Coupling CAM with a High-Order Turbulence Closure

Peter Bogenschutz¹, Andrew Gettelman¹, Hugh Morrison¹, Vincent Larson², David Schannen², Nate Meyer², Cheryl Craig¹

¹National Center for Atmospheric Research, Boulder, CO
²University of Wisconsin, Milwaukee, WI

CESM Workshop, AMWG Session. June 20, 2012
Current CAM5 Physics

- Boundary Layer (Bretherton)
- Deep Convection (ZM)
- Shallow Convection (Park)
- Cloud Macrophysics (Park)
- Microphysics (MG)
- Radiation
- Aerosols
Current CAM5 Physics

- Boundary Layer (Bretherton)
- Deep Convection (ZM)
- Shallow Convection (Park)
- Cloud Macrophysics (Park)
- Microphysics (MG)
- Radiation
- Aerosols
Current CAM5 Physics

- Boundary Layer (Bretherton)
- Deep Convection (ZM)
- Shallow Convection (Park)
- Cloud Macrophysics (Park)
- Microphysics (MG)
- Radiation
- Aerosols
Current CAM5 Physics

- Boundary Layer (Bretherton)
- Deep Convection (ZM)
- Shallow Convection (Park)
- Cloud Macrophysics (Park)
- Microphysics (MG)
- Radiation
- Aerosols
Current CAM5 Physics

- Boundary Layer (Bretherton)
- Deep Convection (ZM)
- Shallow Convection (Park)
- Cloud Macrophysics (Park)
- Microphysics (MG)
- Radiation
- Aerosols
Current CAM5 Physics

- Boundary Layer (Bretherton)
- Deep Convection (ZM)
- Shallow Convection (Park)
- Cloud Macrophysics (Park)
- Microphysics (MG)
- Radiation
- Aerosols

CLUBB
CLUBB

- CLUBB = Cloud Layers Unified By Binormals
- First developed by Golaz et al. (2002), maintained by University of Wisconsin Milwaukee (Vincent Larson’s group)
- “Incomplete” third-order turbulence closure (predicting 9 second and third order moments), centered around a trivariate assumed double gaussian PDF
- Concurrently undergoing implementation into AM3 as part of CPT initiative
- Should provide unified treatment of PBL and shallow convection
- Goal is for better representation of boundary layer processes and aerosol effects
• UW PBL (Bretherton and Park), UW Shallow convection (Park and Bretherton), and Cloud macrophysics (Park) are all turned off

• CLUBB is warm cloud parameterization, therefore still strip out a subroutine from Park macrophysics to compute ice cloud fraction

• Detrainment of liquid water into environment still computed per Park macrophysics for deep convection detrained liquid

• CLUBB called after deep convection & before MG, currently with a 5 minute sub-timestep

• Predicted vertical velocity variance passed from CLUBB to MG for SGS vertical velocity variance needed for aerosol activation

• CLUBB drives the MG microphysics scheme (for both stratified and shallow convective cloud)
CAM-CLUBB Status

- Produces a credible climate simulation
- Skill scores are competitive with CAM5
- Computational increase is 4% over CAM5
- At the cusp of beginning to perform science experiments (i.e. AIE, climate sensitivity, etc.)
- Currently in code review to get on trunk, as an option
  - to run CAM-CLUBB just add “-clubb_sgs” to configure line
Single Column Testing


• SCAM-CLUBB tested on many boundary layer & deep convective regimes
  - Cumulus: RICO, BOMEX, ARM_CC
  - Stratocumulus: DYCOMS2RF-01, DYCOMS2RF-02, ATEX
  - Deep convection: GATE, TOGA, ARM97
  - Mixed phase: Storm tracks IOP

• Results show less sensitivity to vertical resolution and timestep compared to CAM5.

• Improved simulation of transitional and shallow convective regimes.
ATEX - Cumulus Under a Strong Inversion

(a) Cloud Fraction

(b) Cloud Liquid Water Mixing Ratio

(c) SGS Vertical Velocity

(d) Cloud Number Concentration
Global Results

- Have been performing two-year testing simulations with the aim of achieving a credible climate simulation

- Testing at both 1 and 2 degree horizontal res, fv dynamical core

- Unless otherwise stated, results shown are from 1 degree simulations

- Julio Bacmeister and John Truesdale have run CAM-CLUBB with SE dycore at 0.25 degree res

- Have run CAM-CLUBB with ZM turned off, results (while preliminary) are encouraging
Shortwave Cloud Forcing

CAM5

TOA SW cloud forcing
mean = -48.79 W/m²

CERES-EBAF

TOA SW cloud forcing
mean = -47.07 W/m²

ANN

Min = -173.25 Max = -0.11

CAM-CLUBB

TOA SW cloud forcing
mean = -49.17 W/m²

CERES-EBAF

TOA SW cloud forcing
mean = -47.07 W/m²

ANN

Min = -147.79 Max = -0.20

cam5_1degcosp - CERES-EBAF

mean = -1.72 rmse = 14.38 W/m²

camclubb51_F2000_5_1deg - CERES-EBAF

mean = -2.10 rmse = 13.18 W/m²

Min = -95.98 Max = 55.65

Min = -71.13 Max = 64.09

Tuesday, June 19, 12
Aerosol Indirect Effect

- Preliminary AIE experiment performed with CAM-CLUBB
- Ran CAM5 and CAM-CLUBB for two years at 1 degree for both present day (PD) and preindustrial (PI) emissions

<table>
<thead>
<tr>
<th></th>
<th>CAM5</th>
<th>CAM-CLUBB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ SWCF</td>
<td>-1.6 W/m²</td>
<td>-1.8 W/m²</td>
</tr>
<tr>
<td>Δ LWCF</td>
<td>0.5 W/m²</td>
<td>0.4 W/m²</td>
</tr>
<tr>
<td>Δ(SWCF + LWCF)</td>
<td>-1.1 W/m²</td>
<td>-1.4 W/m²</td>
</tr>
<tr>
<td>RFP</td>
<td>-1.4 W/m²</td>
<td>-1.6 W/m²</td>
</tr>
</tbody>
</table>

- Reasonable results for a preliminary investigation. Detailed analysis is needed
Simulations at 0.25 degree, HOMME
(courtesy Julio Bacmeister and John Truesdale)
Summary & Future Plans

• CAM-CLUBB is alive and competitive with CAM5
• Evidence that CAM-CLUBB may provide a more “scale aware” solution with increasing resolution
• Testing of longer simulations is needed
• Detailed analysis/validation of low clouds, precipitation, AIE, etc. is planned
• Doing science with CAM-CLUBB (aerosol effects, climate sensitivity)
• Move on to sub-columns for microphysics
• Fully coupled CESM simulations with CAM-CLUBB