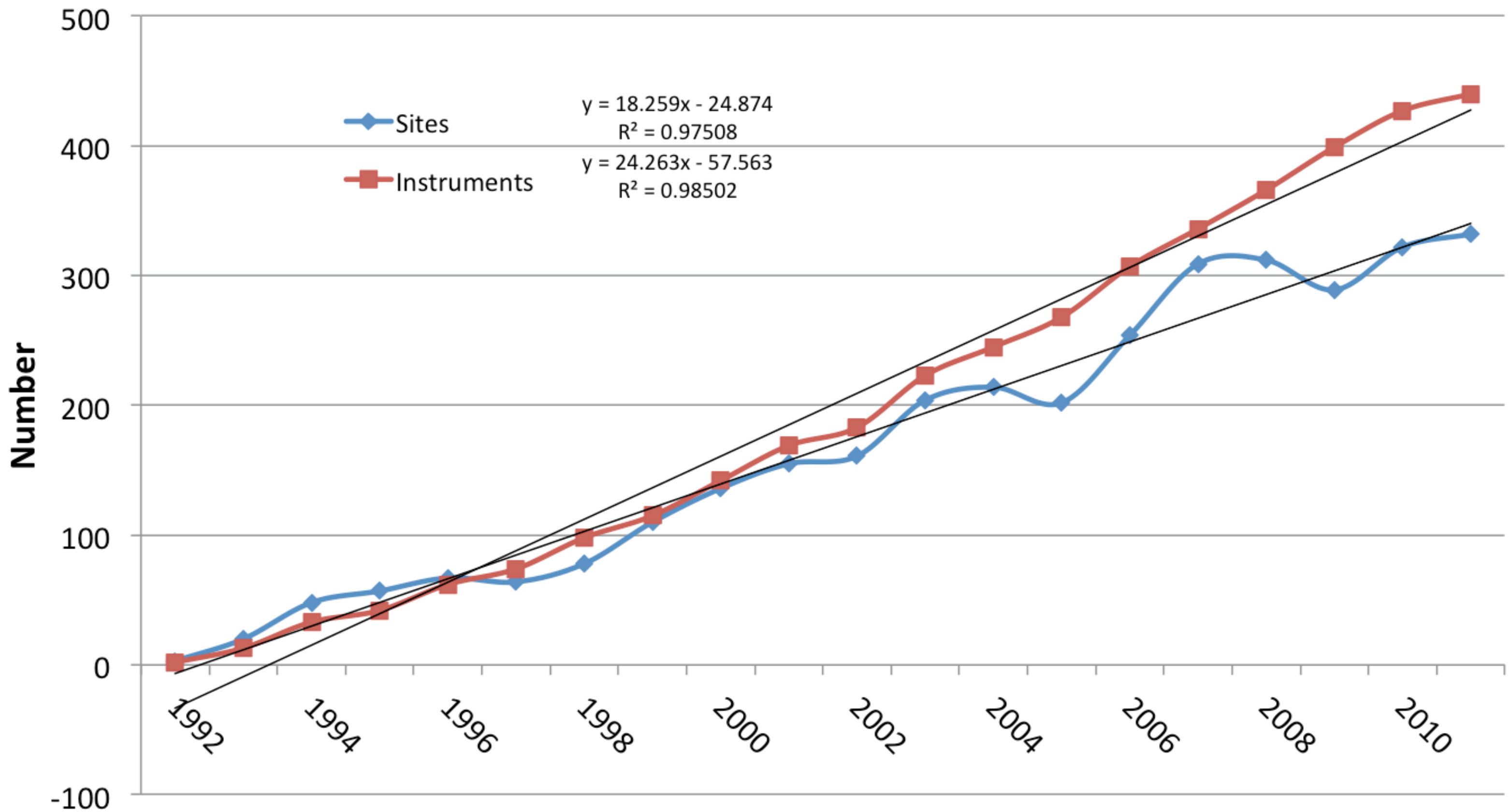
AERONET's Way Forward

DRAGONs DISCOVER new Directions, tracking Version 3

Brent Holben and AERONET teams

Sept. 12-14, 2011, Paris, France

AERONET Growth
1992-2011



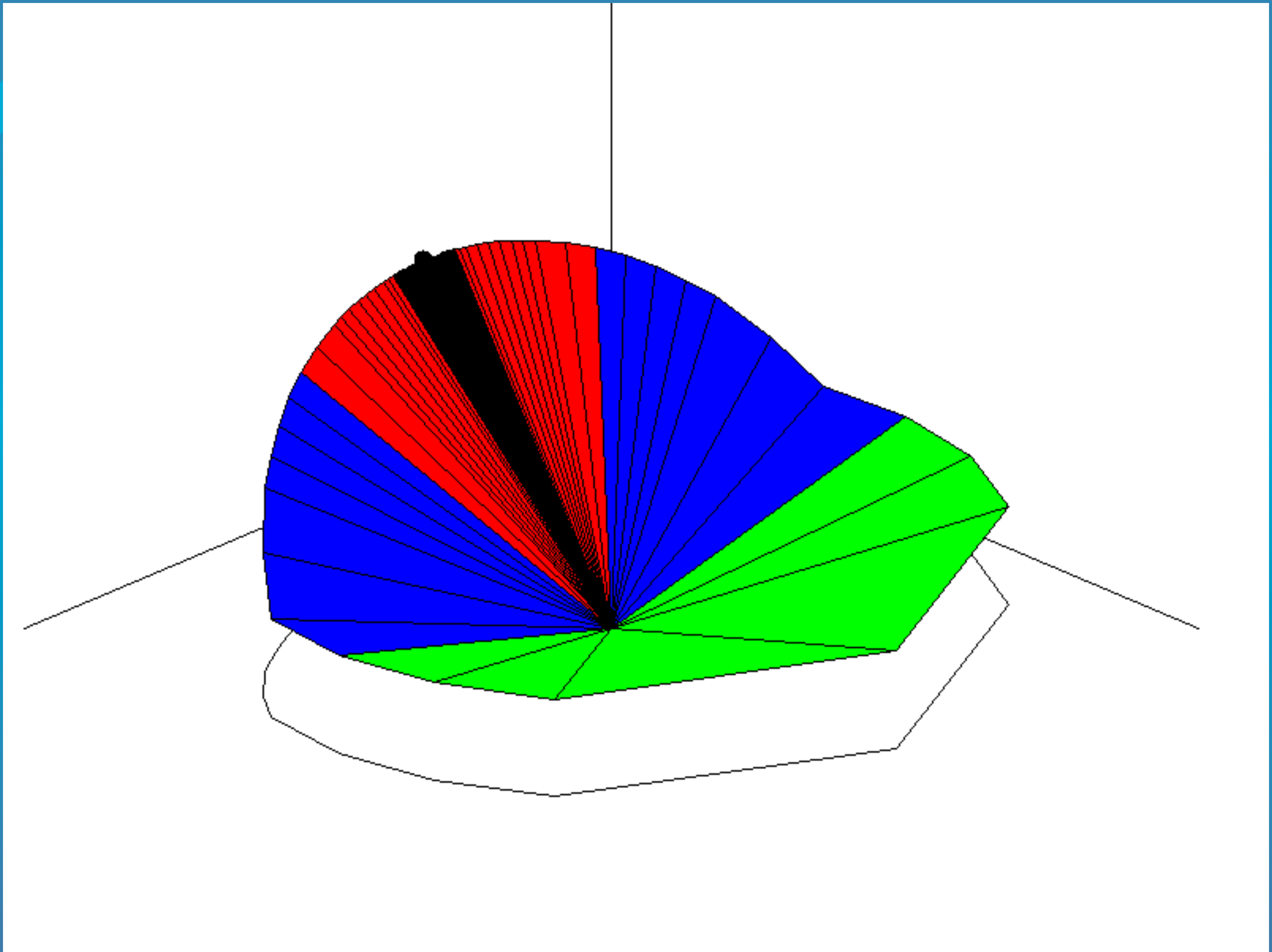
The Plan

- ~~AERONET Version 3~~
- DRAGON Campaigns

The ‘version’ game

- Version 0: 1992 to 1998
- Version 1: 1998 to 2006
- Version 2: 2006 to Present
- Version 3
  - Cloud Screening
  - Real Time QA database
  - New inversion processing/products
  - Uncertainties for each product
  - PP

Proposed Hybrid Skyscan: Combine PP and Almucantar to maximize scattering angle



DRAGON

Parameter\Type	Urban	Biomass Burning	Dust	Sea Salt Maritime	Mixed
SSA (ω_o)	-Ra†#	-H@#, +L, B, C†, Sc&	+T		-O@,+J @,E†
Size Distribution dV/dlnr, r_v	-Re*	+H@#	+Rp#, +Ru	-S†#	+J@
Real Index (n)					
Imaginary (κ)					
Asymmetry (g)					+J@
% Sphericity					

†Regional comparisons

*Nakajima retrievals

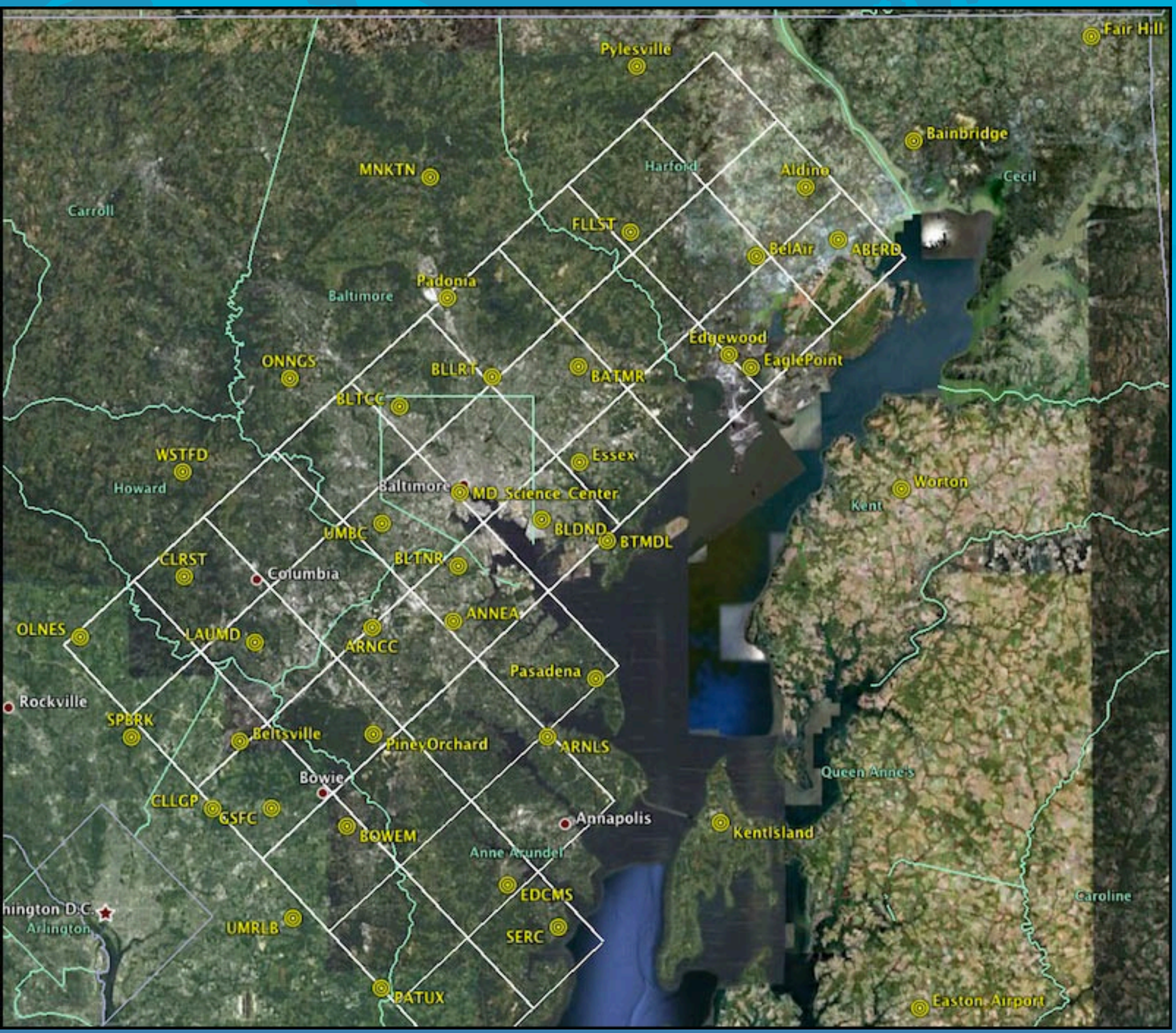
#Version 1

@ Single point

& surface comparison

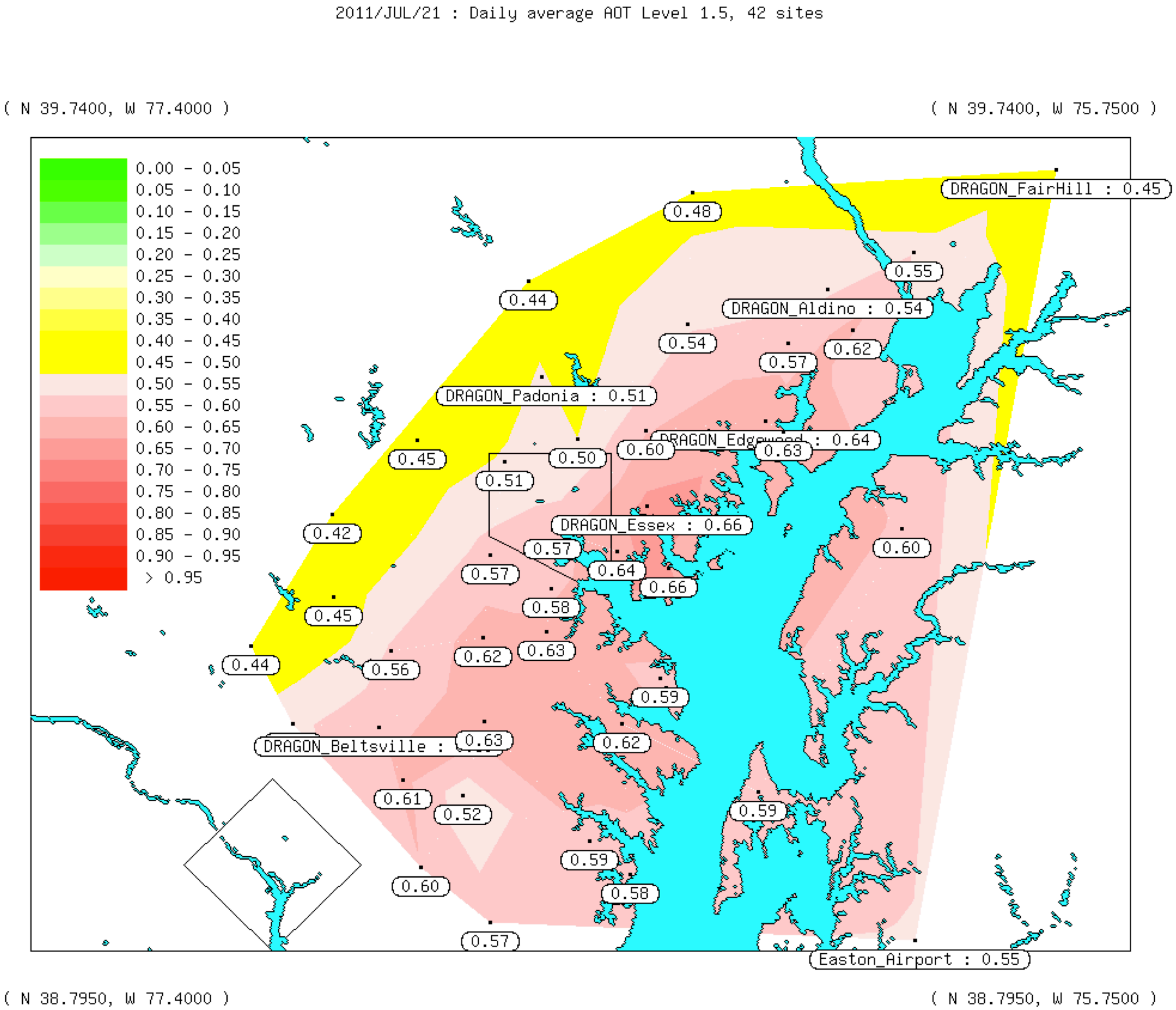
Table 1, shows the principle parameters measured by sun and sky scanning spectral radiometers for the aerosol types likely encountered. Eleven published validations/comparisons were made during field campaigns over the last 16 years; these are Ra=Ramanathan et al, 2000; Re=Remer et al., 1998; H=Haywood et al, 2003; L=Leahy et al., 2008; B=Bergstrom et al., 2003; Chand et al., 2006; E=Eck et al., 2010; Rp=Reid et al, 2003; Ru=Reid et al., 2008; S=Smirnov et al., 2003; Sc=Schafer et al., 2008; T=Toledano et al., 2011; O=Osborne et al., 2008 and J=Johnson et al., 2009. Note that most categories are incomplete, regionally based, not updated and/or lack relevance.

Comes the Distributed Regional Aerosol Gridded Observational Network, DRAGON



44 AERONET sites
I-95 Corridor: Urban to Suburban to Rural to water
~50 x 100 km
May 15 to Aug. 19

DRAGON AOD$_{500}$



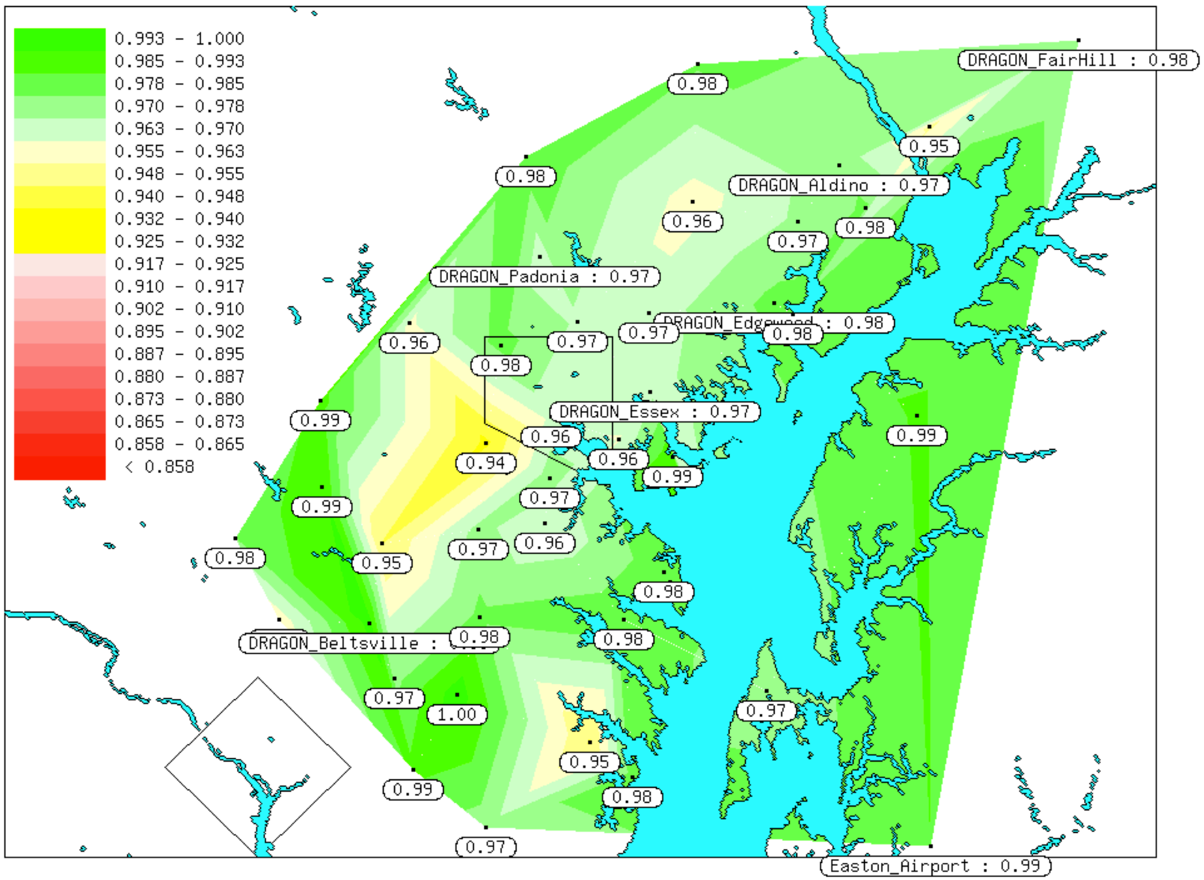
Profile Sites:

Site	Aot(500)	SDA(fine)	Water Vapor	Angstrem	SSA(440)	Reff
DRAGON_FairHill	0.45	0.44	3.7	1.62	0.975	0.209
DRAGON_Aldino	0.54	0.53	3.9	1.59	0.975	0.214
DRAGON_Edgewood	0.64	0.63	4.1	1.62	0.980	0.216
DRAGON_Padonia	0.51	0.50	3.7	1.59	0.965	0.206
DRAGON_Essex	0.66	0.64	4.0	1.59	0.967	0.220
DRAGON_Beltsville	0.59	0.58	4.5	1.57	0.995	0.196
Easton_Airport	0.55	0.53	3.9	1.59	0.985	0.197
DRAGON_WileyFord	0.40	0.37	3.3	1.67	0.976	0.182

DRAGON SSA_{440}

2011/JUL/21 : Daily average SSA(440) Level 1.5, 42 sites

(N 39.7400, W 77.4000) (N 39.7400, W 75.7500)



(N 38.7950, W 77.4000) (N 38.7950, W 75.7500)

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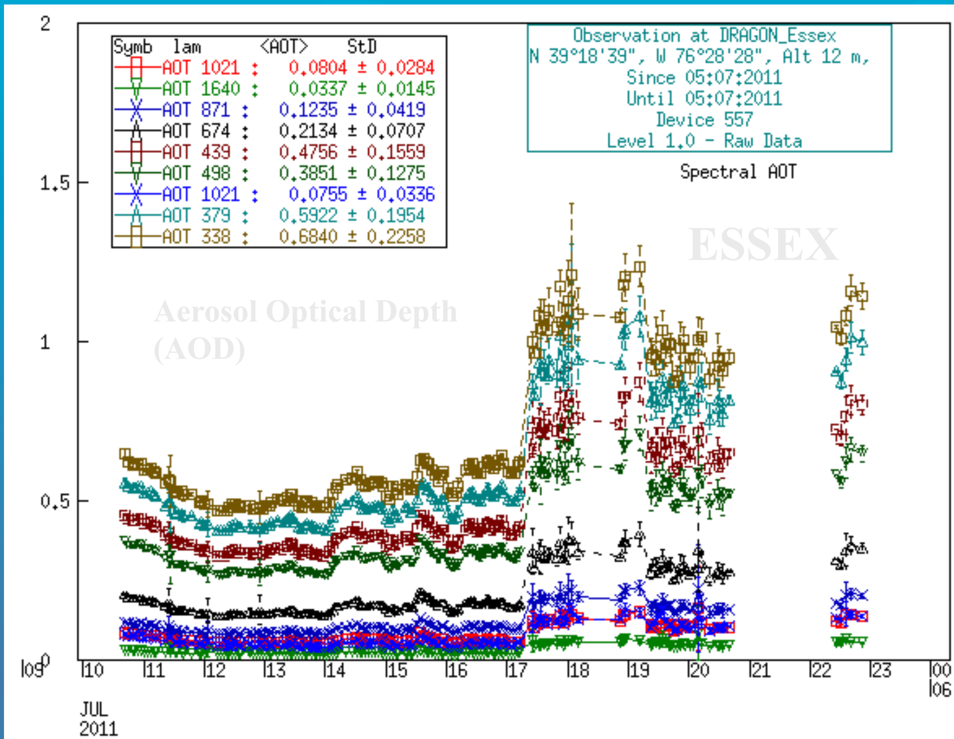
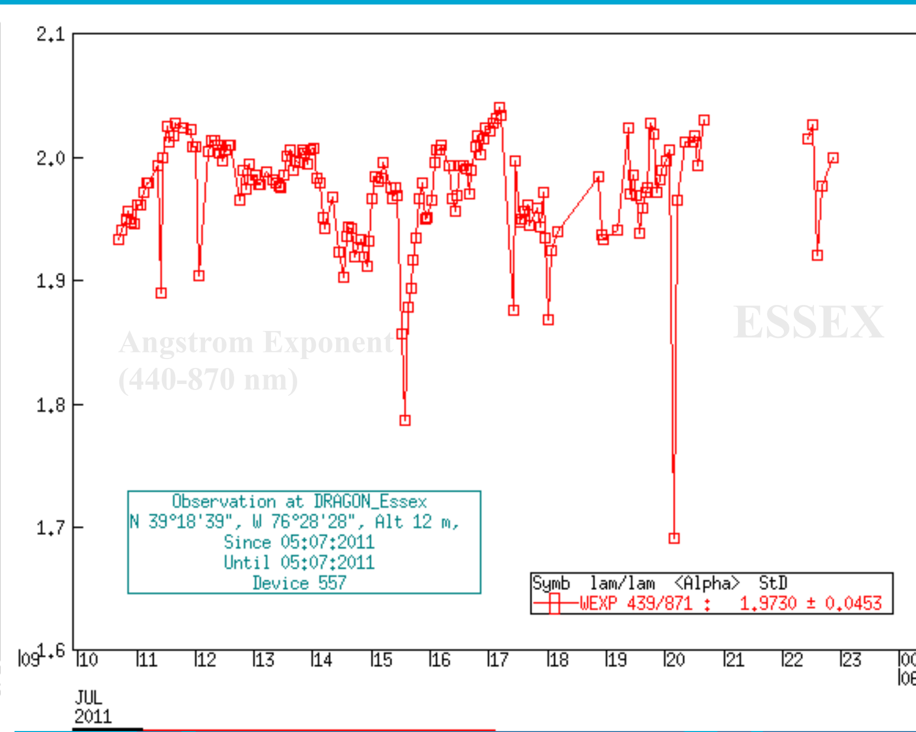
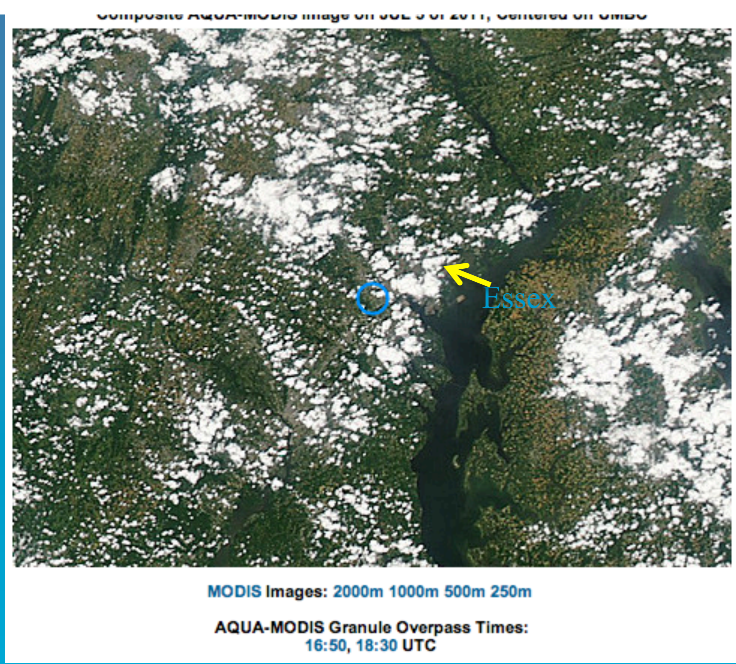
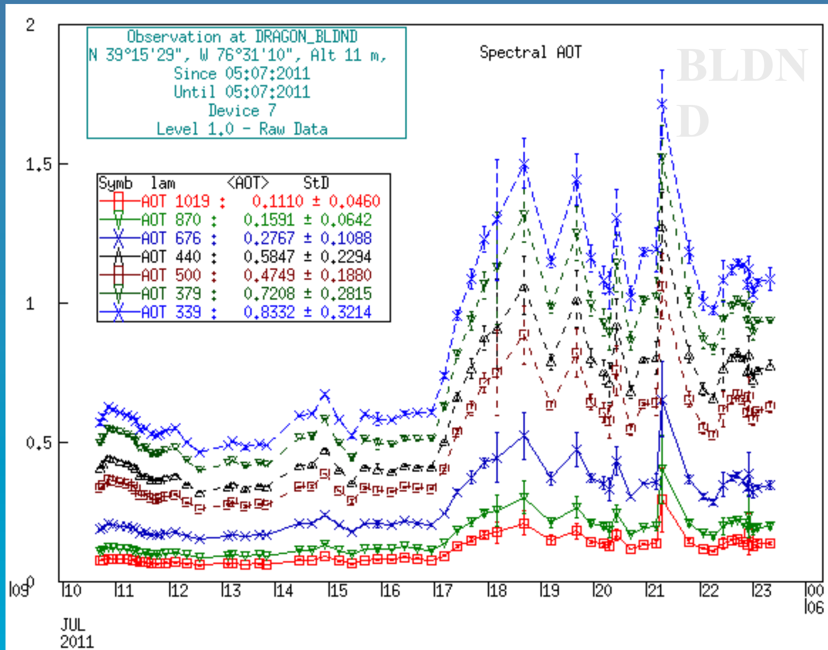
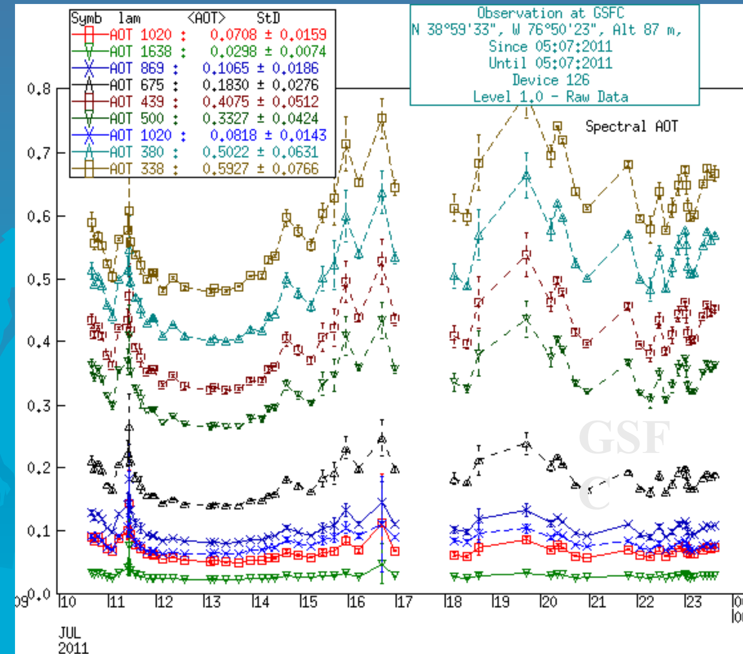




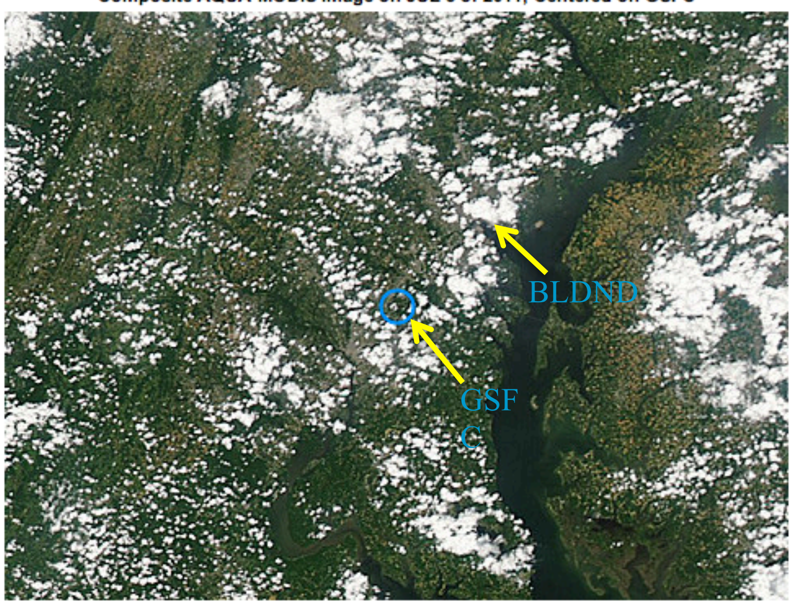


Large jump in AOD (~0.3 at 440 nm) at the DRAGON Essex site occurred just after solar noon on July 5. However, the Angstrom exponent (440-870 nm) remains very high (>1.9) suggesting possible new particle formation in the cloud environment since a particularly dense cluster of clouds is seen in the vicinity of the Essex site. Also note the larger variance of AOD (1 min intervals) in the afternoon versus morning indicating relatively high frequency variation in columnar aerosol.





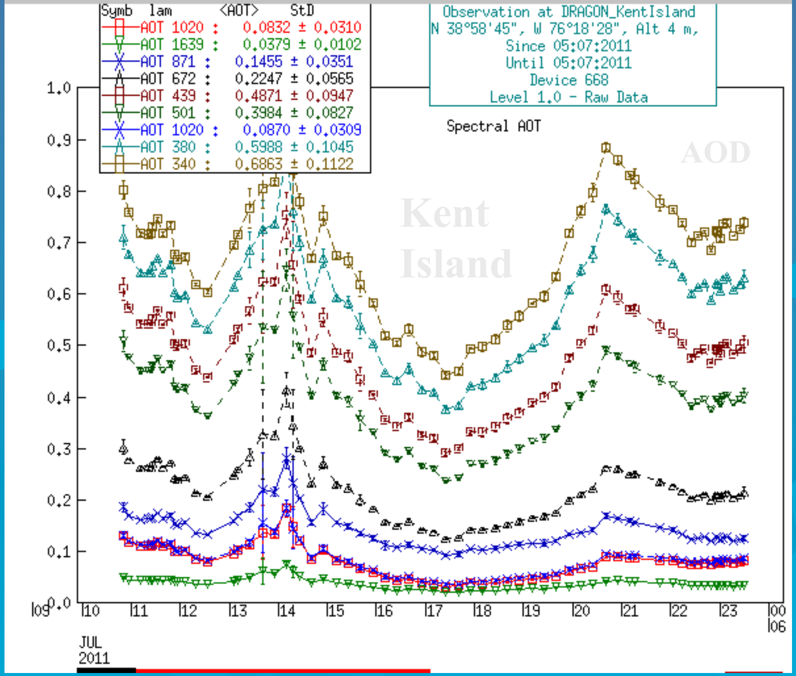
Composite AQUA-MODIS Image on JUL 5 of 2011; Centered on GSFC

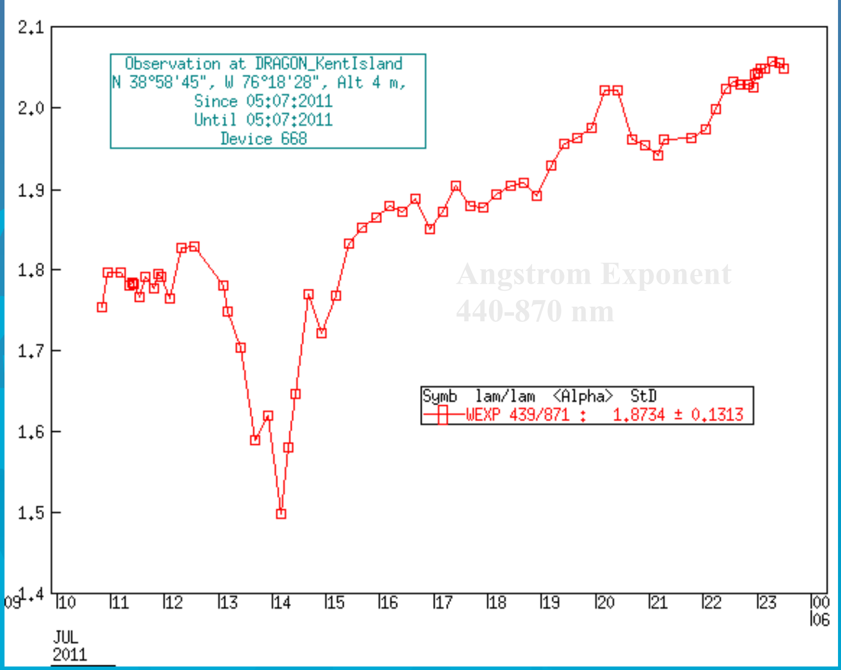


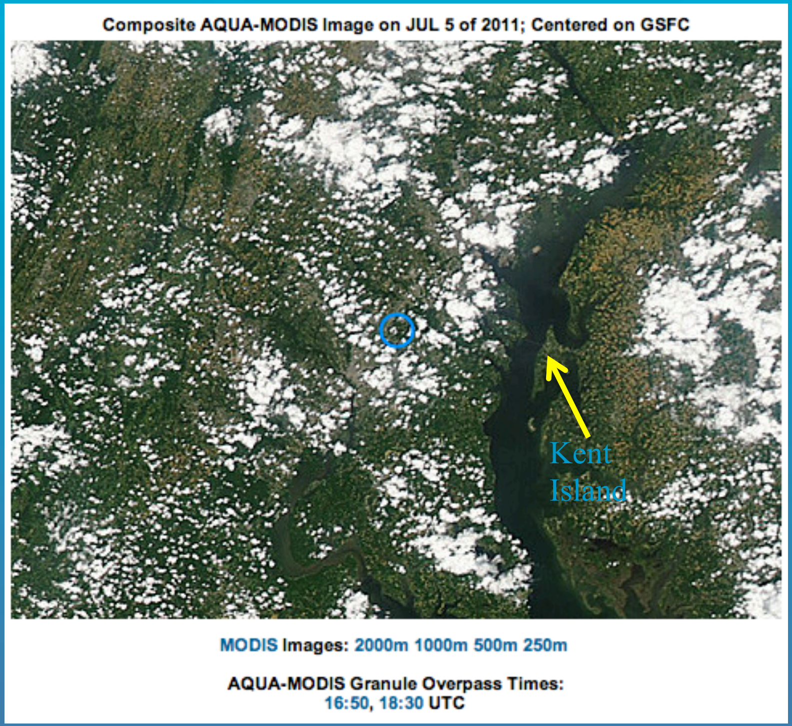
MODIS Images: 2000m 1000m 500m 250m

AQUA-MODIS Granule Overpass Times:
16:50, 18:30 UTC

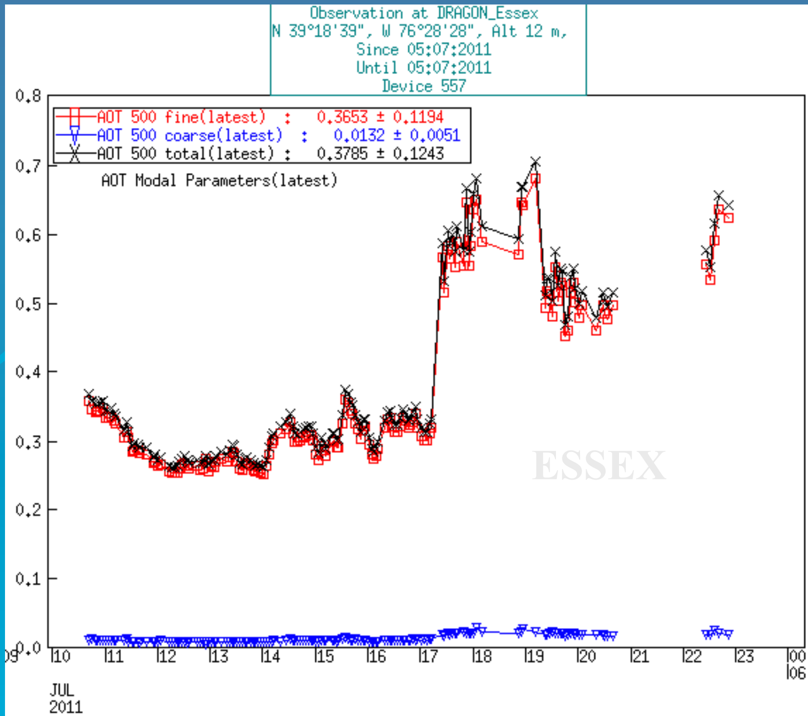
The DRAGON_BLDND site near to Essex also showed a very similar large increase in AOD in the afternoon with greater temporal variance, and with Angstrom exponent remaining very high (mostly ~1.85-2.05). However, at the GSFC site the AOD does not increase significantly in the afternoon (note different vertical scales) although Angstrom exp. remains very high (~2.0-2.1), and there are much fewer and smaller clouds in the vicinity of the GSFC site.

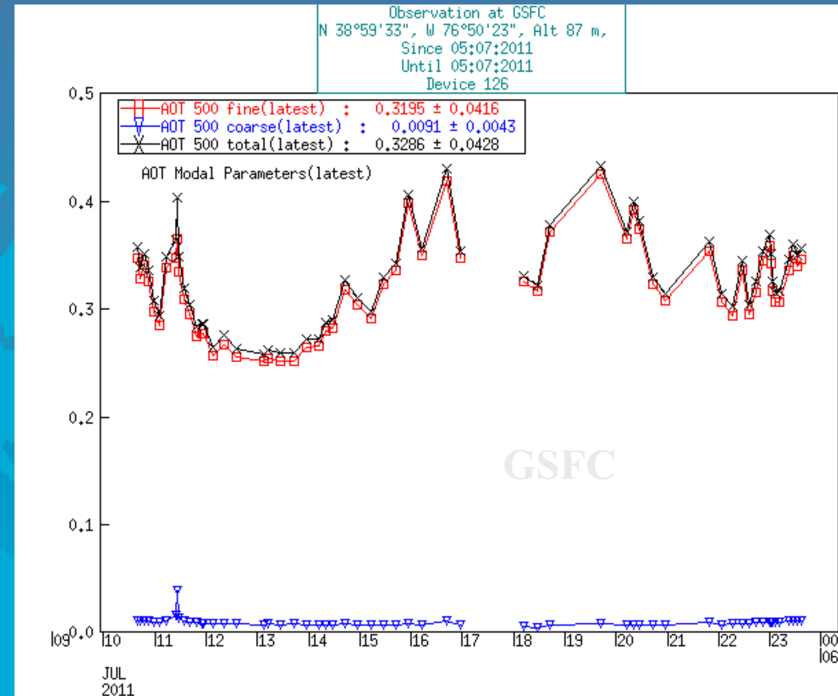


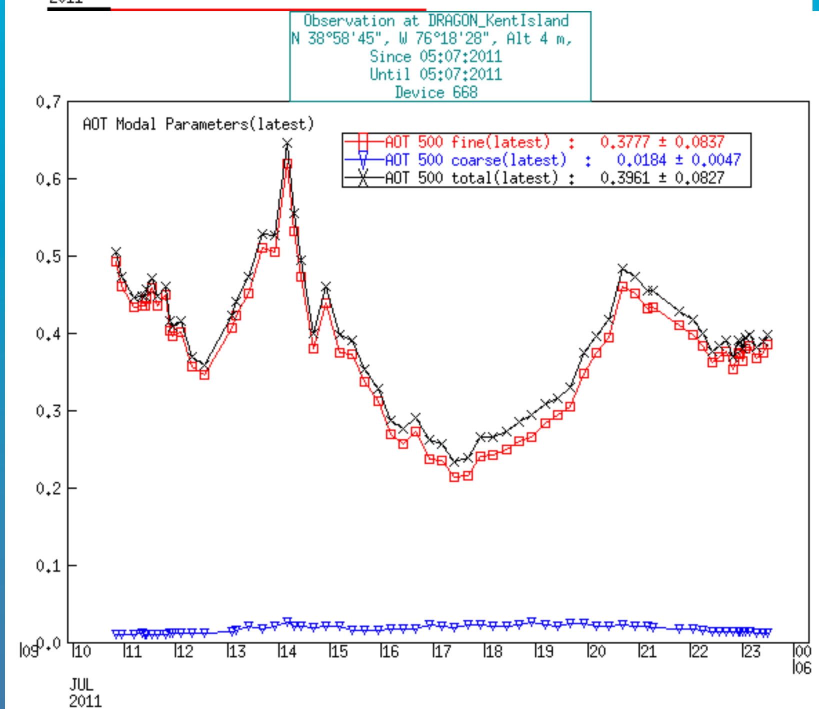




The AOD at the Kent Island site (east of the Chesapeake) does not show any rapid changes in AOD and there are no clouds in the vicinity of that site at Aqua overpass time. However, there are smoothly varying AOD trends throughout the day, with lower Angstrom in the morning than the western sites and similarly high Angstrom at the end of the day. It could be very interesting to analyze the GOES data on cloud cover throughout the day for all DRAGON sites on this date (and probably other dates as well).





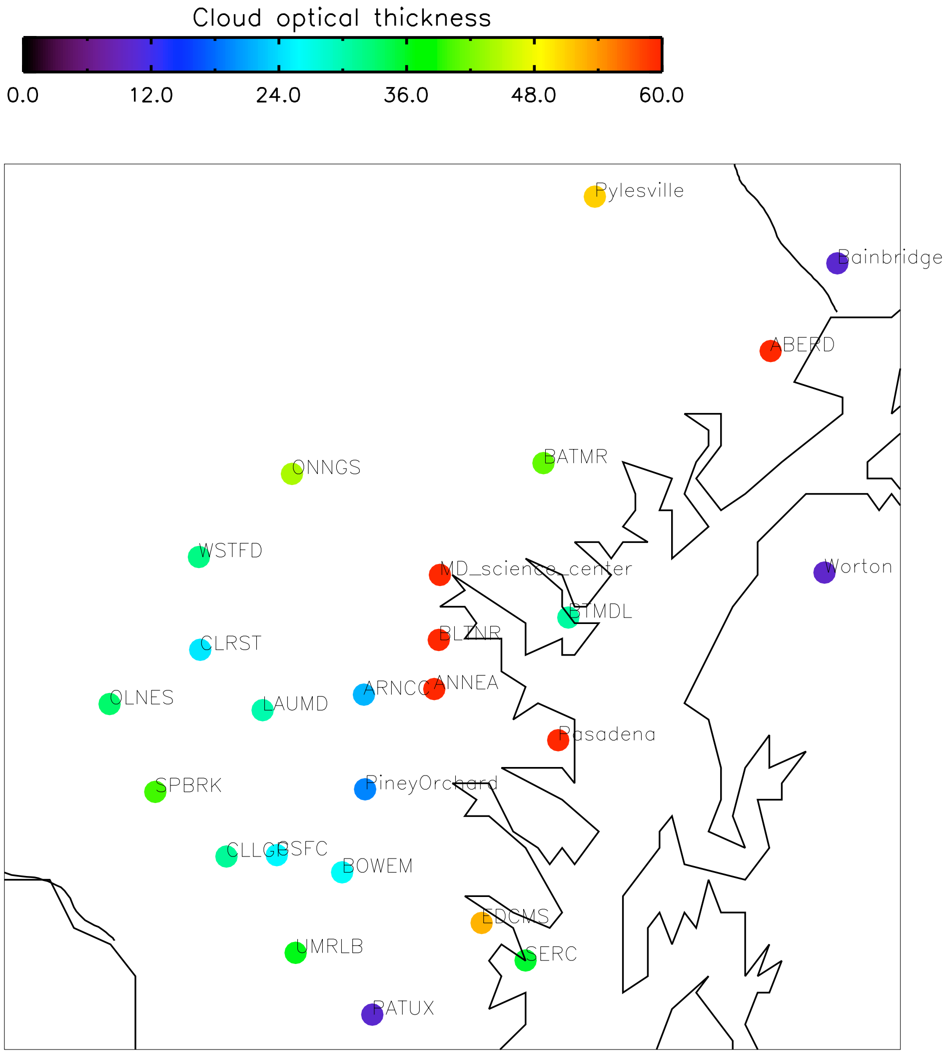


Norm O'Neill's Spectral Deconvolution Algorithm (SDA) utilizes the spectral AOD from 380 to 870 nm and assumptions about coarse mode linear and 2nd order fits of ln AOD versus ln λ, to provide estimates of Fine and Coarse mode AOD at 500 nm.
The coarse mode AOD at the Essex, GSFC, and Kent Island sites are all ~0.01-0.025 nearly all day suggesting that almost all of the variability in total AOD (this is Level 1.0 data, not cloud screened) is due to fine mode pollution aerosol.

AERONET COD product across DRAGON

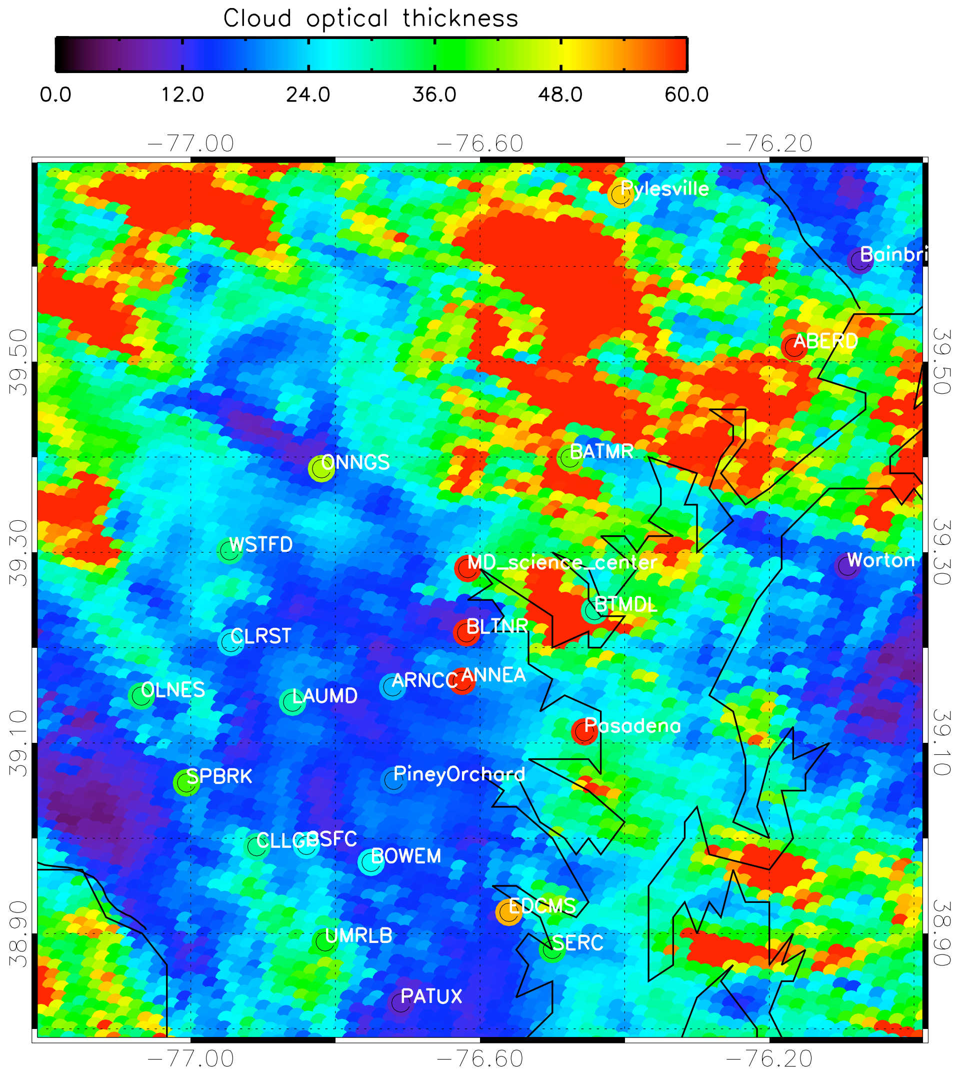
- 34 sites across the DRAGON field campaign.
- 9 cases for intercomparison between ground- and satellite-based data, on a 30 min. time window centered at the MODIS overpass time.
  - ✓ 4 overcast cloud cases on Aug. 3, 4, 9, and 13
  - ✓ 5 broken cloud cases on Aug. 5, 6, 7, 14, and 15
- Regional cloud optical depths from AERONET and MODIS show a similar pattern, the further analysis is under processing.

The distribution of cloud optical depth from AERONET



<u>Captions</u>: 25 AERONET sites provided COD measurements on 16:20 GMT [+/- 15min], Aug. 03, 2011.

The distribution of cloud optical depth from AERONET and MODIS



<u>Captions</u>: A snap shot of regional cloud optical depth distributed from AERONET and MODIS. The underlying map is the COD measurements of MODIS/Terra on 16:20 GMT, Aug. 03, 2011. Based on a 30 min. time window centered at the MODIS overpass time, 25 AERONET sites provided COD measurements indicated by circle.

DISCOVER AQ-Collaboration Surface Measurements

- Lidar-MPLNET
- Trace Gas Spectrometry-PANDORA
- Operational Air Quality site-MDE
- Research Supersites-SMART, NATIVE
- Tethered Balloon profiles-Howard & Mitchelville Univ.

DISCOVER AQ Collaborations- AIRBORNE

NASA P-3B

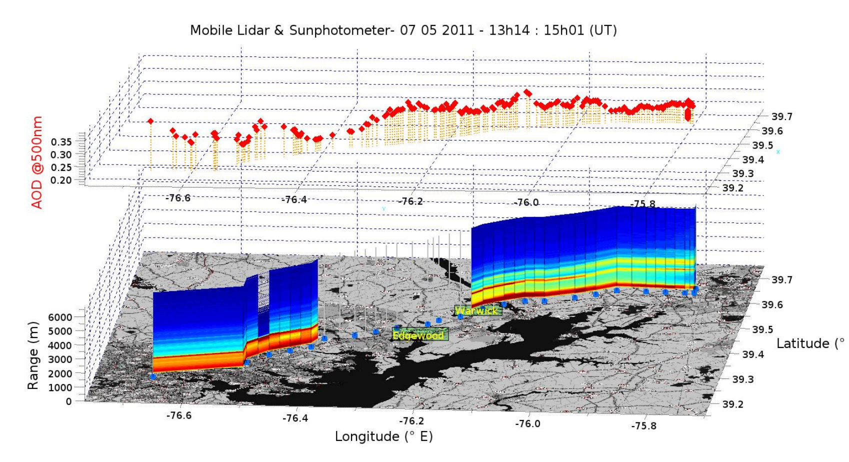
Airborne measurements

- P-3B NASA
  - Aerosol: LARGE
  - Trace Gasses: TD LIF…
- King Air NASA
  - Aerosol: HSRL
  - UV absorption: ACAM
- Cessna 402B Univ. of MD
  - Aerosol
- Where was Phil?

DISCOVER AQ and LOA

Mobile lidar, sun photometer and police

5,000 km of data



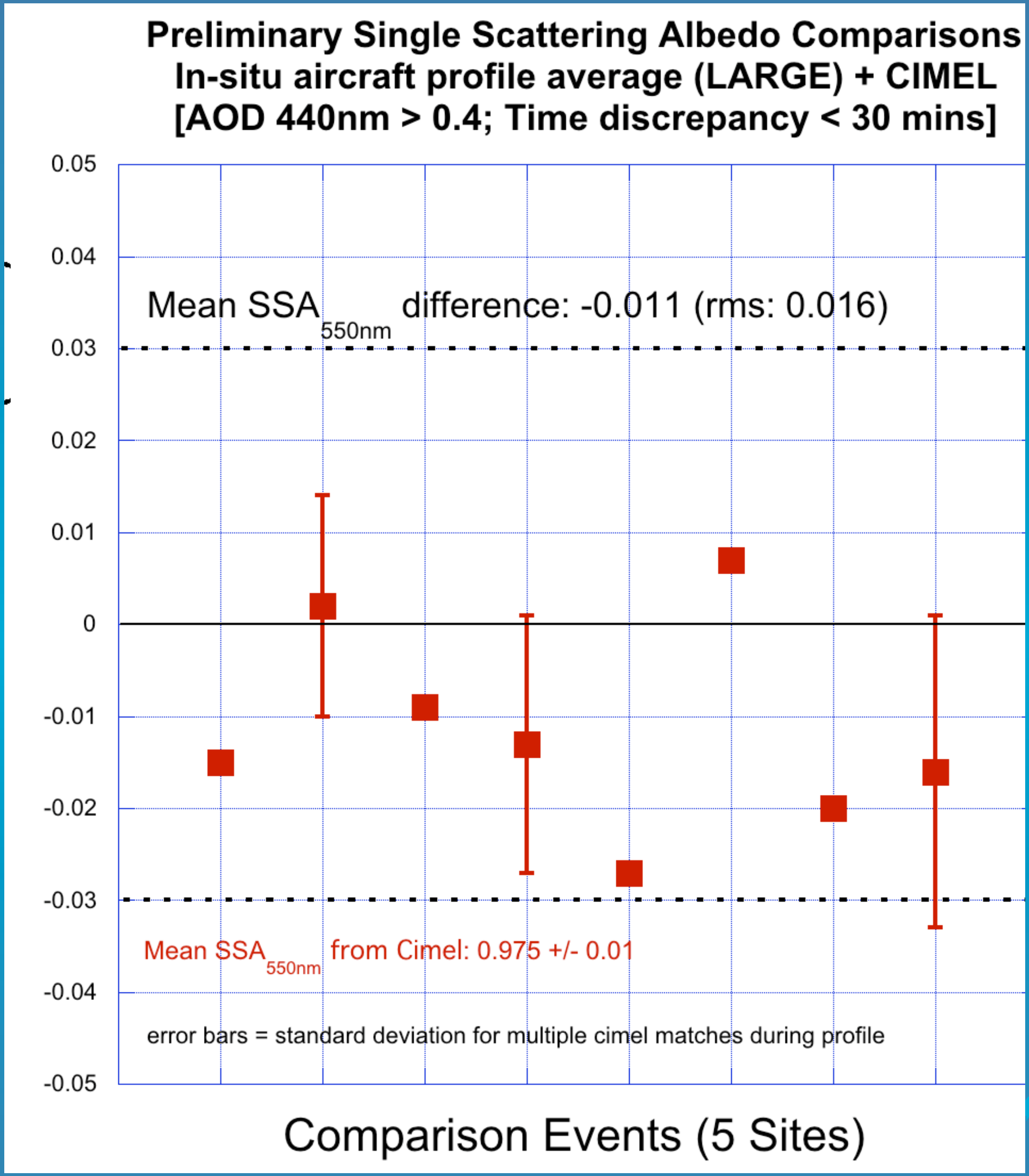
DISCOVER AQ

Fairhill
Harford
Aldino
Cecil
Padonia
Baltimore
NATIVE
Edgewood
Baltimore
UMBC
Essex
Howard
Columbia
Kent
Maryland
Bowie
Annapolis
Queen Anne's
Anne Arundel
SERC
Caroline
ZONE (FRZ)
© 2011 Europa Technologies
© 2011 Google
Image U.S. Geological Survey
Google

DISCOVER AQ & DRAGON SSA comparison

- Six Profile sites
- 118 flight hours
- 252 profiles
- 1302 Almucantars
- 8 coincidences
- Mean difference: -0.01

- The DRAGON NETWORK Concept:
  - AERONET Validation
  - High Resolution Satellite and model validation
  - RS relevance to AQ
  - Synergism w/ in situ & RS databases
- DRAGON Korea & DRAGON Japan 2012



From Mosquito Pits

Thank you Didier

Backup slides

Summary and conclusions

1. Restrictions on SZA currently used to select level 2 retrieval product are rather strict and applied regardless of aerosol type.
2. Sensitivity to aerosol absorption as a function of scattering angle is different for large and small aerosol particles.
3. Theoretical analysis and comparison to actual retrievals shows that SZA restrictions can be relaxed for small aerosol particles:
   - for 440 nm channel SSA retrievals can be used for SZA as small as 20 dg.
   - for longer channels and for SZAs smaller than 40 dg. SSA retrievals are less stable but can be improved by using combination of ALM/PP or ALM and the scan with large and constant view angle (LCVA)
4. For large dust particles variability of SSA retrievals with SZA is amplified by some bias in theoretical modelling of atmospheric radiation. Possible reasons include surface reflectance model and dust particles non-sphericity.
5. For the mixture of large and small particles SZA restrictions could be expressed as a function of angstrom parameter and will take intermediate values between two boundary values.

The dawn of ubiquitous AOD measurements

F.E. Volz developed the Volz sun photometer
- Schott interference filters
- Stable photodiodes
- Small, portable and accurate instruments

Flowers et al. 1969
- US Turbidity Network
- 5 yr record
- Monthly averages
- 43 sites

M. D. King et al., 1978
- Size distribution from Inversion of Spectral AOD

Add sky radiance

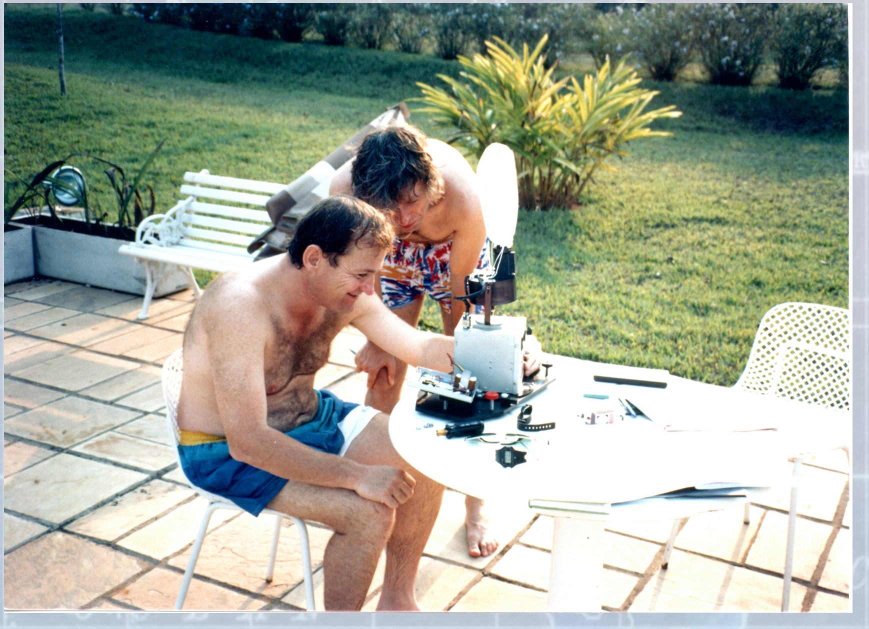
Tanaka, M. et al.,1982
Nakajima, T. et al., 1983, ‘89, ‘96

- Inversion yielded improved particle size distributions
- skyrad.pak
- Required accurately pointing sun sky radiometer
- Lost portability/convenience

Enter: Kaufman, Tanre, Buis

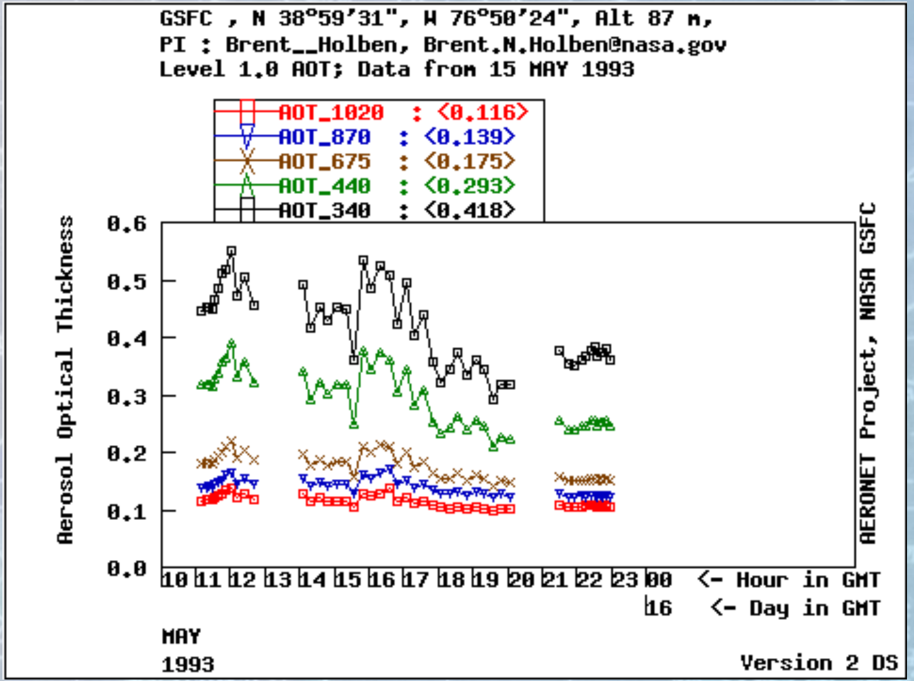
The next step

Kaufman and Tanre, 1989



J.P. and Mme. Buis

AERONET's First Light (1993)



Holben et al., 1998

Dubovik and King 2000

- No assumptions…
- Absorption, Shape …

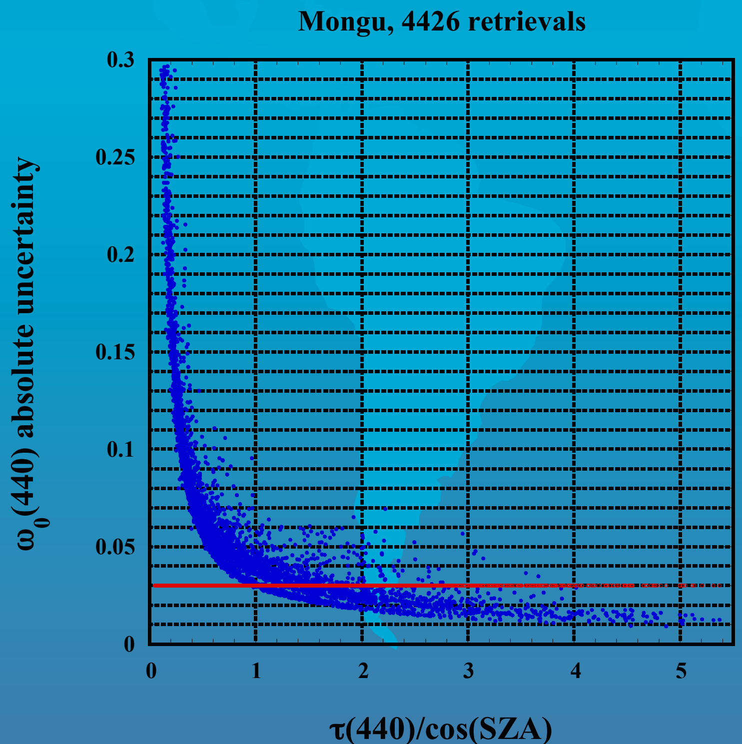
Ground-based aerosol measurements-the Tanre Factor (an insiders view)

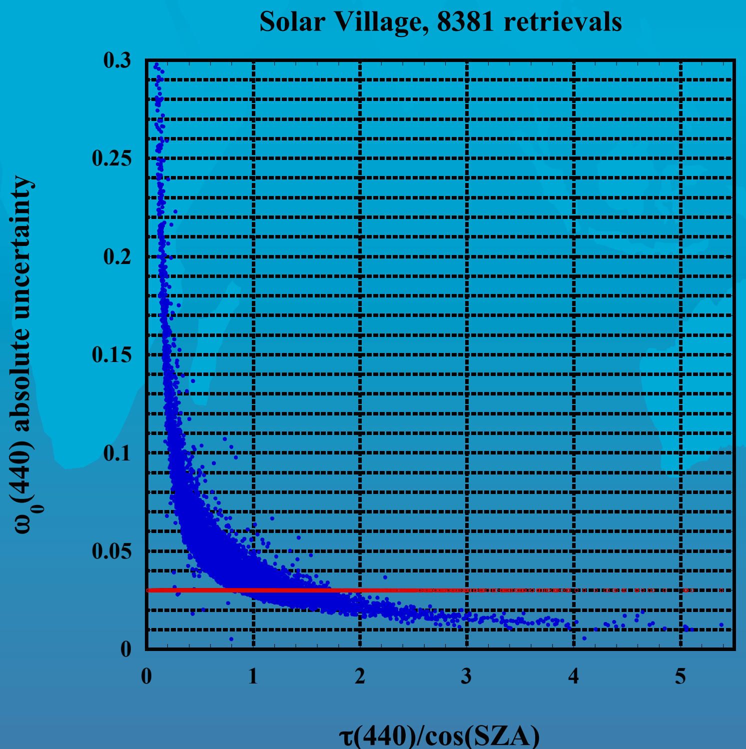
From Past to Present-Leadership, new directions

Estimation of uncertainties of retrieved aerosol parameters

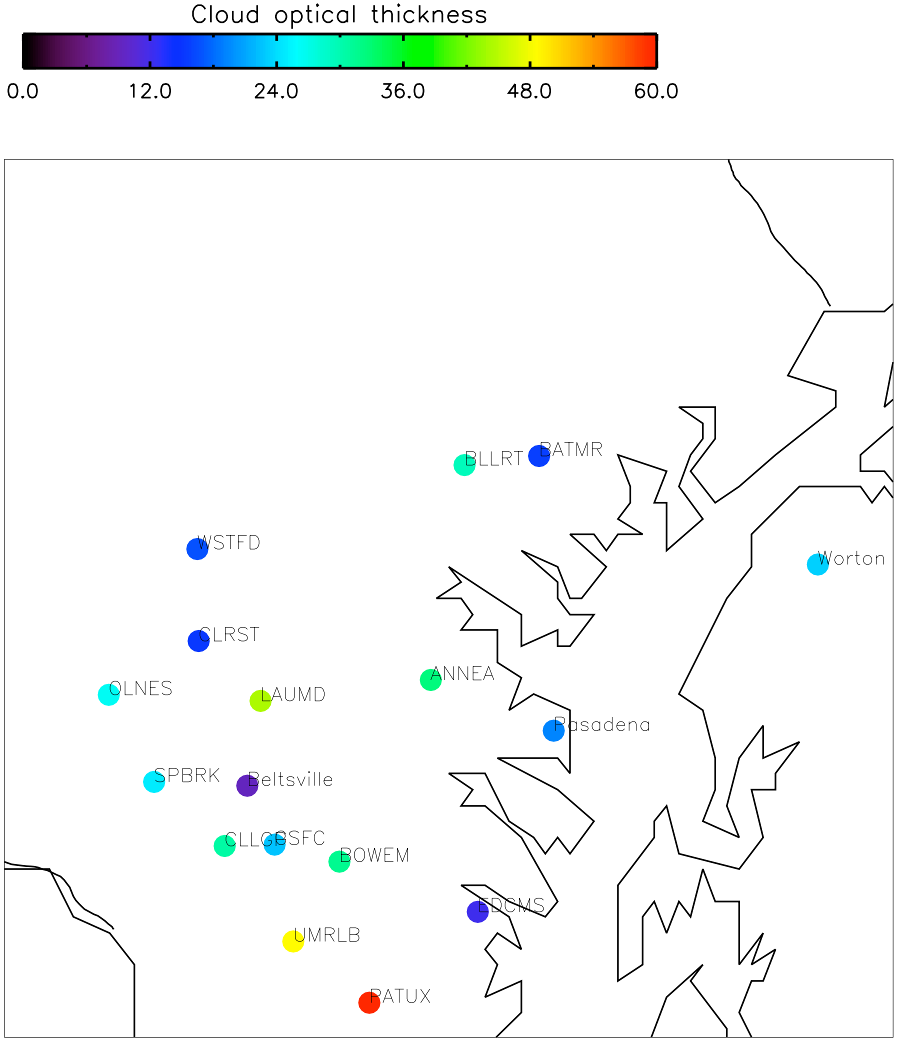
Uncertainties are estimated using general approach described in Dubovik, 2004*: Photopolarimetry in Remote Sensing, 65-106, 2004, Kluwer Academic Publisher.*

The examples below show that the product of optical depth by air mass is a natural parameter to classify uncertainties in retrieved aerosol parameters. In particular, for SSA retrievals, estimated uncertainties are smaller than 0.03 for the values of this parameter smaller than 2.



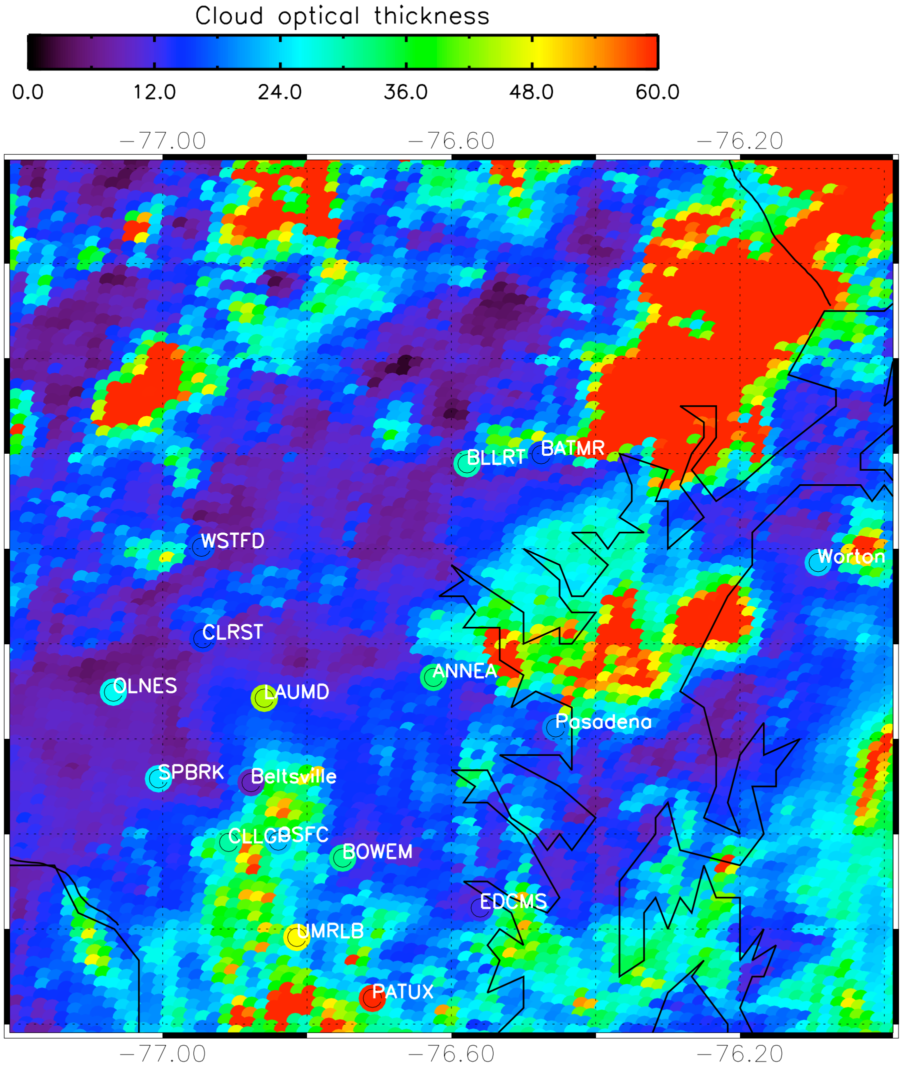


The distribution of cloud optical depth from AERONET



<u>Captions</u>: 17 AERONET sites provided COD measurements on 15:45 GMT [+/- 15min], Aug. 09, 2011.

The distribution of cloud optical depth from AERONET and MODIS

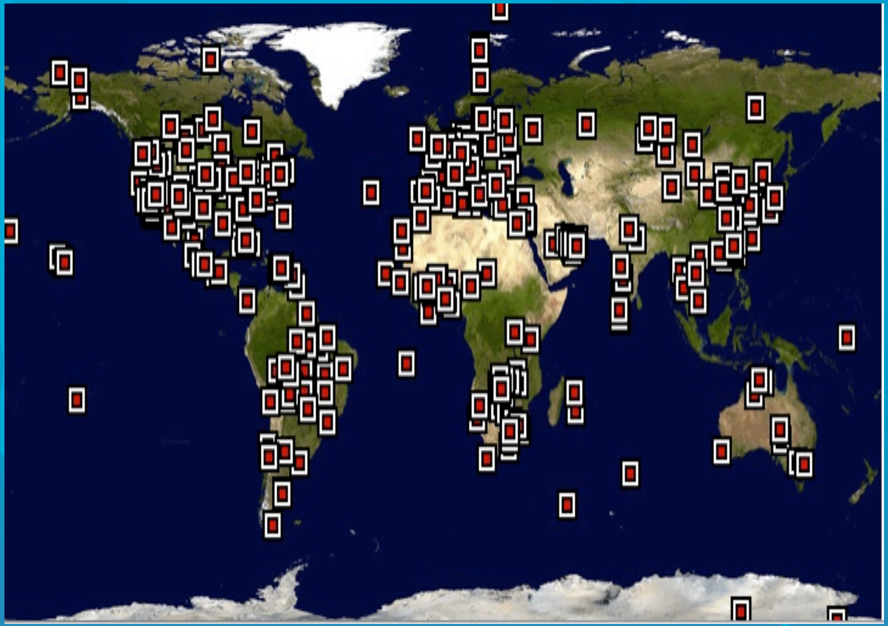


<u>Captions</u>: A snap shot of regional cloud optical depth distributed from AERONET and MODIS. The underlying map is the COD measurements of MODIS/Terra on 15:45 GMT, Aug. 09, 2011. Based on a 30 min. time window centered at the MODIS overpass time, 17 AERONET sites provided COD measurements indicated by circle.

AERONET- The ground based Satellite

Mission Objectives:
•Characterize aerosol optical properties
• Validate Satellite & model aerosol retrievals
• Synergism with Satellite obs., ESS and CC

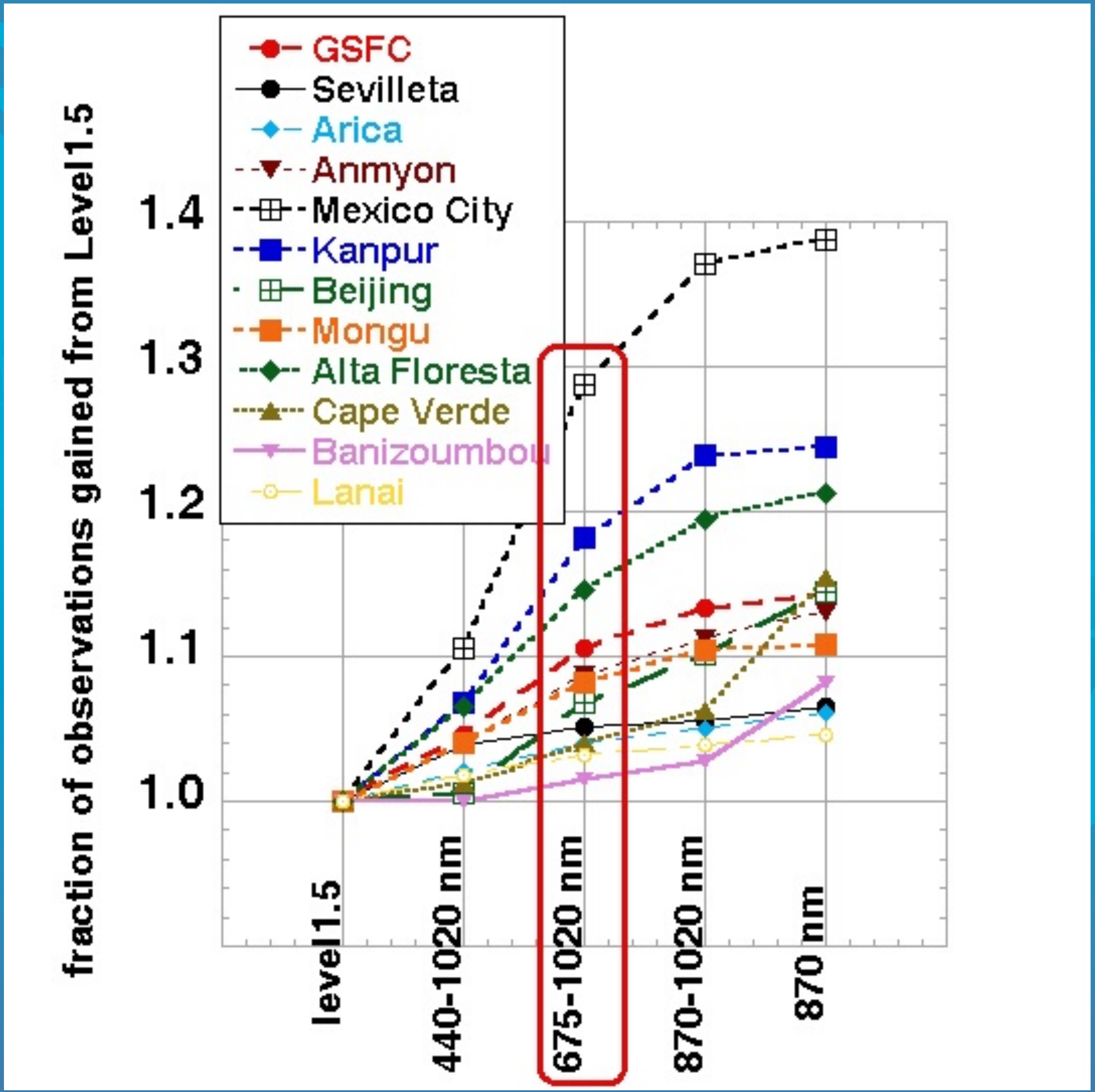
- Internationally Federated
  - GSFC 134 sites
  - PHOTONS (Fr) 70 sites
  - Canada 40, Spain 16…
- 443 instruments
- ~375 Operational sites
- Distributed calibration facilities: US, France, Spain, Canada
- Expansion to Asia, Africa, high latitudes and over water sites
- Support NASA ESS activities



Parameters measured: τ, ω_o, Θ, size, n, k and WV, cld OD, L_{wn}

Open data access via website: http://aeronet.gsfc.nasa.gov/

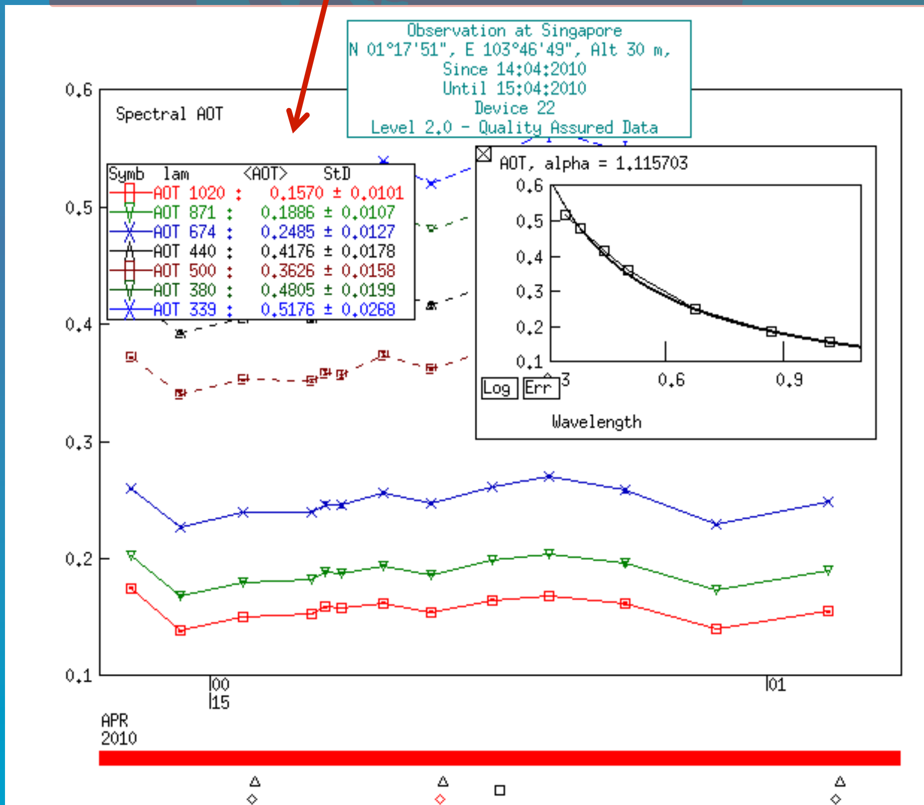
Version 3 triggered by a change in the database: Cloud screening

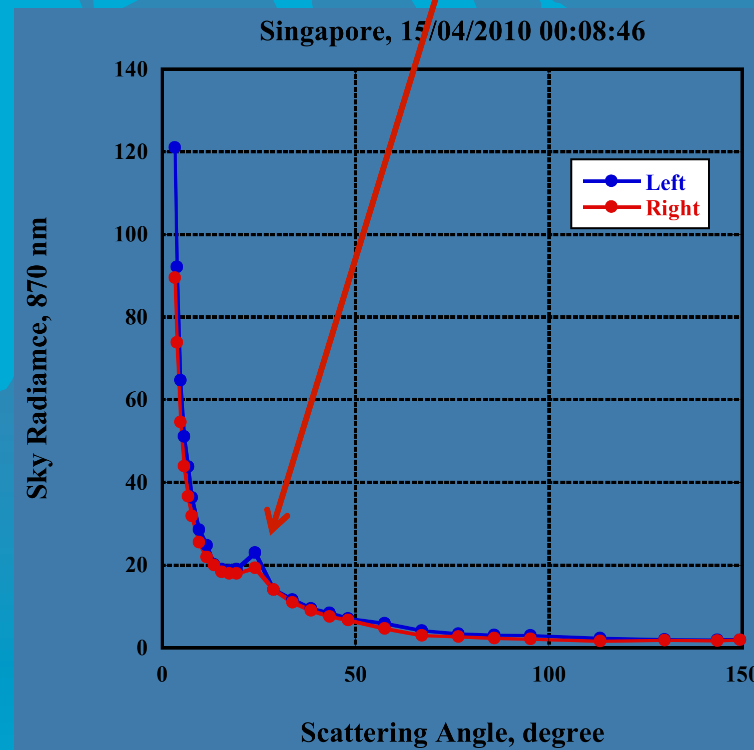


Detection of cirrus clouds using 22 degree halo feature

Increase of scattering in the vicinity of 22 degree scattering angle is a typical feature of ice crystals scattering phase function. It is also observed in sky radiances in the presence of cirrus clouds and can be used for their detection.

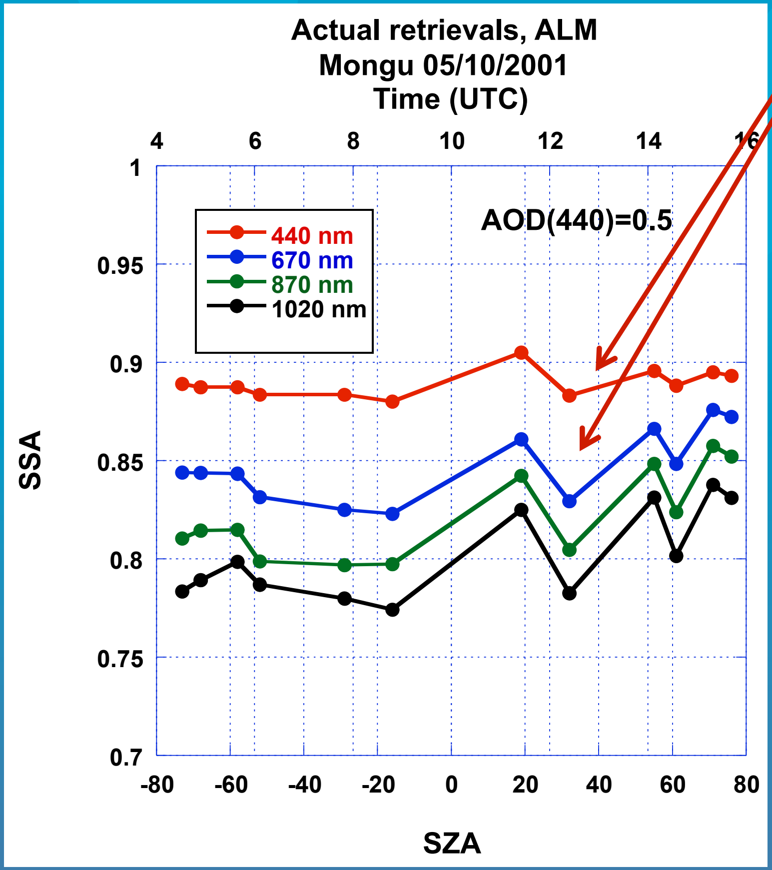
Cirrus was not detected: relatively high Angstrom parameter and stable optical depth. It could be detected using 22 degree halo features in sky radiance.

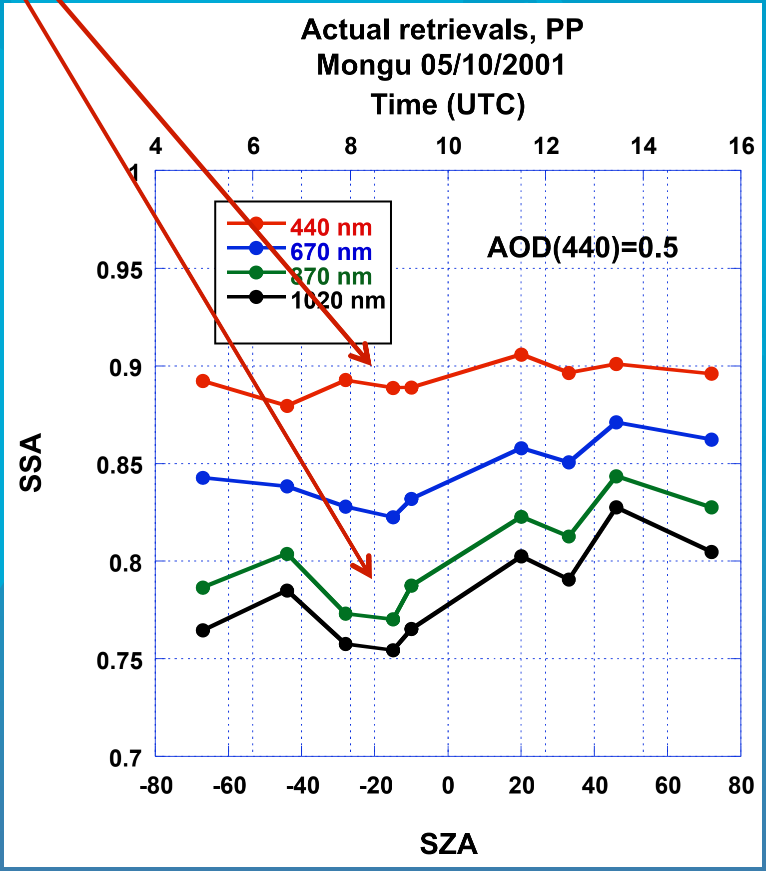




Dependence retrieved SSA on SZA: fine mode aerosols

- SSA(440) retrievals are stable for both ALM and PP
- other channels are less stable: the features in temporal variability of SSA(440) are amplified for longer wavelengths.

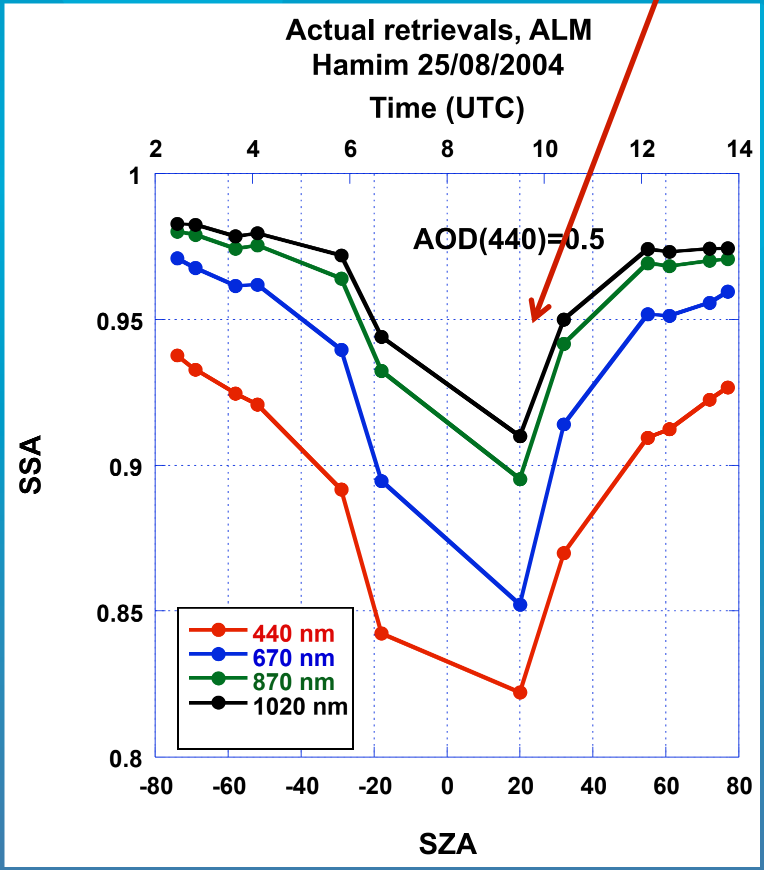


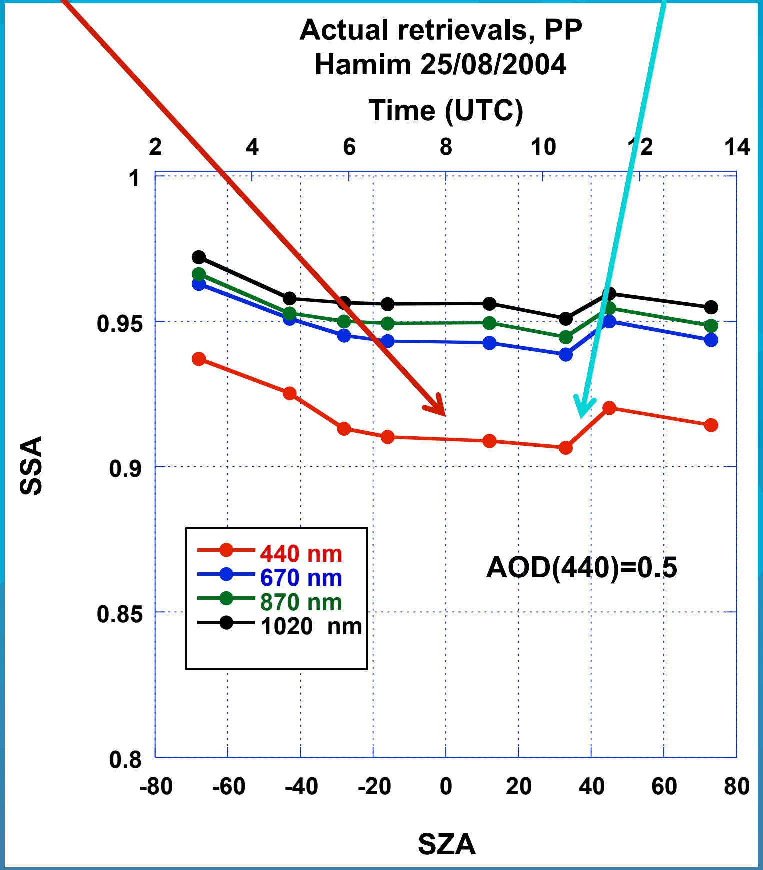


Dependence retrieved SSA on SZA: dust

Artificial dependence of retrieved SSA on SZA

For PP this dependence is less pronounce
Due to extended range of scattering angles

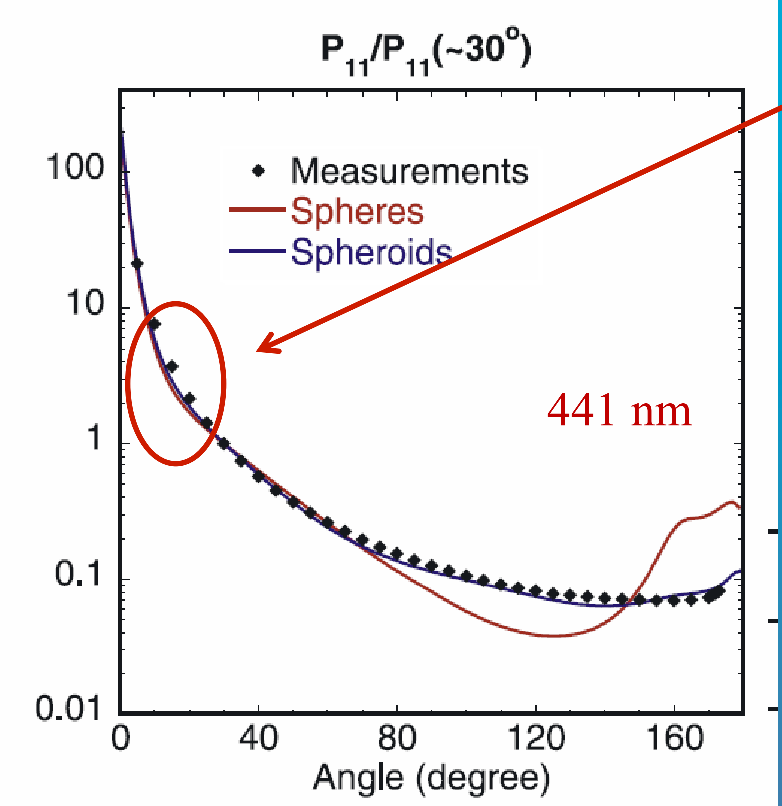


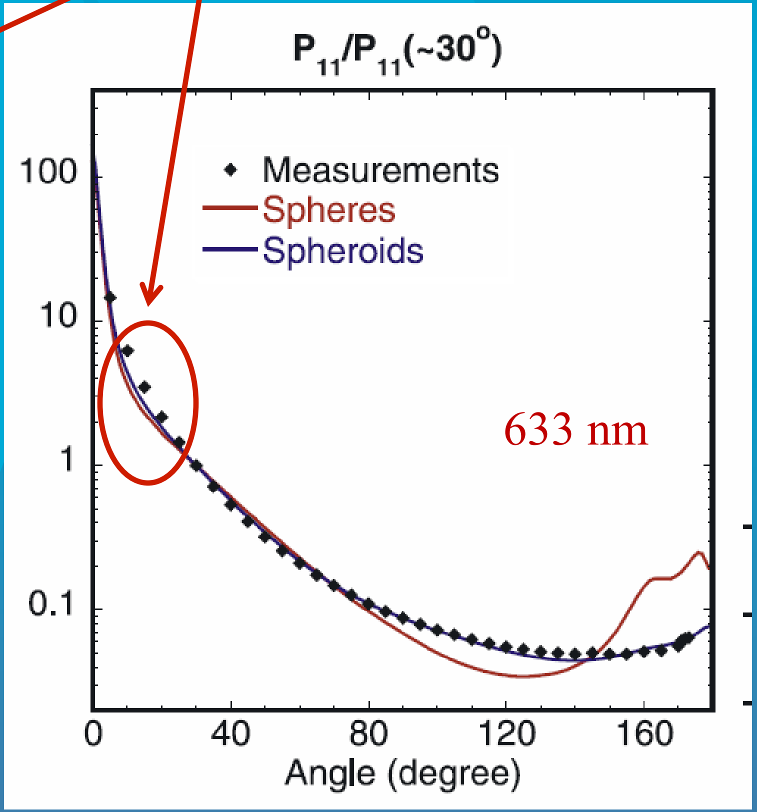


Dependence retrieved SSA on SZA: bias in modeling of light scattering properties of mineral dust

Fitting of phase function measured for feldspar sample from Dubovik et al., 2006

Bias in fitting by both spheres and spheroids. Might be specific feature of natural mineral dust aerosol which is difficult to model

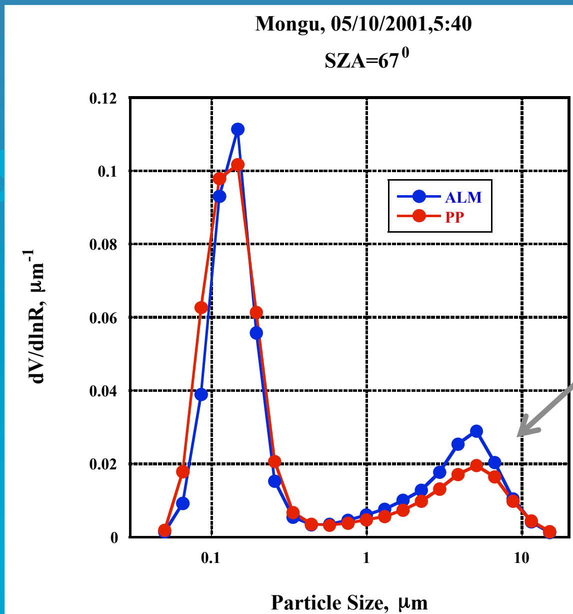


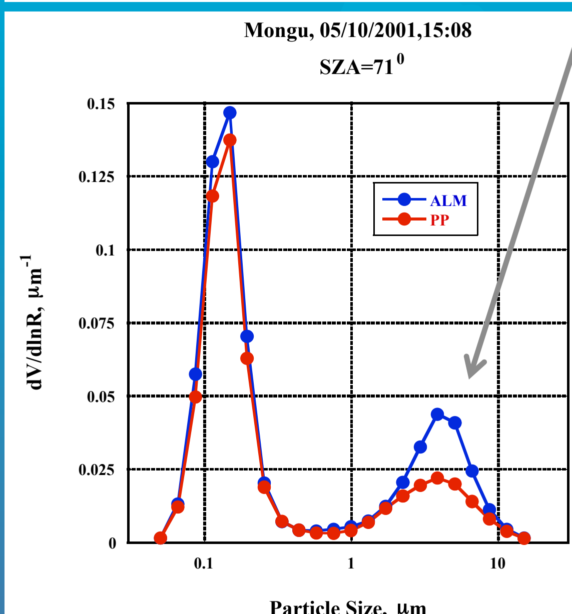


Dependence retrieved SSA on SZA: summary

1. Dust:
   1.1 Artificial dependence of retrieved SSA which can not be explained by decrease in the range of scattering angles only.
   1.2 Our current assessment of the problem: theoretical bias in modeling of light scattering properties of dust aerosol due to the different adjustments of aerosol parameters required to fit this bias for different observation geometry.
2. Fine mode aerosols: restrictions on SZA could be relaxed down to 30 degree.

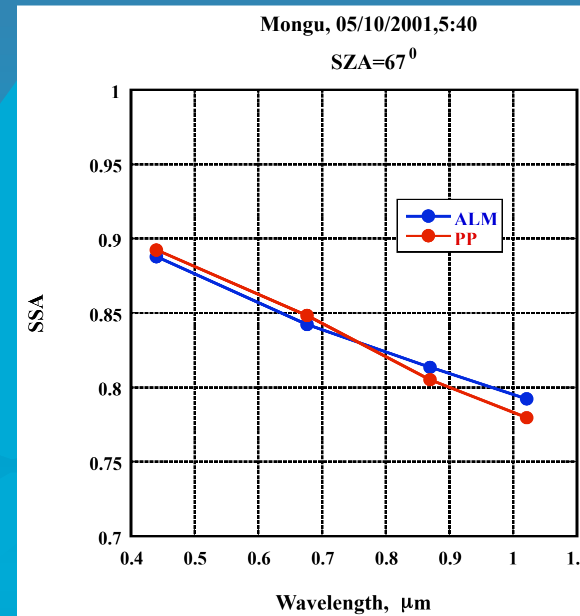
ALM vs. PP: fine mode dominated aerosol

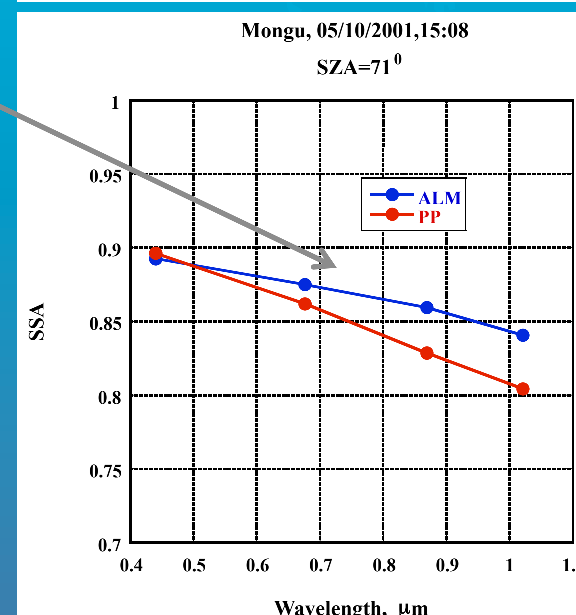




Difference in coarse mode retrievals for ALM and PP

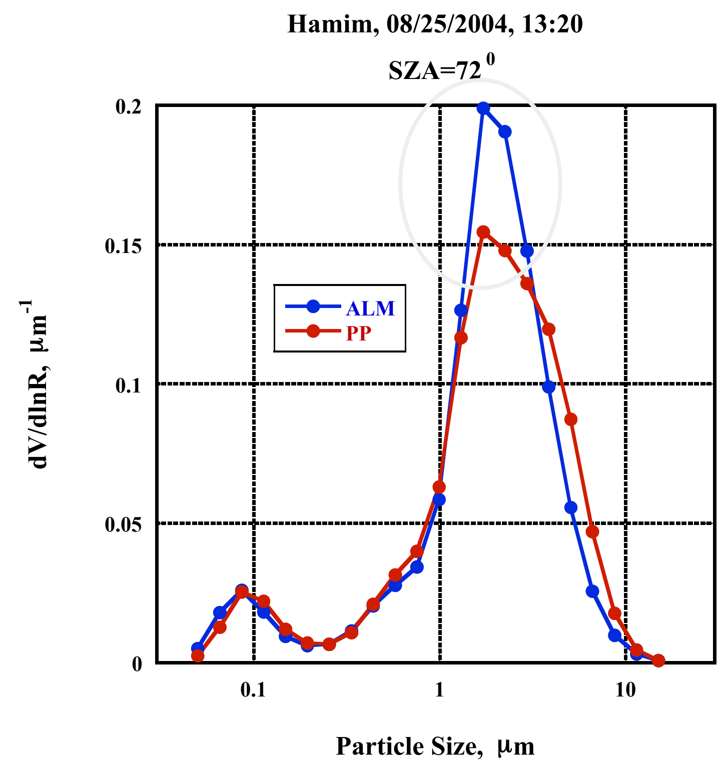
Difference in SSA retrievals at longer wavelengths for ALM and PP, second case

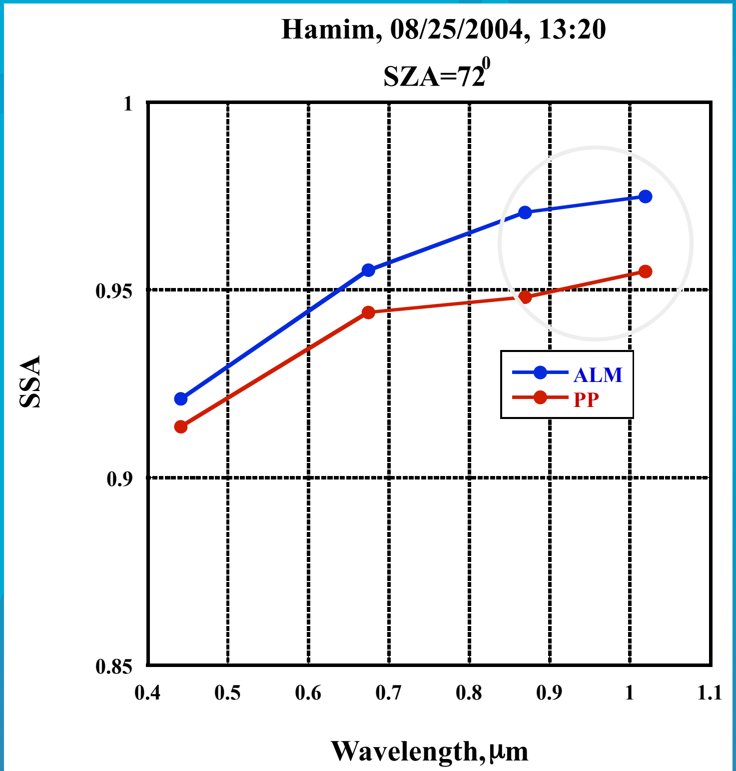




ALM vs. PP: dust case

Similar to Mongu: difference in coarse mode and SSA retrieved at longer wavelengths.





ALM vs. PP: summary

1. Difference in near time collocated ALM and PP retrievals could not be explained by angular pointing bias: the sign of bias should be the same for all the instruments.
2. Our current assessment of the problem:
   - 2.1 Dust: the difference can result from theoretical bias in modeling of light scattering properties of natural dust aerosols due to different sensitivity to the bias of ALM and PP observations.
   - 2.2 Fine mode aerosol: difference can result from treating of the coarse mode of size distribution as spherical particles instead of non-spherical.
3. Question to be answered: what retrievals, ALM or PP, are close to real properties of aerosols?
4. The way to answer the question:
   - 4.1 retrieve phase function and SSA instead of microphysical properties
   - 4.2 use retrieve phase function to generate synthetic observations
   - 4.3 invert synthetic observations using model of randomly oriented spheroids
   - 4.4 compare retrieval results from ALM and PP

The insider's history

- 1989- we were not yet 40 relegated to a windowless warehouse at GSFC
- 1989-Tanré, Nakajima, Kaufman, Prospero, Holben: Cruise on L. Geneva
- 1989-Brazil Amazon aerosol survey
- 1991-Funding and a new concept
- 1992-PHOTONS: Tanré, Lavenue & Holben + Buis, the kitchen meetings
- 1996-The AERONET high court of Advice