CAM standalone development simulations

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Thanks to: Mat Rothstein, and John Truesdale

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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
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<th>Release</th>
<th>2004</th>
<th>2007</th>
<th>April 2010</th>
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<tr>
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<td><strong>CAM4/Track1 (L26)</strong></td>
<td><strong>CAM5/Track5 (L30)</strong></td>
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<tr>
<td>Boundary Layer</td>
<td>Holtslag and Boville (93)</td>
<td>Holtslag and Boville</td>
<td>Holtslag and Boville</td>
<td>UW <strong>Diagnostic TKE</strong> Bretherton et al. (09)</td>
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<tr>
<td>Shallow Convection</td>
<td>Hack (94)</td>
<td>Hack</td>
<td>Hack</td>
<td>UW <strong>TKE/CIN</strong> Park et al. (09)</td>
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<td>Deep Convection</td>
<td>Zhang and McFarlane (95)</td>
<td>Zhang and McFarlane</td>
<td>Zhang and McFarlane Neale et al. (08), Richter and Rasch (08) mods.</td>
<td>Zhang and McFarlane Neale et al., Richter and Rasch mods.</td>
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<td>Stratiform Cloud</td>
<td>Rasch and Kristjansson (98)</td>
<td>Rasch and K.</td>
<td>Rasch and K.</td>
<td>Morrison and Gettelman (08) <strong>Double Moment</strong></td>
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<td></td>
<td><em>Single Moment</em></td>
<td><em>Single Moment</em></td>
<td><em>Single Moment</em></td>
<td>Park Macrophysics <strong>Park Macrophysics</strong></td>
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<tr>
<td>Radiation</td>
<td>CAMRT (01)</td>
<td>CAMRT</td>
<td>CAMRT</td>
<td>RRTMG Iacono et al. (2008)</td>
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<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>
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<tr>
<td>Dynamics</td>
<td>Spectral</td>
<td>Finite Volume (96,04)</td>
<td>Finite Volume</td>
<td>Finite Volume</td>
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</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

**CMAP**

New parameterization of autoconversion reduces the excessive land precipitation

**CAM5 (Track 5) - CMAP**

Same autoconversion rate over land and ocean

**CAM5 (Track 5) - CMAP**

Autoconversion rate weaker over land
Improvement of the ice microphysics

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

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


Courtesy: Andrew Gettelman
Sea-level pressure, ANN

Turned on the Turbulent Mountain Stress (TMS) parameterization (~take into account mountain roughness)

NCEP

CAM5 (Track5)
TMS off

CAM5 (Track5)
TMS on

TMS improves the sea-level pressure
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
Longwave cloud forcing (LWCF), ANN

Underestimates LWCF in the **mid-latitudes**

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

Track5 underestimates global LWCF by 10 W/m²!
Global LWCF and OLR (W/m²)

LWCF = OLR_{all sky} – OLR_{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 (Track 5): 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

- Improved SWCF in stratocumulus regions
- Due to the new PBL scheme
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
condense information about variance and RMSE of a particular model run when compared with observations

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

<table>
<thead>
<tr>
<th>cor coef: Space-Time</th>
<th>CAM3.5</th>
<th>CAM5 (Track 5)</th>
<th>CAM4 (Track 1)</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>
</tr>
<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 $\Rightarrow$ better ice # and Re
- Autoconversion $= f(\text{Ind}, \text{ocn}) \Rightarrow$ better land precip
- Turned on turbulent mountain stress $\Rightarrow$ 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