

Tropical Storm Simulations Using a High-Resolution GCM

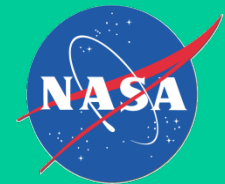


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Global Modeling and Assimilation Office/ NASA GSFC



US-Korea Workshop on Use of High Resolution Model
for ISI Prediction of Extreme Events and Its Regional Impacts
October 18, 2011, Hawaii

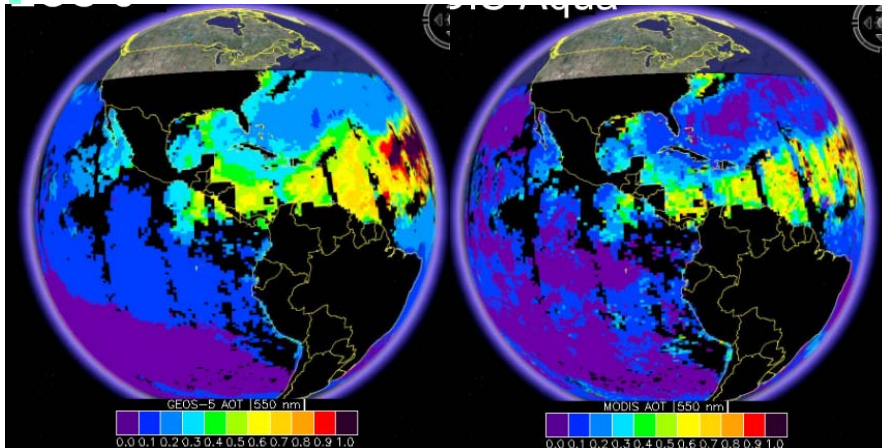
Explore the **potential predictability of tropical storms** based on long-term high-resolution (25-50 km) GCM experiments

- Realism of simulated tropical storms
- Climatological-mean genesis and tracks
- Intensity at the maximum development
- Interannual variation of tropical storm activity

- Developed by NASA/GMAO
- Fully coupled with the ocean GCM, and with the GOCART-aerosol/chemistry
- Use a version of **atmospheric model only** in this study

**Simulation
(GEOS-5)**

**Satellite
(MODIS)**



total aerosol optical depth

- Finite Volume (FV) dynamical core (Lin and Rood, 1996; Lin 2004) with 72 vertical levels (top: 0.01 hPa)
- **RASconvection (Moorthi and Suarez, 1992)**
- Chou –Suarez Radiation (1994;1999)
- Prognostic Clouds (Bacmeister et al., 2000, 2006)
- Modified Lock Turbulence (Lock et al., 2000)
- Catchment LSM (Koster et al., 2000)
- Gravity Wave Drag (NCAR)



Modified Cumulus Scheme for Tropical Convection

Stochastic Determination of Cumulus Entrainment Limit

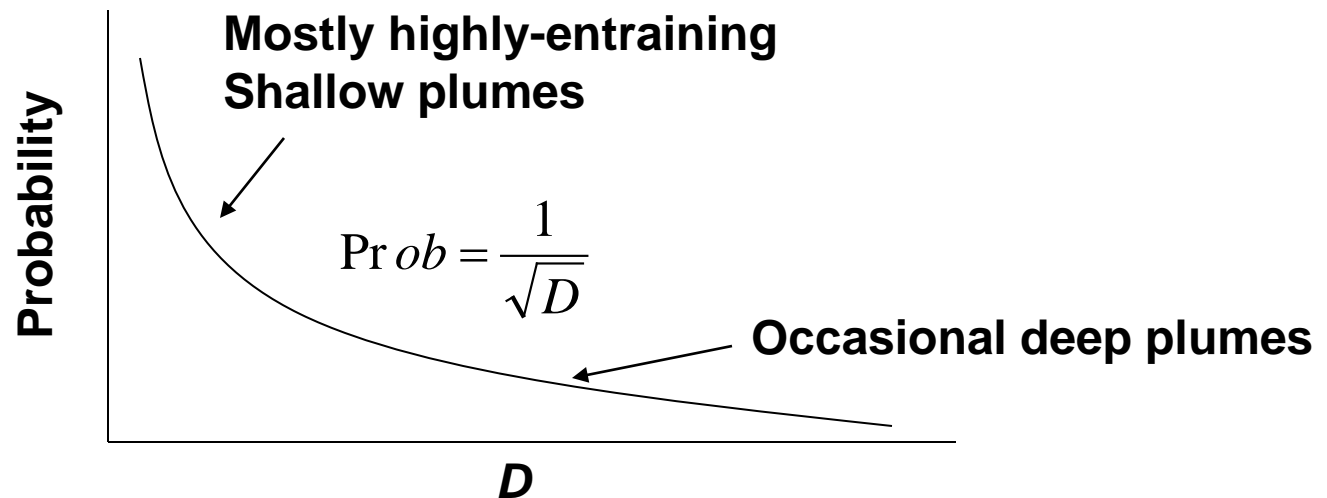
- Random selection of the minimum entrainment rate (μ)

$$\mu_{\min} = \frac{\alpha}{D}$$

$\alpha = \text{const}$ (positive),

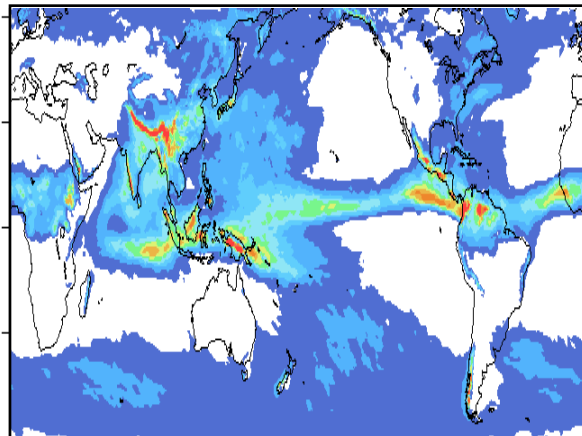
$D = \text{PBL depth} \sim \text{Diameter for the largest convective plume}$

- **Random, but probabilistic determination of D**

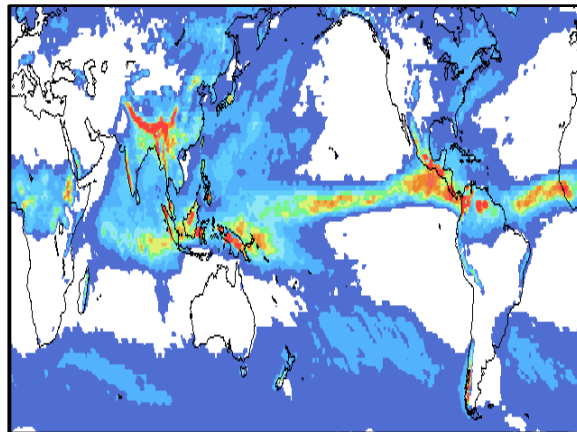


Seasonal-mean Precipitation (JJA 2005-06)

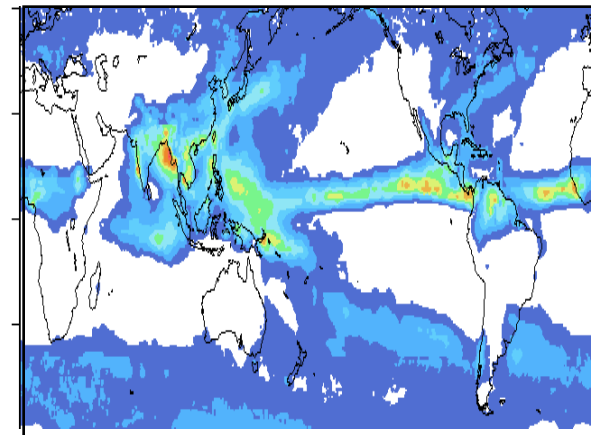
CTRL (50 km)



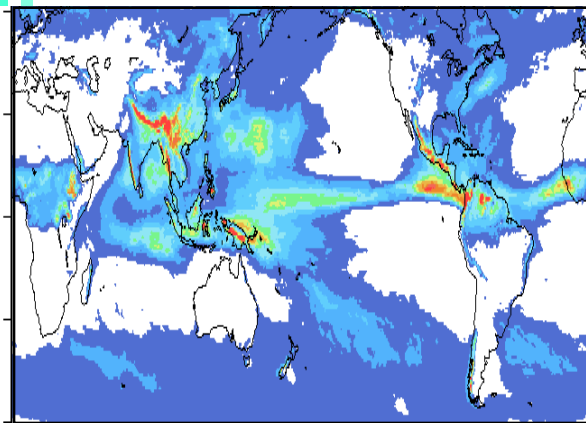
New Tokioka (50 km)



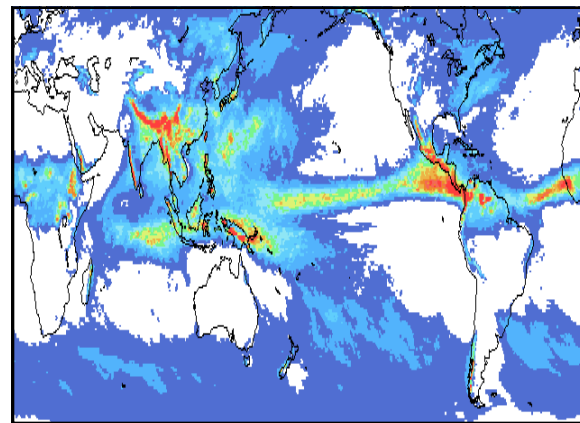
GPCP



CTRL (25 km)



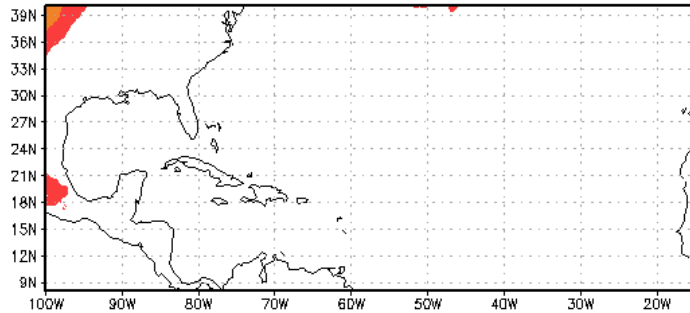
New Tokioka (25 km)



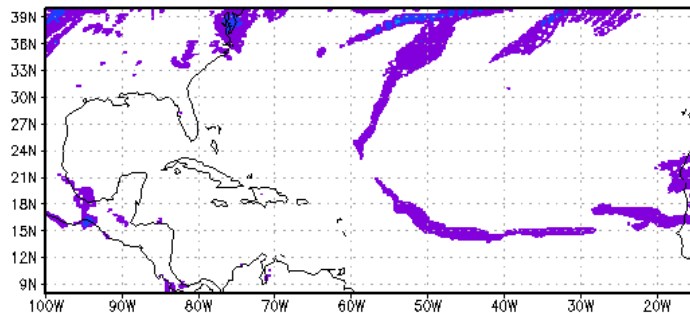
mm/d

Control Run (25-km Res)

1–30 Sep 2005 f0_ras05 min slp (hPa)

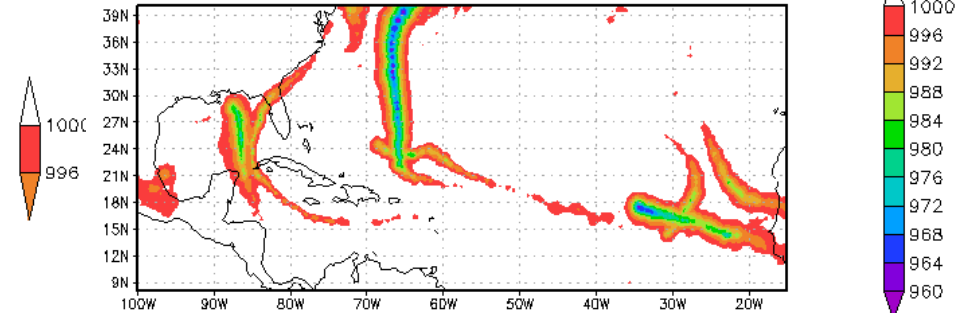


max 900hPa RVorticity (s⁻¹)

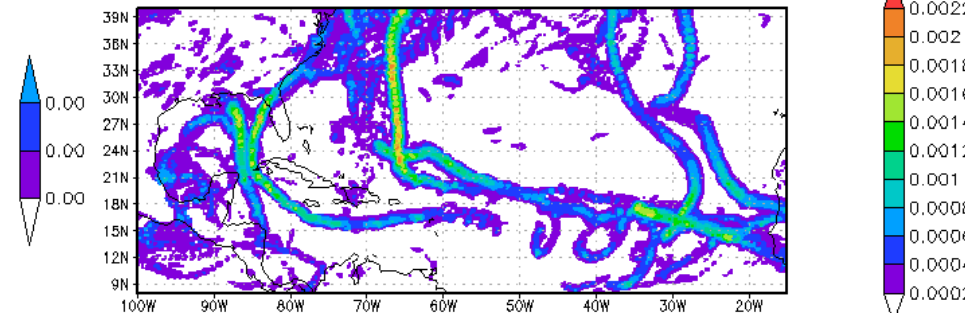


Modified Run (25-km Res)

1–30 Sep 2005 f9_ras05 min slp (hPa)

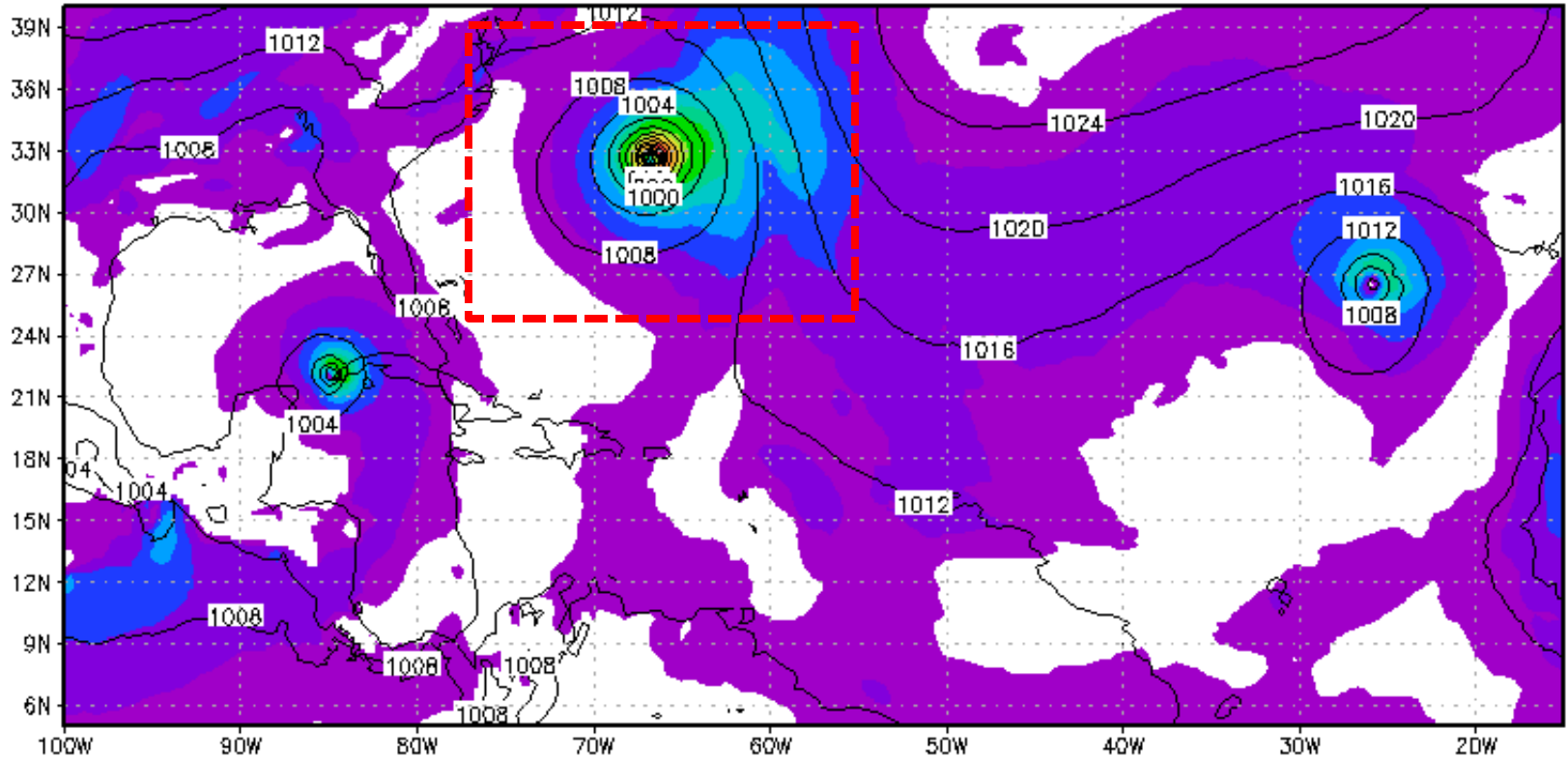


max 900hPa RVorticity (s⁻¹)



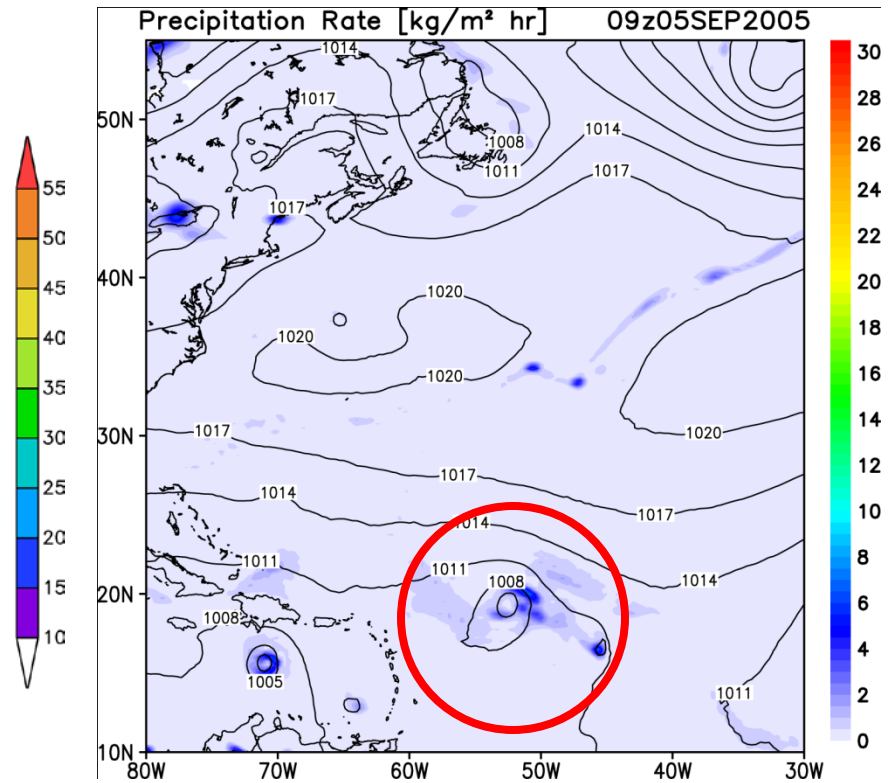
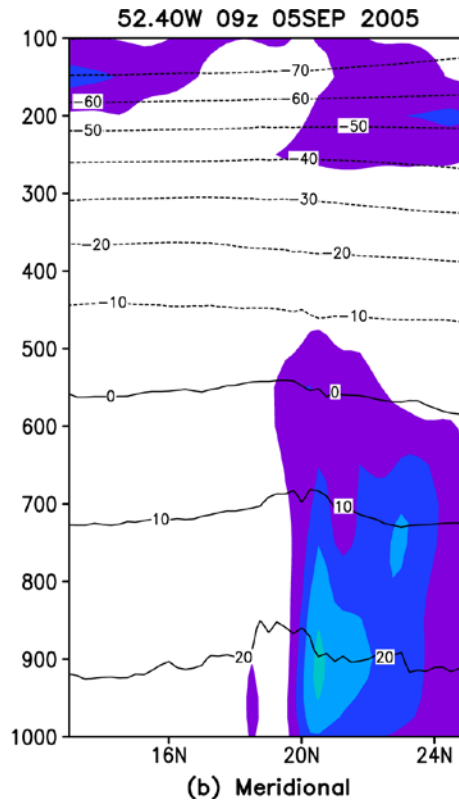
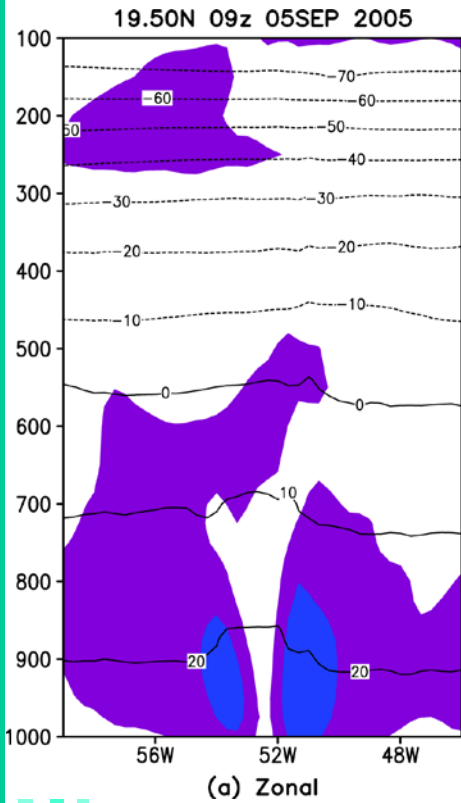
No cyclone reaches 1000hPa in the Control during September.
At least 7 cyclones below 1000 hPa in the GEOS-5 w.Tok. One hurricane goes below 960hPa. Very realistic track variability, scale.
Even non-developing waves are well captured.

slp and 925hPa Wind 3z 11Sep

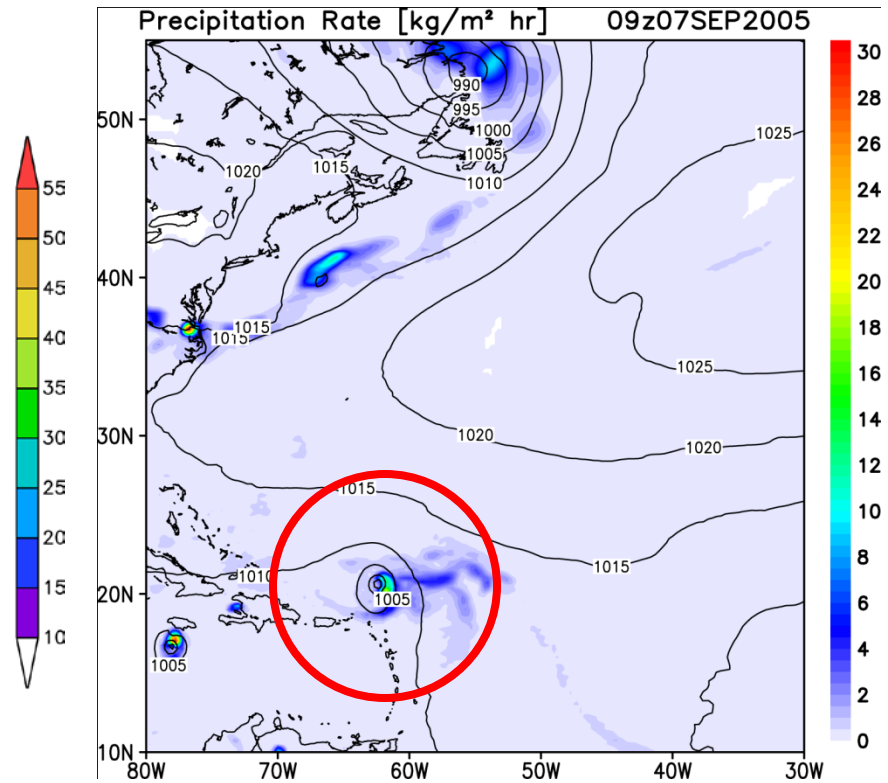
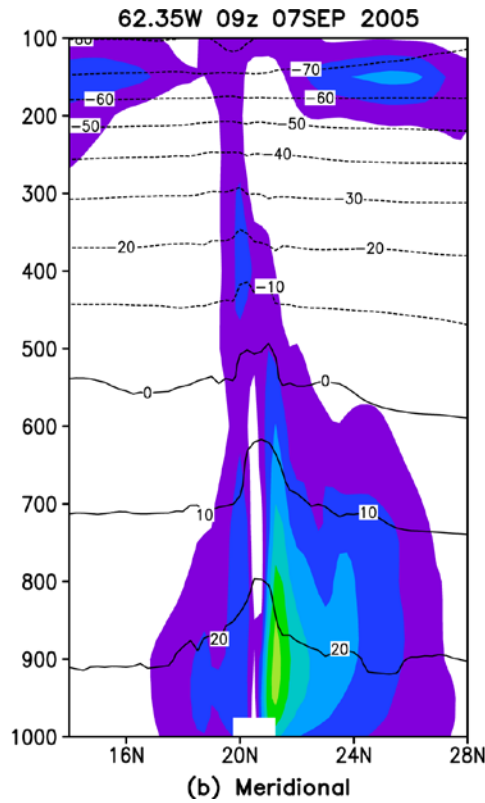
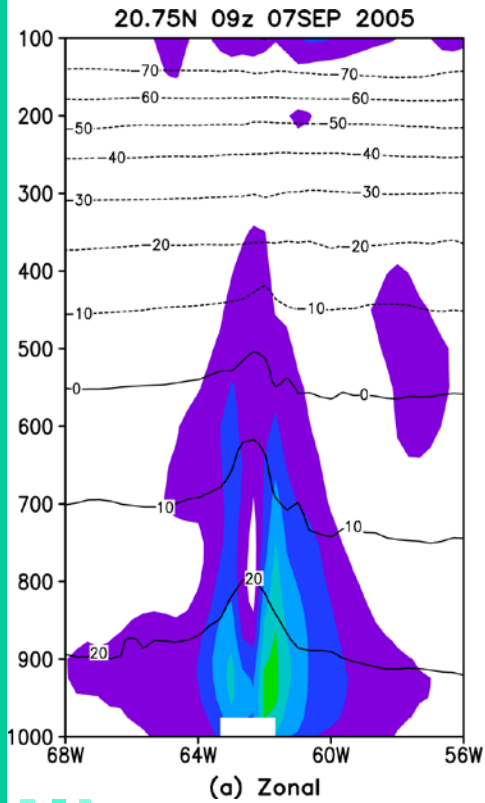


Slp (hPa) and 925 hPa wind (m/s)

Strongest Hurricane in the “New Tokioka” 25-km Run

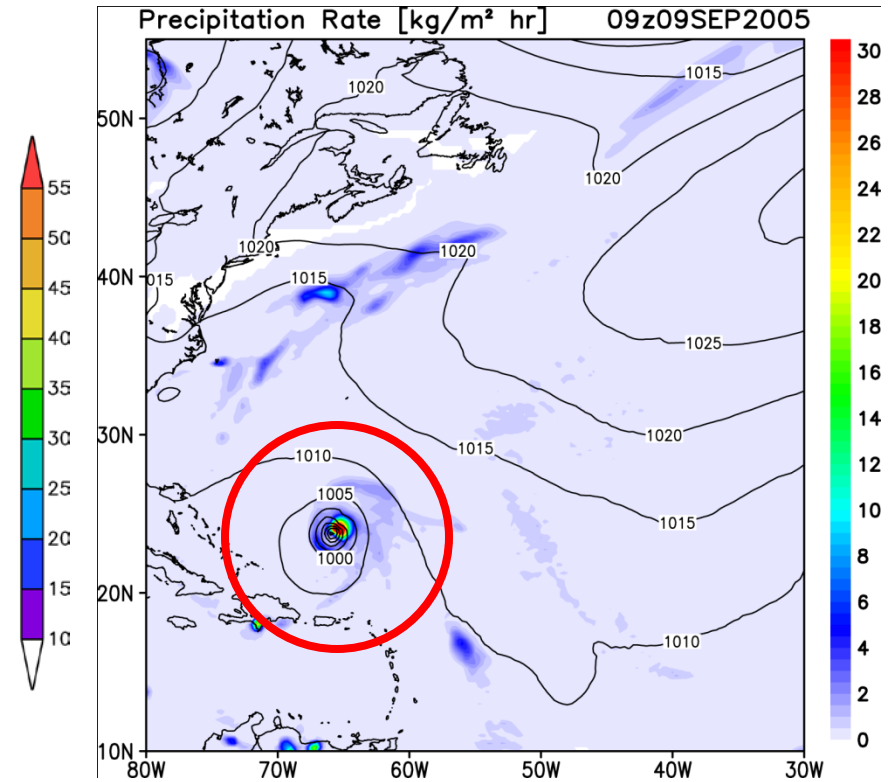
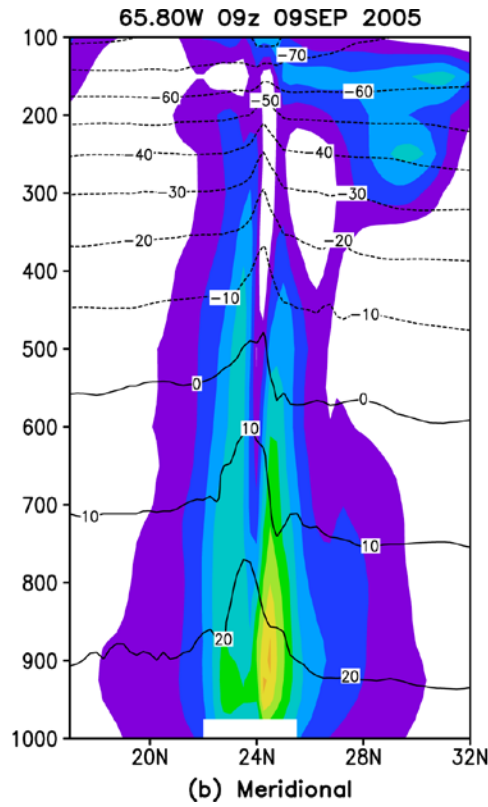
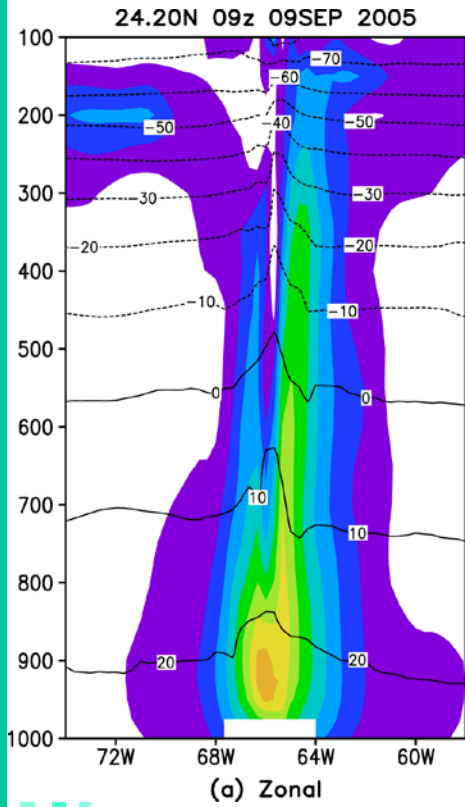


Strongest Hurricane in the “New Tokioka” 25-km Run



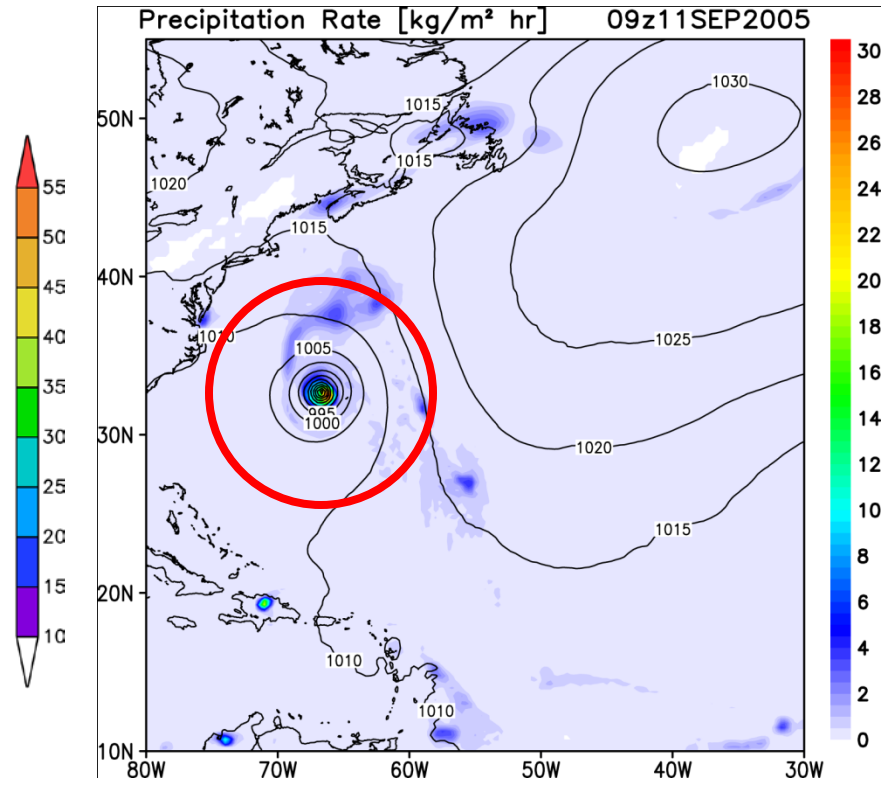
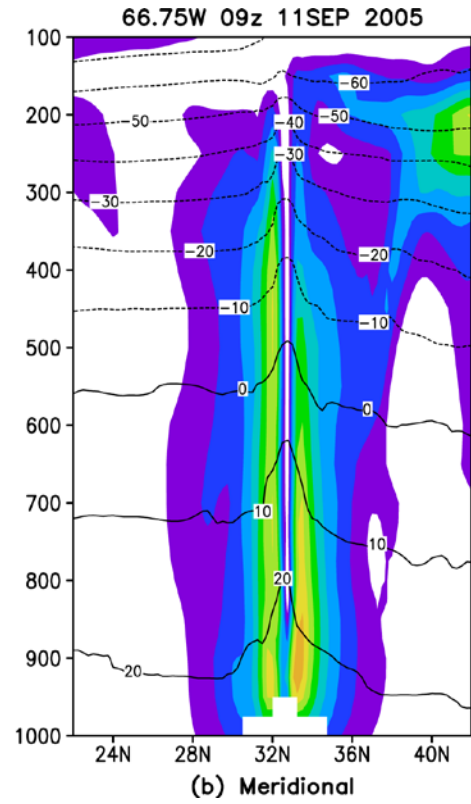
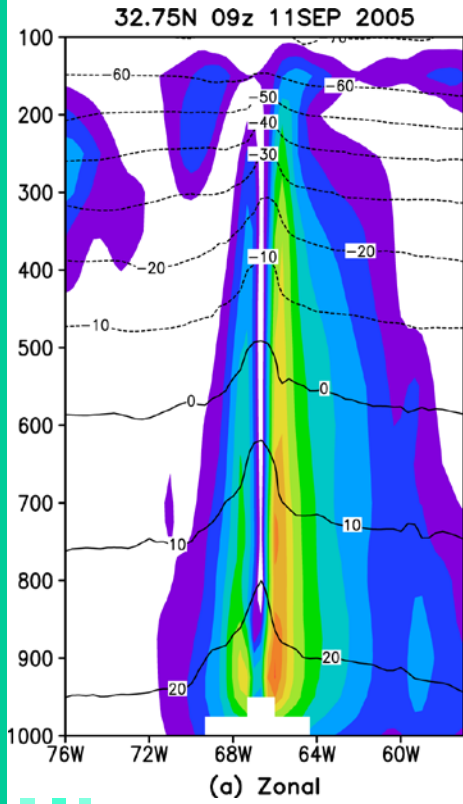
**Developing into
vertical storm with
axially-symmetric
structure**

Strongest Hurricane in the “New Tokioka” 25-km Run



**Barotropic structure
stretching to the upper
troposphere**

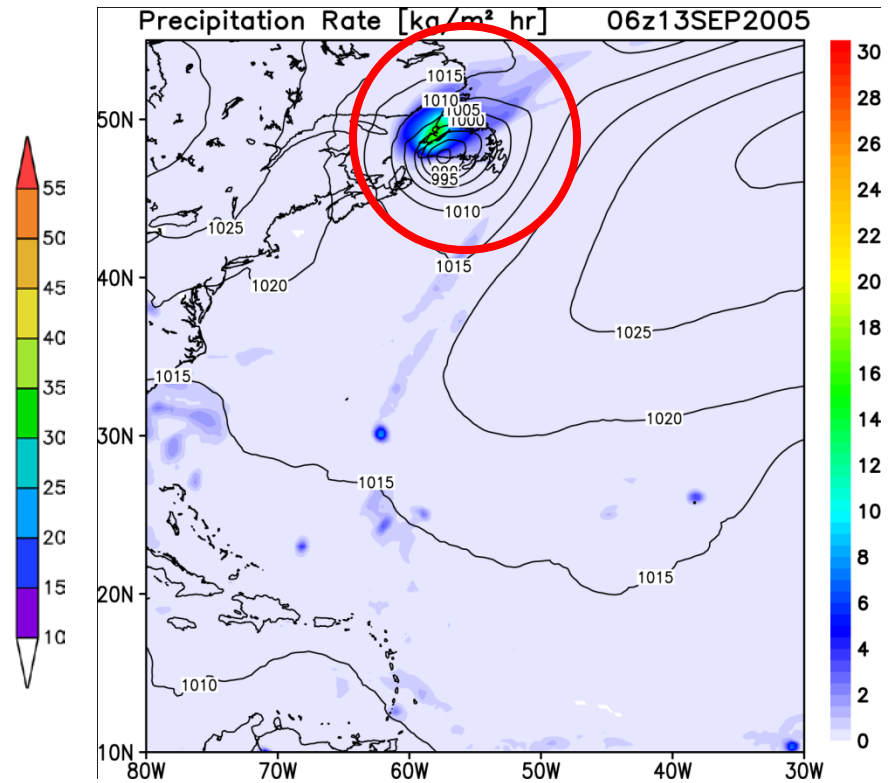
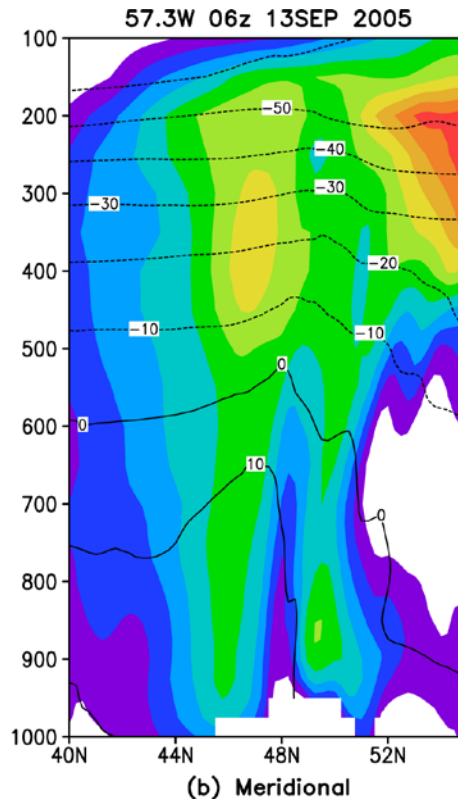
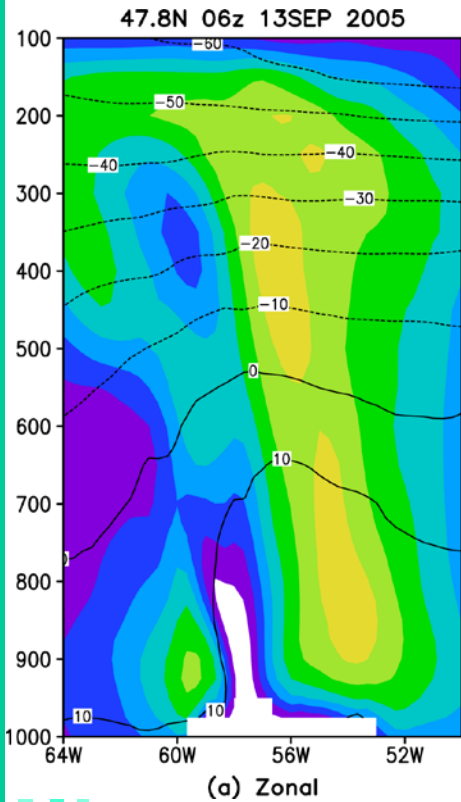
Strongest Hurricane in the “New Tokioka” 25-km Run



Wind up to 50 m/s
Wind max at less Than 900hPa
Min Pressure~960 hPa

Exceptionally well-defined warm core and the eye of the hurricane

Strongest Hurricane in the “New Tokioka” 25-km Run



**Dissipating into the
baroclinic extratropical
storm**



Multi-Year Ensemble Simulations for Tropical Storm

- Modified RAS cumulus scheme (New Tokioka)
- 50-km runs with **prescribed, observed SST** for 11 years (1997 – 2007)
- 5 member ensembles for each year
- Integration for 15 May - 1 December



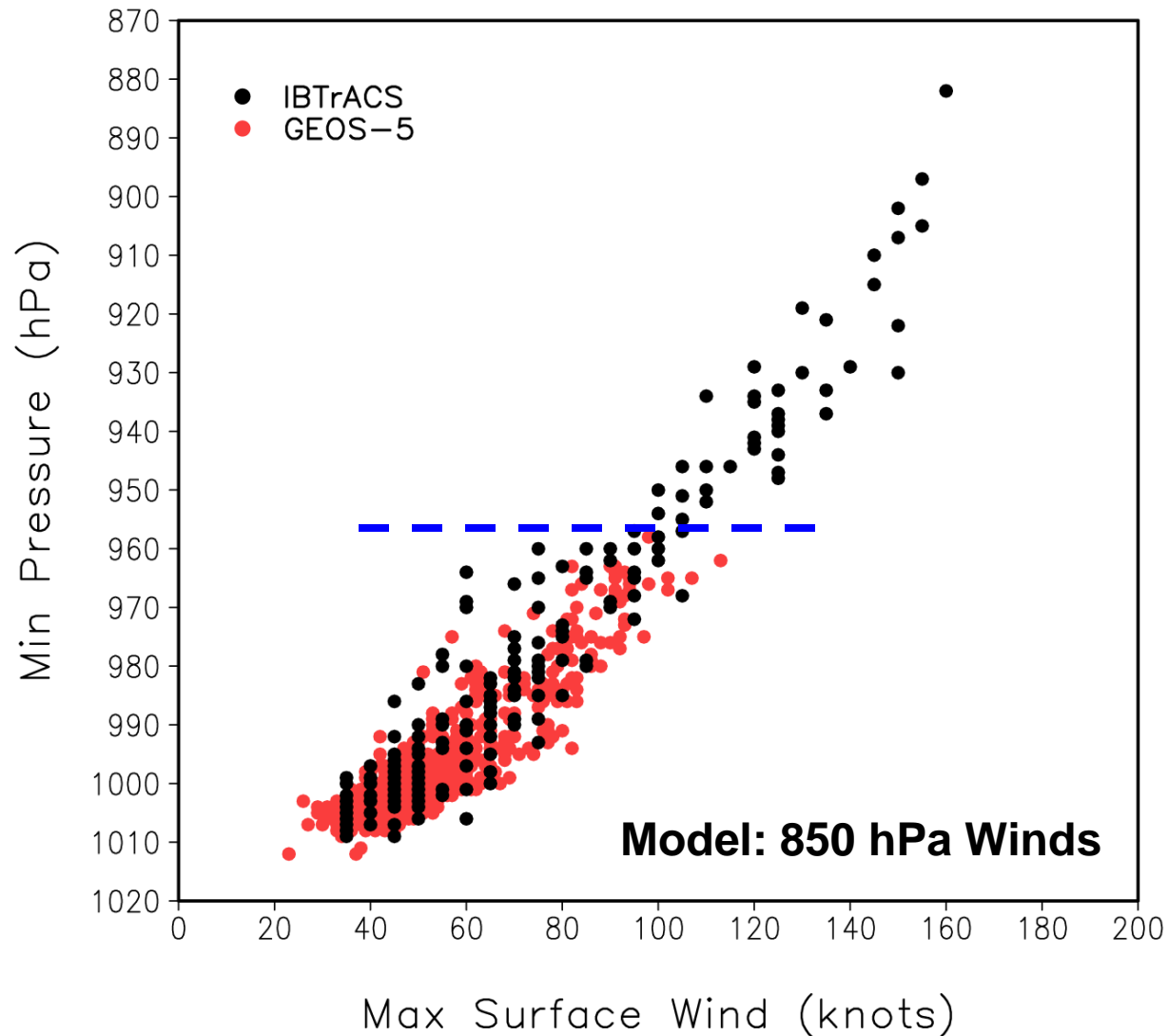
Tropical Storms Tracking

- Tracking tools based on the method of Camargo and Zebiak (2002)
 - ; basin-dependent thresholds of vorticity@850, 10-m wind, and vertically integrated temperature anomaly
- NCEP/CPC tracking version (Lindsey Long/Jae Schemm)
- Applied to 3 hourly, native grid outputs

Tropical Storms in Atlantic Ocean

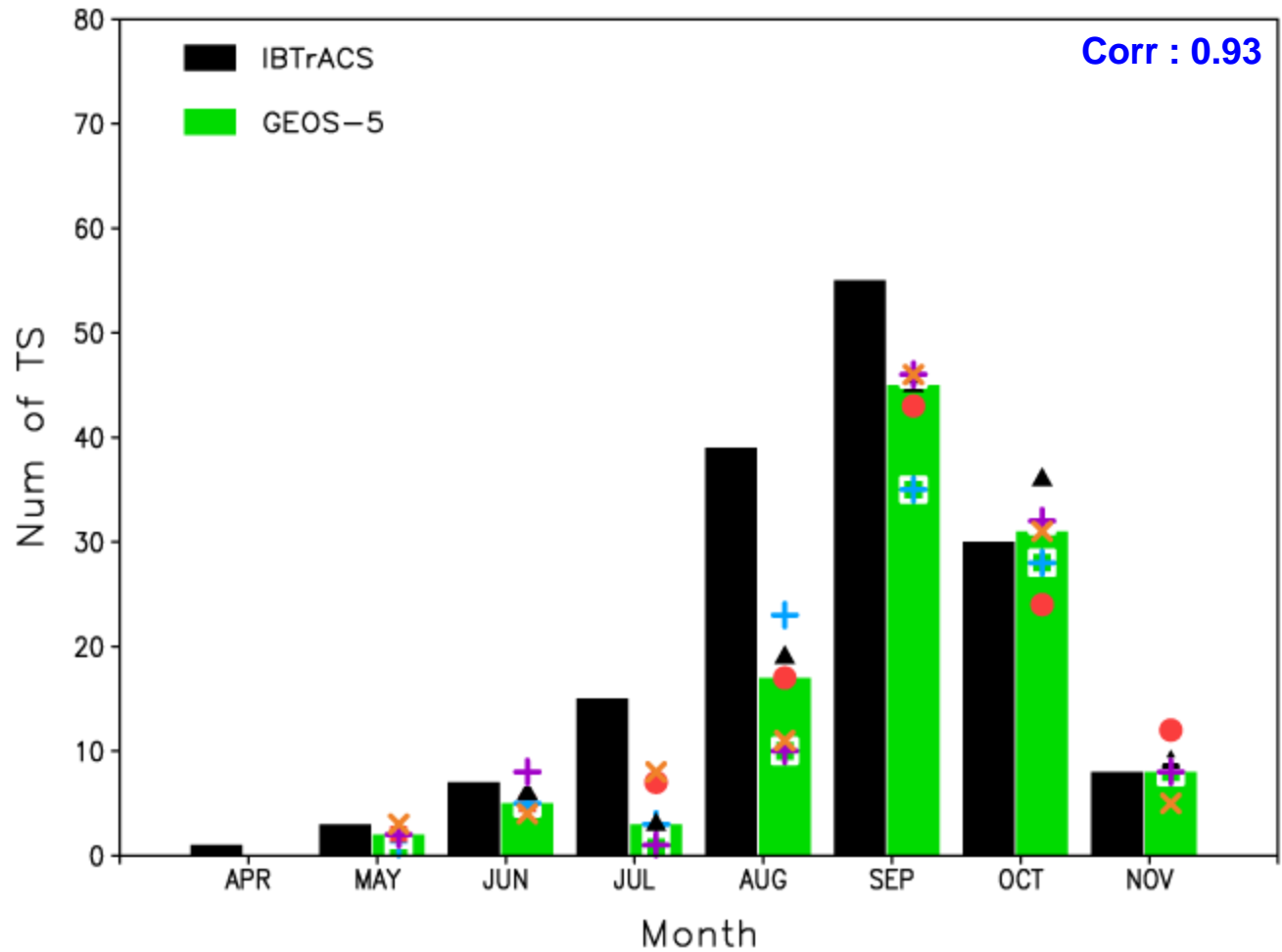
Maximum intensity of Tropical Storms

Tropical Storm Intensity in Atlantic Ocean (1997–2007)

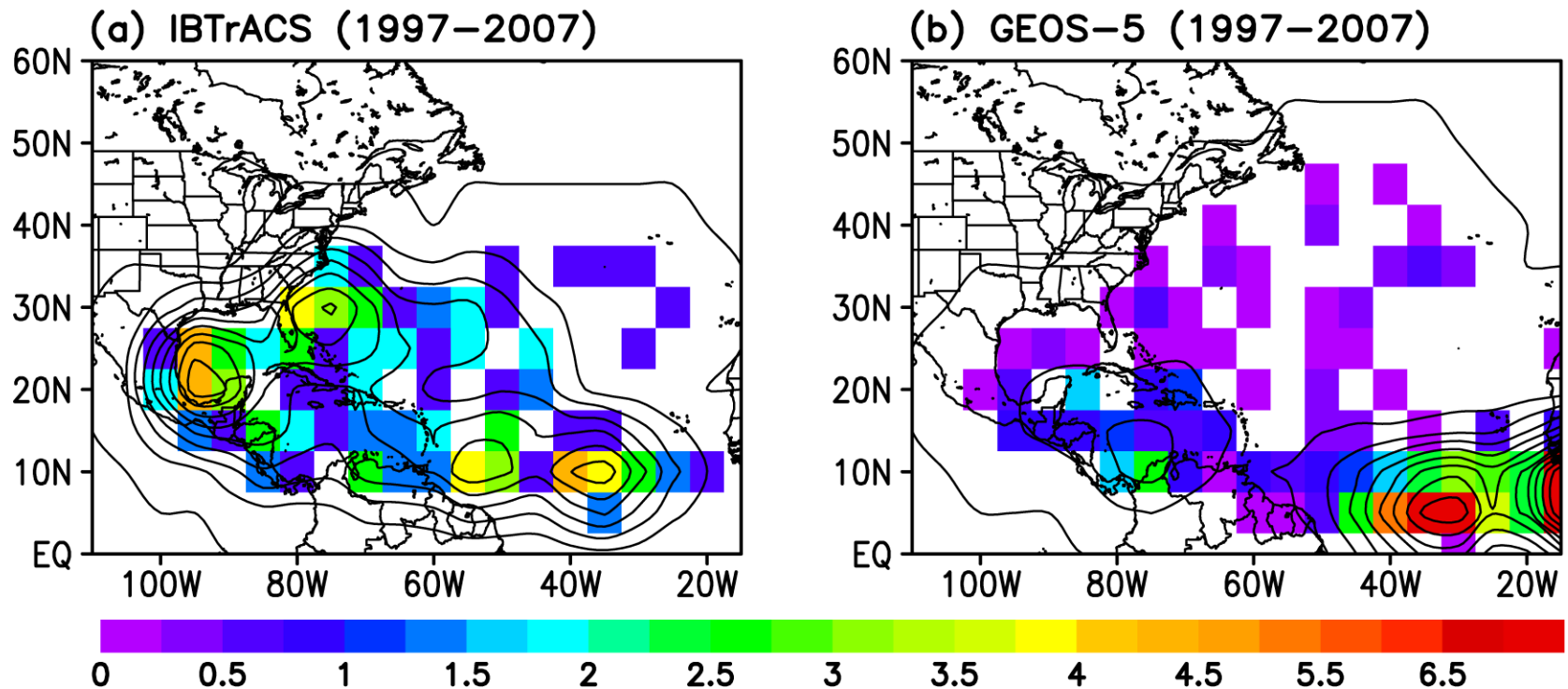


Interseasonal variation of TS

Number of TS in Atlantic Ocean (1997–2007)

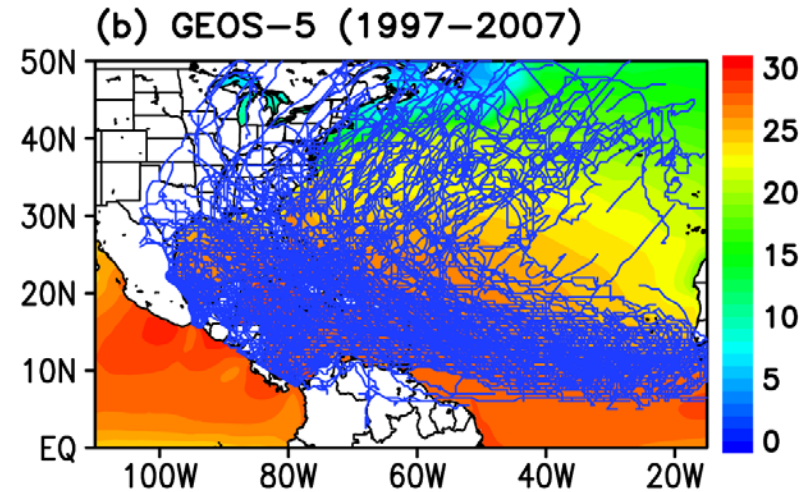
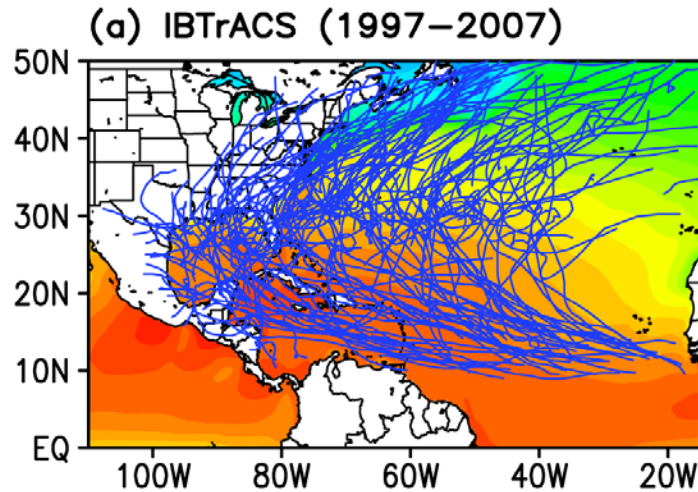


TC Frequency of origin in Atlantic Ocean

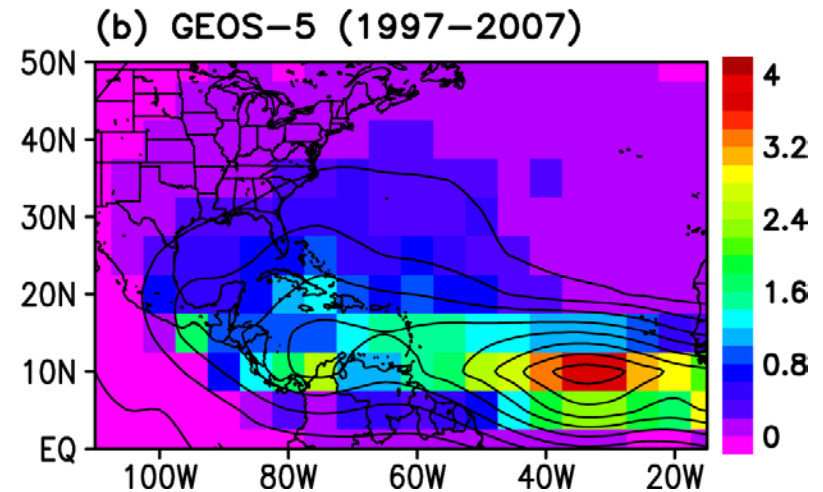
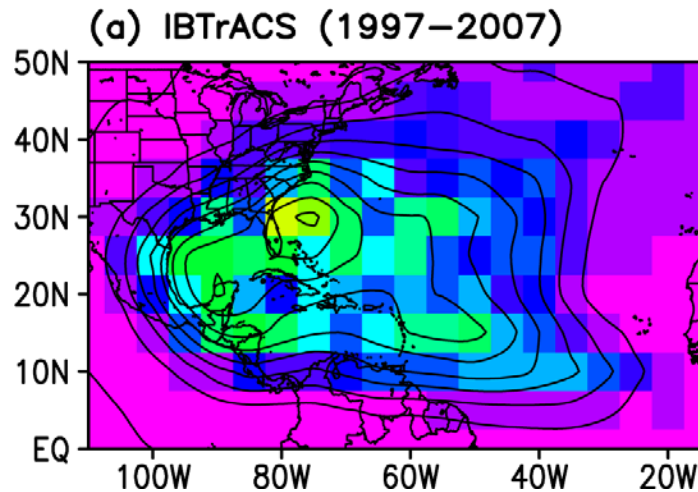


Tracks of Tropical Storm

TS Track in Atlantic Ocean

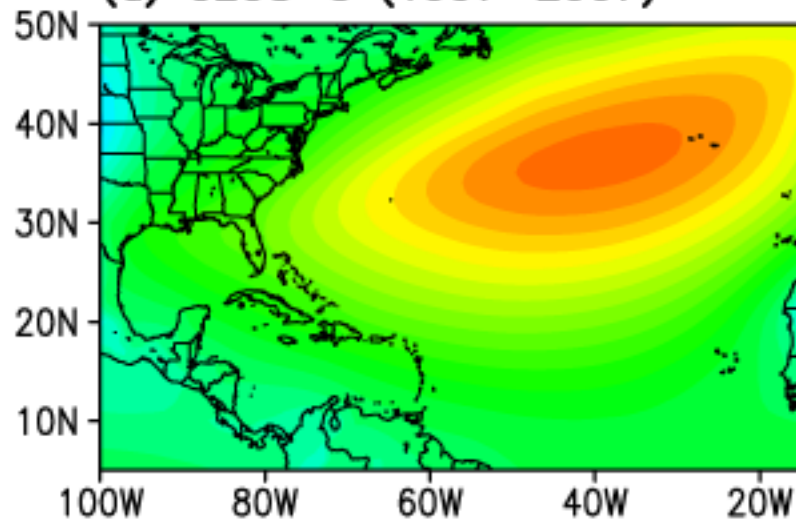


Percentage of TS pathway in Atlantic Ocean

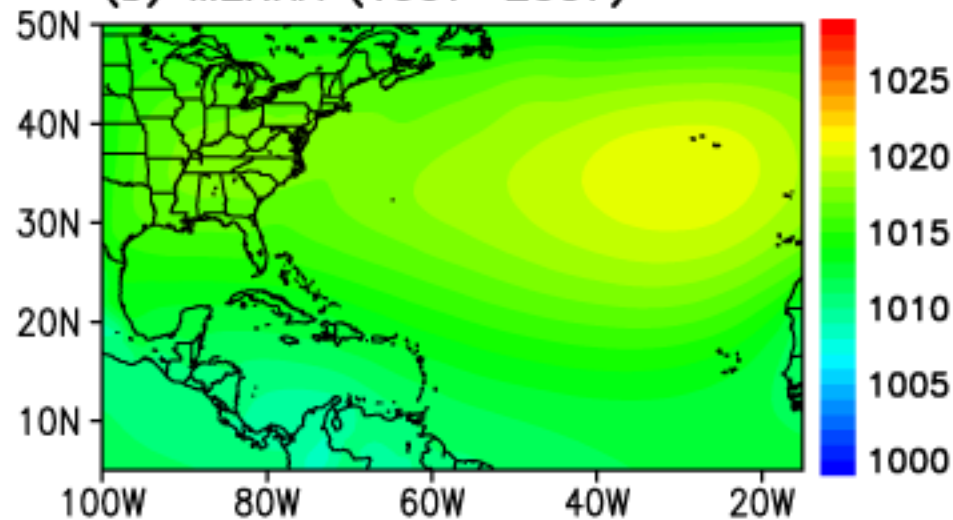


SLP in Atlantic Ocean

(a) GEOS-5 (1997-2007)

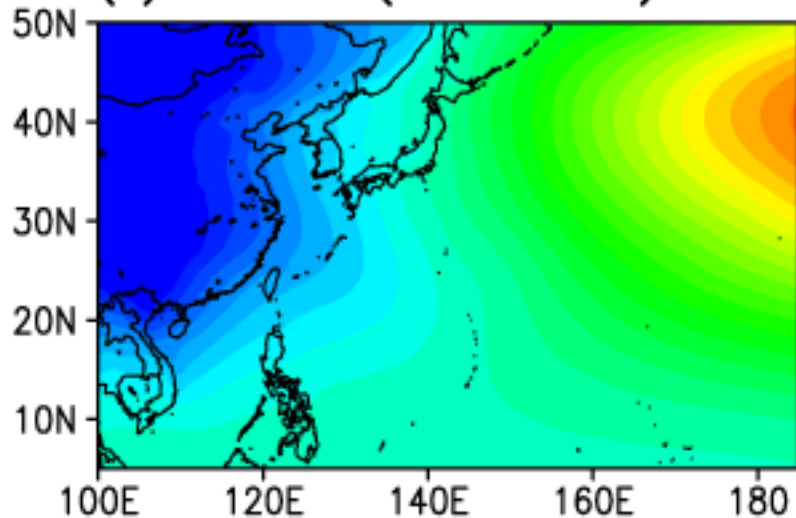


(b) MERRA (1997-2007)

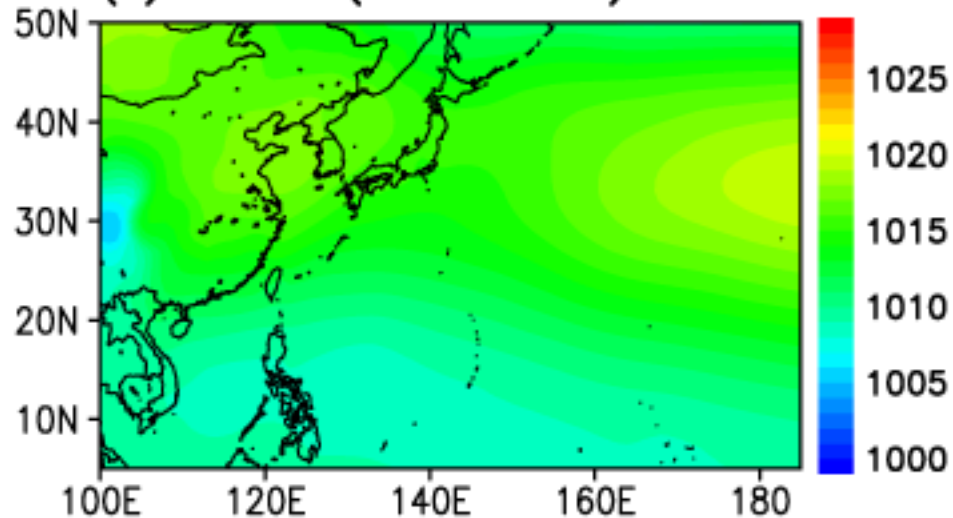


SLP in Northwestern Pacific

(a) GEOS-5 (1997-2007)

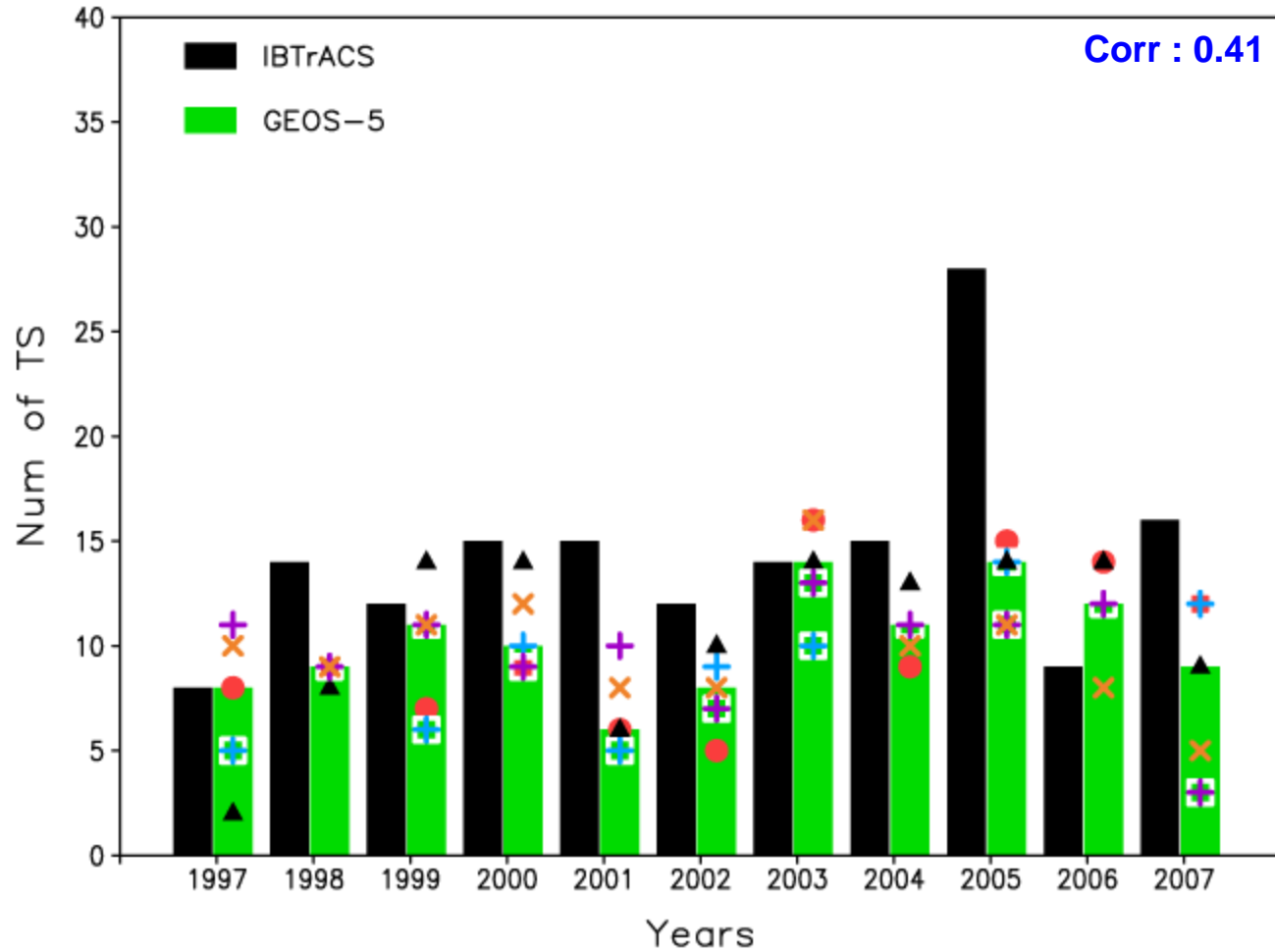


(b) MERRA (1997-2007)



Interannual variation of TS

Number of TS in Atlantic Ocean (1997–2007)



Relationship between PDI and SST

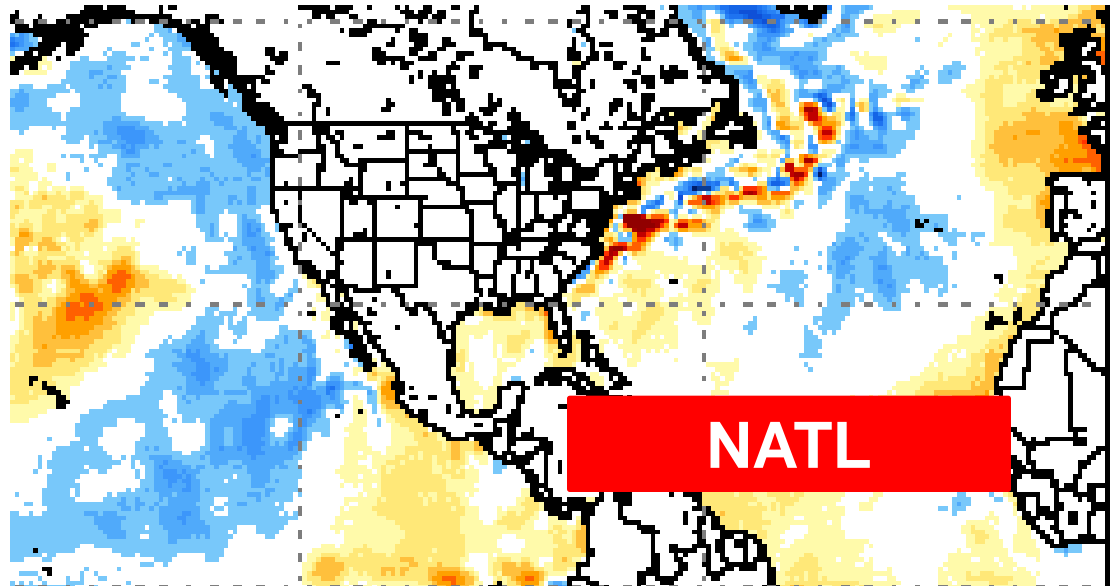
Power Dissipation Index (PDI, Emanuel, 2005): $PDI = \int_0^{\tau} (V_{max})^3 dt$

PDI is further separated into two parts of “Duration” and “Intensity”:

$$PDI = PDI^I * PDI^d = \overbrace{(V_{max})^3}^{\text{Intensity}} \times \underbrace{\int_0^{\tau} dt}_{\text{Duration}}$$

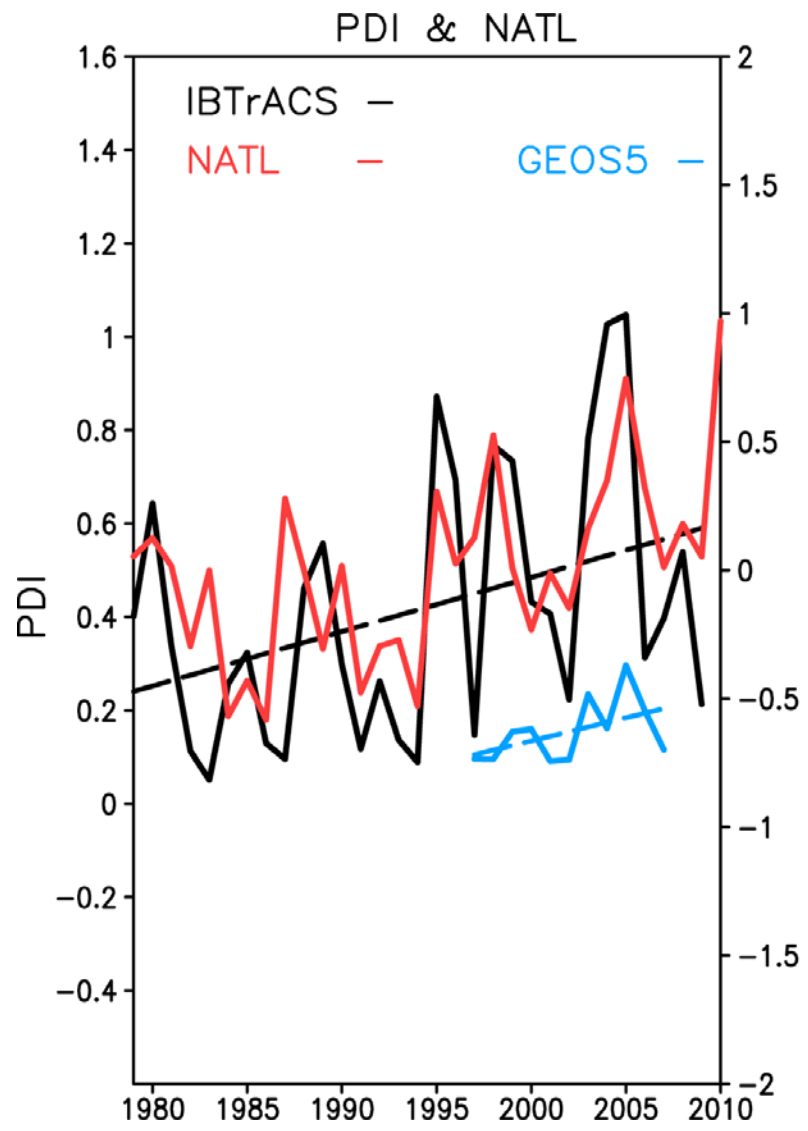
The relation between PDI and North Atlantic Index (NATL) over Atlantic ocean

NATL : Sea surface temperature anomalies averaged over the region 10°N - 20°N latitude, 20°W - 80°W longitude

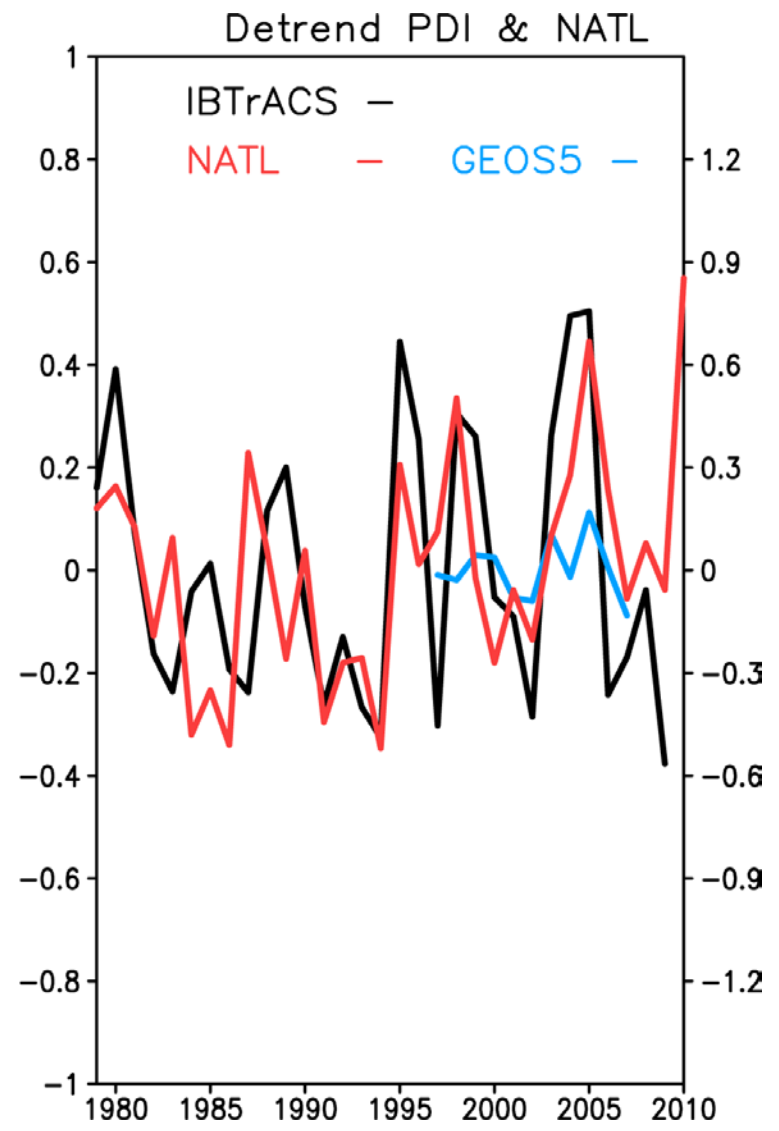




Relationship between PDI and SST



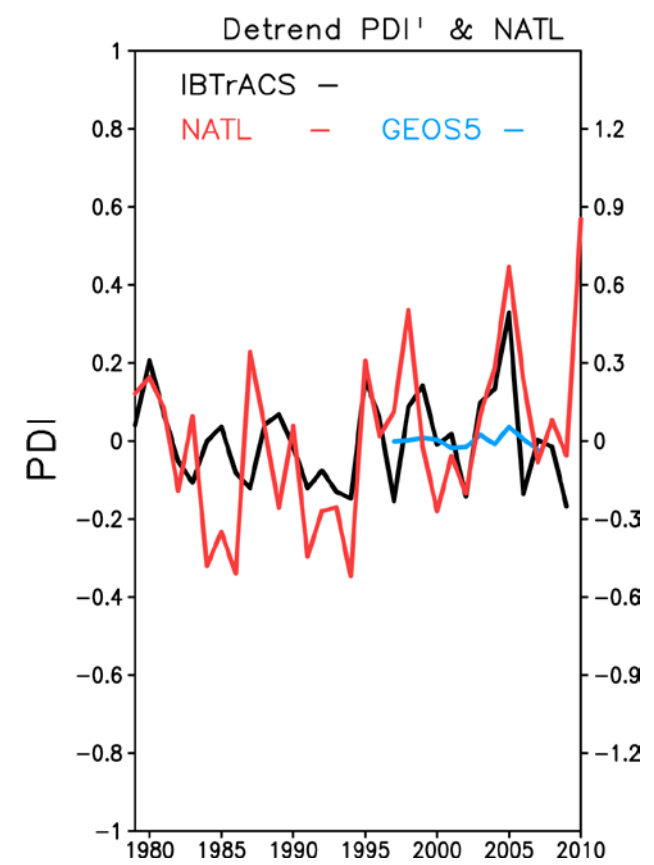
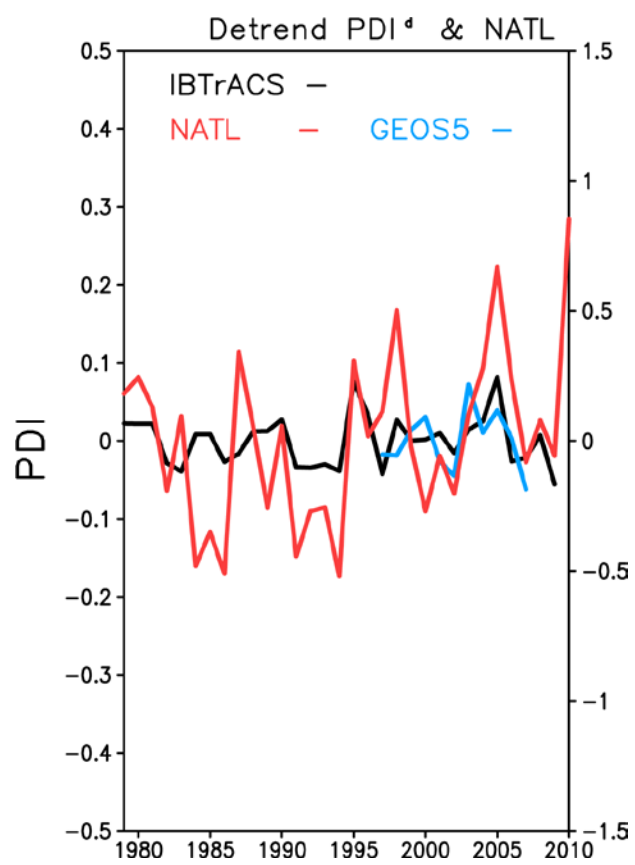
IBTrACS : 0.64 GEOS-5 : 0.53



IBTrACS : 0.56 GEOS-5 : 0.50



Relationship between PDI and SST

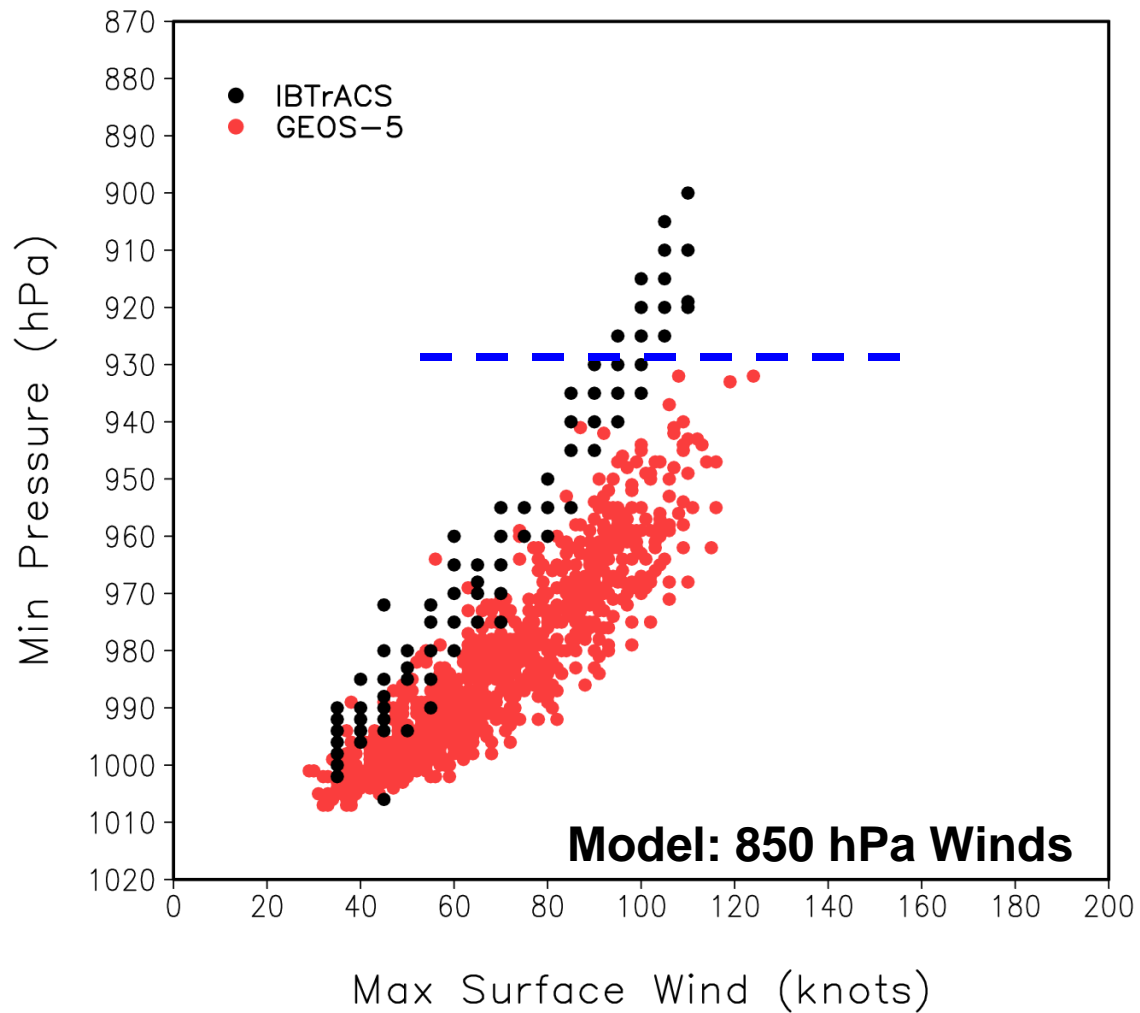


	IBTrACS	GEOS-5
PDI	0.56	0.50
PDI (Duration)	0.53	0.29
PDI (Intensity)	0.56	0.61

Tropical Storms in Western North Pacific

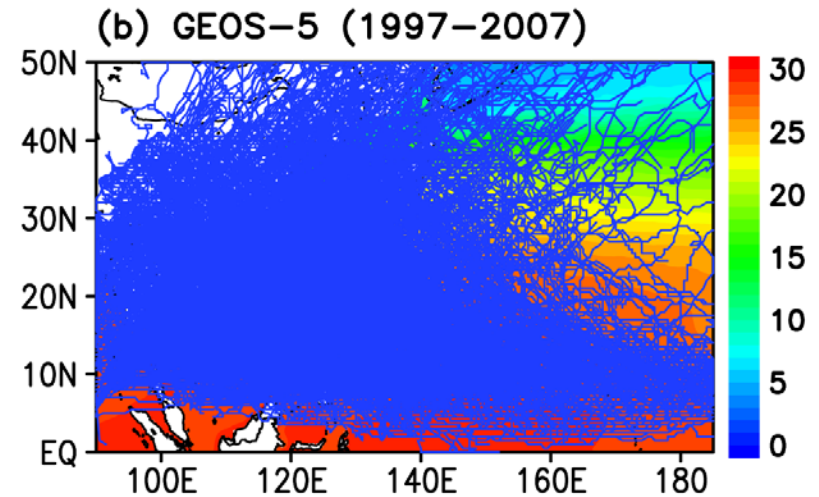
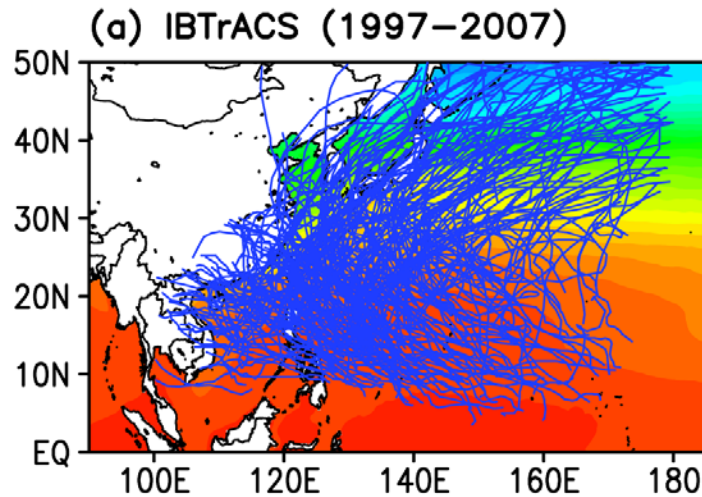
Maximum intensity of Tropical Storms

Tropical Storm Intensity in Northwestern Pacific (1997–2007)

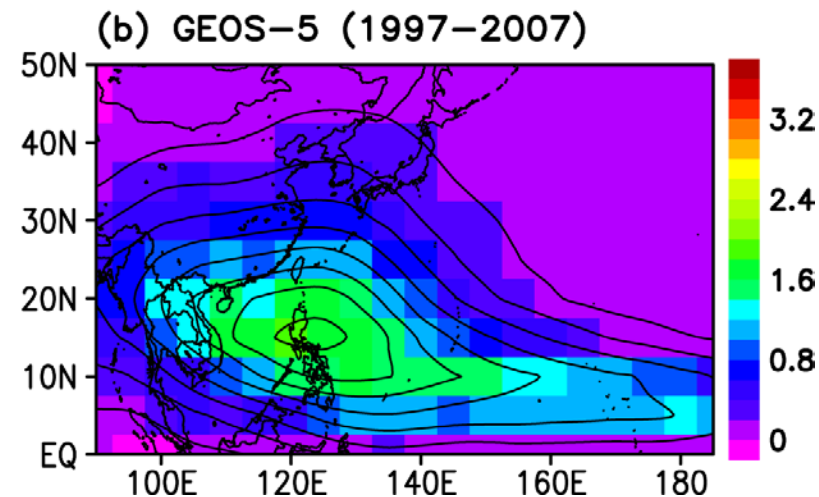
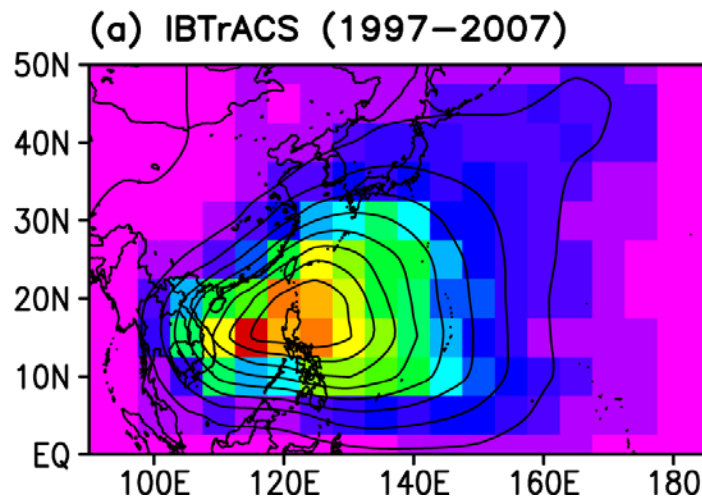


Tracks of Tropical Storm

TS Track in Northwestern Pacific

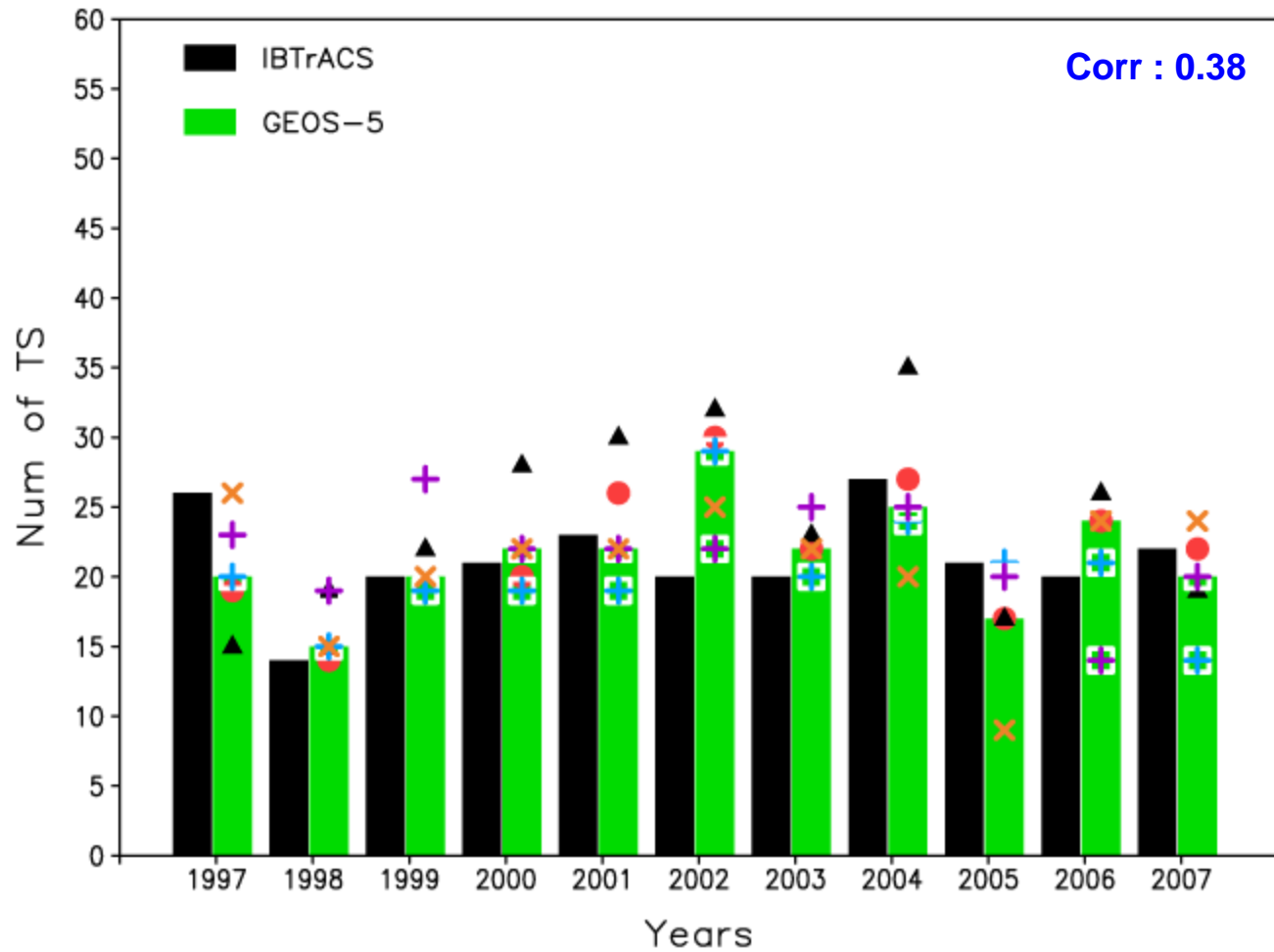


Percentage of TS pathway in Northwestern Pacific



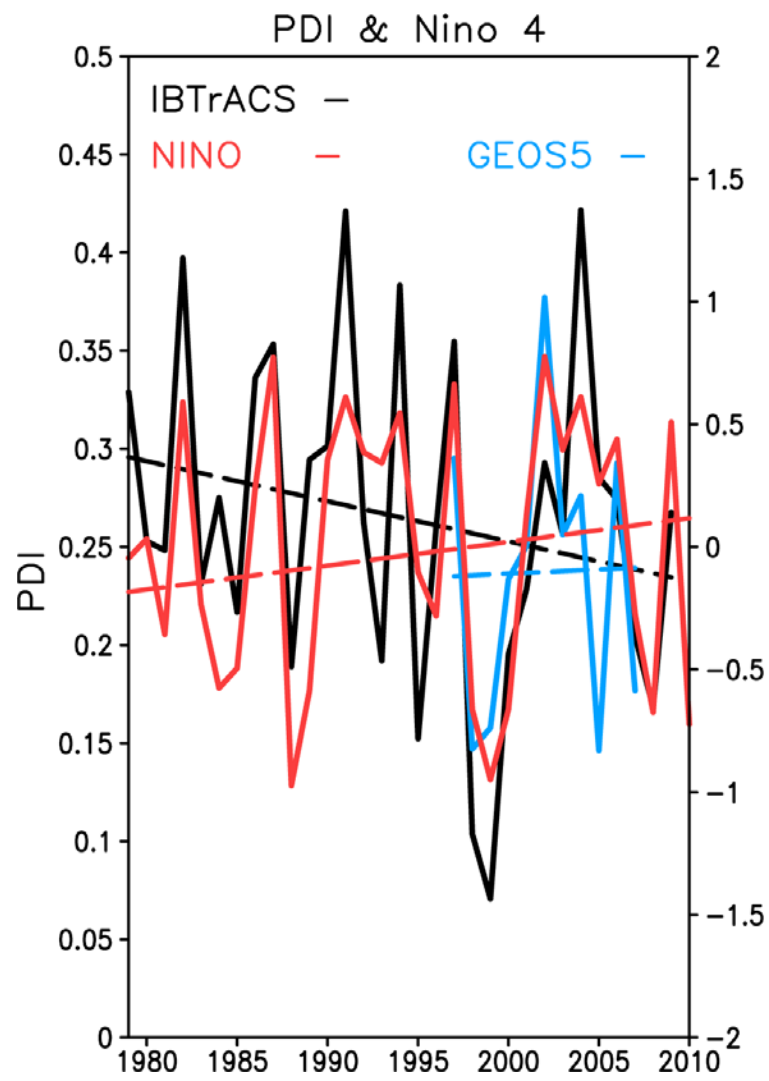
Interannual variation of TS

Number of TS in Northwestern Pacific (1997–2007)

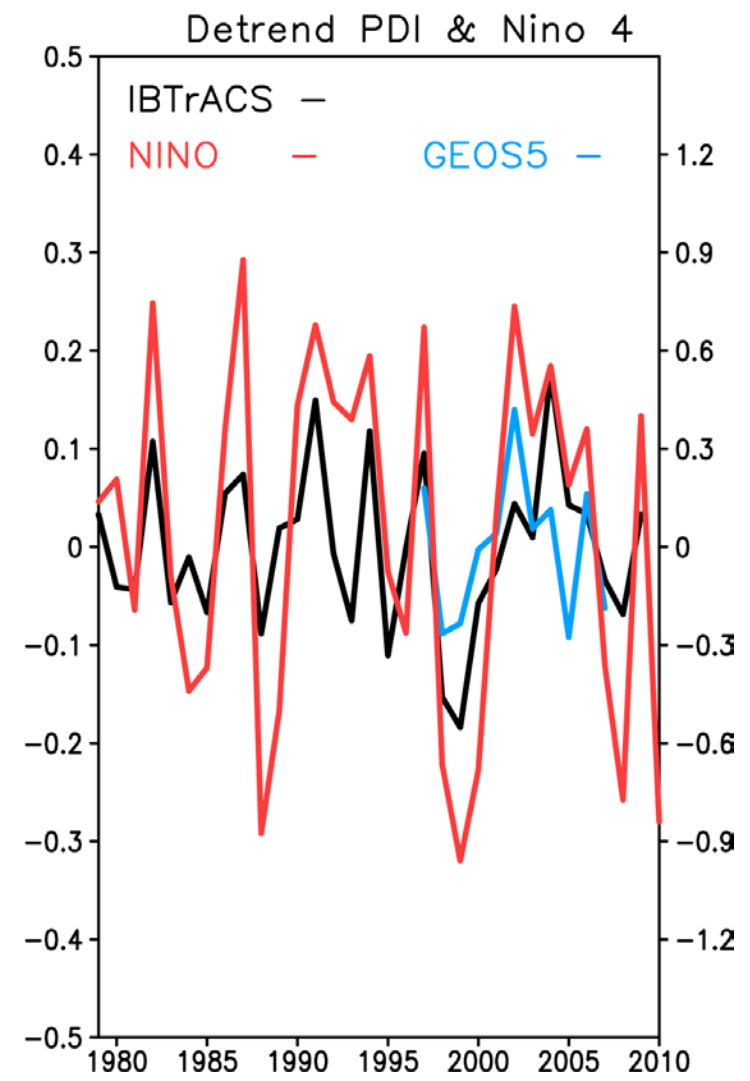




Relationship between PDI and SST



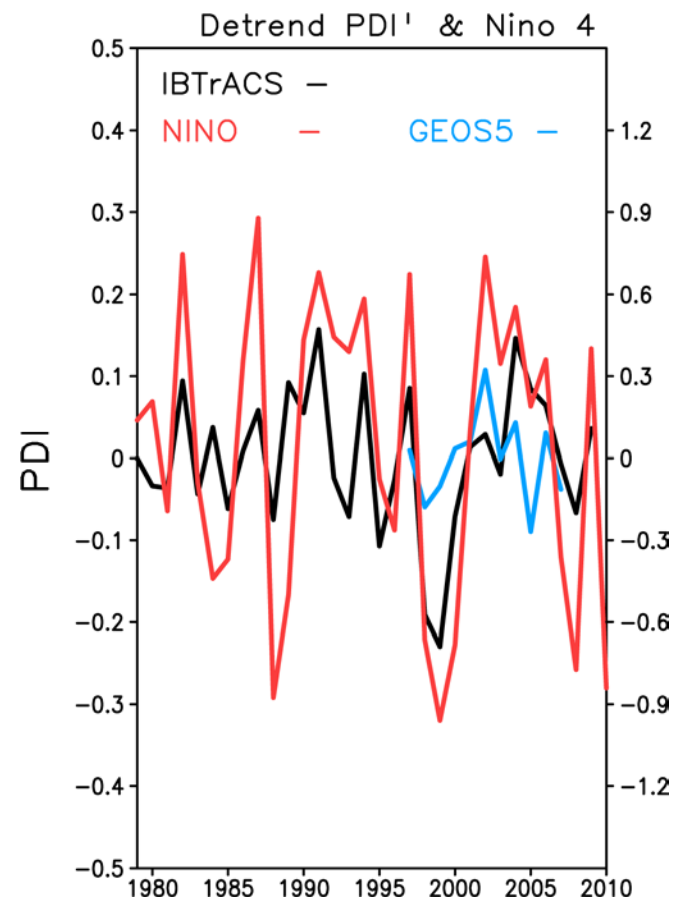
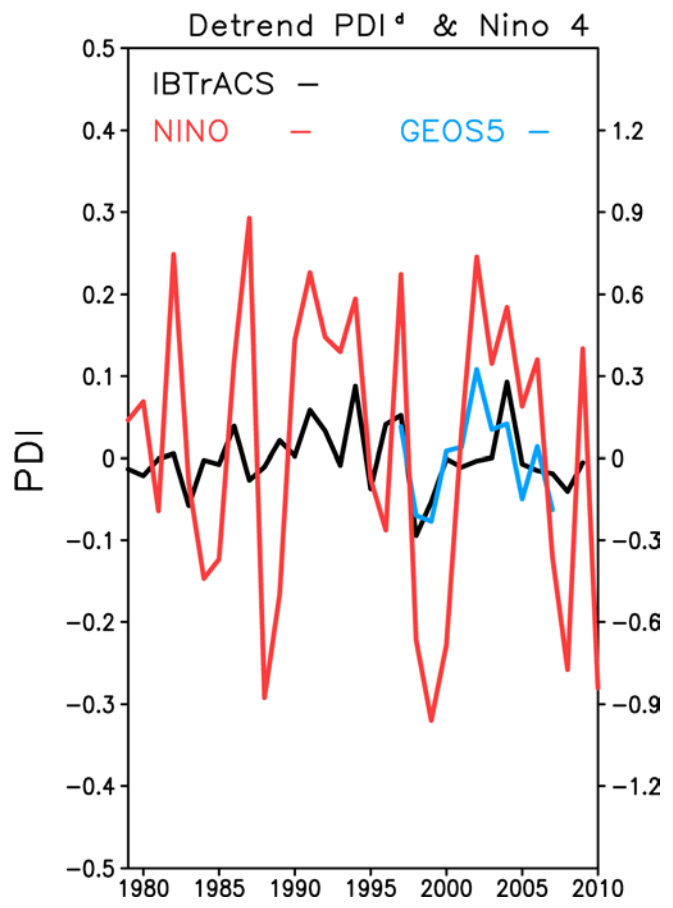
IBTrACS : 0.73 GEOS-5 : 0.75



IBTrACS : 0.78 GEOS-5 : 0.75



Relationship between PDI and SST

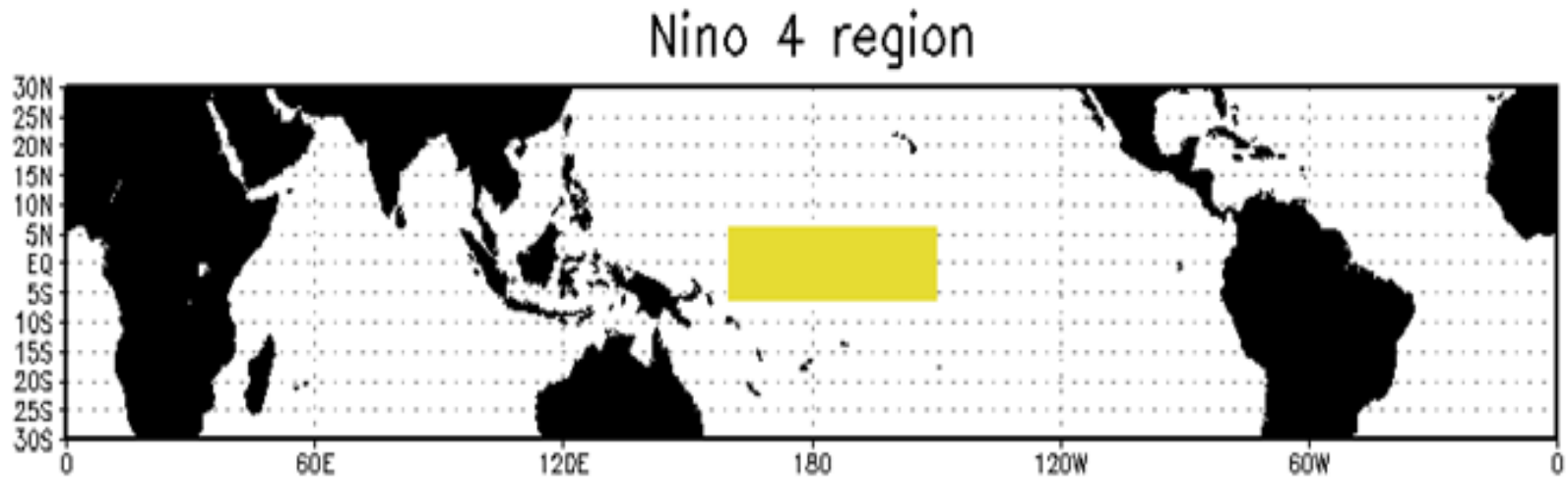


	IBTrACS	GEOS-5
PDI	0.78	0.75
PDI (Duration)	0.49	0.79
PDI (Intensity)	0.69	0.56

- The high-resolution AGCM tends to simulate the tropical storms (TS) in realistic structure – However, the capability and the intensity of storms is **quite sensitive to the deep convective parameterization**.
- Climatological-mean distribution of TS genesis and tracks are realistic, although the model tends to simulate less recurving storms in the extratropics, probably due to the abnormally strong subtropical Highs – Emphasizing the **important role of model basic climate structure**.
- The dynamical ensemble prediction of tropical storms shows a marginal skill in capturing the interannual variation – **SST is the dominant role** in modulating TS.
- It seems to have **much room to improve** the simulation by improving moist physics parameterization, and the initialization of land surface.

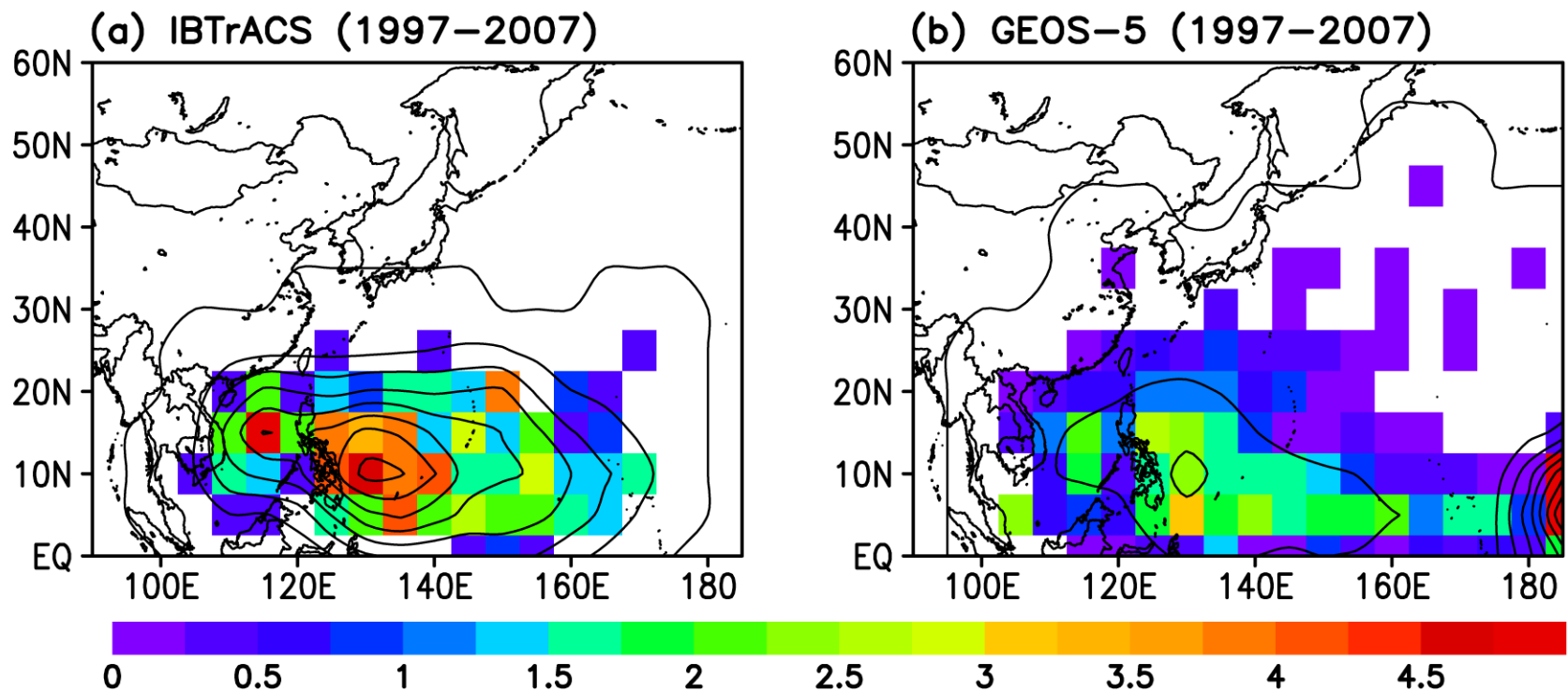
- **Spare slides**

The relation between PDI and NINO 4 index



NINO 4 : Sea surface temperature anomalies averaged over the region 5°S - 5°N latitude, 150°E - 160°W longitude

TC Frequency of origin in Northwestern Pacific



Interseasonal variation of TS

Number of TS in Northwestern Pacific (1997–2007)

