SP-CAM5 with CLUBB: progress and remaining issues

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The Multi-scale Modeling Framework (MMF)

Super-Parameterization (SP)
(Grabowski, 2001; Khairoutdinov and Randall, 2001)

- Conventional cloud parameterizations are replaced by CRMs
- MMFs are much faster than GCRMs
The MMF with aerosol-cloud interactions (PNNL-MMF)

CAM5 with modal aerosols

Two-moment microphysics

PNNL-MMF (Aerosol-MMF) (Wang et al., 2011a, GMD; 2011b, ACP; 2012, GRL)

CLUBB: a high-order turbulence/sub-grid cloud scheme (Golaz et al. 2002; Larson et al., 2012)

CRM cloud/precipitation statistics used for cloud processing of aerosols
CLUBB in MMF

- Low clouds have been underestimated in MMF simulations (4km grid-spacing)
- Improved turbulence/sub-grid cloud treatment is expected to improve the simulation of deep clouds and the transition from shallow to deep clouds as well
- CLUBB in MMF serves as an early test of CLUBB’s scale-aware capability
- CLUBB: assumed, dynamical PDF approach

\[ P = P(w, q_t, \theta_l) \]

\( w \), vertical velocity; \( q_t \), total water mixing ratio; \( \theta_l \), liquid water potential temperature
Porting the MMF (both aerosol and non-aerosol versions) into CAM5 trunk (SP-CAM5)

- This is supported by the NSF/DOE through two EaSM projects, and led by Cheryl Craig and Andrew Gettelman at NCAR
- The PNNL-MMF (based on the tag cam3_6_26) has been merged into a most recent CAM5 tag (cam5_2_09)
- SPCAM has been merged with CESM1.1.1, and the SPCAM branch of CESM1.1.1 will be released in weeks
- It includes two compsets:
  - F_2000_SPCAM_sam1om1 (single-moment, non-aerosol)
  - F_2000_SPCAM_m2005 (double-moment, aerosol)
Single-moment (sam1mom) vs. double-moment microphysics (m2005) (No CLUBB, at 1.9x2.5 degree)

<table>
<thead>
<tr>
<th></th>
<th>Sam1mom (MMF)</th>
<th>M2005 (MMF)</th>
<th>CAM5</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWP (g/m²)</td>
<td>87</td>
<td>55</td>
<td>48</td>
<td>50-87</td>
</tr>
<tr>
<td>IWP (g/m²)</td>
<td>47</td>
<td>11</td>
<td>16</td>
<td>10-65</td>
</tr>
<tr>
<td>SWCF (W/m²)</td>
<td>-52</td>
<td>-50</td>
<td>-50</td>
<td>-46 to -53</td>
</tr>
<tr>
<td>LWCF (W/m²)</td>
<td>28</td>
<td>27</td>
<td>22</td>
<td>27-31</td>
</tr>
<tr>
<td>PRECT (mm/day)</td>
<td>2.85</td>
<td>2.82</td>
<td>2.95</td>
<td>2.61</td>
</tr>
<tr>
<td>CLDTOT (%)</td>
<td>52.1</td>
<td>51.2</td>
<td>62.7</td>
<td>65-75</td>
</tr>
</tbody>
</table>
Improved low cloud simulations with CLUBB (at 4x5 degree)

- sam1mom: 33.2%
- m2005: 31.9%
- sam1mom+CLUBB: 42.3%
- m2005+CLUBB: 40.8%
## High clouds and deep convection in m2005

<table>
<thead>
<tr>
<th>Metric</th>
<th>sam1mom CLUBB (no clubb)</th>
<th>M2005 CLUBB (no clubb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IWP (g/m2)</td>
<td>52 (47)</td>
<td>7 (11)</td>
</tr>
<tr>
<td>CLDHGH (%)</td>
<td>24 (24)</td>
<td>21 (28)</td>
</tr>
<tr>
<td>LWCF (W/m2)</td>
<td>30 (28)</td>
<td>22 (27)</td>
</tr>
<tr>
<td>Aerosol optical depth (AOD)</td>
<td></td>
<td>0.06 (0.13)</td>
</tr>
<tr>
<td>Black carbon burden (Tg/yr)</td>
<td></td>
<td>0.09 (0.16)</td>
</tr>
<tr>
<td>Wet removal from convective clouds (%)</td>
<td></td>
<td>12 (34)</td>
</tr>
</tbody>
</table>
Sensitive to the microphysical coupling for deep clouds in SAM_CLUBB (ARM9707 case over SGP site, 16 4-km CRM columns)

Ice water content (g/kg)

Droplet freezing rate (g/kg/day)
Variance of total water: resolved variance is too weak, while variance from CLUBB is strong.
Summary and Future work

- A next generation MMF model has been built to simulate multi-scale interactions between aerosols, clouds, and precipitation.

- This MMF model has been ported into a most recent tag of CAM5 (cam5_2_09).

- SPCAM branch of CESM1.1.1 will be released to the public in weeks.

- Further work is needed to improve the SPCAM simulations with CLUBB: time evolution of budget terms; resolution dependence; applying UQ to quantify the parameter dependence of CLUBB.