Evaluation of the BC / OC ratios for aerosol emissions from biomass burning in Siberia using AERONET retrievals

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INTRODUCTION

Biomass burning (BB) aerosol is known to have a considerable impact on the radiation budget of the atmosphere as a result of both scattering and absorption of the solar shortwave radiation and increasing the downward longwave radiation. A balance between the cooling and warming effects of aerosol critically depends on the ratio of the major absorbing and scattering components in particles, such as black carbon (BC) (or elemental carbon, EC) and organic carbon (OC), respectively. Available direct measurements of this ratio in remote regions (like Siberia) are limited and rather uncertain.

We examine a simple method to estimate the BC (EC) / OC ratio in BB aerosol by using retrievals of aerosol optical properties from Aerosol Robotic Network (AERONET) measurements along with an empirical relationship between the EC / OC ratio and the single-scattering albedo (SSA).

METHOD

An empirical relationship between EC/OC ratio and SSA (Pokhrel et al., 2016):

\[ \frac{[\text{EC}]}{[\text{EC} + \text{OC}]} \approx a \times \text{SSA}^{-b} + \frac{b}{a} \]

where \( a \) and \( b \) are the coefficients of the linear regressions.

The coefficients of the linear regressions fitted to the Fourth Fire Laboratory at Missoula Experiment (FLAME-4) [Pokhrel et al., 2016]

<table>
<thead>
<tr>
<th>Wavelength (( \lambda ))</th>
<th>Intercept (( \alpha ))</th>
<th>Slope (( \beta ))</th>
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<tbody>
<tr>
<td>405 nm</td>
<td>-1.07 (±0.08)</td>
<td>0.94 (±0.007)</td>
</tr>
<tr>
<td>532 nm</td>
<td>-1.06 (±0.04)</td>
<td>0.94 (±0.004)</td>
</tr>
<tr>
<td>660 nm</td>
<td>-1.11 (±0.04)</td>
<td>0.99 (±0.004)</td>
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Distinctive features of the different cases of estimation of the EC/OC ratio using the AERONET observations

Case 1 The estimates are obtained using Eq. (2) and SSA observations at 675 and 869 nm
Case 2 The same as Case 1, but using SSA observations at 440 nm
Case 3 The estimates are obtained using the available parameterization (Eq. 3) for SSA at 660 nm
Case 4 The same as Case 3, but using the parameterization for SSA at 485 nm

RESULTS

Average values of the EC/OC ratio estimates derived from the AERONET observations according the different estimation cases along with the corresponding value predicted with simulations of the CHIMERE model.

Case 1 0.036 (±0.009)
Case 2 0.038 (±0.035)
Case 3 0.031 (±0.009)
Case 4 0.002 (±0.011)
CHIMERE 0.061

The relationship between the EC/OC mass ratios derived from the AERONET data estimated with the CHIMERE. The 90% conf. intervals (green error bars) considering the uncertainty of the approximation and the probable error (0.03) of individual SSA observations, while the 90% confidence intervals (black solid line) based on only the uncertainty of the approximation. The dot-dashed line depicts the 1:1 ratio.

CONCLUSIONS

\[ a \text{AD} = \frac{[\text{EC}]}{[\text{EC} + \text{OC}]} \approx a \times \text{SSA}^{-b} + \frac{b}{a} \]

A linear fit (red line) and an ODR fit (black line) for the relationship between the EC/(EC + OC) ratio and SSA(660) (black line) for the relationship between the EC/(EC + OC) ratio and SSA(660)

\[ \text{AAOD} = \frac{[\text{EC}]}{[\text{EC} + \text{OC}]} \approx a \times \text{SSA}^{-b} + \frac{b}{a} \]

We used the AERONET observations to estimate the EC/OC mass ratio in BB aerosol in Siberia. The EC/OC ratio values in June–August 2012 are found to range from 0.015–0.017, with the mean value of 0.016 (±0.009). The estimated mean value of the EC/OC ratio is found to be significantly smaller than the corresponding value (0.06) predicted by the BB aerosol simulations based on the emission factors specified in the GFE14.1 emission inventory, but in a very good agreement with the value of the EC/OC enhancement ratio (0.08) evaluated in long-term in situ measurements of carbonaceous aerosol at Zotino [Mikhailov et al., 2017].

The EC/OC ratio estimates derived from the AERONET SSA observations using the combination of observations at 869-nm and 675-nm wavelengths are found to be consistent with the corresponding estimates derived from the combination of observations at 660-nm and 440-nm wavelengths: There are significant discrepancies between the estimates derived from the AERONET data with the original FLAME-4 parameterizations for SSA of fresh BB aerosol at the 660- and 440-nm wavelengths. The parameterization for 405 nm is found to strongly underestimate the EC/OC ratio; this may be due to a decrease of BC absorption in aging BB aerosol phases.

The results suggest that the AERONET retrievals are capable of estimating the EC/OC ratio for BB aerosol in Siberia with high accuracy, providing valuable insights into the atmospheric chemistry and radiative forcing in this remote region.