CAM standalone development simulations

Cécile Hannay, Rich Neale, Andrew Gettelman, Sungsu Park, Joe Tribbia, Peter Lauritzen, Andrew Conley, Hugh Morrison, Phil Rasch, Steve Ghan, Xiaohong Liu, and many others

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Outline

• The evolution of CAM

• Status of the model at the last AWMG meeting

• Development since the last AWMG meeting

• AMIP simulations

• Conclusions
# CAM Evolution

<table>
<thead>
<tr>
<th>Release</th>
<th>2004</th>
<th>2007</th>
<th>April 2010</th>
<th>June 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>CAM3 (L26)</td>
<td>CAM3.5 (L26)</td>
<td>CAM4/Track1 (L26)</td>
<td>CAM5/Track5 (L30)</td>
</tr>
<tr>
<td>Boundary Layer</td>
<td>Holtslag and Boville  (93)</td>
<td>Holtslag and Boville</td>
<td>Holtslag and Boville</td>
<td>UW Diagnostic TKE Bretherton et al. (09)</td>
</tr>
<tr>
<td>Shallow Convection</td>
<td>Hack (94)</td>
<td>Hack</td>
<td>Hack</td>
<td>UW TKE/CIN Park et al. (09)</td>
</tr>
<tr>
<td>Deep Convection</td>
<td>Zhang and McFarlane (95)</td>
<td>Zhang and McFarlane</td>
<td>Zhang and McFarlane Neale et al., Richter and Rasch (08) mods.</td>
<td>Zhang and McFarlane Neale et al., Richter and Rasch mods.</td>
</tr>
<tr>
<td>Radiation</td>
<td>CAMRT (01)</td>
<td>CAMRT</td>
<td>CAMRT</td>
<td>RRTMG Iacono et al. (2008)</td>
</tr>
<tr>
<td>Aerosols</td>
<td>Bulk Aerosol Model (BAM)</td>
<td>BAM</td>
<td>BAM</td>
<td>Modal Aerosol Model (MAM) Ghan et al. (2010)</td>
</tr>
<tr>
<td>Dynamics</td>
<td>Spectral</td>
<td>Finite Volume (96,04)</td>
<td>Finite Volume</td>
<td>Finite Volume</td>
</tr>
</tbody>
</table>

*Courtesy: Rich Neale*
Development status at Breckenridge

- **CAM4 (Track 1)**: Frozen model
- **CAM5 (Track 5)**: Still in development
  - standalone simulation: competitive with CAM4 (Track 1)
  - coupled simulation: worse than CAM4 (Track 1)
    - too low clear-sky OLR and LWCF
    - sea-ice too thin
    - excessive precipitation over tropical land
      => affects river run-off
    - aerosol indirect effect: ~1.5 W/m²
    - no big volcanoes eruption
What happened since Breckenridge?

Since Breckenridge
• CAM5 (Track 5): 200 CAM standalone experiments

Some highlights of the accomplishments
• Improved parameterization of autoconversion
• Improved ice microphysics
• Turned on turbulent mountain stress parameterization
• Included the effect of big volcanoes
• Improved low cloud over the Arctic
• 4th-order divergence damping
  + Laplacian near model top
• New emission datasets for aerosols
Autoconversion parameterization

- Convective precipitation is controlled by the **autoconversion rate** (~ process of coalescence that leads to the formation of new rain drops)

- Precipitation formation is **easier over ocean** than land (over land: more CCN => smaller droplet => less rain)

- Improved parameterization
  Autoconversion efficiency: $c_0(\text{ocn}) > c_0(\text{Ind})$
Tropical precipitation, DJF

New parameterization of autoconversion reduces the excessive land precipitation

Same autoconversion rate over land and ocean

Autoconversion rate weaker over land
Improvement of the ice microphysics

Features
• **Reduces the nucleation** of ice crystal
• **Freezes** supercooled rain at -5°C

Impact
• Better **ice size and concentration**
• Increases **high cloud fraction**
• Improve the **spring sea-ice**


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**Total cloud fraction**

**Cloud top: ice number**

**Cloud top: ice re**

© Courtesy: Andrew Gettelman
Sea-level pressure, ANN

Turned **on** the **Turbulent Mountain Stress (TMS)** parameterization (\(~ take into account mountain roughness\)
Includes big volcanoes impact

- Use prescribed volcanic aerosol mixing ratio

- June 1991: Eruption of the volcano Pinatubo
  - warms stratosphere by 3 K (absorbs upwelling LW)
  - cools troposphere by a few 0.1 K (reflects SW)
Simulations

Model versions
- CAM4 (Track 1)
- CAM5 (Track 5)

Run settings
- AMIP runs with observed SSTs
- Horizontal resolution: finite volume 1.9x2.5 degrees
- Vertical resolution: CAM4 (Track 1): 26 levels
  CAM5 (Track 5): 30 levels

Comparison with observations
- 25-years climos (1978-2002)
**Shortwave cloud forcing (SWCF), ANN**

\[ \text{SWCF} = \text{Net SW}_{\text{all sky}} - \text{Net SW}_{\text{clear sky}} \]

**Observations:** CERES-EBAF (Energy Balanced And Filled)

- **CAM4 (Track 1)**: Overestimates SWCF in the tropics
- **CAM5 (Track 5)**: More accurate SWCF
SWCF: CERES-EBAF versus ERBE

Impact of the observation dataset
- CAM3 <= ERBE
- CAM4 and beyond <= CERES-EBAF

Global SWCF, ANN
Longwave cloud forcing (LWCF), ANN

Underestimates LWCF in the mid-latitudes

Underestimates LWCF everywhere!
Global LWCF and OLR (W/m²)

Track 5 underestimates global LWCF by 10 W/m²!
Global LWCF and OLR (W/m²)

LWCF = OLR\textsubscript{all sky} – OLR\textsubscript{clear sky}

• Track 5 underestimates clear-sky OLR (and LWCF)
• New radiation code: RRTMG ⇔ CAMRT
• Problem in clear sky longwave is likely due to the vertical distribution of T and q
• Difference in “clear-sky” definition
Both versions of CAM are too moist compared to observations and reanalysis.

CAM5 (Track5): improvement since Breckenridge.
Tropical precipitation: DJF

Over ocean:
- Same precipitation pattern in CAM4 (Track 1) and CAM5 (Track 5)
- Same deep convection scheme

Excessive land precipitation

Improved land precipitation
(land autoconversion efficiency)
SWCF in stratocumulus decks: JJA

**CERES-EBAF**

| TOA SW cloud forcing | mean = -45.03 | W/m² |

- Improved SWCF in **stratocumulus** regions
- Due to the new PBL scheme

**CAM4 (Track 1)**

| TOA SW cloud forcing | mean = -54.35 | W/m² |

**CAM5 (Track 5)**

| TOA SW cloud forcing | mean = -47.62 | W/m² |
PBL height: JJA

CAM4 (Track 1)

CAM5 (Track 5)

CAM5 (Track 5) - CAM4 (Track 1)

- Improved PBL height in stratocumulus regions
- Entrainment of dry air at the top of the cloud => increase PBL height
Taylor diagrams

condense information about variance and RMSE of a particular model run when compared with observations

<table>
<thead>
<tr>
<th></th>
<th>RMSE</th>
<th>Bias</th>
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</thead>
<tbody>
<tr>
<td>CAM3.5</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>CAM4</td>
<td>1.01</td>
<td>1.15</td>
</tr>
<tr>
<td>(Track1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAM5</td>
<td>0.89</td>
<td>1.18</td>
</tr>
<tr>
<td>(Track5)</td>
<td></td>
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</tbody>
</table>
### Correlation: Space-Time

<table>
<thead>
<tr>
<th>cor coef: Space-Time</th>
<th>CAM3.5: cam3_5_fv1.9x2.5</th>
<th>CAM5 (Track 5): f40_amip_t5_02b</th>
<th>CAM4 (Track 1): f40_amip_t1_01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level Pressure (ERA40)</td>
<td>0.949</td>
<td>0.967</td>
<td>0.953</td>
</tr>
<tr>
<td>SW Cloud Forcing (CERES2)</td>
<td>0.707</td>
<td>0.726</td>
<td>0.706</td>
</tr>
<tr>
<td>LW Cloud Forcing (CERES2)</td>
<td>0.820</td>
<td>0.832</td>
<td>0.799</td>
</tr>
<tr>
<td>Land Rainfall (30N-30S, GPCP)</td>
<td>0.785</td>
<td>0.832</td>
<td>0.775</td>
</tr>
<tr>
<td>Ocean Rainfall (30N-30S, GPCP)</td>
<td>0.802</td>
<td>0.831</td>
<td>0.793</td>
</tr>
<tr>
<td>Land 2-m Temperature (Willmott)</td>
<td>0.876</td>
<td>0.874</td>
<td>0.873</td>
</tr>
<tr>
<td>Pacific Surface Stress (5N-5S, ERS)</td>
<td>0.872</td>
<td>0.896</td>
<td>0.875</td>
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<tr>
<td>Zonal Wind (300mb, ERA40)</td>
<td>0.967</td>
<td>0.974</td>
<td>0.967</td>
</tr>
<tr>
<td>Relative Humidity (ERA40)</td>
<td>0.900</td>
<td>0.924</td>
<td>0.895</td>
</tr>
<tr>
<td>Temperature (ERA40)</td>
<td>0.912</td>
<td>0.933</td>
<td>0.918</td>
</tr>
</tbody>
</table>

Green means better  
Red means worse
Conclusions (1): CAM development since Breckenridge

CAM4 (Track 1): Frozen model

CAM5 (Track 5): Improvements include

- Improved ice microphysics => better ice # and Re
- autoconversion = f(Ind, ocn) => better land precip
- Turned on turbulent mountain stress => better SLP
- Included the effect of big volcanoes
Conclusions (2): 25-year AMIP simulations

**CAM4 (Track 1)**

- overestimates SWCF in the tropics
- underestimates LWCF in mid-latitude
- excessive precipitation over land
- poor representation of *stratocumulus* deck

**CAM5 (Track 5)**

- better overall score than CAM4 (Track 1)
- better SWCF in the tropics
- worse clear sky OLR and LWCF
- better tropical land precipitation
- improved *stratocumulus* deck (and PBL height)
Conclusions (3): what’s next?

In CAM5 (Track 5)

- improve precipitation
- clear sky OLR and LWCF
- indirect effect