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Global validation of the Particulate Observing Scanning Polarimeter (POSP) Aerosol Optical Depth products over land

Zhe Ji et al.

Correspondence to: Zhengqiang Li (lizq@radi.ac.cn)

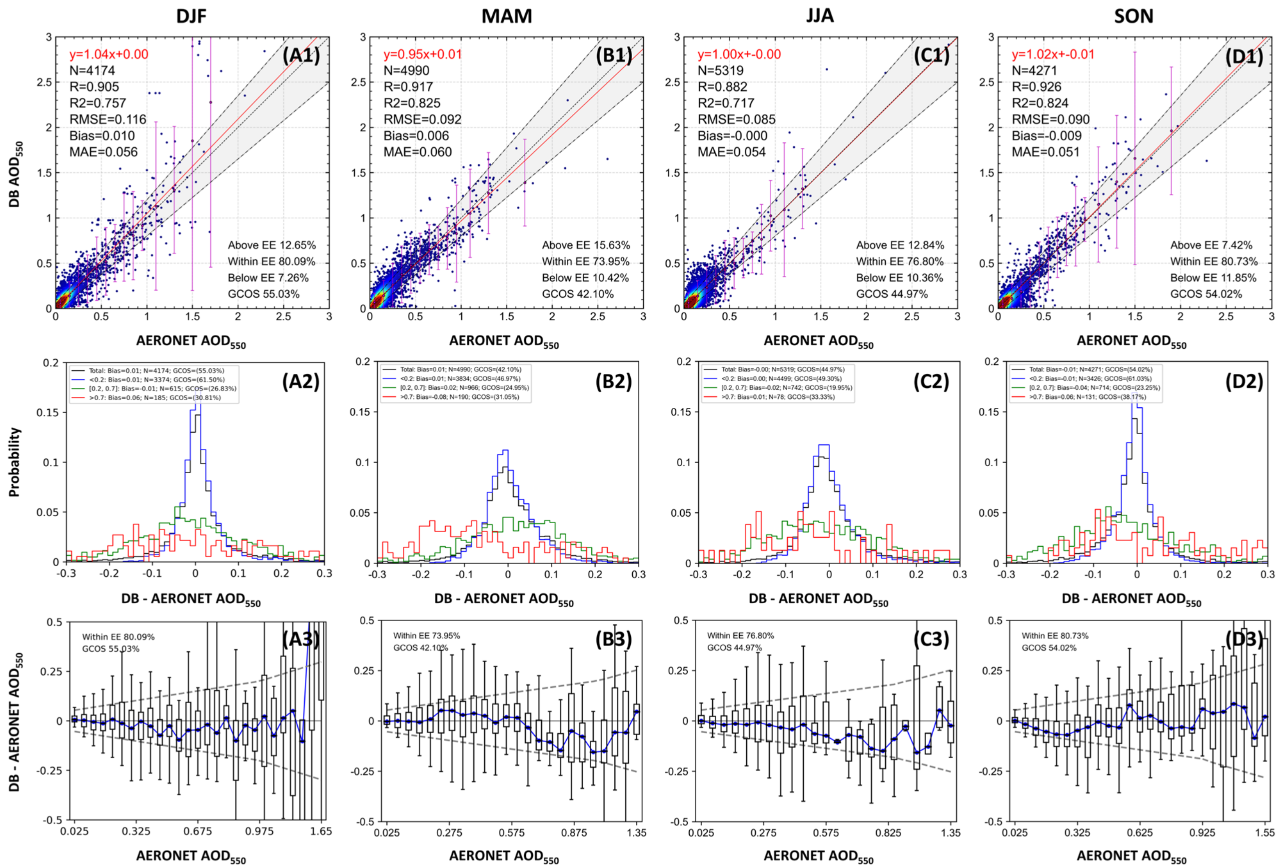

Figure S1: The same as Figure 1 but for different seasons. (1) Density scatter plots of DB AOD with AERONET AOD; (2) The probability density functions of differences (DB-AERONET); (3) Box plots of difference between DB AOD and AERONET AOD against AERONET AOD, in (A) DJF, (B) MAM, (C) JJA, and (D) SON.

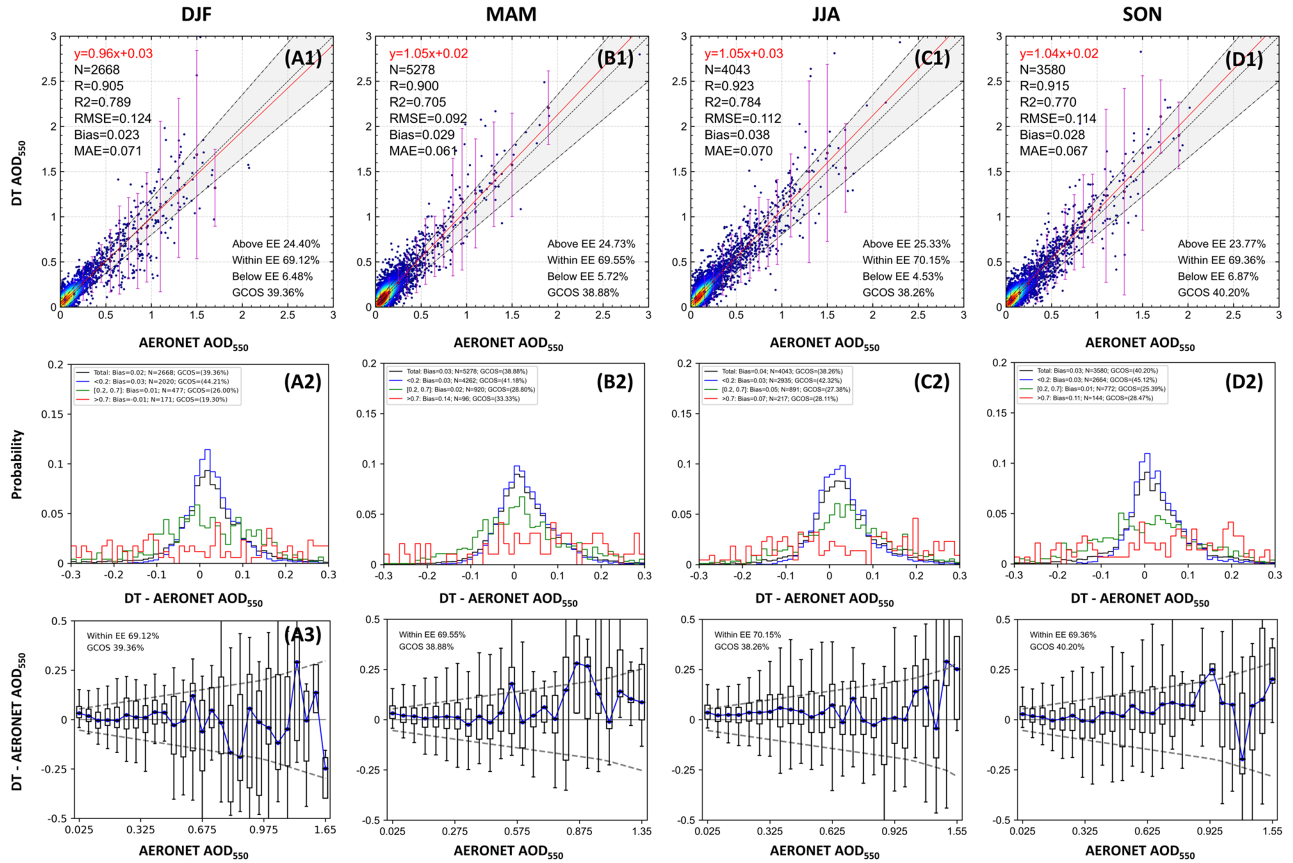

Figure S2: The same as Figure S1, but for DT.

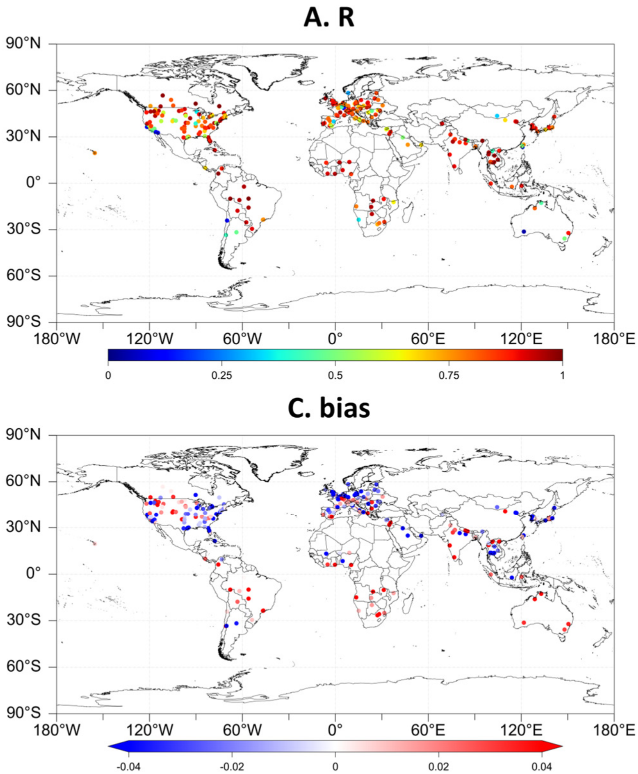

Figure S3: Site-scale statistics of the comparison of DB AOD versus AERONET AOD: (A) R, (B) RMSE, (C) Bias, and (D) GCOS.

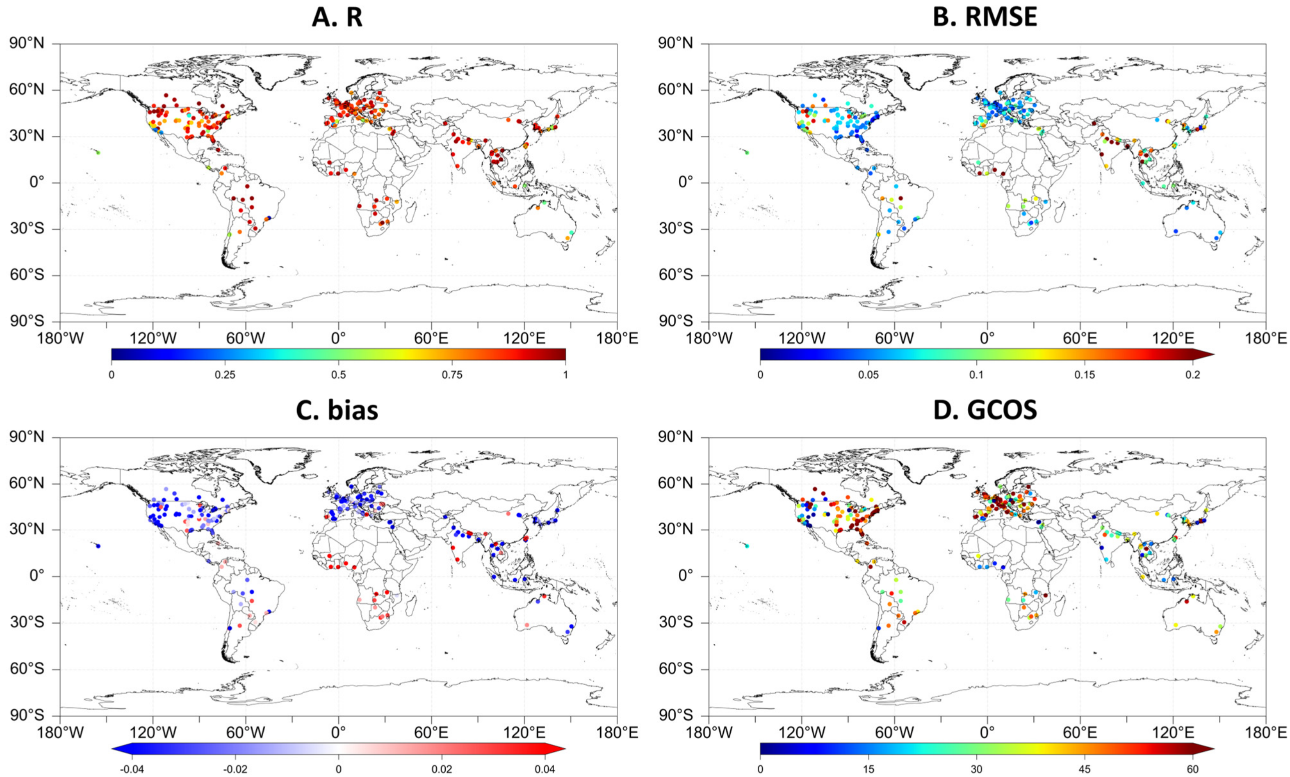

Figure S4: The same as Fig. S4, but for DT.

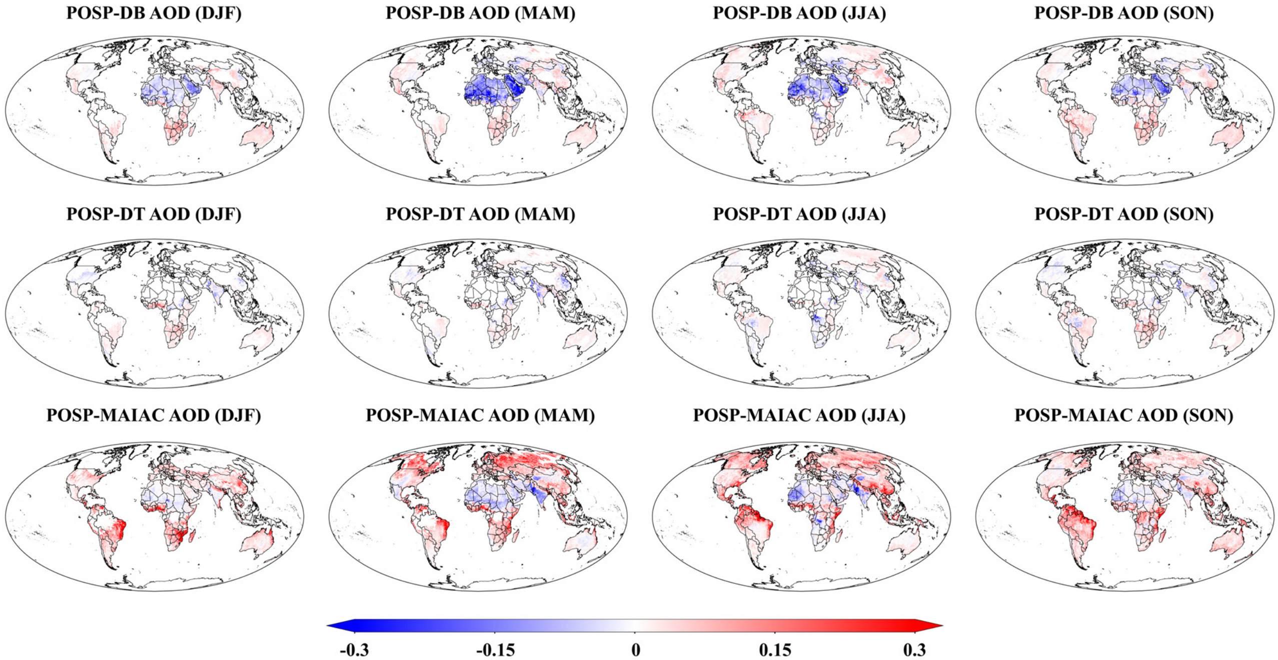

Figure S5: The differences between the seasonally averaged AOD from POSP and MODIS product for the year 2022.

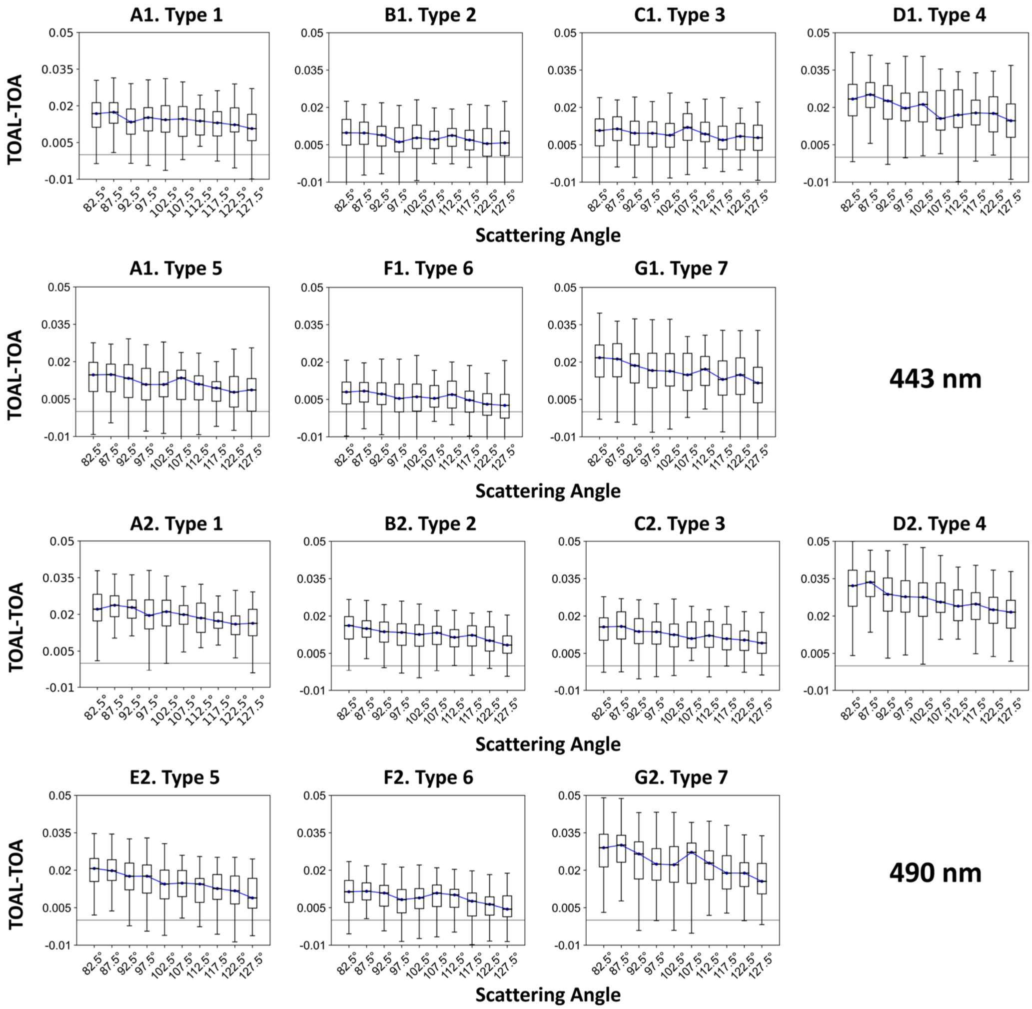

Figure S6: The boxplot of the differences for apparent reflectance between the results calculated based on the Lambertian forward radiative transfer model (TOAL) and the non-Lambertian forward radiative transfer model (TOA). The upper panel shows the differences as a function of AOD, while the lower panel presents the differences as a function of the scattering angle.

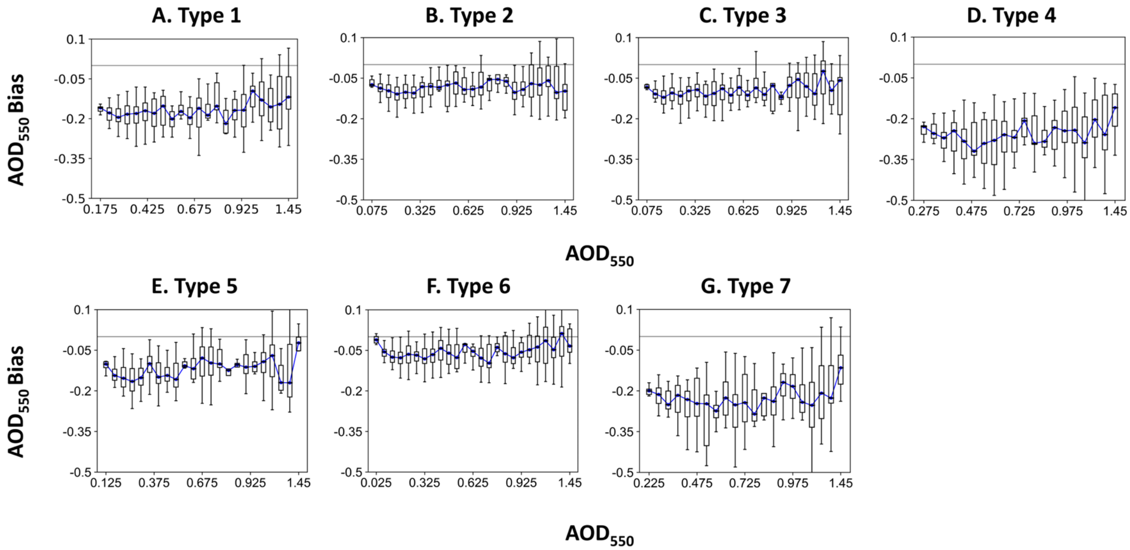

Figure S7: AOD bias as a function of aerosol loading for different urban surface types.

BRDF model

The Ross-Thick Li-Sparse (RTLS) model is a widely used semi-empirical kernel-driven model and is also the model used in the MODIS BRDF/Albedo product (MCD43) (Schaaf et al., 2002).The kernel functions are calculated as follows:

$$K_{iso}(\theta_s, \theta_v, \varphi) = 1 \tag{S1}$$

$$K_{vol}(\theta_s, \theta_v, \varphi) = \frac{\left(\frac{\pi}{2} - \xi\right)\cos\xi + \sin\xi}{\cos\theta_s + \cos\theta_v} - \frac{\pi}{4} \tag{S2}$$

where ζ is the phase angle calculated as:

$$\cos\xi = \cos\theta_s \cos\theta_v + \sin\theta_s \sin\theta_v \cos\varphi \tag{S3}$$

$$K_{geo}(\theta_s, \theta_v, \varphi) = O(\theta_s, \theta_v, \varphi) - \sec\theta'_s - \sec\theta'_v + \frac{1}{2}(1 + \cos\xi')\sec\theta'_s \sec\theta'_v \tag{S4}$$

where $O(\theta_s, \theta_v, \varphi)$ is the overlap area between the view and solar shadows, calculated as

$$O(\theta_s, \theta_v, \varphi) = \frac{1}{\pi}(t - \sin t \cos t)(\sec\theta'_s + \sec\theta'_v) \tag{S5}$$

with

$$\cos t = \frac{h}{b}\frac{\sqrt{D^2 + (\tan\theta'_s \tan\theta'_v \sin\varphi)^2}}{\sec\theta'_s + \sec\theta'_v} \tag{S6}$$

$$D = \sqrt{\tan^2\theta'_s + \tan^2\theta'_v - 2\tan\theta'_s \tan\theta'_v \cos\varphi} \tag{S7}$$

$$\cos\xi' = \cos\theta'_s \cos\theta'_v + \sin\theta'_s \sin\theta'_v \cos\varphi \tag{S8}$$

$$\theta'_s = \tan^{-1}\left[\frac{b}{r}\tan\theta_s\right] \quad \theta'_v = \tan^{-1}\left[\frac{b}{r}\tan\theta_v\right] \tag{S9}$$

In the RTLS model, h is the distance from the center of the ellipsoid to the ground, b is the length of the long half-axis radius of the ellipsoid, and r is the length of the short half-axis radius of the ellipsoid. In the MODIS BRDF product, h/b=2,b/2=1 is assumed (Lucht et al., 2000).

Non-Lambertian forward radiative transfer model

Qin et al. (2015) proposed an non-Lambertian forward radiative transfer model as an improvement over the original four-stream radiative transfer model:

$$\rho_{TOA} = \rho_0 + \frac{\vec{T}(\mu_s)^T \boldsymbol{R}\vec{T}(\mu_v) - e^{-\tau/\mu_s}|\boldsymbol{R}|e^{-\tau/\mu_v}}{1 - \rho_{BHR}S} \tag{S10}$$

$$\boldsymbol{R} = \begin{bmatrix} \rho & \rho_{DHR} \\ \rho_{HDR} & \rho_{BHR} \end{bmatrix} \tag{S11}$$

where, μ_s and μ_v refer the cosine of solar zenith angle and viewing zenith angle, respectively; ρ0 refers to the path reflectance; S is the spherical albedo of the atmosphere. R denotes the reflectance matrix, ρ_{DHR} is the directional–hemispherical reflectance (DHR), ρ_{HDR} is the hemispherical–directional reflectance (HDR), ρ_{BHR} is the bihemispherical reflectance (BHR) equal to the surface albedo, and |R| is the determinant of R. $\vec{T}(\mu_s) = \left[e^{-\frac{\tau}{\mu_s}} \quad t_d(\mu_s)\right]^T$ and $\vec{T}(\mu_v) = \left[e^{-\frac{\tau}{\mu_v}} \quad t_d(\mu_v)\right]^T$ are transmission matrices, td refers to the diffuse transmission. The description of the model is excerpted from (Ji et al., 2025).

Lambertian forward radiative transfer model

Assuming a uniform Lambertian surface, a horizontally averaged atmosphere, and atmospheric molecules primarily exist above the aerosol layer, the Top-of-Atmosphere (TOA) reflectance can be expressed as follows:

$$\rho^* = T_{gas}\left[\rho^R + T^R(\mu_s)\frac{\rho_G}{1 - S\rho_G}T^R(\mu_v)\right] \tag{S12}$$

Where ρ^* is the apparent reflectance at the satellite observation, T_{gas} is the gas transmittance, $T^R(\mu_s)$ and $T^R(\mu_v)$ are the upward and downward atmospheric transmittances, respectively, ρ_G is the surface-coupled reflectance, and S is the spherical albedo. The description of the model is excerpted from (Ji et al., 2024).

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