AERONET's Version 2.0 quality assurance criteria

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ABSTRACT

The AERONET inversion products provide powerful information for understanding column integrated aerosol properties particularly given the wide global distribution of sites and the 13 year record for some sites. Significant evolution of the instrument, data quality, ancillary input data and inversion algorithm has necessitated release of Version 2.0 and establishment of criteria for quality assured products. This paper documents version 1.0 quality assurance criteria and the analysis of the entire retrieval record available for the Version 2.0 to revise the quality assured criteria. The result is an improvement in the number and quality of aerosol inversion parameters for most sites through the entire AERONET data record.

Keywords: AERONET, aerosol retrievals, quality assurance, criteria, remote sensing

1. INTRODUCTION

The AERONET inversion retrievals represent a wide number of parameters and characteristics that are important for comprehensive interpretation of the optical aerosol regime. The RAD.PAK code (Nakajima et al., 1996) was the first code used in AERONET in beginning in 1993 that provided the volume size distribution and phase function. This was followed in 2000 by the operational implementation of the Dubovik and King (2000) code that became Dubovik Version 1.0 (hereafter referred to as Version 1.0) in 2003 with the implementation of quality assurance criteria (Level 2). Several major improvements have led to the release of Version 2.0. This includes significant changes to the inversion code, the input data and the criteria for quality assurance that notably depart from Version 1.0. Most significant among the inversion code changes is that the spherical and spheroid model outputs are internally evaluated to produce one set of retrievals rather than two products as in Version 1.0. In that regard Version 2.0 provides a parameterization of the degree of non-sphericity (Dubovik and Sinyuk, 2006). Noteworthy among the input changes is the characterization of surface albedo. Version 1.0 uses the static assumption of a spectrally, temporally and spatially green world that is replaced in Version 2.0 by a dynamic spectral and spatial satellite and model estimation of the surface albedo, including BRDF. This accounts for vegetation dynamics, snow, ice and wind speed effects over water. Please read the 'Version 2 Inversion Product Descriptions' on the AERONET website for a thorough discussion and references. The third major difference is the Level 2 'quality assured' database that taken collectively may significantly alter the retrieval product values and or the number and circumstance of retrievals available compared to Version 1.0. This paper will briefly describe the Version 2.0 output parameters and analyze the new criteria applied to the input parameters and screening of the Version 2.0 inversion products that comprises a Level 2 (quality assured) data product.

1.1 Background-The need for Version 2

The Version 1 retrievals are computed by the inversion code of Dubovik and King, (2000) that employs a spherical aerosol particle shape model and a spheroidal aerosol model (Dubovik et al., 2002) yielding aerosol output parameters for each with specific use criteria for each. The two particle shape model outputs resulted in a great deal of confusion in the user community. Version 2.0 simplifies the products, providing one set of aerosol retrievals and an estimate of the percentage of spherical particle scattering (sphericity parameter). The Version 2.0 AERONET retrieval products are expanded and improved by providing total estimated errors (systematic, random and bias) for the radiometric and microphysical inversion products. Note that the error bars are estimated and dynamic and may not necessarily represent true uncertainties particularly for systematic errors in the measurement data. Because of the great improvement in surface albedo characterization with the dynamic surface albedo inputs, the retrieval products (especially absorption) have greatly improved in Version 2.0 particularly where the green earth assumption was not appropriate.

Finally there has been an evolution in the instruments and data collection since 1993. This includes the optical design of the radiometer and the almucantar protocol and spectral wavelengths. For example the Almucantar measurements may have various numbers of spectral almucantars due to instrument type, how it was set up and the functionality of data collection. The historical standard of four almucantar scans (440, 675, 870 and 1020 nm) is designated as the reference retrieval standard database for Version 2.0. A second database using more than the four standard wavelength almucantars may incorporate additional wavelengths from 340 to 1640 nm but will be developed at a later time. Evolution of CIMEL instrument optics also requires assessment and updating for Version 2.0. These points will be discussed in detail in the following sections with respect to Level 2 criteria.

The following parameters compose the Version 2.0 suite of retrieval products:

- Particle Volume Size distribution in 22 size bins, Volume concentration (C_v), volume median radius (R_v), standard deviation and effective radius for total, fine and coarse modes
- % Spherical particles
- Spectral Complex Index of Refraction (real and imaginary),
- Spectral Phase function
- Spectral Asymmetry Parameter
- Spectral Extinction optical depth
- Spectral Absorption Optical Depth

- Spectral Single Scattering Albedo (ω_o)

Instantaneous:

- Spectral upward and downward fluxes (TOA and BOA*)
- Broadband upward and downward fluxes (TOA and BOA)
- Radiative forcing (TOA and BOA)
- Radiative forcing efficiency (TOA and BOA)

* TOA= Top of Atmosphere BOA=Bottom of Atmosphere

2. VERSION 2.0 CONSTRAINTS ON THE INPUT DATA FOR LEVEL 2 INVERSIONS

AERONET input criteria were re-evaluated and updated to provide quality assured (Level 2) inversion products that is stable and physically realistic. The principle retrieval products evaluated are volume size distribution, R_v, C_v, and ω_o and to lesser extent real index of refraction, n. The input parameters include spectral AOD (Version 2, see AERONET webpage for details), surface albedo and the solar aureole/sky radiance measurements taken during almucantar scans.

Holben et al., 1998 reported the almucantar measurements for the Cimel Electronique CE 318 radiometer in azimuth angles reproduced in Table 1. That spectral measurement sequence (440 nm, 675 nm, 870 nm and 1020 nm) was a single counterclockwise sweep of predetermined azimuth angles that provided redundant observations at all azimuth angles except 180°. The sequence was revised in 1999 to streamline the observations and eliminate mechanical problems associated with a 360° rotation. The resulting clockwise and counter clockwise 180° scans also provided two observations at 180° azimuth allowing a more robust cloud screening check commensurate with the other angles. In 2002 AERONET began providing a quality assured Version 1.0 inversion product with the Dubovik and King, (2000) inversion (spherical model) and the Dubovik et al. 2002 spheroid inversions. The input criteria for these inversions were rather simple but poorly researched. Additional experience resulted in further Level 2 post processing criteria that are presented in Table 2.

Table 1, Almucantar azimuthal measurements are relative to the sun (0°). The combined measurements represent 360 K almucantars of which 253 K have Level 2 potential.

Year Implemented	**Almucantar Azimuth Sequence**	**Potential # Version 2.0 level 2 Inversions**	**Comment**
1993 to ~1999	0, -6 – A, -5, -4, -3.5, -3, -2.5, -2, 2, 2.5, 3, 3.5, 4, 5, 6 – A, 6 – K*, 7, 8, 10, 12, 14, 16, 18, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, -160, -140, -120, -100, -90, -80, -70, -60, -50, -45, -40, -35, -30, -25, -20, -18, -16, -14, -12, -10, -8, -7, -6 – K, -6 – A, -5, -4, -3.5, -3, -2.5, -2, 2, 2.5, 3, 3.5, 4, 5, 6 – A*	46,000	Single 360 degree counterclockwise sweep; single measurement at 180° Azimuth angle; Approximate time for 4 λ sequence- 6 min.
~1999 to present	Counterclockwise sequence: 0, 3, 3.5, 4, 5, 6 – A, 6 – K, 7, 8,10, 12, 14, 16, 18, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 120, 140, 160,180 Clockwise sequence: 0, 3, 3.5, 4, 5, 6 – A, 6 – K, 7, 8,10, 12, 14, 16, 18, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 120, 140, 160,180	207,000	Clockwise and counter clockwise rotation, all azimuth angles taken twice for consistency check; Approximate time for 4 λ sequence: 5 min

*Note-'A' refers to the sun collimator optics and 'K' refers to the sky radiance collimator optics

The Version 2.0 Level 2 pre and post criteria are presented in Table 3. These criteria are based on analyst' experience and a statistical analysis of the 360,000 almucantars. Some of the Version 1.0 criteria were retained, others modified and new criteria introduced to take better advantage of the new measurement sequence and further adapted to accommodate the old measurement sequence. Those criteria highlighted in Table 3 show the differences in the Version 2 criteria (compare to Table 2) and will be analyzed in the following sections.

Table 2 Pre and post processing criteria required for Version 1.0, Level 2 inversion products.

Inversion Parameter	**Data Preparation/Level 1.5 Inversion Criteria**	**Additional Level 2 Inversion Criteria**
All parameters	All 4 spectral bands (440, 675, 870, 1020 nm) required	
All parameters	Level 2 AOD; AOD measured within ±16 min of almucantar measurement and immediately preceding AOD must be present; 20% symmetry check for all angles,	
All parameters	All azimuth angles < 3.5° eliminated	
All parameters	Scattering angles: ≥ 10 scattering angles	21 azimuth angles from 0° to 160° scan must be included and spectrally coincident
All parameters-Spherical Model		5% residual
All parameters-Spheroid Model		10% residual
All parameters		$\Theta_0 > 50°$
ω_0, n, k		$\tau_{a440} > 0.40$

Table 3, Input data preparation and level 1.5 criteria, and Level 2 Inversion Criteria for Version 2.0 Inversion processing.

Aerosol Parameter affected	**Data input Preparation/Level 1.5 inversion criteria**	**Additional Level 2 Inversion Criteria**
All parameters	All 4 spectral bands (440, 675, 870, 1020 nm) required	
All parameters	Version 2 Level 2 AOD; AOD measured within ±16 min of almucantar measurement and AOD immediately preceding almucantar must be present; 20% agreement for sky radiance symmetry check for all angles except 180° azimuth (see next)	Calibration check (duel detector system only for all instruments manufactured prior to 2004 and apply only if detectors not saturated) $\lvert(A-K)\rvert/(A+K)/2 < 5\%$ *At this writing, Oct, '06, this criterion is provisional pending further study.*
All parameters	Dual 180° azimuth measurements (since ~1999): $\lvert(L^{\dagger}-R^{\dagger})/(L+R)/2\rvert \leq 5\%$ Single 180 measurement prior to 1998: referenced to mean of 160° azimuth angle & passing angular radiance consistency check- $\lvert(160-180)/160\rvert \leq 5\%$	
All parameters	Scattering angles: Select scattering angles ≥ 3.2° within each spectral almucantar; Remove all saturated or 0 value scattering angles	

Table 3. Cont.

Aerosol Parameter affected	**Data input Preparation/Level 1.5 inversion criteria**	**Additional Level 2 Inversion Criteria**
All parameters	Scattering angles: ≥ 10 scattering angles and 1 angle in each angle range bin for each λ: ≥3.2 to 6.0: at least 1 in range ≥6.0 to 30.0: at least 1 in range ≥30.0 to 80: at least 1 in range ≥80.0: at least 1 in range	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
All parameters		Sky Residual errors as a function of τ_{a440}: 0 to 0.20: 5% ≥ 0.20 to 1.50: **$Y = -1.09X^2 + 4.07X + 4.33$** **Where x is τ_{a440} and Y=residual** ≥1.50: 8%
All parameters except coarse mode size distribution		$\theta_o \geq 50°$; Dubovik et al., 2000
ω_0, n, k		$\tau_{a440} \geq 0.40$, Dubovik et al., 2000
% sphericity		$\alpha < 1.2$ and $\tau_{a440} > 0.10$

†Note-L and R refer to the clockwise and counterclockwise almucantar scans.

2.1 Calibration check

All Cimel instruments manufactured up to 2004 had dual optics with two independent detectors to provide sufficient sensitivity to measure bright direct sun irradiances to dark sky radiances in the standard wavebands. Thus two calibrations were required. The measurement protocol required an observation (~1 second delta) from each detector at + and – 6° azimuth where the majority of time the measurements were within the detector sensitivity range for both detectors. Version 1.0 had no requirement to compare the radiances. Version 2.0 provisionally requires a 5% check (See table 3) as any number of issues can contribute to differences. The radiance calibration is done by comparing to reference integrating spheres that historically have a ±5% accuracy although most modern systems report ~2%. We thus chose 5% as our benchmark for this check. Several issues can cause the criteria to be exceeded, such as miscalibration at the lab, an obstruction in the field instrument collimator(s), mechanical errors such as backlash and filter wheel positioning, and electronic issues. Figure. 1 illustrates such a case in which ratios from an instrument used in the UAE[2] field campaign had ratios exceeding 5% for the duration of the experiment. The exact cause was never diagnosed however the retrievals passed all Version 1.0 Level 2 criteria. The inversion products of size distribution and ω_0 departed markedly from other regional measurements due the apparent miscalibration/instrumental problems. Establishing appropriate A-K criteria will screen similarly corrupted data from the database. At this writing analysis of ~1/3 of the AERONET almucantar database, the 5% averaged A-K criteria of Version 2 Level 2 removes 13% of all successful inversions after all other thresholds were passed while a 10% criteria eliminates 7.5%, (Table 4 for summary). The criteria is highly site dependent. Further investigation will involve spectral analysis of this threshold before establishing the criteria.

As the solar zenith angle becomes smaller, the scattering angles become smaller for any prescribed measurement azimuth angle, thus for almucantars taken at small solar zenith angles, the K optics (sky) tends to saturate. Additionally, at solar zenith angles <50°, there may be significant measured differences due to small collimator differences such as field of view. In these cases no A-K check is implemented. Additionally no 'calibration' check is made for the single optical system used on the newer radiometers, since all measurements are made though the same optics system.

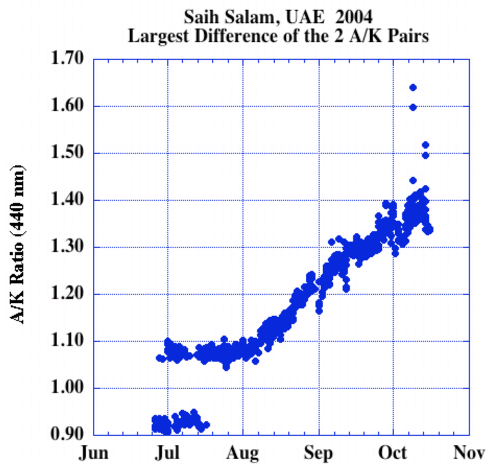

Fig. 1. The A/K ratio for an instrument showed approximately ±8% difference for 1 month followed by a three-month drift. These data passed all Version 1.0 criteria however the retrieval products were very anomalous and largely unphysical compared to nearby instruments.

2.2 Symmetry Check (20%)

Almucantar retrievals assume aerosols to be uniformly distributed across the sky measurement hemisphere. Clouds and aerosol plumes violate that assumption. To assess the uniformity we compared the sky brightness complimentary observation pairs made relative to the sun. For example, a spectral radiance measured at +120° azimuth is compared to the complimentary observation at -120° azimuth for selected azimuth angles, Figure 2. The results indicate that ≥90% of the values fall within 20% of the mean of the two observations, thus we established the general criteria to reject paired data that exceeds 20%, (Table 3). The accepted values are then averaged and made available as input data to the inversion process. We further assessed the effect of the asymmetry on the retrievals by plotting the parameter vs. AOD at three threshold ranges, ≤10%, 10 to 15% and 15 to 20%, Fig 3 is an example for Goddard Space Flight Center for Rv and ω_0.

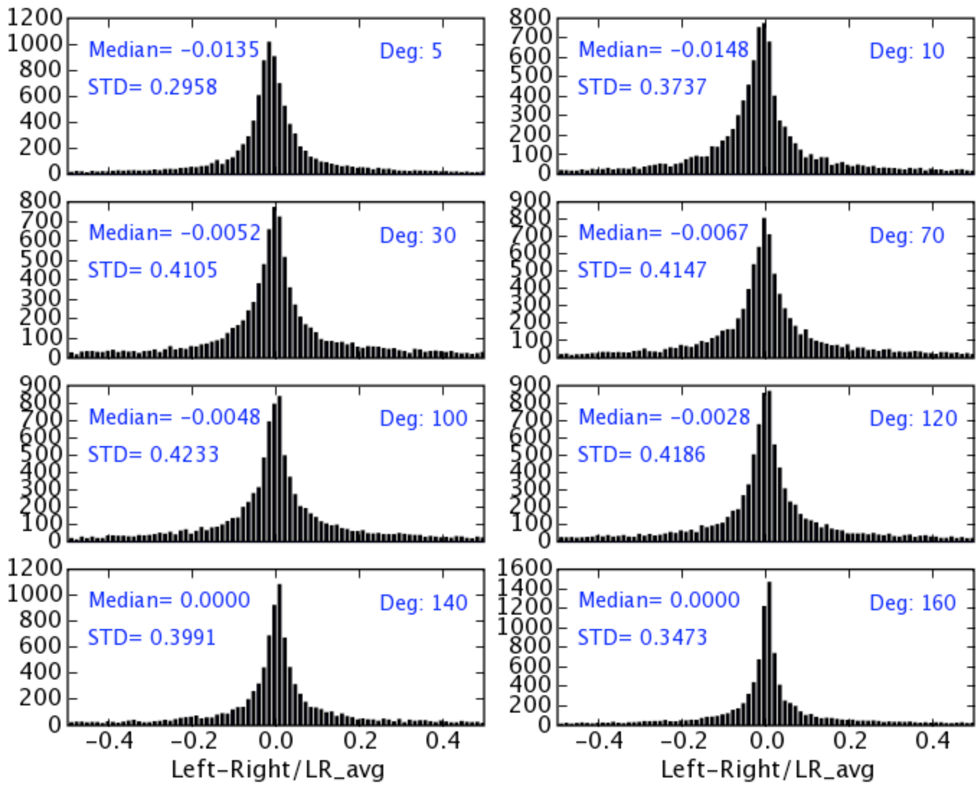

Fig. 2. Data taken for all level 2 candidate almucantars (Level 2 AOD) at GSFC illustrates that the majority of the angular radiance pairs fall within the 20% relative difference criteria regardless of the azimuth angle.

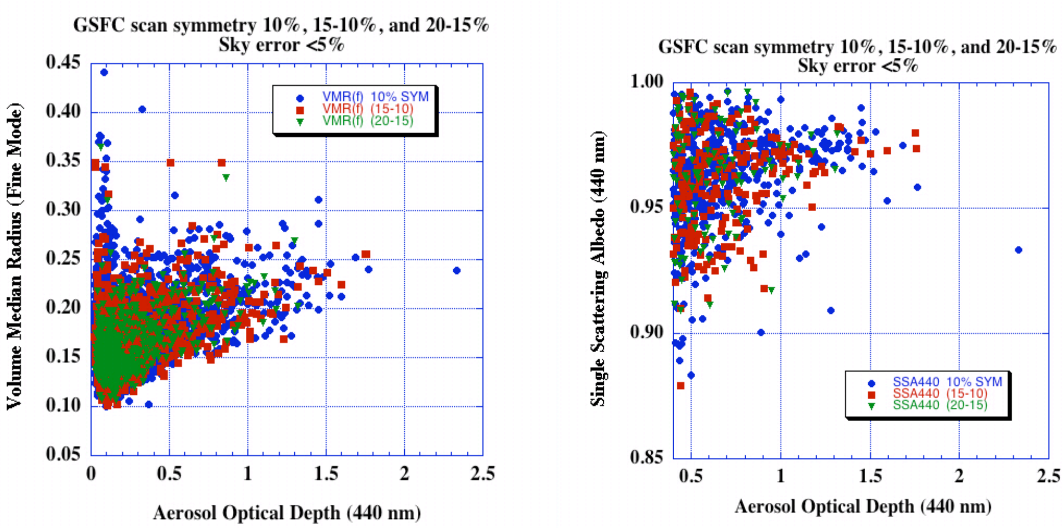

Fig. 3. The distribution of R_v fine and ω_0 were largely independent of the symmetry criteria for GSFC and all sites considered, at sky radiance residual errors of <5%.

The plots in this example are representative of all sites considered. The distribution for each rejection rate bin is very similar regardless of the parameter considered. Since no bias is observed at the larger bin compared to the most restrictive bin, we conclude that the inversion parameters will be acceptable for the less restrictive parameter. These plots are for 21 'symmetric' angles and therefore if just 1 angle differs by 15-20% then that almucantur would fall into the 15-20% symmetry category. This may help explain why the retrievals are so similar, that perhaps most angles are in agreement with 10% or better sky radiance symmetry, so a few out of 21 angles may not affect the final retrieval result very much for cases with low residual sky errors (<5%). Therefore we have maintained the 20% criteria from the heritage Version 1.0 criteria.

2.3 Inclusion of 180 Azimuth angle

All almucantars include measurements at 180° azimuth angle but have never been incorporated in the inversion input. Prior to 1998 one observation was made at this angle thus it was felt that we had no good check for cloud contamination and quite frankly no one investigated these data. With the inception of the pair of clockwise and counter clockwise 180 degree almucantar scans, two spectral measurements were available. Given that the instrument views the same part of the sky, unlike the other azimuth angles and the observations are approximately 1 minute apart, we adopted a more stringent criteria similar to the triplet variability adopted for cloud clearing of the direct sun AOD measurements (Smirnov, 2000). The criteria we adopted is ≤ %5 variability relative to the mean (Table 3). The criteria can be applied to 81% of available almucantars in the database.

The remaining almucantars have one 180 degree spectral observation in each complete scan. To preserve that observation, an extensive analysis was made of the successful (<5% temporal variance at 180 degrees criteria) retrievals of the dual 180 degree measurements relative to coincident 160° azimuth retrievals. The relative difference (180° - 160°)/180° for solar zenith angles ranging from 50 to 65 and 65 to 80 degrees for sites dominated by coarse mode dust, marine aerosols, fine mode biomass burning and non biomass burning fine mode aerosols were investigated. Histograms for all cases but one showed that >90% of all cases had differences between 160° and 180° azimuth within ±5% , Figure 4.

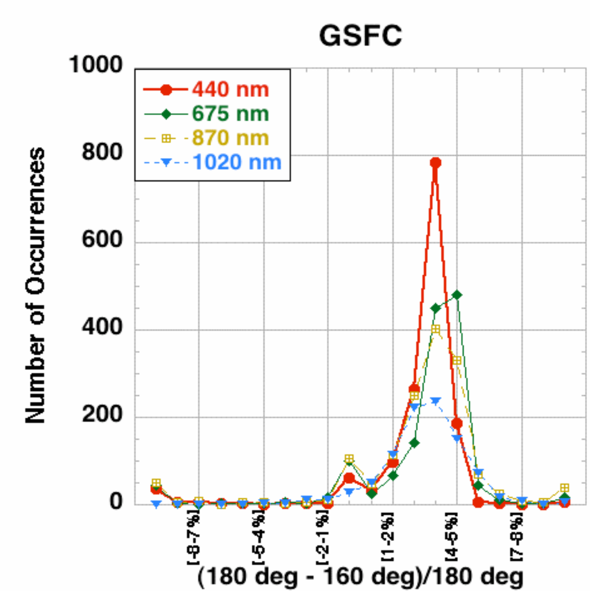

Fig. 4. Example of a histogram showing the distribution of relative radiance difference (160 vs. 180 deg.) in 1% bins about the 180° mean azimuth angle for GSFC. Note a slight shift of the distribution, however ~90% fall within the ≤ 5% criteria.

The exception is for marine sea salt dominated aerosol at large solar zenith angles. For the extreme case (65 to 80° solar zenith angle and 1020 nm wavelength, 90% of the observations exceeded a 5% relative difference, (Figure 5). This may be explained from evaluation of the phase function of large spherical particles (such as hydrated sea salt) that have a strong gradient as a function of scattering angle at large scattering angles only. To put this in perspective, only 19% of all almucantars have one 180° azimuth observation, 25% of those have high solar zenith angles and approximately 10% of those sites are influenced by marine aerosols. Thus less than 0.5% of the total database is affected. Additionally the criteria will only reject the 180° azimuth angle observation, leaving the rest for the inversion. Finally this percentage will increasingly diminish as the single measurement is no longer part of the network wide measurement protocol. The agreed upon criteria is to accept the single 180° azimuth measurement for inversion only if the 160 degree pair is accepted and the 5% relative difference criteria is achieved relative to the accepted 160° azimuth observation.

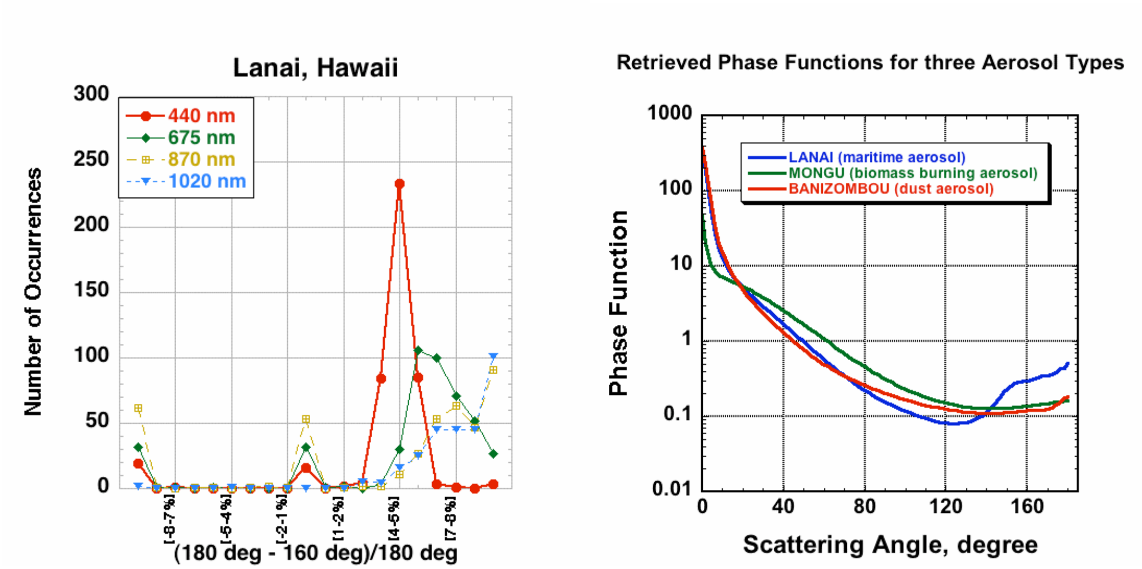

Fig. 5. Marine aerosols have a large rejection rate well above the 5% criteria at high solar zenith angle and long wavelength (left). The phase function for marine aerosols shows a minor peak in the backscatter that illustrates the observed effect whereas other aerosol types are flat in this region (right).

2.4 Scattering angle criteria

The scattering angle is defined by the pre-selected azimuth angles (relative to the sun), thus as the solar zenith angle decreases the scattering angles decrease. Therefore it is important to refer to the inversion retrieval parameters in terms of the scattering angles that contribute to the input radiance dataset. The following analysis was preformed to analyze the angular regions of the spectral scan that contribute most significantly to the retrieved parameters. Depending on solar zenith angle, the scattering angle range can be from <2° to ~154° with the current protocol. Based on requirements to provide sufficient information to retrieve all parameters, four regions were identified with a minimum number of angles imposed for each bin that we expect to represent the sky radiance distribution.

The sky radiance as a function of scattering angle are represented by two contrasting cases, Mongu, Zambia (fine mode biomass burning) and Banizoumbou, Niger (coarse mode mineral dust), shown in Fig. 6. In both examples, the full observed angular range is represented by the green curve. The binned angular ranges were selected to insure capture of the shape of these curves. Further we required a minimum number of angles in each bin to provide adequate sensitivity to the retrieved aerosol parameter, see Table 3. This was nominally selected to be half of the maximum number of potentially available scattering angles. Analysis of the bin ranges was preformed for a variety of cases but the Mongu and Banizombou examples will be illustrated here. The retrievals were preformed under relatively high aerosol loading, ~1. 0 at 440 nm and ~75° solar zenith angle. Each had the full compliment of scattering angles (27) with the exception of the 80 degree azimuth observation, which was excluded. The angular data was then reduced to the minimum bin requirements and the inversion retrievals computed again. The results are presented for volume size distribution, single scattering albedo and real index of refraction, Fig. 7.

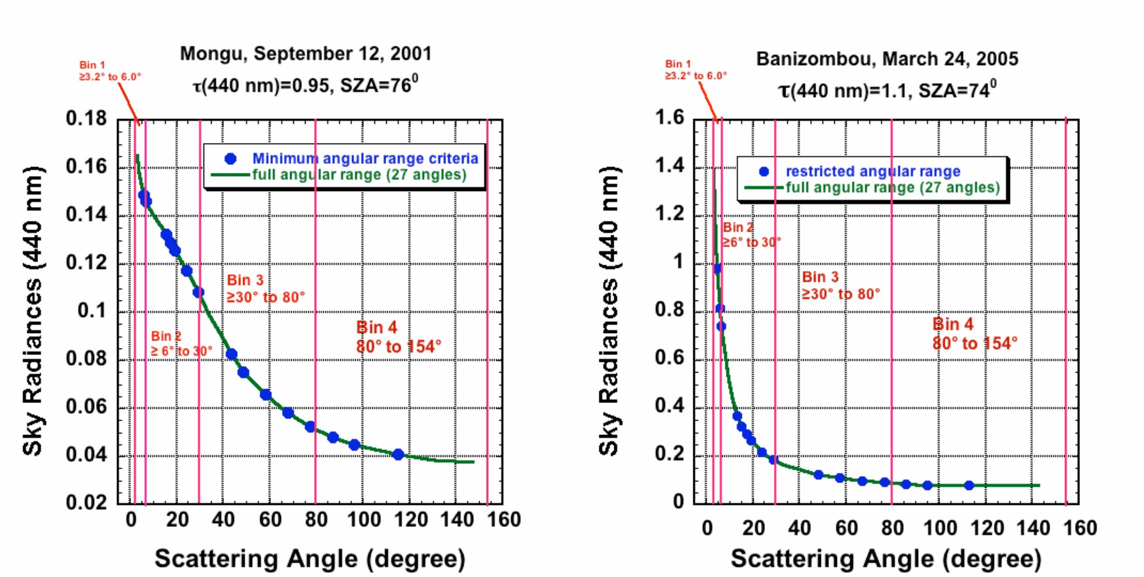

Fig. 6. Radiance at 440 nm vs. scattering angle for fine mode (left) and coarse mode (right) aerosols. The green curve shows the full angular distribution, while the superimposed blue dots show the restricted angles falling in the four bins (red line partitions) with the mandatory minimum number of angles (see Table 3).

2.5 Bin 1: ≥ 3.2° to 6.0°

The new CIMEL optical system post-2004 was designed for 95% stray light rejection at a scattering angle of 2.5 degrees and qualitatively appears to have achieved that for instruments prior to deployment. The original instruments were designed for 2.0 degrees stray light rejection but did not achieve that standard. Subsequently several iterations were made to arrive at the current optical instrument design. In order to accommodate the range of optics variability, a minimum scattering angle criterion was established that analysis showed eliminated stray light peak radiance contamination apparent in some solar aureole observations. Two scattering angles are required to fall within Bin 1, a very narrow band but showing great dynamic radiometric change particularly for large particle sizes. Information from large particle forward scattering is provided from this region and will affect the coarse mode size distribution. The retrieved size distributions for Banizoumbou show extremely good agreement between the full and restricted coarse mode size distributions. The concentration is slightly reduced in this example and there is a very small shift to small particles on the larger particle side compared to the full distribution. As expected, there is no effect on the volume median radius of the fine mode evident from both sites. These results were confirmed in other tests and simulations. The results of the median coarse mode Rv uncertainty fall within our estimated uncertainty of 0.5 micron for the coarse mode retrievals, thus we feel the two angle requirement is satisfactory for bin 1.

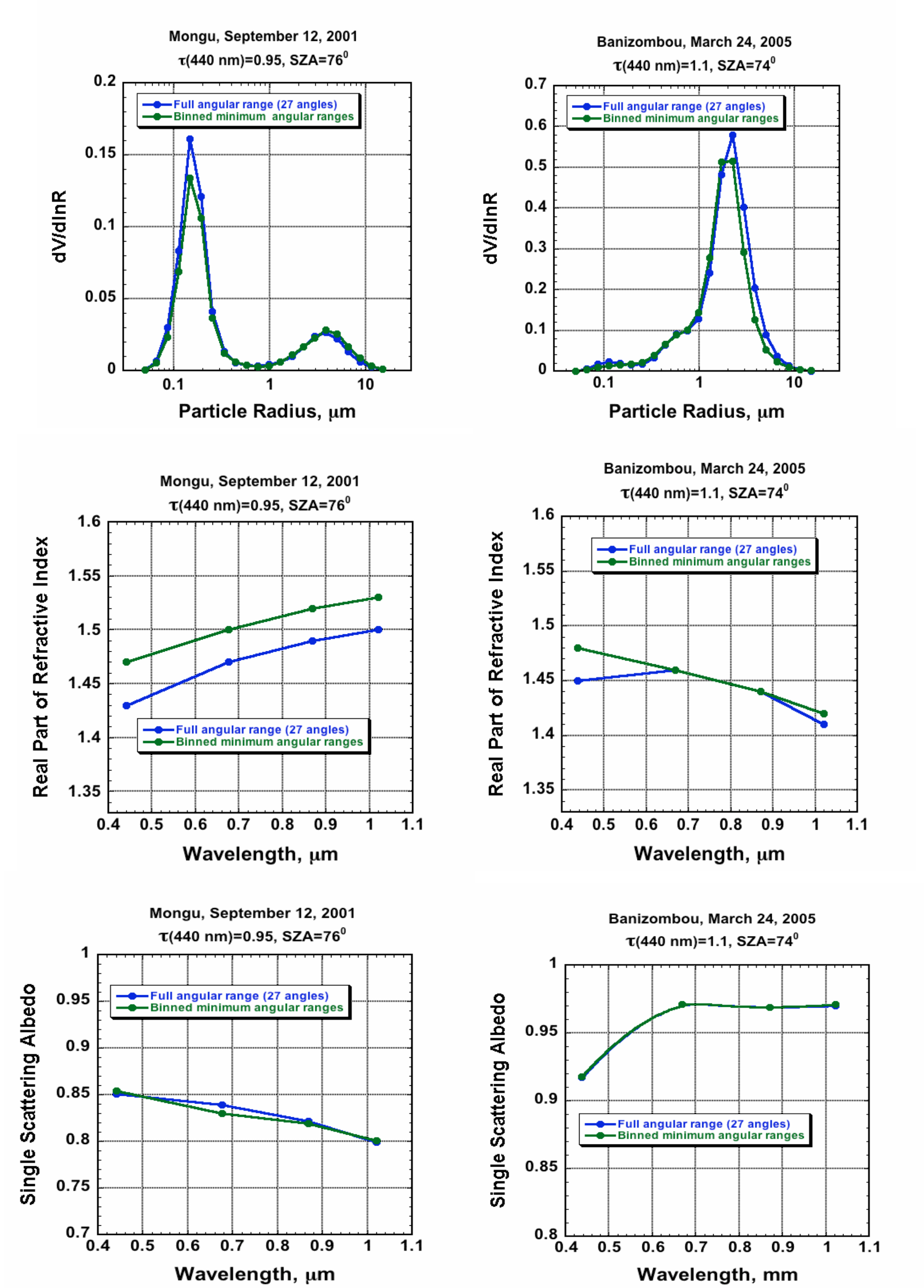

Fig. 7. Show comparisons of size distribution, real index of refraction and single scattering albedo retrievals comparing from full angle measurements to the minimum required angles.

2.6 Minimum bin analysis assessment

Analysis of the effects of missing scattering angles as a function of bin is beyond the scope of this paper due to non linear multi-angle interactions with aerosol size, shape, absorption and scattering properties however collectively it is reasonable to evaluate the overall effect on the retrieved parameters. Our examples are quite representative for fine mode and coarse mode aerosol. The fine mode volume median size distribution (Figure 7 top left panel) shows good agreement, particularly the computed R_v, which is 0.16 µm in both cases however the volume concentration (C_v) is reduced from 0.127 to 0.108. For biomass burning fine mode aerosols, the real index of refraction, n, was elevated ~ 3 to 4 percent (0.05) above the full angle retrieval for all wavelengths, in contrast the coarse mode dominated particles from Banizoumbou showed only notable variation at 440 nm but well within our prescribed uncertainty of 0.05. Note that in both examples the angularly restricted retrievals properly capture the slope and the magnitude to acceptable accuracy.

The single scattering albedo is a critically important parameter particularly for absorbing aerosols such as mixtures of flaming and smoldering combustion phase generated biomass burning aerosols (Eck et al., 2002) and UV absorbing aerosols such as mineral dust (Dubovik et al., 2002). Capturing these phenomena with the restricted angular measurements is fundamental for the level 2 criteria quality control. In both biomass burning and mineral dust cases, the restricted retrievals were nearly identical to the full angular retrievals (Figure 7 lower two panels). The accuracy is ≤ 0.01, well within the 0.03 retrieval uncertainty.

Overall the minimum bin angle range criteria provide sufficient data for the retrieval of all parameters to fall within their specified uncertainty. Clearly a subset of the sky radiance data will not reproduce the exact results of a full compliment of angles, however only three minor issues were identified where we caution the user: the fine mode volume concentration is slightly underestimated, the coarse mode Rv is slightly underestimated and the real index of refraction for fine mode aerosols maybe slightly overestimated. With the Version 2 retrievals this is less of an issue since errors are provided for each parameter that can then be assessed by the user. Additionally, the binned angle distribution is part of each Version 2 retrieval output, therefore available for later assessment.

2.7 Dynamic Residual error check

The residual error check is the principle evaluation criteria for the level 2 quality check of the retrieval parameters (Dubovik et al. 2002). The residual is computed from the delta between the measured sky radiances and the computed sky radiance field generated from the forward computation of the radiative transfer model. The Version 1 value of 5% was derived from the assumption that the absolute calibration of the integrating sphere is approximately 5%. A great deal of empirical analysis has shown the values of the retrieval products that fall within the 5% threshold are very consistent and provide the basis of our uncertainty for the individual retrieval parameters. However we found that a residual error threshold of 5% for sky radiances utilized in the Version 1 of our algorithm cut off a substantial number of retrievals that had residual errors within 5% to 8% range for aerosol optical depths higher than 0.7-0.8 (at a wavelength 440 nm). Rejected retrievals looked similar to the accepted ones for a large range of high aerosol optical depths, thus a higher error seemed to be acceptable for large aerosol loadings.

Residual errors as a function of aerosol optical depth were analyzed. The histogram of the residual errors is shown in Fig. 8 (left). Total (or overall) residual sky errors and errors in each spectral channel show that for all cases, over 80% have a residual error less than or equal to 5%. A small percentage of all cases have residual errors over 10% (2.5% for the 870 nm channel and 3.8% for the 440 nm channel). Overall and spectral errors are distributed similarly and there are no apparent biases for any of the spectral channels.

The AOD (440 nm) was partitioned into four bins, 0.0 to 0.4, 0.4 to 0.8, 0.8 to1.2 and > 1.2. Because of the small number of available retrievals for high optical depth cases we did not create additional bins for optical depth beyond 1.2. A rejection rate (percentage of rejected retrievals to the total number of retrievals) for a residual error of 5% was generated for the aerosol optical depth bin 0.0-0.4. Then for the optical depth bin 0.4-0.8, the error margin that will have same rejection rate 0.129 (i.e. ~13%) was computed. Similarly computations for the 0.8-1.2 bin and the bin with all optical depths over 1.2 were made, presented in Fig.8 (red curve) and fit to a 2^{nd} order polynomial. In order to check the robustness of the relationship between the residual error and aerosol optical depth, the analysis was reversed. The rejection rate was computed for a residual error of 8% within the bin 1.2 and higher, and found to be 0.126. Then we made computations for the optical depth bins 0.8-1.2, 0.4-0.8 and 0.0-0.4 preserving the rejection rate of 0.126. The results are presented in Fig.8 (green curve). The polynomial fit and coefficients are very similar to the case considered above.

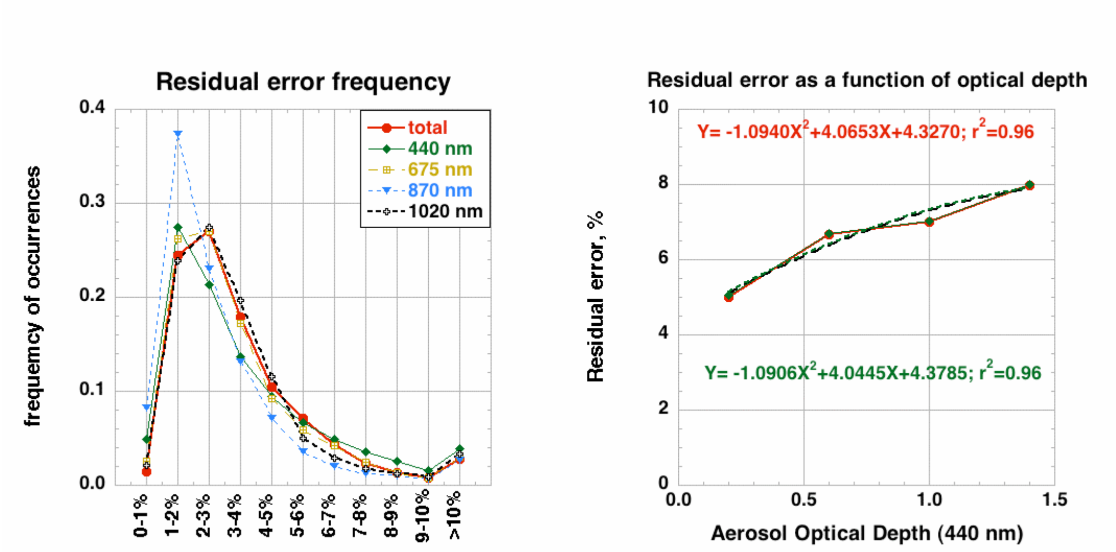

Fig. 8. The residual error distributions left and the residual error as a function of optical depth.

Therefore, as can be seen from Fig.8 and Table 3 the following dynamic thresholds for the residual sky radiance error are used for Version 2 Level 2:

- Optical depth range less than 0.20: 5% error threshold
- Optical depth range 0.2-1.5: Y=-1.0940X^2+4.0653X+4.3270,
- Optical depths over 1.5: Constant threshold of 8%.

3. CONCLUSION

The Version 2.0 input and post inversion screening criteria have been redefined based on analysis of a decade of observations, improved capability and flexibility of the inversion algorithm to handle variable input parameters and a more thorough understanding of the instrumental measurements and algorithmic requirements. Of the 1/3 subset of available almucantars analyzed at this writing, 54% passed the Level 2 criteria, Table 4. Further analysis of the data are required to refine the calibration criteria prior to an anticipated November release of the Version 2.0 AERONET inversion parameter database. Clearly development of quality assurance criteria will remain an ongoing process as instruments and algorithms develop. Other criteria must follow to address quality assurance of products from other AERONET observations such as principle plane data, > four spectral almucantar inversion products, polarization retrievals and SeaPRiSM's water leaving radiances.

Table 4, Preliminary summary of criteria on analysis of 126,933 almucantar candidates for level 2 (see Table 2 'data preparation') applied consecutively left to right.

		Version 2.0 Level 2 Criteria					
	Total Available	**Dynamic residual error**	**Θ_o> 50°**	**Bin Minimum angle**	**A/K Cal. 5%**	**A/K Cal 10%**	**AOT >0.4 (relative to 10% A/K)**
Percentage Cumulative Acceptance	-	78.9%	71.8%	61.1%	48.1%	53.6%	10.5%
Number of Almucantars Remaining	126,933	100, 188	91,164	77,591	61,068	68,059	14,968

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