Developments at GFDL

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WGCM October 2011
GFDL CMIP5 Activities
4 “Streams”

• CM3: Atmosphere-Ocean-Land-Sea Ice Model with Aerosol-Cloud Interactions
  – Atm chem (trop and strat) and aerosol-cloud interactions

• Decadal Prediction Model (DECP, CM2.1, CM2.5)
  – Unique initialization method

• Earth-System Models (ESM2M, ESM2G)
  – Close carbon cycle, 2 different oceans

• High-Resolution Atmosphere-only Models (C180 (50km), C360(25km))
### GFDL CMIP5 status (13 Oct 11)

<table>
<thead>
<tr>
<th>Stream/model</th>
<th>Production complete</th>
<th>Normal Post processing</th>
<th>CMOR post processing</th>
<th>Data on server</th>
<th>METAFORE questionaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESM2M</td>
<td>12/2010</td>
<td>12/2010</td>
<td>75%</td>
<td>50%</td>
<td>9/2011</td>
</tr>
<tr>
<td>ESM2G</td>
<td>85%</td>
<td>80%</td>
<td>1%</td>
<td>0%</td>
<td>Model done</td>
</tr>
<tr>
<td>CM3</td>
<td>12/2010</td>
<td>90%</td>
<td>70%</td>
<td>5%</td>
<td>Model done</td>
</tr>
<tr>
<td>DECP</td>
<td>9/2011</td>
<td>99%</td>
<td>0%</td>
<td>0%</td>
<td>Model done</td>
</tr>
<tr>
<td>C180</td>
<td>Complete</td>
<td>Complete</td>
<td>9/2011</td>
<td>50%</td>
<td>90%</td>
</tr>
<tr>
<td>C360</td>
<td>Complete</td>
<td>Complete</td>
<td>10/2011</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
CM3
CM3:
- Relatively large climate sensitivity
  - 4.3K for 2XCO2
- Large aerosol indirect effect
  - Near 0 global direct effect
Decadal Prediction with Higher-Resolution Coupled Models using GFDL IPCC AR4 Physical Parameterizations (DECP)
### Sequence of coupled models with increasing resolution

<table>
<thead>
<tr>
<th>Model</th>
<th>Atmosphere</th>
<th>Ocean</th>
<th>Land</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM2.1</td>
<td>2° lon x 2.5° lat 24 levels</td>
<td>1° lon x 1/3-1° lat</td>
<td>LM2</td>
<td>IPCC AR4 model</td>
</tr>
<tr>
<td>CM2.1.1</td>
<td>2° lon x 2.5° lat 24 levels</td>
<td>1° lon x 1/3-1° lat</td>
<td>LM2</td>
<td>Higher order advection in ocean, and low viscosity</td>
</tr>
<tr>
<td>CM2.3</td>
<td>1° lon x 1.25° lat 24 levels</td>
<td>1° lon x 1/3-1° lat</td>
<td>LM2</td>
<td>Same ocean as CM2.1, higher resolution atmosphere</td>
</tr>
<tr>
<td>CM2.4</td>
<td>1° lon x 1.25° lat 24 levels</td>
<td>25Km in Tropics to 9 Km in polar regions Square grid.</td>
<td>LM2-</td>
<td>Same atmosphere as CM2.3, higher resolution ocean</td>
</tr>
<tr>
<td>CM2.5</td>
<td>50 Km atmosphere, 32 levels, cubed sphere grid</td>
<td>Similar to CM2.4, uses z* as vertical coord.</td>
<td>LM3</td>
<td>Uses icebergs in ocean Similar ocean to CM2.4, higher resolution atmosphere</td>
</tr>
<tr>
<td>CM2.6</td>
<td>50 Km atmosphere, 32 levels</td>
<td>10 Km in Tropics to 3 Km in polar regions</td>
<td>LM3</td>
<td>Same atmosphere as CM2.5, higher resolution ocean</td>
</tr>
</tbody>
</table>
Ocean Eddy Kinetic Energy – Observed and Simulated

CM2.1: 200 Km atmosphere, 100 Km ocean

CM2.5: 50 Km atmosphere, 10-25 Km ocean

CM2.6: 50 Km atmosphere, 4-10 Km ocean

(a) Observations

(b) CM2.1

(c) CM2.5

(d) CM2.6

Delworth et al. (J. Climate, submitted)
Delworth et al. (J. Climate, submitted)
Annual precipitation (mm/day)

Delworth et al. (*J. Climate*, Submitted)
Delworth et al. (*J. Climate*, submitted)
Earth-System Model ESM2M
ESMs concentration (C1) and emission (E1) driven runs show similar Global Surface Air Temperature Response

- Two different forcings (C & E) give very similar responses
- Both models (M&G) do good job of simulating observed trend using emissions and concentrations.
ESMs C1 and E1 also Similar in Future (RCP8.5)

C1=concentration; E1=emission

Surface Air Temperature Response

- Two different forcings give very similar responses
  - ESM2M: Emission driven run slightly warmer than concentration run
  - ESM2G: Slightly cooler than 2M in middle of this century
ESM emissions driven runs show similar atmospheric pCO$_2$ response to each other and observations.

- Emission driven runs have concentrations similar to observed.
- ESMs about 20ppm high in 2005 versus observations.
- ESMs about 70ppm higher than RCP8.5 by 2100.
Summary

- GFDL, in support of IPCC AR5, has developed a new generation of coupled physical and earth-system models.
- Integrations for AR5 are mostly completed with results becoming available to community.
- New models have been applied to regional climate change, chemistry, and carbon cycle.
NOAA Climate Modeling and Research System (CMRS)
NOAA Climate Modeling and Research System (CMRS) Computing Capability Timeline at Oak Ridge National Lab

- CMRS.1
  - Installation
  - Operational NLT 1 Oct 2010
- CMRS.2
  - Installation
  - Negotiated Options for both FY2015 and FY2016
  - Operational NLT 1 Oct 2011

- CMRS.1 UPG 260 TF
- CMRS.2 720 TF
Climate Modeling and Research System: Initial Capability (CMRS.1)

**Cray XT6 LC**
- 2,576 Socket G34 AMD 2.1 GHz 12-core Magny-Cours processors
- 30,912 compute cores, 1,288 24-core nodes
- 82.4 TB DDR3 memory, 64 GB/node, 2.67 GB/core
- Peak performance: 260 TF

- 14 cabinets in a 2x7 cabinet configuration
- Liquid cooled using Cray ECOphlex cooling technology
- Peak Electrical Consumption: 792 kVA
  - Peak demand to date: 512 kVA (64.6%)
- Cooling Requirement: 225 tons
  - Peak demand to date: 145 tons (64.4%)
- Connectivity to the external Lustre-based Fast Scratch and Long Term File Systems
CMRS Year Two System (CMRS.2)

Cray XE6 LC (Separate System Partition)

- **Scheduled Delivery in 2011**
- 4,896 AMD Interlagos processors
  - 2,448 nodes
- 156.7 TB DDR3 memory, 64 GB/node
- Gemini High Speed Interconnect

- **Infrastructure**
  - 26 cabinets (total of 40 compute cabinets among CMRS.1 and CMRS.2)
  - Cray ECOphlex liquid cooling
  - Peak Electrical Consumption: 1,455 kVA
  - Cooling Requirement: 413 tons
CMRS.1 Upgrade

Cray XE6 LC

• Original Configuration
  – 2,576 Socket G34 AMD 2.1 GHz 12-core Magny-Cours processors
  – 30,912 compute cores, 1,288 24-core nodes
  – 82.4 TB DDR3 memory, 64 GB/node, 2.67 GB/core
  – Peak performance: 260 TF

• Upgraded Configuration
  – 2,624 AMD Interlagos processors
    • 1,312 32-core nodes
  – 84 TB DDR3 memory, 64 GB/node
  – Scheduled Delivery in Q2 CY2012

After the successful introduction to operation of the CMRS.2 Interlagos-based system, the initial CMRS.1 system will receive an architecturally identical upgrade.
Interactive chemistry to link emissions to aerosol composition

Sub-grid vertical velocity PDFs for convective and stratiform clouds => Supersaturation at cloud scale for aerosol activation on sulfate/black carbon, organic carbon, and sea salt

Stratospheric model for chemistry and possible links to troposphere on multi-year time scales (e.g., Southern Hemisphere Annular Mode)

More realistic land precipitation for land carbon and nitrogen models

Cubed-sphere finite-volume dy-core

Dynamic vegetation model with hydrology and land use
Parameterizations based on sub-grid PDFs of vertical velocity have been implemented in AM3


• **Shallow convection**: Bretherton *et al.* (2004, *Mon. Wea. Rev.*) implemented by Ming Zhao

• **Stratiform**: modification of Tiedtke (1993, *Mon. Wea. Rev.*) by Chris Golaz, to include $w$ PDF for activation only
• Emission driven run has concentrations very similar to observed

• ESM2M about 23ppm high in 2005 versus observations

• ESM2M about 70ppm higher than RCP8.5 by
CM3

- Atm chemistry and higher top (lower Mesosphere)
  - Focus: atm chem and aerosol-cloud
- 2 deg atm, 48 levels
- New land module – LM3
- Old ocean and sea ice components
  - 1 deg ocean (1/3 in tropics), 50 levels
DecP

- Uses unique initialization method
  - Runs multiple oceans under data atm while ingesting ocean observations
- Uses CMIP3 model – CM2.1
- 2 deg atm, 24 levels
- 1 deg ocean, 50 levels (MOM4p0)
- Old sea ice and land components
- Much higher resolution model version coming next spring
High Res Atm-only

- ½ and ¼ deg versions
- FV cubed sphere atm dy core
- LM3 with static vegetation
- Minimal subgrid physics
  - Convection mainly explicitly resolved
- Run with different SST data sets
  - Obs, CM3, ESM2M
ESM

- Two models developed using diff oceans
- 2 deg atm, 24 levels – same as CM2.1
- LM3 – new hydro and veg/carbon components
- CM2.1 Sea ice with slight albedo change
- Only can handle carbon emissions
  - Lamarque et al. aerosol concentrations, etc
ESM Oceans

• MOM4p1 – ESM2M
  – 1 deg (1/3/ in tropics) 50 levels
  – Z* based vertical coor
  – Lots of changes from CM2.1 ocean

• GOLD – ESM2G
  – 1 deg (1/3/ in tropics) 63 layers
  – Isopycnal based vertical coor + bulk mixed layer

• TOPAZ – ocean bio-geochemistry