Update on CAM and the AMWG: Recent activities and near-term priorities.

by the AMWG

OMWG meeting 21 January 2013
# The CAM family

<table>
<thead>
<tr>
<th>Model</th>
<th>CAM3 CCSM3</th>
<th>CAM4 CCSM4</th>
<th>CAM5 CESM1.0 (CESM1.0.3)</th>
<th>CAM5.2 CESM1.1</th>
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<tr>
<td><strong>Aerosols</strong></td>
<td>Bulk Aerosol Model</td>
<td>Bulk Aerosol Model BAM</td>
<td>Modal Aerosol Model Ghan et al. (2011)</td>
<td>Modal Aerosol Model Ghan et al. (2011)</td>
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<tr>
<td><strong>Dynamics</strong></td>
<td>Spectral</td>
<td>Finite Volume</td>
<td>Finite Volume</td>
<td>Spectral element</td>
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</table>

= New parameterization/dynamics
What’s in CAM5.2?

- New dynamical core (Spectral Element: SE)

- New topography for CAM-SE

- 6 bug fixes
  - Fix for the land scaling of dust
  - Fix to wet radius calculation in the modal_aero_wateruptake module.
  - Fix for the value for the Obukhov length used in dry deposition calculations.
  - Fix in zm_conv to fix some inconsistency in the initialization of moist static energy.
  - Fix in uw_shallow for the unreasonable concentration of some species in WACCM.
  - Mods in MAM to generalize the method for calculating pH value of cloud water.

  => Very little impact (25-year coupled run at FV-1deg)

- Tuning for CAM-SE (dust and stratocumulus)
Coupled simulations

CESM-CAM-FV 1 degree: 25 years

CESM-CAM-FV 2 degree: 25 years

CESM-CAM-SE ne30 (~1 deg): 25 years

similar to CESM1.0
⇒ bugfixes have small impact

Compared with FV
except for stratocumulus
Temperature biases

**CESM1.0**  FV 1 deg
mean = -0.13
RMSE = 0.97

**CESM1.1**  SE ne30
mean = 0.19
RMSE = 0.94
SWCF

CERES-EBAF
mean = -47.1

FV 1deg
mean = -47.5

Future development:
Change in vertical advection of $T$
Precipitation

GPCP
mean = 2.67

FV 1 deg
mean = 3.06

SE ne30
mean = 3.10
Taylor diagram

Reference Grids Used

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<thead>
<tr>
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<th>RMSE</th>
<th>Bias</th>
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<tr>
<td>CESM1.0 (FV 1 deg)</td>
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<tr>
<td>CESM1.1 (SE ne30)</td>
<td>0.794</td>
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- / +  Bias
\( \nabla \triangle \) >20%
\( \nabla \triangle \) 10-20%
\( \nabla \triangle \) 5-10%
\( \nabla \triangle \) 1-5%
○ ○ <1%

0 - Sea Level Pressure (ERAI)
1 - SW Cloud Forcing (CERES-EBAF)
2 - LW Cloud Forcing (CERES-EBAF)
3 - Land Rainfall (30N-30S, GPCP)
4 - Ocean Rainfall (30N-30S, GPCP)
5 - Land 2-m Temperature (Willmott)
6 - Pacific Surface Stress (5N-5S,ERS)
7 - Zonal Wind (300mb, ERAI)
8 - Relative Humidity (ERAI)
9 - Temperature (ERAI)
Current/near-term model development

• **Dynamics**
  - Lagrangian vertical transport (all variables)
  - Conservative Semi-LAgrangian Multi-tracer (CSLAM) advection
  - MPAS dycore and regional mesh refinement in CAM-SE

• **Resolution**
  - High resolution runs (0.25 and finer). Horizontal resolution dependence (climate change response).
  - Vertical resolution dependence (L30 -> L31, L60)

• **Diagnostics**
  - COSP cloud phase diagnostics
  - Refactored diagnostics package

• **Address systematic precipitation biases (see next slide)**
  - double ITCZ, Asian monsoon, summertime US rainfall
  - CAPT framework, high-resolution, UNICON, …

• **Documentation (CESMwide)**
  - Moving from latex file to web-based documentation
Near-term model development (moist physics/radiation)

- **Unified Convection (UNICON)**
  - unifies treatment deep + shallow

- **Cloud Layers Unified By Binormals (CLUBB):**
  - third-order turbulence closure centered around an assumed double Gaussian PDF
  - treatment for shallow+PBL+macrophysics

- **Consistent PDF-based macrophysics**

- **SP-CAM**: super-parameterization on branch

- **Next generation MG microphysics**
  - prognostic precipitation, mixed phase ice nucleation and convective microphysics

- **Aerosol scheme**
  - Prescribed Aerosol (BAM /MAM)
  - MAM4

- **Sub-columns infrastructure**
  - all schemes see the same sub-columns: consistency among processes
Physics framework in CAM5+

Single grid-column state

\[ \dot{q}_v, \dot{q}_l, \dot{q}_i \]

Convection
Macrophysics
Microphysics

Sub-Column Generator

Radiation

\[ \dot{d}(q_v, q_l, q_i) \]

Sub-Column Generator

\[ \dot{d}(q_v, q_l, q_i) \]

Cloud Mass = \[ \int s \cdot \text{PDF}(s) \, ds \]

Cloud Fraction = \[ \int \text{PDF}(s) \, ds \]

a) PDF
Gaussian

b) CLUBB
UnICON
Deep conv.
Microphysics

Deep conv.
Microphysics

UNICON
Macrophysics

Slide courtesy: Rich Neale

(More grid resolution/scale tolerant)
Timings on Yellowstone for CESM1.0.5
http://www.cesm.ucar.edu/models/cesm1.0/timing_cesm_1.0.5/

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<th>Timeful yrs/day</th>
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<th>Ind pes</th>
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NOTE:  
FV_2° 1850CN pe-hrs/yr=237  
T31 pe-hrs/yr=56  
FV_2° for Paleo and WACCM  

Low-res option
Timings on Yellowstone for CESM1.1

http://www.cesm.ucar.edu/models/cesm1.1/timing/

NOTE:
FV_1° 1850C5CN pe-hrs/yr=1650
ne30  pe-hrs/yr=2657

Spectral core no longer supported SCIENTIFICALLY (will be functionally)
Thanks
Extra slides
CAM-CLUBB

- CLUBB = Cloud Layers Unified by Bi-normals (third-order turbulence closure centered around an assumed double Gaussian PDF)
- Prognostic moments of the PDF: allows testing of physics ‘across scales’ and a way to drive sub-columns.
- CLUBB unifies treatment of shallow convection, PBL, and cloud macrophysics parameterizations
- CAM-CLUBB is a developmental release in CAM5.2
- Simulations currently equal metrics for CAM5. Some aspects are better, some are slightly worse (e.g.: SW Cloud Radiative Effects below). Still testing and exploring. Computational cost similar to CAM5.2
- Exciting new foundation for further experimentation

Slide courtesy: Peter Bogenschutz, Andrew Gettelman, Hugh Morrison, Vincent Larson, and Cheryl Craig
UNICON

- UNICON is a sub-grid vertical transport scheme by non-local asymmetric turbulent eddies and a scale-aware parameterization well harmonized with CAM5 moist turbulence scheme without double-counted transport.

- UNICON simulates all shallow-deep, dry-moist, and forced-free convections within a single framework in a seamless, consistent and unified way.

- UNICON simulates MJO and diurnal cycle of precipitation with improved climatologies.

- UNICON knows how to turn on-and-off MJO and diurnal cycle of precipitation. The key process controlling MJO and diurnal cycle of precip is the feedback among convective updraft, convective downdraft and meso-scale flows.

Lag-Correlation of PRECT (Color) and U850 (Line).

Slide courtesy: Sungsu Park
PDF-Based Stratiform Cloud Physics

- In *stratiform* regions, subgrid moisture variability typically follows a Gaussian.

- Consistent cloud fraction and mass can be computed via:

\[
\text{Cloud Fraction} = \int_{0}^{\infty} PDF(s) \, ds
\]

\[
\text{Cloud Mass} = \int_{0}^{\infty} s \cdot PDF(s) \, ds
\]
Microphysics Development: MG2

- Refactored code (Model independent code)

- Prognostic precipitation
  - Why? Improvements in process rates (like accretion) that impact cloud lifetime

- Activation fix from Caldwell

- Hail/Graupel (mixed) phase hydrometeors

- Use in convective clouds (strong updraft)
  - Probably means additional transport code

- Resulting MG2 code will ‘unify’ scheme with Morrison et al 2005 WRF code: maintain a single code for WRF and CESM

Slide courtesy: Andrew Gettelman
Sub-columns

- Sub-columns are a key conceptual method for physics ‘across scales’: as scale gets smaller, sources of variance decrease, and PDF narrows

- We prognose a PDF (‘macrophysics’)

- Total water and vertical velocity PDFs critical

- Sample the PDF generate consistent sub-columns (‘sub-column generator’)

- Use sub-columns for determining microphysics and radiation

- Some doubts remain: need to test the ideas

- Infrastructure also used for SP-CESM (embedded cloud model)

Slide courtesy: Andrew Gettelman