Development of a 4-Mode Version of Modal Aerosol Module for CAM5

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With support from DOE Polar Project
Benchmark 7-Mode Modal Aerosol Model (MAM)

- **Aitken**
  - number
  - sulfate
  - ammonium
  - secondary
  - OM
  - sea salt

- **Accumulation**
  - number
  - sulfate
  - ammonium
  - secondary OM
  - primary OM
  - BC
  - sea salt

- **Fine Soil Dust**
  - number
  - soil dust
  - sulfate
  - ammonium

- **Fine Sea Salt**
  - number
  - sea salt
  - sulfate
  - ammonium

- **Primary Carbon**
  - number
  - primary OM
  - BC

- **Coarse Soil Dust**
  - number
  - soil dust
  - sulfate
  - ammonium

- **Coarse Sea Salt**
  - number
  - sea salt
  - sulfate
  - ammonium

All modes log-normal with prescribed width.

Total transported aerosol tracers: 31

Cloud-borne aerosol and aerosol water predicted but not transported.

Liu et al (2012)
3-mode version of MAM

Assume primary carbon is internally mixed with secondary aerosol.
Sources of dust and sea salt are geographically separate
Assume ammonium neutralizes sulfate.

<table>
<thead>
<tr>
<th>Aitken number</th>
<th>Accumulation number</th>
<th>Coarse number</th>
</tr>
</thead>
<tbody>
<tr>
<td>sulfate</td>
<td>sulfate</td>
<td>soil dust</td>
</tr>
<tr>
<td>secondary OM</td>
<td>secondary OM</td>
<td>sea salt</td>
</tr>
<tr>
<td>sea salt</td>
<td>primary OM</td>
<td>sulfate</td>
</tr>
<tr>
<td></td>
<td>black carbon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>soil dust</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sea salt</td>
<td></td>
</tr>
</tbody>
</table>

Total transported aerosol tracers: 15

coagulation
condensation

Liu et al (2012)
Goal

- Improve the treatment of aging (mixing state) of black carbon (BC) and primary organic matter (POM)
- Reproduce the results of MAM7 for BC and POM, but with a small increase in computer time
4-Mode version of MAM

- **Aitken number**
  - sulfate
  - secondary OM
  - sea salt

- **Accumulation number**
  - sulfate
  - secondary OM
  - primary OM
  - BC
  - soil dust
  - sea salt

- **Coarse number**
  - soil dust
  - sea salt
  - sulfate

**Coagulation and condensation**

**Primary Carbon number**
- primary OM
- BC

All modes log-normal with prescribed width.

Total transported aerosol tracers: **18**

Cloud-borne aerosol and aerosol water predicted but not transported.

**Computer time is ~10% higher than MAM3**
CAM5 Simulations (CAM5.1)

- Free CAM5 run with prescribed climatological SST and sea ice
- 6 years at 1.9°x2.5° resolution with 1-year spin-up
- Emissions: IPCC AR5 emissions for anthr. OM, BC, SO2
- 3-mode, 4-mode and 7-mode version of MAM
- Low hygroscopicity of POM ($\kappa=0$) and slow aging of primary carbon mode for MAM4 and MAM7 (coating thickness = 8 monolayers)

- MAM3 ($\kappa=0.1$)
- MAM4 and MAM7 ($\kappa=0$ and slow aging)
Aerosol mass burden %diff. \((MAM4-MAM3)/MAM3\)
Aerosol mass burden MAM4

- Sulfate, mg/m²
- BC, mg/m²
- POM, mg/m²
- SOA, mg/m²
- DUST, mg/m²
- Sea Salt, mg/m²
Aerosol mass burden %diff. \((MAM4-MAM7)/MAM7\)

10-20% higher than MAM7, but concentrations there are very low
BC compared with SP2 (tropics and midlat.)
BC compared with SP2 (highlat.)
Seasonal BC at surface (highlat.)

(a) Barrow (157°W, 71°N)

(b) Alert (62°W, 83°N)

(c) Zeppelin (12°E, 79°N)

(d) Halley (26°W, 76°S)
Arctic BC:

As we found in the Berkeley mtg, MAM4 is the critical thing.
Code Changes

• Add configuration option “trop_mam4”
• Merge the code changes to CAM5.2
Summary

- MAM4 reproduces BC and POM simulations from MAM7 with an increase in computer time by ~10%
- MAM4 (and MAM7) significantly increase (and improve) BC concentration in Arctic compared to MAM3
- The remaining underestimation of BC concentration in Arctic in MAM4 is very likely due to wet scavenging by precipitation and/or emission