Future change of western North Pacific Typhoons: Projections by a 20-km-mesh global atmospheric model

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Reference: H. Murakami, B. Wang, and A. Kitoh (*J. Climate*, 2011)

Review and Motivations

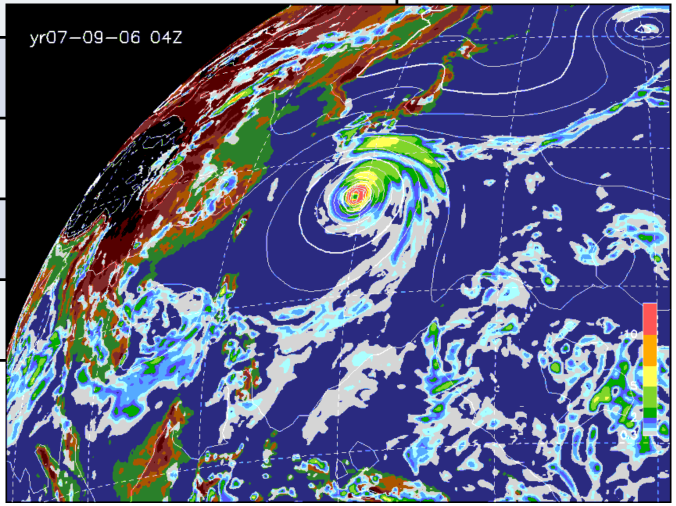
- Among many studies investigating future changes in tropical cyclone (TC) activities, few investigated TC track changes.

- Bengtsson et al. (2007, *Tellus*) suggests that future changes in TC density are different between T63 and T213, indicating high-resolution model is necessary for accurate future projections.

- The present study examines future changes in TC tracks, especially in the western North Pacific (WNP), simulated by the 20-km-mesh MRI/JMA-AGCM.

Model Specifications

	MRI-AGCM3.0, 3.1 (Mizuta et al. 2006)
Horizontal resolution	TL959 (20km)
Vertical resolution	60 levels (top at 0.1hPa)
Time integration	Semi-Lagrangian
Time step	6minutes
Cumulus convection	Prognostic Arakara-Schubert
Cloud	Smith (1990)
Radiation	Shibata and Aoki (1989) Shibata and Uchiyama(1992)
GWD	Iwasaki et al. (1989)
Land surface	SiB ver0109(Hirai et al.2007)
Boundary layer	MellorYamada Level2
Aerosol (direct)	Sulfate aerosol
Aerosol (indirect)	No



Experimental Designs

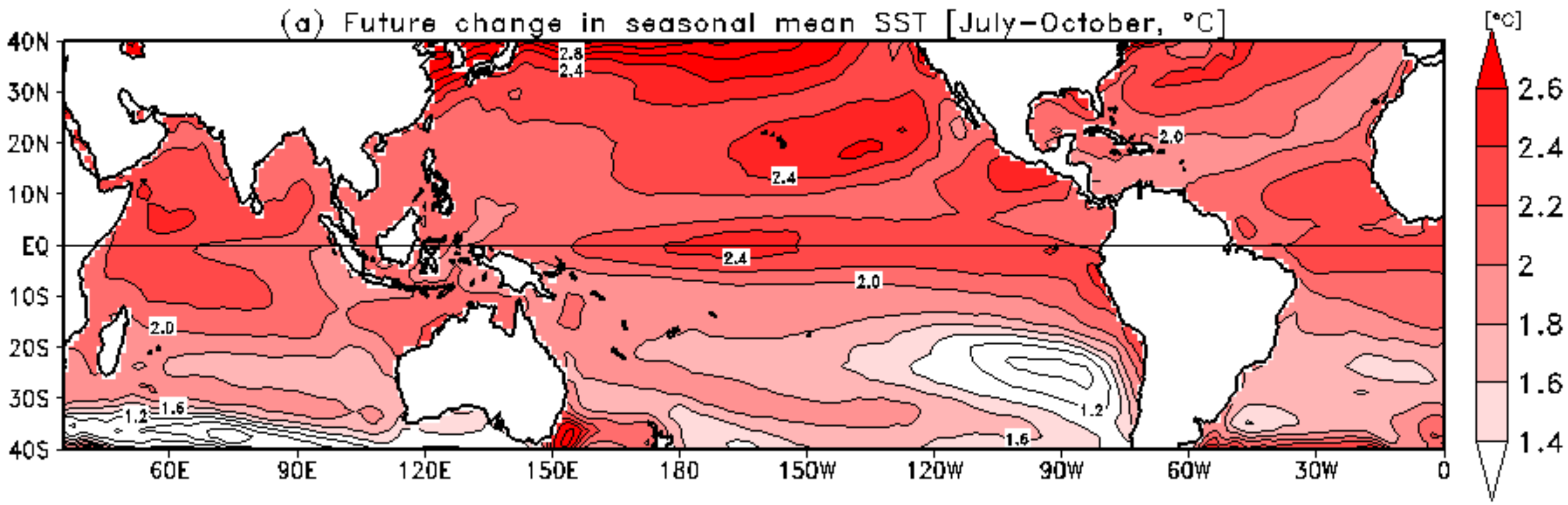
- Model: MRI AGCM 3.1 (20 km-mesh)
- Projection periods:

  Present-day exp. (PD) : 1979-2003 (25 yr)

  Future global warmed exp. (GW): 2075-2099 (25 yr)
- Prescribed Lower Boundary Conditions:

  PD: Observations (HadISST)

  GW: Ensemble mean of 18 CMIP3 models' SST under the IPCC A1B scenario



- Relatively larger increase in SST in the Northern Hemisphere than in the Southern Hemisphere.
- The SST increase is the largest in the tropical Central Pacific.

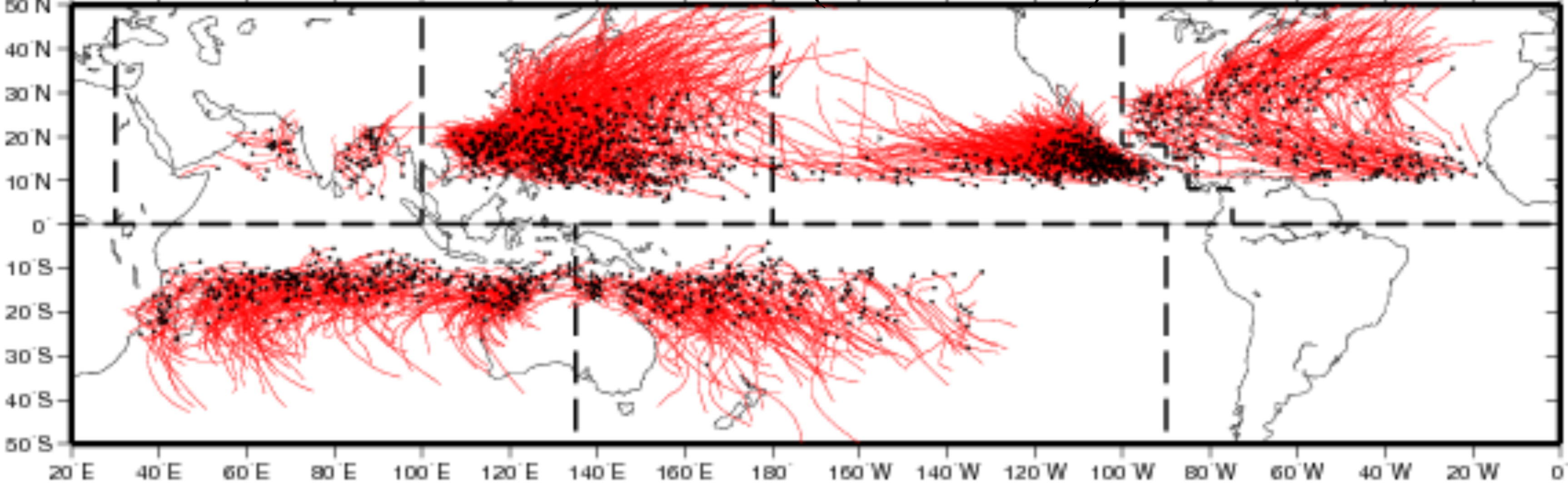
TC Detection Criteria

Based on Oouchi et al. (2006)

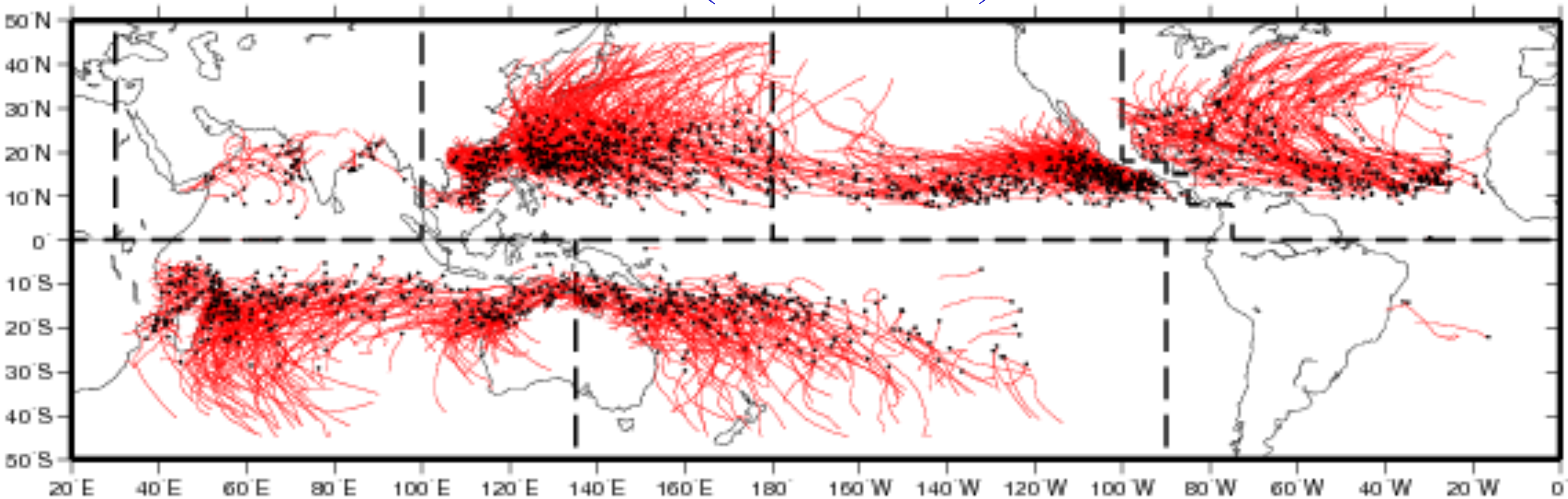
- Sea level pressure = 2.0 hPa lower than the surroundings area.
- 850 hPa Relative volticity = 3.0×10^{-5} /s
- 850 hPa Maximum wind speed = 10.0 m/s
- Warm Core: 1.0 K
- Duration =36 hours
- Maximum wind speed at 850 hPa should be greater than the 300 hPa (to exclude extra-tropical cyclones).

<u>Simulated Global TC Tracks</u>

Observations (1979-2003)



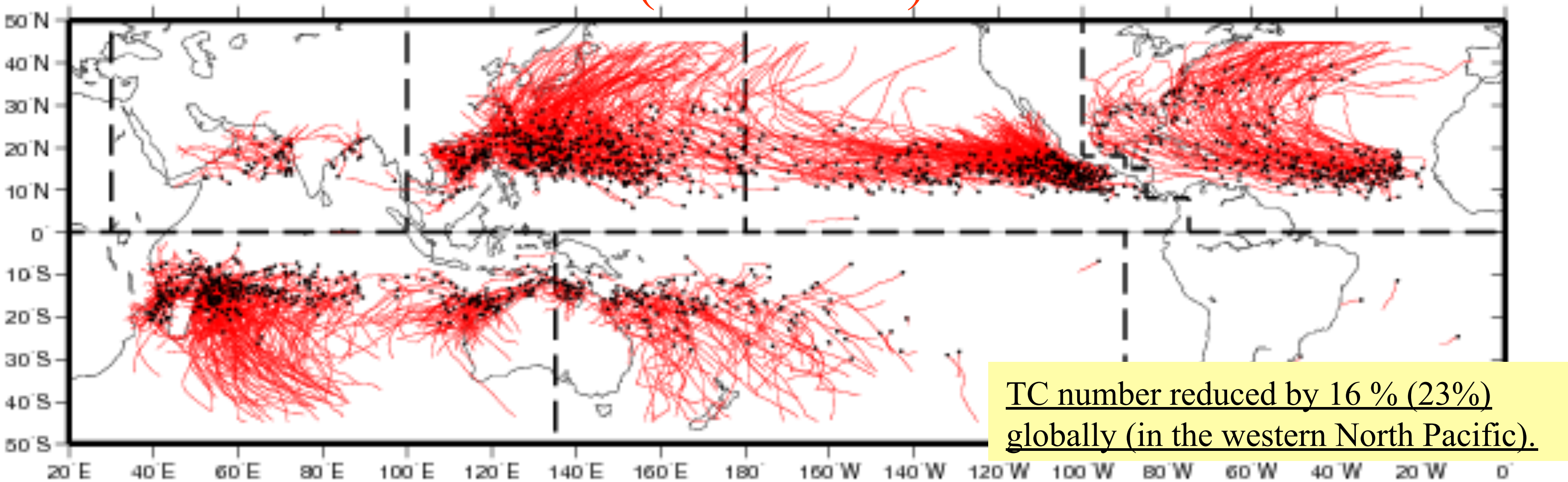
PD (1979-2003)



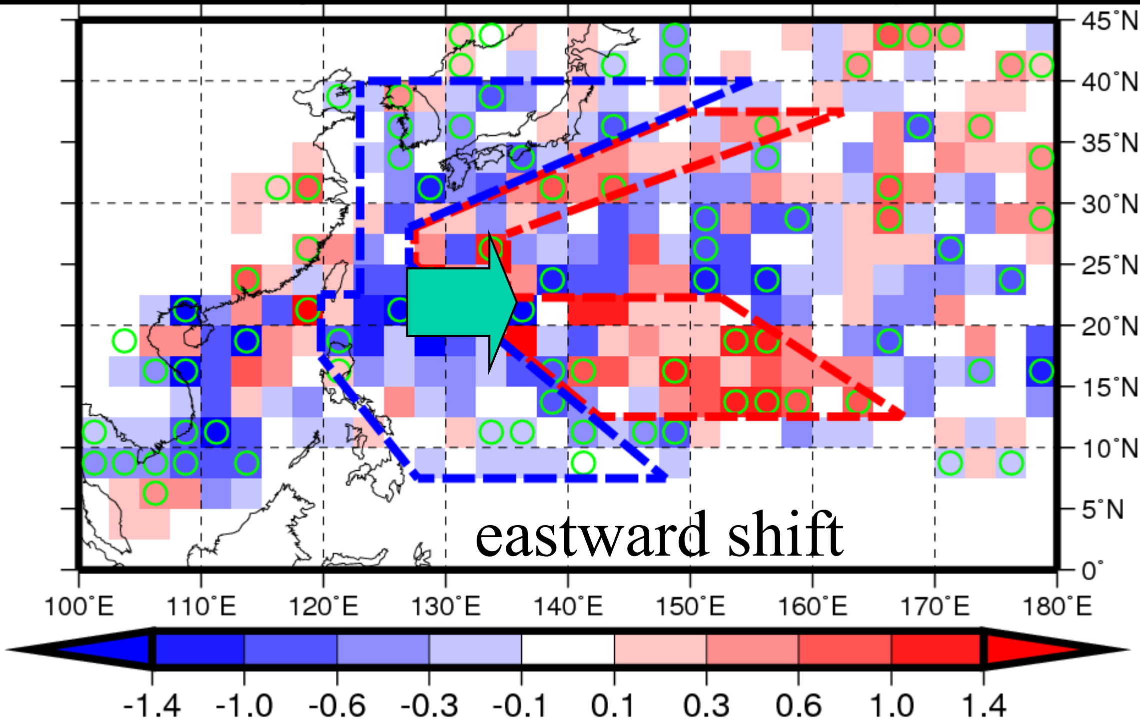
TC tracks are well simulated by the PD experiment.

Future Changes in the Simulated Global TC Tracks

GW (2075-2099)

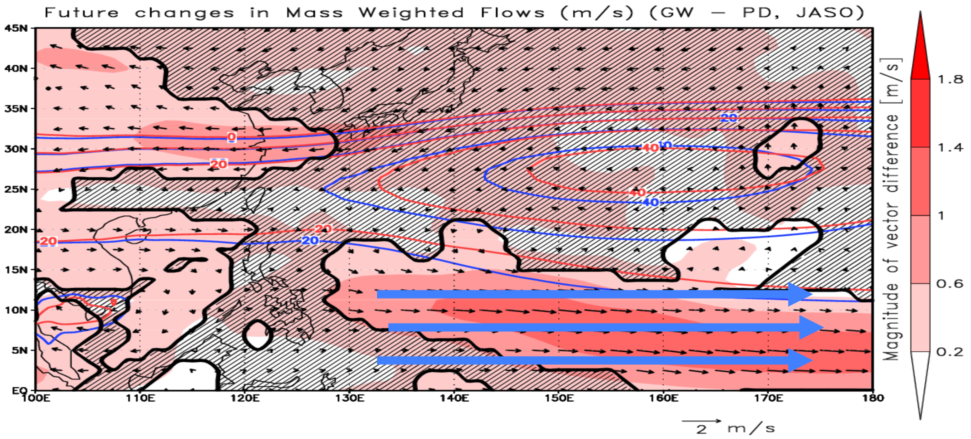


Future changes in the TC frequency (GW-PD)



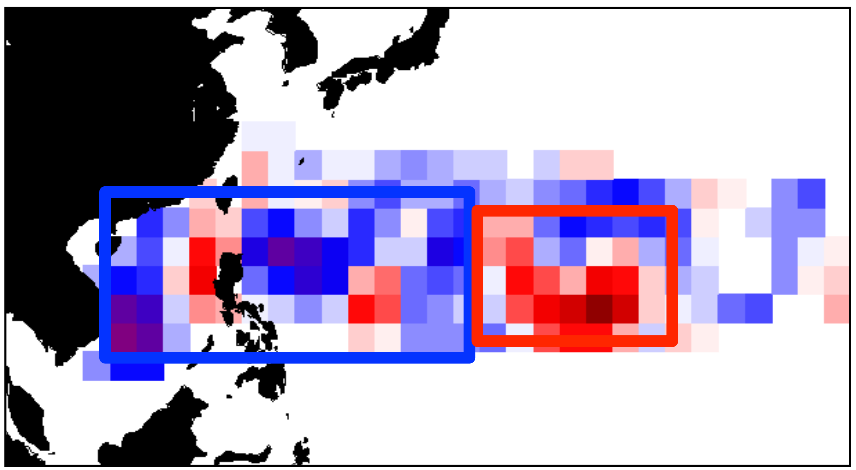
What causes TC track changes?

Steering flow (850-300hPa) changes



Steering flow changes (westerly flow anomaly) **partly** explain TC track changes by inhibiting westward TC motion.

TC genesis frequency changes



TC genesis location changes (eastward shift) **mainly** explain TC track changes.

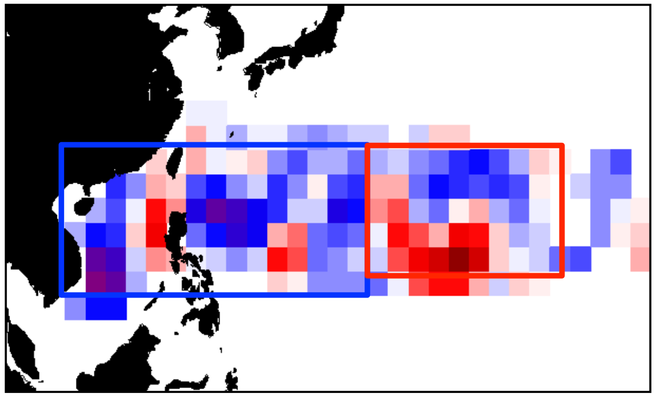
Genesis potential index

To determine the factors behind such genesis changes, we used a Genesis Potential Index (GPI) by Emanuel and Nolan (2004) with some modifications.

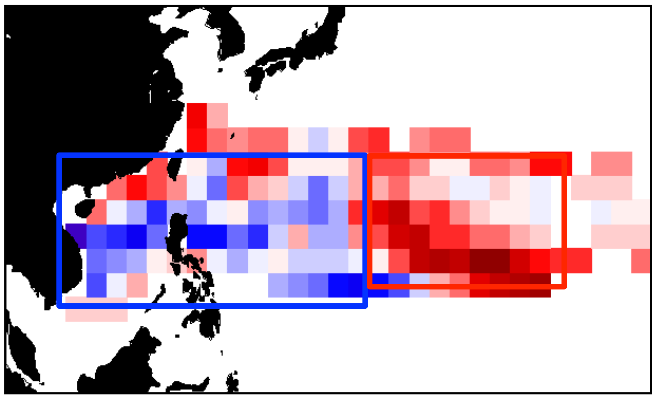
$$GPI' = \left|10^5 \eta\right|^{\frac{3}{2}} \left(\frac{RH}{50}\right)^3 \left(\frac{V_{pt}}{70}\right)^3 \left(1 + 0.1V_s\right)^{-2} \left(\frac{-\omega + 0.1}{0.1}\right),$$

Absolute Vorticity at 850hPa	Relative Humidity at 700hPa	Maximum Potential Intensity	Vertical Wind Shear (850-200hPa)	Vertical Wind Velocity at 500hPa

Future changes in TC genesis frequency



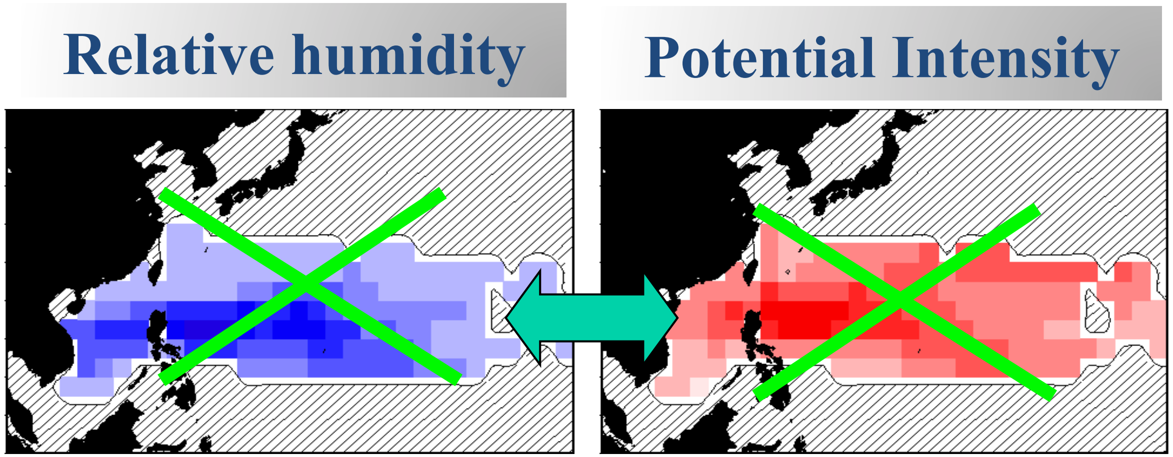
GPI changes



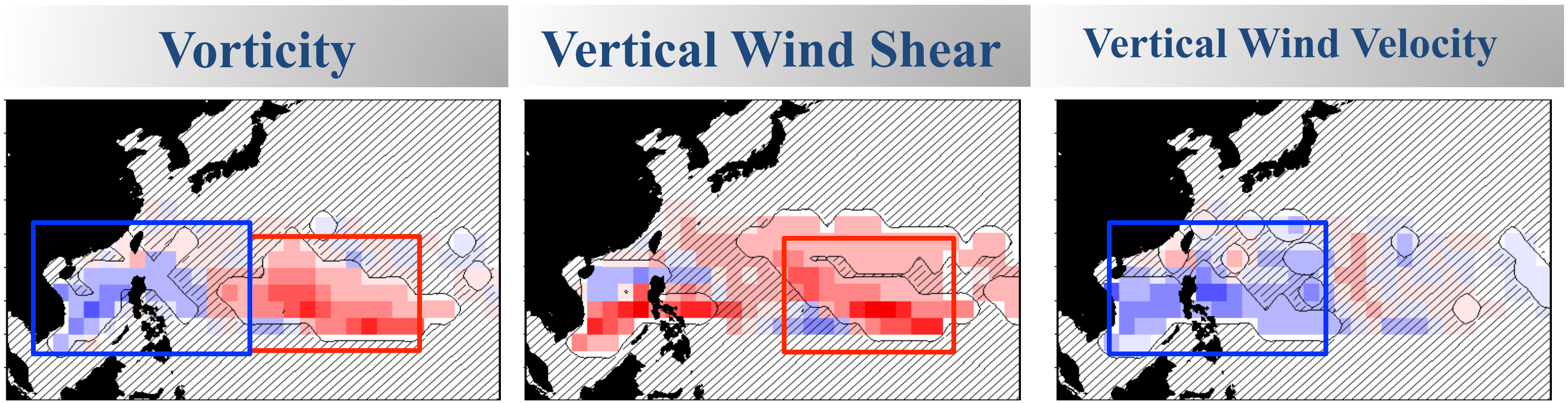
<u>Spatial correlation coefficient is 0.55.</u>

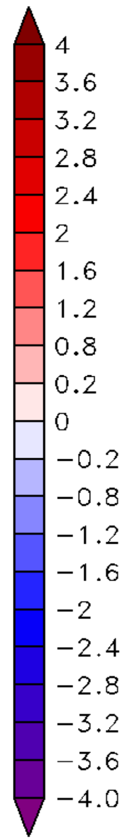
<u>GPI performs reasonably well in reflecting the changes in TC genesis frequency.</u>

Each term contribution to the changes in GPI



1. **Thermodynamic changes has less influence.**
 =>Relative humidity and Potential intensity tend to **cancel each other**.





2. **Dynamical changes have great influences.**

=>**Vorticity** and **vertical wind shear** contribute to the **increase** in GPI in the **eastern** WNP.

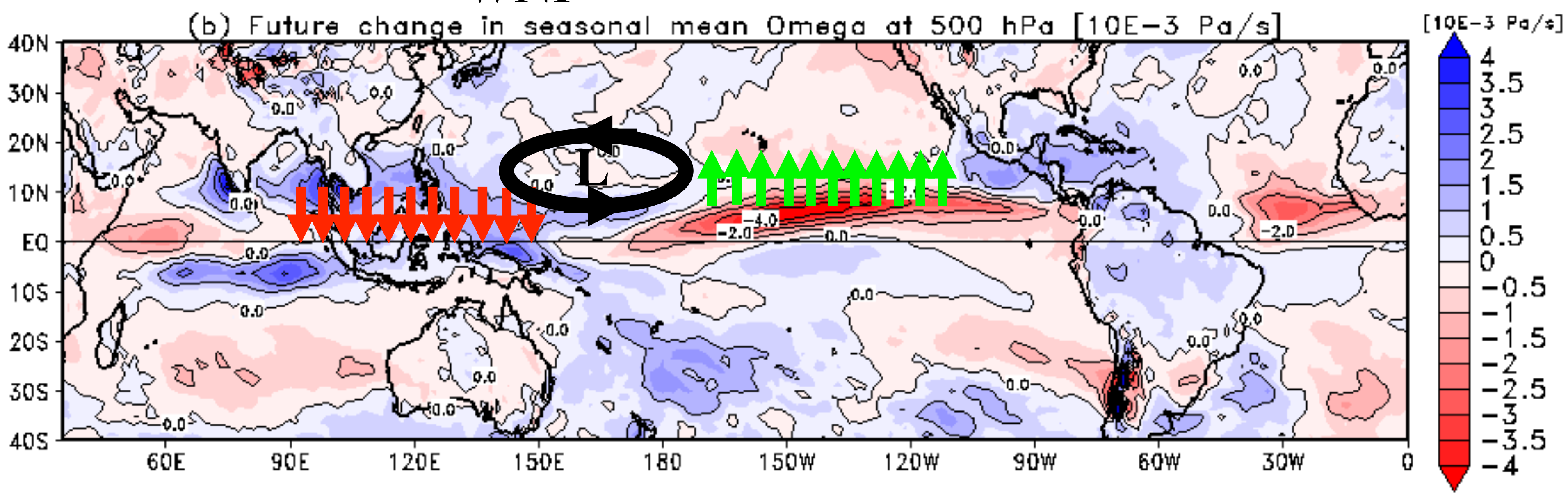
=>**Vorticity** and **vertical wind velocity** contribute to the **decrease** in GPI in the **western** WNP.

Mechanisms of future changes in TC genesis

Future changes in vertical wind velocity at 500 hPa

Rossby wave response:
Positive vorticity => Increase in TC genesis in the eastern WNP

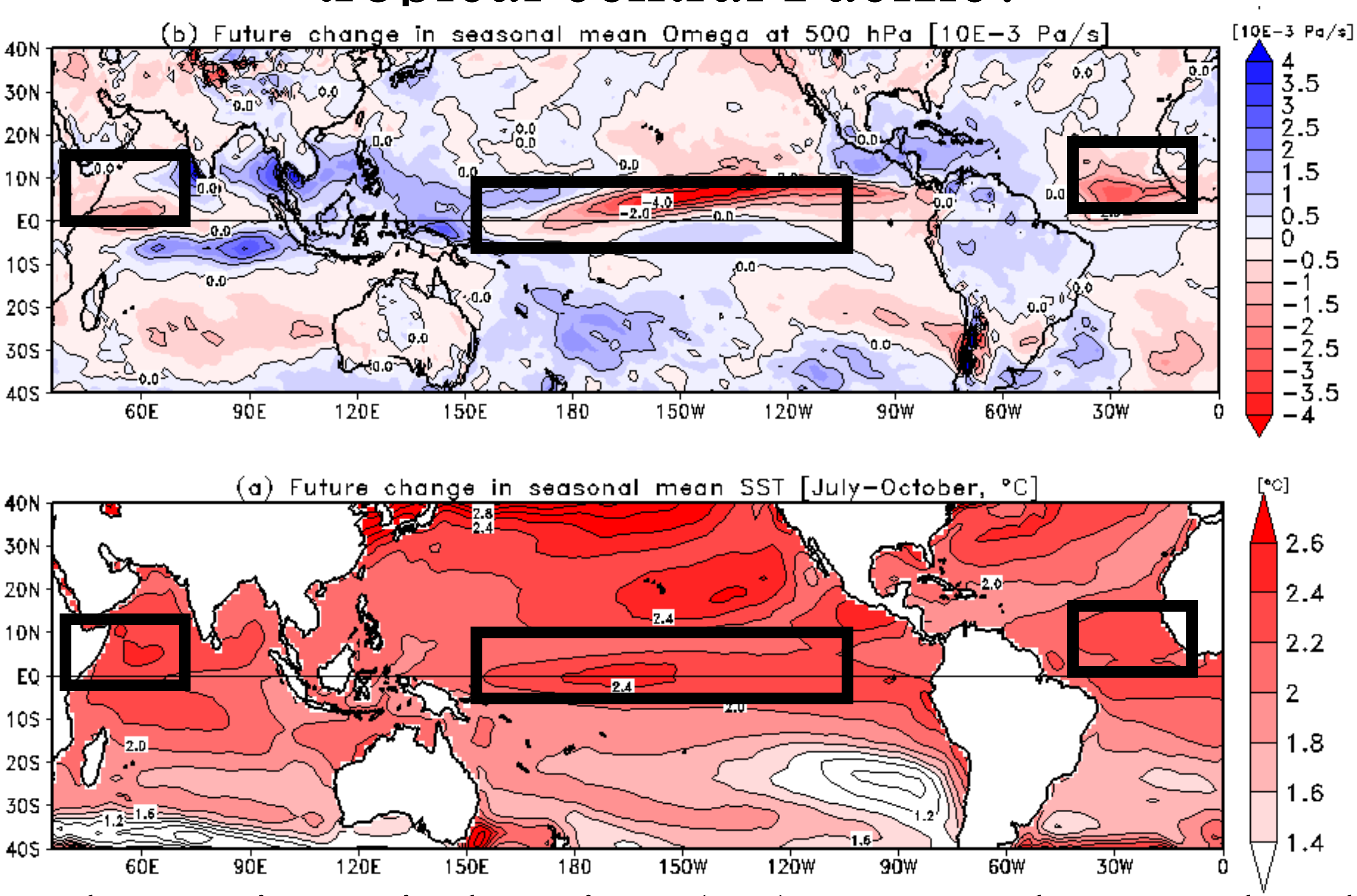
Downward anomaly



Weakening of the Walker circulation:
Decrease in upward motion => Decrease in TC genesis in the western WNP

Upward anomaly

Why is upward motion enhanced in the tropical central Pacific?



Future changes in vertical motions (top) appear to be strongly related to the prescribed SST anomaly (bottom), indicating that spatial distribution of tropical SST may be a key factor for TC activities.

Conclusion

The projected TC activity change during the peak typhoon season (JASO) indicates:

(a) Positions of the prevailing northward recurving TC tracks will shift eastward over the open ocean of the WNP;

(b) TC track changes are partially due to changes of the large scale steering flows, but primarily owning to the changes in TC-genesis locations: TC formation will be less to the west of 140E, whereas more in eastern WNP (0-17N, 140-180E)

(c) The decrease in the TC genesis frequency in the western WNP are mainly due to *in situ* reduction of the large scale ascent, which is caused by the enhanced descending branch of the zonal circulation (i.e., weakening of the Walker circulation).

(d) The enhanced TC genesis in the eastern WNP is due to the increased in situ low-level cyclonic vorticity, reduced vertical wind shear, caused by Rossby wave response induced by enhanced adiabatic heating in the central tropical Pacific.