Recent Results with the GFDL High-Resolution Coupled Modeling Systems

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High Resolution Model Development

Scientific Goals:
• Developing improved models (higher resolution, improved physics, reduced bias) for studies of variability and predictability on intra-seasonal to decadal time scales
• Explore impact of atmosphere and ocean on climate variability and change using a high resolution coupled models
• New global coupled models: CM2.4, CM2.5, CM2.6

<table>
<thead>
<tr>
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<th>Ocean</th>
<th>Atmos</th>
<th>Computer</th>
<th>Status</th>
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<tbody>
<tr>
<td>CM2.1</td>
<td>100 Km</td>
<td>250 Km</td>
<td>GFDL</td>
<td>Running</td>
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<td>CM2.3</td>
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<td>100 Km</td>
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<td>CM2.4</td>
<td>10-25 Km</td>
<td>100 Km</td>
<td>GFDL</td>
<td>Running</td>
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<tr>
<td>CM2.5</td>
<td>10-25 Km</td>
<td>50 Km</td>
<td>GAEA/GFDL</td>
<td>Running</td>
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<td>CM2.6</td>
<td>4-10 Km</td>
<td>50 Km</td>
<td>GAEA</td>
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</table>
Coupling on Oceanic Mesoscale in Western Arabian Sea

Resolution enhancement allows model to better represent processes
Some Aspects of Tropical Climate Improve with Resolution

Annual Tropical Precipitation on 2.5x2.5 Grid

Adapted from Delworth et al (2012)
Some Aspects of Tropical Climate Improve with Resolution
Near-equatorial Zonal Winds

Adapted from Delworth et al (2012)
Some Aspects of Tropical Climate Improve With Resolution

Structure of tropical SST variability

Delworth et al (2012)
South Asian Monsoon Rainfall Improves with Resolution

CM2.1 (lo-res)

CM2.5 (hi-res)

TRMM (1998-2010)

Delworth et al (2012)
Enhanced Resolution and Coupling Improve Asian Monsoon Rainfall

Observations
Lau and Ploshay (2009)

GFDL AM2.1 M180
50km Atm.

GFDL AM2.1 M45
50km Atm.

GFDL CM2.5
25km Oc.; 50km Atm.

GFDL CM2.1
100km Oc.; 200km Atm.

SST-Forced AGCM Runs
From Lau and Ploshay (2009, J. Climate)

June-August Mean Rainfall (mm/day)
Intraseasonal Variability

Daehyun Kim (LDEO, Columbia U.) and Bill Stern (GFDL)

• Physics
• Resolution
• Coupling

MJO improvement from one can depend on the others.
Coupling appears to improve GFDL high-res model’s MJO

Figure: Daehyun Kim (LDEO, Columbia U.)
Impact of Physics: AM2.1 vs. HiRAM

OLR Sym Modes

OLR Asym Modes
Impact of coupling: HiRAM C180 AGCM vs. Coupled

Normalized Power Spectra for Symmetric Modes

Normalized Power Spectra for Asymmetric Modes
Response to $2\times CO_2$

- Global-scale response (with a few exceptions) similar between high and low resolution models
  - High resolution model has higher climate sensitivity and warms more quickly.
  - Southern Ocean warms robustly in high-res model, but not in low-res model
- Regional rainfall response can differ considerably
- Must understand sources of difference in order to judge relative plausibility.
  
  Higher-res does not necessarily mean "better".
Indian Ocean 1950-2000 SLP changes in an SST-forced AGCM differ from observed changes.

GFDL-CM2.1 CGCM shows an SLP increase over this period when forced with radiative forcing…but different model.
Global Surface Temperature Response to 2xCO₂

Delworth et al (2012)
Global Surface Temperature Response to 2xCO₂

CM2.1 (lo-res)

CM2.5 (hi-res)

Delworth et al (2012)
Global Zonal-mean Response to $2\times$CO$_2$

Poleward jet shift

"Wet get wetter, dry drier"
Equatorial Zonal Wind Response to $2\times$CO$_2$

Equatorial winds weaken in both models.

Location of weakening in Pacific different.
South Asian Monsoon Rainfall Improves with Resolution

CM2.1 (lo-res)  
CM2.5 (hi-res)  
TRMM (1998-2010)

Delworth et al (2012)
South Asian Monsoon Response to 2xCO₂

Response model dependent, hi-res model shows orographically-tied features

Why is response different?
Response to 2xCO2

Figures: Takeshi Doi
Enhanced interannual anomalies of WGI rainfall

Figures:

Monsoon Variability Changes from CO$_2$
Tropical Cyclones in CM2.5

Mean Regression to SOI

Kim et al. (2012, in prep.)

Figures: Hyeong-Seog Kim

Kim et al. (2012, in prep.)
Tropical Cyclone Response to CO$_2$ in CM2.5

CM2.5 CO3 (2xCO2 minus 1xCO2)

(a) The number of TC Genisis

(b) The number of TC Passage

(c) Days of TC occurrence

(d) PDI

Figures: Hyeong-Seog Kim

Kim et al. (2012, in prep.)
Summary

• New high-resolution coupled climate models being developed and run at GFDL.

• Enhanced resolution important both to resolve phenomena/features (cyclones, orography), and to resolve processes (eddies, etc).

• Some aspects of tropical climate improve from increasing resolution: tropical precipitation, near-equatorial winds, structure of interannual SST variability, monsoon rainfall.

• Some aspects of large-scale response to CO2 similar in climate models with very different resolution, but others differ: in hi-res model climate sensitivity larger, southern hemisphere warming stronger, more eastern equatorial Pacific warming, weakened equatorial Pacific easterlies more to the east.

• Regional precipitation response to increased CO2 can differ fundamentally between models of differing resolution. High-res model shows orographically-tied features: what are mechanisms for various differences?

• Why do models differ? Is one of the responses more plausible?

  Higher resolution does not necessarily mean a “better” model/response.