# Estimation of Regional Aerosol Diffuse Ratio & Direct Aerosol Radiative Effects over in the Mid-Atlantic Corridor

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## 1.0 Introduction

A thorough assessment of the direct influences of aerosols on Earth's radiative energy budget is required to better understand climate and estimate how it may change in the future. An approach using 2yrs (Jan. 2005 – Sept. 2006) of surface irradiance and aerosol optical depth ($\tau_a$) data is presented to investigate aerosol effects on the surface radiative energy budget at the Howard University Beltsville Site (HUBS) (39.054$^0$N; 76.877$^0$W). Aerosol radiative effects are assessed through estimation of the direct aerosol effect (difference b/w measured & "aerosol-free" irradiances) and "aerosol diffuse ratio" (ADR), i.e., contribution of diffuse to global SW irradiance due to the attenuation of atmospheric transmission by aerosols.

## 2.0 Instruments and Data

•440 AERONET (NASA GSFC) & 412 nm MFRSR $\tau_a$ (**Figure 1**). Systems show good agreement, indicating spatial homogeneity of $\tau_a$ b/w locations (**Figure 2**).

•Eppley and Kipp & Zonen broadband sensors on a Kipp & Zonen solar tracker: down total, diffuse & direct SW (0.285 to 2.8μm), and LW (3.5-50 μm) (**Figure 1**). Similar set inverted on a nearby 31m flux tower.

## 3.0 Method

### 3.1 SW Flux Analysis (SWFA) Diffuse Limit

The SWFA is used to quality assure data, identify cloudless skies, and for continuous estimates of clear-sky SW irradiance and fractional sky cover[2,3,4]. The SWFA is modified for polluted ($\tau_a \geq 0.1$) and clean ($\tau_a < 0.1$) conditions, to establish a (subjective) diffuse limit representative of climatological clear-sky diffuse SW (**Figure 3**). This limits the amount of haze one chooses not to be considered as clear-sky; higher the set limit, the thicker the acceptable haze[2].

### 3.2 Estimation of the Aerosol Diffuse Ratio

Aerosols exhibit changes in both the diffuse and direct SW; therefore the diffuse ratio (DR) and normalized diffuse ratio ($D_N$) are estimated, given their sensitivity to subtle changes in $\tau_a$. Using a power law function of the cosine of the SZA as an independent variable for normalization of DR:

$$D_N = \frac{DR}{\mu_0^b} \quad (1)$$

where $\mu_0$ is the cosine of the SZA, and b is a constant[2]. **Figure 4** presents a scatter plot of $\tau_a$ and $D_N$. The data may be fit with a linear equation:

$$D_N = \frac{DR}{\mu_0^b} = C_1 + C_2 * \tau_a \quad (2)$$

where C1 & C2 are regression coefficients. Reorganizing (2), (3) is defined as follows:

$$DR = \mu_0^b (C_1 + C_2 * \tau_a) \quad (3)$$

where the 1$^{st}$ and 2$^{nd}$ terms on the right-hand side represent, respectively, DR when $\tau_a$=0 and the aerosol contribution to the DR due to extinction of direct irradiance by $\tau_a$ at a specific solar zenith angle (SZA) & $\tau_a$. "Aerosol-free" clear-sky DR ($\tau_a$=0) is estimated from (3) as follows:

$$DR^{clr} = C_1 \mu_0^b \quad (4)$$

where $DR^{clr}$ is the "aerosol-free" clear-sky DR. The ADR, i.e., difference of DR with and without aerosols, may be computed from (4) as:

$$ADR = DR^{obs} - DR^{clr} \quad (5)$$

where $DR^{obs}$ is the observed DR for only SZA ≤ 55$^0$, to minimize blockage errors associated with the surrounding tree line. **Continued in upper right panel.**

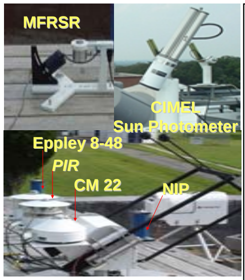


**Figure 1:** MFRSR, sun photometer & broadband sensors on solar tracker.

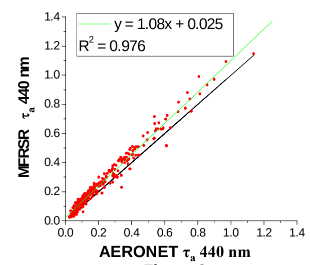


**Figure 2**

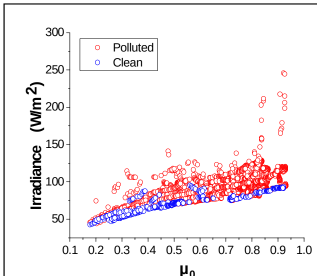


**Figure 3**

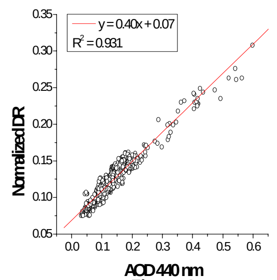


**Figure 4**

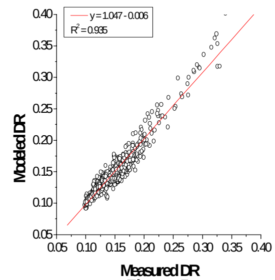


**Figure 5**

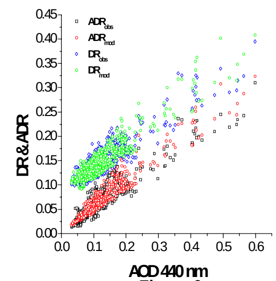


**Figure 6**

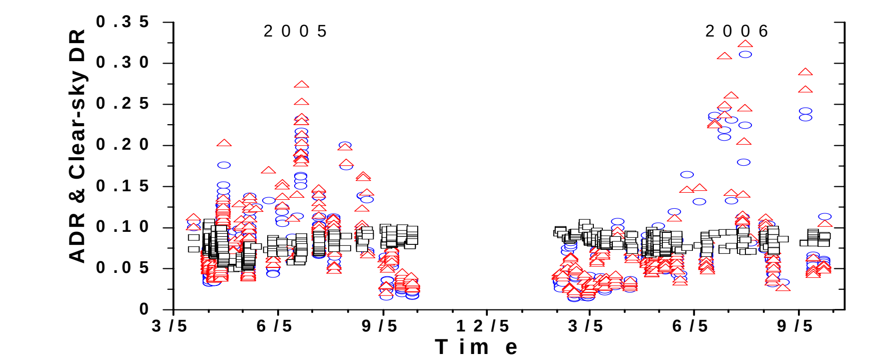


**Figure 7:** Time series of clear-sky DR (black) & ADR estimates from measured (blue) & modeled DR (red).

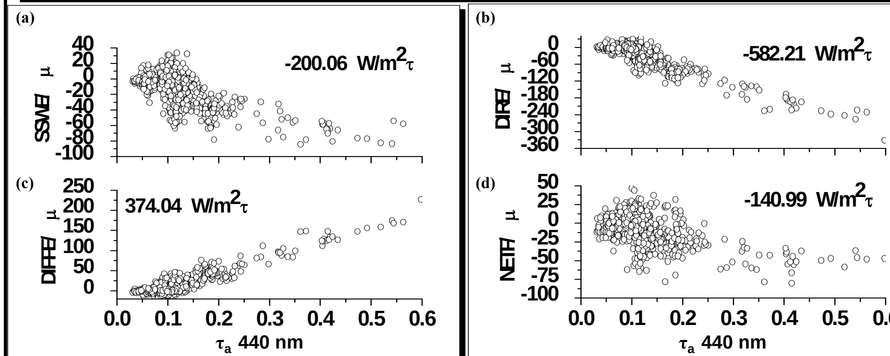


**Figure 8:** (a) $\tau_a$ vs. global NAE. (b) & (c) Same as (a), but for direct & diffuse NAE. (d) Same as (a), but for NAF. Included are aerosol forcing & effect efficiency estimates.

## 4.0 Results:

• Modeled (3) & observed DR show good agreement. (**Figure 5**). Increasing $\tau_a$ results in comparatively increased magnitudes of DR & ADR (**Figure 6**).

•For "aerosol-free" clear-sky no more than 10% of global SW is associated with diffuse SW, & 2-30% due to aerosols (**Figure 7**).

•Mean normalized aerosol effect (NAE) for 2005 (-14.77 W/m$^2$) is larger in magnitude than 2006 (-13.21 W/m$^2$); the corresponding loss in net irradiance at the surface for 2006 (-10.42 W/m$^2$) exceeds 2005 (-8.49 W/m$^2$).

•IR aerosol effects may explain the larger mean normalized aerosol forcing (i.e, change in net irradiance summed over the solar & IR spectrum with & without aerosol) for 2006 vs. 2005, though mean NAE for 2005 exceeded 2006.

• Surface temp: 295.3K (2005) & 292.19K (2006)

•Aerosol forcing (& effect) efficiency, i.e., instantaneous change of clear-sky irradiance per unit $\tau_a$, is the slope regression line (**Figure 8**).

•normalized global, direct, & diffuse decreases by 20.01 W/m$^2$, 58.22 W/m$^2$, & increase by 37.4 W/m$^2$, respectively, with an increase of 0.1 in $\tau_a$ (**Figure 8**).

•Normalized net decreases by 14.1 W/m$^2$ (**Figure 8d**).

## 5.0 Summary:

**Using two years of surface-based hemispheric broadband irradiance and $\tau_a$ measurements, an empirical equation is derived using linear regression, to investigate the aerosol effect on the surface radiative energy budget over a heterogeneous landscape located within the Mid-Atlantic corridor. The parameterization developed is used to calculate an ADR, described here as the difference of the DR with & without aerosols. This ratio explains the increase in the clear-sky diffuse SW due to increasing aerosol concentrations; results show there is a larger attenuation of the direct SW, resulting in an overall reduction in total SW reaching the surface.**

### References

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