Global budget of black carbon: constraints from HIPPO

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Multimodel intercomparisons and comparisons to observations

- Models differ by order of magnitude, do not reproduce observed gradients
- Differences reflect treatment in scavenging
Global BC simulation in GEOS-Chem

- 2°x2.5° resolution, 47 vertical levels, GEOS-5 meteorological data
- Anthropogenic and biomass burning (GFED3) emissions w/monthly resolution (aircraft emissions are not included yet)

### BC emissions in 2009

**Anthropogenic (4.9 Tg a\(^{-1}\))**

**Open fires (1.6 Tg a\(^{-1}\))**

- Anthropogenic emission dominates globally, biomass burning may dominate regionally and seasonally
- Anthropogenic emissions previously evaluated with surface networks in US, Europe, East Asia; error is ± 40%
BC removal in GEOS-Chem

- Cloud updraft scavenging
- Anvil precipitation
- Large scale precipitation
- In-cloud
  - IN/CCN
  - IN
  - IN/CCN

- Below-cloud
  - washout: for all BC
  - re-evaporation

- BC removal is mainly by wet deposition with hydrophobic/hydrophilic distinction
- Scavenging scheme previously evaluated with aerosol surface/aircraft observations
- Use HIPPO to evaluate sensitivity to impaction scavenging, CCN/IN assumptions, cirrus precipitation
Previous application to Arctic spring (ARCTAS)

- Model was unbiased in reproducing vertical profiles, deposition to snow
- HIPPO provides far more extensive test of model scavenging and implications for global transport

[Wang et al., 2011]
Using HIPPO data to test/improve BC removal in GEOS-Chem

- How reliable are the observations of BC < 0.1 ng m⁻³?
Observed vs. model curtains for HIPPO BC (West Pacific)

- data averaged over the model grid
Probability density function for BC

0-20° N   60-90° N   0-20° S

Jan > 6km     Mar-Apr > 6km     Jan > 6km

<table>
<thead>
<tr>
<th>Observation</th>
<th>Model</th>
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<tr>
<td>-2</td>
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<tr>
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- generally lognormal distribution
- model reproduced the spread
- low tail in the observations but missed in the model

log BC (ng m⁻³)
Comparison of vertical profiles

vertical gradients
- decrease with altitudes by orders of magnitude

seasonality
- higher concentrations in spring in both NH and SH
Normalized mean bias ($\text{NMB} = \Sigma (M_i - O_i) / \Sigma O_i$)
-14% in all (-10% in Jan; 10% in Oct-Nov; -25% in Mar-Apr)
• Anthropogenic influence dominates in both NH and SH, consistent with the observed high correlation between CO and CH2Cl2.

• Open fire emissions important in spring.
Zonal mean BC in GEOS-Chem ‘educated by HIPPO’

Global tropospheric BC lifetime in model is 4-5 days depending on season