Forecast Performance and Study on RI process of Typhoons Rammasun (1409) and Hato (1713)

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# Why do we focus on rapidly intensification (RI) ?

- Big challenge in intensity forecast
- Prepare for the future

Why do we focus on RI?

Do we have the capability to do the forecast of RI?

☐ RI makes the weighty challenge in TCs' intensity forecast.

☐ The statistics tells that RI dedicates **over half** of the top 5% huge forecast errors.

☐ While in operational work scene, RI is almost completely be under-estimated.

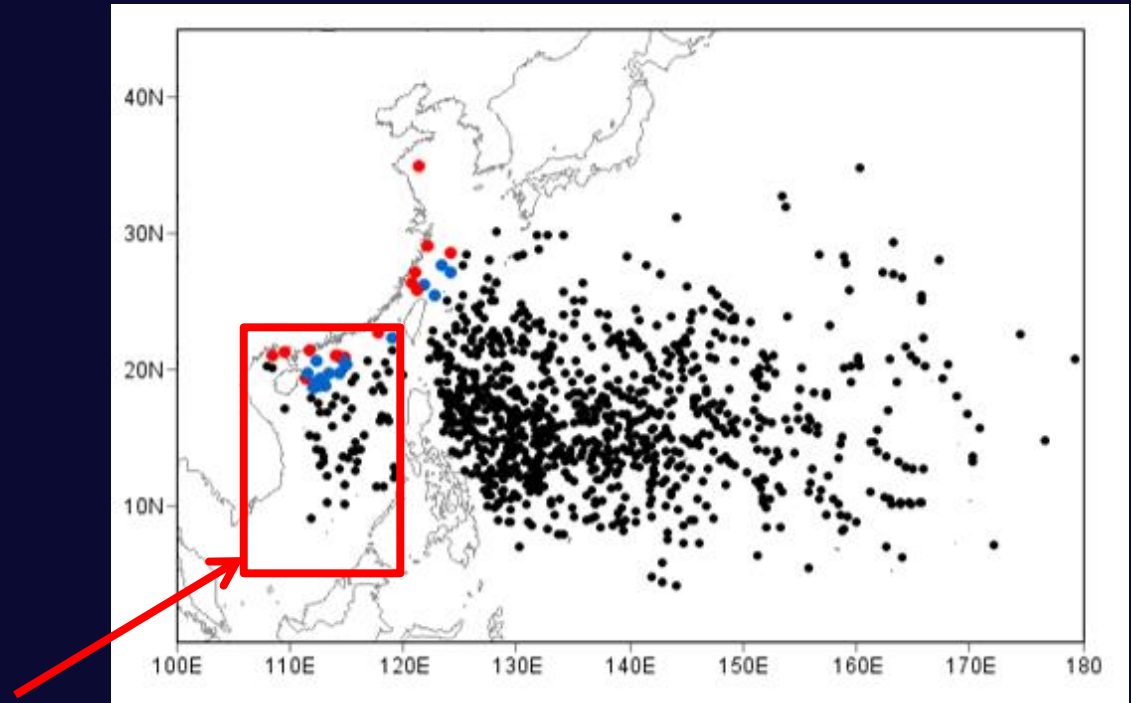**24~120hr intensity forecast error of CMA**
(from 2000 to 2017)
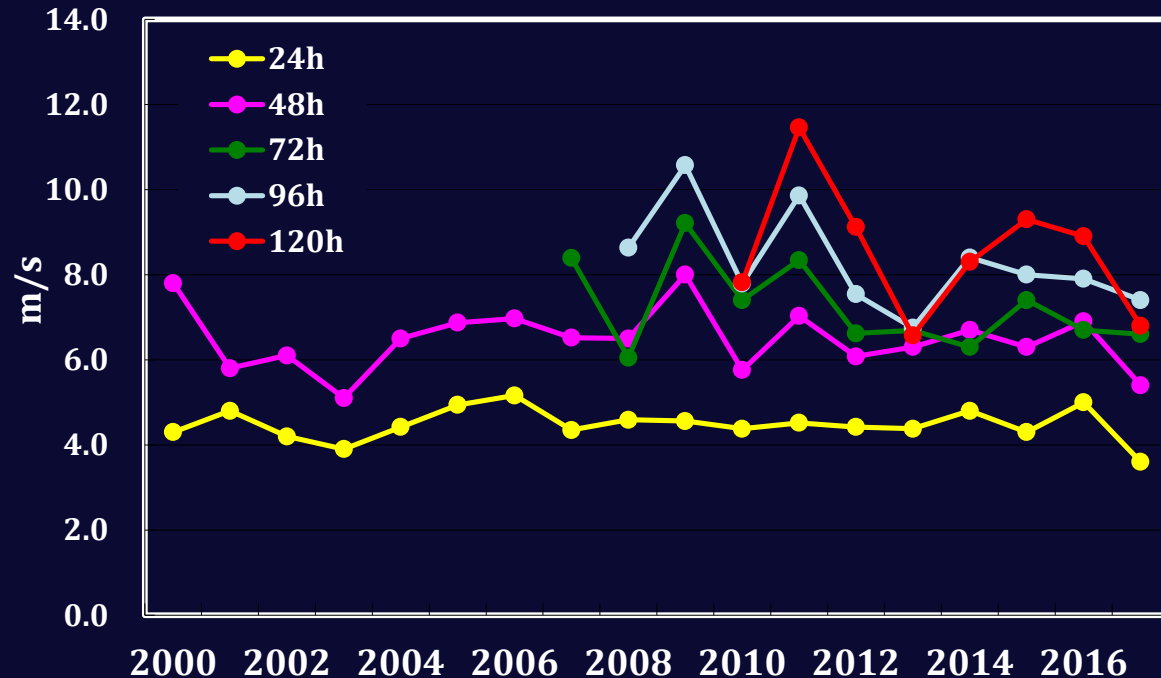
Why do we focus on RI?

Do we have the capability to do the forecast of RI?

From <u>forecast</u> to <u>service</u>

☐ **RI happened within 24hr before the TC made landfall in coastal area would draw tremendous challenge to the early warning system.**

**Positions of RI in the western North Pacific and South China Sea**

Red dots: RI within **6 hrs** before landfall,
Blue dots: RI within **12 hrs** before landfall.

Why do we focus on RI?

Do we have the capability to do the service in a RI case?

☐ **Especially in the South China Sea, RI cases are prone to northwestern track and make landfall after or during the RI process, which strike the DRR work to the surrounding members.**

Tracks of Typhoons underwent RI process and the position of RI in the South China Sea
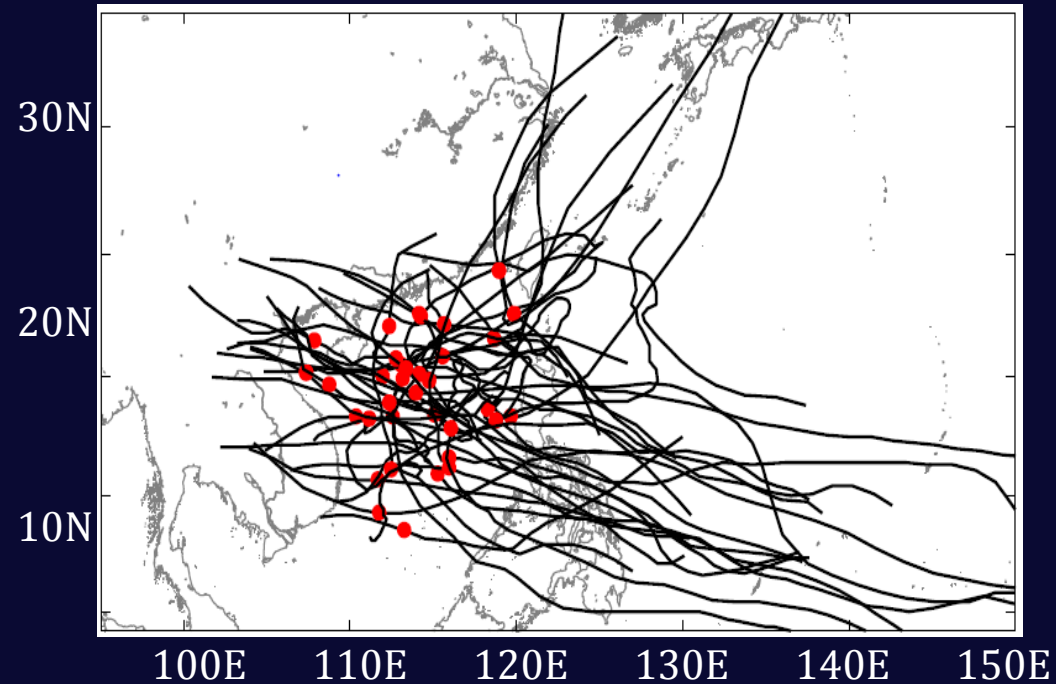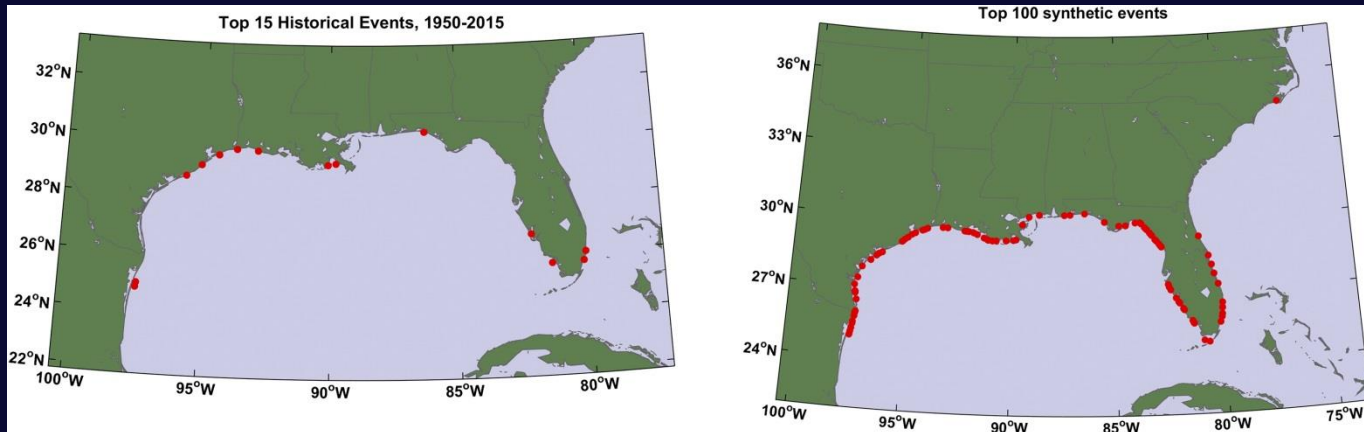
(Zhang, 2017)

Why do we focus on RI?

What is the situation like in the future.

☐ **Kerry Emanuel suggested that: The risk of near-shore TC occurrence RI will increase under the background of global warming, and the potential risk of disaster and prediction of TC will increase.** *(Emanuel, 2016)*

Points of landfall of the (left) 15 most rapidly intensifying historical and (right) 100 most rapidly intensifying synthetic events.

☐ **Almost all the super typhoons underwent RI in their life time. It seems that we will got more super typhoons in the future.**
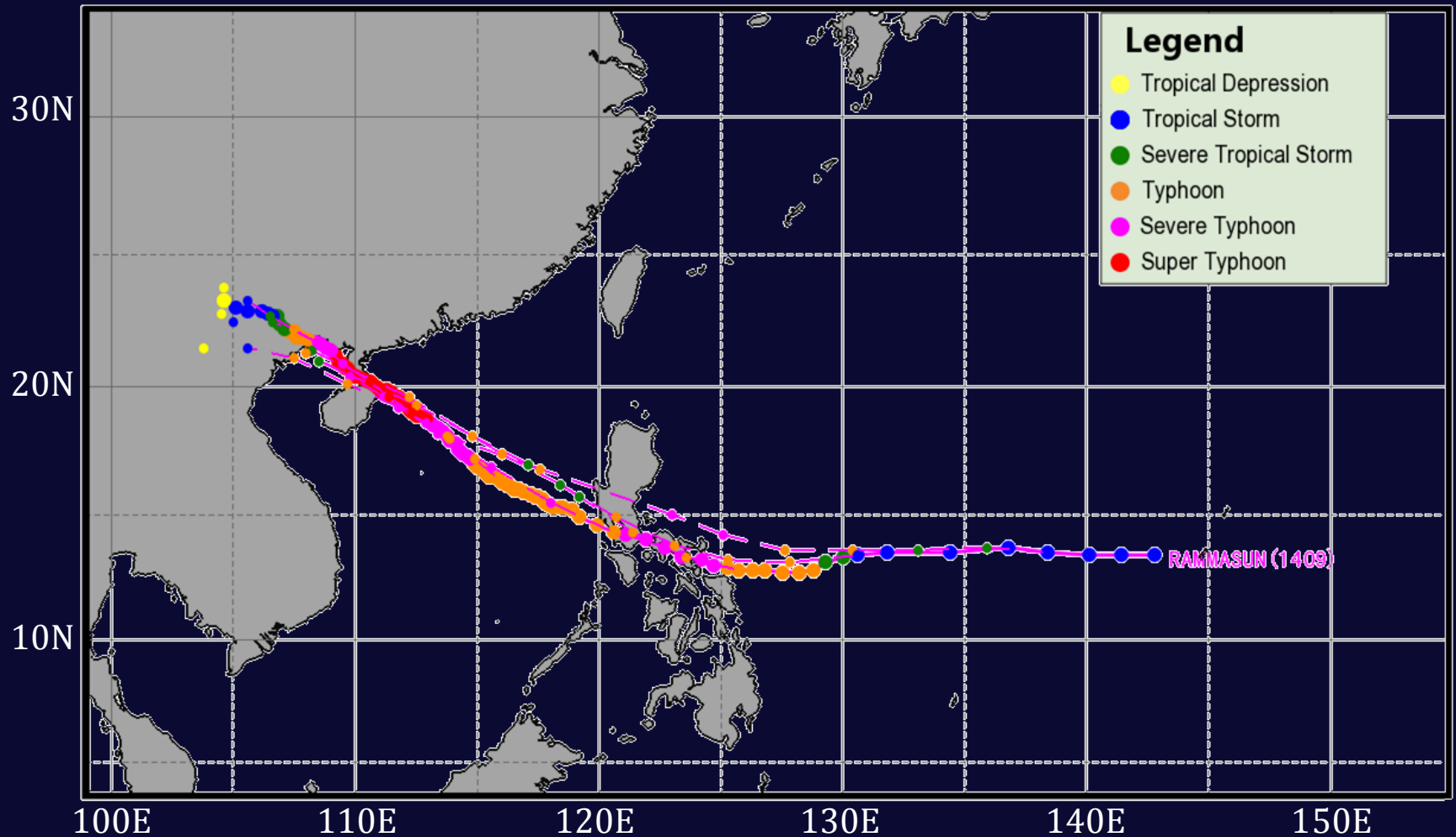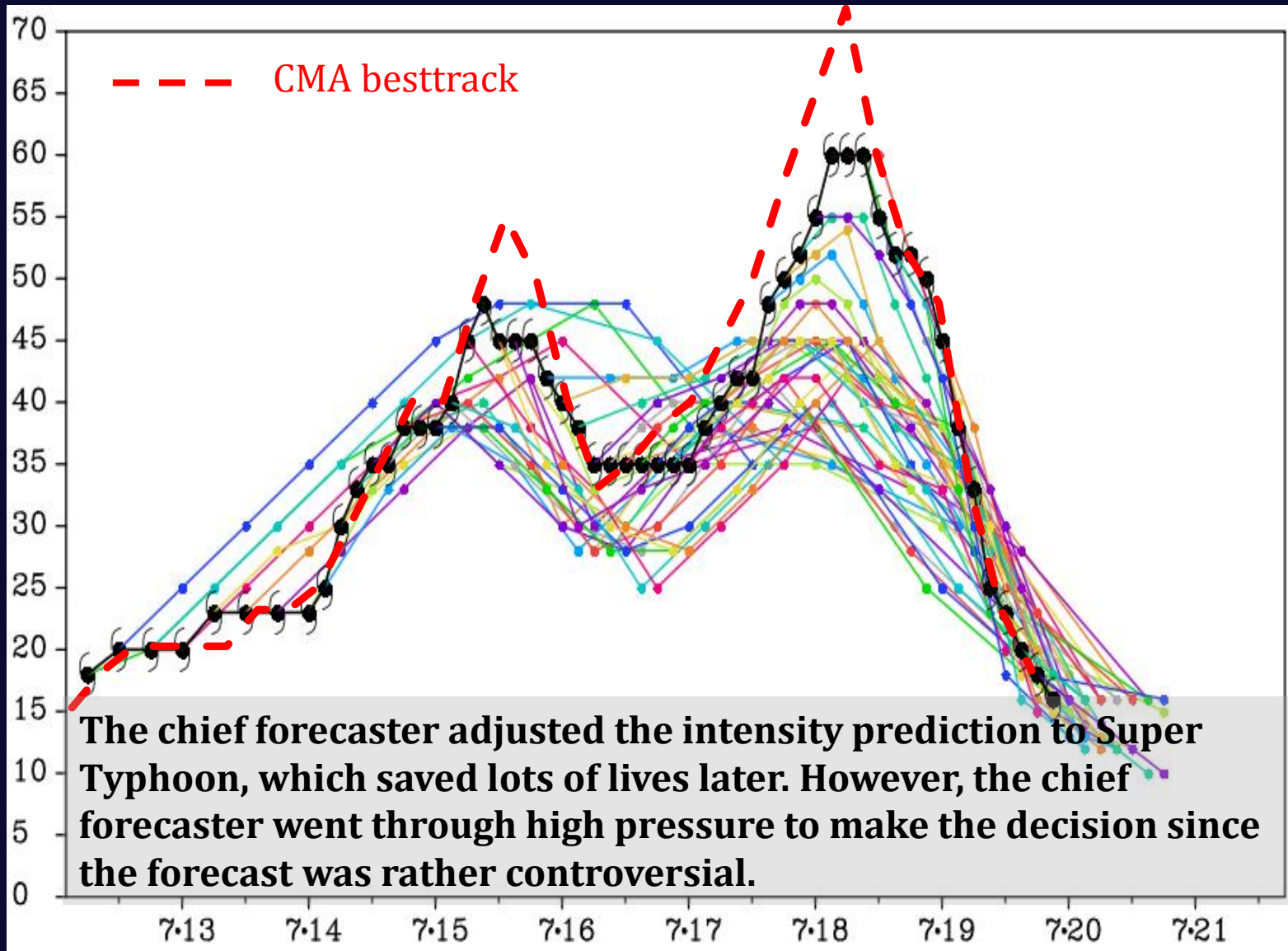
(Kaplan and DeMaria,2003)
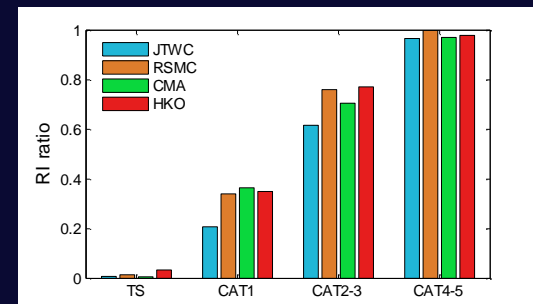
Cases: RAMMASUN (1409) and HATO (1713)

- Both underwent RI over South China Sea
- Both made landfall in China
- Big challenge for forecasters in real-time operation

Track Forecast of RAMMASUN in real-time

Intensity Forecast of RAMMASUN in real-time

The chief forecaster adjusted the intensity prediction to Super Typhoon, which saved lots of lives later. However, the chief forecaster went through high pressure to make the decision since the forecast was rather controversial.

Early Warning Service of RAMMASUN (1409)

Track and intensity of RAMMASUN

Jul., 2014

Legend:
- TD
- TS
- STS
- TY
- STY
- SUPER TY

The appropriate estimated landfall intensity just before the landfall!

Time (BJT, +8hr)

	Typhoon Warning	Fcst Landfall intensity	
15th 18:00	Blue		
16th 06:00	Yellow	40-45m/s	
10:00	Orange	42-48m/s	
18:00	Orange	42-48m/s	
17th 06:00	Orange	42-48m/s	
10:00	Orange	42-48m/s	
18:00	Red	42-48m/s	
18th 06:00	Red	50-55m/s	
10:00	Red	55-60m/s	
15:30 Made 1st landfall, 60m/s,			70
18:00	Red	58-60m/s	
19:30 Made 2nd landfall, 60m/s,			62
19th 06:00	Red	48-50m/s	
07:10 Made 3rd landfall, 48m/s,			50
10:00	Orange		
18:00	Yellow		
20th 06:00	Warning Dismissed		

Forecast Error of CMA (Case: RAMMASUN)
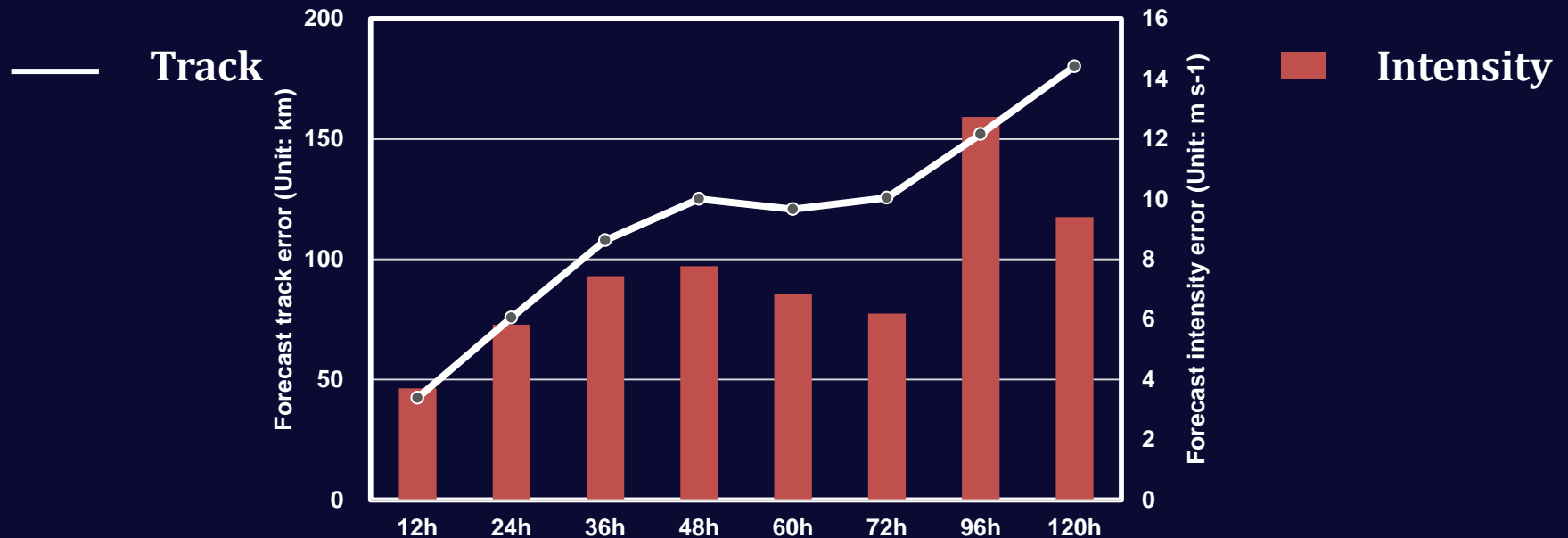
	Track				Intensity		
	AVE	Landfall Point	Time Bias		AVE	MAX	.
24hr	75.8km	12.8 km	3.0 h earlier		5.8 m/s	15 m/s	
48hr	125.1km	29.6 km	3.5 h earlier		7.8 m/s	20 m/s	
72hr	125.6 km	3.2 km	1.5 h later		6.2 m/s	20 m/s	.

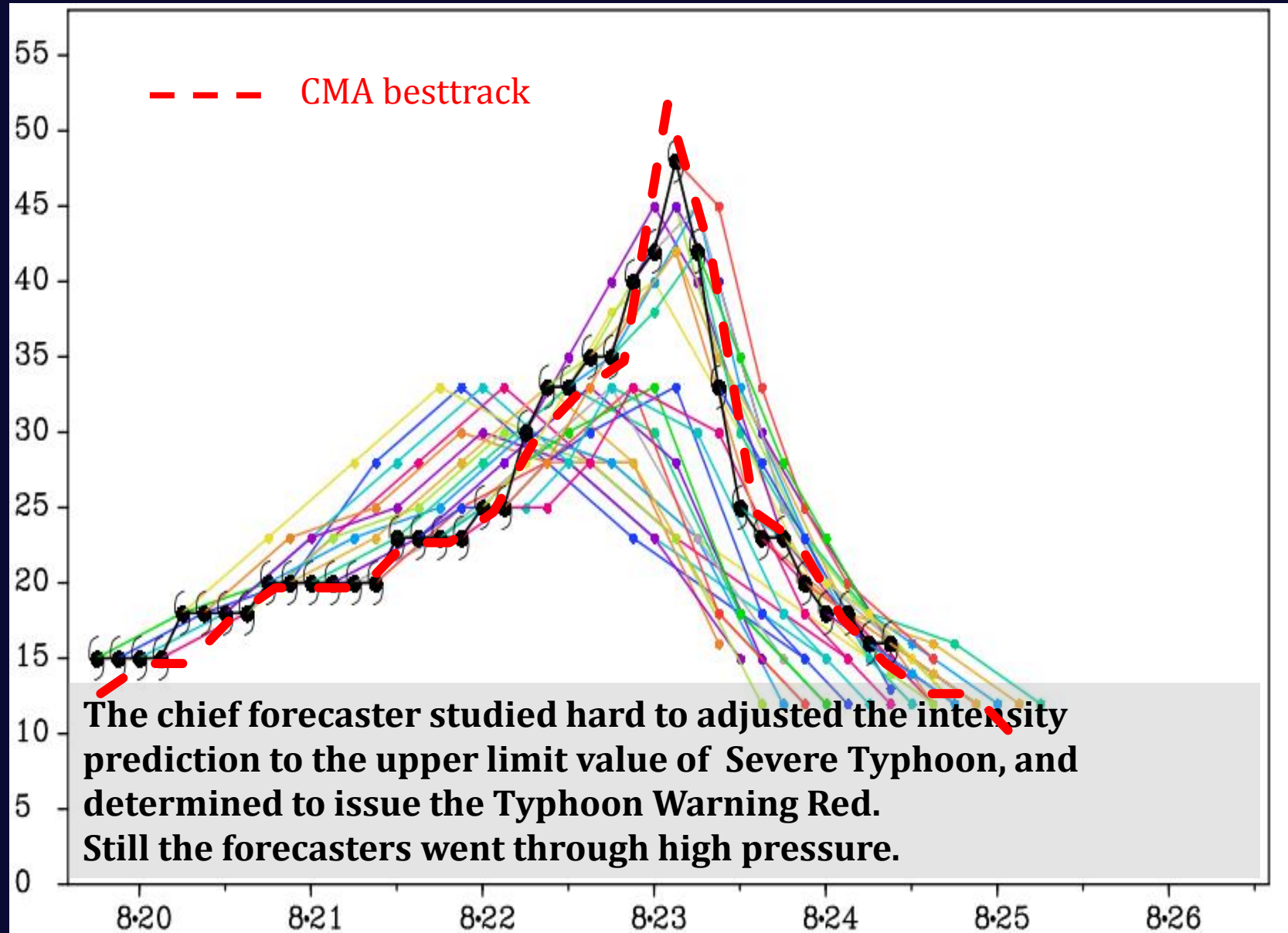# Track Forecast of HATO in real-time
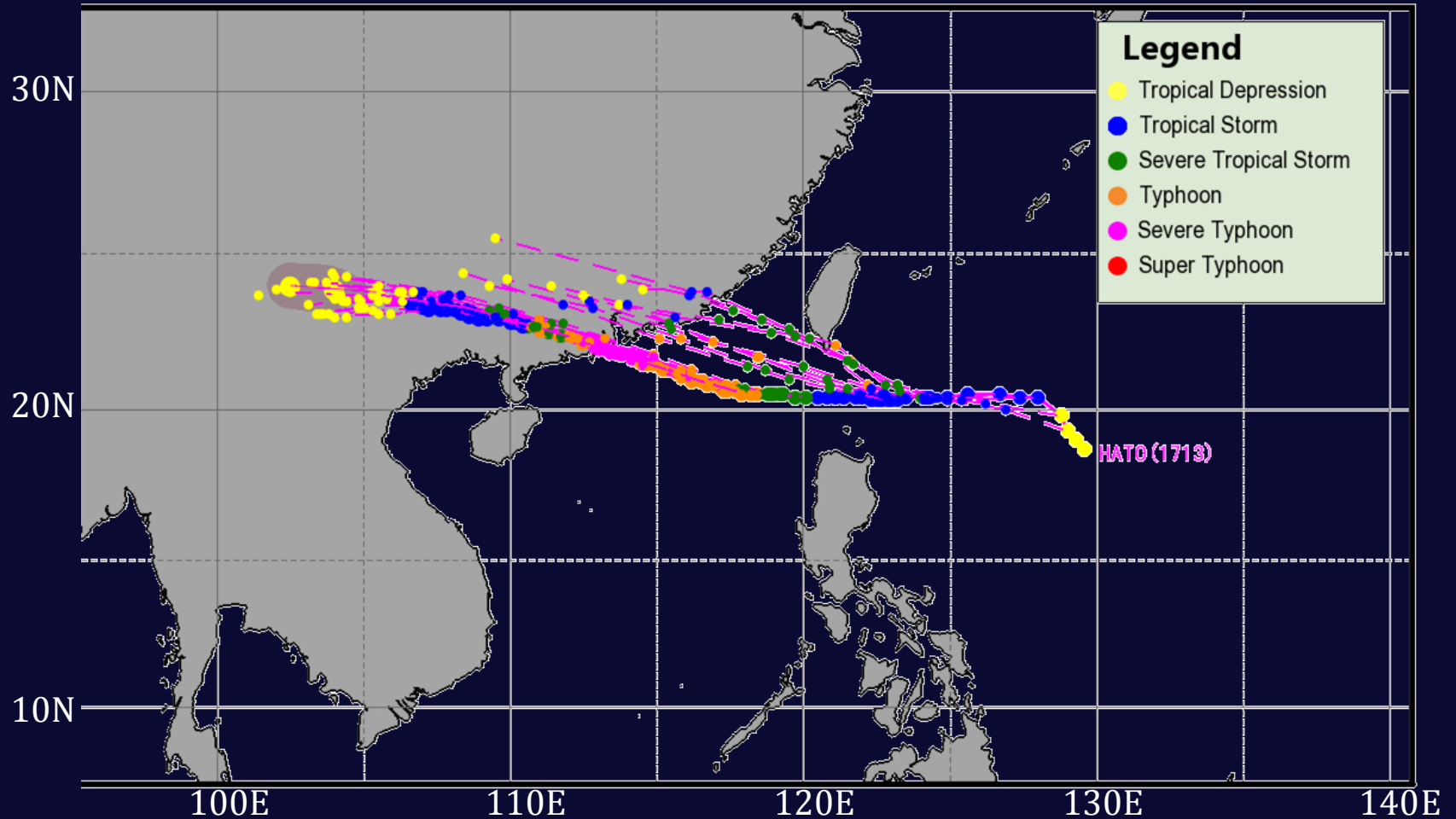
Forecast performance of Subjective forecast

- **All the agencies shift their forecast to the west from 21~23 Aug..**
- **Because of the WSW-NE coastline, the forecast landing point changed about 300 km.**
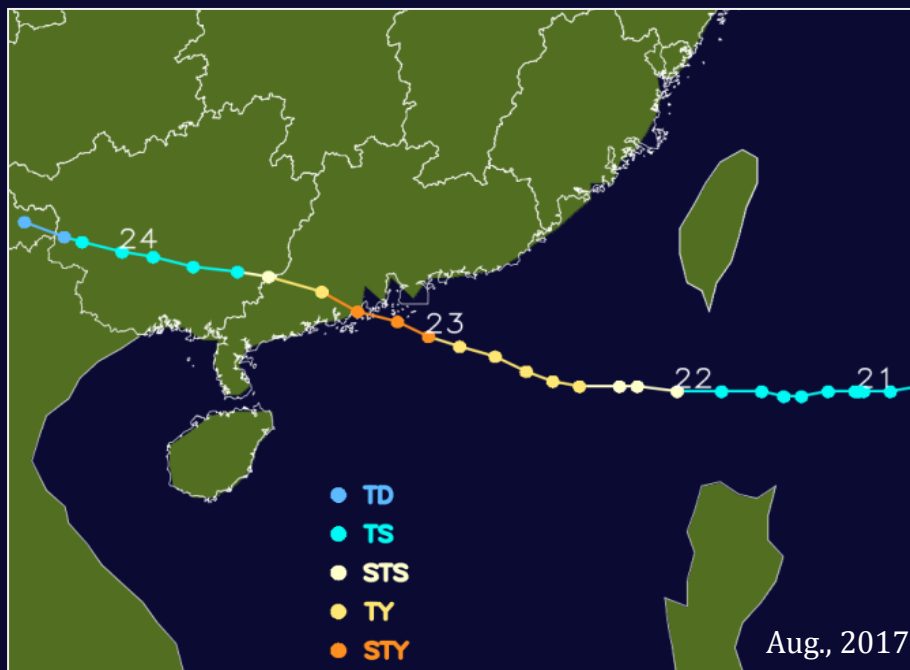- **The estimated landfall area is Pearl River Delta, which is densely populated and economically developed.**

Intensity Forecast of HATO in real-time

CMA besttrack
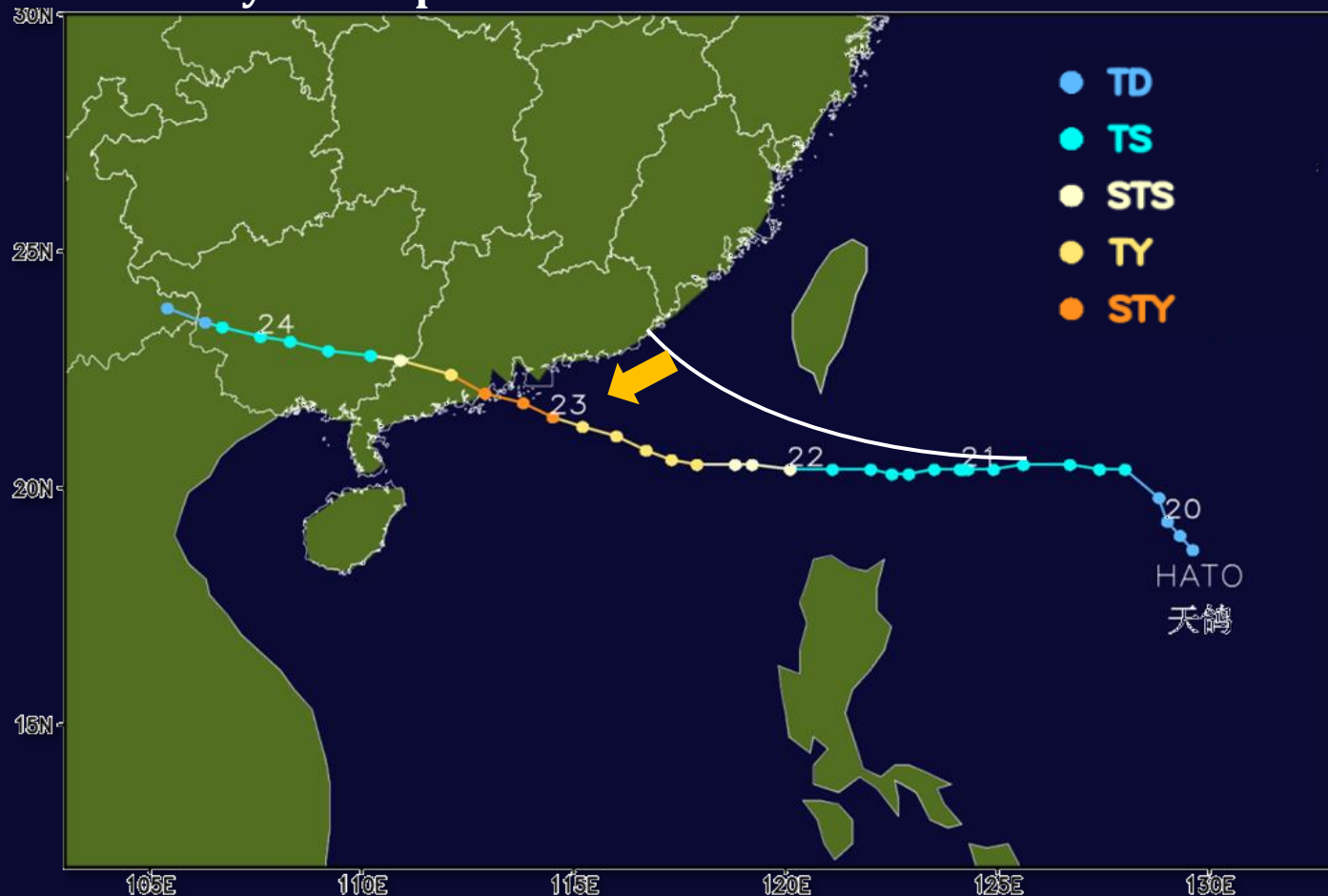
The chief forecaster studied hard to adjusted the intensity prediction to the upper limit value of Severe Typhoon, and determined to issue the Typhoon Warning Red.
Still the forecasters went through high pressure.

Early Warning Service of HATO (1713)

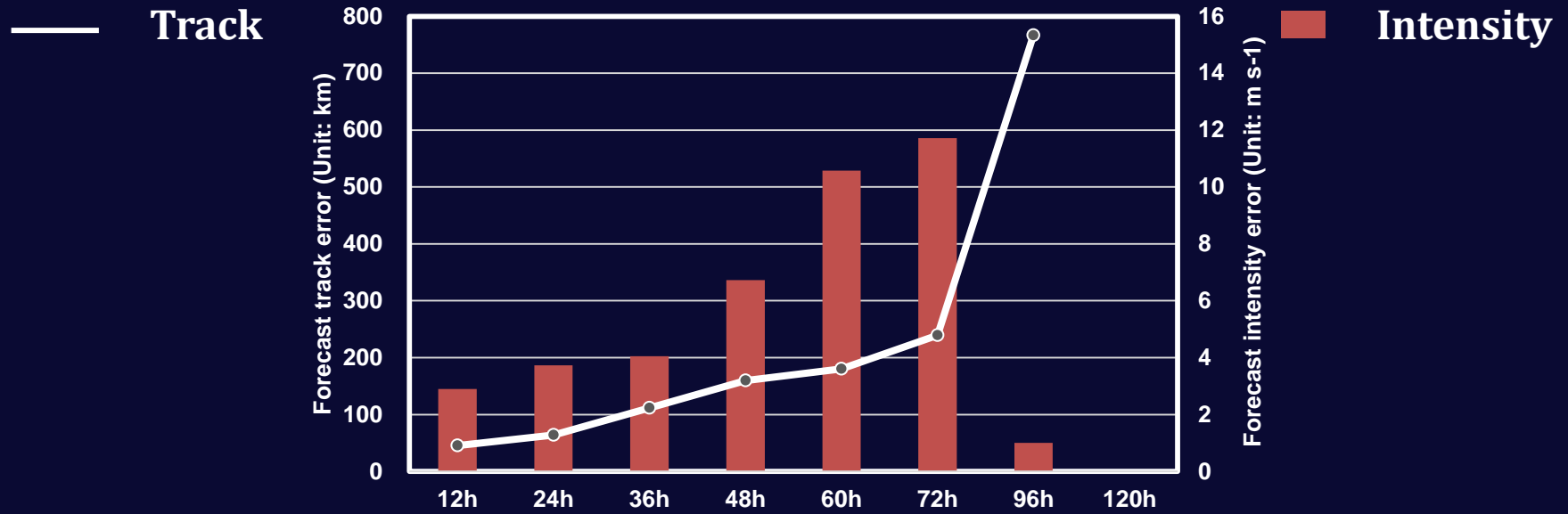## BABJ Track and intensity of HATO

Aug., 2017

Note: The analyzed maximum intensity of HATO maybe adjusted to Super Typhoon in CMA Besttrack Dataset.

Time (BJT, +8hr)

	Typhoon Warning	Fcst Landfall intensity
21st 06:00	Blue	23-28m/s
10:00	Blue	25-30m/s
18:00	Yellow	25-33m/s
22nd 06:00	Orange	33-40m/s
10:00	Orange	33-40m/s
18:00	Orange	38-45m/s
23rd 06:00	Red	40-48m/s
10:00	Red	42-50m/s
12:50	Made landfall, 45m/s, 950hPa	
18:00	Orange	
24th 06:00	Blue	
10:00	Blue	
18:00	Warning Dismissed	

The appropriate estimated landfall intensity only 18hrs earlier!

Forecast Error of CMA (Case: HATO)

Track ── **Intensity** ▮

Forecast track error (Unit: km) / Forecast intensity error (Unit: m s-1)

12h 24h 36h 48h 60h 72h 96h 120h

☐ **Track**

	AVE	Landfall Point
24hr	63.7km	23.8 km
48hr	159.5km	85.1 km
72hr	239.6 km	262.7 km

☐ **Intensity**

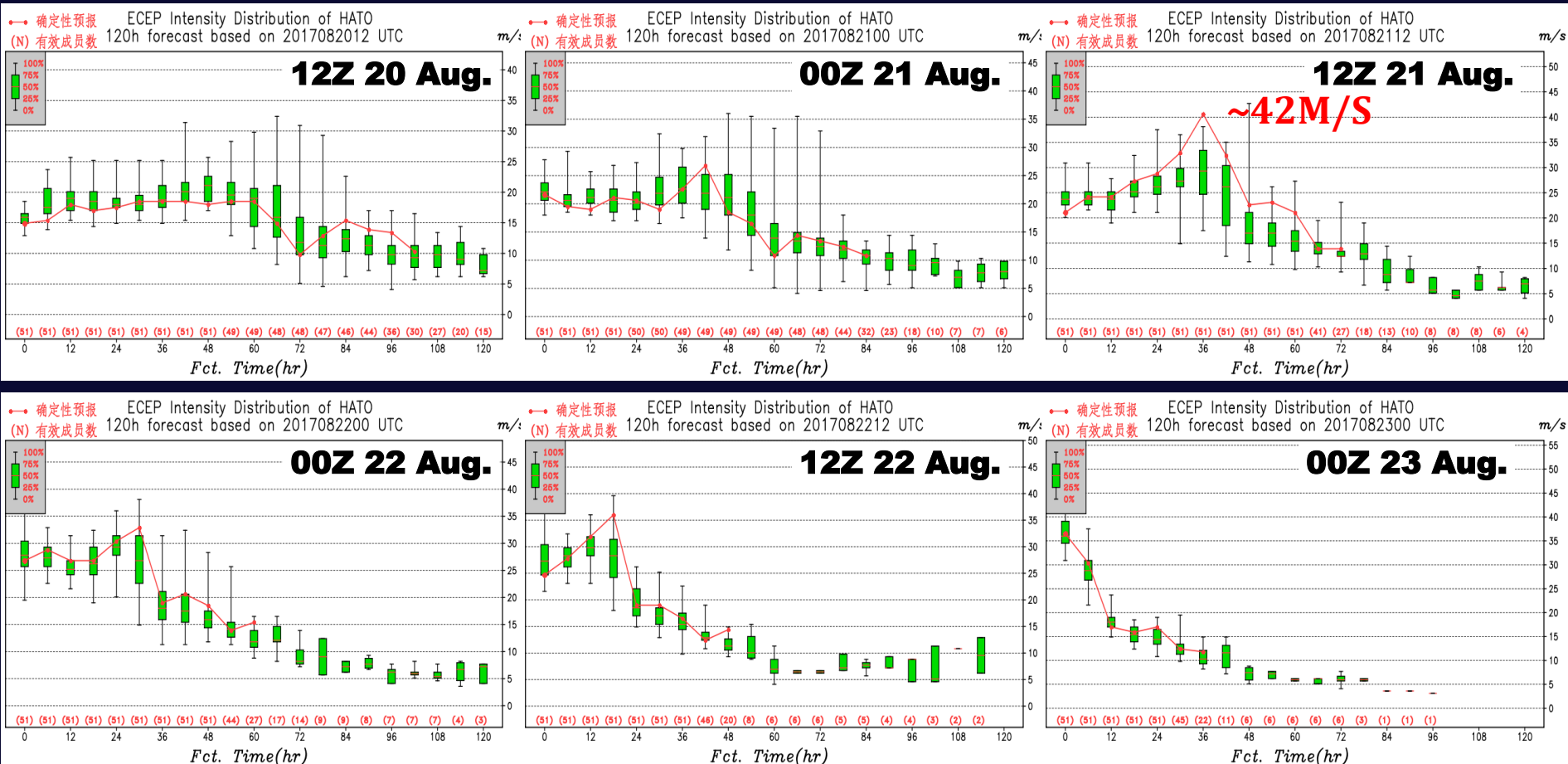| Models	
28.9 km (EC)	26.8 km (NCEP)
40.1 km (EC)	29.3 km (NCEP)
267.5 km (EC)	261.7 km (NCEP)

Forecast performance of Numerical Models

Analysis of track forecast of HATO. (Multi-models Ensemble Tracks EC/NCEP)
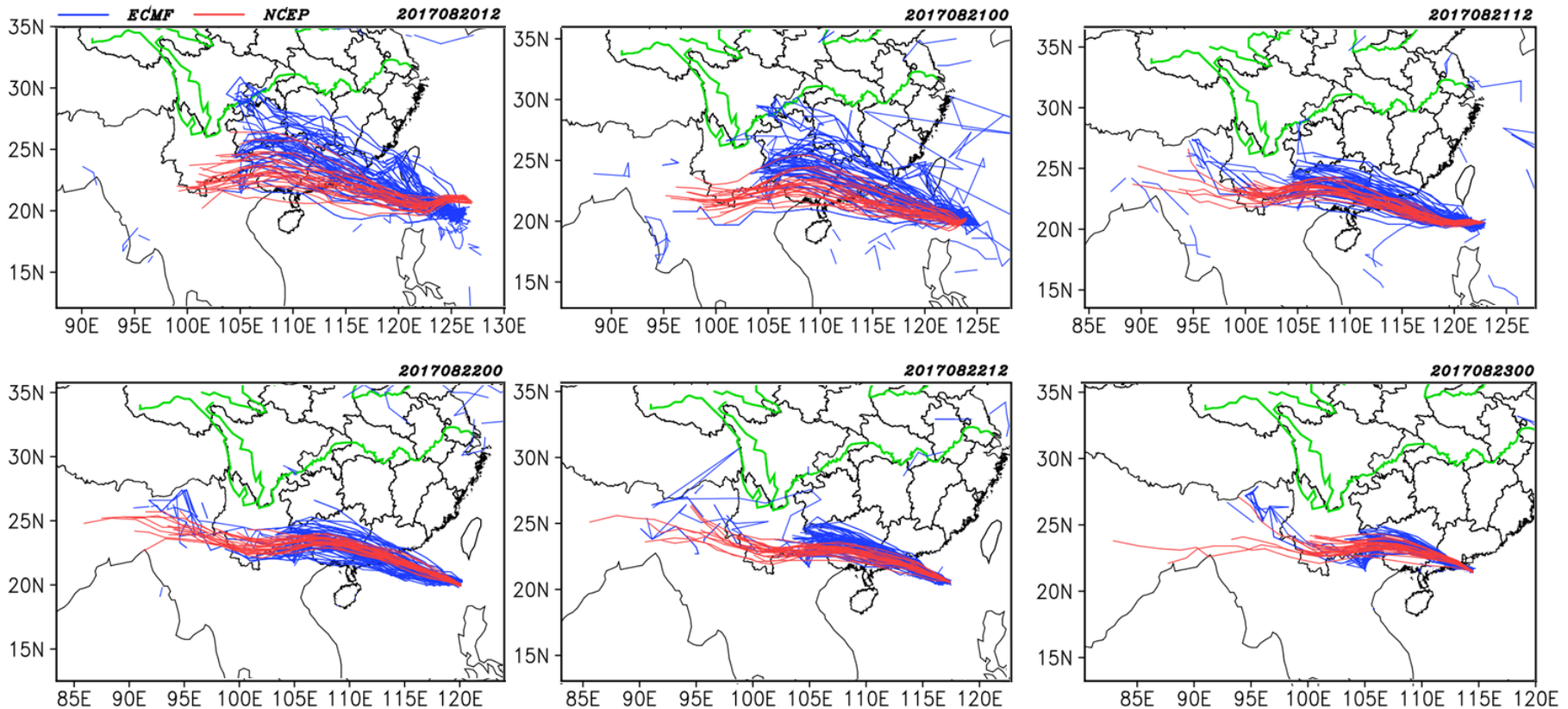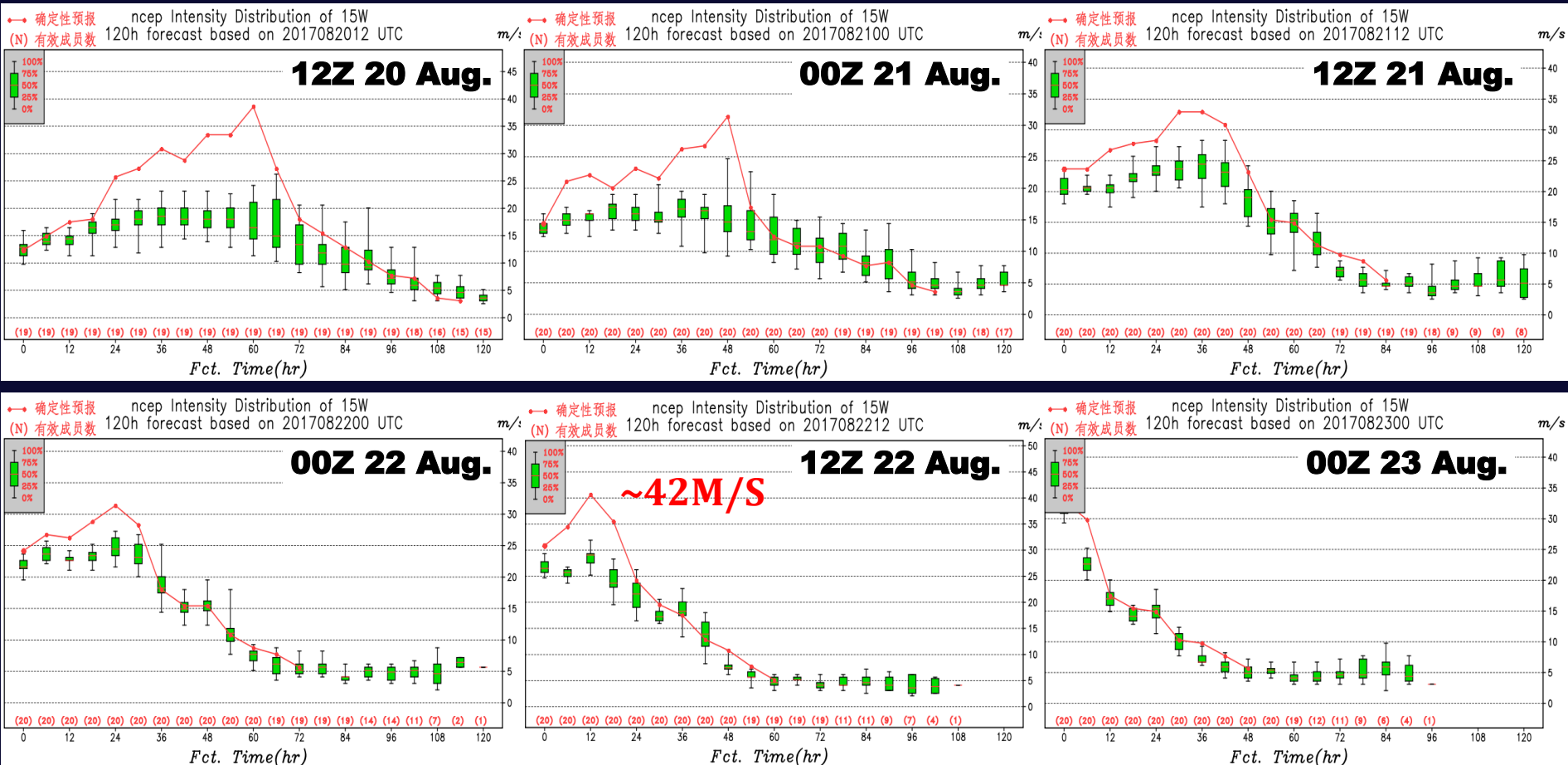
Forecast performance of Numerical Models

Analysis of intensity forecast bias of HATO. (ECMWF Ensemble)

Forecast performance of Numerical Models

Analysis of intensity forecast bias of HATO. (NCEP Ensemble)

When CMA over-estimated TC intensity?

Early Warning Service of NIDA (1604)

BABJ Track and intensity of NIDA

TD
TS
STS
TY
STY

Nida
(1604)

Jul. to Aug., 2016

Time (BJT, +8hr)

Typhoon Warning		Fcst Landfall intensity
30th 18:00	Blue	38-45m/s
31st 06:00	Blue	38-45m/s
10:00	Yellow	38-45m/s
18:00	Orange	38-45m/s
01st 06:00	Orange	40-48m/s
10:00	Orange	40-48m/s
18:00	Red	42-48m/s
02nd 03:35	Made landfall,	33m/s, 975hPa
06:00	Orange	
10:00	Yellow	
18:00	Blue	
03rd	Warning Dismissed	

An excessive defense case

The Government of Guangdong province issued the defense work emergency mobilization order.
The whole province entered the level-I emergency response status. 7 cities put the suspensions in daily work, school, traffic, market and service.

Study on RI Processed of RAMMASUN and HATO

Highlight

❑ RAMMASUN (1409)
- Environmental *V.S.* TC inner core
- Double warm core structure

❑ HATO (1713)
- Local SST distribution

RAMMASUN (1409)

The most severe typhoon landed in China (70m/s, 890 hPa) since 1949.

RI process:
- Maximum wind increases 27 m/s in 24 hrs.
                                   increase 15 m/s in 12 hrs.
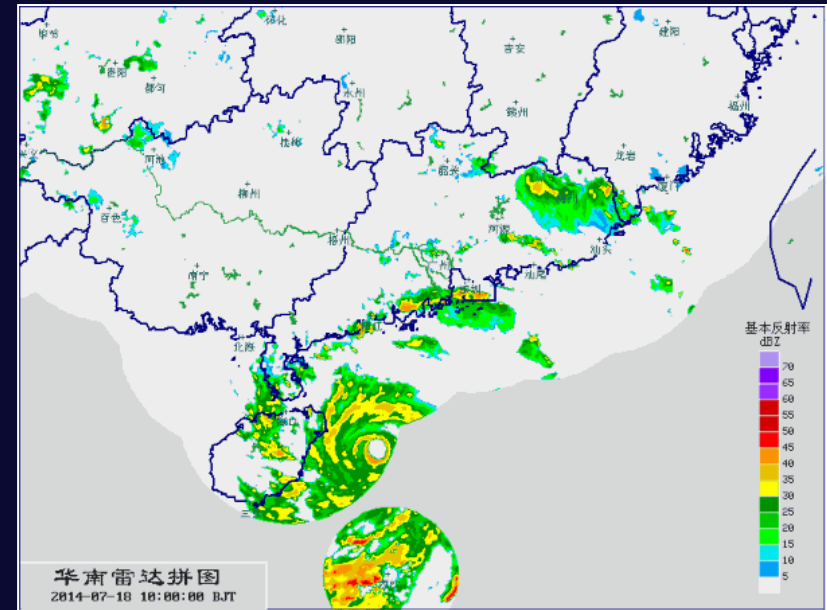- SLP_{MIN} decreases 62 hPa in 24 hrs.

Environmental situations:
<u>Favor</u> for cyclones to intensify,
but are almost <u>stable</u> during the RI process, with
- 200hPa   NE jet
- 500hPa   Subtropical high
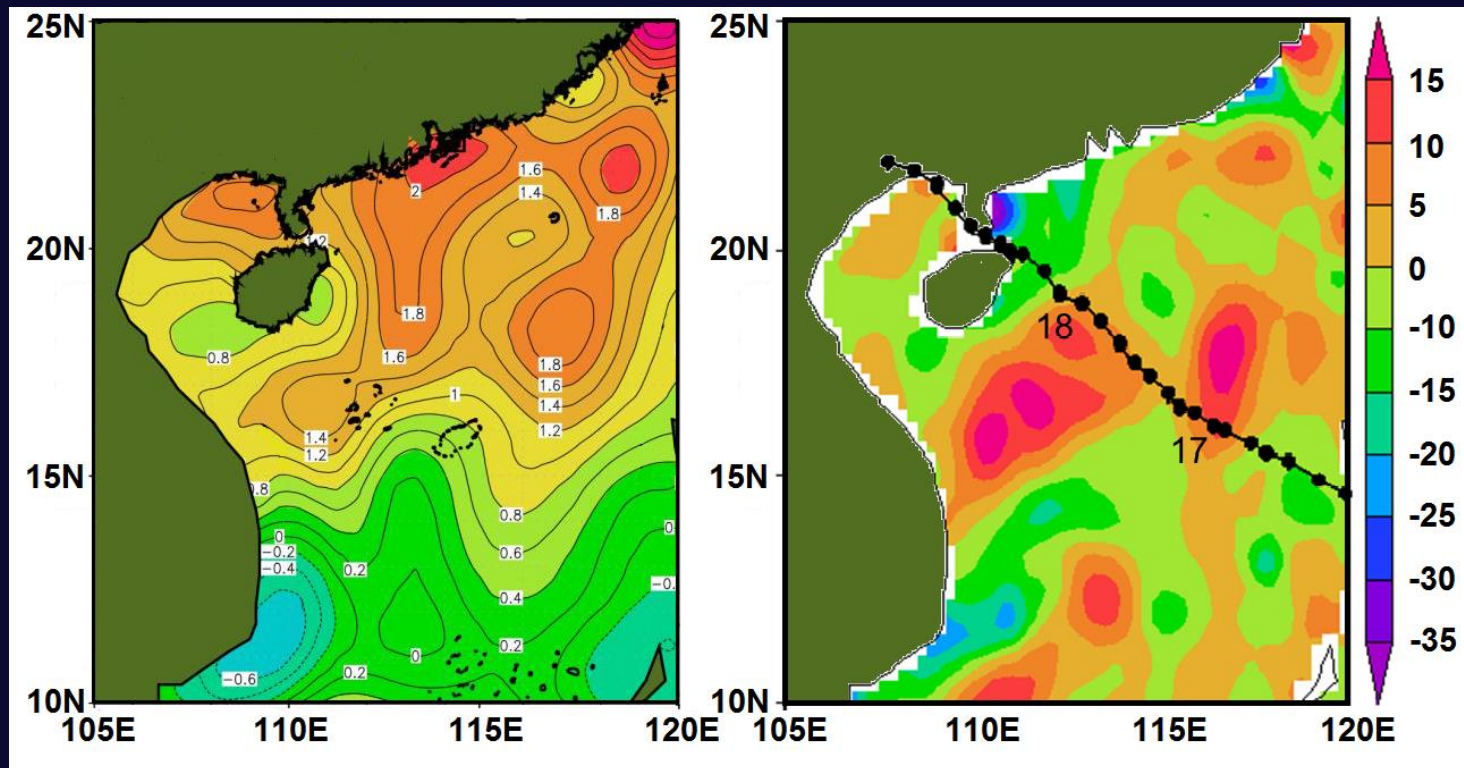- 850hPa   Monsoon trough; Somali Jet joined the cross-EQ flow

- **Maybe response to RI**
- **Vertical wind shear declined**
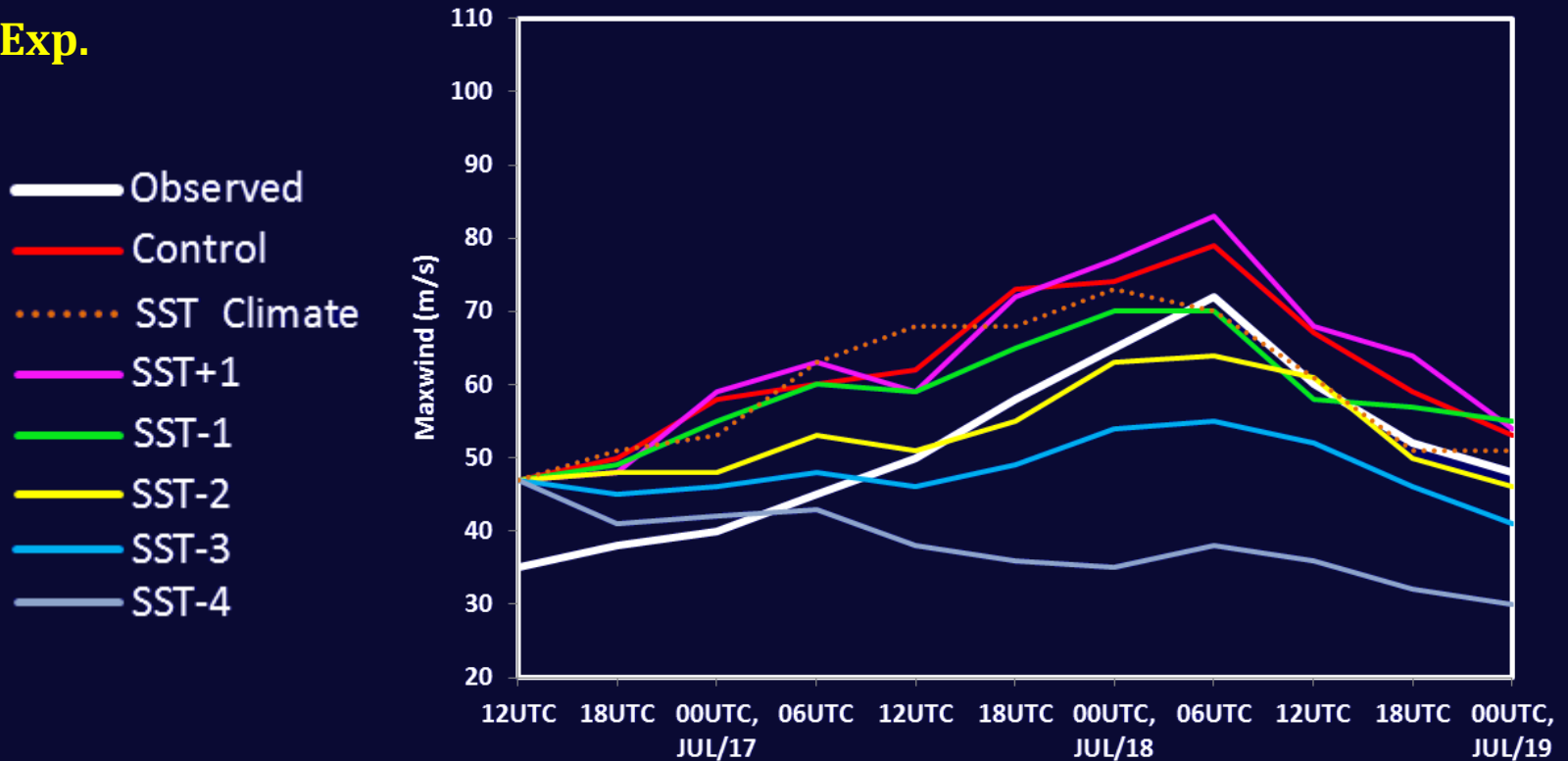- **upper-level outflow increase**

Radar imagery during landfall

RAMMASUN (1409) the role of the ocean

Deep and warm water in the northern part of SCS, with SST > 30ºC (1~2ºC higher than climatology), with warm eddied in the forecast track of typhoon.

RAMMASUN (1409) the role of the ocean
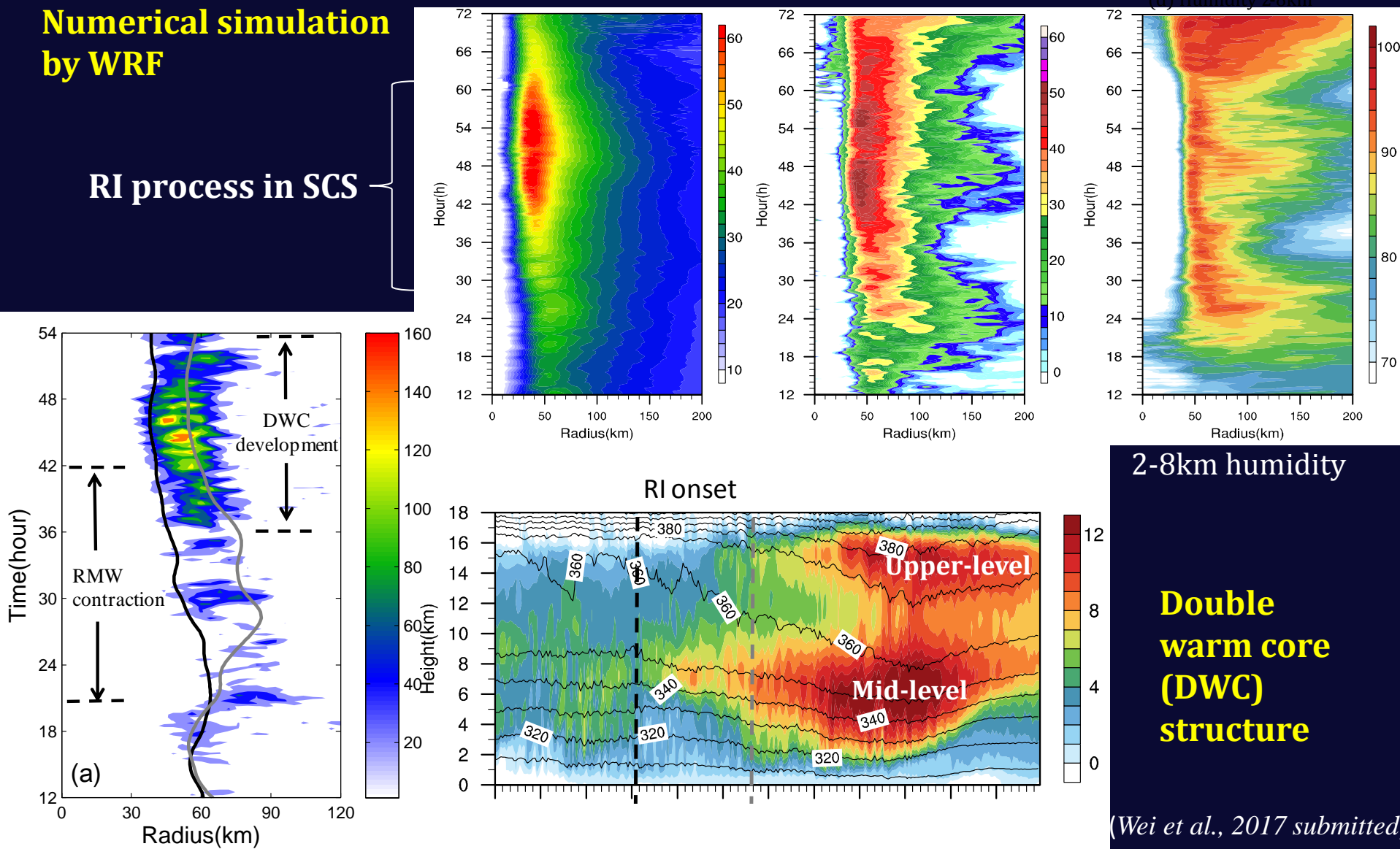
Sensitive Exp.

- **The RI process is sensitive to the SST.**
- **SST still plays a significant role to the intensity of cyclones over SCS under favorable large-scale circulations.**

RAMMASUN (1409) the TC inner-core

Numerical simulation by WRF

RI process in SCS

(d) Humidity 2-8km

2-8km humidity

Double warm core (DWC) structure

(Wei et al., 2017 submitted
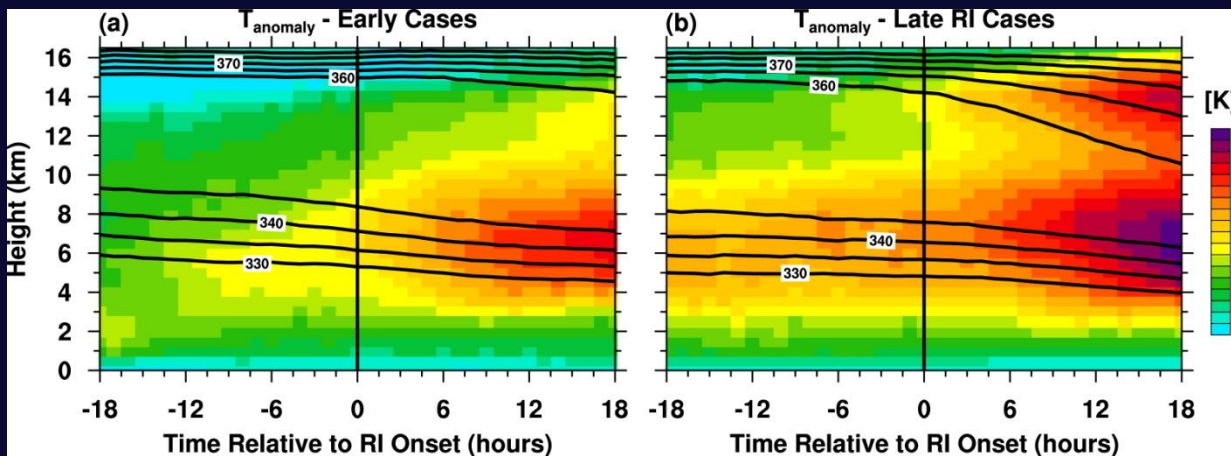
RAMMASUN (1409) the TC inner-core

Performance in ensemble members
-- A case study on RI Hurricane Earl (2010)
**Blue: Early RI members**
- **Accompany RMW contractions**
- **Have only a single warm core structure**

Red: Late RI members
- **Did not significantly contract in RMW**
- **Have double warming structure**

Time–height composites of the temperature anomaly at the storm center from (a) early and (b) late RI cases (shading), overlaid with potential temperature isotherms from 330 to 345 K and 360 to 380 K (contours, 5-K intervals).
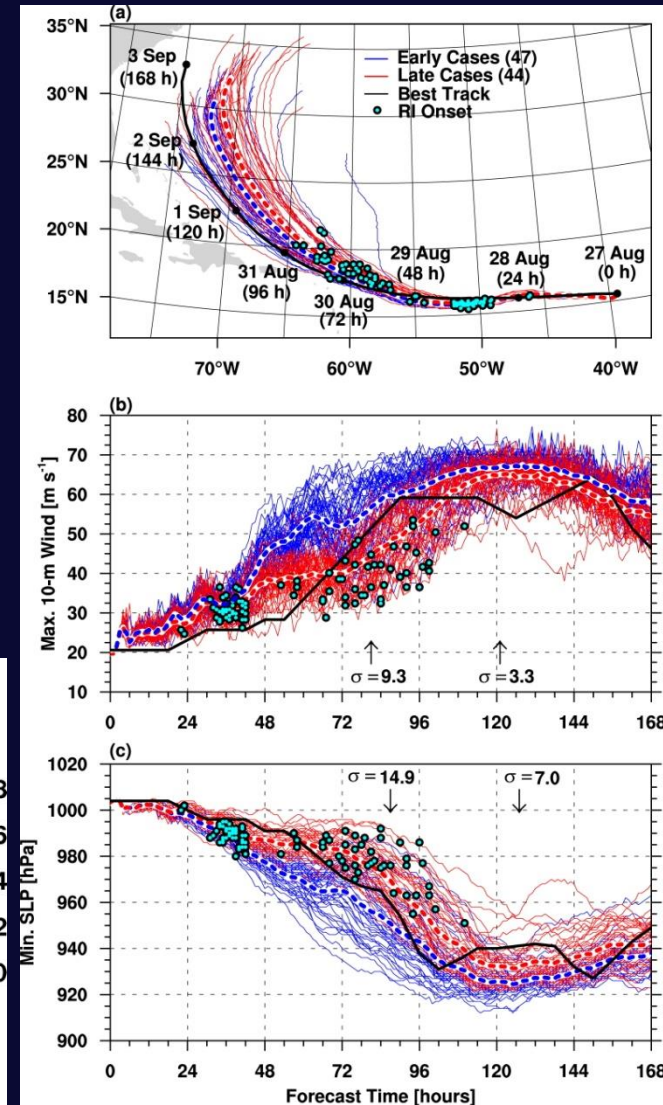
(Judt and Chen., 2016)

HATO (1713)

The most severe typhoon landed in China in 2017.

RI process:
- Maximum wind increases 23 m/s in 24 hrs.
  increase 13 m/s in 12 hrs.
- SLP_{MIN} decreases 45 hPa in 24 hrs.

Environmental situations:
Favor for cyclones to intensify
- **100hPa   Enhanced tropical easterly jet**
- **200hPa   Enhanced subtropical tropical**
- **850hPa   cross-EQ flow**

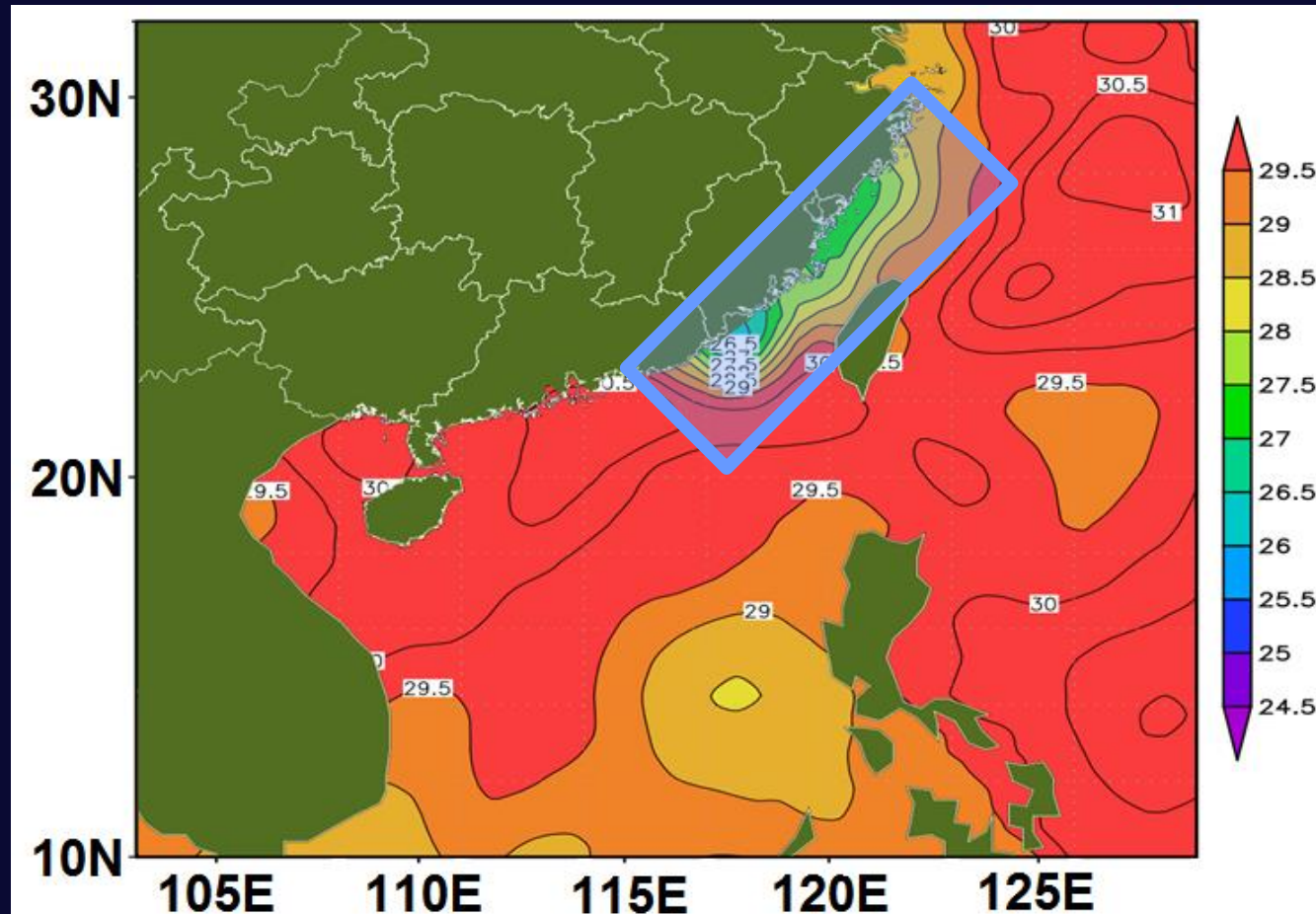Station Tai Po Kau in usual days. (~1.3m)

Station Tai Po Kau on 23rd Aug. 2017. (~4.0m)

香港地下天文台提供片段

天鴿襲港當日

(Liu Disen and Chen Shichou, 2017, NWTC-18)

HATO(1713) the role of the ocean

Lower SST < 28°C over Taiwan Strait and coastal area in the forecast track of typhoon. (21st Aug. 2017)
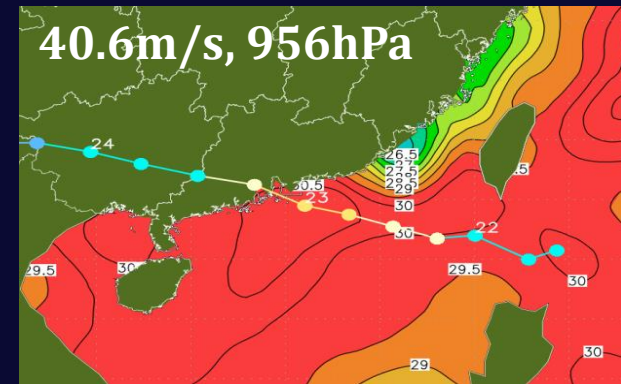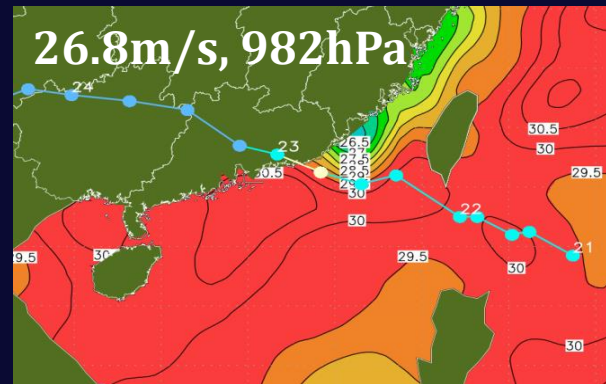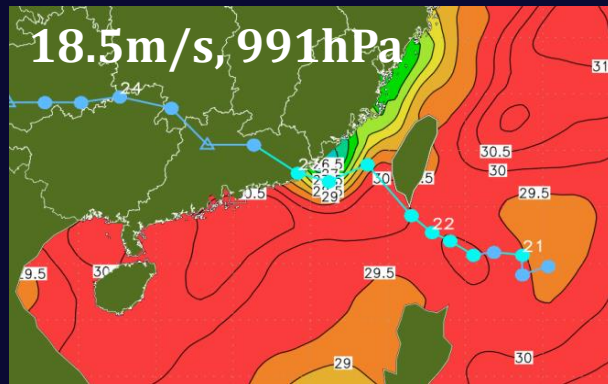
HATO(1713) the role of the ocean

EC deterministic prediction

18.5m/s, 991hPa

26.8m/s, 982hPa

40.6m/s, 956hPa

EC ensemble prediction

(member 3)

(member 33)

(member 2)

32.4m/s, 966hPa

36.0m/s, 965hPa

42.7m/s, 952hPa
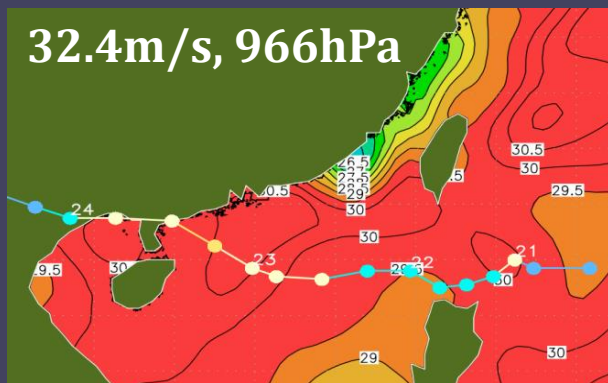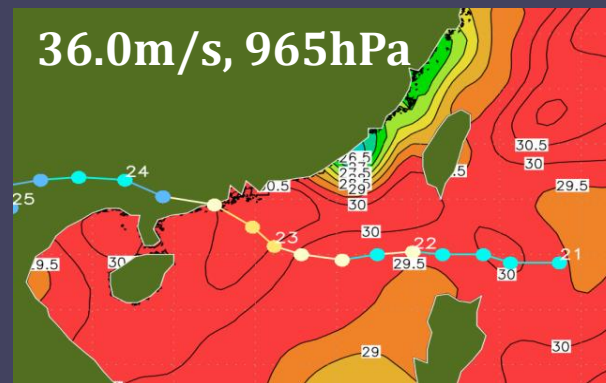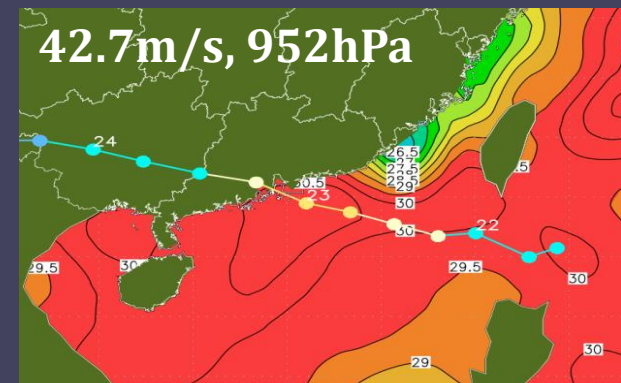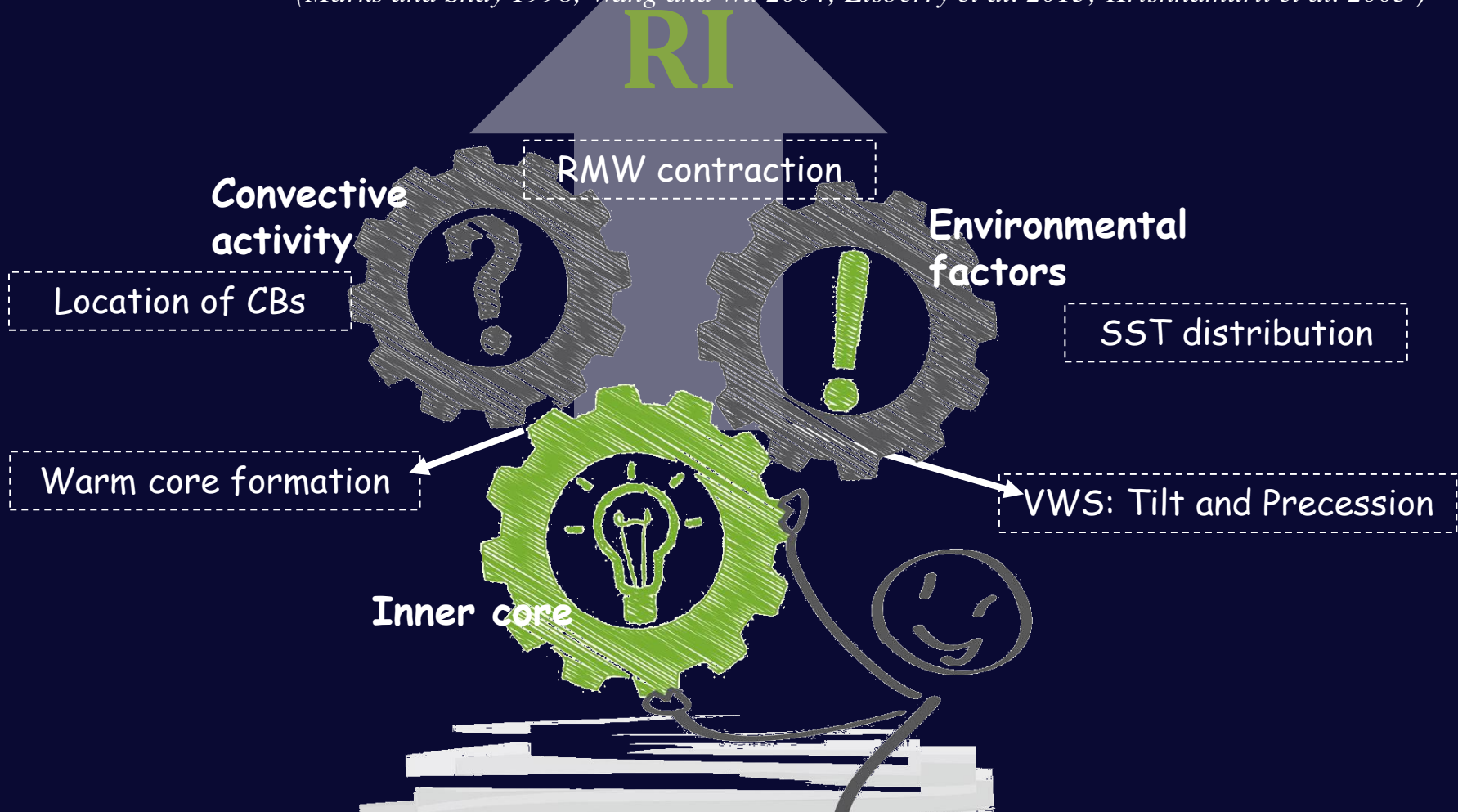
Summary and Discussions

Summary and Discussions

Why is the forecast of RI so difficult?

- **The precursors of RI have not been well identified.**
- **The main reason is that the Multi-scale interactions are not fully understood.**

(Marks and Shay 1998; Wang and Wu 2004; Elsberry et al. 2013; Krishnamurti et al. 2005)

RI

RMW contraction

Convective activity

Location of CBs

Environmental factors

SST distribution

Warm core formation

VWS: Tilt and Precession

Inner core

Summary and Discussions *highlight*

Environmental
V.S.
TC inner core
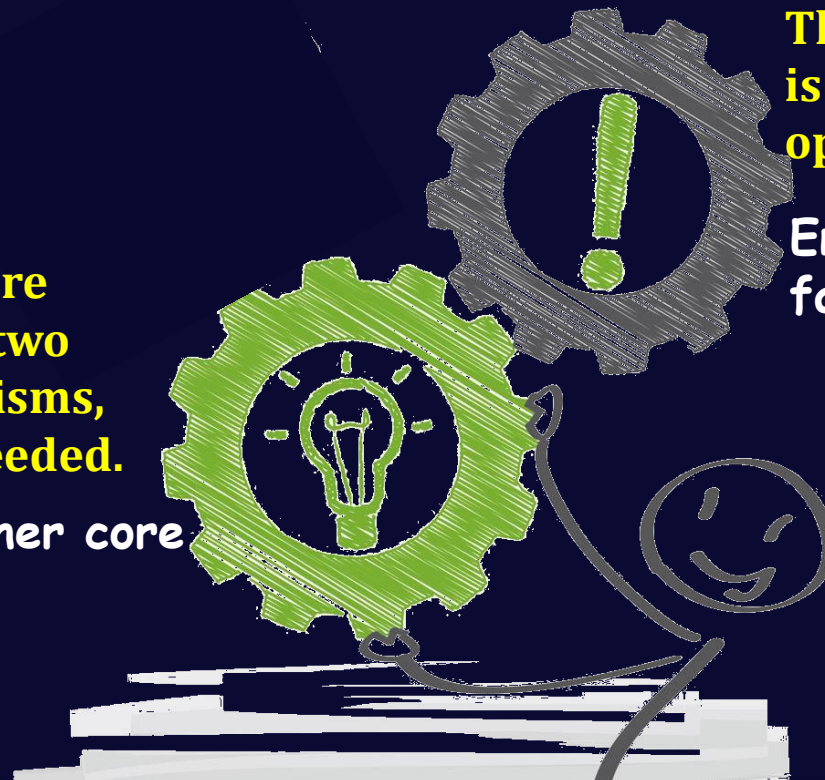
The coupled A-O models is not satisfactory in operational models

Environmental factors

The double warm core structure indicated two different RI mechanisms, more diagnosis is needed.

Inner core

Discussions on forecast of RI

- The role of a forecaster in real-time service
- The contribute of a forecaster besides models

Forecasters

- TD
- TS
- STS
- TY
- STY

23

22   21

20

HATO

Thank you for your attention!

For more discussions please contact
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National Meteorological Center of CMA

Summary and Discussions

rapid intensification favoured occurring in the daytime.
Based on a statistics from 1979 to 2012