Supplement of

Optical properties of atmospheric fine particles near Beijing during the HOPE-J$^3$A Campaign

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S1 Mass extinction efficiencies of each chemical composition at different wavelength

The mass extinction efficiencies (MEE) for a single sphere particle can be calculated by using Mie theory (Bohren and Huffman, 1998):

\[
MEE = \frac{3Q_{\text{ext}}(m, D_p, \lambda)}{2 \rho D_p} \tag{1}
\]

where \( m = n + i k \) is the complex refractive index (CRI) of the particle (\( n \) and \( k \) corresponding to the real and imaginary parts of the CRI, respectively), \( D_p \) is the mean diameter per unit volume, \( \lambda \) is the incident light wavelength, and \( \rho \) is the density of the particle.

The MEE of each chemical composition can be calculated by using Mie algorithm with the measured volume size distributions and with an assumed CRI of each compound, as shown in equation (2) (Cheng et al., 2008; Cheng et al., 2015):

\[
MEE(j) = \frac{\sum_{bin=1}^{D_{\text{bin}}} MEE(j, D_{\text{bin}}) V_{j,bin}}{\sum_{bin=1}^{D_{\text{bin}}} V_{j,bin}} \tag{2}
\]

where \( MEE(j, D_{\text{bin}}) \) is the \( j \)th component of \( MEE \) in the size bin \( (D_{\text{bin}}) \), which can be calculated using equation (1). \( \sum_{bin=1}^{D_{\text{bin}}} V_{j,bin} \) is the volume size distribution and \( V_{j,bin} \) is the volume concentration.

In this study, since size-segregated chemical composition was not available, the following method was used to calculate the MEE of each composition. We assumed that the particles were external mixed and each chemical components were uniformly distributed, and we also assumed that the CRIs do not vary with the wavelength. The densities and CRIs of different types of aerosols were shown in Table S1 (Cheng et al., 2008). The size-distribution of each component (organic mass, ammonium nitrate, ammonium sulfate, sea salt, and element carbon) was calculated by the volume size distribution (observed data from Scanning Mobility Particle Sizer Spectrometer (SMPS)) and the mass concentrations. Thus, the
wavelength-dependent $MEE$ of each component can be calculated by equation (1) and (2). Fig. S1 shows the values of $MEE$s decreased with increasing light incident wavelength, and depended on the air pollution levels. As an average result, the calculated dry mass extinction efficiencies of inorganic mass (including sulfate, nitrate and sea salt), organic mass and element carbon at $\lambda = 470$ nm were 1.31, 1.30 and 1.08 times larger than that at $\lambda = 550$ nm.

Fig. S1 Calculated wavelength dependent mass extinction efficiencies of inorganic mass (including sulfate, nitrate and sea salt), organic mass and element carbon.
Table S1 Densities and complex refractive indexes of different types of aerosols. (adapted from Cheng et al., 2008)

<table>
<thead>
<tr>
<th>Chemical Species</th>
<th>Density (g cm$^{-3}$)</th>
<th>Complex Refractive Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>(NH$_4$)$_2$SO$_4$</td>
<td>1.748</td>
<td>1.54 - 10$^{-7}$ i</td>
</tr>
<tr>
<td>NH$_4$NO$_3$</td>
<td>1.725</td>
<td>1.54 - 10$^{-7}$ i</td>
</tr>
<tr>
<td>OM</td>
<td>1.4</td>
<td>1.55 - 0.001 i</td>
</tr>
<tr>
<td>Sea salt</td>
<td>2.0</td>
<td>1.54 - 10$^{-7}$ i</td>
</tr>
<tr>
<td>EC</td>
<td>1.5</td>
<td>1.80 - 0.54 i</td>
</tr>
</tbody>
</table>

S2 Relationships between aerosol optical properties and wind directions

The local wind direction and wind speed were measured on the roof of building with a Gill MetPak-II weather station. Fig. S2 presents the relationship of $\alpha_{sp,470}$, $\alpha_{ap,470}$ and $\omega_{470}$ to local wind directions and wind speed during the campaign. On these graphs, Beijing centre would be at ~206°. Fig. S2a and S2b display the wind direction versus wind speed, with $\alpha_{sp,470}$ and $\alpha_{ap,470}$ as the color scale. From November 2014 to January 2015, the winds were mostly from the southeast and southwest. There was no obvious correlation between extensive optical properties and wind direction. The average wind speed was 1.2 m s$^{-1}$ during the field campaign. When the instantaneous wind speeds were higher than the average wind speed, the values of $\alpha_{sp,470}$ and $\alpha_{ap,470}$ decreased. The average values of $\alpha_{sp,470}$ for $v < 1.2$ m s$^{-1}$ and $v > 1.2$ m s$^{-1}$ were 198 Mm$^{-1}$ and 54 Mm$^{-1}$, respectively. Similarly, the average values of $\alpha_{ap,470}$ for $v < 1.2$ m s$^{-1}$ and $v > 1.2$ m s$^{-1}$ were 41 Mm$^{-1}$ and 11 Mm$^{-1}$, respectively. When $v > 1.2$ m s$^{-1}$, lower values of $\alpha_{sp,470}$ ($< 100$ Mm$^{-1}$) and $\alpha_{ap,470}$ ($< 50$ Mm$^{-1}$) occurred more frequently when the local wind came from 225 - 270°, which indicated that the air parcel was relatively clean in the wind direction. When $v < 1.2$ m s$^{-1}$, values of $\alpha_{sp,470}$ and $\alpha_{ap,470}$ occurred similar frequently and ranged widely when the local wind came from the south. Fig. S2c shows the relationship between the wind direction and $\omega_{470}$, with the color scale as wind speed. The average value of $\omega_{470}$ ranged from 0.7 to 0.9 and was not strongly correlated with the wind direction. However, higher values $\omega_{470}$ (0.9 - 1.0) occurred more frequently when the local wind came from 270 - 160°, which indicated that the air parcel in this wind direction contained less light absorbing particulate matter.
Fig. S2 Local wind direction and wind speed plots for the campaign: (a) wind direction versus wind speed (m s\(^{-1}\)), with \(\alpha_{\text{sp}, 470} \text{ (Mm}^{-1}\) as the color scale, (b) wind direction versus wind speed (m s\(^{-1}\)), with \(\alpha_{\text{ap}, 470} \text{, (Mm}^{-1}\) as the color scale, and (c) wind direction versus \(\omega_{470}\), with the color scale as wind speed (m s\(^{-1}\)).
References

