AERONET Version 3
Aerosol Optical Depth and Inversion Products

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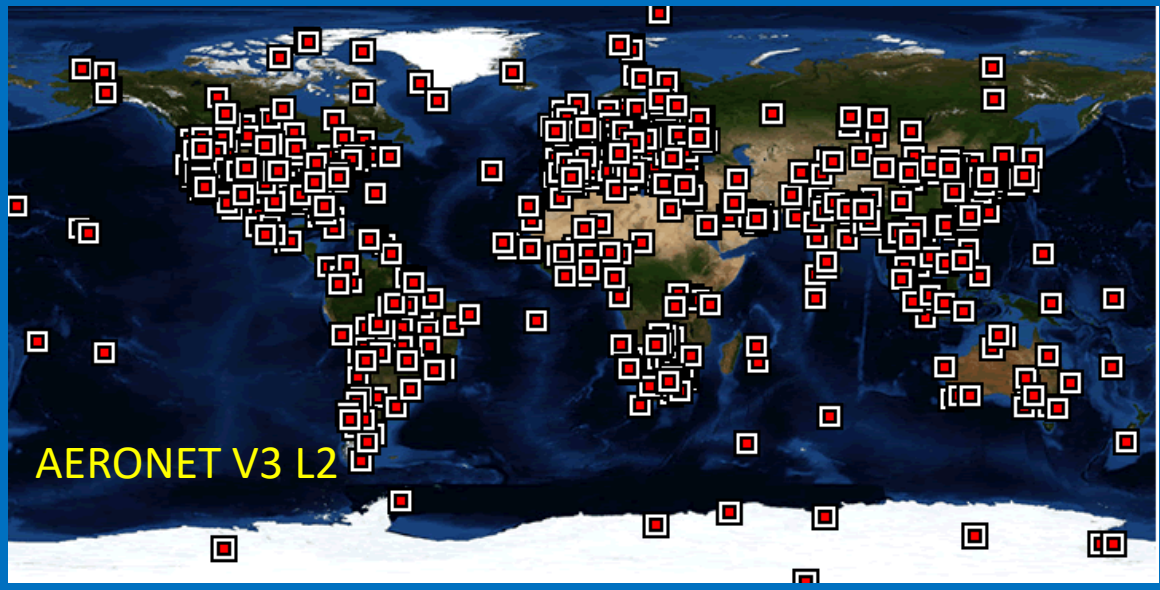
E-Poster Presentation

AeroCenter Poster Bash

February 1, 2018

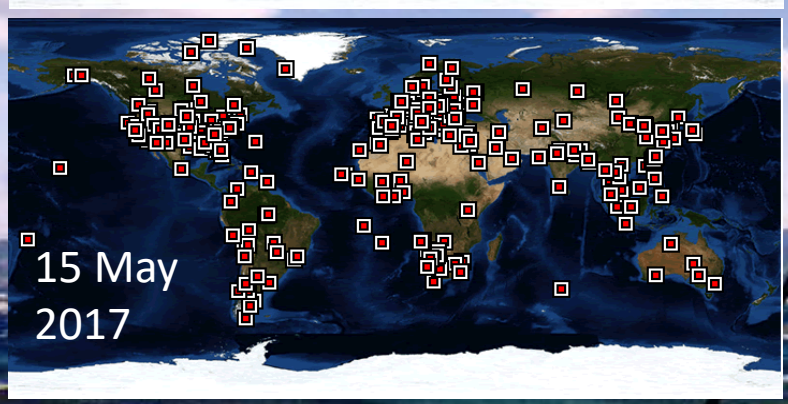
Outline

- Need for Higher Quality NRT Observations
- V3 AOD Cloud Screening and Quality Control Improvements
- V3 AOD Assessment
- Version 3 Inversion Updates and Improvements
- Quality Assured Data Release



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

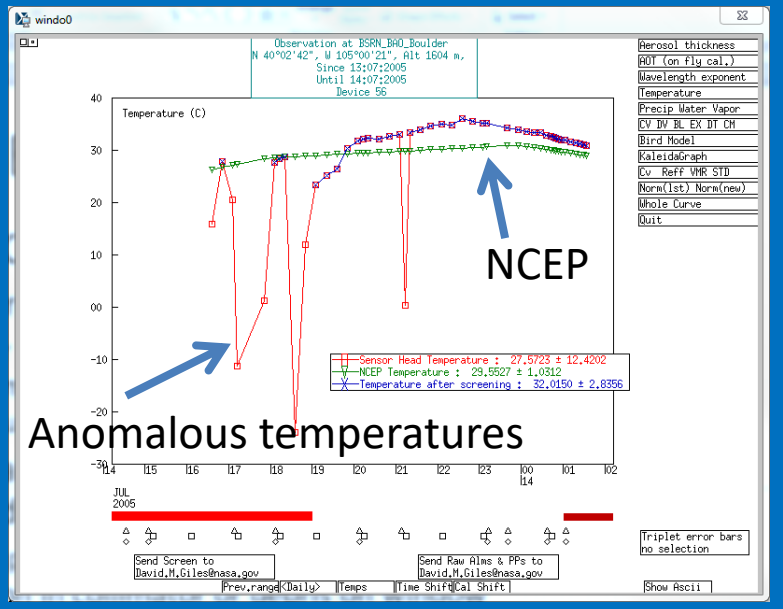
Multi-Platform Need for Near Real-time Aerosol Observations

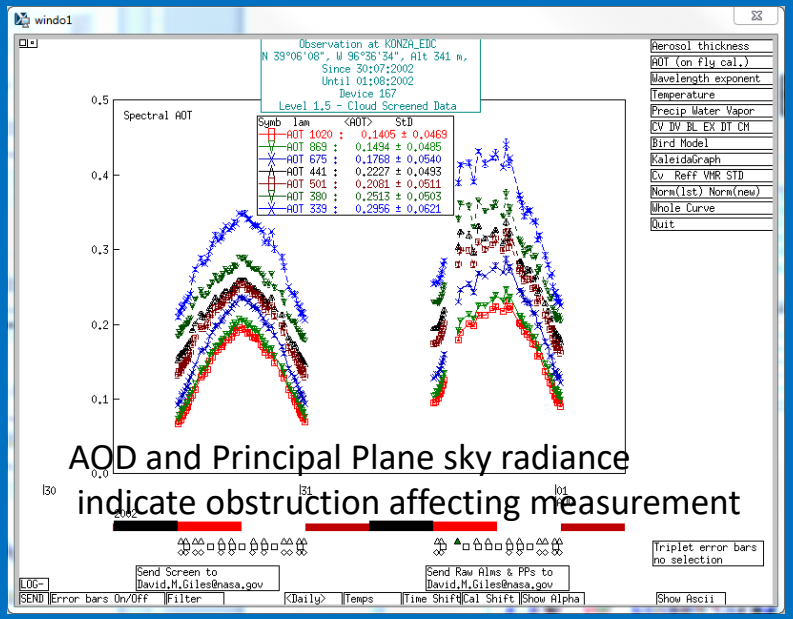
- Polar Orbiting and Geostationary Satellites
  - *VIIRS, MODIS, MISR, OMI, GOES, Himawari-8, Sentinel 3, GOCI*
- Surface-based Instrumentation
  - *MPLNET, SPARTANS, GreenNet*
- Aerosol Forecasts, Assimilation, and Reanalysis
  - *ICAP, GOCART, NAAPS, MERRA-2*
- Weather Prediction Models
  - *NCEP, 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 and Ozone OMI L3 climatology (2004-2013)
  - Applies updated absorption coefficients (Literature/HITRAN)
- **V3 Level 1.5**: Based on Level 1.0 (NRT)
  - **Improved cloud screening**
  - **New quality controls applied**
- **V3 Level 2.0**: Based on Level 1.5 with pre- and post-calibration and temperature characterization applied
  - Level 2.0 data quality confirmed during post-field calibration evaluation and released 30 days afterwards to allow for updates to ancillary databases
  - **Significantly improves timeliness of Level 2.0 data availability**

- Giles et al. 2018, in preparation
- AERONET Version 3 AOD Algorithm Quality Control Technical Description (2018)





V2 vs. V3 Cloud Screening

Algorithm/Parameter	Version 2	Version 3
Very High AOD Restoration	N/A	τ870 >0.5; α675-1020>1.2 or α870-1020>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*τ_a}	λ=675,870,1020nm AOD range > MAX{0.01 or 0.015*τ_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 τ_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 (2018)

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 for first point, 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 τ_a points will be removed in the ±30 minutes period from sky measurement. For CCS, all τ_a points will be removed ±2 minutes period.
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

Slope of Curvature

- **Input:**
  - **Natural logarithm of Scattering Angles (Φ) between 3.2° and 6°**
  - **Natural logarithm of Radiances (R) (uW/cm^2/sr/nm) for 1020nm**
  - **Must be more than 3 scattering angles (usually 4 or 5)**

- **Perform linear regression fit (ln R vs ln Φ) and determine the intercept (A) and slope (b) when correlation coefficient >0.99**

Curvature of Aureole Radiances

- **The curvature (K) at the first Φ is the defined by**

$$K = \frac{y''}{(1 + y'^2)^{3/2}}$$

- **y = A * Φ^b : power law function**
- **y' = A * b * Φ^{b-1}**
- **y'' = A * b * (b-1) * Φ^{b-2}**

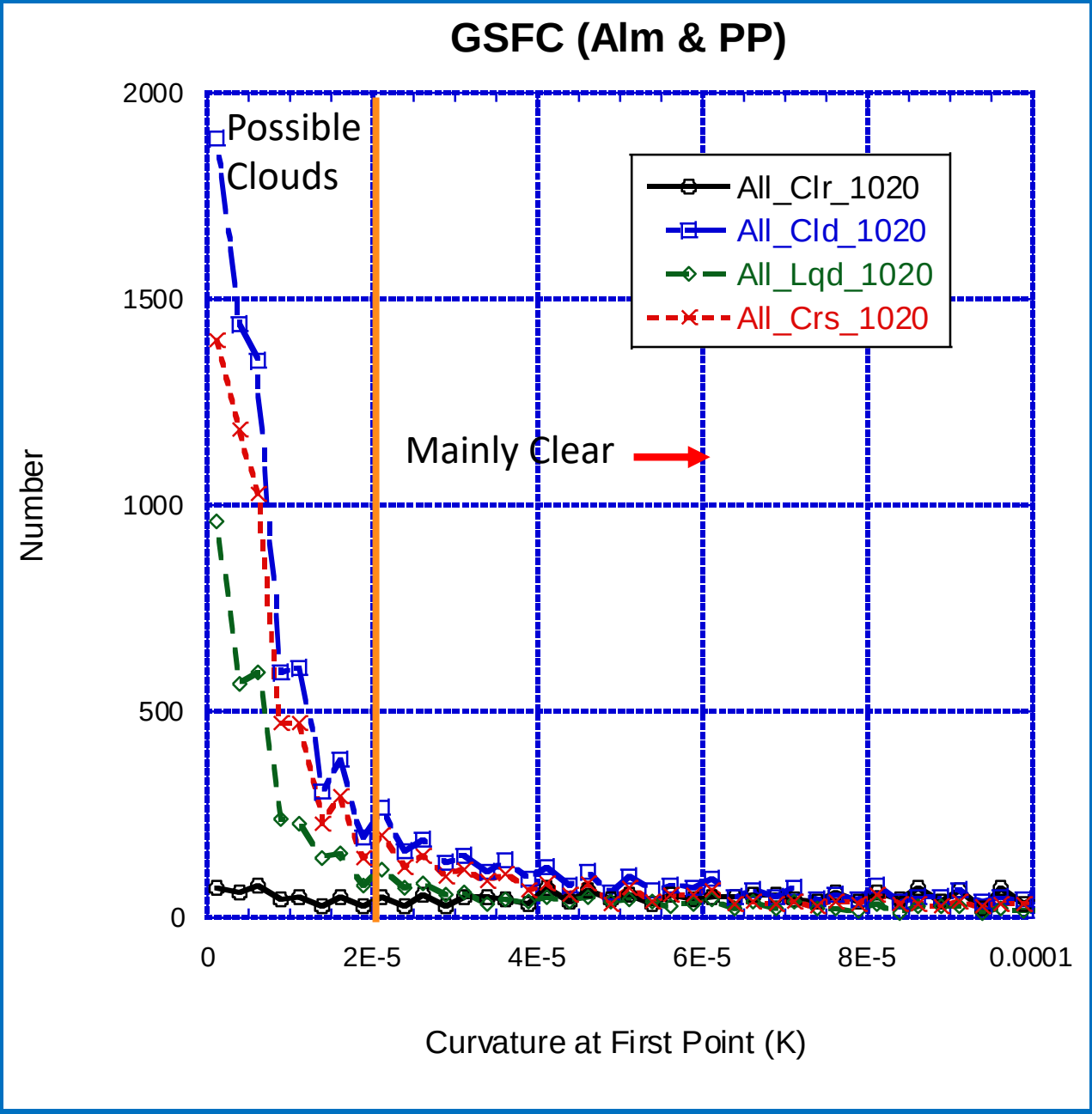
- **Calculate slope of curvature (M) assuming y'^2 >>1:**

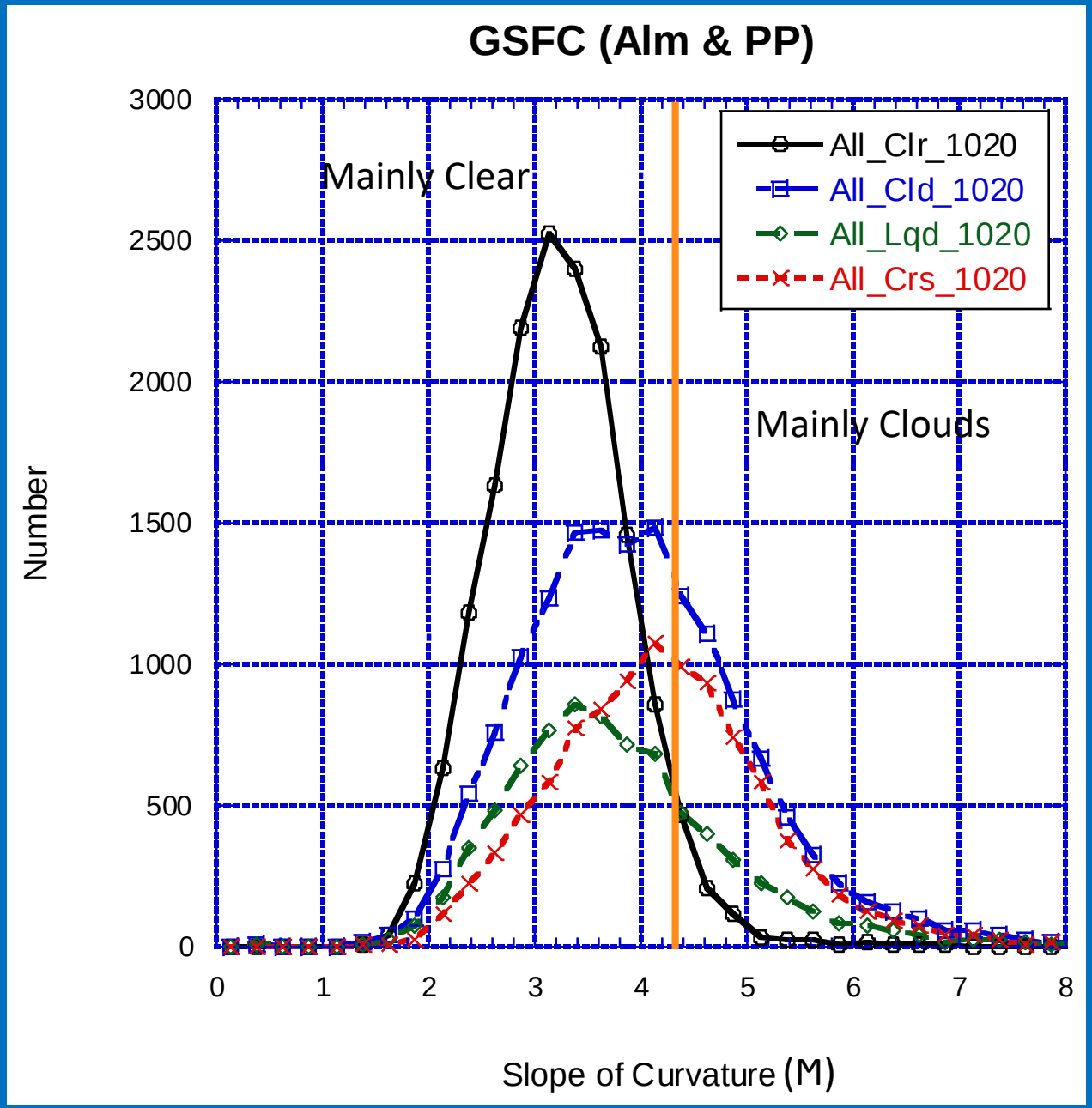
M = 1 – 2b

Lidar-Assisted Empirically Derived Curvature Coefficients

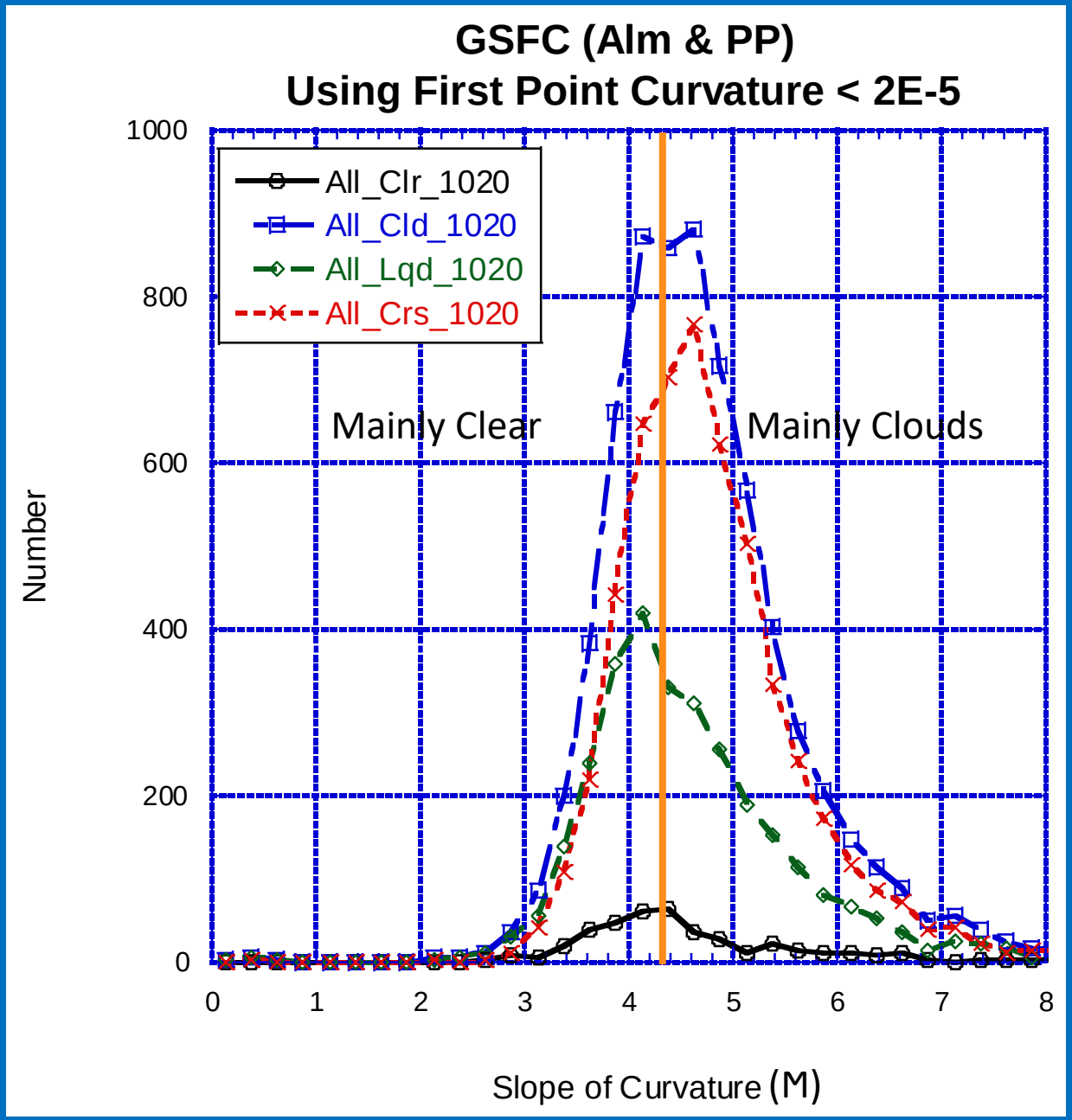
- **K < 2E-5 indicates increased probability of coarse particles**
- **M > 4.3 indicates increased probability of coarse particles**
- **Combining these two thresholds provides a much better assessment of cloud presence**
- **Utilized MPLNET LIDAR database (8 sites) cirrus and liquid cloud identification**
  - **LIDAR cloud base height corresponding to MERRA geopotential height temperature <-37°C designated as cirrus**
  - **Coincident with AERONET to determine cloud phase and determine thresholds up to 30° solar zenith angle**

MPLNET Data Acknowledgement: James Campbell, Jasper Lewis, Judd Welton

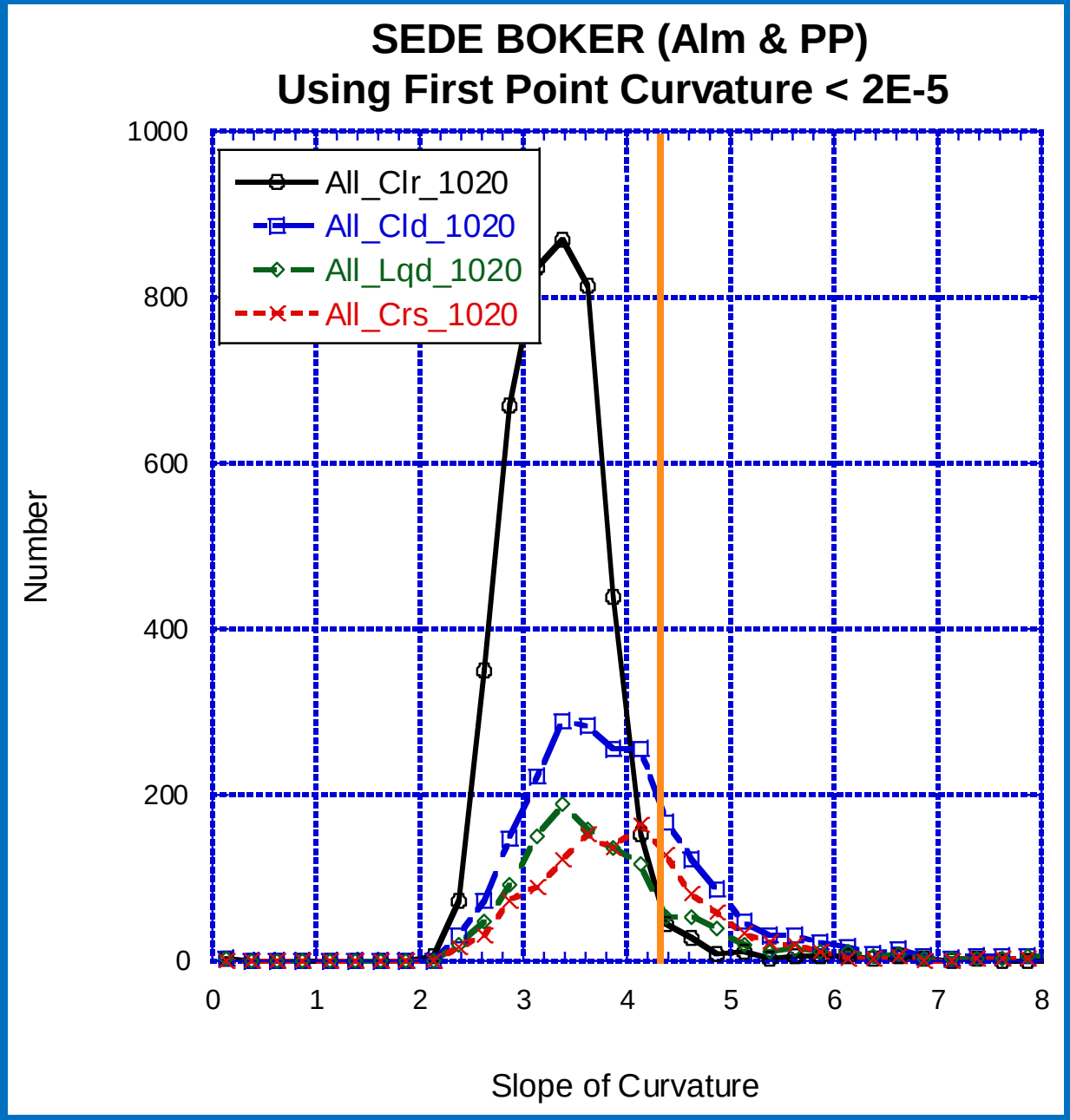

GSFC (Alm & PP)
Possible Clouds
Mainly Clear
All_Clr_1020
All_Cld_1020
All_Lqd_1020
All_Crs_1020
Number
2000
1500
1000
500
0
0
2E-5
4E-5
6E-5
8E-5
0.0001
Curvature at First Point (K)



All Slope of Curvature Points without K 2E-5 threshold

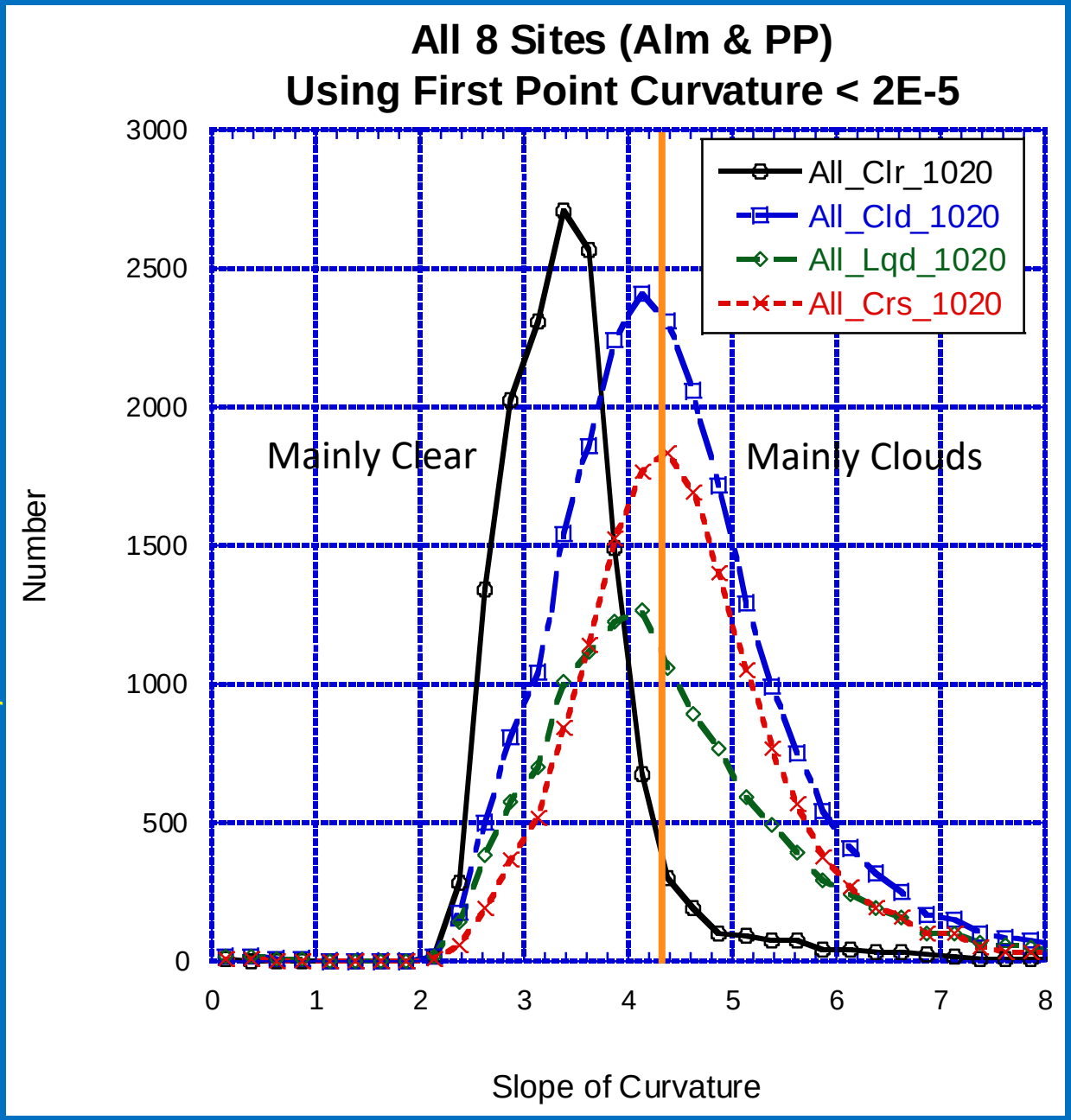


All Slope of Curvature Points with 2E-5 threshold



Dusty site also shows distinction between clear and cirrus

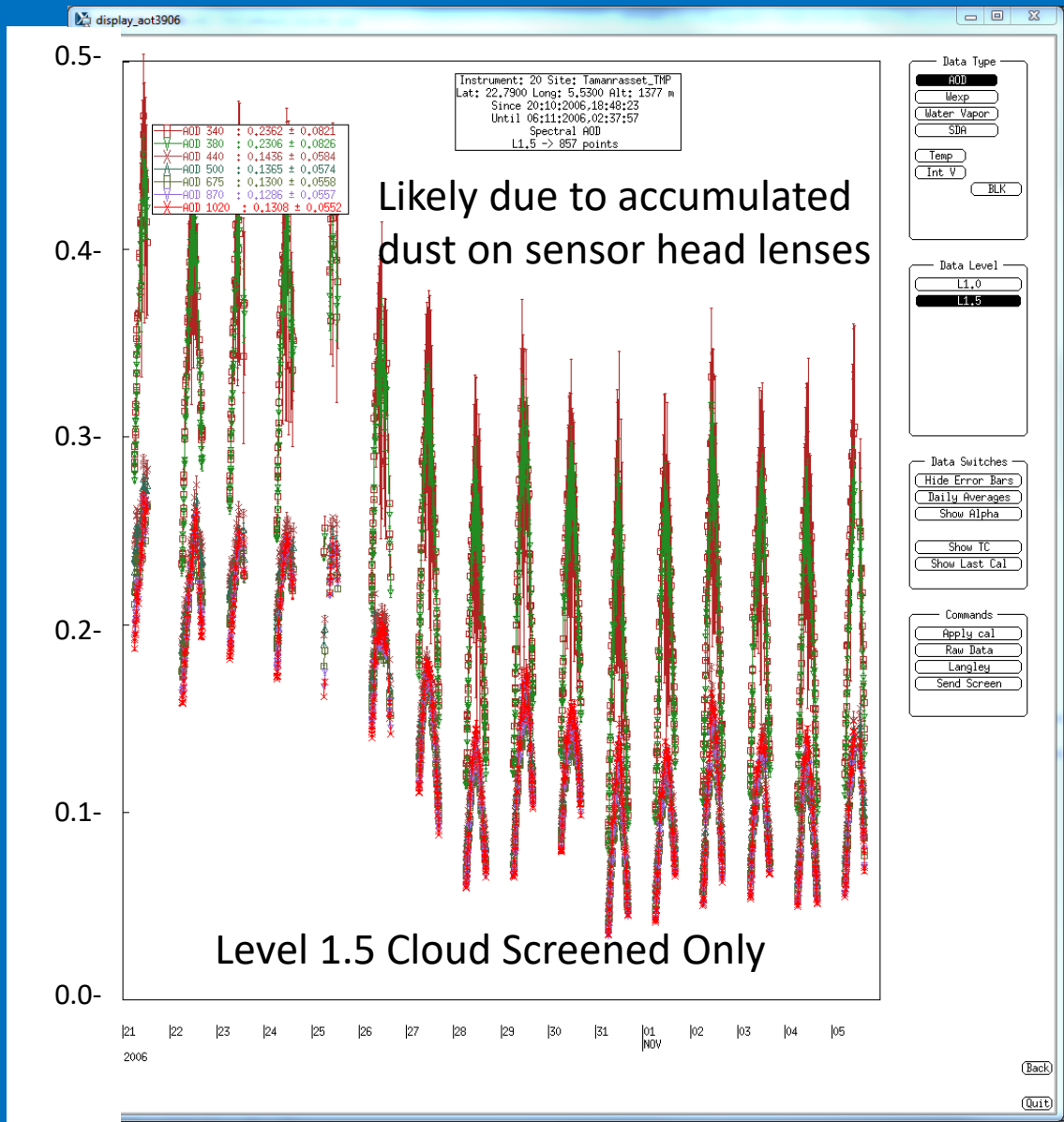
Note:
Additional removal of data ±30 minutes of sky scan for Alm/PP/Hyb (and ±2 minutes for CCS) likely removes much more cirrus after this screening



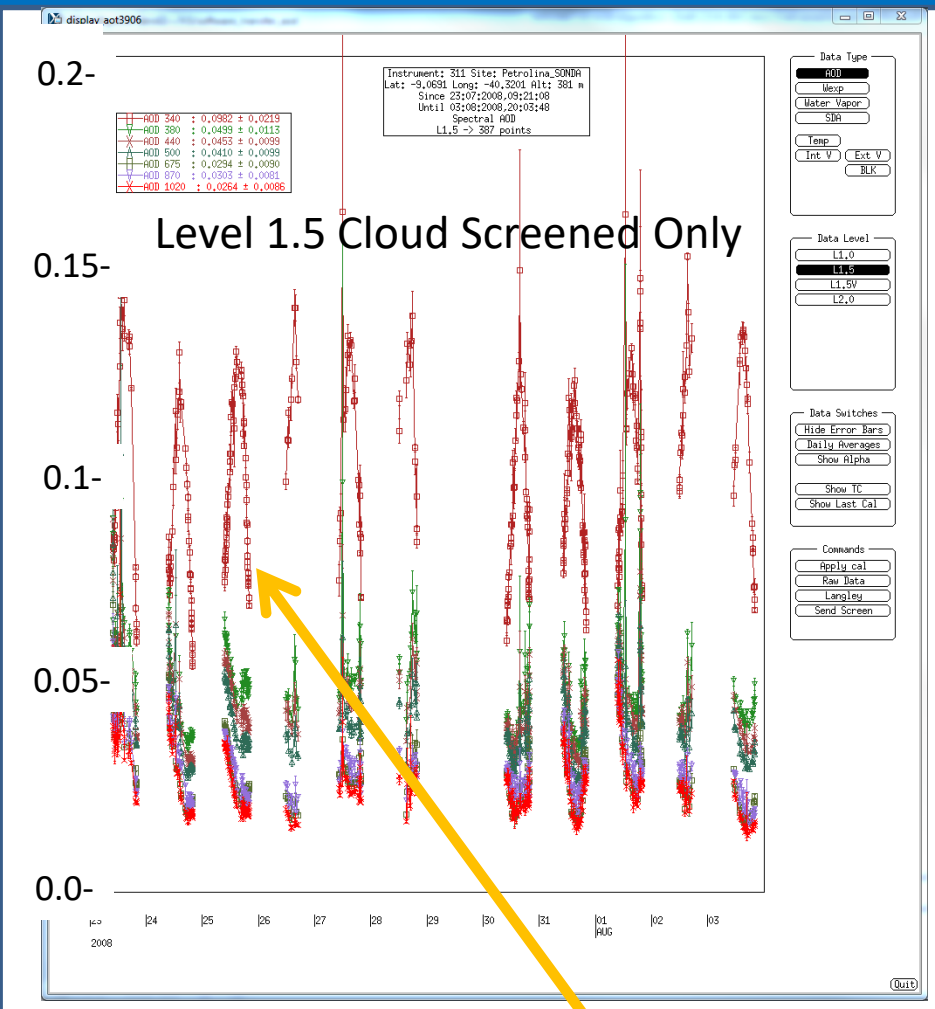
COVE, GSFC, Kanpur, SEDE_BOKER, Santa Cruz Tenerife, Singapore, Ragged Point, Trinidad Head

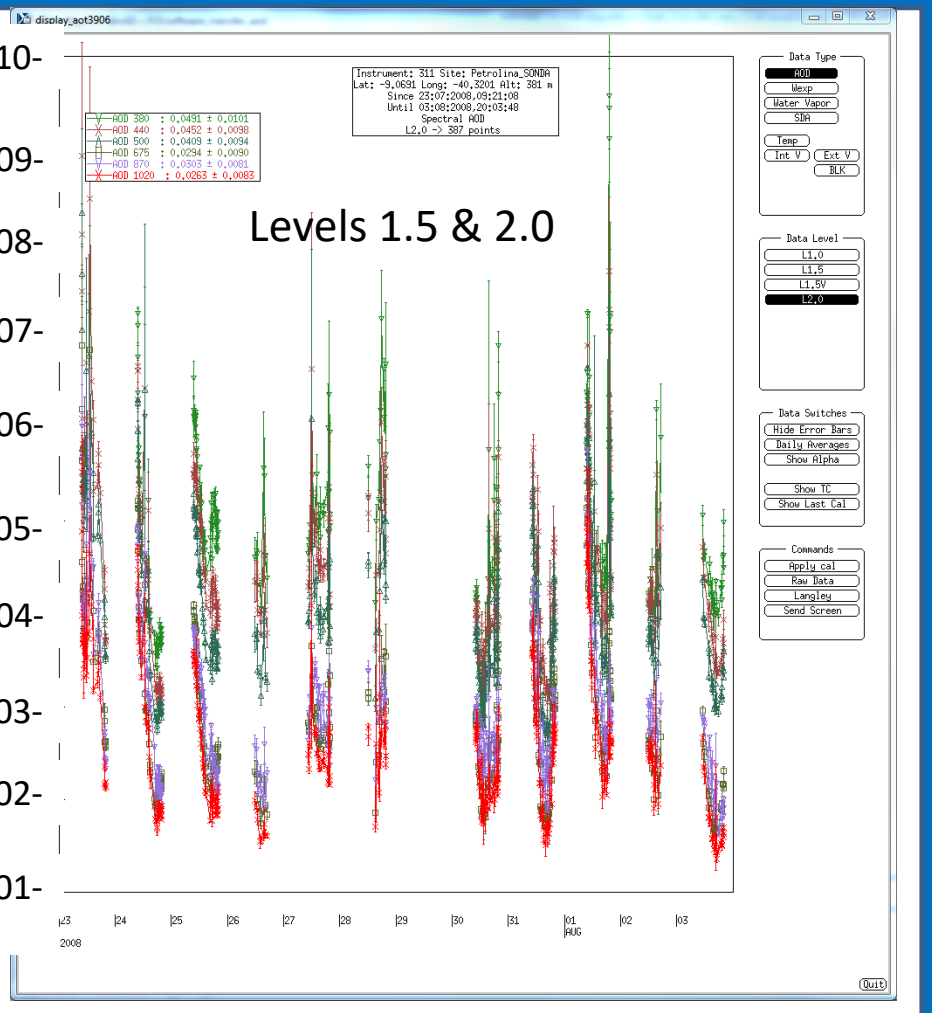
AERONET V3 L1.5 Quality Control: AOD Diurnal Dependence

- 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

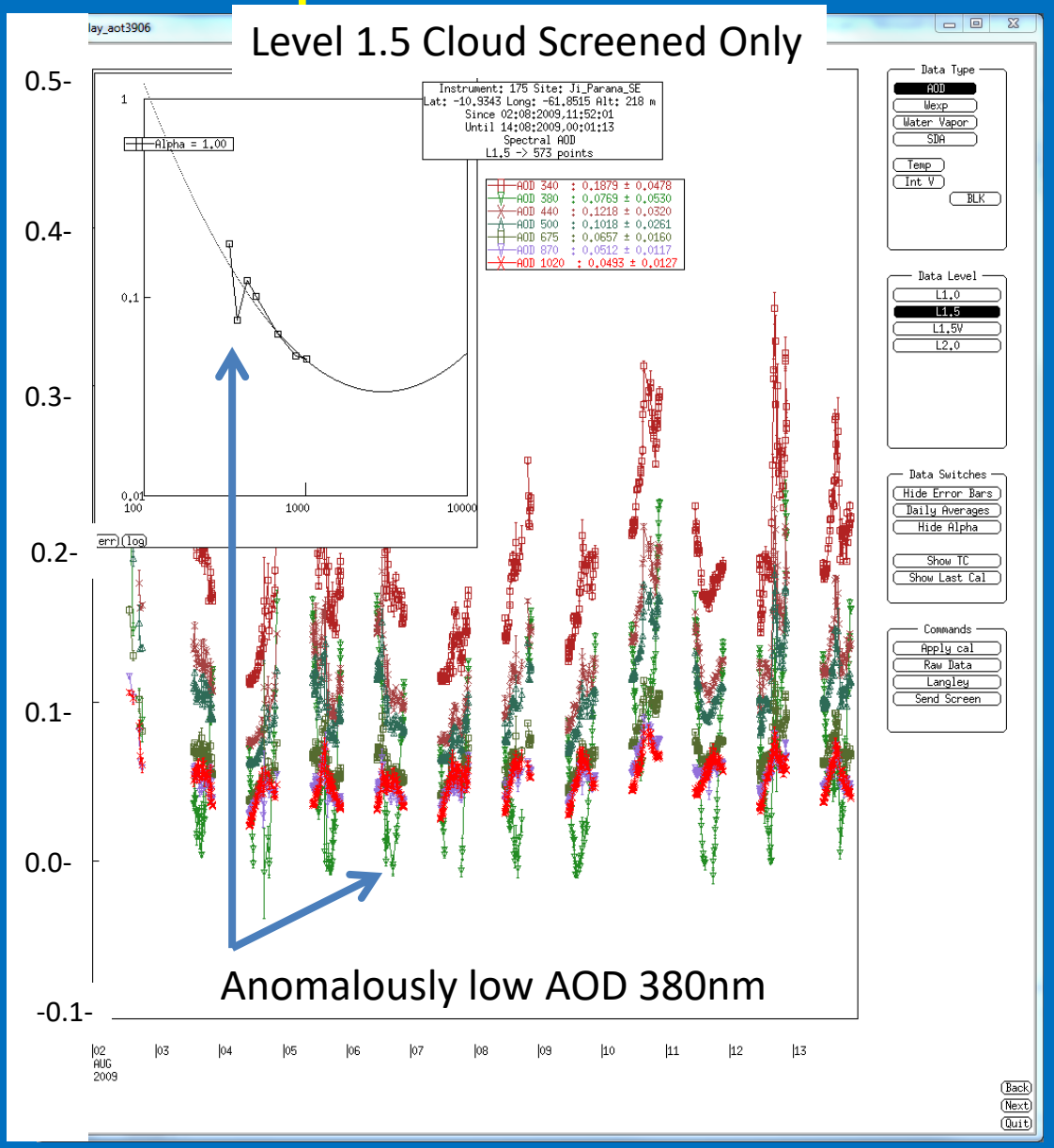




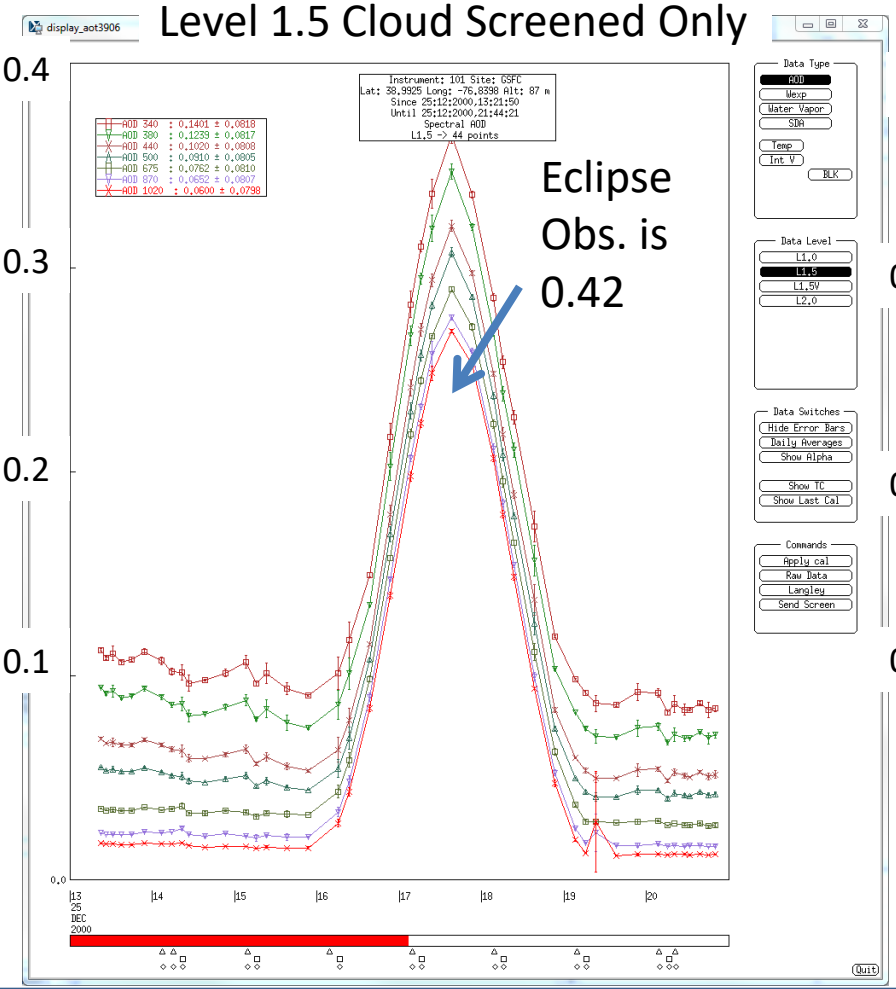
Only AOD 340nm data removed

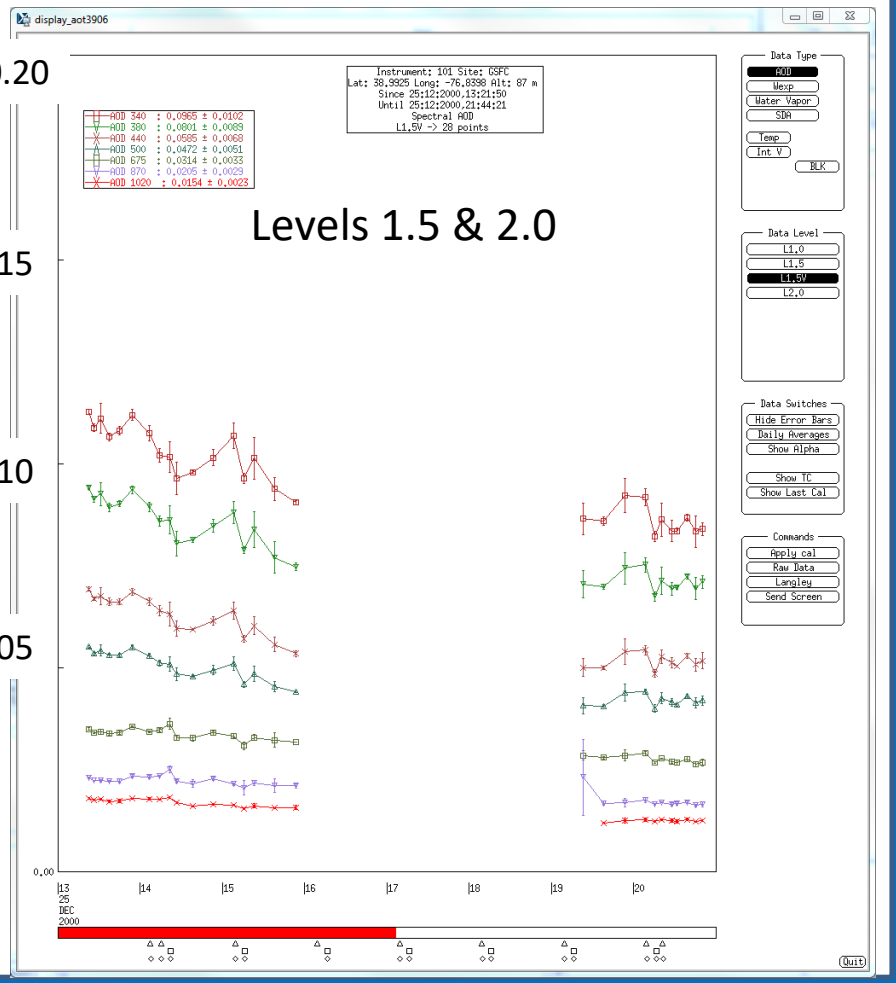
AERONET V3 L1.5 Quality Control: AOD Spectral Dependence

- 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

NRT Level 1.0 and 1.5 AOD Processing

- Data processing
  - Data are received generally within 30 minutes (often within 15 minutes) of the instrument measurement
    - A few sites delay data transmission for a week or two
  - Processing occurs last 90 days every 5 minutes (data only modified if inputs changed)
  - Full reprocessing every night (data only modified if inputs changed)
- Final NCEP pressure and temperature reanalysis fields received 3 days after initial measurements
- For some quality controls, up to 3 weeks of data from real-time are evaluated for data anomalies, which may impact data availability

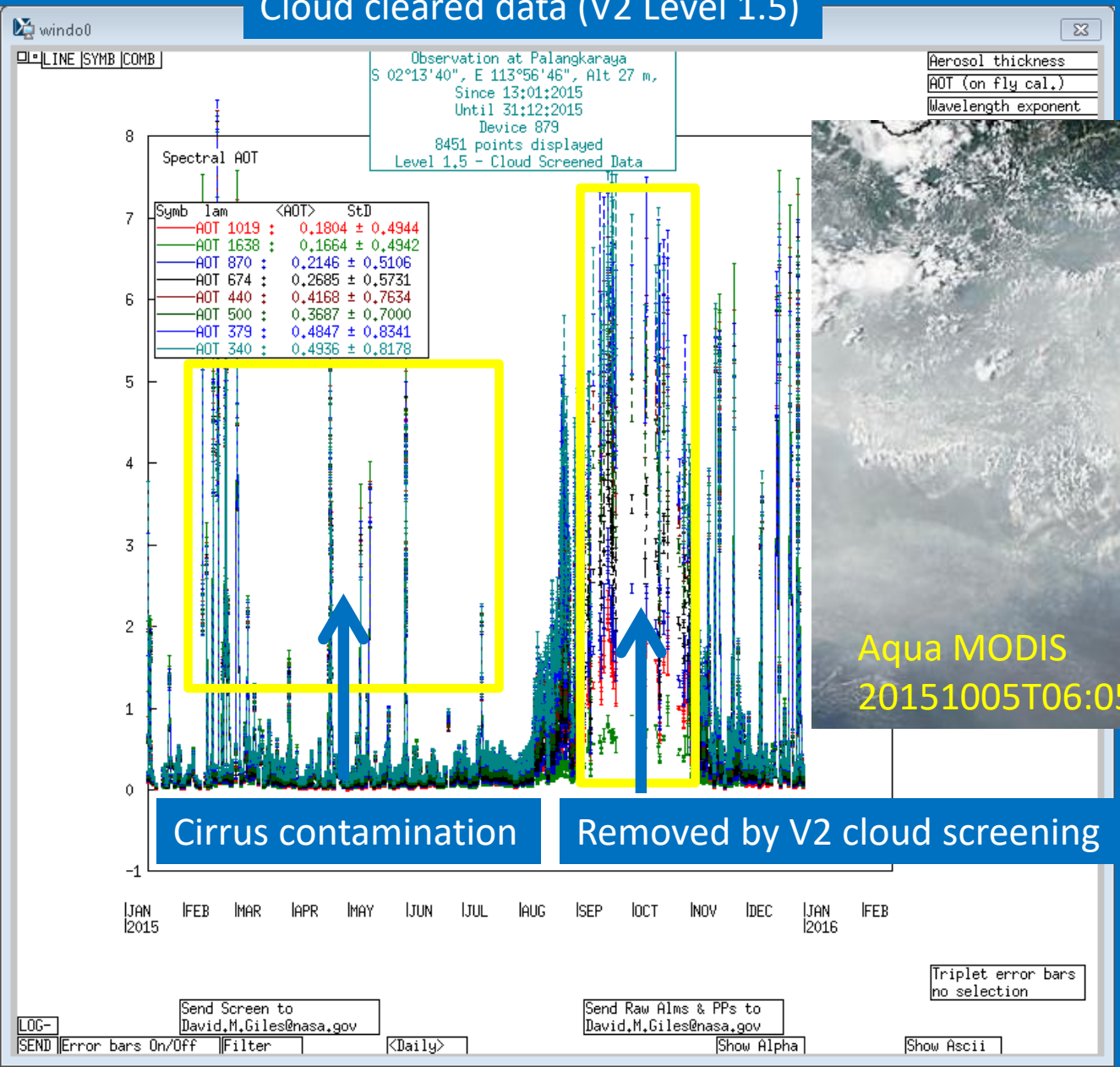
Level 2.0 AOD Processing

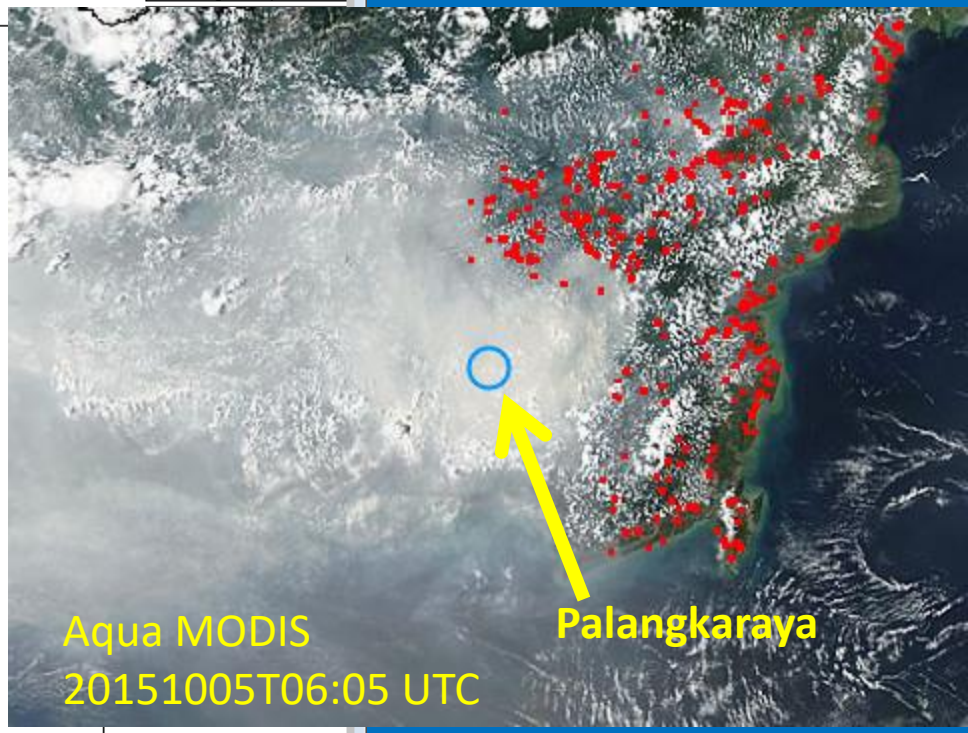
- Utilize Level 1.5 cloud screened and quality controlled data set from deployment
- After post-field calibration is applied, saved, and confirmed, data will typically be available at Level 2.0 within 30 days.
  - Delay is necessary for pre and post field calibration assessments and to ensure final ancillary data sets are updated for final processing.
  - Some data may be sequestered from Level 2.0 due to instrument calibration issues
- After 30 days from post-field calibration, Level 2.0 is generally not expected to be modified.

- Level 2.0 data should be used for publications unless an anomalous situation exists and is justified.

Indonesian Fires 2015 (Palangkaraya) – V2

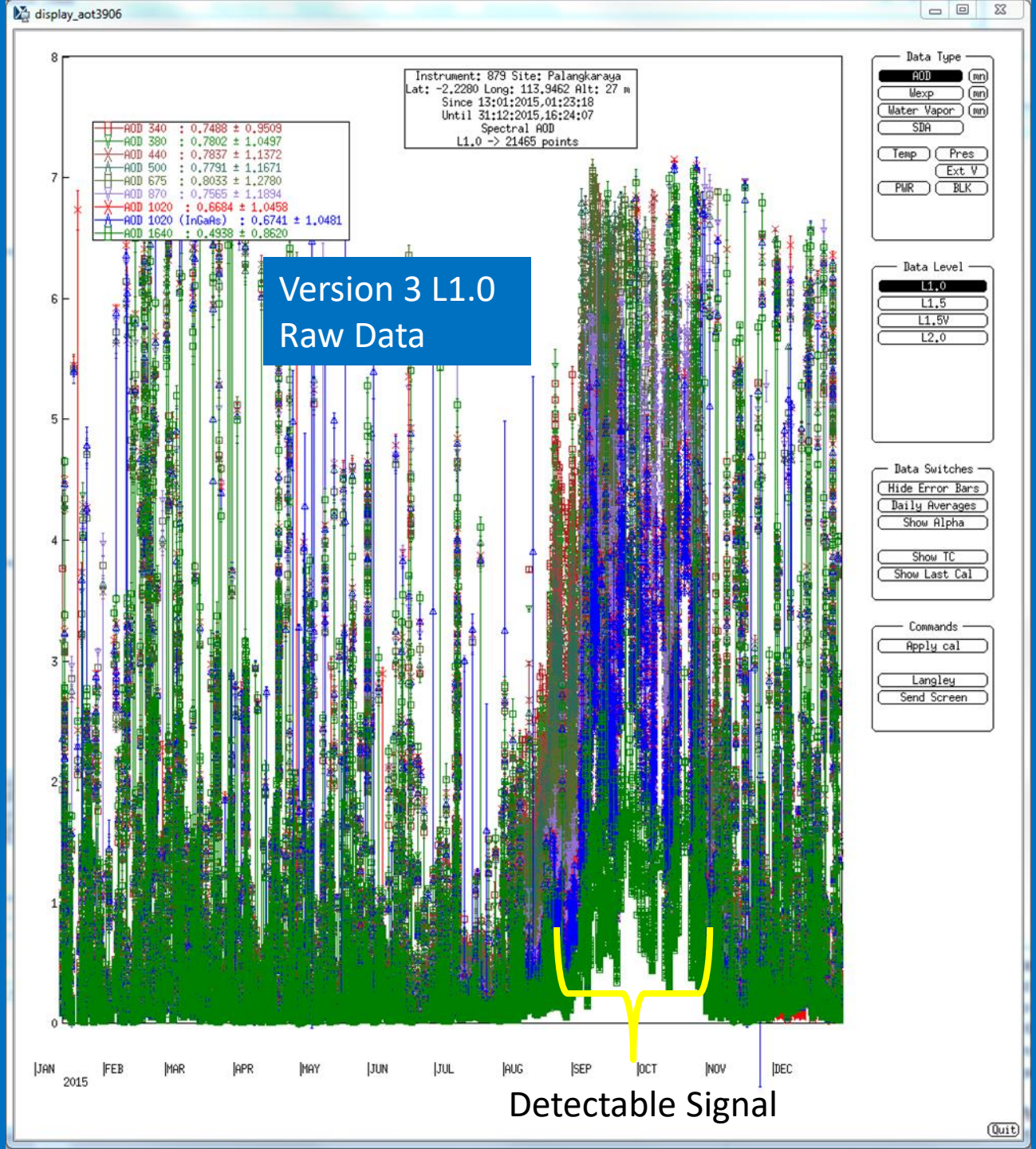
Cloud cleared data (V2 Level 1.5)

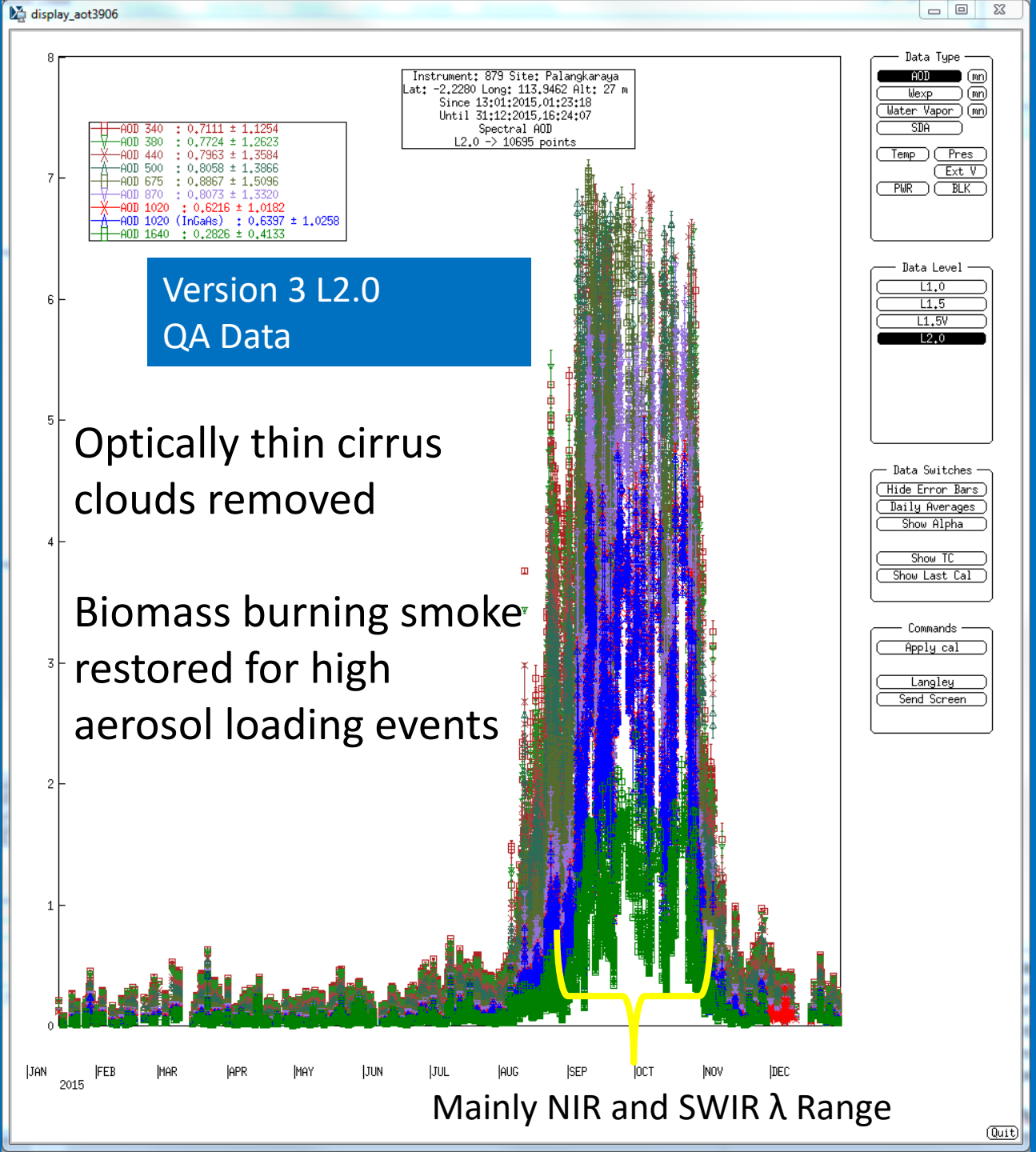




Cirrus contamination

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 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
0
1
2
3
4
5
6
7
8
JAN
2015
FEB
MAR
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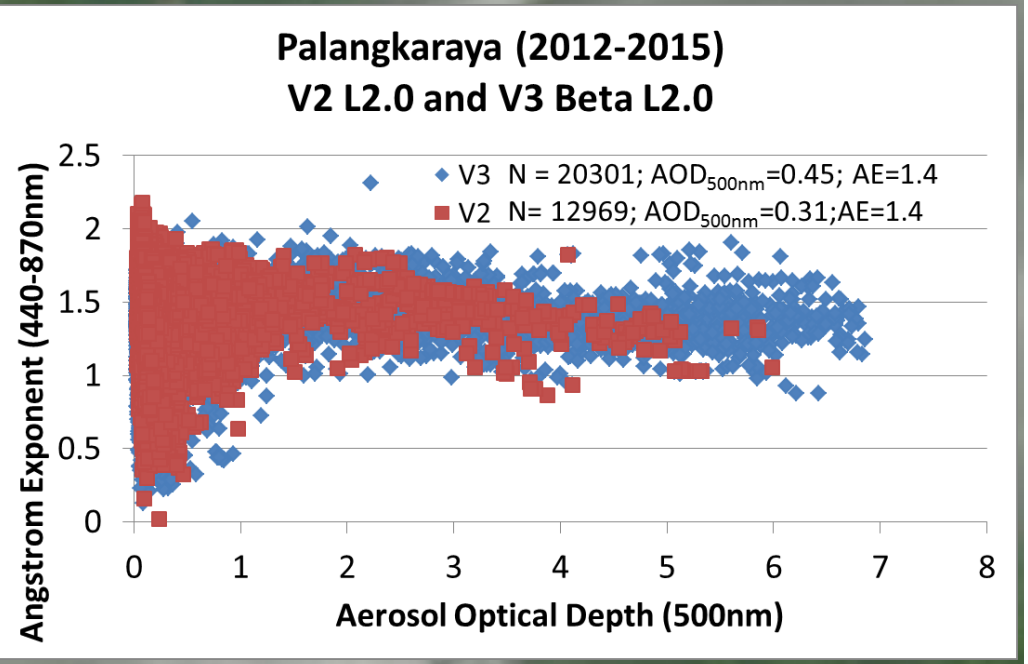
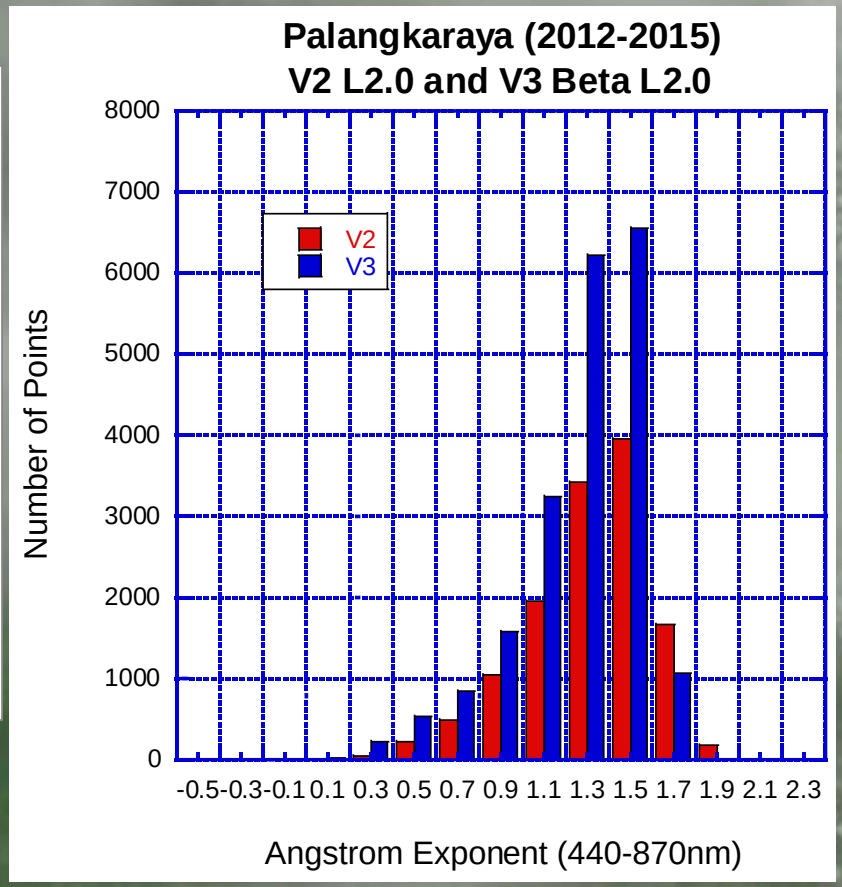
SEP
OCT
NOV
DEC

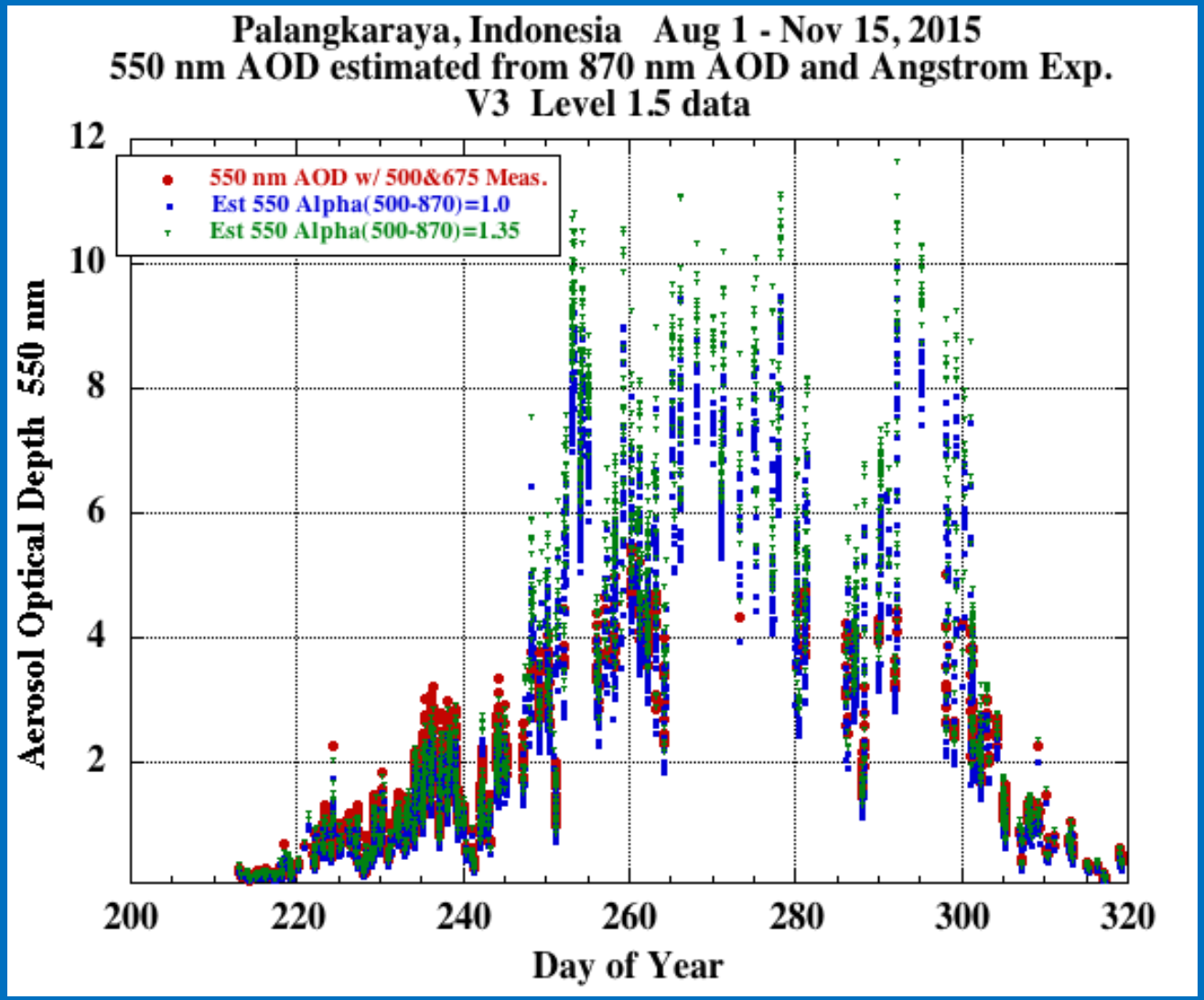
AERONET V3 L2.0 Quality Assured

Palangkaraya



More measurements overall especially for AE $\geq$ 1.0

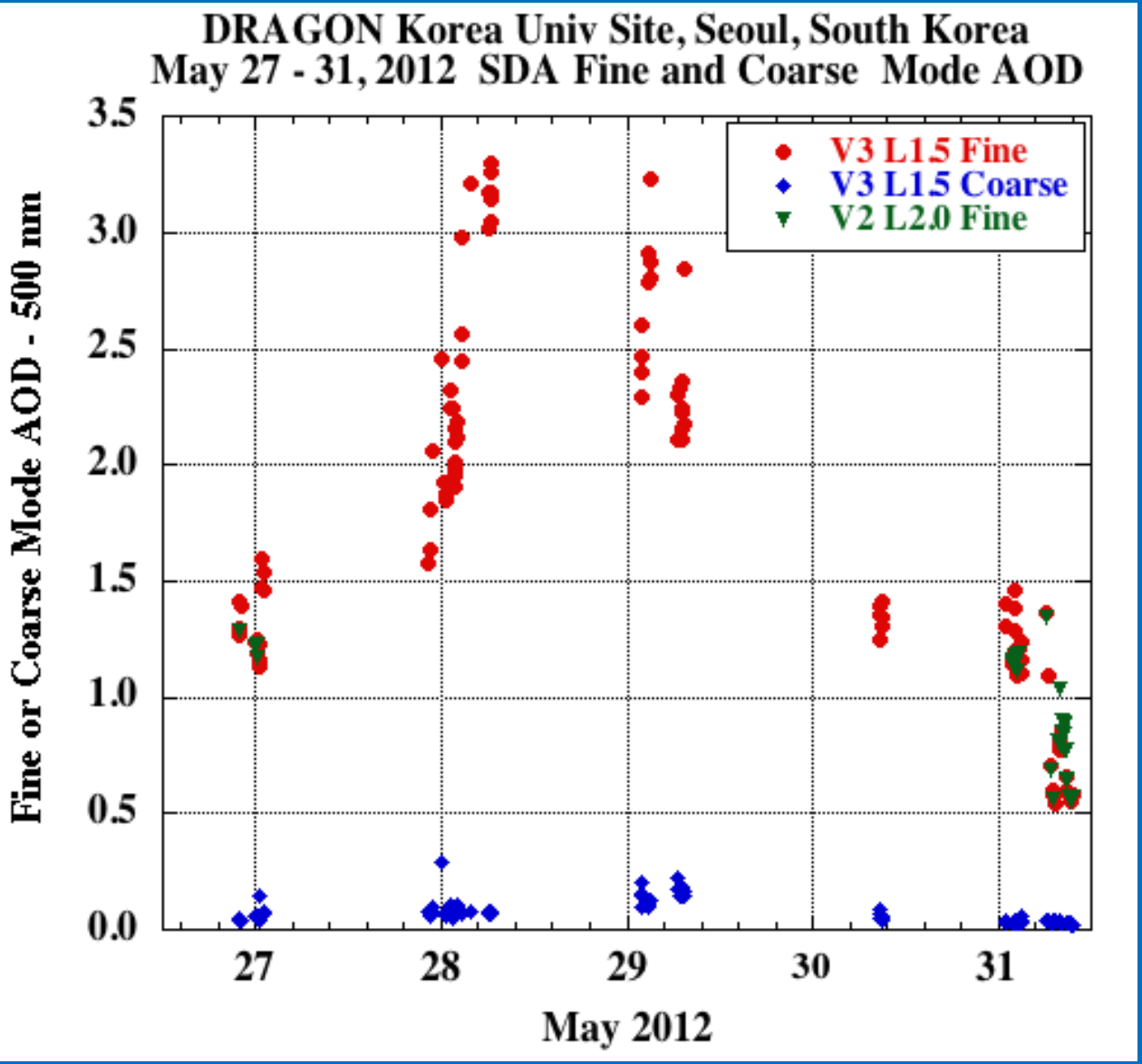




These estimated AOD levels at mid-visible exceed (to our knowledge) any values ever reported in the published literature.
This biomass-burning event in 2015 in Indonesia was the largest magnitude AOD event in terms of AOD levels ever monitored by AERONET to date, in the 24-year history of the network

Eck et al., 2018, in preparation

Seoul, S. Korea – Major 5 day pollution event from May 27-31, 2012
Version 2 Level 2 Cloud Screening eliminated 3 days – May 28-30
These 3 days are retained in Version 3 level 2 data



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 in many cases are expected to be very similar

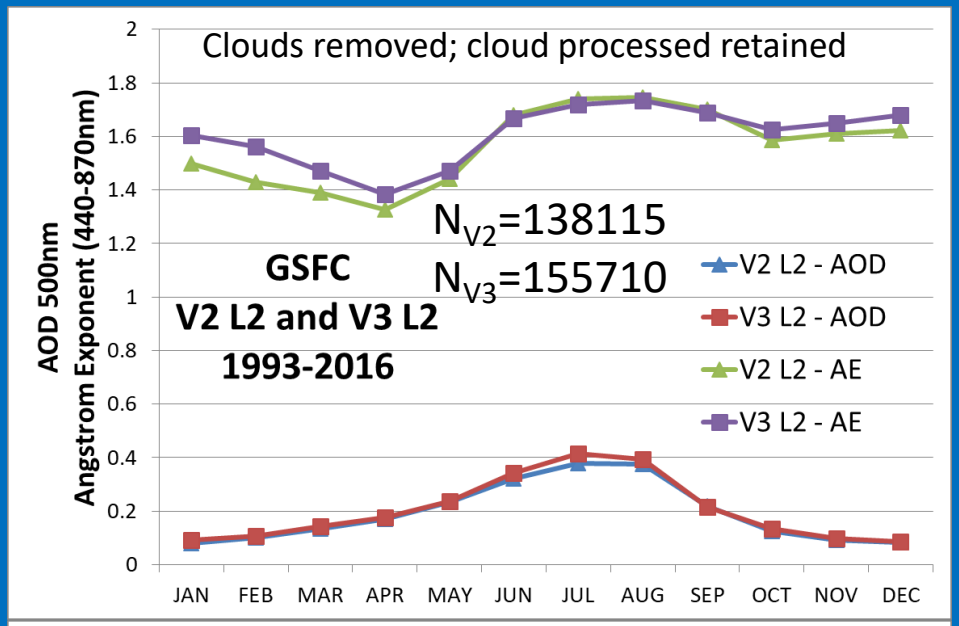
Nauru, #168, 2000-2005, 2010

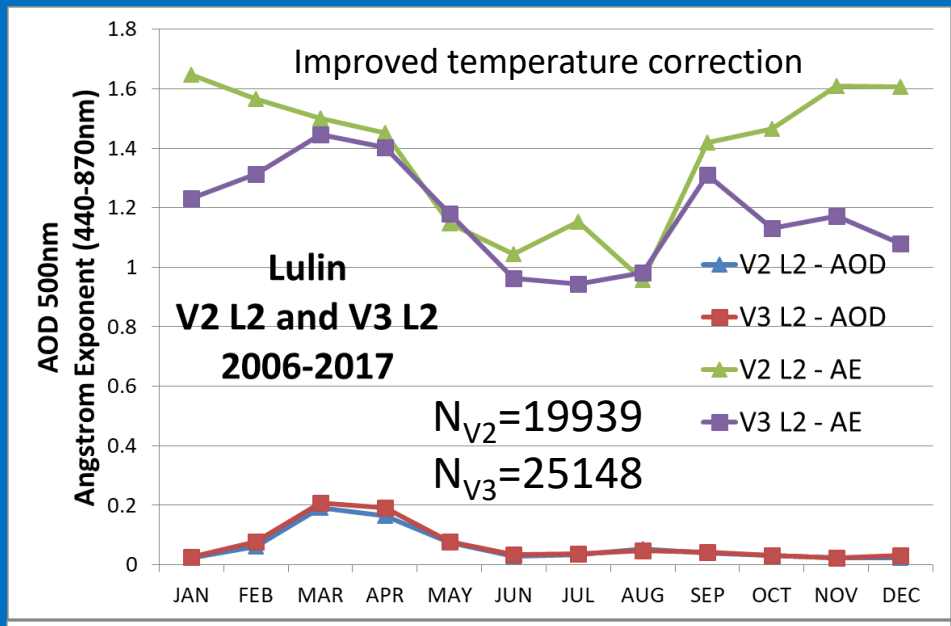
Level	N	AOD	α
V2 L1.0	25579	0.23	0.31
V2 L1.5	13326	0.11	0.47
V2 L2.0	9371	0.08	0.54
V3 L1.5 CldScr	10233	0.07	0.47
V3 L1.5	8917	0.06	0.52
V3 L2.0	8917	0.06	0.52

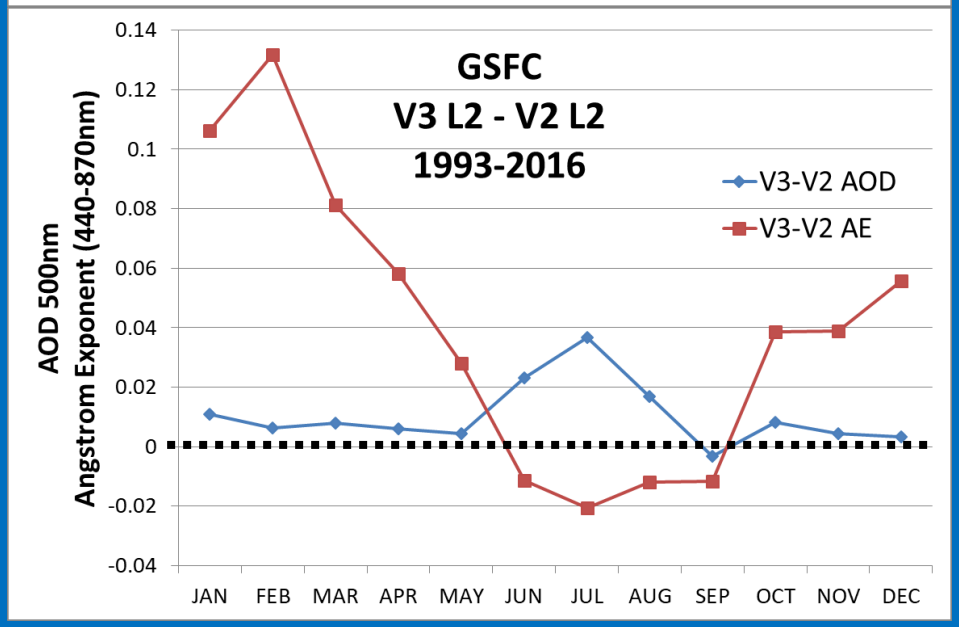
Singapore, #22, 2007-2011

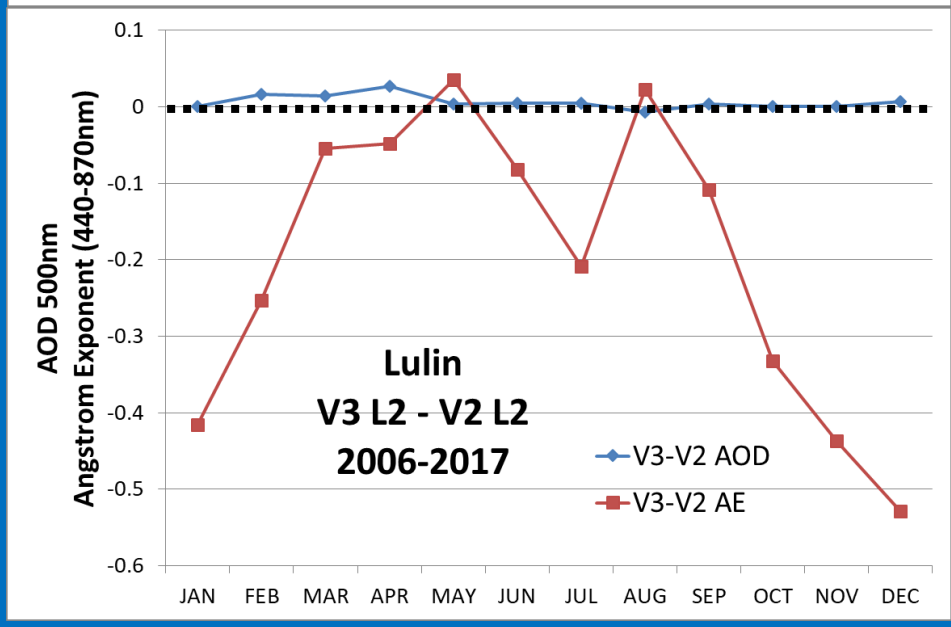
Level	N	AOD	α
V2 L1.0	25500	0.61	0.86
V2 L1.5	8680	0.46	1.03
V2 L2.0	6920	0.35	1.20
V3 L1.5 CldScr	6876	0.35	1.52
V3 L1.5	6597	0.35	1.51
V3 L2.0	6597	0.35	1.51

Climatology





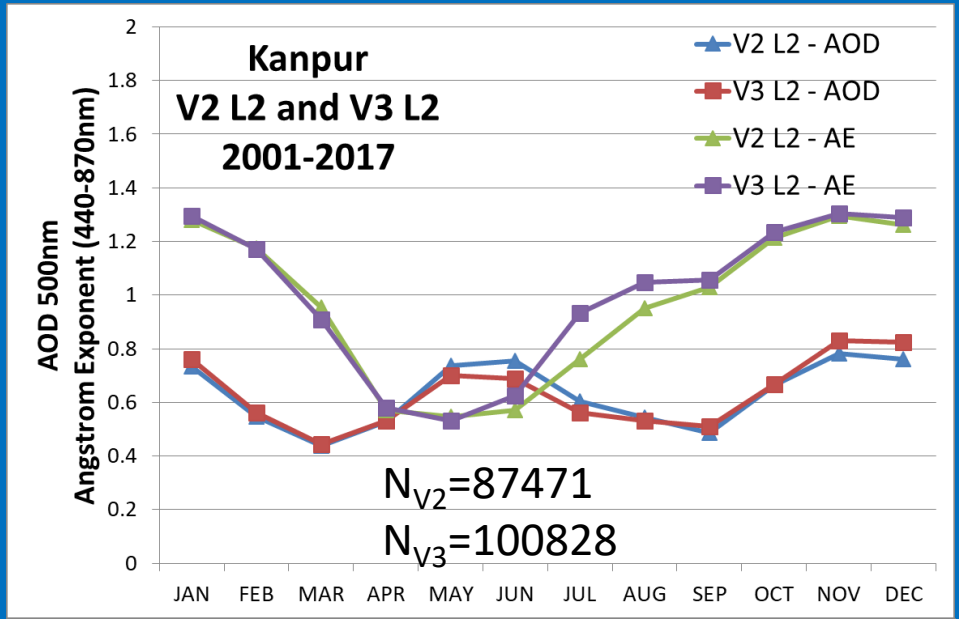


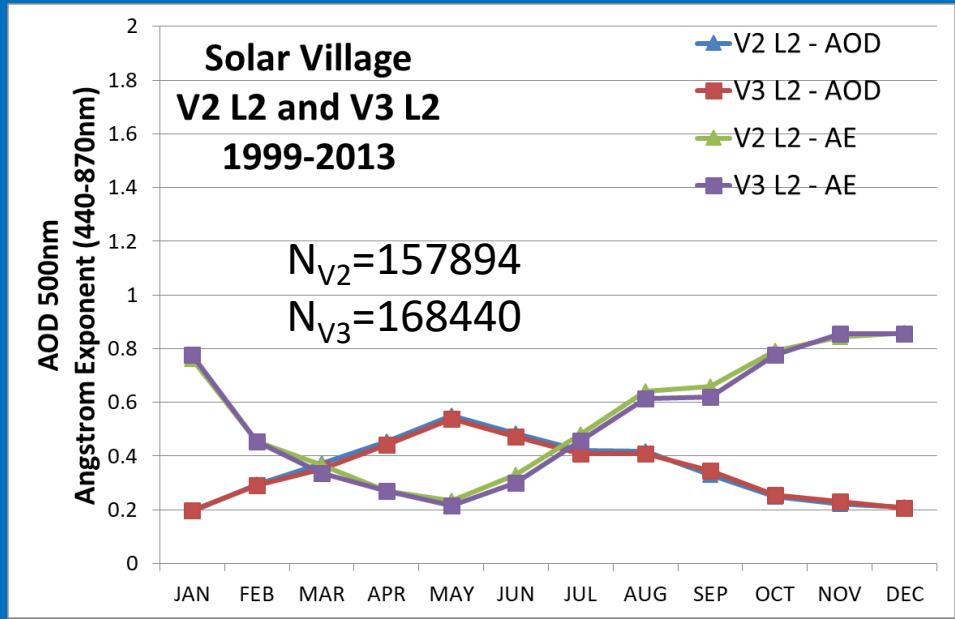


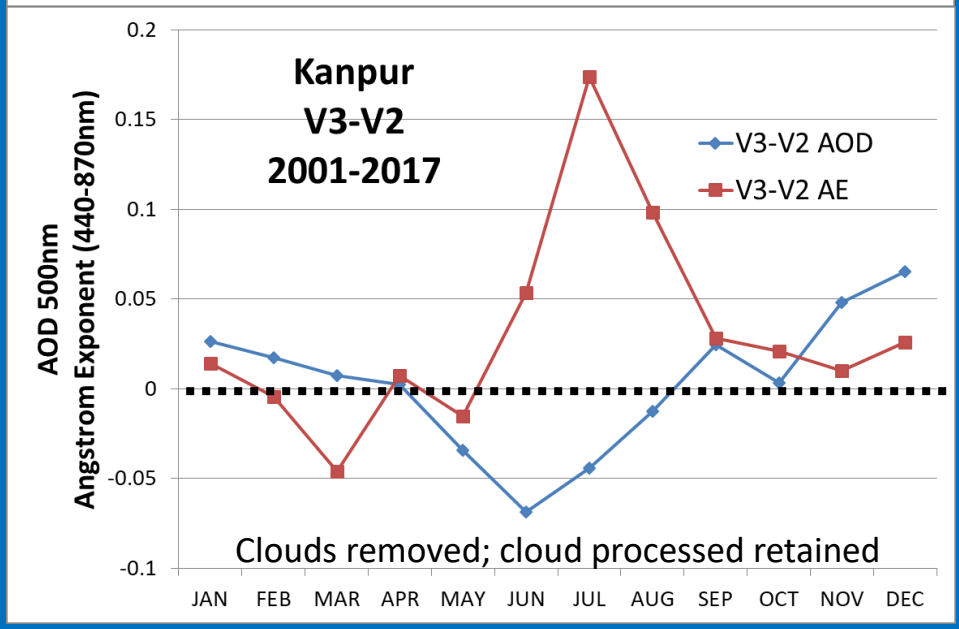
Clouds removed; cloud processed retained

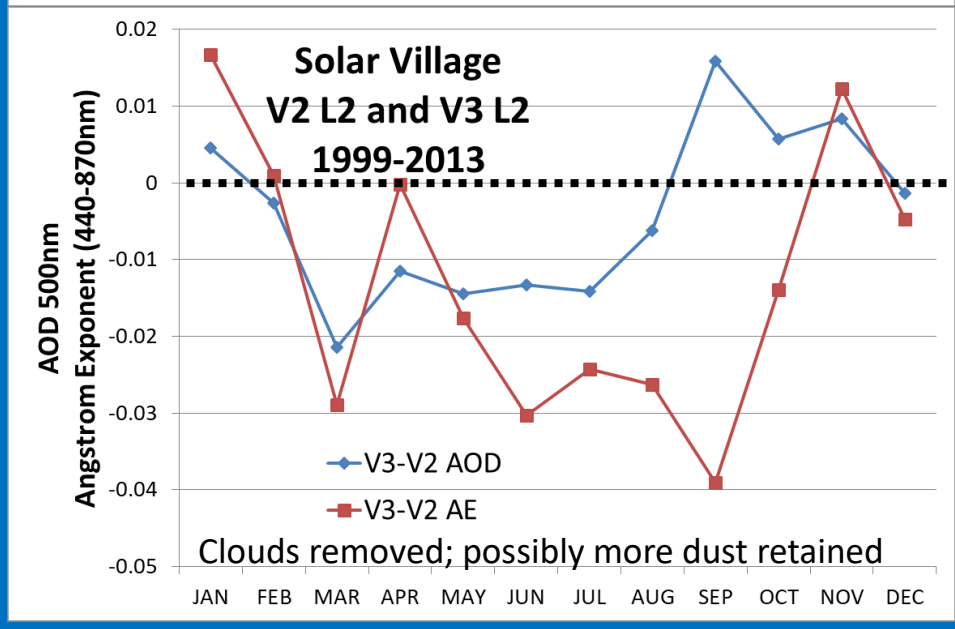
Improved temperature correction

Climatology



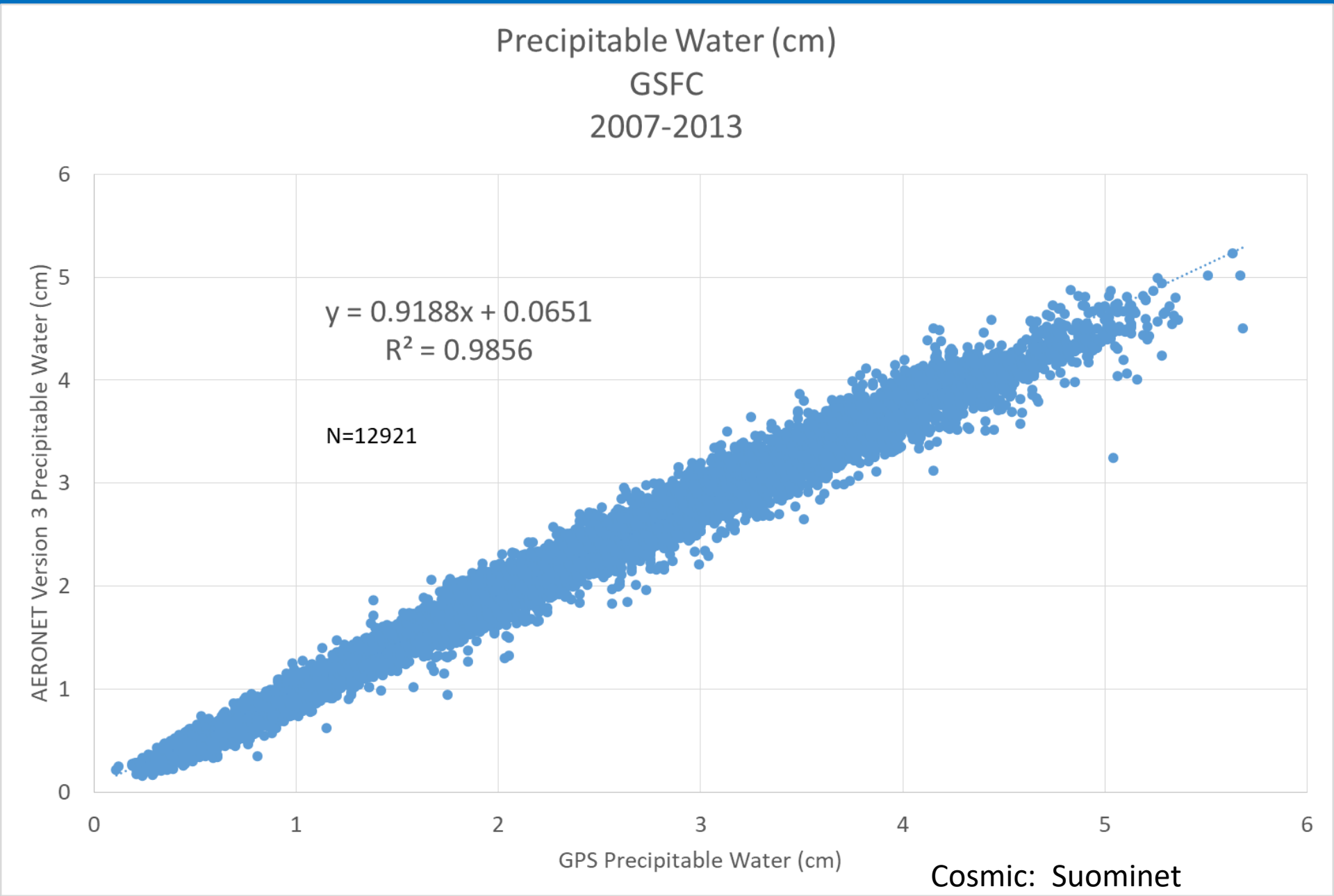






Clouds removed; cloud processed retained

Clouds removed; possibly more dust retained

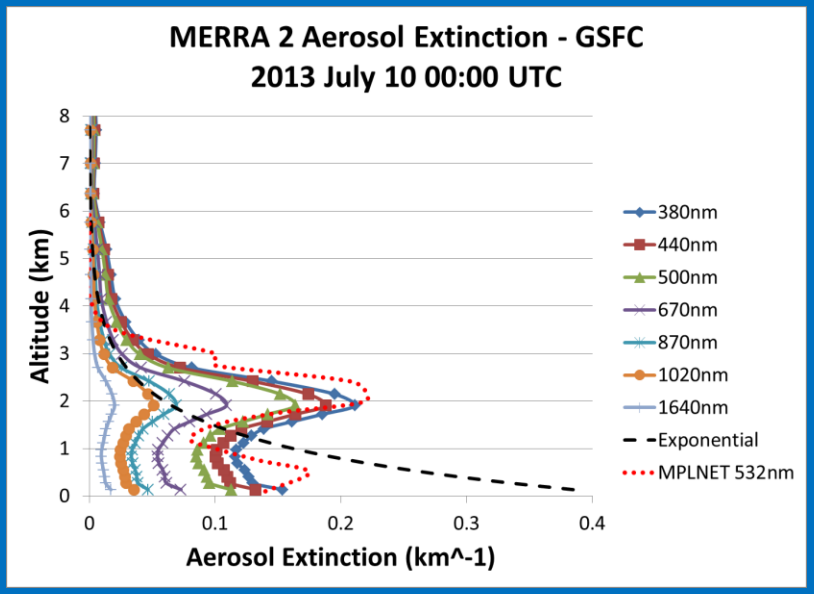


Cosmic: Suominet

Coincident within 15 minutes

AERONET Version 3 - Inversions

- MERRA-2 aerosol extinction and O_3 profiles (Randles et al., 2016; Wargan et al. 2017)
- Snow-free (with permanent snow) MODIS BRDF Gap-Filled Climatology (2003-2015) (Sun et al., 2017)
- Snow MODIS BRDF (2000-2014) (Schaaf et al., 2002; 2008; 2011)
- Full Vector radiative transfer code using Successive ORDers of scattering (SORD) (Korkin et al., 2016)
  - Radiation field in UV (e.g., 380 nm retrieval)
  - Degree of linear depolarization



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

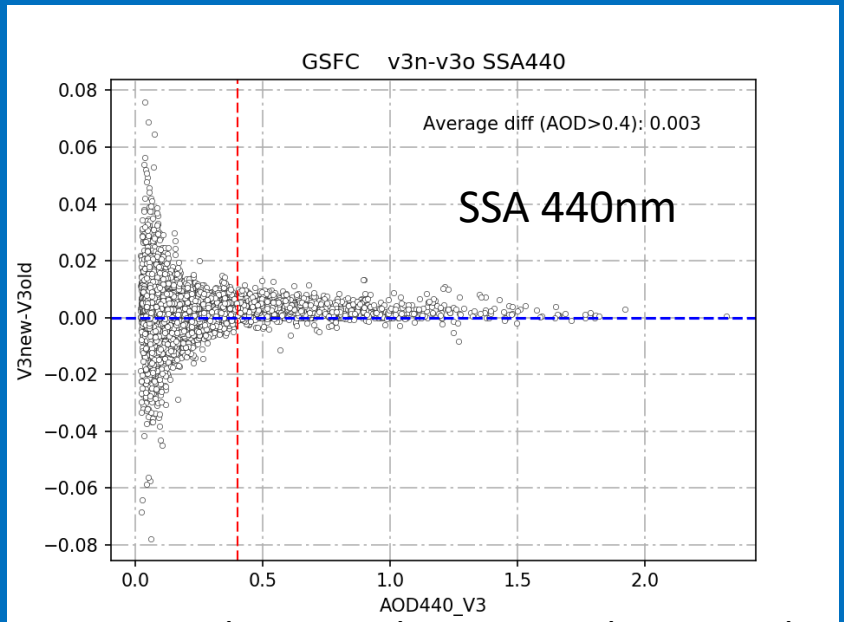
Notes

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

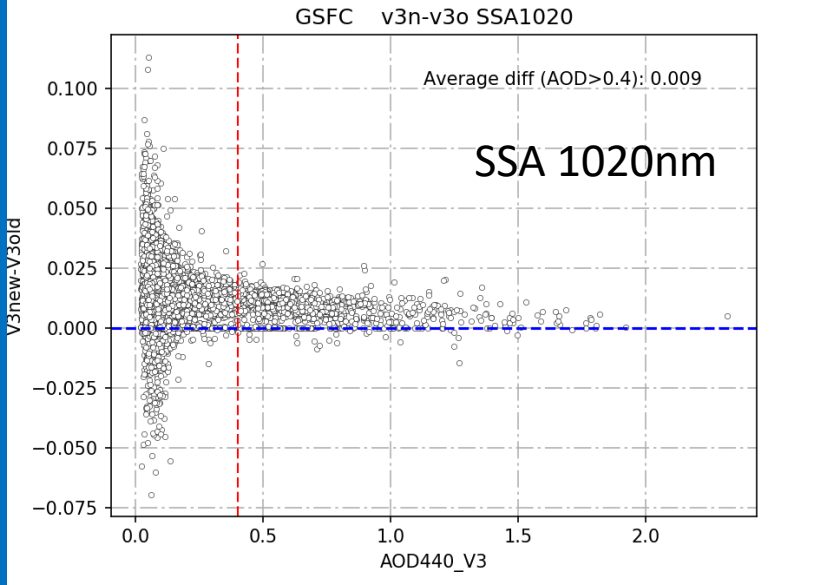
Sergey Korkin [a,b,*], Alexei Lyapustin [b], Alexander Sinyuk [c,b], Brent Holben [b], Alexander Kokhanovsky [d,e]

AERONET Version 3 - Inversions

- *Solar Spectrum Irradiance (SSI) for Quiet Sun* developed by Univ. of Colorado LASP and NRL based on Solar Radiation and Climate Experiment (SORCE) data (Coddington et al., 2016)
- Lidar and depolarization ratio products (Dubovik et al., 2006)
- V2 inversion product quality assurance (Holben et al., 2006)
- NASA High End Computing (NCCS/GSFC) inversion processing (ongoing)
- Inversion product estimated uncertainties (in progress and to be released later)

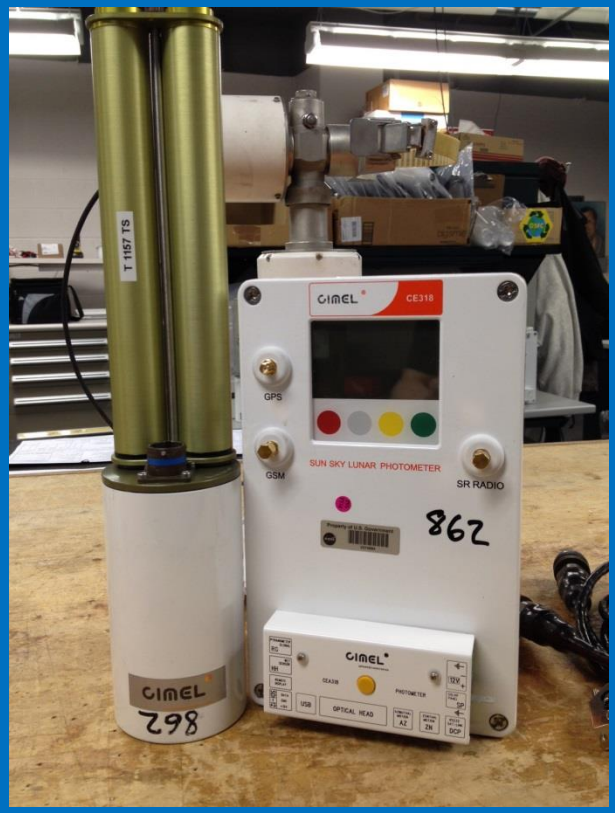


V3 SSA (LASP SSI) – V3 SSA (NREL SSI)



AERONET
New Instrumentation/Enhancements

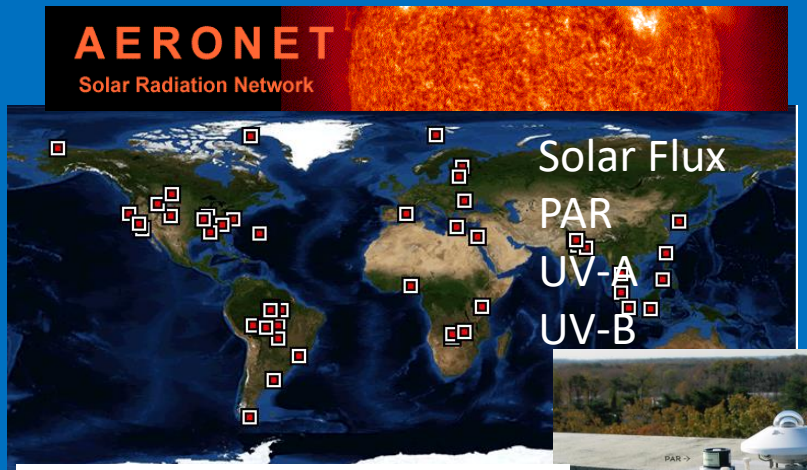
- Improved solar tracking reducing triplet variance
- Greater control over instrument measurement scenarios (e.g., **Hybrid**)
- **Lunar measurements**
  - 1st to 3rd quarter lunar phase (waxing to waning gibbous)
  - Processing for lunar measurements (e.g., ROLO, Tom Stone)
- Development toward attachment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



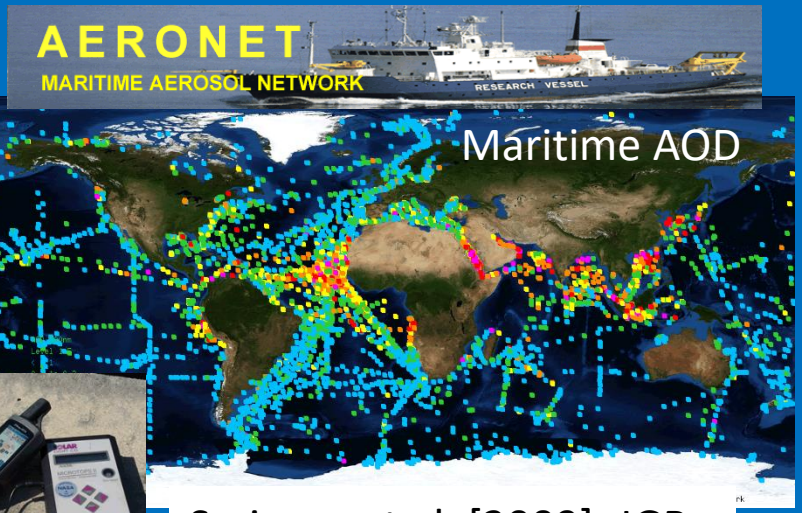
Cimel Sun/Sky/Lunar Radiometer

Aerosols and More

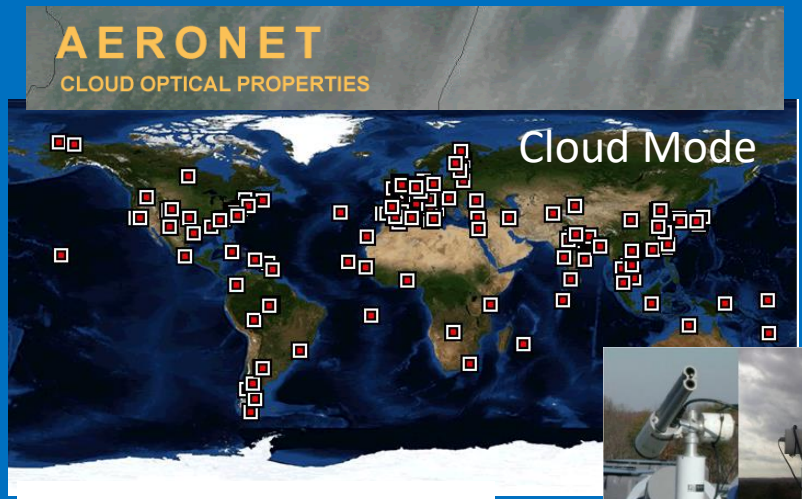
Zibordi et al. [2009], JAOT



Schafer et al. [2004], JGR



Smirnov et al. [2009], JGR



Chiu et al. [2010], JGR

http://aeronet.gsfc.nasa.gov

V3 AOD, SDA, and inversions

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

Version 3 Releases

- V3 AOD Level 1.0 and Level 1.5 NRT:
  July 14, 2016

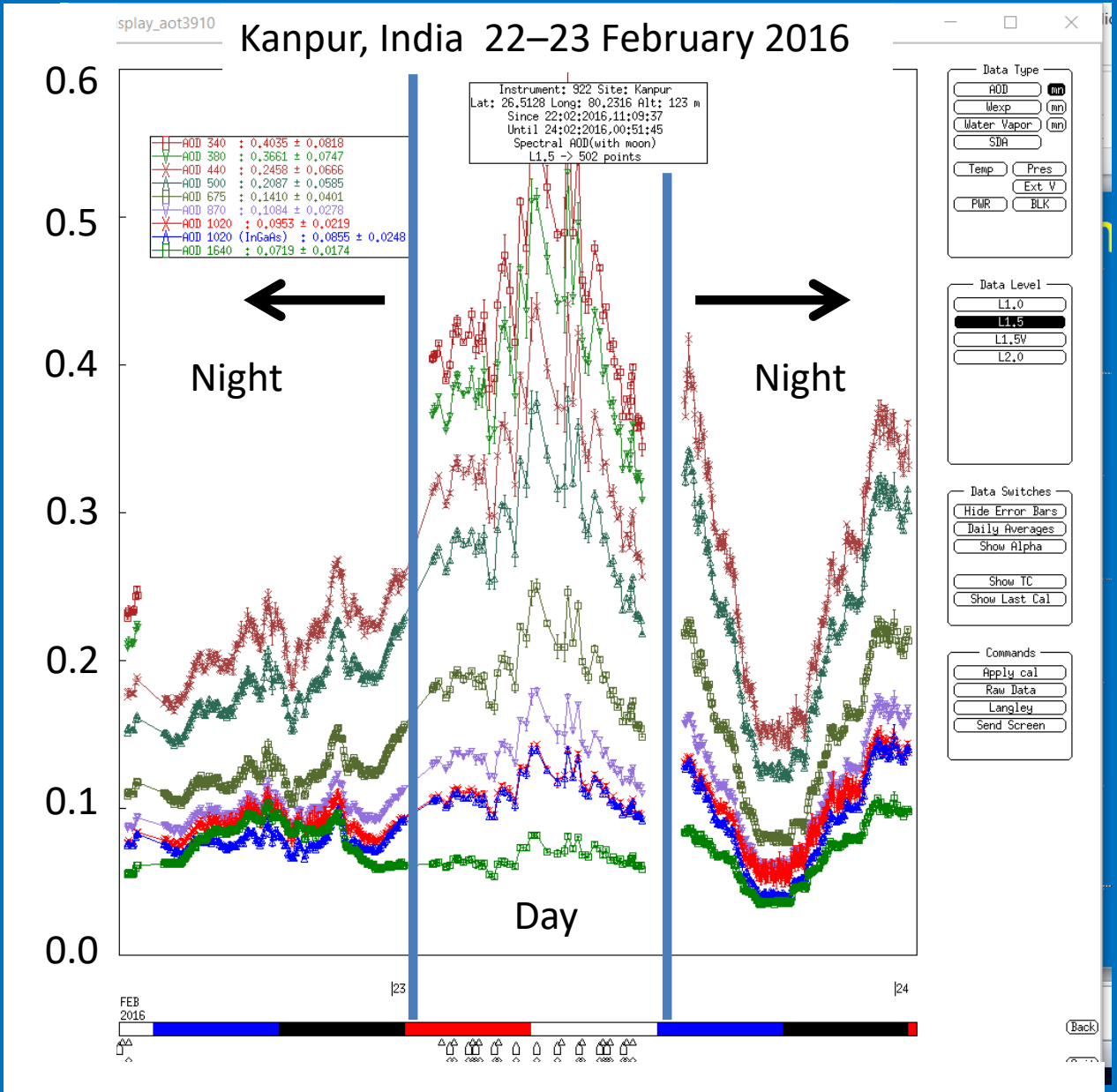
- V3 AOD Level 2.0 release:
  January 5, 2018

- V3 Inversions release (Levels 1.5 and 2.0):
  January 5, 2018

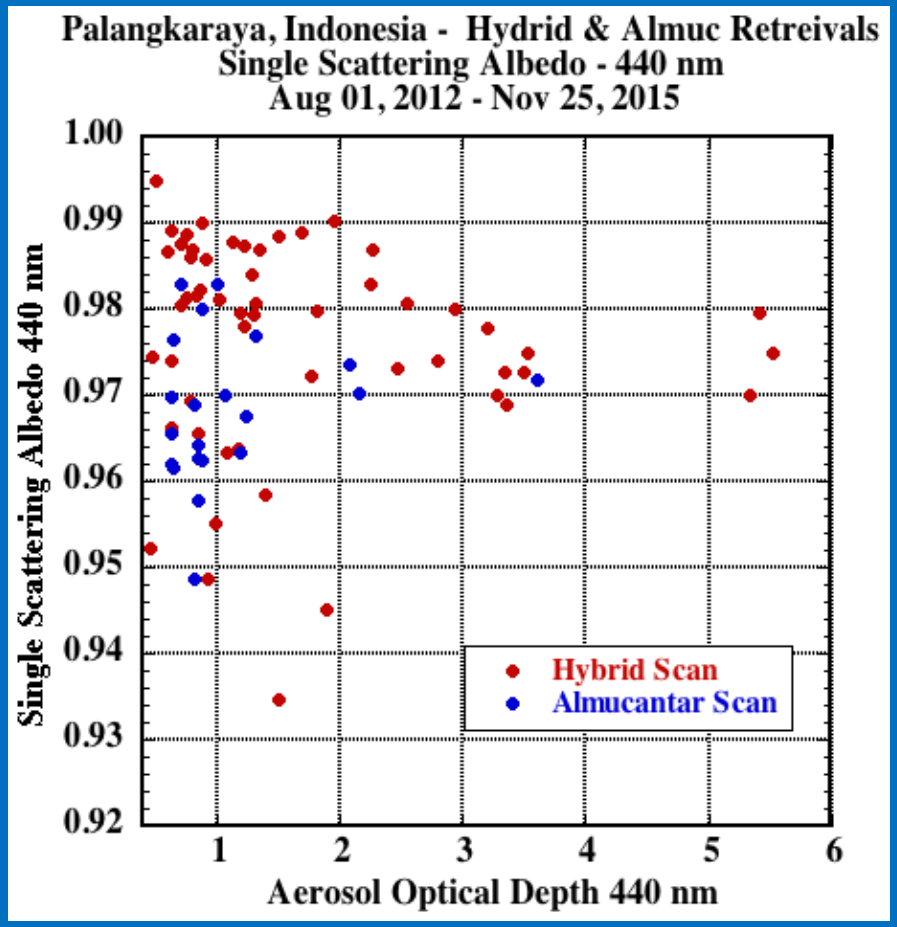
Upcoming Product V3 Release

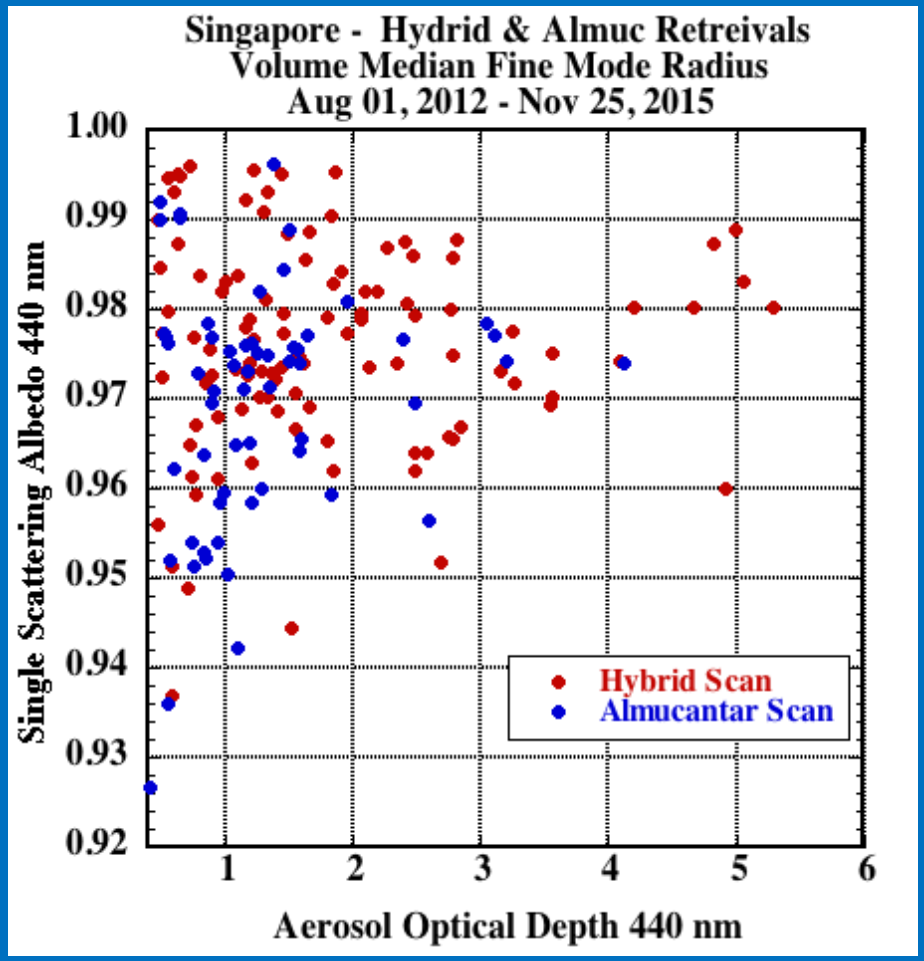
- Normalized Water Leaving Radiances
- Lunar AOD
- Hybrid Sky Scan Inversions
- Inversion Uncertainty Estimates
- Expanded Wavelength Inversions (including 380nm and 1640nm)

Provisional Lunar AOD



Hybrid and Almucantar





Hybrid Scan results in many more retrievals at AOD> 2 at 440 nm since Hybrid scans can be made at mid-day with low Solar Zenith Angle (SZA). Almucantar scans require SZA > 50 degrees – this results in insufficient signal to measure 440 nm AOD when AOD is very high