Aerosol module of CAM4-Oslo linked with Mozart

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Overview

- CAM-Oslo aerosol scheme
- Comparison with other aerosol schemes
- Coupling CAM-Oslo with Mozart gas-phase chemistry
- Results
- Conclusions - final remarks
CAM-Oslo / NorESM

CAM2, CAM3, CAM4, ...
  ▶ Microphysics
  ▶ Aerosols

NorESM: based on CCSM-4
  ▶ atmosphere: CAM4-Oslo (Oslo) (1.9° x 2.6°, 26 levels)
  ▶ land model: CLM
  ▶ sea ice: CICE
  ▶ land ice:
    ▶ ocean model: MICOM (Bergen) (1° x 1°, 53 levels)

UiO, UiB, Met.no
Contribution to CMIP5
## Aerosols in CAM-Oslo

### Aerosol modes

<table>
<thead>
<tr>
<th></th>
<th>Component (ac)</th>
<th>Radius [μm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SO4(n)</td>
<td>0.0118</td>
</tr>
<tr>
<td>2</td>
<td>BC(n)</td>
<td>0.0118</td>
</tr>
<tr>
<td>3</td>
<td>BC/OC(ni)</td>
<td>0.04</td>
</tr>
<tr>
<td>4</td>
<td>BC(ax)</td>
<td>0.1</td>
</tr>
<tr>
<td>5</td>
<td>SO4(na)</td>
<td>0.04</td>
</tr>
<tr>
<td>6</td>
<td>BC(a)</td>
<td>0.04</td>
</tr>
<tr>
<td>7</td>
<td>BC/OC(ai)</td>
<td>0.04</td>
</tr>
<tr>
<td>8</td>
<td>SO4(pr)</td>
<td>0.075</td>
</tr>
<tr>
<td>9</td>
<td>DU</td>
<td>0.22</td>
</tr>
<tr>
<td>10</td>
<td>DU</td>
<td>0.63</td>
</tr>
<tr>
<td>11</td>
<td>SS</td>
<td>0.022</td>
</tr>
<tr>
<td>12</td>
<td>SS</td>
<td>0.13</td>
</tr>
<tr>
<td>13</td>
<td>SS</td>
<td>0.74</td>
</tr>
</tbody>
</table>

### Remarks

- 13 log-normal modes, with fixed dry median radius; 20 aerosol tracers
- SO4 (aq)
- Number concentrations is a diagnostic based on mass
- An extension of CAM
Aerosols in Mozart

Aerosol modes

<table>
<thead>
<tr>
<th>SO4</th>
<th>BC1</th>
<th>BC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>OC1</td>
<td>OC2</td>
<td>SOA</td>
</tr>
<tr>
<td>DU1</td>
<td>DU2</td>
<td>DU3</td>
</tr>
<tr>
<td>SS1</td>
<td>SS2</td>
<td>SS3</td>
</tr>
<tr>
<td>NH4</td>
<td>(NH4)NO3</td>
<td></td>
</tr>
</tbody>
</table>

Remarks

- 16 aerosol tracers
- Aging of hydrophobic OC1 and BC1 to hydrophylc BC2 and OC2
# HAM-M7

Stier et al. (2005), Pozzoli et al. (2008)

- HAM-M7

## Aerosol types

<table>
<thead>
<tr>
<th>Radius [µm]</th>
<th>SO4</th>
<th>BC</th>
<th>OC</th>
<th>DU</th>
<th>SS</th>
<th>#</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insoluble</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.005 ≤ r ≤ 0.05</td>
<td>n</td>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.05 ≤ r ≤ 0.5</td>
<td>BC</td>
<td>OC</td>
<td></td>
<td>DU</td>
<td></td>
<td>n</td>
<td>r</td>
</tr>
<tr>
<td>r &gt; 0.5</td>
<td>DU</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n</td>
<td>r</td>
</tr>
<tr>
<td><strong>Soluble</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r ≤ 0.005</td>
<td>SO4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n</td>
<td>r</td>
</tr>
<tr>
<td>0.005 ≤ r ≤ 0.05</td>
<td>SO4</td>
<td>BC</td>
<td>OC</td>
<td></td>
<td></td>
<td>n</td>
<td>r</td>
</tr>
<tr>
<td>0.05 ≤ r ≤ 0.5</td>
<td>SO4</td>
<td>BC</td>
<td>OC</td>
<td>DU</td>
<td>SS</td>
<td>n</td>
<td>r</td>
</tr>
<tr>
<td>r &gt; 0.5</td>
<td>SO4</td>
<td>BC</td>
<td>OC</td>
<td>DU</td>
<td>SS</td>
<td>n</td>
<td>r</td>
</tr>
</tbody>
</table>

## Remarks

- 7 log-normal modes
- tracers: 18 for mass, 7 for number or radius
Role of aerosols in CAM-Oslo

**Role**

- **Primary emissions**
  - Aerosols
  - CCN → CDNC → Effect

- **Indirect emissions**
  - Aerosols
  - Precursor emissions
  - Secondary aerosol formation

**Physical transformations of the aerosols**

- Nucleation of SO4 aerosol
- Aging through condensation of H2SO4 on existing aerosols
- Coagulation
- Wet and dry deposition
Secondary aerosol formation in CAM-Oslo (1)

H2SO4 formation

- Model only 2 gas-phase species: DMS and SO2 (emissions, transport, chemistry with oxidants, deposition, ...)
- Prescribed oxidants as monthly mean 3D climatologies
  - O3
  - H2O2 (take into account replenishment)
  - OH (imposed daily cycle)
  - NO3
Secondary aerosol formation in CAM-Oslo (2)

Secondary organic aerosol (SOA) formation

- DMS $\rightarrow$ MSA $\rightarrow$ OC
- All other SOA emitted as primary organic carbon (POA)

Consequences

- No short time-scale variability of oxidants
- Same 3D oxidant climatologies in changing climate
- Same SOA-emission data set in changing climate
Modifications

Mozart → CAM-Oslo

- Include MSA and MSA-formation in Mozart and use this production in CAM-Oslo
- Use gas-phase H2SO4 and aqueous phase SO4 production from Mozart in CAM-Oslo
- Use SOA-formation from Mozart as source of OC in CAM-Oslo

CAM-Oslo → Mozart

- Use CAM-Oslo SO4 in NH4/NH4(NO3)/HNO3/NH3/SO4 equilibrium
- Use CAM-Oslo aerosol surfaces for heterogeneous reactions in Mozart
Results

Comparison

- Mozart
- CAM-Oslo
- CAM-Oslo coupled to Mozart gas-phase

Period

- 1990’s
- Only results for July

Emissions

- Differences between Mozart and CAM-Oslo
Sulphur cycle

DMS [ppt]  SO2 [ppt]  SO4 [ppt]

Mozart

CAM-Oslo

CAM-Oslo/Mozart
Organic matter

**Mozart**:

\[ 2 \times \text{OC1} + 2 \times \text{OC2} + \text{SOA} \text{ [ppb]} \]

**CAM-Oslo**:

\[ \text{POM} \text{ [ppb]} \]

**CAM-Oslo/Mozart**:

\[ \text{POM} \text{ [ppb]} \]
Heterogeneous chemistry (1)

Surface area density

- No nitrate available in CAM-Oslo

Uptake coefficient $\gamma$: Liao and Seinfeld [2005], Pozzoli et al. [2008]

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Aerosol</th>
<th>$\gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{N}_2\text{O}_5 \rightarrow 2 \text{HNO}_3$</td>
<td>$\text{SO}_4$</td>
<td>$f(RH, T)$</td>
</tr>
<tr>
<td></td>
<td>BC</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>$\text{OC}$</td>
<td>$f(RH)$</td>
</tr>
<tr>
<td></td>
<td>mineral dust</td>
<td>$f(RH)$</td>
</tr>
<tr>
<td></td>
<td>sea salt</td>
<td>$f(RH)$</td>
</tr>
<tr>
<td>$\text{NO}_3 \rightarrow \text{HNO}_3$</td>
<td>wet aerosols</td>
<td>0.001</td>
</tr>
<tr>
<td>$\text{NO}_2 \rightarrow 0.5 \text{HNO}_3 + 0.5 \text{HNO}_2$</td>
<td>wet aerosols</td>
<td>0.0001</td>
</tr>
<tr>
<td>$\text{HO}_2 \rightarrow 0.5 \text{H}_2\text{O}_2$</td>
<td>wet aerosols</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Further specifications

- Wet aerosols: if $RH > 50\%$
- Hygroscopic growth is taken into account
- Internally mixed aerosols: which fraction of surface is covered by which aerosol type
Heterogeneous chemistry (2)

**Surface area density** [cm²/cm³]

**Impact on mixing ratios** \( \gamma_{N_2O_5} = 0.1 \)

- **N2O5 [pptv]**
- **NO3 [pptv]**
- **HO2 [pptv]**

**Impact on mixing ratios** \( \gamma_{N_2O_5} = f(RH, T) \)
Heterogeneous chemistry (3)

Impact on mixing ratios ($\gamma_{N_2O_5} = 0.1$)

O3 [ppbv]

Impact on mixing ratios ($\gamma_{N_2O_5} = f(RH, T)$)
SOA formation (1)

CAM-Oslo
- Standard emissions: 37.2 Tg/yr

Mozart
- Under 1850 conditions: 11.4 Tg/yr
- Under 1994-1998 conditions: 9.6 Tg/yr

Comment
- No SOA formation from isoprene in Mozart
SOA formation (2)

Mozart (9.45 Tg/yr)

CAM-Oslo (8.21 Tg/yr)
NH3/NH4/(NH4)NO3 equilibrium

Mozart

NH3 [ppt]  

NH4NO3 [ppt]  

NH4 [ppt]  

CAM-Oslo/Mozart
Conclusions - final remarks

Plans

- Longer simulations
- Quantify impact on AOD, indirect effect
- Move aerosols (processes) from CAM4-Oslo to Mozart

Other tests

- Taking into account aerosols in long-wave calculation
- \( \gamma = f(RH, T) \) for heterogeneous reactions
- Using nitrate aerosol for heterogeneous reactions
- Conversion DMS \( \rightarrow \) MSA, SO2
- Conversion MSA \( \rightarrow \) H2SO4, OM
Questions?