CESM Atmosphere Model Working Group Session
Wednesday, 21 June 2017
NCAR – Boulder, Colorado – Center Green Auditorium – Center Bay

Webcast: http://www.fin.ucar.edu/it/mms/cg-center-live.htm

1:30 p.m. Julio Bacmeister – Overview of CAM development for CESM2
1:45 p.m. Cecile Hannay – Where are we with the CESM2 coupled simulations?
2:00 p.m. Colin Zarzycki – Early investigations of climate extremes in variable-resolution CESM2 experiments
2:15 p.m. Alan Rhoades – A variable-resolution CESM case study of the comparative importance of model resolution and microphysics in a mountainous region
2:30 p.m. Guang Zhang – Adding stochasticity to the Zhang-McFarlane scheme in CAM5
2:45 p.m. Xue Zheng – Improving the representation of drizzling MBL clouds in climate models
3:00 p.m. Break
3:30 p.m. I-Kuan Hu – Radiative-convective equilibrium in single column CAM
3:45 p.m. Peter Lauritzen – Revisiting viscosity coefficients and topography in NCAR CAM-SE
4:00 p.m. Shaocheng Xie – The status of the ACME low- and high-resolution atmosphere model development
4:15 p.m. Hui Wan – Compressive sensing shows potential for atmosphere model emulation
4:30 p.m. Discussion
5:00 p.m. Adjourn

Julio Bacmeister, Rich Neale, Peter Caldwell, Christiane Jablonowski, Cecile Hannay, Andrew Gettelman
and many, many others!

AMP/CGD
National Center for Atmospheric Research
Boulder, Colorado
New co-chair

Rich Neale

2010

2017

EXIT
New co-chair

Julio Bacmeister

March 2017

June 2017
Up to #180 from around #125 in March
• Each “experiment” can have multiple cases, e.g. B1850, 20thC, AMIP …
Community Atmosphere Model, version 5 (CAM5)
Other recent changes in CAM not discussed previously

In before March meeting

- CLUBB supersaturation. Current version can leave supersaturation due to process ordering. Cleaning this up via *ad hoc* cloud formation led to large climate sensitivity (6K). We now simply allow supersaturation to occur.
- CAPETEN – ZM stops at **first** level of no-buoyancy (before was 5) ➔ better precipitation simulation mean and variability

Since March meeting

- Dust tuning ➔ significant decrease in clearsky SW 0.1-0.2 Wm$^{-2}$
Improvements in CAM6/CESM2
Skill Score (simulation: #125)

- General monotonic improvement from CESM1 (DJF/ANN)
- Large initial degradation in JJA mostly recovered
- Removing super-saturation -> improved skill, but high climate sensitivity
- Land model strongly impacts JJA score (new land at 118).
Precipitation (Annual) - AMIP

- Greatest success in IO/Monsoon region
- Reduced SPCZ
- Gain Pacific ITCZ bias
- Reduced in CAM6
- Largest improvement
Temperature (Annual) - AMIP

- Lower stratospheric ‘cold-pole’ problems see significant decrease (*Mountain waves?*)
- Polar near-surface, improved stable PBLs
- Tropics go warm, cold, warm, cold, colder, cold
- A response to continued changes to deep convection
Tropical Variability (Precipitation) - CESM

- Largest variation in MJO power
- Increased power and zonal wavenumber extent
Tropical Wave Variability - Precipitation

Madden Julian Oscillation

- Winter (1979-1999)
- Isolate wave wavenumber frequency regions
- Regional variance
- Significant increase in MJO activity
- Coupled much improved over AMIP for CAM6
Model looks pretty good ... ...
What happened???

- Dust tuning and land model changes led to significantly colder model. (these changes are not considered optional)
- CMIP6 emissions
• “bad” CMIP6 emissions contribute, but may not be the whole story
161 (1951-1970) – (1851-1870)

OCEAN: CORR= 1.00; DEV=1.01; RMSE= 2.56; BIAS= -0.06
LAND: CORR= 1.00; DEV=1.01; RMSE= 3.52; BIAS= -0.33
GLOBAL: CORR= 1.00; DEV=1.01; RMSE= 2.64; BIAS= -0.31

151 (1951-1970) – (1851-1870)

OCEAN: CORR= 1.00; DEV=1.00; RMSE= 2.48; BIAS= 0.37
LAND: CORR= 1.00; DEV=1.00; RMSE= 3.29; BIAS= -0.67
GLOBAL: CORR= 1.00; DEV=1.00; RMSE= 2.74; BIAS= 0.06

ANN RESTOM

Community Earth System Model

CESM Workshop, Boulder CO

Wednesday, August 2, 2017
What else can we do???

• Patterns of RESTOM change suggestive of AIE

• 2nd aerosol indirect effect (lifetime effect): more droplets ➞ slower autoconversion ➞ thicker longer-lived clouds
  – Poorly constrained. Some obs (e.g. in Hawaiian volcanic plumes) suggest is not very big

• Surgically-remove 2nd AIE by overwriting drop number input to autoconversion subroutine
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- 2nd aerosol indirect effect (lifetime effect): more droplets ➔ slower autoconversion ➔ thicker longer-lived clouds
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- Surgically-remove 2nd AIE by overwriting number input to autoconversion subroutine
PDFs of instantaneous droplet # density
(accumulated every 25hrs over 3 months)

- Droplet number density going into autoconversion subroutine “pre-processor” is overwritten with a constant number density of n=15 cm\(^{-3}\)
- Does not impact any other aspect of simulation e.g. radiation ...

Might be “tiny” clouds – under investigation
<table>
<thead>
<tr>
<th>New Land ‘Older’ Land</th>
<th>Run (all 2000-1850 emis)</th>
<th>dAOD</th>
<th>dSRF</th>
<th>dTOA</th>
<th>dSWClr</th>
<th>dSWCF</th>
<th>dLWCF</th>
<th>dLWP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CMIP5 (125)</td>
<td>+0.014</td>
<td>-1.20</td>
<td>-1.22</td>
<td>-0.3</td>
<td>-1.5</td>
<td>+0.4</td>
<td>8.1%</td>
</tr>
<tr>
<td>B</td>
<td>CMIP6orig</td>
<td>+0.013</td>
<td>-1.59</td>
<td>-1.60</td>
<td>-0.2</td>
<td>-1.8</td>
<td>+0.4</td>
<td>9.8%</td>
</tr>
<tr>
<td>C</td>
<td>CMIP6 (mod)</td>
<td>+0.019</td>
<td>-1.42</td>
<td>-1.42</td>
<td>-0.2</td>
<td>-1.9</td>
<td>+0.6</td>
<td>8.4%</td>
</tr>
<tr>
<td>D</td>
<td>CAM157 PD-PI (C6mod)</td>
<td>+0.012</td>
<td>-1.69</td>
<td>-1.70</td>
<td>-0.22</td>
<td>-2.1</td>
<td>+0.5</td>
<td>10.9%</td>
</tr>
<tr>
<td>E</td>
<td>CAM157 PD-PI (C5)</td>
<td>+0.014</td>
<td>-1.61</td>
<td>-1.61</td>
<td>-0.17</td>
<td>-1.6</td>
<td>+0.1</td>
<td>8.8%</td>
</tr>
<tr>
<td>F</td>
<td>CAM157 PD-PI (C6fin)</td>
<td>+0.014</td>
<td>-1.40</td>
<td>-1.36</td>
<td>-0.28</td>
<td>-1.7</td>
<td>+0.5</td>
<td>9.0%</td>
</tr>
<tr>
<td>G</td>
<td>CAM169 PD-PI (C6fin)</td>
<td>+0.012</td>
<td>-0.93</td>
<td>-0.92</td>
<td>-0.14</td>
<td>-1.1</td>
<td>+0.3</td>
<td>1.2%</td>
</tr>
<tr>
<td>H</td>
<td>CAM169+ PD-PI (C6fin)</td>
<td>+0.010</td>
<td>-0.70</td>
<td>-0.79</td>
<td>-0.09</td>
<td>-1.2</td>
<td>+0.4</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

Emissions: C5 = CMIP5, C6orig = default vertical, C6mod = 157, lower SO2, C6fin = 161+ (POM fix, all anthro SO2 lower). Note: Not the new CMIP6
Immediate plan

- Re-running simulations with “good” CMIP6 emissions
  - Reasons for optimism: corrected aerosol on sea-ice albedo, land albedos ...

- Prepared to run with fixed $N_{drop}$ autoconversion
  - Retuning required
Immediate plan

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Breaking News:
*NCAR’s CMIP6 timetable has been put on hold.*
*Understanding AIE is top priority*
*Accretion? Cloud macrophysics/subgrid variability?*
• Despite preceding discussion CAM physics have been nearly unchanged since last fall
**Plans for Release**

- CESM2.0 (August?)
  - FV-latlon (1°) Scientifically supported B1850, BHIST, F2000, FHIST compsets
  - CAM-SE codebase onto trunk
  - **New CIME-based SCAM.** Full CESM-column.
    - Limited forcing datasets
    - Still uses Eul dycore vertical advection
    - Needs resources
  - Simple models (had their own session)

- CESM2.x (August+N months)
  - Compsets for CAM-SE (ne120 and ne30) CONUS-grid?
• **SE**
  – Code on trunk soon (week[s])
  – Science compsets/forcing data in development
  – Dry-mass vertical coordinate

• **MPAS**
  – Work ongoing to integrate MPAS into CESM so that it can be supported in CESM
  – Evaluation of climate is on-going

• **FV3**
  – Integration into CESM has begun
• Time to think about new physics. NOW is the time to contribute
  – e.g. Guang Zhang – *new* stochastic ZM convection
  – Forecast based techniques for evaluation?? Refined grids

• Resolution: *vertical* as well as horizontal. Raise model top?

• Remaining biases
  – US midwest warm bias –missing MCSs
  – Double-ITCZ
  – Southern ocean wind stress

• More attention to interactions with other components
Will there be a CMIP7?
More emphasis on sub-seasonal, seasonal decadal forecasting?
Questions?
Community Atmosphere Model, version 6 (CAM6)
CESM2 Simple Models

“Out-of-the-box” support for:

- Aquaplanet configurations (Medeiros et al., 2016; …)
- Idealized moist baroclinic wave (Ullrich et al., 2014)
- Held-Suarez forcing (Held and Suarez, 1994)
- Kessler Microphysics (Kessler, 1969)
- Toy terminator chemistry (Lauritzen et al., 2015)
- Moist Held-Suarez (Reed and Jablonowski, 2012; …)

New version of SE

- Dry mass vertical coordinate
- Condensate loading
- “Correct” moist energy
- Optional CSLAM transport
- Separate physics grid (CSLAM grid, coarser or finer finite-volume grid in each element)
- Massive code cleanup
Regional Grid Refinement: US

High Resolution precipitation field. Variable resolution grid (0.25° fine mesh)
Low intensity in low resolution region, higher intensity in high resolution region
Variable resolution grid (1°>0.5°>0.25° fine mesh)
20-day hindcasts: Day-1 hindcast below (9 Jan, 2010)
Question: Which region is the most for the MJO
Ridge orientation determines wave orientation and direction of drag force not low-level wind.

Ridge height estimate is based on min and max elevations of mean ridge profile not based on subgrid variance.

Parameterization allows flow around obstacles – *form drag* - as well as “downslope wind” high-drag dynamics (e.g. Scinocca&McFarlane 2000).
PBL Form Drag (from smooth small obstacles)

TMS:

\[ F_x = C_D |U| U(z_{LM}), \quad C_D = \kappa \left( \ln \left( \frac{z_{LM}}{z_0} \right) \right)^{-2}, \quad z_0 \propto \sqrt{\langle h'^2 \rangle} \]

- Logarithmic in \( h'_\delta \). Only applied in lowest model layer.

Beljaars et al. (2004):

\[ F_x = -\alpha \beta C_{md} C_{corr} |\vec{U}(z)| \vec{U}(z) 2.109 e^{-(z/1500)1.5} a_2 z^{-1.2}, \quad a_2 \propto \langle h'^2 \rangle \]

- Proportional to \( h'^2 \). Applied over physically based vertical profile.

\( h'_\delta \) are topographic perturbations with scales below 3km derived from GMTED data, <> represents averaging to model grid.

"Greenland mods" to fix precipitation.
US Precipitation: Summer

May Precipitation Climatology

June Precipitation Climatology

July Precipitation Climatology

NOAA-CPC

CESM1 (LENS)

CESM2

Too Wet

Too Dry

Comm...
US Precipitation: Winter

January Precipitation Climatology

February Precipitation Climatology

March Precipitation Climatology
• Skill scores
• Surface stress + Greenland mods
• SB2001
• Super-saturation (past plots?)
• CLUBB tunings (gamma coeff, ck_10, C_14 and PS/PRECT plots)
• Ck_10 higher 0.5->1.0 in stable PBLs
• CLUBB MG2 subcycling
• Restriction of CLUBB in the vertical
• No angular momentum conservation fixes
• Ocean coupling frequency (24 -> 2 -> 1hrly)
• Sea-salt emission?
• Estuary model
• New solar file
• Capeten/MJO plots
• Background volcanoes
• Oxidation ozone files
• Tropopause definitions
• ENSO plots
• Simple models

• SLD core removal
• New topography
• Climate sensitivity SOM plots
• Lifetime effect changes?
• 20th plots
• Will be using new CMIP6 emissions
• Low resolution
• High resolution
• Regional refinement
• Merging of NCAR modeling?
20th Century

Surface sensible heat flux (SHFLX) norm: 1961-1990 - Smoothed

Global

Flux anomaly (W/m²)

Year

1860 1890 1920 1950 1980

0.8 0.4 0.0

-0.4 -0.8

CESM1 (LENS)

CESM2 (125)

HADCRU

N. Hem.

Flux anomaly (W/m²)

Year

1860 1890 1920 1950 1980

0.8 0.4 0.0

-0.4 -0.8

S. Hem

Flux anomaly (W/m²)

Year

1860 1890 1920 1950 1980

0.8 0.4 0.0

-0.4 -0.8
20th Century

Surface latent heat flux (LHFLX) norm: 1961-1990 - Smoothed

Global

- CESM1 (LENS)
- CESM2 (125)
- HADCRU

N. Hem.

S. Hem

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ENSO in CESM2

CESM2

Obs.

CESM1 (LENS)
Madden Julian Oscillation (MJO)

- Lag correlation with Indian-Ocean precip
- 20-100 day band pass filter, 10S-10N
- 9 years, DJFMAM
Atmospheric High Pressure Blocking

- Daily 500-mb height in the northern hemisphere mid-latitudes
- Reversal in gradient
- Lies mostly within LENS ensemble spread
- DJF W. Europe and MAM Greenland increases/improvements
Climate Sensitivity: 2xCO2/Gregory

- Climate sensitivity
- CESM1: 3.9K
- CESM2: 4.2K
- Significant sensitivities
- Remove liquid supersaturation: High
- With in-cloud variances used in CLUJB calculations: High
20th Century

Surface temperature (radiative) (TS) norm: 1961-1990

Global

N. Hem.

S. Hem

TS anomaly (K)

Year

 CESM1 (LENS)
 CESM2 (125)
 HADCRU

Community Earth System Model

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Wednesday, August 2, 2017
20th Century

Surface temperature (radiative) (TS) norm: 1961-1990 - Smoothed

Global

Year
TS anomaly (K)
-0.60
-0.30
0.00
0.30
0.60
1860 1890 1920 1950 1980

CESM1 (LENS)
CESM2 (125)
HADCRU

N. Hem.

Year
TS anomaly (K)
-0.60
-0.30
0.00
0.30
0.60
1860 1890 1920 1950 1980

S. Hem

Year
TS anomaly (K)
-0.60
-0.30
0.00
0.30
0.60
1860 1890 1920 1950 1980
Longwave cloud forcing (LWCF) norm: 1961-1990 - Smoothed

Global

Flux anomaly (W/m²)

Year

CESM1 (LENS)
CESM2 (125)
HADCRU

N. Hem.

S. Hem

Flux anomaly (W/m²)

Year
Autoconversion Changes - > Seifert and Beheng (2001)

CAM5.4

SWCF: Subtropics and Middle Latitudes: Shallow convection Regime
Arctic effects decrease

CAM5.5

CAM6-125