New Modeling Capabilities

Advancing NOAA Climate Science

Presented by

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Exploring the next frontier of climate modeling

with

ultra-high resolution non-hydrostatic model

using the GFDL FV3:

The non-hydrostatic Finite-Volume dynamical core

on the Cubed-sphere

Ultra-high-res Models under development

Goals:

- To unify "regional-global" and "weather-climate" models - A true seamless modeling system, a model that has no built-in scale limitation!
- To improve realism of climate simulations and to provide regional details for stakeholders
- To enable seasonal to decadal predictability of high impact weather events previously thought too difficult or impossible

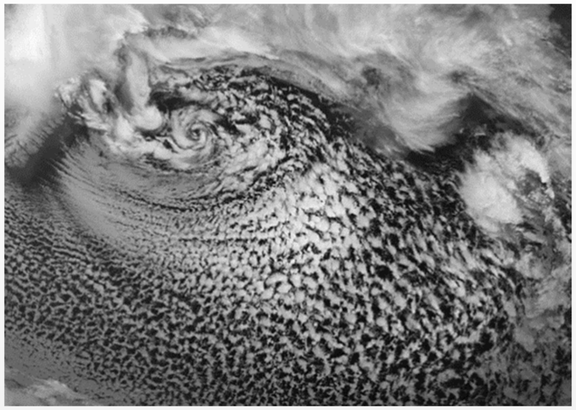
Examples:

1. Coupled ***cloud-permitting*** model (~3.5 km, global quasi-uniform resolution): computationally expensive; use mainly as a learning tool (software, dynamics & physics) –> lessons learned trickling down to main stream production models
2. A *km-scale* ***thunderstorm-resolving*** *"*Global *regional climate* model" with 3-5 km over CONUS (Continental US), and ~1 km with a 2-way nest (Harris & Lin 2013)
   - Seasonal prediction of ***hurricanes with region specific information***
   - Seasonal prediction of ***tornado outbreak***
3. Same as 2, but for W. Pacific to study Asian monsoon & typhoons

Some fine-scale phenomena that used to be impossible to simulate in a global model are now within reach

Cloud streets off US east coast

Polar low near Iceland



Tornado-producing thunderstorm

Pineapple express

Extending the predictability of high-impact weather events from seasonal to decadal

Main sources of the seasonal predictability:

- Initialized state (atmosphere, land, and ocean) – counting on long memory in the land model and ocean
- Low-frequency tropospheric oscillations: **MJOs** (Madden Julian Oscillations)

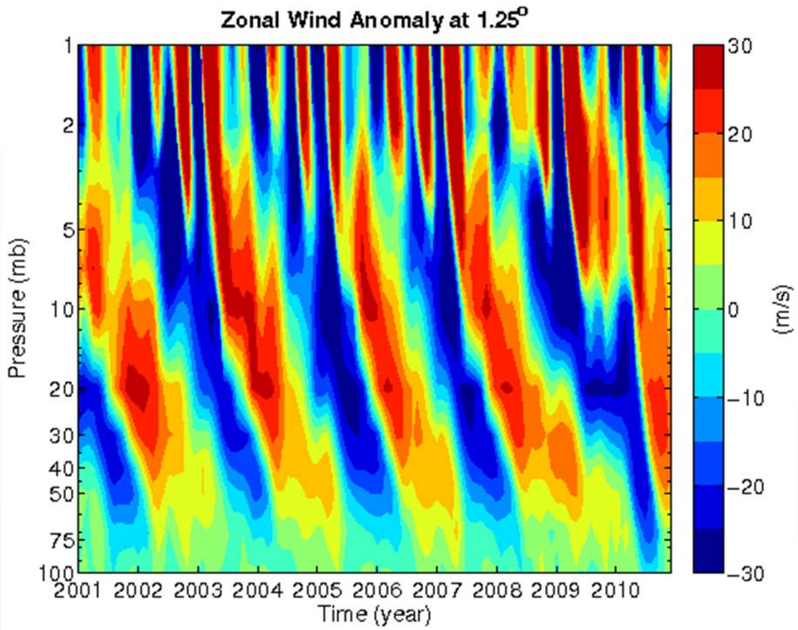
Decadal predictability?

- Large-scale stratospheric phenomena: **QBOs** (Quasi-Biennial Oscillations)

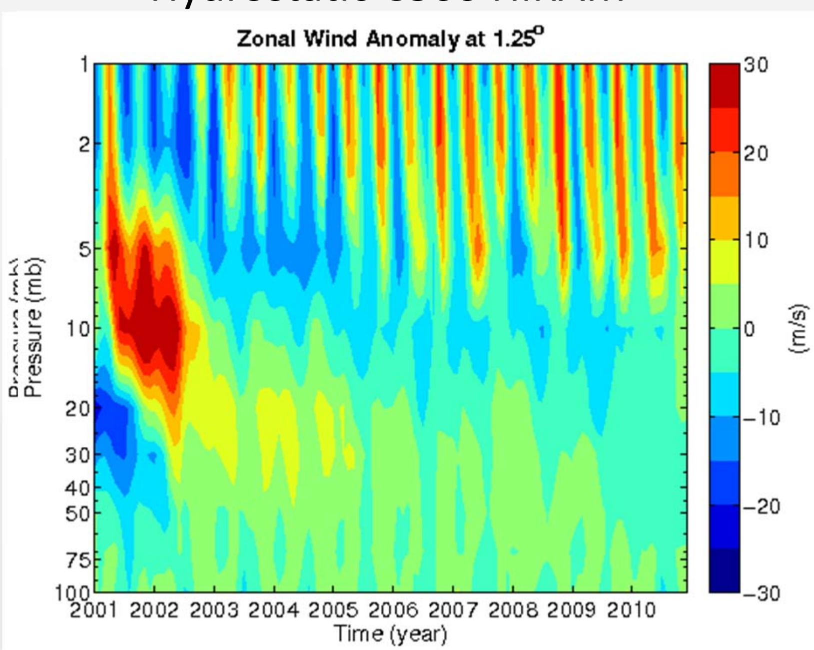
QBOs:

- QBOs are extremely difficult to simulate in free-running GCMs
- QBOs are believed to have significant impacts to sudden warming, stratospheric ozone, monsoon, and (some also believe) hurricanes & winter storms
- Some decadal predictability is achievable with an initialized state and if the model can simulate QBOs

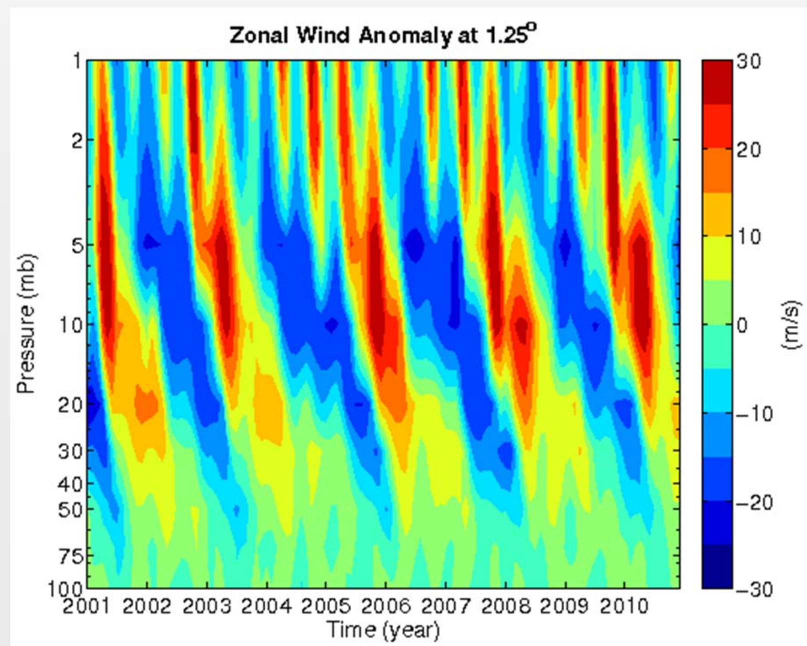
NASA Merra Data (analysis)



Hydrostatic C360 HiRAM

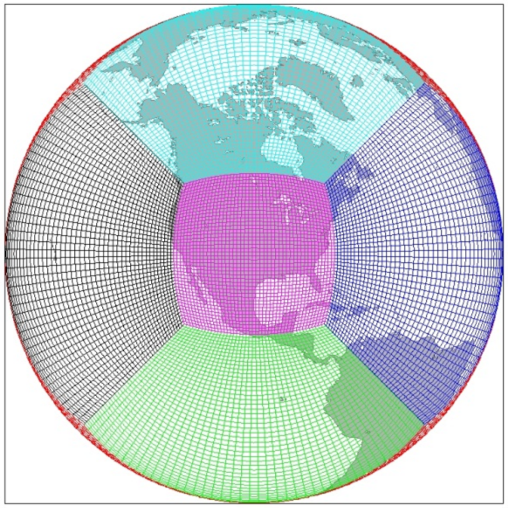


Non-hydrostatic C360 HiRAM

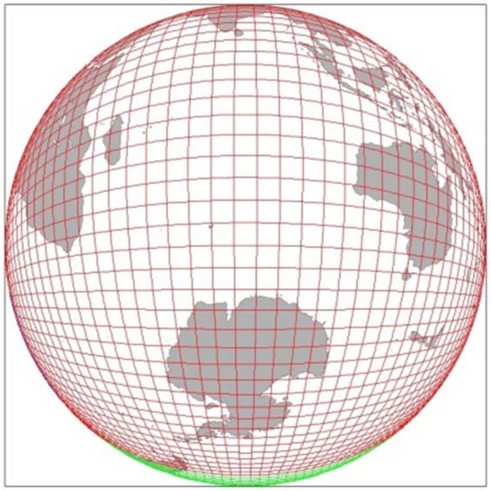


GFDL's thunderstorm-resolving model for CONUS (center: Oklahoma City)

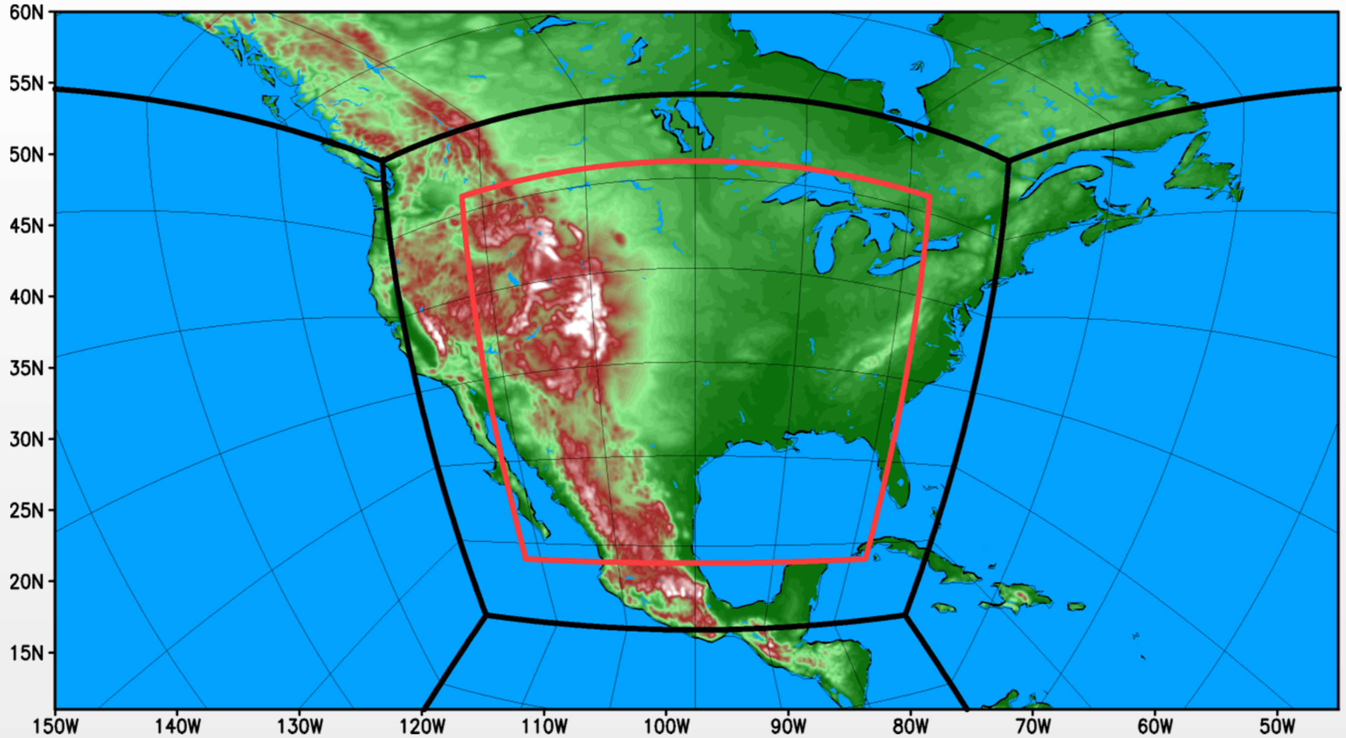
Oklahoma City



Back side of OKC



Stretched + nested weather-climate model

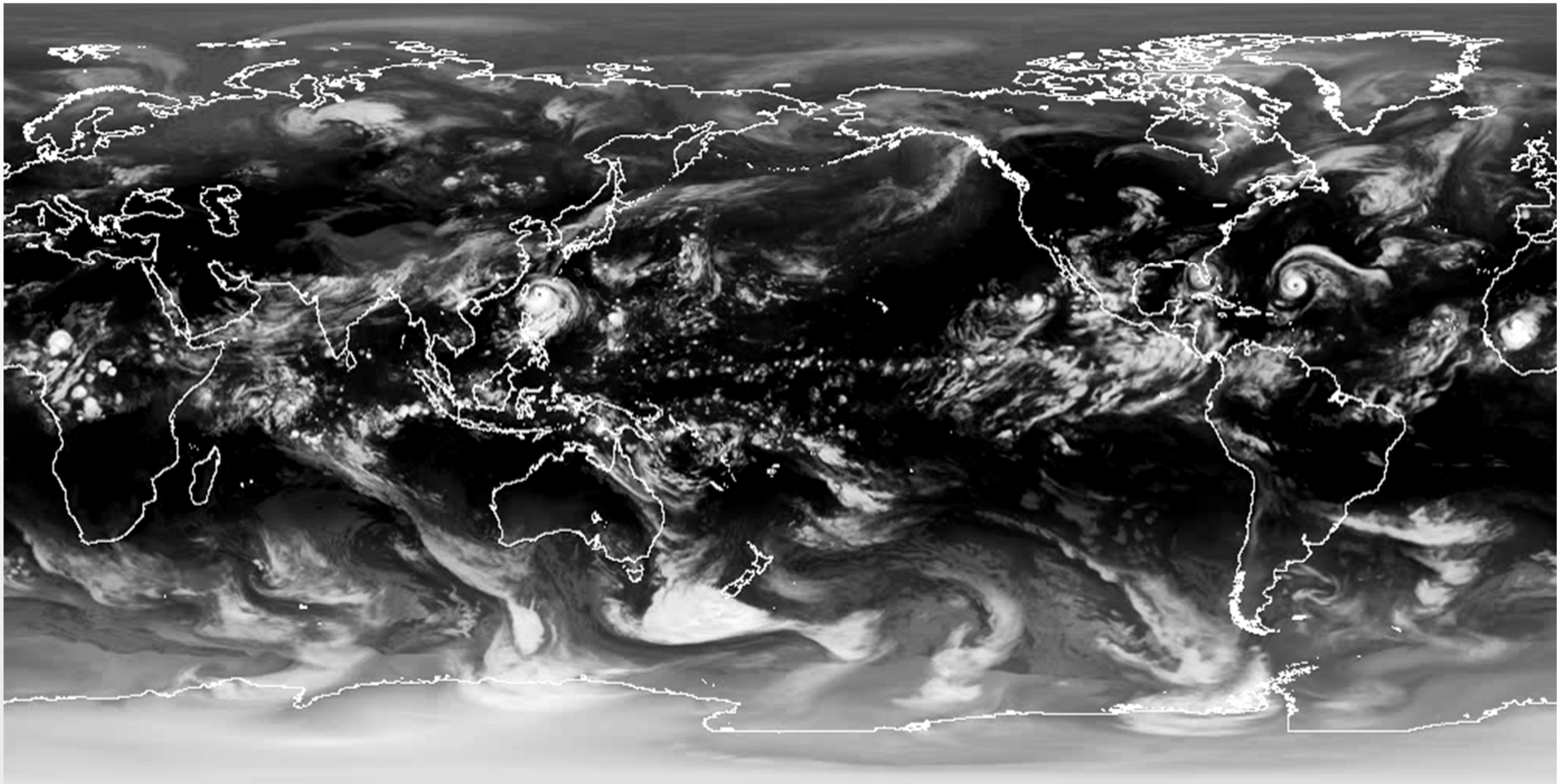


Resolution: 3-5 km without the nest (black)
~1 km with a 2-way nest (red)

Cloud-permitting simulation of the 2008 hurricane season

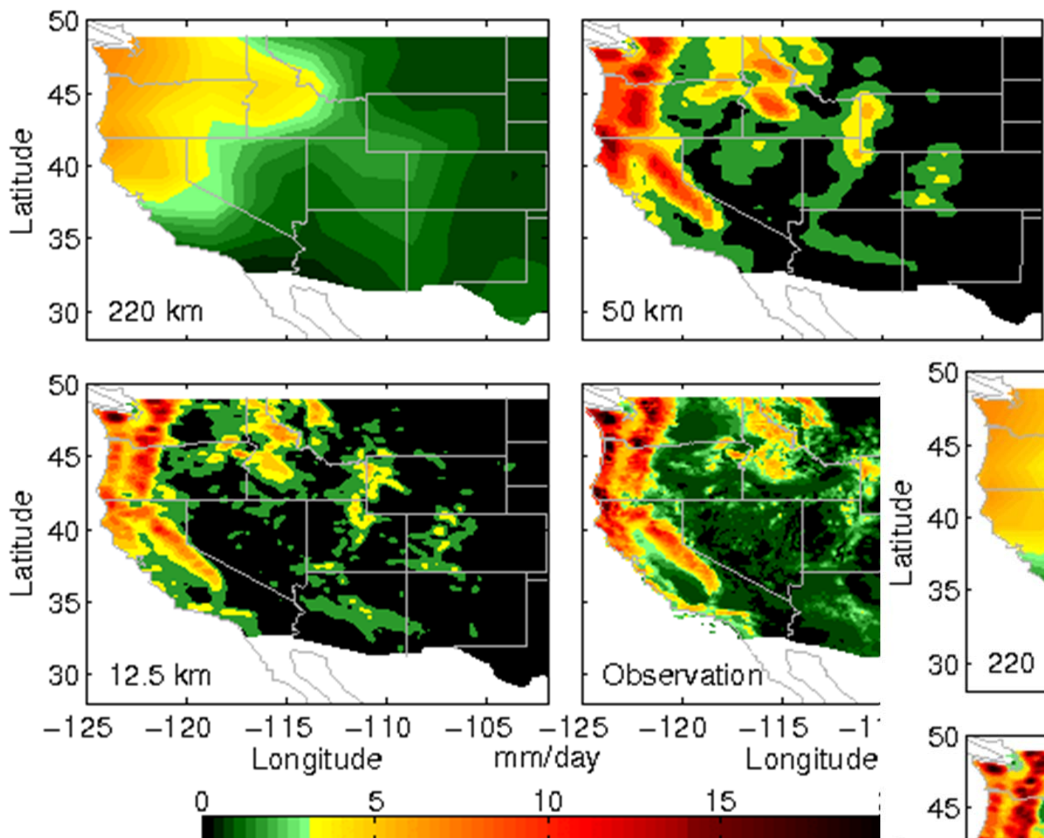
(3-5 km over E. Asia)

OLR: Aug 24 – Sep 04, 2008



Resolving cat-5 typhoons
intensity may be too strong without ocean-coupling

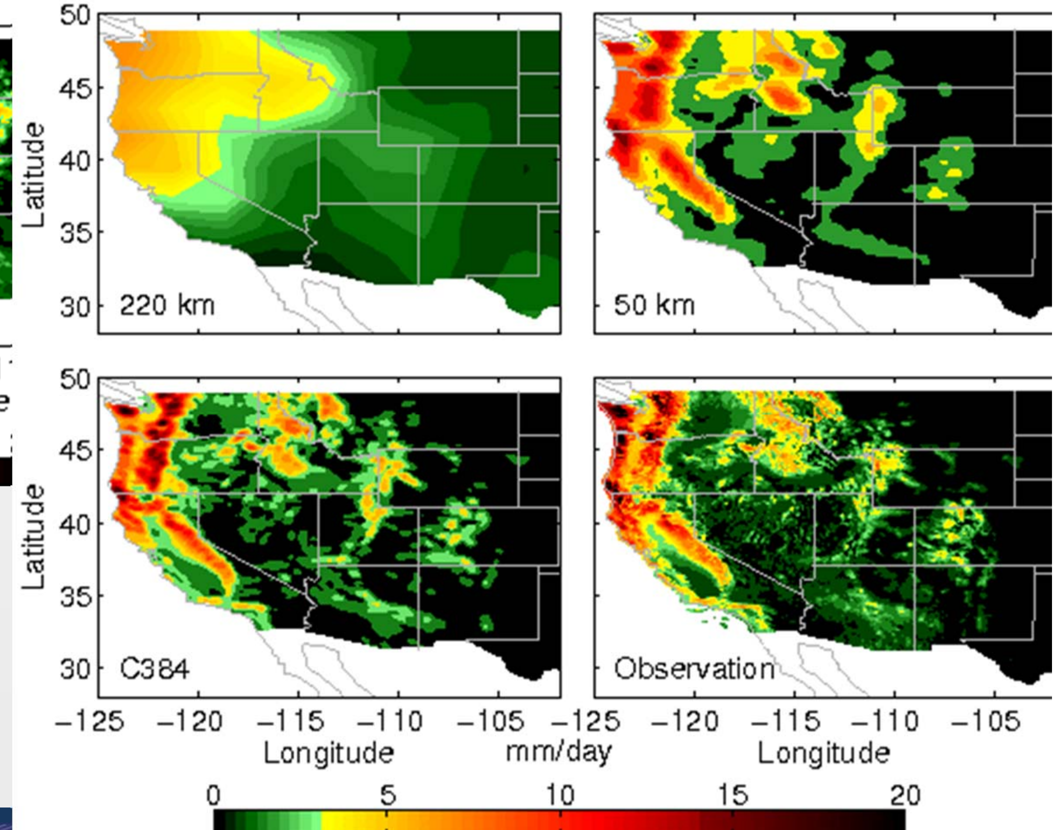
DJF precipitation: GFDL HiRAM vs. Observation



Need hi-res to provide regional details. But global uniform resolution is still too expensive

→

Make hi-res affordable with variable-res approach

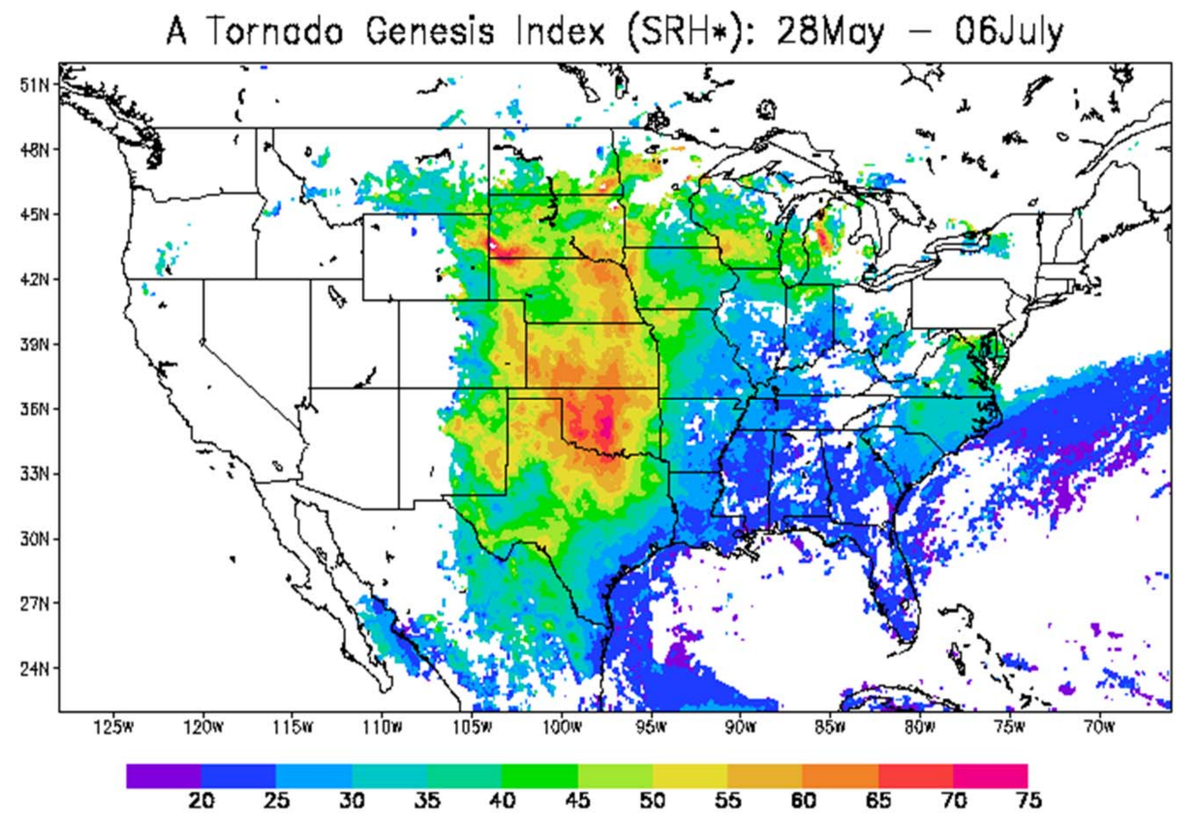


C384 stretched

(~10 km over CONUS)

Simulation of the "Tornado alley"

Preliminary results from GFDL thunderstorm-resolving model
(40-day average of the Storm Relative Helicity*)



- Stretched C1024 HiRAM centered at OKC with 3-5 km resolution over the whole CONUS
- Climate SST

Quality of simulated mean climate with "global regional climate model"

It is important that integrity of large-scale general circulation be maintained (or improved) in the variable-resolution GCM

RMS errors (simulated present-day climate *vs* NCEP re-analyses)

	Variable resolution HiRAM (~10 km over CONUS)	AM2.1	Uncertainties (EC MWF– NCEP)
NH SLP (mb)	0.96	1.8	N/A
Zonal mean T	1.50	1.97	0.88
Zonal mean U-wind (m/s)	1.06	1.71	1.09

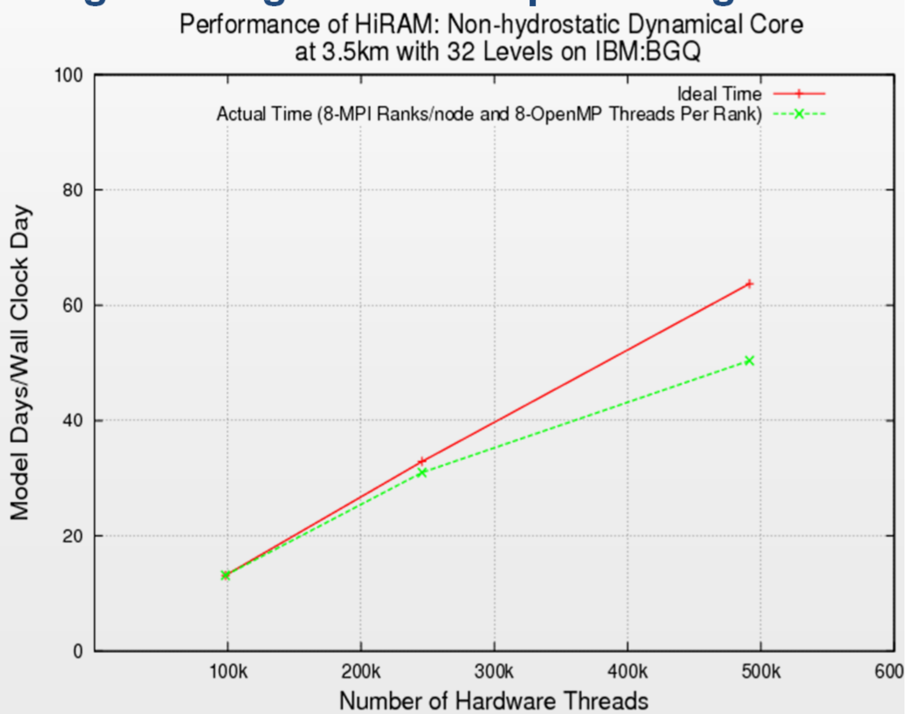
Summary

- **GFDL is leading the community in the development of the ultra-hi-res non-hydrostatic models to improve realism of climate simulations and to provide regional details for stakeholders**. These models are being evaluated for seasonal predictions of high-impact weather events (landfall hurricanes and tornado outbreaks).

- The applications of ***the km-scale climate models*** at GFDL are severely limited by computational resources.

The throughput of the global cloud permitting model (3.5 km) is only ~60 days per day on IBM B/G using 800,000 hardware threads. The throughput of the variable-resolution "global regional climate model" (3-5 km over CONUS) is ~20 days per day on GAEA using 6,144 cores.

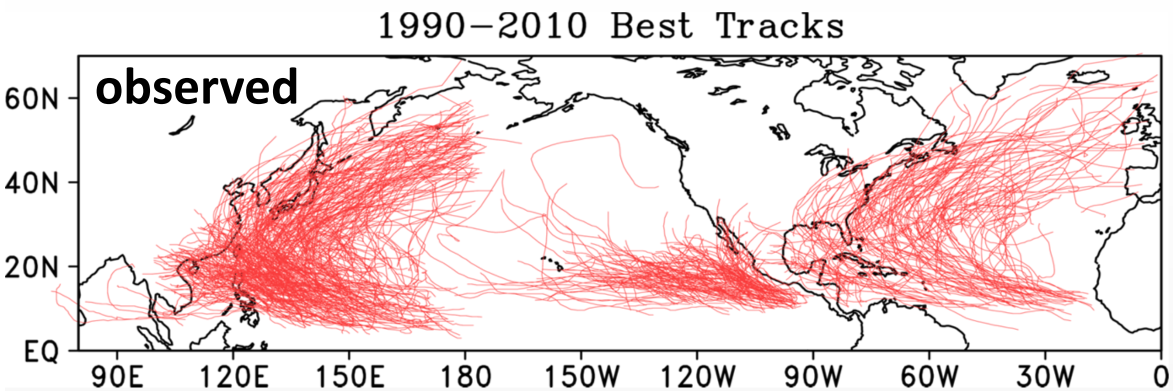
Scaling of the global cloud-permitting model

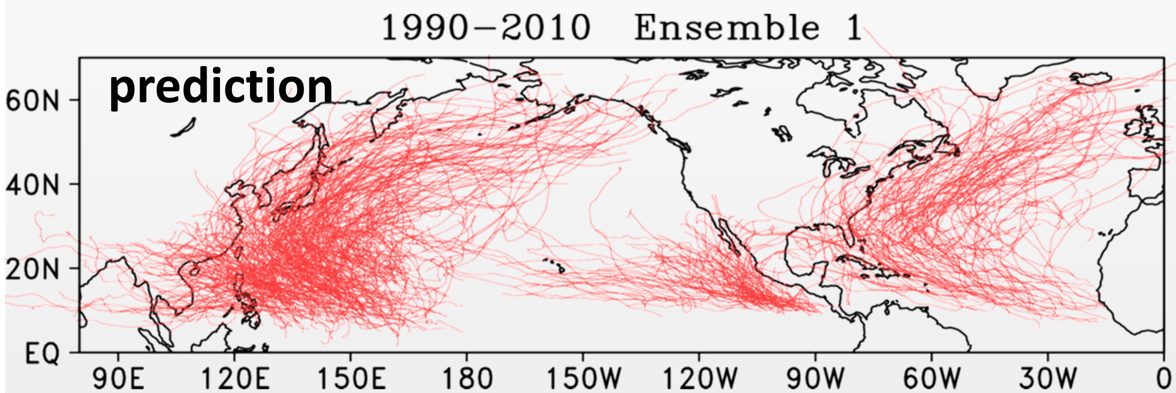


Backup slides

Seasonal hurricane predictions with the 25-km HiRAM

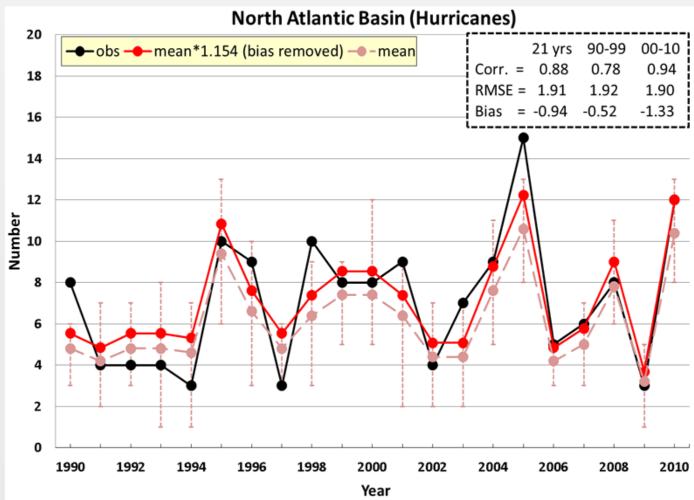
(Chen & Lin 2013)





1990-2010 (J-A-S-O-N)

r = 0.88



Caveat:

Prediction is for total hurricane counts.

Seasonal Prediction of “Katrina” type or “Snady” type hurricanes would be much more useful than just the total numebr.