Supplementary Materials: Quantifying Light Absorption of Iron Oxides and Carbonaceous Aerosol in Seasonal Snow across Northern China

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Derivation of the total absorption optical depth on a filter (τ_{tot}), the absorption Ångström exponent of non-BC components ($Å_{nonBC}$) and the estimated BC loading (L_{BC}^{est})

The calculation of light absorption due to different insoluble light-absorbing particles (ILAPs) is based on the optical analysis using the Integrating Sphere/Integrating Sandwich (ISSW) spectrometer, which was first introduced by Grenfell et al. [1] and readers can find more details in [1].

1. τ_{tot}

The ISSW spectrophotometer measures the absorption spectrum from 450 to 750 nm for all ILAPs collected on a filter. A set of standard filters (Monarch-71 soot) with known black carbon (BC) loading was used to calibrate the system. All amounts of ILAPs on a filter corresponds to an equivalent BC loading (L_{BC}^{equiv}), resulting from the same attenuation signal according to the calibration curve. The total absorption optical depth (AOD) at a certain wavelength λ ($\tau_{tot}(\lambda)$) on a filter can be derived from

$$\tau_{tot}(\lambda) = L_{BC}^{equiv} \cdot MAC_{BC}(\lambda) \quad \text{(S1)}$$

where MAC_{BC}represents the mass absorption coefficient of BC, which was chosen to be 6.3 $m^2 \cdot g^{-1}$ at 550 nm, following Wang et al. [2].

2. $Å_{nonBC}$

Similar to the absorption Ångström exponent of all particles on the filter ($Å_{tot}$), the absorption Ångström exponent of non-BC components ($Å_{nonBC}$) can be expressed as

$$Å_{nonBC} = f_{OC} \cdot Å_{OC} + f_{Fe} \cdot Å_{Fe} \quad \text{(S2)}$$

where f_{OC} and f_{Fe} refer to the fractional contributions to total absorption by OC and iron oxides.

3. L_{BC}^{est}

Because we were able to determine $Å_{tot}(\lambda_0)$ $Å_{BC}$, and $Å_{nonBC}$, the light absorption fraction of BC at λ_0 $f_{BC}(\lambda_0)$ can be derived using the equation transformed from Equation (6):

$$f_{BC}(\lambda_0) = \frac{Å_{tot}(\lambda_0) - Å_{nonBC}}{Å_{BC} - Å_{nonBC}} \quad \text{(S3)}$$

The estimated absorption optical depth of BC at $\lambda_0 \tau_{BC}^{est}(\lambda_0)$ can be represented as follows:

$$\tau_{BC}^{est}(\lambda_0) = f_{BC}(\lambda_0) \cdot \tau_{tot}(\lambda_0) \quad \text{(S4)}$$

and, using Equation (5), τ_{BC}^{est} can be scaled across the full spectrum (450 nm to 750 nm).

Finally, the estimated BC loading L_{BC}^{est} is as follows:

$$L_{BC}^{est} = L_{BC}^{max} \cdot f_{BC}^{650\text{-}700} \quad \text{(S5)}$$

where $f_{BC}^{650\text{-}700}$ is given by $f_{BC}^{650\text{-}700} = \tau_{BC}^{est}(650\text{-}700) / \tau_{tot}(650\text{-}700)$.

References

1. Grenfell, T.C.; Doherty, S.J.; Clarke, A.D.; Warren, S.G. Light absorption from particulate impurities in snow and ice determined by spectrophotometric analysis of filters. *Appl. Opt.* **2011**, *50*, 2037–2048.
2. Wang, X.; Doherty, S.J.; Huang, J. Black carbon and other light-absorbing impurities in snow across Northern China. *J. Geophys. Res. Atmos.* **2013**, *118*, 1471–1492.