AERONET
AEROSOL ROBOTIC NETWORK

AERONET Version 3 Database Update and Evaluation

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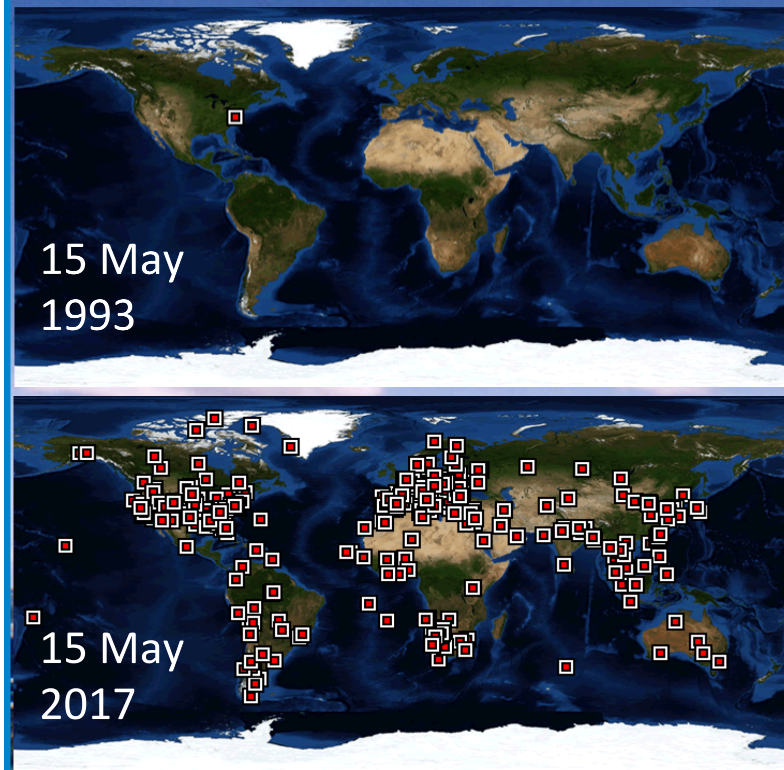
AeroCom/AeroSat

Helsinki, Finland Oct 12, 2017

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.

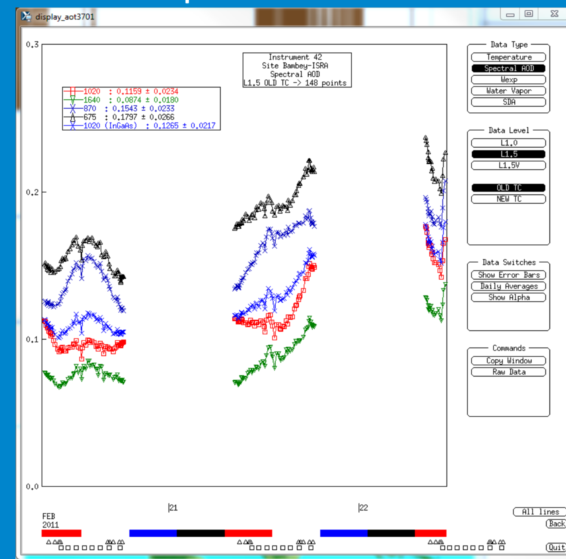
AERONET provides a long-term, continuous public database of aerosol optical, microphysical, and radiative properties for aerosol research and characterization, validation of satellite measurements, and synergism with other databases.

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

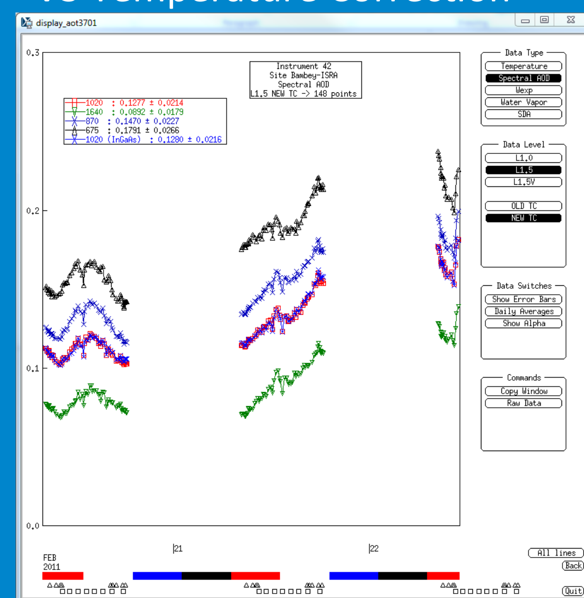
AERONET Version 3: AOD

- <u>V3 Level 1.0:</u> Unscreened data (NRT)
  - **Applies new temperature characterizations**
  - Applies NO_2 & O_3 OMI L3 climatology (2004-2013)
  - Applies updated absorption coefficients (Literature/HITRAN)
- **<u>V3 Level 1.5</u>: Based on Level 1.0 and uses new automatic quality controls (NRT)**
  - **<u>Cloud Screening</u>**
    - **Improves removal of optically thin cirrus contamination**
    - **Preserves more highly variable fine mode AOD**
    - **Compares well to Version 2 Level 2**
  - **<u>Quality Controls</u>**
    - **Removes sensor temperature artifacts**
    - **Removes AOD impacted by window obstructions**
    - **Removes AOD with poor spectral dependence**
    - **Removes AOD affected by solar eclipses**
- <u>V3 Level 2.0</u>: Based on Level 1.5 with pre- and post-calibration applied
  - Significantly improves timeliness of Level 2.0 data availability
  - Applies an <u>objective</u> removal scheme
  - No manual analysis

V2 Temperature Correction



V3 Temperature Correction



V2 vs. V3 Cloud Screening

Algorithm/Parameter	Version 2	Version 3
Very High AOD Restoration	N/A	$\tau870 > 0.5$; $\alpha675\text{-}1020 > 1.2$ or $\alpha870\text{-}1020 > 1.3$, 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 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 (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 τ_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

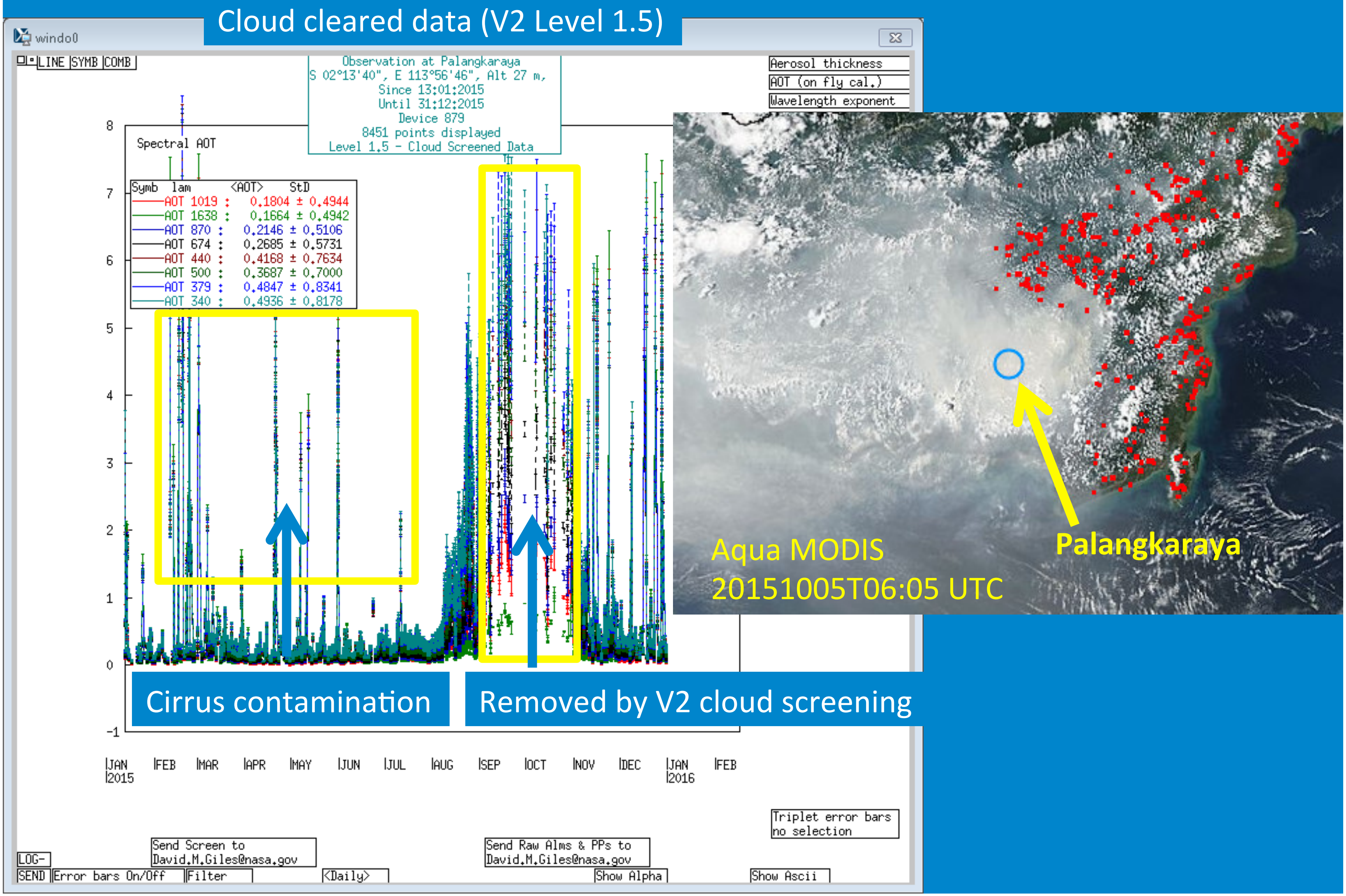
- Raw Data Checks – sensor temperature, digital counts, clock shift, etc.
- Collimator consistency checks
- AOD diurnal dependence checks
- AOD spectral dependence checks
- Solar eclipse screening

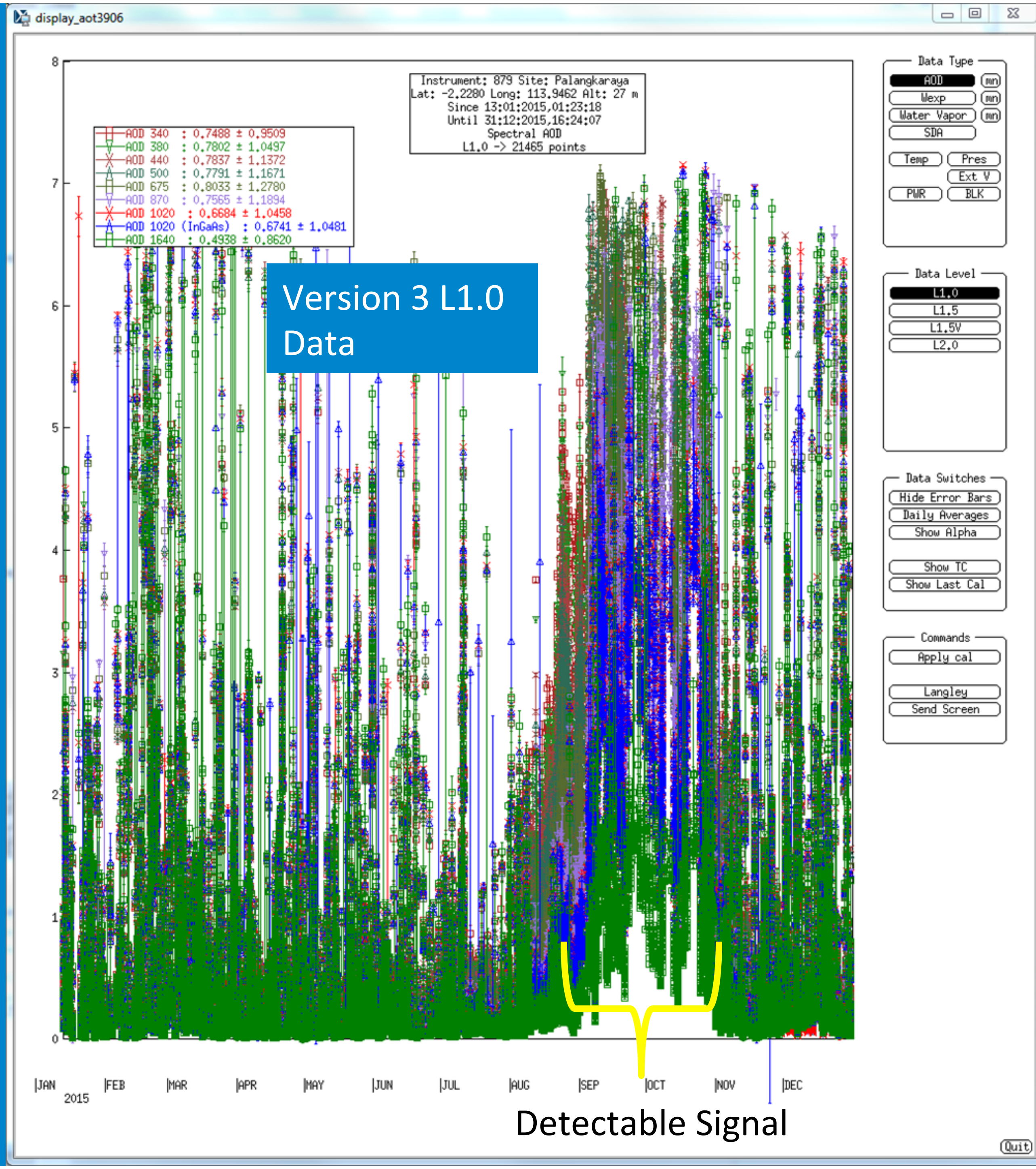
Level 2.0 AOD Criteria

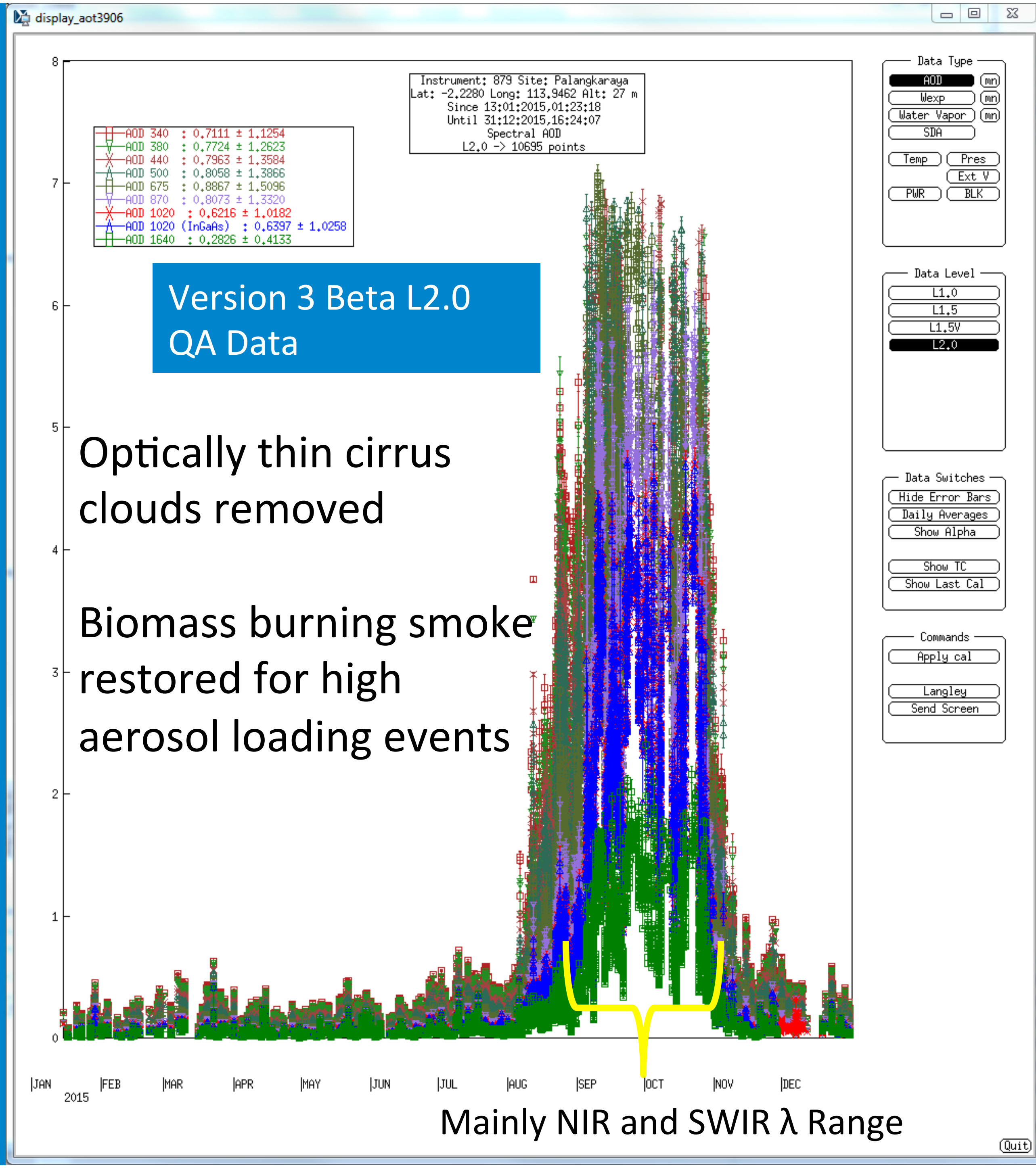
- Must pass the Level 1.5 criteria
- Must utilize pre-field and post-field calibration
- Temperature characterization must be applied for all visible and near-infrared channels (440-1640nm); No characterization for wavelengths <440 nm
- Once calibration assessment is complete, a 30-day pause will be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

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

Indonesian Fires 2015 (Palangkaraya) – Current V2

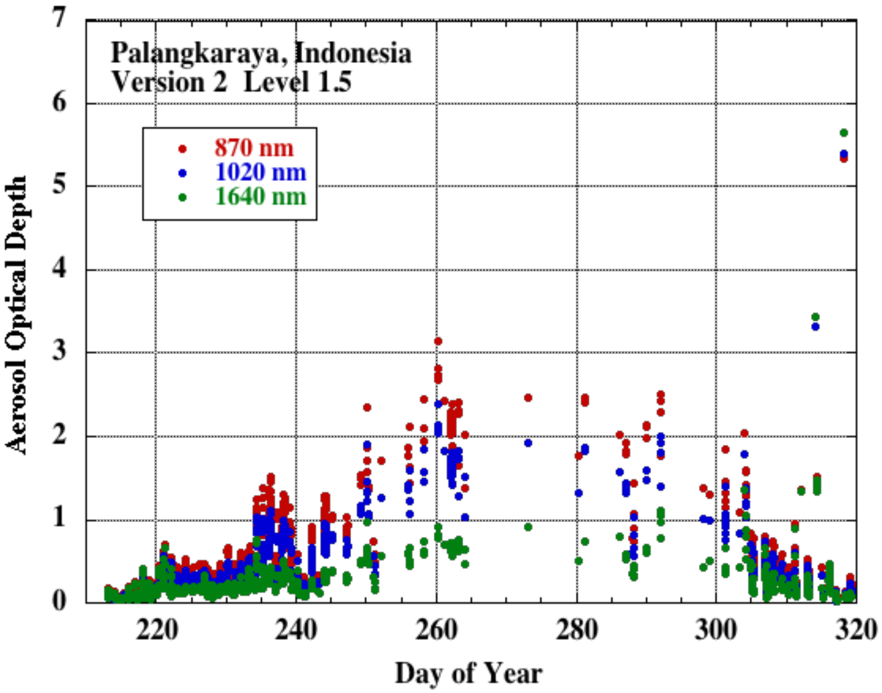


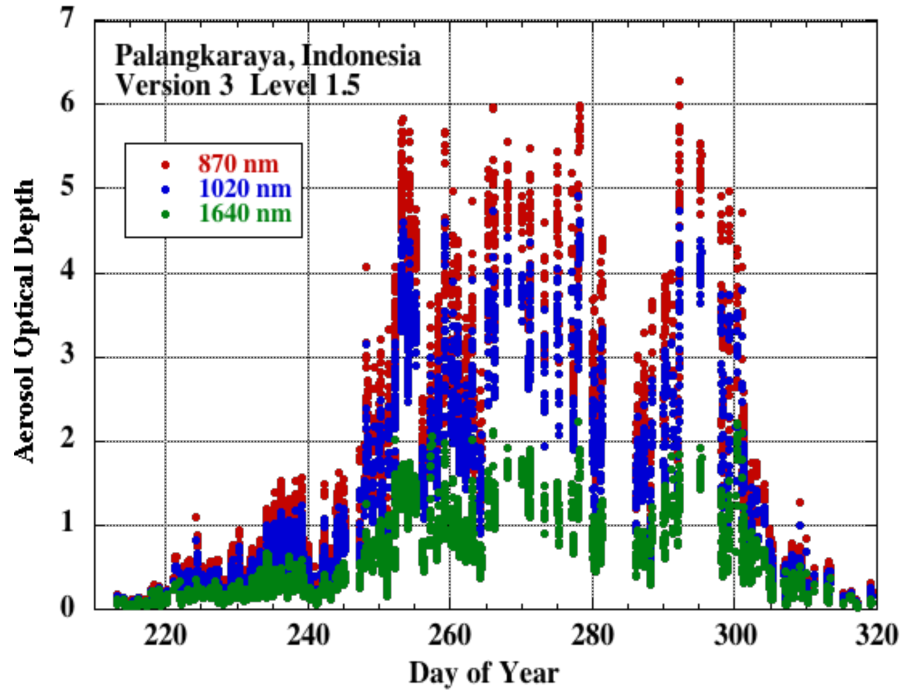

display_aot3906
Instrument: 879 Site: Palangkaraya
Lat: -2.2280 Long: 113.9462 Alt: 27 m
Since 13:01:2015,01:23:18
Until 31:12:2015,16:24:07
Spectral AOD
L1.0 -> 21465 points
AOD 340 : 0.7488 ± 0.9509
AOD 380 : 0.7802 ± 1.0497
AOD 440 : 0.7837 ± 1.1372
AOD 500 : 0.7791 ± 1.1671
AOD 675 : 0.8033 ± 1.2780
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 Data
JAN
2015
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Detectable Signal
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


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

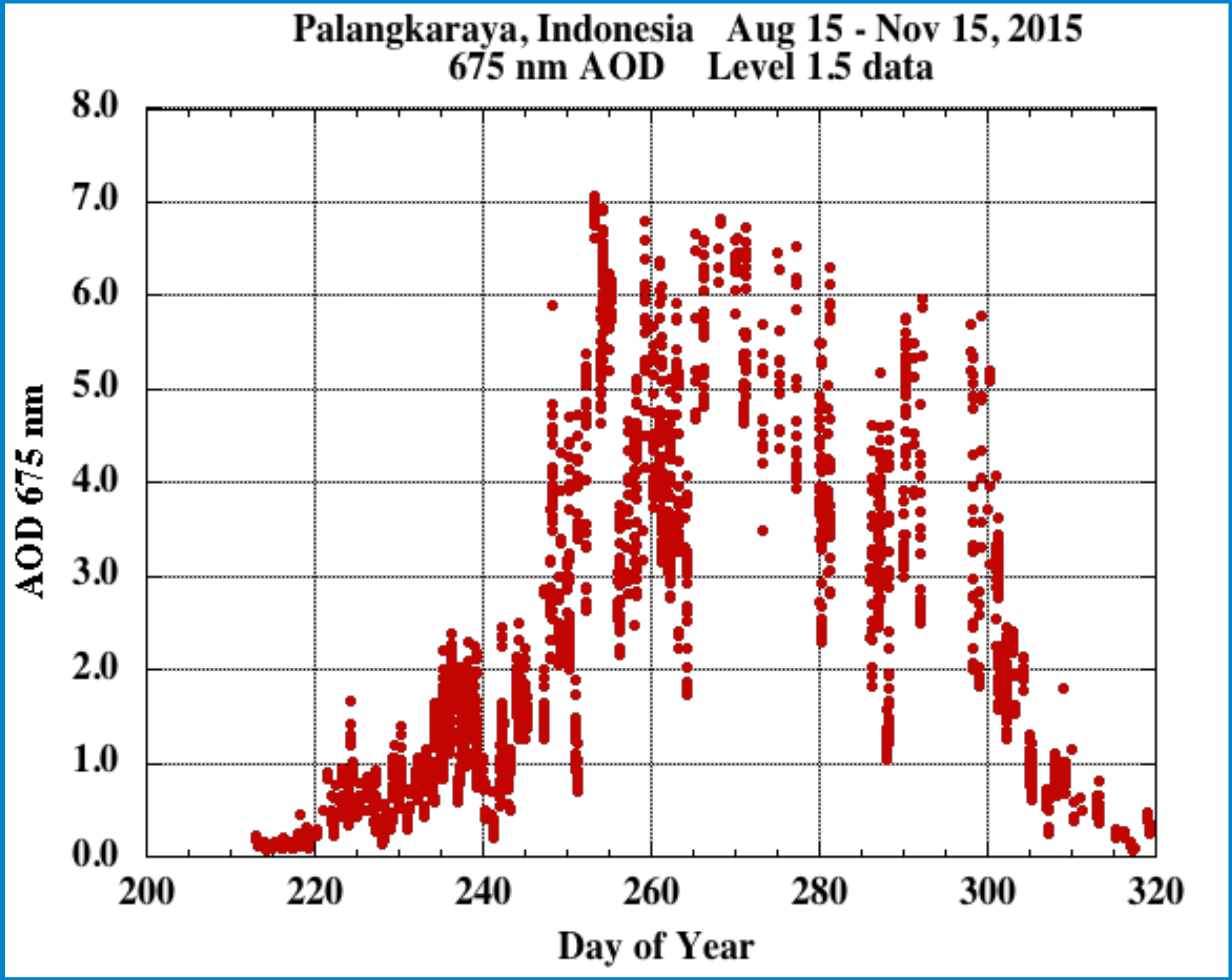
Palangkaraya, Indonesia   Aug 01- Nov 15, 2015

Many Very Heavy smoke AOD days were missed in AERONET V2 due to insufficient direct sun signal in the UV and visible wavelengths
AERONET Cimel 4 quadrant detector is sensitive in the Near Infrared allowing sun tracking when solar disc not detectable in the shorter wavelengths (large Angstrom Exp. for Smoke)

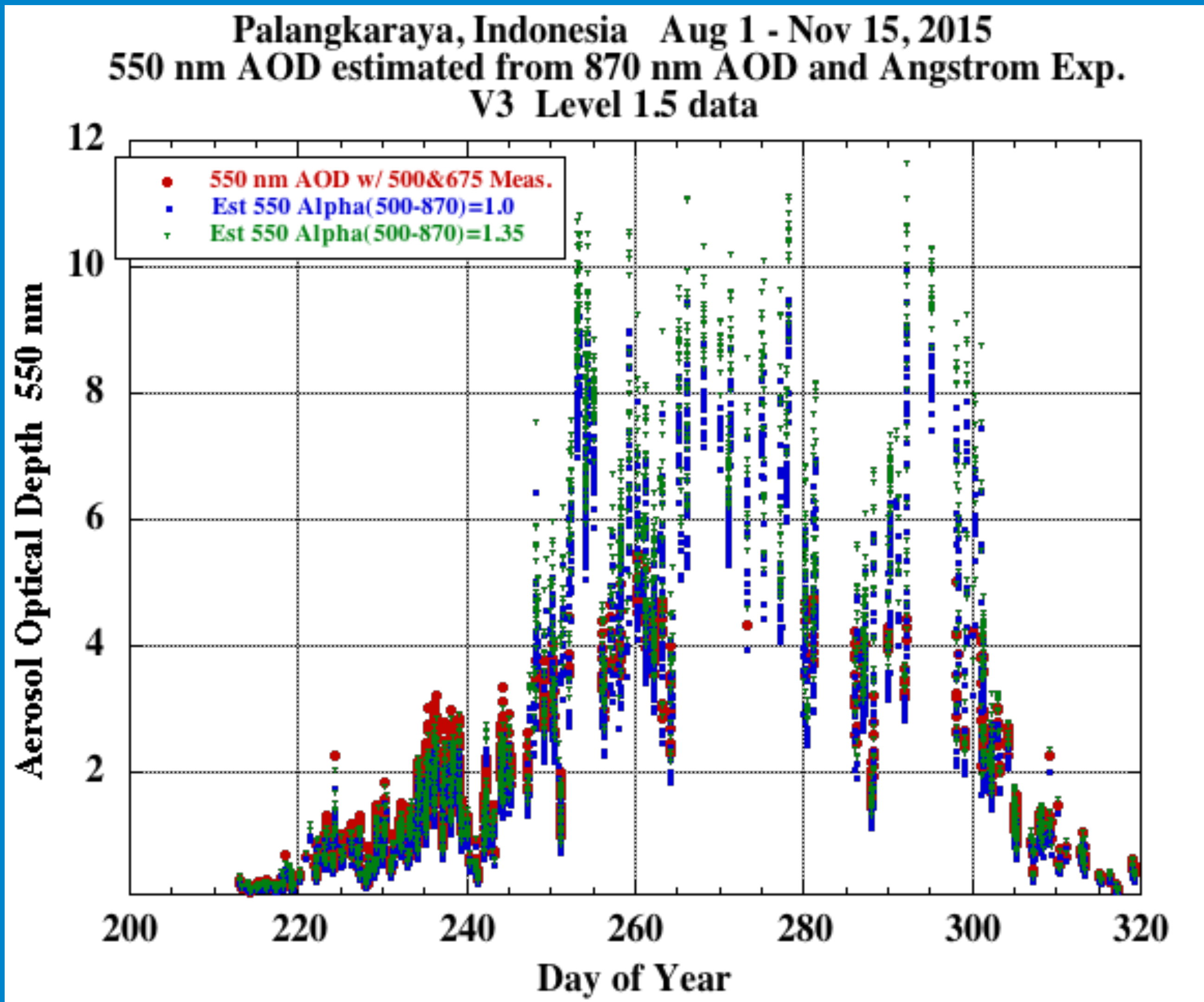




New V3 Algorithm Retains AOD data for longest wavelengths when solar direct beam signal strength is sufficient and Angstrom Exponent (870-1020 nm)>1.3



AOD at 675 nm shows maximum value at ~7
This is approximately the limit of sunphotometry with high sun (optical airmass near to 1); otherwise for AOD*airmass<7



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 V2 vs. V3

- New Level 1.5 AOD_{500nm} and $\alpha_{440\text{-}870nm}$ statistically very close to V2 Level 2.0 averages for many sites
- 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

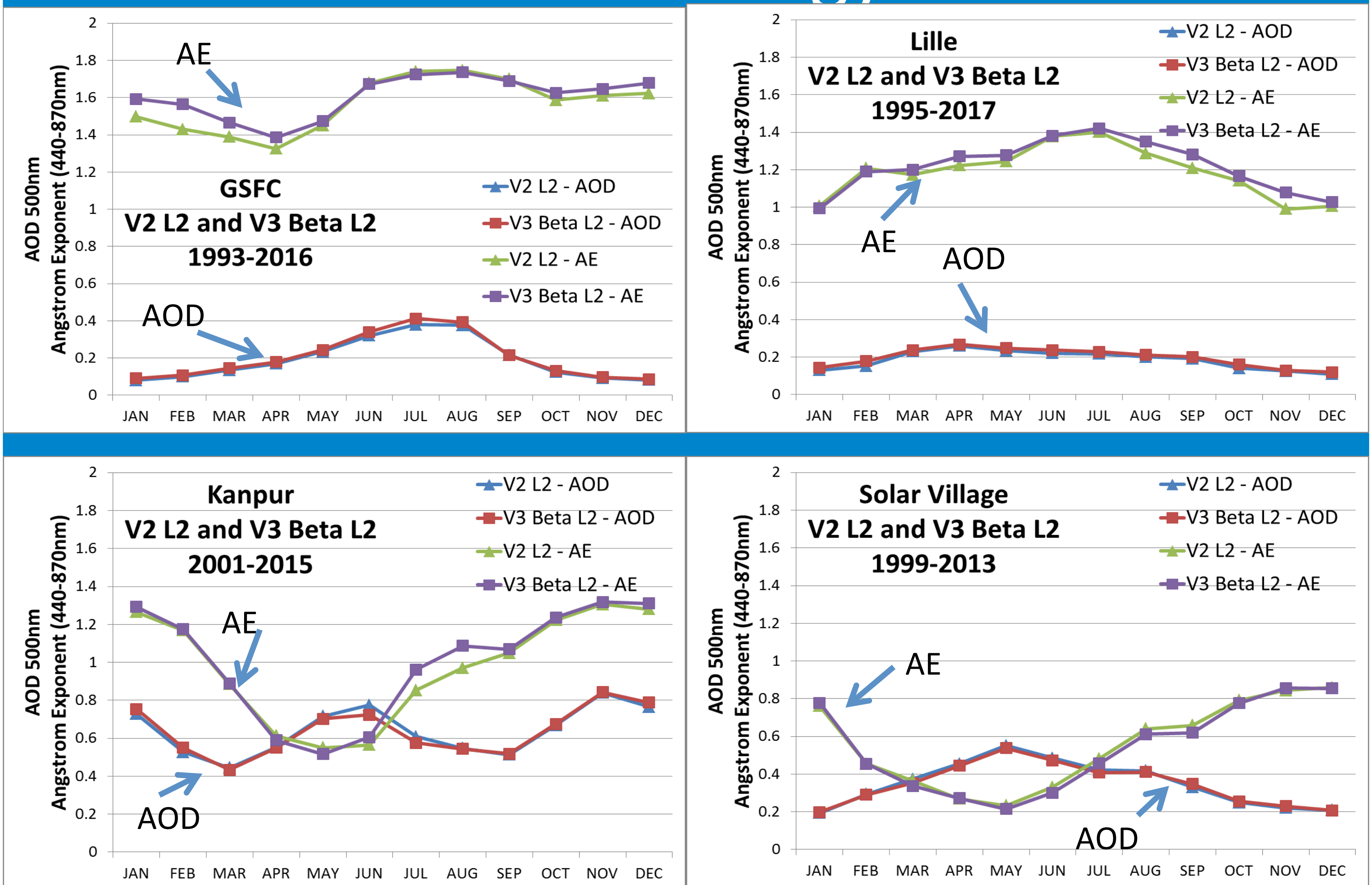
Nauru, #168, 2000-2005, 2010

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

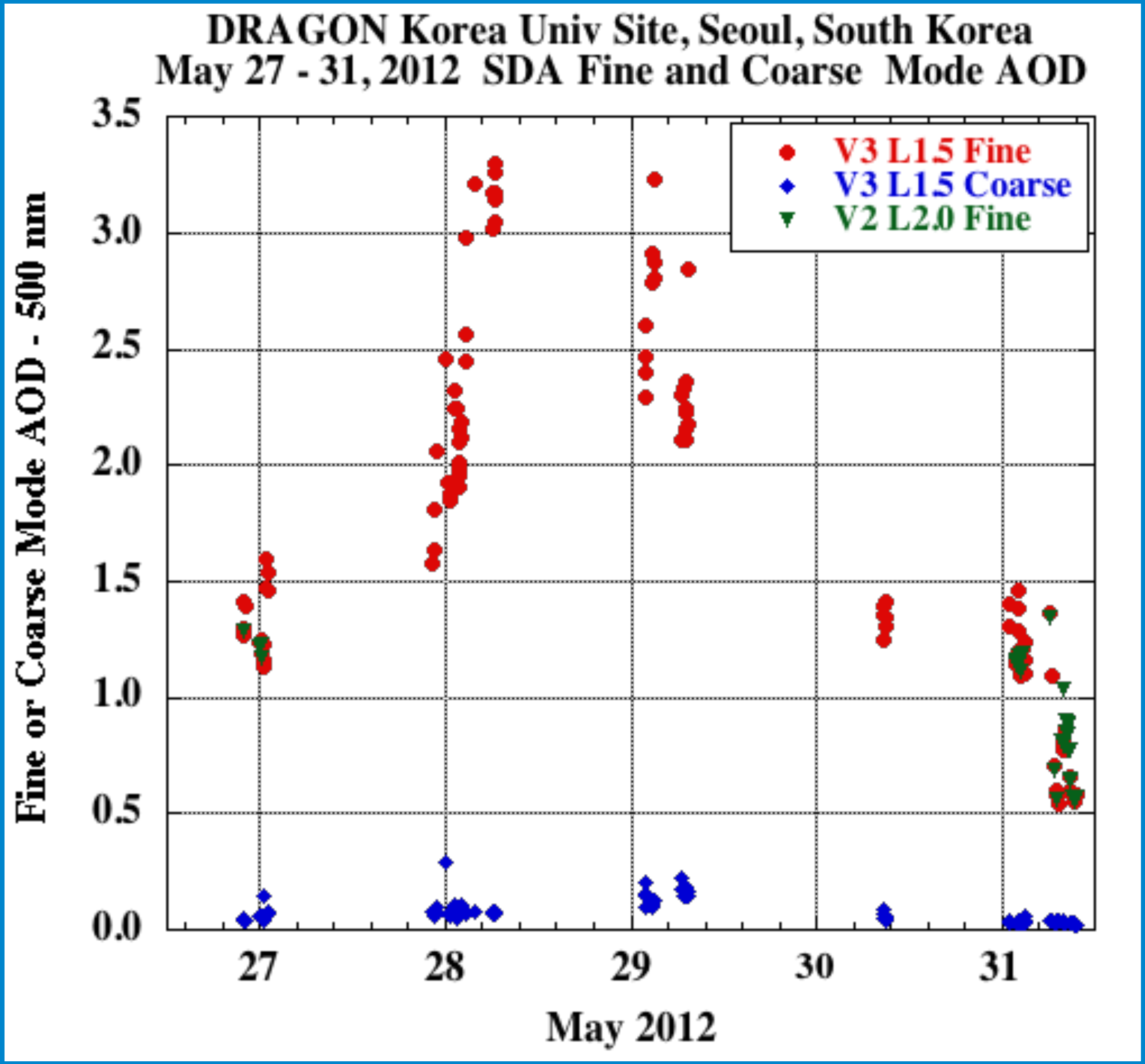
Singapore, #22, 2007-2011

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



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



Fine Mode High AOD Days – Many more days eliminated by Version 2 screening than Version 3 screening in China and Korea

Table 2. In AERONET Version 2 data the Difference in number of days of daily average Fine Mode AOD (500 nm) in Level 1 (non-cloud screened) versus Level 2 (cloud screened) for different lower limits of AOD; Climatological data sets

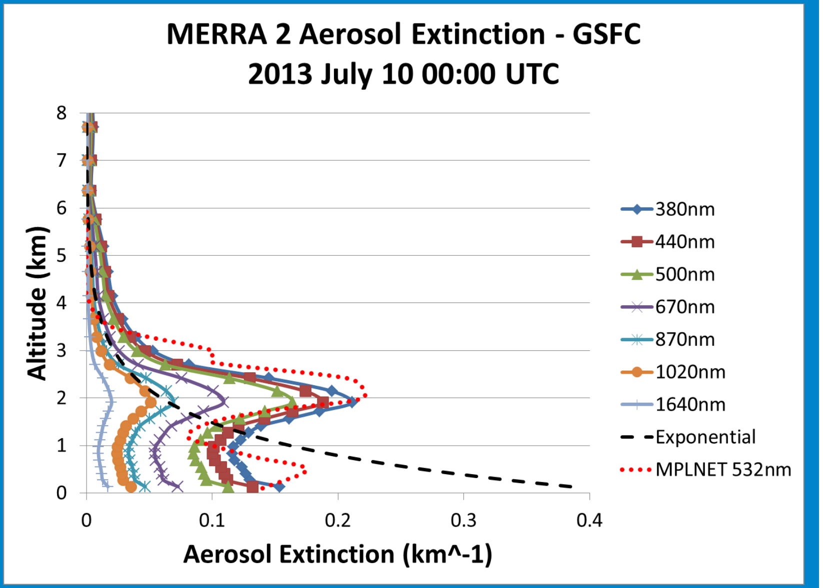
Site Name	Days of L1	Days of L2	Days L1-L2	% Difference	AOD Lower Limit
XiangHe	3223	2703	520	16%	0
XiangHe	798	535	263	33%	1
Xianghe	264	138	126	48%	2
XiangHe	81	29	52	64%	3
XiangHe	25	5	20	80%	4
Yonsei Univ	1721	1370	351	20%	0
Yonsei Univ	164	101	63	38%	1
Yonsei Univ	14	5	9	64%	2

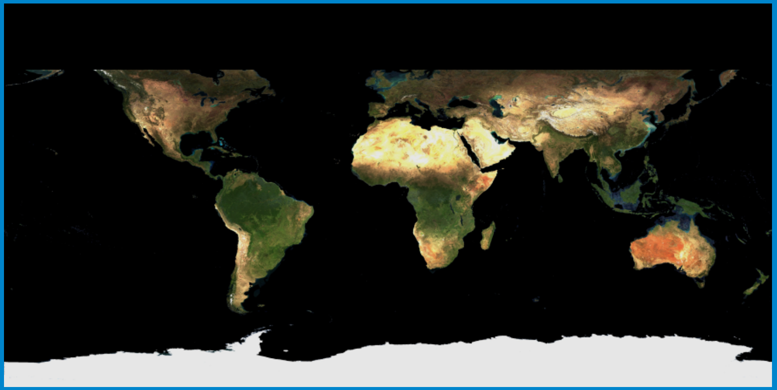
Table 3. In AERONET Version 3 data the Difference in number of days of daily average Fine Mode AOD (500 nm) in Level 1 (non-cloud screened) versus Level 2 (cloud screened) for different lower limits of AOD; Climatological data sets

Site Name	Days of L1	Days of L2	Days L1-L2	% Difference	AOD Lower Limit
XiangHe	3222	2784	438	14%	0
XiangHe	796	672	124	16%	1
Xianghe	256	209	47	18%	2
XiangHe	79	61	18	23%	3
XiangHe	22	16	6	27%	4
Yonsei Univ	1718	1510	208	12%	0
Yonsei Univ	159	139	20	13%	1
Yonsei Univ	14	10	4	29%	2

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 in future)
  - degree of linear depolarization

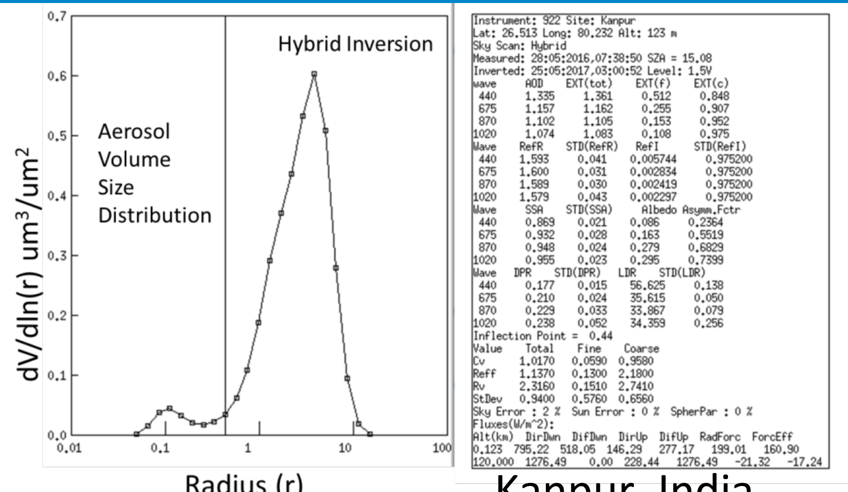




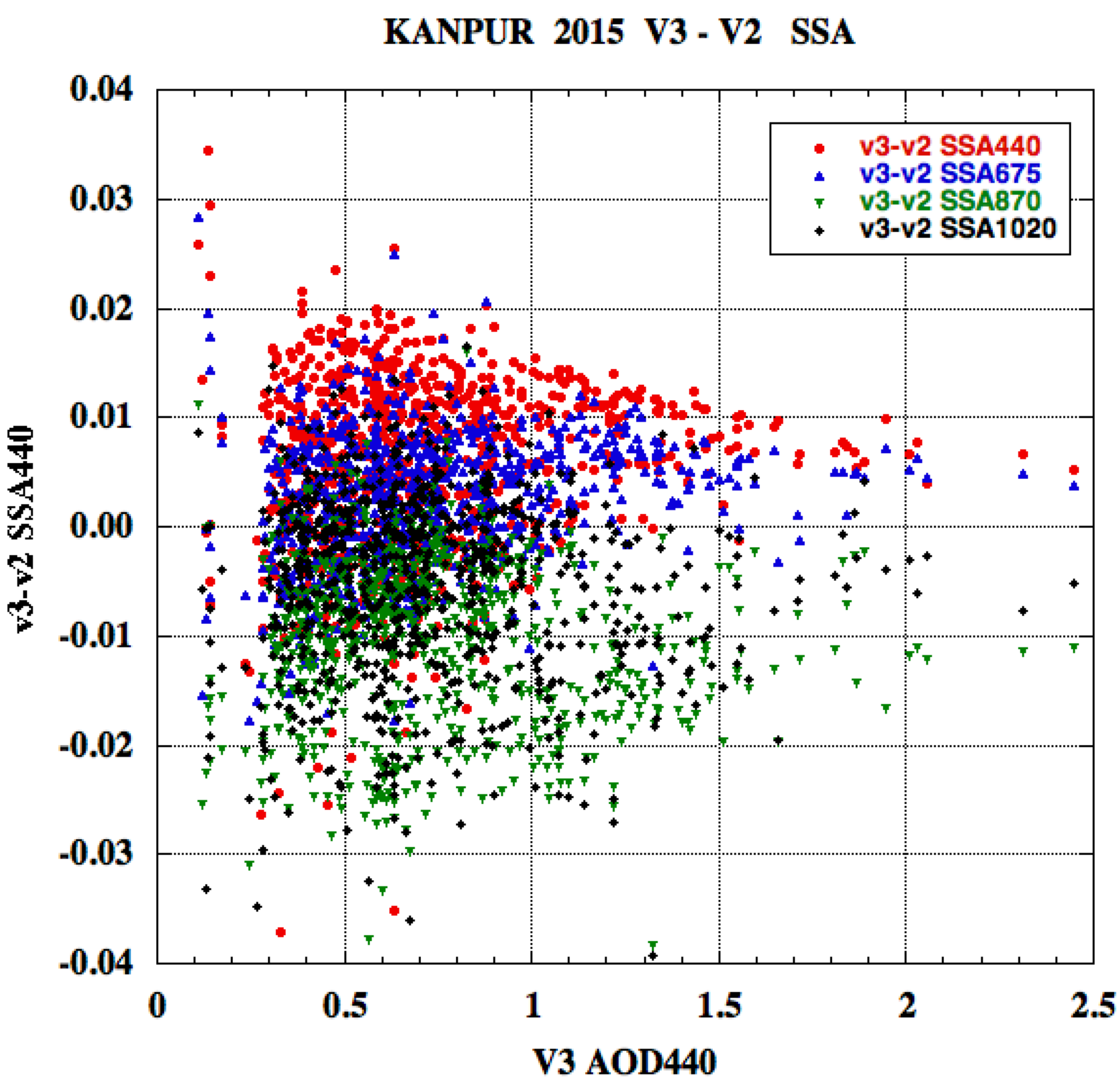
MODIS NBAR January 1-8, 2013

AERONET Version 3 Update - Inversions

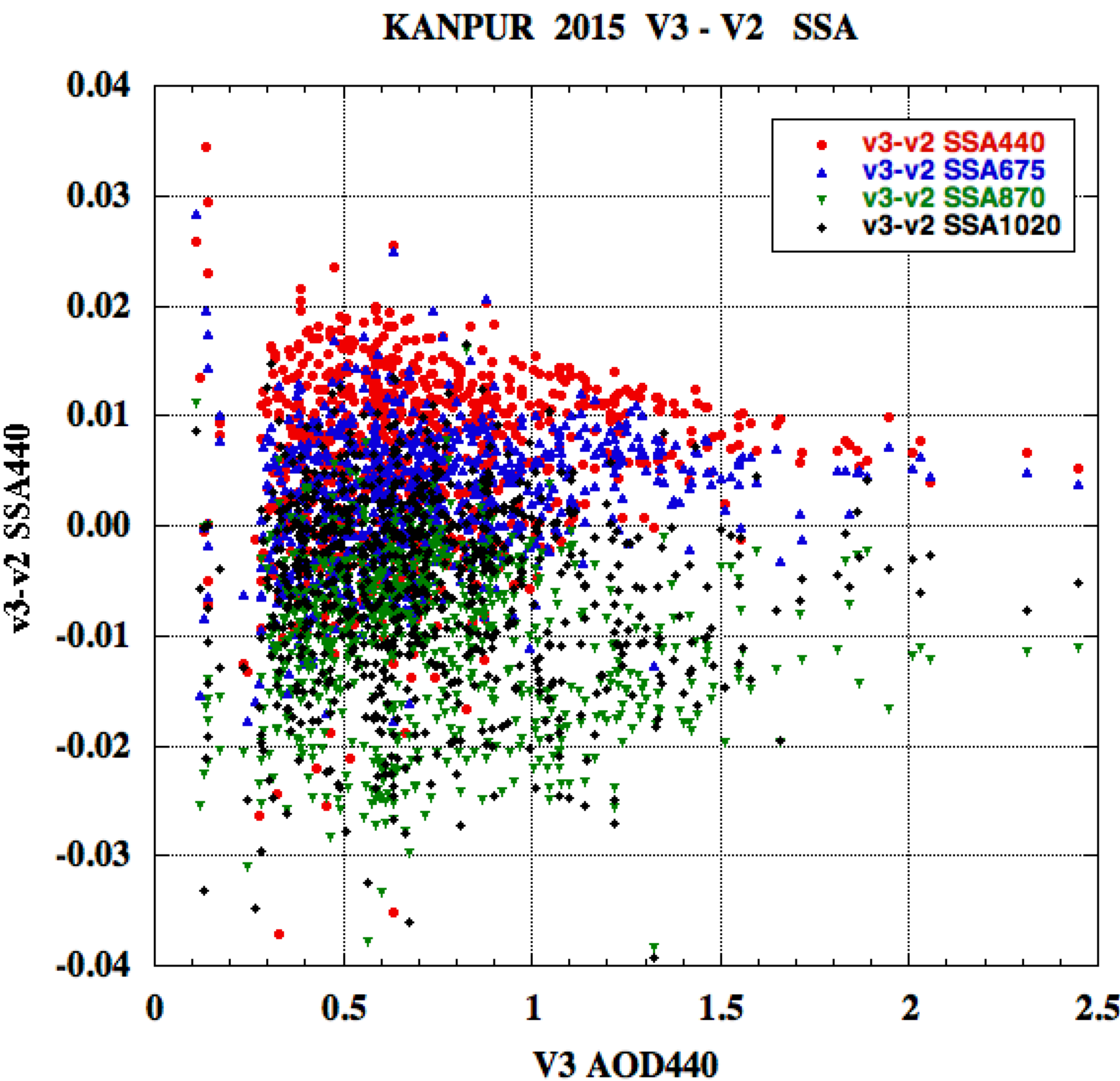
- Maintain V2 inversion product Quality Checks (Holben 2006)
- NASA Supercomputers (GSFC and Ames) processing with help from Arlindo DaSilva
- Estimated uncertainties (e.g., biases due to uncertainty in AOD and sky radiance calibration plus surface albedo)



Kanpur, India



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



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

Wave (nm)	V2 Ext. Irrad	V3 Ext/ Irrad.	Ratio 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**

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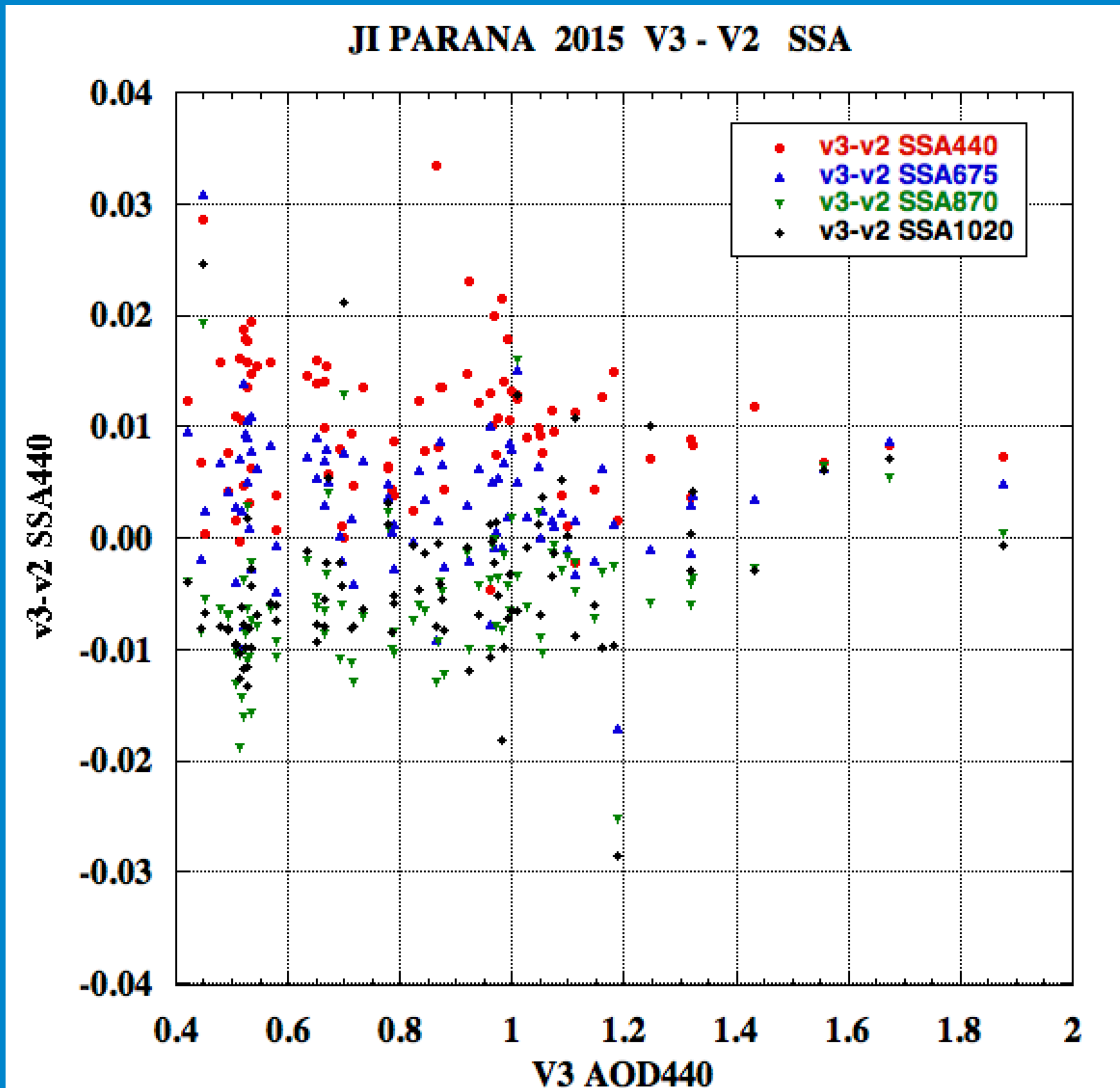
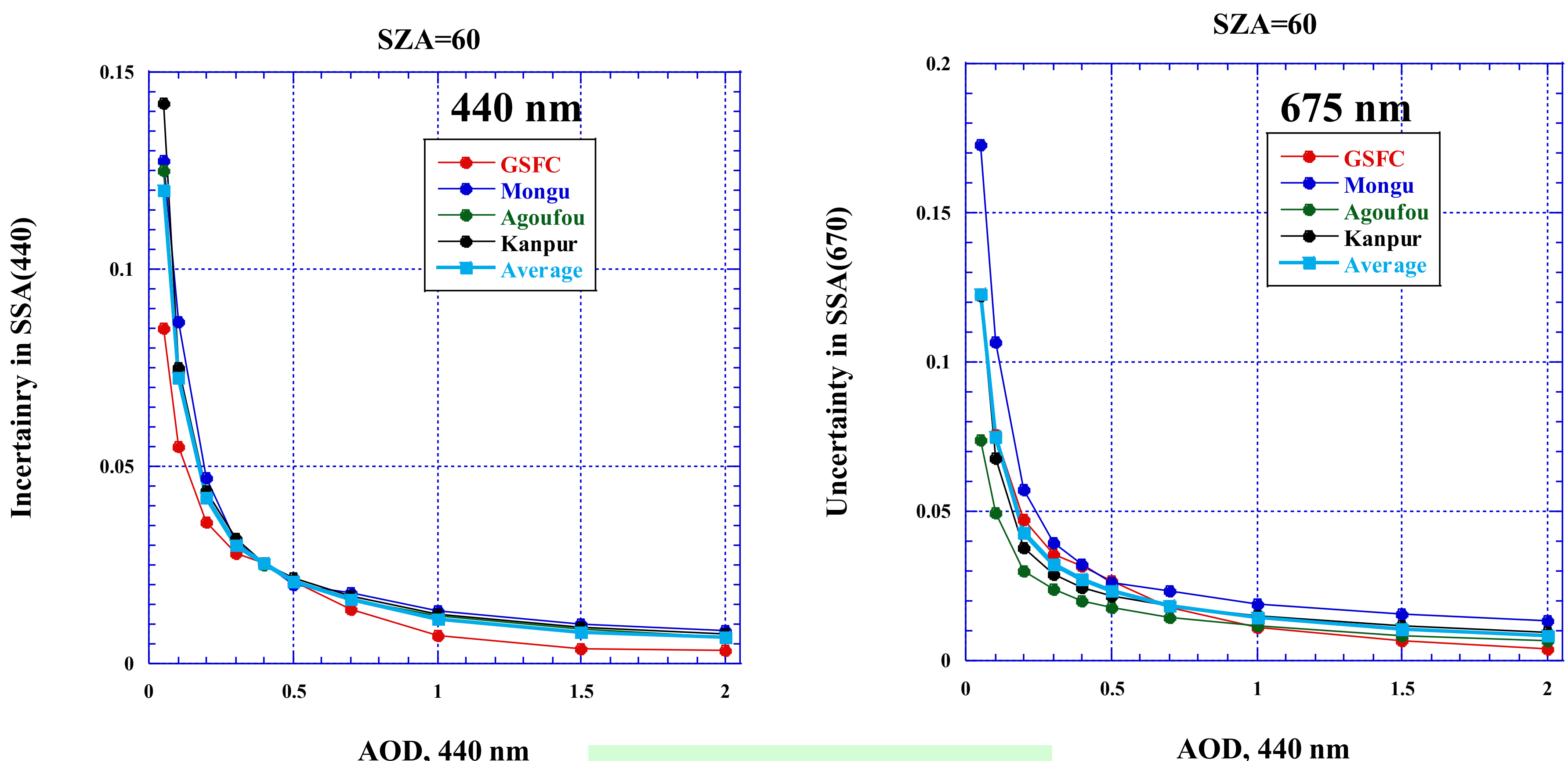


JI PARANA 2015 V3 - V2 SSA
v3-v2 SSA440
v3-v2 SSA675
v3-v2 SSA870
v3-v2 SSA1020
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
v3-v2 SSA440
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
V3 AOD440

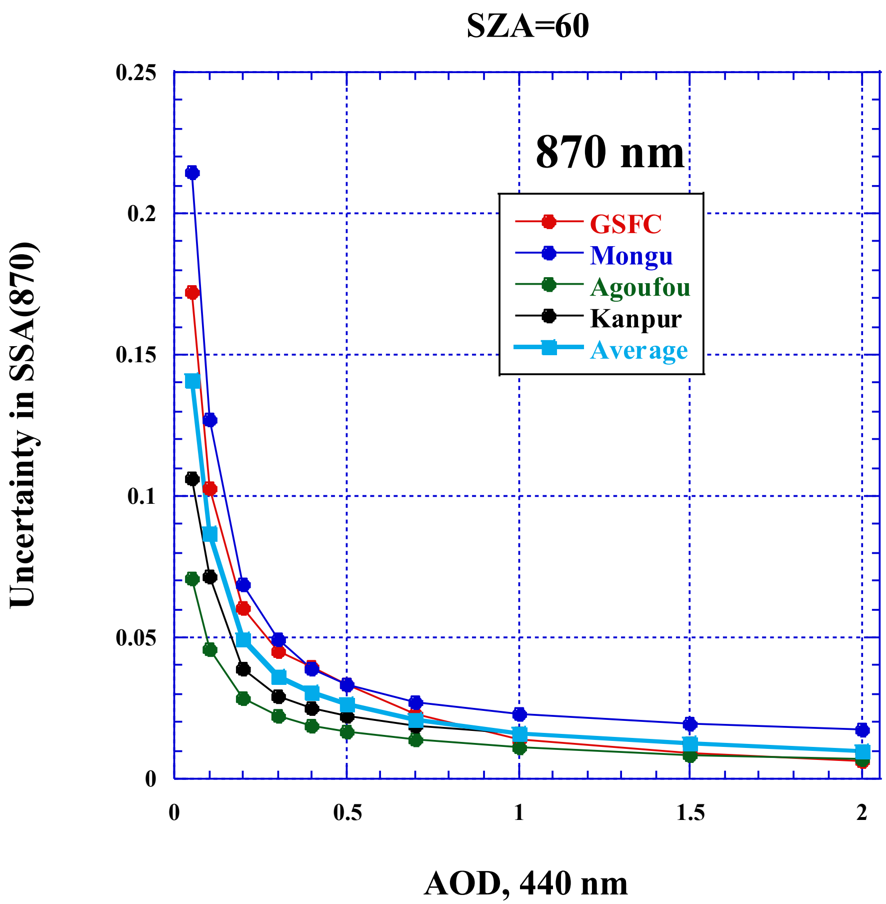
Uncertainty in Aerosol Single Scattering Albedo – Version 3

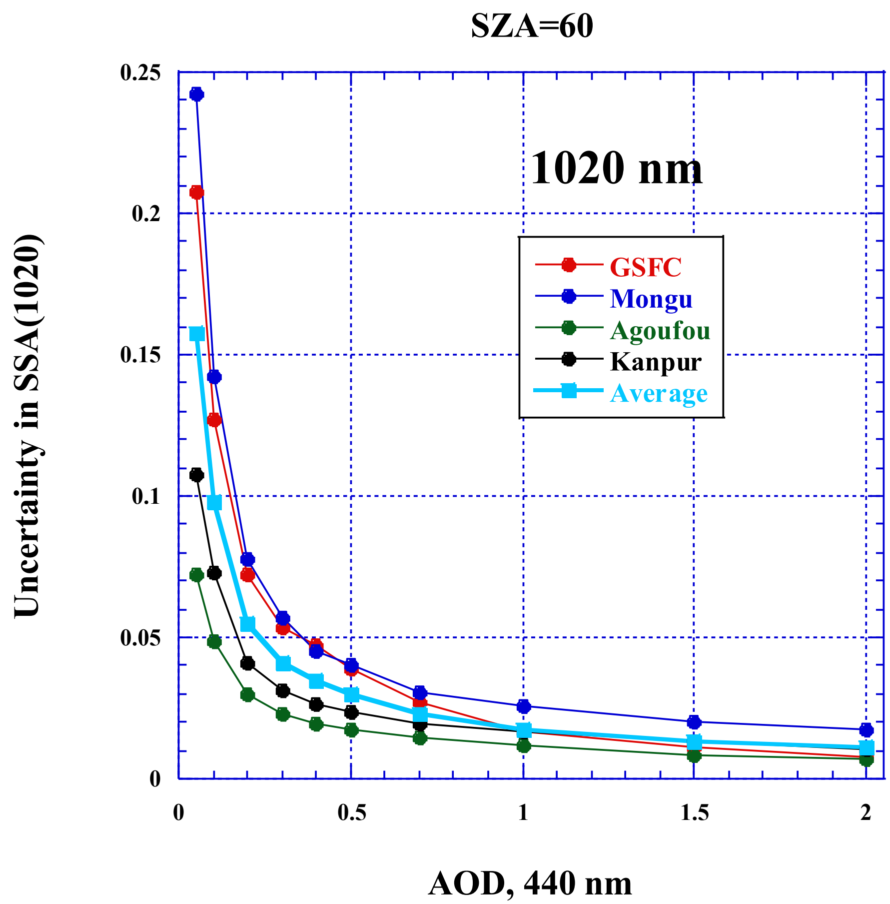


Angstrom Exponent (440-870 nm)
GSFC – 1.75
Mongu – 1.84
Agoufou – 0.12
Kanpur - 0.70

Computed assuming uncertainties in: AOD (0.01 at m=1), Sky Radiance (3% calibration), Surface Albedo (MODIS product = 0.05), Pointing error (0.1 degree)

Uncertainty in Aerosol Single Scattering Albedo – Version 3





Angstrom Exponent (440-870 nm)
GSFC – 1.75
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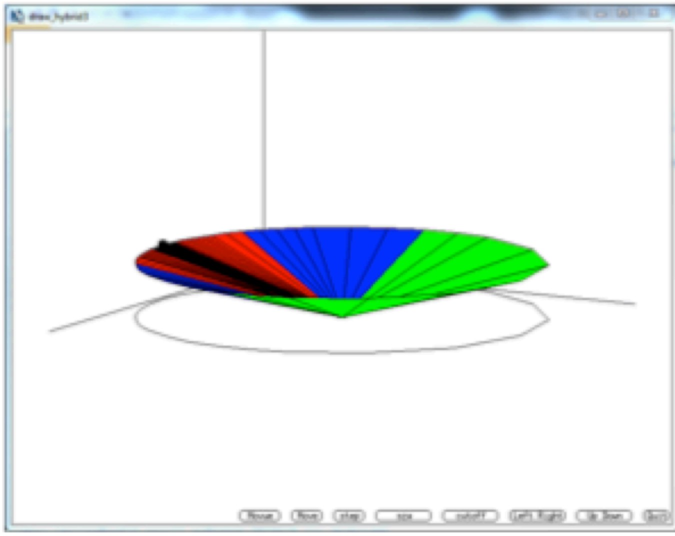
Agoufou – 0.12
Kanpur - 0.70

AERONET
New Instrumentation/Enhancements

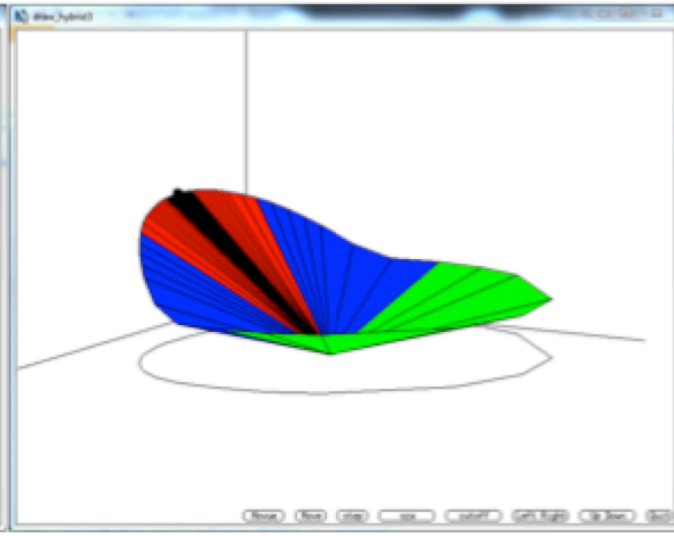
- Improved tracking reducing triplet variance
- Greater control over instrument measurement scenarios (e.g., **Hybrid**)
- Additional capabilities such as SD card storage, GPS, USB, and Zigbee
- **Lunar measurements**
  - 1st to 3rd quarter lunar phase (waxing to waning gibbous)
  - Processing for lunar measurements (e.g., ROLO, Tom Stone)
- Development toward attachment for CO_2 measurements (Emily Wilson)
- Synergism with MPLNET, PANDORA, and in situ measurements

Cimel Sun/Sky/Lunar Radiometer

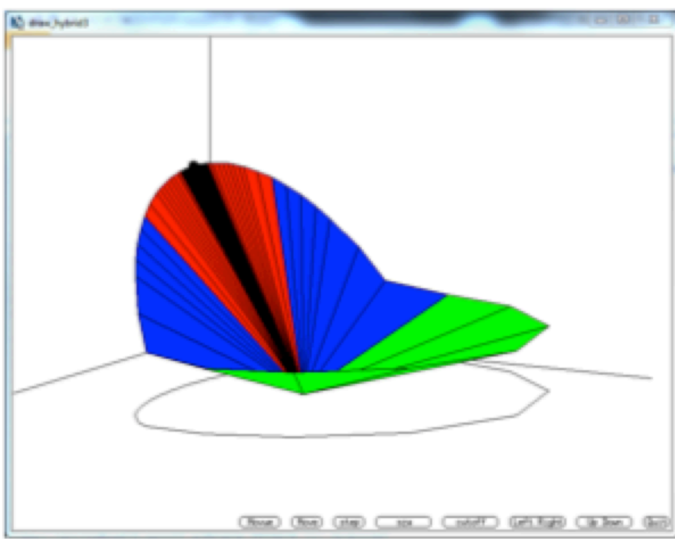
SZA = 75°



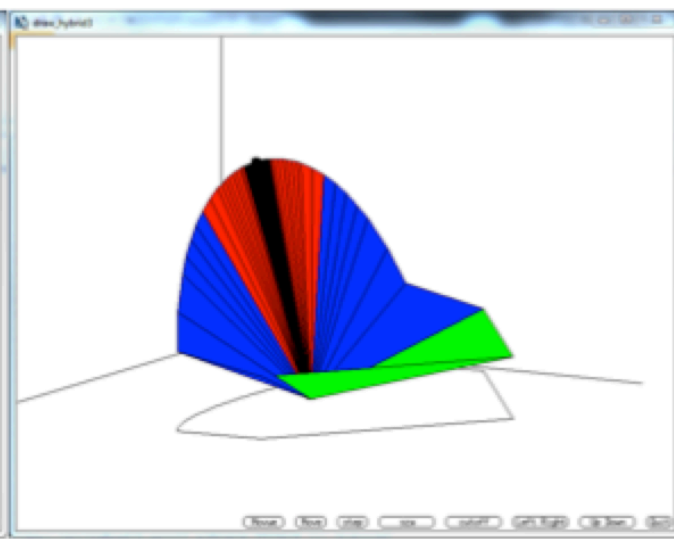
SZA = 50°



SZA = 30°



SZA = 15°



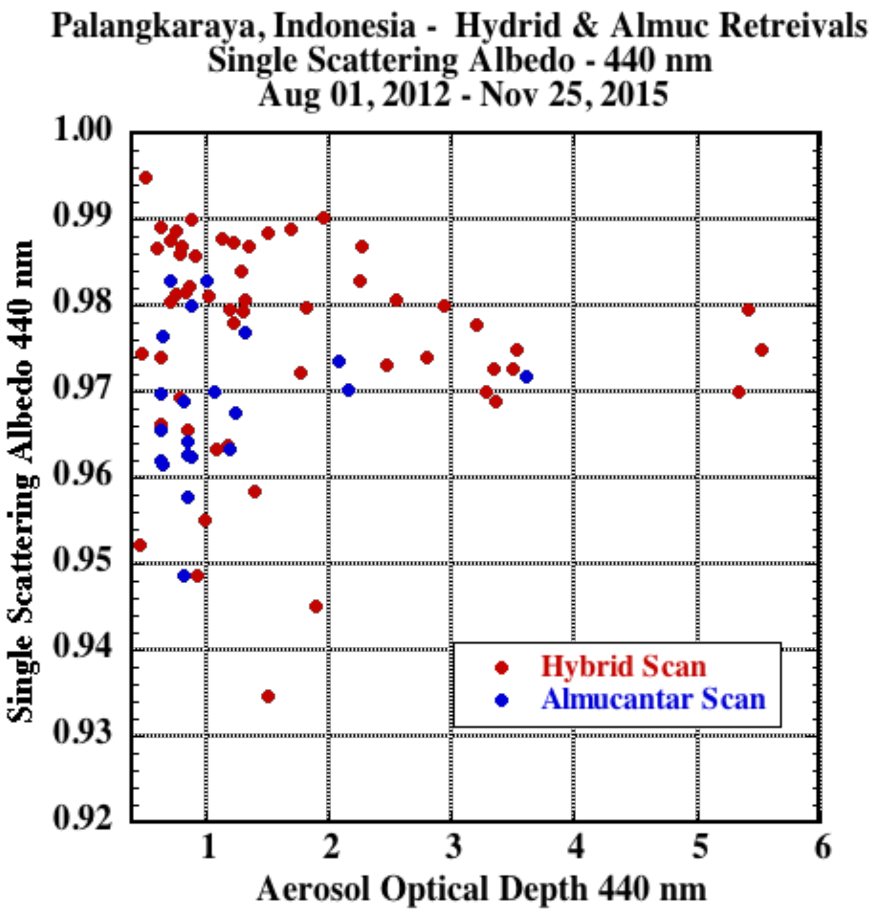
New Hybrid Sky Radiance Scans – Only possible with the new Model-T Cimel Instrument

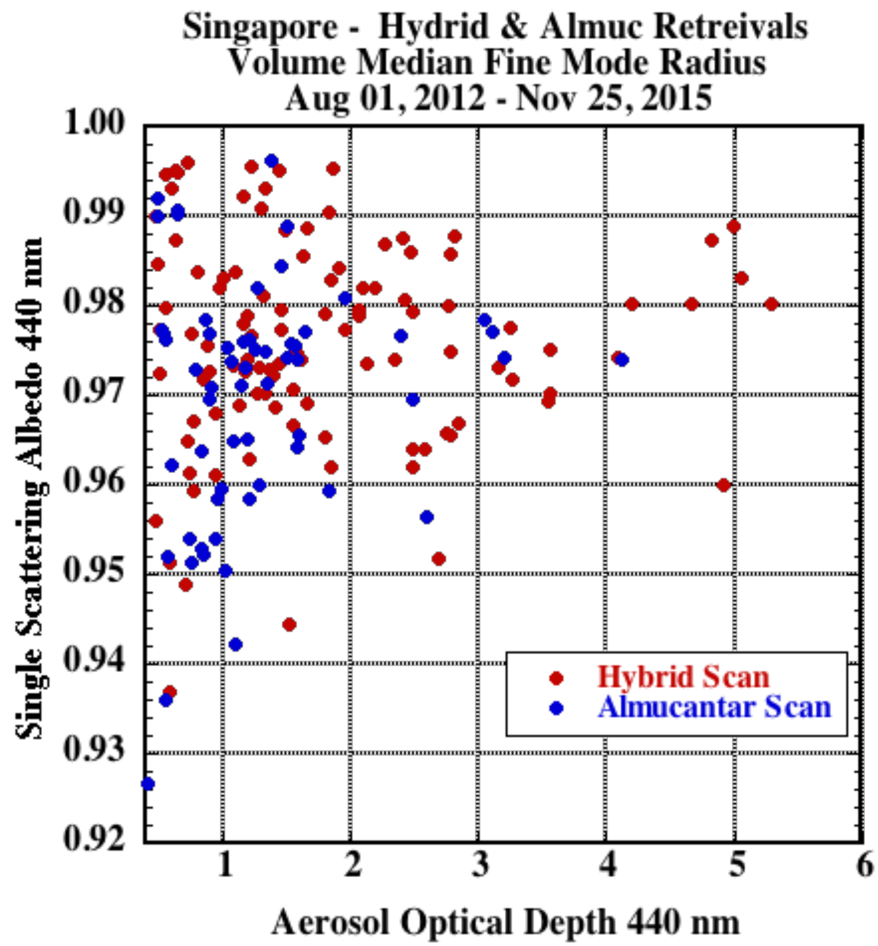
This allows for significantly larger scattering angle measurements at smaller SZA

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





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

Summary and Outlook

- Higher quality 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 & Inversions Level 2.0 expected release: October-November 2017

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 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