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How well do Global Climate Models detect tropical cyclones considering cyclone phase?

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Introduction

- The center of a tropical cyclones (TCs) is searched and tracked by determining whether the model data or the gridded parameters show static or thermodynamic characteristics.
- Similar to existing studies (Oouchi et al. 2006; Bengtsson et al. 2007; Walsh et al. 2007; Murakami and Wang, 2010) on searching and tracking TCs using gridded simulation data, **the searching and tracking of the TCs** in this study was divided into **tracking process**, which searches for the center of the cyclone, and **structure process**, which explores the vertical structure at the center (Suzuki and Parker, 2012).
- Moreover, Hart (2003)'s a **cyclone phase (CP) technique** was also considered when the TC tracking identifies cyclones such as extratropical cyclones.
- **Therefore, we'd like to investigate the effect of modified method to GCMs and reanalysis dataset for 2009-2014 years and 1980-2009 years.**

Data

Used datasets

1) **RSMC (Regional Specialized Meteorological Center)** Tokyo Typhoon Center as a reference data; It was used in case of tropical storm (grade 3) to typhoon (grade 5).
2) **GFS (Global Forecasting System)** analysis data; It is a weather forecast model produced by the National Centers for Environmental Prediction (NCEP). We prepared GFS-Analysis data of 004 (0.5 degree) grid scale.
3) **ERA-Interim reanalysis data**; It is a global atmospheric reanalysis from 1979, continuously updated in real time.
4) **CFSR (Climate Forecast System Reanalysis) data**; It is a global, 0.5 degree, coupled atmosphere-ocean-land surface-sea ice system designed to provide the best estimate of the state of these coupled domains.

Used variables from GCM and reanalysis

- UV wind components at 10 m, 300 and 850 hPa, MSLP, Temperature anomalies at 300, 500 and 700 hPa, and Geopotential height from 900 hPa to 300 hPa every 50 hPa. respectively.

Table 1. List of used datasets and their configuration.

Data	Horizontal Resolution	Temporal Resolution	Analysis Period
RSMC	-	6 hr	1980-2014 years
GFS	50 km	6 hr	2009-2014 years
ERA	75 km	6 hr	1980-2009 years
CFSR	50 km	6 hr	1980-2009 years

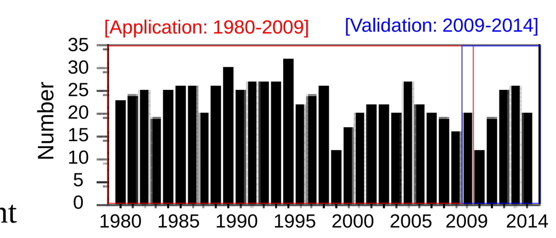

Fig. 1. Annual number of TCs in WNP from RSMC dataset for 1980-2014 years.

Methodology

Tracking Tropical Cyclones from GCM outputs

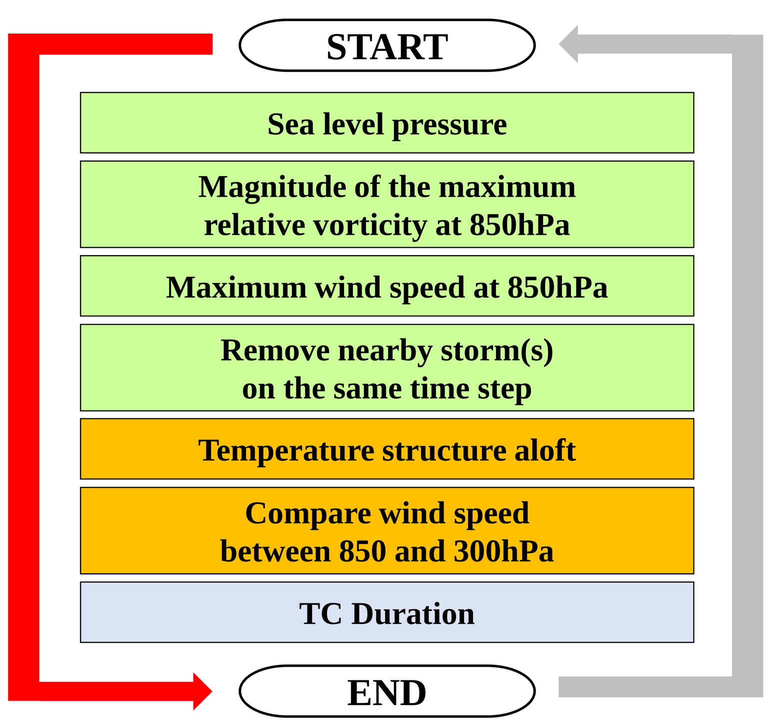

Fig. 2. The tracking method of TCs in this study.

Tracking method used in this study

A. Basic tracking process (Murakami and Wang, 2010)

1) SLP anomaly > $\underline{2\ hPa}$; 2) Relative vorticity at 850 hPa > $\underline{3.0 \times 10^{-5} s^{-1}}$
3) Wind speed at 850 hPa > $\underline{14\ ms^{-1}}$; 4) Duration > $\underline{36\ hour}$;
5) Temperature anomaly at 300/500/700 hPa > $\underline{1.2\ K}$;

B. Structure process (Murakami and Wang, 2010)

1) Maximum tangential wind speed: $V850 > V300$
2) Horizontal temperature anomaly: $T'300 > T'850$

C. Additional Cyclone phase (Hart, 2003)

1) Cyclone thermal symmetry; Parameter B > 10.0

$$B = h\left(\left.\overline{Z_{600hPa} - Z_{900hPa}}\right|_R - \left.\overline{Z_{600hPa} - Z_{900hPa}}\right|_L\right)$$

2) Cyclone thermal wind; Parameter $-V_T^L$ and $-V_T^U > 0.0$

$$-\left|V_T^L\right| = \left.\frac{\partial(\Delta Z)}{\partial lnp}\right|_{900hPa}^{600hPa}, \quad -\left|V_T^U\right| = \left.\frac{\partial(\Delta Z)}{\partial lnp}\right|_{600hPa}^{300hPa}$$

Experimental design for validation

- Table 2 shows lists of experimental designs applied modified method to compare effect of cyclone phase techniques (Hart 2003).
- In the Hart (2003), the B value considering the cyclone thermal symmetry would be difficult to calculate in accordance with horizontal resolution or heading of typhoon.
- The modified tracking method is possible to figure out the formation, movement, and dissipation of candidate TCs, which is a life of the cyclones.

Table 2. List of experimental designs applied modified methods and their references.

Name	Description of Method	Reference	Datasets
OBS	Observation	-	OBS
EXP1	Base tracking + Structure criteria	Murakami and Wang (2010)	E*1, G*1, C*1
EXP2	Base tracking + structure criteria + CP	Murakami and Wang (2010) and Hart (2003)	E2, G2, C2
EXP3	Base tracking + structure criteria + CP *without B-value*		E3, G3, C3

※ E=ERA-Interim, G=GFS, C=CFSR

Flow chart for this study

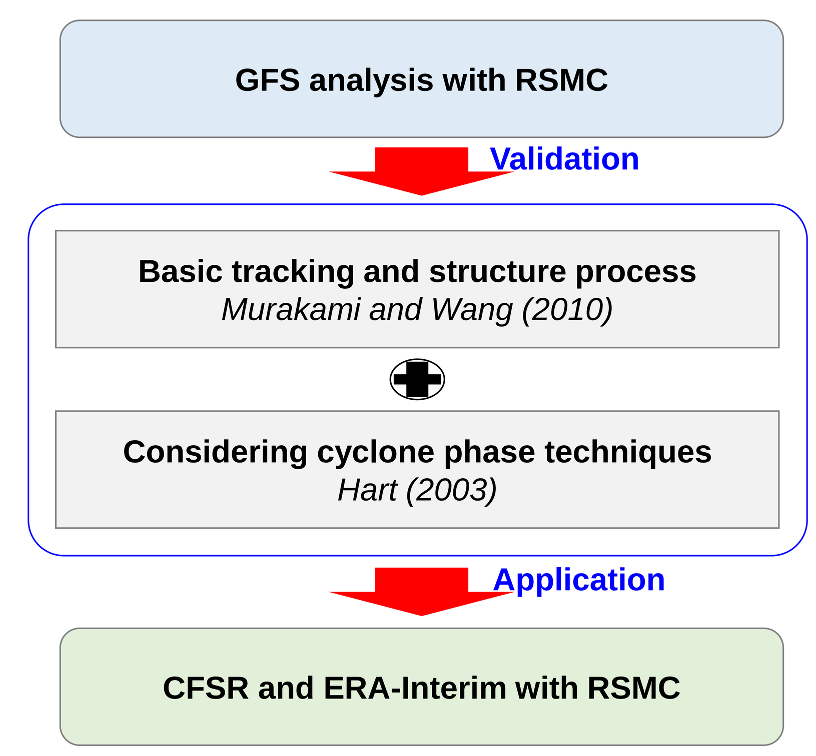

Fig. 3. Flow chart for tracking of TCs

Results: Verification for tracking method for 2009-2014 years

TC Detection Criteria used in this study

Table 3. Applied TC Detection Criteria by Murakami and Wang [2010]

Dataset	SLP anomaly	Vorticity	Wind spped	T. anomaly	Duration
GFS	2.0 hPa	$3.0\times 10^{-5}s^{-1}$	14 m/s	1.2 K	36 hour

Observation (RSMC) for 2009-2014 years

- **A number of TCs occurred over the WNP for analysis period** is total **112** **and annual averaged number of TCs** is **18.7**.
- **Fig. 4** shows **best-tracks** and **track density*** of TCs over the WNP for analysis period.

※ Track density is calculated within each 5° × 5° grid within the WNP yearly.

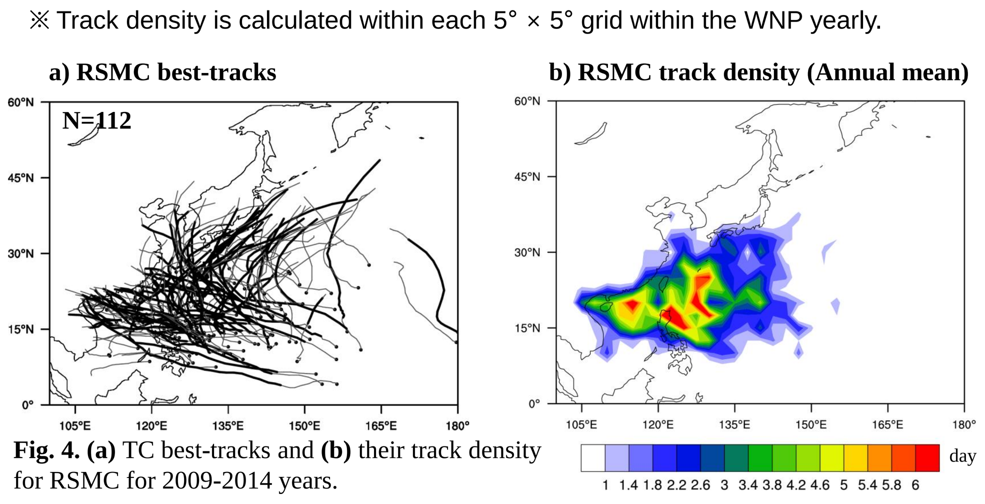

Fig. 4. (a) TC best-tracks and **(b)** their track density for RSMC for 2009-2014 years.

OBS versus EXP1 [G1]

- **A number of TCs detected over the WNP from GFS analysis (EXP1 G1) for analysis period** is total **126** **and annual averaged number of TCs** is **21**.
- Fig. 5a-c shows that **most of TCs formed over the WNP is concentrated in boreal summer** (June to August) **and boreal autumn** (September to November).
- **Their portions accounts for 44% and 45%** in seasonal climatology over the WNP (Fig. 5b).
- Results of detected TCs from EXP1 G1 are similar with RSMC. **Correlation coefficients (r) between RSMC and EXP1 G1 in Fig. 5a-c represent that detected TCs have good agreement with best-tracks of RSMC.**
- But, because **the tracking method would involve other cyclones** such as extratropical cyclones or tropical depression, results of G2 and G3 are compared with G1.

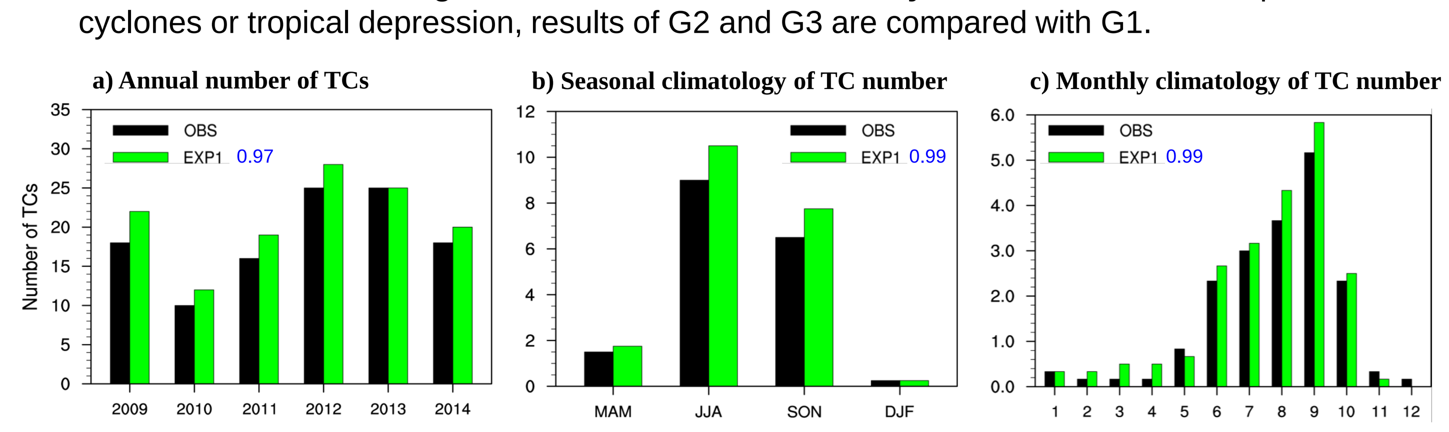

Fig. 5. (a) Annual averaged number of TCs, **(b)** seasonal and **(c)** monthly climatology of TCs number for OBS and EXP1 G1.

Comparison with EXP2 [G2] and EXP3 [G3]

- **Fig. 6a shows that the G1 is more than OBS, which is the RSMC, every year. In addition, seasonal climatology of TCs number represents that G1 is lager than OBS (Fig. 6c).**
- **The results of G2 and G3 was applied the modified tracking method,** respectively.
- **The G2,** which is the mixed algorithm both Murakami and Wang (2010) and Hart (2003), **is over-removed more than the G3.**
- **Considering the cyclone thermal symmetry would be difficult to calculate** in accordance with **a horizontal resolution** or **heading of typhoon at every time step**.
- **The G3, which is same as the method of the G2 but except for considering the B value, shows reasonable number of TCs over WNP with the best-tracks of RSMC.**

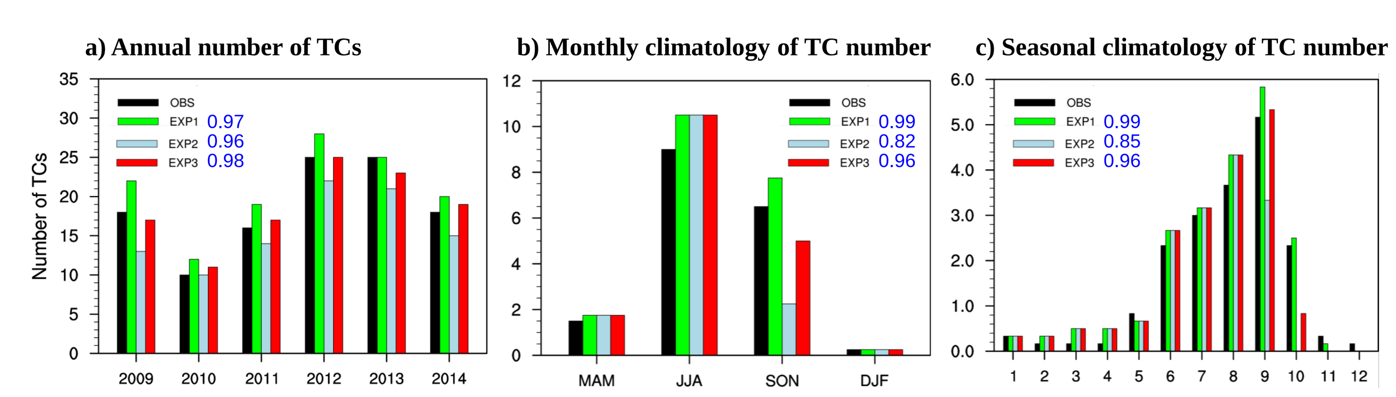

Fig. 6. Same as Fig. 5 but except for OBS and G1, G2, and G3.

Results: Applying method to reanalysis for 1980-2009 years

TC Detection Criteria used in this study

Table 3. Applied TC Detection Criteria by Murakami and Wang [2010]

Dataset	SLP anomaly	Vorticity	Wind spped	T. anomaly	Duration
CFSR	2.0 hPa	$3.0\times 10^{-5}s^{-1}$	14 m/s	1.2 K	36 hour
ERA-Interim	1.2 hPa	$1.0\times 10^{-5}s^{-1}$	10 m/s	0.2 K	36 hour

Observation (RSMC) for 1980-2009 years

- **A number of TCs occurred over the WNP for analysis period** is total **659** **and annual averaged number of TCs** is **22.0**.
- **Fig. 7** shows **best-tracks** and **track density*** of TCs over the WNP for analysis period.

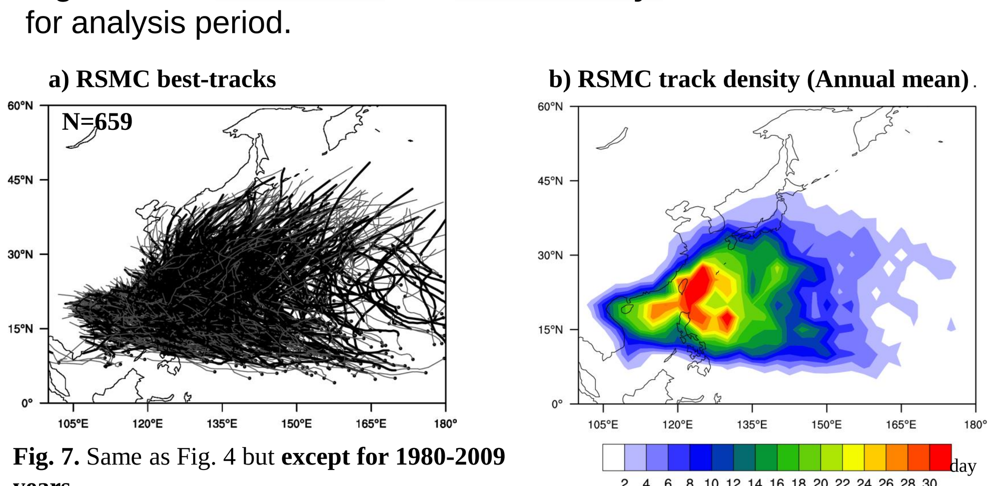

Fig. 7. Same as Fig. 4 but **except for 1980-2009 years.**

Comparison with results of CFSR and ERA-Interim

- **A number of TCs detected over the WNP from CFSR and ERA-Interim reanalysis, which is the EXP1 C1 and E1, for analysis period** is total **612** **and** **415**, **and annual averaged number of TCs** is **20.4** **and** **13.8**.
- Fig. 8a shows that **most of TCs occurred over the WNP is concentrated in boreal summer** (June to August) **and boreal autumn** (September to November) like the OBS.
- **Its portion accounts for 61% and 26%** in seasonal climatology over the WNP (Fig. 8a). The number of TCs in autumn is less than OBS for analysis period.
- However, because **the tracking method would involve other cyclones** such as extratropical cyclones or tropical depression, the EXP2 and EXP3 are compared with EXP1.
- Fig. 8a-d shows that the correlation coefficient was increased the results of EXP3 applied the modified method than the EXP2.
- The C2 and E2, which is the mixed algorithm both Murakami and Wang (2010) and Hart (2003), is over-removed more than the C3 and E3.
- The C3 shows reasonable number of TCs over WNP with the best-tracks of RSMC.

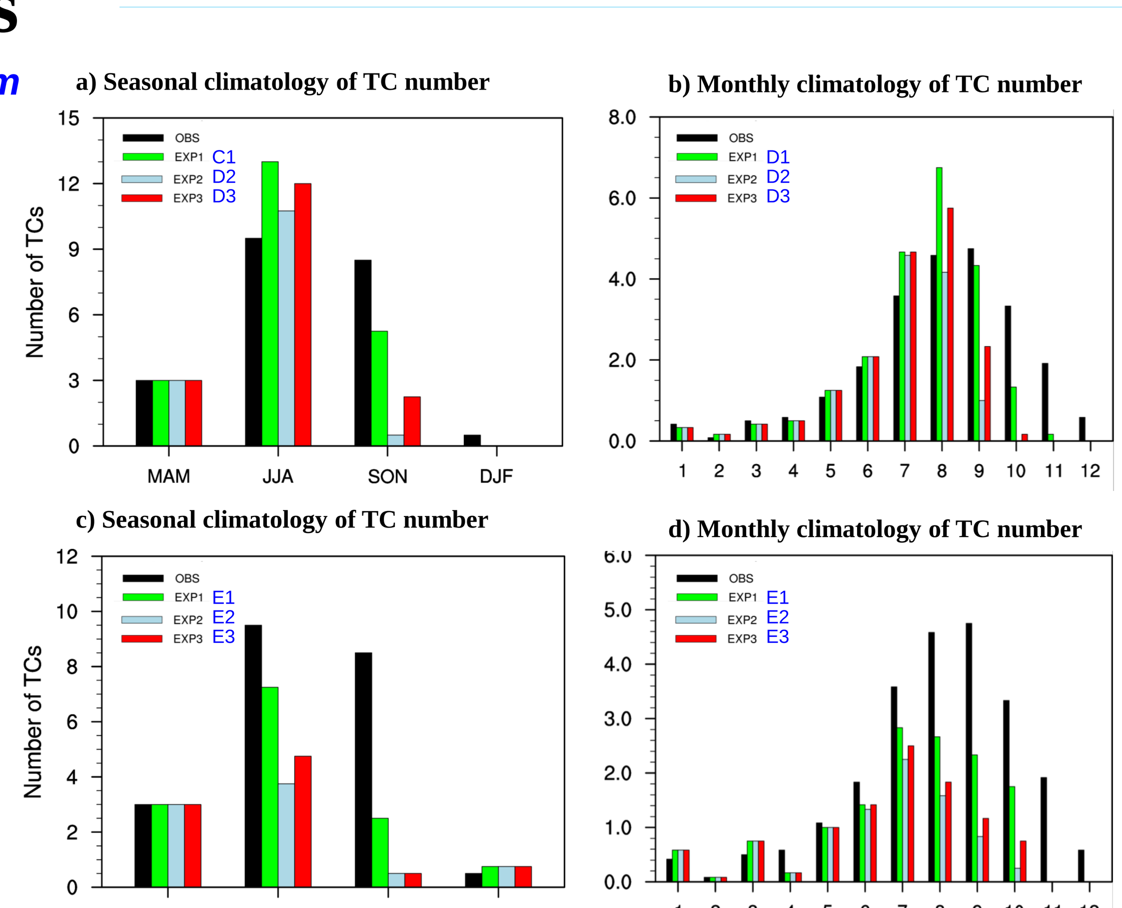

Fig. 8. Same as Fig. 5 but except for CFSR (**a, b**) and ERA-Interim (**c, d**).

The effect of the modified method

☞ As a results, **statistics in the EXP2 and the EXP3 both 1980-2009 and 2009-2014 years**, which is calculated by a correlation coefficient, represents **that the EXP3 was improved comparing the EXP2 in all experiments.**

Table 4. The Correlation Coefficient between OBS and all EXP for seasonal and monthly climatology of TCs in GFS analysis for 2009-2014 years.

Periods	EXP1	EXP2	EXP3
Annual mean	0.97	0.96	0.98
Seasonal climatology	0.99	0.82	0.96
Monthly climatology	0.99	0.85	0.96

Table 5. Same as Table 4 but except for the CFSR and ERA-interim from 1980 to 2009 years.

Periods	Dataset	EXP1	EXP2	EXP3
Seasonal climatology	**CFSR**	0.87	0.60	0.72
	ERA-Interim	0.75	0.30	0.4
Monthly climatology	**CFSR**	0.89	0.61	0.78
	ERA-Interim	0.70	0.17	0.25

Conclusion and Future works

- As in the analysis field research, the results showed that the correlation coefficient of the seasonal variation between the model and observation increased, particularly when the cyclone phase was considered.
- When the criteria of the tracking method used in GCM results is determined in common study, subjective factor would be included. In future work, we should consider to scale the reasonable TC detection criteria every GCM results.

References

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