Aerosol Optical Thickness From The Seawifs And MODIS Sensors Over The Chesapeake Bay

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1.0 INTRDUCTION

As a part of the atmospheric correction effort to retrieve water-leaving radiances in the visible and near IR spectral bands of the SeaWiFS and MODIS sensors, the Ocean Biology Processing Group (OBPG) at the NASA Goddard Space Flight Center also reports the aerosol optical thickness (AOT) for the scene. We have compared the AOT from SeaWiFS and MODIS with AERONET retrievals over the Chesapeake Bay area: SERC (38N, 76W), COVE (36N, 75W) and Wallops Island (37N, 75W), and found that the satellite-retrieved AOT in the near IR bands of SeaWiFS/MODIS sensors are generally higher than the Aerosol Robotic Network (AERONET) retrievals. An example of such a comparison is shown in Figure 1 below.

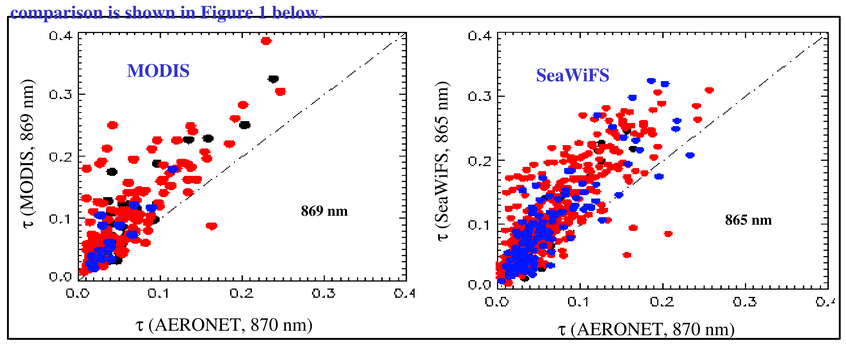


Figure 1a and 1b. Comparison of aerosol optical thickness (AOT) reported by OBPG for MODIS (Figure 1a) and SeaWiFS (Figure 1b), and the AERONET over COVE (red) Wallops Island (blue) and SERC (black). All AERONET data within ± 1 hour of the satellite over pass are included here.

The OBPG operational retrievals are based on a suite of twelve aerosol models that are constructed from Shettle and Fenn's (1979) aerosol models of tropospheric and oceanic aerosols. In this paper we show that the overestimation of AOT is primarily because the operational aerosol models do not represent the Bay area aerosols. We have constructed another suite of aerosol models, and retrieved aerosol optical thickness in the visible and near IR channels of the SeaWiFS sensors, which show significantly improved comparison with the AERONET data. Below, we show some properties of the Bay-area aerosols that were retrieved from the AERONET data, and provide some details of the new aerosol models. We also show some results on the comparison of AOTs from the SeaWiFS sensor with the AERONET using the new aerosol models.

2.0 BAY-AREA AEROSOLS PROPERTIES

We have analyzed AERONET data from the COVE (Oct. 1999 –Dec. 2006) , SERC (Nov. 1994 – June 2006), and Wallops Island (July 1993 – Jan. 2007) sites to determine aerosol characteristics over the Bay-area and found that:

- Aerosols at the three sites have very similar mean geometric radius and variance values, and show similar seasonal behavior (Figs. 2a and 2b). Also, the mean effective radius (area weighted radius), r_{eff}, for the three sites is ~0.30 μm (Fig. 2c)
- Aerosols over the COVE and SERC sites are generally more absorbing and often have low values of single scattering albedo which, ranges from ~ 0.80 to 0.95 (Fig.2d). Also, the mean monthly value of the SSA is almost linear with wavelength at the three sites (Fig. 2e).
- The three sites show similar frequency distribution of SSA and almost half of the time in an year the SSA values are less than 0.95.

These results suggest that the micro-physical and optical properties of the aerosols over the three sites are very similar.

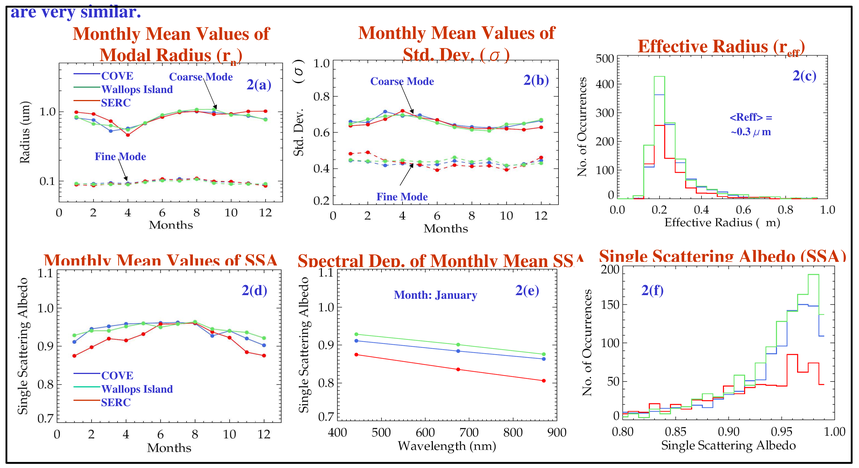


Figure 2(a)-2(f). Aerosol properties over the AERONET sites COVE (blue), SERC (red) and Wallops Island (green). Figs. 2 (a) and 2(b), respectively, show the mean monthly values of modal radius and standard deviation of the fine and coarse modes of the distributions. Fig. 2(c) shows the histogram of effective radius of the aerosols for the three sites. Fig 2(d) shows the monthly mean values of single scattering albedo (SSA), and Fig. 2(e) shows the spectral dependence of SSA. Finally, Fig. 2(f) shows the histogram of SSA for the three sites.

3.0 NEW AEROSOL MODELS

Based on AERONET data, we have constructed a suite of 20 bimodal lognormal aerosol models (Z01-Z20) to represent the Bay area aerosols. Aerosol models: Z01-Z05, Z06-Z10, Z11-Z15, and Z16-Z20 have similar values of aerosol effective radius, r_{eff} which, varies from 0.16 μm to 0.65 μm. Set Z01-Z05 consists of least absorbing aerosols, and set Z16-Z20 consists of most absorbing aerosols. The 412-nm single scattering albedo varies from ~0.995 (set Z01-Z05) to ~0.925 (set Z16-20). In each set, the size distributions are constructed by varying the relative weight of the fine (coarse) mode from zero (one) to one (zero). Details of the fine and coarse mode distributions are summarized in Table1. The effective radii are given in Table 2, and examples of the volume size distribution for models Z02 and Z05 are shown in Figure 3(a). For comparison purposes, the volume size distribution for two of the operational models (HG), C50 and C90, are shown in Figure 3(b). C50 and C90, respectively, refer to coastal aerosol models with relative humidity of 50 and 90 percent.

Table 1. Geometric mean radius (R_n) and geometric standard deviation(σ) of the fine and coarse mode aerosol distributions.

Parameters	Fine Mode	Coarse Mode
Geometric Mean Radius(r_n)	0.09	0.70
Geometric Std. Dev. (σ)	0.45	0.70

Table 2. The effective radii of the new size distributions

SD No.	Model Name	R_{eff} (μm)
1	Z01	0.172
2	Z02	0.260
3	Z03	0.360
4	Z04	0.534
5	Z05	0.679

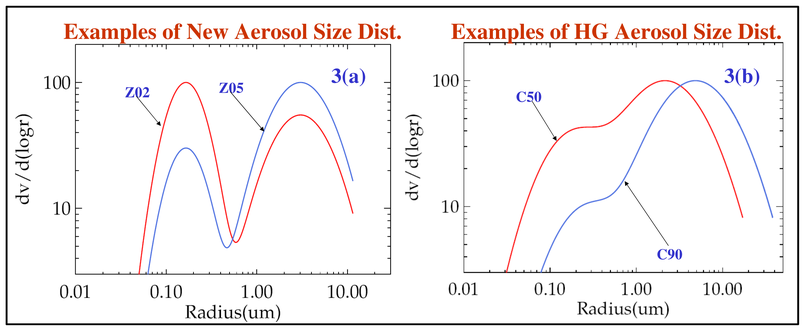


Figure 3(a). Examples of the new size distributions (Z02 and Z05). Both distributions are normalized to a value of 100 at their respective maxima. For comparison purposes, the volume size distribution for two of the operational models, C50 and C90, are shown in Figure 3(b).

Figure 3(b). Example of two (C50, and C90) aerosol size distributions routinely used in the operational processing. C50 and C90 refer to coastal aerosol distributions for relative humidity of 50 and 90 percent, respectively. Here, also, the distributions are normalized to a value of 100 at the respective maxima of the distributions.

4.0 RT SIMULATIONS

We used a modified version of Ahmad-Fraser's (AF, 1982) code to simulate the TOA reflectances. The AF code is a vector code, and properly accounts for the Fresnel reflection from a flat and rough ocean surface as well as all order of scattering and polarization of the diffuse radiation in the atmosphere. Oher details of the simulations are summarized below.

Spectral Bands: MODIS and SeaWiFS Visible Bands

Model Atmosphere: Molecular atmosphere with Aerosols

Aerosols Size Dist: 20 aerosol size distributions (Z01 through Z20)

Aerosol Profile: Elterman's Vertical Profile

Lower Boundary: Flat and Rough Ocean

5.0 SPECTRAL DEPENDENCE

- Although the new aerosol models are derived from AERONET data, it is reassuring that they show correct spectral dependence of SSA. As an example, we show in Fig. 4 the observed spectral dependence of the monthly-average-SSA over COVE site for January and July (green and red lines with the symbols). The solid and dotted lines represent the SSA values for the new aerosol models that bracket the observed data.
- The extinction coefficient of each aerosol distribution shows a unique spectral dependence. Figure 5 shows the spectral dependence of the new aerosol models (Z01-Z05). Here, the extinction coefficient values have been normalized with respect to band 8 (865 nm) of the SeaWiFS sensor. Since the ratio of the extinction coefficients is the same as the ratio of the aerosol optical thickness, Figure 5 provide a unique way of examining the spectral dependence of the optical thickness in the observed AOT data.
- In the operational processing of the SeaWiFS and MODIS data, a parameter called epsilon (ε), is used to select aerosol models for atmospheric correction. Epsilon is defined as the ratio of single scattering reflectance at wavelength λ to single scattering reflectance at λ_o. For the SeaWiFS sensor, λo=865 nm. In Fig. 6(a) we show the spectral dependence of epsilon values for our aerosol models Z01 to Z15. We note that epsilon values are not sensitive to the SSA values of the distributions. Also, epsilon (λ_o) is a well behaved function of effective radius (Fig. 6(b)). We believe that this feature can be used to select the aerosol models and to interpolate the lookup tables

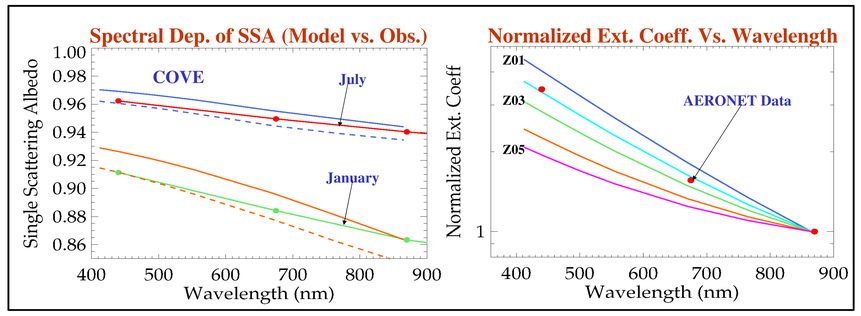


Fig. 4 A comparison of observed and modeled values of SSA over COVE. The green and red lines with symbols, respectively, show the observed values of SSA during the months of January and June. The solid and dotted lines are SSA values for the new aerosol model values that bracket the observed data.

Figure 5. Normalized spectral dependence of the extinction coefficient of the new aerosol models. The solid circles show measurements of the aerosol optical thickness at COVE. The AOTs are normalized with respect to the values at 870 nm.

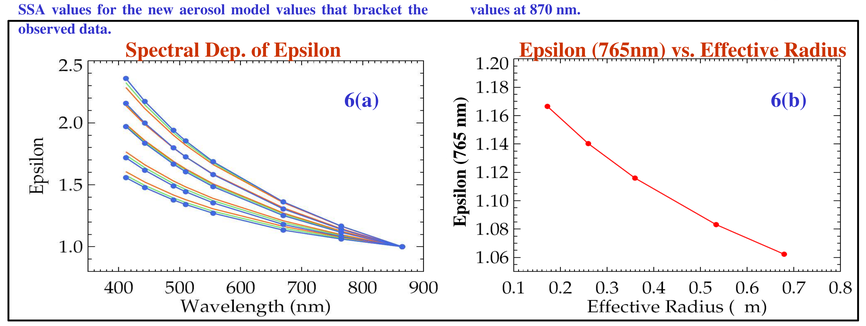
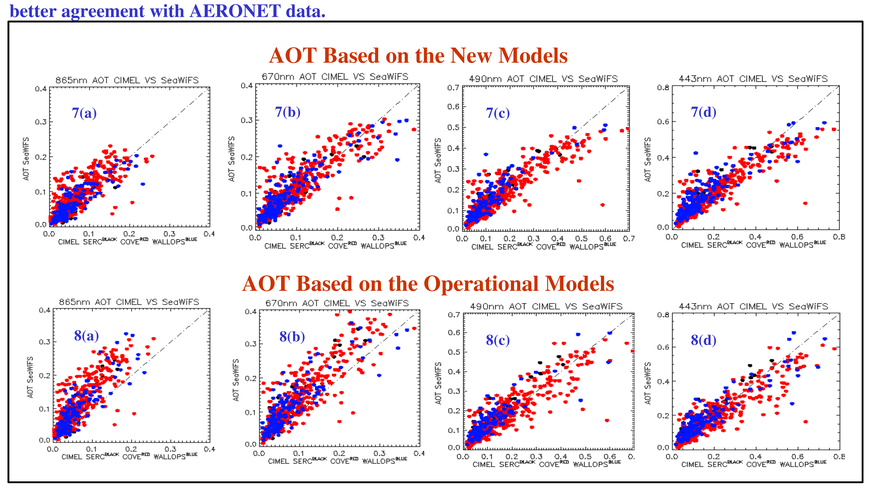


Fig. 6(a) The spectral dependence of epsilon for the new aerosol models Z01 to Z15. It show that the epsilon values are not sensitive to the SSA values of the aerosol distributions

Fig. 6(b) 765-nm epsilon values as functions of effective radii. This relationship can be used to select aerosol models and to interpolate the lookup tables

6.0 AOT USING NEW MODELS

The aerosol optical thickness (AOT) from the new models are shown in Figures 7(a)–7(d) for the four bands (443, 490, 670 and 865 nm) of the SeaWiFS sensor. For comparison purposes, we also show the results from the current operational processing in Figs. 8(a)-8(d). A bio-optical model of Stumpf et al (2003) is used to remove the water-leaving radiance contributions from the near IR bands (765 and 865 nm) of the SeaWiFS sensor. It should be noted that Stumpf et al's correction is a part of the operational processing. We find that, compared to Figure 8a through 8d (operational aerosol models) the results in Figure 7(a) through 7(d) (new aerosol models) show significant improvement in bias, and the retrieved AOTs are in better agreement with AERONET data.



Figs. 7(a)-7(d) SeaWiFS AOTs based on the new aerosol models over COVE (red) Wallops Island (blue) and SERC (black). For comparison purposes, the AOTs based on the current operation are shown in Fig. 8(a)-8(d). A bio-optical model (Stumpf et al., 2003) is used to correct the satellite data for water-leaving radiance in the near IR bands. All AERONET data taken within ± 1 hour of the satellite over pass are included in the analysis.

7.0 CONCLUSIONS

- The new aerosol models are reasonably good representations of the aerosol distributions over the Chesapeake Bay area, however, some fine tuning of the size parameters is needed.
- The water-leaving radiance correction for the near IR bands provide a good first order correction for AOT retrievals over the Chesapeake Bay area.
- The retrieved AOT in the four bands of the SeaWiFS sensor are in fairly good agreement with the AERONET data at COVE, SERC and Wallops Island.