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Aerosol Best Estimate (AEROSOLBE) Value-Added Product

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July 2012

ARM CLIMATE RESEARCH FACILITY

DISCLAIMER

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Acronyms and Abbreviations

AEROSOLBE	Aerosol Best Estimate (value-added product)
AIP	Aerosol Intensive Properties (value-added product)
AOD	aerosol optical depth
AOS	aerosol observing system
ARM	Atmospheric Radiation Measurement (Climate Research Facility)
BBHRP	Broadband Heating Rate Profile (value-added product)
bsf	backscatter fraction
g	asymmetry parameter
MERGESONDE	Merged Sounding (value-added product)
MET	meteorological instrumentation
MFRSR	multifilter rotating shadowband radiometer
NIMFR	normal incidence multifilter radiometer
PSAP	particle soot absorption photometer
RH	relative humidity
RL	Raman lidar
SGP	Southern Great Plains
SSA	single-scattering albedo
VAP	value-added product

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1.0 Introduction

The objective of the Aerosol Best Estimate (AEROSOLBE) value-added product (VAP) is to provide vertical profiles of aerosol extinction, single scatter albedo, asymmetry parameter, and Angström exponents for the atmospheric column above the Central Facility at the ARM Southern Great Plains (SGP) site. We expect that AEROSOLBE will provide nearly continuous estimates of aerosol optical properties under a range of conditions (clear, broken clouds, overcast clouds, etc.). The primary requirement of this VAP was to provide an aerosol data set as continuous as possible in both time and height for the Broadband Heating Rate Profile (BBHRP) VAP in order to provide a structure for the comprehensive assessment of our ability to model atmospheric radiative transfer for all conditions. Even though BBHRP has been completed, AEROSOLBE results are very valuable for environmental, atmospheric, and climate research.

After screening available aerosol optical depth (AOD) measurements for clouds and performing data quality checks, the VAP provides a nearly continuous time-series of aerosol optical depth at 500 nm and aerosol Angström exponent through a combination of simple interpolation and a predictive multivariate regression. The associated extinction profile is selected from the Raman lidar (RL) seasonal climatology of aerosol extinction profiles as a function of aerosol optical depth published in Turner et al. (2001). Single scatter albedo (ω_0) and asymmetry parameter (g) profiles are derived by assuming that the dry aerosol scattering properties measured by the aerosol observing system (AOS) at the surface are well-mixed with height. The aerosol absorption is assumed to have no humidity dependence. The aerosol optical properties are then modulated according to the vertical relative humidity (RH) profile using the surface measured f(RH) relationship as derived from aipfitrh1ogren data.

This application is currently implemented for the Southern Great Plains only.

2.0 Input Data

The algorithm currently utilizes measurements from these datastreams:

1. Normal incidence multifilter radiometer (NIMFR), using the nimfraod1mich datastream
2. Multifilter rotating shadowband radiometer (MFRSR), using the mfrsraod1mich datastream
3. Surface aerosol properties from the aerosol observing system (AOS), using the aip1ogren and aipfitrh1ogren datastreams
4. Relative humidity from radiosonde (mergesonde1mace datastream)
5. Surface humidity from surface meteorological instrumentation (MET) data (met datastream).

The input variables are given in Appendix A.

3.0 Algorithms and Methodology

The most important optical property of aerosols for radiative transfer applications is the AOD. Therefore, significant effort is made in AEROSOLBE to obtain good estimates of AOD. The AEROSOLBE time resolution is set to 10 minutes, so data from each input source are averaged to achieve this temporal resolution. The AEROSOLBE algorithm currently incorporates two direct measurements of AOD: the nimfraod1mich datastream from the NIMFR and the mfrsraod1mich datastream from the MFRSR, with the NIMFR taken in preference over the MFRSR due to lack of necessary cosine correction for the NIMFR (Harrison and Michalsky 1994). If the above two sources are unavailable for a given sample, then the data are interpolated over short gaps. For longer gaps the AOD is predicted using a multivariate regression that includes the surface RH, surface total scattering, and the average RH in the boundary layer. The coefficients of the regression are optimized over a monthly data set to minimize residuals when direct measurements are available.

AEROSOLBE reports time/height profiles of aerosol extinction at 500 nm estimated via a seasonal climatology of RL extinction profiles as a function of column optical depth. AEROSOLBE provides best-estimate time/height profiles of intensive properties of single-scattering albedo (SSA), backscatter fraction (bsf), and asymmetry parameter (g) for the red, green, and blue wavelengths estimated from surface measurements (from the Aerosol Intensive Properties [AIP] VAP) and the vertical profile of relative humidity (from the Merged Sounding [MERGESONDE] VAP), along with the assumption that the dry aerosol properties are vertically well-mixed. The well-mixed assumption allows the humidity dependence measured at the surface to be applied to the vertical column, yielding estimates for the ambient aerosol scattering that reflect the vertical structure in the humidity field, while the ratios involved in computing the intensive properties (SSA, bsf, g) mitigate scale-height effects on the extensive aerosol profiles.

After the best-estimate of the AOD at 500 nm is determined, a lookup table is used to determine the aerosol extinction profile based upon the climatology developed from two years of RL observations (Turner et al. 2001). This lookup table is organized as a function of season and AOD.

AEROSOLBE also provides estimates of the single scatter albedo (ω_0) and asymmetry parameter (g) as a function of height. These values are derived from the surface-based in situ measurements made by the AOS as follows. First, the boundary layer is assumed to be well-mixed such that the dry aerosol optical properties are constant with altitude (or at least constant in relative proportion). Next, relative humidity profiles are drawn from the MERGESONDE VAP, which provides estimates of the relative humidity for all times and heights above the SGP Central Facility. The surface level relative humidity from MERGESONDE is replaced with the surface RH obtained from MET data. Next, the aerosol optical properties of total scattering and hemispheric backscattering are computed for the vertical column by adjusting the dry properties according to the vertical profile of relative humidity. The two-parameter fit provided as part of the AOS (aosfrh) data stream $f(RH) = a(1-u)^{-b}$, where u is the relative humidity interpolated from the radiosonde observation as a fraction, is used to rehumidify the dry aerosol scattering properties. Note that no humidity correction is applied to the aerosol absorption coefficient observed by the AOS. The aerosol optical properties of scattering and absorption as well as the related intensive properties of single-scattering albedo and asymmetry parameter are each reported at the wavelengths adopted in the AIP VAP. Specifically, the nominal red, green, and blue measurements from the nephelometer and the 3-wavelength particle soot absorption photometer (PSAP), initially taken at different wavelengths, are adjusted via Angström exponent relationships to common wavelengths of 660 nm, 550 nm, and 467 nm.

3.1 Flowcharts

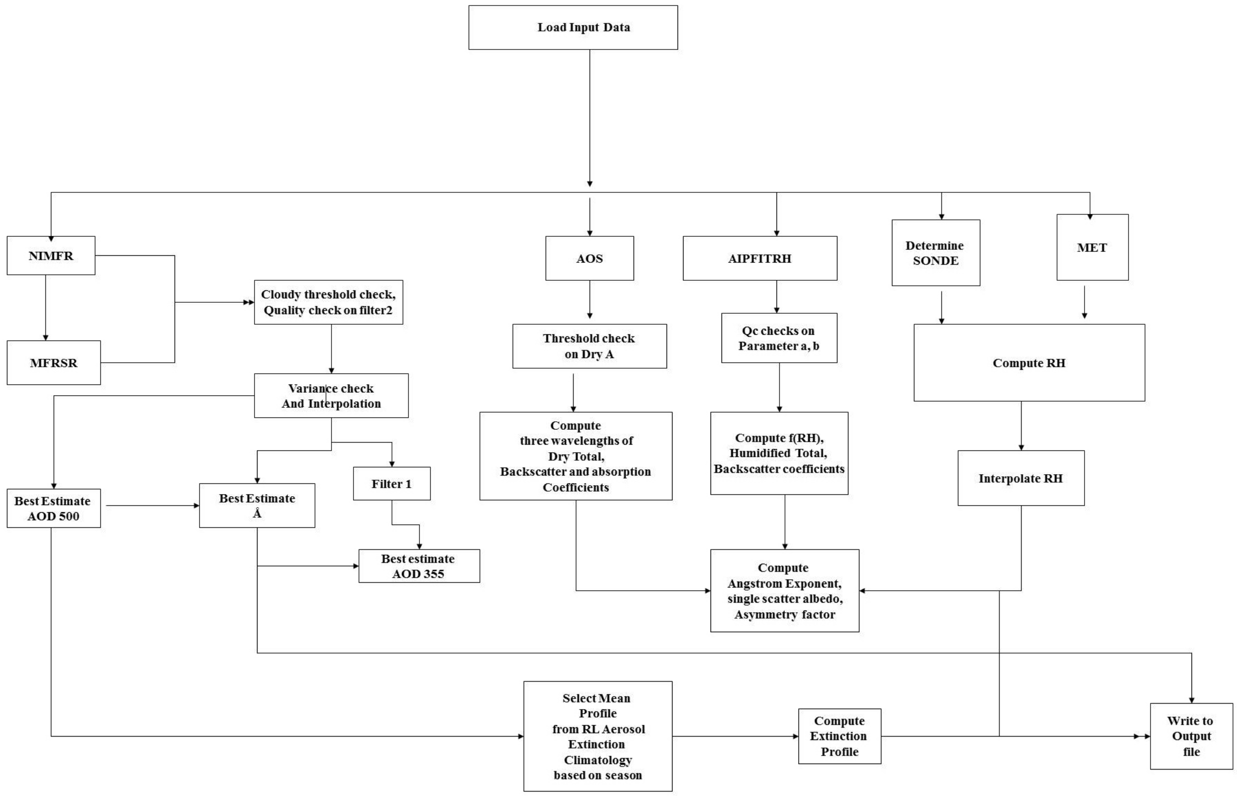

Figure 1. Flowchart describing the AEROSOLBE VAP.

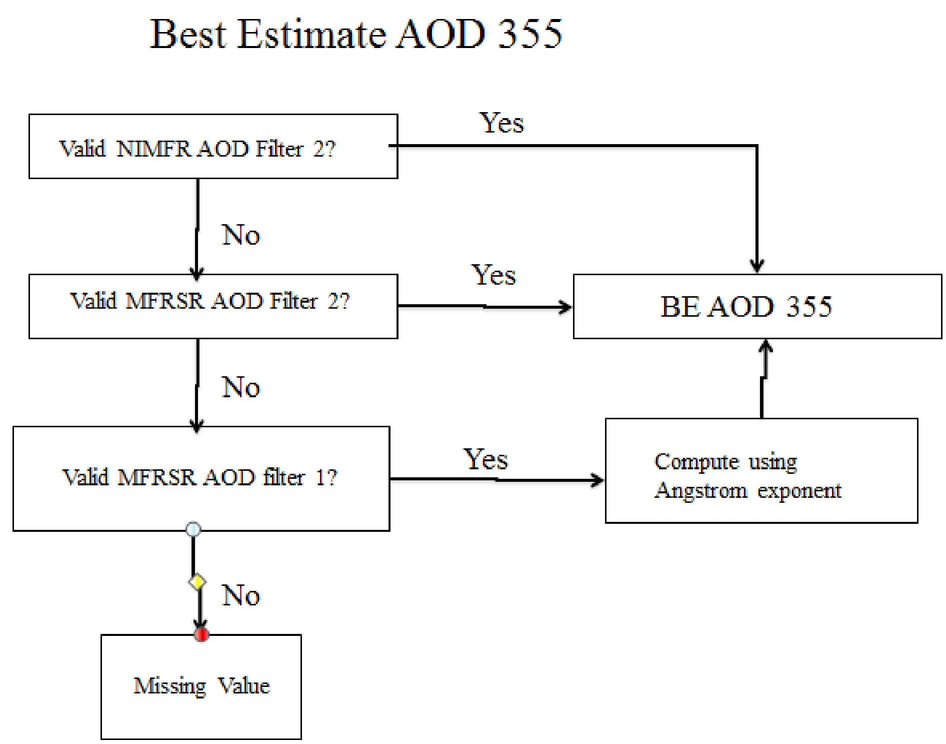

Figure 2. Flowchart describing the process of calculating the best-estimate aerosol optical depth at 355 nm.

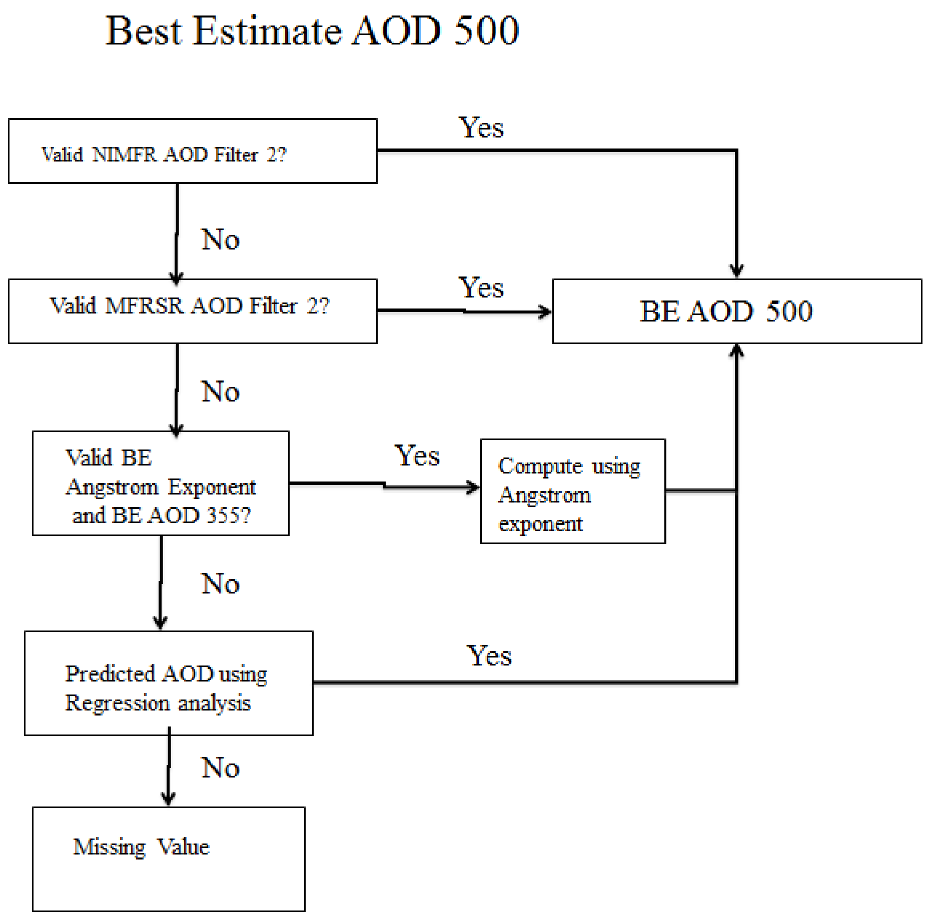

Figure 3. Flowchart describing the process of calculating best-estimate aerosol optical depth at 500 nm.

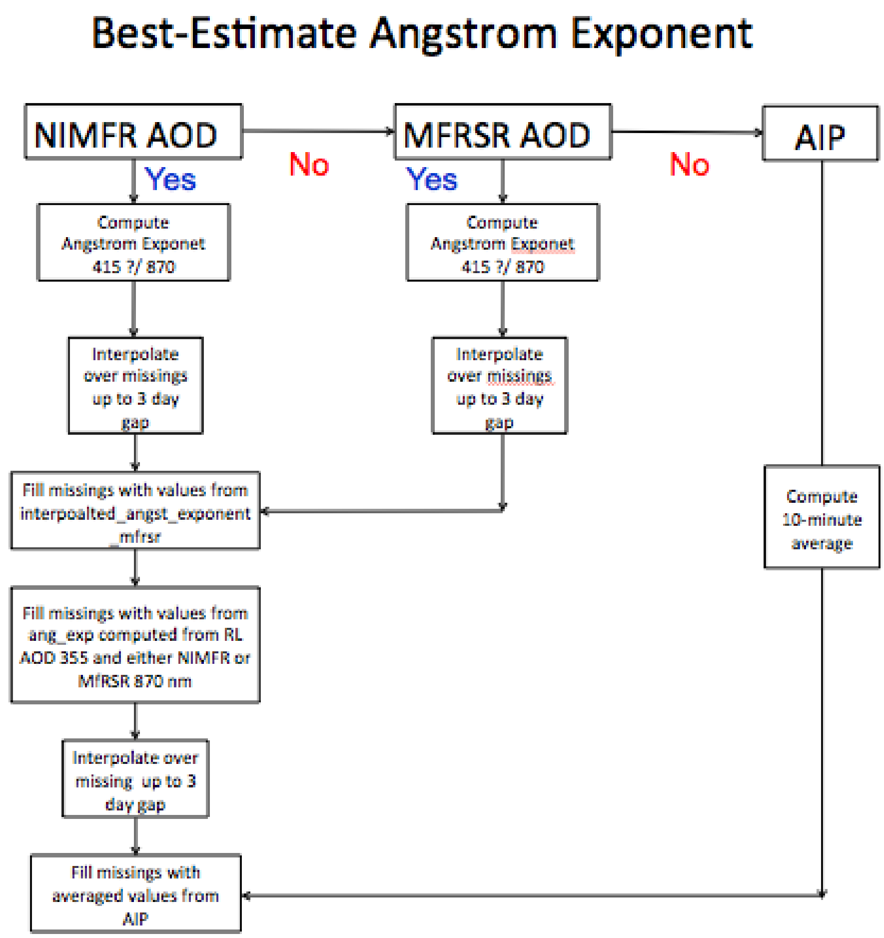

Figure 4. Flowchart describing the process of calculating the best estimate Angström exponent.

3.2 Quicklooks

Quicklook plots of monthly time series are generated for column AOD, vertical profiles up to 4 km of aerosol extinction, SSA, and g, and for the corresponding RH profile. The optical properties are shown for the nominal green wavelength of 500 nm.

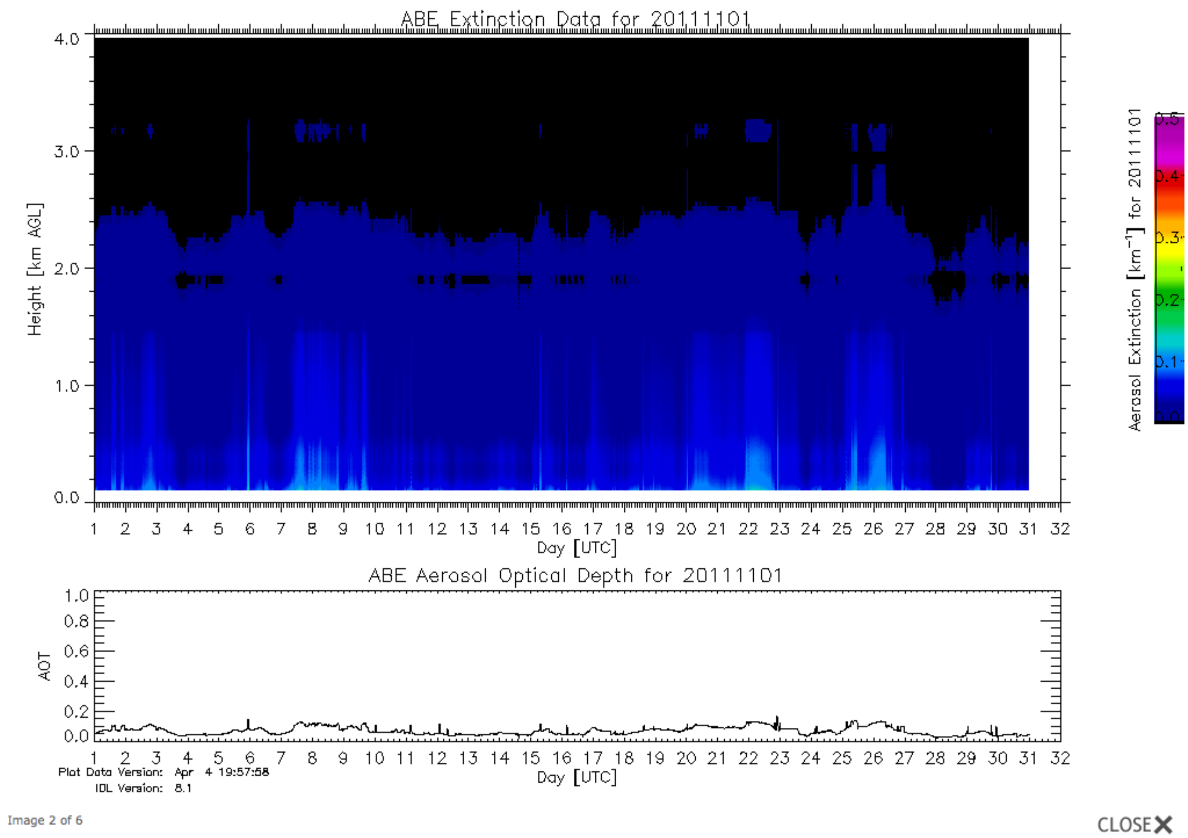

Figure 5. Example quicklook plots of monthly time series for aerosol extinction and aerosol optical depth.

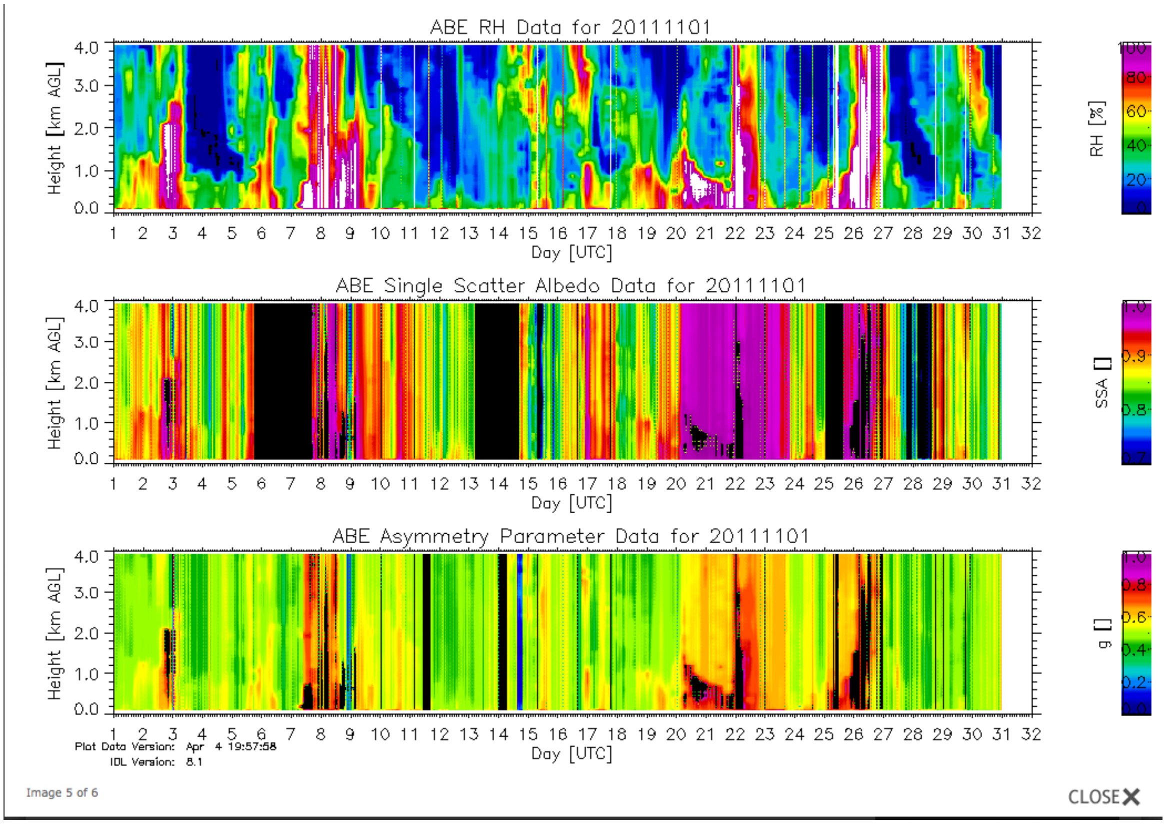

Figure 6. Example quicklook plots of monthly time series for RH profile, SSA, and asymmetry parameter.

3.3 Quality Control Flags

Each datastream goes through a series of quality checks. The quality checks performed for the input datastream are explained below:

1. The nimfraod1mich and mfrsraod1mich datastreams are checked for anomalies by performing the following tolerance test, which establishes a rolling window of 90 samples before and after the sample of interest is established.
   a. Calculate the mean and standard deviation of the samples in the window.
      i. If the standard deviation of the window is greater than .05 and the difference between the absolute value of the sample of interest and the mean value of the window is greater than .05, then the sample of interest is flagged as bad data and replaced with missing value of -9999.0. But after running through a series of data and analyzing the data on October 2004, the test was changed to the following:
      ii. If the standard deviation of the window is greater than .05, the sample of interest is flagged as bad data and replaced with missing value of -9999.0.
   b. The rolling window is then moved up by one sample.
2. Once the data have passed the tolerance test, the nimfraod1imch or mfrsraod1mich data stream is screened for clouds. If the Angström exponent is less than the cloudy threshold of 0.5 or greater than 4.0, then the aerosol optical depths for all the filters are replaced with missing values of -9999.0.

3. The dry Angström exponent from the aip1ogren is screened for bad data as well. If the dry Angström exponent for total scattering, back scattering, and absorption coefficients is not within a range of 0 and 3, then these values are replaced with missing values of -9999.0.
4. The mergesonde1mace profile is discarded if it does not reach a minimum height of 7 km. The relative humidity from SONDE data is set to a minimum value of 50% if the humidity is less than zero.
5. The relative humidity from MET data is set to 99% if the humidity value is above 99.0.
6. The two-parameter fit provided in the aipfitrh1ogren data stream is used to compute *f(RH)* and thus “rehumidify” the scattering coefficients to ambient conditions. This function has the form $f(RH) = a(1\text{-}RH)^{-b}$, where RH is given as a fraction between 0 and 1and *a* and *b* are in the netCDF file as parameters 1 and 2 respectively. The fields for red, blue, and green total and back scatter coefficients from the aipfrh datastream (i.e., parameters 1 and 2) are also checked for quality. The maximum RH range for red, blue, and green is checked to make sure that it is greater than 70%, and the minimum RH range for red, blue, and green is checked to make sure that it is less than 50%. Then, the red, blue, and green total scattering parameters *a* and *b* are checked to make sure that they fall within the range of 0.2 and 1.4, respectively. If the parameters are out of range, they are set to -9999. Finally, the fit parameters are checked to ensure that they are within certain limits, and if not, they are set to prescribed values. See Table 1 below.

Table 1. The wavelengths and the associated parameters.

Wavelength	Parameter 1 (a)	Parameter 2 (b)
Green	0.8043	0.4436
Blue	0.8345	0.3920
Red	0.7619	0.4878

Interpolation

This VAP uses linear regression to interpolate data when data are missing for a certain period of time. The period of time for which the data are interpolated varies by data quantity. The table below gives the gap within which data are interpolated if the values are missing. If any gap is greater than the interval shown, then the values are not interpolated.

Table 2. Gap within which data are interpolated if values are missing.

Field	Interval
Best estimate Angström exponent	3 days
Best estimate aerosol optical depth at 355nm	3 hours
Best estimate aerosol optical depth at 500nm before using regression analysis	3 hours
Best estimate aerosol optical depth at 500nm after using regression analysis	8 hours
All dry coefficients from aip1ogren	3 hours
f(RH) correction coefficients	3 days
All humidified total scattering and back scatter coefficients across time and height	3 hours
Angström exponent using humidified Red and Blue total scattering coefficient	3 days
Single scatter albedo	3 hours
Asymmetry factor	3 hours

4.0 Output Data

sgpaerosolbe1turnFF.c1.YYYYMMDD.hhmmss where:

- aerosolbe = VAP class
- 1turn = identifies that this is Turner's version 1 of aerosol best estimate
- FF = facility (e.g., C1)
- YYYYMMDD = year, month, and day
- hhmmss = hour, minute, second

Currently, AEROSOLBE is executed only for the SGP Central Facility.

5.0 Analysis

Data from 2000 were processed with AEROSOLBE as part of the ongoing BBHRP effort (Mlawer et al. 2004). A time-height cross section of aerosol extinction for March 2000 is provided in Figure 7. Figure 8 is a plot of the mean extinction profiles as drawn from the RL climatology as a function of season and AOD. The extinction profile for this VAP is picked from the climatology based on the AOD, bin, and season. Figure 9 shows the hygroscopic growth function f(RH) for the red, green, and blue total scattering (top) and backscattering (bottom) coefficients from the AOS, using the median parameters from Feb 2000–Feb 2001 in the two-parameter correction equation. An example of the vertical profiles of RH, ω_0, and g for the month of August 2000 derived by AEROSOLBE is shown in Figure 10. The monthly distributions of observed minus predicted AOD as observed by the v1.0 effective height and v1.1 regression fit for 2000 are illustrated in Figure 11.

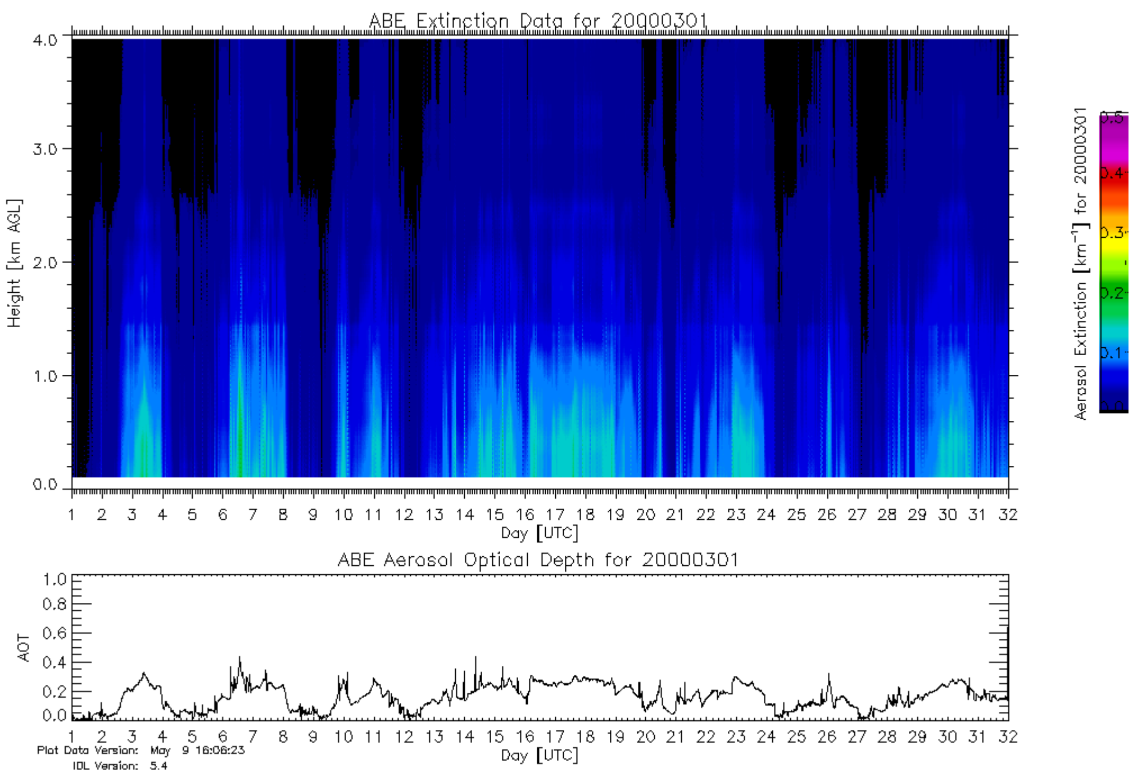

Figure 7. Time-height cross section of the aerosol extinction, together with the AOD, for March 2000 derived by AEROSOLBE.

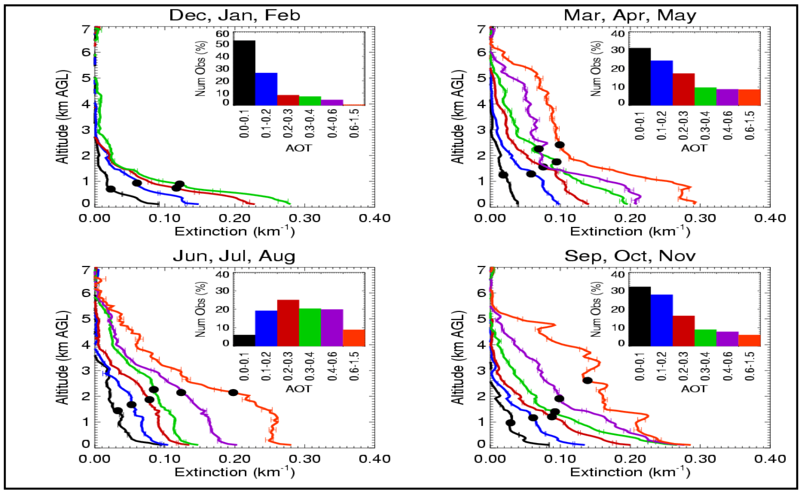

Figure 8. Mean aerosol extinction profiles as a function of season and AOD as observed by the RL in 1999–2000 (Turner et al. 2001).

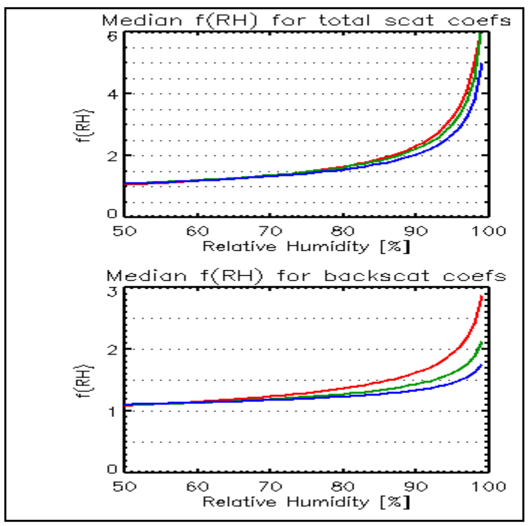

Figure 9. f(RH) corrections for the red, green, and blue total scattering (top) and backscattering (bottom) coefficients from the AOS, using the median parameters from February 2000 to February 2001 in the two-parameter correction equation.

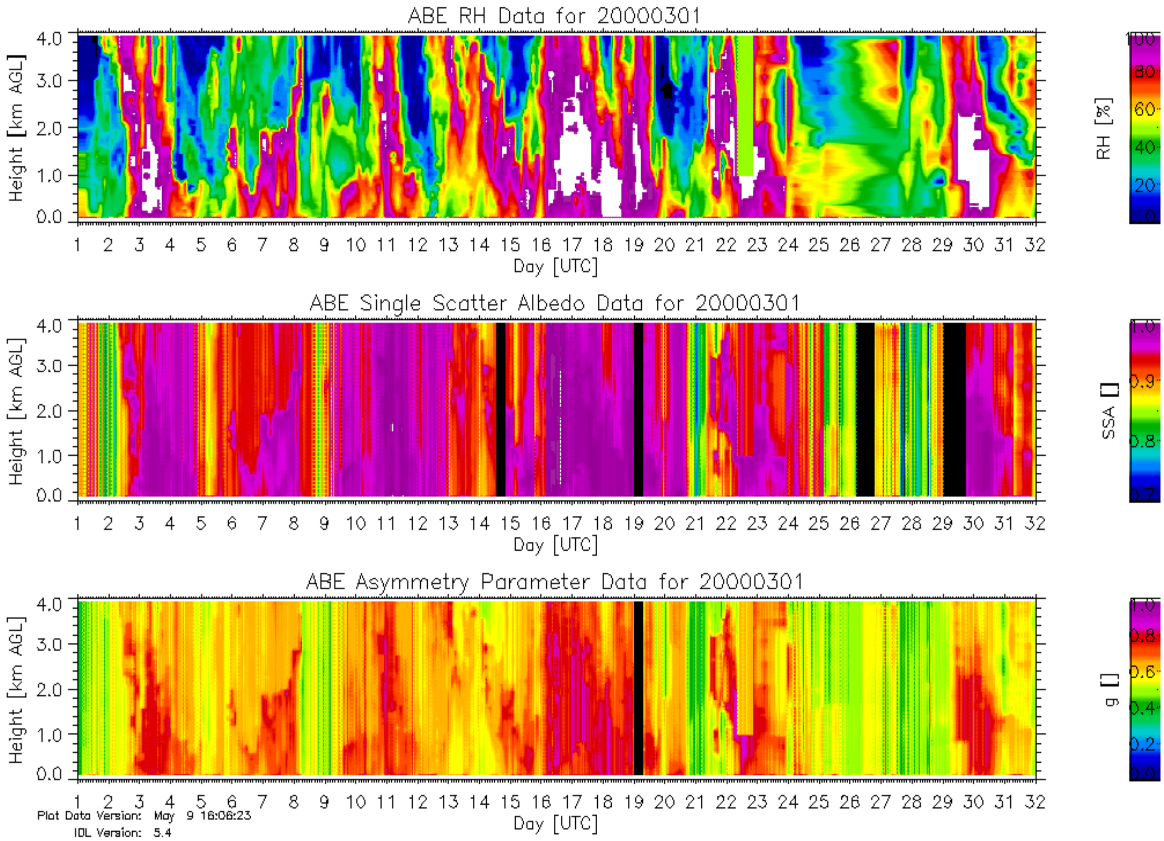

Figure 10. An example of the vertical profiles of RH, ω_0, and g for the month of March 2000 derived by AEROSOLBE.

Table 3. Quarterly Boundary layer height threshold based on Figure 11.

Month	Boundary-layer height
December/January/February	1.0
March/April/May	1.7
June/July/August	2.0
September/October/November	1.5

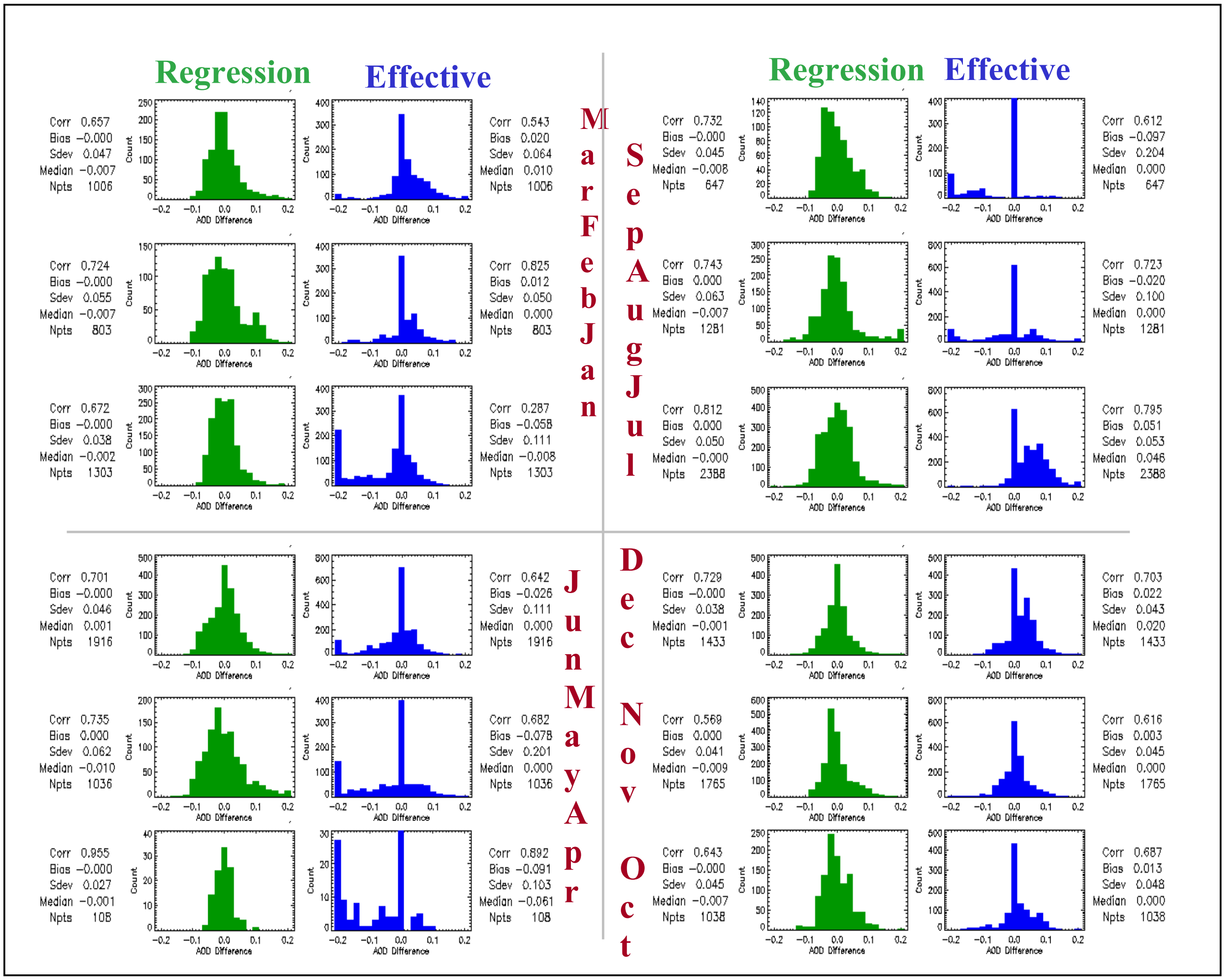

Figure 11. Monthly distributions of observed minus predicted AOD as observed by the v1.0 effective height and v1.1 regression fit for 2000.

6.0 References

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Appendix A

Table 4. Input Platform and the associated fields.

Input Datastreams	Key Input Fields
nimfraod1mich, mfrsraod1mich	aerosol_optical_depth_filter1 qc_aerosol_optical_depth_filter1 aerosol_optical_depth_filter2 qc_aerosol_optical_depth_filter2 aerosol_optical_depth_filter3 qc_aerosol_optical_depth_filter3 aerosol_optical_depth_filter4 qc_aerosol_optical_depth_filter4 aerosol_optical_depth_filter5 qc_aerosol_optical_depth_filter5 angstrom_exponent qc_angstrom_exponent
aip1ogren	Bs_angstrom_exponent_BR_Dry_1um Bs_G_Dry_1um_Neph3W_1 Bbs_G_Dry_1um_Neph3W_1 Bs_B_Dry_1um_Neph3W_1 Bbs_B_Dry_1um_Neph3W_1 Bs_R_Dry_1um_Neph3W_1 Bbs_R_Dry_1um_Neph3W_1 Ba_G_Dry_1um_PSAP1W_1 Ba_G_Dry_1um_PSAP3W_1 Ba_R_Dry_1um_PSAP3W_1 Ba_B_Dry_1um_PSAP3W_1 bsf_R_Dry_1um bsf_G_Dry_1um bsf_B_Dry_1um RH_NephVol_Dry
Aipfitrh1ogren	fRH_Bs_G_1um_2p fRH_Bs_B_1um_2p fRH_Bs_R_1um_2p fRH_Bbs_G_1um_2p fRH_Bbs_B_1um_2p fRH_Bbs_R_1um_2p H_NephVol_Wet_max RH_NephVol_Wet_min
mergesonde1mace	rh_scaled height
met(or smos)	Rh_mean

Appendix B

Table 5. Output variables for the monthly files.

Output Fields	Long Name	Units
be_aod_500	best estimate aerosol optical depth at 500 nm	unitless
be_aod_355	best estimate aerosol optical depth at 355 nm	unitless
be_angst_exp	best estimate Angström exponent	unitless
height	height above ground level	km
extinction_profile	aerosol extinction profile at 500 nm	1/km
single_scattering_albedo_red	aerosol single scattering albedo profile at 700 nm	unitless
single_scattering_albedo_green	aerosol single scattering albedo profile at 500 nm	unitless
single_scattering_albedo_blue	aerosol single scattering albedo profile at 450 nm	unitless
asymmetry_parameter_red	aerosol asymmetry parameter profile at 700 nm	unitless
asymmetry_parameter_green	aerosol asymmetry parameter profile at 550 nm	unitless
asymmetry_parameter_blue	aerosol asymmetry parameter profile at 450 nm	unitless
scat_coeff_red	aerosol total scatter coefficient at 700 nm for 1 μm size cut	1/km
scat_coeff_green	aerosol total scatter coefficient at 550 nm for 1 μm size cut	1/km
scat_coeff_blue	aerosol total scatter coefficient at 450 nm for 1 μm size cut	1/km
backscatter_red	aerosol back scatter coefficient at 700 nm for 1 μm size cut	1/km
backscatter_green	aerosol back scatter coefficient at 550 nm for 1 μm size cut	1/km
backscatter_blue	aerosol back scatter coefficient at 450 nm for 1 μm size cut	1/km
absorp_coef_mean_red	aerosol absorption coefficient at 700 nm for 1 μm size cut	1/km
absorp_coef_mean_green	aerosol absorption coefficient at 550 nm for 1 μm size cut	1/km
absorp_coef_mean_blue	aerosol absorption coefficient at 450 nm for 1 μm size cut	1/km

Table 5 (contd.)

Output Fields	Long Name	Units
rh	relative humidity profile	%
mean_aod_nimfr_filter1	mean aerosol optical depth at 415 nm	unitless
sdev_aod_nimfr_filter1	standard deviation of aerosol optical depth at 415 nm	unitless
mean_aod_nimfr_filter2	mean aerosol optical depth at 500 nm	unitless
sdev_aod_nimfr_filter2	standard deviation of aerosol optical depth at 500 nm	unitless
mean_aod_nimfr_filter3	mean aerosol optical depth at 615 nm	unitless
sdev_aod_nimfr_filter3	standard deviation of aerosol optical depth at 615 nm	unitless
mean_aod_nimfr_filter4	mean aerosol optical depth at 673 nm	unitless
sdev_aod_nimfr_filter4	standard deviation of aerosol optical depth at 673 nm	unitless
mean_aod_nimfr_filter5	mean aerosol optical depth at 870 nm	unitless
sdev_aod_nimfr_filter5	standard deviation of aerosol optical depth at 870 nm	unitless
mean_angst_exponent_nimfr	mean Angström exponent from NIMFR observations	unitless
interpolated_angst_exponent_nimfr	Interpolated Angström exponent from NIMFR observations	unitless
mean_aod_mfrsr_filter1	mean aerosol optical depth at 415 nm	unitless
sdev_aod_mfrsr_filter1	standard deviation of aerosol optical depth at 415 nm	unitless
mean_aod_mfrsr_filter2	mean aerosol optical depth at 500 nm	unitless
sdev_aod_mfrsr_filter2	standard deviation of aerosol optical depth at 500 nm	unitless
mean_aod_mfrsr_filter3	mean aerosol optical depth at 615 nm	unitless
sdev_aod_mfrsr_filter3	standard deviation of aerosol optical depth at 615 nm	unitless
mean_aod_mfrsr_filter4	mean aerosol optical depth at 673 nm	unitless

Table 5 (contd.)

Output Fields	Long Name	Units
sdev_aod_mfrsr_filter4	standard deviation of aerosol optical depth at 673 nm	unitless
mean_aod_mfrsr_filter5	mean aerosol optical depth at 870 nm	unitless
sdev_aod_mfrsr_filter5	standard deviation of aerosol optical depth at 870 nm	unitless
mean_angst_exponent_mfrsr	mean Angström exponent from MFRSR observations	unitless
interpolated_angst_exponent_mfrsr	interpolated Angström exponent from MFRSR observations	unitless
mean_aod_rl	mean aerosol optical depth from Raman lidar at 355 nm	unitless
height_rl	height above ground level from Raman Lidar	km
rh_rl	Relative humidity profile from Raman Lidar	%
angst_exponent_rl	Angström exponent derived from Raman lidar and MFRSR at 870 nm observations	unitless
angst_exponent_mfrsr_filter2	Angström exponent derived from MFRSR at 450 nm observations	unitless
angst_exponent_mfrsr_filter2	Angström exponent derived from MFRSR at 450 nm observations	unitless
angst_exponent_rl_filled	filled Angström exponent derived from Raman lidar and MFRSR at 870 nm observations	unitless
angstrom_exponent_AOS	Angström exponent computed from humidified submicron total scattering coefficients at 450 nm and 700 nm for 1 μm size cut	unitless
GrnTscat_humidified	humidified total scatter coefficient at 500 nm for 1 μm size cut	1/km
GrnBscat_humidified	humidified backscatter coefficient at 500 nm for 1 μm size cut	1/km
BluTscat_humidified	humidified total scatter coefficient at 450 nm for 1 μm size cut	1/km
BluBscat_humidified	humidified backscatter coefficient at 450 nm for 1 μm size cut	1/km
RedTscat_humidified	humidified total scatter coefficient at 700 nm for 1 μm size cut	1/km

Table 5 (contd.)

Output Fields	Long Name	Units
RedBscat_humidified	humidified backscatter coefficient at 700 nm for 1 µm size cut	1/km
rh_mean_surf_boundary	Mean of relative humidity from sonde from surface to boundary level	unitless
predicted_aod	Predicted Aerosol Optical Depth using linear regression	unitless
boundary_layer	boundary layer mixing height	km
rh_mwrp	Relative humidity profile from microwave radiometer profiler	%
mean_aod_aos	Mean aerosol optical depth derived from extinction profile at NSA	unitless
extinction_profile_scaled	Scaled Aerosol extinction profile at 500 nm	1/km
extinction_profile_aos	Aerosol extinction profile at 500 nm	1/km
extinction_profile_clim	Aerosol extinction profile at 500 nm or Climatological Aerosol extinction profile at 500 nm	1/km
rh_sonde	Relative humidity profile from sonde	%
solar_zenith_angle	Solar zenith angle	degree
fRH_Bs_R_1um_2p	Coefficients for 2 parameter fit of Bs_R_1um hygroscopic growth as a function of RH	unitless
fRH_Bs_G_1um_2p	Coefficients for 2 parameter fit of Bs_G_1um hygroscopic growth as a function of RH	unitless
fRH_Bs_B_1um_2p	Coefficients for 2 parameter fit of Bs_B_1um hygroscopic growth as a function of RH	unitless
fRH_Bbs_R_1um_2p	Coefficients for 2 parameter fit of Bbs_R_1um hygroscopic growth as a function of RH	unitless
fRH_Bbs_G_1um_2p	Coefficients for 2 parameter fit of Bbs_G_1um hygroscopic growth as a function of RH	unitless
fRH_Bbs_B_1um_2p	Coefficients for 2 parameter fit of Bbs_B_1um hygroscopic growth as a function of RH	unitless
RH_NephVol_Dry	Relative humidity inside dry nephelometer	%

Table 5 (contd.)

Output Fields	**Long Name**	**Units**
ratio_Bs_R_1um	Computed ratio of Bs_R_1um at rh% and RH_NephVol_Dry	unitless
ratio_Bs_G_1um	Computed ratio of Bs_G_1um at rh% and RH_NephVol_Dry	unitless
ratio_Bs_B_1um	Computed ratio of Bs_B_1um at rh% and RH_NephVol_Dry	unitless
ratio_Bbs_R_1um	Computed ratio of Bbs_R_1um at rh% and RH_NephVol_Dry	unitless
ratio_Bbs_G_1um	Computed ratio of Bbs_G_1um at rh% and RH_NephVol_Dry	unitless
ratio_Bbs_B_1um	Computed ratio of Bbs_B_1um at rh% and RH_NephVol_Dry	unitless
aod_source_flag	flag indicating source of best-estimate AOD at 500 nm	unitless
rh_source	flags describing source of RH	unitless

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