A Preliminary Statistical Study of Extremely Rapid Intensification of Tropical Cyclones over the South China Sea

Gong Yueting ， Cheng Zhengquan

Guangdong Meteorological Service, CMA, CHINA

March 2026

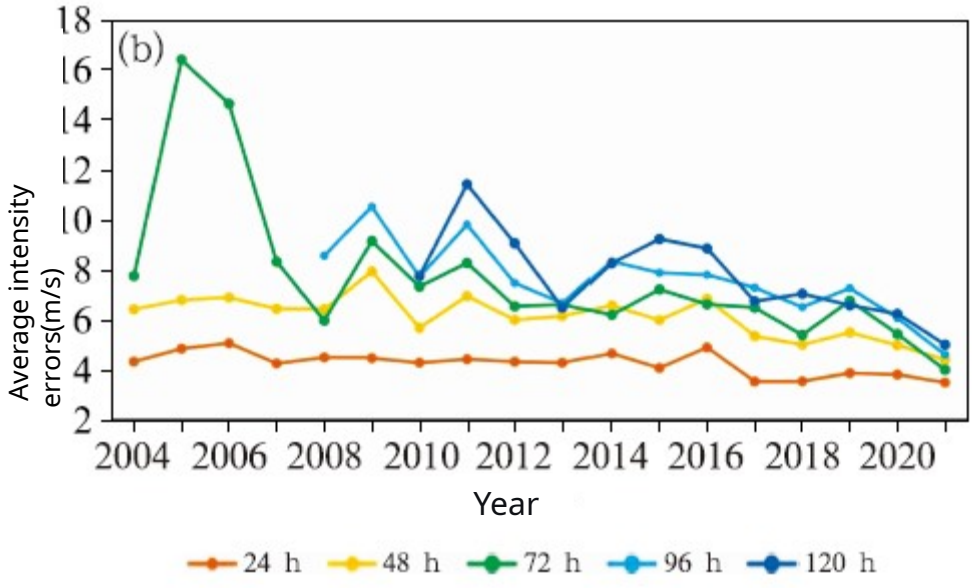
Outline

- Current Status of Operational Tropical cyclone Intensity Forecasting
- Definition of Extremely Rapid Intensification (ERI) in Tropical cyclone
- Statistical Characteristics of ERI Tropical cyclones

Inadequacy of current forecasting capabilities for RI TC

Rapidly Intensifying(RI) TCs: typically defined as $\Delta V_{24} \geq 15m/s$ （ 30kt ）

The intensity forecast still has **no obvious improvement**



Average intensity errors analysis on the operational forecasting data of National Meteorological Center of China
(xiang chunyi, Xu yinglong et.al 2022)

Larger intensity changes lead to a substantial increase in the frequency of large forecast errors.

NA EP **WP**

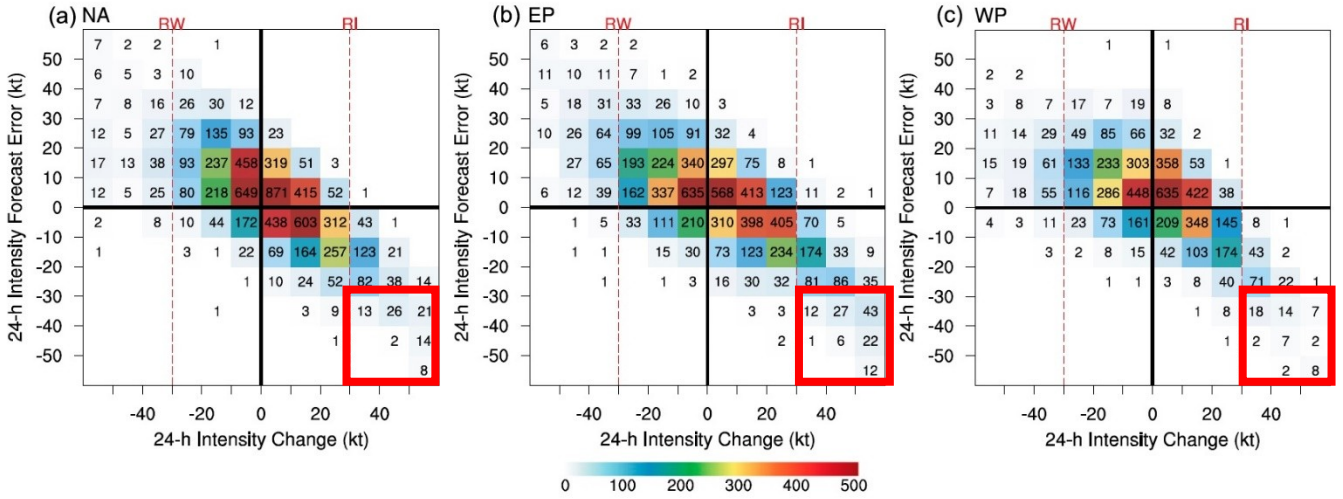
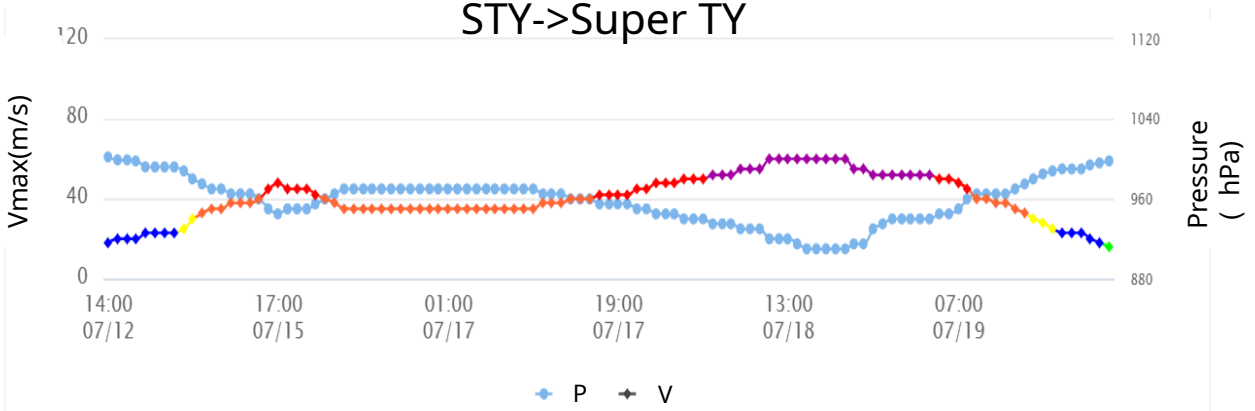


FIG. 1. Distribution of 24-h intensity OFE frequencies with respect to TC 24-h intensity change over (a) NA, (b) EP, and (c) WP. All frequencies are calculated within 10-kt bins and are indicated by numbers in each box.

RI TCs: significant underestimation (~17 m/s)

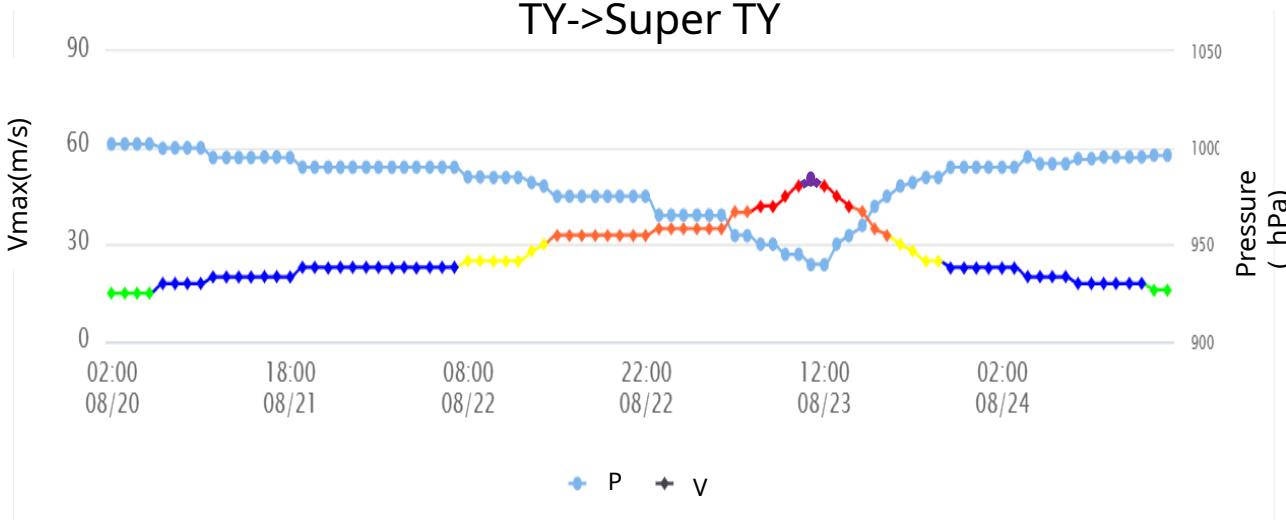
Frequent RI TCs: Severe Disaster Risks

Rammasun increased by **15 m/s within 12 h**, 27m/s within 24 h



Super Typhoon Rammasun (1409): 2.6325 million people affected; 226,380 ha of crops damaged; Direct economic loss of 13.019 billion RMB. (Source: Provincial Department of Civil Affairs, Jul 25,2014)

Hato increased **by 17 m/s within 12 h**



Super Typhoon Hato (1713): 12 people killed in Guangdong; 556,175 people evacuated; Direct economic loss of 19.455 billion RMB. (Source: Provincial Department of Civil Affairs, Jul 25,2017)

ERI TCs: Greater Challenges in Forecasting and Prevention

Current Criteria Fail to Fully Identify ERI Tropical Cyclones

- Limited criteria for ERI TC identification
- Inadequate temporal and spatial resolution

■ Mean method.

RI: $\Delta V \geq \overline{\Delta V} + S$, $\overline{\Delta V}$=Average changes in Vmax, S=Standard deviation

WNP : $\Delta V_{24} \geq 20$m/s , Off the coast of China : $\Delta V_{12} \geq 10$m/s

ERI : $\Delta V \geq \overline{\Delta V} + 3S$

Off the coast of China : $\Delta V_{12} \geq 15$m/s (Yan junyue et.al,1995)

■ Cumulative Frequency percentile (CPF) Method

RI : 95th percentile of TC intensity change samples, Commonly Used Commonly Used Threshold :$\Delta V_{24} \geq 15$m/s

ERI : higher percentile, such as the 99th : $\Delta V_{24} \geq 25$m/s (Song J , Duan Y et.al,2020)

Data and Methods

- **Data** ： 6-hourly TC best track data from the CMA, 1980~2022

  ECMWF ERA5 Reanalysis Dataset (0.25°*0.25°)

  NOAA Daily OISST Dataset (0.25°*0.25°)

- **Study Region** ： Western North Pacific

  South China Sea（ 105 ~ 121°E ， 0 ~ 25 °N ）

- **Intensity Change Samples**:

  The maximum intensity changes of ΔV_6 、 ΔV_{12} 、 ΔV_{24}

- **Methods**:

  Mean method vs. Cumulative Frequency percentile Method

Results from the Mean Method

- **RI:** $\Delta V \geq \overline{\Delta V} + S$
- **ERI** : $\Delta V \geq \overline{\Delta V} + 3S$

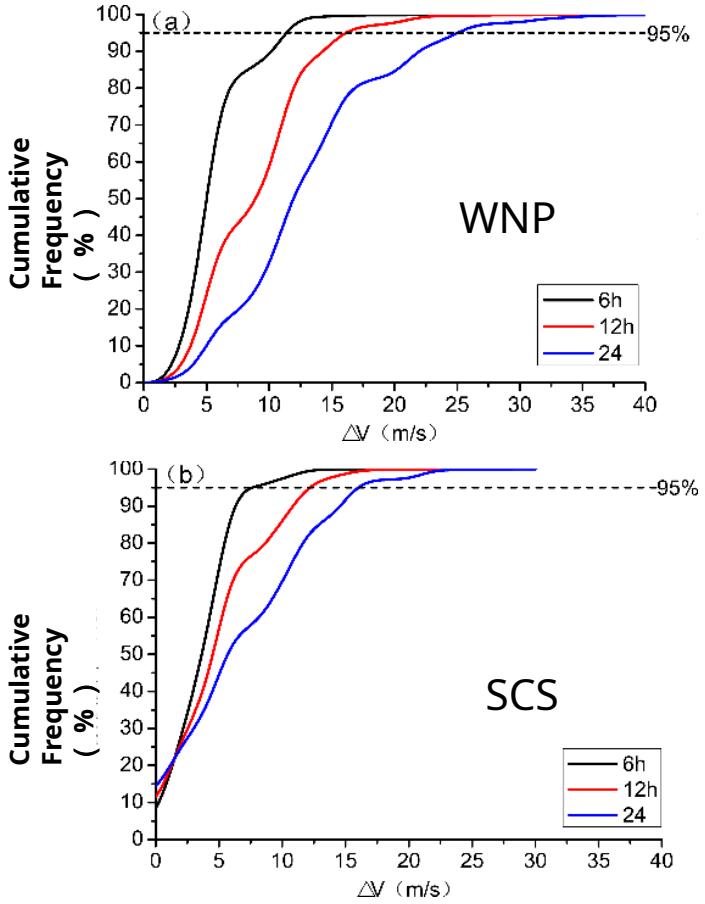
Type	Item	6h		12h		24h	
		WNP	SCS	WNP	SCS	WNP	SCS
RI	△Vmax(m s^{-1})	8	6	13	9	19	13
	Percentage	15%	6%	12%	14%	17%	14%
	Frequency	163	29	13	63	181	64
ERI	△Vmax(m s^{-1})	13	10	21	15	32	22
	Percentage	1%	3%	1%	2%	1%	0.2%
	Frequency	8	12	21	9	12	1

Only 1 ERI event in the SCS

The ERI defined by Mean Method is overly stringent for SCS TCs.

Results from the CFP Method

Cumulative Frequency Distribution of TC Intensity Change over Different Time Intervals



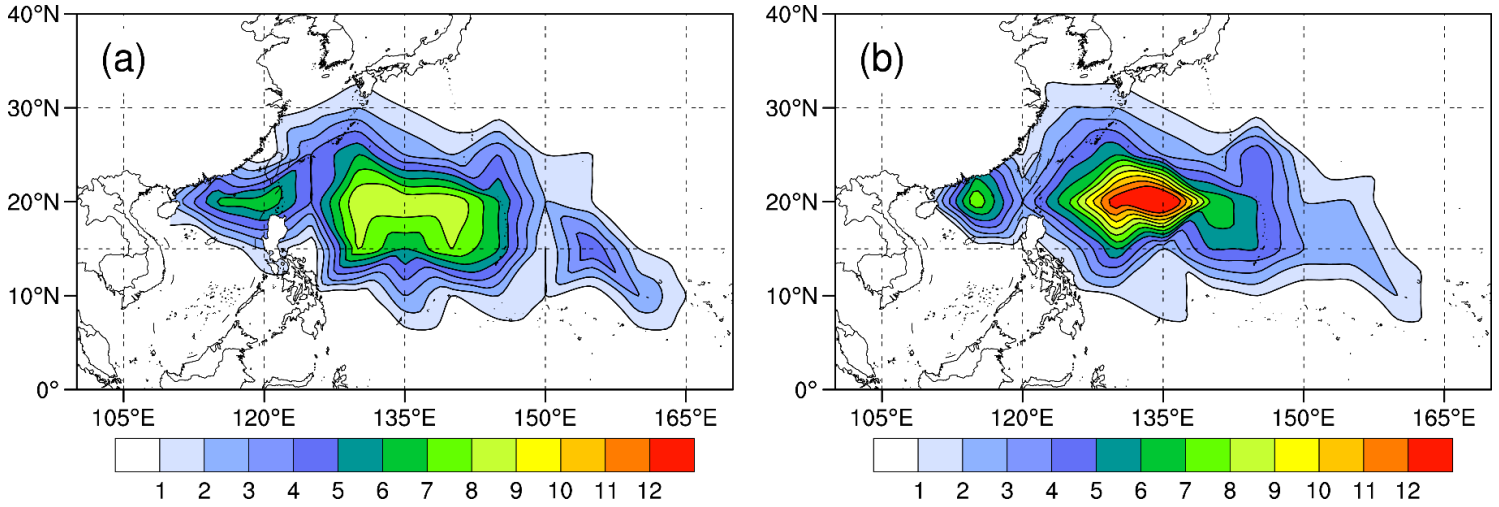
RI and ERI Thresholds by Percentile and Time Interval

Percentile	Item	6h		12h		24h	
		WNP	SCS	WNP	SCS	WNP	SCS
95	△Vmax(m s^{-1})	10	7	15	10	25	15
	Percentage	12%	6%	11%	14%	6%	5%
	Frequency	114	28	103	63	66	23
96	△Vmax(m s^{-1})	10	8	17	12	25	15
	Percentage	12%	5%	4%	4%	6%	5%
	Frequency	114	21	44	19	66	23
97	△Vmax(m s^{-1})	10	8	17	12	27	17
	Percentage	12%	5%	4%	4%	3%	4%
	Frequency	114	21	44	19	34	16
98	△Vmax(m s^{-1})	**10**	**10**	**20**	**13**	**30**	**20**
	Percentage	12%	3%	2%	3%	2%	3%
	Frequency	114	12	26	13	34	12
99	△Vmax(m s^{-1})	12	10	20	15	32	20
	Percentage	1%	3%	2%	2%	1%	3%
	Frequency	12	12	26	9	24	12

Spatiotemporal Distribution of ERI TCs

An increasing trend in ERI TC occurrence

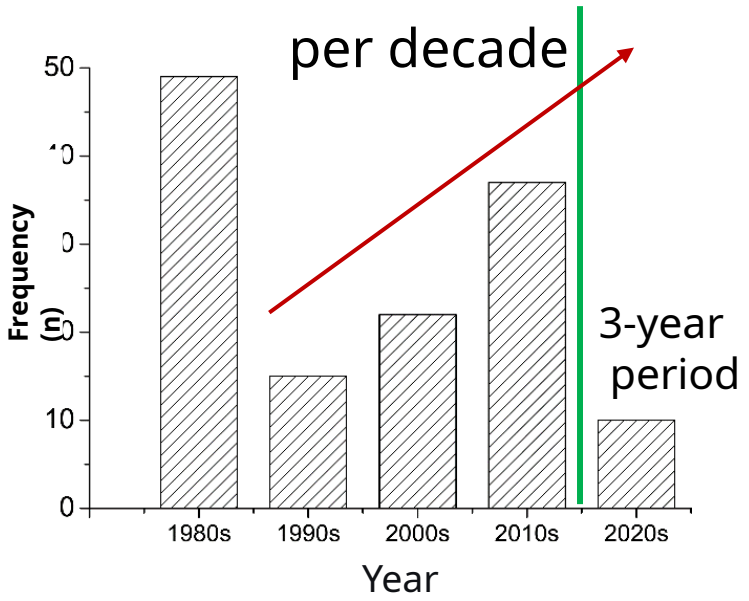
Total 133 ERI TCs



Start of ERI

End of ERI

Geographical Distribution of Gridded ERI Frequencies
(At ERI Onset and Termination, 5°×5° Lat/Lon Grid)



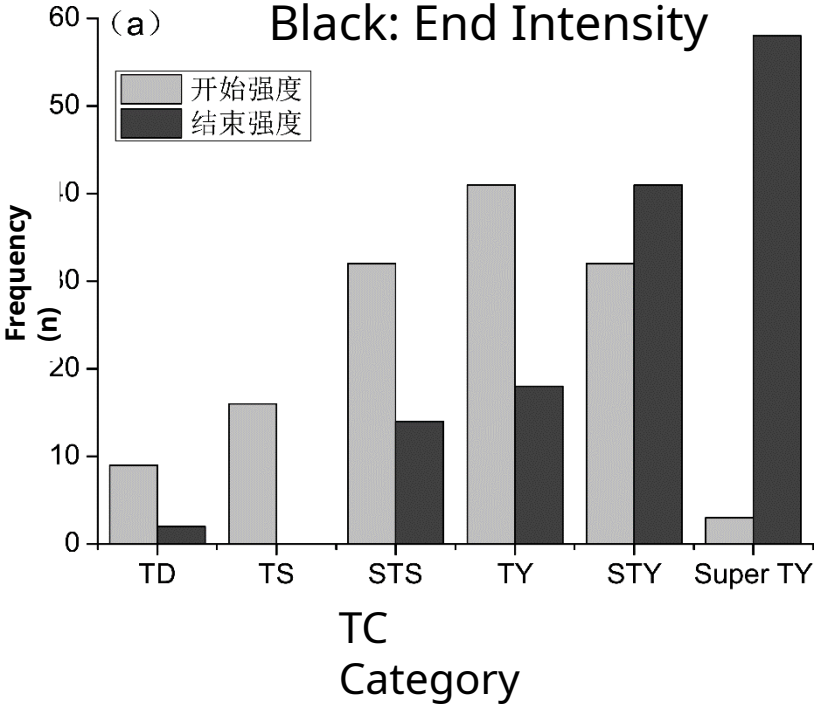
Decadal Frequency Changes of ERI Tropical cyclone

Note: 2020s: 2020–2022

Intensity Changes

Gray: Onset Intensity

Black: End Intensity



TC Category

STS 、 TY->STY, Super TY

Changes in TC Category

24h	TD	TS	STS	TY	STY	SUPER TY
TD	●			1		
TS		●		3		2
STS			●		7	11
TY				●		8
STY					●	3
Super TY						●

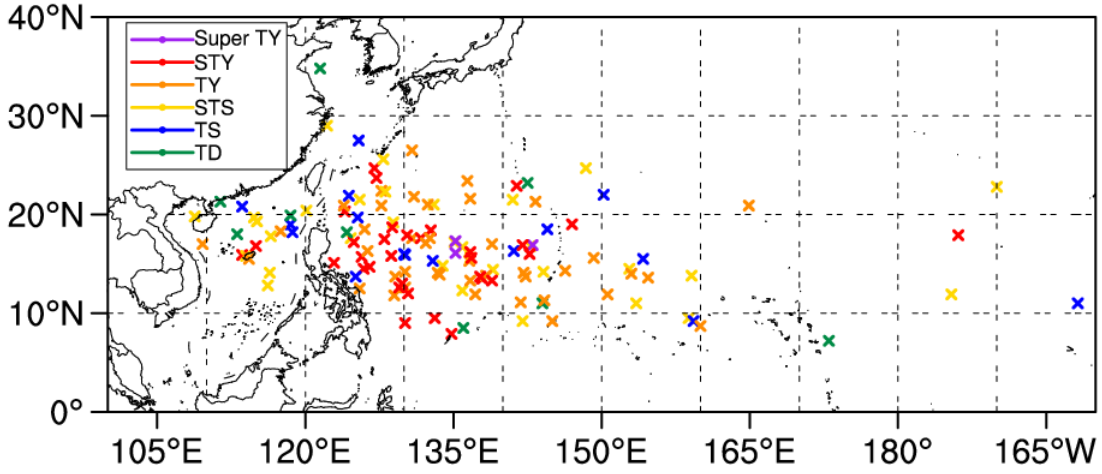
12h	TD	TS	STS	TY	STY	SUPER TY
TD	●		2			
TS		●			1	
STS			●	1	2	
TY				●	1	2
STY					●	2
Super TY						●

6h	TD	TS	STS	TY	STY	SUPER TY
TD	● 2		4			
TS		●	8	2		
STS			●	11		
TY				●	30	
STY					●	27
Super TY						● 3

Summary

Upgrade by 4	2
Upgrade by 3	13
Upgrade by 2	30
Upgrade by 1	83

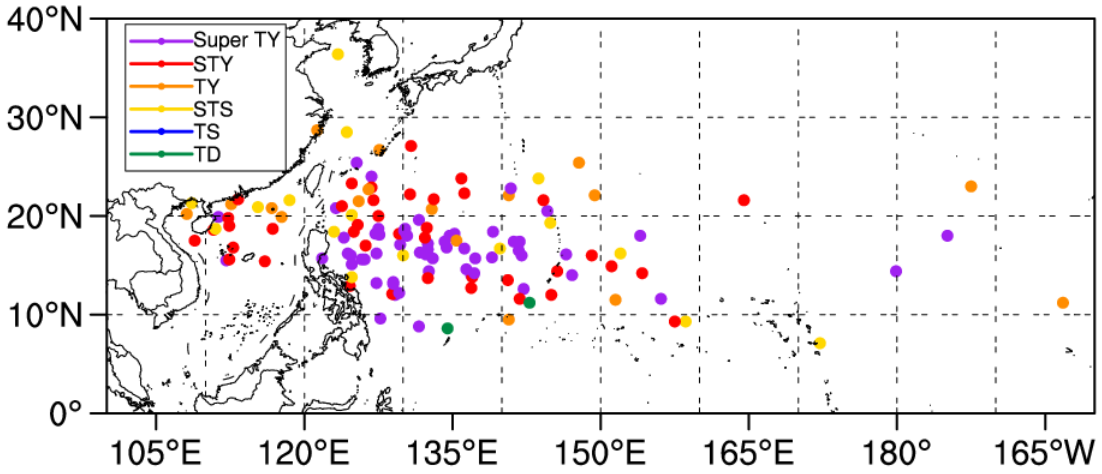
Intensity spatial Distribution of ERI TCs



Start of ERI

SCS: TD to Sever TY

WNP: TD to Super TY



End of ERI

SCS: Mostly TY and STY

WNP: Mostly STY and Super TY

ERI TCs in the SCS: Coastal Proximity, high landfall intensity, Short Warning

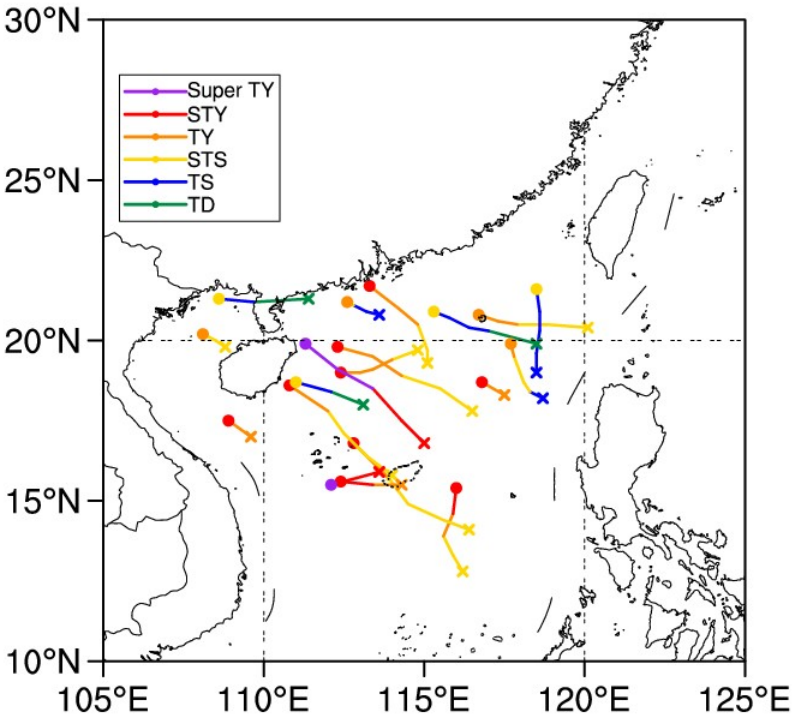
Occurrence: 19 ERI TCs identified, primarily located **North of 15°N**.

Landfall: 13 made landfall in China, and 5 in Vietnam.

Proximity & Timing: ERI TCs occurs 190 km from landfall point,160 km from the Chinese coast, landfall within 24 hours after ERI.

Details of the 13 ERI TCs that made landfall in China

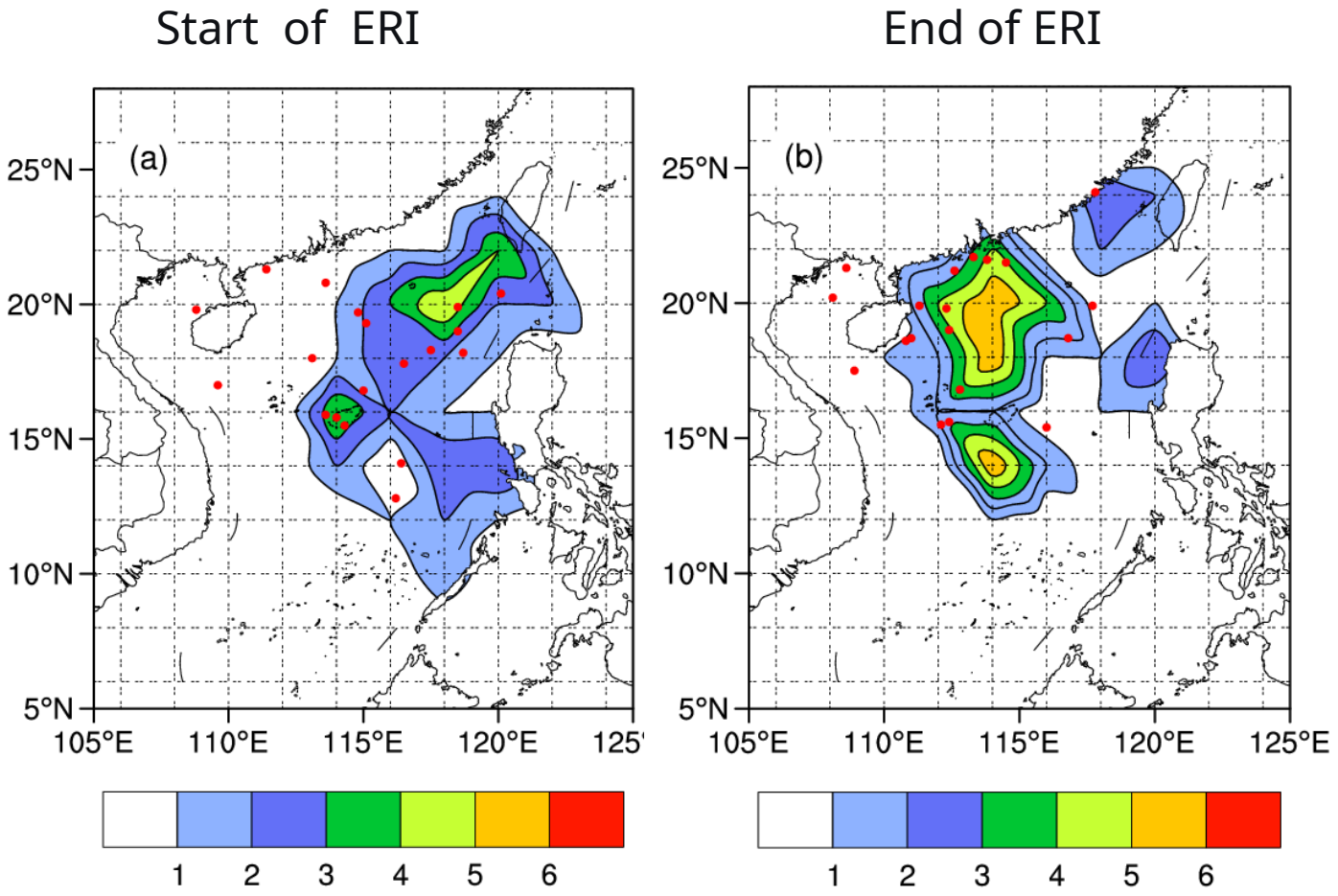
TC	Intensity Change	Landfall Point	Dist. to Landfall/ Coast (km) at ERI end	Time to Landfall (h) at ERI end	Intensity at ERI end	Landfall Intensity
Hato (1713)	12 ms^{-1}/6h	Guangdong	60/40	2	Super TY	STY
Cempaka (2107)	10 ms^{-1}/6h	Guangdog	89/70	19	TY	TY
Mekkhala(2006)		Fujian	0/0	0	TY	TY
Higos (2007)		Guangdong	180/150	10	TY	TY
Damrey (0518)		Hainan	190/190	14	STY	STY
Trix (9106)		Hainan	40/40	3	STY	STY
Wayne (8616)		Hainan	700/500	27	STY	TY
Kelly (8105)		Hainan	360/310	28	STY	STY
Mirinae (1603)	13 ms^{-1}/12h	Hainan	50/50	2	STS	STS
Rammasun(1409)	15 ms^{-1}/12h	Hainan	170/150	10	Super TY	Super TY
Mujigae (1522)	20 ms^{-1}/24h	Guangdong	230/135	12	STY	Super TY
Vicente (1208)		Guangdong	40/40	1	STY	TY
Susan (8802)		Taiwan	390/390	26	TY	TY



ERI TC Tracks

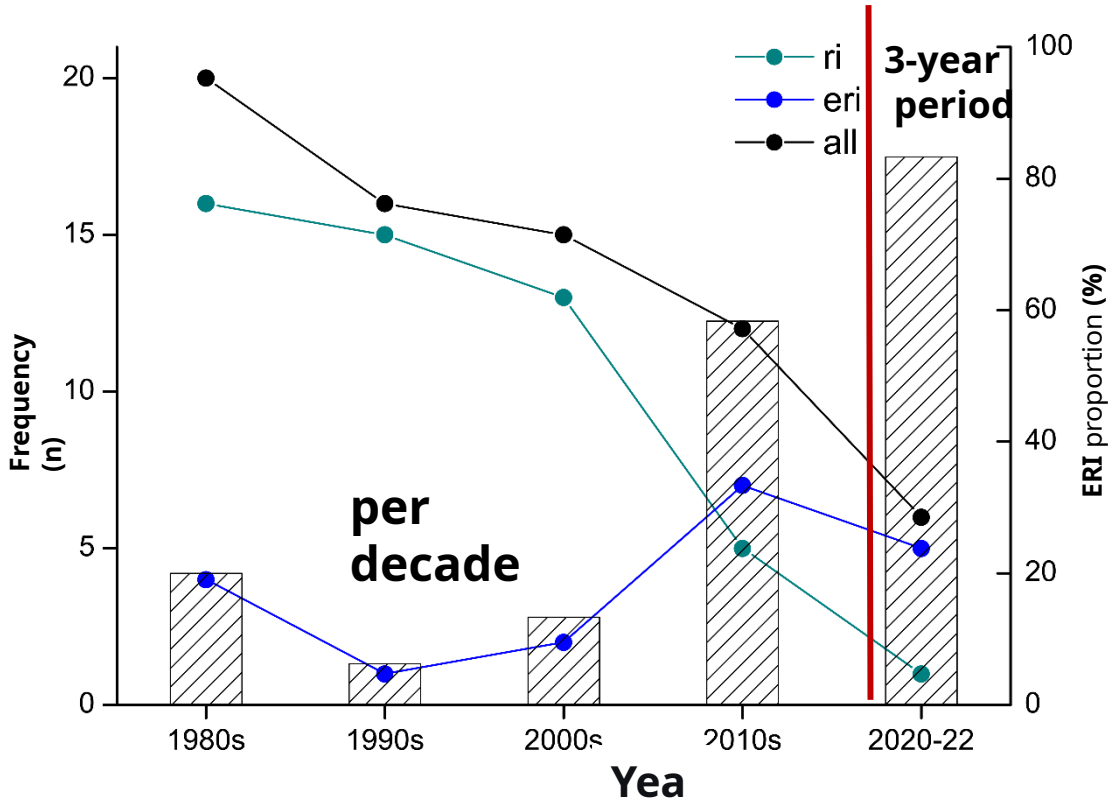
(Start Position × , end Position•)

ERI and RI TCs in the SCS



ERI TC : Red dots , RI TC: Shading

Temporal Distribution



Decadal Frequency Changes of ERI and RI TCs in the SCS

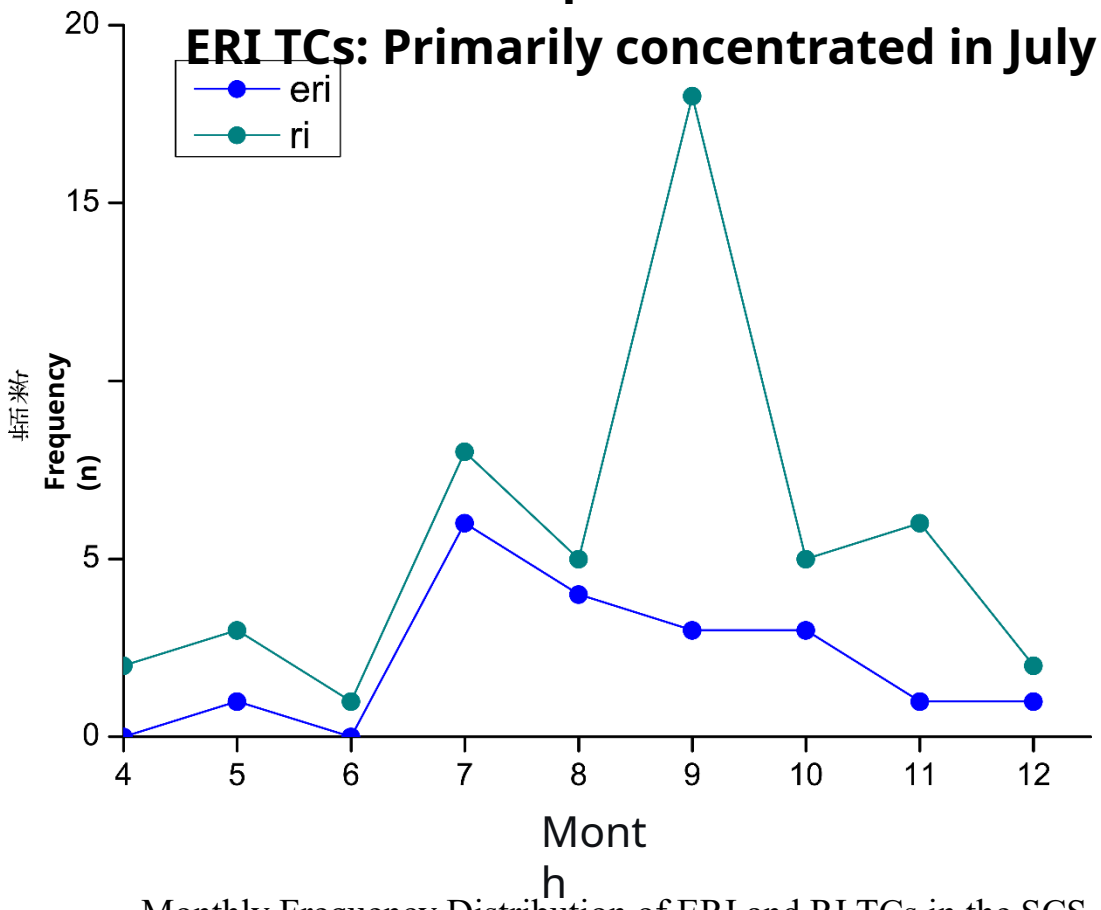
Note: 2020s: 2020–2022

Blue lin: ERI ; Green line: RI ; black line:ERI+RI

Bars: ERI / (RI+ERI) proportion

RI TCs: Bimodal distribution (July & September peaks)

ERI TCs: Primarily concentrated in July



Monthly Frequency Distribution of ERI and RI TCs in the SCS

Intensity Changes

ERI TCs Strengthen Much More than RI TCs

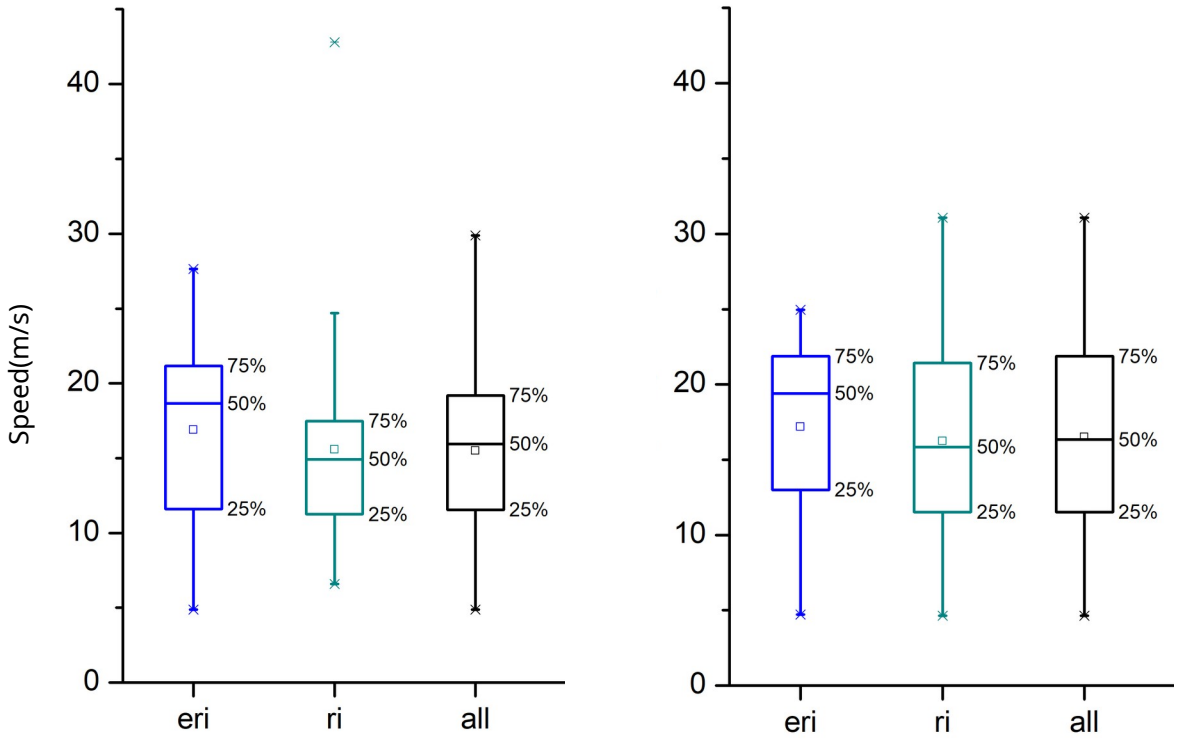
6h / Category Gain	RI	ERI
2		**17%**
1	100%	83%

12h / Category Gain	RI	ERI
2	28%	**54%**
1	72%	46%

24h / Category Gain	RI	ERI
3		**8%**
2	82%	**84%**
1	18%	8%

Translation Speed

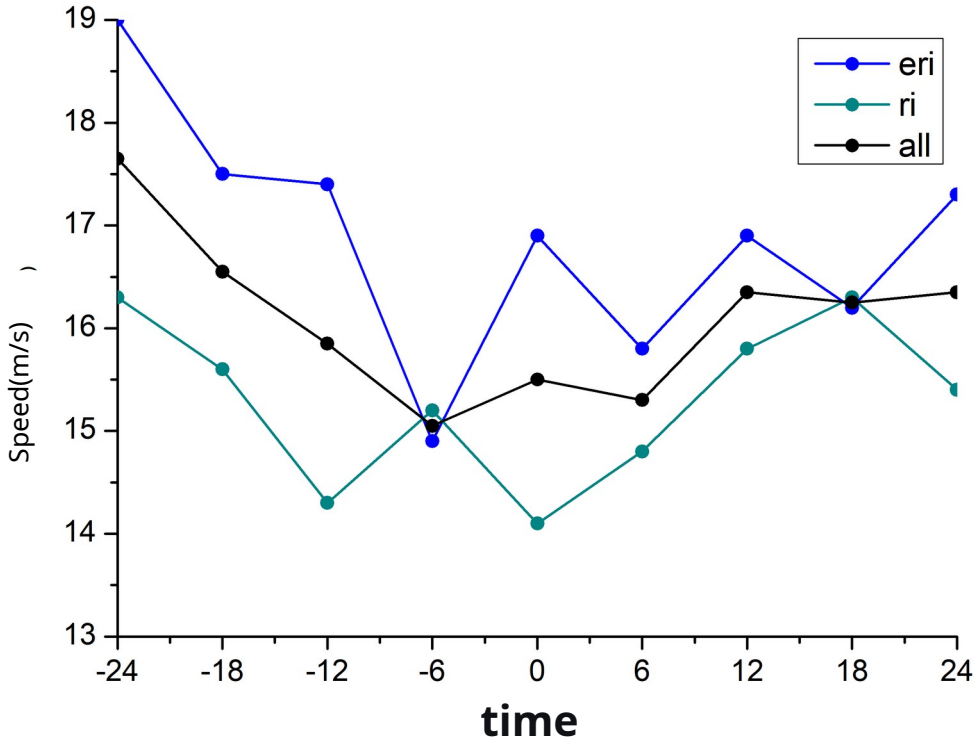
Translation speed 24h before RI/ERI: Declining Trend



24h Pre-Onset

24h Post-Onset

Mean Translation Speed

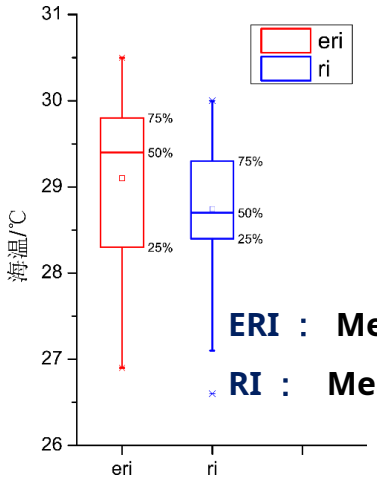


Temporal Variation of Mean Translation Speed

(6-Hour Intervals, t0: RI/ERI onset time)

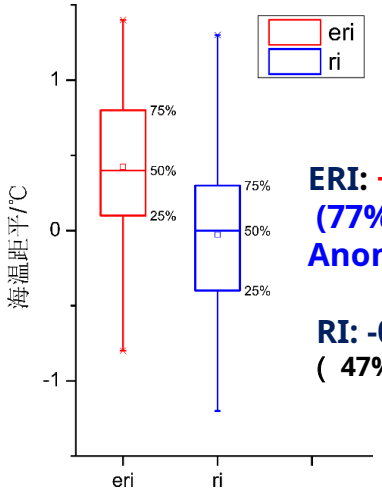
Sea Surface Temperature

ERI events: Higher SST and Positive Anomaly



ERI : Mean 29.3℃

RI : Mean 28.6

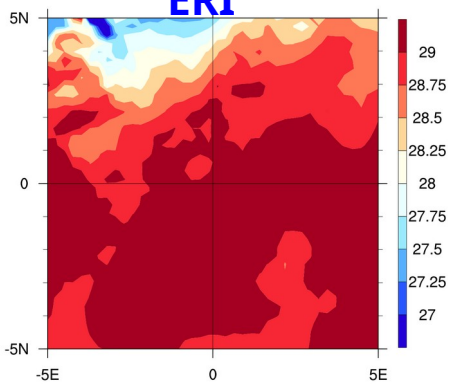


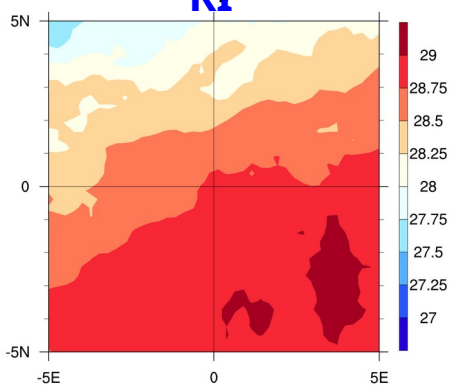
ERI: +0.4℃ (77% Positive Anomaly)

RI: -0.03 ℃ (47% Positive Anomaly)

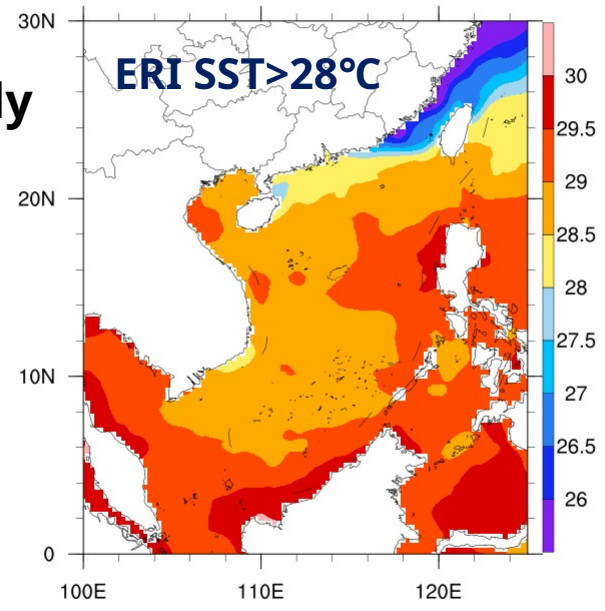
Mean SST in a 4°×4° Box around TC Center

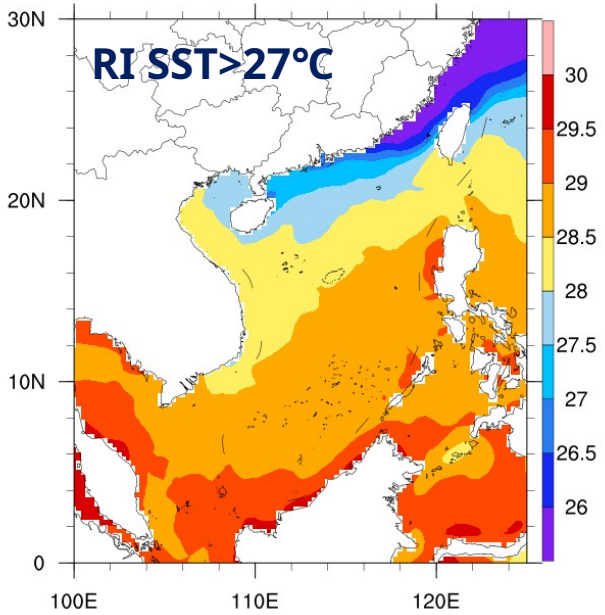
SST Anomaly



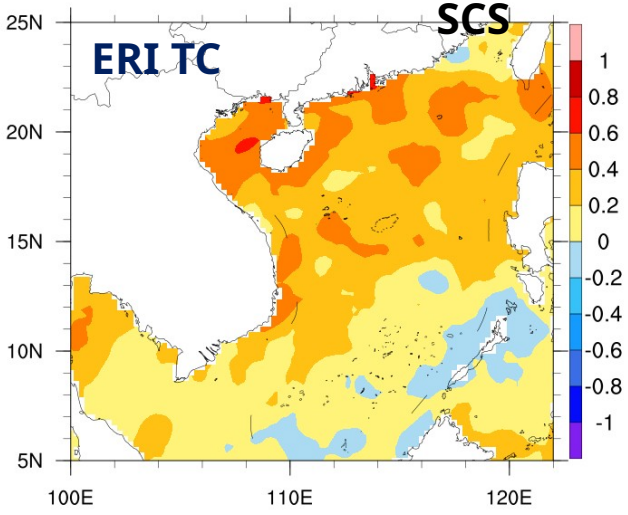


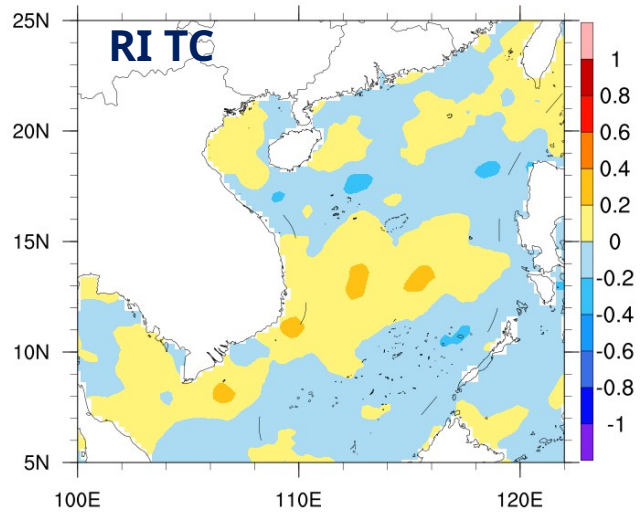
Composite SST Distribution around the TC Center





Mean SST in the SCS



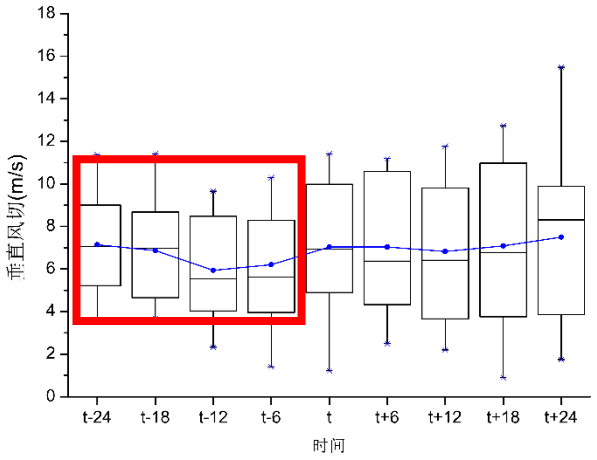


Mean SSTA

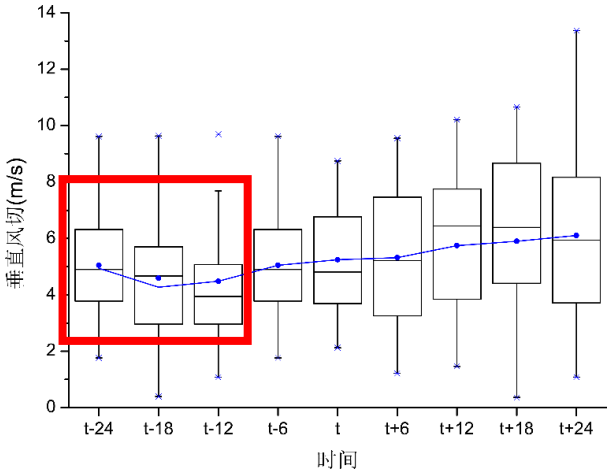
Vertical Wind Shear

- Deep-layer vertical wind shear less than 10m/s , Average: ~7 m/s
- A decreasing trend 12-18 hours prior to the onset of ERI

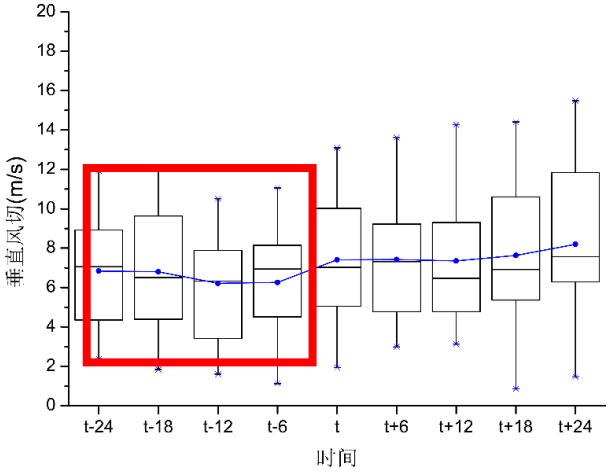
ERI TC



1000Pah-200hPa

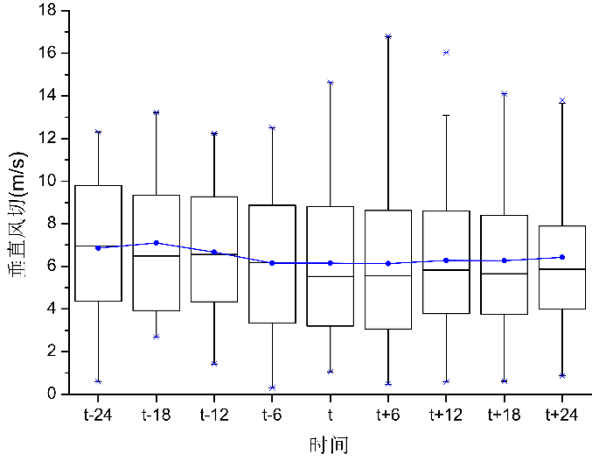


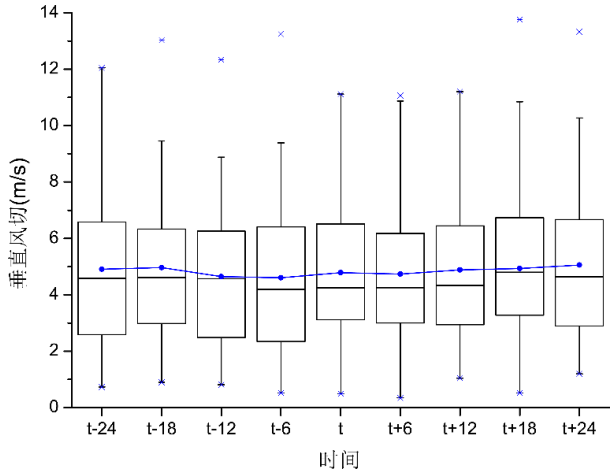
1000Pah-300hPa

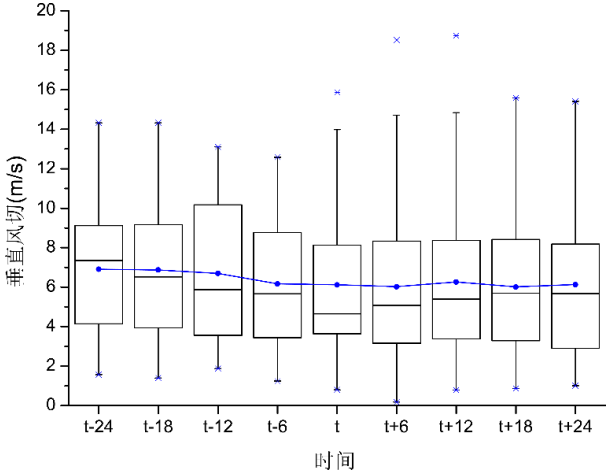


850Pah-200hPa

RI TC

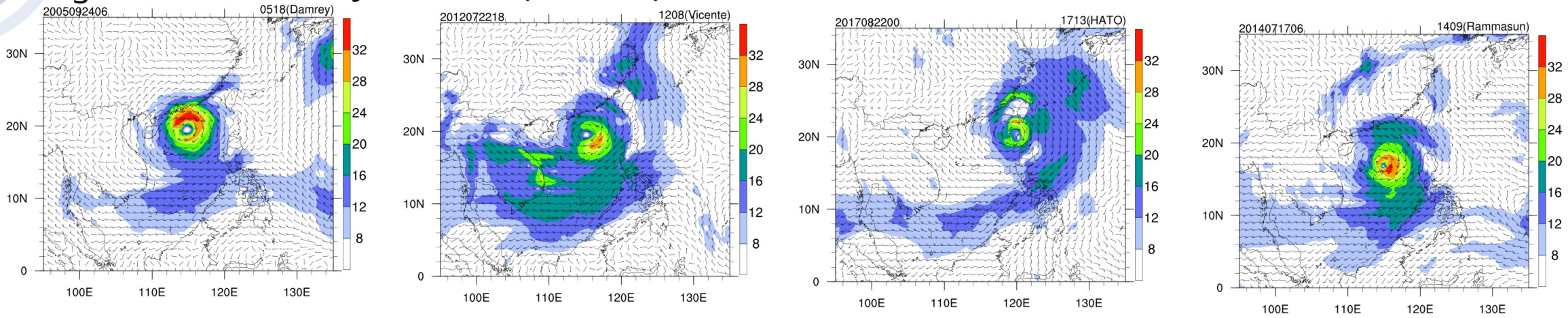




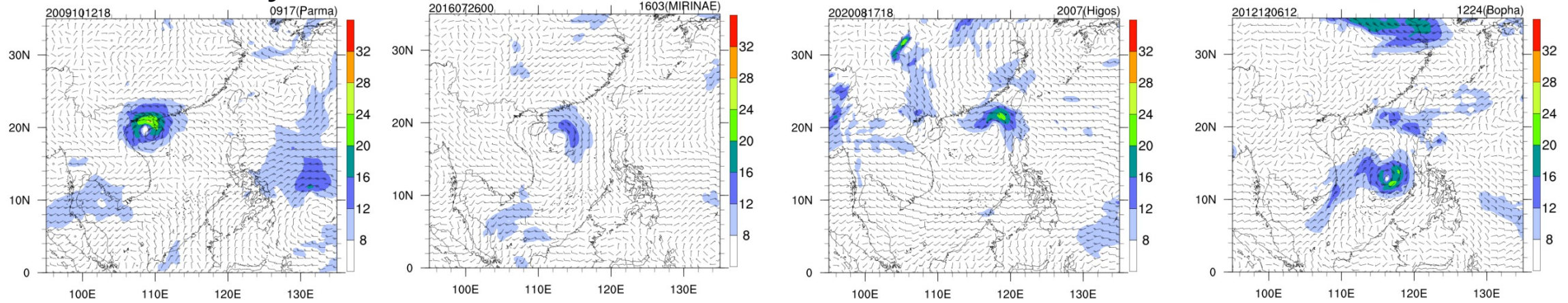


Next Steps

Significant low-level Jet Stream (850 hPa)



Weak low-level Jet Stream



- Upper-Level Outflow, Size, double eyewall……

——Further details to be summarized and studied.

Conclusions

1.An ERI event is defined as an intensity of at least 10 $m \cdot s^{-1} \cdot (6\ h)^{-1}$, 13 $m \cdot s^{-1} \cdot (12\ h)^{-1}$, 20 $m \cdot s^{-1} \cdot (24\ h)^{-1}$ over the SCS, corresponding to the 98th percentile of maximum intensity change of all TCs during 1980~2022 .

2.Only 12% of TCs over the WNP and 4% of TCs over the SCS underwent ERI. These ERI TCs are mainly located over the region bounded by 135°E ~ 145°E , 15°N ~ 20°N and the north part of the SCS around 20°N.

3. 72% of the ERI TCs over the SCS made landfall in China. These TCs were usually close to Chinese mainland with strong intensity which significantly increasing the difficulty of TC prevention and disaster reduction.

4. Both the frequency and proportion of ERI TCs have increased over the past 30 years.

5. Compared with RI events, ERI events occurred with higher SST and positive anomalies. Vertical wind shear showed a decreasing trend 12-18 hours prior to the onset of ERI.

Thank you!

GONG Yueting, CHENG Zhengquan,YANG Shiqi,
Definitionof Extremely Rapid Intensification of Tropical Cyclones over the South China Sea for Operational Forecasting [J].
Journal of Tropical Meteorology,2024,40(4):650-658.