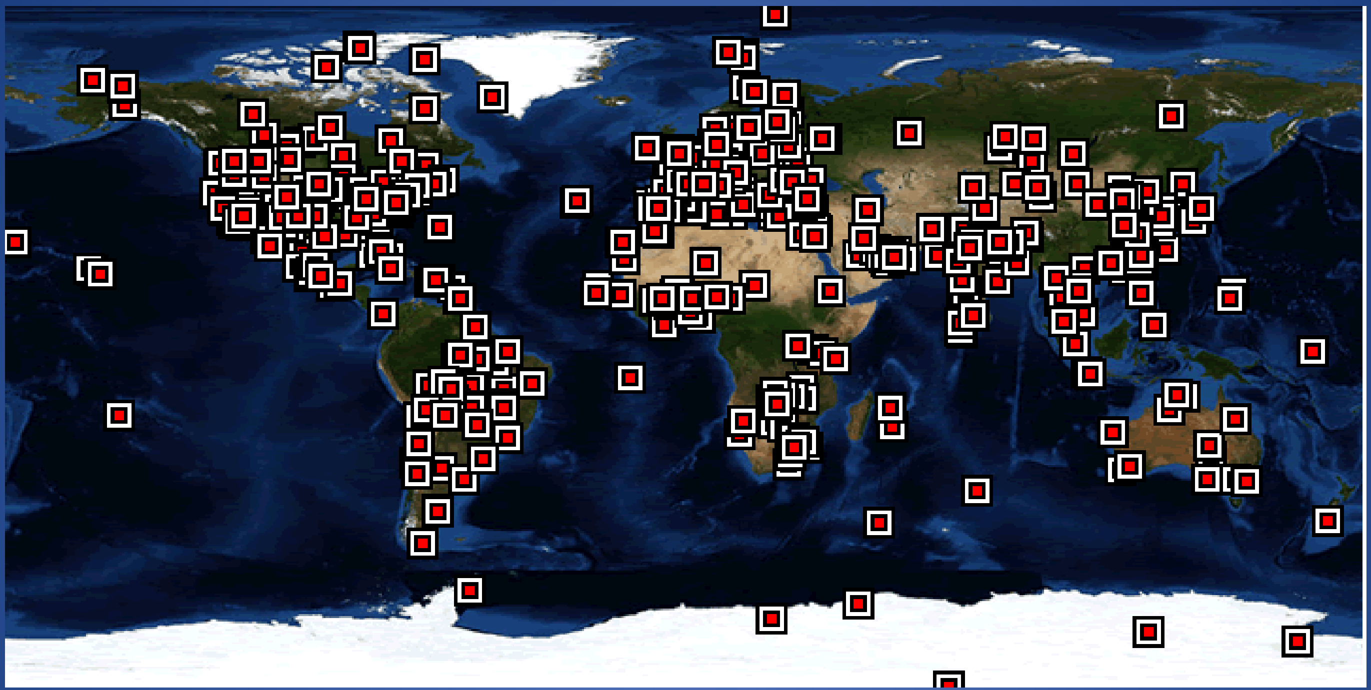
AERONET-An Internationally Federated Network



Presented by Tom Eck (GSFC & UMBC)
AERONET Project Head – Brent Holben (NASA/GSFC)
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Aerosol Observability Workshop – Monterey April 28, 2010

AERONET- Aerosol Robotic Network

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

- Internationally Federated
  - GSFC & PHOTONS (Fr)
  - Spain, Australia, Brazil, Russia
  - Canada, Italy, China …
- Standardized instruments – CIMEL
- Standardized Calibration and Processing
- Near real-time data processing
- ~400 instruments
- ~250 Operational sites

Primary Parameters measured: τ, size dist., n, k, ω_o, Θ, and WV

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

Cimel Sun/Sky Radiometer and Satellite Transmitter

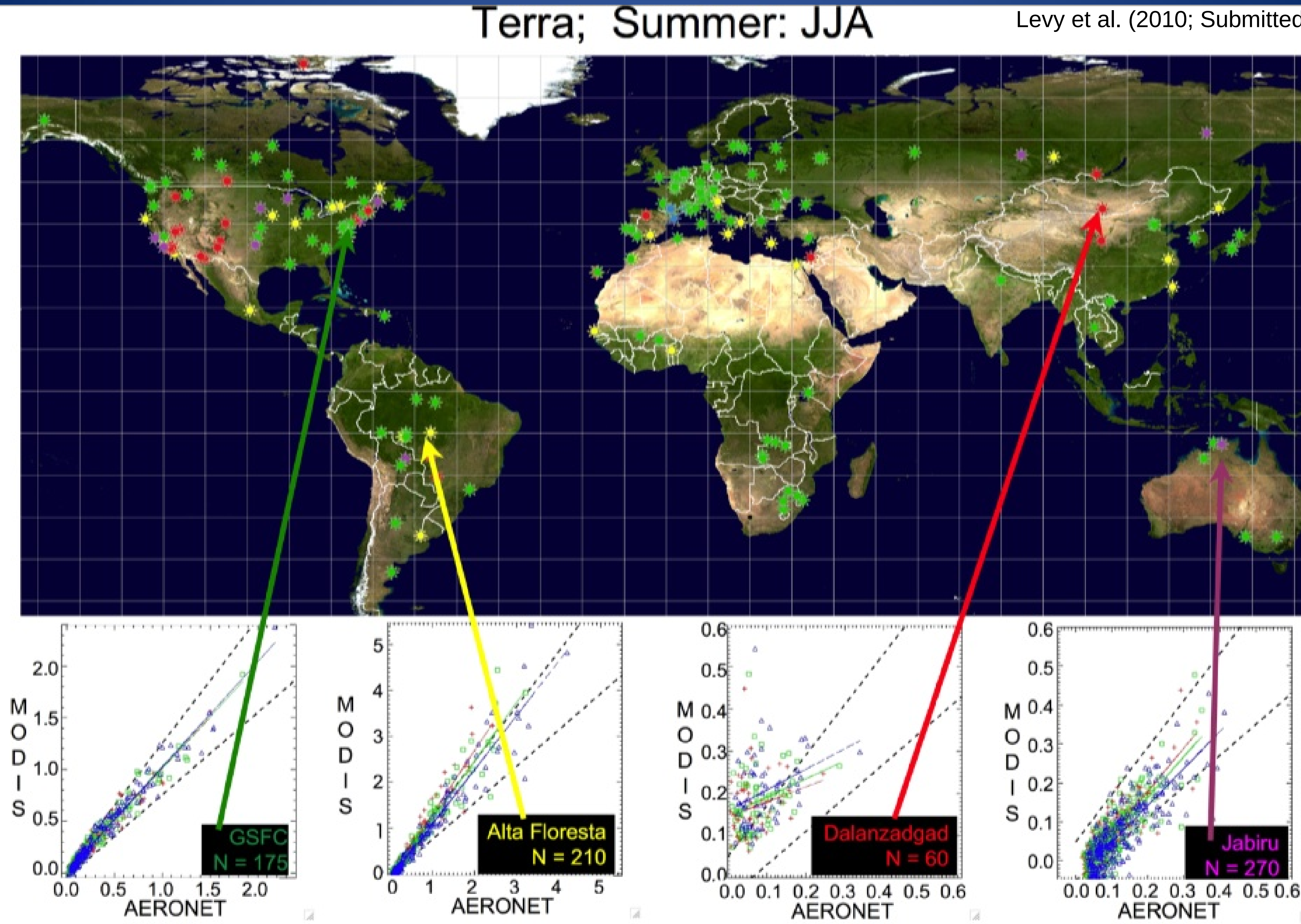
AOD triplet (3 obs in 1 min) taken every 15 minutes (340, 380, 440, 500, 675, 870 and 1020 nm) ~8 sec for spectral measurement sequence

Sky Radiance scans taken 1 per hour (440, 675, 870 and 1020 nm)

~4 minutes for complete sky scan

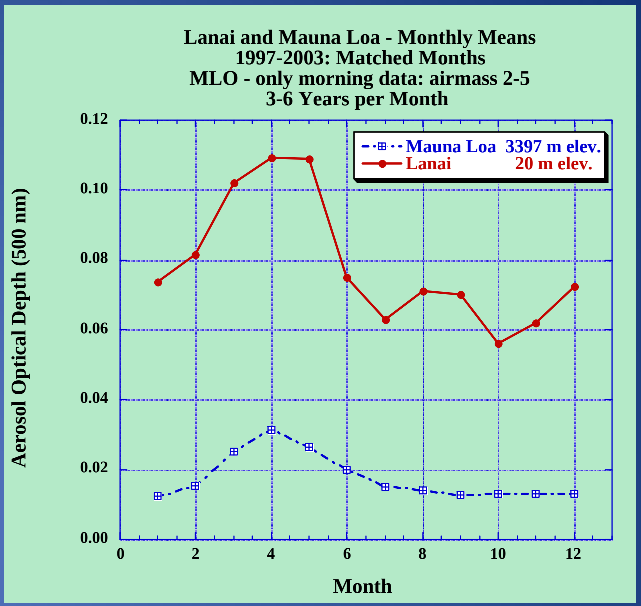
MODIS Satellite AOD Retrieval Validation

Levy et al. (2010; Submitted)



AERONET Calibration for AOD Measurement – Reference Cimels

Mauna Loa Observatory, Hawaii



Mauna Loa Observatory is 3400 m above sea level on of the gently sloping shield volcano (summit is 4170 m).

AERONET reference instruments **(4 to 5 CIMELS)** are typically recalibrated at MLO every ~3-5 months using the Langley plot technique **with morning data only**.

The zero air mass voltages (V_o, instrument voltage for direct normal solar flux extrapolated to the top of the atmosphere (Shaw, 1983)) **are inferred with an uncertainty** of **approximately 0.2 to 0.5%** for the MLO calibrated reference instruments (Holben et al., 1998).

Therefore the uncertainty in τ_a due to the uncertainty in zero airmass voltages (computed as the standard deviation/mean of the V_o values from MLO) **for the reference instruments is better than 0.002 to 0.005.**

Inter-calibration Procedures

Transfer of Calibration from Master Cimels to Field Cimels

The estimated uncertainty in computed AOD (**Level 2**), due primarily to calibration uncertainty, is ~0.010-0.021 for field instruments (which is spectrally dependent with the higher errors in the UV; *Eck et al.* [1999]). *Schmid et al*. [1999] compared τ_a values derived from 4 different solar radiometers (including an AERONET sun-sky radiometer) in a field experiment and found that the AOD values from 380 to 1020 nm agreed to within 0.015 (rms). **For wavelengths >400 nm the AERONET AOD uncertainty is ~0.01-0.015 when using the Level 2 data (includes both pre- and post-deployment calibrations).**

Measurements coincident in space and simultaneous in time – transfer of calibration to field Cimels

Observations Near Solar Noon (±1 hour of solar noon) are utilized for Inter-Calibration of AERONET Cimels. When calibration is made at mid-day (small airmass) the error in AOD is reduced by 1/m at larger airmasses, as shown in the equation below.

$\varepsilon_\lambda = (1/m) * \Delta Vo/Vo$

ε_λ : relative error of AOD

$\Delta Vo/Vo$: relative uncertainty of the calibration coefficient

m : optical air mass

As a result, AOD data taken at large solar zenith angles (high latitude sites, winter at mid-latitudes, early and late day in the tropics) have much lower uncertainty.

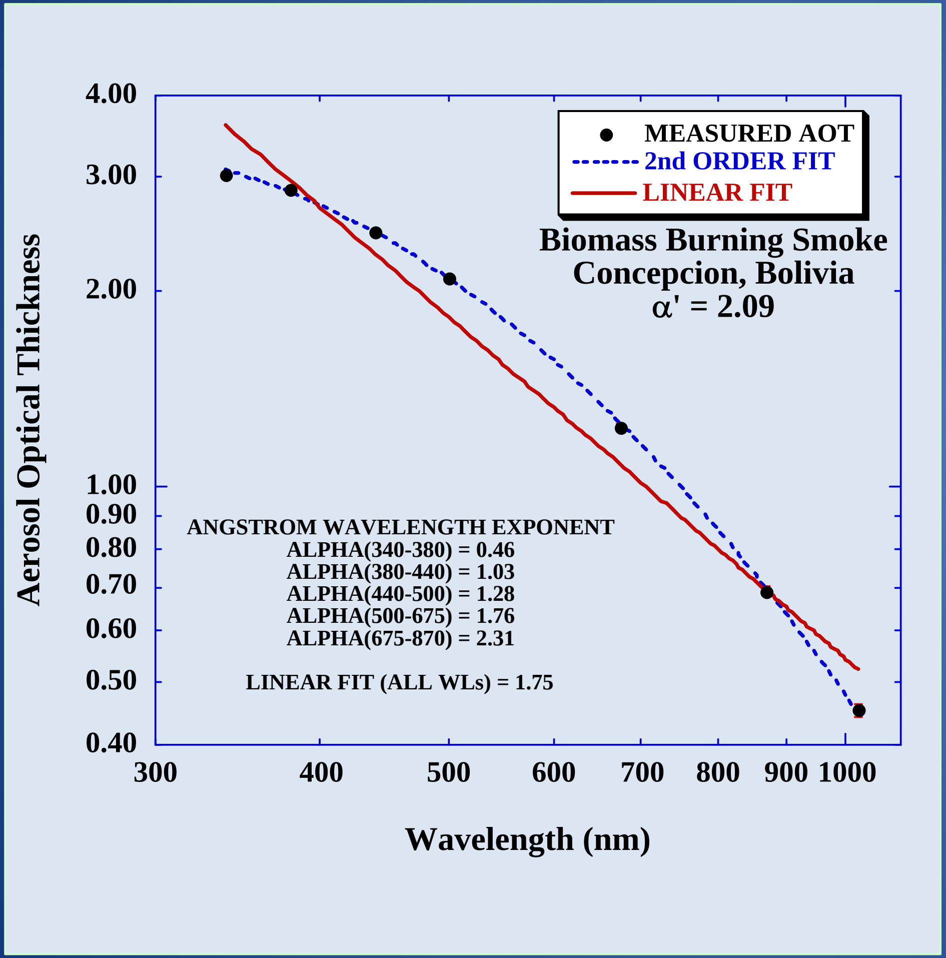
AERONET AOD Data Quality

Calibration:
Pre- and Post- deployment calibrations versus AERONET reference instruments

Cloud Screening:
Based on temporal variance: Two checks: (1) triplet (3 AOD measurements made in 1 minute interval) < 0.02 (higher for AOD >0.67; AOD*0.03); (2) Second order time-series derivative: spike filter

Data Quality Checking (Level 2.0 only):
1)Exclusion of specific channels with large changes in calibration from pre- to post deployment
2)Exclusion of 1020 nm AOD when temperature data is missing or bad, since the Silicon detector has significant temperature sensitivity at 1020 nm
3)Exclusion of data anomalies such as large repeating diurnal dependence due to collimator obstruction or poor electronic contacts
4)Exclusion of cloud contaminated obs. that passed automated filter

A linear or Angstrom (α) fit to all wavelengths is commonly used to interpolate or extrapolate AOD from measured wavelengths. However, with AERONET data we have shown that a second order fit of ln AOD versus ln λ is much more accurate.



Defined a new parameter:

$\alpha' = d\alpha / d \ln \lambda$

α and α' are the the measurement inputs to the Spectral Deconvolution Algorithm (SDA) developed by O'Neill et al. (2003)

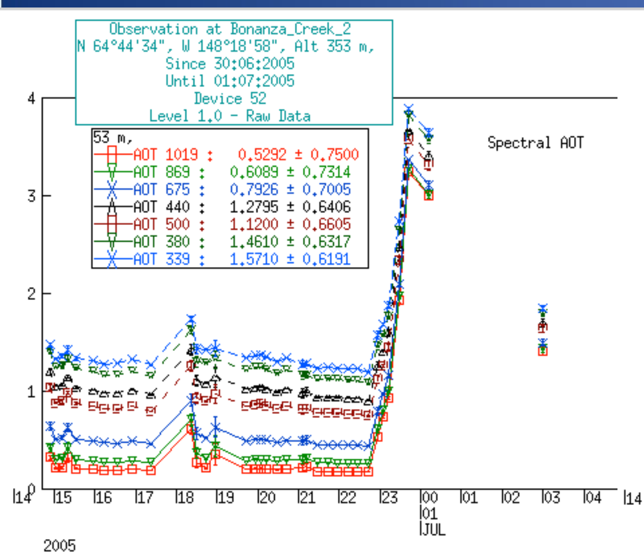
For computing AOD at satellite measurement λ's the AERONET data should be fit by a 2^{nd} order polynomial (quadratic fit)

AERONET: AOD Data Quality Levels : L 1.0, L 1.5 and L 2.0

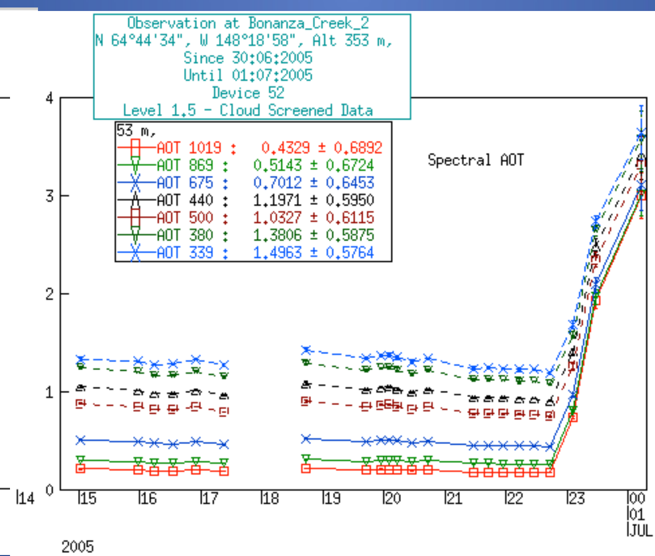
Level 1.0 : No Cloud Screening

Level 1.5 : Cloud Screened but may not have final calibration applied

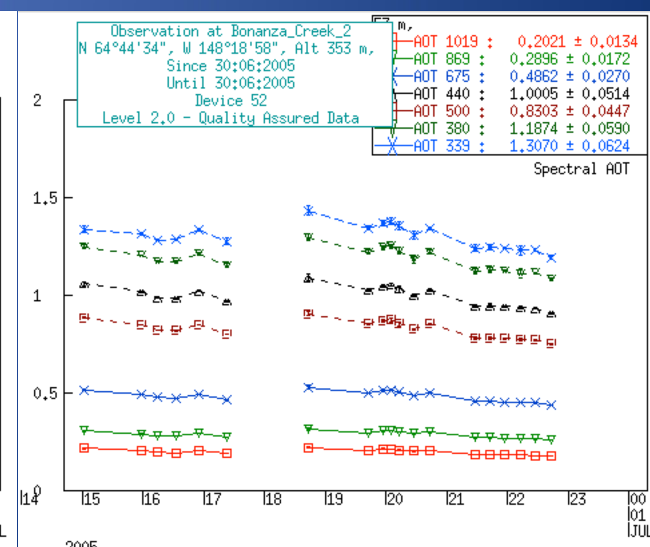
Level 2.0 : Cloud Screened and Quality assured with both pre- and post deployment calibrations (linearly interpolated in time) resulting in accuracy of ~0.01-0.02 at airmass=1 (overhead sun).



Level 1.0

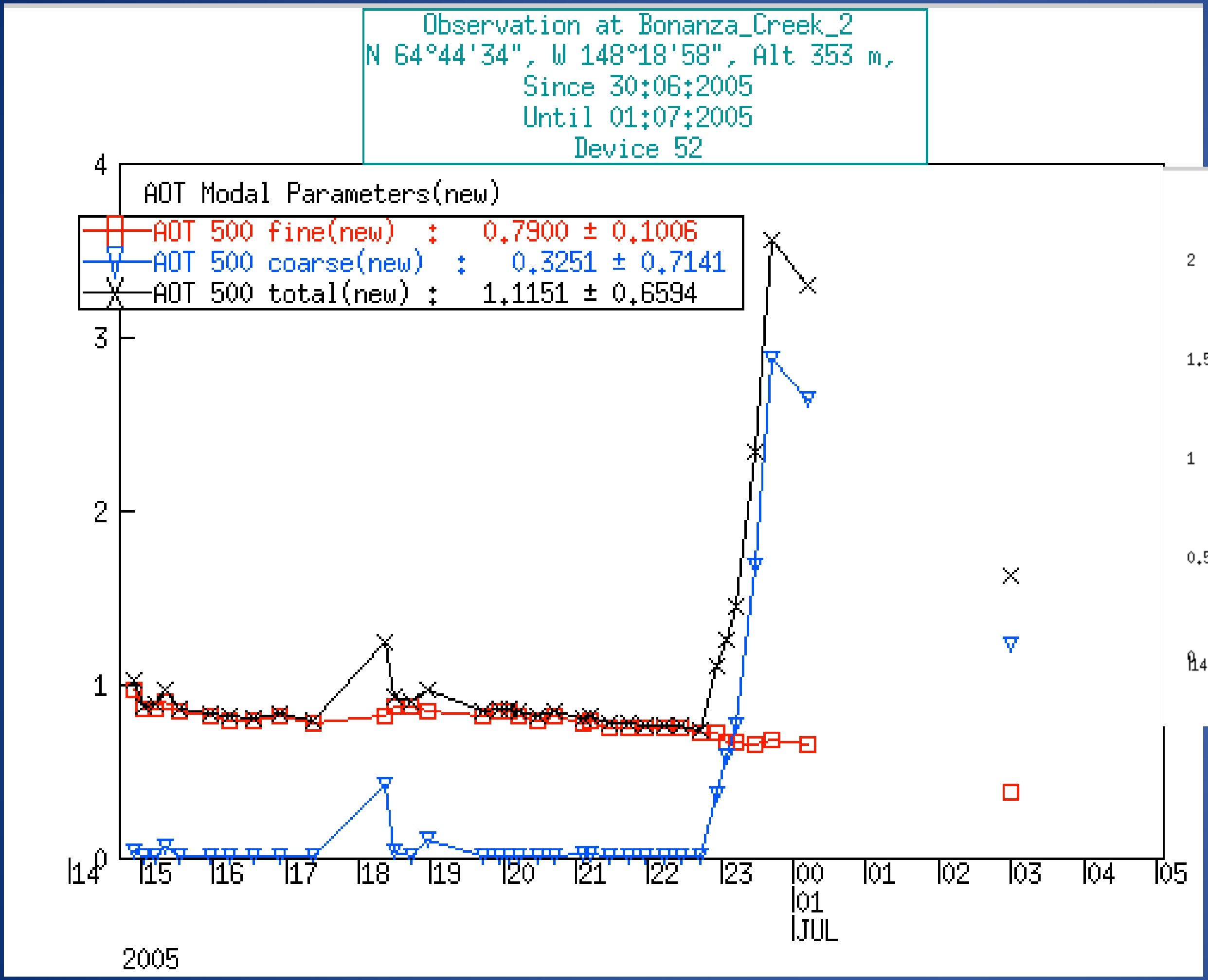


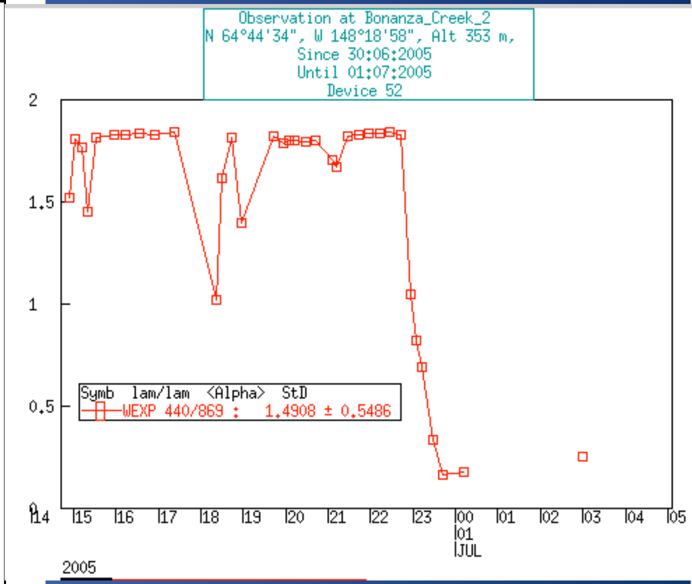
Level 1.5



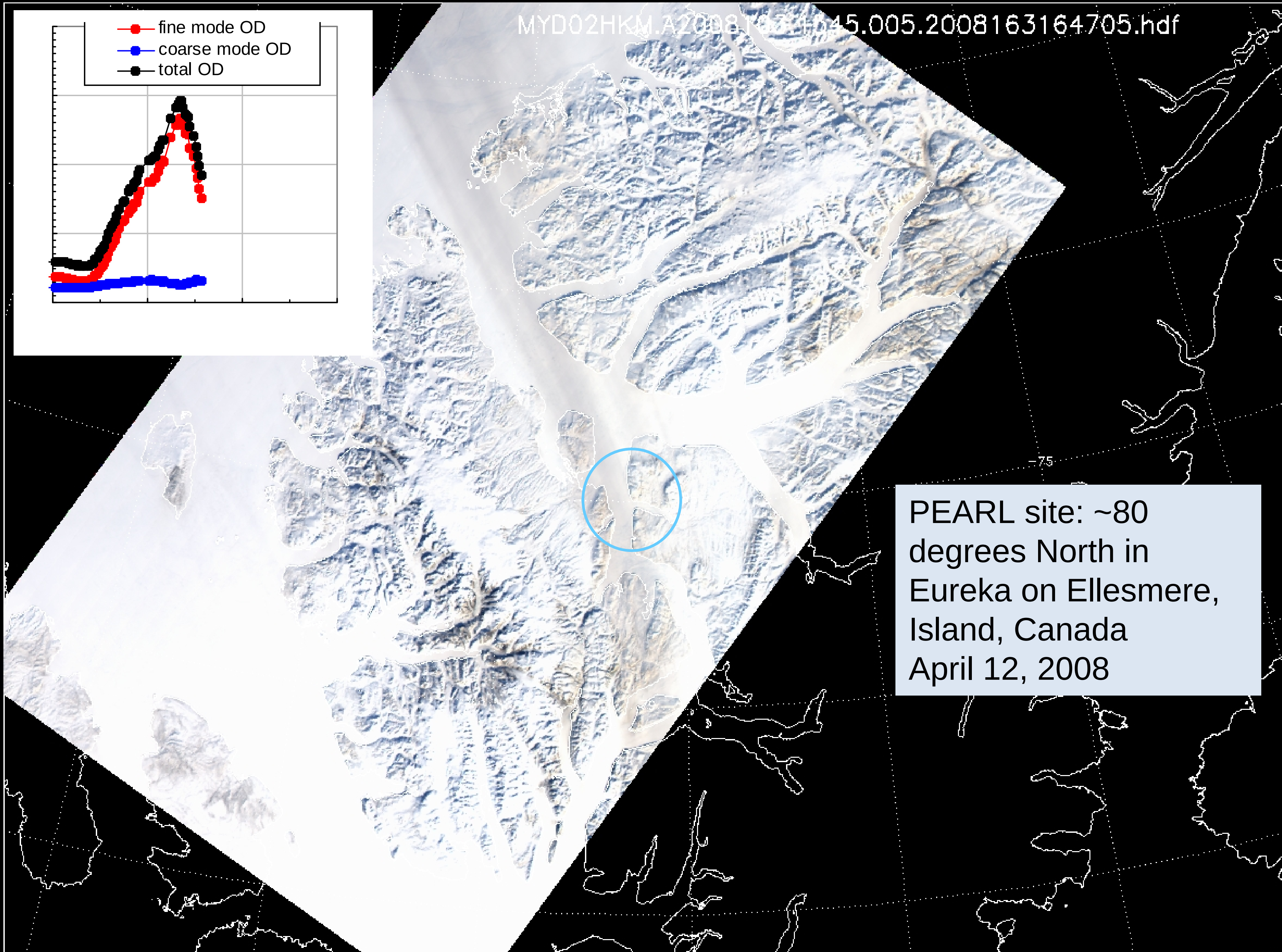
Level 2.0

O'Neill Spectral Deconvolution Algorithm (SDA) applied to Non-cloud screened data (Level 1.0)





SDA effectively computes the Fine mode AOD in mixed cloud-smoke observations



PEARL site: ~80 degrees North in Eureka on Ellesmere, Island, Canada April 12, 2008

AERONET Level 1.5 Data Quality Issues

- **Much of the data that the Aerosol Forecasting and Assimilation Scientists will utilize is the Level 1.5 data that has not had the post deployment calibration applied**

- **As a result the AOD accuracy will be diminished and variable depending on several factors such as time since calibration and exposure to contaminants on optics windows such as dust or sea salt.**

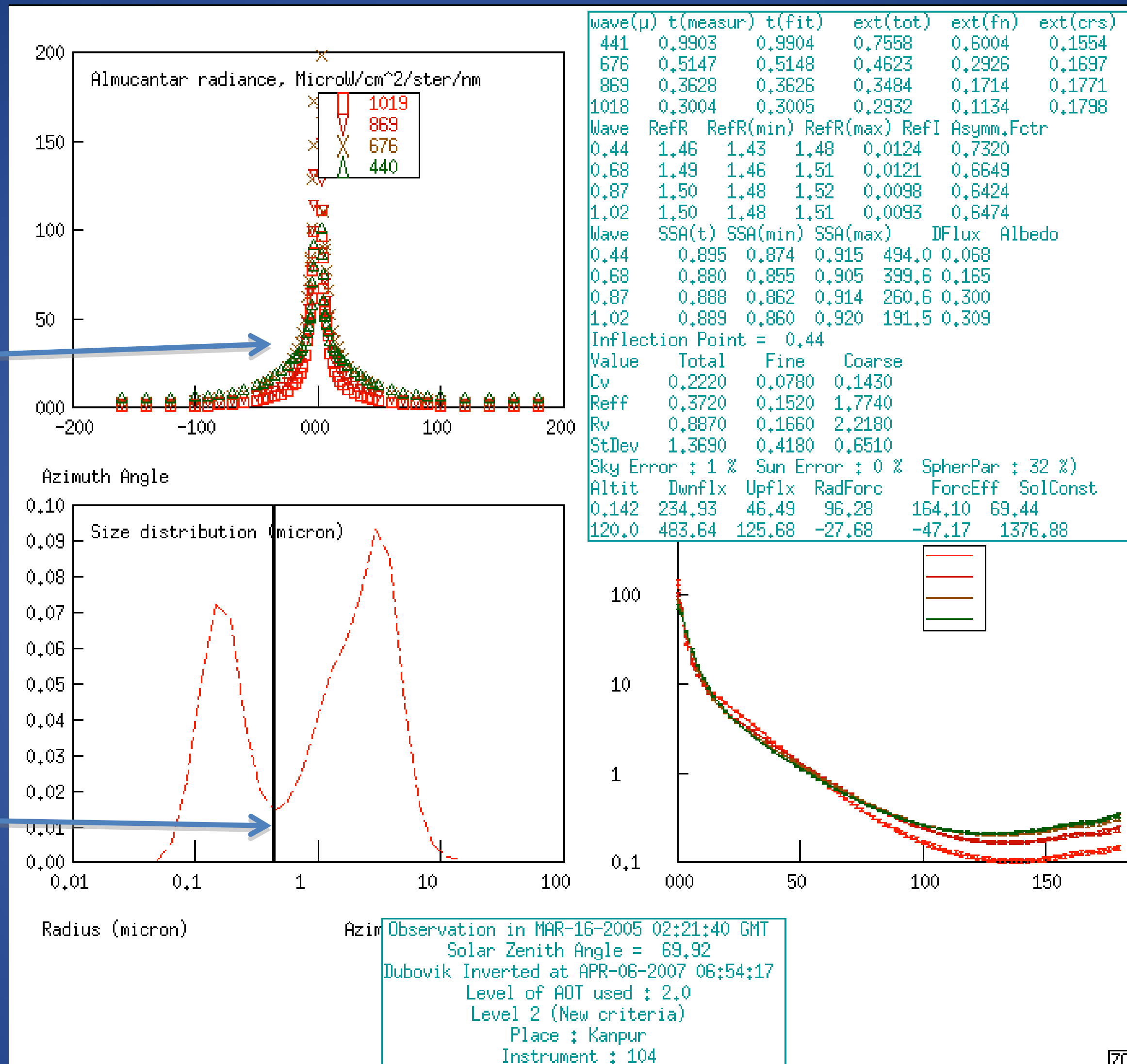
- **Uncertainty in Level 1.5 AOD (before post-deployment cal) is ‘guestimated’ to be in the range ~0.01 to ~0.05 (for m=1). However poorer quality data may be mixed in with the mostly reasonable quality AOD (for example from spider webs in the collimator or poor electronic contacts)**

- **Almucantar retrieval accuracy is often significantly degraded due to both the AOD uncertainty and the change in sky radiance calibration over time. Retrievals of Single Scattering Albedo (SSA) in Level 1.5 should be used with caution (perhaps as only an indicator of weak, moderate or high absorption) and only at high AOD**

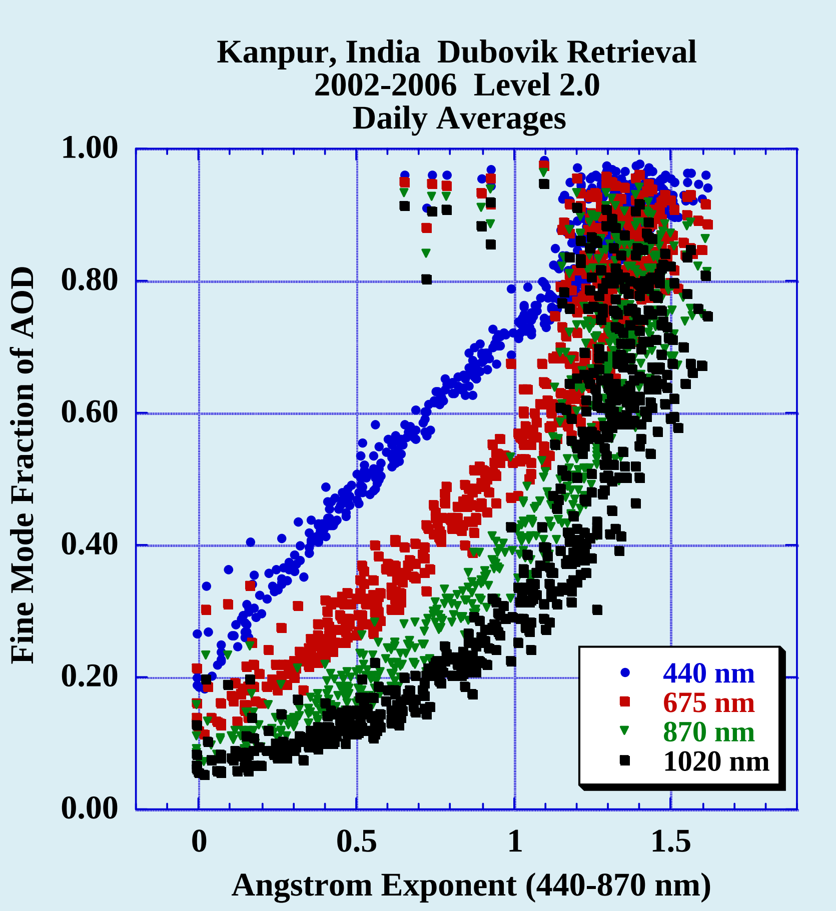
Almucantar Retrieval example – Sky Radiance & Spectral AOD inputs

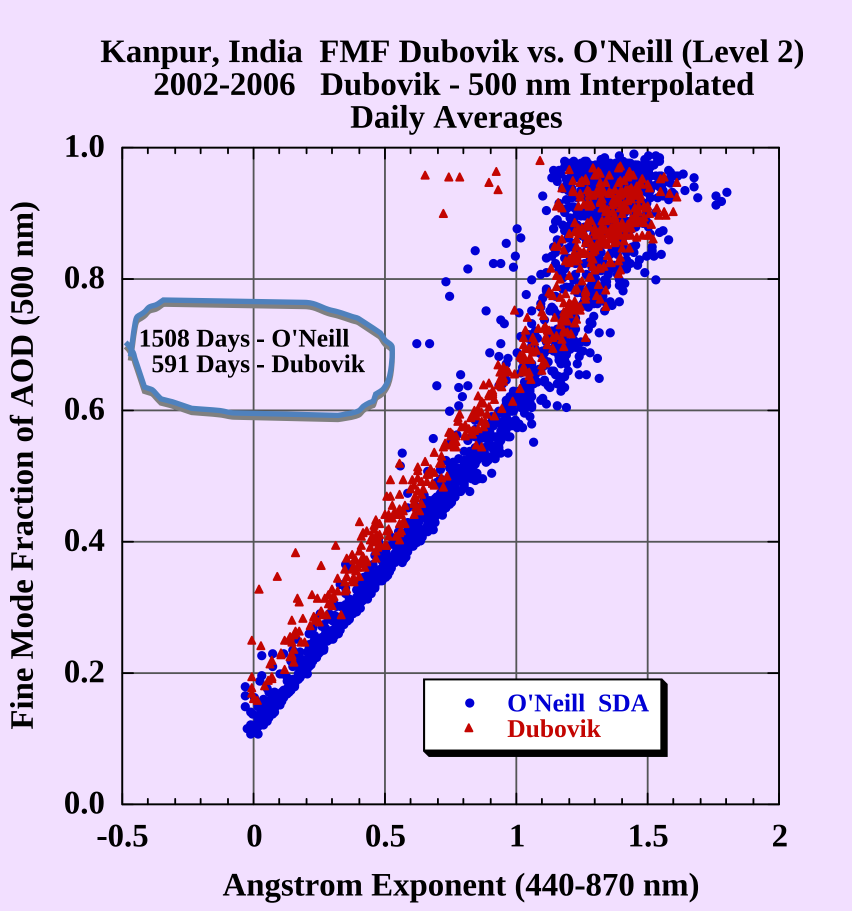
Almucantar Cloud screening has additional check of symmetry of radiances on both sides of the sun

Fine/Coarse Mode cutoff selected as minimum between modes between range of 0.44 to 0.99 μm radius



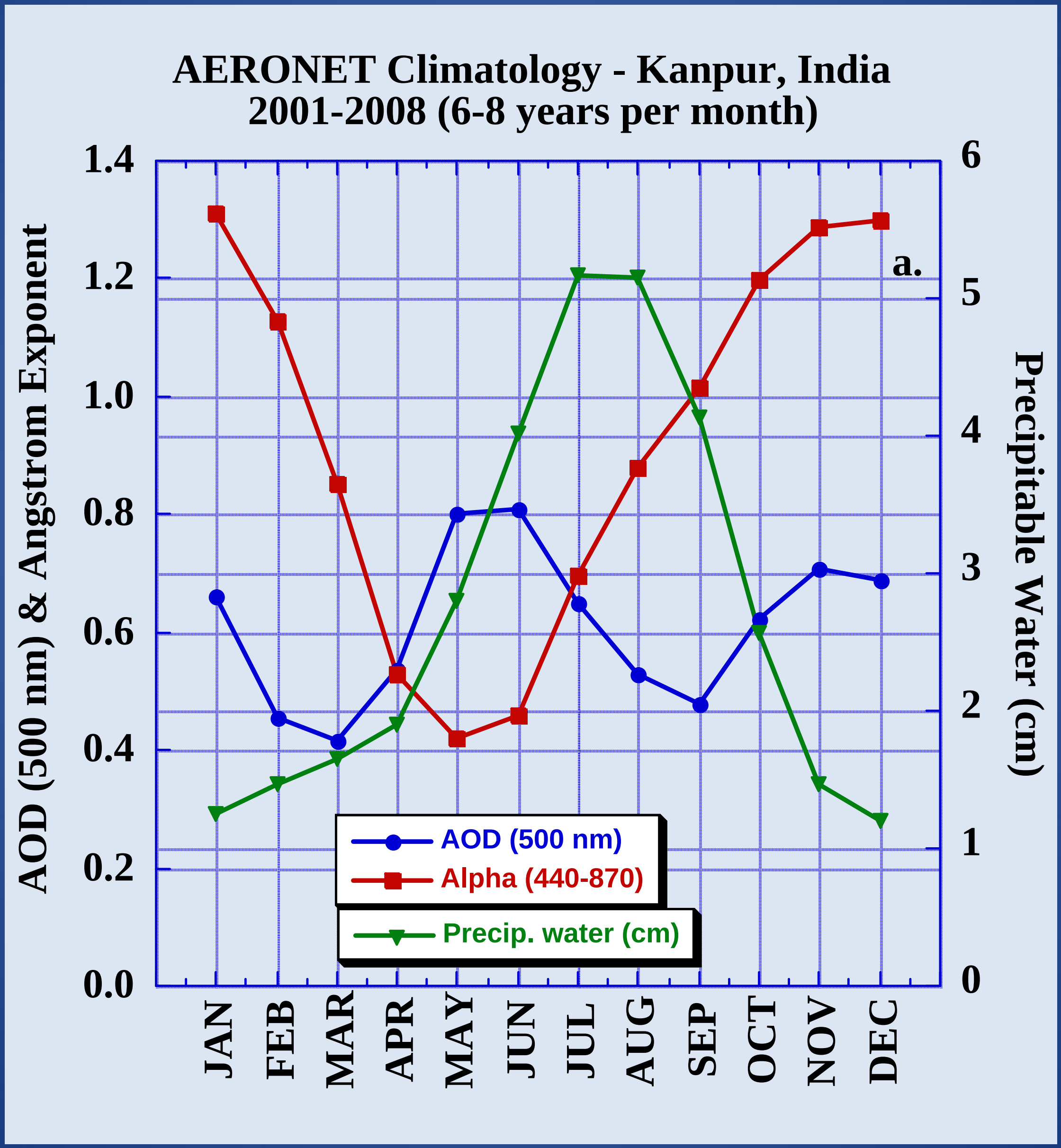
Minimum Solar Zenith Angle of 50 degrees required to obtain sufficient range of scattering angles for sensitivity to absorption – Therefore only early morning and late afternoon retrievals in the tropics and mid-latitude summer



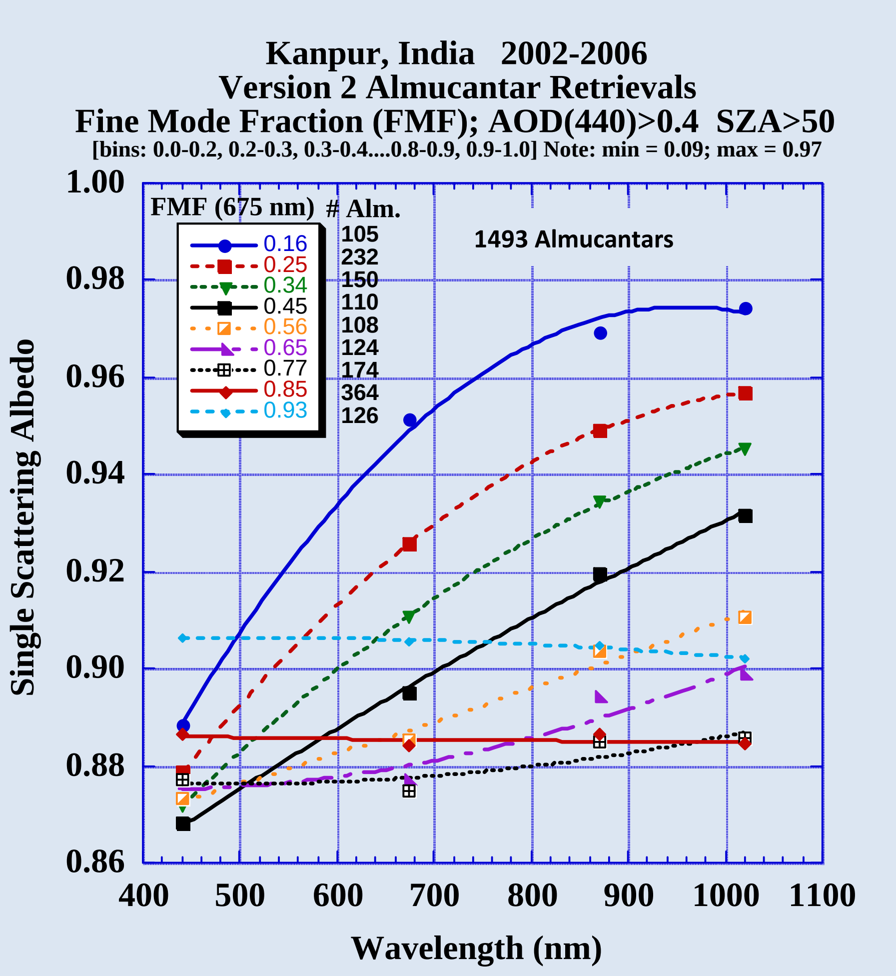


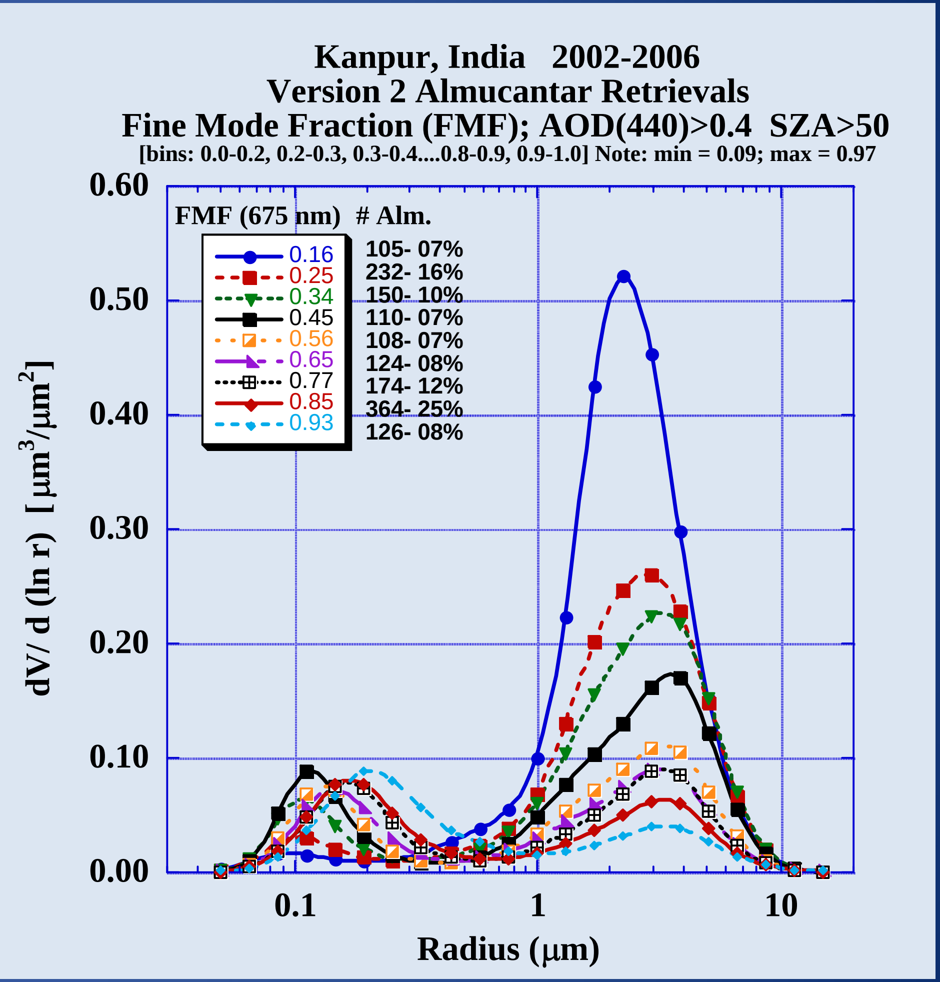
Dubovik FMF of AOD at 500 nm is ~0.05 higher than SDA FMF from Angstrom ~0 to ~1.1, possibly due to small particle ‘wing’ of the coarse mode attributed to coarse mode AOD in the SDA algorithm.

Multi-Year Climatological Statistics are Available for Many Sites/regions



Kanpur - Single Scattering Albedo and Size Distribution Climatology





Johnson et al. (2008; JGR) Aircraft measurements: SSA (Nephelometer + PSAP) versus Angstrom Exp. (Nephelometer)

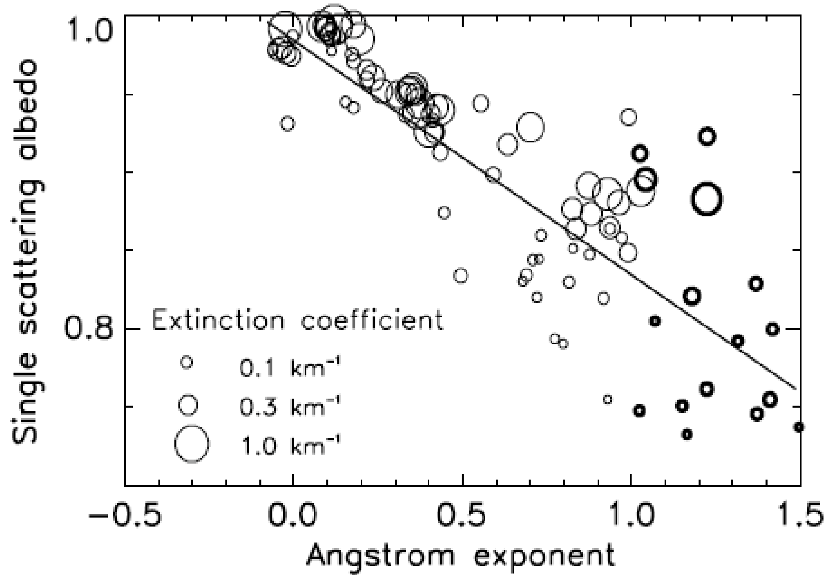
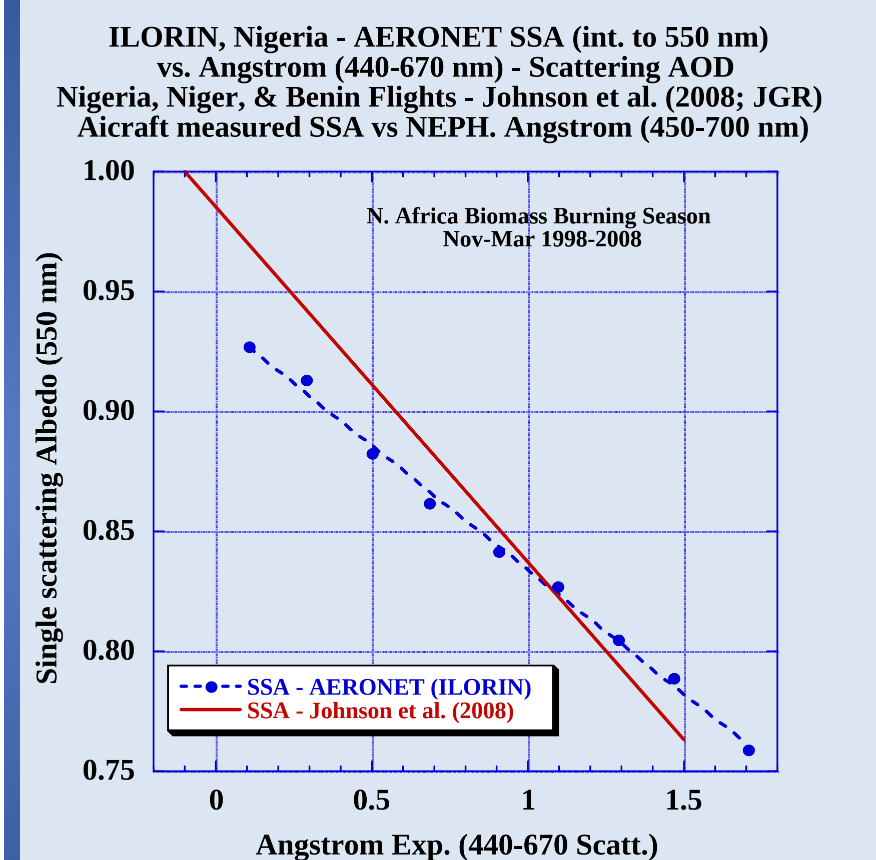
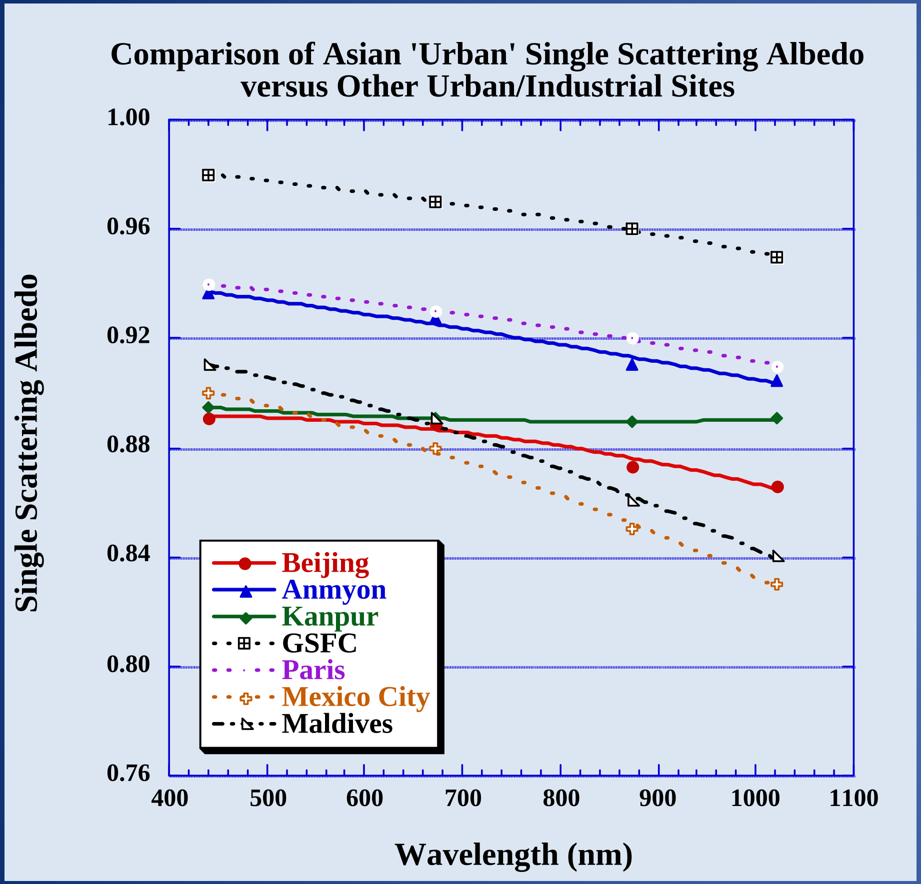


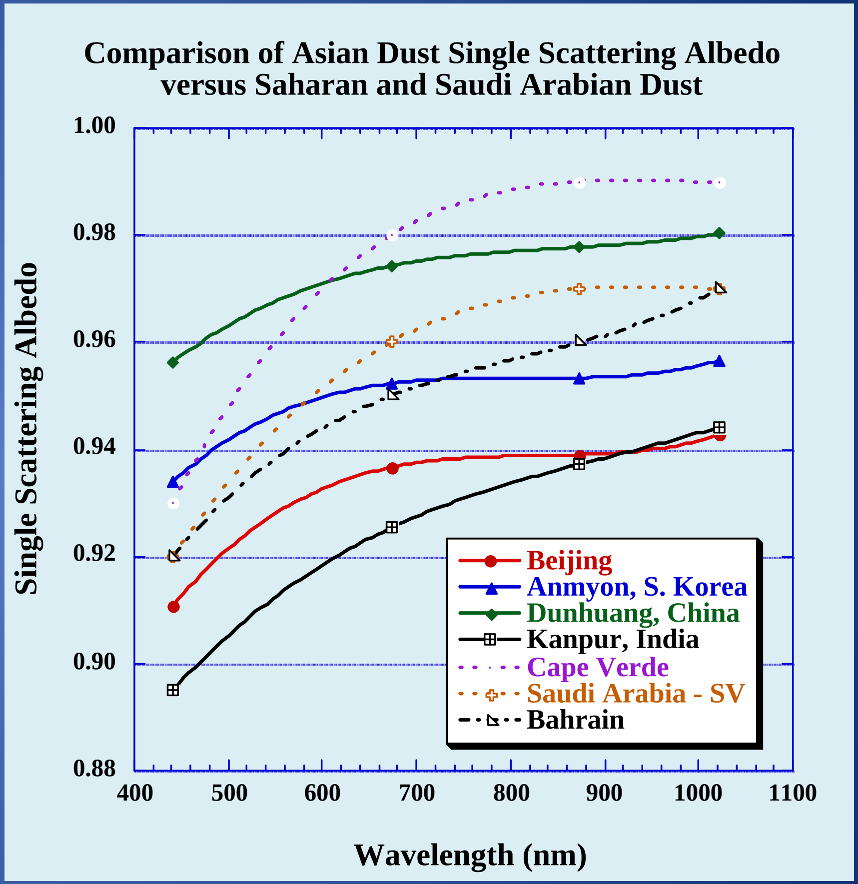
Figure 12. Single scattering albedos from all aircraft runs during DABEX, plotted against Angstrom exponent from the nephelometer. The area of the circles corresponds to the mean aerosol extinction coefficient (at 0.55 μm wavelength) along the run. Runs dominated by aged biomass burning aerosol are in bold symbols.



JOHNSON ET AL. 2008: "The very high single scattering albedos observed in these dust runs are probably overestimated by 0.01–0.02 since losses of large particles in the PSAP instrument can lead to an underestimation of absorption, particularly in dusty conditions."

Climatological range of aerosol absorption (SSA) as determined from AERONET Almucantar Retrievals





Possible Additional Screening of Level 1.5 Data for an Aerosol Forecast Validation Dataset (Level 1.5V ?)

Aerosol Optical Depth:

- Checks on radiance from both collimators (old Model CIMEL) or 1020 nm AOD from both collimators (new models) to screen out data that are affected by material in the collimator or moisture on windows

- Possible additional cloud screening: eliminate days with only 3 observations or less. Possible threshold on temporal variance within a day.

- Eliminate 340 nm AOD since these filters are the least stable

- Possibly eliminate 1020 nm AOD due to temperature sensitivity

- Screen out data when the time since calibration exceeds 18 months

Almucantar Retrievals:

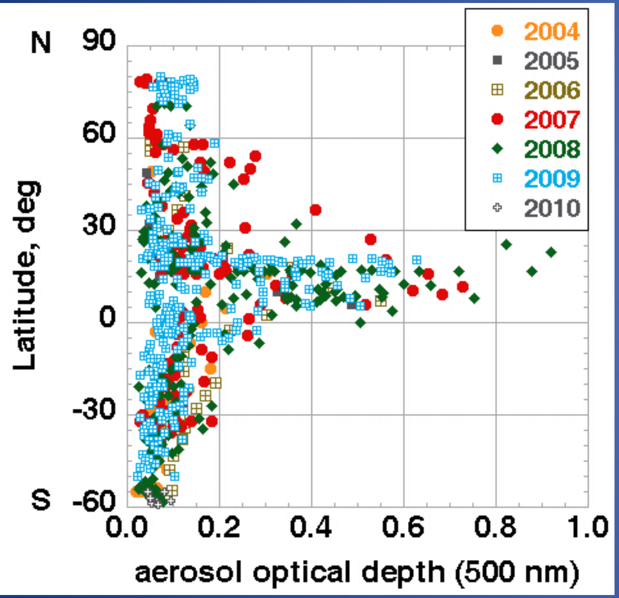
- Solar Zenith Angle > 50 degrees and Sky radiance Error < 6%

- Single Scattering Albedo and Refractive Indices only for AOD(440)>0.6

- Principal plane retrievals made at mid-day may be available in the future

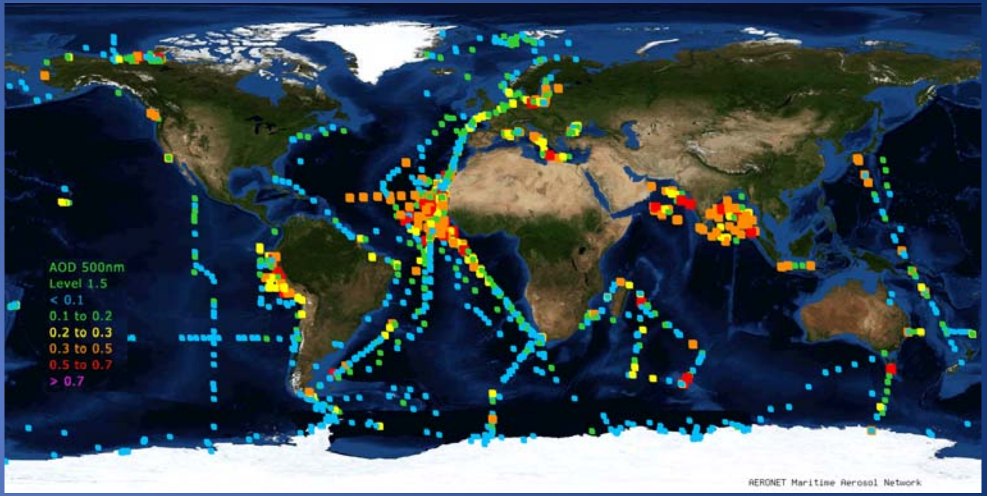
The Maritime Aerosol Network (MAN) Component of AERONET

- In the last several years data acquisition was extended to the areas that previously had very little or no coverage at all



Latitudinal dependence of aerosol optical depth in the Atlantic Ocean

Maritime Aerosol Network global coverage from 2006 to 2010



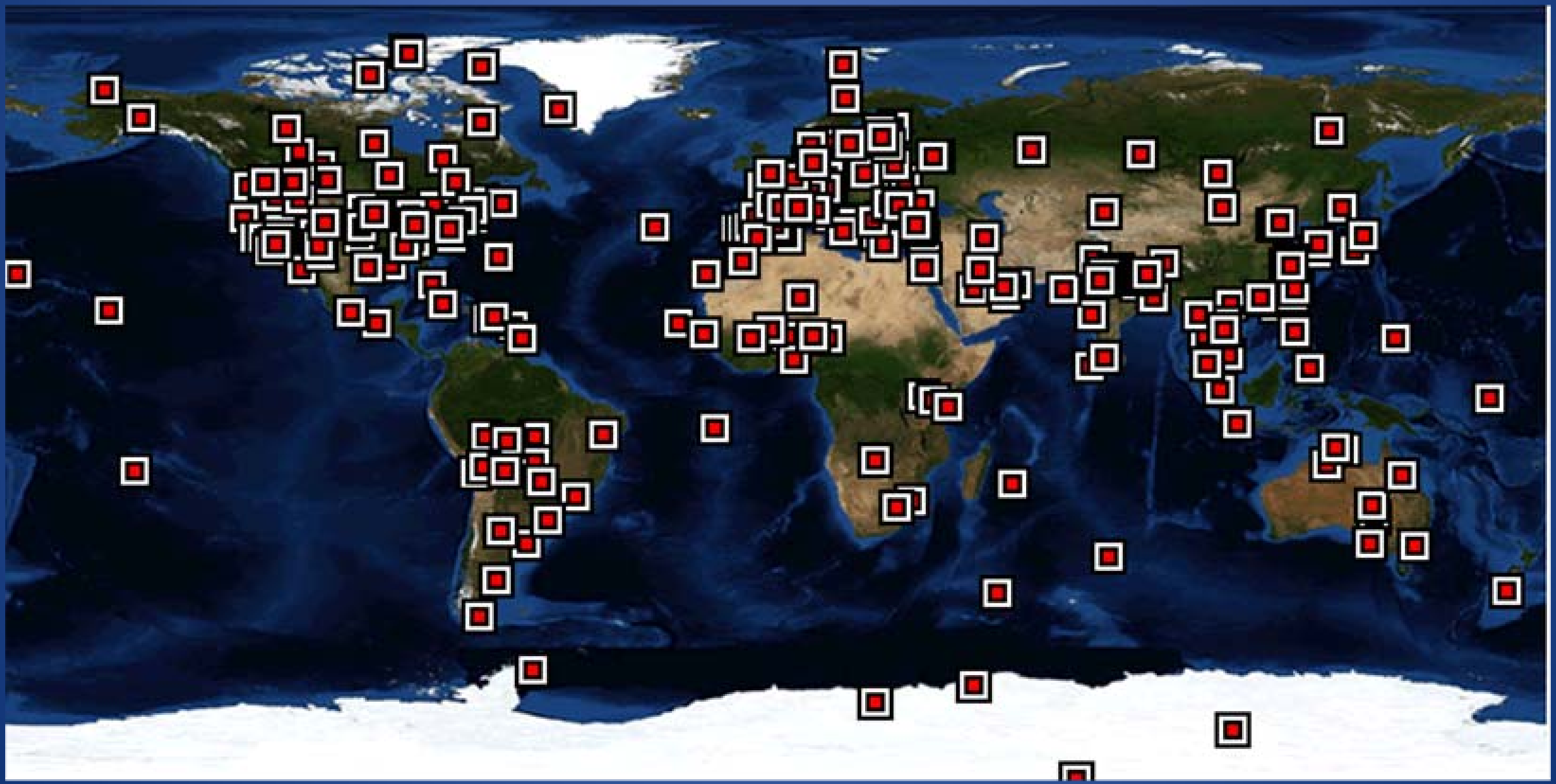
- Aerosol optical depths over the oceans at the high latitudes are not as high as satellite measurements suggest they should be
- Data are easily accessible in the web-based public data archive and will stimulate research and international collaboration in various scientific areas

Smirnov, A., B. N. Holben, I. Slutsker, D. M. Giles, C. R. McClain, T. F. Eck, S. M. Sakerin, A. Macke, P. Croot, G. Zibordi, P. K. Quinn, J. Sciare, S. Kinne, M. Harvey, T. J. Smyth, S. Piketh, T. Zielinski, A. Proshutinsky, J. I. Goes, N. B. Nelson, P. Larouche, V. F. Radionov, P. Goloub, K. Krishna Moorthy, R. Matarrese, E. J. Robertson, and F. Jourdin (2009), Maritime Aerosol Network as a component of Aerosol Robotic Network, J. Geophys. Res., 114, D06204, doi:10.1029/2008JD011257.

What about other Aerosol (AOD) monitoring Networks?

- BSRN: really a flux measurement network, not focusing on aerosol optical properties; Some AERONET instruments co-located at BSRN sites
- SKYNET: Direct sun AOD and sky radiance retrievals with Prede sun/sky radiometer; 10 sites (not all operational at any given time), all in Asia; Data policy is to release data after 2 years; contact with individual PI for each instrument is necessary
- GAW: Direct sun AOD measurements with 4 channel PFR sunphotometer; ~20 sites, 12 currently operational, many at clean “background locations” and several on mountain tops that are not representative of the surrounding regions; data not easily accessible for analysis

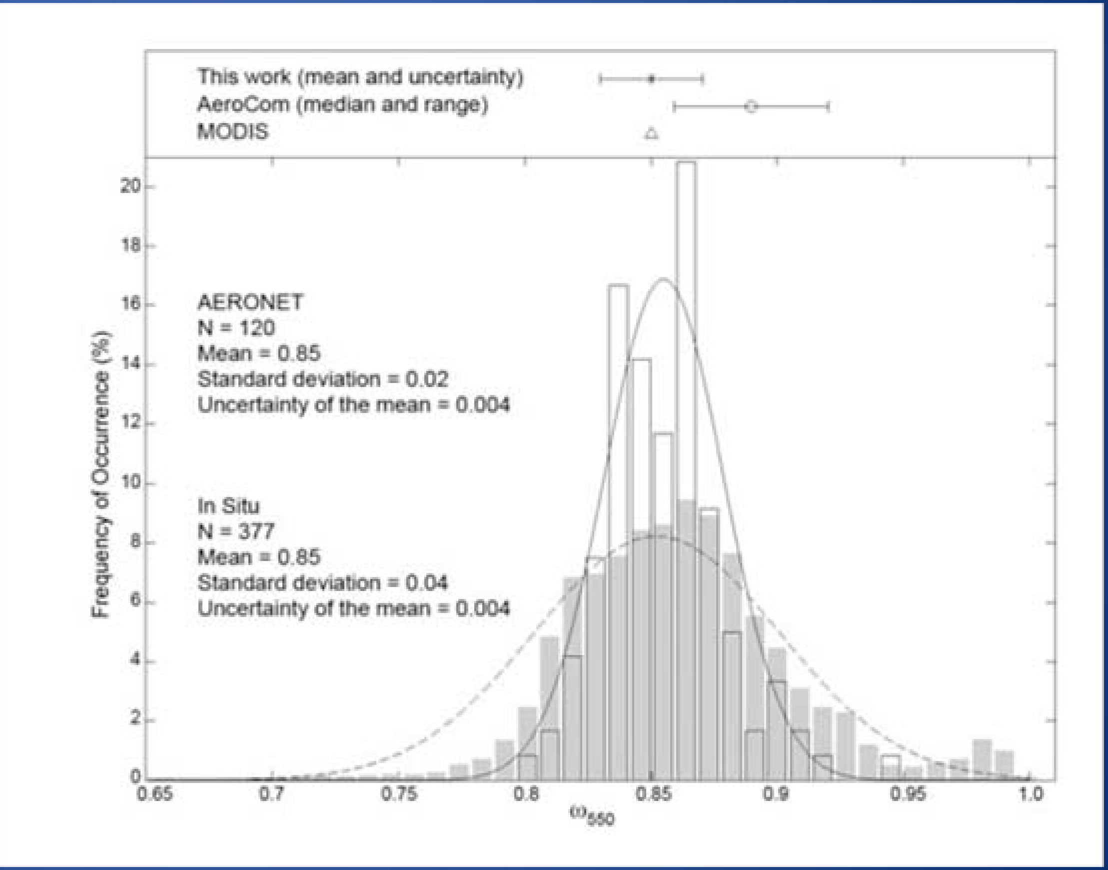
Questions or Comments?



SAFARI2000 Airborne *In Situ* Comparison to AERONET Single Scattering Albedo

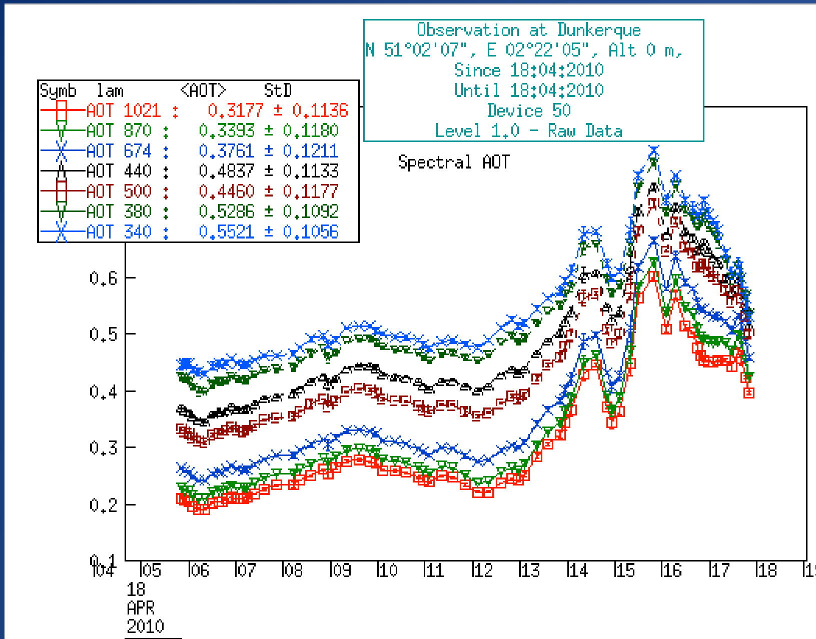
Single Scattering Albedo

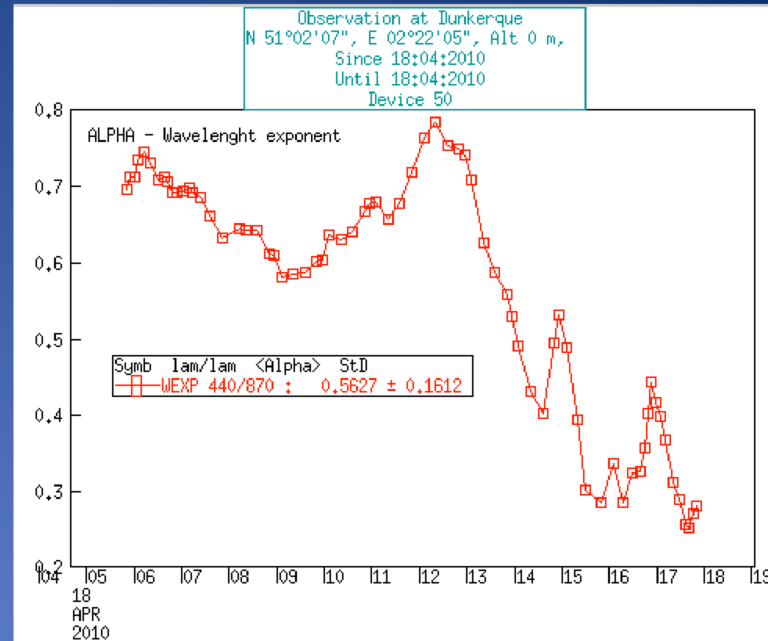
$$SSA = \frac{\tau_{sct}}{\tau_{sct} + \tau_{abs}}$$

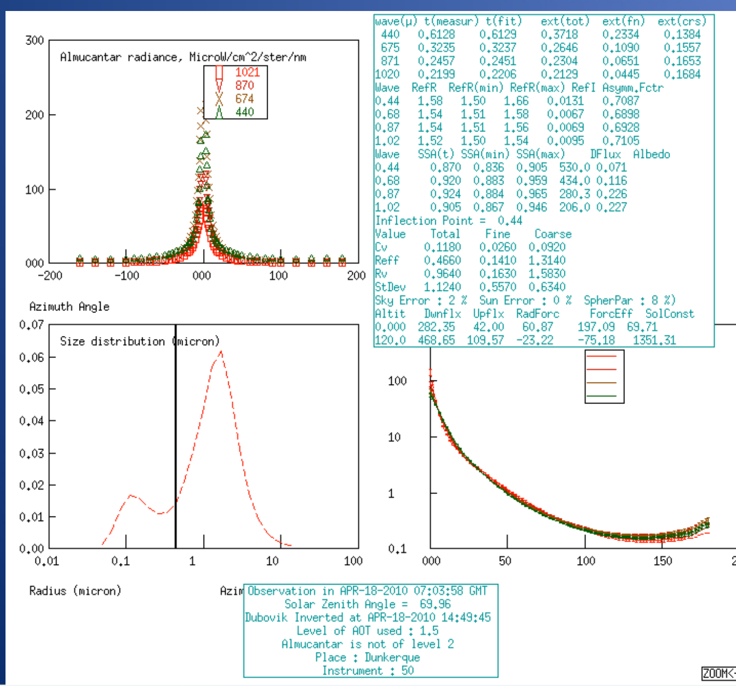


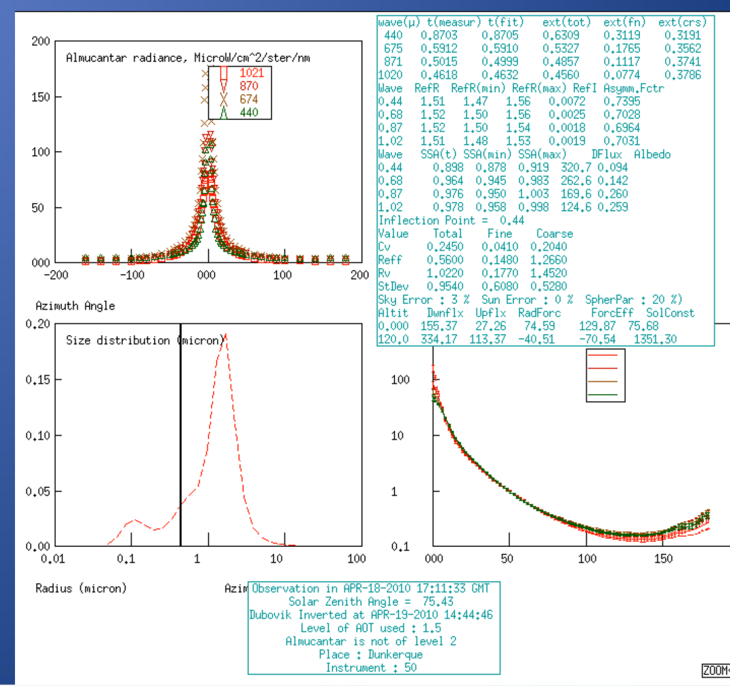
Leahy et al., 2008

Volcanic Ash Observation from the Dunkerque, France AERONET site

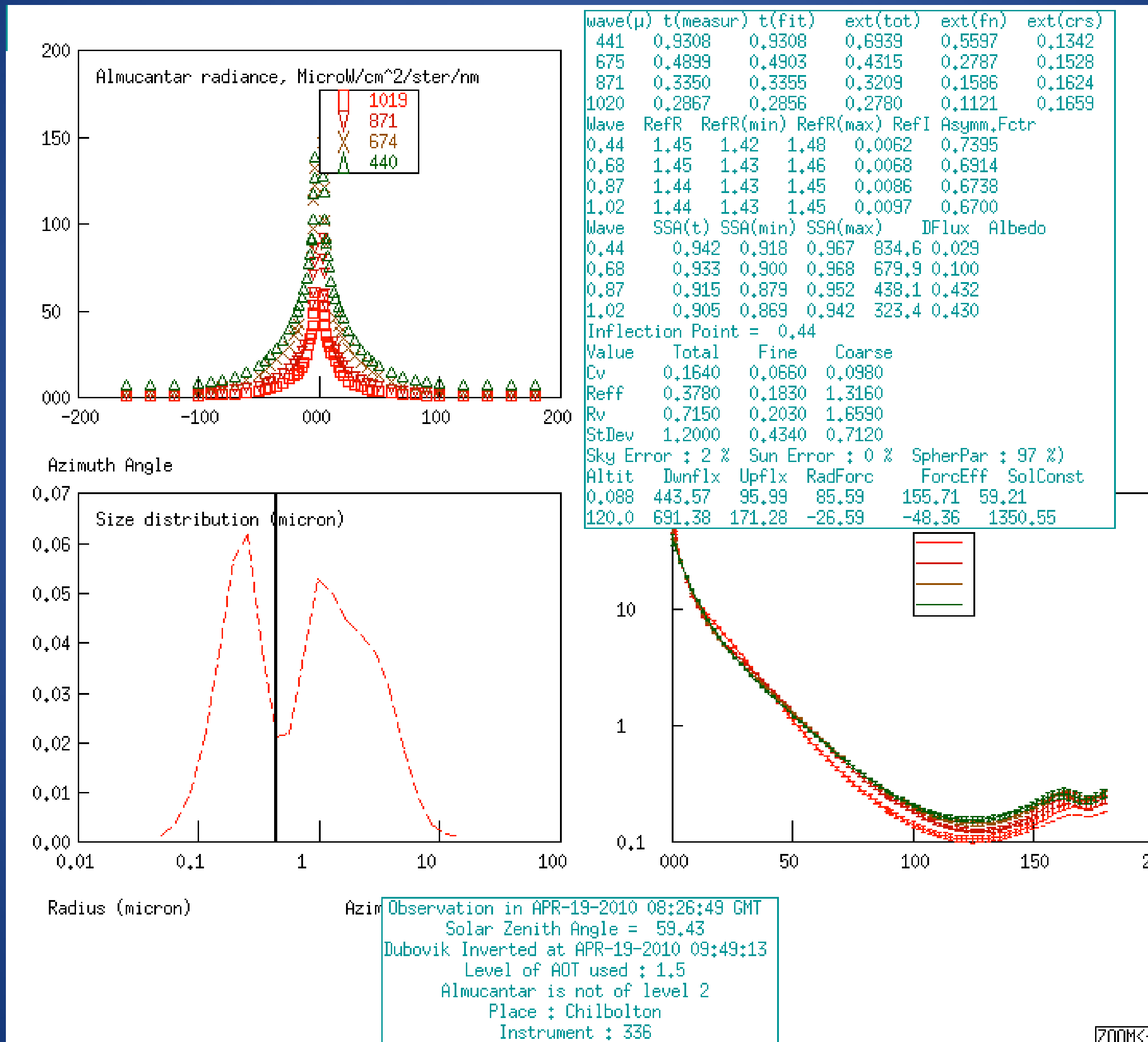






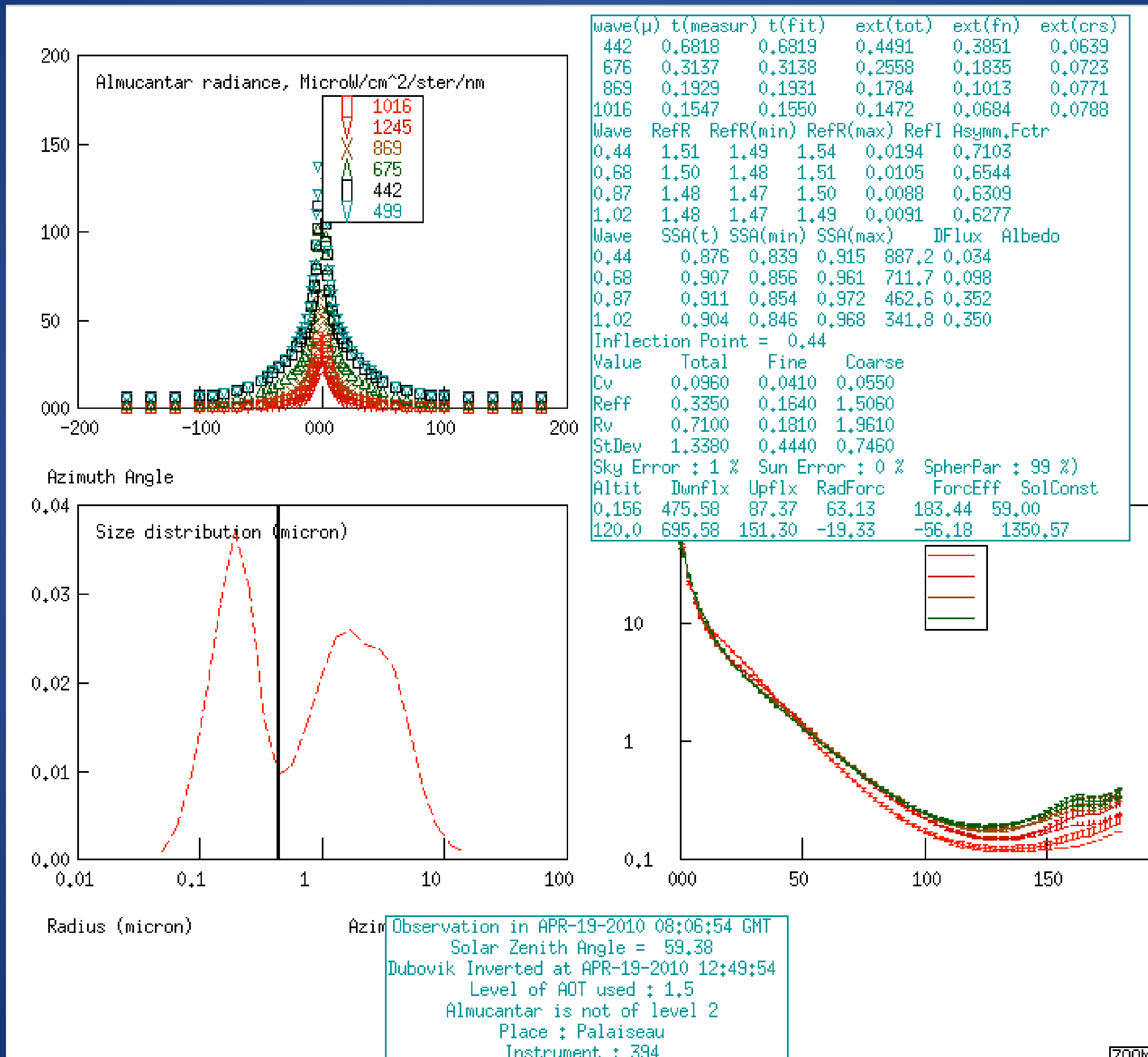


Volcanic Ash Observation from the Chilbolton, England AERONET site



$\alpha_{440-870}$~1.20

Volcanic Ash Observation from the Palaiseau, France AERONET site



$\alpha_{440-870}=1.35$