CESM2 Participation in CMIP6

Two nominal 1º model versions: CAM6 and WACCM6 atmospheric model components

Eyring et al. (GMD, 2016)
DECK & Historical Simulations

<table>
<thead>
<tr>
<th>Experiment</th>
<th>w/ CAM6</th>
<th>w/ WACCM6</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI control</td>
<td>1200 yrs</td>
<td>500 yrs</td>
</tr>
<tr>
<td>1%CO2</td>
<td>1 member</td>
<td>1 member</td>
</tr>
<tr>
<td>4xCO2</td>
<td>1 member</td>
<td>1 member</td>
</tr>
<tr>
<td>AMIP</td>
<td>3 members</td>
<td>3 members</td>
</tr>
<tr>
<td>20C historical</td>
<td>11 members</td>
<td>3 members</td>
</tr>
</tbody>
</table>

Acknowledgment: NSF supplemental support
By the numbers ….

- Since August 2018, about 900 CESM2 simulations for CMIP6 have been run, with about 150 simulations still to complete.
- 1 PB of compressed time series files have been generated.
- About 230 TB of compressed CMIP6 files from > 500 cases have been already published on the Earth System Federation Grid (ESGF), with another 143 TB waiting to be published.
- Over 60,000 files have been published on the ESGF.
- Compared to CMIP5, CESM2 has produced 4x the amount of publishable data so far.
CESM/CMIP6 Workflow

Acknowledgment: CISL…. Mickelson, Nienhouse, User Services Section; Also Strand and Bertini
AGU CESM2 Virtual Special Issue

- Submission deadline: 31 December 2019
- Across several AGU Journals
- 70+ anticipated manuscripts
- 20+ have been already submitted with 8 published
CESM2 *Incremental* Releases

CESM2.1.0 on 10 December 2018

CESM2.1.1 on 10 June 2019

- CESM2.1.1 further expands the available set of out-of-the-box configurations of CESM2 for readily performing all of the DECK, historical, and several MIP Tier 1 simulations.

- It also contains functional release of component sets that use $2^\circ$ CAM6 and WACCM6 versions.
Global-Mean Surface Temperature Time Series

From Fasullo

Baseline: 1850-1870

Legend:
- CAM w/ ensemble spread
- WACCM
- HADCRU45
- GISTEMP
- NOAA
Sea Surface Temperature (SST)

1995-2014 Average

From Phillips
Equilibrium Climate Sensitivity (2 x CO2)
Nominal 1° resolution with a Slab Ocean Model (SOM)

CCSM3: 2.9°C
CCSM4 (CAM4): 3.2°C
CESM1 (CAM5): 4.1°C
CESM2.0: 5.3°C

Our investigations suggest that the increased ECS in CESM2 has arisen from a combination of relatively small changes to cloud microphysics and boundary layer parameters that were introduced during the development process. In particular, the major physics developments such as CLUBB are not themselves responsible for the increased ECS.
Equilibrium Climate Sensitivity (2 x CO2)

From Eyring
Precipitation

1995-2014 Average

From Phillips

mm day$^{-1}$

NCAR UCAR
Short-Wave Cloud Forcing

2000-2013 Average

Updated MG2 microphysics
Improved low clouds via CLUBB*

From Neale

*Cloud Layers Unified By Binormals
Madden Julian Oscillation (MJO)

Lag correlations of the Indian Ocean averaged total precipitation with total precipitation (color) and 850-mb zonal wind (contours) at other longitudes.

Improvements are primarily due to minor changes in the Zhang-McFarlane deep convection scheme and CLUBB.

From Neale
Arctic Sea Ice
(1979-2014 Average)

From Holland, Bailey, and DuVivier
Surface Mass Balance of the Greenland and Antarctic Ice Sheets

From Lipscomb and Lofverstrom
International Land Model Benchmarking (ILAMB) Summary Diagnostics

From LMWG
Land Carbon Accumulation

From LMWG
• 3 AMIP and 3 coupled simulations have been performed.
• WACCM6 can reproduce Southern Hemisphere ozone depletion.
• WACCM6 with specified dynamics reproduces the variability seen in observations (black).

From Gettelman
### Model Performance Summary

#### Mean Pattern Correlation: Sorted for Overall Score

<table>
<thead>
<tr>
<th>Metric</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERALL</td>
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<tr>
<td>ENERGY</td>
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<tr>
<td>WATER</td>
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<tr>
<td>DYNAMICS</td>
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<tr>
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<tr>
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<tr>
<td>wap500</td>
<td>0.77</td>
</tr>
</tbody>
</table>

**From Fasullo; Climate Model Analysis Tool (CMAT)**
CESM2 CMIP6 Last Interglacial Simulation

With enhanced summer insolation

- Proxies indicate reduced summer sea ice in the Arctic
- CESM2 simulates much thinner JAS sea ice & retreat of ice edge in GIN Seas
- Warmer temperatures contribute to the retreat of the Greenland ice sheet

From Bailey, Brady, Otto-Bliesner, and Tomas
CAM6-chem with Variable Resolution

CAM6-chem with Spectral Element (SE) and regional refinement is running with ~14 km over U.S. (~1° elsewhere)

Allows regional-scale air quality modeling in the global model

Current science goals:

• Studying air quality and health impacts in U.S.

• Evaluating importance of greater chemical complexity vs. higher horizontal resolution

From Lacey, Schwantes, Tilmes, Lauritzen, Bacmeister, Callaghan, Walters, Vitt et al.
AMWG and CISL have developed a docker container version of CESM2 configured for a Single Column Model (SCAM6)

- Runs full CESM code (including build, compile, run) with the Jupyter Lab Interactive Development Environment
- Used in last week’s CAM tutorial
- Container install on Mac, Linux, & Windows

 CESM2 runs on the Cloud, but it also runs on a Laptop!

http://www.cesm.ucar.edu/models/cesm2/atmosphere/CAM6tutorial/

From Gettelman, Truesdale, Dobbins, Bacmeister, Larson, and Donner
CESM2 Large Ensemble

• In collaboration / partnership with the Institute for Basic Science (IBS) Center for Climate Physics (ICCP) in Busan, S. Korea, a set of CESM2 Large Ensemble simulations will be performed, starting in September 2019.

• Initial intent is to perform 100 ensemble members for the 1850-2100 period.

• In addition to full forcing simulations, all-but-one forcing experiments are also planned.

• Request for input will be forthcoming.
A Goal for this Workshop.....
..... Towards a CESM Strategic Plan

• What is the niche for CESM?
• What should CESM do / focus on for the next 5 years?
• What are the needs?
Thank You!