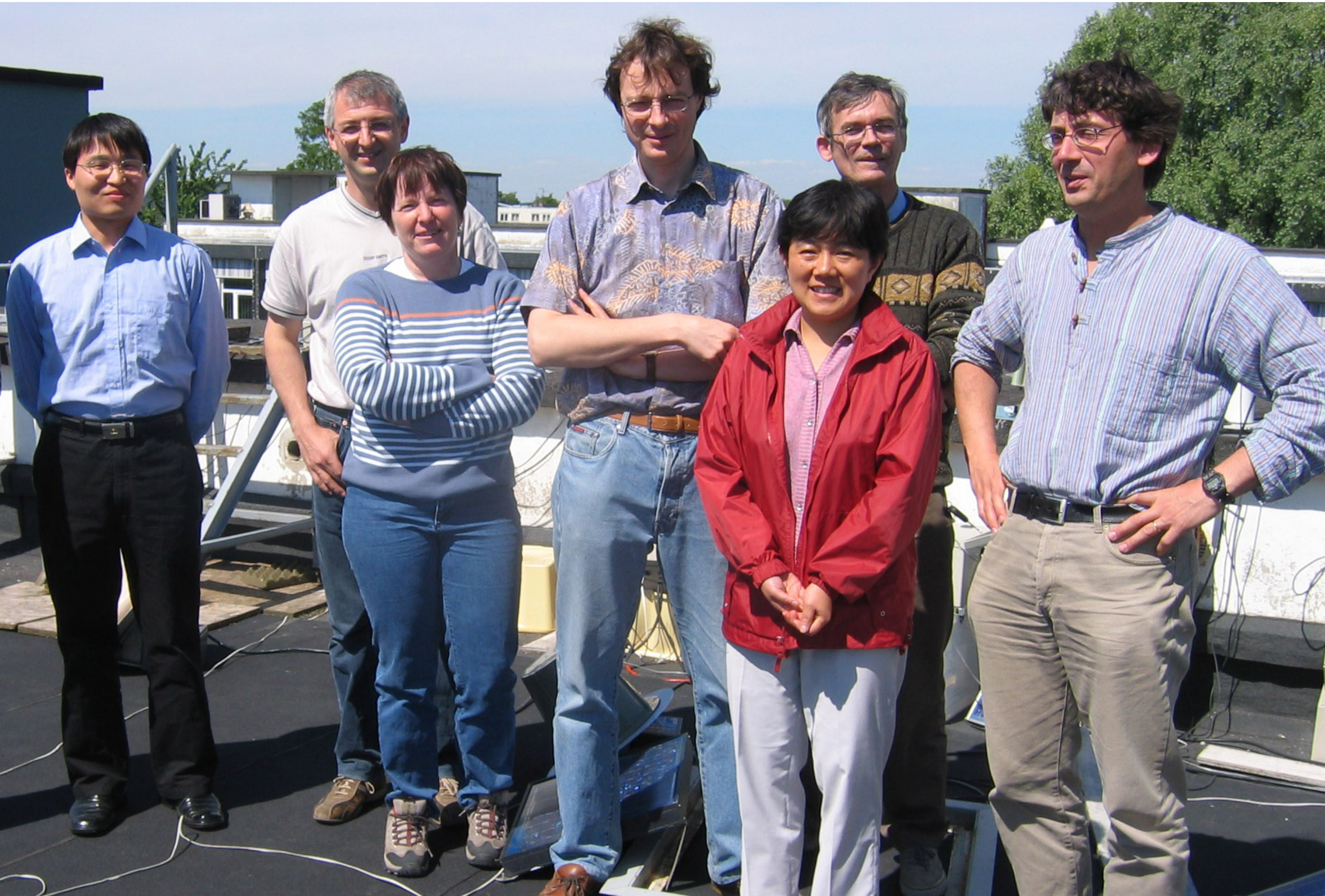


Maritime Aerosol Network (MAN) 2004-present SIMBIOS to Smirnov





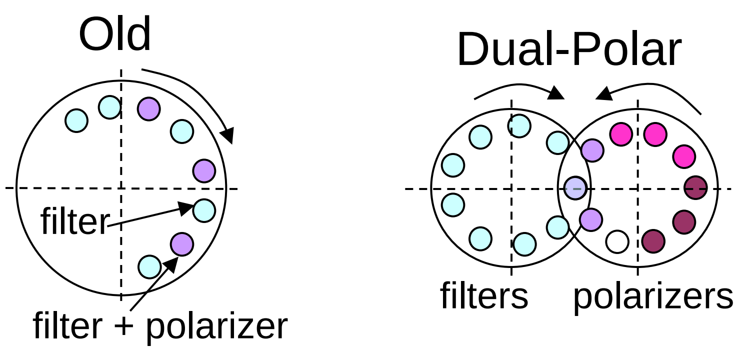
PHOTONS Team-Lille, France

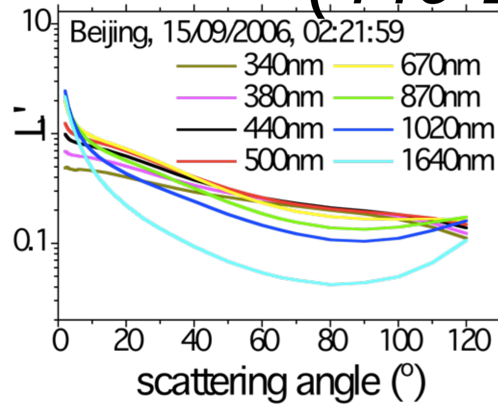


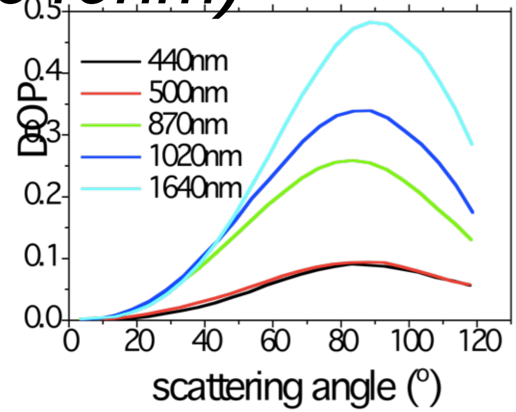
PHOTONS-Z. Li

AERONET Spectral Polarization (440-1640nm)

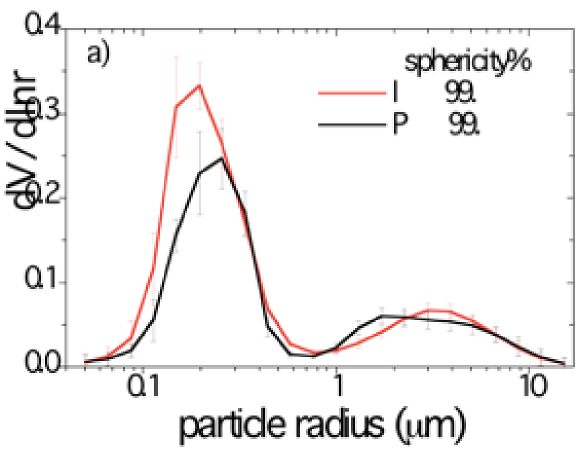
Dual-polar instrument



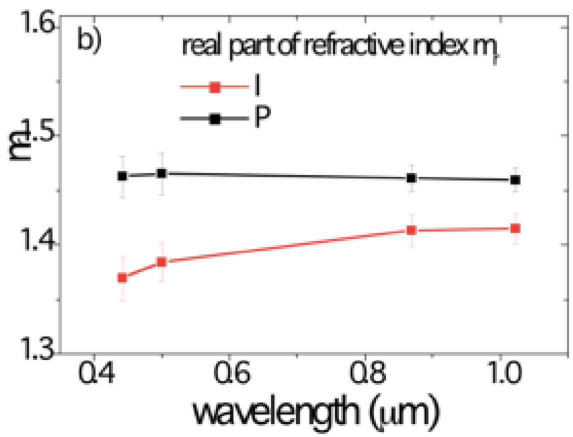




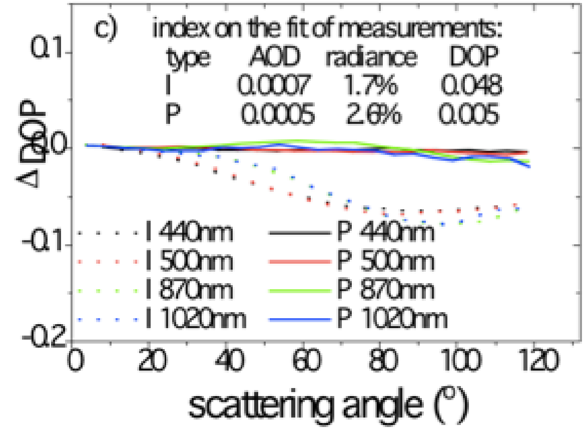
Profiting from nearly doubled input information (intensity + polarization), artifacts in the retrieval of fine mode size distribution, real part of refractive index and particle shape parameter can be reduced, esp. for small particles.



Retrieval of size distribution



Refractive index



Restitution of polarization

(Li et al., submitted, 2009)

The Databases to Ver 3

David Giles:

Out standing…

https://aeronet.gsfc.nasa.gov

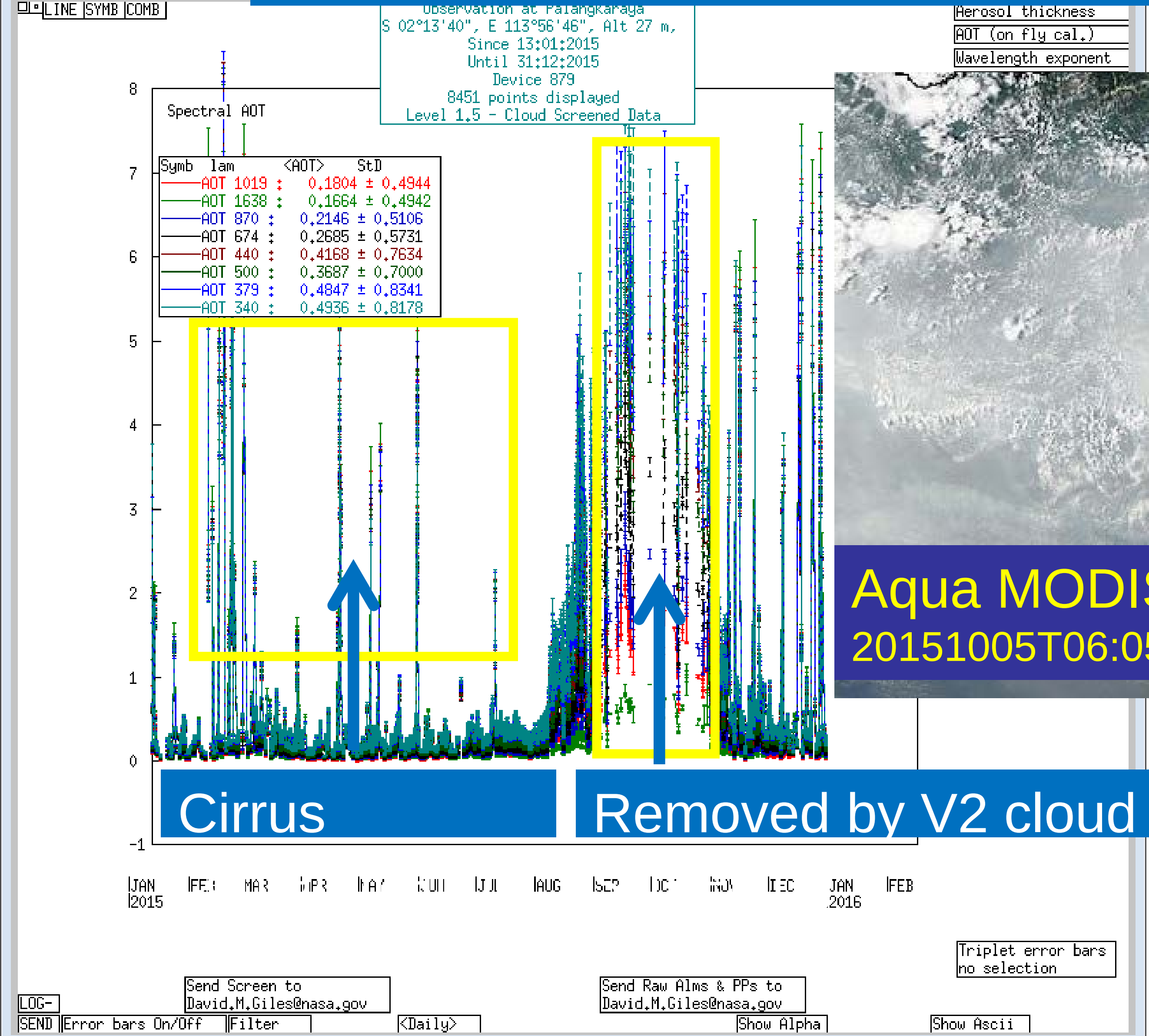
- Data Display
- Download Tool
- Download All Sites
- Climatology Tables
- Web Services
- Synergy Tool

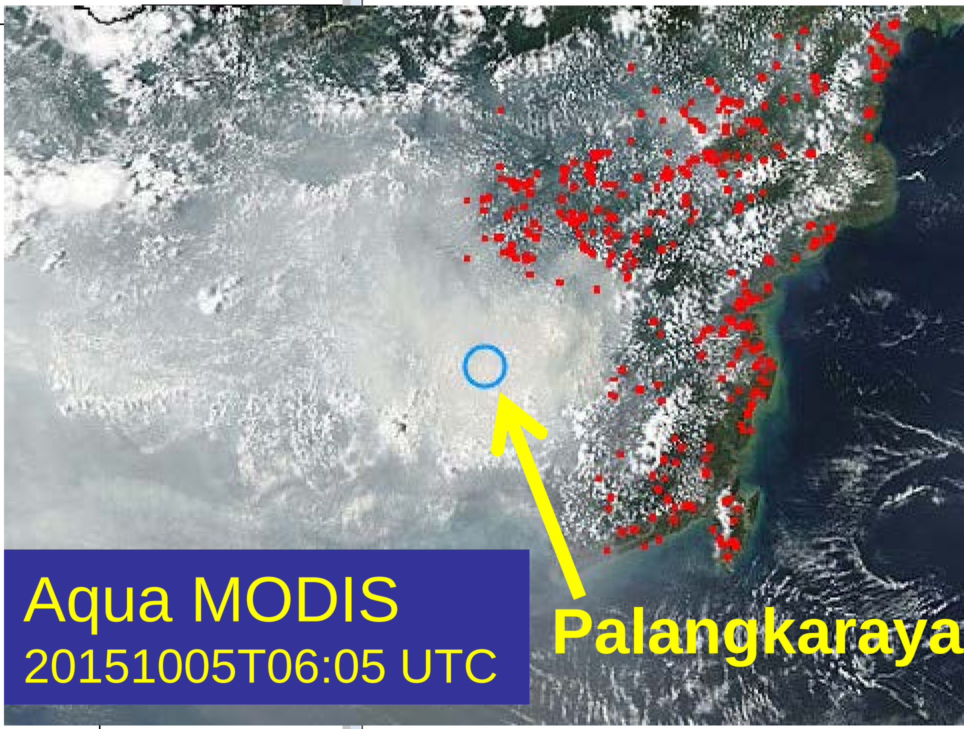
Giles, D. M., Sinyuk, A., Sorokin, M. S., Schafer, J. S., Smirnov, A., Slutsker, I., Eck, T. F., Holben, B. N., Lewis, J., Campbell, J., Welton, E. J., Korkin, S., and Lyapustin, A.: Advancements in the Aerosol Robotic Network (AERONET) Version 3 Database – Automated Near Real-Time Quality Control Algorithm with Improved Cloud Screening for Sun Photometer Aerosol Optical Depth (AOD) Measurements, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2018-272, in review, 2018.

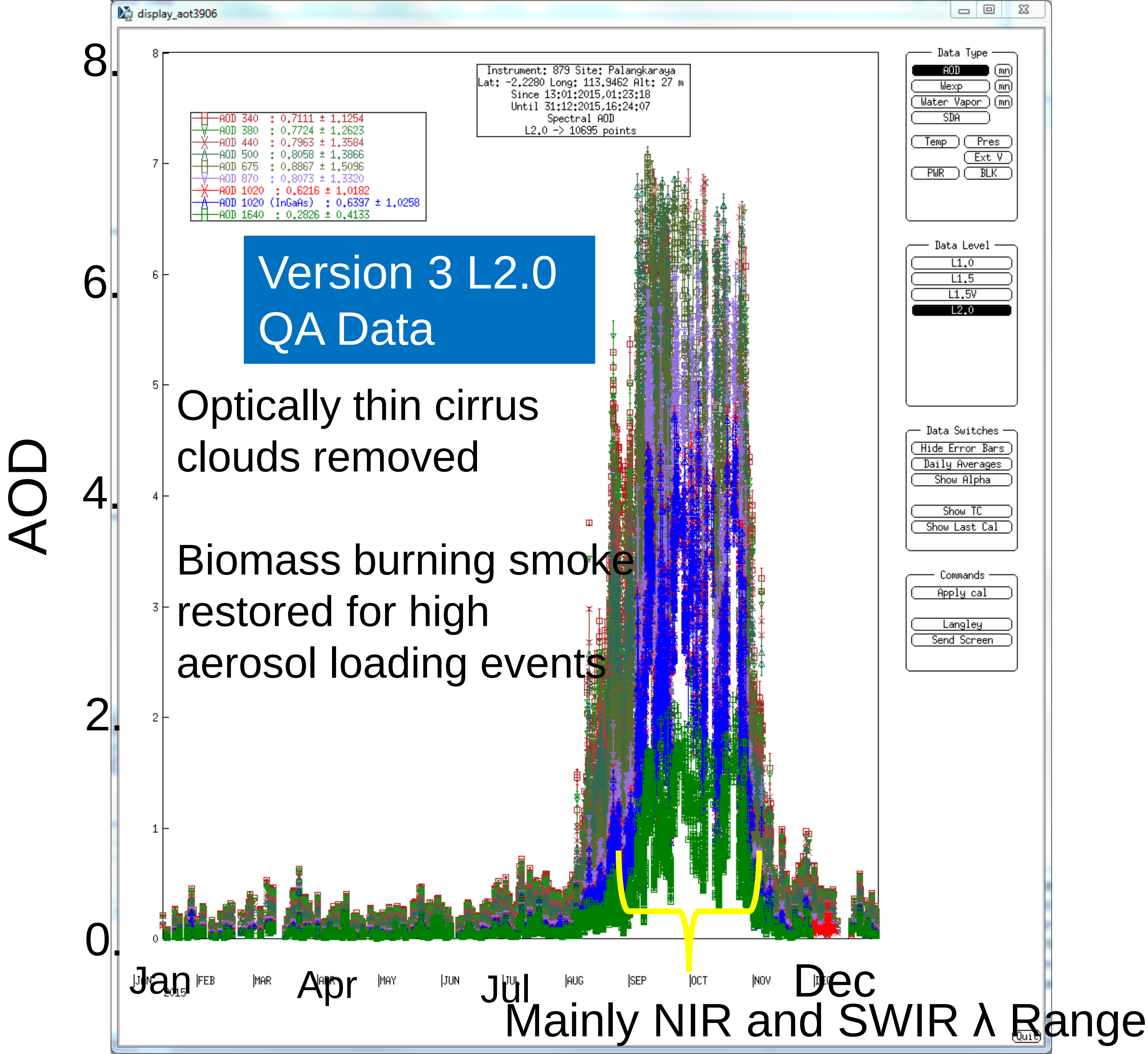
Version 3 Release: 5 Jan 2018

- All Levels: 1.0, 1.5, 2.0
  - AOD:
    - Improved Quality data
    - Level 1.5 NRT QA: Potential for AQ assessment, latency of ~<1 hr
    - Estimated AOD Accuracy: ± 0.01 to 0.02
  - Inversion Products from Almucantars only
    - QA thresholds remain the same: SSA, complex ind. ref.
    - QA thresholds imposed on PSD: >0.05 AOD_{500}
    - No Accuracy assessment

Cloud cleared data (V2 Level 1.5)



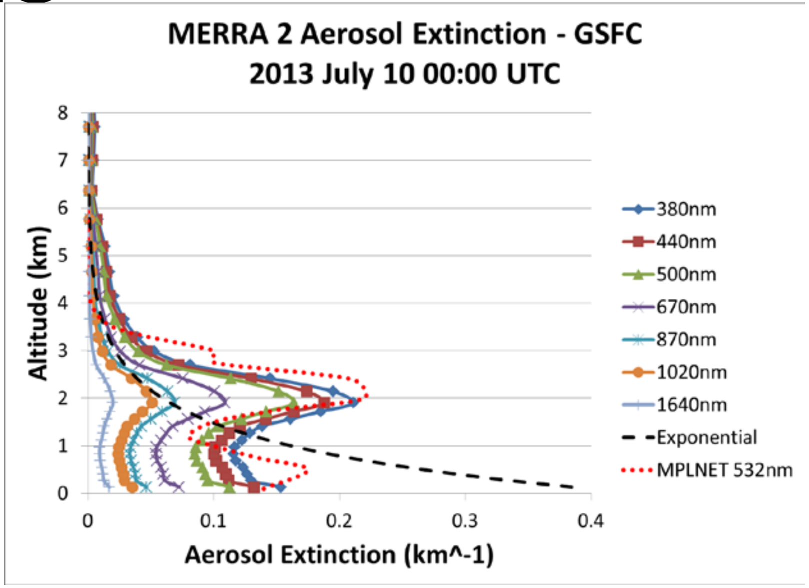


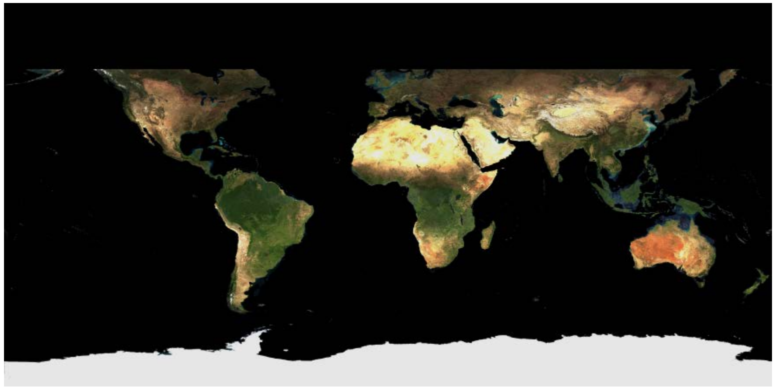


display_aot3906
AOD
8.
6.
4.
2.
0.
Instrument: 879 Site: Palangkaraya
Lat: -2.2280 Long: 113.9462 Alt: 27 m
Since 13:01:2015,01:23:18
Until 31:12:2015,16:24:07
Spectral AOD
L2.0 -> 10695 points
AOD 340 : 0.7111 ± 1.1254
AOD 380 : 0.7724 ± 1.2623
AOD 440 : 0.7963 ± 1.3584
AOD 500 : 0.8058 ± 1.3866
AOD 675 : 0.8867 ± 1.5096
AOD 870 : 0.8073 ± 1.3320
AOD 1020 : 0.6216 ± 1.0182
AOD 1020 (InGaAs) : 0.6397 ± 1.0258
AOD 1640 : 0.2826 ± 0.4133
Version 3 L2.0
QA Data
Optically thin cirrus
clouds removed
Biomass burning smoke
restored for high
aerosol loading events
Jan
Apr
Jul
Dec
Mainly NIR and SWIR λ Range
Data Type
AOD
Wexp
Water Vapor
SDA
Temp
Pres
Ext V
PWR
BLK
Data Level
L1.0
L1.5
L1.5V
L2.0
Data Switches
Hide Error Bars
Daily Averages
Show Alpha
Show TC
Show Last Cal
Commands
Apply cal
Langley
Send Screen
Quit

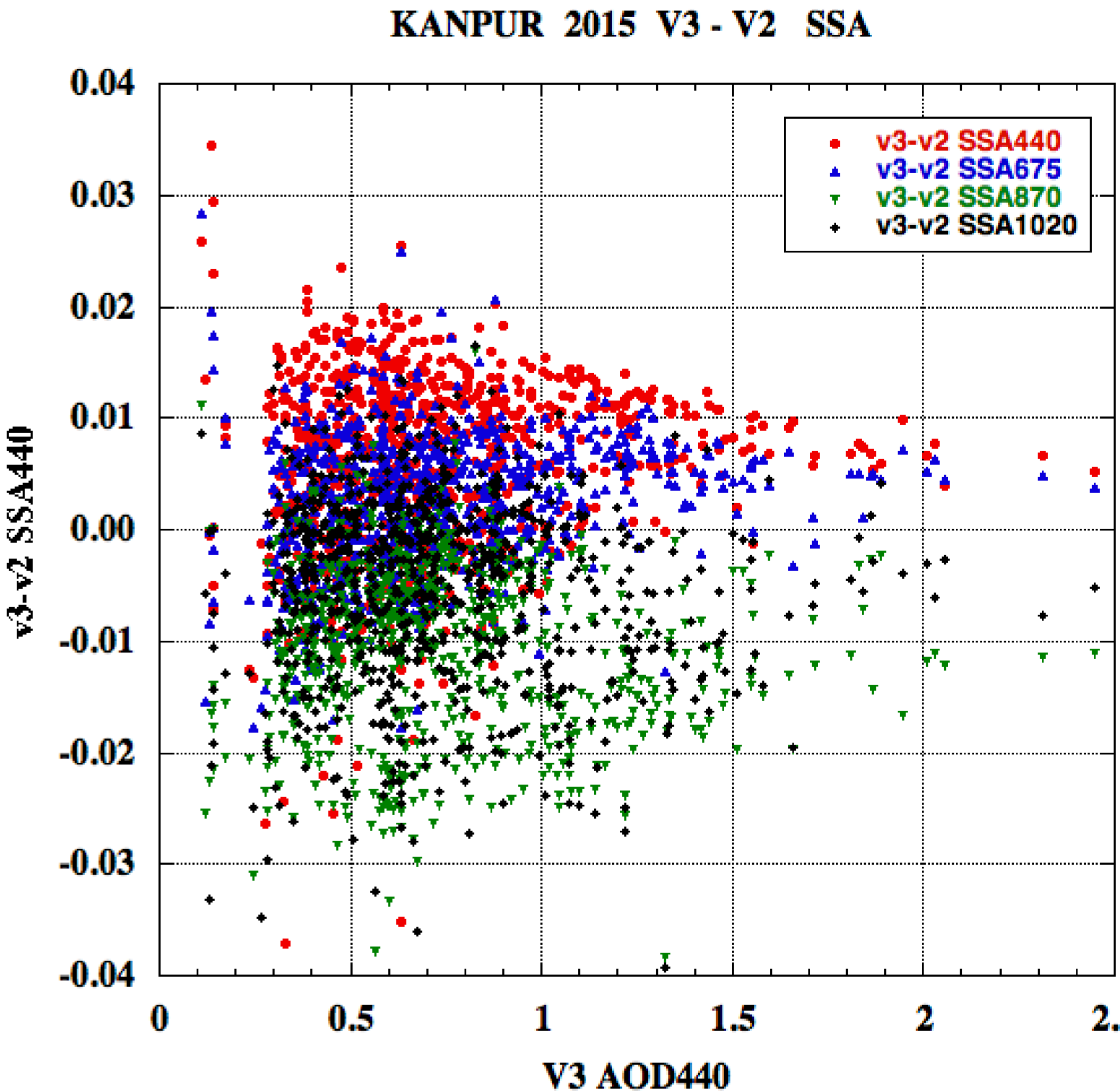
AERONET Version 3 Update - Inversions

- MODIS BRDF
  (snow and snow-free)
- Extraterrestrial Spectrum NRL2
  (Coddington et al. 2016)
- Full Vector radiative transfer code
  - Successive ORDers of scattering (SORD)
  - radiation field in UV (e.g., 380 nm retrieval in future)
  - degree of linear depolarization
- MERRA-2 aerosol extinction profiles





MODIS NBAR January 1-8, 2013



Preliminary Comparis

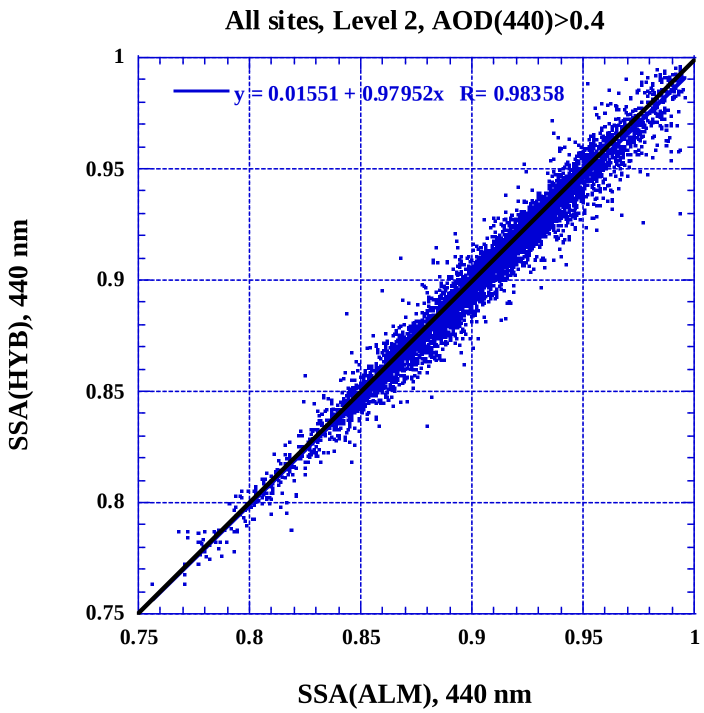
<u>Version 3</u> - Significant increases in slope of SSA versus wavelength in V3 (440 nm increases while 870 and 1020 nm decrease)

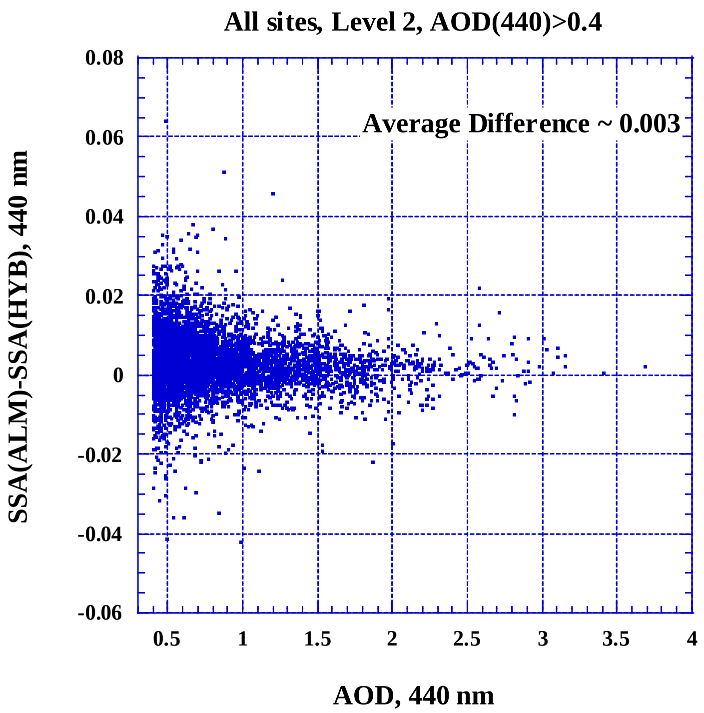
λ(nm)	V2 Ext. Irrad	V3 Ext/ Irrad.	V3/V2
1020	692.67	707.06	1.021
870	933.10	953.68	1.022
675	1530.23	1511.29	0.988
440	1853.88	1822.62	0.983

Near Term Developments

- Hybrid retrievals: 15 Oct. 2018
- Uncertainty of inversion products: Nov.
  - Sensitivity to uncertainty (per inversion)
- Lunar AOD: Dec
- Network Collaboration

Hybrid-Almucantar Comparisons





A. Sinyuk et al., 2019 in preparation

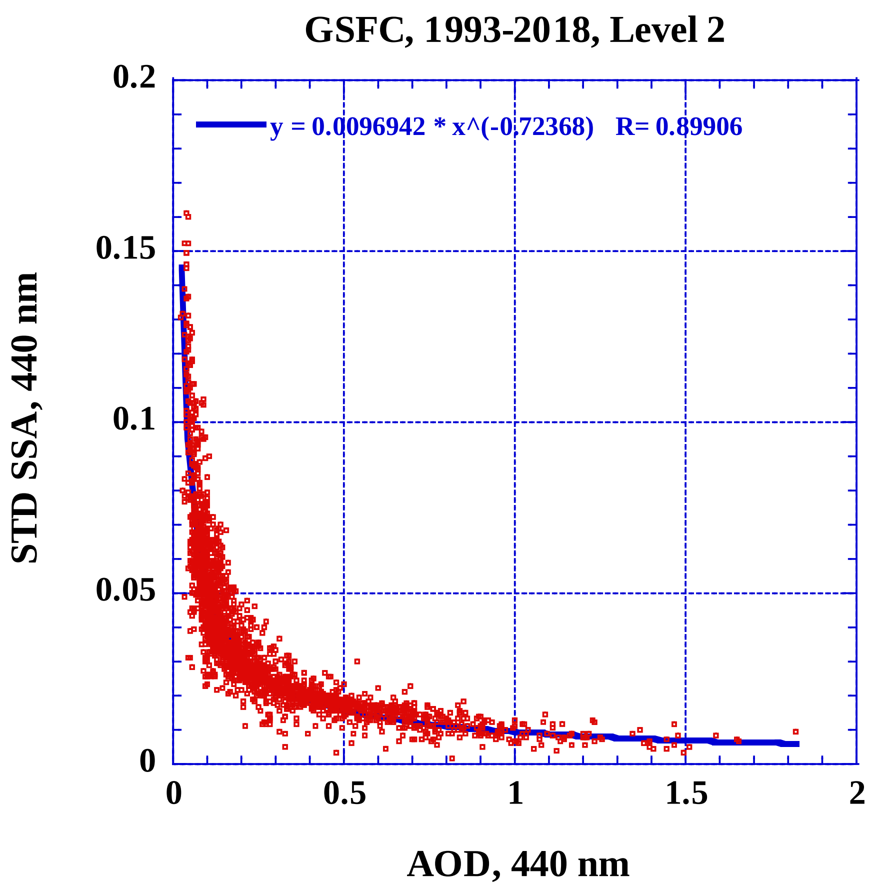
Uncertainty Proxy

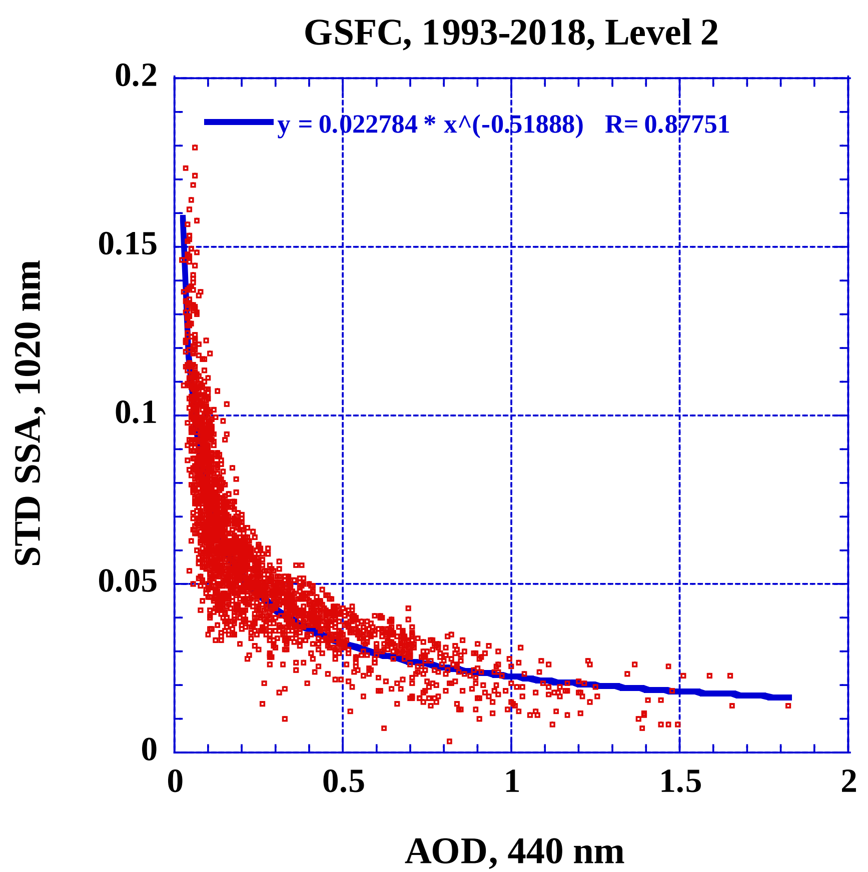
Sensitivity to 1 sigma Input Uncertainty

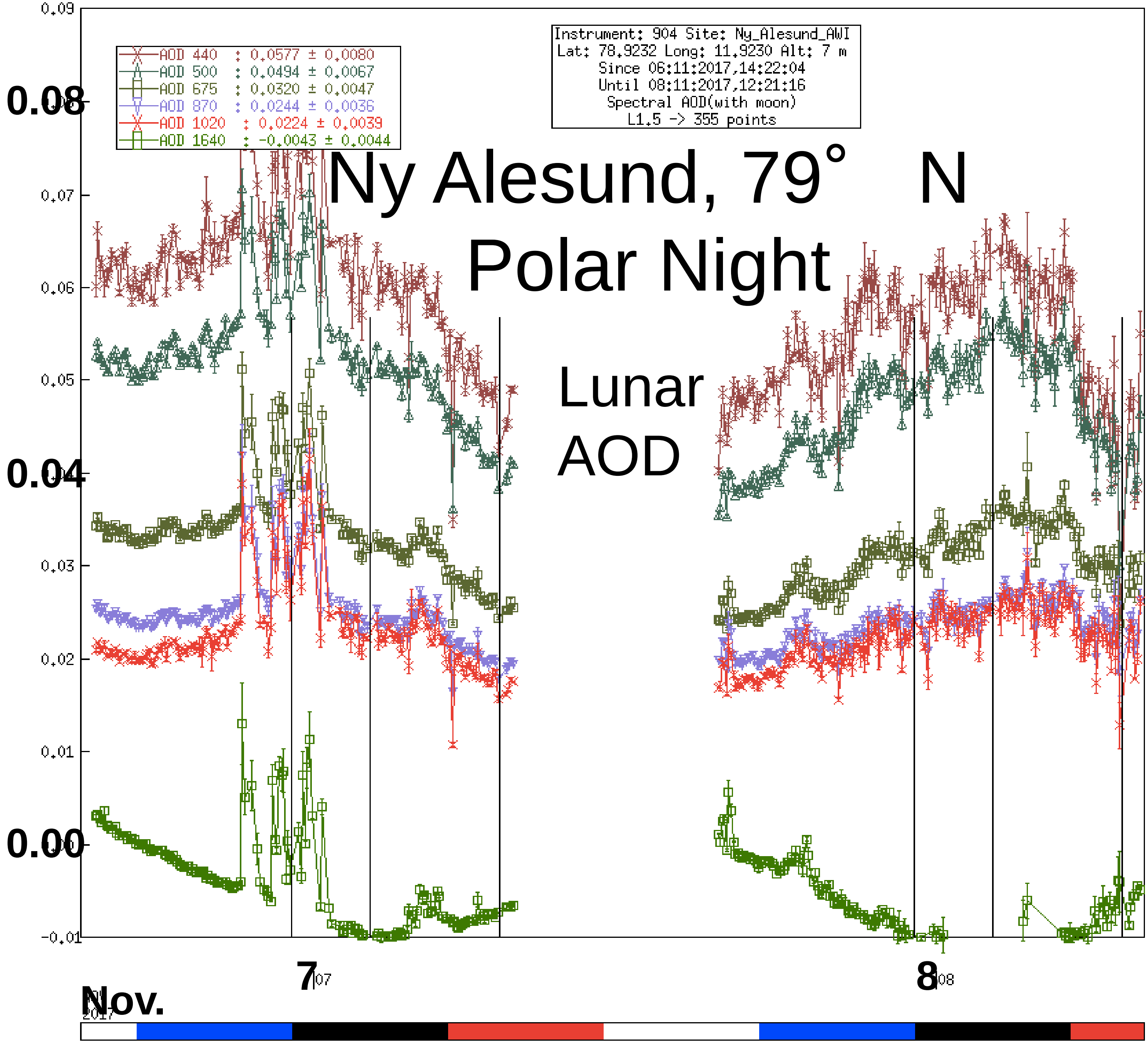
AOD: ± 0.01, BRDF: ± 5.%, Rad. & Irrad: ±5.%

27 inversions: Mean, Stdv, Max, Min

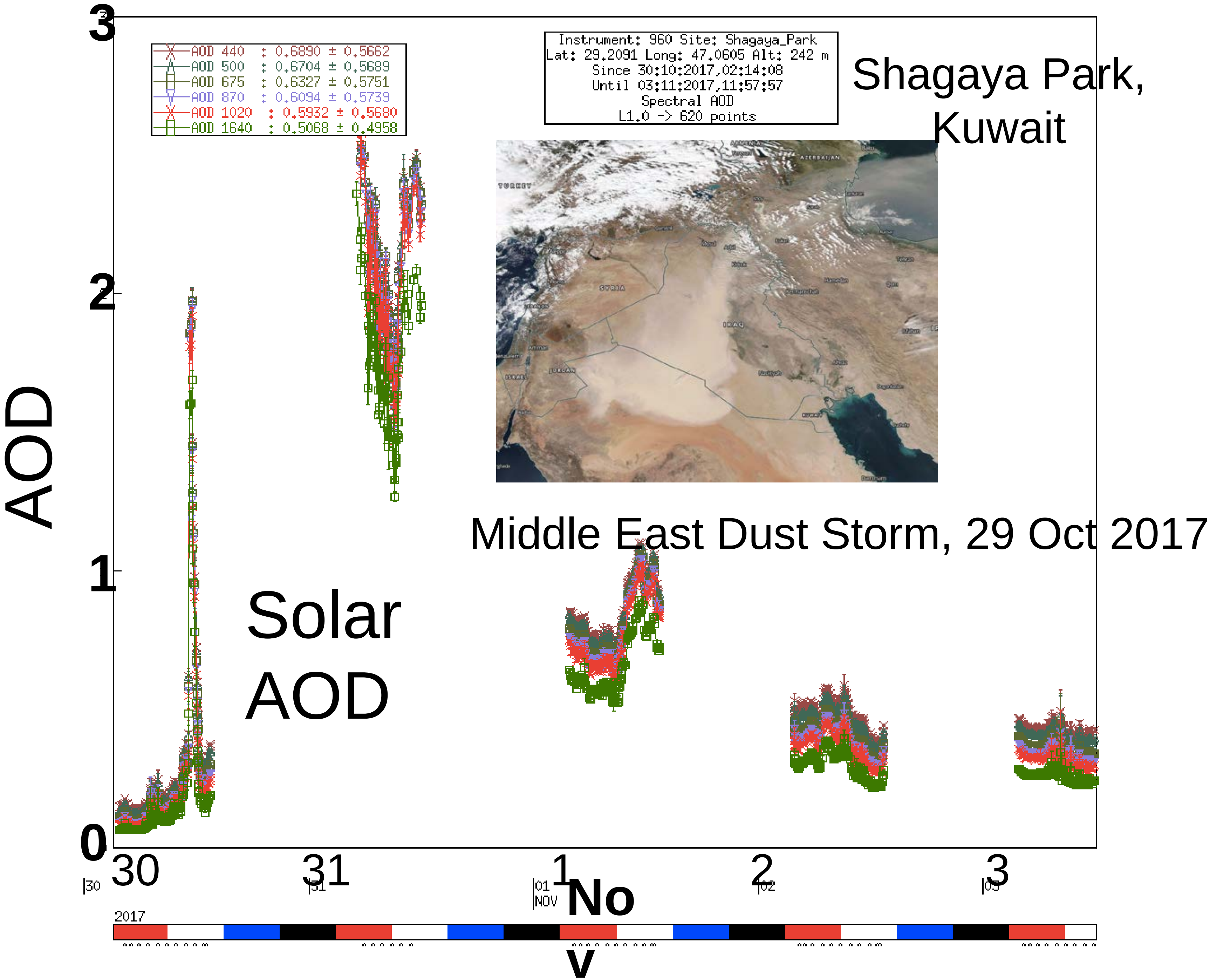
- Stdv: SSA_{440nm} SSA_{1020nm}

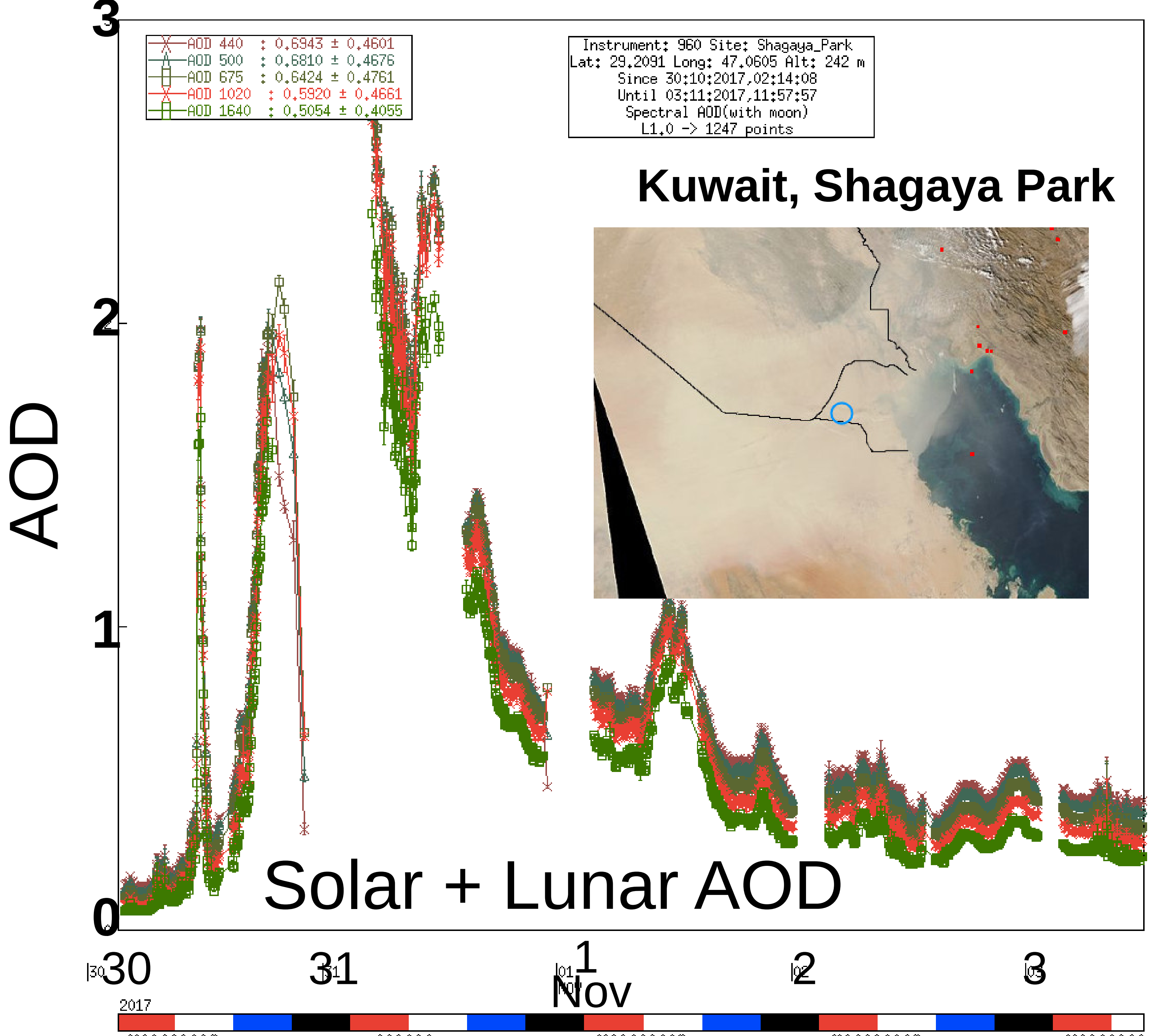






Ny Alesund, 79° N
Polar Night
Lunar AOD
Instrument: 904 Site: Ny_Alesund_AWI
Lat: 78.9232 Long: 11.9230 Alt: 7 m
Since 06:11:2017,14:22:04
Until 08:11:2017,12:21:16
Spectral AOD(with moon)
L1.5 -> 355 points
AOD 440 : 0.0577 ± 0.0080
AOD 500 : 0.0494 ± 0.0067
AOD 675 : 0.0320 ± 0.0047
AOD 870 : 0.0244 ± 0.0036
AOD 1020 : 0.0224 ± 0.0039
AOD 1640 : -0.0043 ± 0.0044
0.08
0.04
0.00
7
8
Nov.


AOD 440 : 0.6890 ± 0.5662
AOD 500 : 0.6704 ± 0.5689
AOD 675 : 0.6327 ± 0.5751
AOD 870 : 0.6094 ± 0.5739
AOD 1020 : 0.5932 ± 0.5680
AOD 1640 : 0.5068 ± 0.4958
Instrument: 960 Site: Shagaya_Park
Lat: 29.2091 Long: 47.0605 Alt: 242 m
Since 30:10:2017,02:14:08
Until 03:11:2017,11:57:57
Spectral AOD
L1.0 -> 620 points
Shagaya Park, Kuwait
Middle East Dust Storm, 29 Oct 2017
Solar AOD
AOD
3
2
1
0
30
31
1
2
3
01 NOV
Nov
2017


AOD 440 : 0.6943 ± 0.4601
AOD 500 : 0.6810 ± 0.4676
AOD 675 : 0.6424 ± 0.4761
AOD 1020 : 0.5920 ± 0.4661
AOD 1640 : 0.5054 ± 0.4055
Instrument: 960 Site: Shagaya_Park
Lat: 29.2091 Long: 47.0605 Alt: 242 m
Since 30:10:2017,02:14:08
Until 03:11:2017,11:57:57
Spectral AOD(with moon)
L1.0 -> 1247 points
Kuwait, Shagaya Park
Solar + Lunar AOD
AOD
3
2
1
0
30
31
1
Nov
2
3
2017

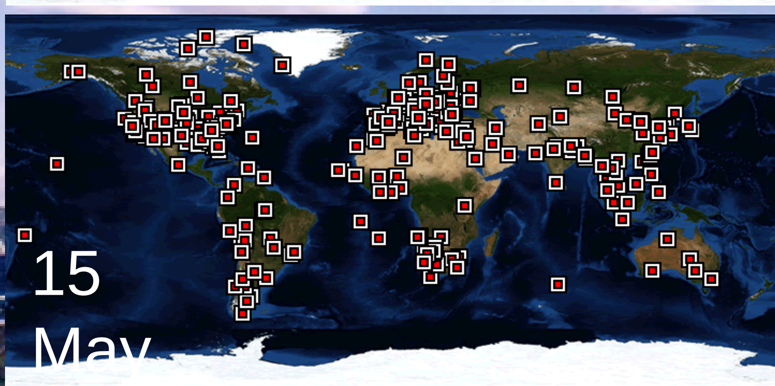
Summary and Outlook

- V3 full release: 5 Jan. 2018
- Significant improvements in AOD and Inversion products
- NRT QA data facilitates new satellite retrieval validations and aerosol assimilation model forecasts
- Hybrid retrievals, uncertainty and Lunar AOD
- Diversified collaboration with modeling, Satellite and RS research community
- Significant collaboration with MPLNET, PANDORA, modelers

Songchon Elementary School site managers

AERONET-PHOTONS

AERONET Aerosol Robotic Network- Over Twenty-Four Years of Observations and Research



The AERONET program is a federation of ground-based remote sensing aerosol networks established by NASA and LOA-PHOTONS (CNRS) and has been expanded by collaborators from international agencies, institutes, universities, individual scientists and partners.

AERONET provides a long-term, continuous public database of aerosol optical, microphysical, and radiative properties for aerosol research and characterization, validation of satellite measurements, and synergism with other databases.

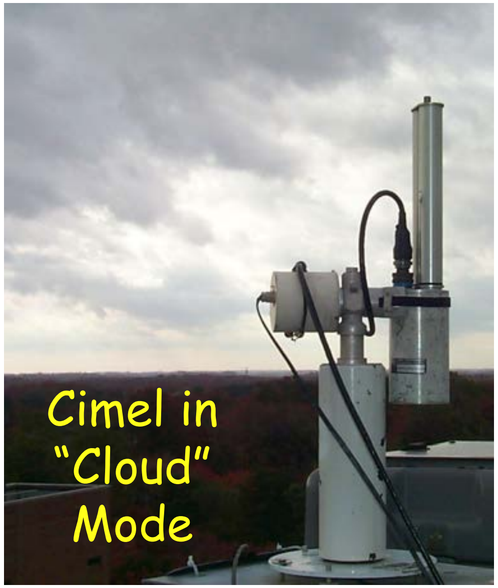
- >7000 citations
- ~500 sites
- Over 90 countries and territories
- http://aeronet.gsfc.gov

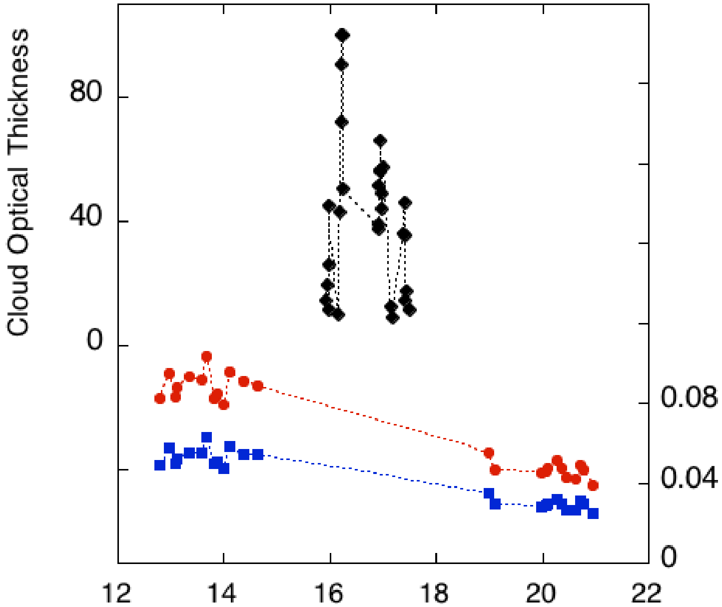
OCO (GOSAT)-NET

Mikhail Sorokin

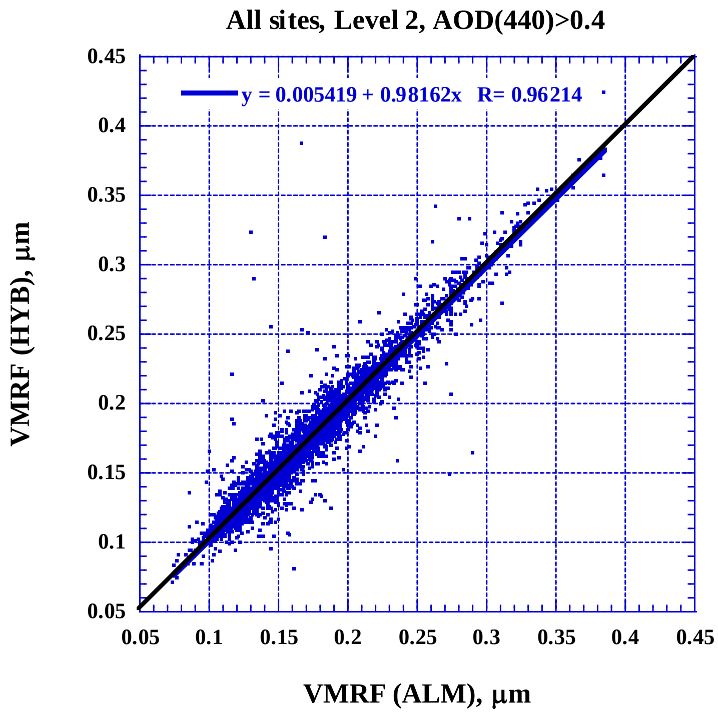
- Engineer
- CO_2
- Polar Research
- Grand Tea Master

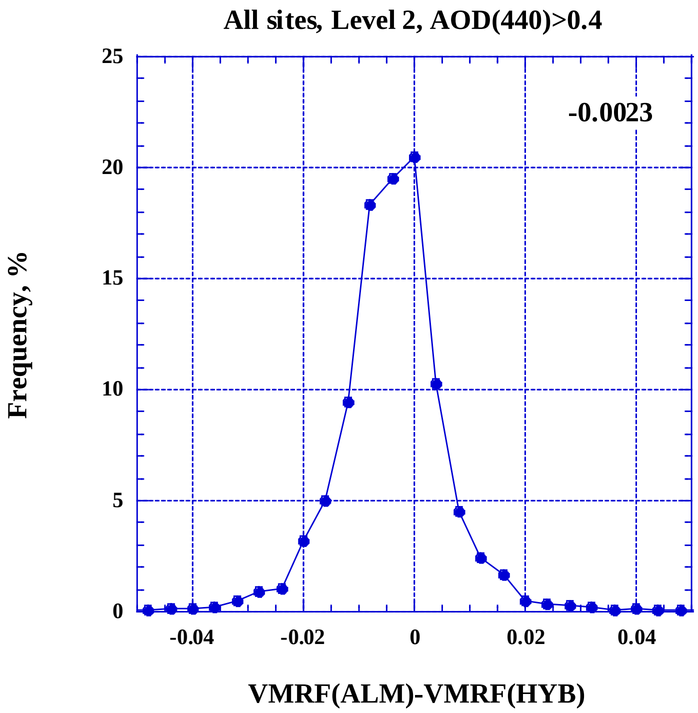
Alexander, Christine, Stefani

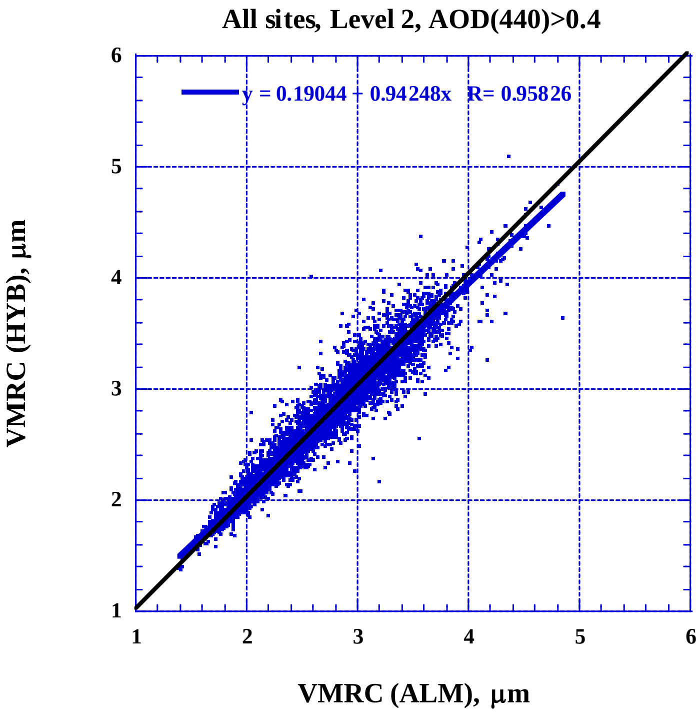


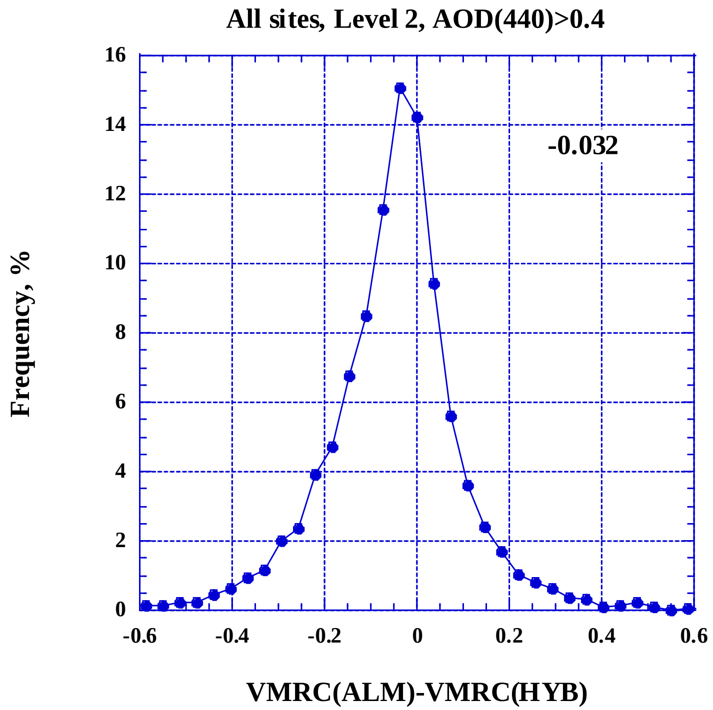


The cloud mode uses AERONET "idle time" inappropriate for aerosol study to monitor cloud optical properties by taking measurements of zenith radiance


All sites, Level 2, AOD(440)>0.4
y = 0.005419 + 0.98162x R= 0.96214
VMRF (HYB), µm
VMRF (ALM), µm
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45


All sites, Level 2, AOD(440)>0.4
-0.0023
Frequency, %
VMRF(ALM)-VMRF(HYB)
0
5
10
15
20
25
-0.04
-0.02
0
0.02
0.04

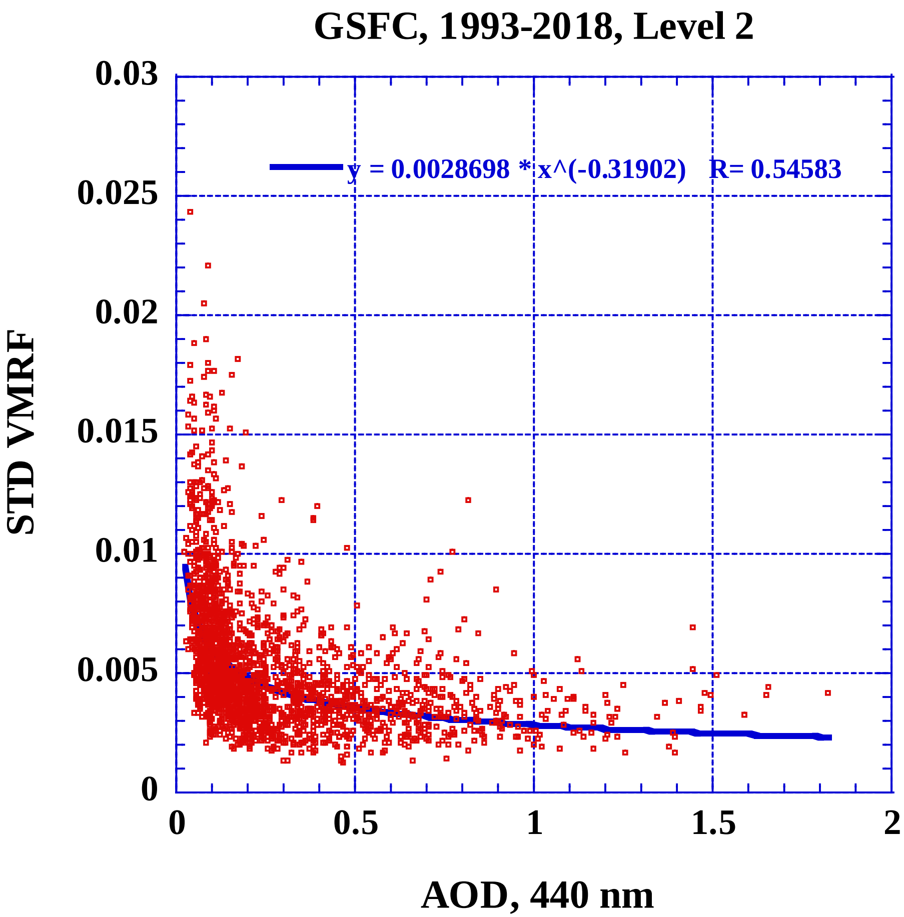

All sites, Level 2, AOD(440)>0.4
y = 0.19044 + 0.94248x R= 0.95826
VMRC (HYB), μm
VMRC (ALM), μm
1
2
3
4
5
6


All sites, Level 2, AOD(440)>0.4
-0.032
Frequency, %
VMRC(ALM)-VMRC(HYB)
0
2
4
6
8
10
12
14
16
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

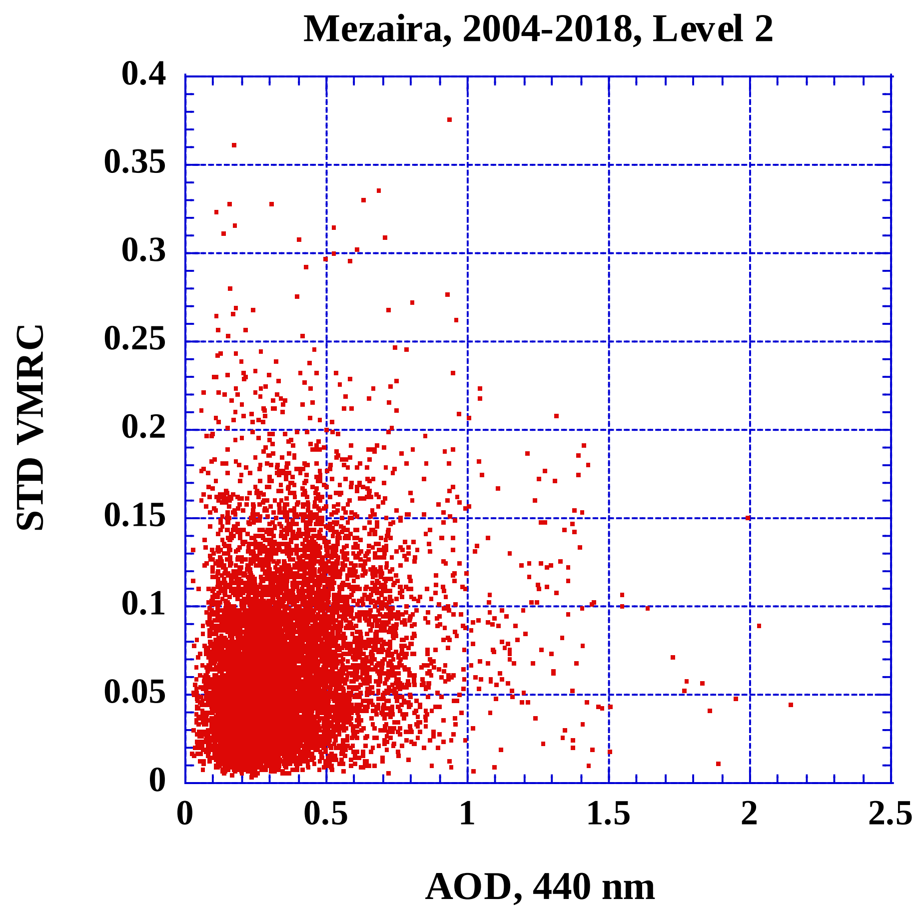
Uncertainty Proxy

Sensitivity to 1 sigma Input Uncertainty

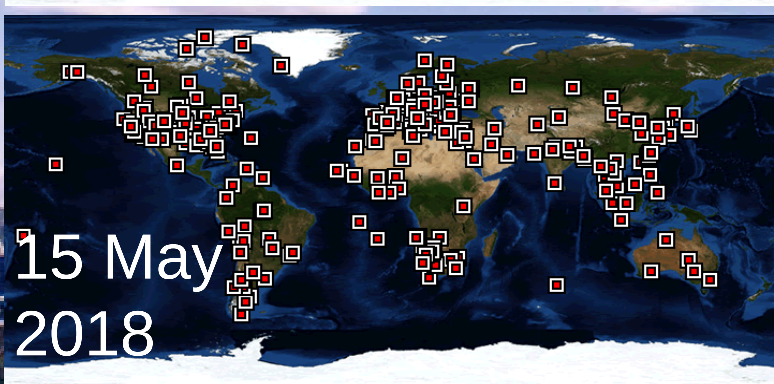
- GSFC VMR_{fine}



- Mezaira VMR_{coarse}



AERONET Aerosol Robotic Network- Over Twenty-five Years of Observations and Research



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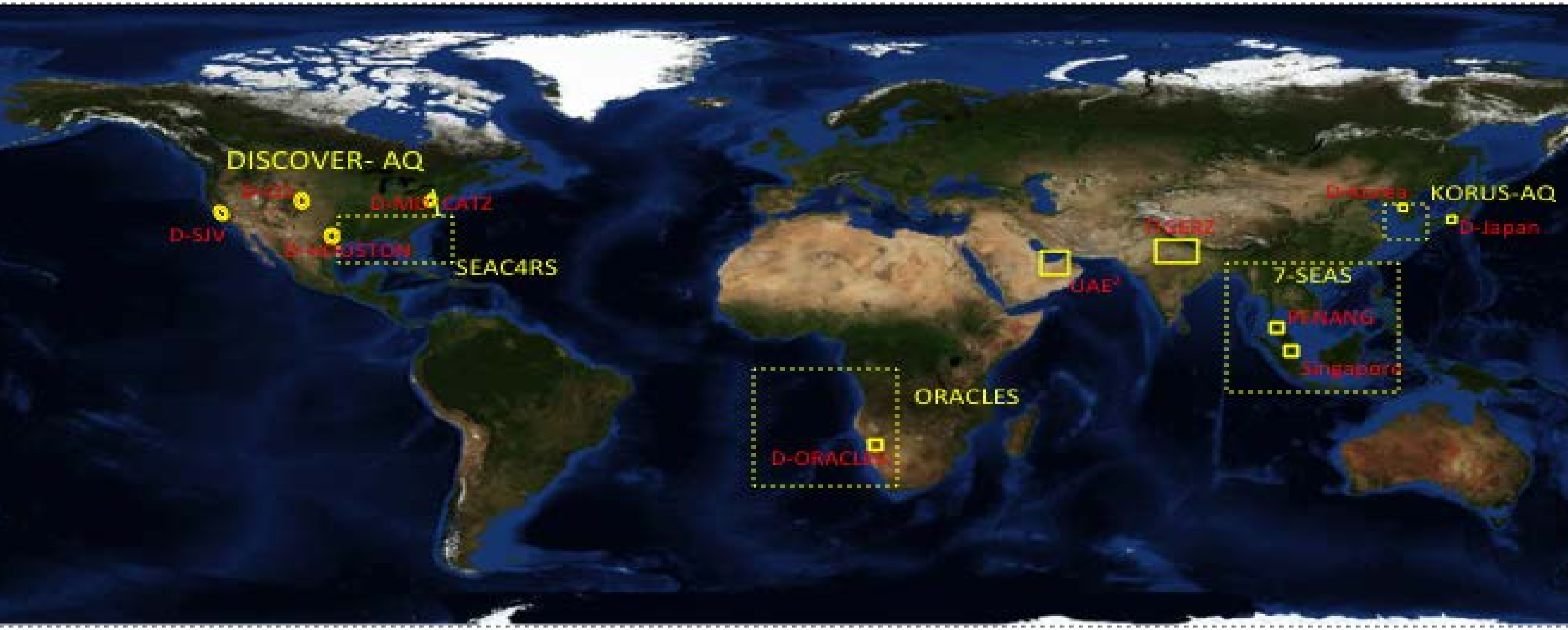
The DRAGON Campaigns

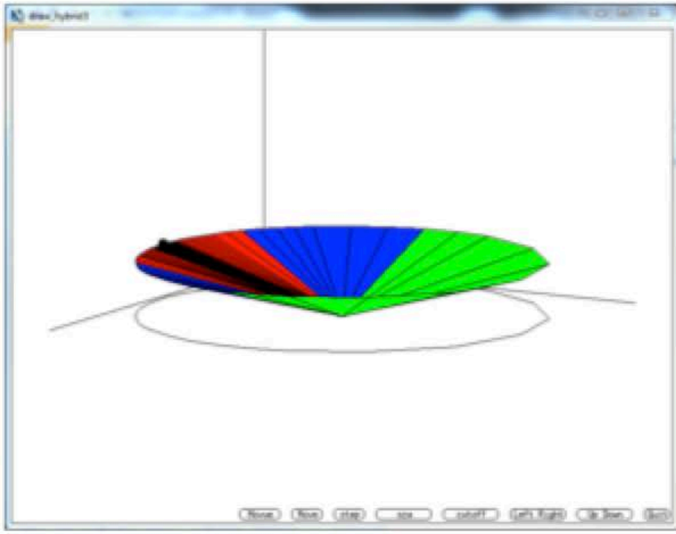


ACP/AMT Special Issue: Meso-scale aerosol processes, comparison and validation studies from DRAGON networks

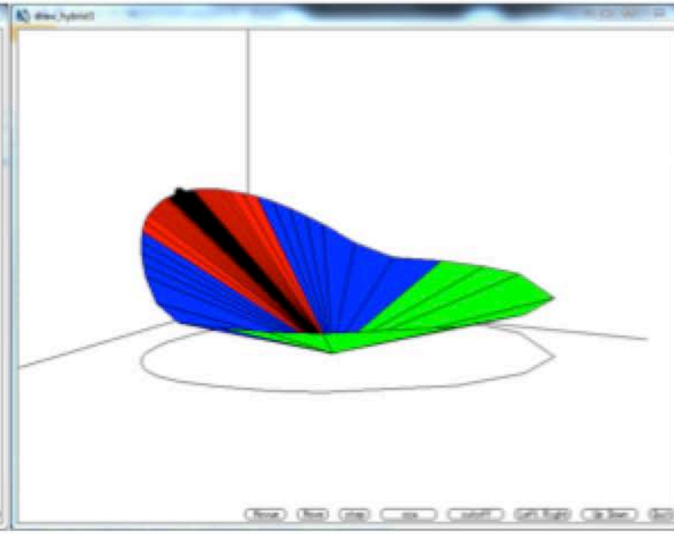
New Hybrid Sky Radiance Scans – Only possible with the new Model-T Cimel Instrument

This allows for significantly larger scattering angle measurements at smaller SZA

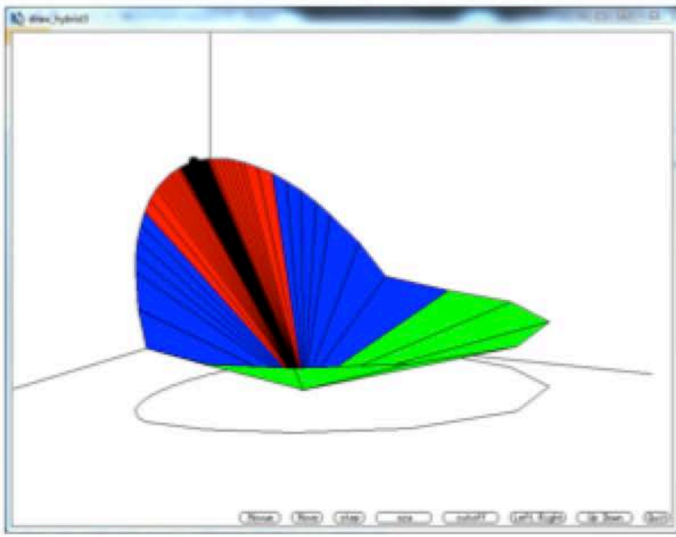
SZA = 75°



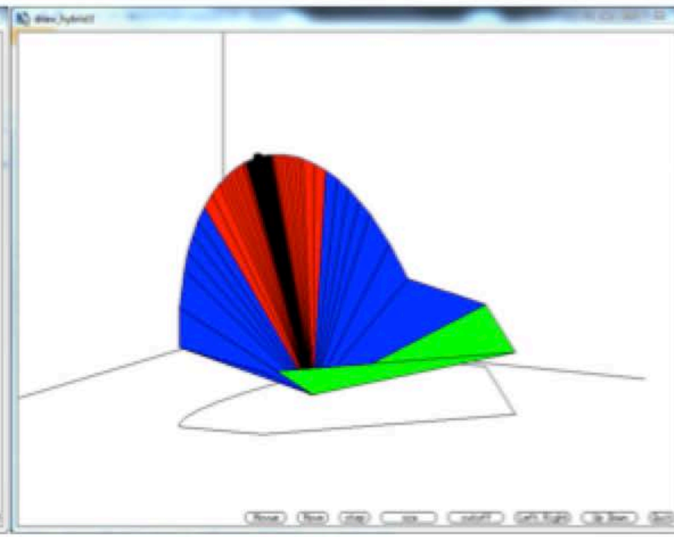
SZA = 50°



SZA = 30°



SZA = 15°

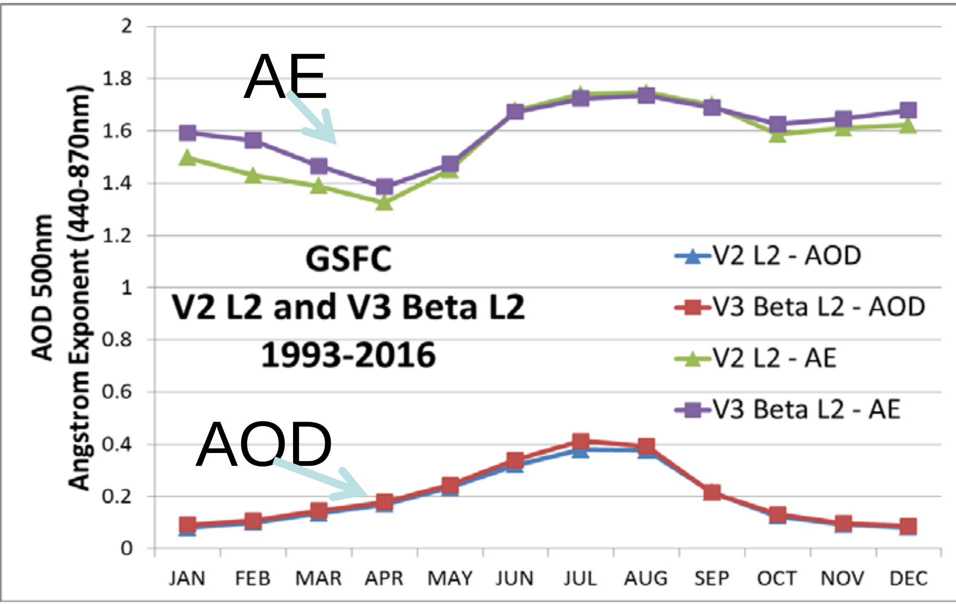


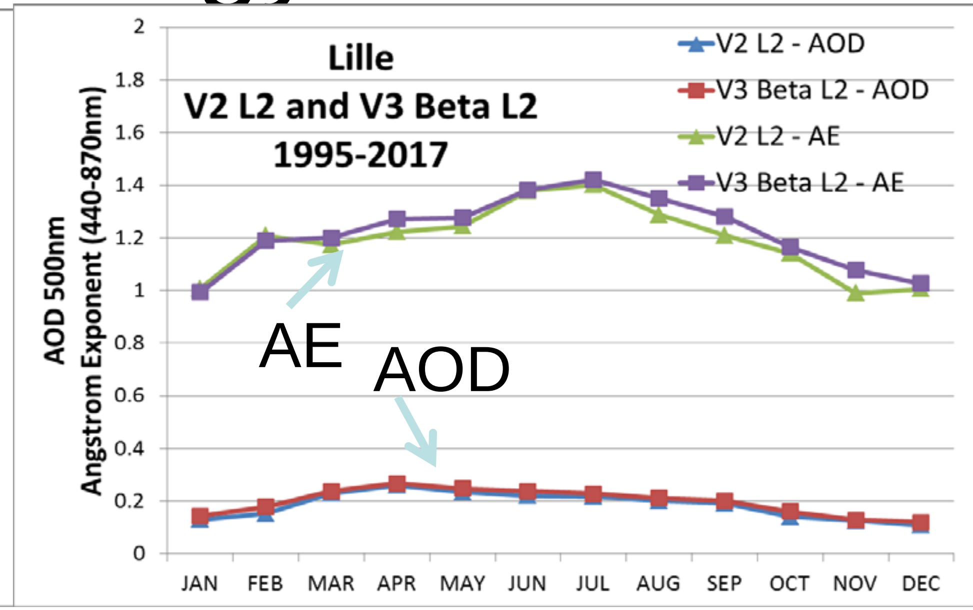
Black: 0<= angle <6.5
Red: 6.5 <= angle <31
Blue: 31 <= angle <81
Green: angle >= 81

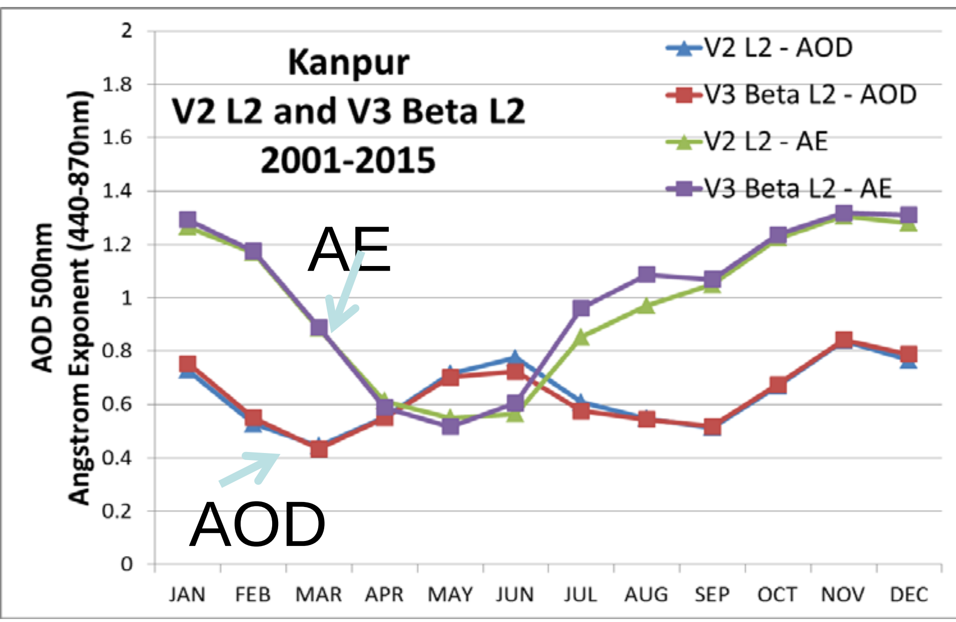
These ranges are similar to the scattering angle bin ranges used for V2 Level 2.0 inversion criteria:

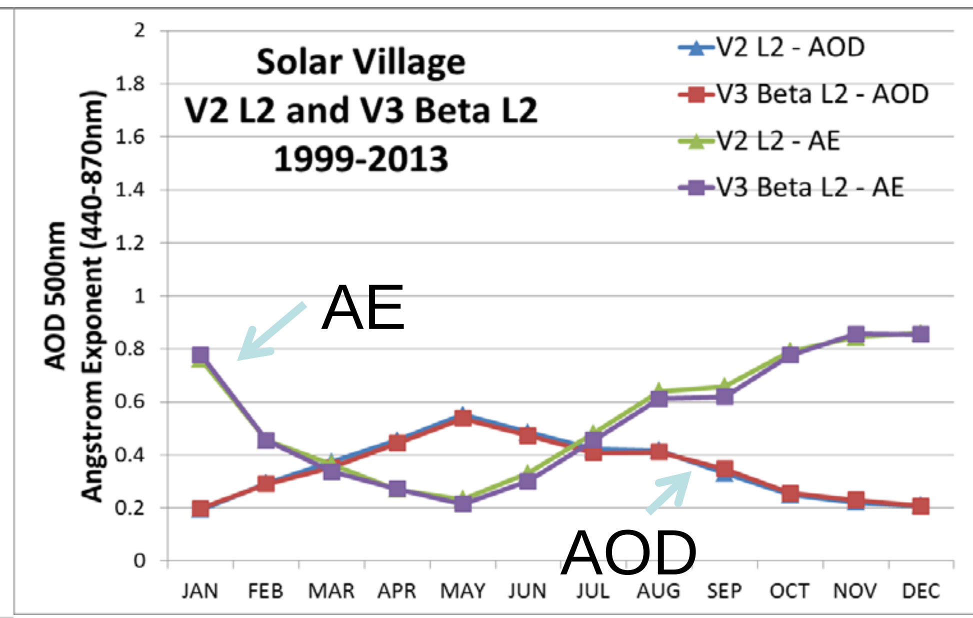
Minimum binned scattering angle requirements for each λ:
≥3.2 to 6.0: at least 2 in range
≥6.0 to 30.0: at least 5 in range
≥30.0 to 80: at least 4 in range
≥80.0: at least 3 in range

Climatology

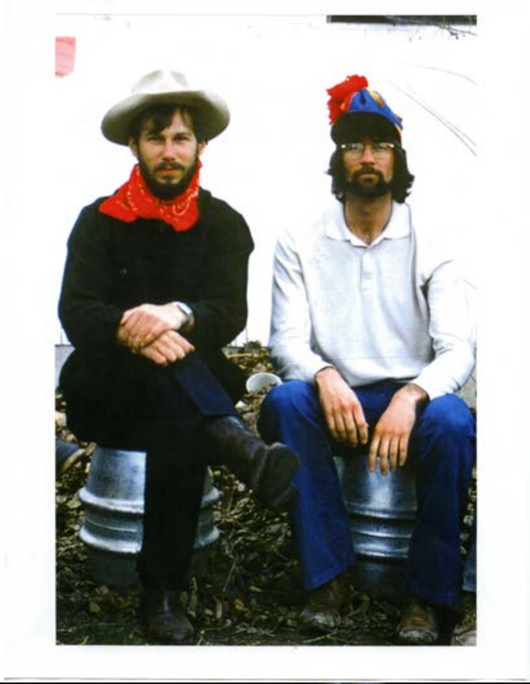








The Beginning-GIMMS Tucker/Justice/Holben (1980)



Early days of sun photometry at GSFC (83-86)