Using hindcasts to improve depiction of the MJO in next-generation climate models

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Global climate simulations with $Δx \sim 30$ km are now routine

e.g., HIRAM (NOAA/GFDL)
However, significant biases and deficiencies still remain

Mean rain bias

Obs. tropical rain spectrum

Model tropical rain spectrum
However, significant biases and deficiencies still remain

Mean rain bias

Too much off-equator rain

Obs. tropical rain spectrum

Model tropical rain spectrum
However, significant biases and deficiencies still remain.

Mean rain bias

Obs. tropical rain spectrum

Model tropical rain spectrum

Kelvin waves too weak
However, significant biases and deficiencies still remain

Mean rain bias

Obs. tropical rain spectrum

Model tropical rain spectrum

Virtually no MJO
What happens if we go to even higher resolution?

NASA GEOS-5 at ~12 km grid spacing (2-yr run)
What happens if we go to even higher resolution?

And still no MJO!

NASA GEOS-5 at ~12 km grid spacing (2-yr run)
Project strategy

- To understand and mitigate these deficiencies, use “high-resolution” global climate models and expanded NOAA computing resources (GAEA) to perform 30-day hindcasts of the MJO.

- Two types of models:
  1) Traditional global model
  2) “Superparameterized” global model

Computing spent on resolving a continuous range of scales (40,000 – 25 km)

Computing spent mainly on resolving the convective scale [O(1 km)] at the expense of intermediate mesoscales.
Models involved

• Traditional models:
  1) HIRAM (GFDL)
  2) GEOS-5 (NASA)
  3) CAM5 (NCAR)

• SP model: WRF

Finite-volume, cubed-sphere dynamical core

Finite-difference, lat-lon dynamical core with polar filtering
Specific MJO event

2009 YOTC Case E* (Nov-Dec)

Note*: Also the focus of a global model hindcast intercomparison project of the WCRP-WRRP/Thorpex MJO Task Force
How representative is Case E?

OLR composite of 24 events

Case E
Hindcast setup

- Models are nudged to an analysis for a period of days to weeks prior to the start date

- Traditional models each have $\Delta x$ of $\sim 25$ km
  - Convection handled partly through explicit dynamics (i.e., grid-scale updrafts) with diagnostic microphysics and partly by standard convection scheme; partitioning is model dependent

- SP-WRF has a global $\Delta x$ of 2.8 deg and CRM $\Delta x$ of 4 km (32 points)
Nov 1 hindcast results: HIRAM

Obs.

HIRAM
Nov 1 hindcast results: HIRAM
Nov 1 hindcast results: HIRAM

Obs.

HIRAM
Nov 1 hindcast results: HIRAM

Obs.

HIRAM
Nov 1 hindcast results: HIRAM
Nov 1 hindcast results: GEOS-5

Obs.

GEOS-5
Nov 1 hindcast results: GEOS-5

Obs.

GEOS-5
Nov 1 hindcast results: GEOS-5

Obs.

GEOS-5

Too strong
Nov 1 hindcast results: GEOS-5

Obs.

Mar. Cont. barrier/hole?
Nov 1 hindcast results: CAM-5

Obs.

CAM-5
Nov 1 hindcast results: CAM-5

Obs.

CAM-5
Nov 1 hindcast results: CAM-5

Obs.

CAM-5

Much too strong
Why is HIRAM’s rain more “pointillistic” than GEOS-5/CAM-5?
Why is HIRAM’s rain more “pointillistic” than GEOS-5/CAM-5?

• Hypothesis: deep convection in HIRAM is handled too much by grid-scale updrafts vs. parameterized updrafts (a single, strongly-entraining bulk-plume model)

• Test: Add a second more weakly-entraining bulk plume
HIRAM 50-km (double plume)

Obs.

HIRAM
Turning to superparameterization for further guidance

Fundamental question: given explicit (4-km) treatment of moist processes in a small 2D domain, what aspects of the problem still remain?
Turning to superparameterization for further guidance

Fundamental question: given explicit (4-km) treatment of moist processes in a small 2D domain, what aspects of the problem still remain?

For example: how do results depend on the treatment of SGS vertical mixing in the CRM? What about horizontal resolution of the large-scale model?
Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

Obs.

MYNN2.5 PBL (more diffusive)

3D SMAGORINSKY (less diffusive)
Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

Obs.

MYNN2.5 PBL (more diffusive)

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Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

Obs.

- MYNN2.5 PBL (more diffusive)
  - Too strong/early

- 3D SMAGORINSKY (less diffusive)
  - Too strong/early
Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

Obs.

MYNN2.5 PBL (more diffusive)

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Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

- MYNN2.5 PBL (more diffusive)
- 3D SMAGORINSKY (less diffusive)

Obs.
Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

Obs.

Too active elsewhere

MYNN2.5 PBL
(more diffusive)

3D SMAGORINSKY
(less diffusive)
Nov 1 hindcast: SP-WRF (sensitivity to GCM resolution)

Obs.

2.8deg (32x4km)

0.7deg (12x4km)
8 x more exp.

Heavy rain develops later
Nov 1 hindcast: SP-WRF (sensitivity to GCM resolution)

Obs.

2.8deg (32x4km)

0.7deg (12x4km)
8 x more exp.
Nov 1 hindcast: SP-WRF (sensitivity to GCM resolution)

Obs.

2.8deg (32x4km)

0.7deg (12x4km)
8 x more exp.

Heavy rain develops later
Nov 1 hindcast: SP-WRF (sensitivity to GCM resolution)

Obs.

2.8deg (32x4km)

0.7deg (12x4km) 8 x more exp.

Rain over Mar. Con.
Lessons learned so far

• MJO simulation in tradition hi-res. models depends crucially on the partitioning between grid-scale vs. parameterized convection; further “tuning” is needed; ultimately, parameterization should be doing most of the job (based on SP results)

• Past focus on convective closure assumptions as the key to simulating the MJO may be misguided; parameterization of vertical turbulent mixing is also clearly important (consistent with other large-domain CRM efforts, e.g., CASCADE, NICAM)

• The Maritime Continent barrier issue seems to be a serious problem in all models studied. High resolution appears to be a necessary but not sufficient condition for improvement