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Statistical-dynamical Guidance and Satellite Nowcasting Method on Rapid Intensification of Super Typhoon Hato

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ESCAP/WMO Typhoon Committee Technical Conference (TECO)
26 – 27 February 2018
Hanoi, Viet Nam

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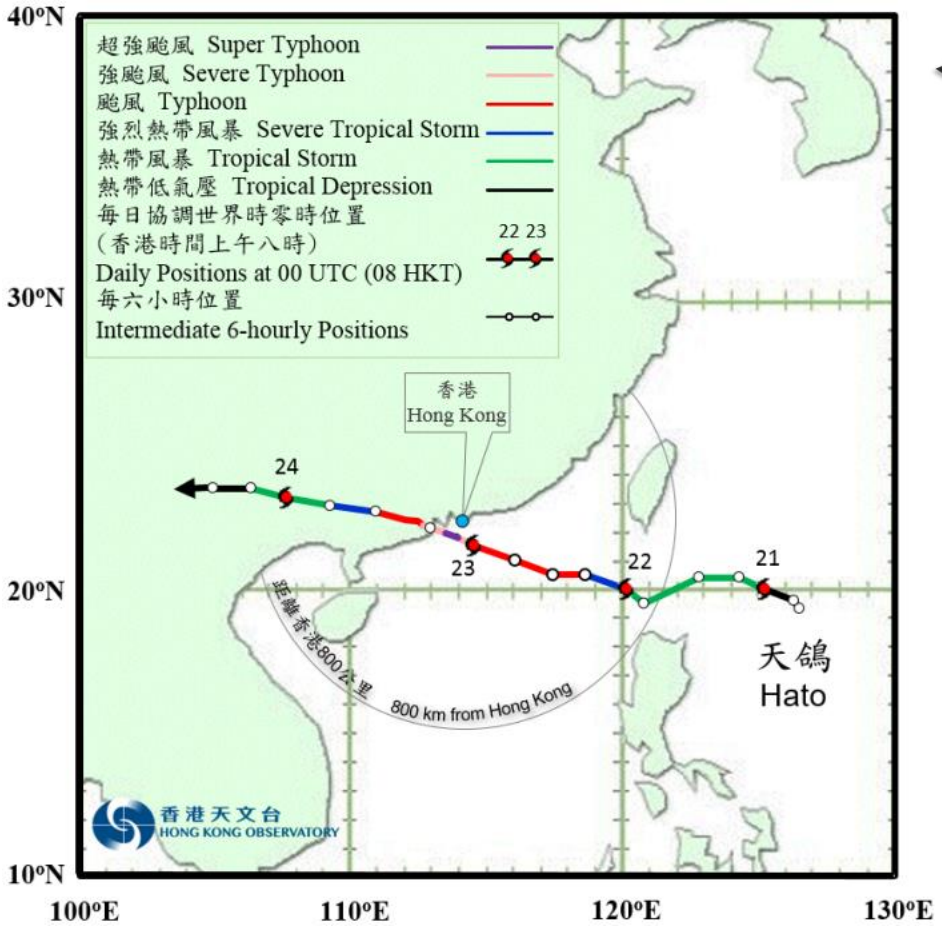
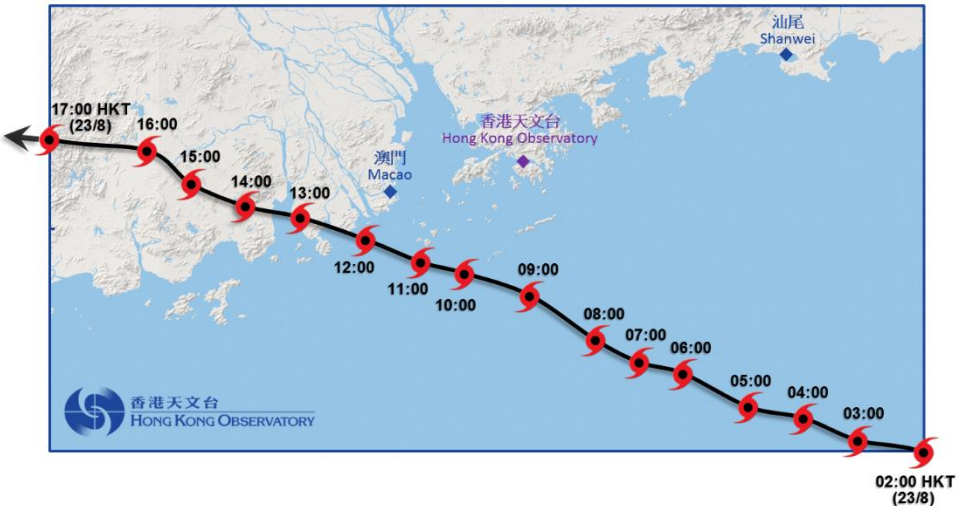
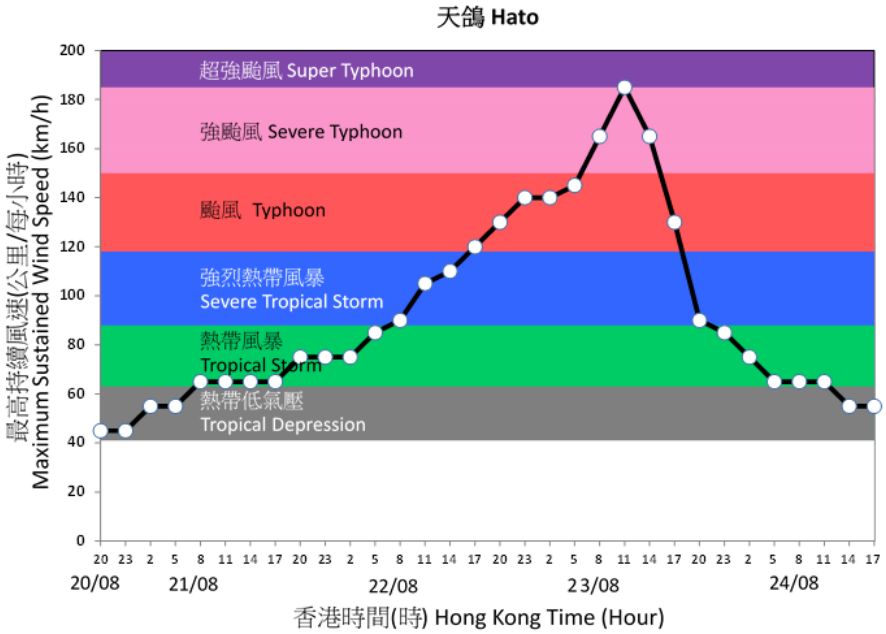
Super Typhoon Hato (1713)

20-24 August 2017







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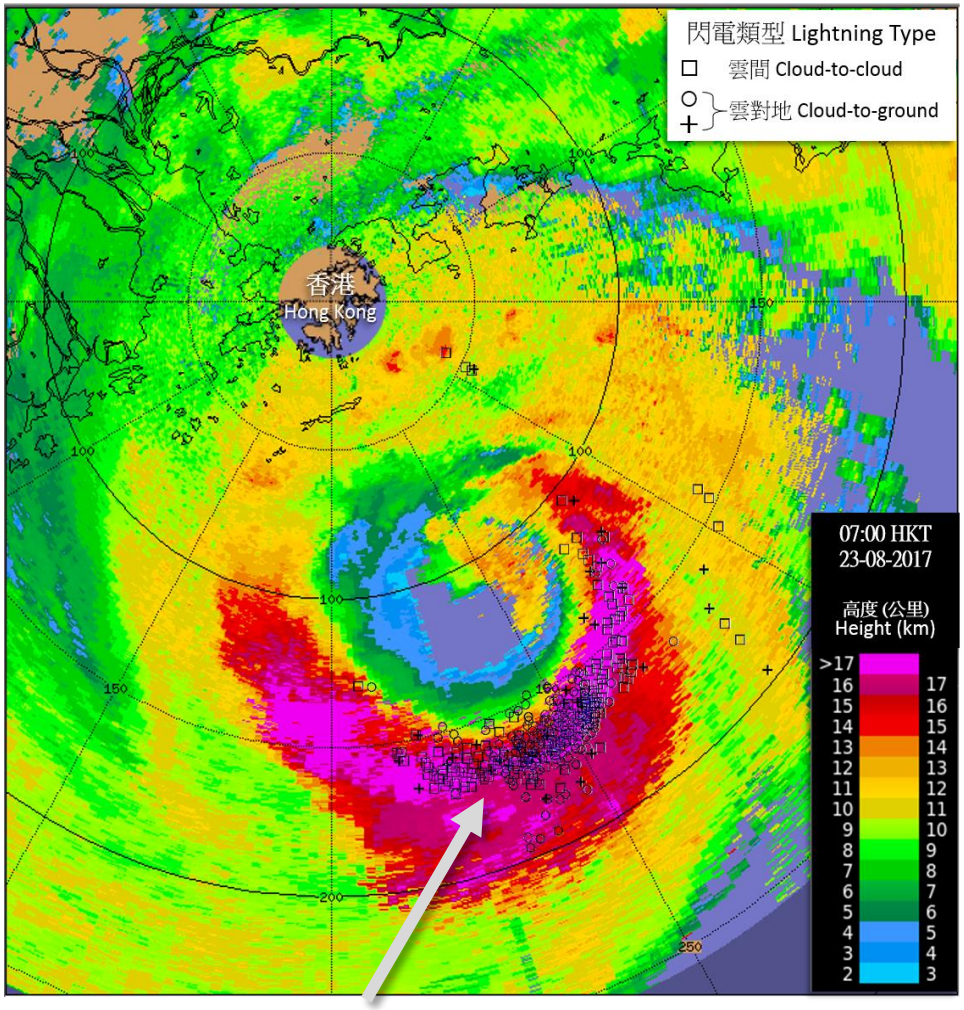
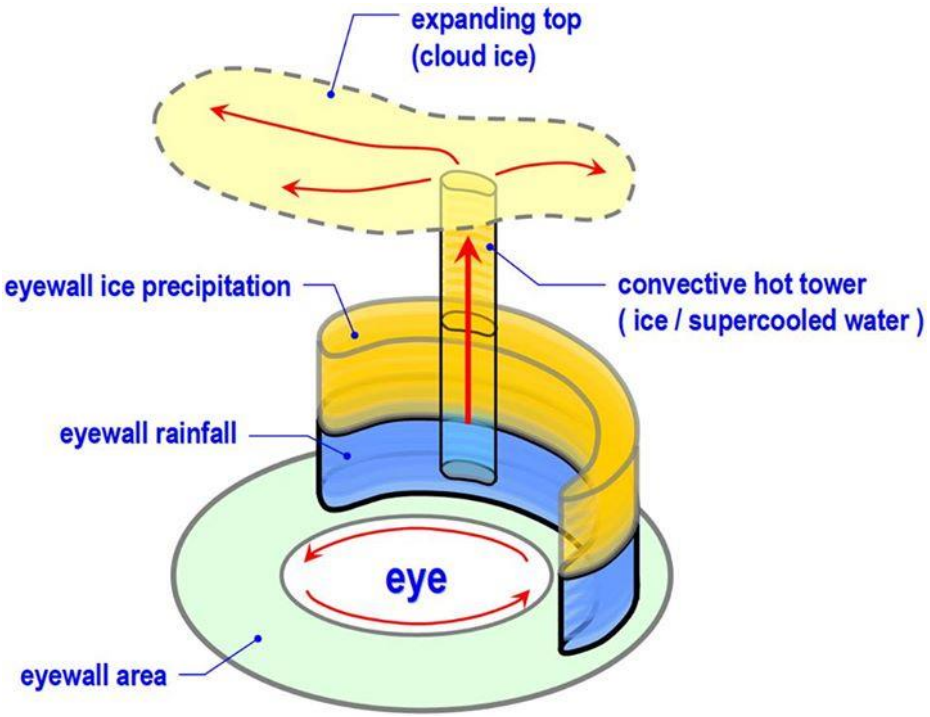
Rapid intensification of Hato



Past 30-min lightning overlaid on radar echo top at 7:00 HKT 23 Aug



Kelley, O.A., J. Stout & J.B. Halverson, 2004: Tall precipitation cells in tropical cyclone eyewalls are associated with tropical cyclone intensification. Geophysical Research Letters, Vol. 31, L24112

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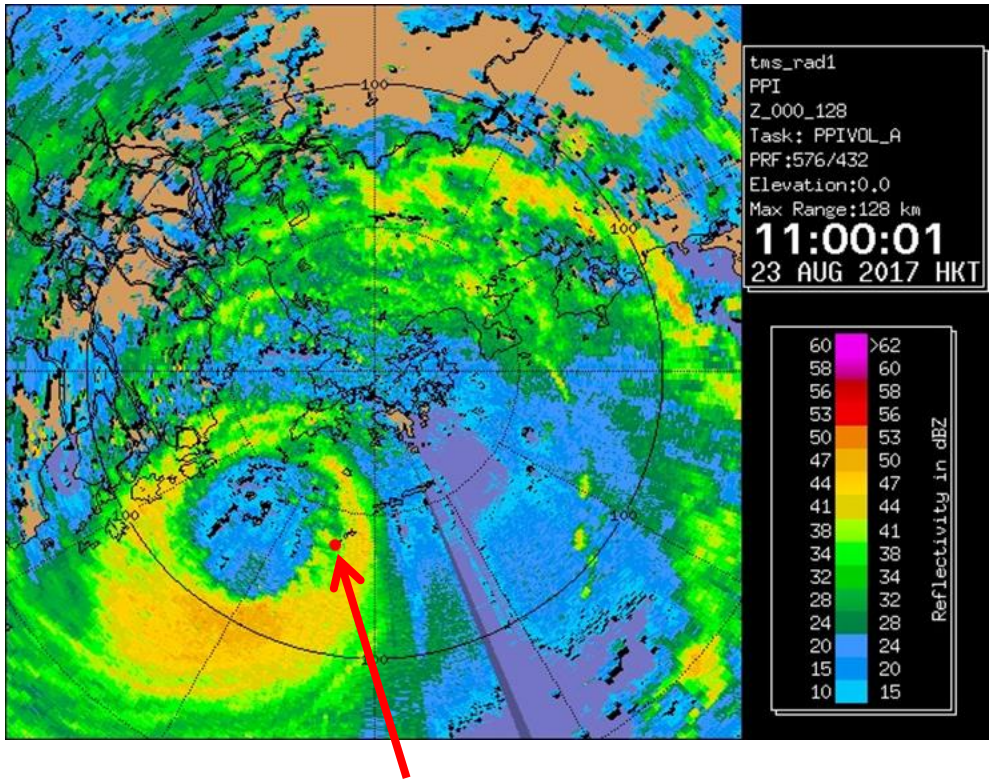

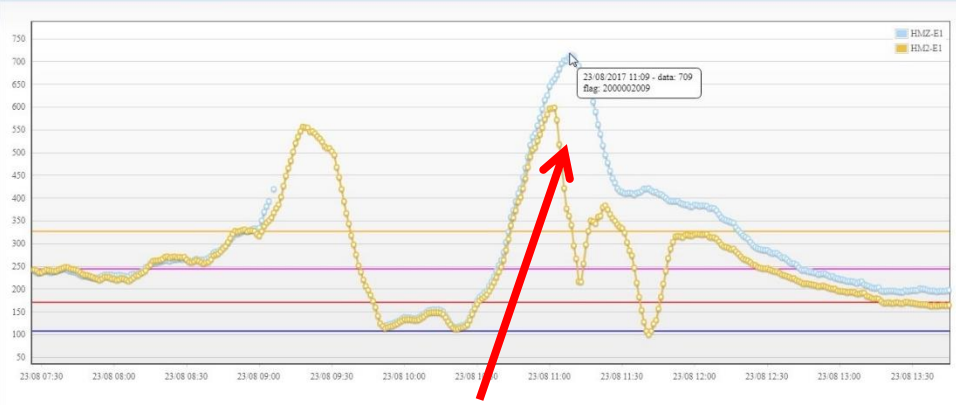

Max. 10-min mean wind at ~ 71 m/s (138 kt) at 11:09 HKT

Min MSLP of 952 hPa at 09:22 HKT

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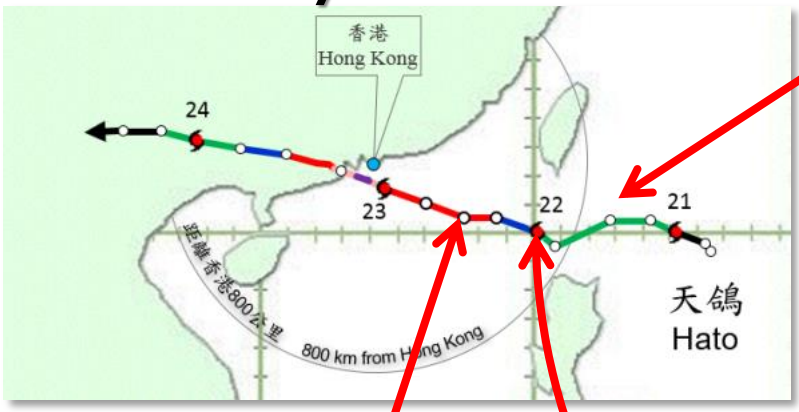
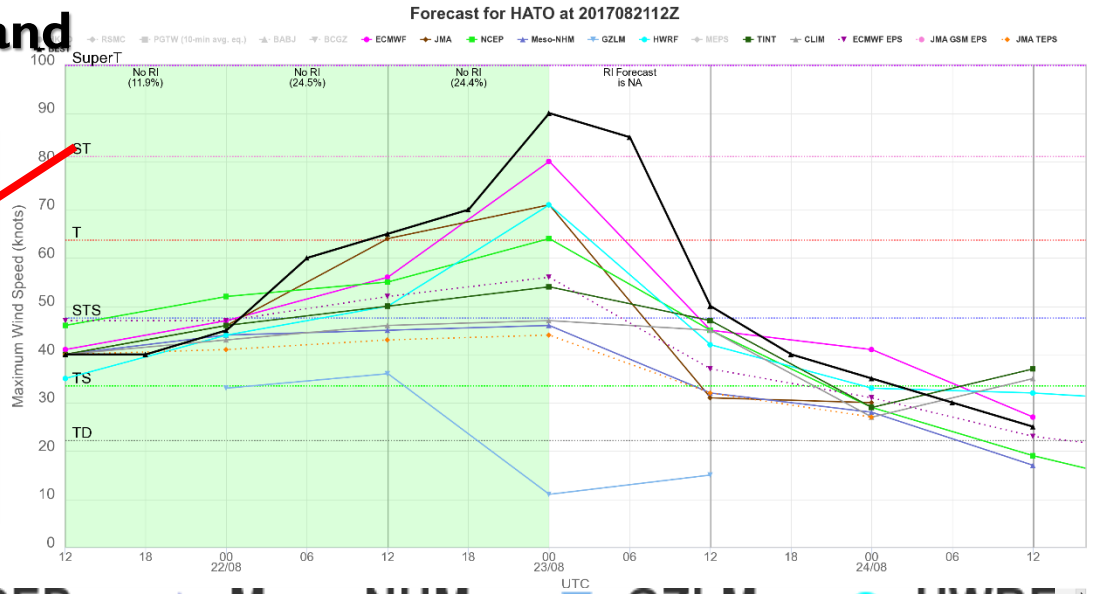
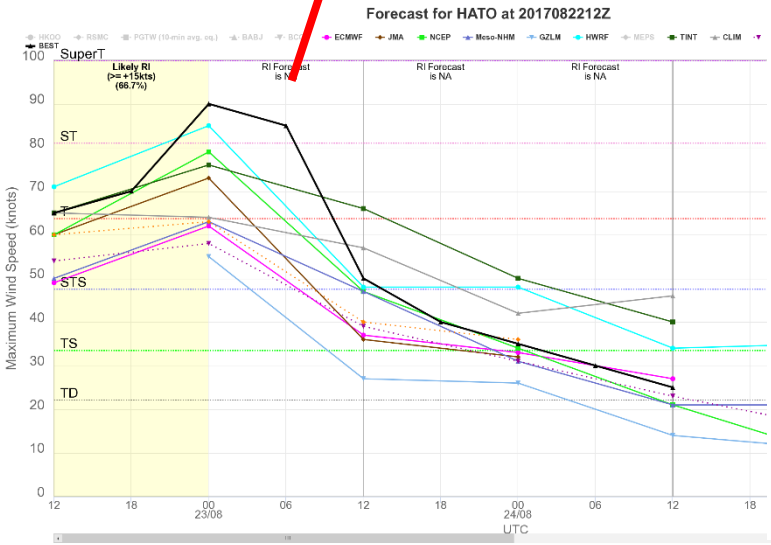
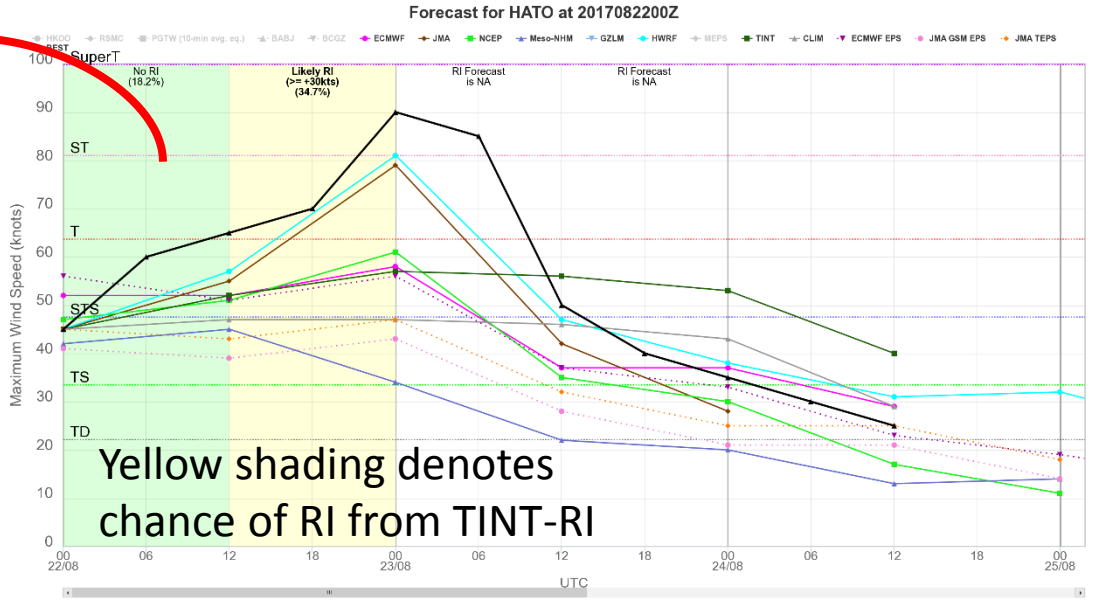
Intensity Forecasts from NWP and Statistical Dynamical Guidance





ECMWF JMA NCEP Meso-NHM GZLM HWRF
TINT CLIM ECMWF EPS JMA GSM EPS JMA TEPS





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A Statistical-dynamical Forecast Guidance on Rapid Intensification of Tropical Cyclone

- Rapid Intensification (RI) is commonly defined by the 95th percentile of intensity change (ref: Kaplan et al. 2010), e.g. RI over the Atlantic and ENP basins would be +30 kt / 24 hrs (1-min average)

- After converting to the WMO 10-min average, RI definition in the western North Pacific and the South China Sea adopt in the study shown in table ➔

Hours	WNP	Atlantic
12 hours	+ 15 kt	+ 20 kt
24 hours	+ 25 kt	+ 30 kt
36 hours	+ 40 kt	+ 45 kt
48 hours	+ 50 kt	+ 55 kt

(Reference : J. Kaplan, M. DeMaria, and J. A. Knaff, 2010: A Revised Tropical Cyclone Rapid Intensification Index for the Atlantic and Eastern North Pacific Basins. *Wea. Forecasting*, **25**, 220-241.)

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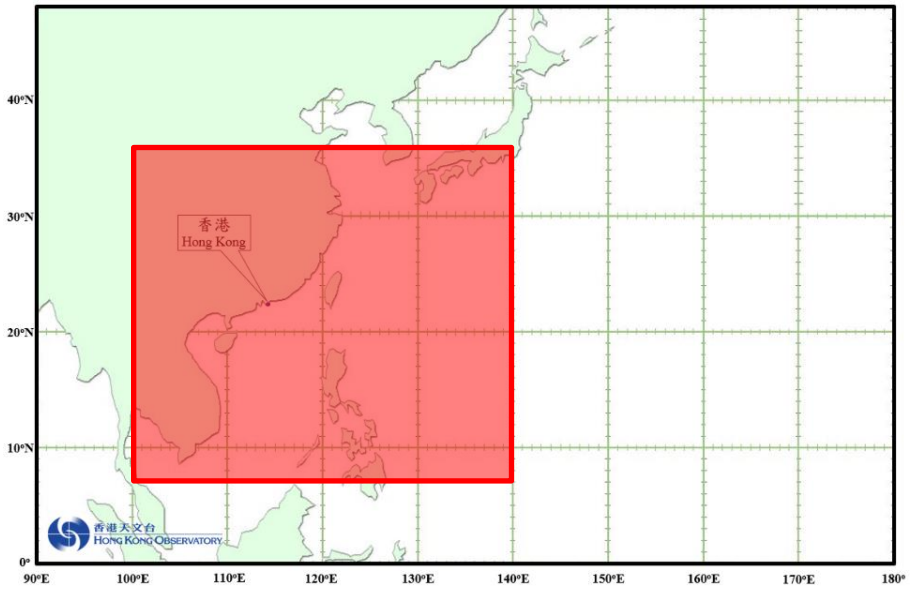
TINT-RI

- a statistical-dynamical forecasting module of HKO's TC INTensity forecast model (TINT) on the probability of RI of tropical cyclones over the western North Pacific, up to the next 48 hours

- Training Data Set
  - HKO Best track data (2009 – 2015)
  - Predictors in TINT-RI including atmospheric and oceanic components ➔

HKO Forecast Area over WNP
7 – 36ºN, 100 – 140º E



Predictors in TINT-RI	
ECMWF ERA-Interim Reanalysis	200hPa Divergence 300-500hPa RH 850-200hPa Vertical Wind Shear (VWS)
HKO TC Best Track	Current Intensity Persistence (i.e. previous 12-hour intensity change)
NOAA AOML TCHP	Tropical Cyclone Heat Potential

Reference:

IWTCLP-4: A Statistical-dynamical Forecast Guidance on Rapid- Intensification

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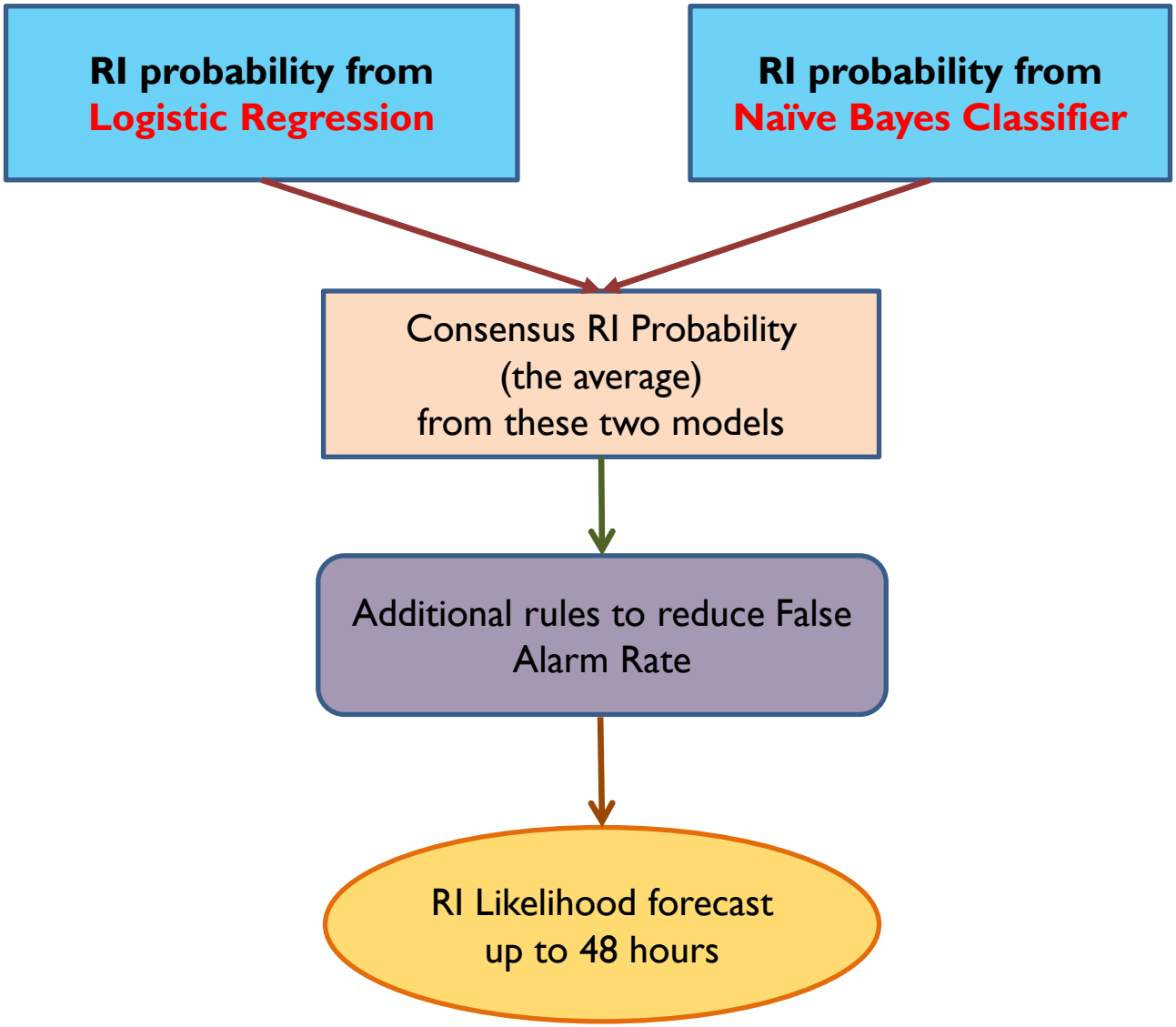
Framework in TINT-RI



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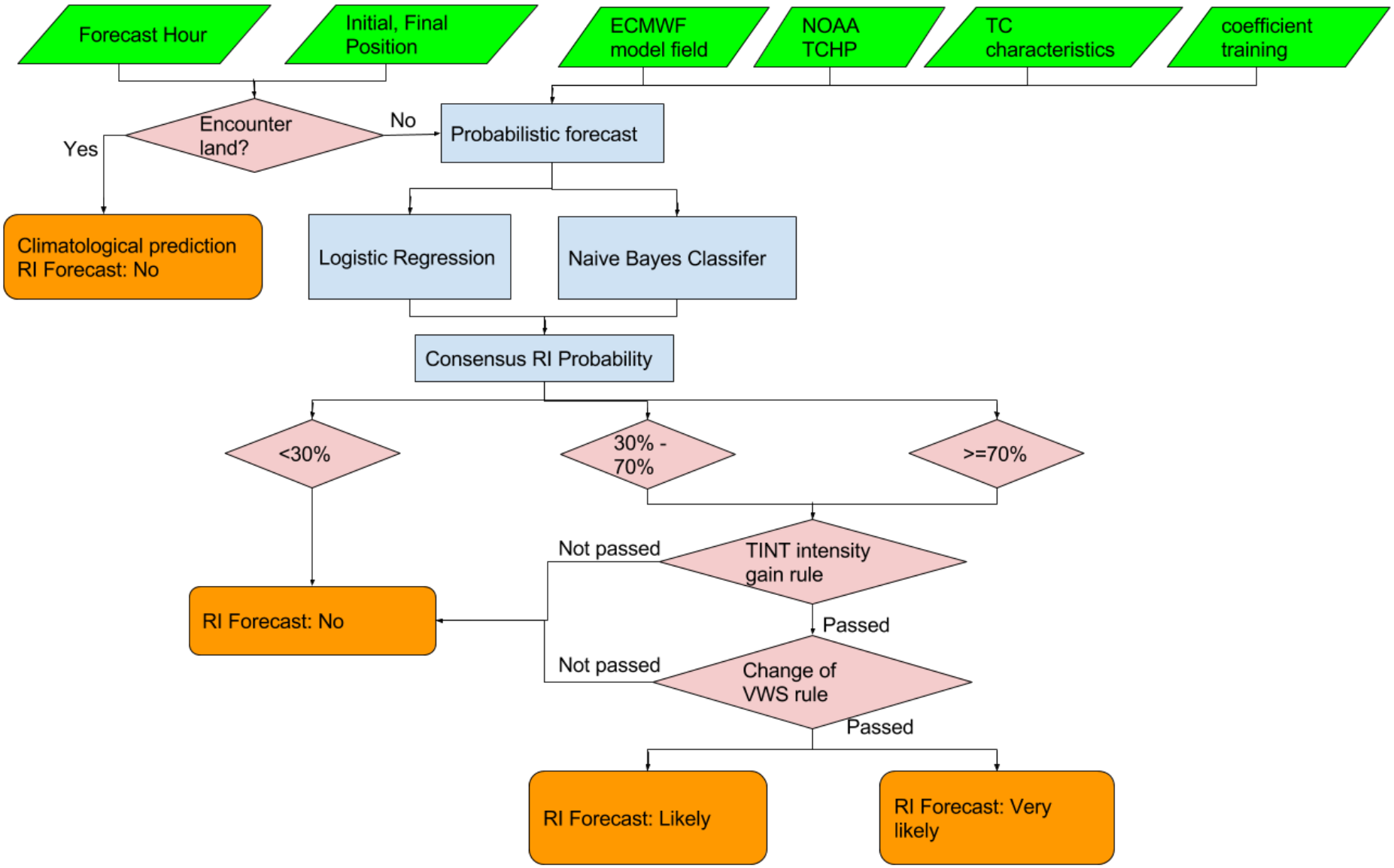
Overall Flow Chart of TINT-RI Operation



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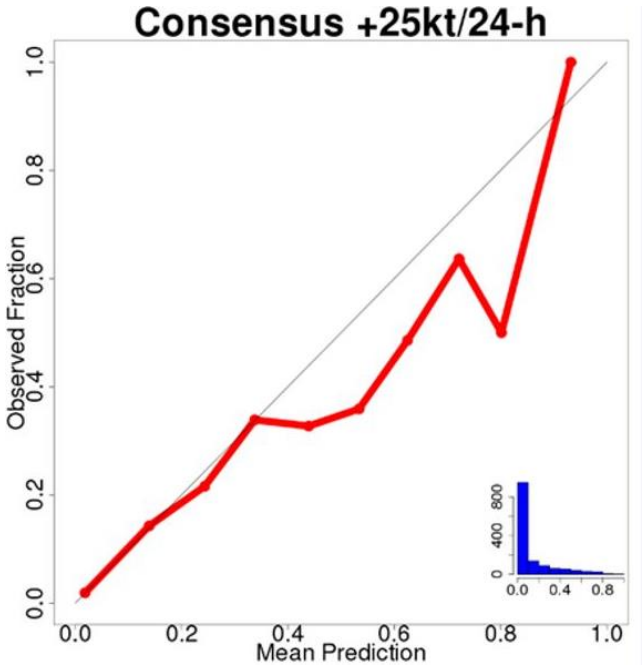
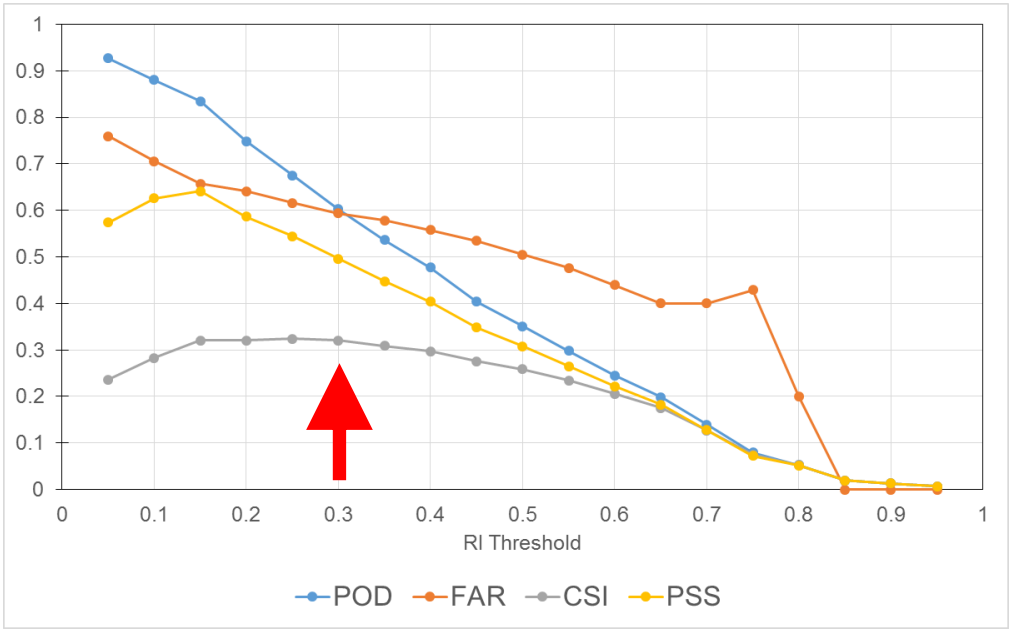
Consensus RI probability

- To optimize the performance, consider consensus RI probability (P_{con})

  $P_{con} = ½(P_{LogR} + P_{Bayes})$

- RI Threshold chosen as 0.3 where the CSI is about maximum





Training data from 2009 to 2015

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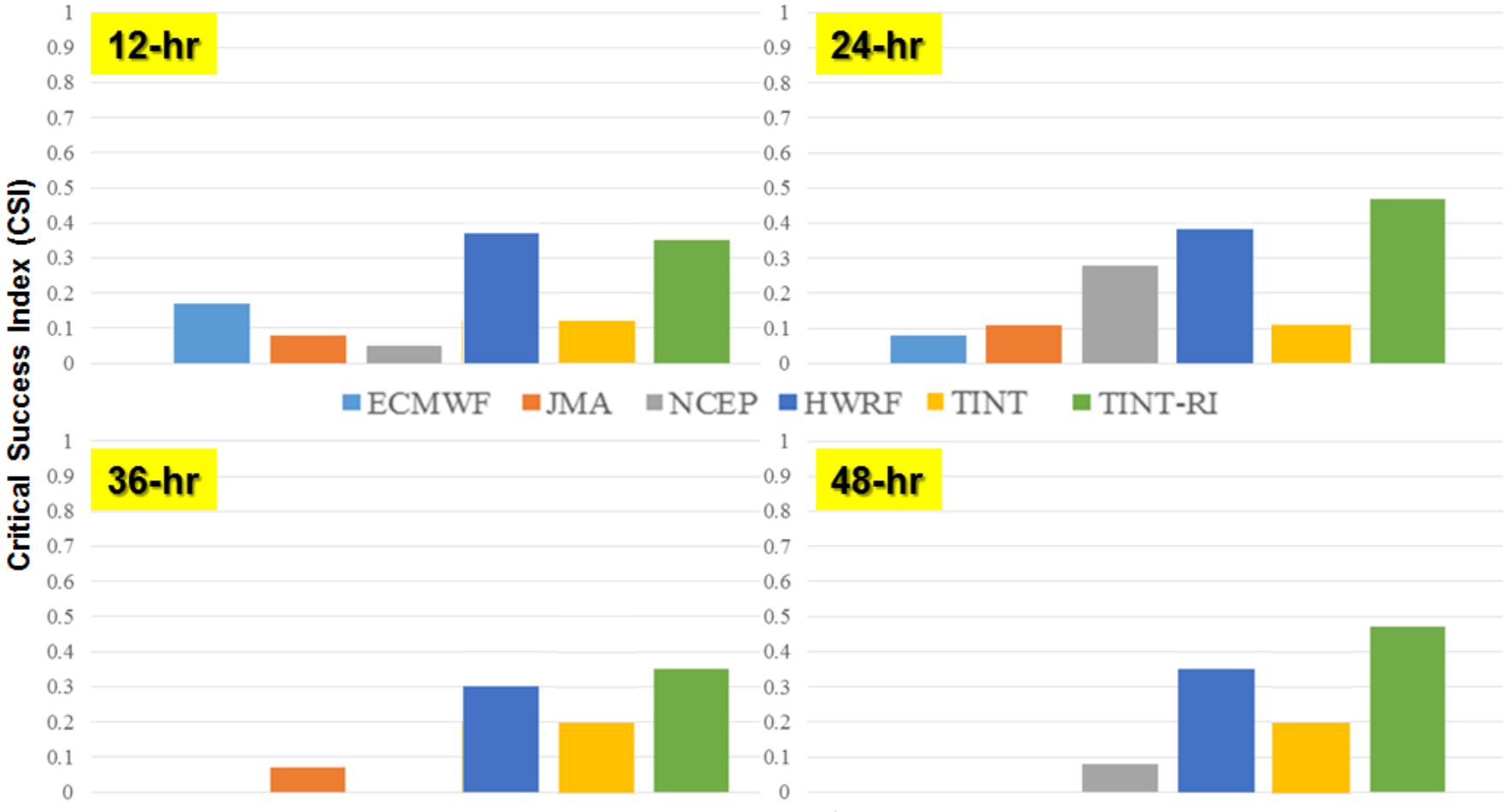
Performance of TINT-RI vs NWP

TINT-RI has been put into trial operation since the TC season of 2016. Over a hundred of forecasts were issued (RI occurred for 12 TCs out of 15 in total) with CSI shown below



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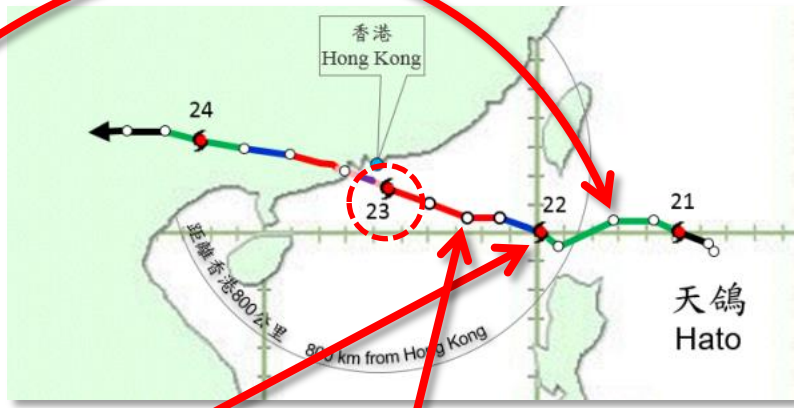
Forecast at 23/00Z

TINT Rapid Intensification Module (TINT-RI)

2017 | Hato(HKID1716) | 2017082112Z

TINT-RI Forecast for Hato at 2017082112Z

	T+12 2200Z	T+24 2212Z	T+36 2300Z	T+48 2312Z
RI Forecast	No	No	No	NA
Intensity gain from T+0 (T+0: 40 knots)	---	---	---	---
TINT intensity gain rule	Passed	Passed	Passed	NA
Change of VWS rule	Passed	Passed	Passed	Passed
RI Probability	11.9%	24.5%	24.4%	NA
Actual RI Occurrence based on Best track (Intensity gain)	N	Y(25knots)	Y(50knots)	N



TINT Rapid Intensification Module (TINT-RI)

2017 | Hato(HKID1716) | 2017082200Z

TINT-RI Forecast for Hato at 2017082200Z

	T+12 2212Z	T+24 2300Z	T+36 2312Z	T+48 2400Z
RI Forecast	No	**Likely**	NA	NA
Intensity gain from T+0 (T+0: 45 knots)	---	>=25knots	---	---
TINT intensity gain rule	Passed	Passed	NA	NA
Change of VWS rule	Passed	Passed	Passed	Passed
RI Probability	18.2%	34.7%	NA	NA
Actual RI Occurrence based on Best track (Intensity gain)	Y(20knots)	Y(45knots)	N	N

TINT Rapid Intensification Module (TINT-RI)

2017 | Hato(HKID1716) | 2017082212Z

TINT-RI Forecast for Hato at 2017082212Z

	T+12 2300Z	T+24 2312Z	T+36 2400Z	T+48 2412Z
RI Forecast	**Likely**	NA	NA	NA
Intensity gain from T+0 (T+0: 65 knots)	>=15knots	---	---	---
TINT intensity gain rule	Passed	NA	NA	NA
Change of VWS rule	Passed	Passed	Passed	Passed
RI Probability	66.7%	NA	NA	NA
Actual RI Occurrence based on Best track (Intensity gain)	Y(25knots)	N	N	N

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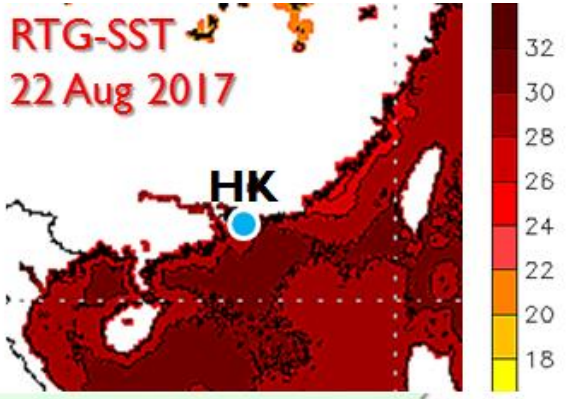
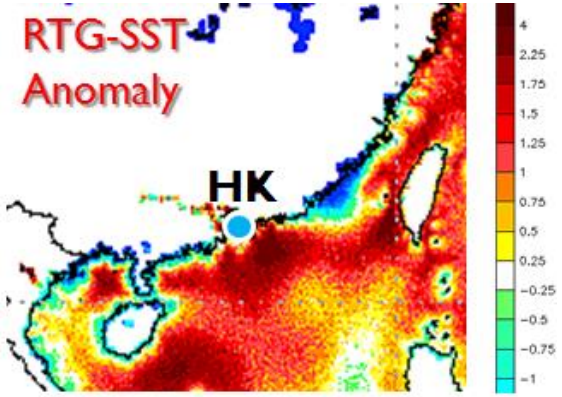
RI potential from SST and SST-anomaly

- As a potential way to improve RI forecasts, probabilistic models were re-trained using the maximum SST and SST anomaly along the forecast track to replace TCHP.
- Using along track maximum SST, TINT-RI successfully forecasted Hato's RI initiation at 21 Aug 12Z, 12 hours before the operational run





TCHP (Operational Run)

TINT Rapid Intensification Module (TINT-RI)

2017 | Hato(HKID1716) | 2017082112Z

TINT-RI Forecast for Hato at 2017082112Z

	T+12 2200Z	T+24 2212Z	T+36 2300Z	T+48 2312Z
RI Forecast	No	No	No	NA
Intensity gain from T+0 (T+0: 40 knots)	---	---	---	---
TINT intensity gain rule	Passed	Passed	Passed	NA
Change of VWS rule	Passed	Passed	Passed	Passed
RI Probability	11.9%	24.5%	24.4%	NA
Actual RI Occurrence based on Best track (Intensity gain)	N	Y(25knots)	Y(50knots)	N

Max SST (Rerun)

T+12	T+24	T+36	T+48
No	Likely (≥30kt)	No	NA
23.9%	39.7%	4.3%	NA

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TC intensity and RI Nowcast

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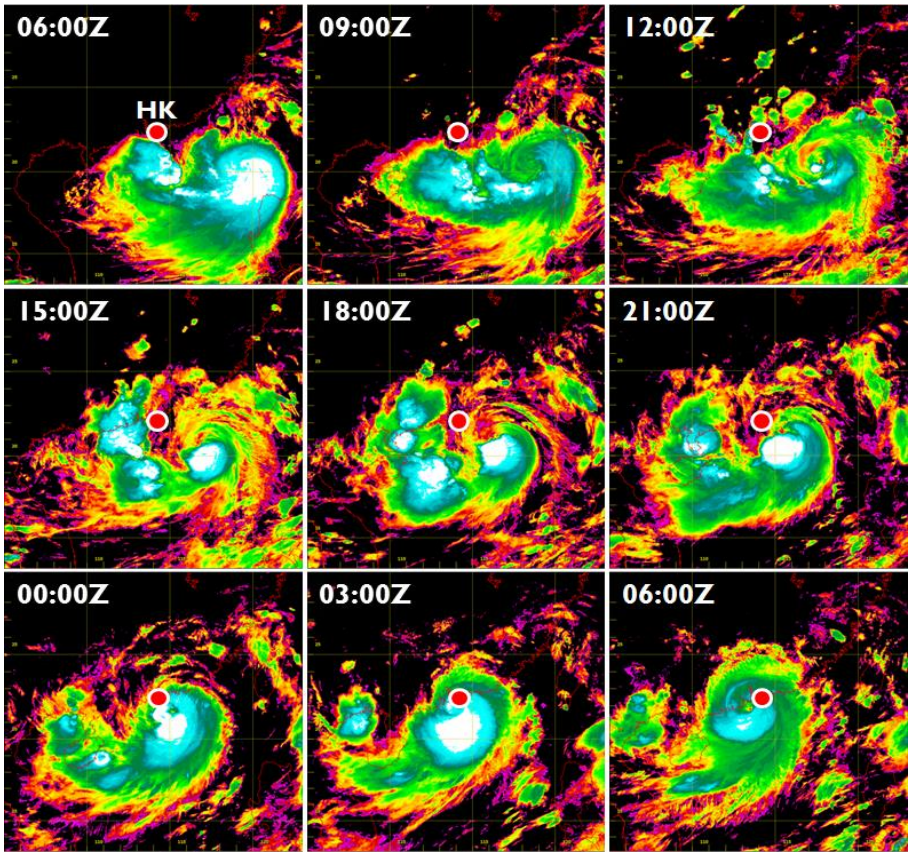
Nowcasting RI of Hato from Himawari-8 data

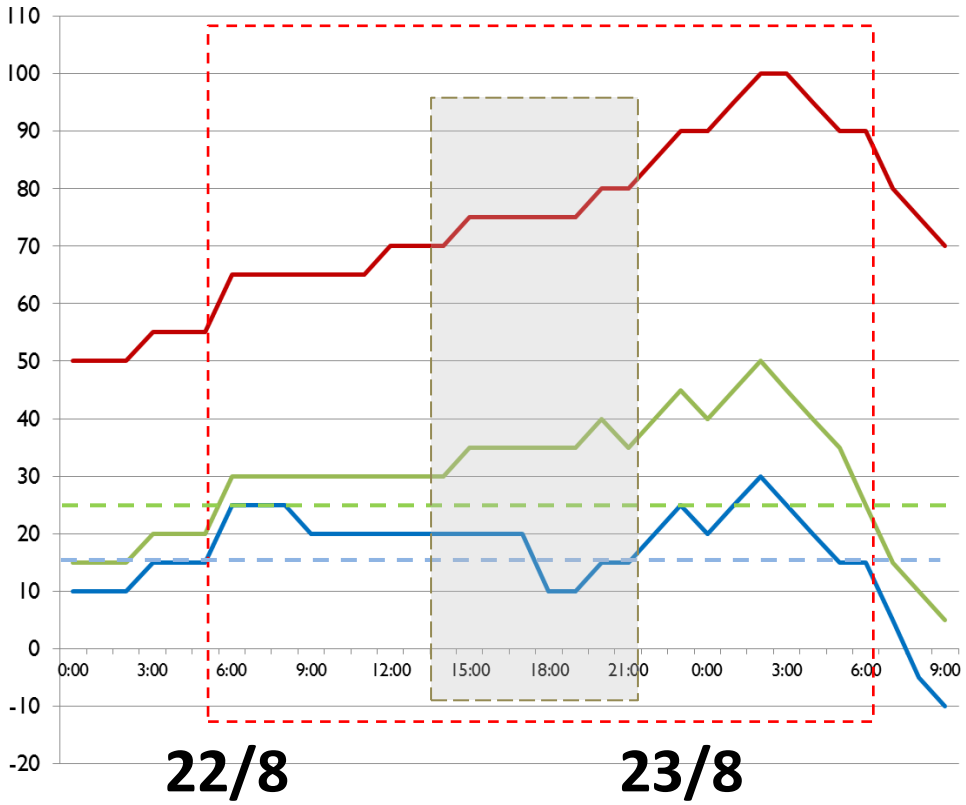
22/8

Hot-Tower Color Enhancement of AHI IR1 channel



23/8

Hours	RI thresholds for WNP
12 hours	+ 15 kt
24 hours	+ 25 kt



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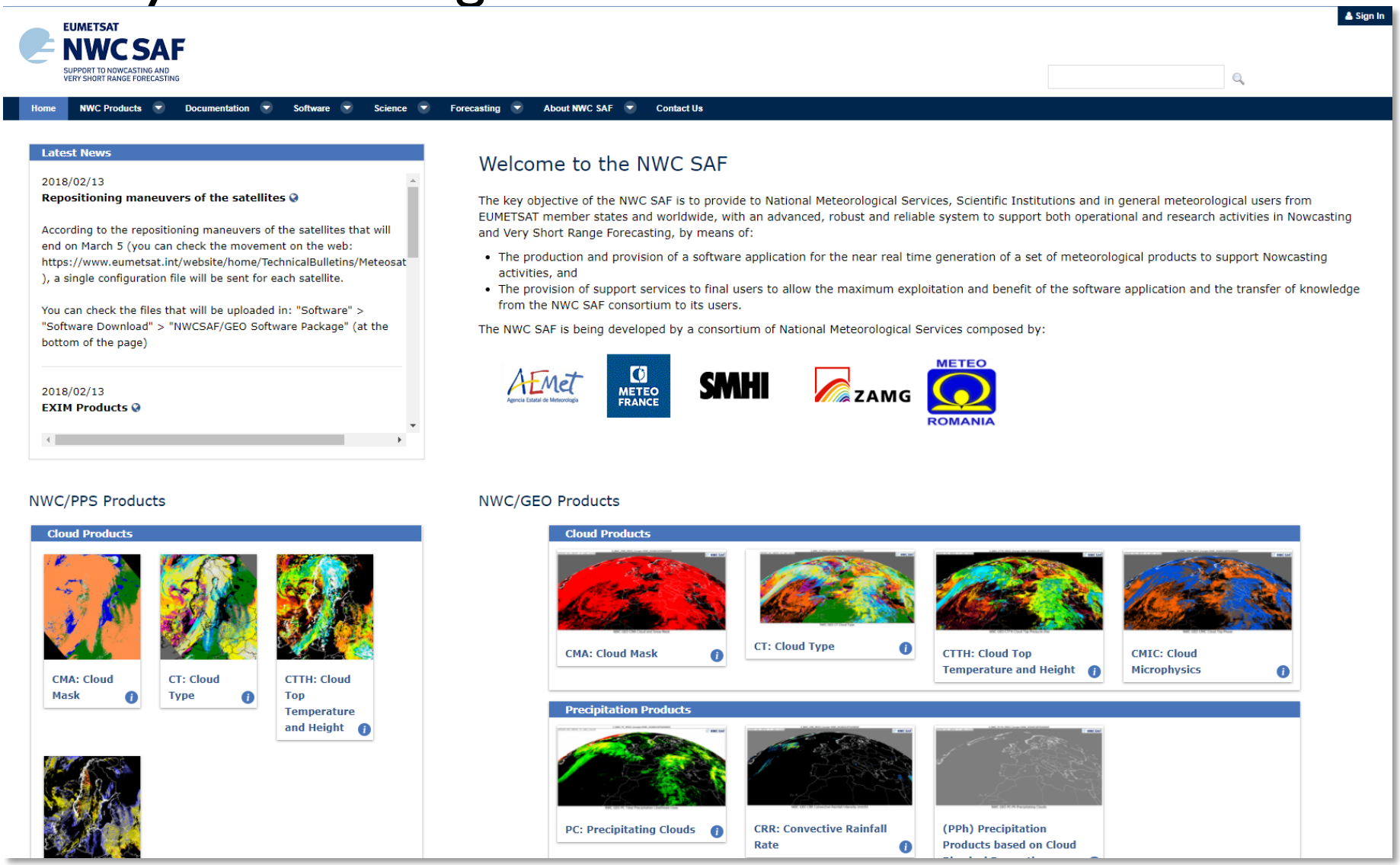
EUMETSAT SAF Support to Nowcasting and Very Short Range Forecast



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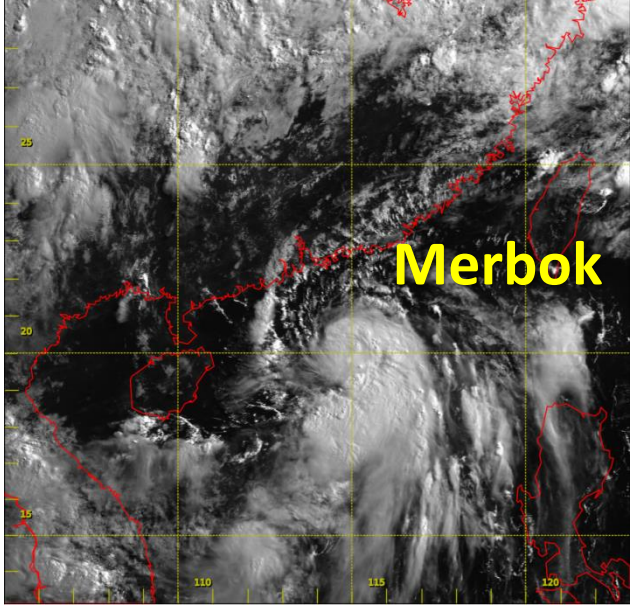
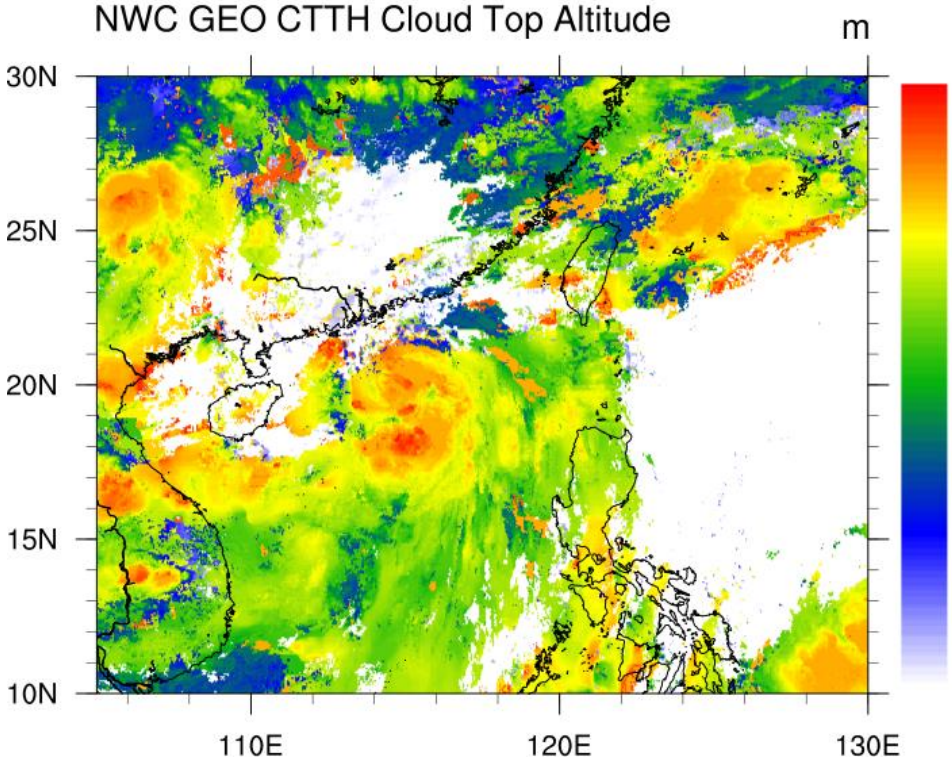
2017-06-12 00:00Z

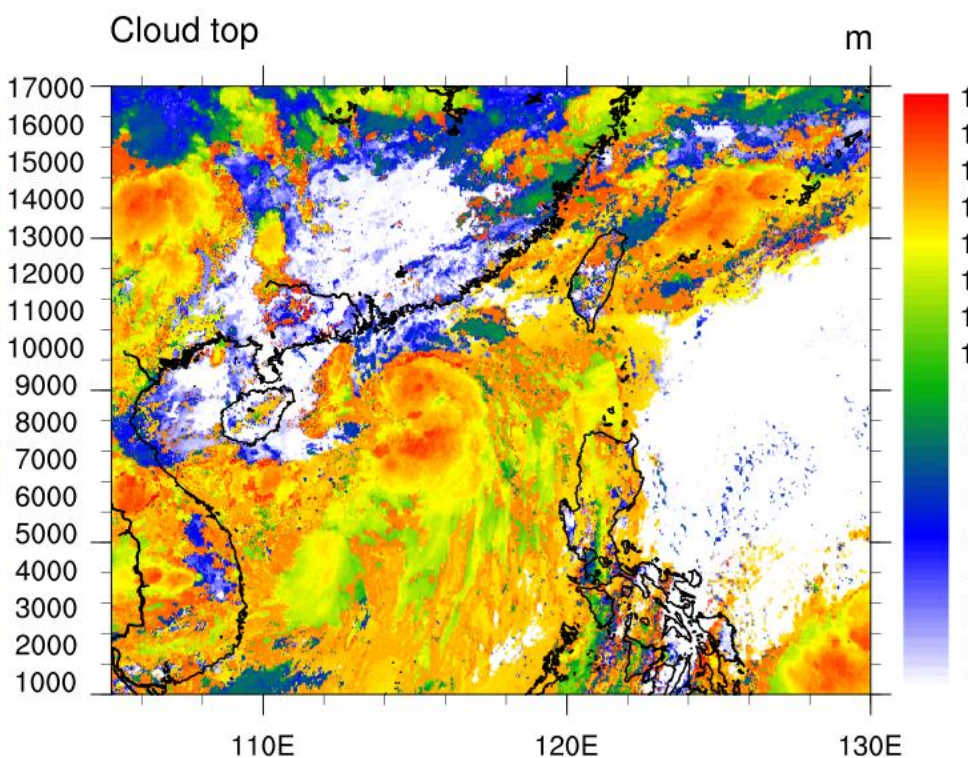


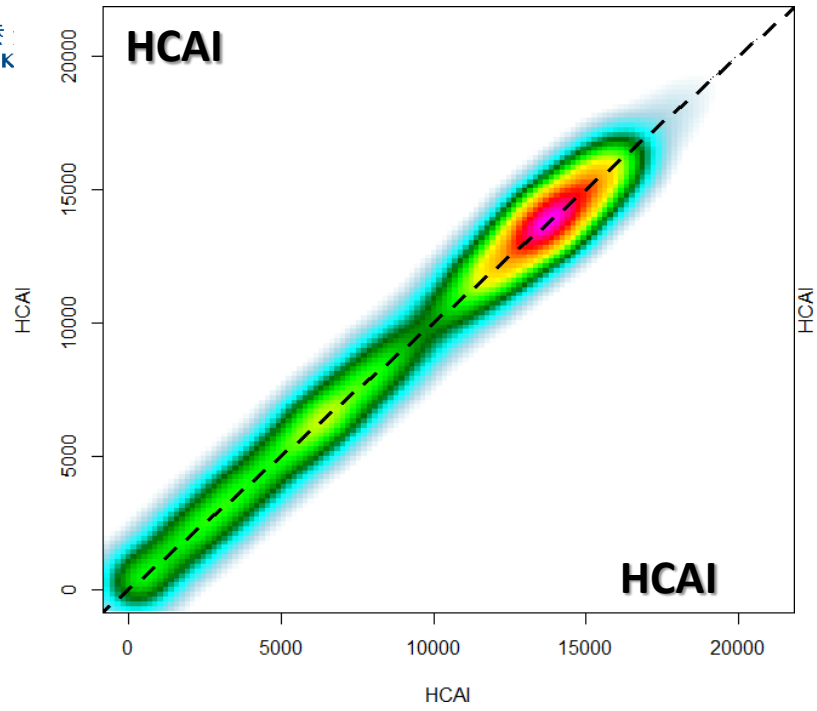
JMA HCAI (High-resolution Cloud Analysis Information)
http://www.data.jma.go.jp/mscweb/en/product/product/hcai/index.html

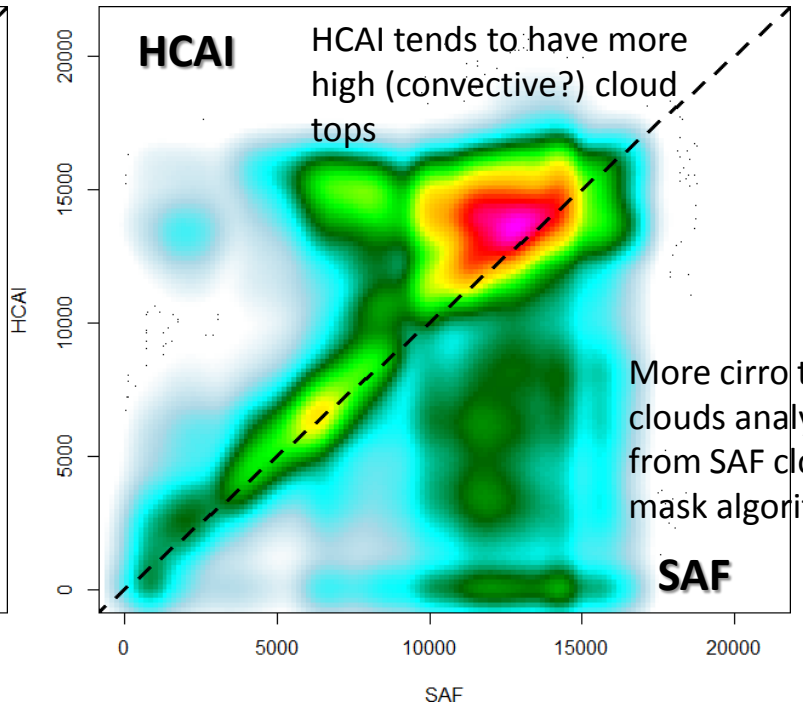
SAF NWC Cloud top height



HCAI Cloud top height







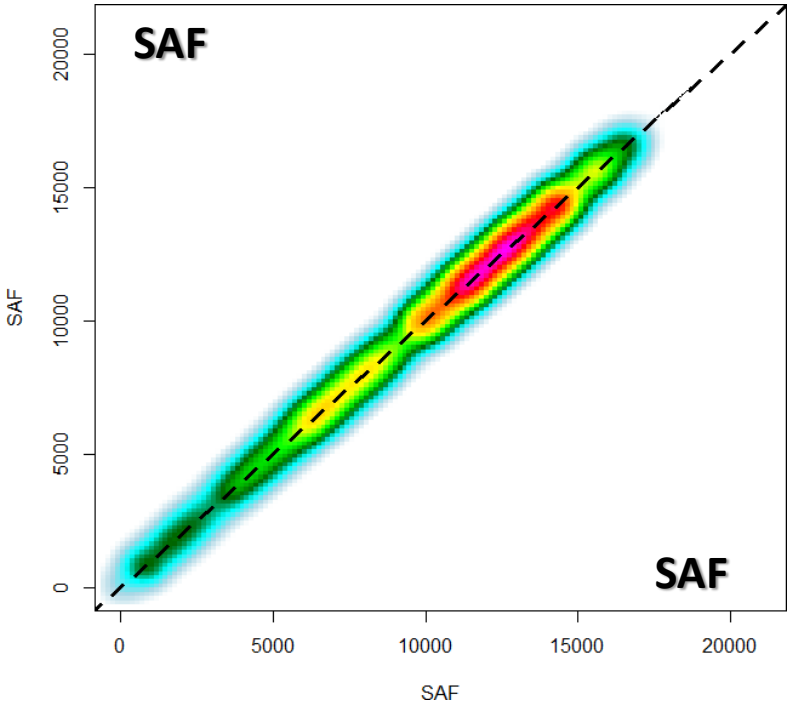
Comparing SAF and HCAI Cloud Top Height

Data period:

00:00 – 23:00 UTC

11 – 13 June 2017

Further study using other satellite data (e.g. cloud Lidar on CALIPSO) to be conducted



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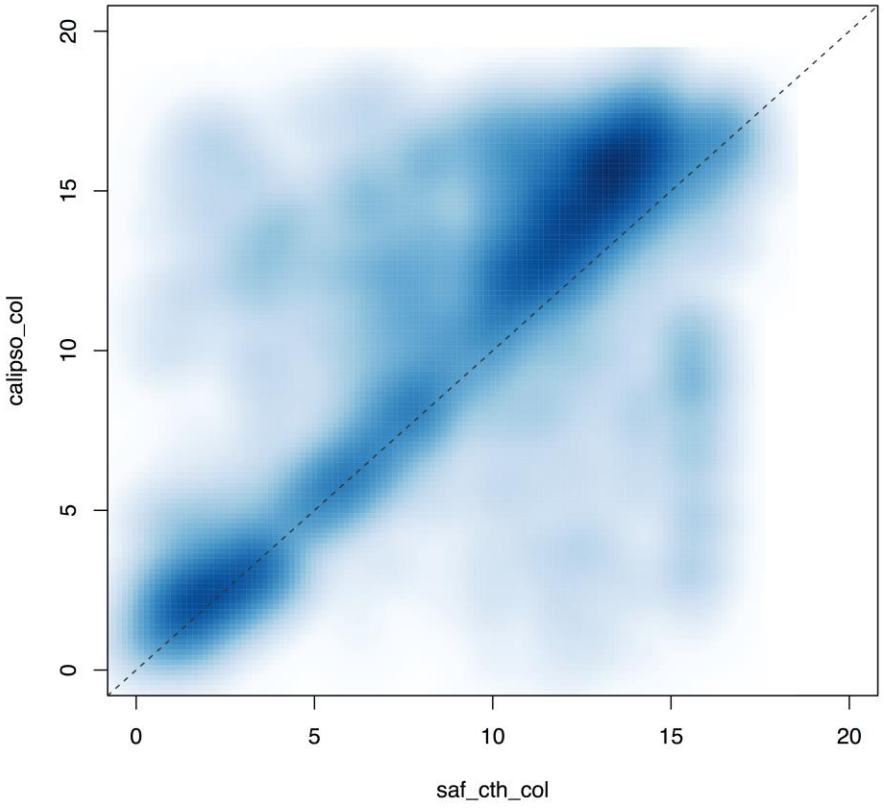
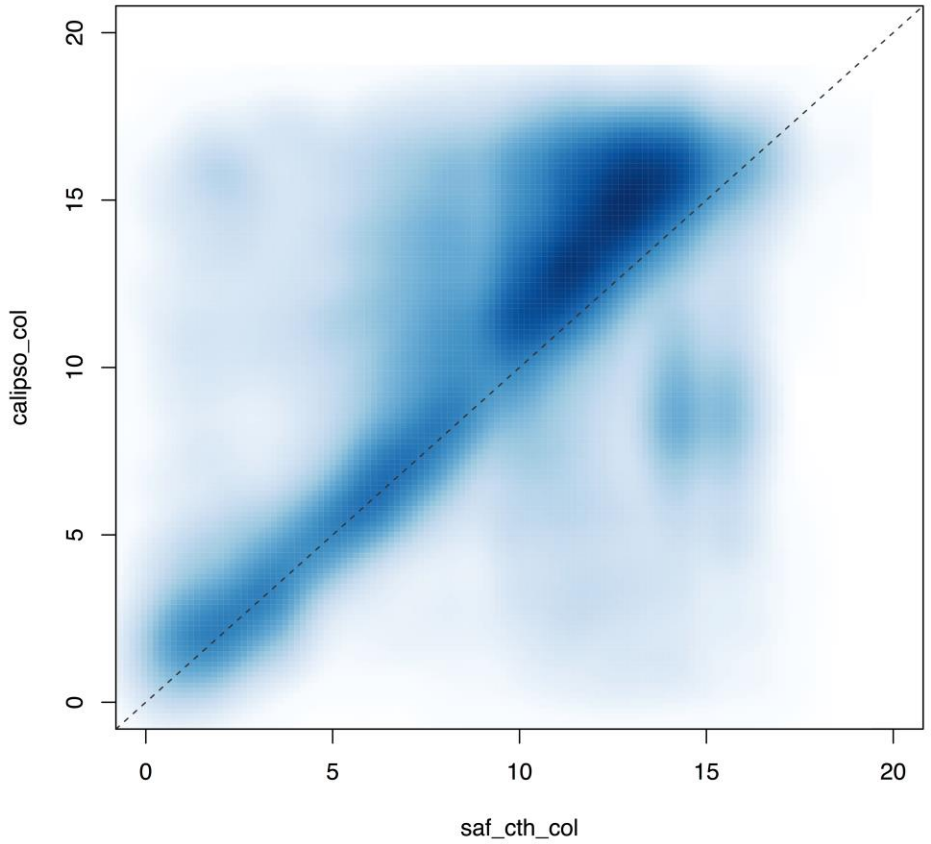
Comparing NWC cloud top heights with NASA Calipso CALIOP data

2016



2017



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Convection Initiation and Rapid Developing Thunderstorm using Advanced Himawari Imager (AHI) data

(A) Convective Initiation (CI) Nowcasting

Group	CI Parameter
Cloud-top glaciation	IR10.8 Brightness Temperature
Cloud-top glaciation	Time spent since crossing freezing level
Cloud-top glaciation	IR10.8-IR8.7
Cloud depth / height	WV6.2-IR10.8
Cloud depth / height	IR13.4-IR10.8
Cloud depth / height	IR12.0-IR10.8
Cloud depth / height	WV6.2-WV7.3
Cloud growth	Change rate of IR10.8 Brightness Temperature
Cloud growth	Change rate of (WV6.2-IR10.8)
Cloud growth	Change rate of (IR10.8-IR8.7)
Cloud growth	Change rate of (IR12.0-IR10.8)
Cloud growth	Change rate of (IR13.4-IR10.8)

Empirical Rules on CI

Probability of Convective Initiation in the next 30min

0	Zero probability to become thunderstorm
1	Very Low probability
2	Low probability
3	Mod probability
4	High probability

(B) Rapid Developing Thunderstorm – Convective Warning (RDT-CW)

- Analysis to identify intense or rapidly developing convective cloud cells
- Cloud-free pixel ➔ Cloudy ➔ CI ➔ RDT-CW

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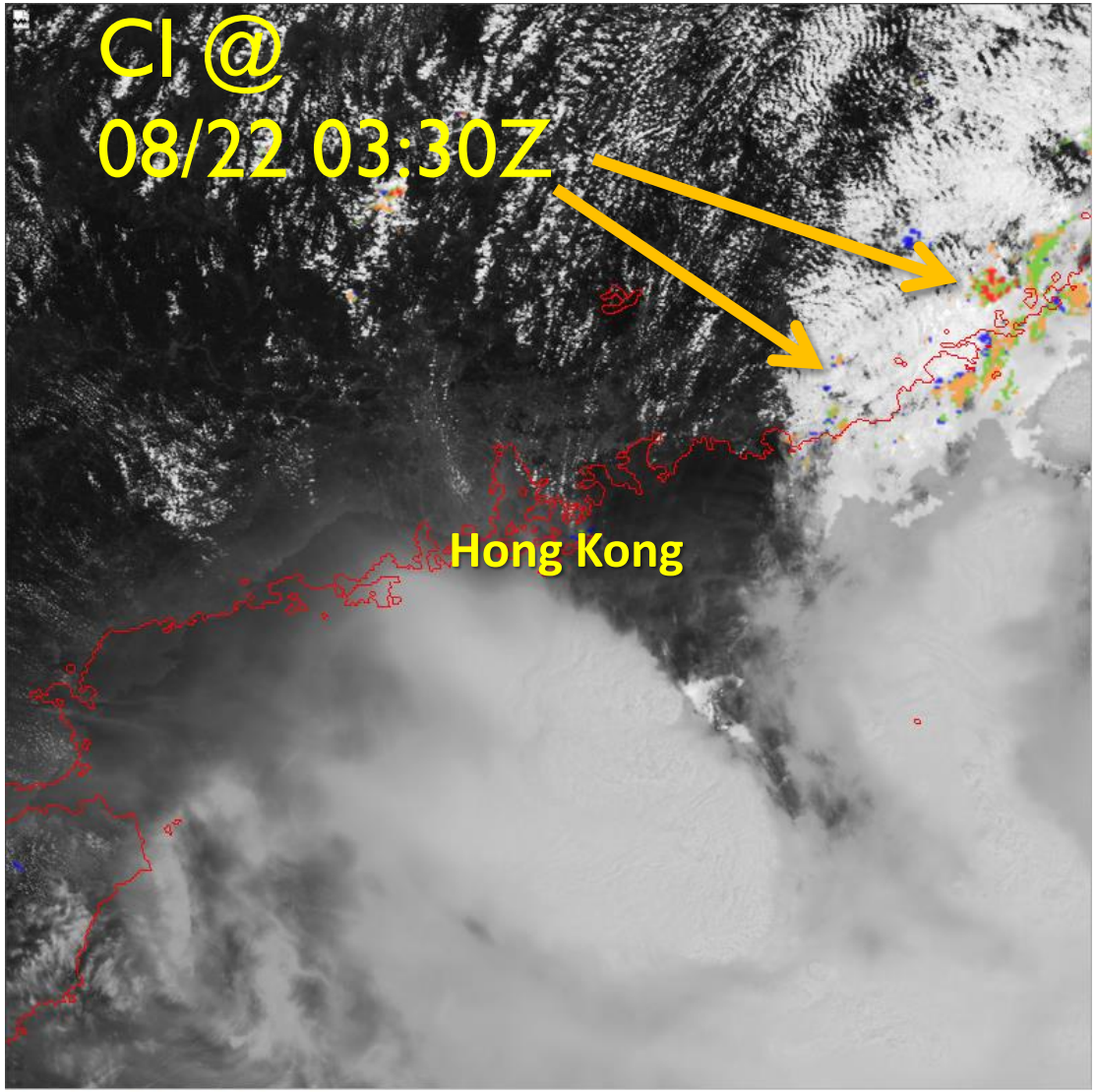
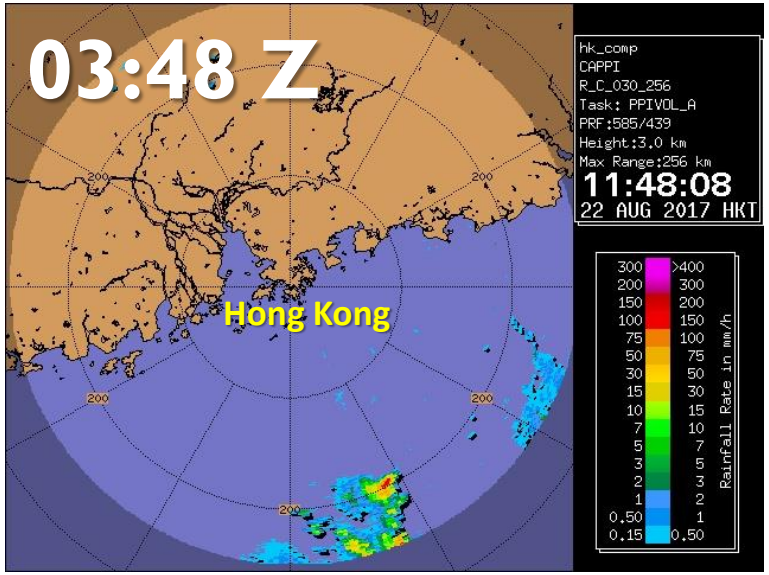
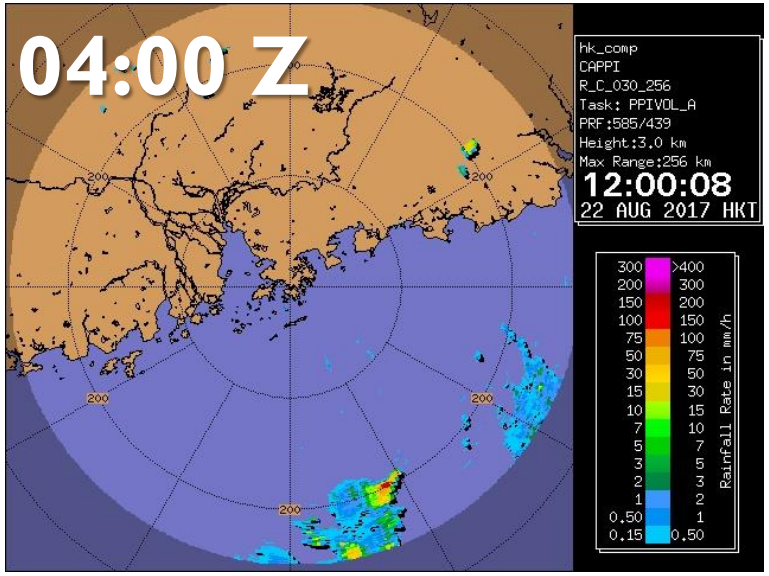
Convective Initiation







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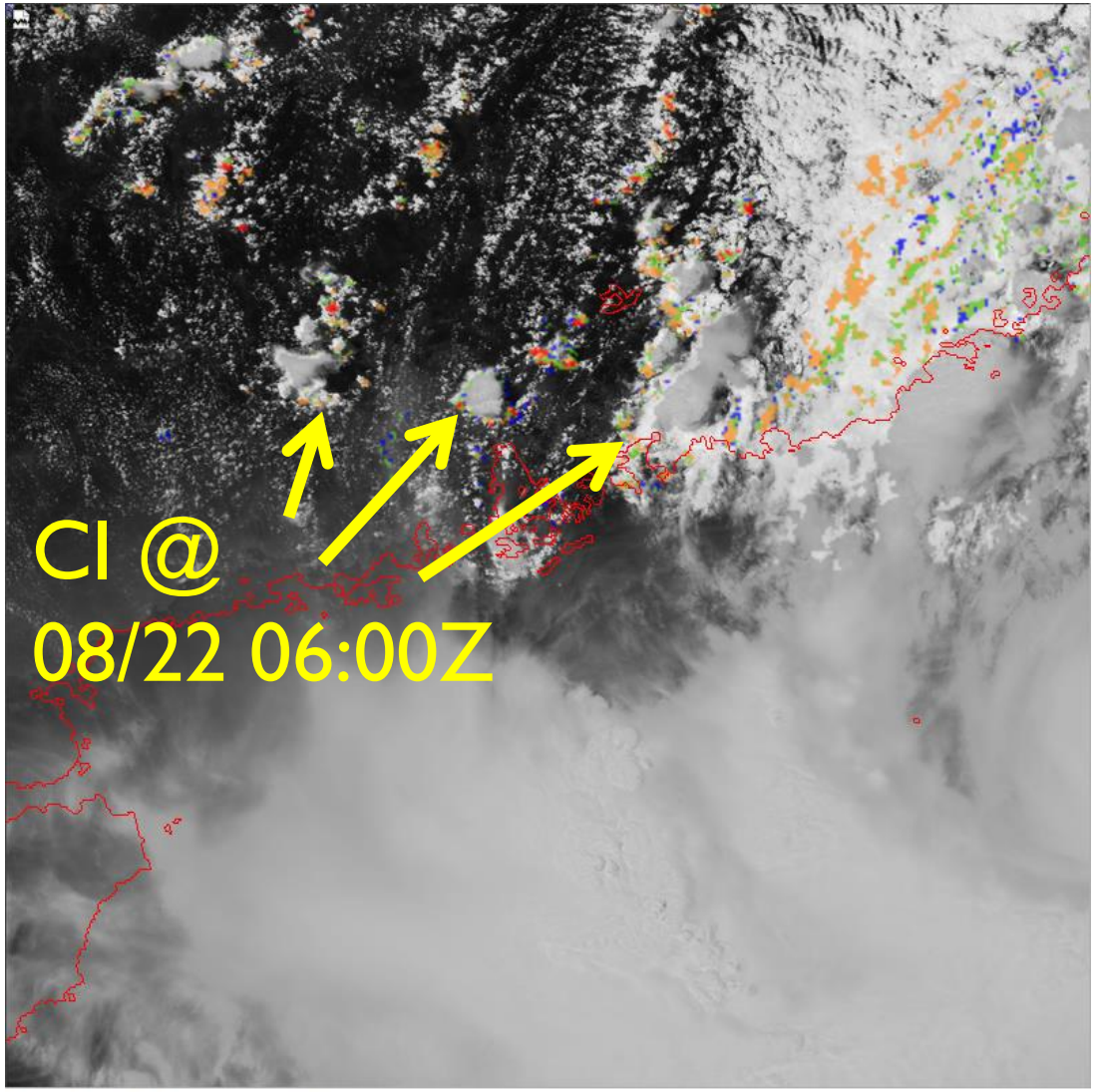
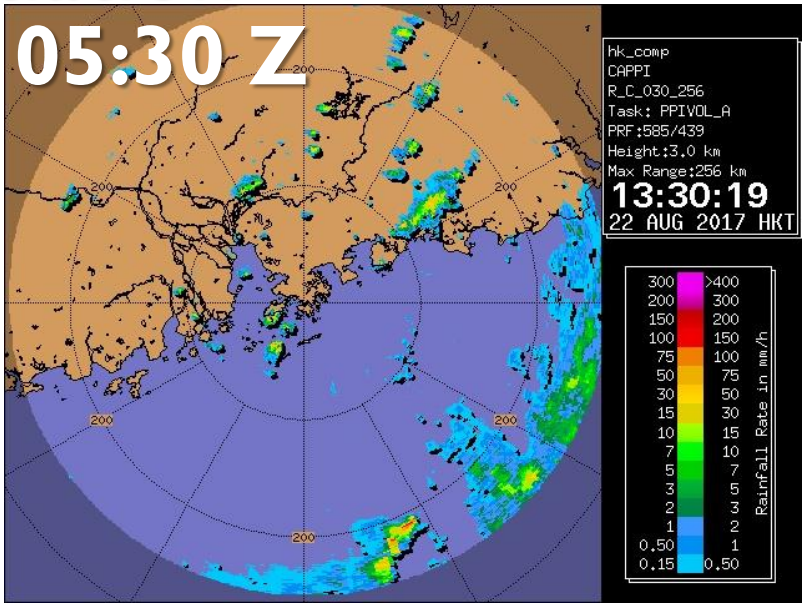
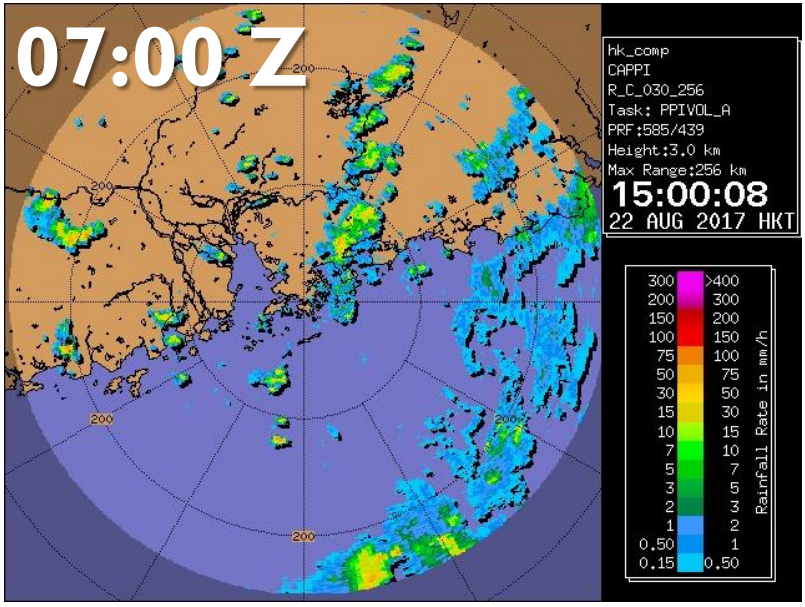
Convective Initiation







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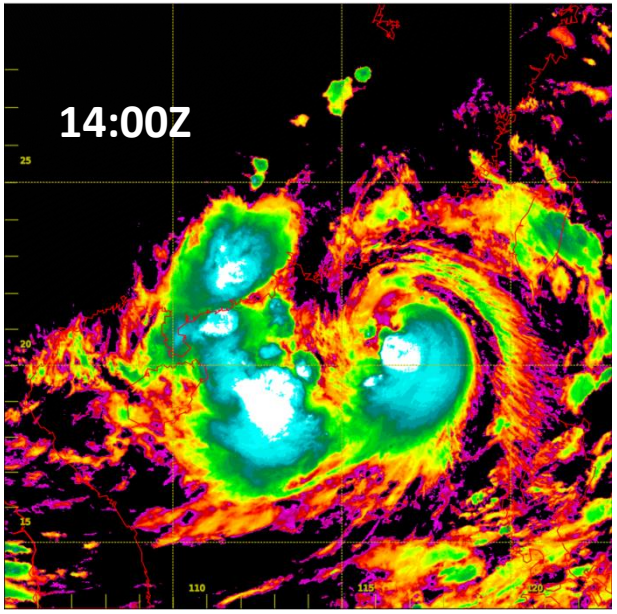

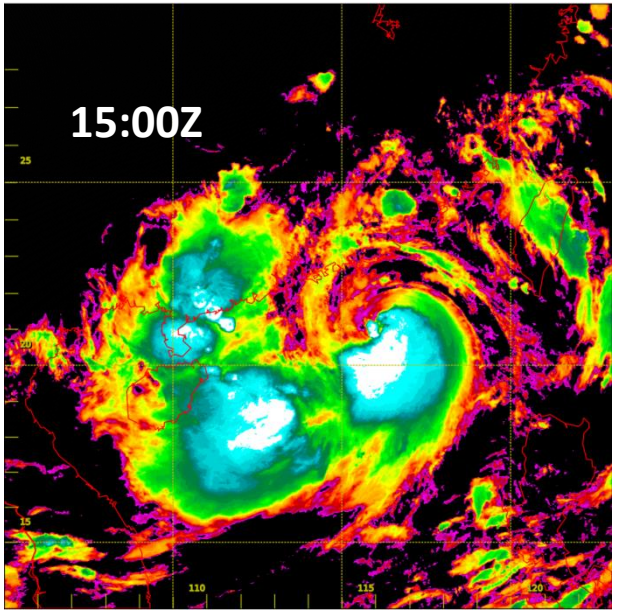

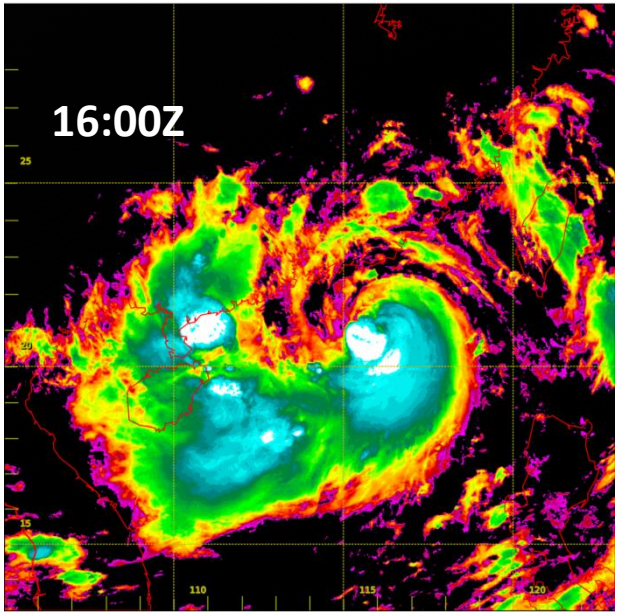

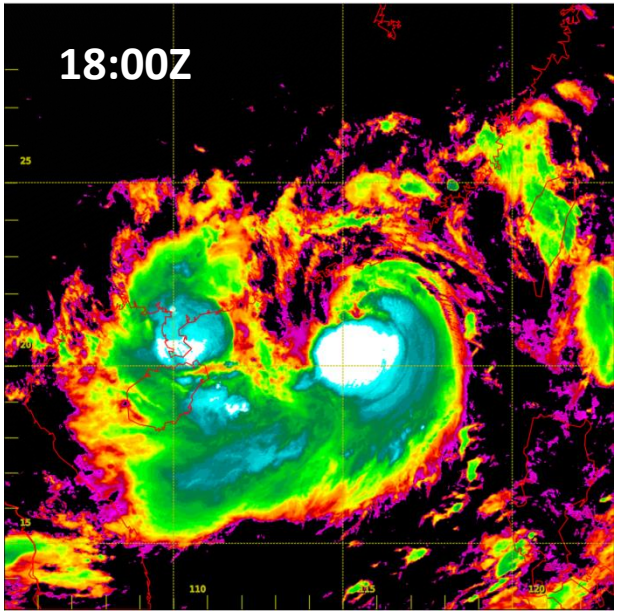

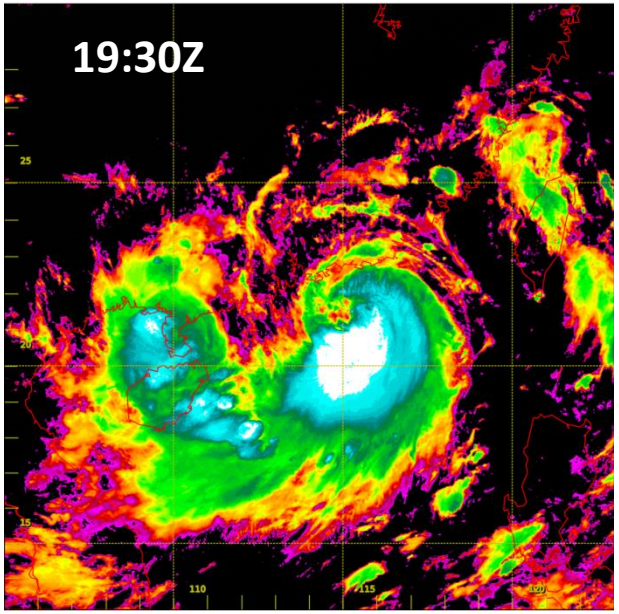

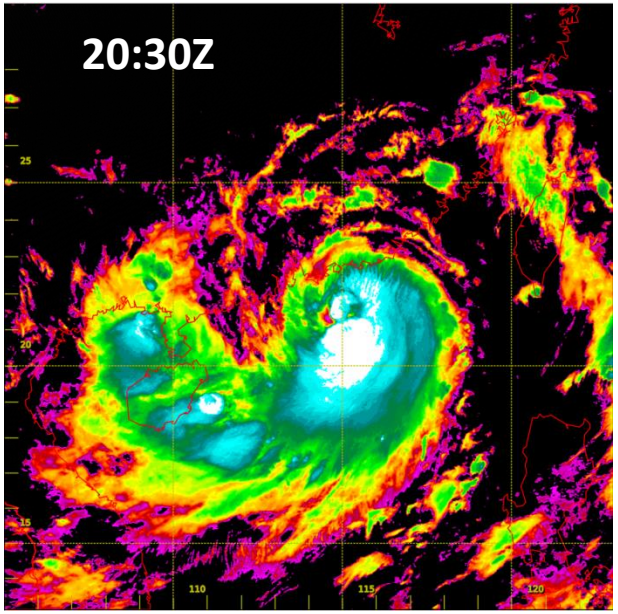

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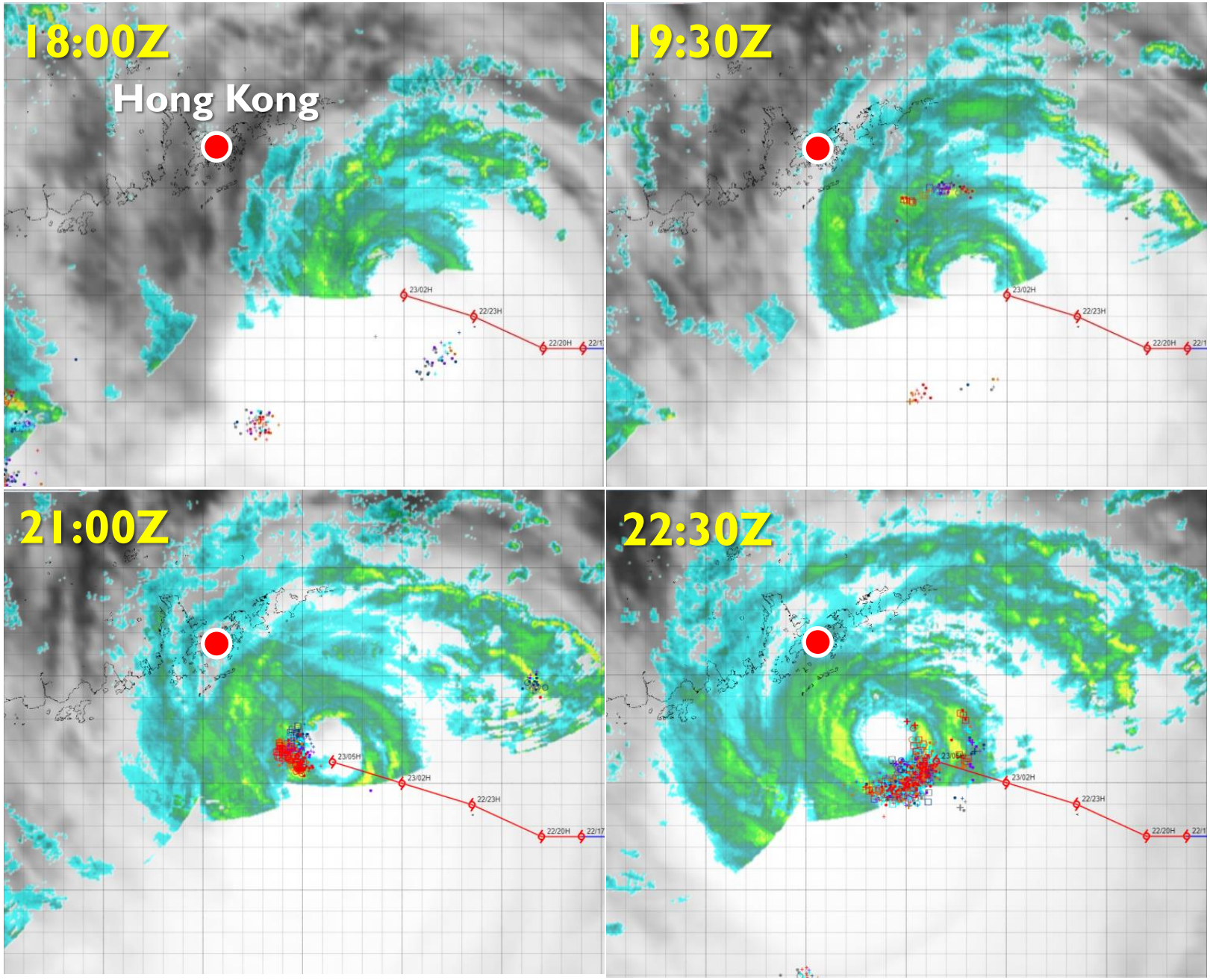

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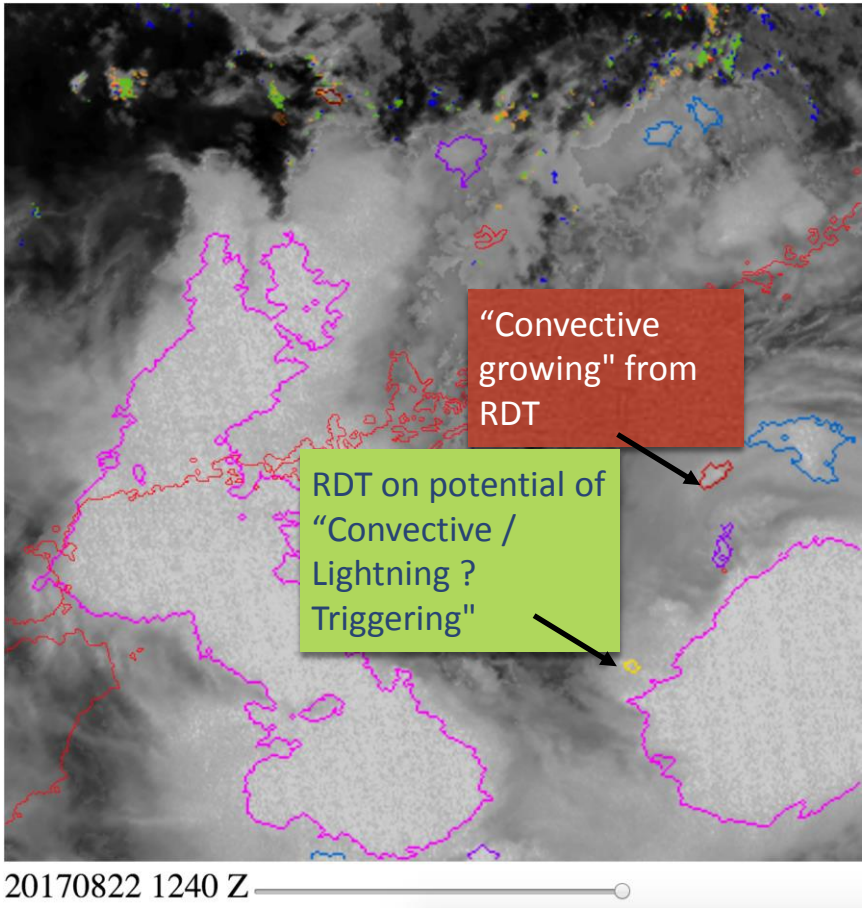
12:40 UTC 22 August 2017



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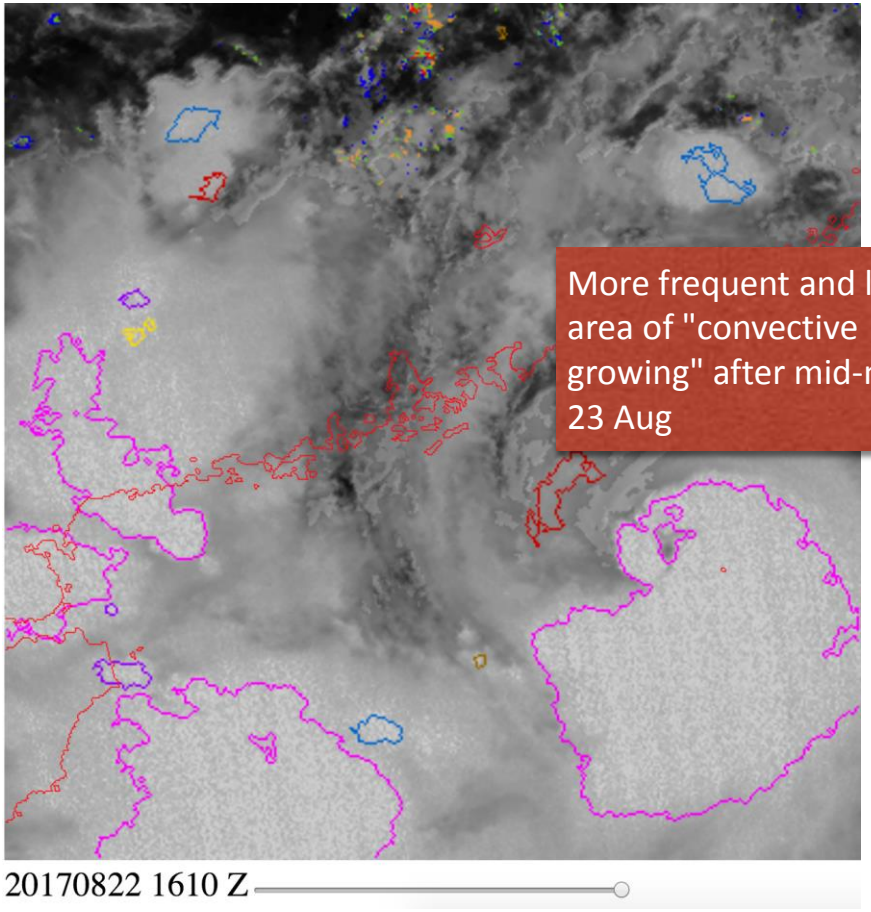

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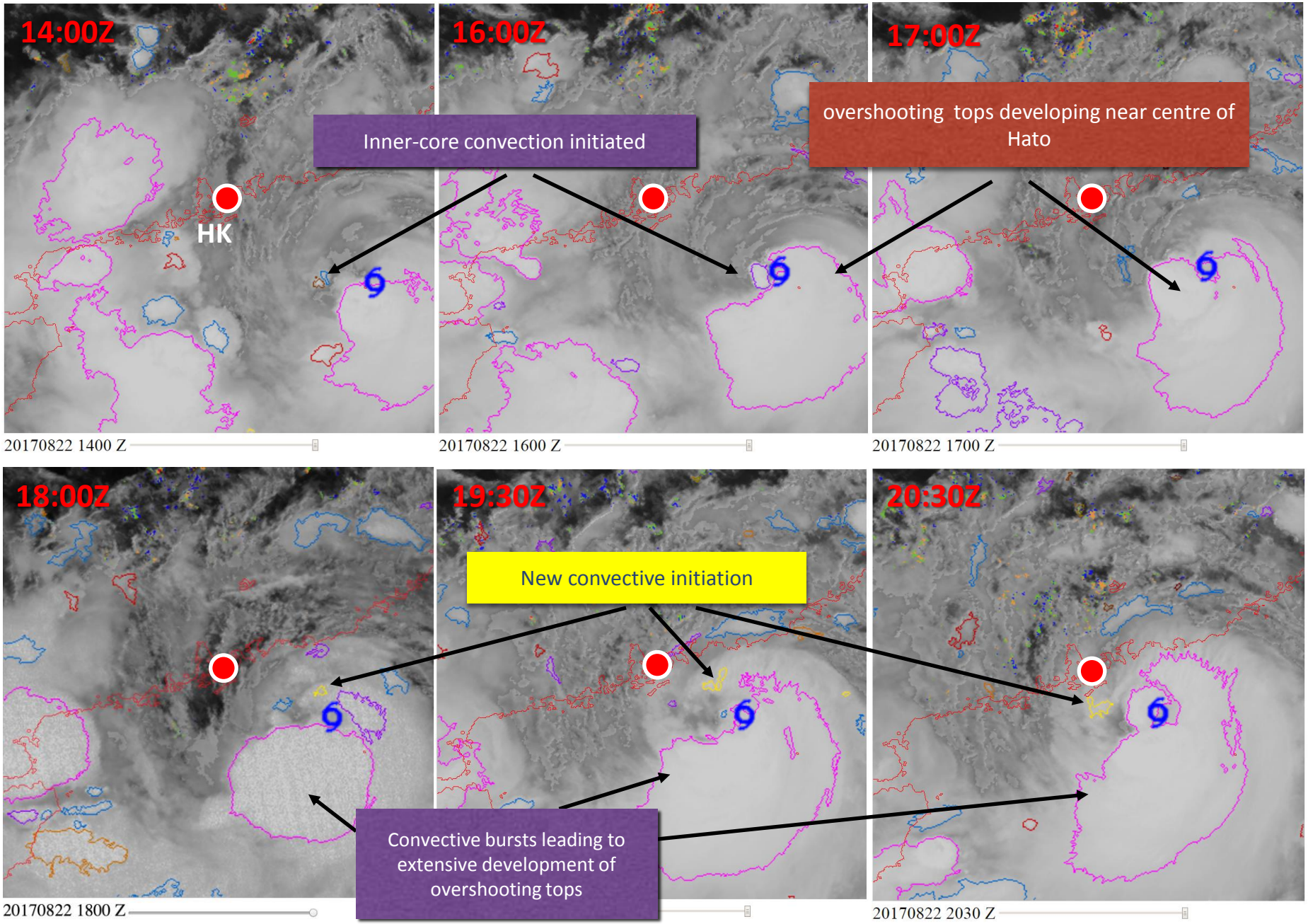

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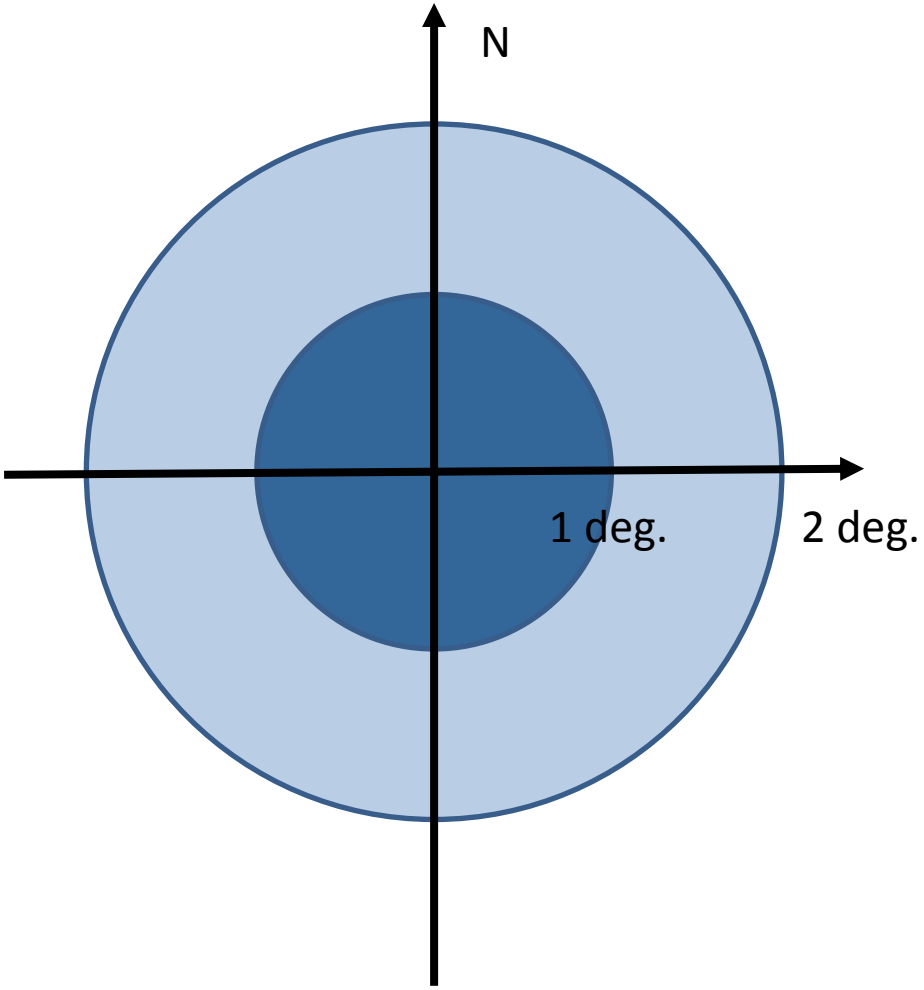
Analysis of RDT signatures within inner core of Hato



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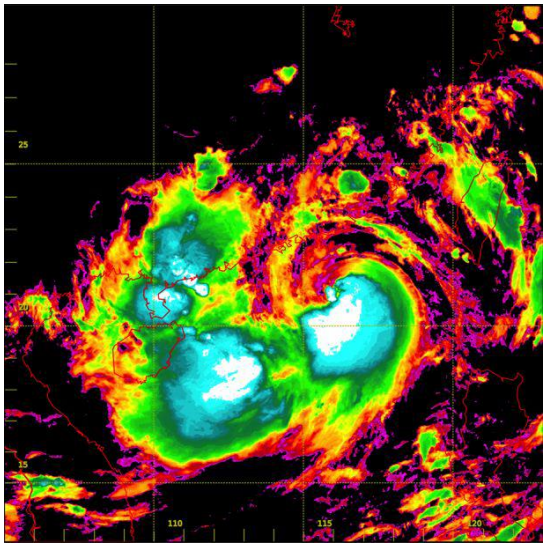
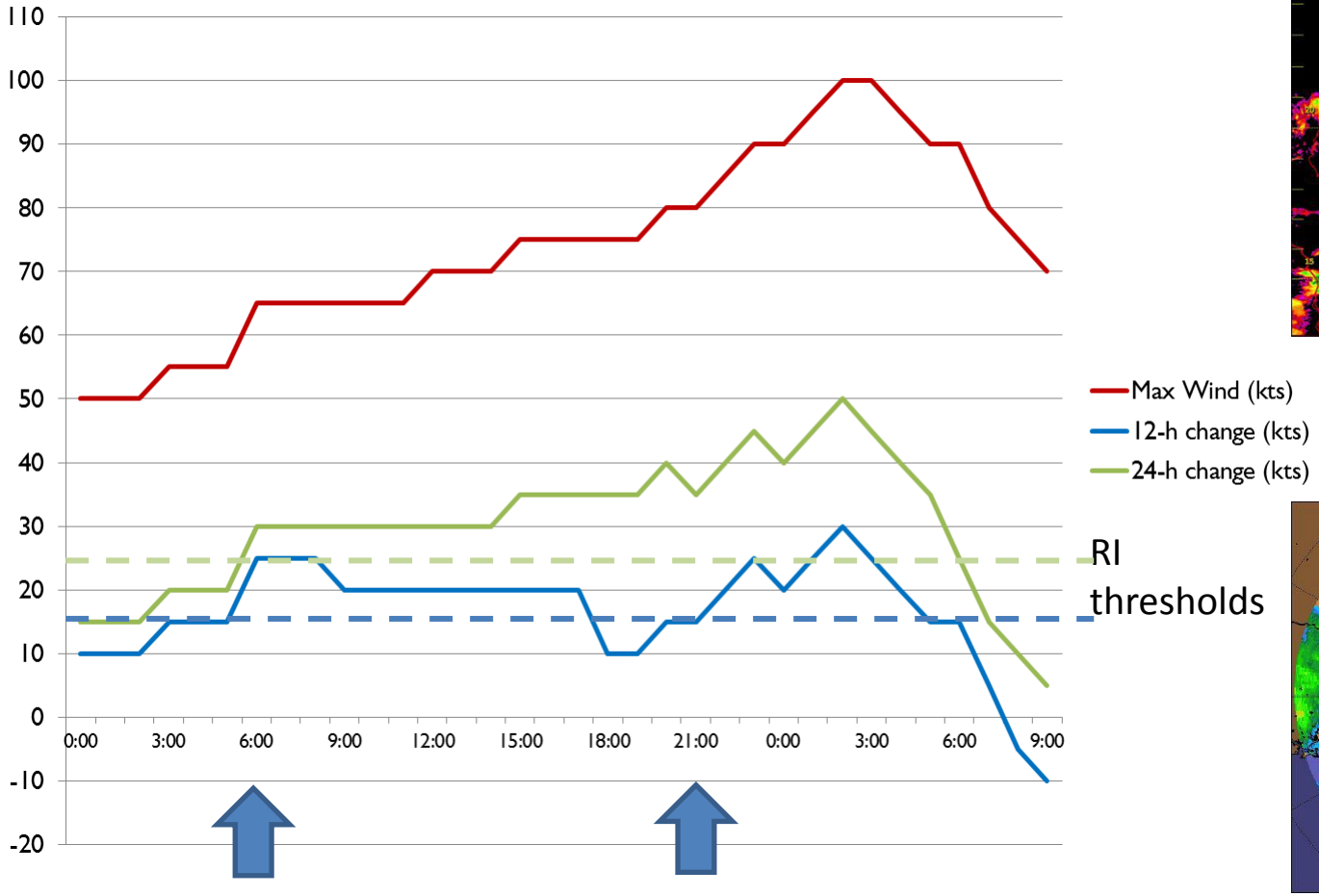
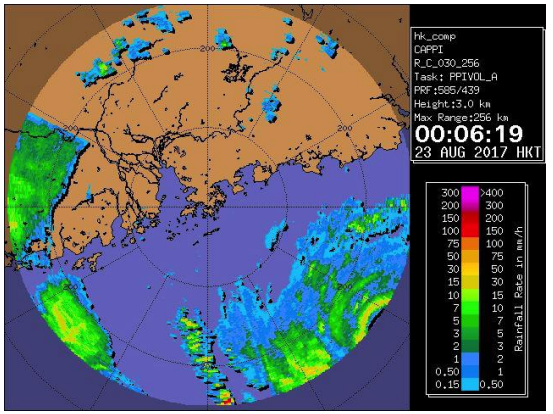
Hato







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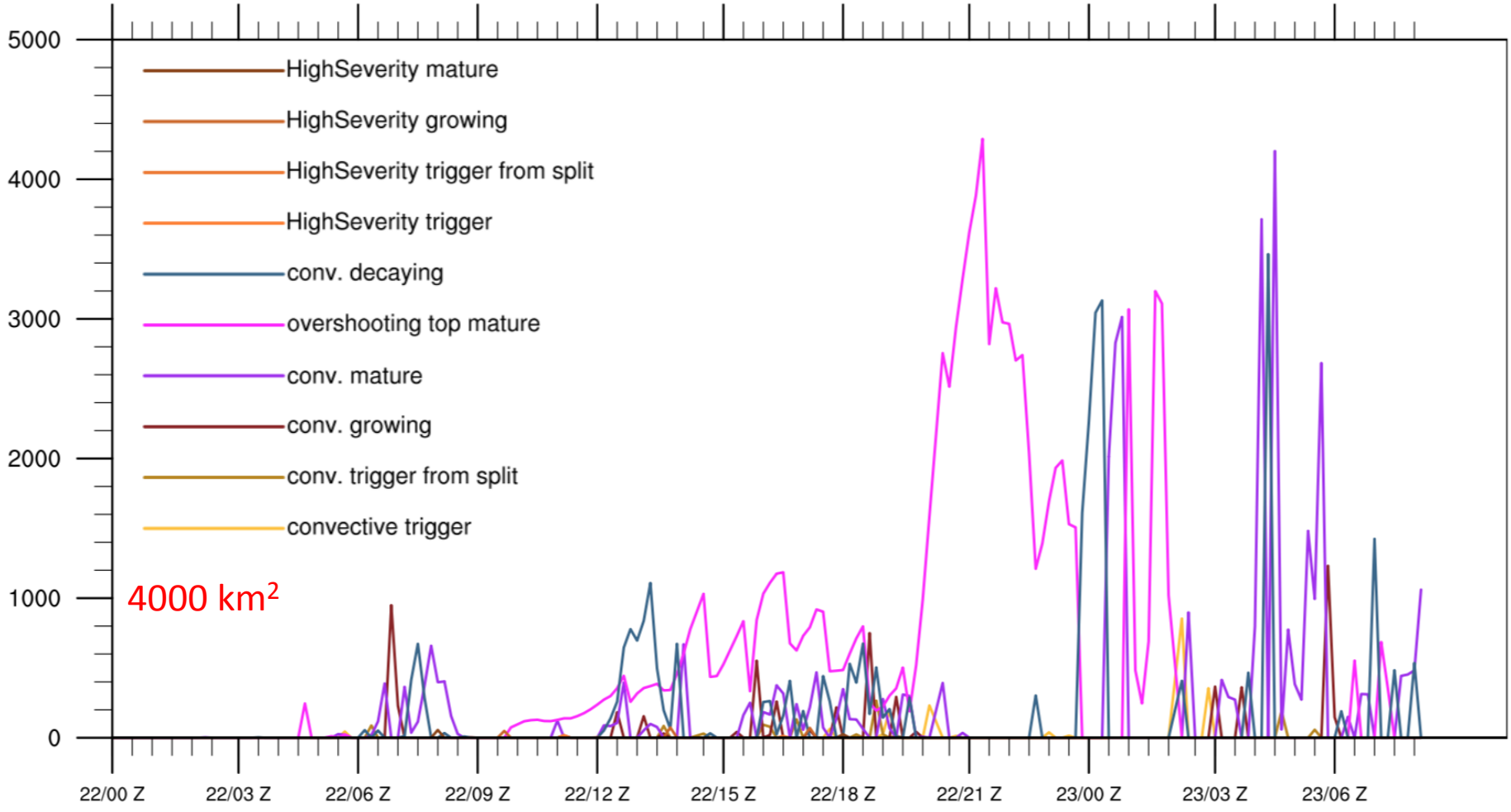
2-degree NW quadrant



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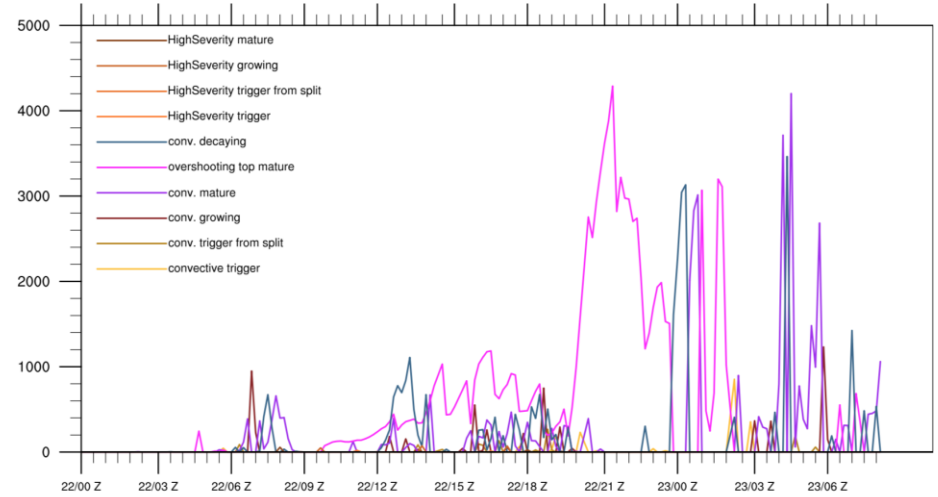
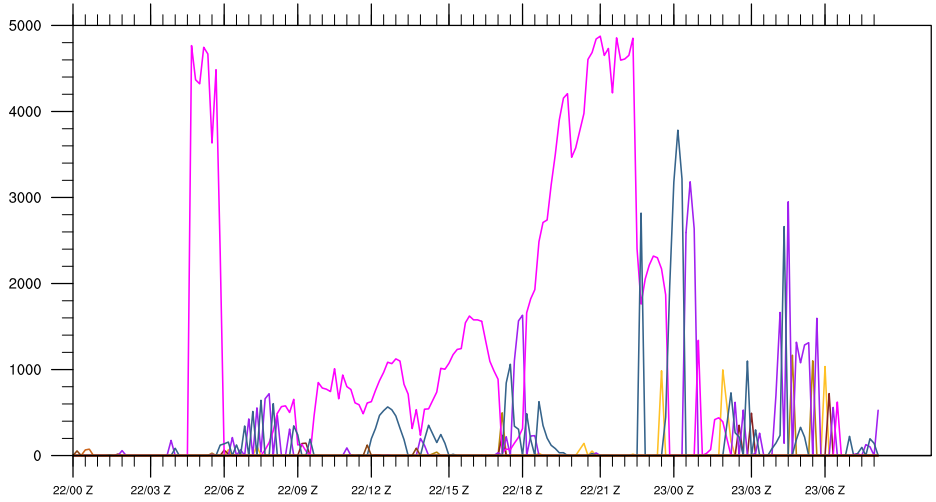
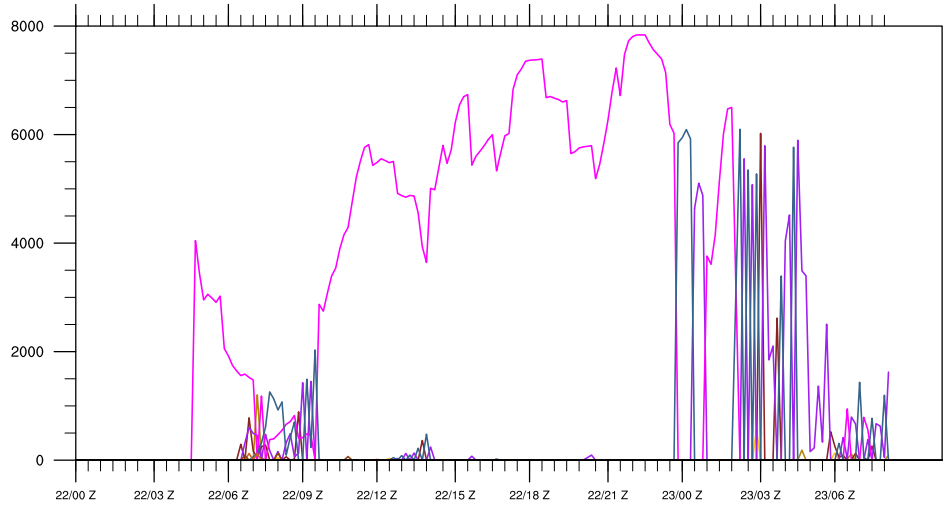
2-degree NW quadrant



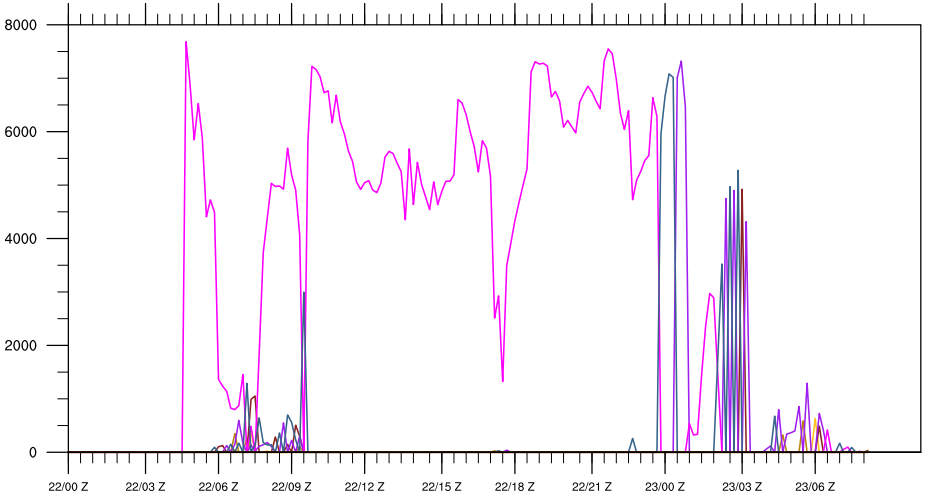
2-degree NE quadrant



2-degree SW quadrant



2-degree SE quadrant



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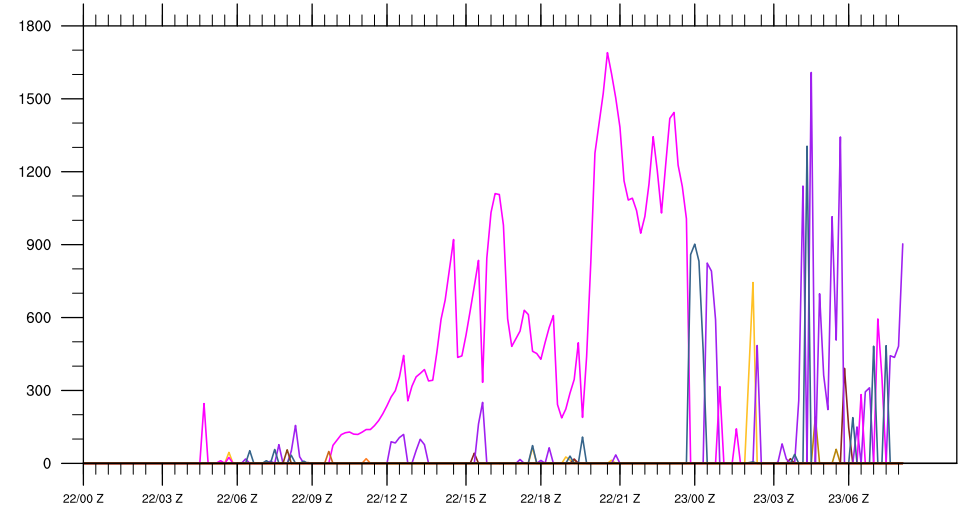
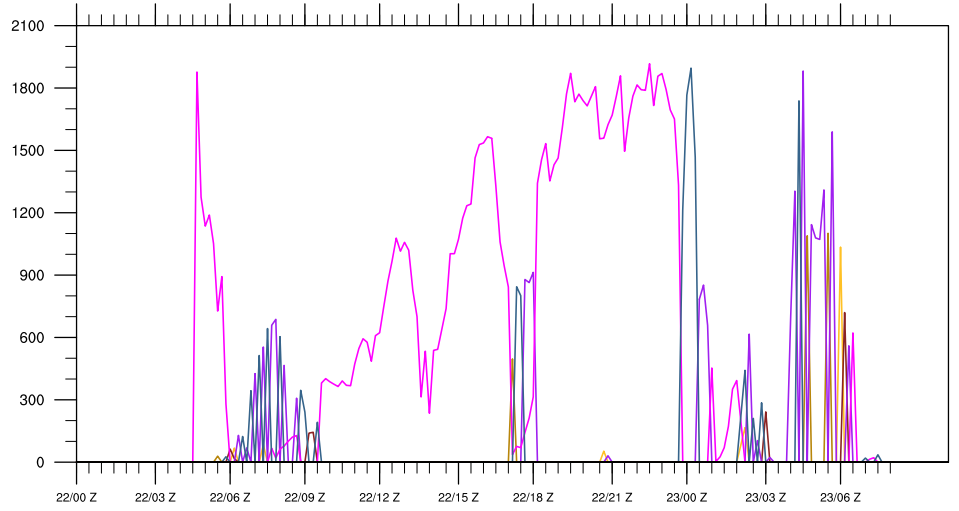
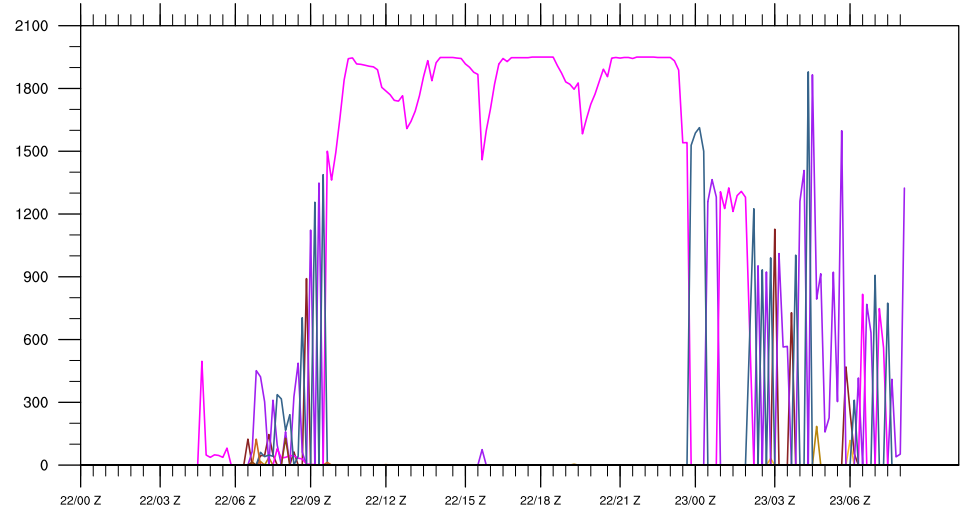
1-degree NW quadrant



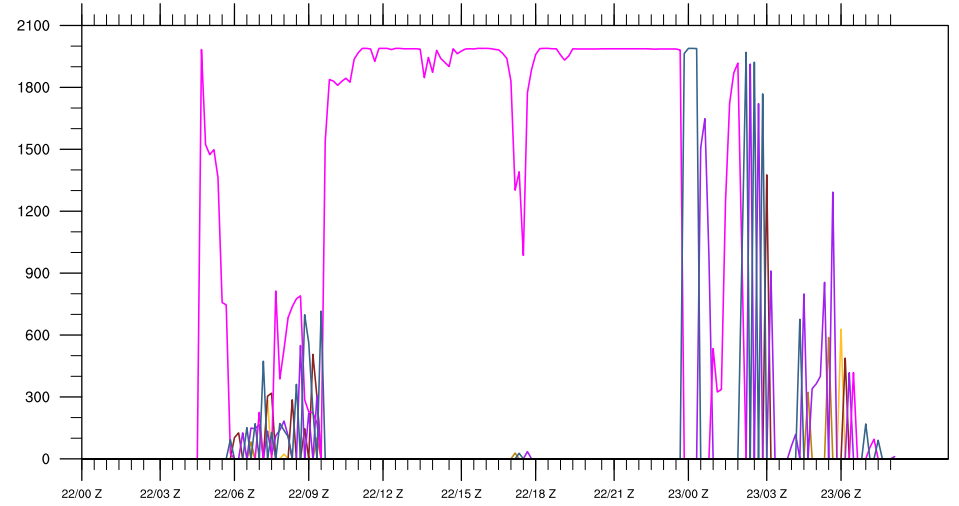
1-degree NE quadrant



1-degree SW quadrant

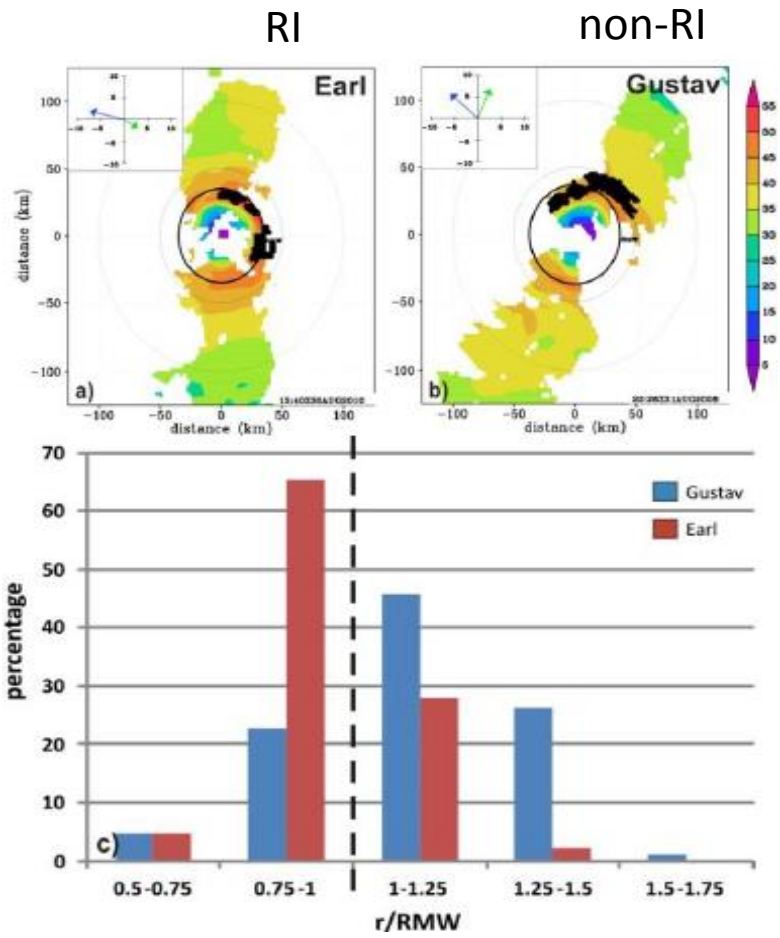


1-degree SE quadrant



Observations from RDT

- (Near and) inner-core extensive development of convective bursts captured by RDT
  - More information on classification of convective clusters (c.f. Hot-Tower)
  - Increasing wrapping of deep convective features from down-shear side conducive to (short-term) potential of RI



Roger (2014)

Summary

- A statistical-dynamical guidance, TINT-RI, combining logistic regression and naïve Bayes classifier was developed to predict RI for tropical cyclones over WNP and SCS. TINT-RI is more skillful than intensity forecasts from major global NWP DMOs and high resolution model such as HWRF
  - For Super Typhoon Hato (1713), the maximum SST along the forecast track demonstrated an earlier and more significant indication of RI. SST and its anomaly could be alternative predictors that replace TCHP or to supplement TINT-RI prediction
  - Developments are underway to improve TINT-RI such as including additional predictors, post-processing (calibration) of EPS forecasts to generate forecast uncertainty or alternative scenarios
- Using EUMETSAT NWC SAF with the Advanced Himawari Imager(AHI) data, a rapidly-update nowcasting guidance products on cloud analysis, Convective Initiation (CI) and Rapid Development Thunderstorms (RDT) are shown to demonstrate useful reference for nowcasting significant convective weather during passage of Hato, as well as convective burst activities in the inner-core of Hato as a precursor on its RI before its landfall over GD coast on 23 Aug 2017.

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Thank you very much