Techniques and Methods Used to Determine the Aerosol Best Estimate Value-Added Product at SGP Central Facility

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Objective

Profiles of aerosol optical properties are needed for radiative closure exercises such as the broadband heating rate profile (BBHRP) project (Mlawer et al. 2002) and the Shortwave Quality Measurement Experiment (QME). Retrieving cloud microphysical properties using radiation measurements in the shortwave, such as the spectral retrieval technique described in Daniel et al. (2002), also require the optical properties of the aerosols so that they can be accounted for in the retrieval process. The objective of the aerosol best estimate (ABE) value-added procedure (VAP) is to provide profiles of aerosol extinction, single scatter albedo, asymmetry parameter, and wavelength dependence for all times and heights above the central facility at the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site for these applications. Therefore, the ABE must provide estimates of the aerosol optical properties in all conditions (clear, broken clouds, overcast clouds, etc.)

The basic outline for this VAP was developed at the Aerosol Working Group breakout session at the ARM Science Team meeting in March 2000. This paper describes the first version of this VAP, which attempts to use a minimum number of datastreams to provide estimates for these aerosol profiles. Future versions of this VAP will incorporate more “conditional retrievals,” i.e., datasets that provide more accurate aerosol optical properties but are only available during certain conditions.

Algorithm and Methodology (Version 1)

To first order, the most important aerosol optical property for radiative transfer applications is the aerosol optical depth (AOD); therefore, significant effort is made in ABE to get good estimates of AOD. The ABE algorithm currently has three sources of AOD: (1) the multi-filter shadowband radiometer (MFRSR, Harrison and Michalsky 1994), (2) Raman lidar (Goldsmith et al. 1998), and (3) from an “effective height” calculation using both MFRSR and aerosol observing system (AOS, Sheridan et al. 2001) data. The ABE logic assigns each data source a priority (i.e., if MFRSR AOD data are available), they are used in the ABE best-estimate optical depth. However, if the MFRSR data are not available for some reason, the Raman lidar’s AOD is the next option. The AOS effective height (described below) is the third option. Finally, if AOD data is not available from any of the three methods, then linear interpolation in time (up to a maximum of 3 hrs) will be used to fill in the gaps.

The ABE time resolution is set to 10-min, so data from the AOS and MFRSR are averaged to achieve this temporal resolution. However, before these data are averaged, a variety of quality control methods are applied. For example, the AODs retrieved from the MFRSR, using the Barnard/Michalsky AOD VAP, are screened for clouds using both a filter on the Angstrom exponent (points where this exponent is less than 0.5 are assumed to be cloudy) and by comparing the standard deviation of the AOD for a rolling 1-hr window with a threshold (windows that have high standard deviations are assumed to be cloudy). After the suspect data points are removed, the MFRSR data are averaged to ABE's temporal resolution.

The Raman lidar data, as processed by the RLPROF VAPs (Turner et al. 2002), are already at 10-min resolution, but only the Raman lidar samples where the AOD is a vertical integral of the aerosol extinction from the surface to 7 km are utilized in the ABE processing. Note that the AOD from the Raman lidar, which is at 355 nm, is converted to AOD at 500 nm (the reference wavelength in the ABE) using the Angstrom coefficient derived from the Raman lidar and MFRSR when data from both instruments are available; it is assumed that the Angstrom coefficient varies slower in time than the AOD and thus this Angstrom coefficient can be interpolated for up to 3 days to fill in gaps in the data.

When valid MFRSR AOD data are available, the AOD is divided by the total scattering coefficient observed by the AOS to derive an "effective height" of the aerosol layer. The effective height is assumed to also vary slowly with time, so if both MFRSR and Raman lidar AOD data are not available, the interpolated effective height together with the instantaneous total scattering coefficient are used to provide an estimate of the AOD. This method does not currently attempt to account for diurnal changes in the height of the boundary layer.

Data from the SGP during 2000 were processed with ABE as part of the ongoing BBHRP effort (Mlawer et al. 2004). A time-height cross section of aerosol extinction for August 2000 is provided in Figure 1. Figure 2 illustrates the source of the AOD reported in the ABE for the daylight hours as a function of season (ABE also provides the aerosol optical properties at night). The ABE AOD comes primarily from the 1st and 3rd option (MFRSR and AOS effective height calculation); in general, when the MFRSR data are not available the reason is clouds, and thus the Raman lidar data often do not extend up to 7 km during these periods.

After the best-estimate of the AOD at 500 nm is determined, a lookup table is used to determine the appropriate aerosol extinction profile based upon the climatology developed from the 2 years of Raman lidar observations([Turner et al. 2001). This lookup table is organized as a function of season and AOD (Figure 3). Future versions of the ABE will incorporate the aerosol extinction profiles observed by the Raman lidar, as well as from the micropulse lidar (Flynn et al. 2004); using the Raman lidar climatology will only occur if extinction profiles are not available from either lidar.

The ABE 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. First, radiosonde humidity profiles are interpolated to provide estimates of the relative humidity (RH) for all times and heights above the central facility. The dry aerosol scattering and absorption properties for the sub-micron particles are assumed to be constant with altitude. The 2-parameter fit provided as part of the AOS datastream $f(RH) = a(1-u)^{-b}$, where u is the RH interpolated from the

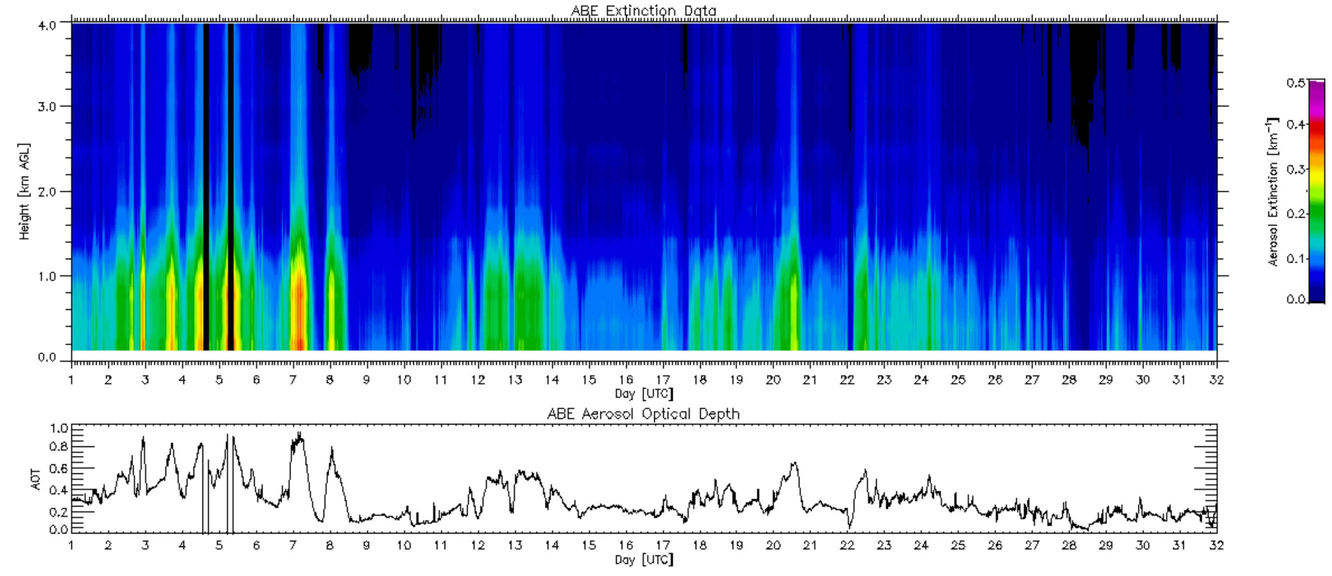

Figure 1. Time-height cross section of the aerosol extinction, together with the AOD, for August 2000 derived by ABE.

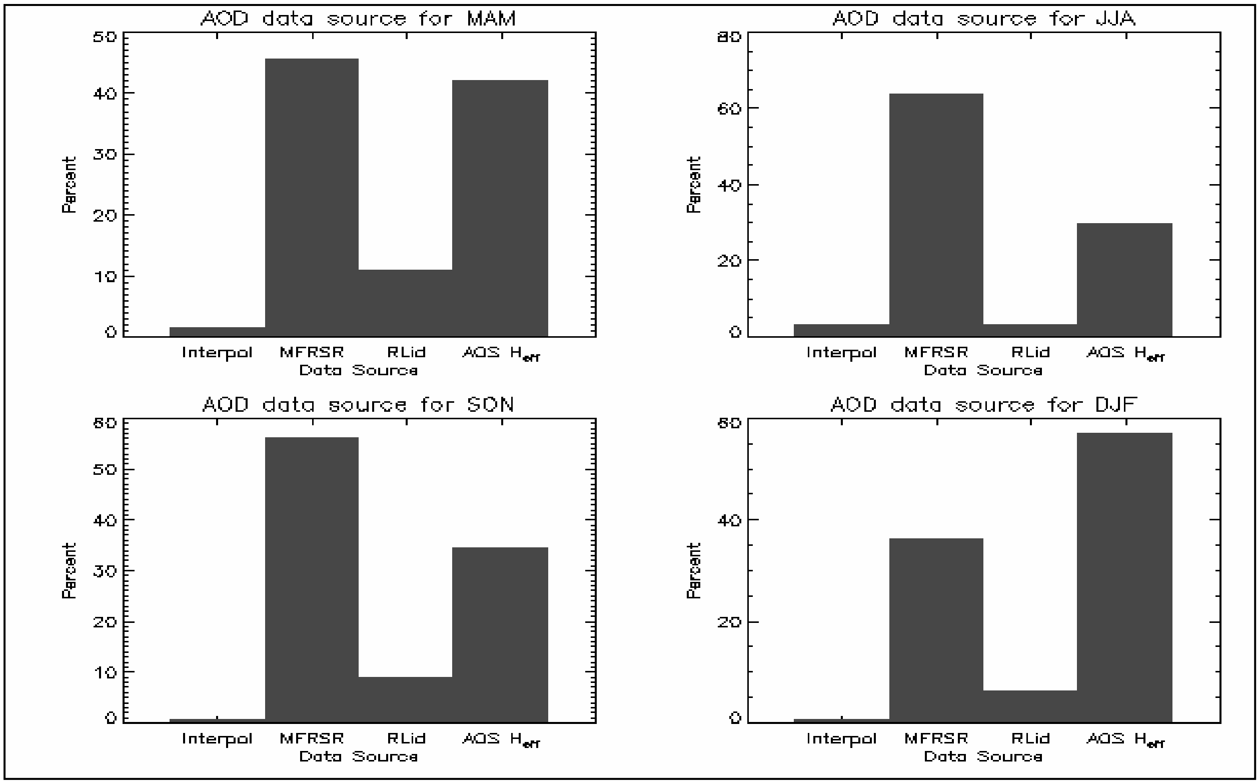

Figure 2. Distribution of the sources of the best-estimate AOD in the ABE for the daylight hours from February 2000 to February 2001.

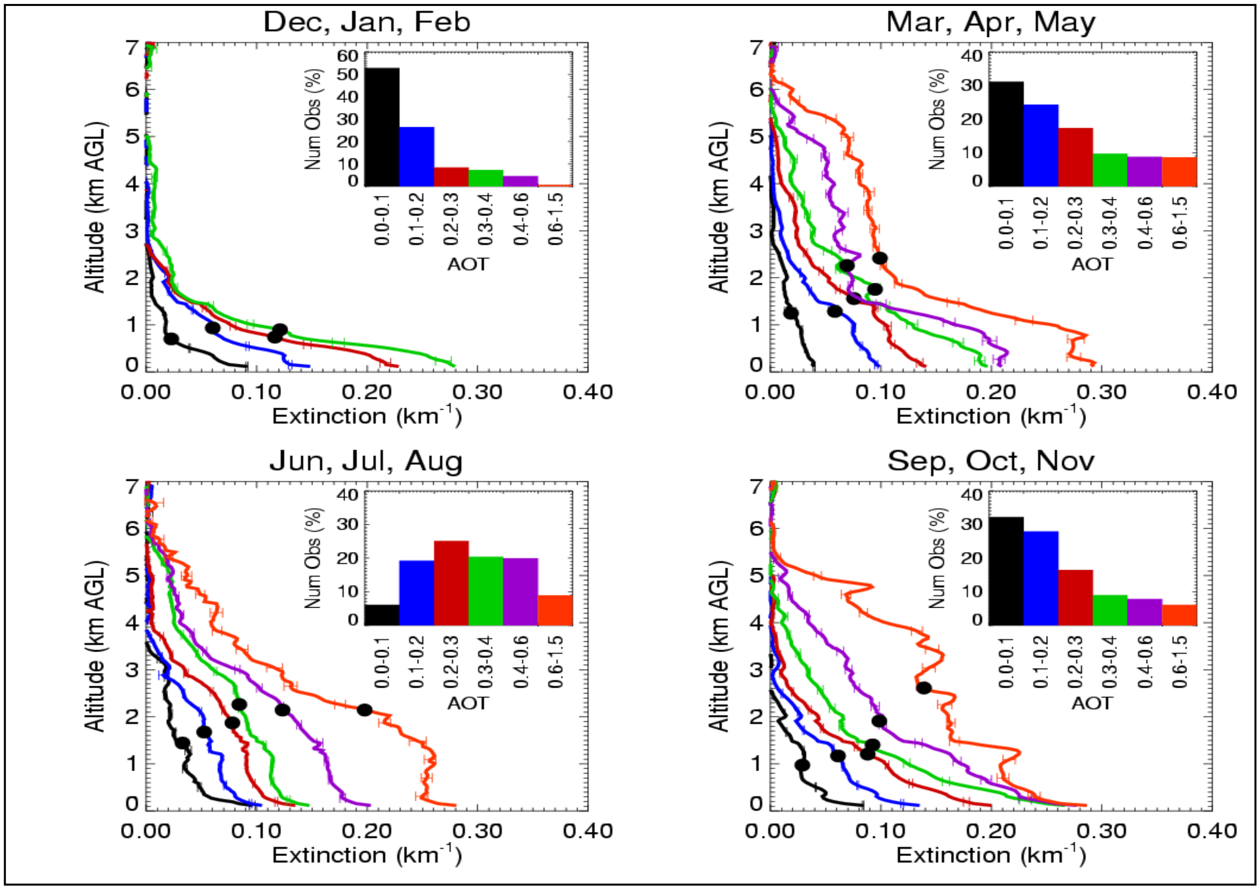

Figure 3. Mean aerosol extinction profiles as a function of season and AOD as observed by the Raman lidar in 1999-2000 (Turner et al. 2001).

radiosonde observation as a fraction is used to rehumidify the dry aerosol scattering properties (Koontz et al. 2003). The correction factors f(RH) for the total and backscattering coefficients at the red, green, and blue wavelengths observed by the AOS using the median correction parameters *a,b* for the year 2000 are shown in Figure 4. Note that no humidity correction is applied to the aerosol absorption coefficient observed by the AOS. The scattering properties at the three wavelengths are used to compute the scattering properties at 500 nm (the reference wavelength for the ABE output), and an inverse wavelength relationship is assumed to convert the aerosol absorption from its observed wavelength (567 nm) to 500 nm.

At this point, the submicron scattering properties have been rehumidified, providing humidified profiles of total scattering coefficient, backscattering coefficient, and aerosol absorption. From these profiles, ω_0 and g are computed (Koontz et al. 2003). A time-series of these profiles, together with the RH observed by the radiosondes, are shown in Figure 5. Note that the vertical variation seen in these profiles is strictly a function of the assumed humidity dependence of the scattering. Future versions of ABE will incorporate aerosol scattering measurements made by the In Situ Aerosol Program (IAP, Andrews et al. 2004).

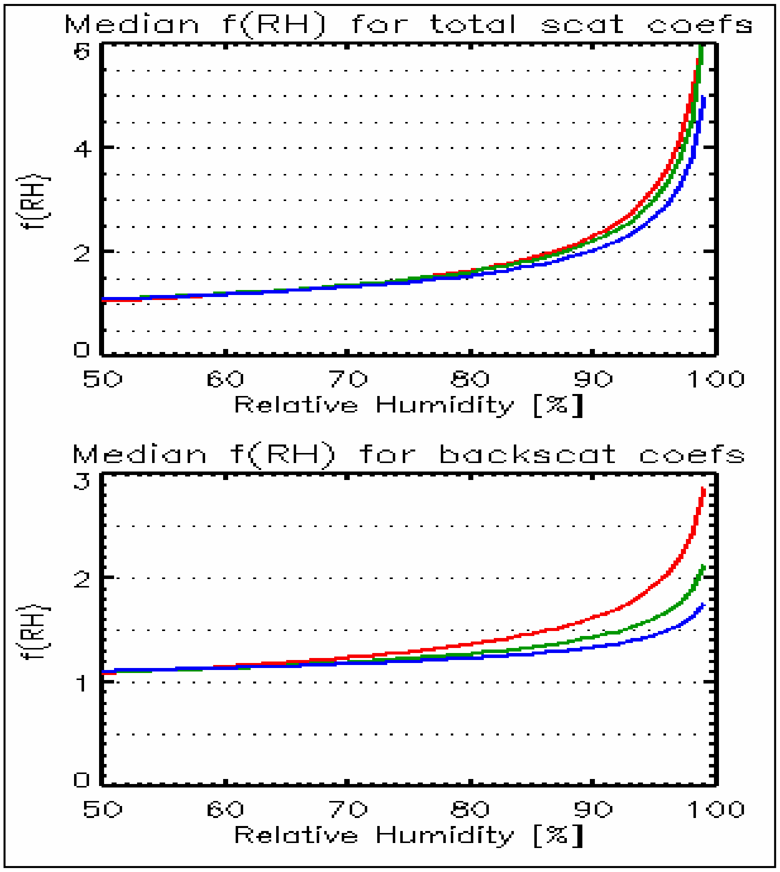

Figure 4. f(RH) corrections for the red, green, and blue total scattering (top) and backscattering (bottom) coefficients from the AOS, using the median parameters from February 2000 to February 2001 in the 2-parameter correction equation.

Summary

The objective of the ABE VAP is to provide profiles of aerosol extinction, single scatter albedo, and asymmetry parameter for all times and heights (up to 7 km) at the ARM SGP site. Version 1 of this algorithm, described here, provides estimates of these fields using a minimum number of datastreams. Figure 6 provides a flow diagram for this VAP. The ABE data have been processed (in a beta mode) from February 2000 to February 2001 and were incorporated into v1.3 of the BBHRP, resulting in much better agreement in observed and computed diffuse shortwave flux for high cloud cases compared to BBHRP v1.2 (Mlawer et al. 2004). Future versions of the VAP will incorporate additional data that may be more conditional in nature. For example, the aerosol extinction profiles derived from the Raman lidar and/or micropulse lidar will be used, when available, to replace the climotologically determined aerosol profiles in this version, and the IAP data will be used to specify the aerosol scattering properties (and hence ω_0 and g) aloft for periods around the aircraft's flight time. Additionally, statistical analysis of aerosol properties (i.e., Payton et al. 2004, Andrews et al. 2004, Sheridan et al. 2001) and boundary layer depth (e.g., Ferrare et al. 2004) will be incorporated to help constrain the VAP's output.

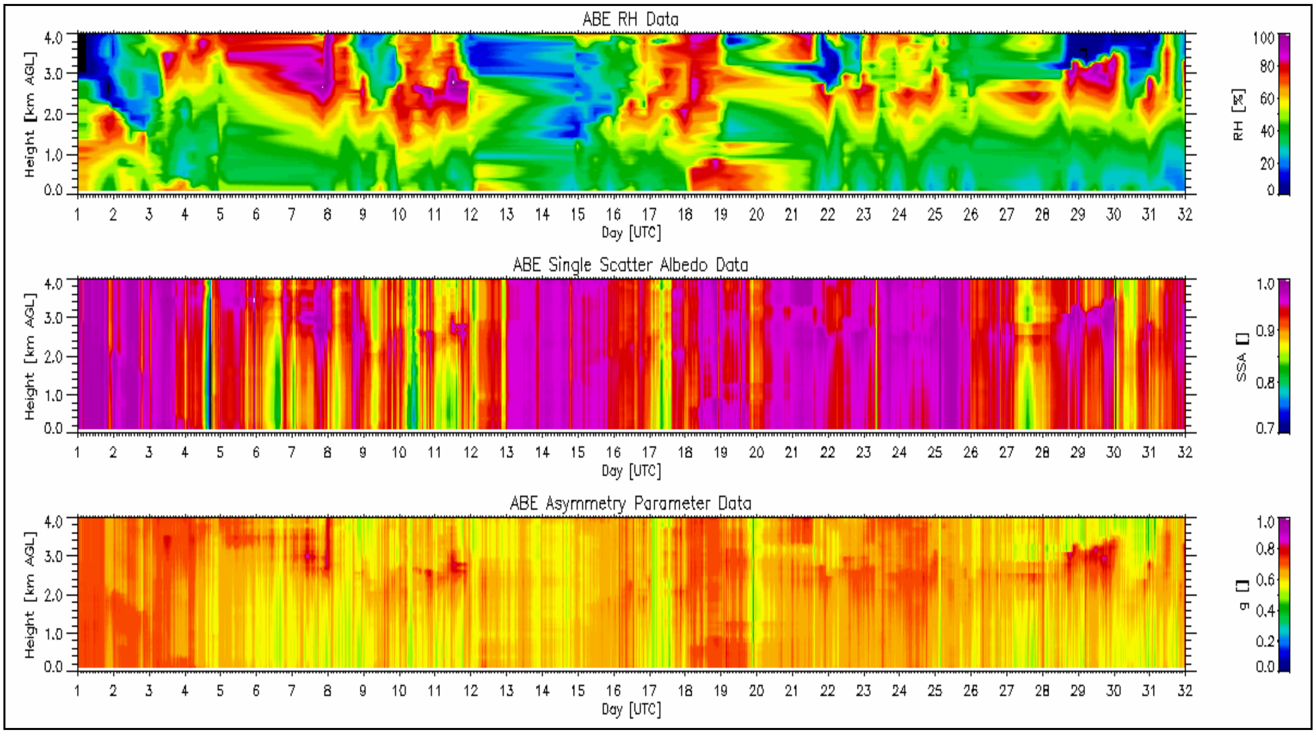

Figure 5. An example of the vertical profiles of RH, ω_0 and g for the month of August 2000 derived by ABE.

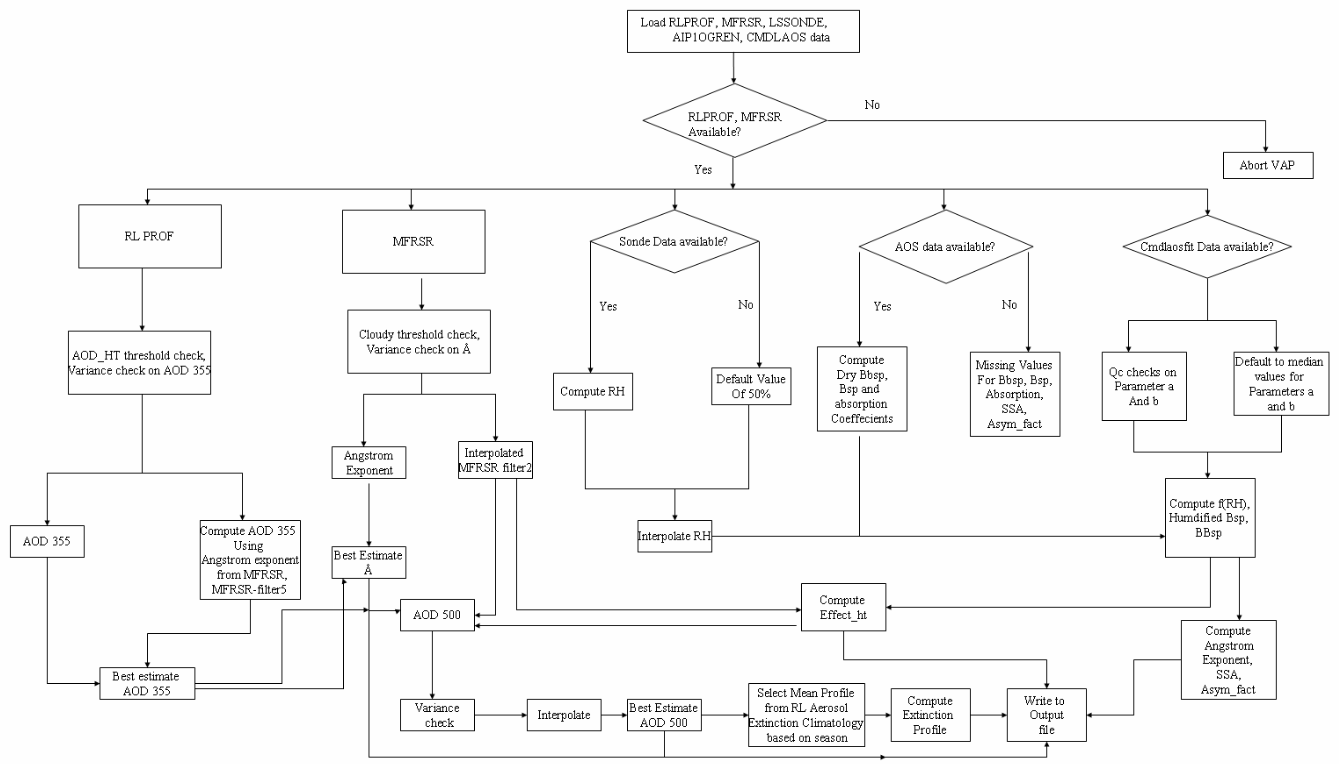

Figure 6. Logic flow diagram for the ABE VAP (Version 1).

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