Development of new computationally efficient treatments of secondary organic aerosols (SOA) for E3SM v3: Sensitivity of SOA to emissions, chemistry, and vertical resolution

MANISH SHRIVASTAVA
SIJIA LOU, RICHARD EASTER, HAILONG WANG, POLUN-MA, YANG YANG, PHILIP RASCH, VIRENDRA GHATE, QI ZHANG, JOSE JIMENEZ, ALLA ZELENYUK, JOHN SHILLING, MANVENDRA DUBEY AND SEVERAL OTHER CO-AUTHORS/COLLABORATORS
Radiative forcing of aerosols more uncertain than reported in IPCC AR5

- Organic aerosols include 1000’s of species whose chemical compositions and properties change dynamically in the atmosphere
- Organic aerosol is represented too simplistically in climate models
- Aerosol radiative forcing is more uncertain than reported in IPCC since
- Latest E3SM results show that SOA itself has a DRF of -0.7 to -1 W/m²

IPCC, 2013
Anthropogenic emissions affect chemistry, formation, growth, properties and lifetimes of natural biogenic SOA.

Complex SOA physical and chemical processes still uncertain and are not included in climate models.

Shrivastava et al. 2017, Reviews of Geophysics
Multiple generations of aging in the atmosphere change SOA formation and volatility distribution

Multigenerational aging not explicitly included in global climate models

Shrivastava et al. 2015, JGR
Results: Decreasing fragmentation increases SOA burdens

- Greatest effects of gas-phase fragmentation are over source regions including the South African biomass burning outflow, the Amazon (South America), and over India.

- High latitudes such as the Arctic show much smaller effects of fragmentation on SOA burdens.
Simulated and satellite AOD over South African biomass burning outflow

- Simulated AOD shows strong sensitivity to SOA
- High fragmentation case agrees better with MODIS AOD
Evaluate model predictions with aircraft measurements over Arctic and Amazon

ARCTAS (Spring)

Chemistry:
- 75% fragmentation
- 50% fragmentation

Smallest difference after long-range transport to arctic

Amazon (Sep.)

Greater difference over source region and near surface
Recent studies reflect large uncertainties in predicting SOA direct radiative forcing

- Previous estimates of SOA direct radiative forcing (DRF) differ by an order of magnitude

<table>
<thead>
<tr>
<th>Studies</th>
<th>DRF (W m(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>AeroCom Phase II Intercomparison experiments (Myhre et al. 2013)</td>
<td>-0.01 to -0.21 (mean: -0.06)</td>
</tr>
<tr>
<td>Spracklen et al. 2011 (observationally constrained but mostly near surface and in North Hemisphere)</td>
<td>-0.26±0.15 (anthropogenic controlled SOA)</td>
</tr>
</tbody>
</table>

- Direct radiative forcing using E3SM model: -0.7 and -0.9 W m\(^{-2}\) for 75% and 50% fragmentation

- Indirect forcing (PD-PI) is -1.2 W m\(^{-2}\) with upto 20% changes with SOA chemistry treatments