
# AERONET Version 3 Database Update

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[1] Science Systems and Applications, Inc.

[2] NASA Goddard Space Flight Center

[3] Universities Space Research Association

9th International Cooperative for Aerosol Prediction (ICAP) Working Group Meeting

27 June 2017

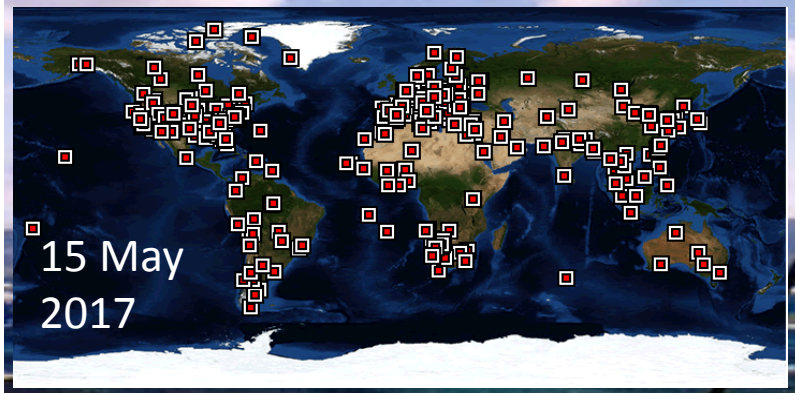
University of Lille, Lille, France

# Outline

- Higher Quality NRT AERONET Products
- Cloud Screening
- Quality Controls
- Quality Assurance
- V3 Results
- Summary


http://aeronet.gsfc.nasa.gov

# AERONET Aerosol Robotic Network- Over 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.

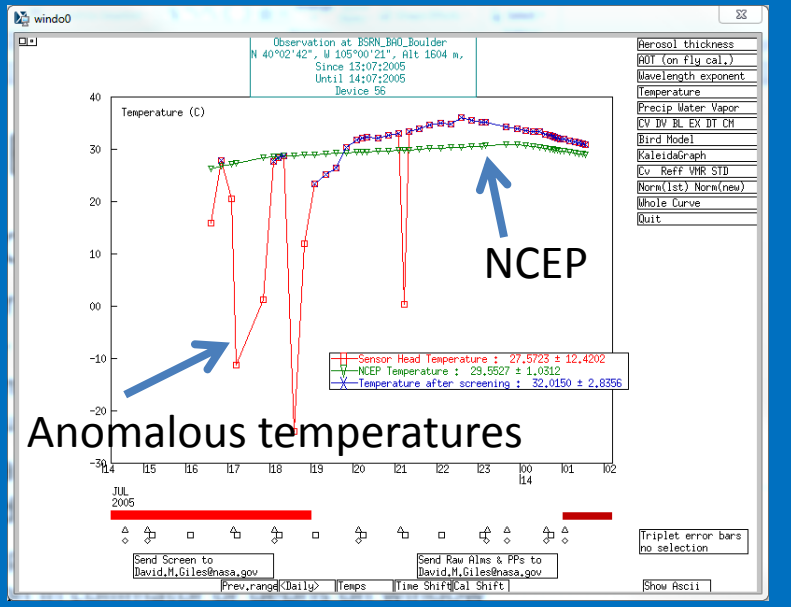
- >7000 citations
- >450 sites
- Over 90 countries and territories
- http://aeronet.gsfc.nasa.gov

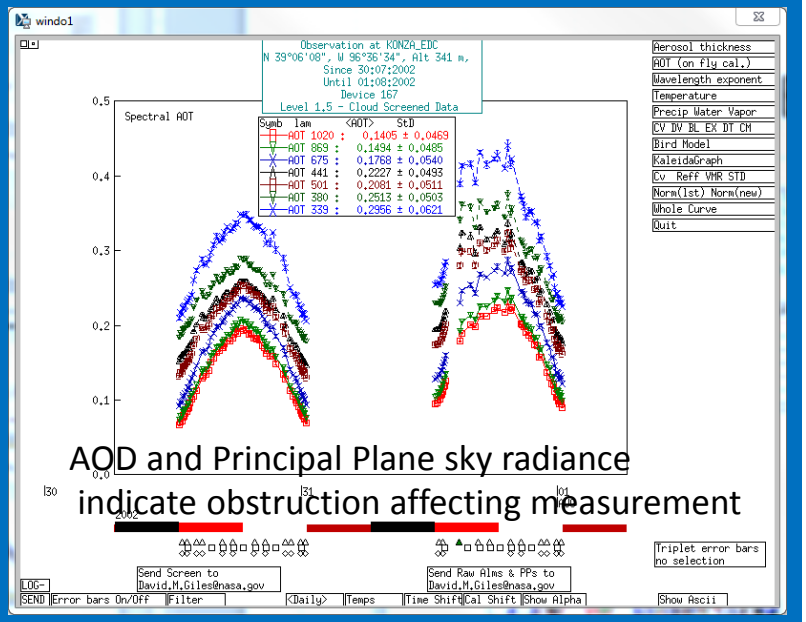
# Growing Need for Higher Quality NRT AERONET Data

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

# AERONET Version 3: AOD

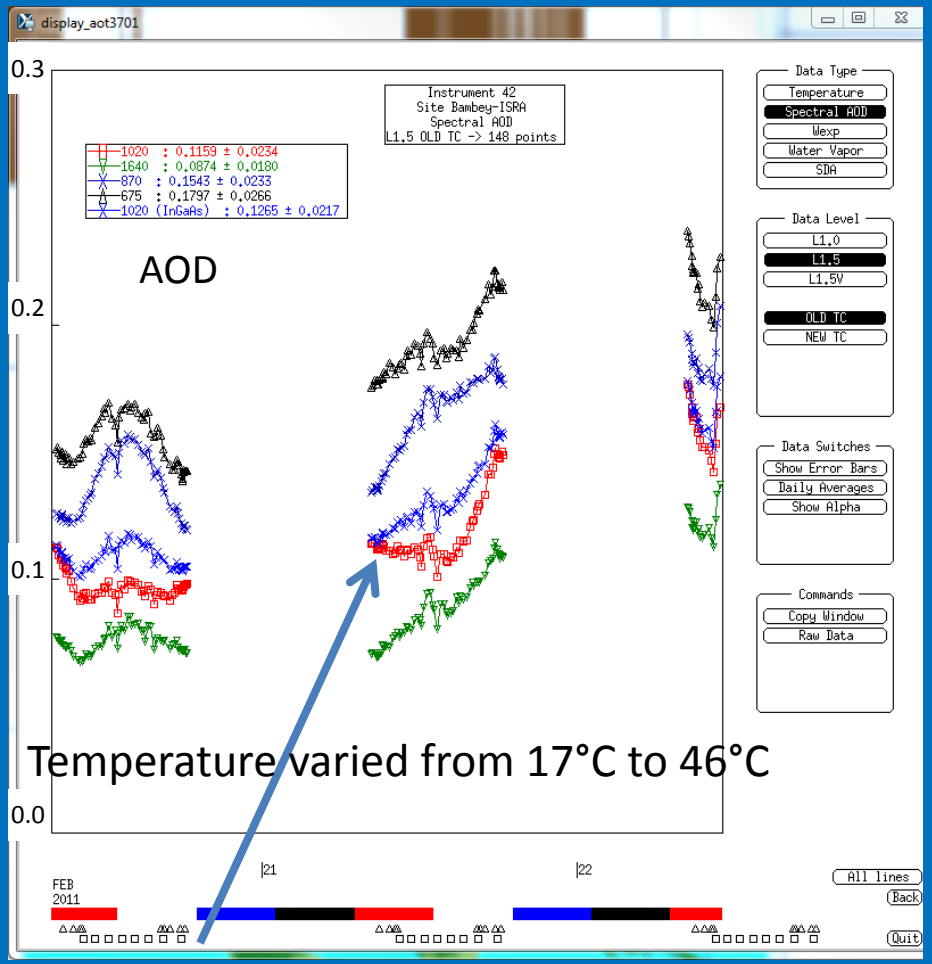
- V3 Level 1.0: Unscreened data (NRT)
  - **Applies new temperature characterizations**
  - Applies NO2 OMI L3 climatology (2004-2013)
  - Applies updated absorption coefficients (Literature/HITRAN)
- **V3 Level 1.5: Based on Level 1.0 and uses new automatic quality controls (NRT)**
  - **Cloud Screening**
    - **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
  - Significantly improves timeliness of Level 2.0 data availability
  - Applies an objective removal scheme
  - Manual analysis not anticipated



# AERONET V3: Spectral Temperature Characterization

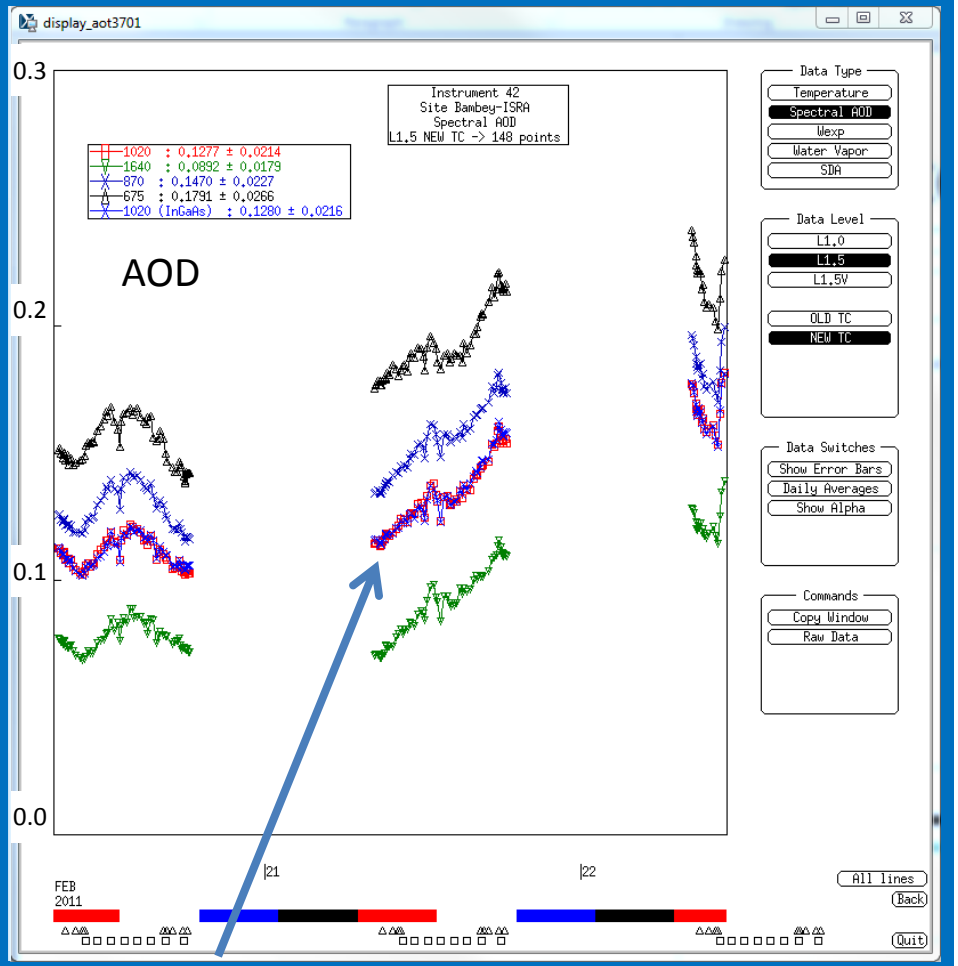
V2 Temperature Correction




Temperature varied from 17°C to 46°C

AOD 1020nm for Silicon and InGaAs detectors do not match

V3 Temperature Correction




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

Note: Temperature characterizations applied to both Sun and sky measurements

# V2 vs. V3 Cloud Screening

| Algorithm/Parameter | Version 2 | Version 3 |
|---|---|---|
| **Very High AOD Restoration** | N/A | $\tau 870 > 0.5$; $\alpha 675\text{-}1020 > 1.2$ or $\alpha 870\text{-}1020 > 1.3$, restore if eliminated by cloud screening |
| **Air Mass Range** | 1 to 5 | 1 to 7 |
| **Number of Potential Measurements** | N < 3, reject day | After all checks applied, reject day if $N_{remain}$ < MAX {3 or <10% of N} |
| **Triplet Criterion** | All λs; AOD range > MAX {0.02 or $0.03*\tau_a$} | λ=675,870,1020nm AOD range > MAX{0.01 or $0.015*\tau_a$} |
| **Angstrom Limitation** | N/A | If AE less than -1.0 or AE greater than 4.0, then eliminate measurement. |
| **Smoothness Check** | D<16 | For AOD 500nm (or 440nm) $\Delta\tau_a > 0.01$ per minute, remove larger $\tau_a$ in pair. Then, the process repeats until no more removal. |

- V2: Smirnov et al. 2000, Cloud screening and quality control algorithms for the AERONET database, Rem.Sens.Env., 73, 337-349
- AERONET Version 3 AOD Algorithm Quality Control Technical Description (2017)

# V2 vs. V3 Cloud Screening

| Algorithm/Parameter | Version 2 | Version 3 |
|---|---|---|
| **Solar Aureole Radiance Curvature Check** | N/A | Compute curvature (**ƙ**) for 1020nm aureole radiances from 3.2°-6.0° ϕ. If **ƙ**< 2.0E-5, compute a slope of ln **ƙ** vs ln ϕ. 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 ±30 minutes period from sky measurement. |
| **Standalone Points** | N/A | No data ±1 hour of point, then reject it unless α440-870nm > 1.0, then keep point |
| **AOD Stability Check** | Same as V3 | Daily Averaged AOD 500nm (or 440nm) has σ less than 0.015, then do not perform **3-Sigma Check** |
| **3-Sigma Check** | Same as V3 | AOD 500nm and α440-870nm should be within MEAN ± 3σ; otherwise reject point(s) |

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

# 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 Version 3 AOD Algorithm Quality Control Technical Description (2017)

# Level 2.0 AOD Criteria

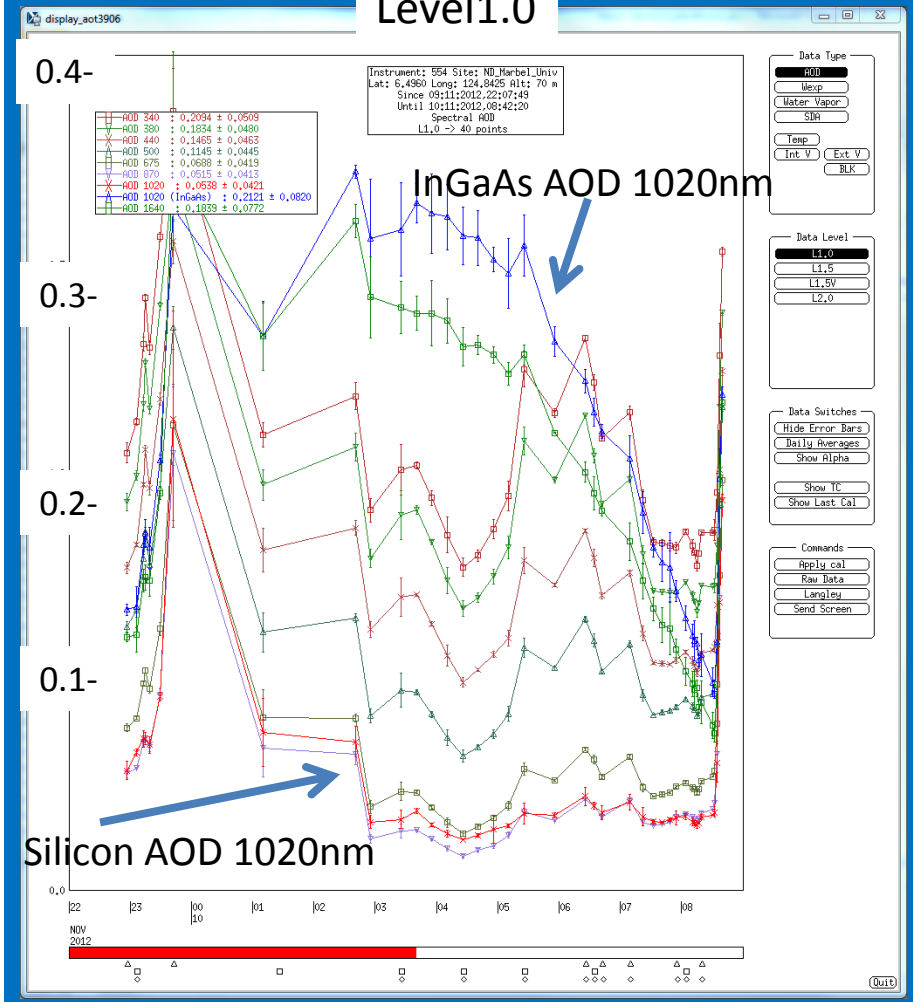
- Must pass the Level 1.5 criteria
- Must utilized pre-field and post-field calibration
- Temperature characterization must be applied for all visible and near-infrared channels (440-1640nm)
  - No characterization for shorter wavelengths
- Once calibration assessment is complete, a 30-day pause will be made to allow the latest updates from ancillary data

**Water Vapor will automatically be raised to Level 2.0

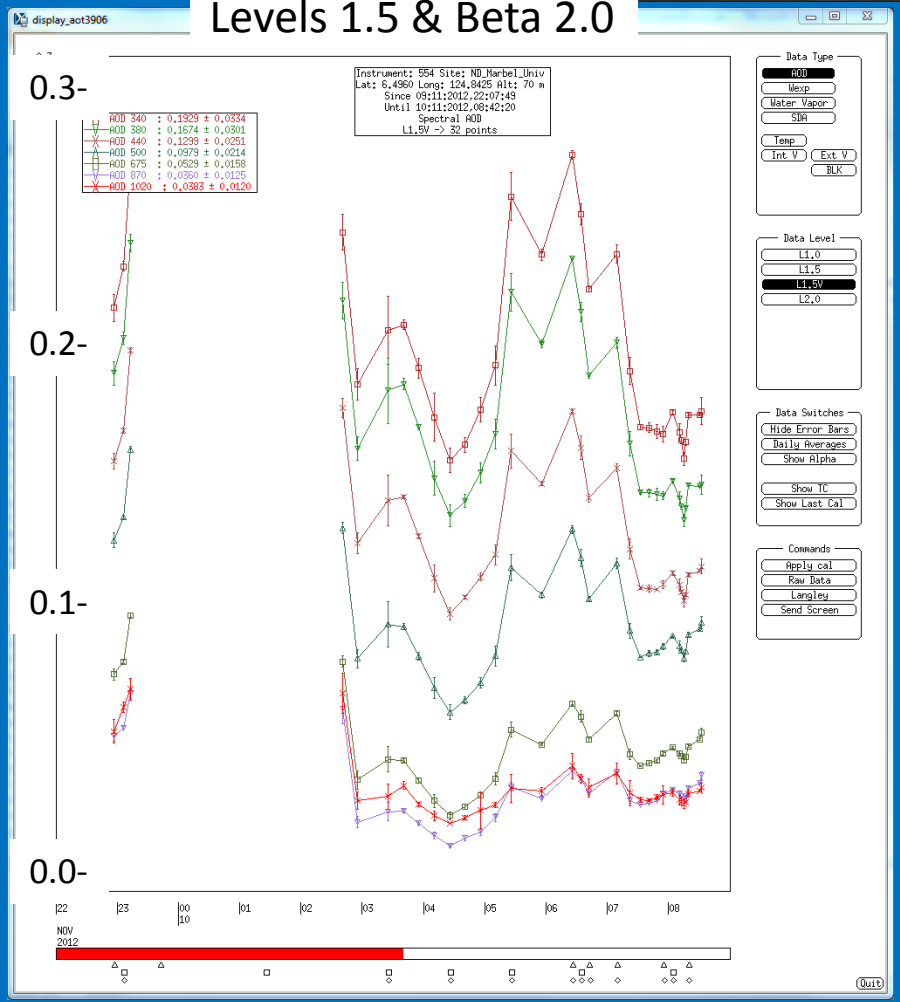
- AERONET Version 3 AOD Algorithm Quality Control Technical Description (2017)

# AERONET V3 L1.5: Collimator Consistency Check

Level1.0



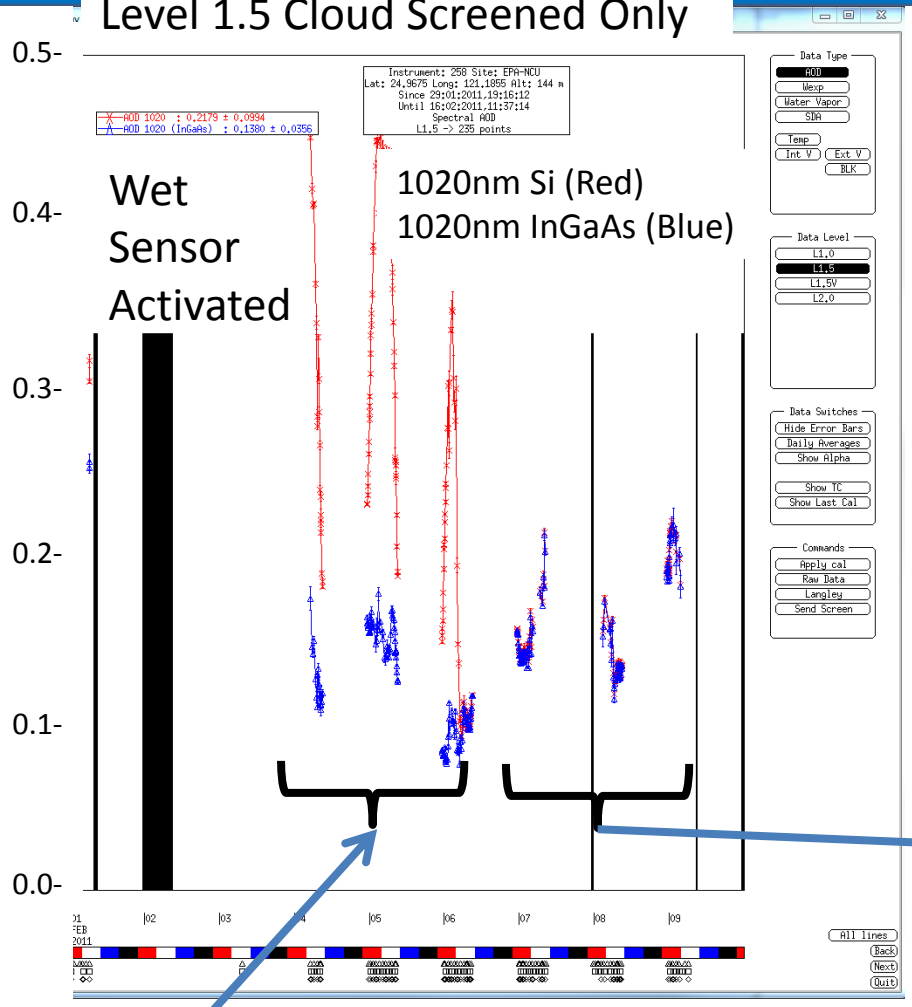

Levels 1.5 & Beta 2.0



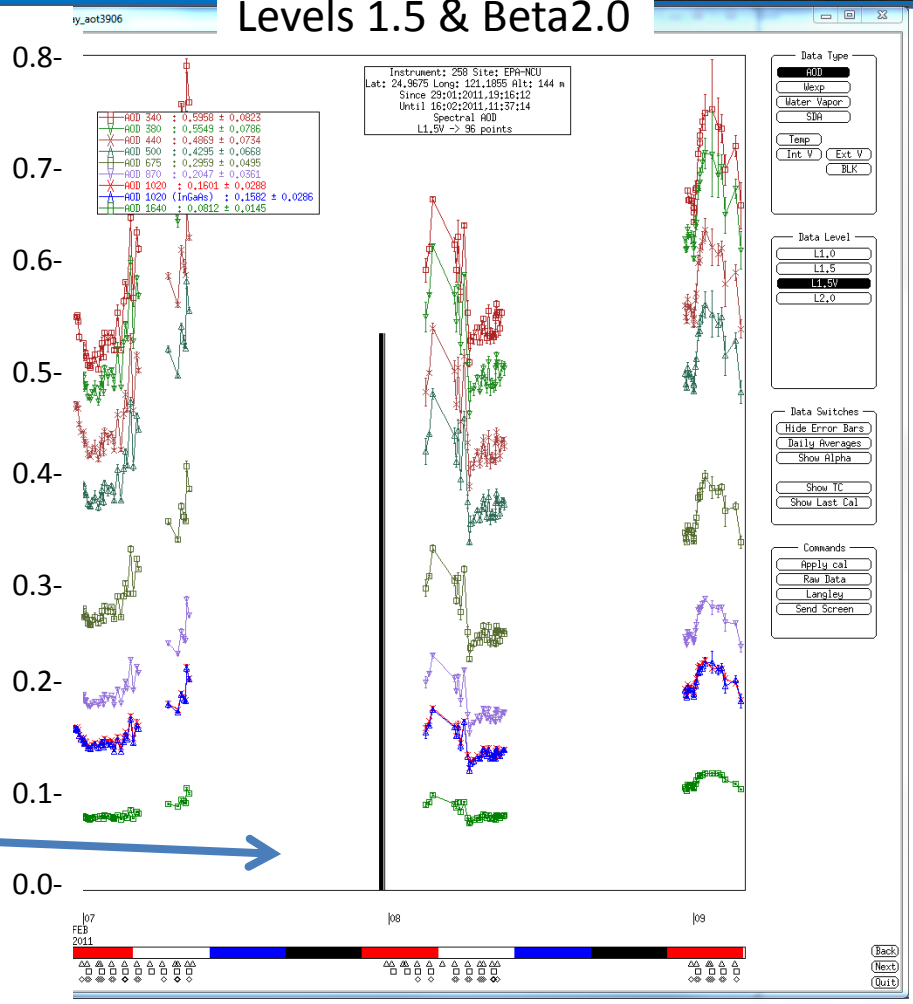

* Only InGaAs Channels Removed: 1020nm and 1640nm

# AERONET V3 L1.5: Collimator Consistency Check

## Level 1.5 Cloud Screened Only




## Levels 1.5 & Beta2.0

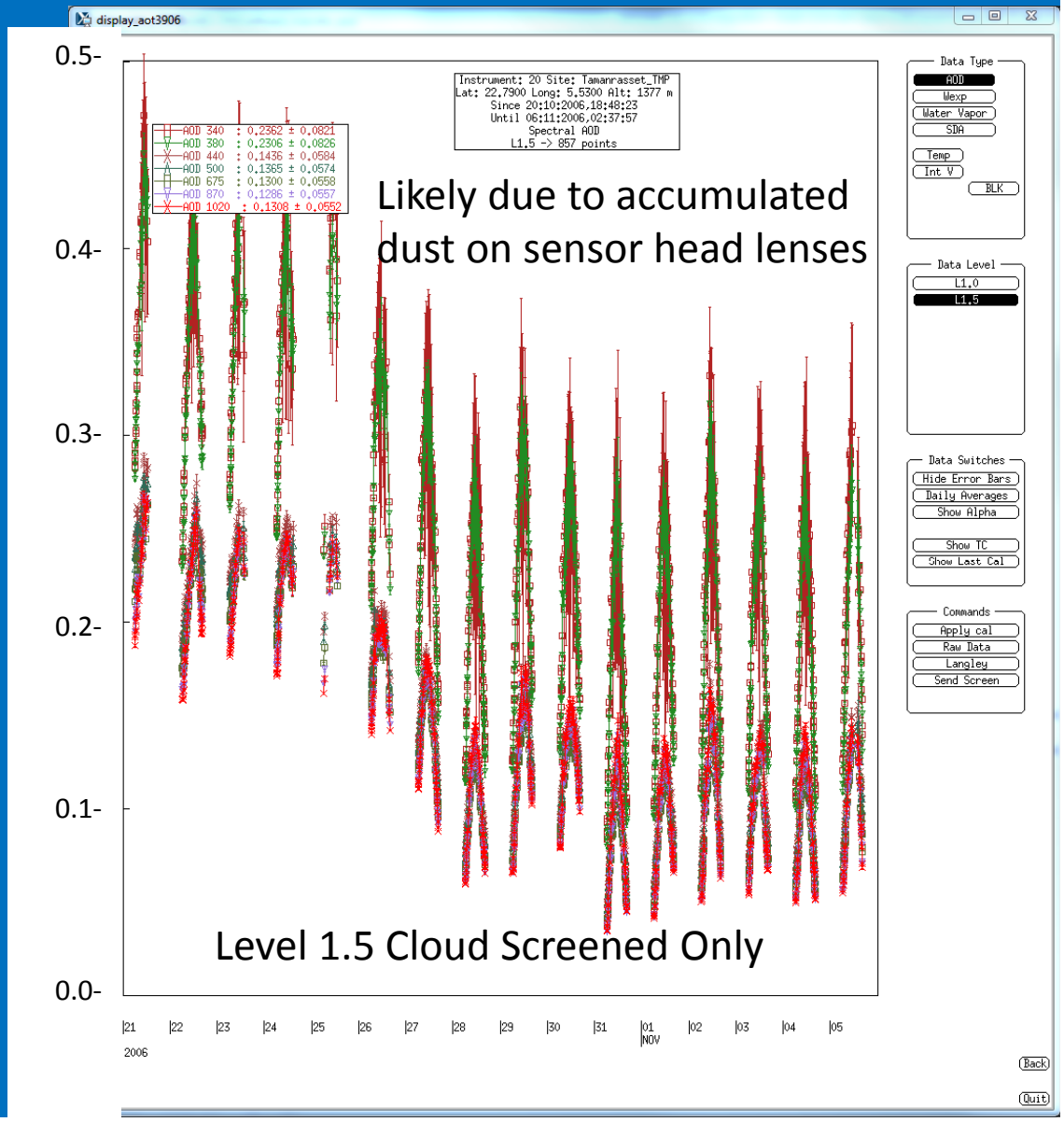



* All Channels Removed: 340 to 1640nm

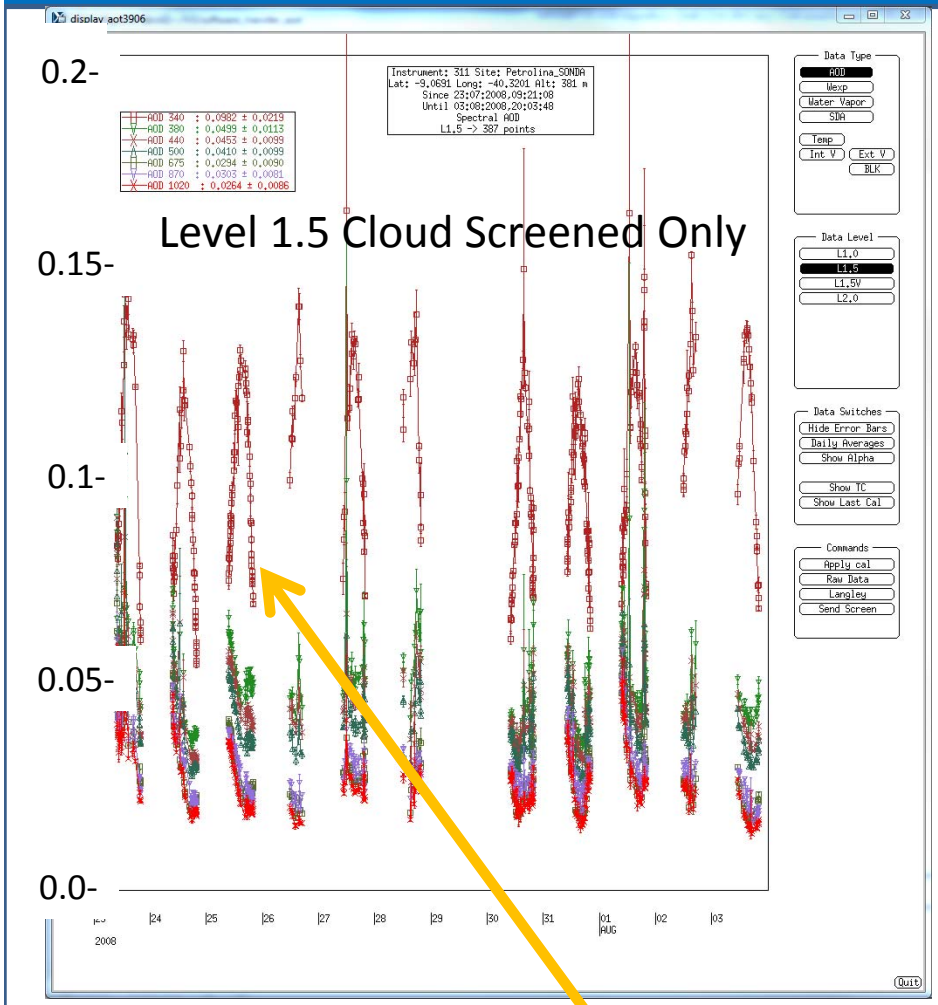
* All Channels Retained

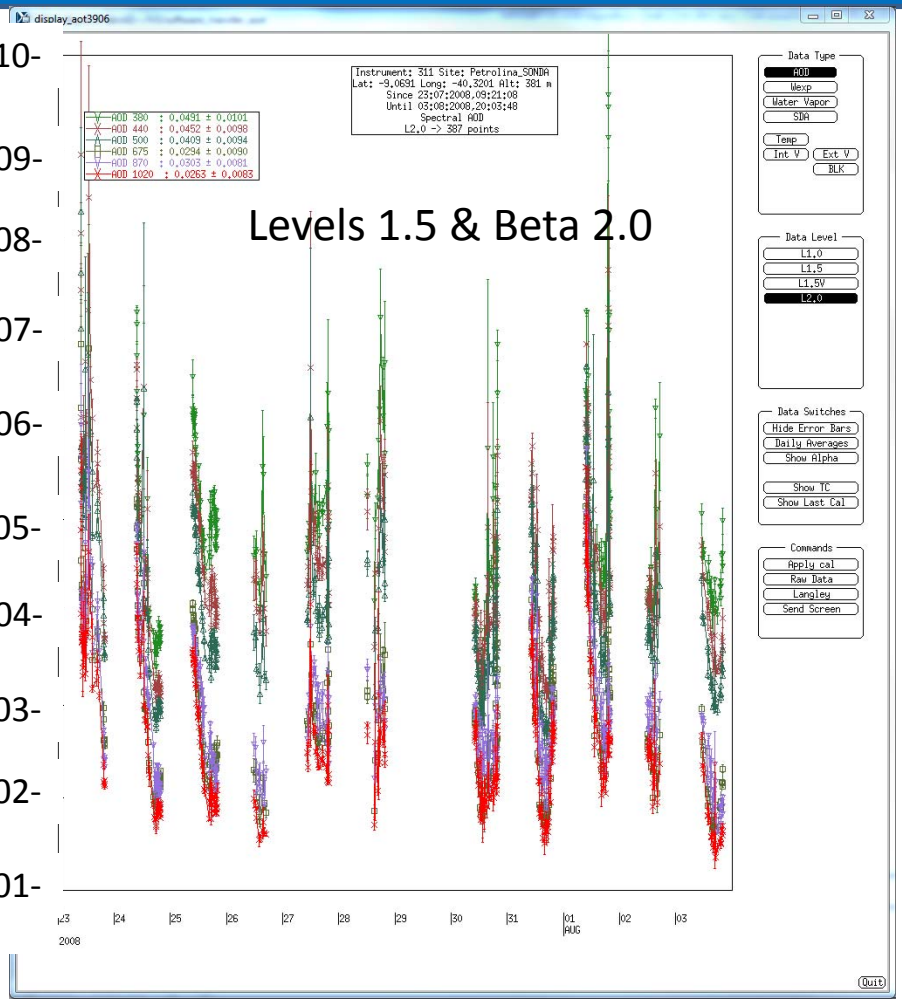
# AERONET V3 L1.5: AOD Diurnal Dependence

- Robust linear regression fit of AOD and cos(SZA)
  - λ(nm)=440, 675, 870, 1020 (Si), and 1640(In)
  - Slope, $R^2$, and RMS
- AM, PM, and full day evaluated
- Independent AOD DD removal only with strong thresholds for linear fit
- Dependent AOD DD removal with weaker thresholds for linear fit but other Level 1.5V flags set
- Multi-day removal (at least 3 days out of last 20)



# AERONET V3 L1.5:
# AOD Diurnal Dependence

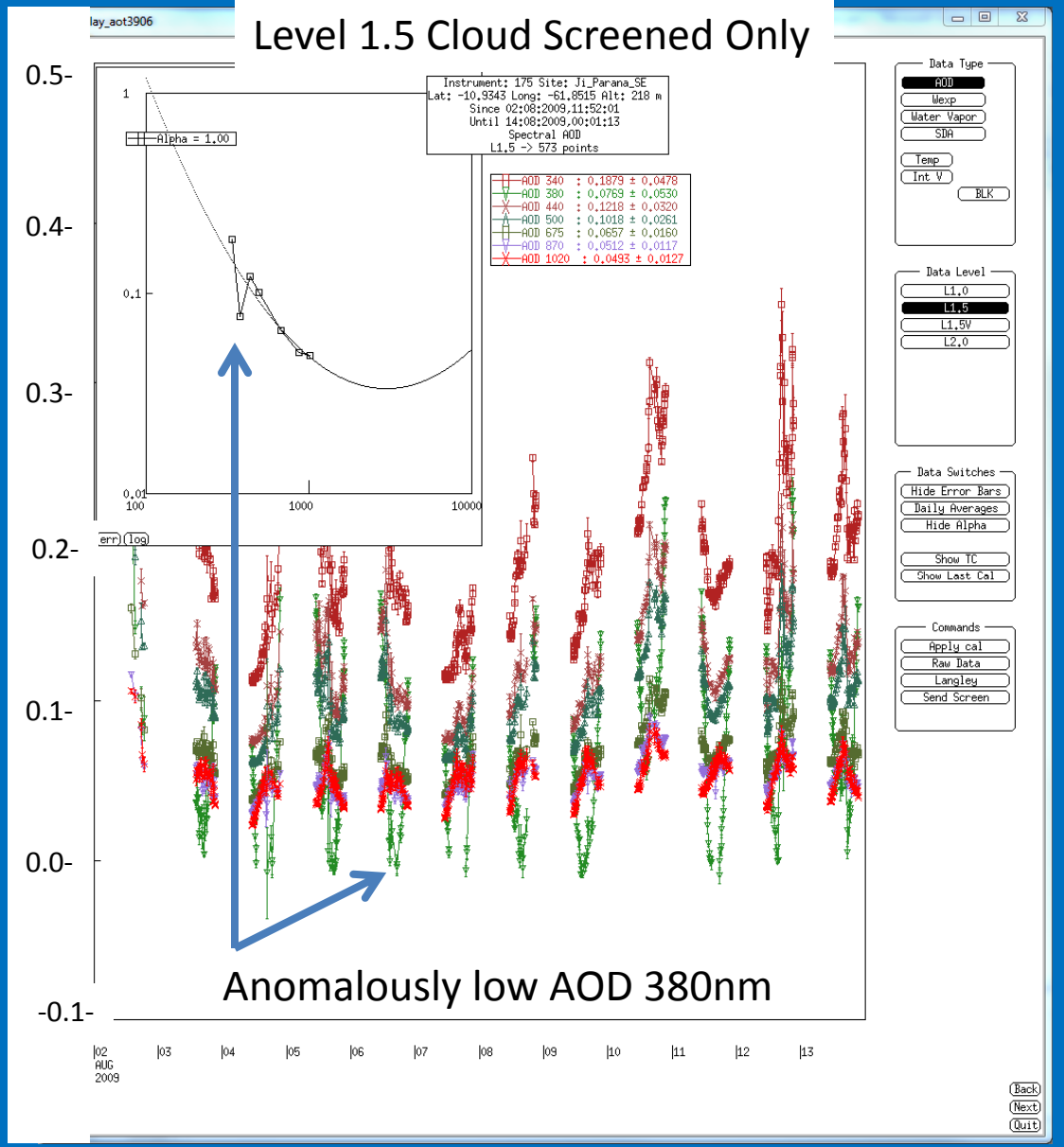


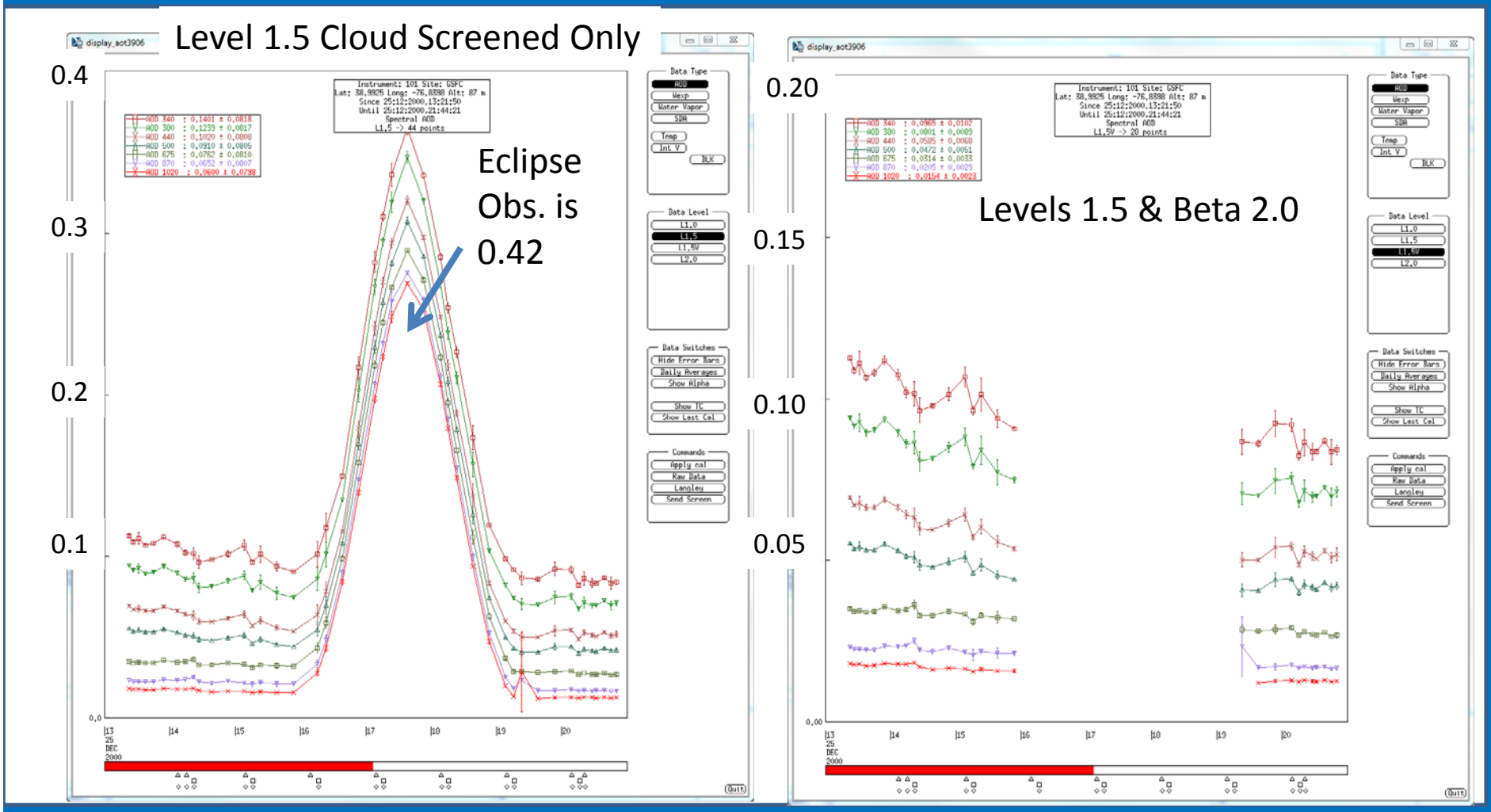

Only AOD 340nm data removed

# AERONET V3 L1.5: AOD Spectral Dependence

- Utilize mainly 1st or 2nd order fit
  - Number of wavelengths
  - AOD magnitude
- Uses robust regression technique less influenced by outliers
- Employ iterative approach to remove outliers based on fit (fit-measurement)
- Combine with other screening techniques



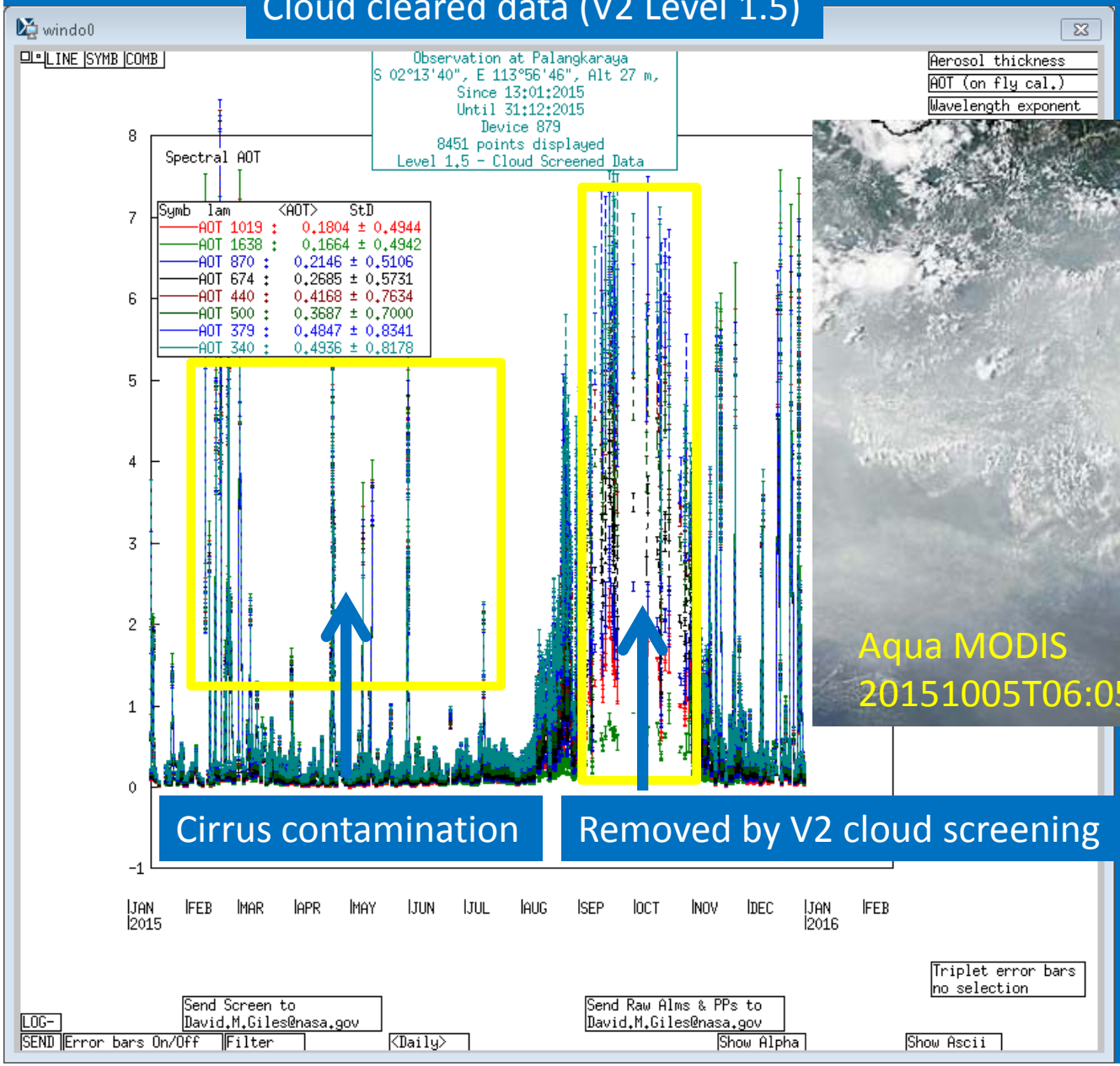
# AERONET Version 3 L1.5: Solar Eclipse Screening

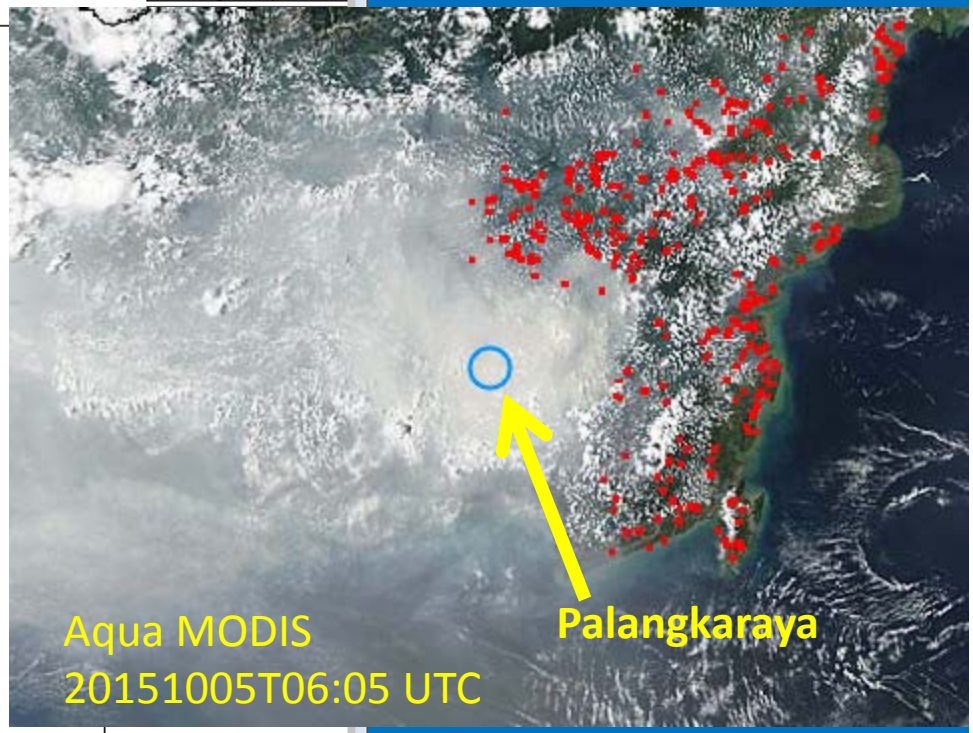



* Uses NASA Eclipse database: http://eclipse.gsfc.nasa.gov
* AOD correction may be implemented

# Indonesian Fires 2015 (Palangkaraya) – Current V2

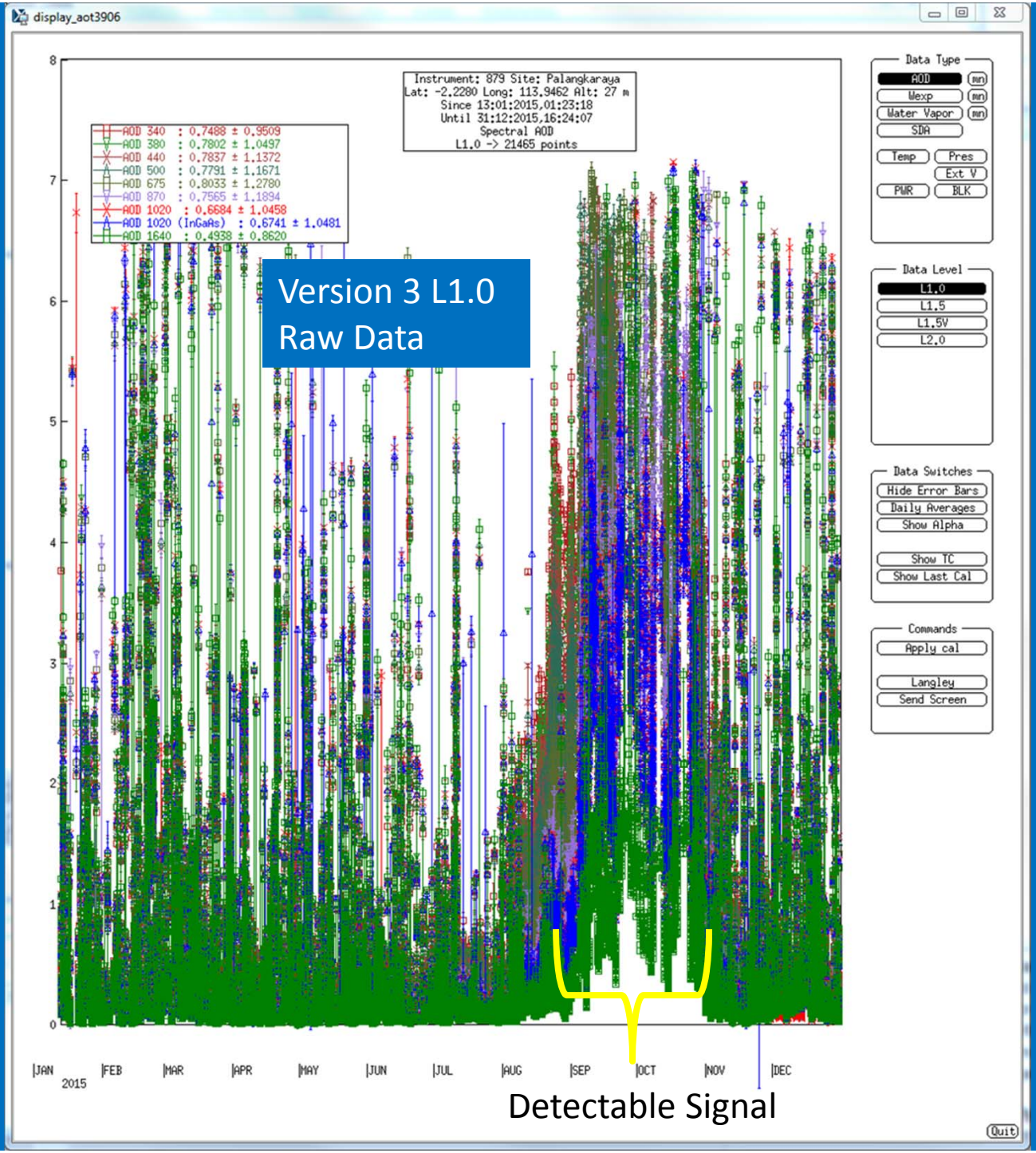
## Cloud cleared data (V2 Level 1.5)

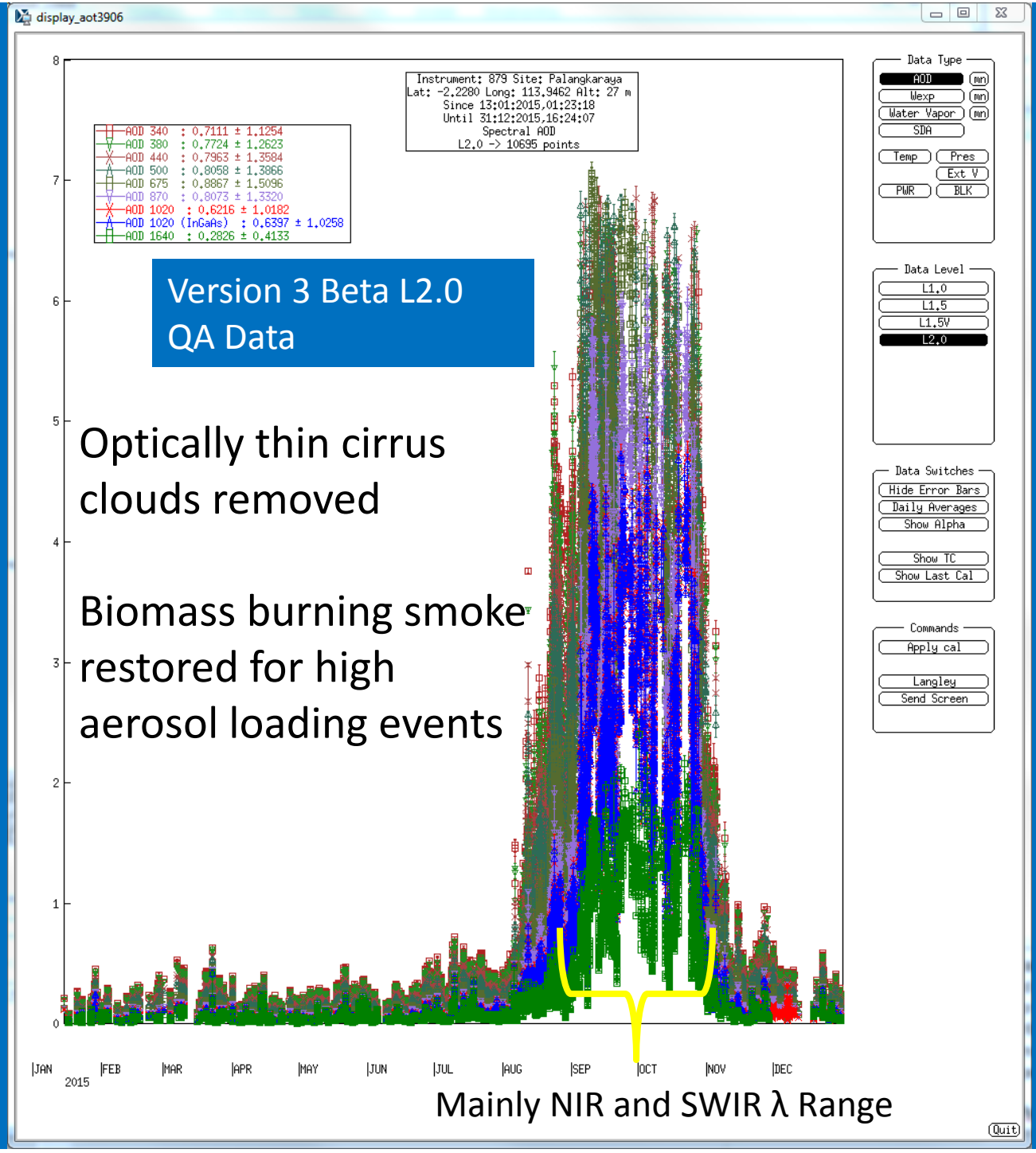



Cirrus contamination

Removed by V2 cloud screening


display_aot3906
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
L1.0 -> 21465 points
AOD 340 : 0.7488 ± 0.9509
AOD 380 : 0.7802 ± 1.0497
AOD 440 : 0.7837 ± 1.1372
AOD 500 : 0.7791 ± 1.1671
AOD 675 : 0.8033 ± 1.2780
AOD 870 : 0.7565 ± 1.1894
AOD 1020 : 0.6684 ± 1.0458
AOD 1020 (InGaAs) : 0.6741 ± 1.0481
AOD 1640 : 0.4938 ± 0.8620
Version 3 L1.0
Raw Data
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
JAN
2015
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Detectable Signal


display_aot3906
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 Beta L2.0
QA Data
Optically thin cirrus clouds removed
Biomass burning smoke restored for high aerosol loading events
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
JAN
2015
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OCT
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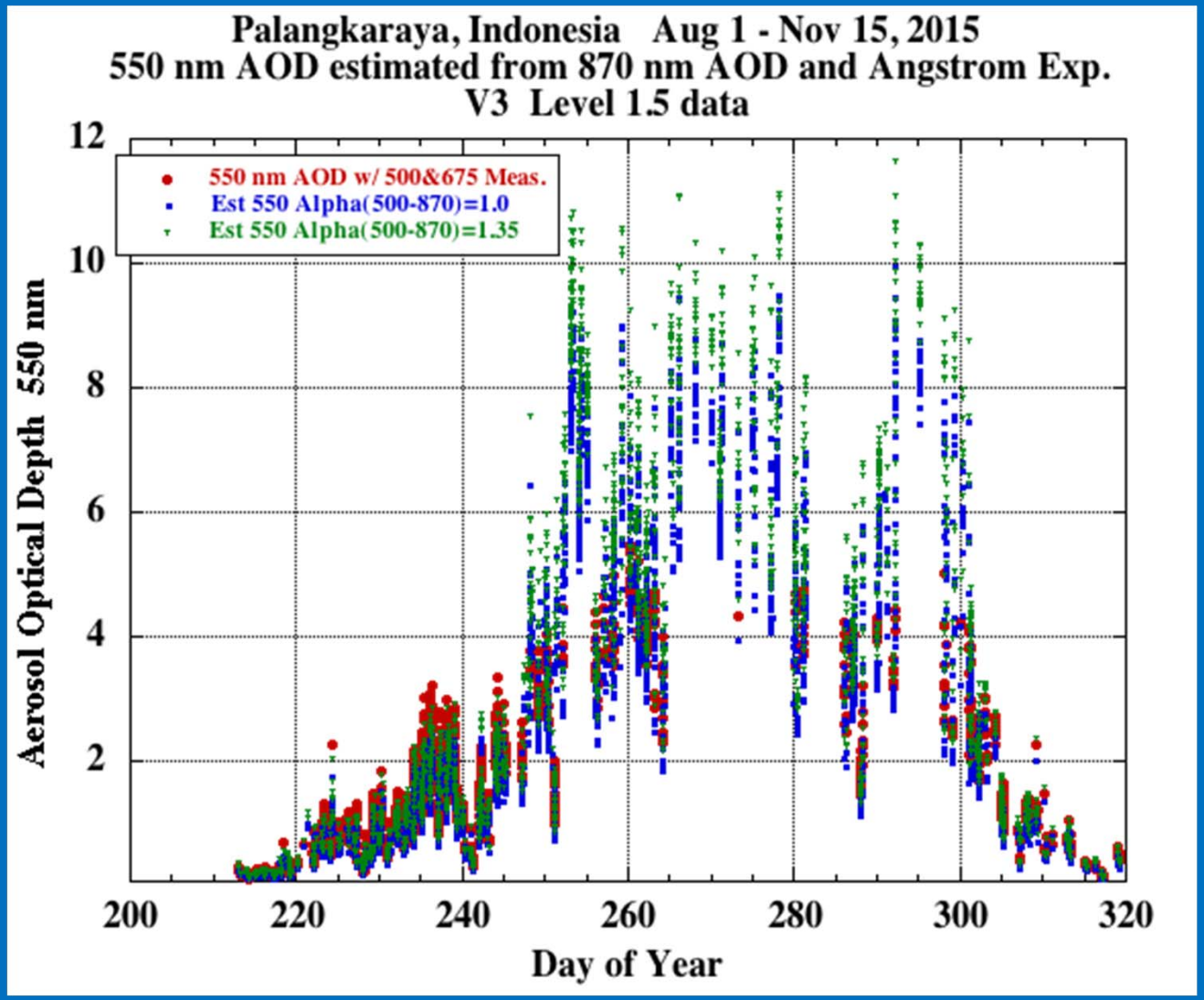
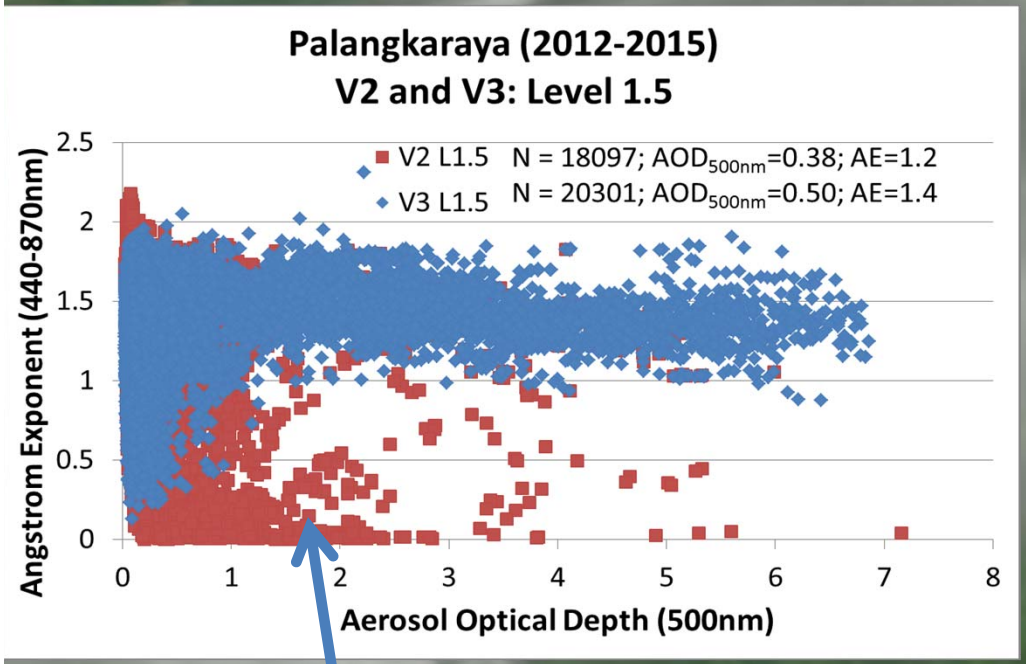



**These estimated AOD levels at mid-visible exceed (to our knowledge) any values ever reported in the published literature.**
This biomass-burning event in 2015 in Indonesia was the largest magnitude AOD event in terms of AOD levels ever monitored by AERONET to date, in the 24-year history of the network

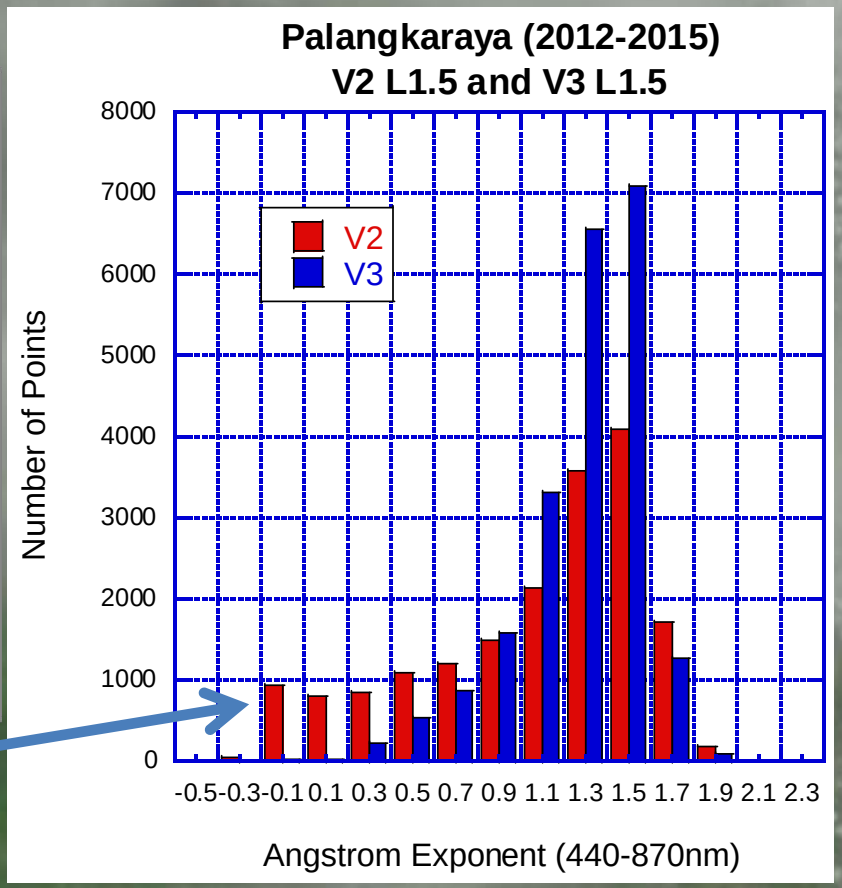
Eck et al., in preparation

# AERONET V3 L1.5

## Palangkaraya

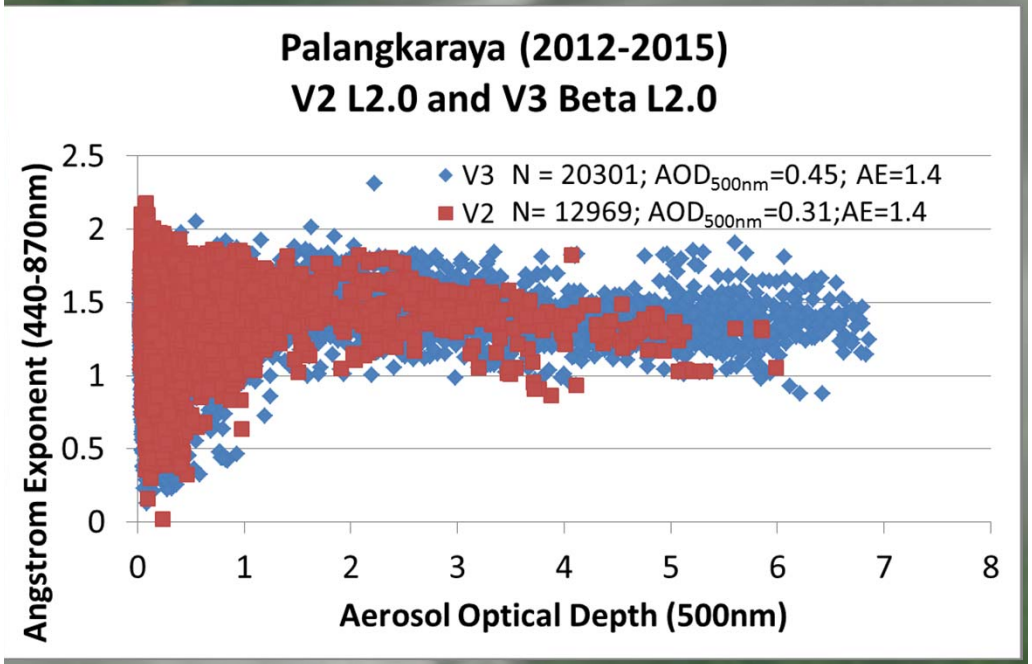


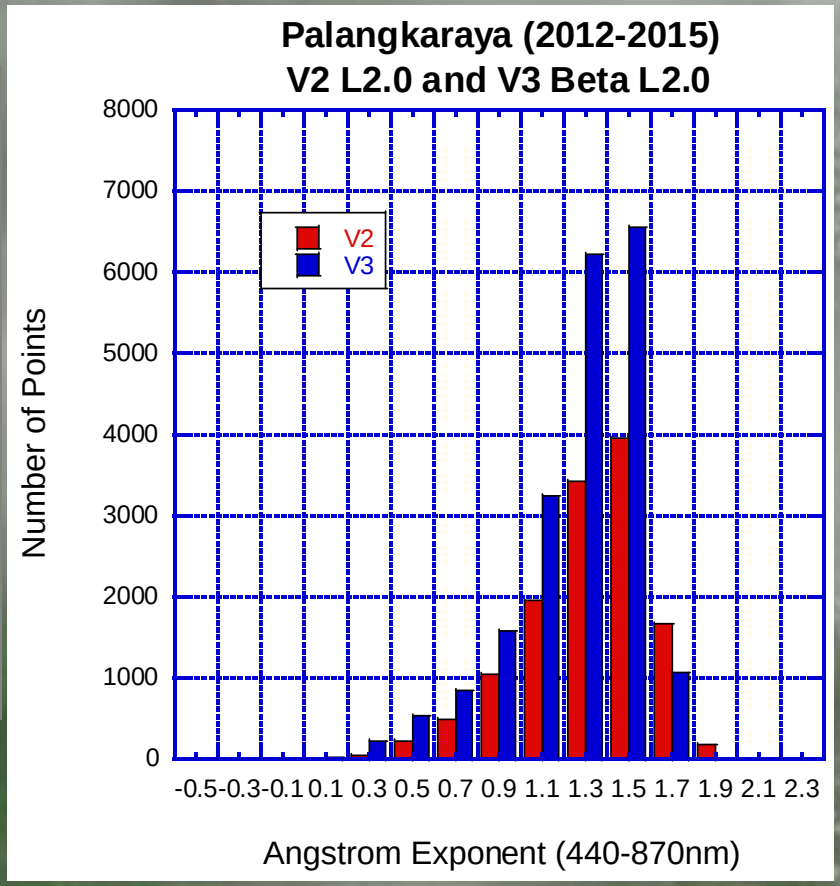

V3 removes more cirrus clouds



# AERONET V3 Beta L2.0 Quality Assured

## Palangkaraya




More measurements overall especially for AE $\geq$ 1.0

# AERONET V2 vs. V3

- New Level 1.5 $AOD_{500nm}$ and $\alpha_{440\text{-}870nm}$ 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)
- V3 L1.5 and V3 L2.0 Beta in many cases are expected to be very similar

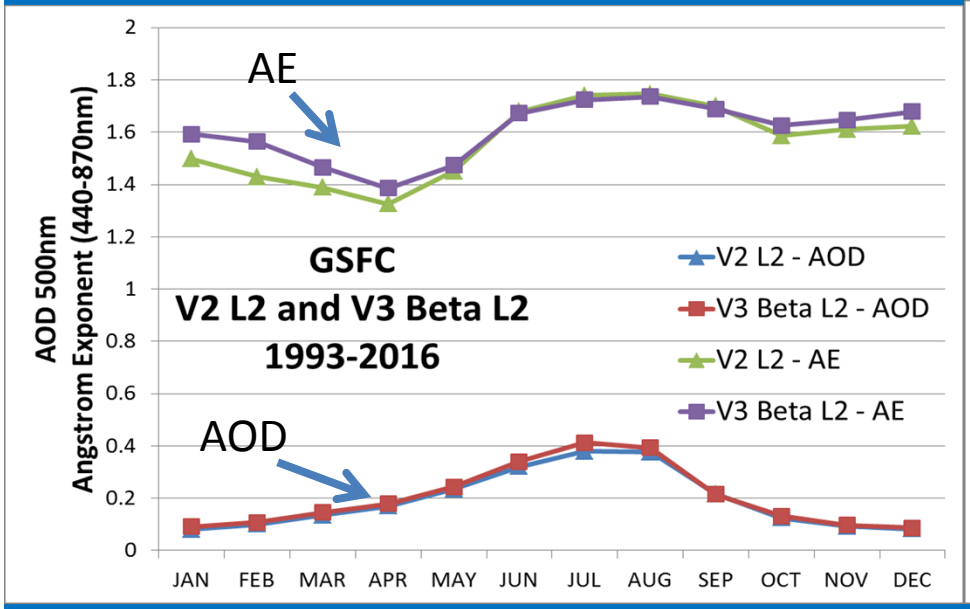
**Nauru, #168, 2000-2005, 2010**

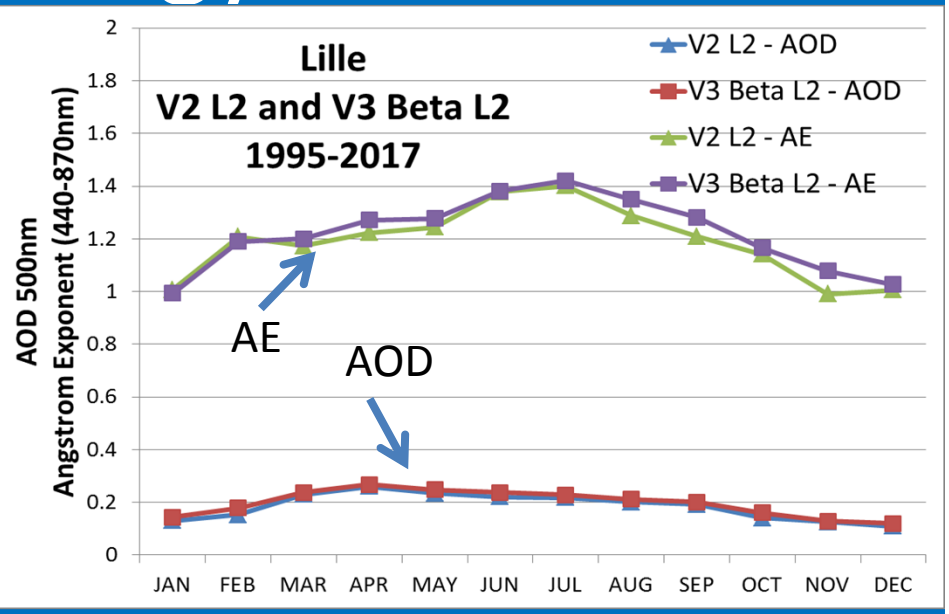
| Level | N | AOD | α |
|---|---|---|---|
| V2 L1.0 | 25579 | 0.23 | 0.31 |
| V2 L1.5 | 13326 | 0.11 | 0.47 |
| V2 L2.0 | 9371 | 0.08 | 0.54 |
| V3 L1.5 CldScr | 10233 | 0.07 | 0.47 |
| V3 L1.5 | 8917 | 0.06 | 0.52 |
| V3 L2.0 Beta | 8917 | 0.06 | 0.52 |

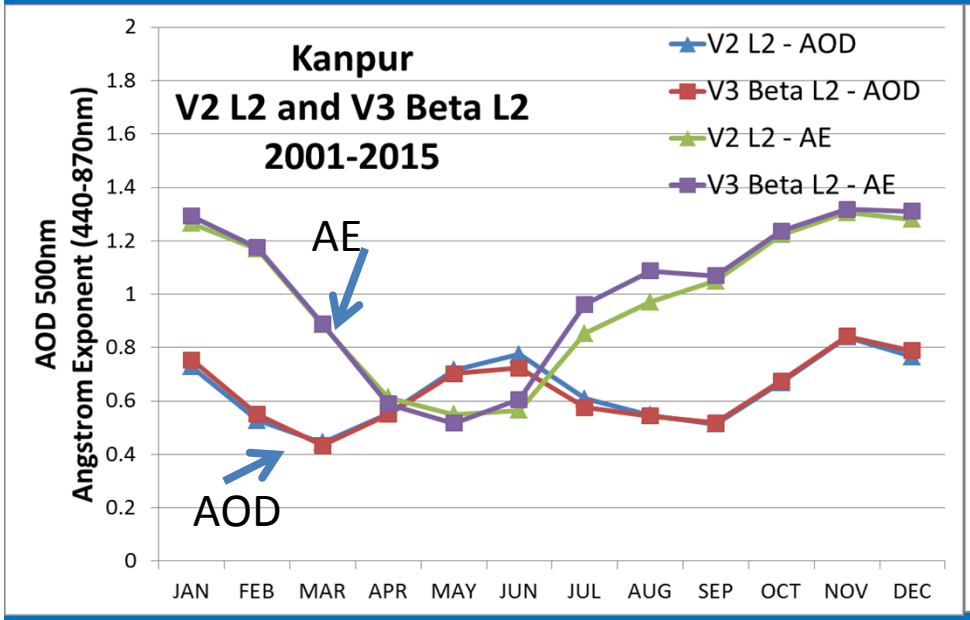
**Singapore, #22, 2007-2011**

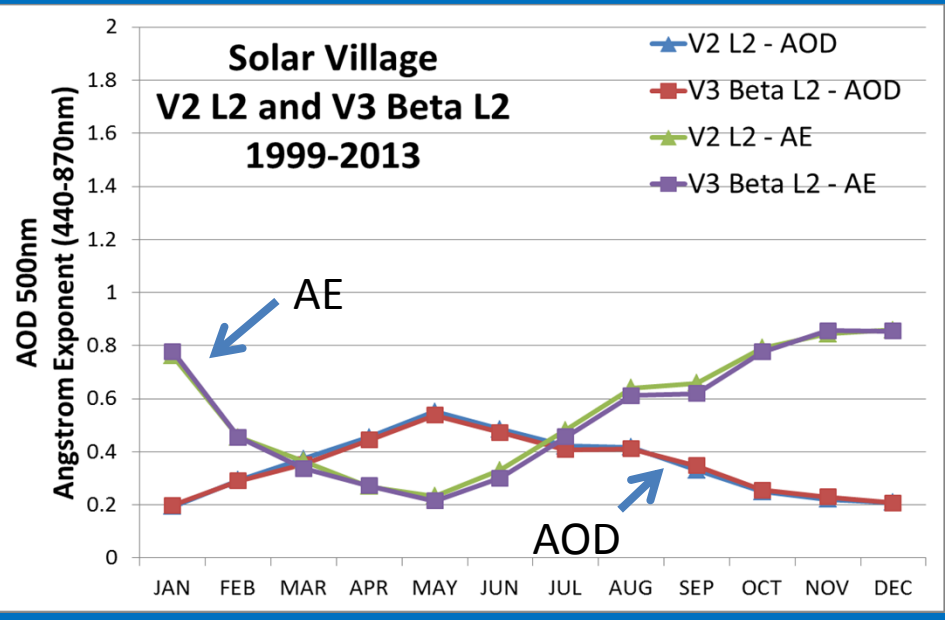
| Level | N | AOD | α |
|---|---|---|---|
| V2 L1.0 | 25500 | 0.61 | 0.86 |
| V2 L1.5 | 8680 | 0.46 | 1.03 |
| V2 L2.0 | 6920 | 0.35 | 1.20 |
| V3 L1.5 CldScr | 6876 | 0.35 | 1.52 |
| V3 L1.5 | 6597 | 0.35 | 1.51 |
| V3 L2.0 Beta | 6597 | 0.35 | 1.51 |

# Climatology



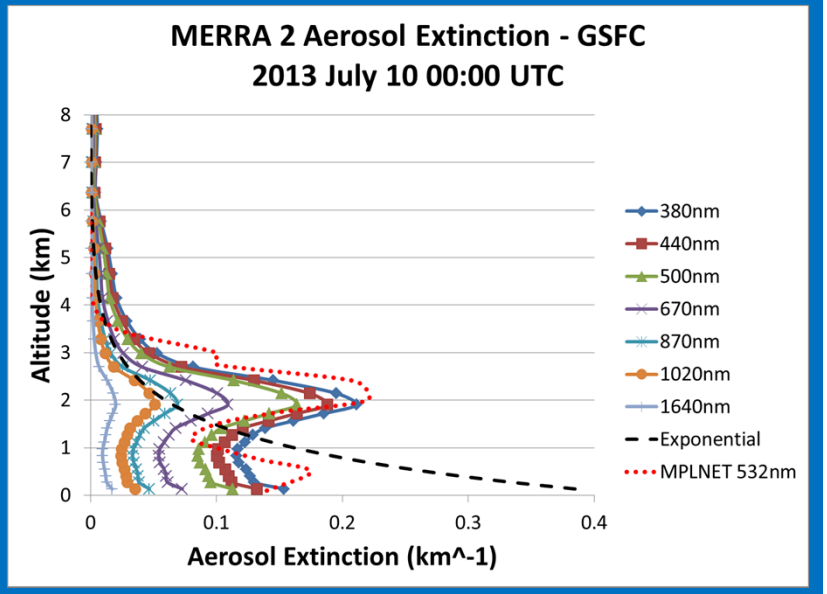



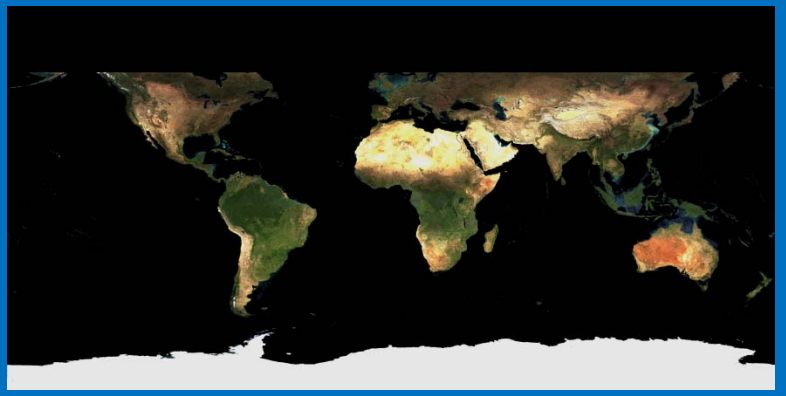



# AERONET Version 3 Update - Inversions

- MERRA-2 aerosol extinction profiles
- MODIS BRDF
  (snow and snow-free)
- Updated ASTM Standard Extraterrestrial Spectrum E-490-00a (reapproved 2006)
- Full Vector radiative transfer code
  - Successive ORDers of scattering (SORD)
  - radiation field in UV (e.g., 380 nm retrieval)
  - degree of linear depolarization

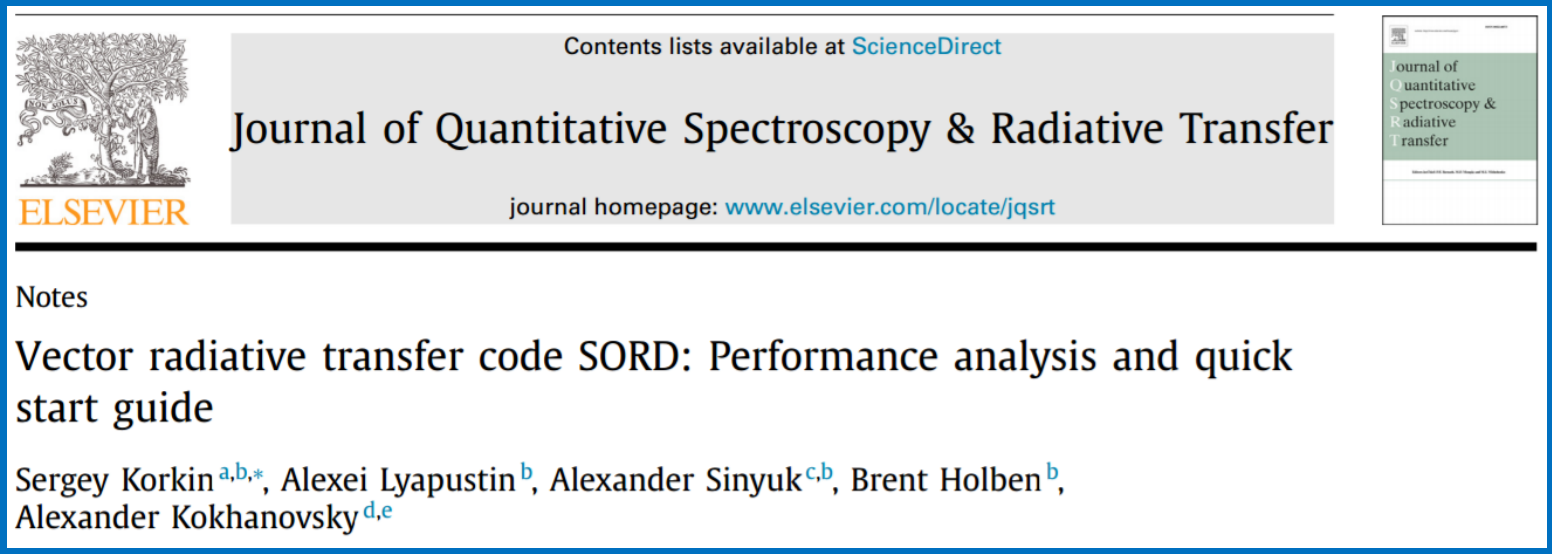


MODIS NBAR January 1-8, 2013

# Forward Modelling with RT code SORD

- New publicly available polarized RT code: SORD (Successive ORDers of scattering)
- The SORD code is local to the AERONET : easy to support and further develop
- Both speed and accuracy are published in JQRST manuscript using 52 benchmarks
- Manuscript explains how to get SORD and independently reproduce all the tests



Contents lists available at ScienceDirect

Journal of Quantitative Spectroscopy & Radiative Transfer

journal homepage: www.elsevier.com/locate/jqsrt

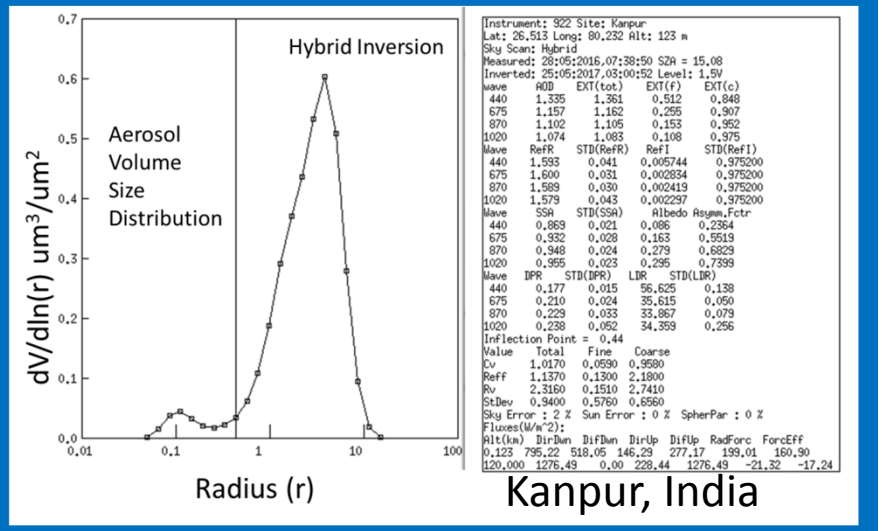
Notes

## Vector radiative transfer code SORD: Performance analysis and quick start guide

Sergey Korkin [a,b,*], Alexei Lyapustin [b], Alexander Sinyuk [c,b], Brent Holben [b], Alexander Kokhanovsky [d,e]

# AERONET Version 3 Update - Inversions

- Lidar and depolarization ratio products
- Estimated uncertainties (e.g., random error plus biases due uncertainty in AOD and sky radiance calibration)
- Maintain V2 inversion product QA (Holben 2006)
- NASA Supercomputers (GSFC and Ames) processing with help from Arlindo DaSilva




Kanpur, India

Instrument: 922 Site: Kanpur
Lat: 26.513 Long: 80.232 Alt: 123 m
Sky Scan: Hybrid
Measured: 28:05:2016,07:38:50 SZA = 15.08
Inverted: 25:05:2017,03:00:52 Level: 1.5V

| wave | AOD | EXT(tot) | EXT(f) | EXT(c) |
|---|---|---|---|---|
| 440 | 1.335 | 1.361 | 0.512 | 0.848 |
| 675 | 1.157 | 1.162 | 0.255 | 0.907 |
| 870 | 1.102 | 1.105 | 0.153 | 0.952 |
| 1020 | 1.074 | 1.083 | 0.108 | 0.975 |

| Wave | RefR | STD(RefR) | RefI | STD(RefI) |
|---|---|---|---|---|
| 440 | 1.593 | 0.041 | 0.005744 | 0.975200 |
| 675 | 1.600 | 0.031 | 0.002834 | 0.975200 |
| 870 | 1.589 | 0.030 | 0.002419 | 0.975200 |
| 1020 | 1.579 | 0.043 | 0.002297 | 0.975200 |

| Wave | SSA | STD(SSA) | Albedo | Asymm.Fctr |
|---|---|---|---|---|
| 440 | 0.869 | 0.021 | 0.086 | 0.2364 |
| 675 | 0.932 | 0.028 | 0.163 | 0.5519 |
| 870 | 0.948 | 0.024 | 0.279 | 0.6829 |
| 1020 | 0.955 | 0.023 | 0.295 | 0.7399 |

| Wave | DPR | STD(DPR) | LDR | STD(LDR) |
|---|---|---|---|---|
| 440 | 0.177 | 0.015 | 56.625 | 0.138 |
| 675 | 0.210 | 0.024 | 35.615 | 0.050 |
| 870 | 0.229 | 0.033 | 33.867 | 0.079 |
| 1020 | 0.238 | 0.052 | 34.359 | 0.256 |

Inflection Point = 0.44

| Value | Total | Fine | Coarse |
|---|---|---|---|
| Cv | 1.0170 | 0.0590 | 0.9580 |
| Reff | 1.1370 | 0.1300 | 2.1800 |
| Rv | 2.3160 | 0.1510 | 2.7410 |
| StDev | 0.9400 | 0.5760 | 0.6560 |

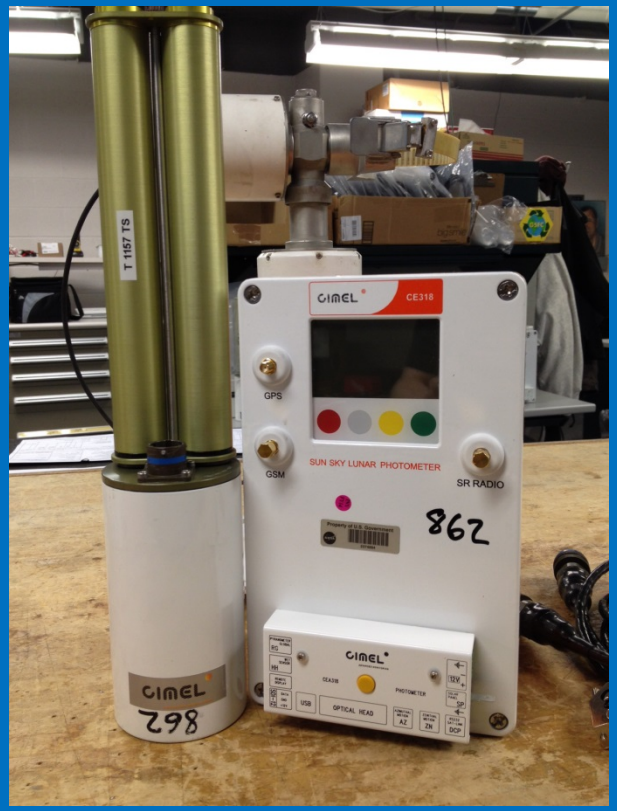
Sky Error : 2 % Sun Error : 0 % SpherPar : 0 %
Fluxes(W/m^2):

| Alt(km) | DirDwn | DifDwn | DirUp | DifUp | RadForc | ForcEff |
|---|---|---|---|---|---|---|
| 0.123 | 795.22 | 518.05 | 146.29 | 277.17 | 199.01 | 160.90 |
| 120.000 | 1276.49 | 0.00 | 228.44 | 1276.49 | -21.32 | -17.24 |

Expected beta V3 inversion product release starting in August 2017

# AERONET
# New Instrumentation/Enhancements

- Improved tracking reducing triplet variance
- Greater control over instrument measurement scenarios (e.g., **Hybrid**)
- Additional capabilities such as SD card storage, GPS, USB, and Zigbee
- **Lunar measurements**
  - 1st to 3rd quarter lunar phase (waxing to waning gibbous)
  - Processing for lunar measurements (e.g., ROLO, Tom Stone)
- Development toward attachment for CO2 measurements (Emily Wilson)
- Synergism with MPLNET, PANDORA, and in situ measurements




Cimel Sun/Sky/Lunar Radiometer

# Summary and Outlook

- Higher quality NRT AOD data will be available in V3
  - Due to temperature characterization and automatic cloud screening and quality controls
- Level 2.0 utilizes Level 1.5 automatic screening and available within 30 days of post-field calibration application
- V3 inversions will utilize new radiative transfer, ancillary data sets, and provide new products

➢ V3 AOD Level 1.0 and Level 1.5 NRT released

➢ V3 AOD Level 2.0 expected release: September 2017

➢ Beta V3 inversions expected release: August 2017

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

V3 NRT →

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
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+ PUBLICATIONS
+ SITE INFORMATION
+ STAFF
+ SYSTEM DESCRIPTION

AERONET DATA ACCESS

DATA SYNERGY TOOL
+ Data Display

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)

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

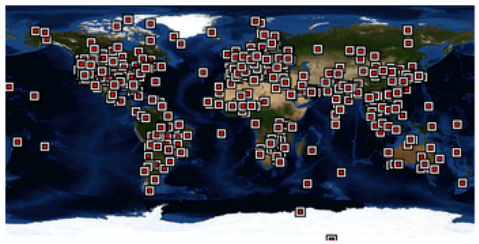
MISSION

The AERONET (**AE**rosol **RO**botic **NET**work) 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

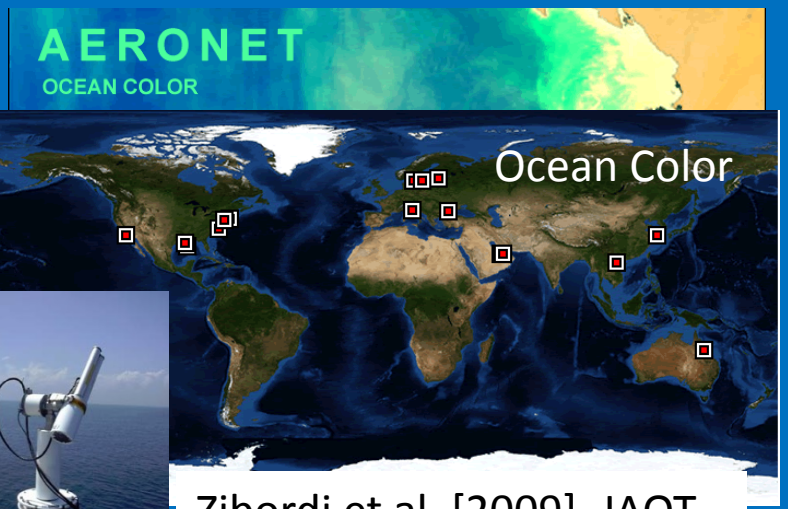


NEWS

**10 May 2016**

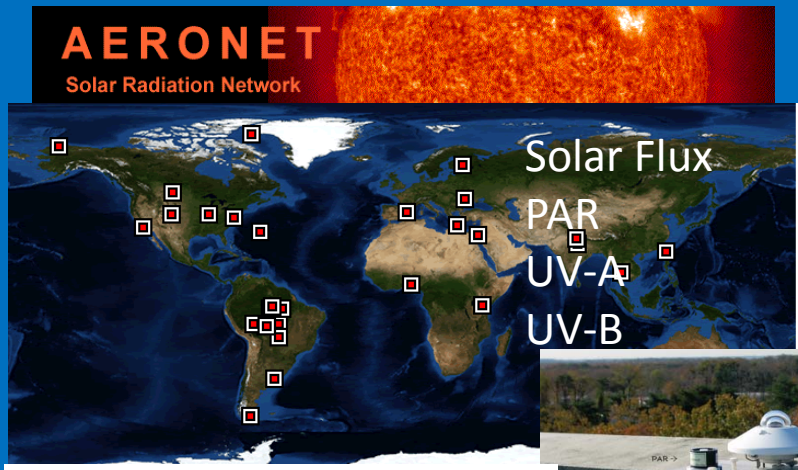
- The Distributed Regional Aerosol Gridded Observation Networks (DRAGON)-KORUS-AQ instrument deployment has been established in South Korea, Japan, and China from 1 April to 31 July 2016. The network will be strategically located to take advantage of KORUS-AQ in situ and airborne resources from mid-June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

# Aerosols and More

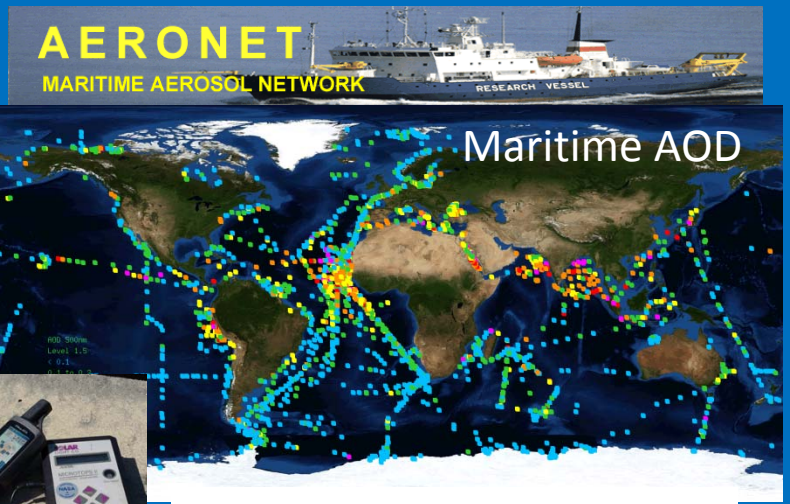




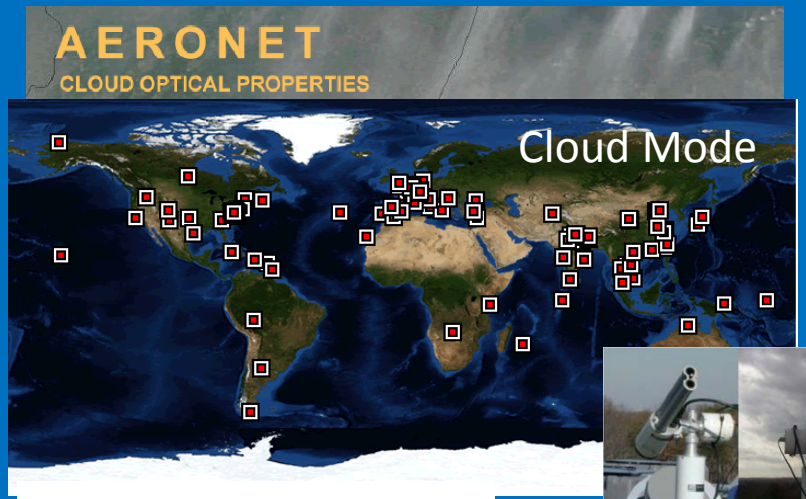

Zibordi et al. [2009], JAOT



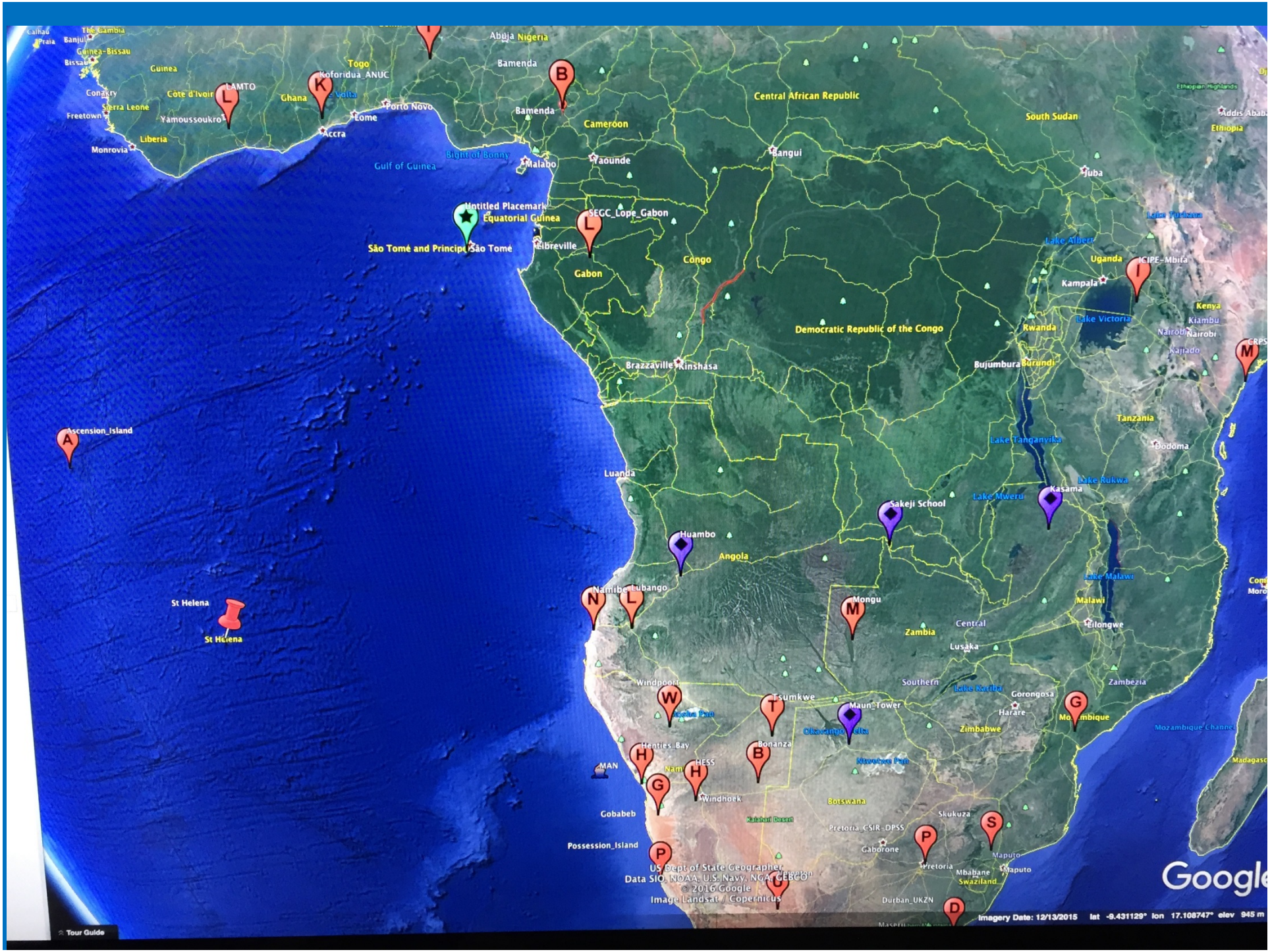

Schafer et al. [2004], JGR




Smirnov et al. [2009], JGR




Chiu et al. [2010], JGR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