GFDL’s next generation climate models: CM4 and ESM4

Presented by Michael Winton
Rationalizing GFDL’s CMIP5 generation models

**5-10 year Strategic Science Plan (2011) goal:**
high resolution Earth System Model combining strengths of GFDL’s multiple AR5 modeling streams
### GFDL’s CMIP6 generation models: CM4 and ESM4

<table>
<thead>
<tr>
<th></th>
<th>CM4 (frozen, starting DECK)</th>
<th>ESM4 (in final development)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Atmosphere: AM4</strong></td>
<td>100 km, 33 levels</td>
<td>100 km, 49 levels</td>
</tr>
<tr>
<td><strong>Atmos. Chem</strong></td>
<td>for aerosol (21 tracers)</td>
<td>aerosol+ozone (103 tracers)</td>
</tr>
<tr>
<td><strong>Ocean: MOM6</strong></td>
<td>1/4°, 75 levels</td>
<td>1/2°, 75 levels</td>
</tr>
<tr>
<td><strong>Ocean BGC</strong></td>
<td>BLINGv2 (6 tracers)</td>
<td>COBALTv2 (30 tracers)</td>
</tr>
<tr>
<td><strong>Land</strong></td>
<td>LM4.0</td>
<td>LM4.1 - PPA</td>
</tr>
<tr>
<td><strong>Sea Ice</strong></td>
<td>SIS2</td>
<td>SIS2</td>
</tr>
</tbody>
</table>

**Note:** All CM4 results shown are *preliminary* (based on potential vegetation historical, 1850- and 2010-forced experiments). We haven’t yet run the official CMIP6 experiments with CM4.
- CM4’s climatology is a distinct improvement over previous GFDL models
- CM4 temp., precip., OLR and reflected SW are the best in this CMIP5 ensemble
- Wind fields are good but not the best
• CM4 SST error is smaller than CM2.6 (GFDL’s previous best simulation)

• We expect CM4’s SSTs can be improved further with higher ocean resolution (as seen refining CM2.5 to CM2.6) or with an eddy parameterization
Atlantic Meridional Overturning

- Strong, stable AMOC
- Deep flow is too shallow and warm
- Heat transport less than observed
Variability: Improved ENSO

- ENSO magnitude is more realistic than previous GFDL models which tended to be too large

- ENSO teleconnection pattern is well simulated
Variability:
PDO and AMO patterns are well-simulated

Pacific Decadal Oscillation

Atlantic Multi-decadal Oscillation
Global Ocean Temperature Drift

- Heat uptake is less than CM2.5 (also using 1/4° ocean)
- Heat uptake is less than the difference in heat uptake between CM2.6 and CM2.5 (eddy-permitting res. effect)
- Warming of deep water points to inadequacy of deep water formation representation (in both hemispheres)
Historical Simulation: Global Temperature and NH Sea Ice Extent

- Historical warming roughly consistent with observed with possible exception of post-Pinatubo period.

- Good simulation of NH extent and its satellite era trend.

- SH sea ice low biased in summer, high biased in winter; recent observed increase is not simulated (not shown).
Thermosteric Sea Level Rise

CM3 thermosteric sea level rise problems:

- Excessive response to volcanoes (common to all CMIP5 models) due to lack of volcanic forcing in control experiment
- Lack of rise due to excessive aerosol forcing

CM4 has reduced aerosol forcing and improved simulation of ocean warming/thermosteric SLR
Summary

● CM4/ESM4 combine strengths of GFDL’s CMIP5 generation of models into two, related models based on the same code with differing emphases on resolution and complexity.

● Expected CM4 strengths:
  ○ Surface climatology
  ○ ENSO variability; ENSO, AMO and PDO teleconnection patterns.
  ○ Reasonable historical climate change simulation

● Expected CM4 weaknesses:
  ○ NADW too shallow and warm as in previous models
  ○ AABW formation only appears after 600 years of spin up
  ○ Ocean warm drift