Description of Aerosol Inversion Uncertainty for Level 2 Products

1. **Estimates of uncertainties produced for retrieved aerosol parameters.**

1.1 Volume median radius (VMR) of particle size distribution (PSD) for both modes.
1.2 Width of PSD for both modes
1.3 Imaginary index of refraction at four standard wavelengths (440, 675, 870, and 1020 nm)
1.4 Single scattering albedo (SSA) at four standard wavelengths
1.5 Asymmetry parameter at four standard wavelengths

2. **Approach for individual inversions.**

Variability in retrieved aerosol parameters is generated by perturbing data input for inversion algorithm. It is assumed that the perturbations in inputs are due to uncertainties (biases, systematic errors) in aerosol optical depth (AOD), radiometric calibration of sky radiances, solar spectral irradiance, and surface reflectance. Sun photometer pointing bias is not included in the list of uncertainties because averaging left and right parts of almucantar scans reduces this uncertainty significantly. Each bias assumes two values: positive and negative. The magnitudes and the signs of biases of the same type are assumed spectrally independent. For example, AODs at different wavelength are biased in the same direction and with the same magnitude. The radiometric calibration and solar irradiance spectrum uncertainties are combined in one bias because both of them affect the sky radiances magnitudes. Therefore, we are left with three distinct biases each assuming two values, which results in 27 distinct combinations in perturbing the inputs to the inversion.

3. **Implementation for individual inversions**.

The following values for one sigma biases are assumed. AOD: ± 0.01/m, where m is optical air mass, radiometric calibration bias: ± 3%, solar irradiance spectrum: ±2%., surface reflectance: ±0.05. For each set of Sun photometer almucantar or hybrid sky measurement, 27 inputs corresponding to 27 combinations of biases are produced. All of these inputs are then inverted and the following statistics of the inversion results are generated for each individual retrieval: average, standard deviation, minimal and maximal values. From these statistics only standard deviation (U27) is used as a proxy for estimated uncertainty.

4. **LUT approach**.

To speed up the operational computations of U27 a lookup table (LUT) approach was designed. A climatological LUT is generated from entire AERONET almucantar and hybrids database by binning U27s in AOD (440 nm), Angstrom Exponent (AE, 440-870nm), and SSA (440, 675, 870, 1020 nm). Using this LUT approach, U27 for each individual retrieval can be obtain by interpolation using the corresponding combination of AOD, AE, and SSA. Also, analysis of U27 for dust aerosol retrievals of SSA at longer wavelengths revealed physically nonrealistic values of U27 related to imaginary part of refractive index hitting its lower limit (boundary) as assumed by the inversion algorithm. Therefore, a second LUT was generated from the subset of U27s original (non-biased) individual inversions for which no boundary hits was detected by any of retrieved parameters. The second LUT is used for obtaining the unbiased estimates of uncertainty in situations when the effect of boundary hitting by retrievals on U27 is substantial.

5. **Implementation of the LUT approach**.

5.1 Binning:

AOD: less than 0.05, 0.05-0.1, 0.1-0.2, 0.2-3.4(in 0.2 increment bins)
AE (440-870 nm): <0.3, 0.3-2.4(in 0.3 increment bins)
SSA:
440, 675 nm: <0.7, 0.7-0.8, 0.8-0.85, 0.85-0.9, 0.9-0.95-0.95-0.975, and 0.975-1.0
870-1020 nm: two additional bins: less than 0.6, and 0.6-0.7.

5.2 LUT generation:

All parameters use AOD and AE in the LUT; however, some absorption dependent parameters also utilize the binning of SSA, which produces two types of LUTs. First LUT is two dimensional with binning in AOD and AE. This LUT is used to generate U27 for the following aerosol parameters: VMR, width of PSD, and asymmetry parameter. The second LUT is binned by AOD, AE, and SSA and used to obtain U27 for imaginary part of refractive index, and SSA to account for the effect of different absorption by aerosols with overlapping AE ranges.

5.3 LUT interpolation:

The 2D LUT can be viewed as a rectangular grid, each node of which corresponds to an AOD, AE pair. Each inversion has its own AOD and AE, and thus represents a point in the AOD, AE 2D space. If point is inside of that grid, four surrounding nodes are used for 2D interpolation. Similarly, 3D LUT can be viewed as parallelepiped lattice, each node of which corresponds to AOD, AE, SSA triad. Each inversion has its own AOD, AE and

SSA, and thus represents a point in the AOD, AE, SSA 3D space. If point is inside of the lattice, we use the eight surrounding nodes for 3D interpolation. If one or more points required for interpolation are missing, the values of the closest nodal points are used. The 2D interpolation is done on original LUT (no restriction on boundary hits). The 3D interpolation uses no hits LUT for the following combination of AE, SSA bins only: AE– less than 0.3, SSA–0.975-1.0.

6. Quality control.

The quality control follows that of Holben et al., 2006, except that it includes the thresholds for Hybrid of 25° solar zenith angle and the minimum AOD_{440nm} of 0.02.

- SSA, imaginary part of refractive index, asymmetry parameter:

  For almucantar (ALM) AOD_{440nm} larger than 0.4 and solar zenith angle (SZA) larger than 50°
  For hybrid (HYB) AOD_{440nm} larger than 0.4 and solar zenith angle (SZA) larger than 25°
- Volume median radius (VMR), width of particle size distribution (WPSD):

  For almucantar (ALM) AOD_{440nm} larger than 0.02 and solar zenith angle (SZA) larger than 50°.
  For hybrid (HYB) AOD_{440nm} larger than 0.02 and solar zenith angle (SZA) larger than 25°.

7. Examples.

Graphs below show U27 estimated for all level 2 inversions at Mongu AERONET site for five aerosol parameters defined in 1. In general, the variability of U27 with AOD and AE has a clear physical reasoning. For example, increase of U27 for VMRC at higher AODs can be explained by domination of aerosol loading by fine mode aerosols for which coarse mode is not well defined.

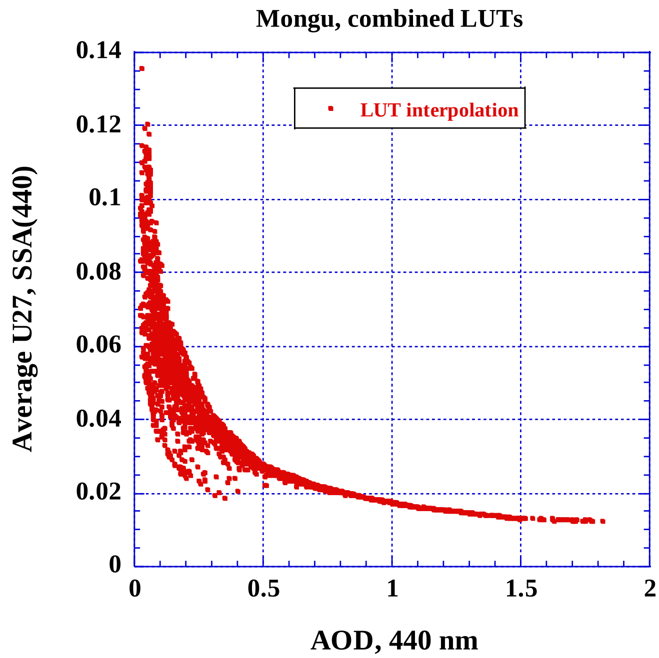
References:

Holben, B. N., T. F. Eck, I. Slutsker, A. Smirnov, A Sinyuk, J. Schafer, D. Giles, O. Dubovik, 2006: AERONET's Version 2.0 quality assurance criteria, Proc. SPIE 6408, Remote Sensing of the Atmosphere and Clouds, 64080Q, doi:10.1117/12.706524.

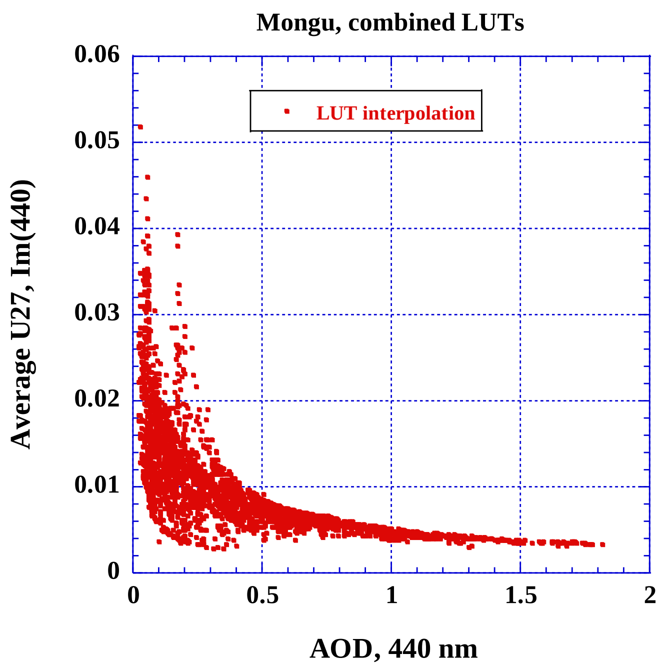
Graphs

3D LUT interpolation

1. SSA, 440 nm

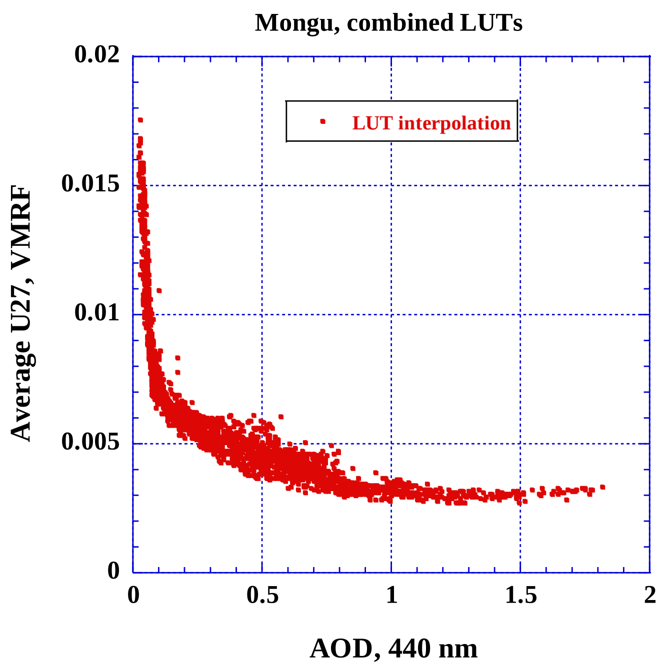


2. Imaginary part of refractive index, 440 nm

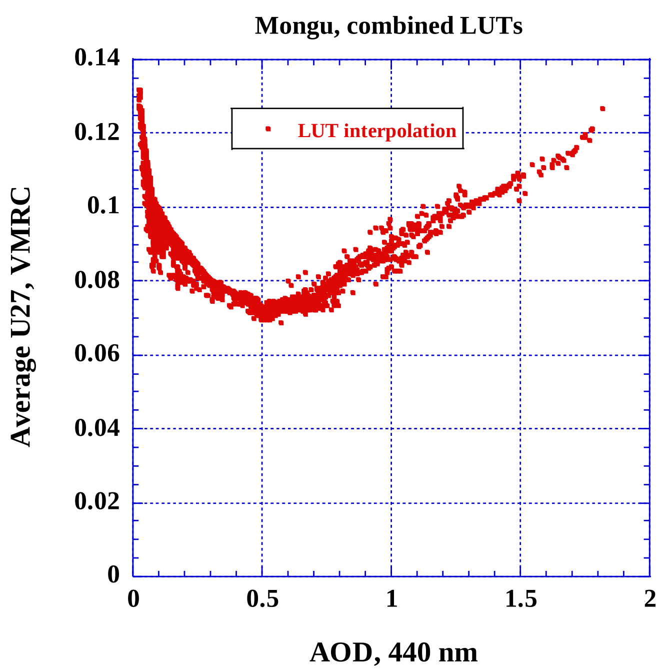


2D LUT interpolation

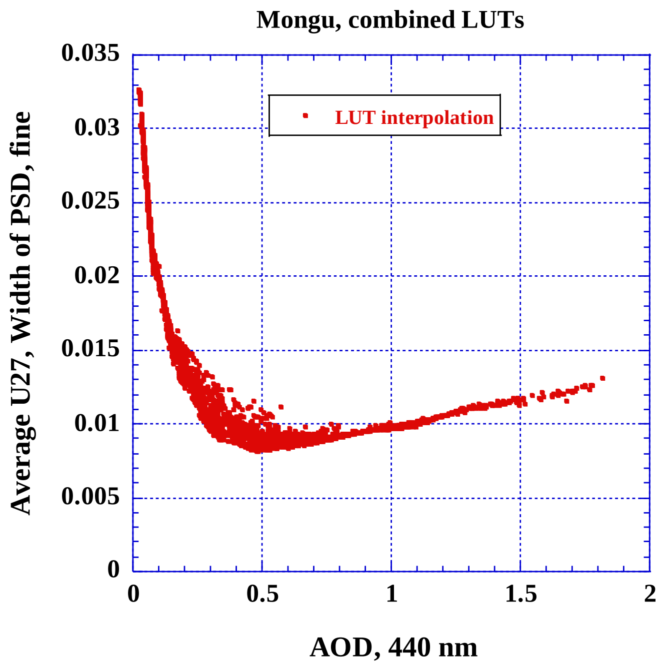
1. VMR, fine mode.



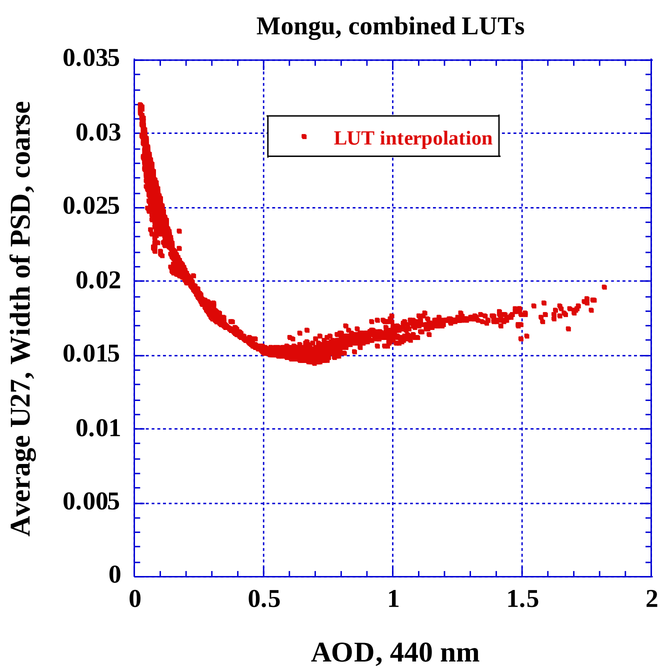
2. VMR, coarse mode



3. Width of PSD, fine mode



4. Width of PSD, coarse



5. Asymmetry parameter, 440 nm