On-line Aerosols in the Oslo Version of CAM3: Some shortcomings

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“CAM-Oslo” extended from “CCM-Oslo”

- Basis: NCAR CAM3 extended with
  - aerosol lifecycling, production-tagged composition
  - Particle interactions with radiation
  - Particle interaction with clouds

From CCM-Oslo
(based on CCM3.2; used in AeroCom B):

- Sulphur and Black carbon
  (Iversen and Seland, 2002; Kirkevåg and Iversen, 2002; Kristjansson, 2002; Kristjansson et al., 2005)
- Particulate organic matter (Kirkevåg et al. 2005)

Major change to CCM-Oslo:

- Lifecycling of sea-salt and mineral aerosols
- Aitken size category included separately
- Numerous different combinations of internal mixing from condensation and coagulation
Size, optical properties and Cloud Condensation Nuclei from precalculated tables

Mass/specific extinction coeff.  
MEC = AOD/[ss-Column] (m²/g)
Both pure atmospheric simulations and climate equilibrium calculations coupled to slab ocean

Atmosphere off-line:
run for 5 years -
the last 3 are used for analysis

Equilibrium:
Up to 50 years simulations with first 10 years regarded as spin-up
Model Evaluation Summary

As most aerocom-models or better when compared to
- most standard observations at ground level,
- a few aircraft campaigns (all in Pacific Ocean)
- Modis and MISR Satellite and aeronet retrievals of AOD and Angstrom parameter
- Lidar vertical profiles

Some important concerns:
- Underestimations in tropical biomass burning regions
- Wintertime Arctic haze underestimated
- Very few particles in some remote regions (Pacific) (– error?)
- Slightly positive direct aerosol forcing;
  - practically unsensitive to many uncertain assumptions
- Indirect effects almost cancel 1.63xCO2-warming
Total Aerosol Optical Depth, $\tau_{550}$
AOD ($\tau_{550}$), anthrop. SO4, OC and BC
Increment from Pre-industrial to aerosolB (2000)
(B - Pre)

CAM-Oslo
DRF (Wm\(^{-2}\)) due to anthrop. SO4, OC and BC (aerocomB - Pre) CAM-Oslo

Sea-salt and dust prescribed

CCM-Oslo

TOA (-0.012)

Surface (-0.84)

TOA (0.036)

Surface (-1.12)
Cloud droplet number concentrations, \( \text{CDNC} \) (cm\(^{-3}\))

\[ \eta = 0.87 \]

\begin{align*}
\text{CCM-Oslo (Aerocom B)} & & \text{CAM-Oslo (Aerocom B)} \\
115 \text{ cm}^{-3} & (82 \text{ in Pre}) & 118 \text{ cm}^{-3} & (51 \text{ in Pre})
\end{align*}

\begin{table}
\begin{tabular}{|c|c|c|c|}
\hline
below ca. 870 hPa & CAM3, prescribed & CAM-Oslo, Diagnostic & Observations (Seinfeld and Pandis, 1997; Ghan et al., 1997) \\
\hline
Marine & \sim 150 & \sim 5 - 200 & \sim 20 - 200 \\
& \sim 75 (sea-ice) & & \\
\hline
Continental & \sim 200 - 400 & \sim 20 - 1000 & \sim 100 - 1000 \\
\hline
\end{tabular}
\end{table}
$\Delta T_{2m} (^\circ C)$ vs. $1.63 \times CO_2$ vs. anthropogenic aerosols

- $\Delta T_{2m}$: $-1.93^\circ C$
- $Bco2-B$: $1.97^\circ C$
- $B-Pre$: $-5.5\%$
- $\Delta$ Precipitation: $3.8\%$
- $Bco2-B$: $3.8\%$
- $B-Pre$: $-5.5\%$
Table 5: Experiments with CAM-Oslo run as an atmospheric GCM, testing the sensitivity to background droplet number concentrations (CDNC). Changes in liquid water path (LWP), effective cloud droplet radii as seen from satellite ($R_{\text{m.s.}}$: as in Kristjánsson, 2002), as well as the combined first and second indirect forcing by anthropogenic aerosols (since pre-industrial time) are global annual means.

<table>
<thead>
<tr>
<th>CDNC treatment</th>
<th>Change in LWP (g m$^{-2}$)</th>
<th>Change in $R_{\text{m.s.}}$ ($\mu$m)</th>
<th>$1^{\text{st}} + 2^{\text{nd}}$ Indirect Forcing (W m$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard CDNC</td>
<td>9.25</td>
<td>-1.41</td>
<td>-2.34</td>
</tr>
<tr>
<td>Standard CDNC + 15 cm$^{-3}$</td>
<td>5.09</td>
<td>-0.99</td>
<td>-1.36</td>
</tr>
</tbody>
</table>

**STD CDNC**

Anthropogenic change in SWCF (W/m$^2$)

**STD CDNC + 15 cm$^{-3}$**

Anthropogenic change in SWCF (W/m$^2$)
What’s missing?

- Improved cloud droplet budgets
  - Storelvmo et al (2006), based on droplet scheme of Ghan and Abdul-Raszak et al, reduced indirect effect from -1.1 to -0.1 W m$^{-2}$

- Ice-cloud effects

- Nitrate aerosols

- Primary aerosols:
  - Non-desert, dust-producing areas underestimated
  - No primary biological particles
Thank You
Aerosol optical depth and direct radiative forcing:

<table>
<thead>
<tr>
<th>Exp.</th>
<th>AOD (B)</th>
<th>AOD (B) SO4</th>
<th>AOD (B) POM</th>
<th>AOD (B) BC</th>
<th>AOD (B) Sea-salt</th>
<th>AOD (B) Dust</th>
<th>DRF (B-Pre) (W/m²)</th>
</tr>
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<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Surface</td>
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<td>TOA,</td>
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<tr>
<td>E1</td>
<td>0.138</td>
<td>0.0238</td>
<td>0.0217</td>
<td>0.0018</td>
<td>0.0704</td>
<td>0.0203</td>
<td>-1.13</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>0.036</td>
</tr>
<tr>
<td>E2</td>
<td>0.136</td>
<td>0.0205</td>
<td>0.0222</td>
<td>0.0018</td>
<td>0.0706</td>
<td>0.0206</td>
<td>-1.15</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.080</td>
</tr>
<tr>
<td>E3</td>
<td>0.107</td>
<td>0.0244</td>
<td>0.0224</td>
<td>0.0019</td>
<td>0.0375</td>
<td>0.0205</td>
<td>-1.15</td>
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<td></td>
<td>0.027</td>
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<tr>
<td>E4</td>
<td>0.140</td>
<td>0.0248</td>
<td>0.0212</td>
<td>0.0018</td>
<td>0.0716</td>
<td>0.0203</td>
<td>-1.12</td>
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<td>0.027</td>
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</tbody>
</table>

E1: Base run

E2: 75nm SO4 primary acc. mode $\rightarrow$ H2SO4 gas

E3: standard Aerocom sea-salt

E4: 0.1% ss_coarse re-allocated to ss_aitken
Acknowledgement and references

• Acknowledgement
  – The project is financed by the Norwegian Research Council through the project AerOzClim
  – The project has received support from NRC through a grant of computing time

• References
  – Iversen and Seland (2002) JGR 107 D24 4751;
  – Textor et al. (2005) ACP 5 8331-8420;
Lognormal externally mixed modes (Primary “Background”)  
Basis for Condensation and Coagulation

<table>
<thead>
<tr>
<th>modes</th>
<th>modal median radius (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SO_4(n)$, $BC(n)$</td>
<td>0.0118</td>
</tr>
<tr>
<td>$OC(Ait)$</td>
<td>0.04</td>
</tr>
<tr>
<td>$BC(ac)$</td>
<td>0.1 (&quot;fluffy&quot; fractal)</td>
</tr>
<tr>
<td>$BC(Ait)$</td>
<td>0.04</td>
</tr>
<tr>
<td>$OCBC(Ait)$</td>
<td>0.04</td>
</tr>
<tr>
<td>$SO_4(ac)$</td>
<td>0.075</td>
</tr>
<tr>
<td>MINERAL</td>
<td>0.22, 0.63</td>
</tr>
<tr>
<td>SEA-SALT</td>
<td>0.022, 0.13, 0.76</td>
</tr>
</tbody>
</table>

For internal mixtures involving Sulfate, OC and BC:
- $SO_4$ from condensation
- $SO_4$ from cloud processing
- BC from coagulation
- OC from coagulation

onto mode
all pre-existing particles (ex. BC(ac))
min. & ss. & Ait & a modes
min. & ss. modes
min. & ss. modes

These processes, the optical properties, and the Kohler growth
Are tabulated in CAM3, based on process specific aerosol concentrations
Total mass concentrations / ppm(mass)

Lowest model surface

Aerosol concentration ppm(mass)
Total number concentrations / cm\(^{-3}\)

Lowest model surface

Aerosol number concentration (N/cm\(^3\))