A Study of Simulating Tropical Cyclone Formation in the Western North Pacific

Speaker: Yi-Huan Hsieh[1]

Advisers: Cheng-Shang Lee[1,2], Chung-Hsiung Sui[1]

[1]Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan

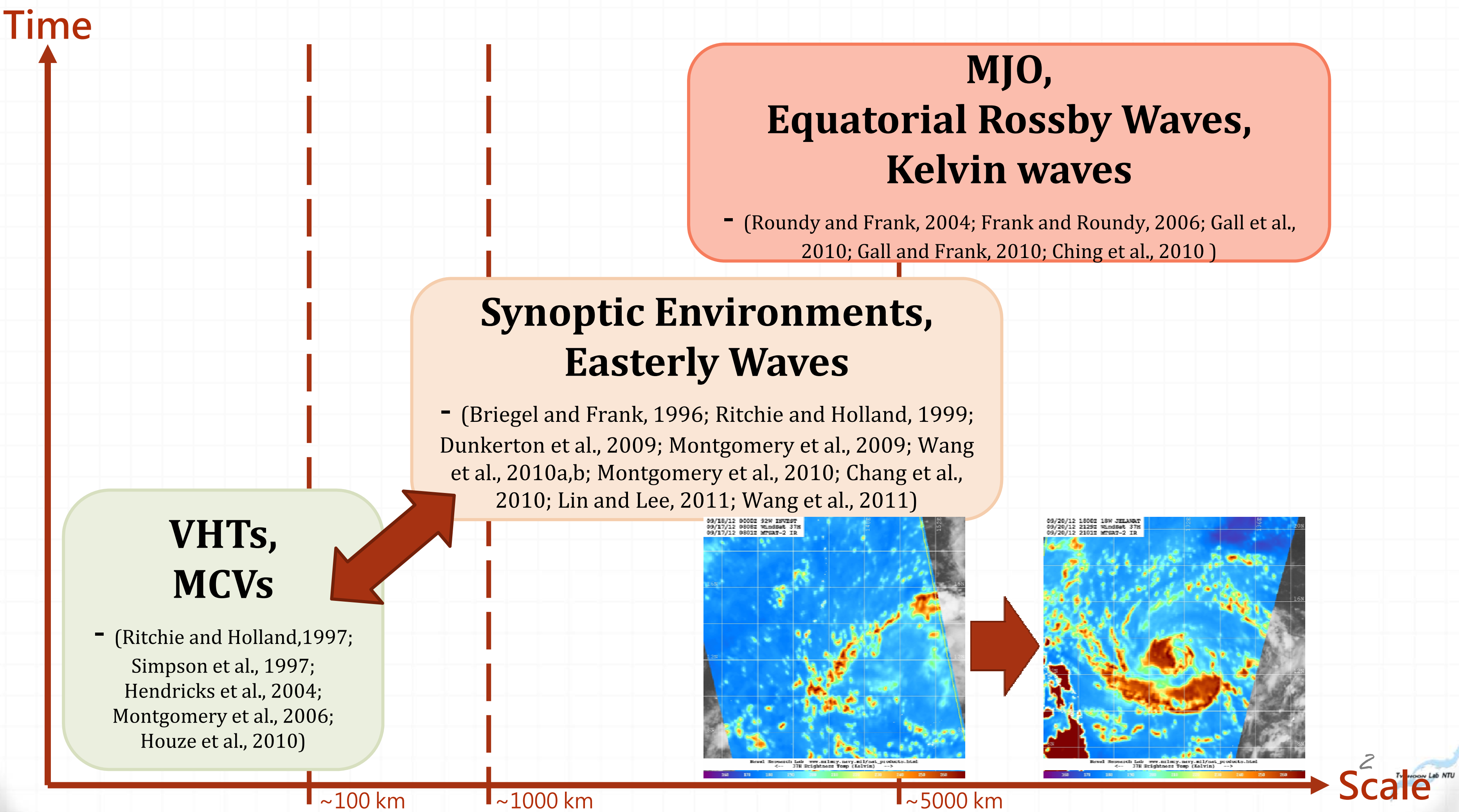
[2]Taiwan Typhoon and Flood Research Institute, National Applied Research Laboratories, Taiwan

Special Thanks to : Dr. Chien-Ming Wu; Dr. Hsiao-Chung Tsai; Dr. Lin Ching ; Dr. Michael Fiorino

Department of Atmospheric Sciences
National Taiwan University
No. 1, Section 4, Roosevelt Road,
Taipei, Taiwan 10673, R. O. C.
Phone: +886-2-33663944
Email: fishball@nat.as.ntu.edu.tw

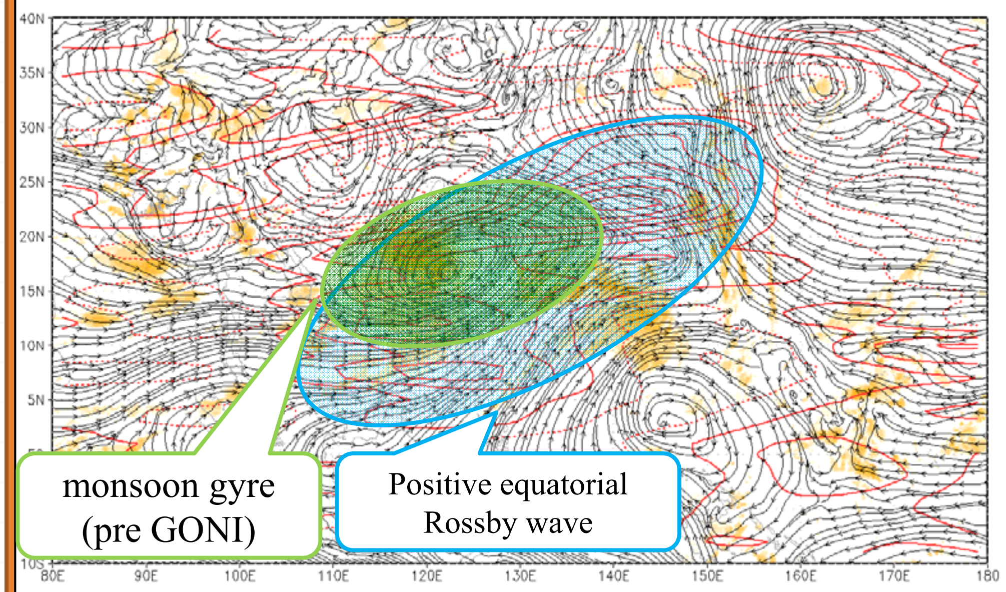
…it is far more natural to assume that genesis is a series of events, arising by chance from quantitative fluctuations of the normal disturbances, with the probability of further evolution gradually increasing as it proceeds. **According to this view, the climatological and synoptic conditions do not directly determine the process of genesis, but may certainly affect the probability of its happening.**

-Ooyama, 1982

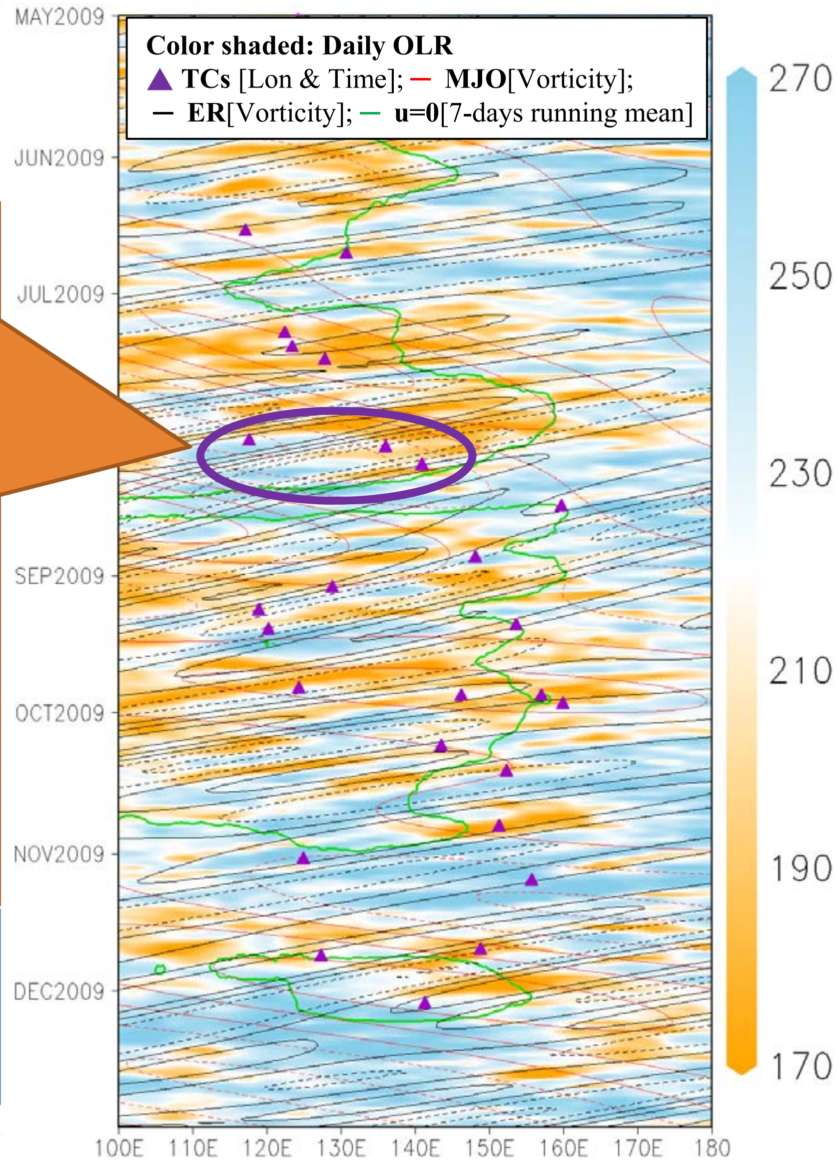


OBJECTIVE

20090801 12z [Tbb & stream line, vorticity of ER @850 hPa]



Difficult to classify and quantify the degree of influences from various mechanisms in the WNP.



■ **To understand quantitatively the dominant mechanisms of TC formation.**

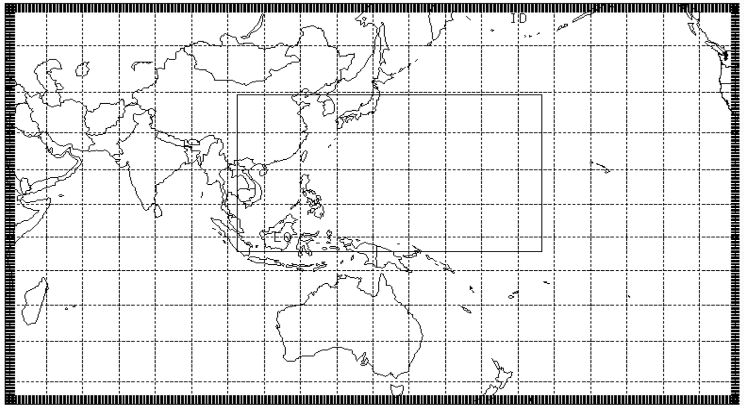
EXPERIMENT DESIGN

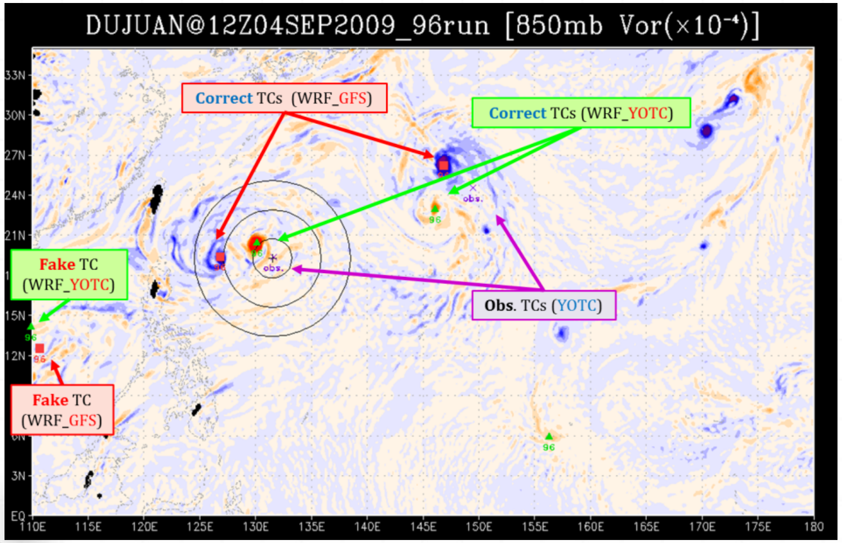
- To analyze the systematic errors of model simulation of TC formations in the WNP **by dynamic-consist modeling approaching**.
- **Model settings :**
  - **Four** distinct initial times (-48h, -72h, -96h and -120h) * **Two** different initial data (NCEP-GFS & ECMWF-YOTC) = **8 members** of each TC

WRF V3.2.1

- **Input Data : EC_YOTC & NCEP_GFS**
- **Domain 1 : 569 x 340 [36km]**
- **Domain 2 : 706 x 400 [12km]**
- **Microphysics : WDM6**
- **Cumulus Parameterization : Kain-Fritsch**
- **PBL Physics : YSU**

-Kieu and Zhang, 2008; Chiao and Jenkins, 2010; Wang et al., 2010





Identify of TCs [obs. (EC_YOTC) & simulation results (WRF)]

- **Target-period: -12 hr ~ +18 hr of 1^{st} 25kt based on best track data**

Criteria:

1. **Circulation center and maximum vorticity center@ 850 mb**
2. **Vorticity @ 850 hPa (necessary condition):**
   - **Mean vorticity inside 1.5∘**
     - **> $5 * 10^{-5}$ s^{-1} (min. of obs. in EC-YOTC data)**
   - **Mean vorticity inside 3∘(or 5∘)**
     - **> $2.5 * 10^{-5}$ s^{-1} (or $0.6 * 10^{-5}$ s^{-1})**
3. **Distance ≤ 750 km**
4. **Satisfy 1~3 ≧ 12hr**

Sugi et al., 2002; Chauvin et al., 2006; Yoshimura et al., 2006; Stowasser et al., 2007; Jourdain et al., 2011; Zhan et al., 2011

Question:

- Are the simulation periods or initial conditions the cause of TC not formation in the model?

TC detect rate (%)	-48 hr	-72 hr	-96 hr	-120 hr	Avg.
EC-YOTC (n=52)	84.6	86.5	63.5	51.9	71.6
NCEP-GFS (n=52)	82.7	80.8	65.4	40.4	67.3

- what are the causes of TC not formation in the model?
  - The strength of pre-TC?

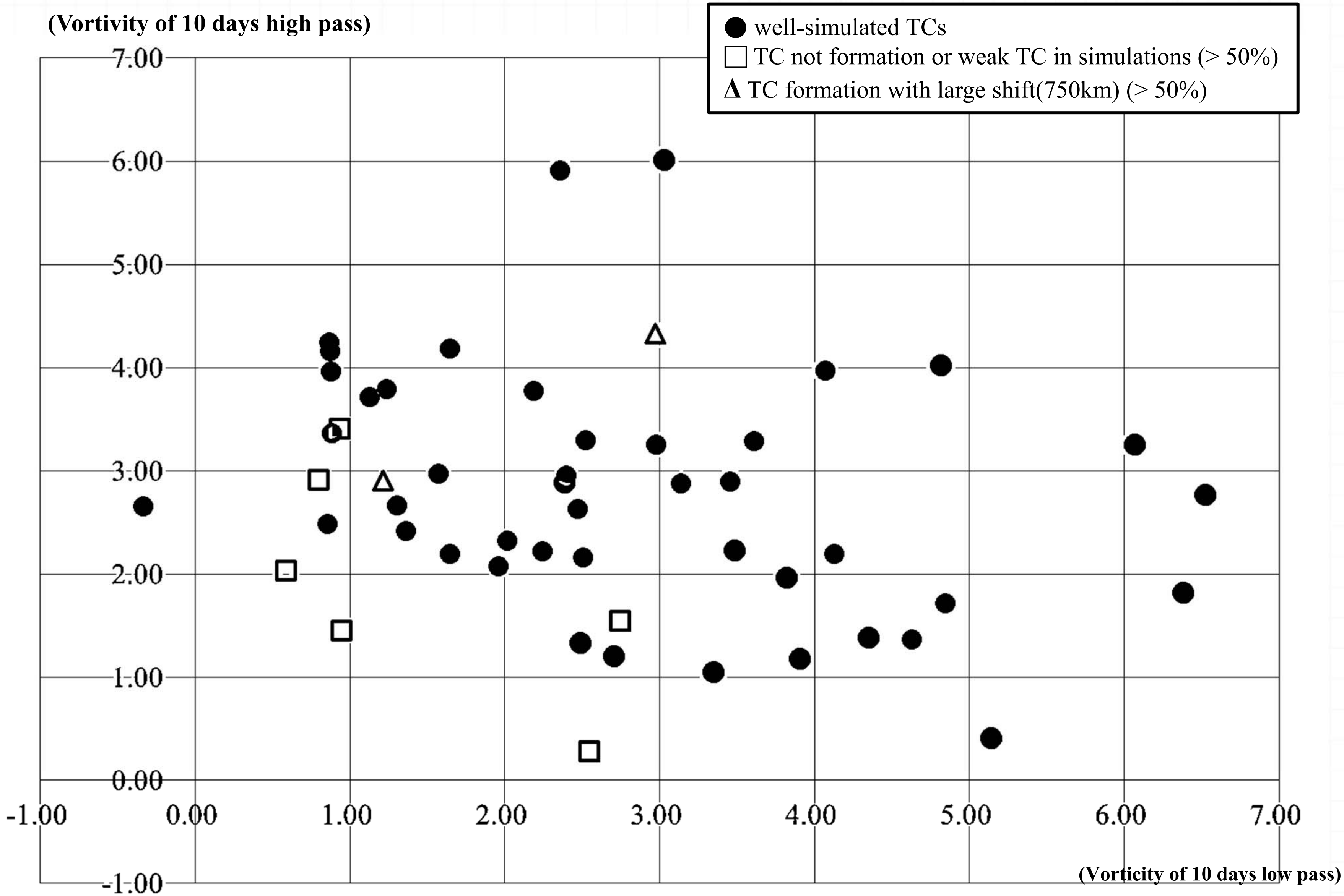


Fig. 1. Scatter diagrams of the EC-YOTC 10-day filtered 850 hPa vorticity (-24h~0h, 3°-radius average) (10-day low pass vs 10-day high pass) for 52 TCs in 2008-2009.

Angular momentum transports
(cylindrical coordinate)

-Chan and Kwok, 1999; 黃麗蓉, 2001

$$M(r) = r\bar{u}\bar{v} + r\overline{u'v'} + \frac{f_0 r^2 \bar{u}}{2} + \frac{r^2 \overline{fu'}}{2}$$

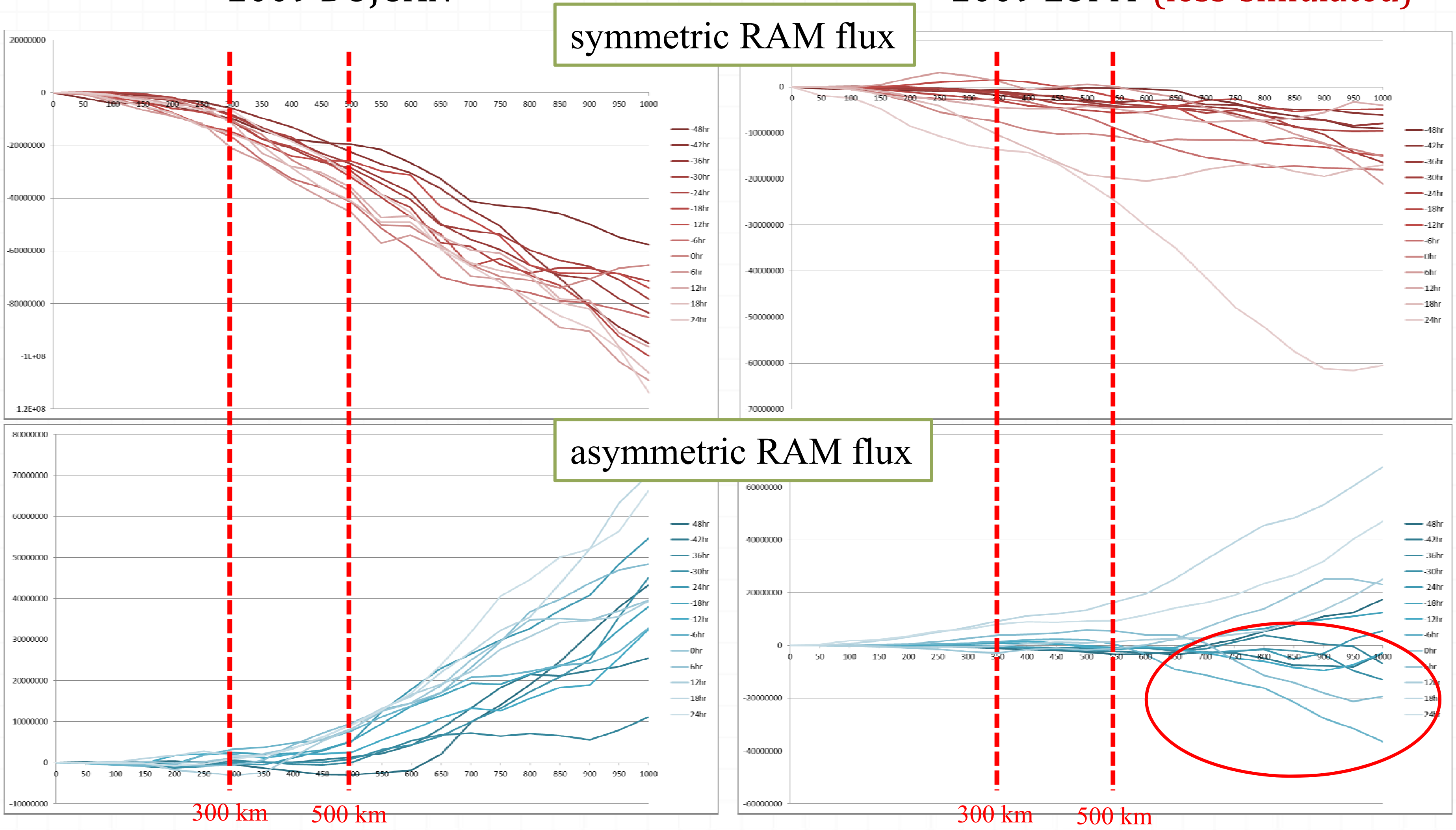
(1) (2) (3) (4)

u : radial wind
v : tangential wind
— : azimuthal average

(1) the symmetric relative angular momentum (RAM) flux
(2) the asymmetric or eddy RAM flux
(3) the symmetric Coriolis torque
(4) the asymmetric or eddy Coriolis torque
(1)+(3) : total symmetric flux
(2)+(4) : total asymmetric flux

- **Data:** EC_YOTC (0.25°) [U, V]
- **Time:** 6-hourly
- **Calculate Level**: 1000, 950, 925, 900 mb
- **Output resolution**: 50 km

2009 DUJUAN | 2009 LUPIT (less-simulated)



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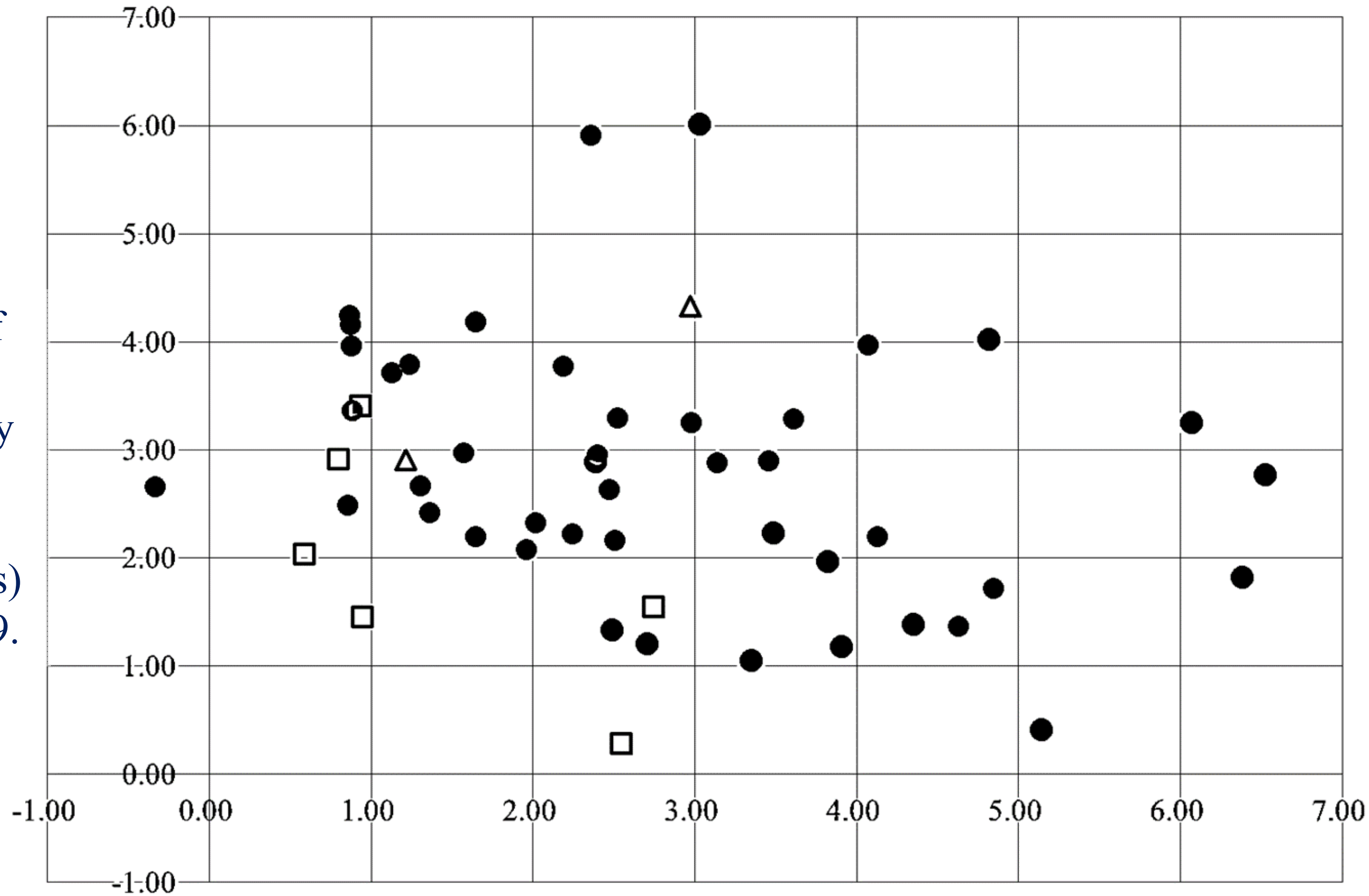
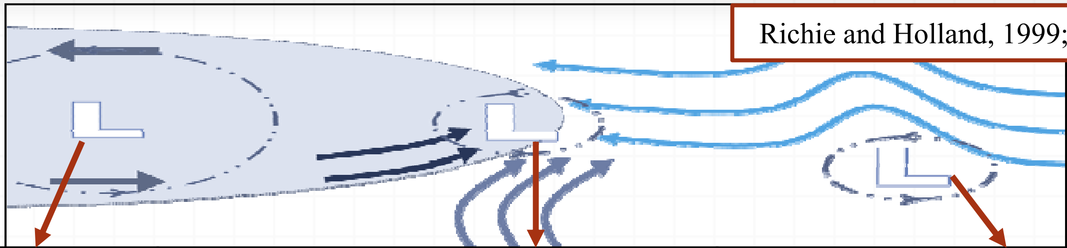


- The strength of pre-TC?
  - Less vorticity in less-simulated TCs (pass 95% T-test)
  - Following the 850hPa circulation center, the low-level angular momentum transports (Chan and Kwok, 1999) were calculated with EC-YOTC data. The results indicate that most well-simulated TCs were with higher inner-ward total symmetric flux (300 &500 km average, including symmetric RAM flux and Coriolis torque) before formation, and pass the 95% t-test.(In 300 & 500 km radius, pass 95% T-test)

SYNOPTIC ENVIRONMENT

Richie and Holland, 1999; Lee et al., 2008



Within the monsoon trough	On the monsoon trough	Out of the monsoon trough
(14/52)	(17/52)	(21/52)
• **Monsoon shear** • Monsoon gyre	• **Monsoon confluence** • Energy dispersion	• **Easterly wave** • Energy dispersion & else

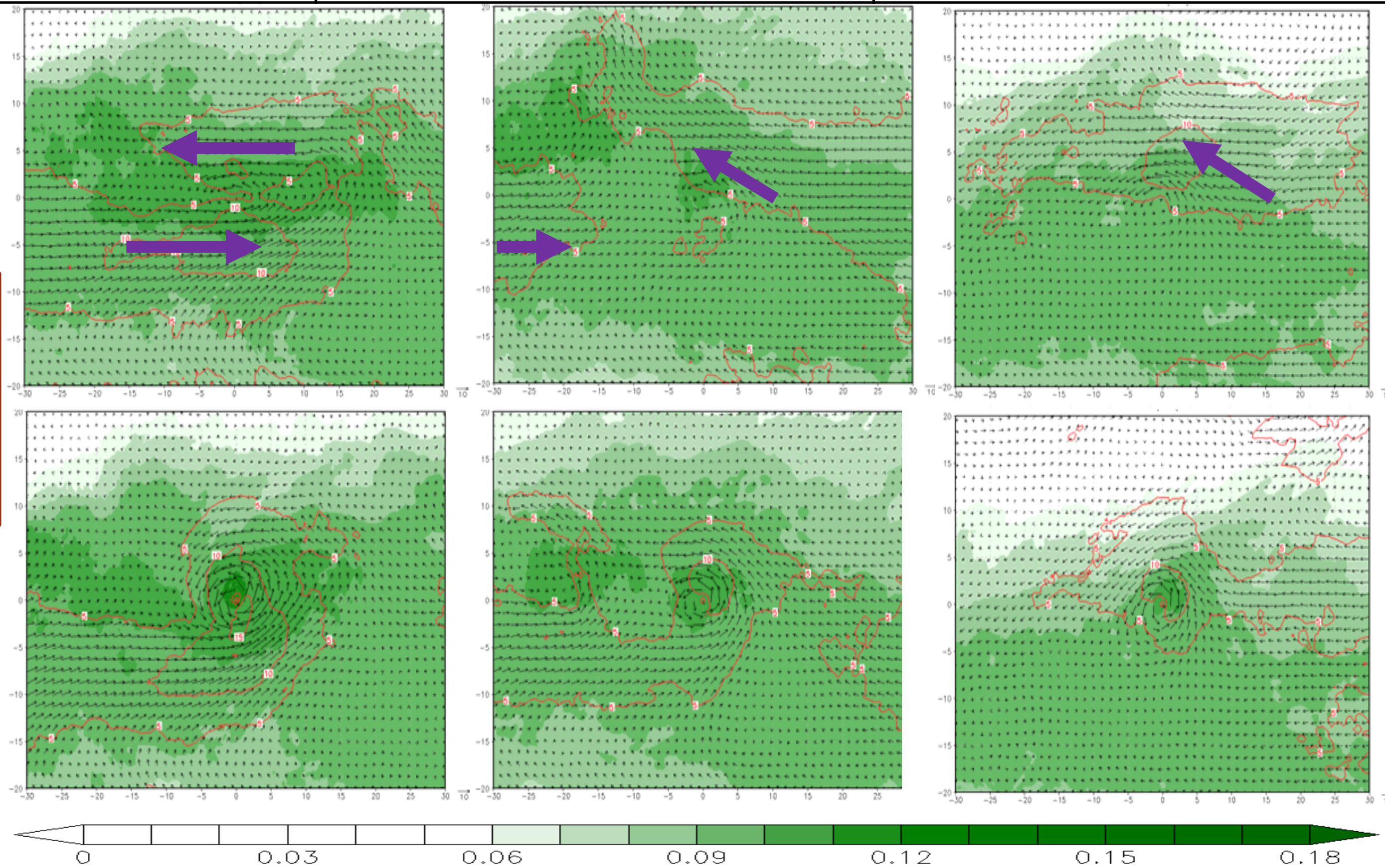
-48 hr

0 hr

Composite:
- Wind (vector)
- Wind speed

(contour; 850mb; m/s)
- Low level q

(shaded; 1000-700 mb; g/kg)



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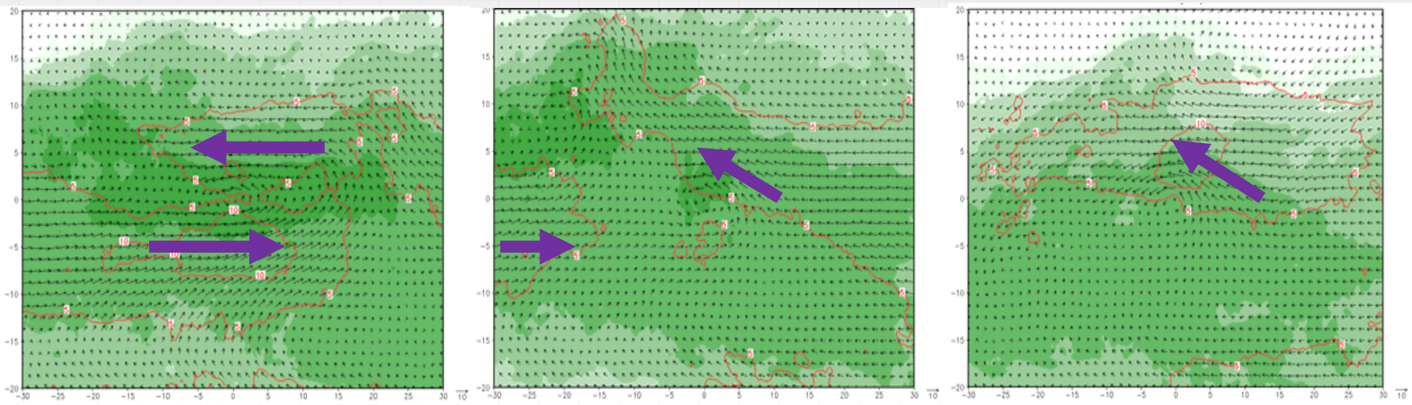
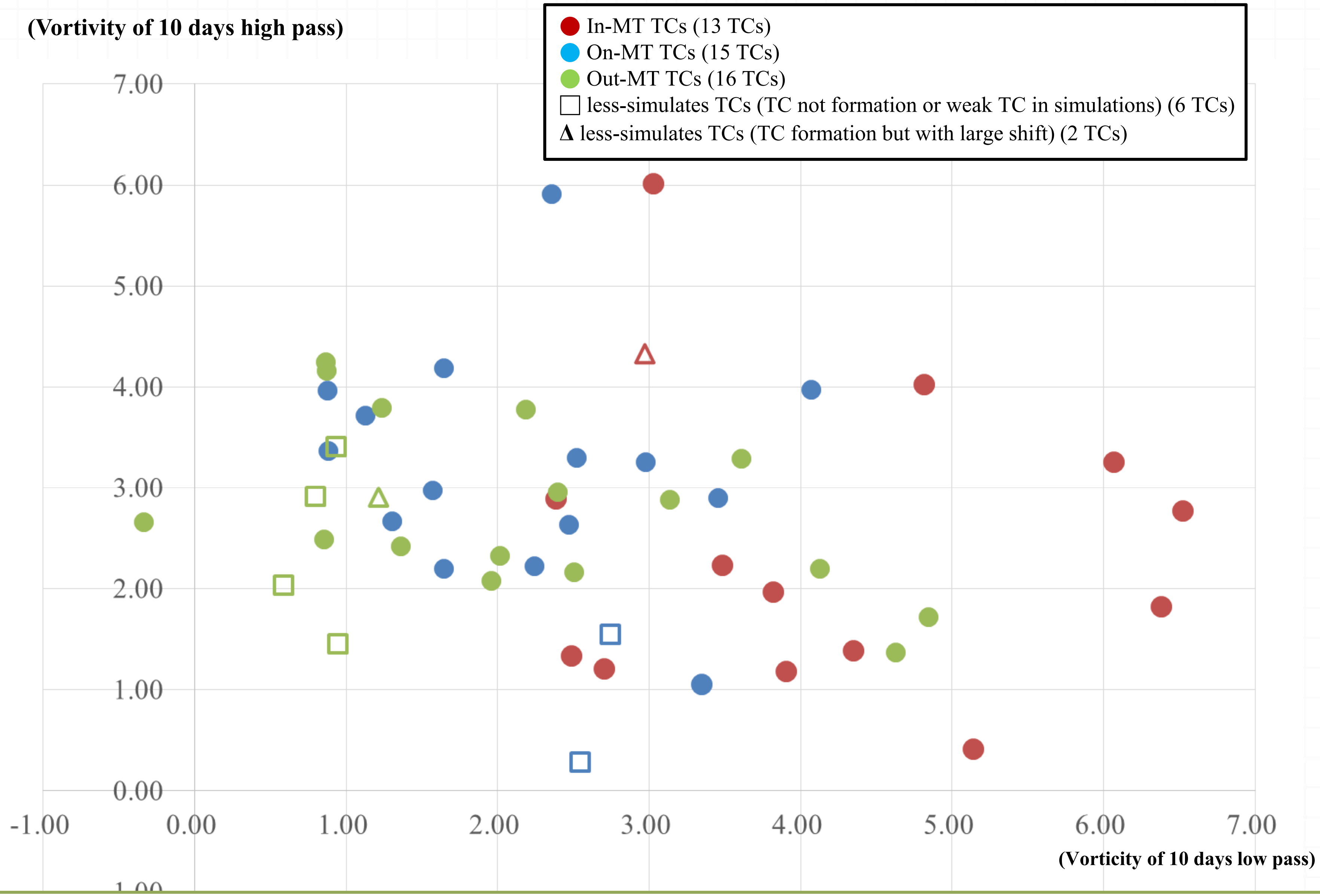


	In-MT	On-MT	Out-MT
TC number	(14/52) (2008/2009)=(4/10)	(17/52) (2008/2009)=(9/8)	(21/52) (2008/2009)=(12/9)
Type	• **Monsoon shear** • Monsoon gyre	• **Monsoon confluence** • Energy dispersion	• **Easterly wave** • Energy dispersion & else
Vorticity	-	-	Min
Vorticity change	-	-	Min
TC speed	Min	medium	Max
Wind shear	-	Min	-
q (1000-700mb)	-	-	Min
Convection (1.5°)	-	Min	-

Pass 95% T-test

Following the circulation center from **-24h to TC formation** in observations, the mean of environment conditions were calculated with EC-YOTC 6-hourly analysis data in 3°-radius.



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NCEP-GFS (n=52)	82.7	80.8	65.4	40.4	67.3
In-MT TCs (n=28)	92.9	85.7	60.7	53.6	73.2
On-MT TCs (n=34)	88.2	88.2	61.8	35.3	68.4
Out-MT TCs (n=42)	73.8	78.6	69.0	50.0	67.9

	In-MT	**On-MT**	**Out-MT**
TC number	(**14**/52) (2008/2009)=(4/10)	(**17**/52) (2008/2009)=(9/8)	(**21**/52) (2008/2009)=(12/9)
Type	• **Monsoon shear** • Monsoon gyre	• **Monsoon confluence** • Energy dispersion	• **Easterly wave** • Energy dispersion & else
Number of well-simulated TCs (>50%)	13 (92.9 %)	15 (88.2 %)	16 (76.2 %)

SUMMARY

- This study analyzes the systematic errors of model simulation of TC formations in the WNP by dynamic-consist modeling approaching.
- Angular momentum transports indicates the strength of total symmetric flux ($\bar{u}$ domainated) would be the key factor of TC formation simulations.
- Considering the TC number and synoptic pattern, we simplified the synoptic environments into three types: In-MT TCs, On-MT TCs and Out-MT TCs.

	In-MT	**On-MT**	**Out-MT**
TC number	(**14**/52=%) (2008/2009)=(4/10)	(**17**/52=%) (2008/2009)=(9/8)	(**21**/52=%) (2008/2009)=(12/8)
Number of well-simulated TCs (>50%)	13 (92.9 %)	15 (88.2 %)	16 (76.2 %)
TC detect rate (-48& -72)	89.3 %	88.2 %	76.2 %
TC detect rate (-96& -120)	57.1 %	48.5 %	59.5 %

- In addition cumulus parameterization experiments in 11 TCs that suggests the TC formations in WRF model would not relay on cumulus parameterizations within large environmental forcing, but sensitive within less environmental forcing TCs.