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# The ARM Aerosol Optical Properties (AOP) Value-Added Product

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November 2020

ARM
CLIMATE RESEARCH FACILITY

## DISCLAIMER

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# Acronyms and Abbreviations

| | |
|---|---|
| AAE | absorption angstrom exponent |
| AEP | aerosol extensive properties |
| AP | asymmetry parameter |
| ARM | Atmospheric Radiation Measurement |
| AOP | aerosol optical property |
| AOS | aerosol observing system |
| ASI | Ascension Island |
| BF | backscatter fraction |
| BNL | Brookhaven National Laboratory |
| CAPS | cavity-attenuated phase shift extinction monitor |
| CLAP | continuous light absorption photometer |
| DMF | Data Management Facility |
| DOD | Data Object Design |
| DOE | U.S. Department of Energy |
| ENA | Eastern North Atlantic |
| MAO | Manacapuru, Amazonas, Brazil |
| MAR | Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean |
| NetCDF | Network Common Data Form |
| NOAA | National Oceanic and Atmospheric Administration |
| NSA | North Slope of Alaska |
| OLI | Oliktok Point |
| PCM | Process Configuration Manager |
| PI | principal investigator |
| PNNL | Pacific Northwest National Laboratory |
| PSAP | particle soot absorption photometer |
| RGB | red-green-blue |
| RH | relative humidity |
| QC | quality check |
| SAE | scattering angstrom exponent |
| SAF | submicron absorbing fraction |
| SGP | Southern Great Plains |
| SSA | single-scattering albedo ($\omega_0$) |
| SSF | submicron scattering fraction |
| STP | standard temperature and pressure |
| TAP | tricolor absorption photometer |
| VAP | value-added product |

# Contents



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# 1.0 General Description

Aerosols, tiny liquid and solid particles suspended in air, are involved in several critical processes in the atmosphere. They affect the thermodynamic profile of the atmosphere directly through scattering and absorption of radiation, and indirectly by modulating cloud formation and life cycle. The U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) user facility has deployed aerosol observing systems (AOS) containing numerous instruments to measure in situ aerosol optical properties and related parameters at multiple sites worldwide. For measurement of aerosol light absorption, the AOS includes filter-based instruments (particle soot absorption photometer [PSAP], continuous light absorption photometer [CLAP], and tricolor absorption photometer [TAP]) that infer in situ aerosol absorption coefficients at nominal red, green, and blue wavelength bands from the attenuation of light passing through a particulate filter on which aerosols are deposited. The filter-based measurement technique is a very sensitive approach but also has inherent measurement artifacts that are comparable in magnitude or even larger than the actual absorption signal. Quantitative correction for these effects is critical and is a matter of active research.

The central purpose of the Aerosol Optical Properties (AOP) value-added product (VAP) is to apply published corrections to the filter-based absorption measurements from the PSAP and CLAP to yield aerosol absorption coefficients permitting comparison and assessment of these corrections, and also to provide additional derived aerosol properties including angstrom exponents for scattering and absorption, hemispheric backscattering fraction, asymmetry parameter, and single-scattering albedo. Currently, two full-correction algorithms are implemented, Bond/Ogren (originally Bond 1999, extended by Ogren 2010) and Virkkula 2010. This document describes the data flow and processing of the AOP VAP, the corrections applied to the filter-based measurements, and the related derived products.

In addition, this document describes the subsequent generation of hourly-averaged quantities and size-resolved properties inferred from the automated alternating impactor operation by the “aoppsapavg” and “aopclapavg” AOP-1hr processes.

# 2.0 The Algorithm, Data, and Methodology

The “raw” absorption coefficients reported by the PSAP and CLAP (Equation 1) need to be corrected for amplification effects, for shadowing or filter-loading effects, and for scattering. Two independent published corrections, Bond1999/Ogren2010 in Equation 2 (hereafter Bond correction) and Virkkula 2010 in Equation 3 (hereafter Virkkula correction) have been implemented in the AOP VAP for community use and to permit comparison and assessment of these two corrections.

Each of the corrections applied in AOP are summarized in Virkkula 2010. Raw “uncorrected” absorption coefficients $\sigma_o$ computed from Beer’s Law (Equation 1) require the area A on the filter over which aerosol is deposited, the aerosol sample flow rate Q, and the light intensity $I_t$ transmitted through the particulate filter over some duration $\Delta t$ during which the absorption is measured.

$$\sigma_0 = \frac{A}{Q\Delta t} \ln\left(\frac{I_{t-\Delta t}}{I_t}\right) \quad (1)$$

These raw absorption coefficients are corrected by Bond/Ogren (Equation 2), which requires either the raw instrument intensities or the normalized filter transmittance Tr and the aerosol scattering coefficient to account for apparent absorption from aerosol scattering.

$$\begin{aligned}\sigma_{\mathrm{AP,O2009}} &= \frac{1}{1.22}\left(\frac{0.97\cdot 0.873}{1.0796\cdot Tr+0.71}\sigma_0 - 0.02\cdot\sigma_{\mathrm{SP}}\right)\\ &= \frac{1}{1.5557\cdot \mathrm{Tr}+1.0227}\sigma_0 - 0.0164\cdot\sigma_{\mathrm{SP}}\\ &= \frac{1}{2.58}\times\frac{1}{.6Tr+.4}\sigma_0 - 0.0164\sigma_{sp}\end{aligned} \tag{2}$$

The Virkkula correction also includes the effects of single-scattering albedo (SSA or $\omega_0$) of particles embedded in the filter. Virkkula presents an iterative correction in Equation 3 where $\sigma_0$ is the raw absorption coefficient, $\sigma_{SP}$ is the corrected total scattering coefficients, Tr is the filter transmittance, $\omega_0$ is the single-scattering albedo, and $k_0$, $k_1$, $h_0$, $h_1$, and s are the wavelength-averaged values of these parameters as provided in the last column of Table 1 Virkkula 2010. The SSA $\omega_0$ is iteratively retrieved in the course of applying the correction.

$$\sigma_{\mathrm{AP}} = (\mathrm{k_0} + \mathrm{k_1}\ (\mathrm{h_0} + \mathrm{h_1}\omega_0)\ \ln(\mathrm{Tr}))\sigma_0 - \mathrm{s}\sigma_{\mathrm{SP}} \tag{3}$$

Finally, having no explicit preference for either of these independent corrections, the arithmetic average of both is computed. So, three different sets of corrected absorption coefficients are produced from the raw absorption coefficients: Bond-corrected values, Virkkula-corrected values, and the combination as the arithmetic mean of the two. The "combined" absorption coefficients along with scattering properties converted to match the wavelengths of the absorption measurements are used to calculate the following aerosol intensive properties: single-scattering albedo (SSA or ω0), absorbing angstrom exponent (AAE), scattering angstrom exponent (SAE), the hemispheric backscatter fraction bsf, and asymmetry parameter (AP or g), as defined in Equations 4-8 below:

$$SSA = \frac{\sigma_{scat}}{\sigma_{scat}+\sigma_{absp}} \tag{4}$$

$$AAE_{12} = \frac{\log[\sigma_{ap}(\lambda_2)]-\log[\sigma_{ap}(\lambda_1)]}{\log(\lambda_1)-\log(\lambda_2)} \tag{5}$$

$$SAE_{12} = \frac{\log[\sigma_{sp}(\lambda_2)]-\log[\sigma_{sp}(\lambda_1)]}{\log(\lambda_1)-\log(\lambda_2)} \tag{6}$$

$$BAE_{12} = \frac{\log[\sigma_{bsp}(\lambda_2)]-\log[\sigma_{bsp}(\lambda_1)]}{\log(\lambda_1)-\log(\lambda_2)} \tag{7}$$

$$bsf = \frac{back\ scattering}{total\ scattering} \quad (8)$$

$$g = 0.9893 - 3.9636\ bsf + 7.4644\ bsf^{2} - 7.1439\ bsf^{3} \quad (9)$$

$$\sigma_{scat\lambda 2} = \sigma_{scat,\lambda 1} \times \left({}^{\lambda 1}/_{\lambda 2}\right)^{SAE_{12}} \quad (10)$$

$$\sigma_{bscat\lambda 2} = \sigma_{bscat,\lambda 1} \times \left({}^{\lambda 1}/_{\lambda 2}\right)^{BAE_{12}} \quad (11)$$

Here $\lambda_1$ and $\lambda_2$ can be any wavelength from red, blue, or green bands. In other words, we report angstrom exponents for all possible wavelength pairs—that is, from blue-green, blue-red, and green-red. The asymmetry parameter in Equation 3 is based on Andrews et al. (2006). Each of these properties is reported at nominal red, green, and blue wavelengths, but the exact wavelengths differ from instrument to instrument. For consistency, the total and back hemispheric scattering coefficients reported by the nephelometers are adjusted from their original nominal wavelengths to wavelengths matching the absorption measurements using angstrom exponents via Equation 10 for total scattering and Equation 11 for the back hemispheric scattering. Each of the properties described above are computed as 1-minute averages computed over the 60 seconds from the start of one minute (inclusive) to the start of the next (exclusive).

A follow-on process (aoppsapavg, aopclapavg) produces daily files of hourly averages. All 1-minute values not flagged as "bad" at the 1-minute level and occurring in a given hour are segregated according to the impactor position (which alternates throughout each hour between 1 micron and 10 micron upper cut-off positions) to generate hourly-averaged, size-resolved properties to which more stringent quality checks (qc) are applied. These quality checks vary by field and property but are explicitly recorded in the "qc" fields in the datastreams ending in ".c1".

## 2.1 Input Datastreams and Fields

Depending upon whether the absorption measurements are from the PSAP or CLAP (and soon TAP), the AOP VAP requires aospsap3w1m.b1 or aosclap1m.b1 (or aostap1m.b1) datastreams as inputs and also scattering measurements from aosnephdry1m.b1 datastreams. For historical reasons, the Bond/Ogren correction uses scattering coefficients that, while corrected to conditions of standard temperature and pressure (STP; 0 °C, 1013.25 hPa), do not include size-dependent corrections for truncation effects associated with forward scattering. The Virkkula correction in contrast uses fully corrected aerosol scattering coefficients. In either case, the scattering properties as reported by the nephelometer at nominal red, green, and blue wavelengths are adjusted to match the specific wavelengths of the corresponding absorption measurement as noted in the preceding section. The AOP VAP generates aopclap1flynn1m.c1 or aoppsap1flynn1m.c1 output datastreams containing 60-second (1-minute) averages.

### 2.1.1 Light Absorption Inputs

The preliminary absorption coefficients and related parameters are taken from aospsap3w1m.b1 and/or aosclap3w1m.b1 data products. The values provided by the "b1" products are not those reported directly from the instrument. Instead, as described in Springston and Sedlacek (2007), a 60-second sliding window is applied to full-precision transmittances computed from the raw hexadecimal data packets from

the PSAP, and also to the calibrated PSAP sample flow rate (listed below). The raw absorption coefficients (Ba_B_raw, Ba_G_raw, Ba_R_raw) are computed as per Equation 1 from these smoothed transmittances, smoothed calibrated flow rates, and accurate spot size area.

The absorption coefficients are measured in nominal red-green-blue (RGB) bands corresponding to about 650 nm, 530 nm, and 465 nm wavelengths. The specific wavelengths vary slightly from instrument to instrument and from PSAP to CLAP. The actual measurement wavelengths are reported uniquely for each instrument and channel in the "wavelength" attribute in the data file. The field names and long names of critical input fields are listed below:

Ba_B_raw: Uncorrected aerosol light absorption coefficient, blue channel at dry or reference RH,
Ba_G_raw: Uncorrected aerosol light absorption coefficient, green channel at dry or reference RH,
Ba_R_raw: Uncorrected aerosol light absorption coefficient, red channel at dry or reference RH,
Ba_B_Weiss: Aerosol light absorption coefficient, blue channel at dry or reference RH,
Ba_G_Weiss: Aerosol light absorption coefficient, green channel at dry or reference RH,
Ba_R_Weiss: Aerosol light absorption coefficient, red channel at dry or reference RH,
transmittance_blue: Transmittance, blue channel,
transmittance_green: Transmittance, green channel,
transmittance_red: Transmittance, red channel,

### 2.1.2 Light-Scattering Inputs

Total light-scattering and back-scattering coefficients at blue (450 nm), green (550 nm), and red (700 nm) wavelengths from aosnephdry1m.b1 and aospsap3w1m.b1 are taken as inputs for the AOP product. In the resulting AOP datastream, the field names from the input datastreams are renamed as:

Bs_B_Dry_Neph3W_uncorrected: (Uncorrected aerosol total light-scattering coefficient, nominal blue wavelength at dry or reference RH)
Bs_G_Dry_Neph3W_uncorrected: (Uncorrected aerosol total light-scattering coefficient, nominal green wavelength at dry or reference RH)
Bs_B_Dry_Neph3W_uncorrected: (Uncorrected aerosol total light-scattering coefficient, nominal blue wavelength at dry or reference RH)
Bs_R_Dry_Neph3W_uncorrected: (Uncorrected aerosol total light-scattering coefficient, nominal red wavelength at dry or reference RH)
Bbs_B_Dry_Neph3W: Aerosol back-hemispheric light-scattering coefficient, nominal blue wavelength at dry or reference RH
Bbs_G_Dry_Neph3W: Aerosol back-hemispheric light-scattering coefficient, nominal Green wavelength at dry or reference RH
Bbs_R_Dry_Neph3W: Aerosol back-hemispheric light-scattering coefficient, nominal Red wavelength at dry or reference RH
Bs_B: Aerosol total light-scattering coefficient, truncation corrected, nominal blue wavelength adjusted to measured absorption wavelength
Bs_G: Aerosol total light-scattering coefficient, truncation corrected, nominal green wavelength adjusted to measured absorption wavelength
Bs_R: Aerosol total light-scattering coefficient, truncation corrected, nominal red wavelength adjusted to measured absorption wavelength
Bbs_B: Aerosol back-hemispheric light-scattering coefficient, truncation corrected, nominal blue wavelength adjusted to measured absorption wavelength

Bbs_G: Aerosol back-hemispheric light-scattering coefficient, truncation corrected, nominal Green wavelength adjusted to measured absorption wavelength
Bbs_R: Aerosol back-hemispheric light-scattering coefficient, truncation corrected, nominal Red wavelength adjusted to measured absorption wavelength

These renamed fields are then used to compute related angstrom exponent, hemispheric backscatter fractions, and asymmetry parameter fields as per Equations 6, 7, and 8.

AE_Bs_BG_uncorrected: Angstrom exponent computed from blue/green total scattering without truncation correction
AE_Bs_BR_uncorrected: (Angstrom exponent computed from blue/red total scattering without truncation correction)
AE_Bs_GR_uncorrected: (Angstrom exponent computed from green/red total scattering without truncation correction)
AE_BG: Angstrom exponent computed from blue/green total scattering with truncation correction
AE_BR: Angstrom exponent computed from blue/red total scattering with truncation correction
AE_GR: Angstrom exponent computed from green/red total scattering with truncation correction
AE_Bbs_BG: Angstrom exponent computed from blue/green hemispheric back-scattering with truncation correction
AE_Bbs_BR: Angstrom exponent computed from blue/red hemispheric back-scattering with truncation correction
AE_Bbs_GR: Angstrom exponent computed from green/red hemispheric back-scattering with truncation correction
bsf_B_1um: Backscattering fraction, 1 micron impactor, truncation corrected, nominal blue wavelength adjusted to measured absorption wavelength
bsf_G_1um: Backscattering fraction, 1 micron impactor, truncation corrected, nominal green wavelength adjusted to measured absorption wavelength
bsf_R_1um: Backscattering fraction, 1 micron impactor, truncation corrected, nominal Red wavelength adjusted to measured absorption wavelength
g_B: Asymmetry parameter, truncation corrected, nominal blue wavelength adjusted to measured absorption wavelength
g_G: Asymmetry parameter, truncation corrected, nominal green wavelength adjusted to measured absorption wavelength
g_R: Asymmetry parameter, truncation corrected, nominal red wavelength adjusted to measured absorption wavelength

P_Neph_Dry: Pressure inside reference nephelometer
T_Neph_Dry: Temperature inside reference nephelometer

As noted previously, the final optical properties produced by this value-added product are reported at wavelengths matched to the absorption instruments, but the initial scattering input fields are at nephelometer measurement wavelengths as reported in the “wavelength” attribute. In addition, to distinguish the input fields and output fields, the tag “Neph3W” is added to field names of optical fields reported at the original nephelometer wavelengths. This tag is dropped when the quantity is converted to the absorption wavelength. For example, the field “Bs_B_uncorrected” represents the input field “Bs_B_Dry_Neph3W_uncorrected” after converting to the corresponding absorption wavelength using Equation 9.

### 2.1.3 Weiss/Bond/Ogren Absorption Corrections

The first step of the Bond/Ogren correction is to apply the Weiss filter-loading correction. The raw absorption coefficients Ba_{BGR}_raw are multiplied by the factor *f_w = 1/1.22 * ((0.97*0.873)/(1.0796 Tr + 0.71)) = 1 / (1.5557Tr + 1.0227)* from Equation 2 where *Tr* is the filter transmittance at the given wavelength. This single processing step essentially incorporates the original vendor-provided PSAP transfer function with results of Bond 1999, Sheridan 2005, and Ogren 2010 as summarized in Virkkula 2010.

The Weiss correction (described above) is essentially a *partial* correction since it neglects scattering effects. The Bond correction also includes a term K1 to subtract the effects of scattering from the original green wavelength PSAP that appears in Equation 2 as the factor 0.02, but was developed with a single-wavelength (green) PSAP and includes an implicit conversion from the PSAP green wavelength (574 nm) to the nephelometer green wavelength (550 nm). Ogren 2010 removes this implicit wavelength conversion using an assumed angstrom exponent for the nigrosin suspension used in Bond 1999. Thus, application of the Ogren-adjusted corrections yield absorption coefficients at the measured PSAP wavelengths without any wavelength-specific elements or adjustment. The fields *Ba_{R G B}_BondOgren* incorporate the Bond scattering. For PM1 (with *impactor_state* == 1), the proportionality constant "*K1*" is 0.02 or 2% of the uncorrected scattering coefficient as published in Bond 1999. For PM10 (with *impactor_state* == 10), the proportionality becomes a size-dependent factor that depends on the filter wavelength (private communication, Ogren and Jefferson). For blue, *K1_B = 0.00668* for *AE_Bs_BG_uncorrected < 0.2*, *K1_B = 0.02* for *AE_Bs_BG_raw > 0.6*, or *K1_B = 0.0334 * AE_Bs_BG_uncorrected* otherwise. For red and green, the same relative factors are used but *K1_{R G}* is scaled against *AE_Bs_GR_uncorrected* instead.

### 2.1.4 Virkkula Absorption Corrections

The fields *Ba_{R G B}_Virkkula* contain the converged results from iterative application of the five-parameter correction (Virkkula 2010) in Equation 3 in section 2.0 above. Although five parameters are indicated in Virkkula 2010, in fact only four are linearly dependent. For consistency with the literature we have retained the as-published 5-parameter form. The iteratively determined fields *ssa_{R G B}_Virkkula* are physically consistent with the *Bs_{R G B}* and *Ba_{R G B}_Virkkula* pairs. Note that the total scattering with truncation correction is used in determining Virkkula corrections, while the uncorrected total scattering without truncation correction is used in Bond/Ogren corrections.

### 2.1.5 Combined Absorption Product

The Bond-Ogren and Virkkula corrections represent comparable schemes to correct for filter-loading effects and scattering subtractions, and are each referenced against independent measurements. Having no preference for one over the other, we report the arithmetic mean of these two as Ba_{R G B}_combined, and this is used for subsequent derived products described below that involve absorption.

## 2.2 AOP Output

This section describes fields provided in the AOP netcdf datastreams. The netcdf structure may also be examined via the PCM (Process Configuration Manager) at https://pcm.arm.gov/pcm/. This site may be accessed without logging in.

**Contents of 1-minute-averaged data files:**

To see the structure of the 1-minute-averaged files, type "aoppsap1flynn1m" or "aopclap1flynn1m" in the search field (entry box) on the upper left-hand side. Then drill into the datastream name to expose the defined DOD (Data Object Design) icons. Continue drilling down into the desired DOD in the left-hand pane or double-click to open in the right-hand pane. Here Bs, Bbs, and Ba are corrected scattering, hemispheric backscattering, and absorption coefficients at B, G, and R wavelengths. AE is angstrom exponent derived from pairs of scattering or absorption wavelengths (e.g., AE_Bbs_BG, AAE_BG). SSA, bsf, and g are single-scattering albedo, backscatter fraction, and asymmetry parameter. Within parentheses, capital B, G, and R represent nominal blue, green, and red wavelengths, respectively.

impactor_state: reports whether the impactor is in 1 um (PM1) or 10 um (PM10) mode.

Scattering properties
- Bs_(B|G|R), AE_(BG|BR|GR),
- Bbs_(B|G|R), AE_Bbs_(BG|BR|GR)
- bsf_(B|G|R), g_(B|G|R)

Absorption properties
- Ba_(B|G|R)_Virkkula, ssa_(B|G|R)_Virkkula
- Ba_(B|G|R)_BondOgren
- Ba_(B|G|R)_Weiss [subsumed in Bond-Ogren and provided here for completeness only.]
- Ba_(B|G|R)_combined
- AAE_(BG|BR|GR)
- ssa_(B|G|R)

Groupings within parentheses are expanded for each included element. Thus Bs_(B|G|R) represents three distinct fields: Bs_B, Bs_G, and Bs_R, and so on.

**Contents of 1-hourly averaged data files:**

To see the structure of the 1-hour averaged files, type "aoppsap1flynn1h" or "aopclap1flynn1h" in the search field (entry box) on the upper left-hand side. Then drill into the datastream name to expose the defined DOD icons. Continue drilling down into the desired DOD in the left-hand pane or double-click to open in the right-hand pane.

Scattering properties
- Bs_(B|G|R)_(1um|**10um**), AE_(BG|BR|GR)_(1um|**10um**)
- Bbs_(B|G|R) _(1um|**10um**), AE_Bbs_(BG|BR|GR) _(1um|**10um**)
- bsf_(B|G|R) _(1um|**10um**), g_(B|G|R) _(1um|**10um**)
- submicron_scattering_fraction_(B|G|R)
- supermicron_Bs_(B|G|R)

Absorption properties

Ba_( B|G|R)_combined_(1um|**10um**)
AAE_(BG|BR|GR) _(1um|**10um**)
ssa_( B|G|R) _(1um|**10um**)
Ba_( B|G|R)_Virkkula_(1um|**10um**)
Ba_(B|G|R)_BondOgren_(1um|**10um**)
submicron_absorption_fracton_(B|G|R)
supermicron_Ba_(B|G|R)
supermicron_SSA_(B|G|R)
supermicron_AAE_BG|BR|GR)

Groupings within parentheses are expanded for each included element. Thus Bs_(B|G|R)_(1um|**10um**) represents six distinct fields: Bs_ B_1um, Bs_G_1um, and Bs_R_1um, Bs_G_**10um**, Bs_G_**10um**, and Bs_R_**10um**, and so on.

## 2.3 Data Quality Assessment

The AOP datastream assesses automated quality checks (QCs) for each of the primary fields described above and for many auxiliary fields. All the tests pertaining to the quality of a given field are captured in a “qc” field named after the field of interest. Although stored as integers, these “qc” fields are more properly referred to as “bit-mapped” or “bit-packed” fields wherein each individual bit represents the result of a true/false expression designed to test data quality. In this way, a single “qc” field encapsulates the results of numerous tests. ARM convention is that quality tests be articulated such that a “true” or logical “1” value represents a failure condition. Therefore, the qc value for “good” data is 0. In addition, ARM supports quality checks that characterize the data quality as “bad” or alternately as merely “indeterminate” (suspect). The specific quality tests and the implication for data quality are stored in the ARM netcdf files as metadata under each named qc field. The definition for quality test “N” is listed under the metadata attribute “bit_N_description” while the impact on the data quality is reported under “bit_N_assessment”.

For example, the qc field for the quantity “submicron_absorption_fraction_B” is named “qc_submicron_absorption_fraction”. The first qc test defined under the metadata attribute “bit_1_description” is “Value is equal to missing_value” indicating that no valid value was available. The implication for data quality is reported under “bit_1_assessment” as “bad”.

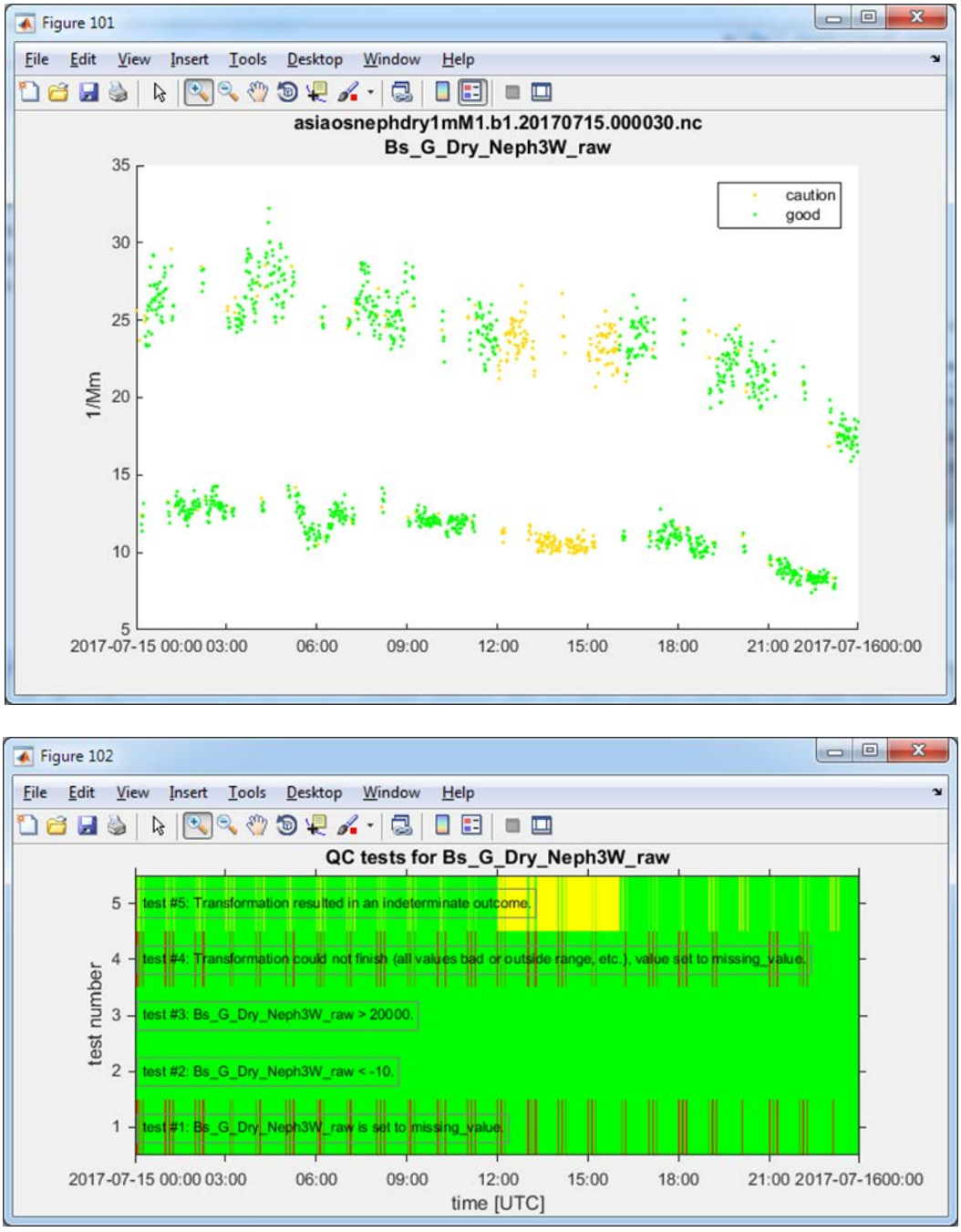


**Figure 1**. Time series of one of the input parameters used to derive the AOP (Bs_G_Dry_Neph3W_raw). The QCs of the field are shown in the lower panel.

## 2.4 Data Plots

Go to http://www.dmf.arm.gov/ql.php → data → click on 'Data' and then select datastream 'asiaoppsap1flynn1mM1.c1' or whichever site/datastream is desired.

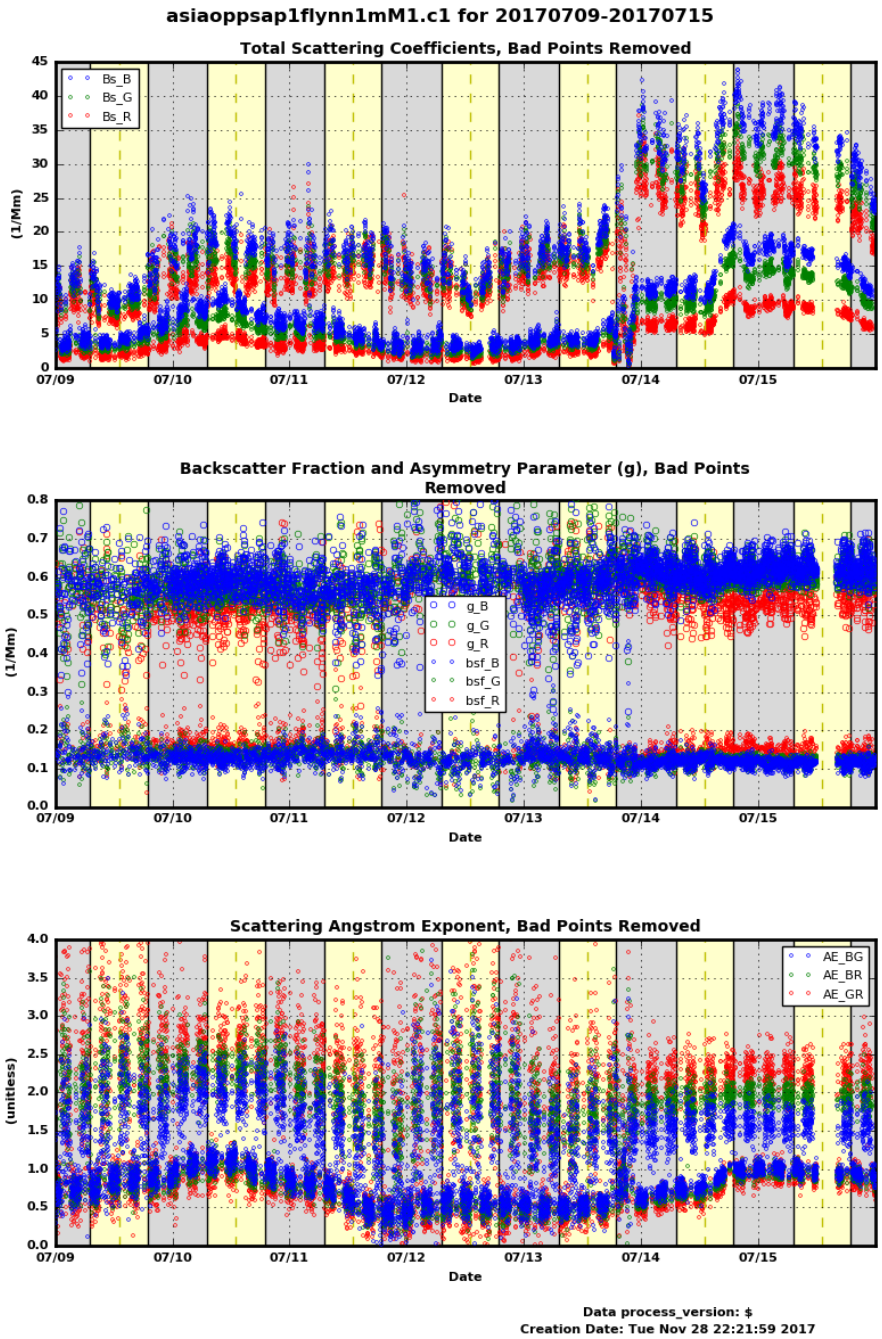


**Figure 2**. Time series of total scattering coefficient (top), backscatter fraction and asymmetry parameter (middle), and scattering angstrom exponent (bottom) for selected days at the ARM Ascension Island (ASI) site.

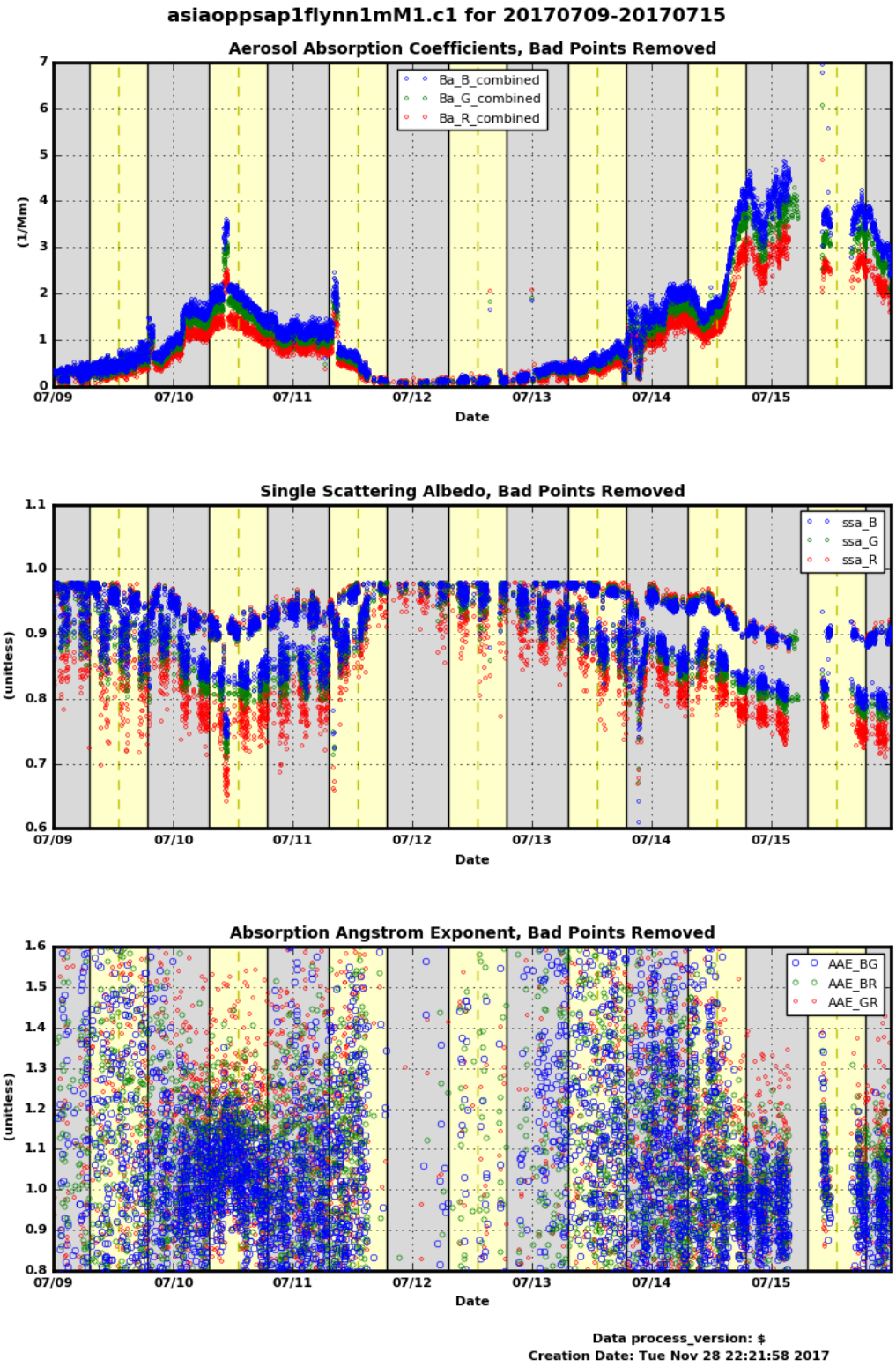


**Figure 3**. Time series of aerosol absorption coefficient (top), single-scattering albedo (middle), and absorption angstrom exponent (bottom) for selected days at the ARM ASI site.

## 2.5 Known Algorithm Caveats

Most of the intensive properties (SSA, AAE, SAE, BSF, g) are computed from ratios of the measured extensive properties. When the aerosol loading in air is low, the signal-to-noise ratio for the extensive measurements can be close to detection limit of the instrument, leading to larger uncertainty in the extensive and intensive properties. Although such conditions are flagged, the user is advised to treat such data with caution. It should be noted that the single-scattering albedo measurement uses absorption data from the PSAP, a filter-based technique. The particles have to be collected on the filter before their measurement. This technique has a good sensitivity range for absorption measurement but may have scattering artifacts from deposits on the surface. Very low absorption coefficients and/or high scattering coefficient lead to higher uncertainty in corrected absorption coefficient and hence to the SSA. For example, the high SSA (SSA>0.98) are a result of highly uncertain absorption coefficient and the data are not shown in the middle panel of Figure 3 as a result of large uncertainty. The asymmetry parameter is parameterized and not strict derivations, so some systematic errors are possible.

# 3.0 AOP Status and Version History

Version 1.2 (vap-aosaop-1.2-0.el6) was the first released operational version of the AOP. It is the latest version.

## 3.1 Time Periods Processed

### 3.1.1 AOP PSAP Datastreams

- SGP E13 (sgpaoppsap1flynn1mE13.c1): Available from November 2016 until March 2018
- OLI M1: aoppsap1flynn1m.c1: Available from August 2016 until March 2018
- ENA C1 to generate aoppsap1flynn1m.c1: Available from October 2013 until January 2018
- MAR M1 to generate aoppsap1flynn1m.c1: Available from June 2017 until January 2018
- ASI M1 to generate aoppsap1flynn1m.c1: Available from May 2016 until October 2017
- MAO S1 (not processed yet)

### 3.1.2 AOP CLAP Datastreams

- SGP C1 (sgpaopclap1flynn1mC1.c1): Available from November 2016 until September 2017
- NSA X1 to generate nsaaopclap1flynn1mC1.c1: Available from October 2015 until October 2017
- MAO M1 (not processed yet)

## 3.2 Data Level/Version Information

The initial production release was in January 2018.

## 3.3 Plans for Future Modifications

We anticipate extending the AOP to process TAP data.

A version using CAPS extinction measurements in place of nephelometer scattering measurements is under evaluation.

A constrained two-stream correction approach has also been published for PSAP and CLAP and may be added to the AOP for assessment.

## 3.4 Expected Reprocessing Efforts

We expect to process data from past, historical, AOS mobile facility deployments, starting with GoAmazon2014/15 (Manacapuru [MAO] M1 and MAO S1 facilities).

## 3.5 AOP-Related Products, Data, and Links

aosnephdry1m.b1, aosnephdry.b1, aospsap3w1m.b1, aospsap3w.b1, aos{psap3w clap tap}1m.b1

## 3.6 Data Tools for ARM netCDF

The Unidata netCDF Home Page (https://www.unidata.ucar.edu/software/netcdf/) is the authoritative source for netcdf. A broad variety of tools (freely available and commercial) is accessible through this website. However, some netcdf tools expect netcdf files having a particular convention.

# 4.0 Frequently Asked Questions

Q: What is an aerosol optical property (AOP)?

A: Property of aerosols related to light absorption or scattering leading to cooling or heating of the atmosphere. The AOPs are key inputs for estimating the aerosol intensive or extensive properties.

Q: How often does the AOP VAP run?

A: The AOP VAP is planned to run daily after receipt of new nephelometer, PSAP, or CLAP data at the ARM Data Center.

Q: How different are the data from CLAP and PSAP?

A: The techniques and nominal wavelengths are the same in both instruments. The only difference is that CLAP is more compact and the filters are not changed as frequently as with PSAP. The principle of working and data outcomes are equivalent.

Q: Is there any difference in AOP outputs if inputs are used from any of the multiple AOS or ARM sites?

A: Irrespective of the AOS number or ARM site location, the output AOP format is the same.

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