Seasonal predictability of tropical cyclone formation by the JMA/MRI-CGCM

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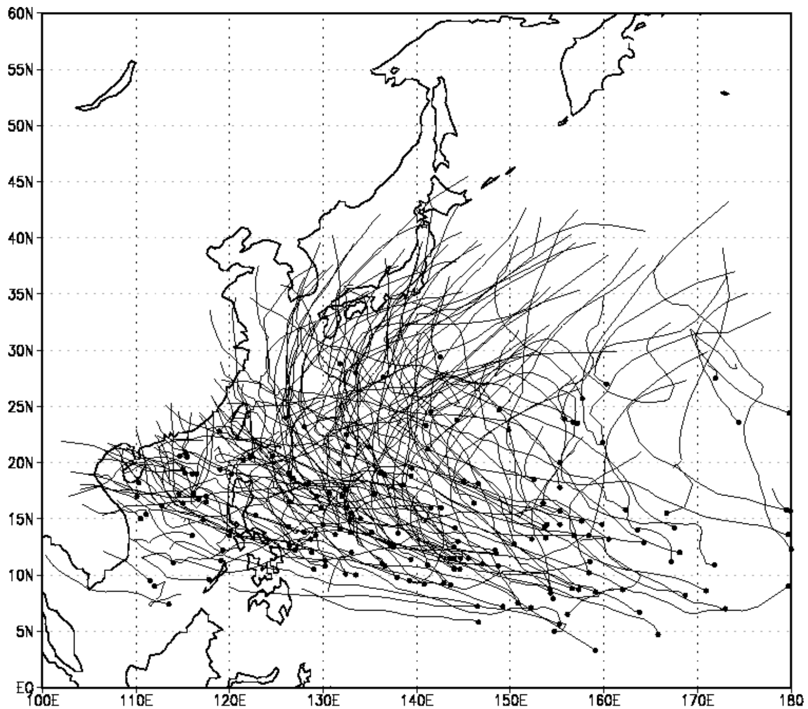
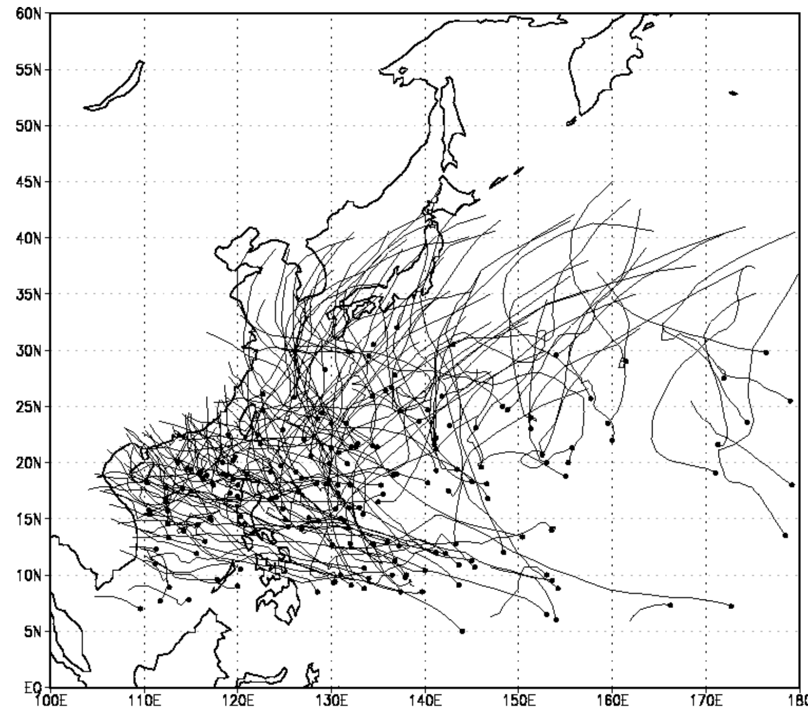
1. Introduction

Tropical cyclone and ENSO

- The tropical cyclone (TC) often causes socio-economic damages in the Asia & Pacific regions.
- The TC activity has a strong interannual variability related to the ENSO (e.g. Chen et al. 1998).



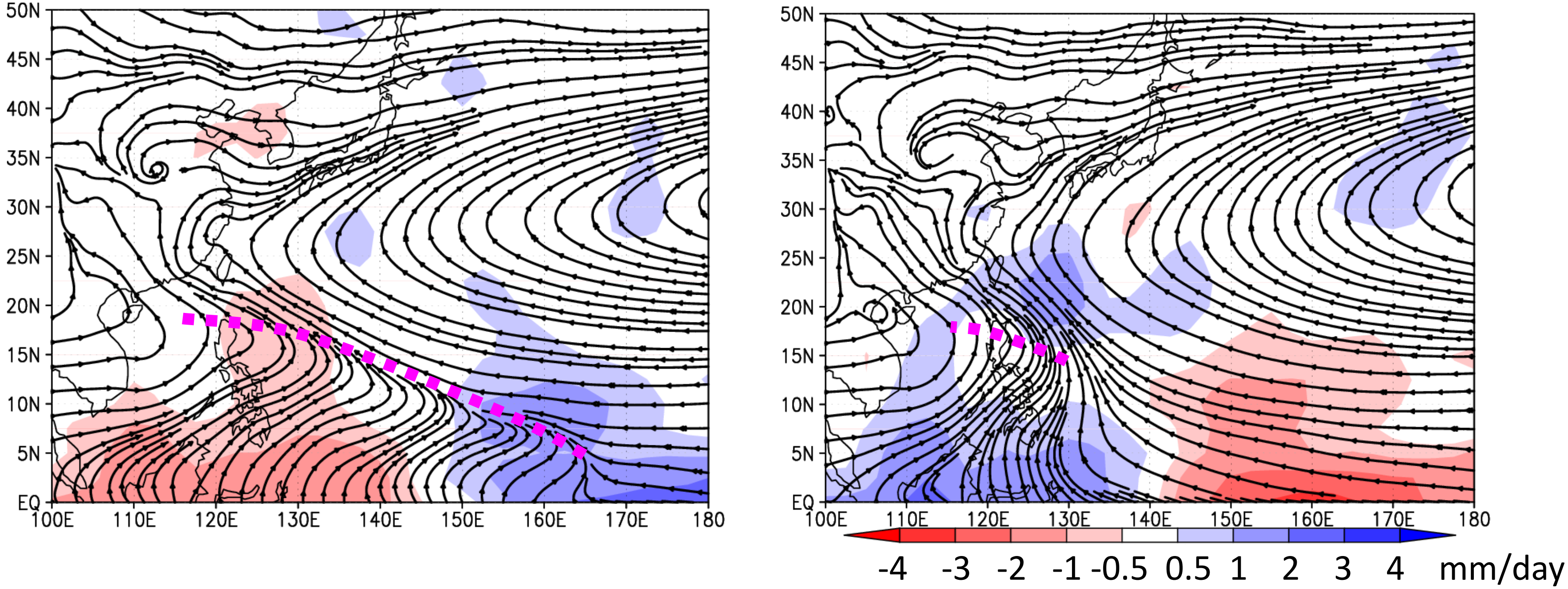


El-Niño years Observed TCs track La-Niña years

Monsoon trough and ENSO

Composites of 850-hPa streamline and precipitation anomaly (shade)
(JJASO 1981-2010)

El-Niño years　　　　La-Niña years



・About 70% of TCs in the western North Pacific (WNP) occur over the monsoon trough (e.g. Richie and Holland 1999).

・The monsoon trough tends to extent (retreat) eastward (westward) during El Niño (La Niña) year (e.g. Takaya et al. 2008).

Motivation

- Early Study (Takaya et al. 2010)
  - The JMA/MRI-CGCM has a good skill in predicting SST variability related to the ENSO.
  - It is capable of well predicting the interannual variability of TC activity in the WNP.
- Motivation in this study
  - We verify the TC activity with the next operational model (JMA/MRI-CGCM2).

2. Data and TC detection algorithm

Data and Hindcast Settings

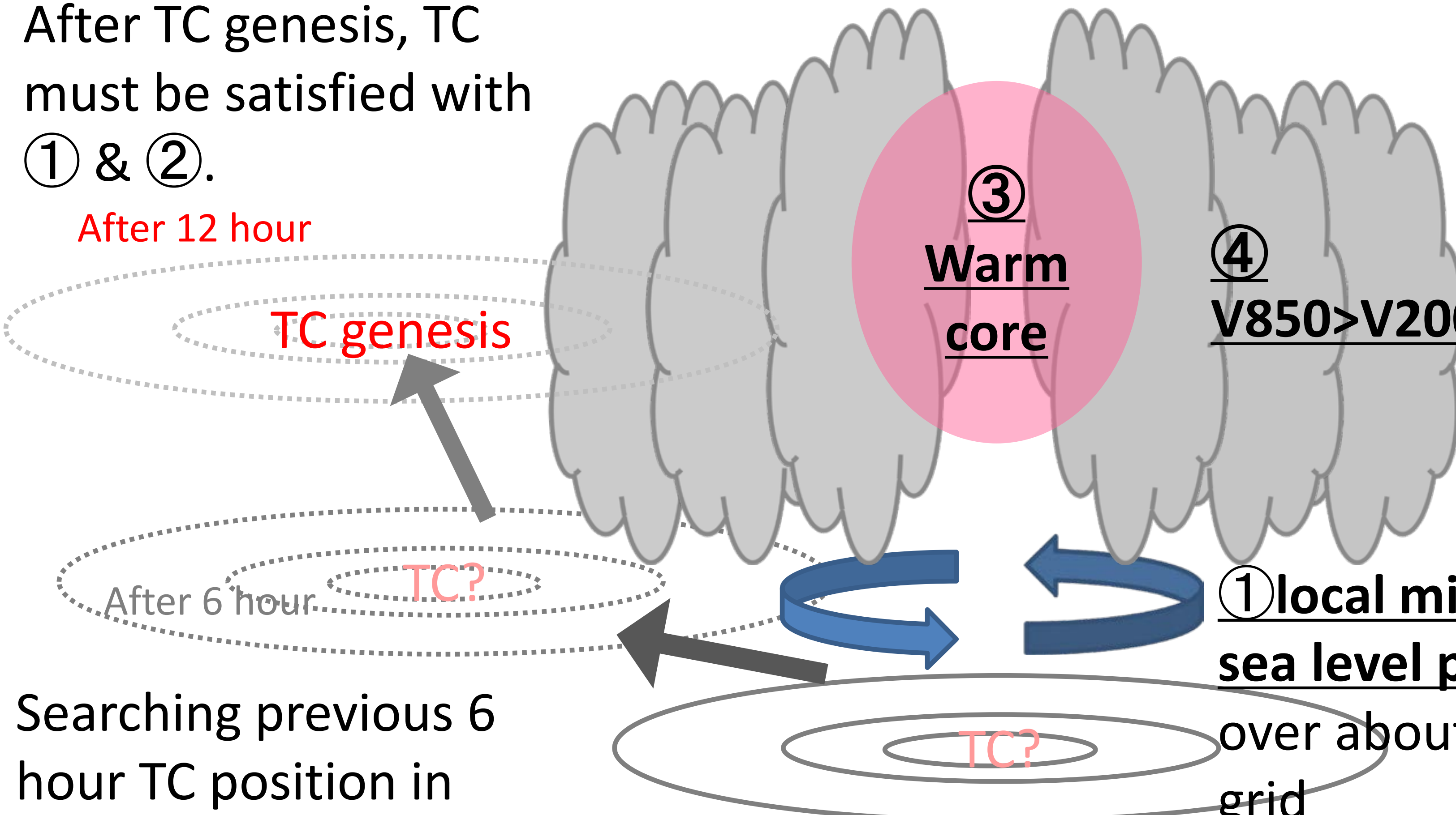
- Validating datasets :

RSMC Tokyo besttrack, JRA-55(Kobayashi et al. 2015), GPCP

	JMA/MRI-CGCM Hindcast	JMA/MRI-CGCM2 Hindcast
Atmospheric Model	TL95L40 (~180km, Top 0.4hPa)	TL159L60 (~110km, Top 0.1hPa)
Gridded data	$2.5^{\circ} \times 2.5^{\circ}$	$1.5^{\circ} \times 1.5^{\circ}$
Period	30 years (1981-2010) June-October (JJASO)	
Initial date	4/16 & 5/1	
ensemble size	Total 10 members	

Schematic Drawing of TC Detection Algorithm

After TC genesis, TC must be satisfied with ① & ②.



①local minimum of sea level pressure over about 5.0° x 5.0° grid

Searching previous 6 hour TC position in about 13° × 13°

②850hPa relative vorticity

above $3.2 \times 10^{-5}\ s^{-1}$ for JMA/MRI-CGCM

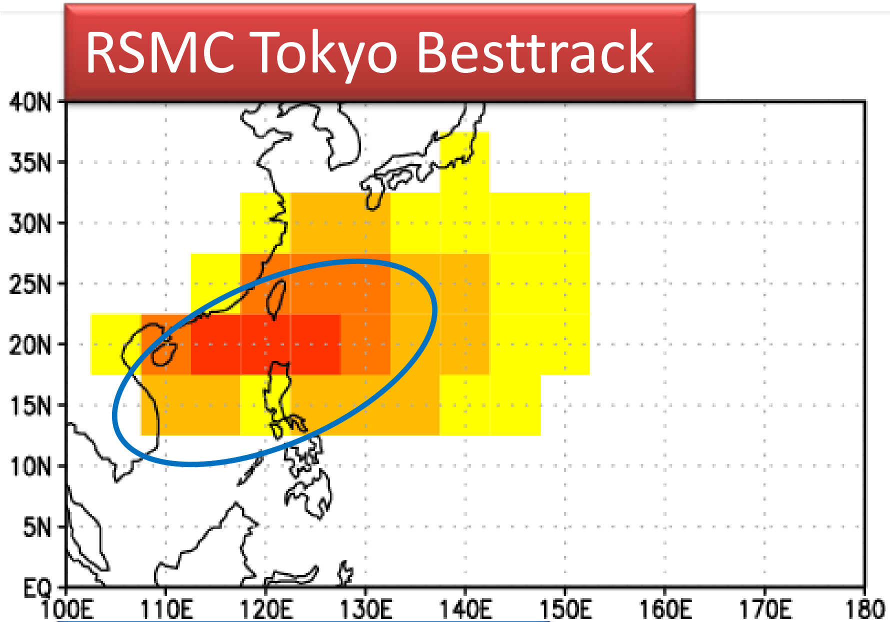
above $5.0 \times 10^{-5}\ s^{-1}$ for JMA/MRI-CGCM2

Genesis region : equator-30N at the sea

Thanks to Mr. Sugimoto

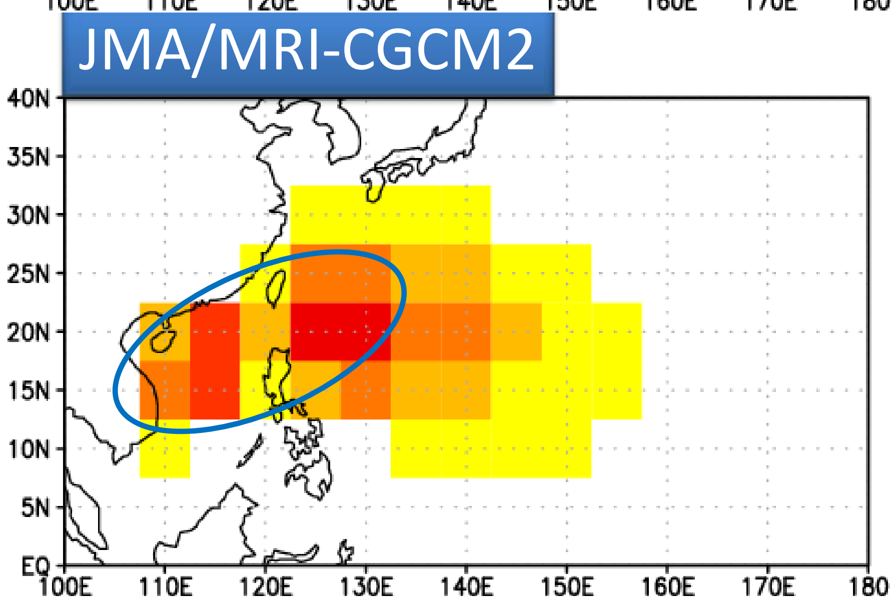
3. Verification of interannual variability of seasonal TC activity by CGCMs

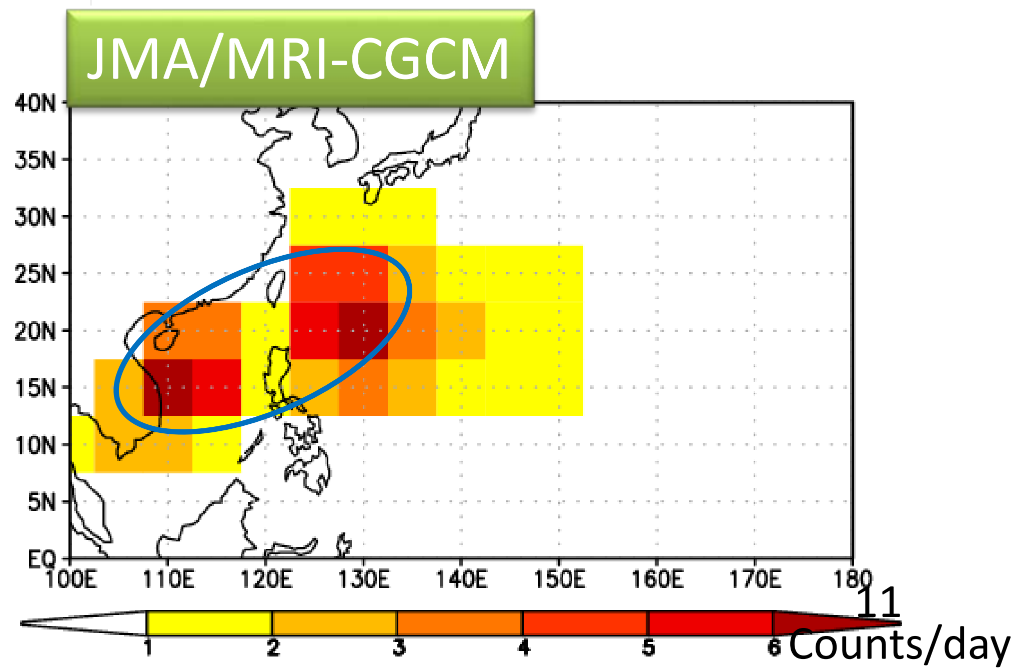
Climatological mean of TC frequency



・Both the JMA/MRI-CGCM2 and the JMA/MRI-CGCM predict the climatological location of TCs.

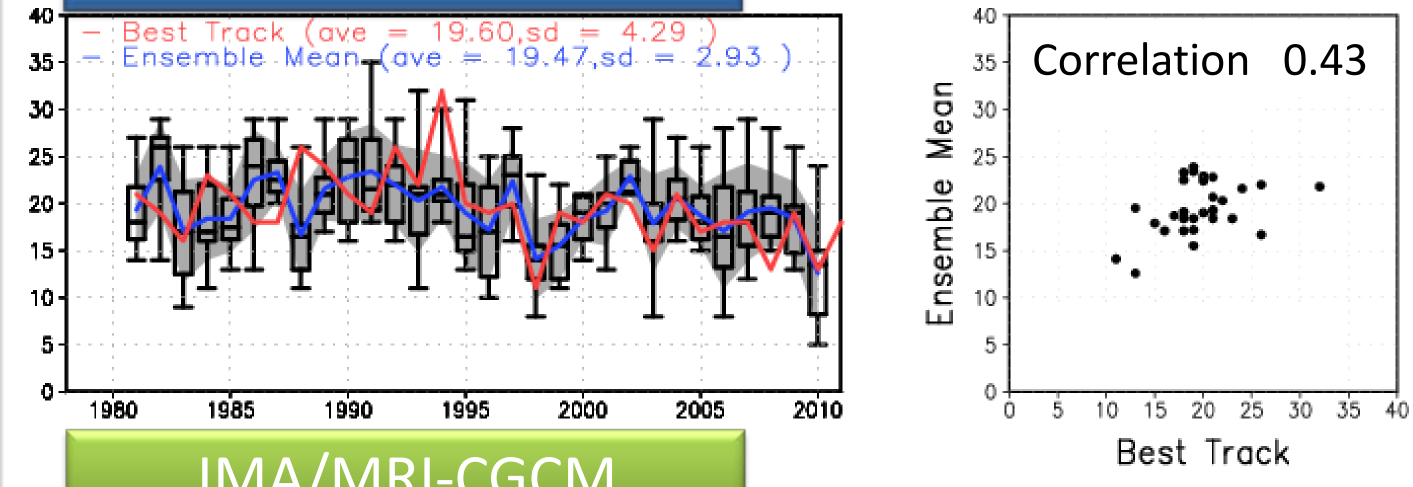
・The JMA/MRI-CGCM2 has a less systematic error in South China Sea and the east of Philippine.



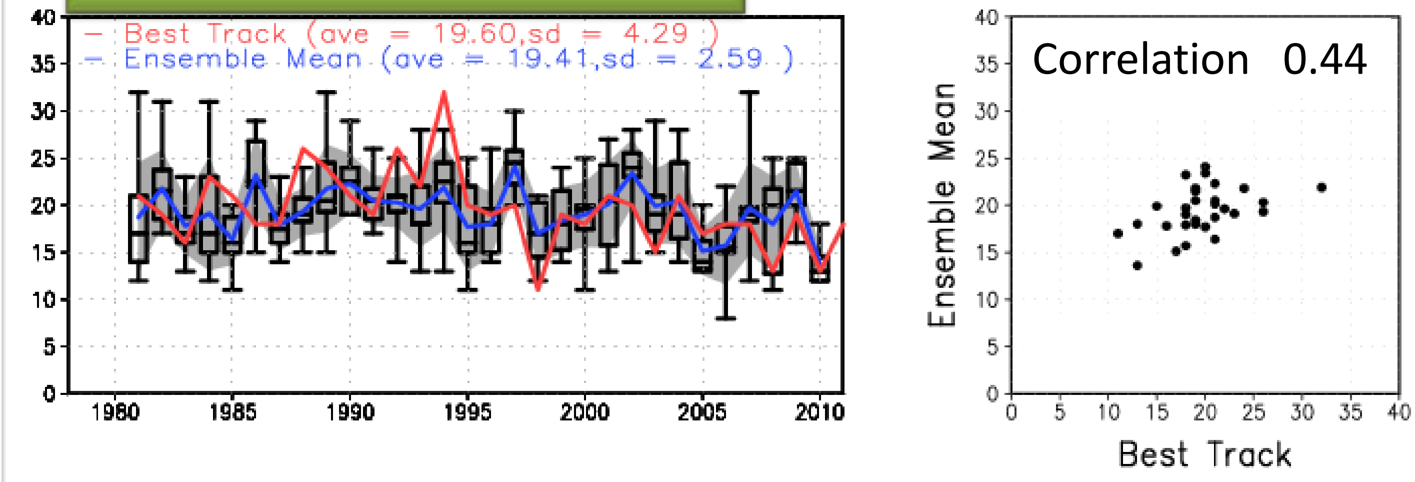


The number of TC predicted in CGCMs

JMA/MRI-CGCM2

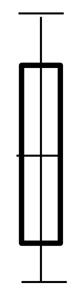


JMA/MRI-CGCM



red : besttrack
blue : ensemble mean
shade : standard deviation
Regions: 0-30N, 100E-180E

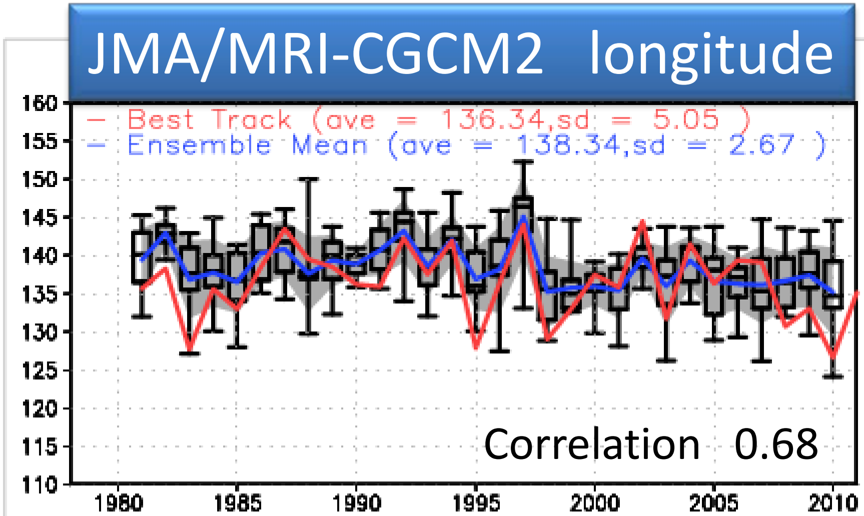
Box and whisker :

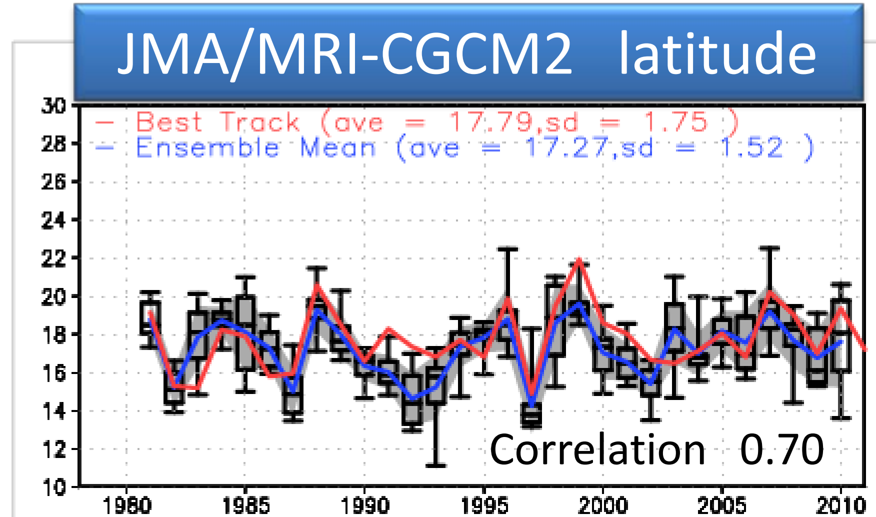


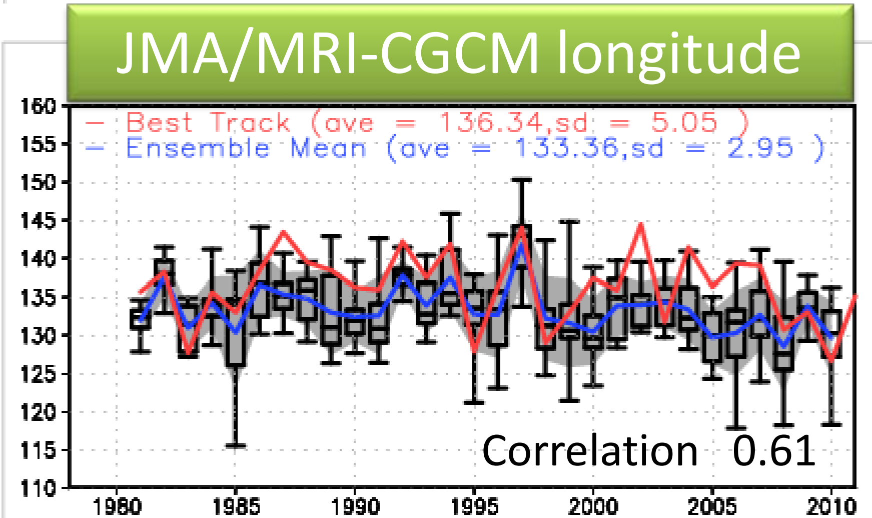
maximum
75%
mean
25%
minimum
in ensemble members

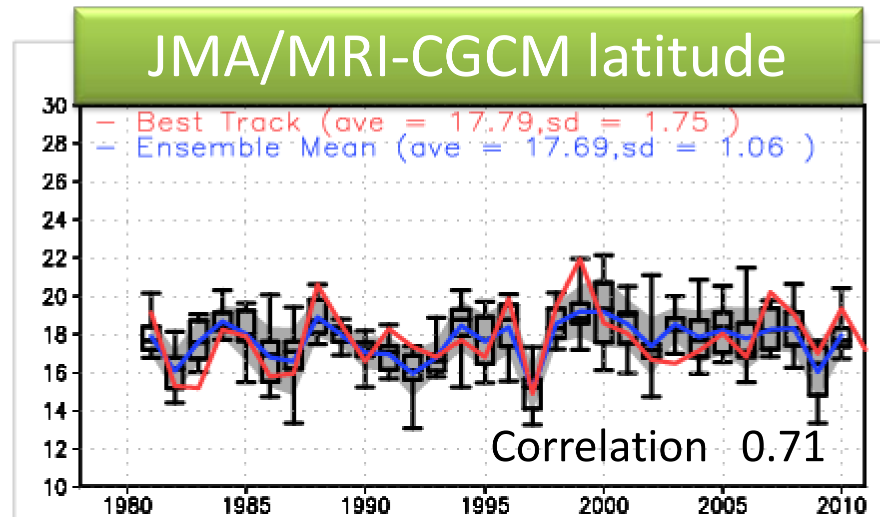
・The CGCMs are capable of predicting the interannual variability of the TC number.

The location of TC predicted for CGCMs



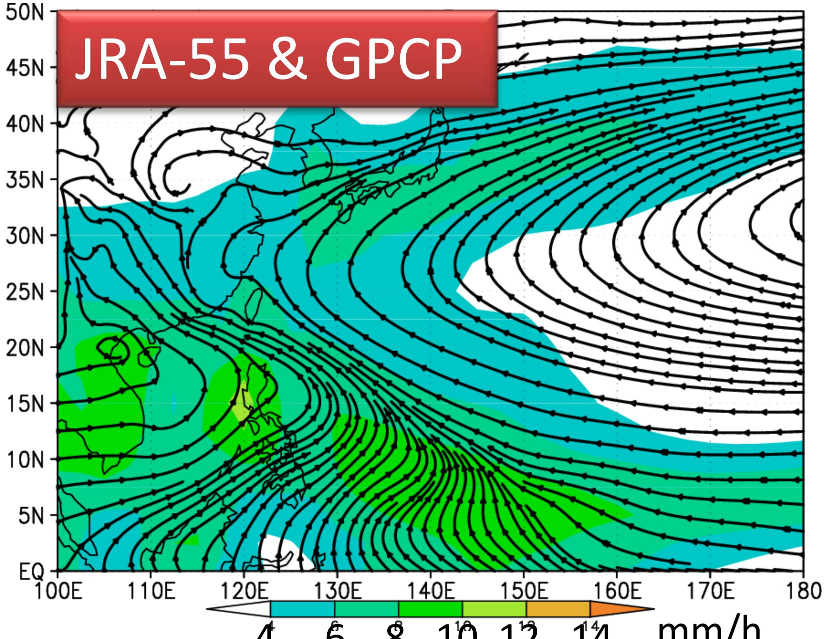






- The CGCMs well predict the interannual variability of the TC location.
- The JMA/MRI-CGCM2 has a less systematic location error in longitude.

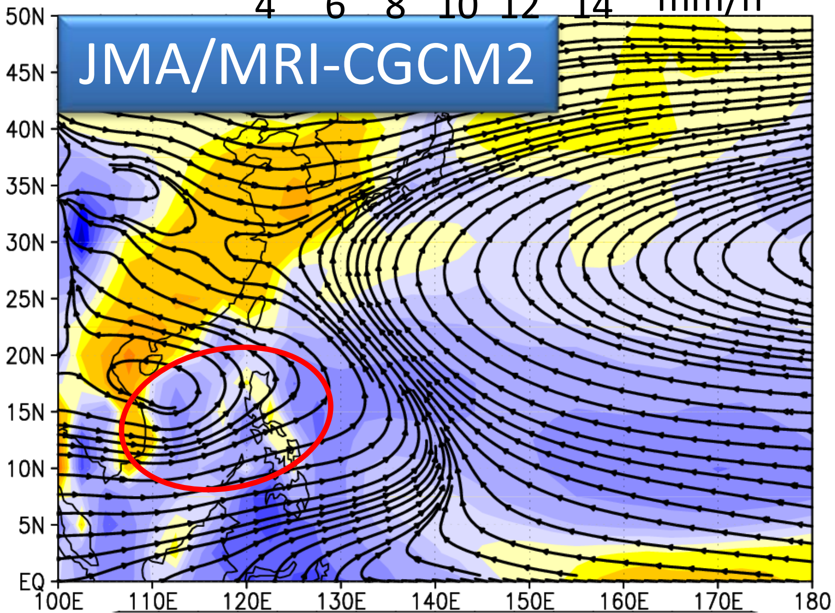
Environmental field

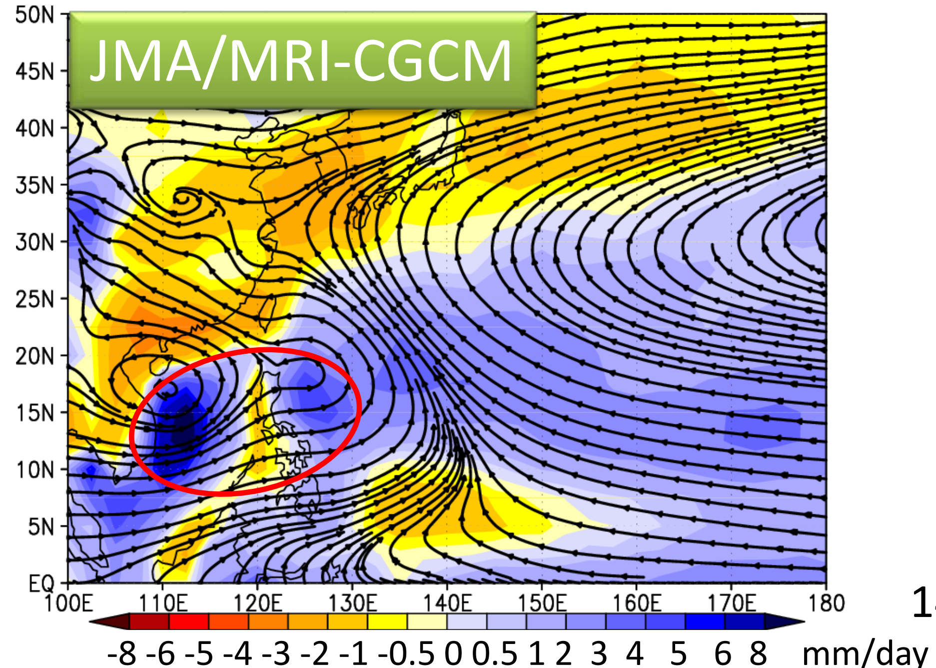


・The JMA/MRI-CGCM2 has less precipitation biases over the monsoon trough region.

・The JMA/MRI-CGCM2 has a better reproducibility of low-level circulation.

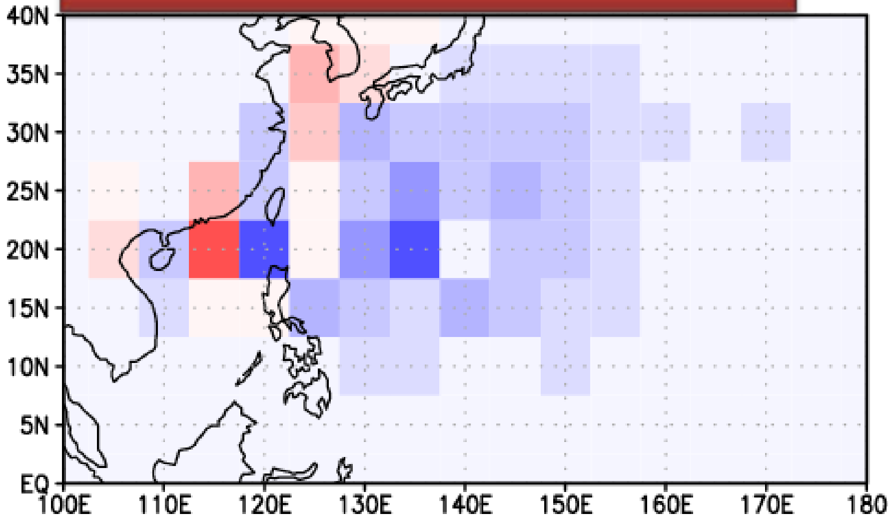
Climatological mean (1981-2010) of 850hPa stream line and precipitation biases for CGCMs.





Case Study (2010)

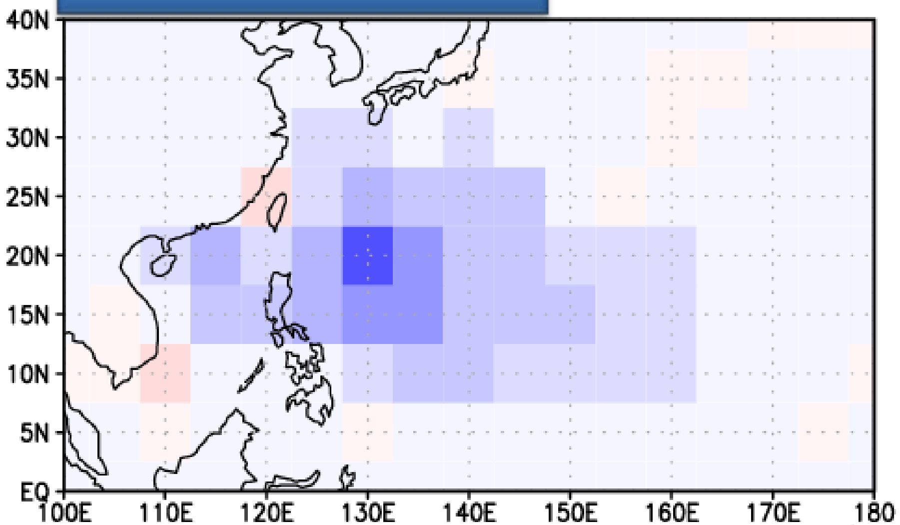
RSMC Tokyo Besttrack



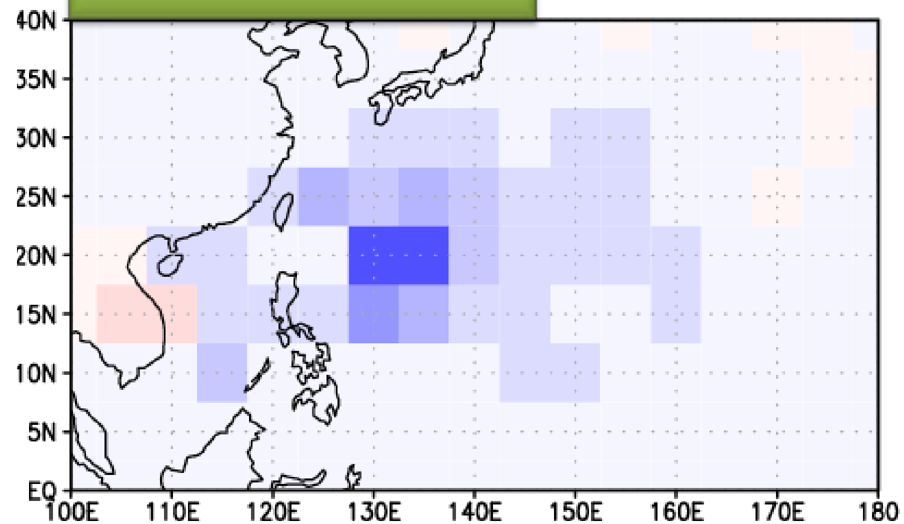
- Indian Ocean warming year.
- Both seasonal prediction systems well predict the TC activity.

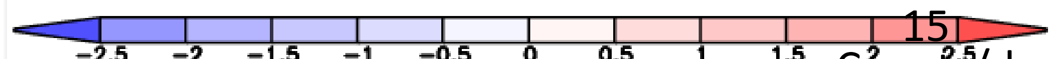
Shade: TC frequency anomaly in 2010

JMA/MRI-CGCM2



JMA/MRI-CGCM

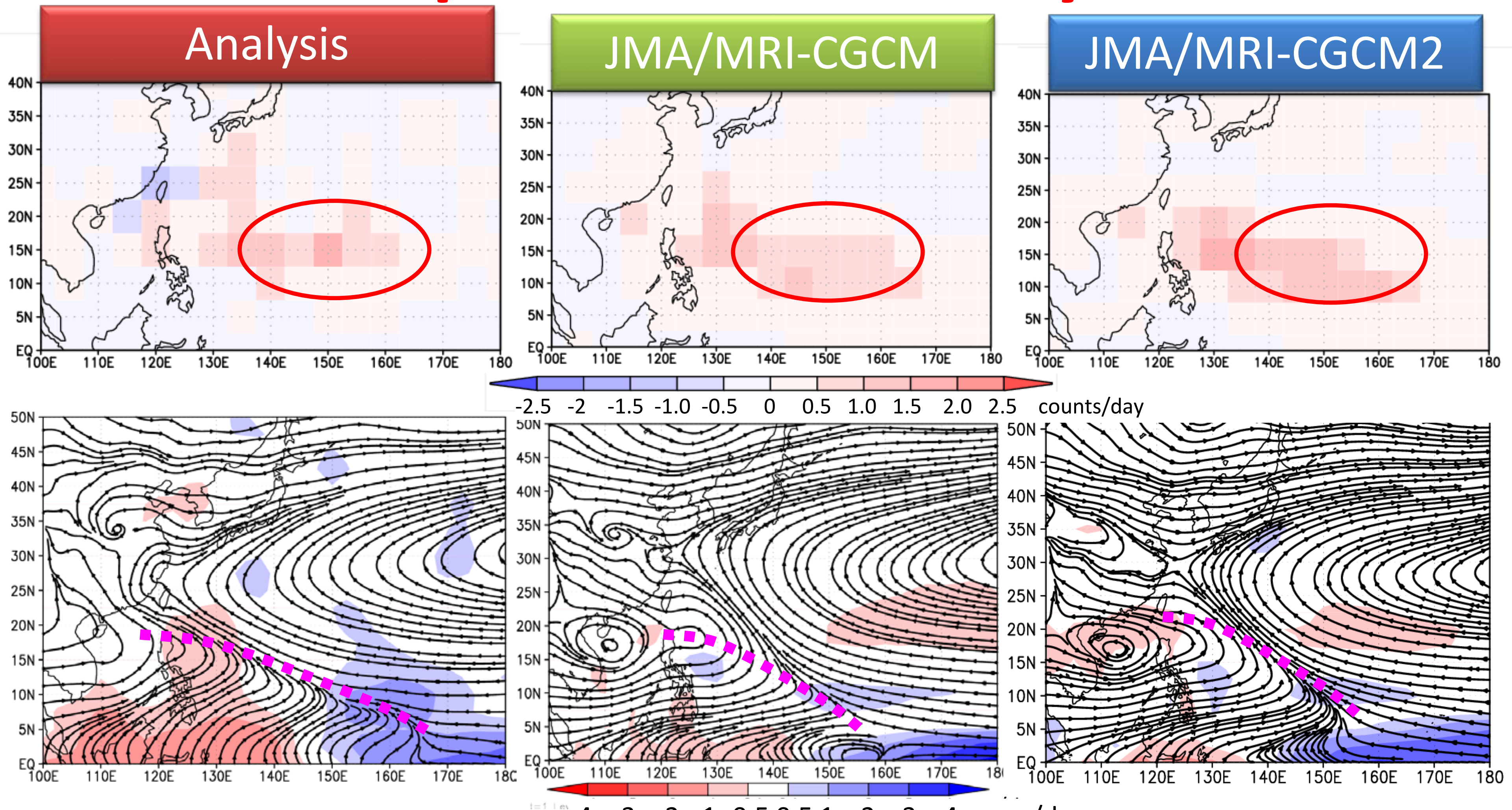




Counts/day

4. Discussion of the effect of TC activity due to El-Niño/La Niña phenomenon

Composite for El Niño years



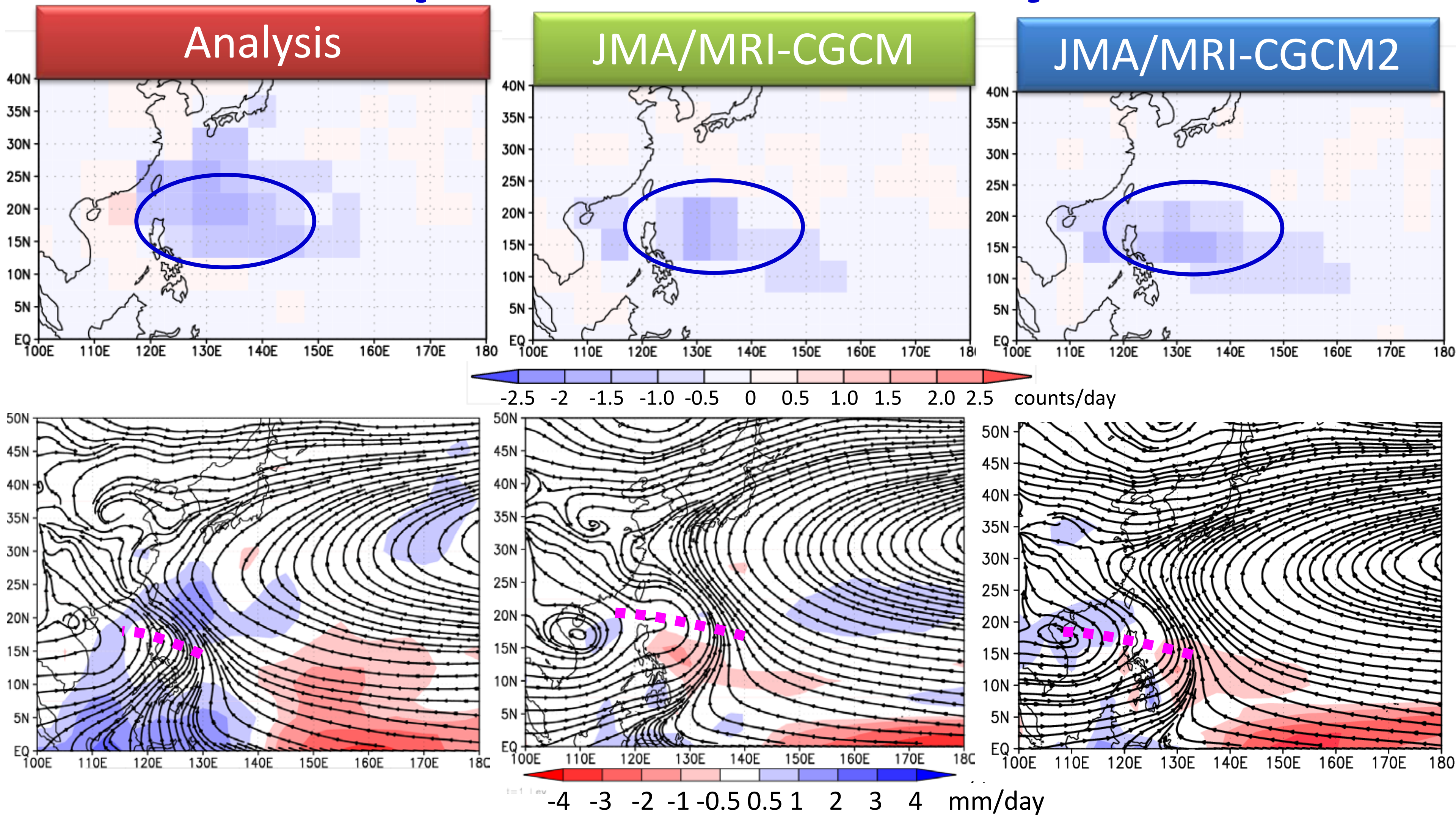
Top: TC frequency anomaly

Bottom: 850hPa stream line and precipitation anomaly

El Niño years : 1982,83,87,91,97,2002,09

・The CGCMs well predict extension of the monsoon trough and enhanced TC activity shifted southeastern part during El-Niño years.

Composite for La Niña years



La Niña years : 1984,85,88,95,98,99,2007,10

・The CGCMs well predict retreat of the monsoon trough and less TC activity in the northwestern part during La-Niña years.

5. Summary

Summary

- We examined the capability of TC seasonal prediction with the JMA/MRI seasonal prediction systems.
- The JMA/MRI-CGCMs are capable of well predicting the interannual variability of TC formation in the WNP.
  - It well predicts the location of the monsoon trough condition related the ENSO.
- The JMA/MRI-CGCM2 has better performance at predicting in the location of TCs.
  - Interannual variability of mean longitude of TC formation
  - mean longitude of TC formation

Reference

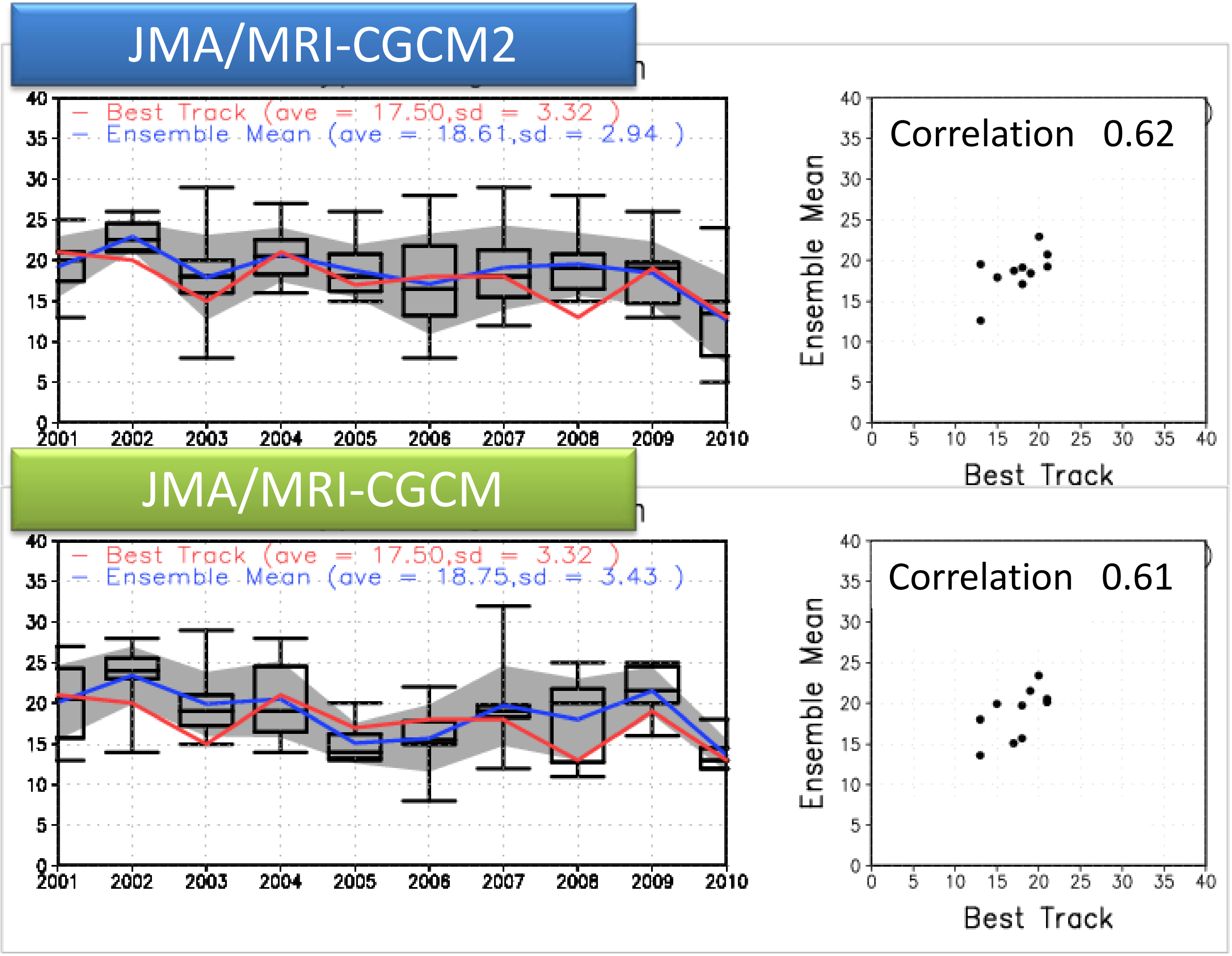
Chen, T., S.-P. Weng, N. Yamazaki, and S. Kiehne, 1998: Interannual variation in the tropical cyclone formation over the western North Pacific. *Mon. Wea. Rev.,* **126,** 1080–1090.

Kobayashi, S., Y. Ota, Y. Harada, A. Ebita, M. Moriya, H. Onoda, K. Onogi, H. Kamahori, C. Kobayashi, H. Endo, K. Miyaoka, and K. Takahashi, 2015: The JRA-55 reanalysis: General specifications and basic characteristics. *J. Meteor. Soc. Japan*, Accepted.

Ritchie, E. A., and G. J. Holland, 1999: Large-scale patterns associated with tropical cyclogenesis in the western Pacific. *Mon. Wea. Rev.,* **127,** 2027–2043.

Takaya, Y., T. Yasuda, T. Ose, and T. Nakaegawa, 2010: Predictability of the mean location of typhoon formation in a seasonal prediction experiment with a coupled general circulation model. *J. Meteor. Soc. Japan,* **88,** 799–812.

The number of TC formation (2001-10)



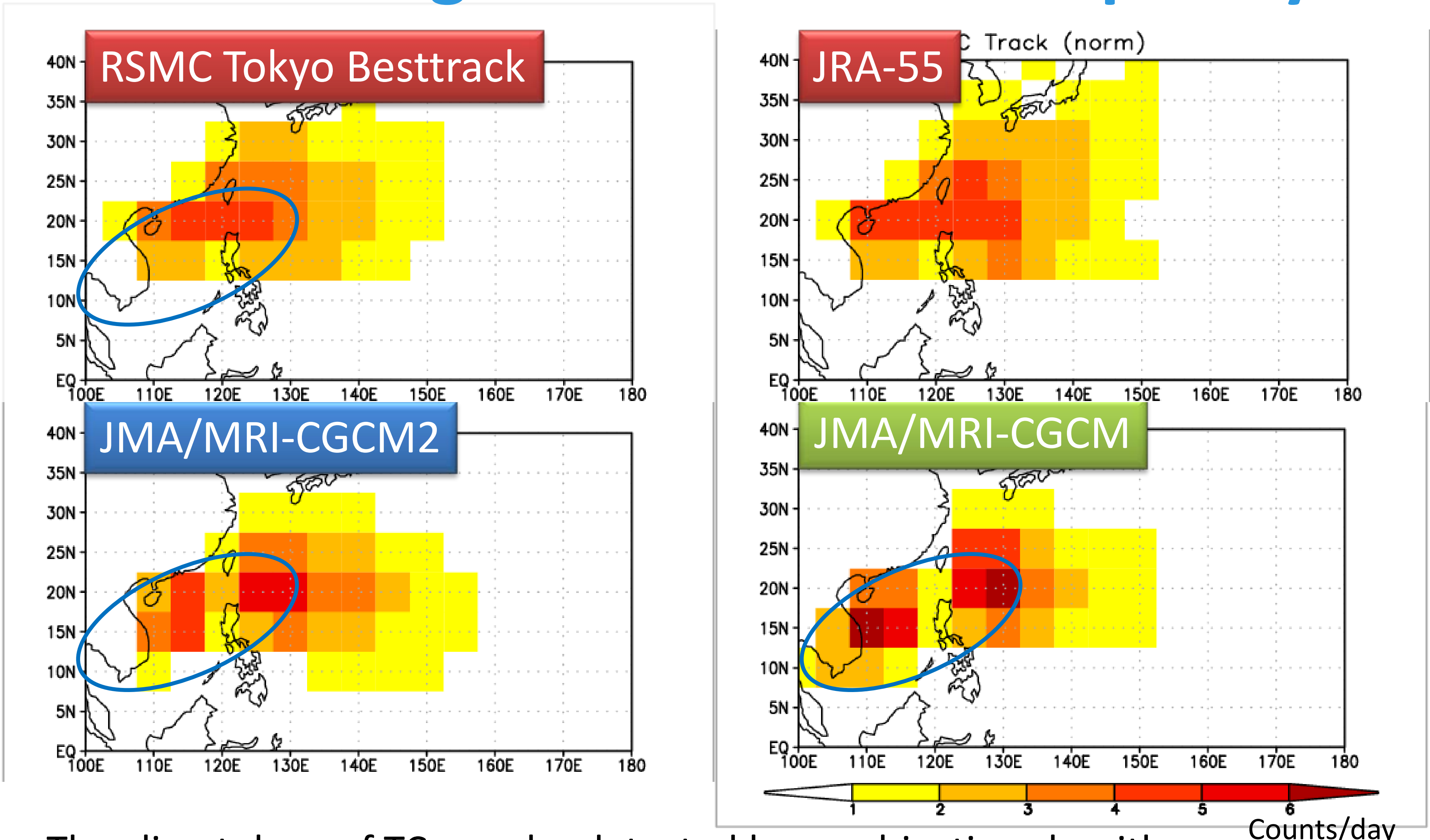
・For the last 10 years (2001-10), CGCMs have a good skill for the number of TC formation.

The threshold for TC detection

・The higher a horizontal resolution is, the larger a low-level vorticity is (Walsh et al. 2007).
→ The threshold must be set severely.

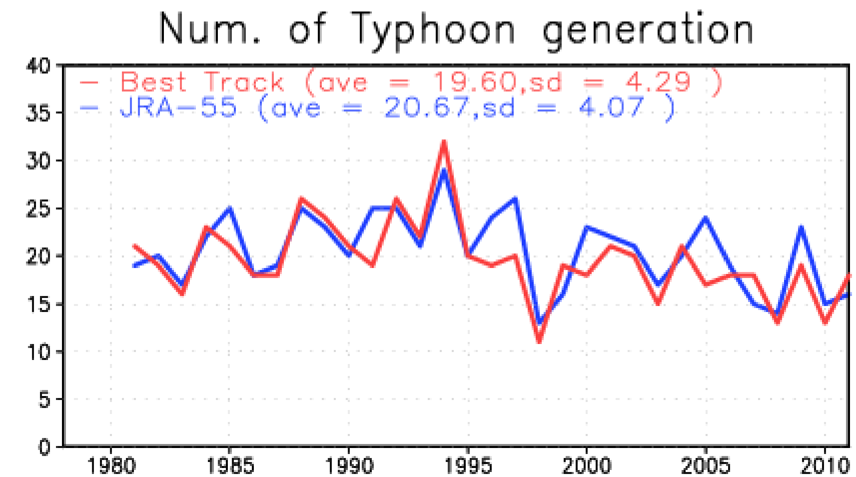
	Takaya et al.(2010)	This study
resolution	1.875° ×1.875° 1 day	1.5° ×1.5° 6 hours
The minimum of SLP	7° ×7°	6° ×6°
850hPa relative vorticity	$4.6\times10^{-5}\ s^{-1}$	$5.0\times10^{-5}\ s^{-1}$
Warm core	5gpm	7gpm
After TC genesis, threshold	70% of the original threshold	none

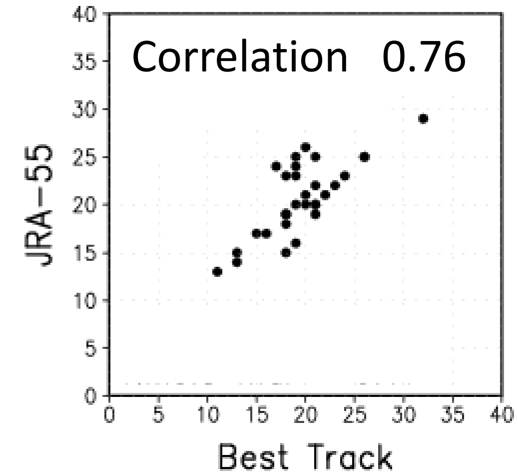
Climatological mean of TC frequency

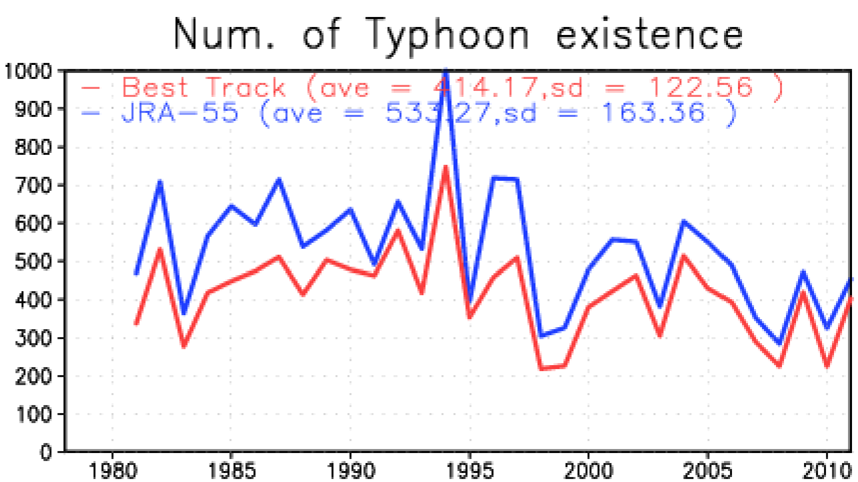


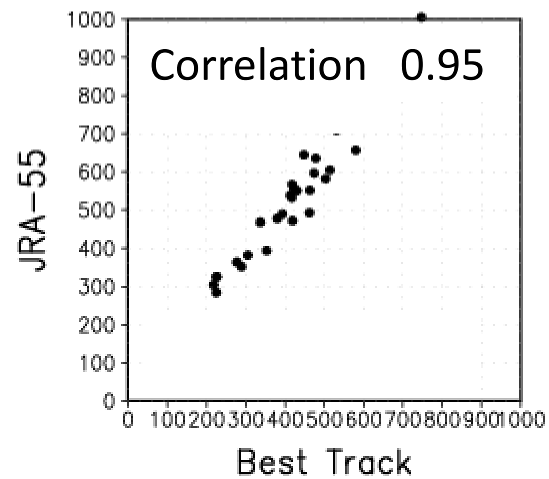
- The climatology of TCs can be detected by an objective algorithm.
- The CGCM can predict the location of TCs.
- The JMA/MRI-CGCM2 has a less systematic error in East and South China Sea.

The number of TC for JRA-55





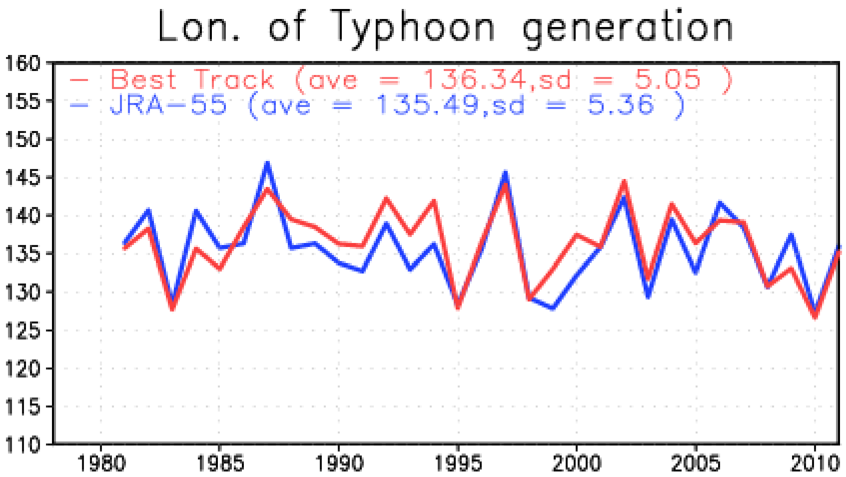


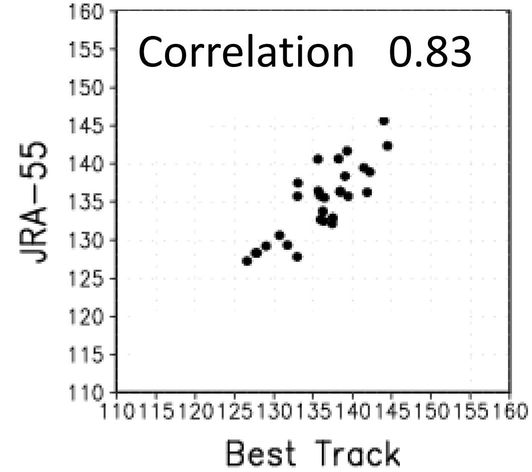


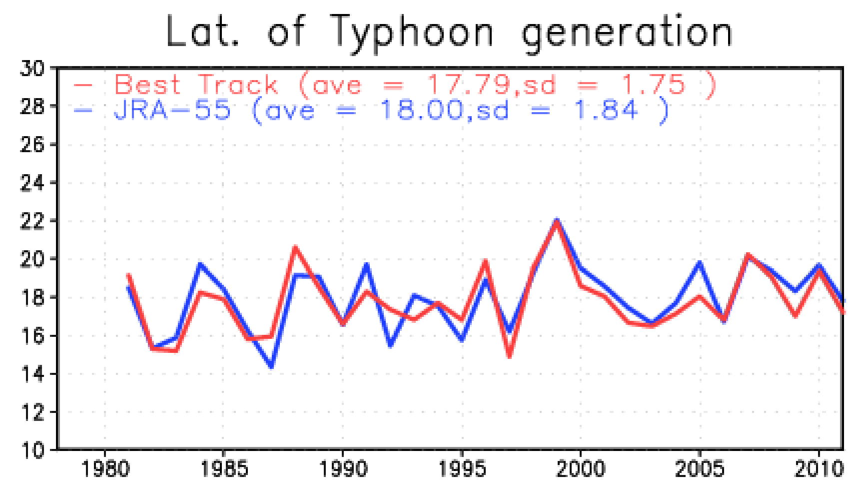
red : besttrack
blue : JRA-55
Regions: 0-30N, 100E-180E

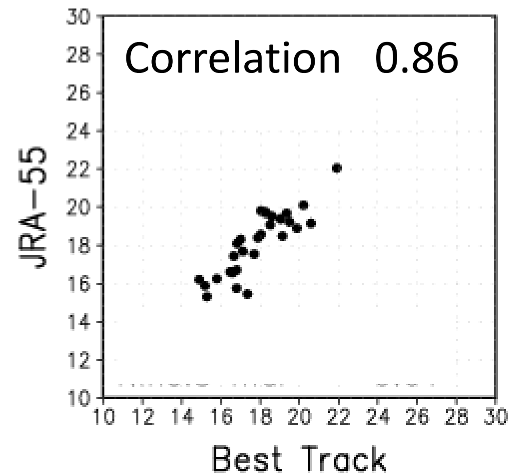
・The interannual variability of the number can be detected by an objective algorithm.

The location of TC formation for JRA-55









・The interannual variability of the location can be detected by an objective algorithm.

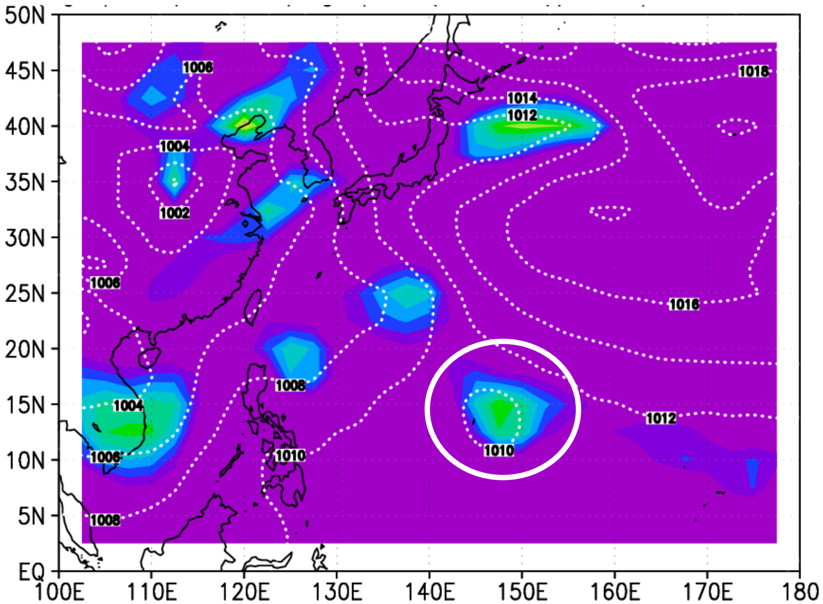
Correlation between TC and Nino.3 index

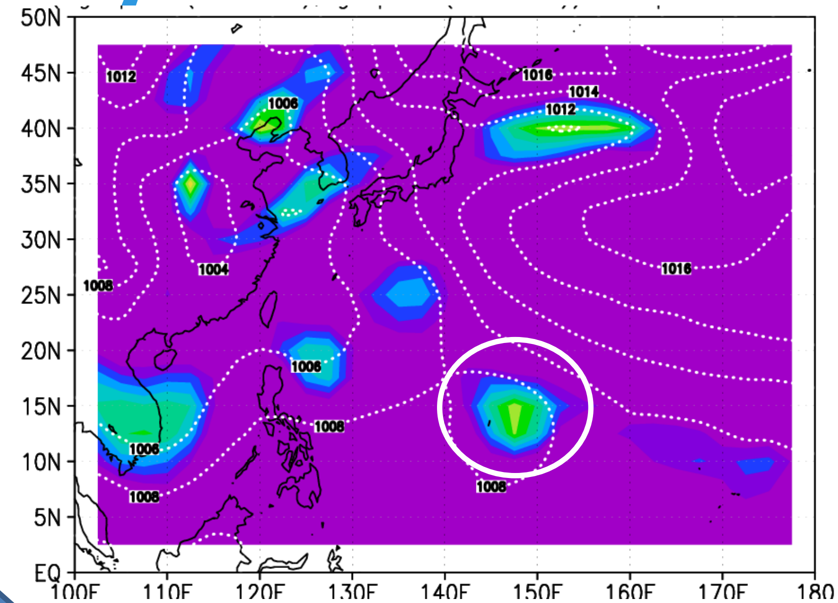
	JMA best track	JMA/MRI-CGCM	JMA/MRI-CGCM2
Genesis	−0.05	0.47	0.64
Longitude	0.39	0.52	0.68
Latitude	−0.79	−0.78	−0.77

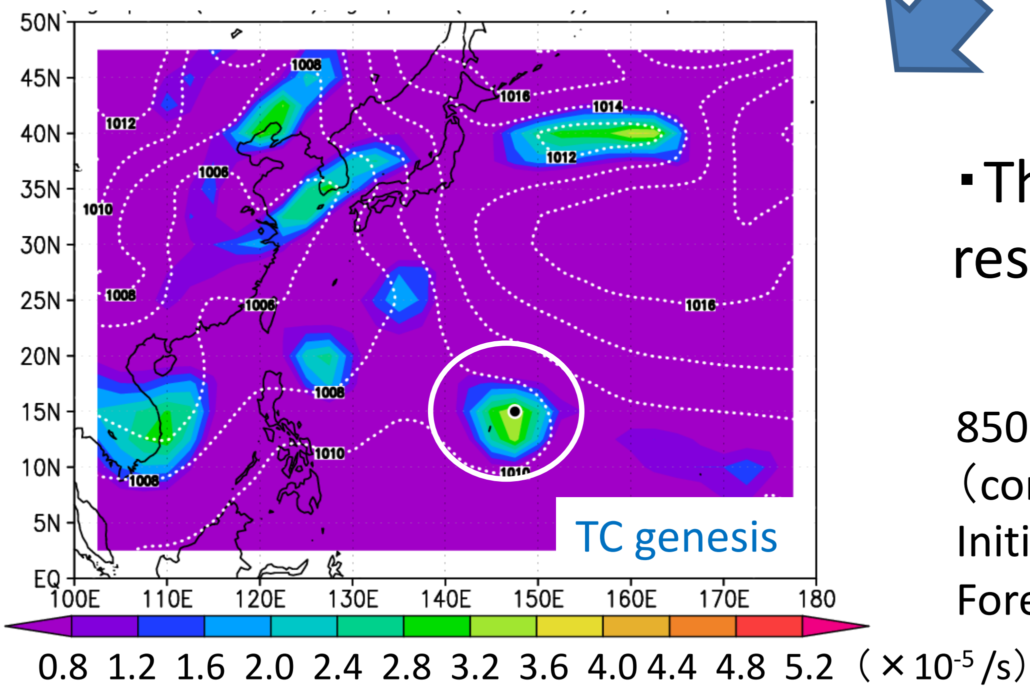
	JMA best track	JMA/MRI-CGCM	JMA/MRI-CGCM2
Frequency	0.40	0.69	0.79
Longitude	0.26	0.58	0.58
Latitude	−0.58	−0.63	−0.62

・The CGCMs capture the location modification by the ENSO.
・The relationship between CGCMs and TC genesis location is more robust than the analysis.

TC structure By CGCM



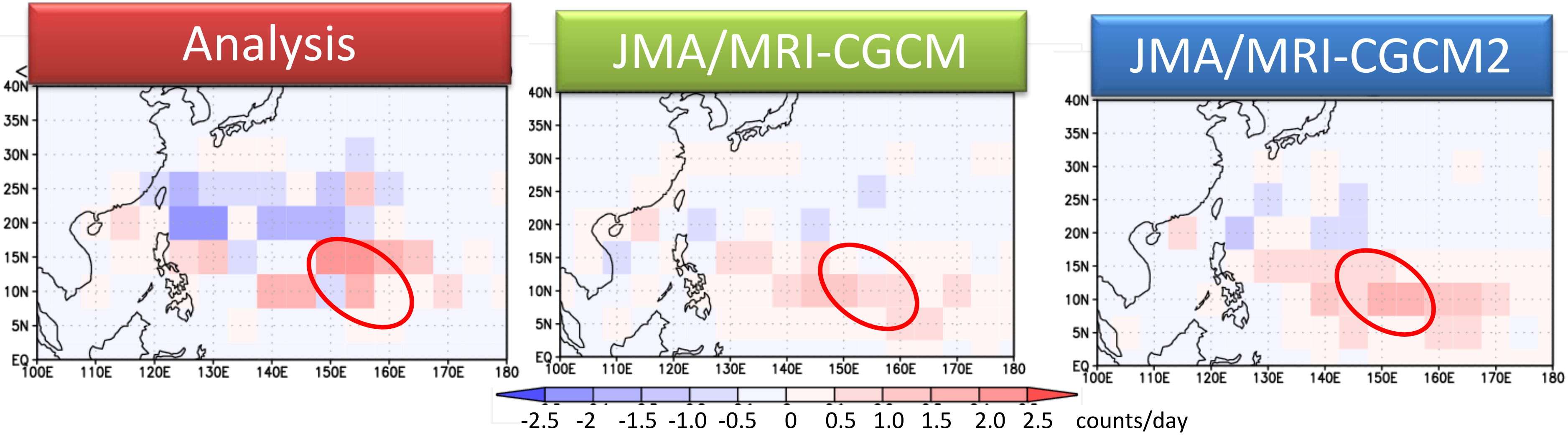




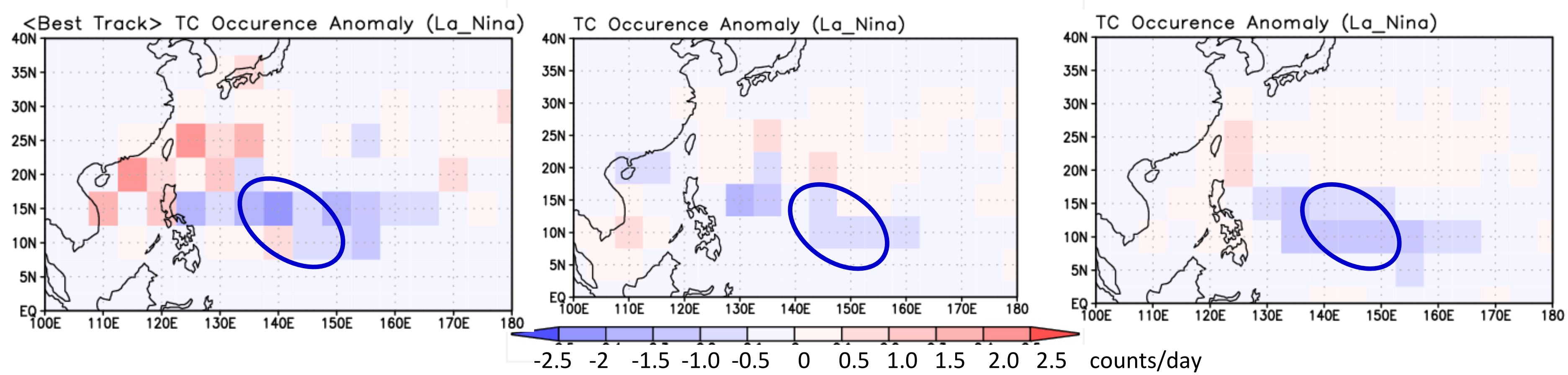
- The CGCM of low horizontal resolution can express low vorticity.

850hPa relative vorticity（color） & SLP（contour） for CGCM（control member）
Initial date: 2010/5/1
Forecast date: 8/24 12UTC～8/25 00UTC

The location of TC formation



El Niño years



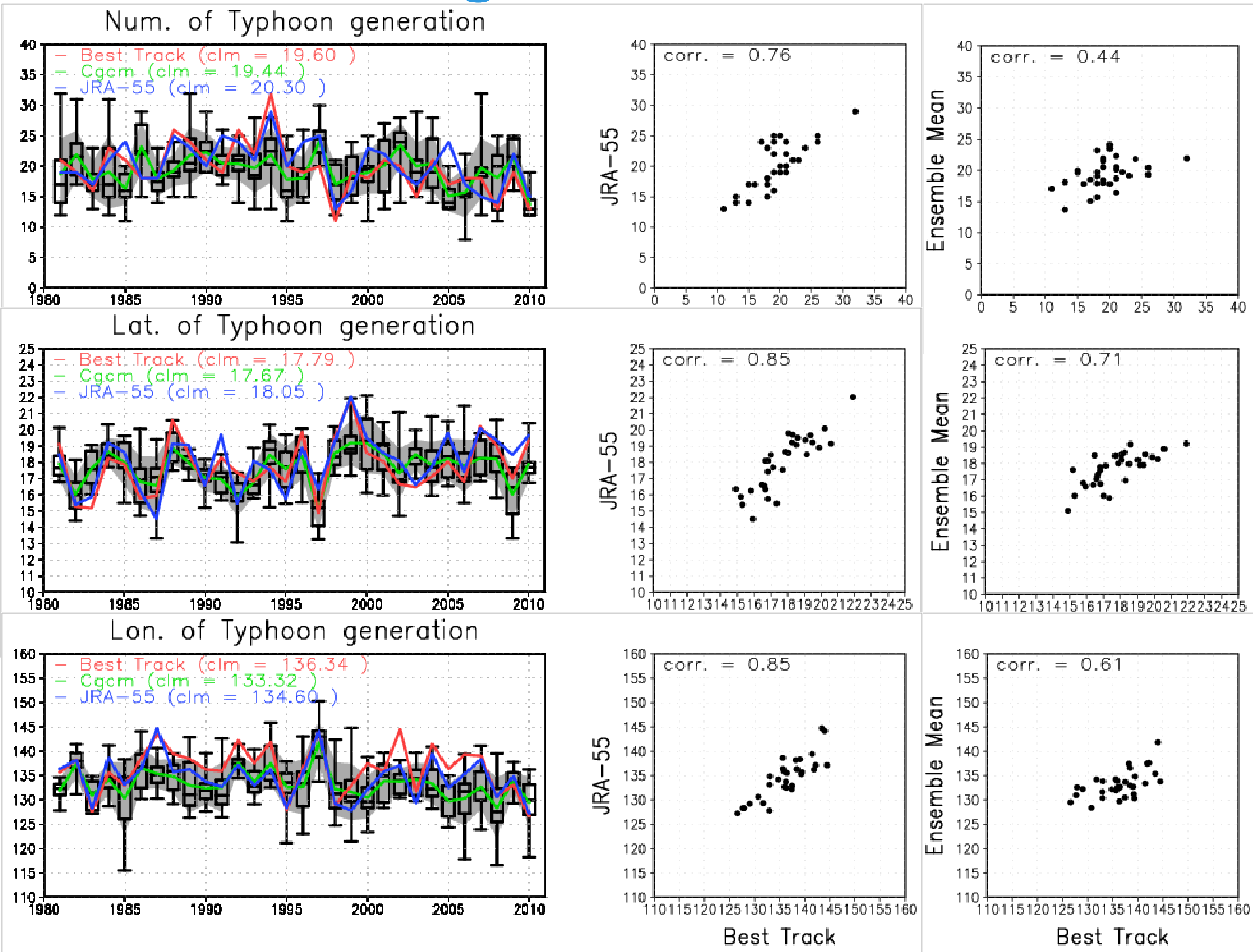
La Niña years

Time series of TC genesis number and locations

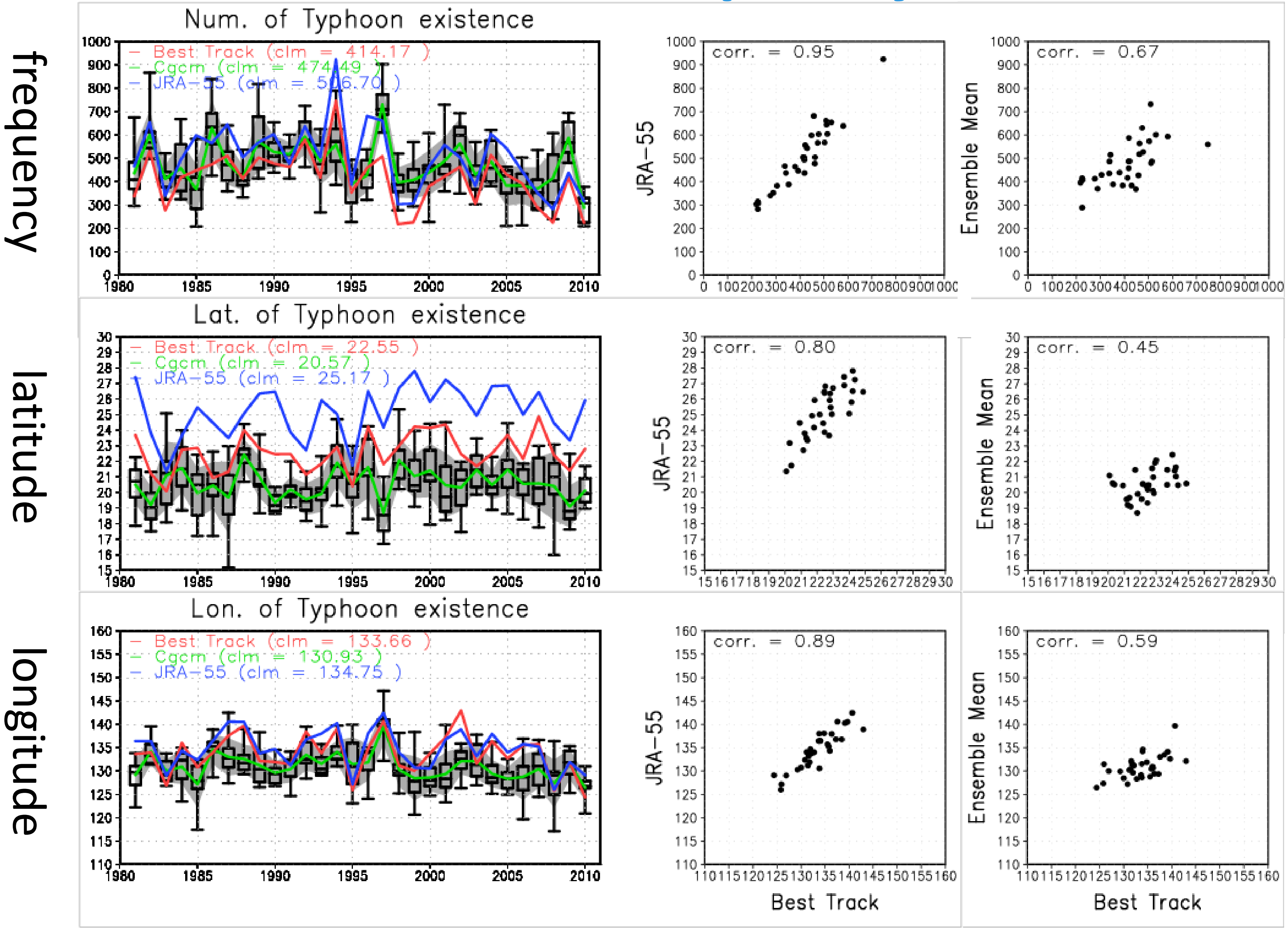
genesis

latitude

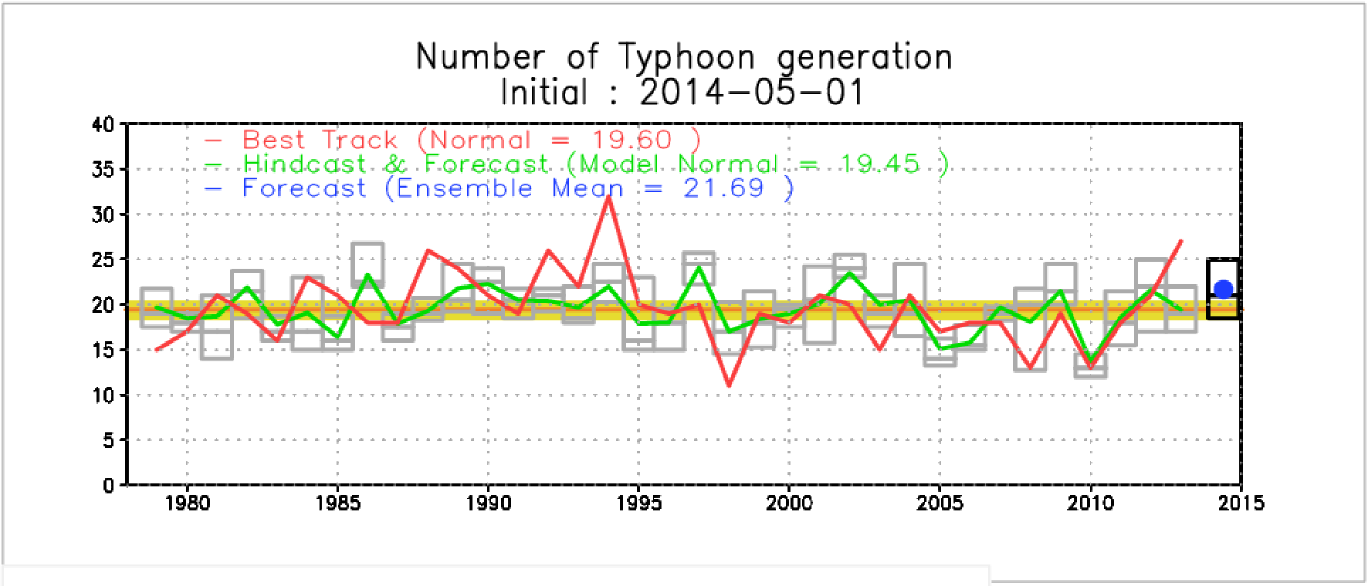
longitude

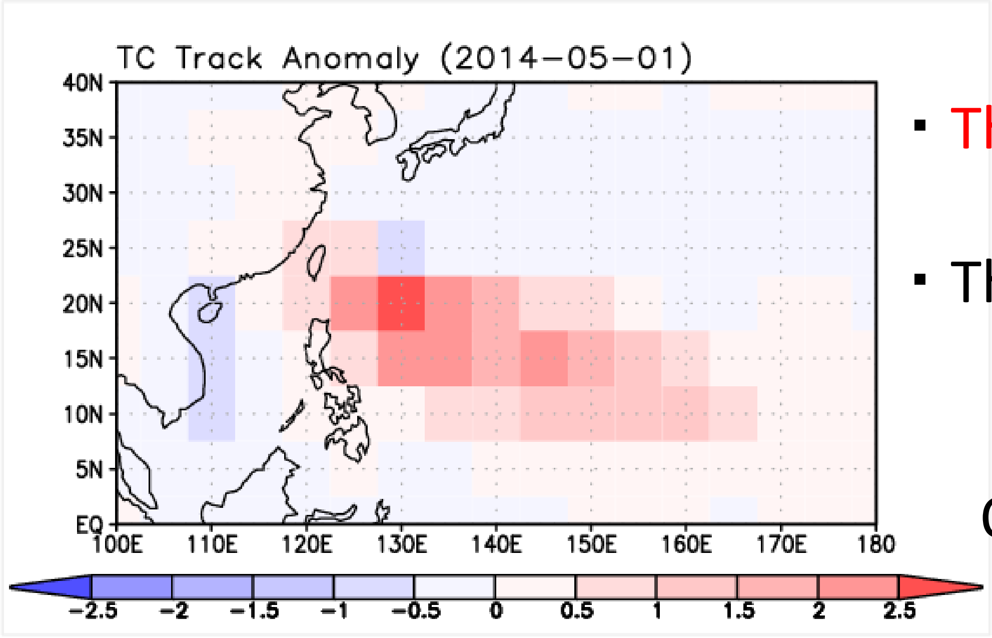


Time series of TC frequency and locations



JMA prediction (2014)



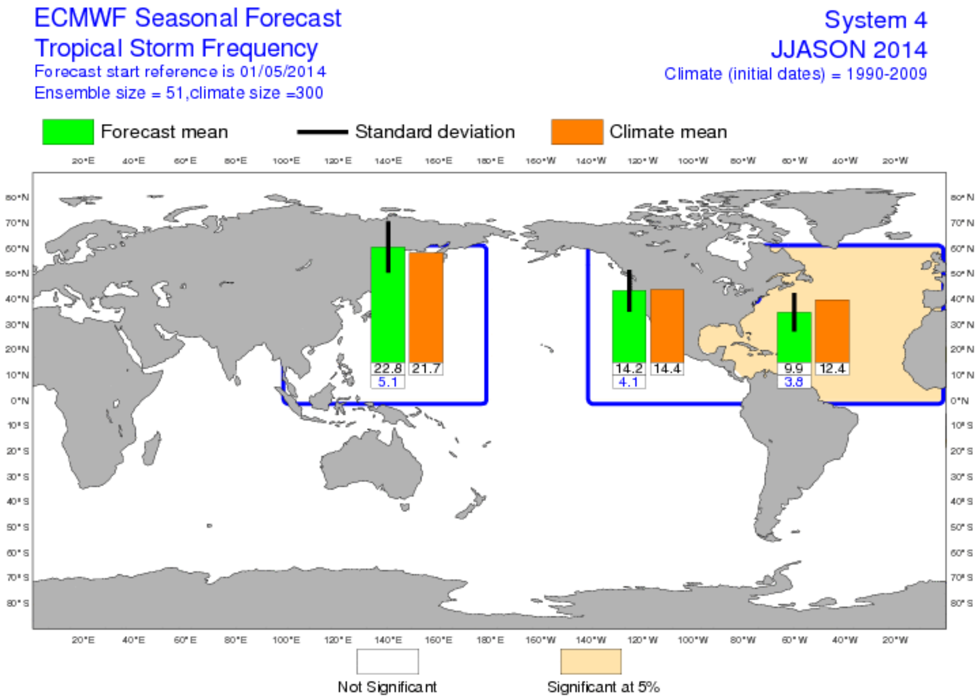


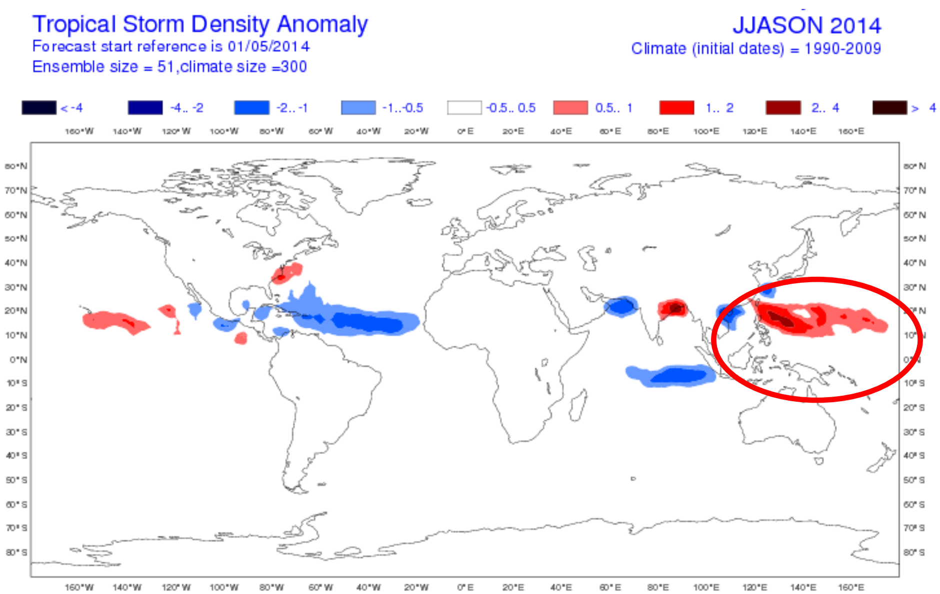
- The number of TC formation: 21.69
  (normal 19.6)
- The location of TC:
  southeast of normal

Observation: 14 (as of 29th Oct.)

Initial date: 5/1 Ensemble size: 51

ECMWF forecast (2014)





periods: JJASON

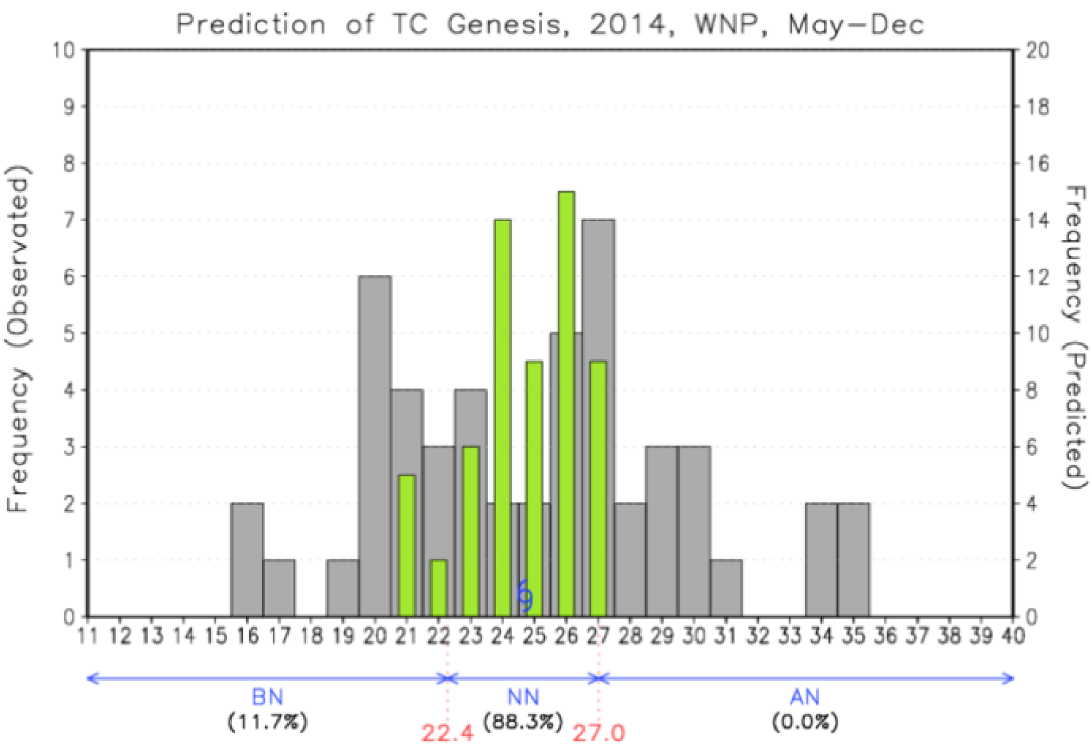
Initial date: 5/1

Ensemble size: 51

Prediction : 22.8 (normal:21.7)

KMA forecast (2014)

Multiple Linear Regression Model (NTC-KNU Model)



Western North Pacific TY frequency (WNP, MJJASOND)

Ensembel Prediction Mean:25

less than climatological mean:24.2

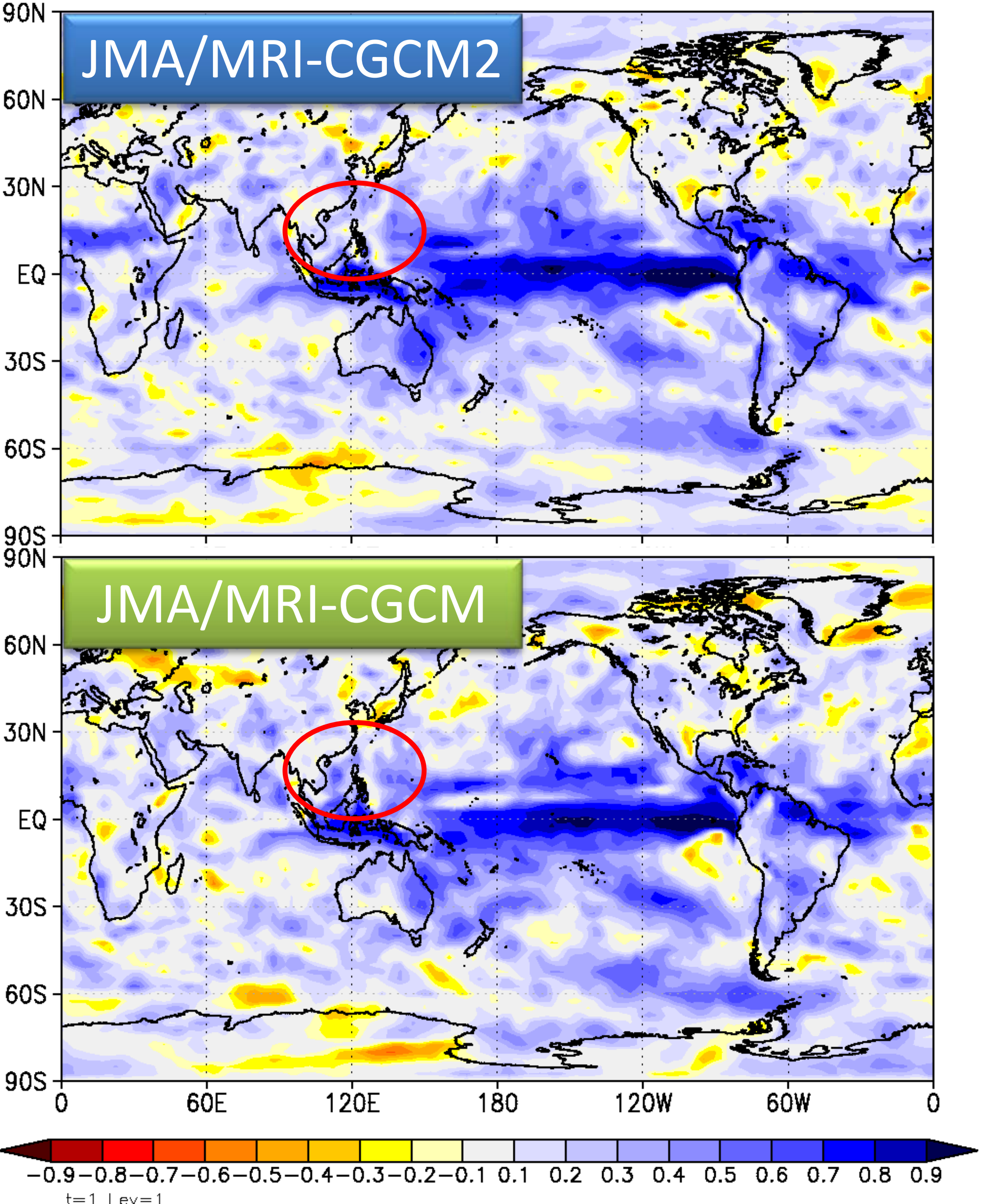
Probability: Below Normal 11.7%

Near Normal:88.3%

Above Normal:0.0%

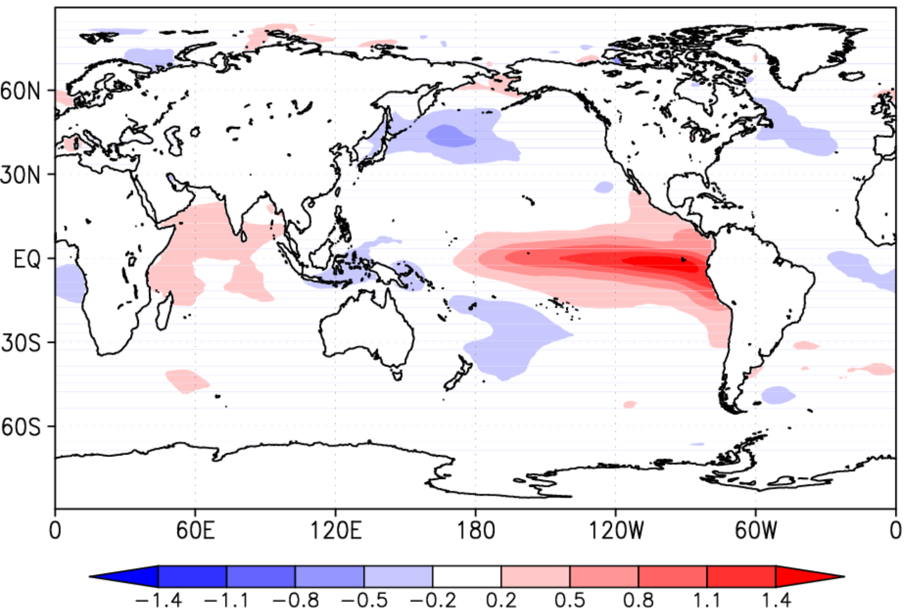
Multiple Linear Regression Model (NTC-KNU Model)

Precipitation ACC

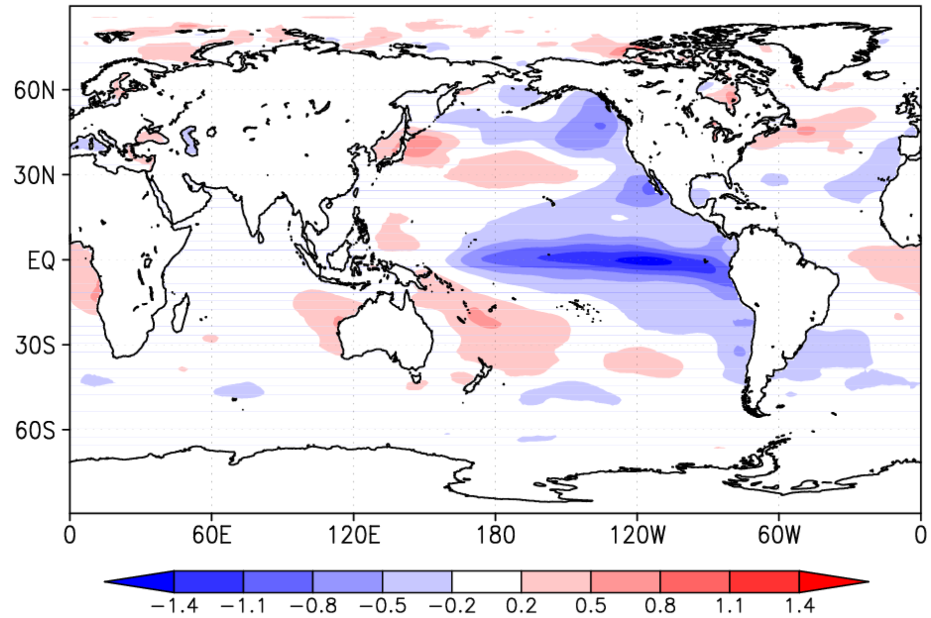


SST anomaly

El Niño years



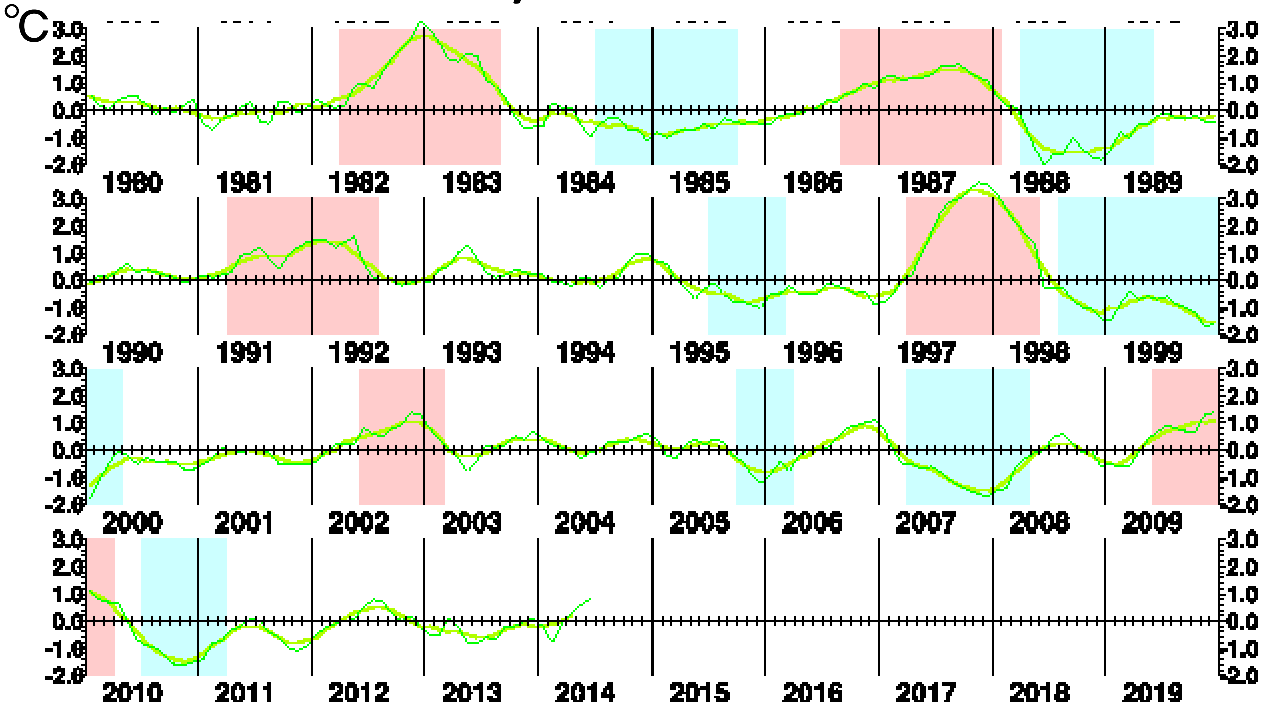
La Niña years



COBE-SST anomaly

Definition of El Niño/La Niña year

- 5 monthly running mean of Niño.3（5S-5N,150W-90W） is above/below 0.5℃ in August.
  - El Niño years：1982,83,87,91,97,2002,09
  - La Niña years：1984,85,88,95,98,99,2007,10



Nino.3 SST index

From JMA Web site

TC Objective Algorithm

- TC detection

  ①local minimum SLP：existing within about 5°×5° grid points

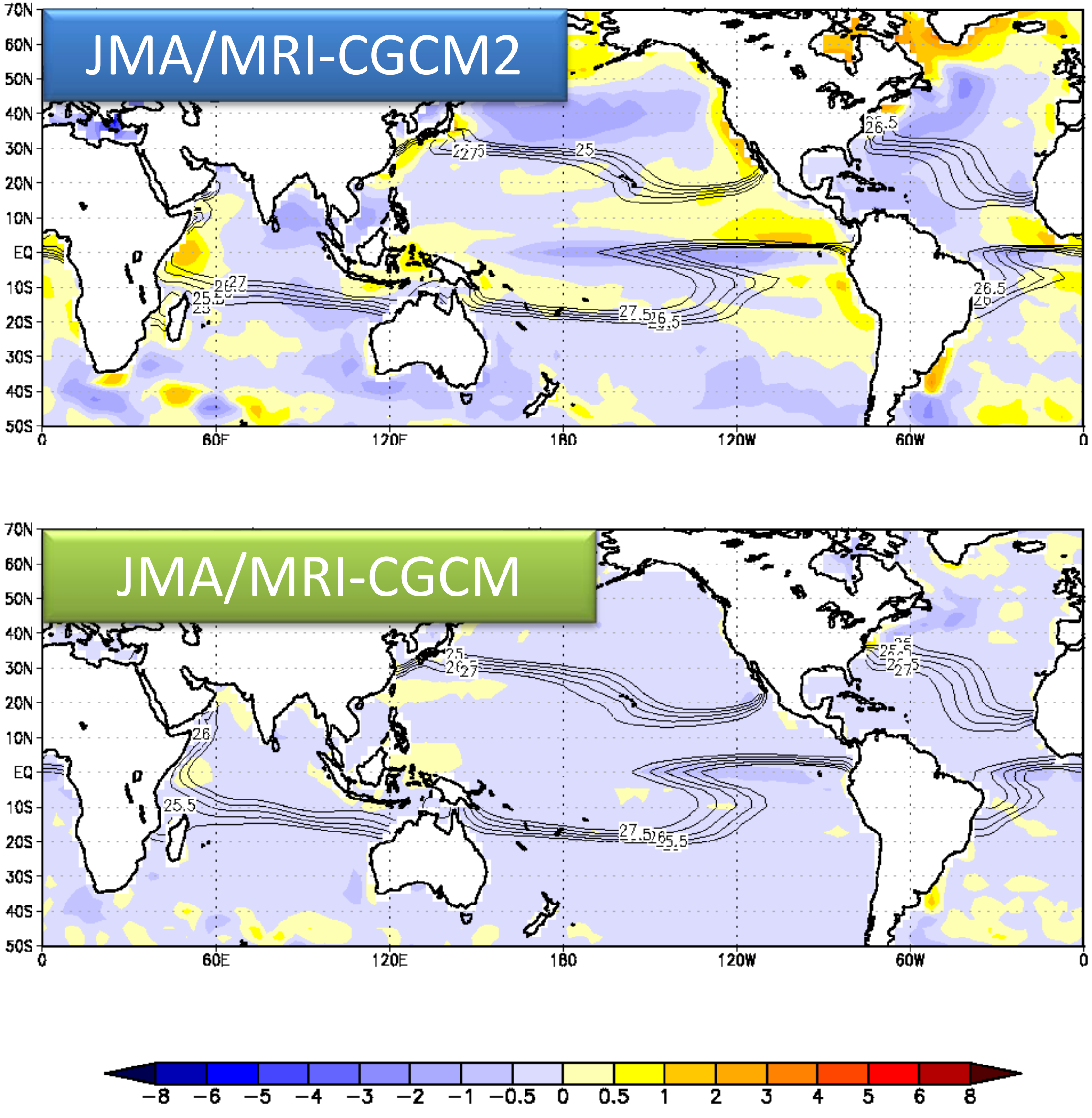
  ②850hPa relative vorticity：above $5.0 \times 10^{-5}\ s^{-1}$ for CGCM

  ③warm core：Z200－Z500（above 7gpm for CGCM）

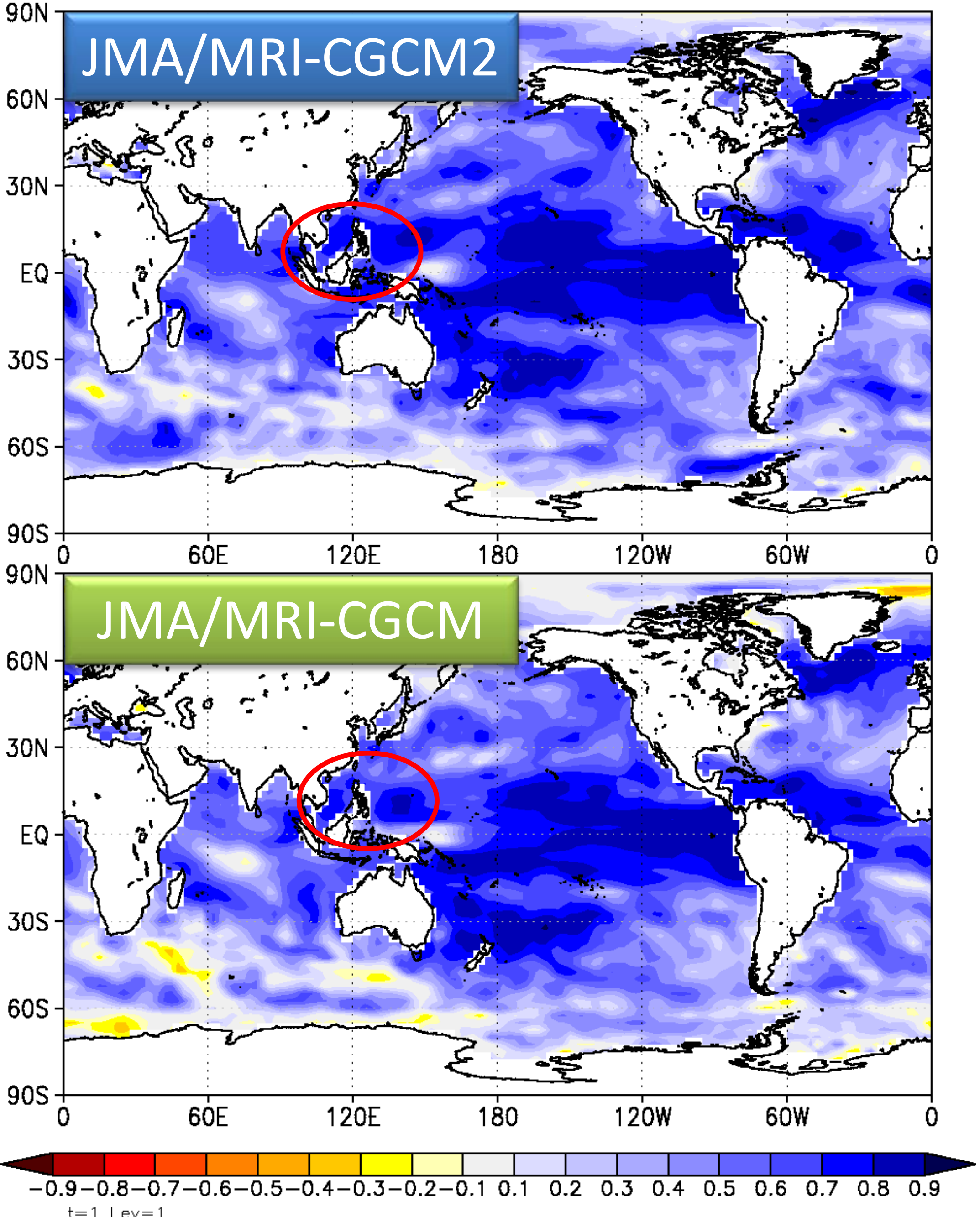
  ④vertical wind sheer：V850＞V200

- TC tracking
  - Searching previous 6 hour TC position in about 13°×13°
  - at 12 consecutive hours
  - Genesis location : equetor-30N
  - After TC genesis, TC must be satisfied with ① & ②

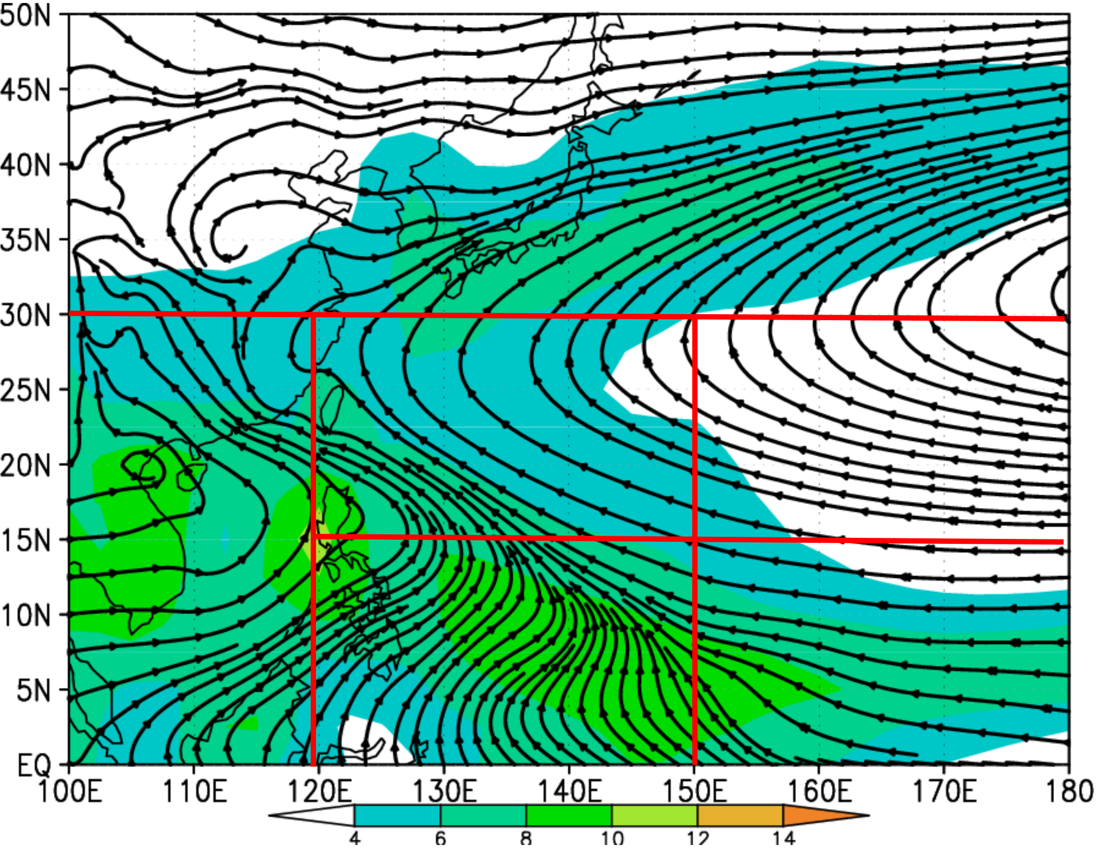
SST BIAS


JMA/MRI-CGCM2
JMA/MRI-CGCM
70N
60N
50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
0
60E
120E
180
120W
60W
−8 −6 −5 −4 −3 −2 −1 −0.5 0 0.5 1 2 3 4 5 6 8

SST ACC



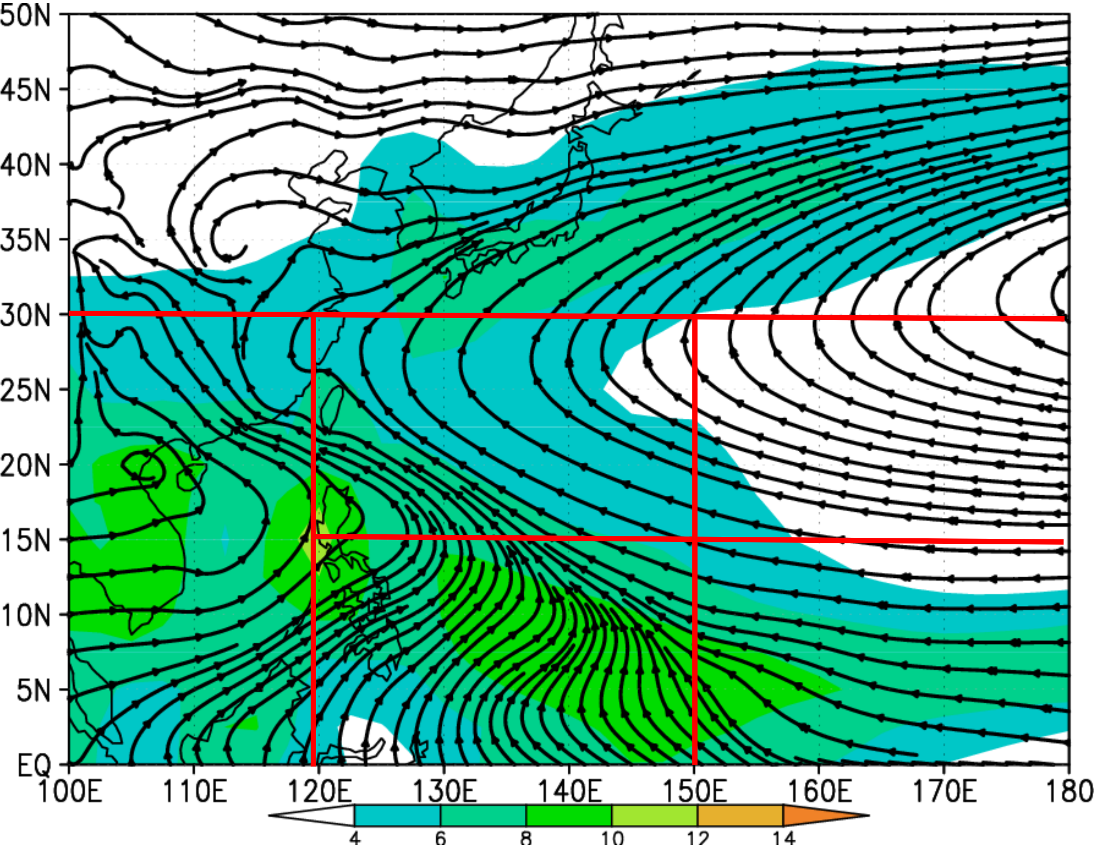
JMA/MRI-CGCM2
JMA/MRI-CGCM
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−0.9 −0.8 −0.7 −0.6 −0.5 −0.4 −0.3 −0.2 −0.1 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9



JMA/MRI-CGCM2

genesis		NW		NE		SW		SE		South China	
Anl	Mdl	8. 03	8. 27	2. 3	2. 36	3. 87	3. 66	1. 53	2. 29	3. 87	2. 89
Acc		0. 39		0. 23		0. 34		0. 62		−0. 26	

SST		NW		NE		SW		SE		South China	
Anl	Mdl	−0. 64	−0. 42	−0. 24	−0. 24	0. 50	0. 62	0. 57	0. 75	−0. 08	−0. 03



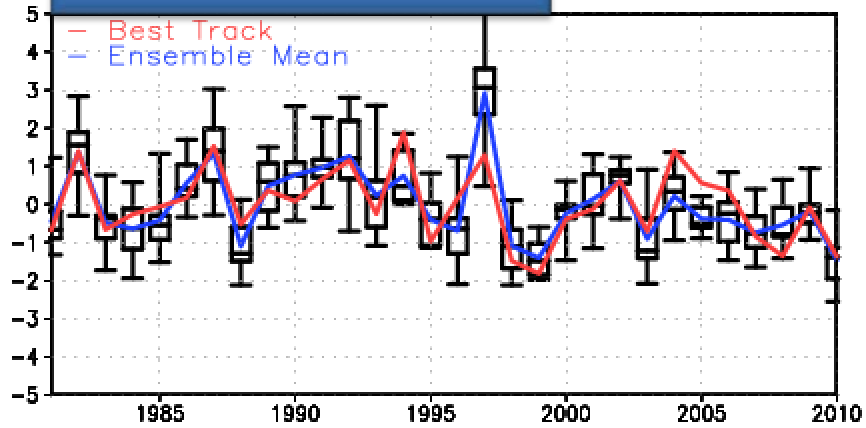
JMA/MRI-CGCM

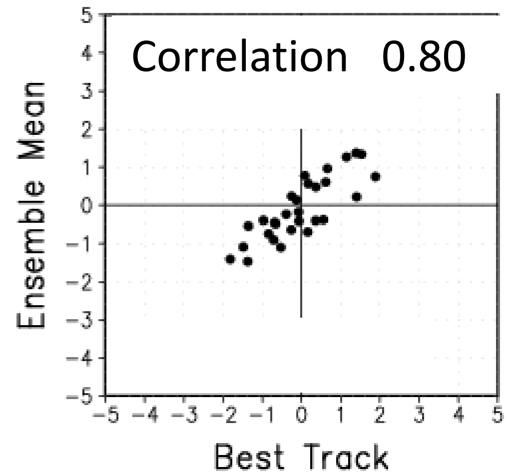
genesis		NW		NE		SW		SE		South China	
Anl	Mdl	8.03	6.95	2.30	2.16	3.87	2.97	1.53	1.60	3.87	5.75
Acc		0.55		0.45		0.36		0.57		0.05	

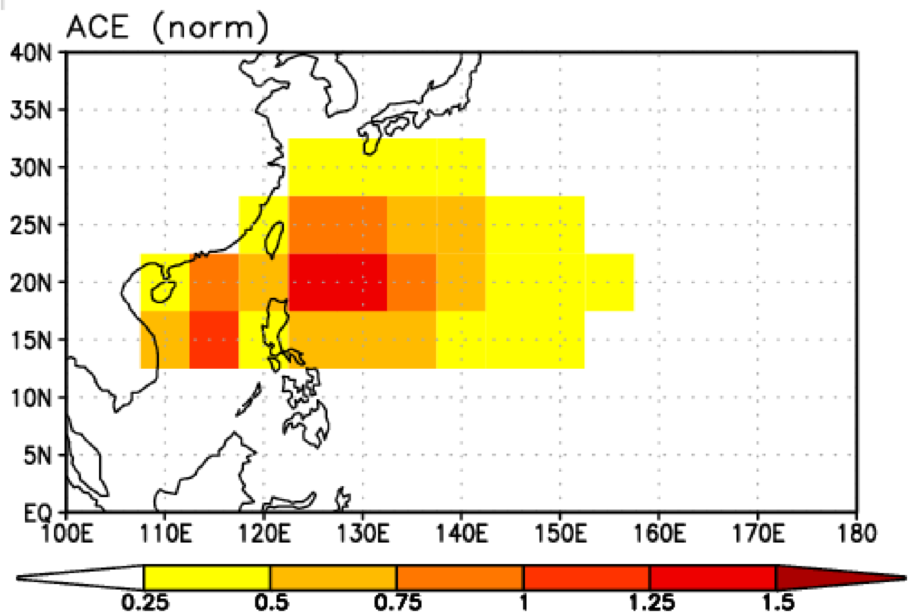
SST		NW		NE		SW		SE		South China	
Anl	Mdl	−0.64	−0.44	−0.24	−0.32	0.50	0.64	0.57	0.70	−0.08	−0.02

ACE

JMA/MRI-CGCM2







10^{-4} m^2/s^2

Accumulated cyclone energy (ACE) :

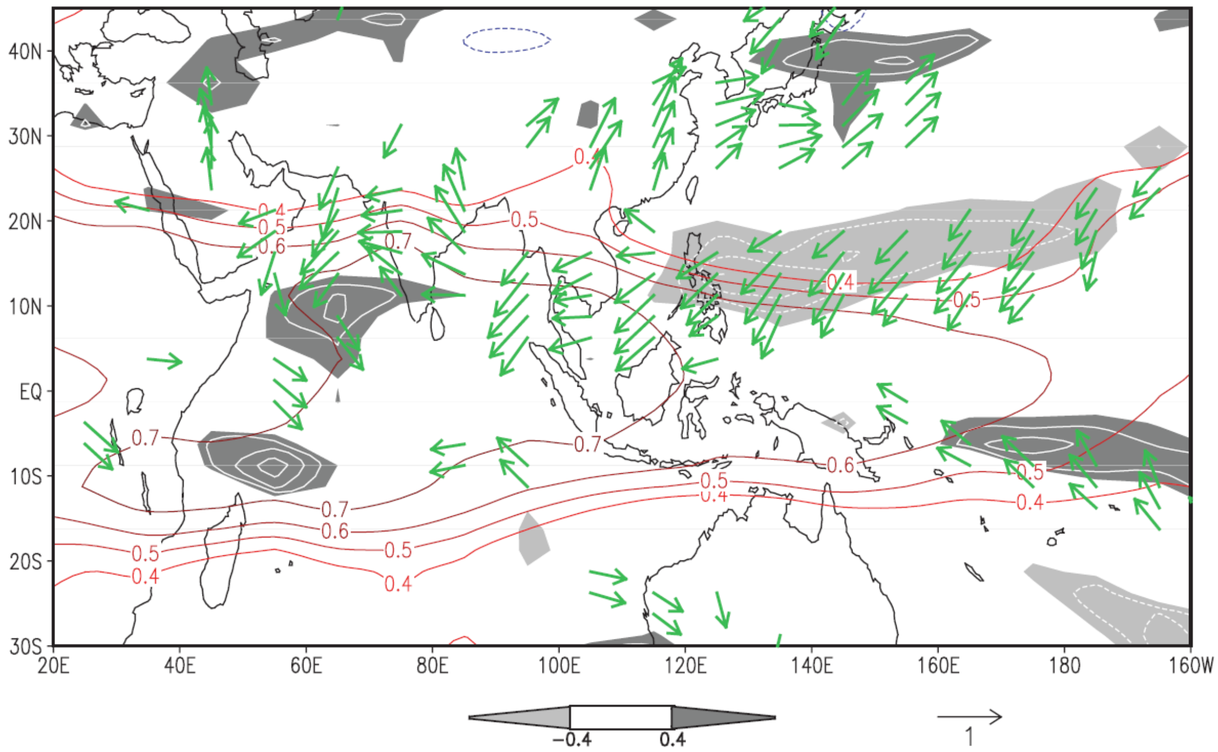
In the case of TC existence, it is accumulated TC maximum velocity every 6 hours.

$$ACE = 10^{-4} \Sigma v^2 max$$

Including TC lifetime and strength information

→ more higher skill than others

Indian Ocean Capacitor Effect



JJA correlation with NDJ Nino3.4 SST index.

Red contours: 850-200hPa temperature

White contours & shade: precipitation

Vector: surface wind

Xie et al. 2008

Developing El-Nino (previous winter) year

→ Indian Ocean warming(summer)

→ Kelvin wave in the western Pacific (Matsuno-Gill response)

→ northeast surface wind anomaly in WNP

→ divergence, non-active convection anomaly in WNP