Takamura, T., and H. Irie, 2019: Forward scattering effect on the estimation of the aerosol optical thickness for Sun photometry. *J. Meteor. Soc. Japan*, **97**, 1211-1219.
https://doi.org/10.2151/jmsj.2019-059

Plain Language Summary: Sun photometry is one of the most popular methods to estimate optical thickness of aerosols (AOT), and has a long history because it is simple and easy to use. The observed direct normal irradiance, however, includes a part of forward scattering by aerosols so that the resultant AOT has some errors to be underestimated. Such erroneous AOT can lead an increase of ambiguity when estimating the radiative forcing of aerosols. This is dependent on an optical geometry of the measuring instrument and aerosol characteristics. In this report, the forward scattering effects on the AOT estimation are assessed by using several typical aerosol types and opening angles (OA) of instrumental geometry.

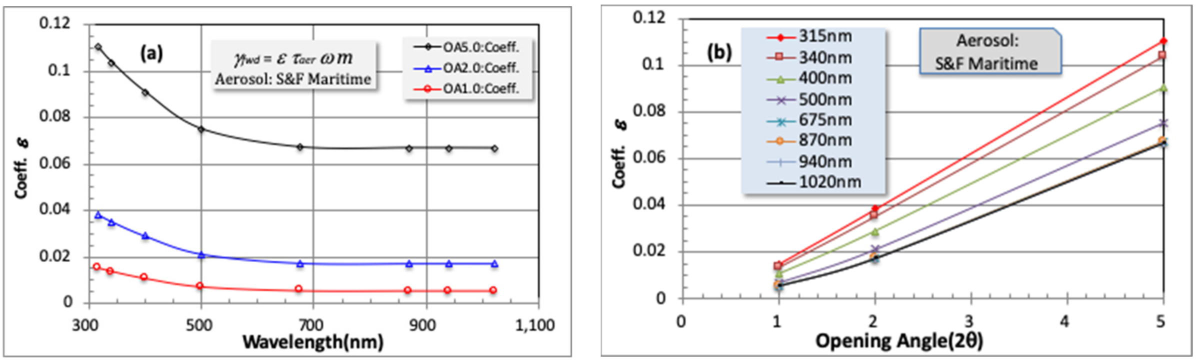

Fig.1 Wavelength dependence (a) and opening angle dependence (b) of a coefficient ε for the aerosol model "Maritime" compiled by Shettle and Fenn(1979). The coefficient ε is roughly proportional to the error ($\Delta\tau_{\lambda,aer}$ / $\tau_{\lambda,aer}$) on the AOT estimation. For example, when a sun photometer with an OA of 5°is used, an error of the AOT will be about 7.5% at 500 nm for this aerosol type .

Forward scattering ratio $\gamma_{\lambda,fwd}$, which is defined as a ratio of the forward scattering part to the true direct normal irradiance (I_λ), by $I_{\lambda,obs} = I_\lambda(1+\gamma_{\lambda,fwd})$, is calculated as functions of AOT($\tau_{\lambda,aer}$), OA, and relative air mass(m), where several typical aerosol types are used in the simulation. As a result, the ratio is approximately expressed by the following term, $\varepsilon_\lambda\omega_\lambda\tau_{\lambda aer}m$, where ε_λ is a proportional coefficient and ω_λ is a single scattering albedo of aerosols. Figure 1 shows an example of the variation of the coefficient ε_λ. These patterns are primarily dependent on the size distribution of aerosols.

- Forward scattering ratio($\gamma_{\lambda,fwd}$), defined by $\gamma_{\lambda,fwd} = \Delta I_{\lambda,fwd} / I_\lambda$, is approximately proportional to the product of the optical thickness ($\tau_{\lambda,aer}$), the single scattering albedo (ω_λ) of aerosols and the relative air mass (m), i.e., $\gamma_{\lambda,fwd} \approx \varepsilon_\lambda\omega_\lambda\tau_{\lambda aer}m$.
- Then, the error of the estimate of $\tau_{\lambda,aer}$ can be approximately expressed by $\Delta\tau_\lambda \approx -\varepsilon_\lambda\omega_\lambda\tau_{\lambda\mathrm{aer}}$.
- The proportional coefficient ε_λ is dependent on the aerosol characteristics as well as the opening angle of measurement instruments.