Optical Properties of Aerosol Emissions from Laboratory Peat Combustion

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Introduction

Globally, organic soils and peats may store as much as \(6.1 \times 10^{17}\) t of terrestrial C, representing one-fifth and one-third of the planet’s terrestrial organic carbon (Gorham, 1994). This is approximately the same mass of C as that contained in Earth’s atmosphere, despite peatlands occupying only 3% of its surface (Figure 1, Ruesch and Gibbs 2008). The contribution from smoldering combustion of organic soils to global releases of terrestrial carbon to the atmosphere may increase under scenarios of warming and drying climatic conditions (IPCC 2007).

Since the identification of optical properties of aerosol organic carbon (OC) from combustion two decades ago, an increasing number of researchers have investigated the enhanced potential of radiative forcing (RF) impacts of aerosol emissions from wildfires (e.g., See et al. 2007). These studies have identified smoldering as a major contributor of black carbon (BrC) aerosol compared to flaming combustion (e.g. Hadden 2011).

Methods

Samples of peat soils from four locations representing the various biomes in which these soils occur (Siberia, Russia, and Alaska, USA, representing boreal and arctic ecosystems, and two locations in Florida, USA, representing temperate and subtropical ecosystems), were burned in the DRI combustion facility (Figure 2, left), at moisture levels approximating those found during droughts and under which peat soils will support combustion. Aerosol emissions were characterized for optical properties with three-wavelength photoacoustic spectrometer and nephelometer (Moosmüller et al. 2009) including online and offline smoke analysis.

Data Analysis

We compared optical properties of peat samples collected in three biomes at two different moisture levels to determine whether peats from across multiple biomes differ in the optical properties of their emissions. Two fuel moisture levels were used in our work to enable us to determine whether peat source or fuel moisture content was more important to emissions optical characteristics. Aerosol absorption and scattering coefficients, measured at three wavelengths (405, 532, and 870 nm) were analyzed for single scattering albedo (SSA) and absorption Ångström coefficients (AAC) (405-870 nm). While SSA was comparable to that of emissions from other smoldering fuels, AAC was substantially higher. Moisture content also played an important role; AAC was higher for lower moisture levels for all peat samples. Florida lake peat (at 10% moisture level) exhibited the highest AAC value (~7.2).

Results and Discussion

Figure 3: Aerosol absorption coefficients as function of wavelength in a log-log plot. The Absorption Ångström Coefficient (AAC) is the negative slope. Note the larger curvature at higher fuel moistures.

Figure 5: Optical characteristics of peat emissions (top) compared with those of other fuels.

Table 1. Mean organic mass-normalized absorption cross-section (MAC) calculated from absorption Ångström coefficients (AAC) and single scattering albedo (SSA) at 405, 532, and 781 nm for various peat samples at 10%, 25%, and 50% moisture levels.

<table>
<thead>
<tr>
<th>Peat sample</th>
<th>Fuel moisture (%)</th>
<th>AAC (m²/g)</th>
<th>SSA</th>
<th>MAC (m²/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida Lake</td>
<td>50</td>
<td>0.22</td>
<td>0.89</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>0.52</td>
<td>0.81</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.86</td>
<td>0.92</td>
<td>0.98</td>
</tr>
<tr>
<td>Florida Swamp</td>
<td>25</td>
<td>0.27</td>
<td>0.82</td>
<td>0.02</td>
</tr>
<tr>
<td>Alaskan Peat</td>
<td>50</td>
<td>0.31</td>
<td>0.86</td>
<td>0.01</td>
</tr>
<tr>
<td>Siberian Peat</td>
<td>50</td>
<td>0.31</td>
<td>0.86</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Compared with reported values for many other common wildland fuels, emissions from the four peats measured in this study displayed similar values for single scattering albedo, with values in the 0.9-1.0 range at 405nm (Figure 5). However, observed values for absorption Ångström coefficients (405-870 nm) were substantially higher for peats than for other fuels. Furthermore, our observations appear to indicate that as moisture content of a peat sample decreased, AAC values for their emissions increased.

Conclusions

As changes to climate and land-use patterns result in increasing desiccation to peatlands worldwide, wildfire activity is widely expected to increase in these areas. However, one unforeseen consequence to scenarios of peatlands burning at decreasing moisture levels is the potential change to optical characteristics of their emissions. This preliminary study appears to suggest that:
1. Despite the geographical difference of the peat samples, smoke aerosols from all three types of peat show strong wavelength dependence of light absorption.
2. Wavelength dependence of aerosol light absorption of peat smoke aerosol was found to decrease with increasing moisture content.
3. All peat smoke exhibited highAAC, mass absorption coefficients (MACs) were found to be quite low, in the range 0.01-0.03 m²/g to 0.001 m²/g for humic-like substances (Hoff et al., 2006).

Acknowledgments

The authors wish to thank Michelle Mack of University of Florida (present address Northern Arizona University) and Anna Tobias of Lomonosov Moscow State University (for kindly providing samples of Alaskan and Siberian peat used in this study). Many thanks are also due to the Desert Research Institute for the financial support that this study was provided by the Science for a Secure Environment (S4E) program. Funding for this study was provided by the Desert Research Institute.

References


