Climate Research Based on High-Resolution Modeling at NASA GMAO

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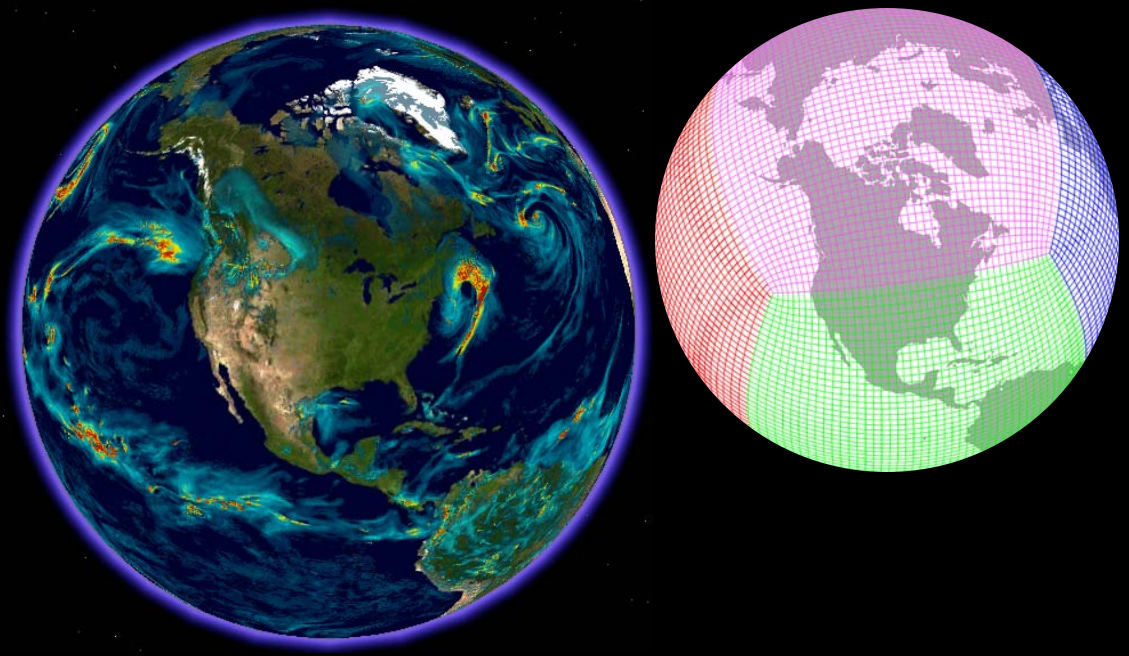


APEC Climate Symposium 2009, Singapore, 12-15 July, 2009

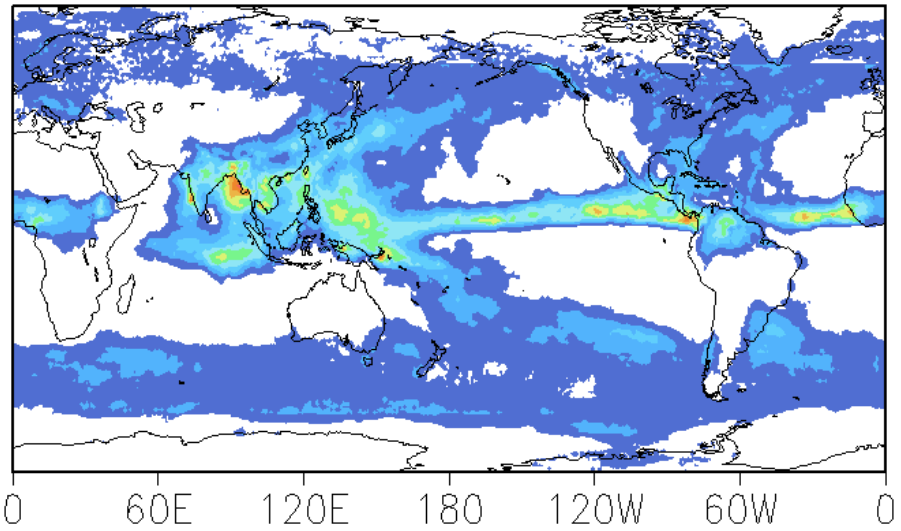
Contents

- High-resolution global climate modeling with 20-50 km resolution
  - Based on long-term climate simulations
  - Assess the impact of convective parameterization (seasonal-mean, variability, MJO, tropical storm)
- Global climate modeling with less than 10 km
  - Non-hydrostatic cubed-sphere dynamical core
  - Evaluation from the short-term weather forecast experiment

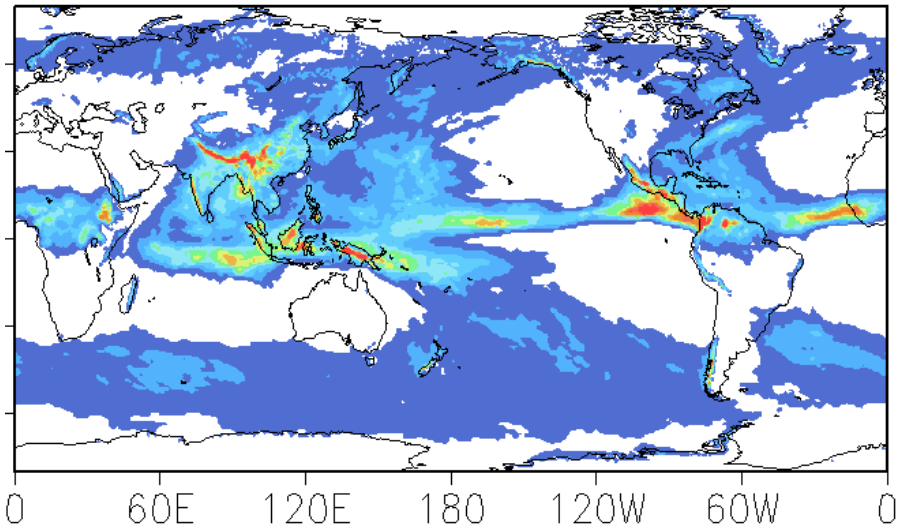
Seasonal mean precipitation

(JJAS, 2005-06)

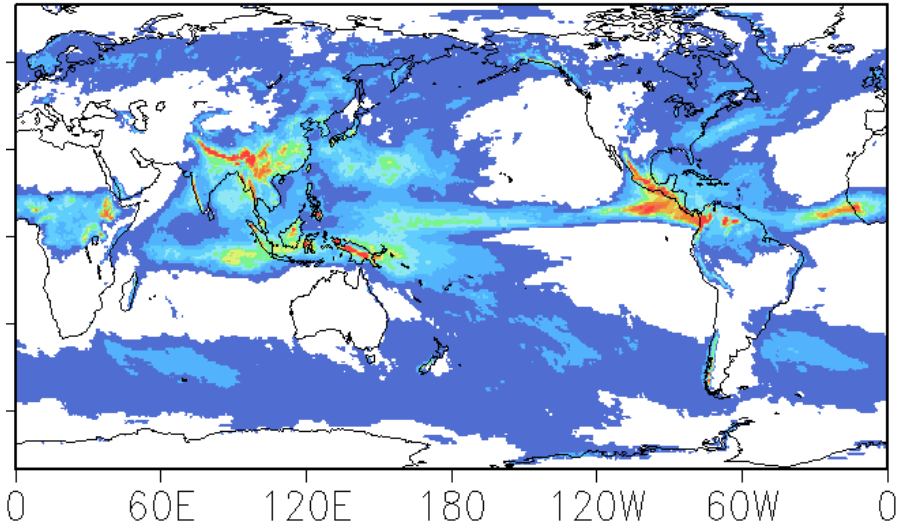
GPCP Observation

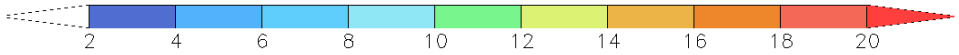


GEOS-5 50-km Simulations



GEOS-5 25-km Simulations

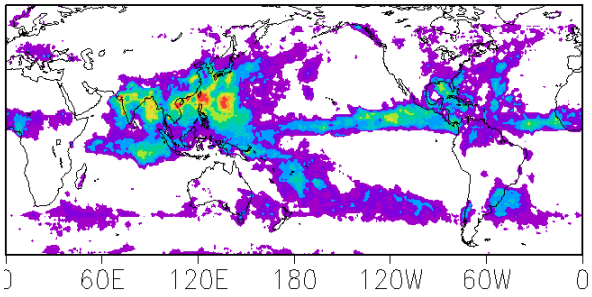




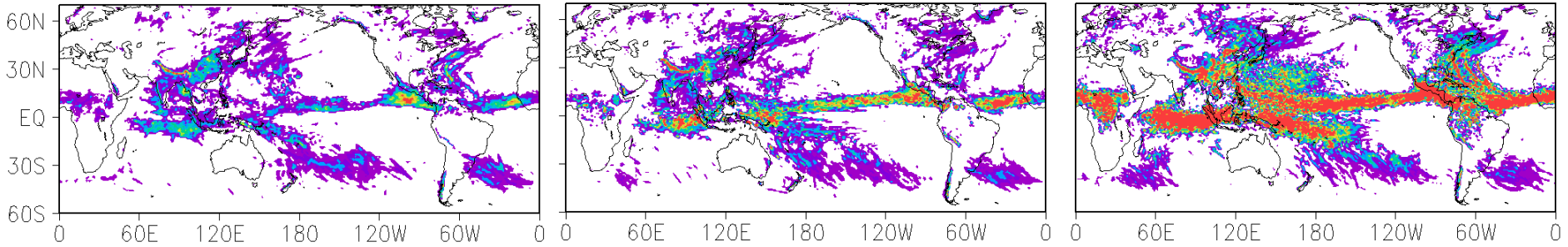
mm/day

Variance of Daily Precipitation (JJAS)

GPCP (Obs)

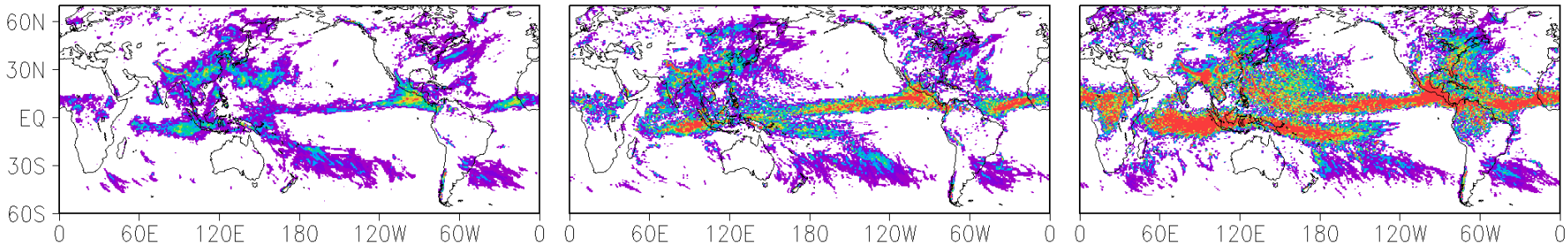


GEOS-5 50-km Simulations



T ~ 6 h (Control) **T = 12 h** **T = 11.2 d**

GEOS-5 25-km Simulations



[mm/d]

Known Problems

- A simple increase of resolution doesn't substantially improve the fundamental of time-mean and variability – Parameterizations still play a key role

- Relaxed Arakawa-Schubert scheme:
  - Less dilution of convective plumes
  - Too-much and too-frequent adjustment tend to make less time variability (Lee et al. 2001, 2003)

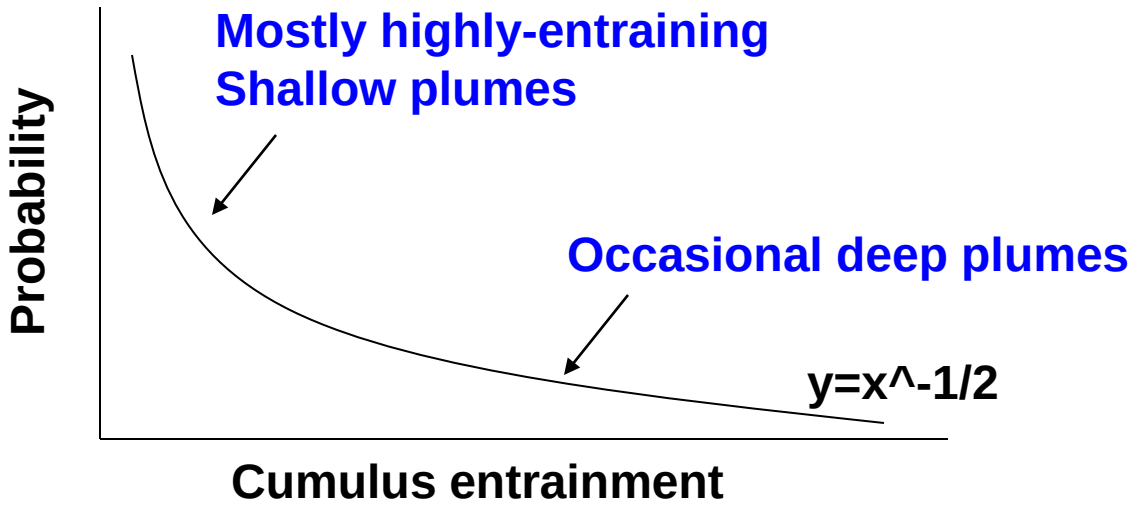
Stochastic Determination of Cumulus Entrainment

- Selective suppression of RAS convection scheme
- Stochastic Tokioka Exp ("*Stochioka*"):

  Minimum entrainment rate,

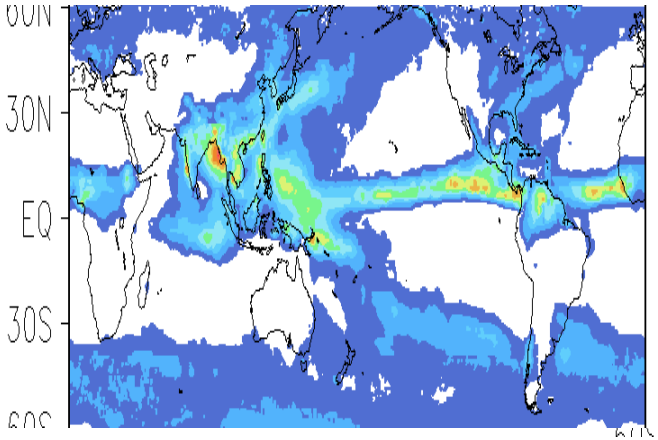
  $\mu_{min} = 0.2/D$

  D, diameter for the largest convective plume determined in *random*

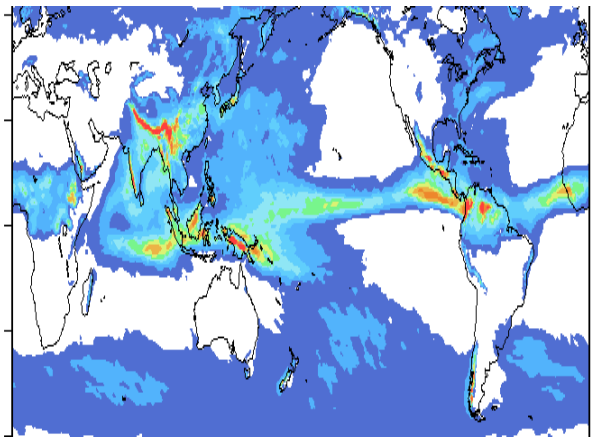


Seasonal-mean Precipitation (JJA 2005-06)

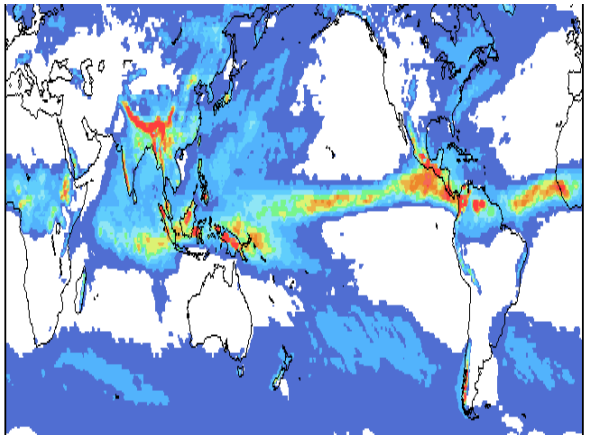
GPCP



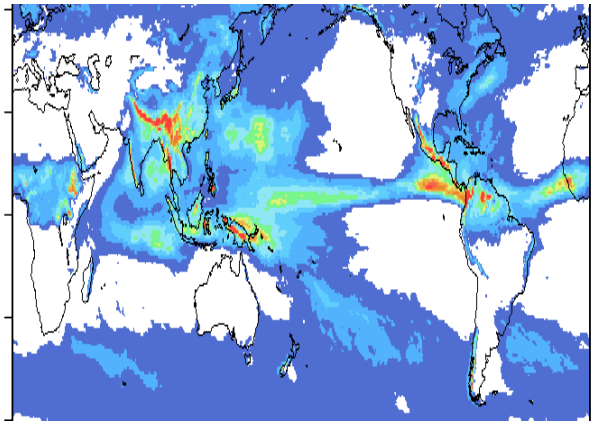
CTRL (50 km)



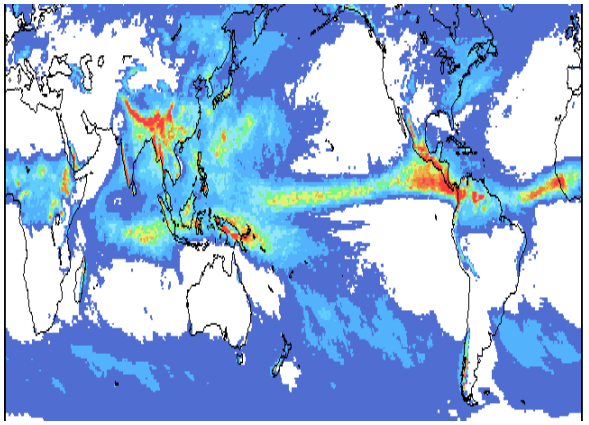
Stochioka (50 km)

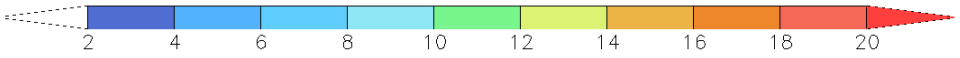


CTRL (25 km)



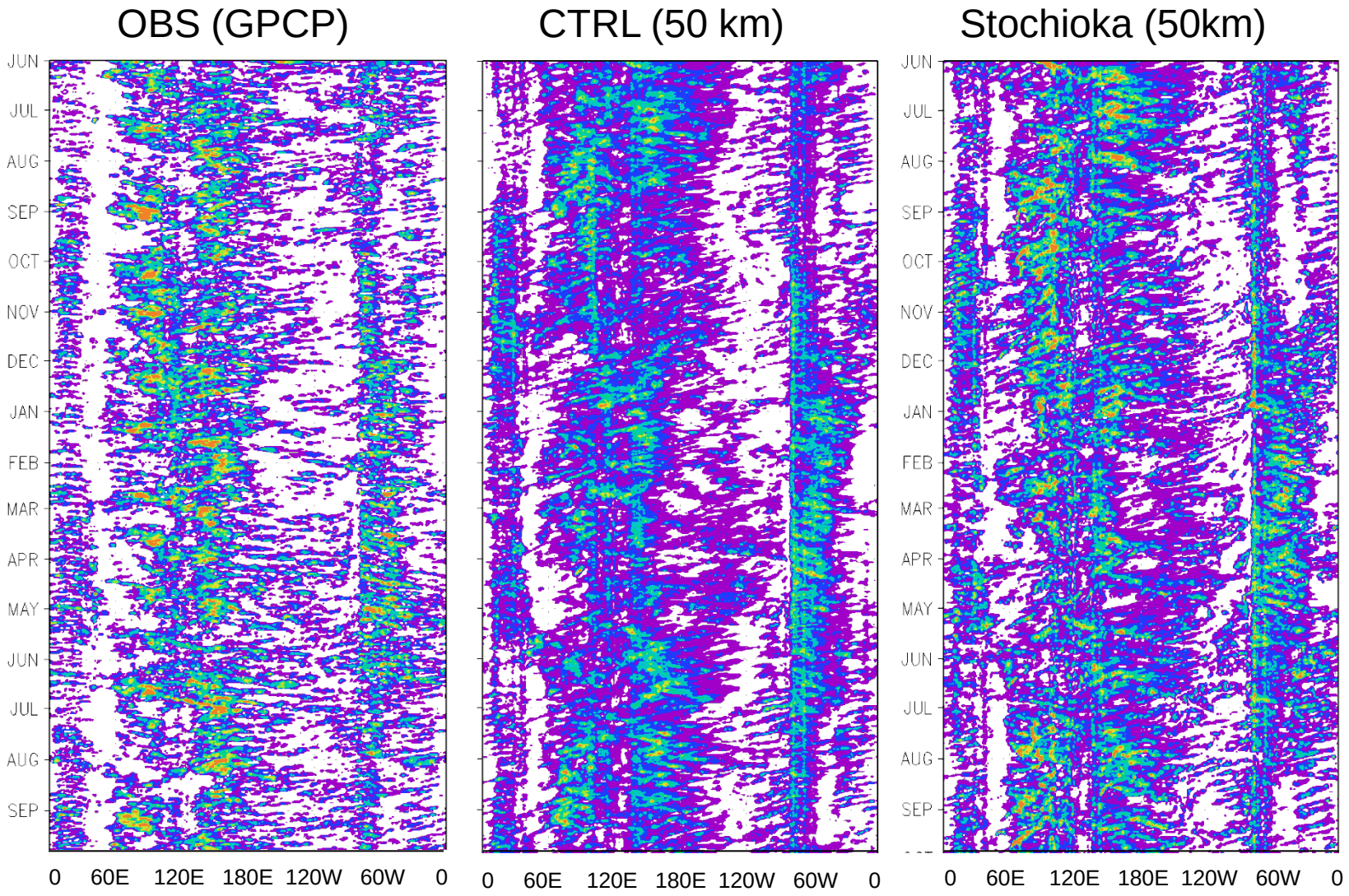
Stochioka (25 km)





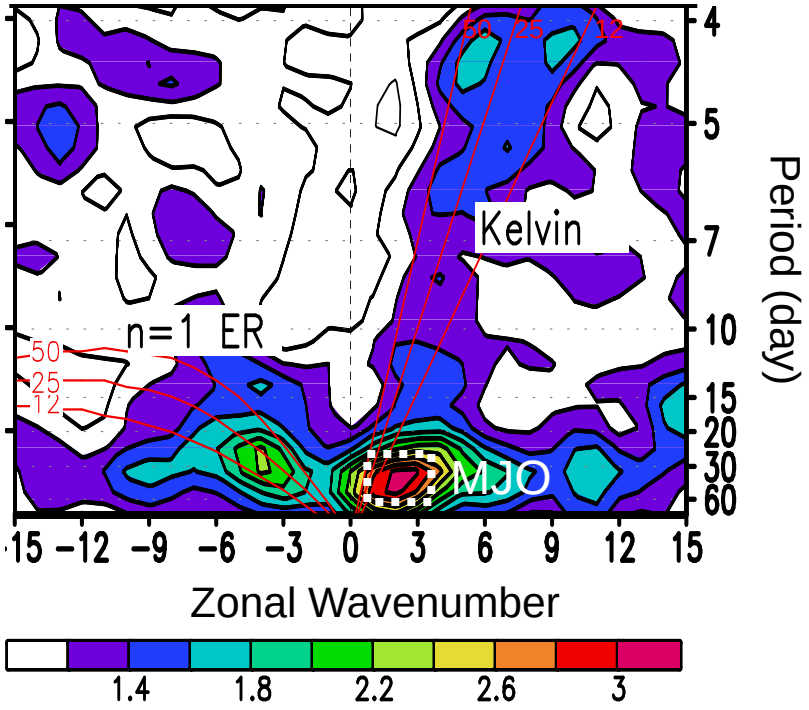
mm/d

Hovmuller Precipitation (10S-10N avg)



Tropical Waves and MJO

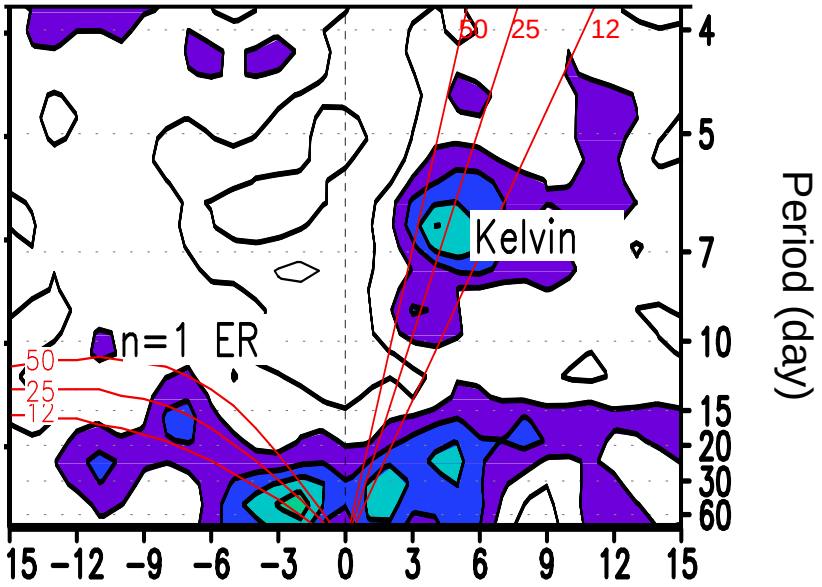
Observed (GPCP 1DD)



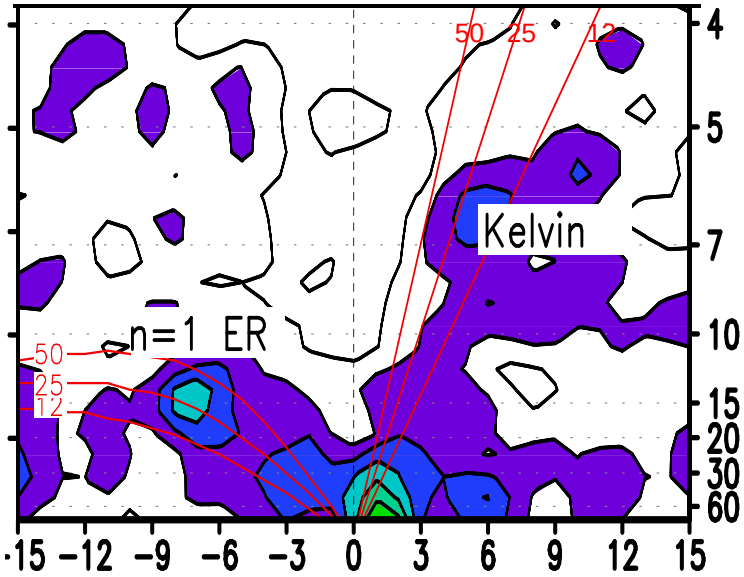
Power Spectrum of Precipitation
Tropical Belts (10S-10N)

Symmetric Component

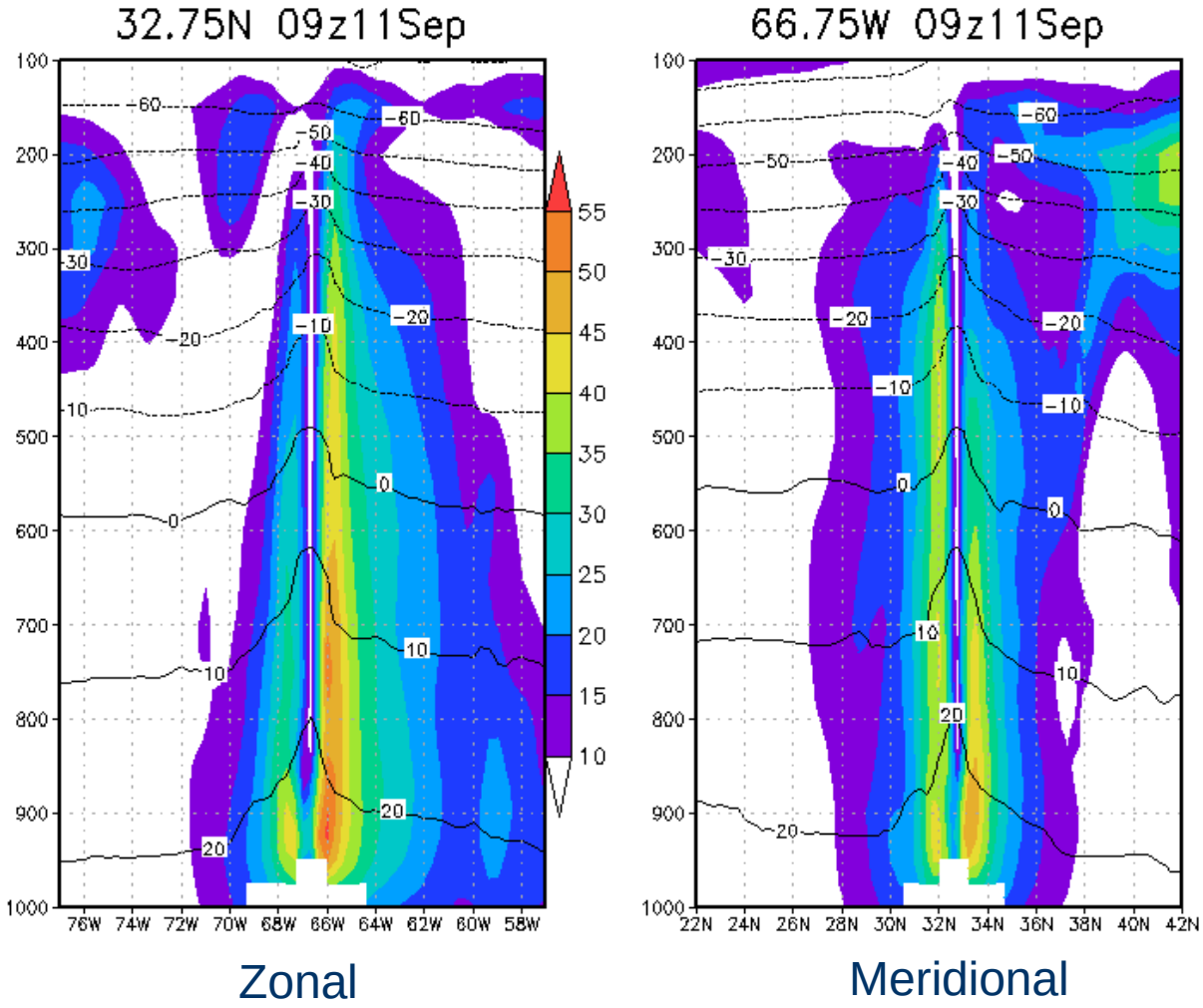
CTRL (50 km)



Stochioka (50 km)



Strongest Hurricane in the "Stochioka" Run



Zonal

Meridional

Wind up to 60 m/s

Wind max at less Than 900hP

Exceptionally well-defined warm core

Very realistic scale

Tropical Storm Simulations (50-km resolution)

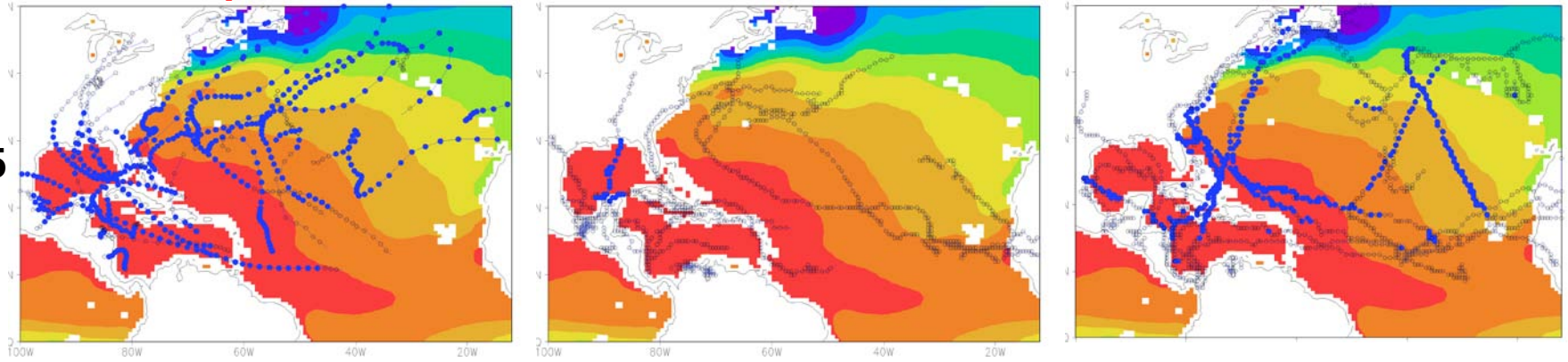
Contrasting Two Seasons in 2005 and 2006

Obs (Best Track) | **Control** | **Stochioka**

2005

27 Tropical Storms

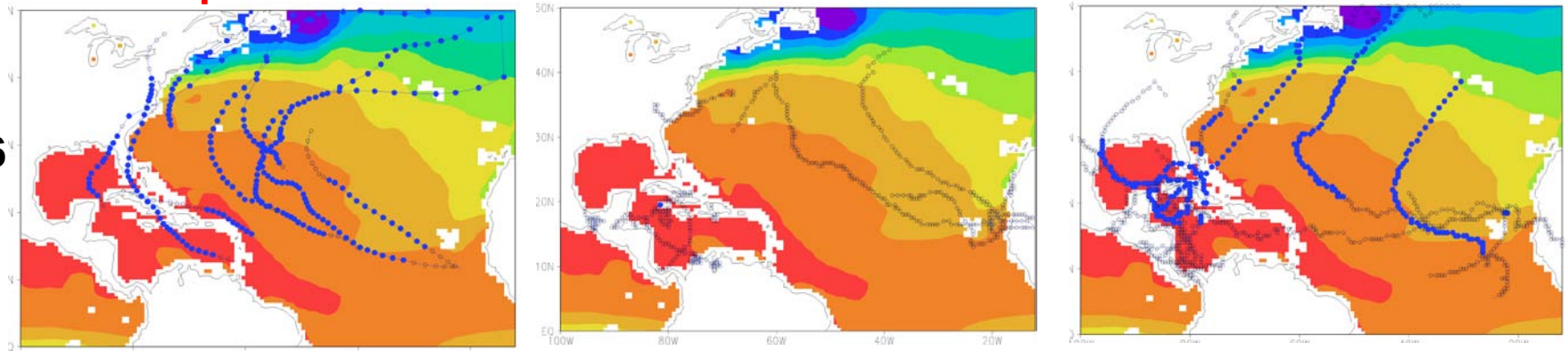
16 TSs



2006

10 Tropical Storms

7 TSs



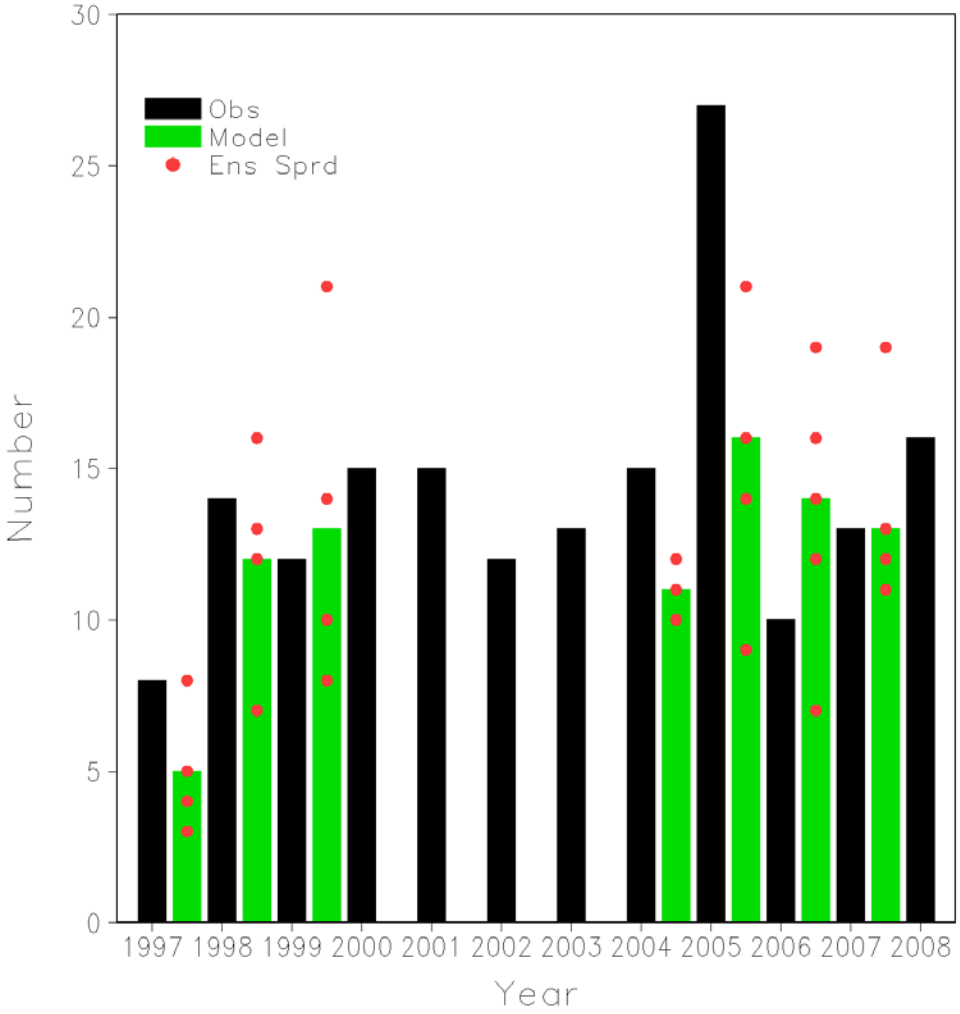
SST (K)

Location defined as a tropical storm (max 10-m wind > 34 knots)

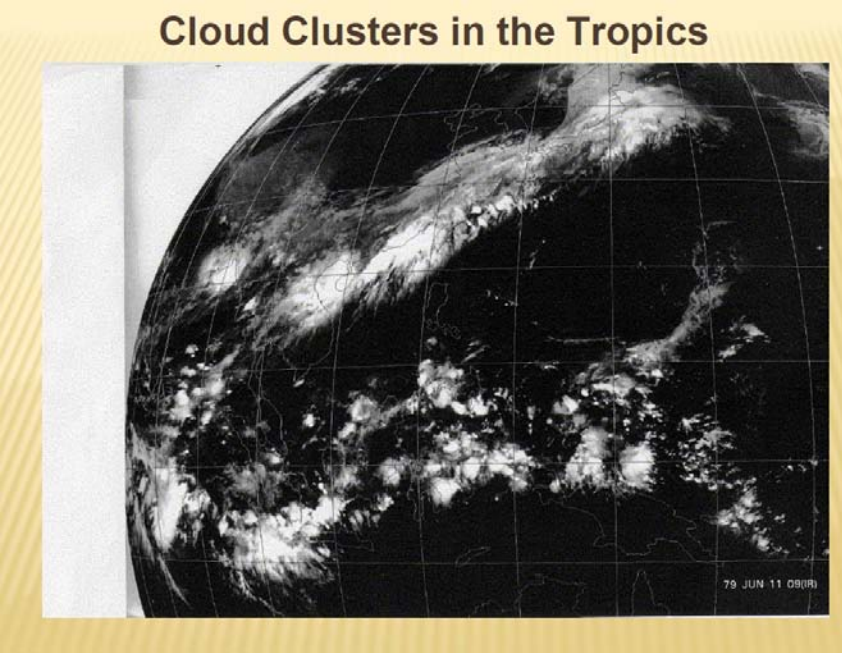
Multi-Year Ensemble Simulations for Tropical Storm

- Stochioka modification in RAS
- ½-deg runs with different SST
  1997, 1998, 1999
  2004, 2005,2006,2007
- 5 member ensembles for each year
- Initialized at 15 May
- Integration for 15 May to 1 December

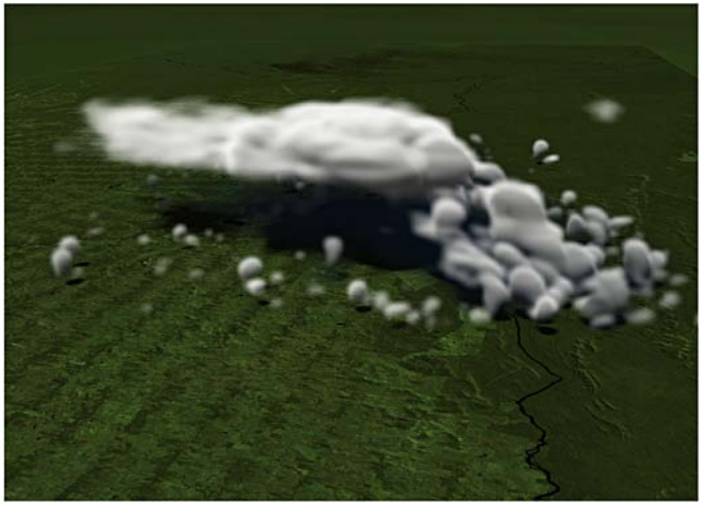
Number of Tropical Storms in Atlantic
(16 may to 30 November)

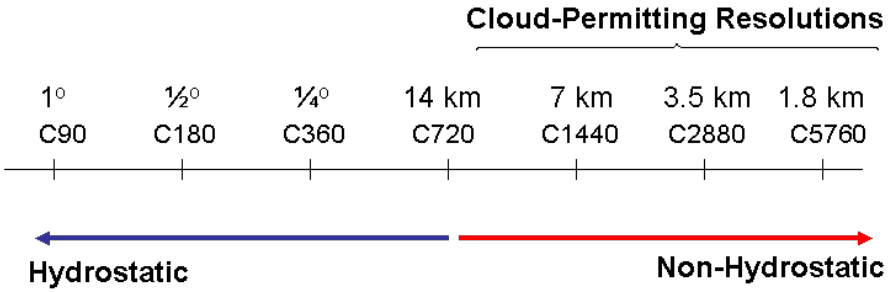


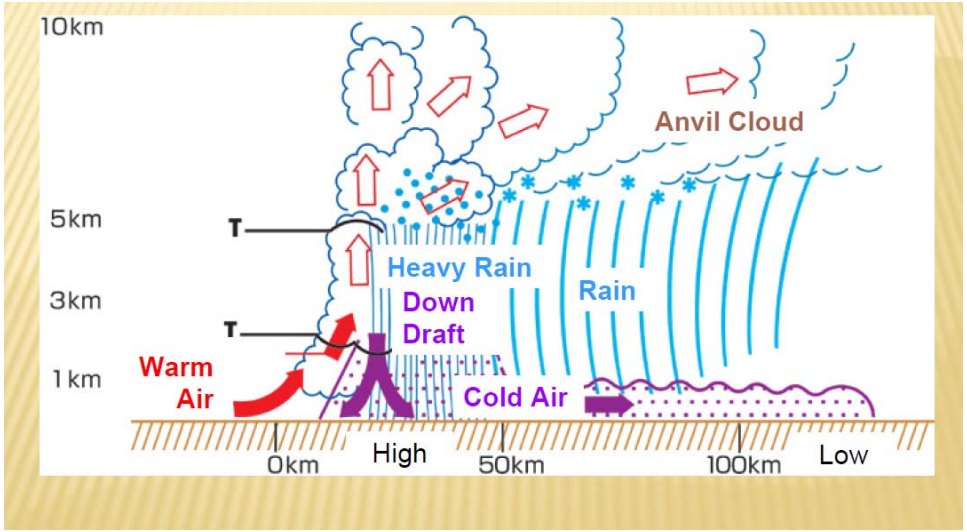
Toward a Next Generation Global Climate Model



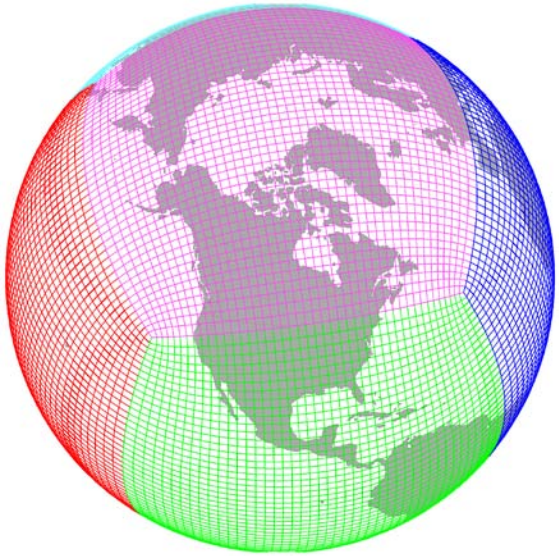
GCE Simulation







First Results of GEOS-5 Cubed-Sphere Runs

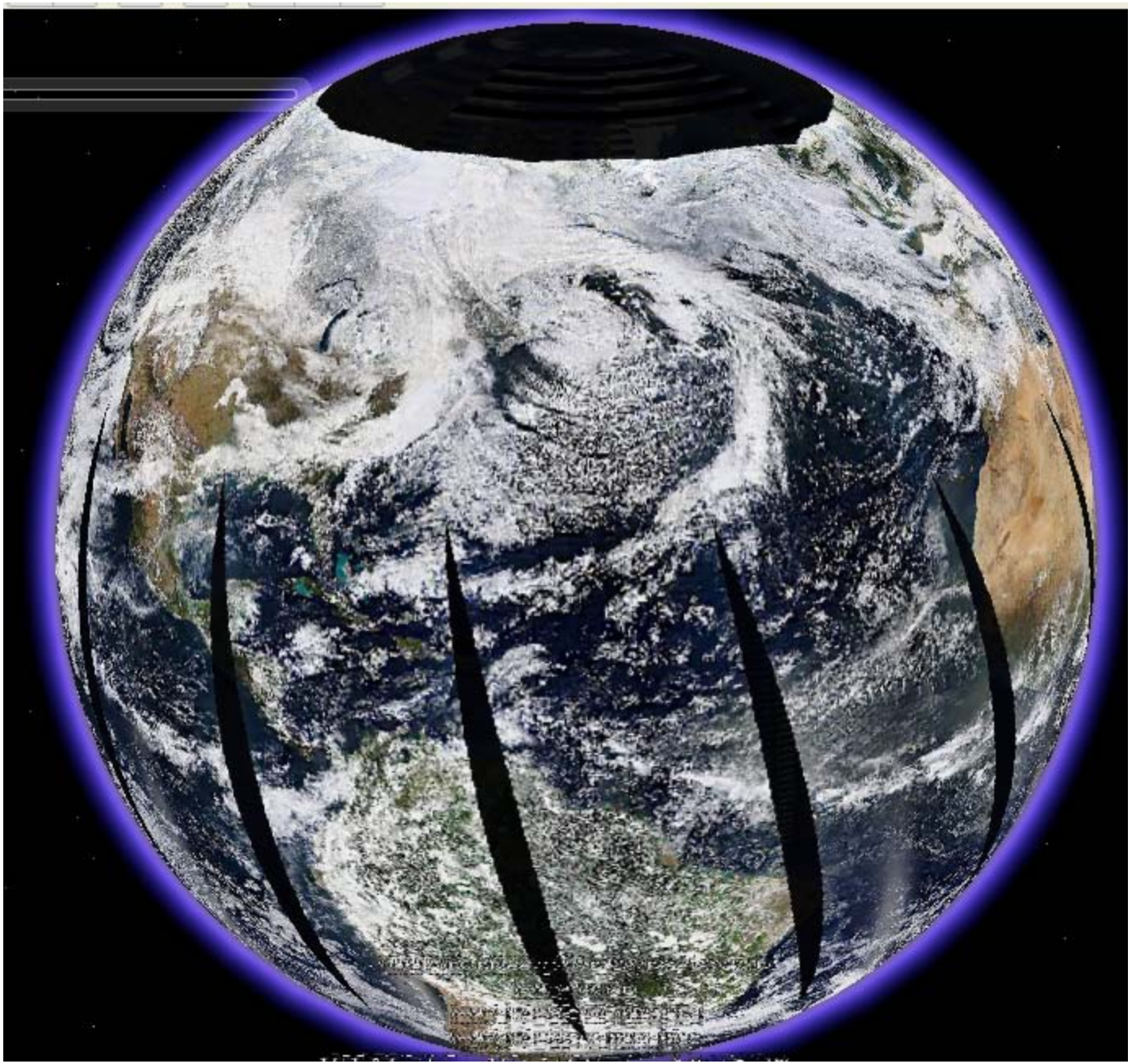


- Have access to two large computing systems: Pleiades at NAS (50000) and Jaguar at ORNL (150000).
- Selected as part of team of ~20 groups that will be experimenting on running very large (many cores) jobs on Jaguar until it is opened to more general use in July.
- Make forecasts and simulations with the atmospheric model at unprecedented resolutions, pushing both problem size and processor counts.

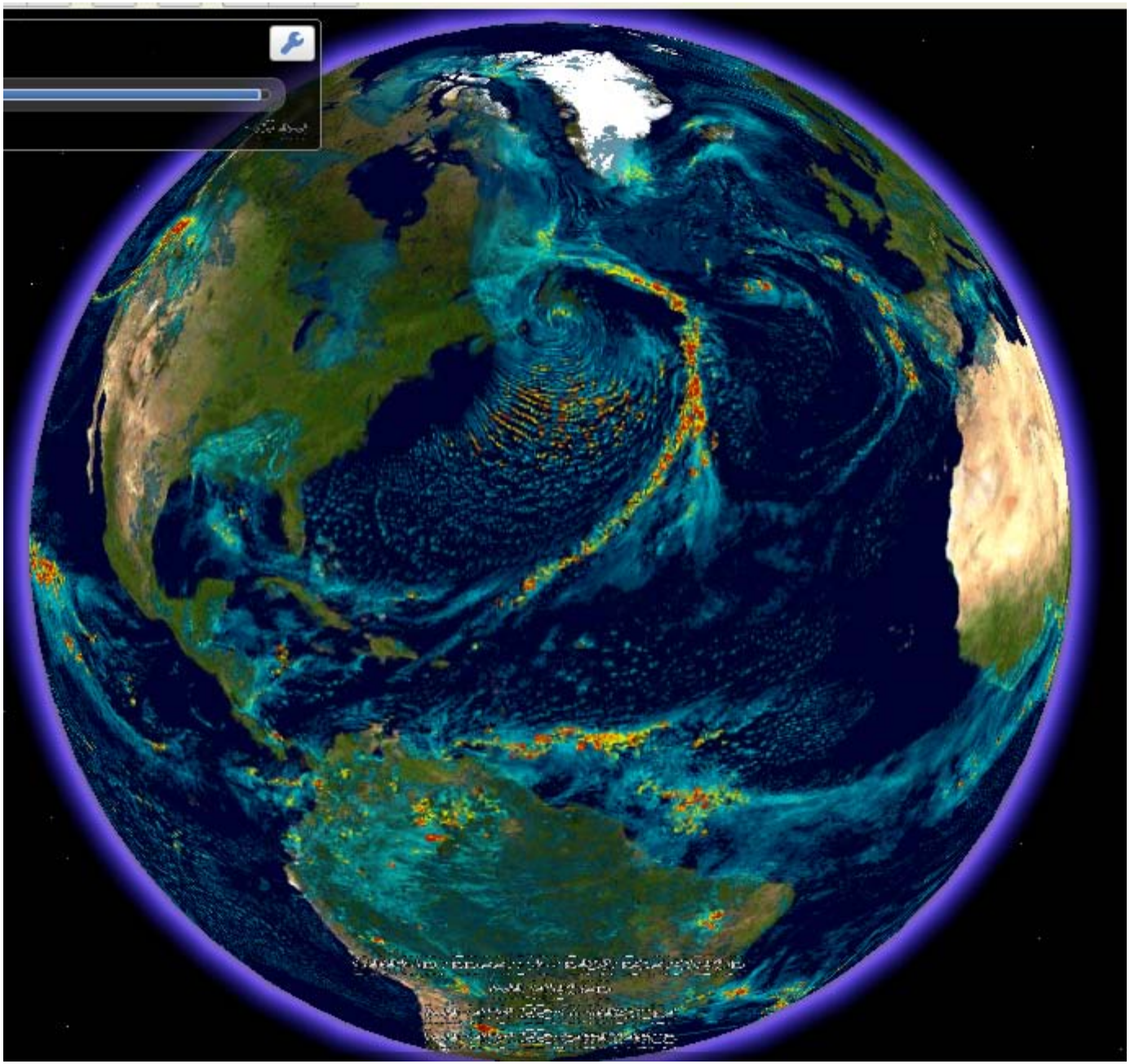
C180	(55 km)	500 cores	produces 440 d/d
C360	(27 km)	2000	220 d/d
C720	(14 km)	8000	110 d/d
C1440	(6.9 km)	32000	55 d/d
C2880	(3.4 km)	128000	27.5 d/d
C5760	(1.7 km)	512000	13.75 d/d

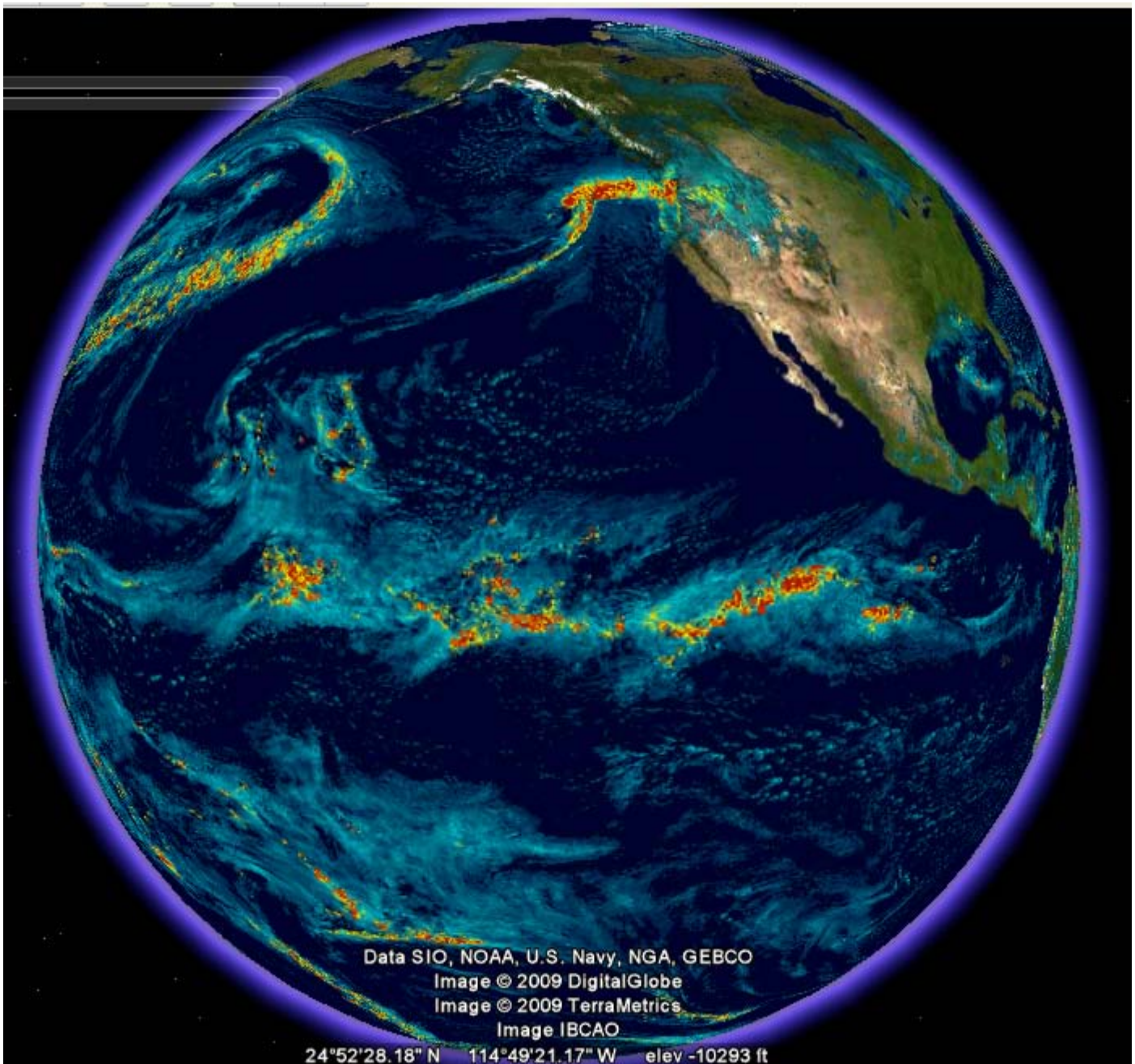
Current testing

- **MODIS/Aqua**



GEOS-5 Cubed Sphere 6.9 km Simulation



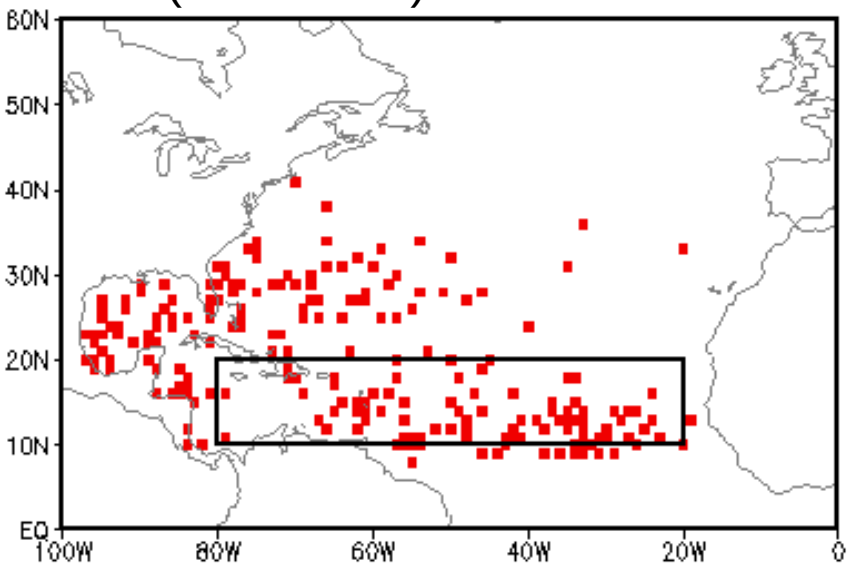

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2009 DigitalGlobe
Image © 2009 TerraMetrics
Image IBCAO
24°52'28.18" N 114°49'21.17" W elev -10293 ft

Summary

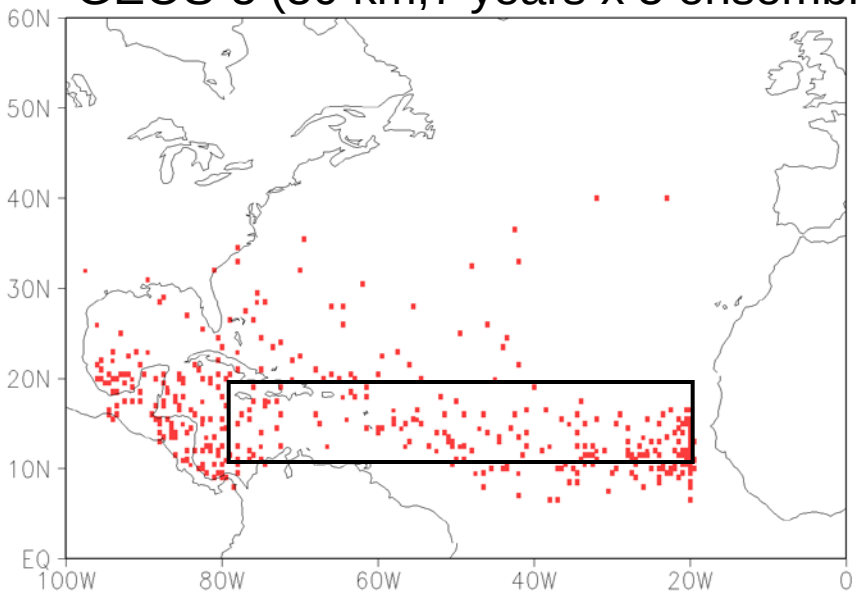
- At resolutions of 25-50 km, the convective parameterization is still needed and plays a key role in dictating mean climate and temporal variability.
- Further understanding and improvement on the deep convection process is required: Stochastic treatment for cumulus entrainment process improves many parts of weather-climate variability (e.g., MJO and tropical storms)
- We keep moving on to develop a next generation version of global climate model. The 7-km non-hydrostatic model produces a very promising result, and tends to capture the organized convective systems and their fine, mesoscale structure. More test and development are under way.

Tropical Storm Origins
(August-September-October)

Obs (1981-2007)



GEOS-5 (50 km,7 years x 5 ensembles)



(Image courtesy: Jae Schemm)

Box: Main Development Region (MDR)

Annual Cycle of Tropical Storm Origins (GEOS-5)