



# Evaluation of AERONET AOD Measurements in the Version 3 Database

*AERONET is funded by the NASA Earth Observing System project office and the Radiation Sciences Program (NASA HQ), Joint Polar Satellite System (NOAA), and large field campaigns.*

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ICAP 8<sup>th</sup> Working Group Meeting  
July 14, 2016

# Outline

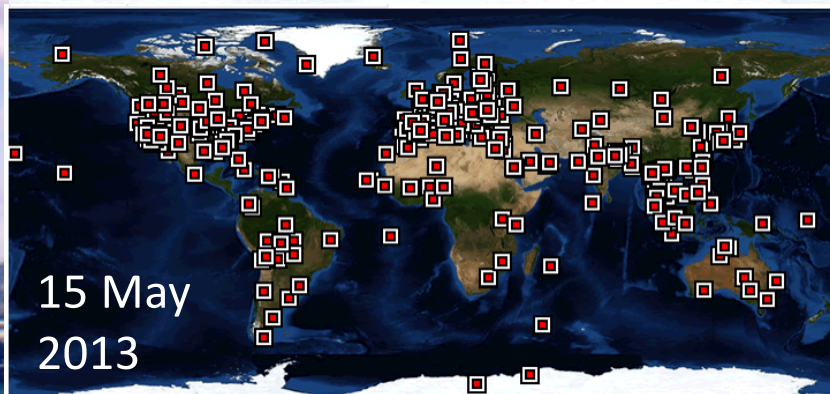
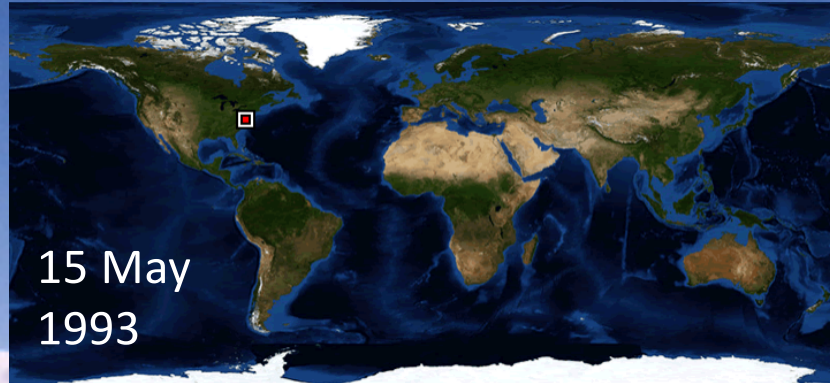
- Need for Higher Quality NRT AOD
- Cloud Screening
- Quality Controls
- NRT AOD Results
- Outlook and Summary



<http://aeronet.gsfc.nasa.gov>



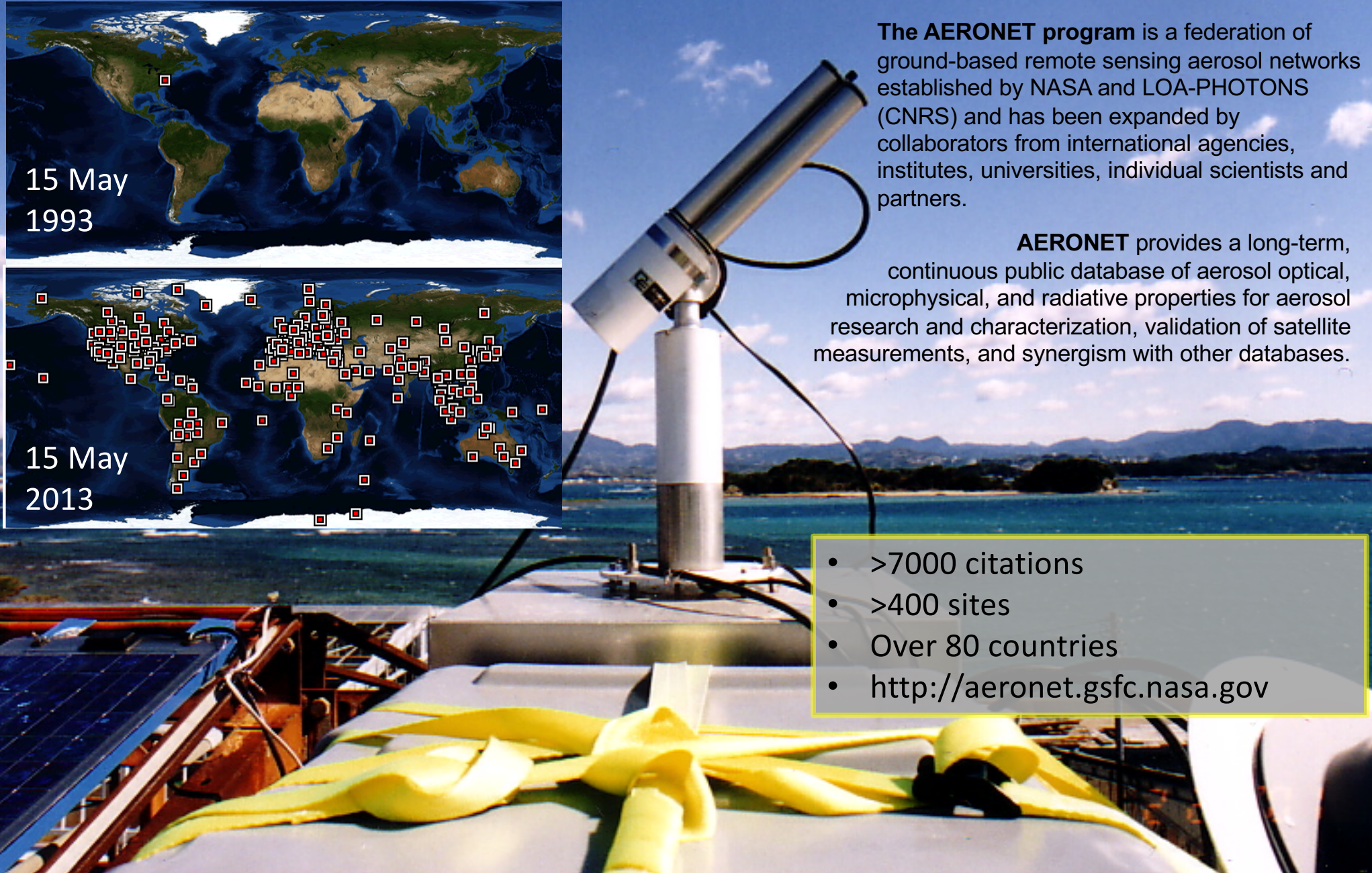
# AERONET Aerosol Robotic Network-Twenty Years of Observations and Research



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
- >400 sites
- Over 80 countries
- <http://aeronet.gsfc.nasa.gov>

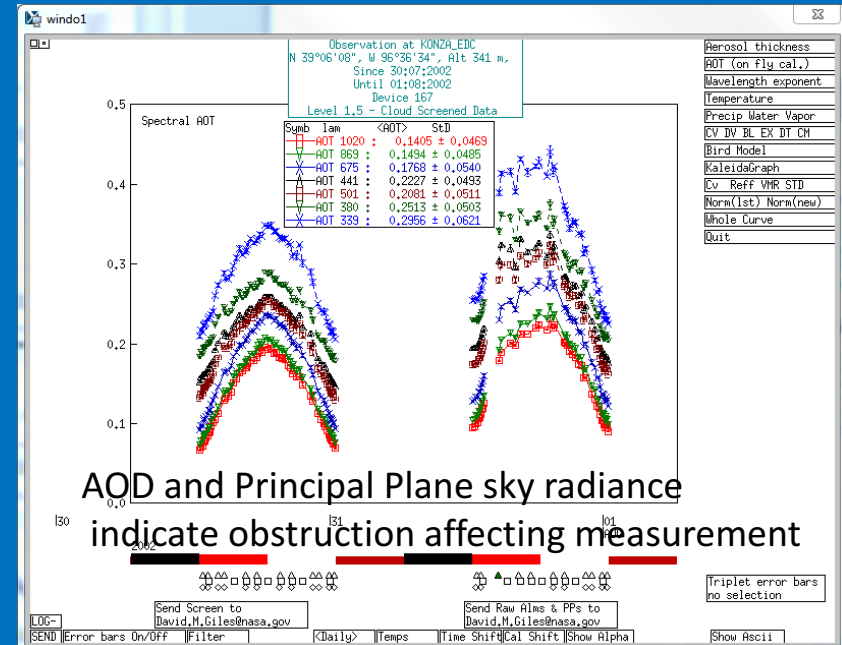
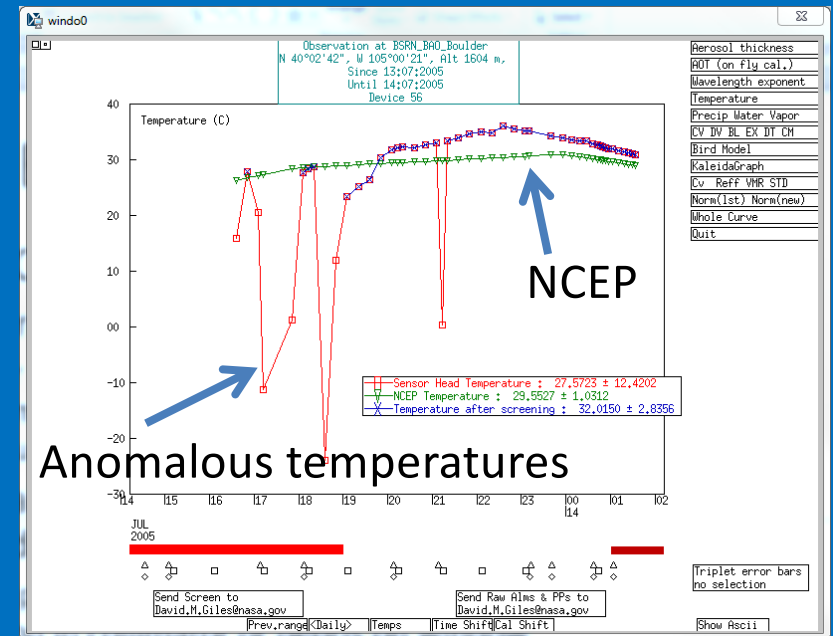


# Growing Need for Higher Quality NRT AERONET Data

- Satellite evaluation
  - VIIRS, MODIS, MISR, OMI, GOES, Himawari-8, Sentinel 3, GOCI
- Data synergism
  - MPLNET, SPARTANS, GreenNet
- Aerosol forecast models and reanalysis
  - GOCART, ICAP, NAAPS, MERRA-2
- Meteorological models
  - NCEP, ECMWF, GEOS-5
- Field Campaign Support
  - KORUS-AQ, ORACLES, FIREX, CAMPex

# AERONET Version 3: AOD

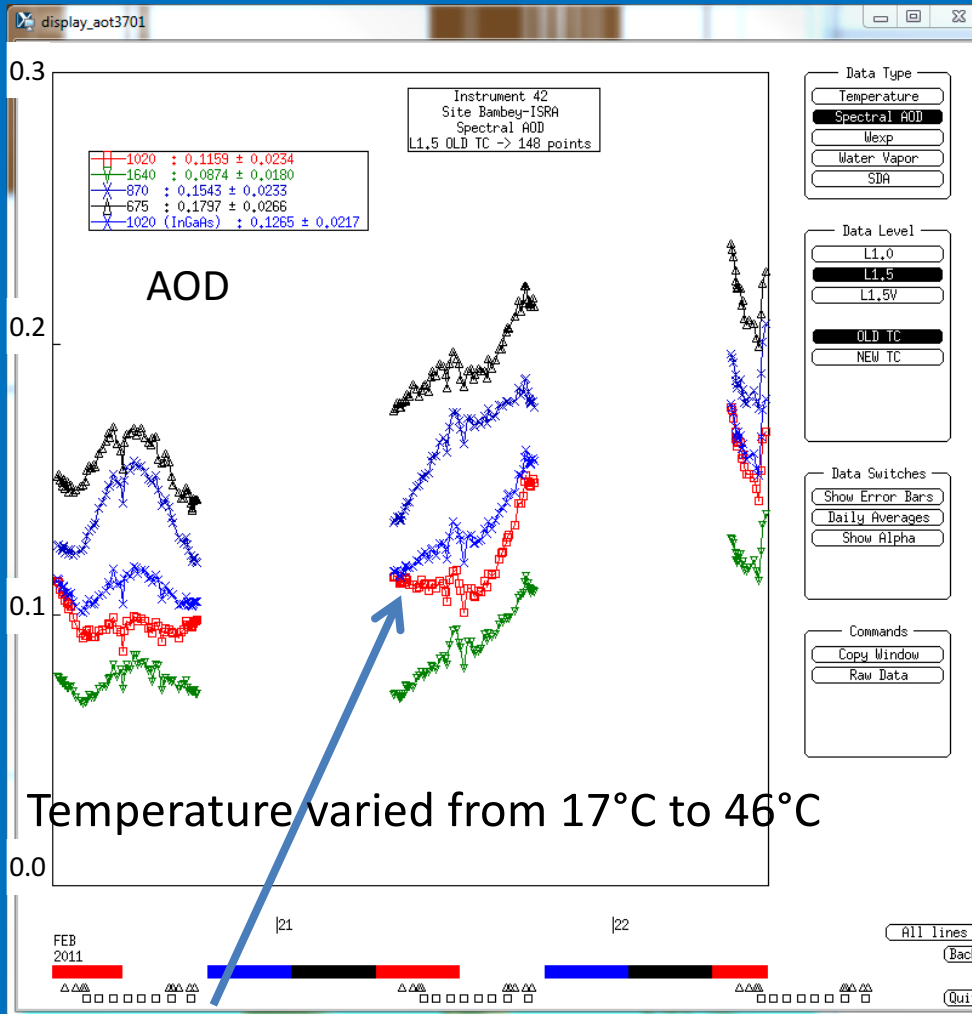
- V3 Level 1.0: Unscreened data (NRT)
  - Applies new temperature characterizations
  - Applies NO2 OMI L3 climatology (2004-2013)
- V3 Level 1.5: Based on Level 1.0 and uses new automatic quality controls (NRT)
  - Cloud Screening
    - Improves removal of optically thin cirrus contamination
    - Preserves more highly variable smoke
    - Compares well to Version 2 Level 2
  - Quality Controls
    - Removes sensor temperature artifacts
    - Removes AOD affected by solar eclipses
    - Removes AOD impacted by window obstructions
    - Removes AOD with poor spectral dependence
- V3 Level 2.0: Based on Level 1.5 with pre- and post-calibration applied and minimal manual intervention
  - Significantly improves timeliness of Level 2.0 data availability
  - Applies more objective removal scheme
  - Requires minimal manual analysis to remove uncommon data anomalies



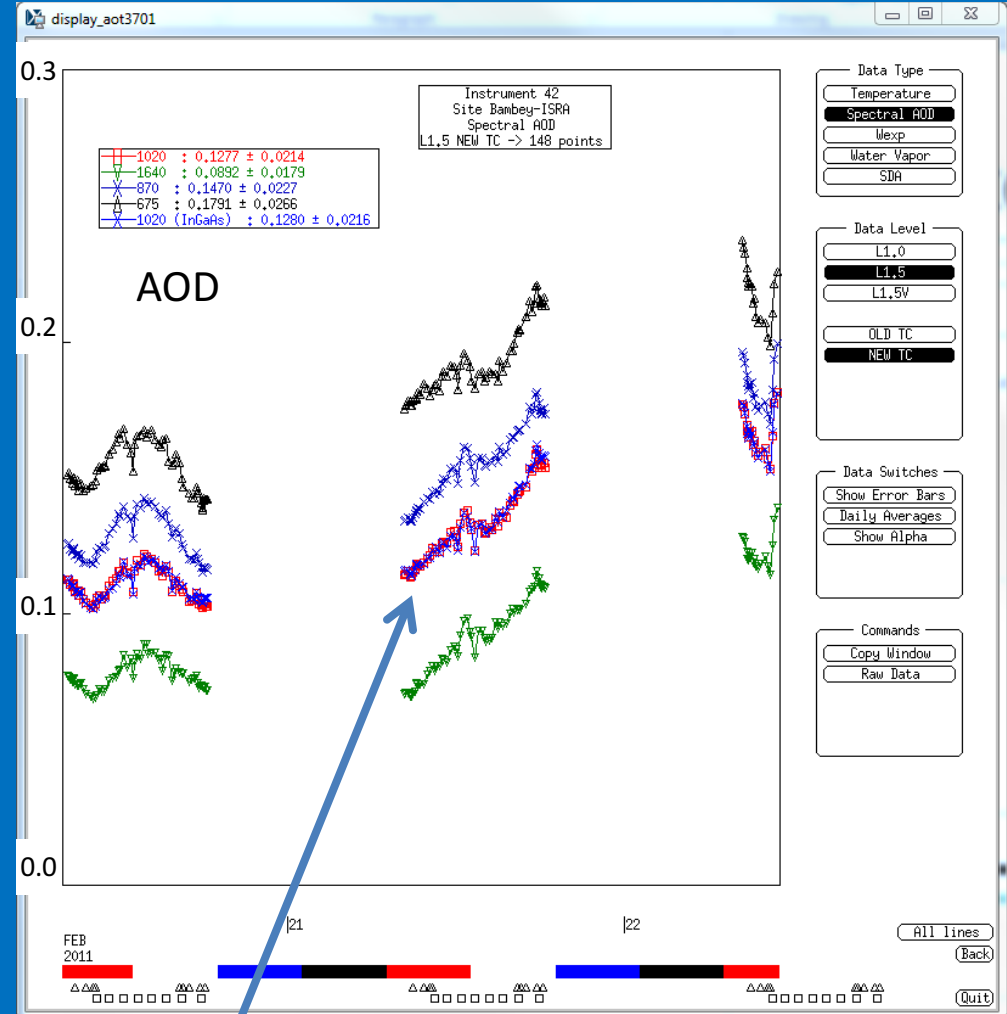


# AERONET V3: Spectral Temperature Characterization

## V2 Temperature Correction



## V3 Temperature Correction



AOD 1020nm for Silicon and InGaAs detectors do not match

AOD 1020nm Silicon matches 1020nm InGaAs after V3 temperature correction

# V2 vs. V3 Cloud Screening

Algorithm/Parameter	Version 2	Version 3
<b>Air Mass Range</b>	5 to 5	7 to 7
<b>Remaining Measurements</b>	$N < 3$ , reject day	After all checks applied, reject day if $N_{\text{remain}} < \text{MAX} \{3 \text{ or } <10\% \text{ of } N\}$
<b>Low Count Restoration</b>	N/A	If Digital Count $< 5$ , $\tau_{870\text{nm}} > 0.5$ , $\alpha_{675-1020\text{nm}} > 1.2$ or $\alpha_{870-1020\text{nm}} > 1.3$ , then restore measurement for evaluation
<b>Triplet Criterion</b>	All $\lambda$ s; AOD range $> \text{MAX}$ {0.02 or $0.03 * \tau_a$ }	$\lambda = 675, 870, 1020\text{nm}$ AOD range $> \text{MAX}\{0.01 \text{ or } 0.015 * \tau_a\}$
<b>AOD Stability Check</b>	Same as V3	Daily Averaged AOD 500nm (or 440nm) has $\sigma$ less than 0.015, then do not perform <b>3-Sigma Check</b>
<b>3-Sigma Check</b>	Same as V3	AOD 500nm and $\alpha_{440-870\text{nm}}$ should be within $\text{MEAN} \pm 3\sigma$ ; otherwise reject point(s)

# V2 vs. V3 Cloud Screening

Algorithm/Parameter	Version 2	Version 3
<b>Smoothness Check</b>	D<16	For AOD 500nm (or 440nm) $\Delta\tau_a > 0.01$ per minute, remove larger $\tau_a$ in pair
<b>Standalone Points</b>	N/A	No data $\pm 1$ hour of point, then reject it unless $\alpha_{440-870nm} > 1.0$ , then keep point
<b>Solar Aureole Radiance Curvature Check</b>	N/A	Compute curvature ( $k$ ) for 1020nm aureole radiances from $3.2^\circ$ - $6.0^\circ$ $\phi$ . If $k < 2.0E-5$ , compute a slope of $\ln k$ vs $\ln \phi$ . If slope is greater than 4.3 (empirically derived), then point is “cloud contaminated.” For ALM, PP, and HYB, all $\tau_a$ points will be removed in the $\pm 30$ minutes period from sky measurement.
<b>Low Count Restoration</b>	N/A	If Digital Count<5, $\tau_{870nm} > 0.5$ , $\alpha_{675-1020nm} > 1.2$ or $\alpha_{870-1020nm} > 1.3$ , then restore measurement for evaluation
<b>Very High AOD Restoration</b>	N/A	$\tau_{870} > 0.5$ ; $\alpha_{675-1020} > 1.2$ or $\alpha_{870-1020} > 1.3$ , restore if eliminated by cloud screening

Algorithm Step Change Summary: 2 same, 4 modified, and 5 new

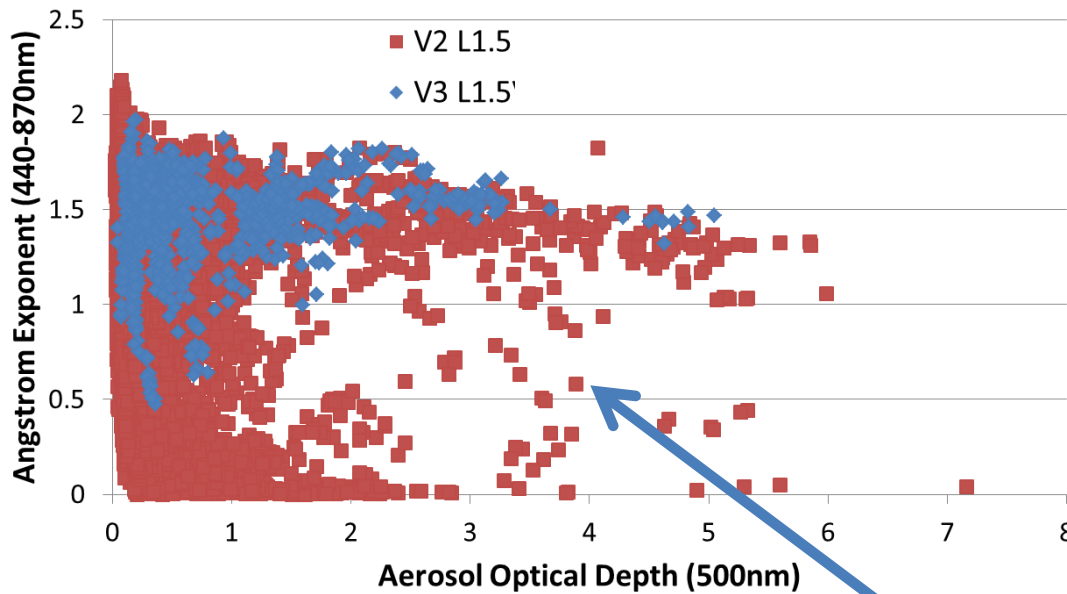


# AERONET V3 L1.5 (Cloud Screening Only)

Palangkaraya

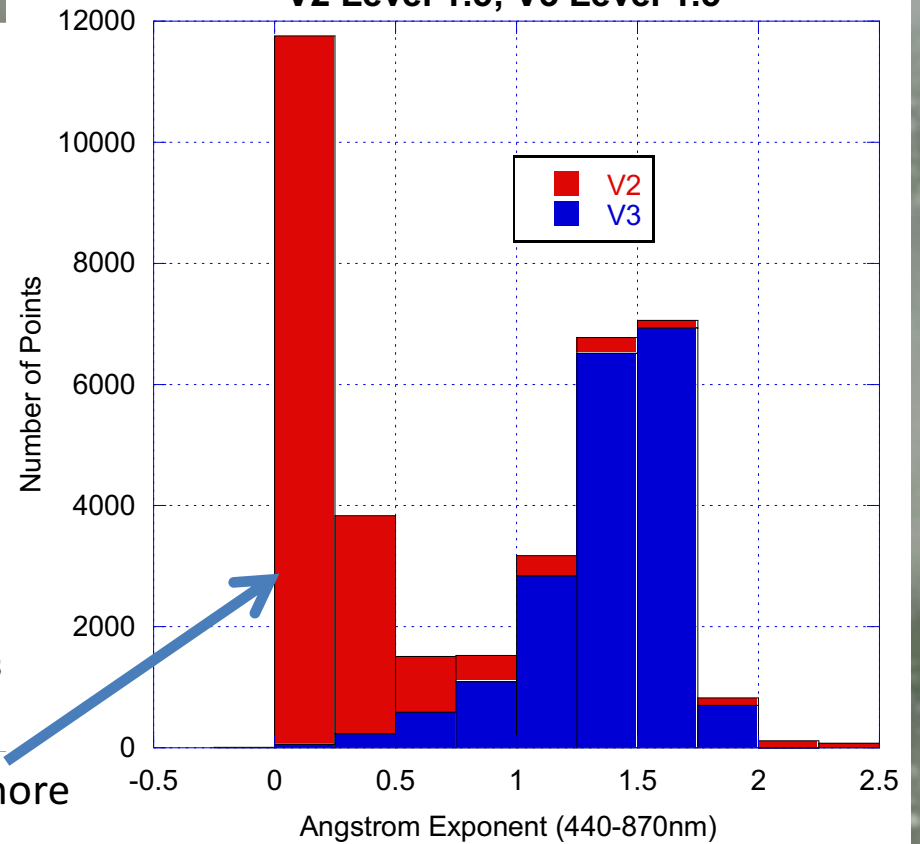


V2 vs V3: Level 1.5  
Palangkaraya, Indonesia (2012-2015)



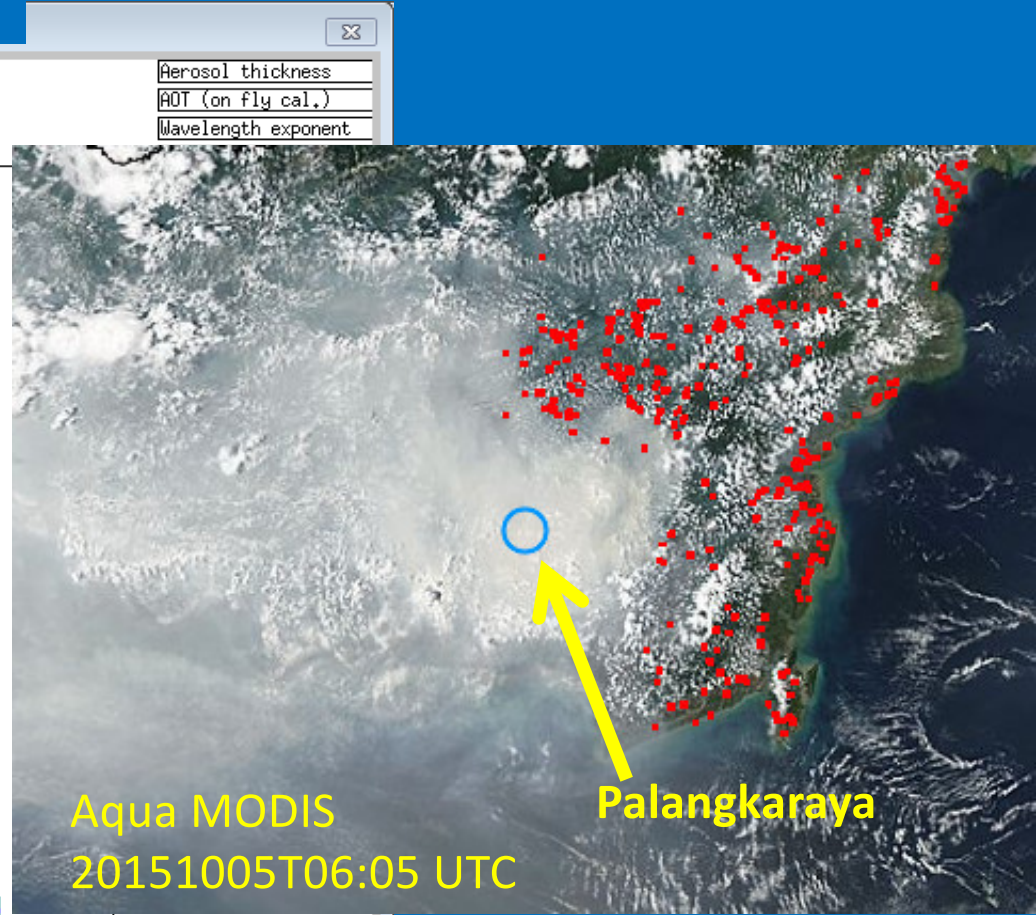
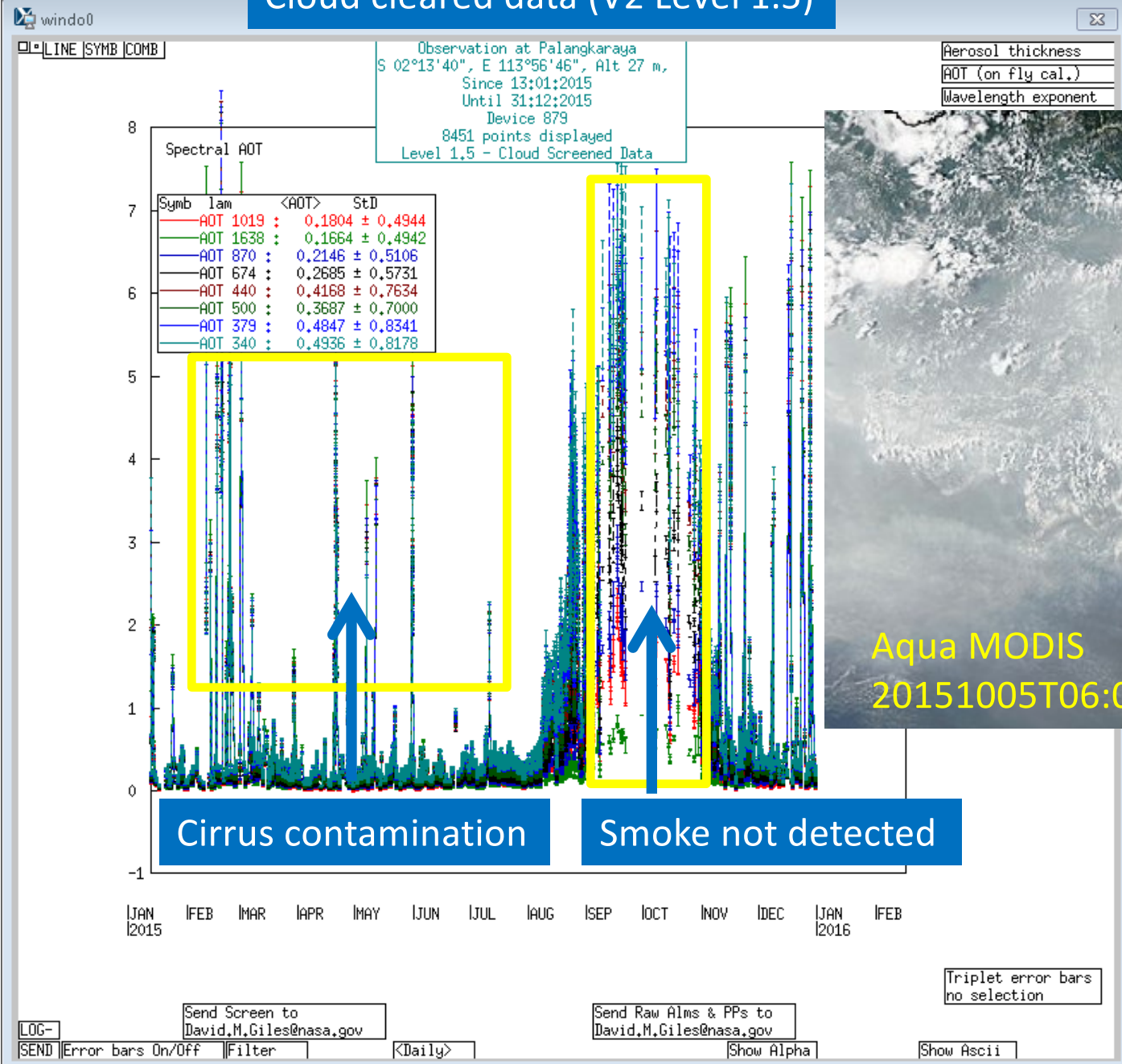
V3 removes more  
cirrus clouds

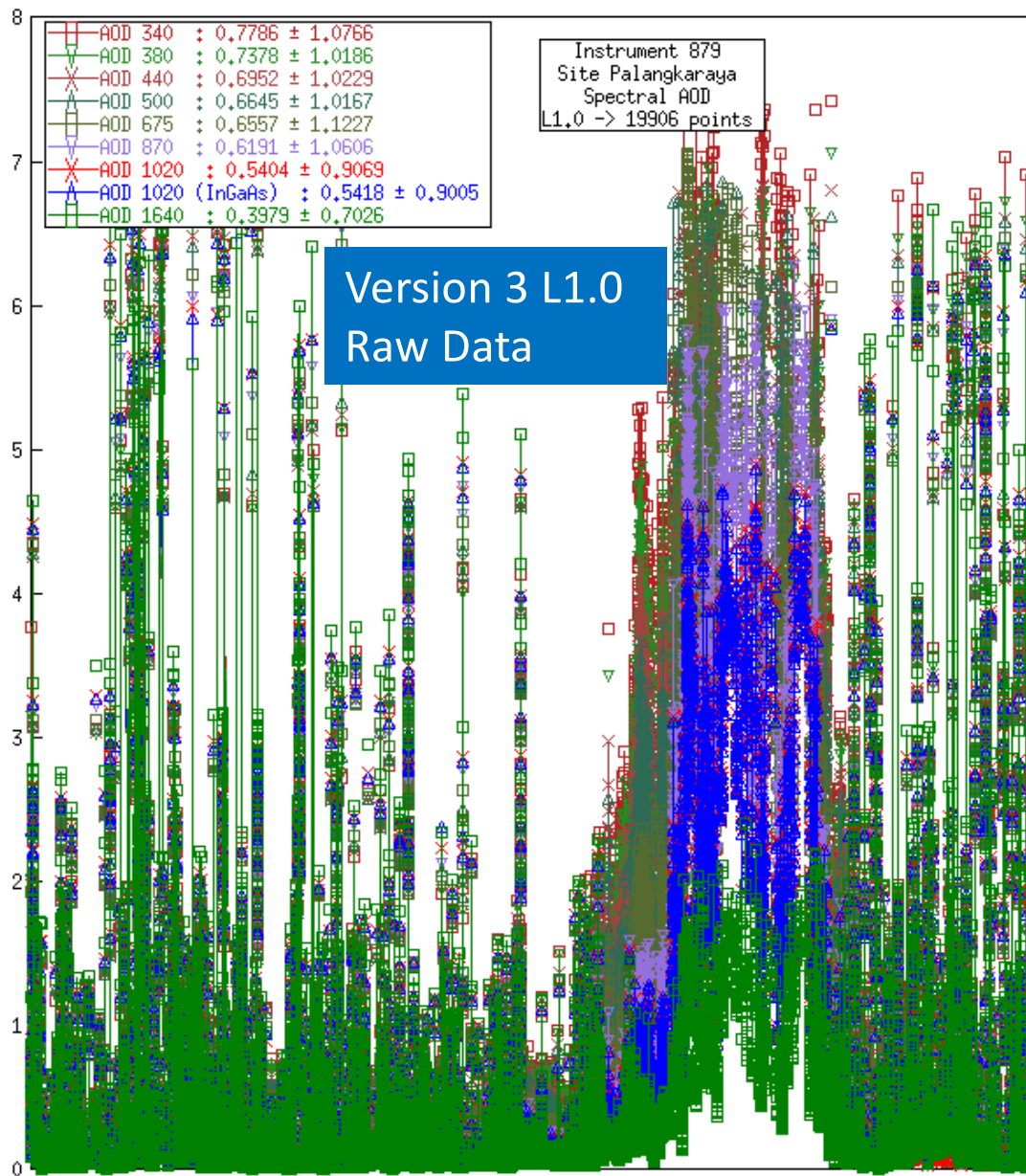
Palangkaraya, Indonesia (2012-2015)  
V2 Level 1.5; V3 Level 1.5'



# Indonesian Fires 2015 (Palangkaraya) – Current V2

Cloud cleared data (V2 Level 1.5)





Data Type

- Spectral AOD
- Wexp
- Water Vapor
- SDA

Temp    Pres

Ext V

PWR    BLK

Data Level

- L1.0
- L1.5
- L1.5V

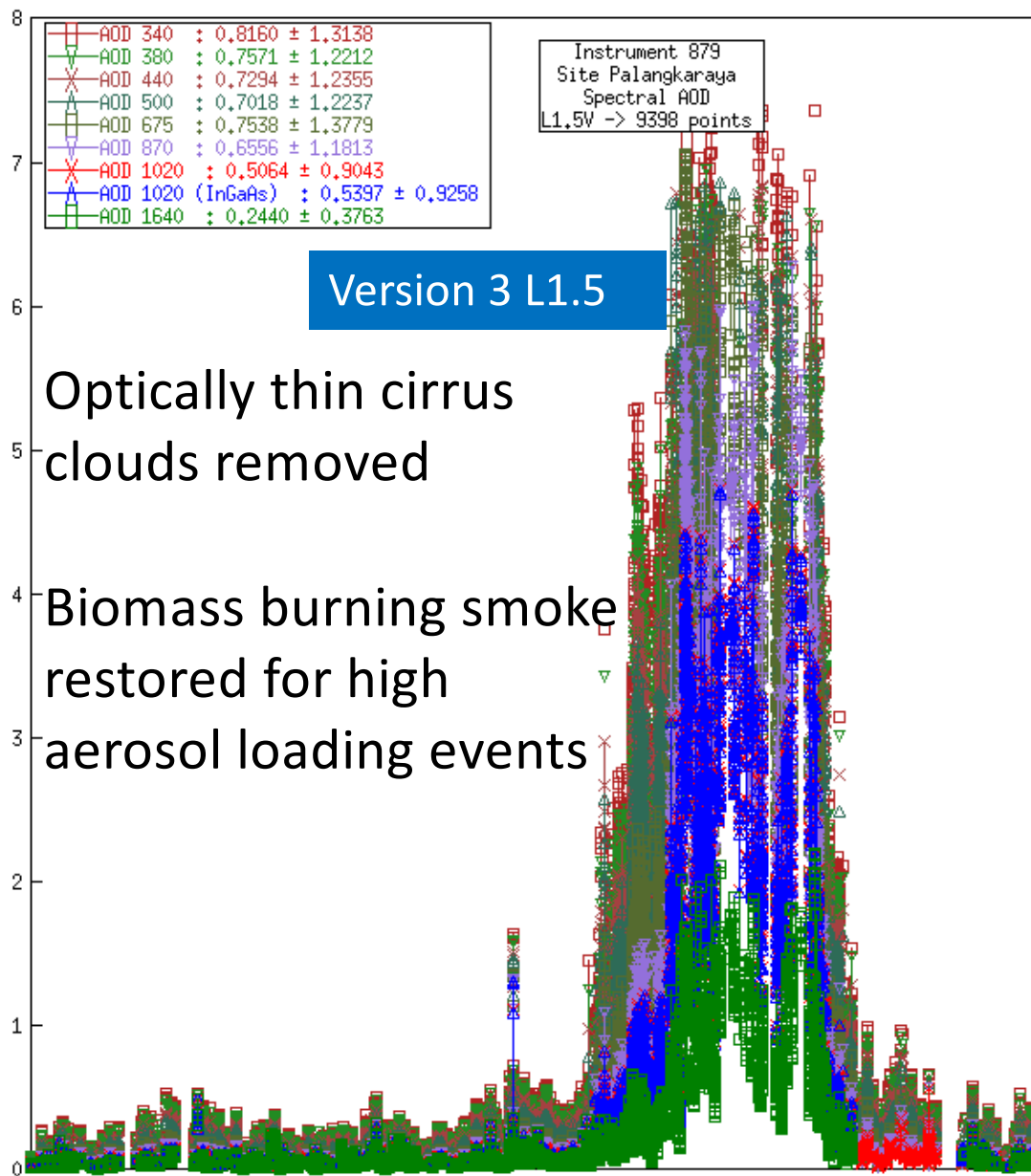
Data Switches

- Show Error Bars
- Daily Averages
- Show Alpha

Commands

- 
- 
- 

JAN 2015 | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN 2016



Version 3 L1.5

Optically thin cirrus clouds removed

Biomass burning smoke restored for high aerosol loading events

Data Type

Spectral AOD

Wexp

Water Vapor

SDA

Temp

Pres

Ext V

PWR

BLK

Data Level

L1.0

L1.5

L1.5V

Data Switches

Show Error Bars

Daily Averages

Show Alpha

Commands

JAN 2015 | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN 2016

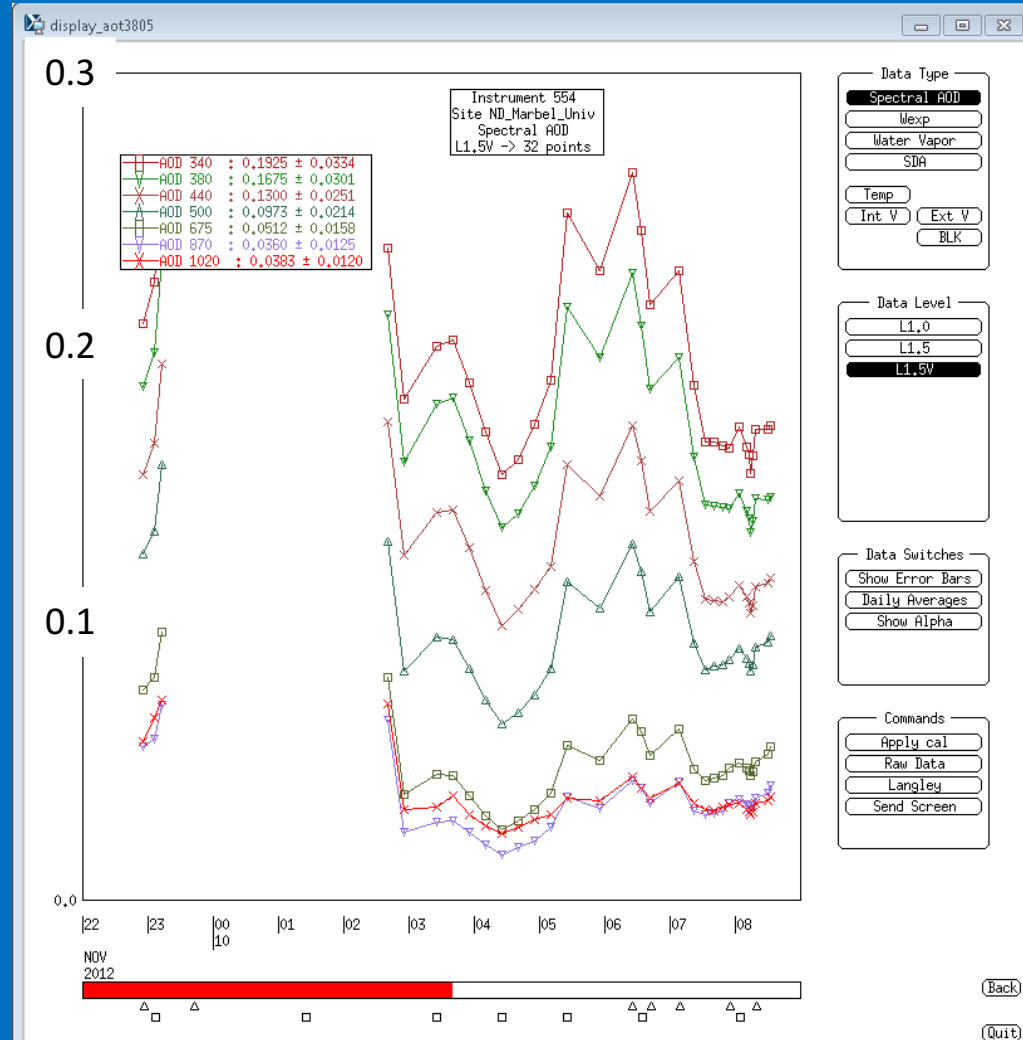
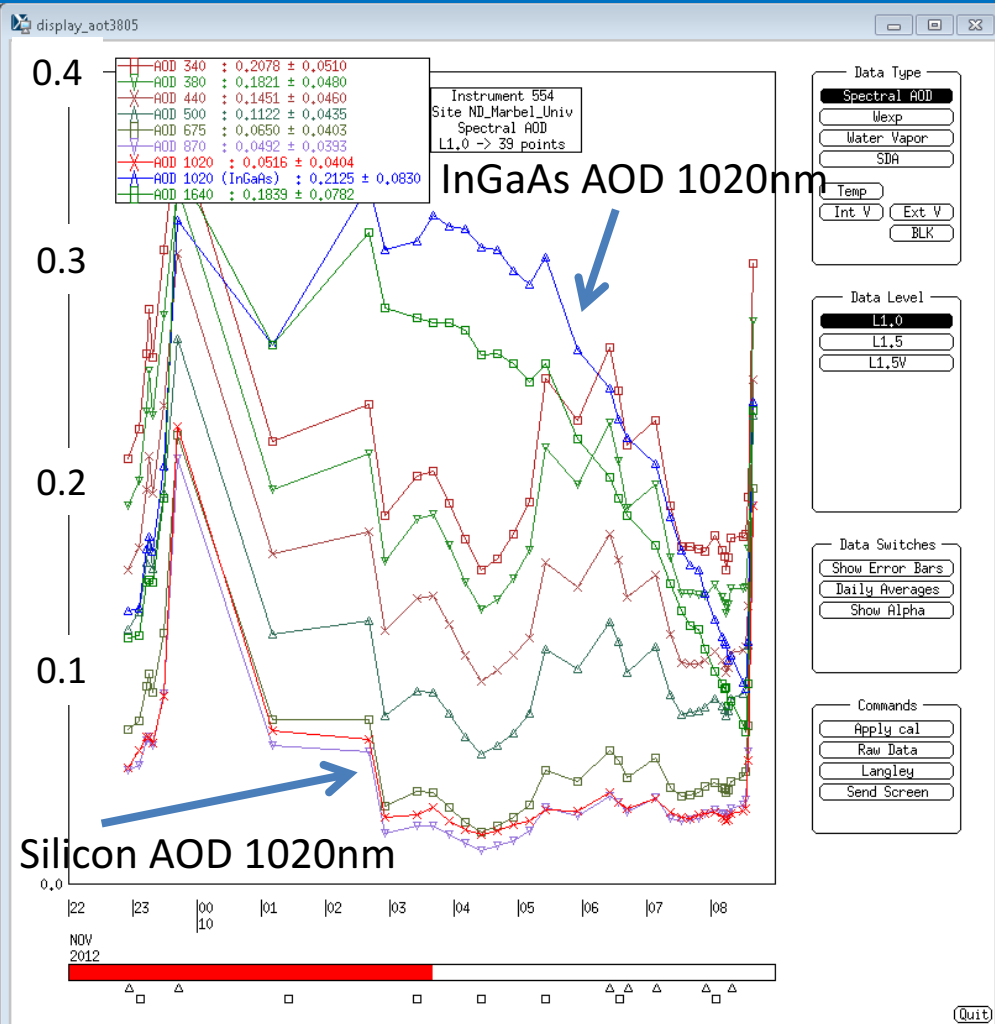


# Level 1.5 Quality Controls

- Raw Data Checks – sensor temperature, digital counts, clock shift, etc.
- Collimator consistency checks
- AOD diurnal dependence checks
- AOD spectral dependence checks
- Solar eclipse screening

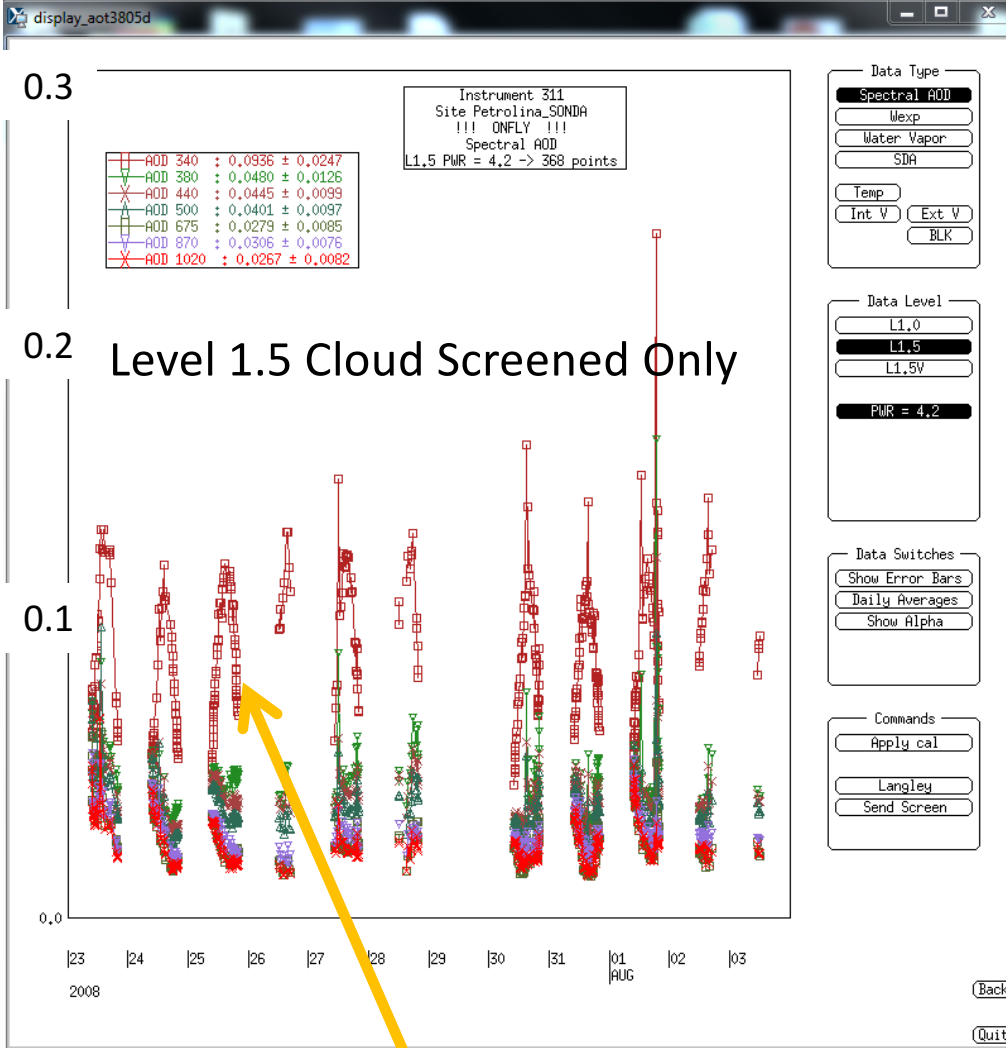


# AERONET V3 L1.5: Collimator Consistency Check

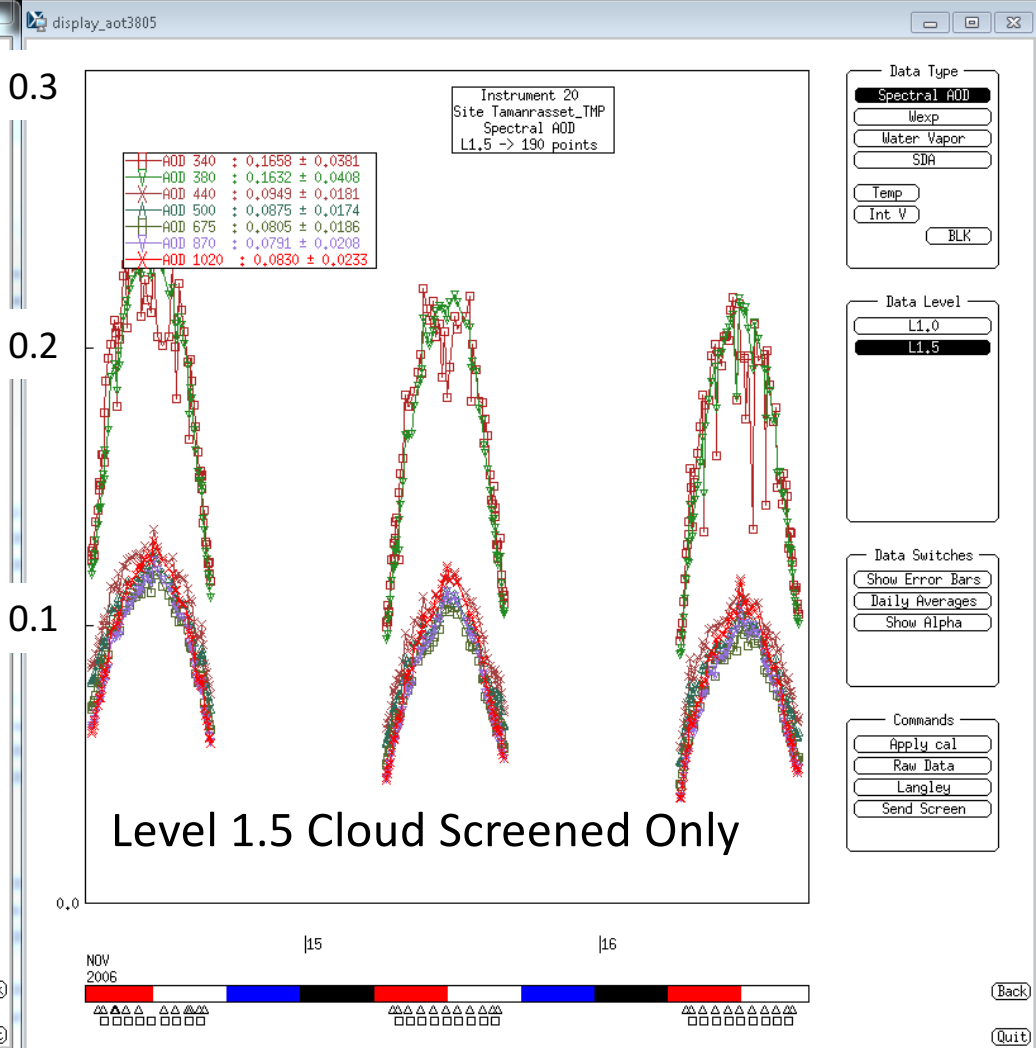


\* InGaAs Channels Removed: 1020nm and 1640nm

# AERONET V3 L1.5: AOD Diurnal Dependence



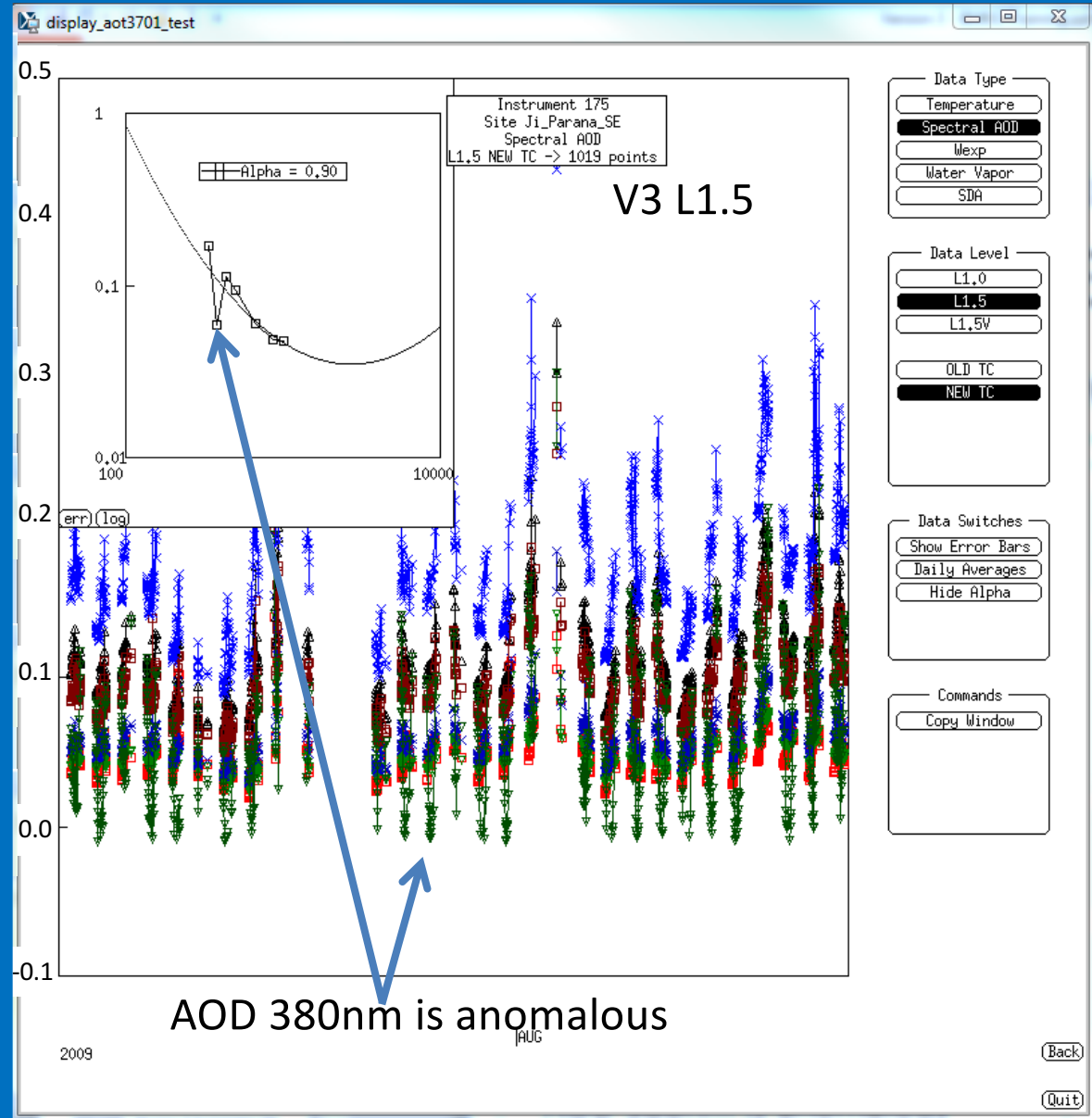
Only AOD 340nm data removed



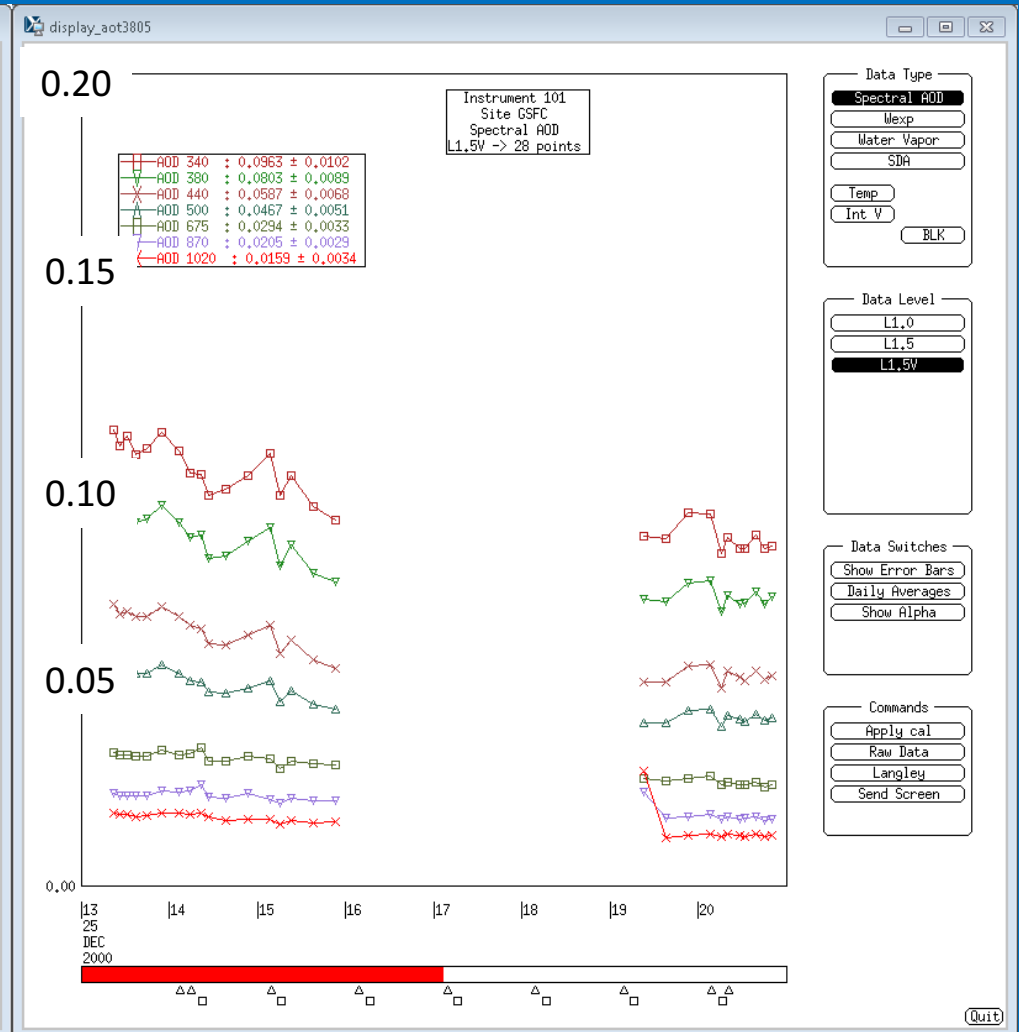
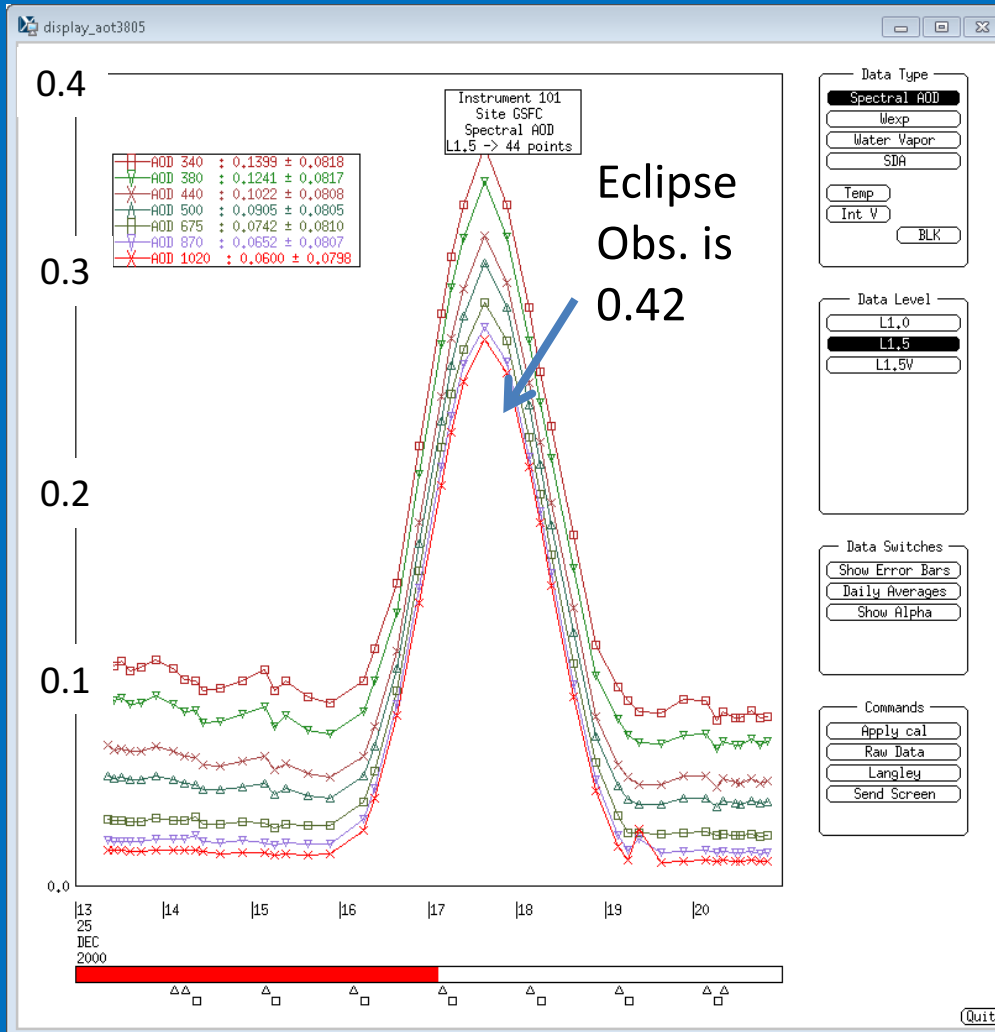
All spectral measurements removed

# AERONET V3 L1.5: AOD Spectral Dependence

- Utilize mainly 1<sup>st</sup> or 2<sup>nd</sup> order fit
  - Number of wavelengths
  - AOD magnitude
- Employ iterative approach to remove outliers based on fit (fit-measurement)
- Combine with other screening techniques



# AERONET Version 3 L1.5: Solar Eclipse Screening



- \* Uses NASA Eclipse database: <http://eclipse.gsfc.nasa.gov>
- \* AOD correction may be implemented

# AERONET V3 Level 1.5

**Nauru, #168, 2000-2005, 2010**

Level	N	AOD	$\alpha$
V2 L1.0	25579	0.23	0.31
V2 L1.5	13326	0.11	0.47
V2 L2.0	9371	0.08	0.54
V3 L1.5 CldScr	10385	0.07	0.48
V3 L1.5	9702	0.07	0.51

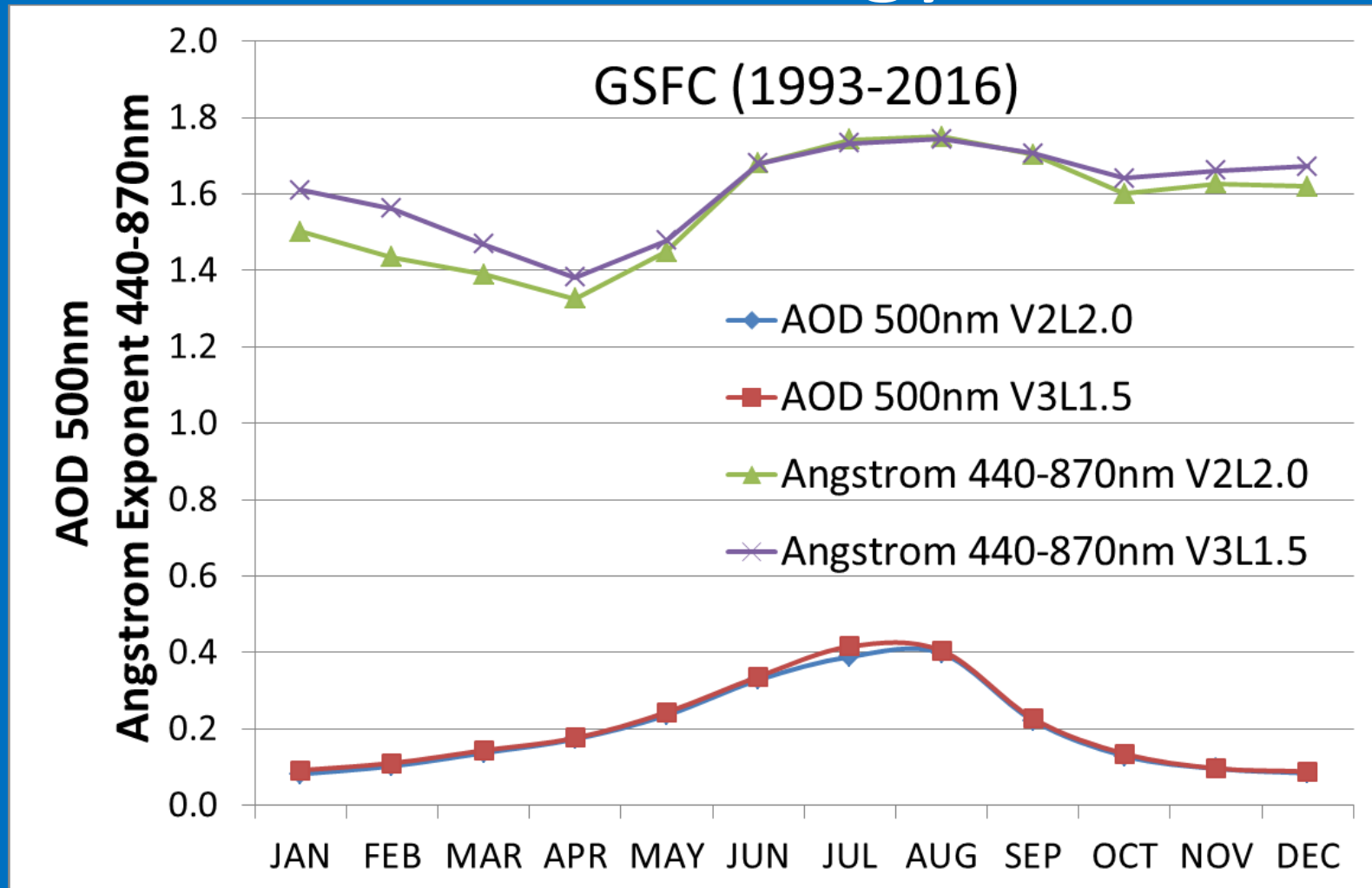
- New Level 1.5  $AOD_{500nm}$  and  $\alpha_{440-870nm}$  statistically very close to V2 Level 2.0
- Improperly filtered highly variable AODs (dominated by fine aerosols) may be restored in the V3 database
- Stable thin cirrus becomes less of an issue (less residual contamination)

**Singapore, #22, 2007-2011**

Level	N	AOD	$\alpha$
V2 L1.0	25500	0.61	0.86
V2 L1.5	8680	0.46	1.03
V2 L2.0	6920	0.35	1.20
V3 L1.5 CldScr	6794	0.34	1.53
V3 L1.5	6534	0.35	1.52



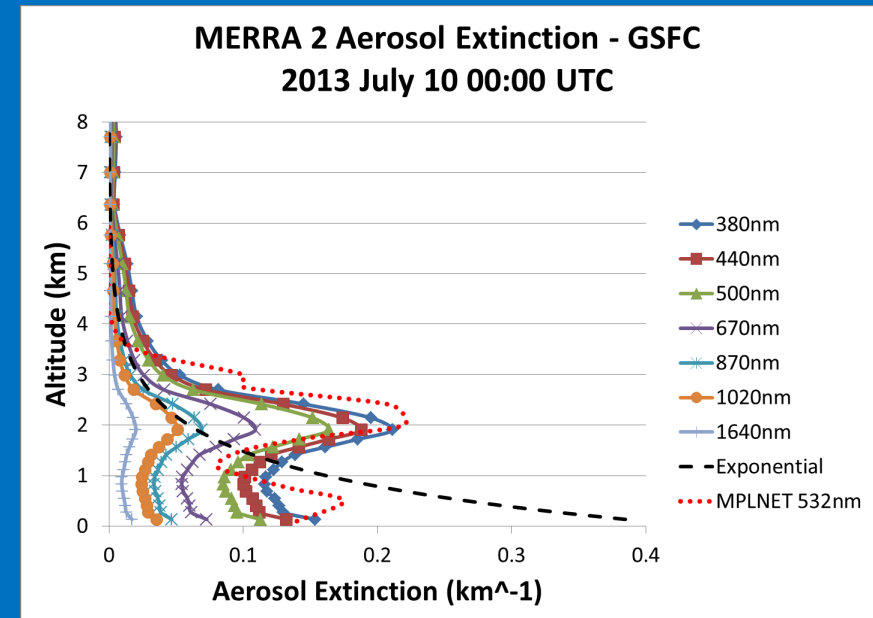
# Climatology



V3 AOD: Level 1.0 and Level 1.5 released June 2016  
V3 AOD: Level 2.0 expected August 2016

# AERONET Version 3 Update - Inversions

- Implement a vector radiative transfer code
  - radiation field in UV (e.g., 380 nm retrieval)
  - degree of linear depolarization
- Integrate spectral MERRA-2 aerosol extinction profiles to estimate aerosol vertical profile (Hybrid scans)
- Incorporate MODIS snow-free BRDF and snow BRDF to characterize surface albedo
- Provide lidar and depolarization ratio products
- Estimate uncertainties for each retrieval (e.g., random error plus biases due to uncertainty in AOD and sky radiance calibration)
- Update inversion quality assurance criteria



MODIS NBAR January 1-8, 2013

V3 Level 1.5 NRT: starting in August 2016

V3 Level 2.0 Inversion: expected December 2016

# AERONET

## New Instrumentation/Enhancements

- Greater control over instrument measurement scenarios (e.g., **Hybrid**)
- Additional capabilities such as SD card storage, GPS, USB, and Zigbee
- **Lunar measurements**
  - 1<sup>st</sup> to 3<sup>rd</sup> quarter lunar phase (waxing to waning gibbous)
  - Processing for lunar measurements (e.g., ROLO, Tom Stone)
- Development toward attachment for CO<sub>2</sub> measurements (Emily Wilson)
- Synergism with MPLNET, PANDORA, and in situ measurements



Cimel Sun/Sky/Lunar Radiometer



# Aerosols and More

## AERONET OCEAN COLOR



Zibordi et al. [2009], JAOT

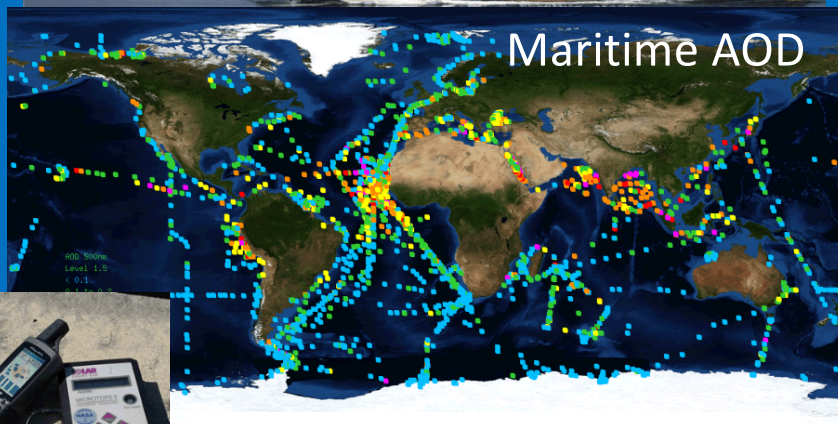
## AERONET Solar Radiation Network



Schafer et al. [2004], JGR

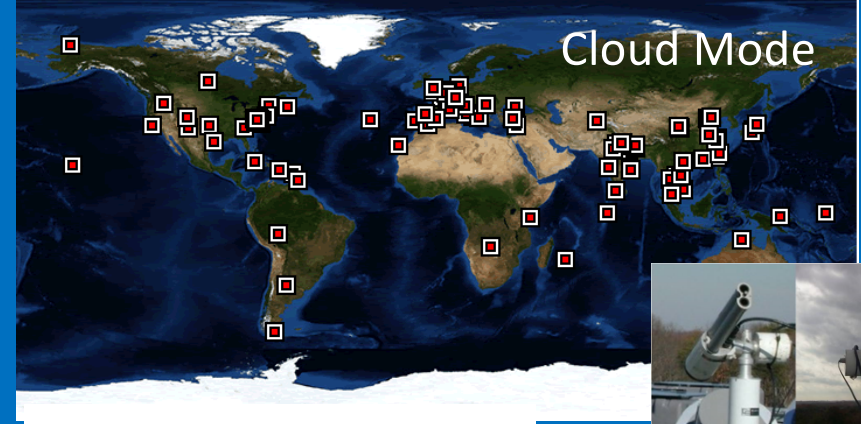


## AERONET MARITIME AEROSOL NETWORK

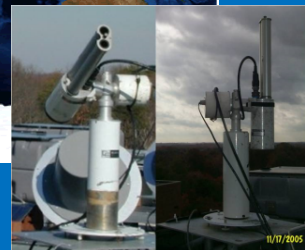


Smirnov et al. [2009], JGR

## AERONET CLOUD OPTICAL PROPERTIES



Chiu et al. [2010], JGR



# Summary and Outlook

- Automatic quality controls perform objective assessments throughout the entire database and provide comparable results to manual screening
- Higher quality AOD data will be available in V3 NRT
  - Due to temperature characterization, improved cloud screening, and quality controls
- Level 2.0 will likely utilize the Level 1.5 automatic screening with minimal manual input



# Summary and Outlook

- New Cimel T instrument control boxes will enhance capabilities (e.g., Hybrid, Lunar)
- V3 inversions will utilize new radiative transfer, ancillary data sets, and provide new products
- Hybrid scenario will improve temporal coverage of aerosol characteristics near satellite overpass times

# Summary and Outlook

- ✓ V3 AOD Levels 1.0 & 1.5 NRT: Released June 2016
- V3 AOD Level 2.0: Expected August 2016
- V3 Inversions Level 1.5: Expected August 2016
- V3 Inversions Level 2.0: Expected December 2016
- V2 processing will continue through December 2017

# http://aeronet.gsfc.nasa.gov

**GODDARD SPACE FLIGHT CENTER**+ Visit NASA.gov

## AERONET

### AEROSOL ROBOTIC NETWORK



+ AEROSOL OPTICAL DEPTH+ AEROSOL INVERSIONS+ SOLAR FLUX+ OCEAN COLOR+ MARITIME AEROSOL

Web Site Feature [AERONET Data Synergy Tool - Access Earth Science data sets for AERONET sites](#)

-Home

**Home**

+ AEROSOL/FLUX NETWORKS

+ CAMPAIGNS

+ COLLABORATORS

+ DATA

+ LOGISTICS

+ NASA PROJECTS

+ OPERATIONS

+ PUBLICATIONS

+ SITE INFORMATION

+ STAFF

+ SYSTEM DESCRIPTION

**15 January 2014 - MODIS Rapid Response images are not available between January 2011 and mid-December 2013 ([More Information](#))**

**MISSION**

The AERONET (Aerosol RobotiC NETwork) program is a federation of ground-based remote sensing aerosol networks established by NASA and PHOTONS (PHOTométrie pour le Traitement Opérationnel de Normalisation Satellitaire; Univ. of Lille 1, CNES, and CNRS-INSU) and is greatly expanded by networks (e.g., RIMA, AeroSpan, AEROCAN, and CARSNET) and collaborators from national agencies, institutes, universities, individual scientists, and partners. The program provides a long-term, continuous and readily accessible public domain database of aerosol optical, microphysical and radiative properties for aerosol research and characterization, validation of satellite retrievals, and synergism with other databases. The network imposes standardization of instruments, calibration, processing and distribution.

AERONET collaboration provides globally distributed observations of spectral aerosol optical depth (AOD), inversion products, and precipitable water in diverse aerosol regimes. Aerosol optical depth data are computed for three data quality levels: Level 1.0 (unscreened), Level 1.5 (cloud-screened), and Level 2.0 (cloud-screened and quality-assured). Inversions, precipitable water, and other AOD-dependent products are derived from these levels and may implement additional quality checks.

The processing algorithms have evolved from Version 1 to Version 2.0 (fully released in July 2006) and are available from the AERONET and PHOTONS web sites. Version 1 data may be downloaded from the web site through 2006 and thereafter upon special request. New AERONET products will be released as new measurement techniques and algorithms are adopted and validated by the AERONET research community. The AERONET web site also provides AERONET-related news, a description of research and operational activities, related Earth Science links, and an AERONET staff directory.

[+ Read More](#)



**NEWS**

**10 May 2016**

- The Distributed Regional Aerosol Gridded Observation Networks (DRAGON)-KORUS-AQ instrument deployment has been established in South Korea, Japan, and China from 1 April to 31 July 2016. The network will be strategically located to take advantage of KORUS-AQ in situ and airborne resources from mid-June 2016.

[+ Read More](#)

V3 NRT



AEROSOL OPTICAL DEPTH (V3)

- + Data Display
- + Download Tool
- + Web Service

AEROSOL OPTICAL DEPTH (V2)

- + Data Display
- + Download Tool
- + Download All Sites
- + Climatology Tables
- + Climatology Maps
- + Data Availability (L2.0)

AERONET Web Service: [http://aeronet.gsfc.nasa.gov/cgi-bin/print\\_web\\_data\\_v3](http://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_v3)

The following tables and examples show how to use the AERONET web data service for Version 3 products.

**Table 1: Explanation and Values for Mandatory and Optional Web Service Parameters**

<b>Mandatory Parameters</b>	<b>Explanation</b>	<b>Values</b>
year,month,day	Starting time moment (year= 1992 to present), (month=1 to 12), (day = 1 to max num, depends on month)	Year: 1992 to present (must be 4-digits) Month: 1 to 12 Day: 1 to max_day_of_month
AVG	Data Format	All points: AVG=10 Daily average: AVG=20
[data_type]	Data Types (See Table 2)	[data_type]=1
<b>Optional Parameters</b>		
year2,month2,day2	Ending time moment**	Year: 1992 to present (must be 4-digits) Month: 1 to 12 Day: 1 to max_day_of_month  **if year2,month2, and day2 are omitted, then the current day is assumed
hour, hour2	Specified beginning (hour) and ending hour (hour2)	Hour: 0 to 23  if not specified, then the hour is set to zero; time2 is incremented to next day and hour2=0
site	AERONET site name	Exact match of AERONET database name  If none specified, then all sites are searched for data during the time interval specified  <a href="#">AERONET Site Name List</a>
lat1,lon1,lat2,lon2	Bounding Box **	lat1,lon1 - Lower Left lat2,lon2 - Upper Right  **values must be in decimal degrees (including the decimal)

**Table 2: Explanation of Data Types for the Web Service**

<b>Data Types</b>	<b>Explanation</b>
AOD10	Aerosol Optical Depth Level 1.0
AOD15	Aerosol Optical Depth Level 1.5
AOD20	Aerosol Optical Depth Level 2.0
SDA10	SDA Retrieval Level 1.0
SDA15	SDA Retrieval Level 1.5
SDA20	SDA Retrieval Level 2.0
TOT10	Total Optical Depth based on AOD Level 1.0 (all points only)
TOT15	Total Optical Depth based on AOD Level 1.5 (all points only)
TOT20	Total Optical Depth based on AOD Level 2.0 (all points only)

**EXAMPLES**

Level 1.0 data from the "Cart\_Site" for AOD daily averages

[http://aeronet.gsfc.nasa.gov/cgi-bin/print\\_web\\_data\\_v3?site=Cart\\_Site&year=2000&month=6&day=1&year2=2000&month2=6&day2=14&AOD10=1&AVG=20](http://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_v3?site=Cart_Site&year=2000&month=6&day=1&year2=2000&month2=6&day2=14&AOD10=1&AVG=20)

Level 1.5 data from all sites with available data for all AOD points

[http://aeronet.gsfc.nasa.gov/cgi-bin/print\\_web\\_data\\_v3?year=2000&month=6&day=1&hour=15&year2=2000&month2=6&day2=14&hour2=23&AOD15=1&AVG=10](http://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_v3?year=2000&month=6&day=1&hour=15&year2=2000&month2=6&day2=14&hour2=23&AOD15=1&AVG=10)

Level 1.5 data from the "Cart\_Site" for all AOD points

[http://aeronet.gsfc.nasa.gov/cgi-bin/print\\_web\\_data\\_v3?site=Cart\\_Site&year=2000&month=6&day=1&year2=2000&month2=6&day2=14&AOD15=1&AVG=10](http://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_v3?site=Cart_Site&year=2000&month=6&day=1&year2=2000&month2=6&day2=14&AOD15=1&AVG=10)

Level 1.5 data from the "Cart\_Site" for all SDA points

[http://aeronet.gsfc.nasa.gov/cgi-bin/print\\_web\\_data\\_v3?site=Cart\\_Site&year=2000&month=6&day=1&year2=2000&month2=6&day2=14&SDA15=1&AVG=10](http://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_v3?site=Cart_Site&year=2000&month=6&day=1&year2=2000&month2=6&day2=14&SDA15=1&AVG=10)