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HONG KONG OBSERVATORY

Strengthening Resilience: Integrated Early Warning and Impact-Based Forecasting for Enhanced Typhoon Preparedness

Insights from Super Typhoon Ragasa – Hong Kong Experience

20th IWS

Danice Yin-lam NG
Hong Kong Observatory

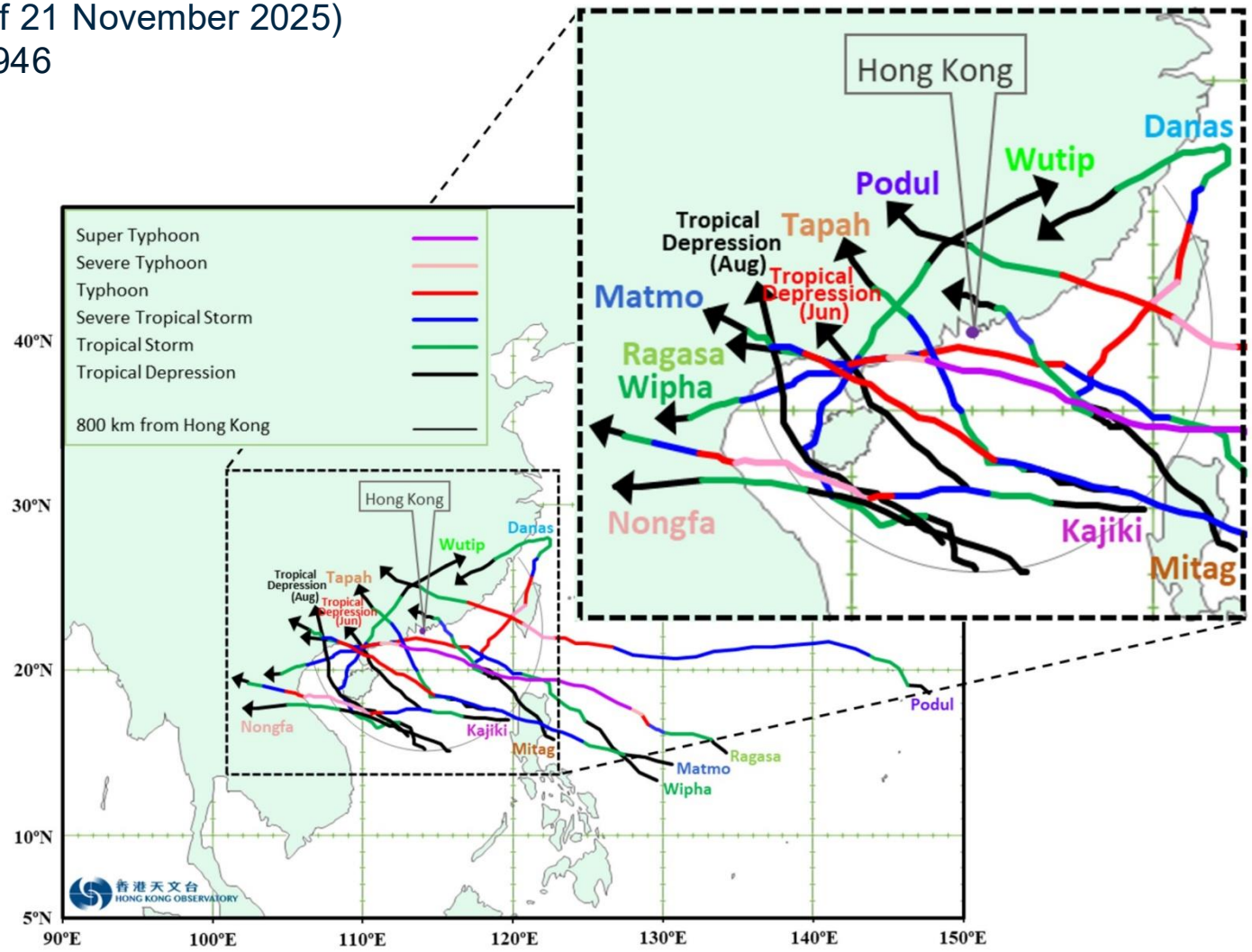
Why Typhoon Resilience Matters Now More Than Ever

- **2025 set a new record:** 14 tropical cyclones (as of 21 November 2025) affected Hong Kong — the highest number since 1946

- Two Hurricane Signal No. 10s issued in one year (Wipha in July, Ragasa in September) — a first since 1964

- Climate trends suggest increasing intensity and erratic behaviour of tropical cyclones in the Western North Pacific and South China Sea

- Urban coastal centres like Hong Kong require integrated, impact-focused early warning systems to protect lives and infrastructure



Provisional tracks of tropical cyclones affected Hong Kong in 2025 (up to Matmo in early October)

The Four Pillars of “Early Warnings for All”

Disaster risk knowledge

Systematically collect data and undertake risk assessments

- Are the hazards and the vulnerabilities well known by the communities?
- What are the patterns and trends in these factors?
- Are risk maps and data widely available?

Detection, observations, monitoring, analysis and forecasting of hazards

Develop hazard monitoring and early warning services

- Are the right parameters being monitored?
- Is there a sound scientific basis for making forecasts?
- Can accurate and timely warnings be generated?

Preparedness and response capabilities

Build national and community response capabilities

- Are response plans up to date and tested?
- Are local capacities and knowledge made use of?
- Are people preapred and ready to react to warnings?

Warning dissemination and communication

Communicate risk information and early warnings

- Do warnings reach all of those at risk?
- Are the risks and warnings understood?
- Is the warning information clear and usable?

THE “EARLY WARNINGS FOR ALL” FRAMEWORK IN PRACTICE

Hong Kong Observatory (HKO) aligns its services with the four pillars:

- **Hazard monitoring & forecasting**

  AI + NWP ensembles, dropsonde missions

- **Risk knowledge**

  Impact thresholds (e.g., anemometer network for signal decisions, tide gauge for water levels)

- **Warning communication**

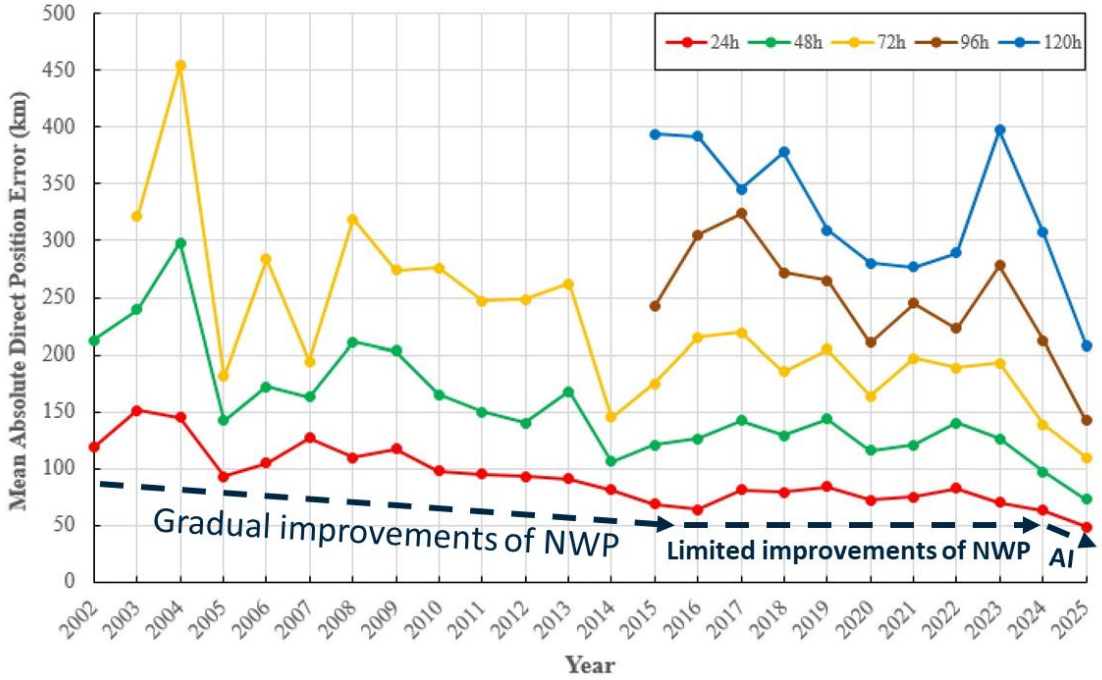
  Hourly briefings, social media, MyObservatory app

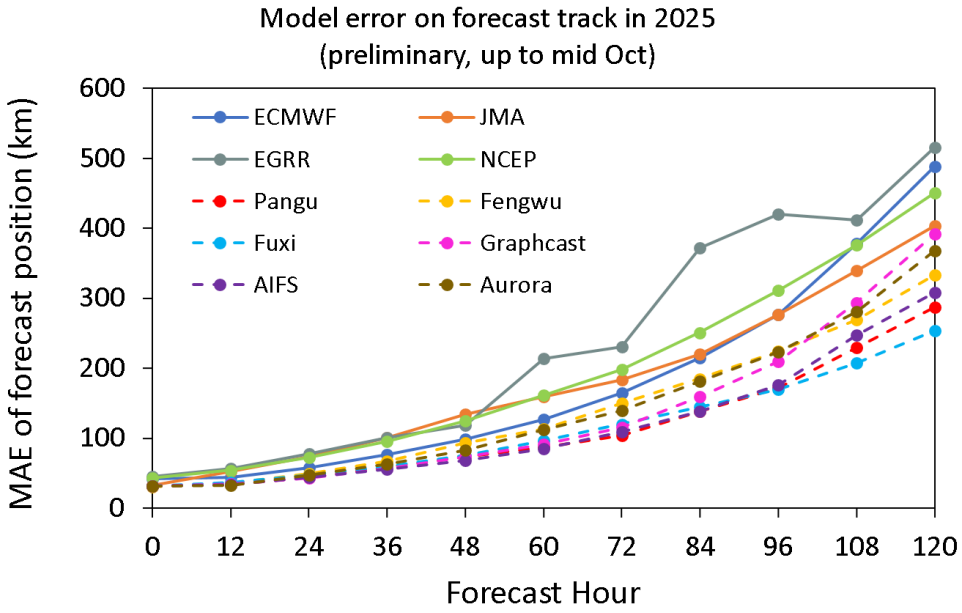
- **Preparedness & response**

  Inter-departmental Steering Committee on Extreme Weather

HKO TC track forecast performance over the years

- Since the early 2000s, HKO has been employing an ensemble technique for operational TC track forecasting based on a few state-of-the-art global NWP and EPS.
- With gradual and incremental advancements achieved by NWP, operational TC track forecasts have shown steady improvement from 2000s into the early 2010s, but the improvement generally plateaued in the past decade.

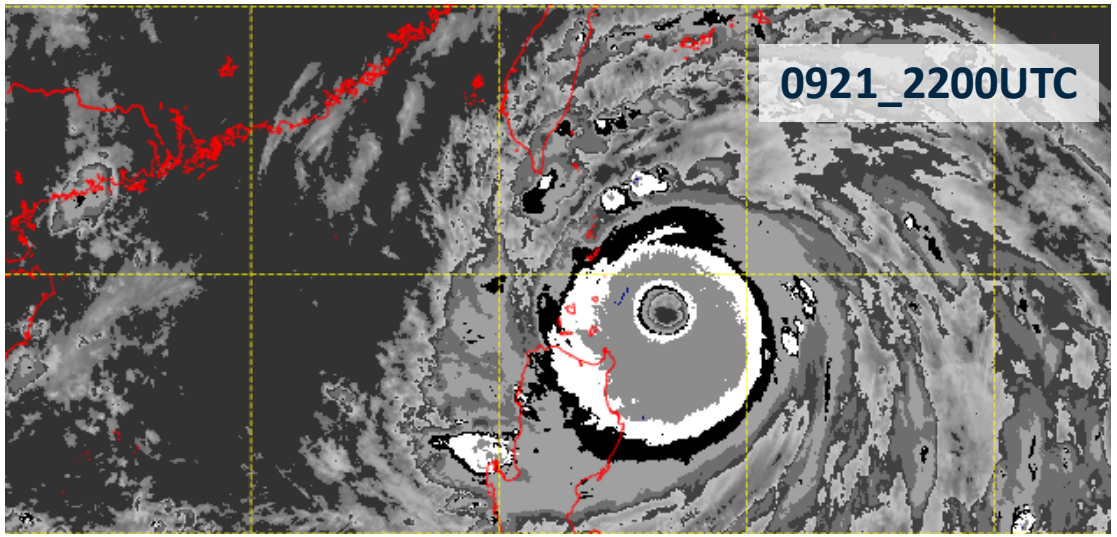


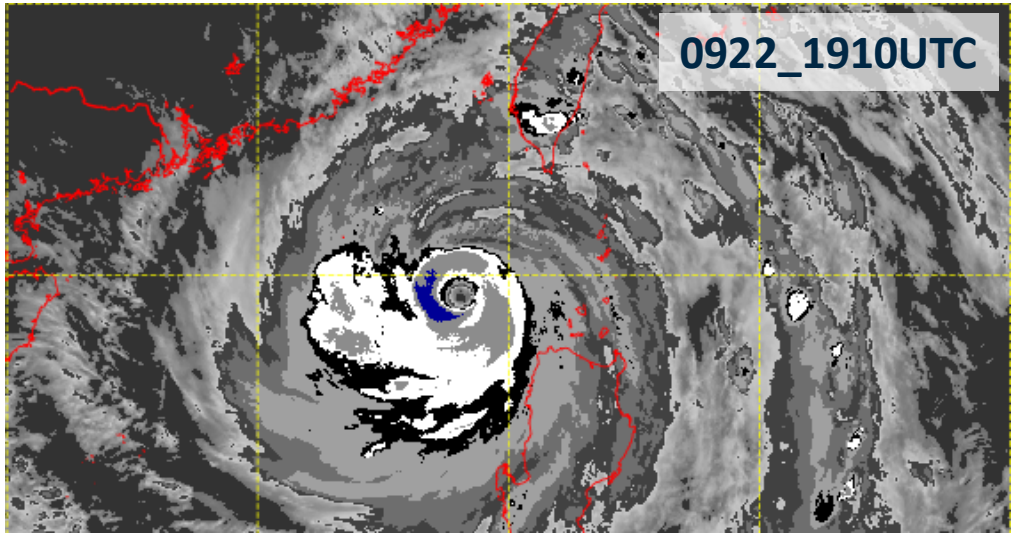


- HKO further introduced AI models into the operational ensemble consensus track in 2025, resulting in lower TC forecast position errors to levels **lower than those recorded in any previous year, for all forecast hours**.
- While the statistics for 2025 forecast errors were preliminary and only up to 19 October 2025, this **might be for the first time that the 24-hour TC track forecast error can get as low as 50 km approximately**.

Ragasa – The most intense TC over the SCS and WNP in 2025

- Peak intensity: **125 knots – strongest TC in the Western North Pacific and the South China Sea in 2025**
- It is also **the second strongest TC in the SCS since the HKO's records began in 1950, on par with Super Typhoons Saola in 2023 and Yagi in 2024.**
- Maintained super typhoon strength due to favourable oceanic/atmospheric conditions and no land interaction
- Came closest 120 km south of Hong Kong – furthest distance ever to trigger Hurricane Signal No. 10 (since 1946)
- Caused hurricane-force winds, >200 mm rainfall, and storm surge coinciding with astronomical high





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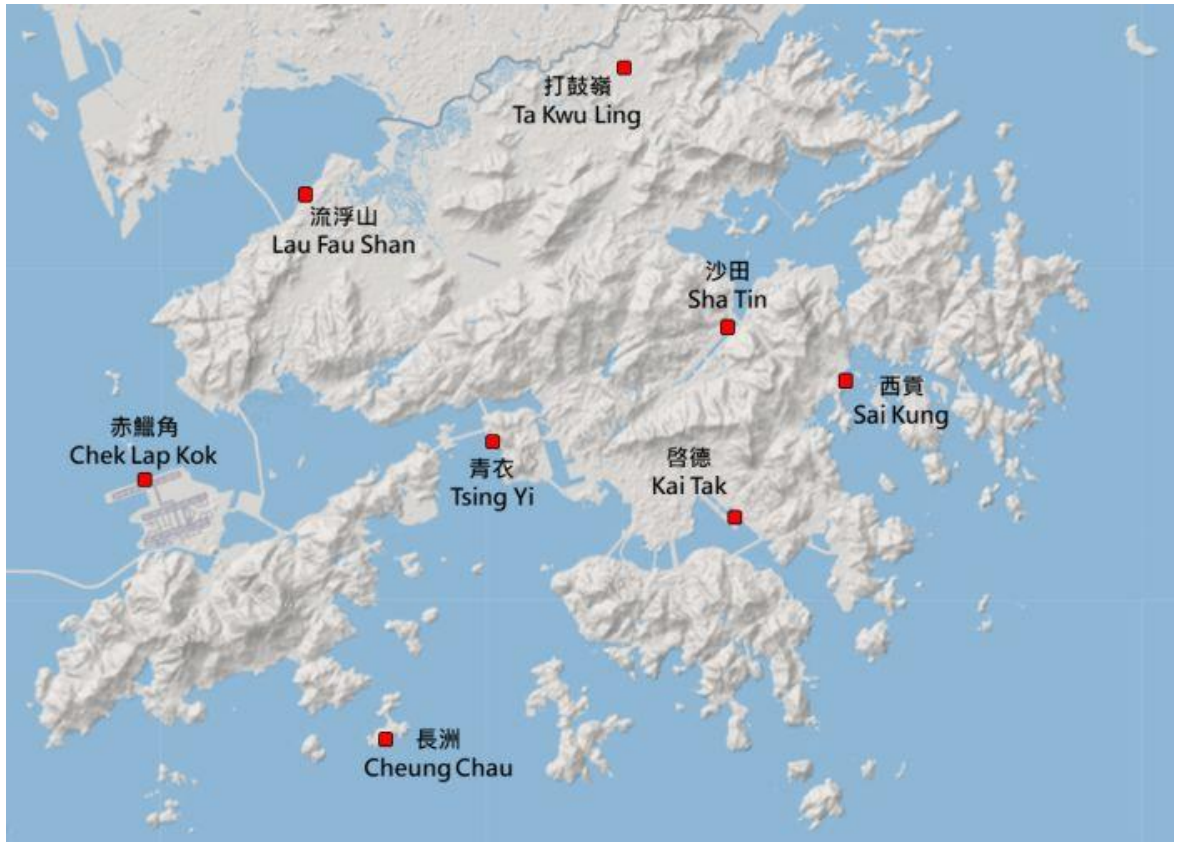
REFERENCE FOR THE ISSUE OF NO.3 AND NO.8 SIGNALS

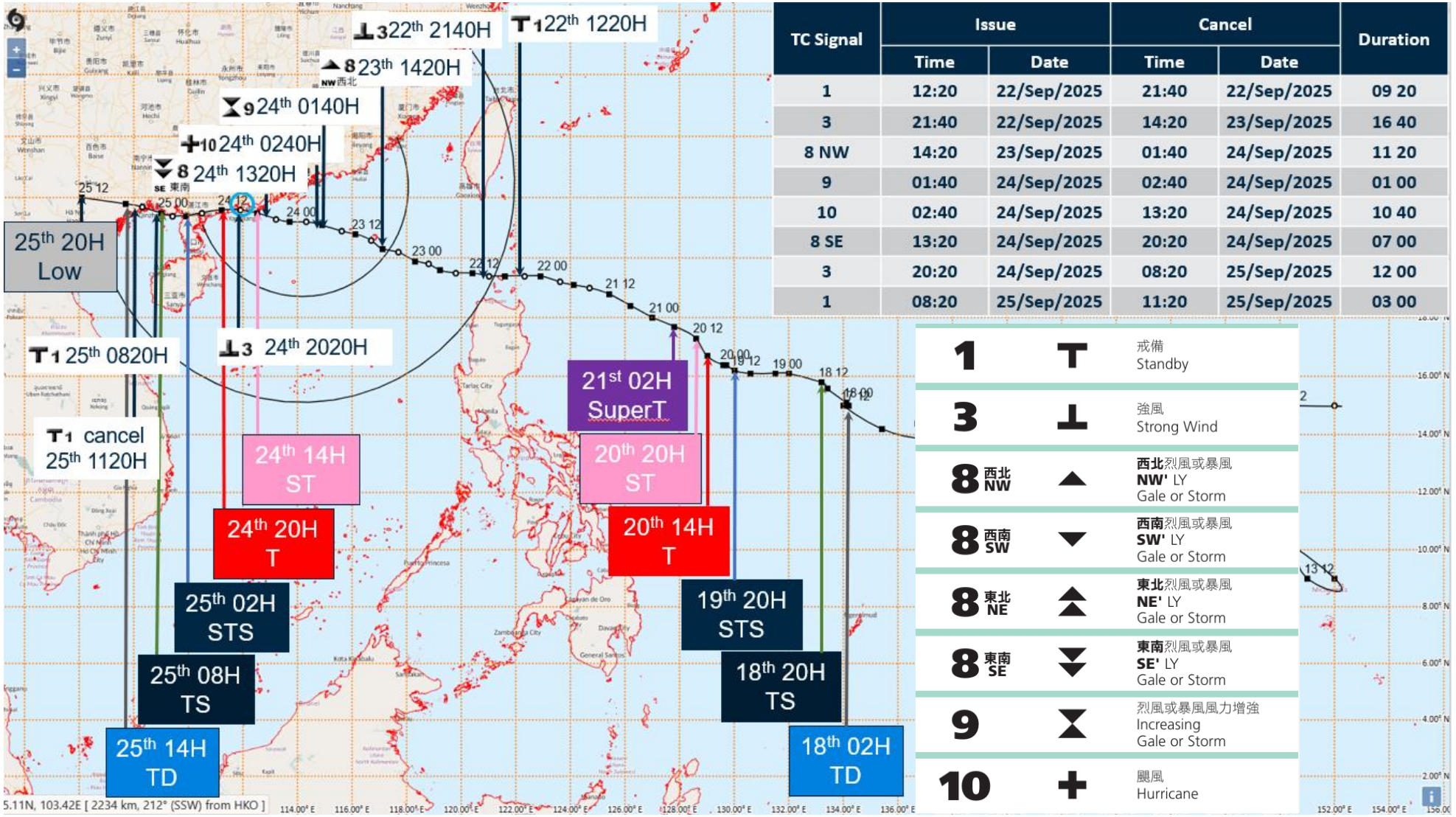
- Since 2007, the Hong Kong Observatory makes reference to the wind data recorded from a network of eight near-sea level reference anemometers covering the whole of Hong Kong when considering the issuance of Tropical Cyclone Warning Signals, No.3 and No.8. The figure below depicts the network of reference anemometers.



1	T	戒備 Standby
3	⊥	強風 Strong Wind
8 西北 NW	▲	**西北**烈風或暴風 **NW'** LY Gale or Storm
8 西南 SW	▼	**西南**烈風或暴風 **SW'** LY Gale or Storm
8 東北 NE	▲▲	**東北**烈風或暴風 **NE'** LY Gale or Storm
8 東南 SE	▼▼	**東南**烈風或暴風 **SE'** LY Gale or Storm
9	⧗	烈風或暴風風力增強 Increasing Gale or Storm
10	✚	颶風 Hurricane

SUPER TYPHOON RAGASA (SEPTEMBER 2025)

2ND TC SIGNAL NO 10 IN HK IN A YEAR



TC Signal	Issue		Cancel		Duration
	Time	Date	Time	Date	
1	12:20	22/Sep/2025	21:40	22/Sep/2025	09 20
3	21:40	22/Sep/2025	14:20	23/Sep/2025	16 40
8 NW	14:20	23/Sep/2025	01:40	24/Sep/2025	11 20
9	01:40	24/Sep/2025	02:40	24/Sep/2025	01 00
10	02:40	24/Sep/2025	13:20	24/Sep/2025	10 40
8 SE	13:20	24/Sep/2025	20:20	24/Sep/2025	07 00
3	20:20	24/Sep/2025	08:20	25/Sep/2025	12 00
1	08:20	25/Sep/2025	11:20	25/Sep/2025	03 00

1	T	戒備 Standby
3	⊥	強風 Strong Wind
8 西北 NW	▲	**西北**烈風或暴風 **NW'** LY Gale or Storm
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8 東北 NE	▲▲	**東北**烈風或暴風 **NE'** LY Gale or Storm
8 東南 SE	▼▼	**東南**烈風或暴風 **SE'** LY Gale or Storm
9	⧗	烈風或暴風風力增強 Increasing Gale or Storm
10	✚	颶風 Hurricane

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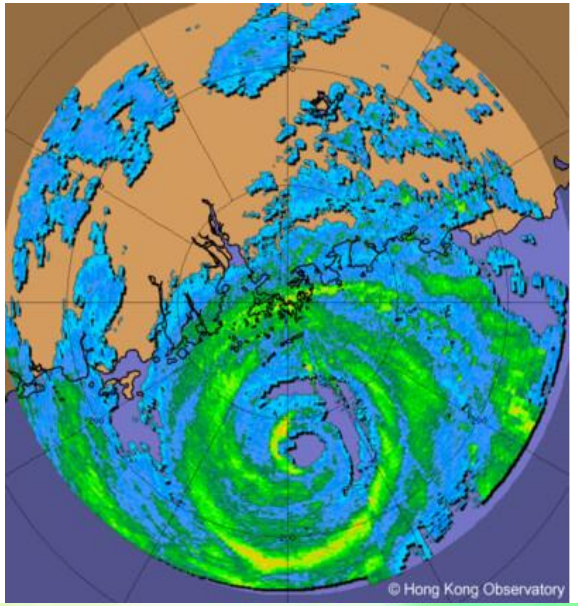
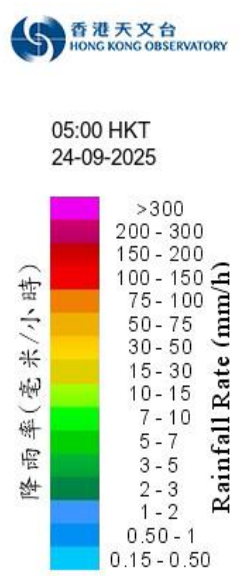
* Preliminary analysis

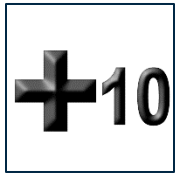
OPERATION

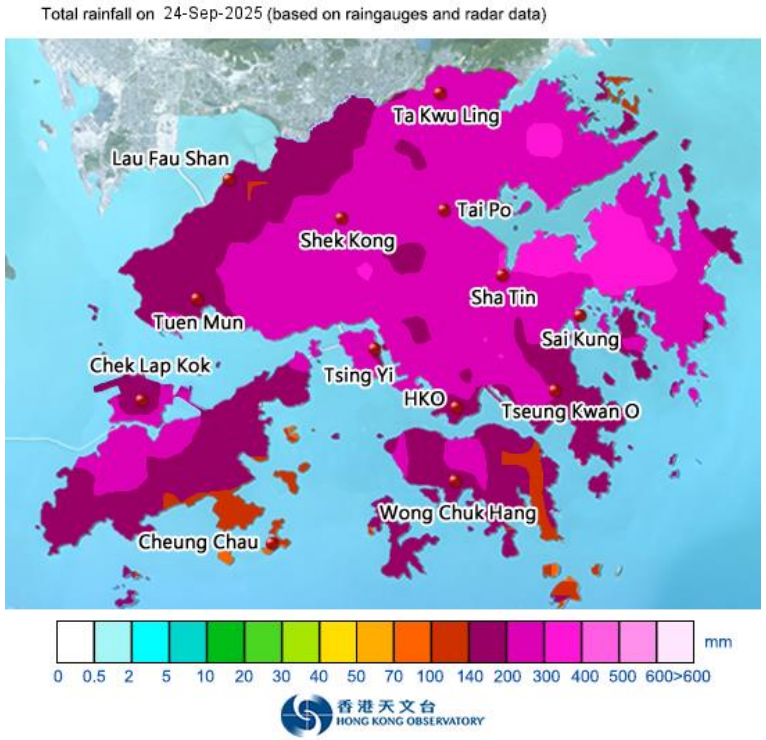
WINDS & RAINFALL

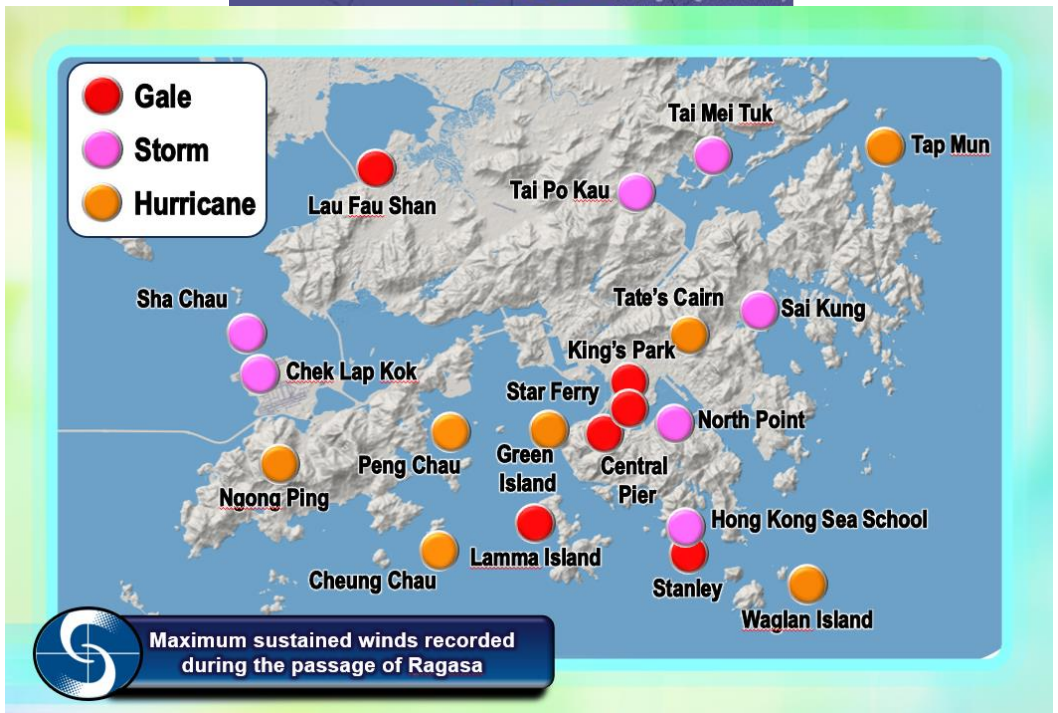
- Hurricane force winds were recorded over many places.
- More than 200 millimetres of rainfall were generally recorded over the territory.
- Hurricane Signal No. 10 (highest TC warning signal), Amber Rainstorm Warning, Localised Heavy Rain Advisory, Landslip Warning, Special Announcement on Flooding in the Northern New Territories were issued during the passage of Ragasa.











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IMPACT

CASUALTIES & INCIDENTS

Super Typhoon Ragasa *Hong Kong / Health & Environment*

Mother and son, 5, in intensive care after being swept into Hong Kong sea

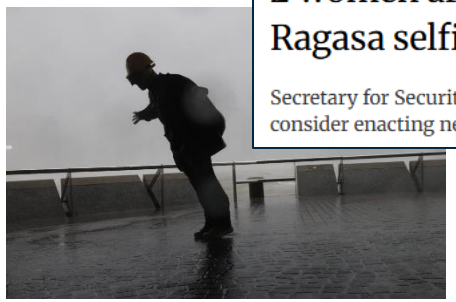
Father attempts to save family swept in by wave during No 8 signal for Super Typhoon Ragasa, leading to rescuers pulling all three from water

Source: SCMP

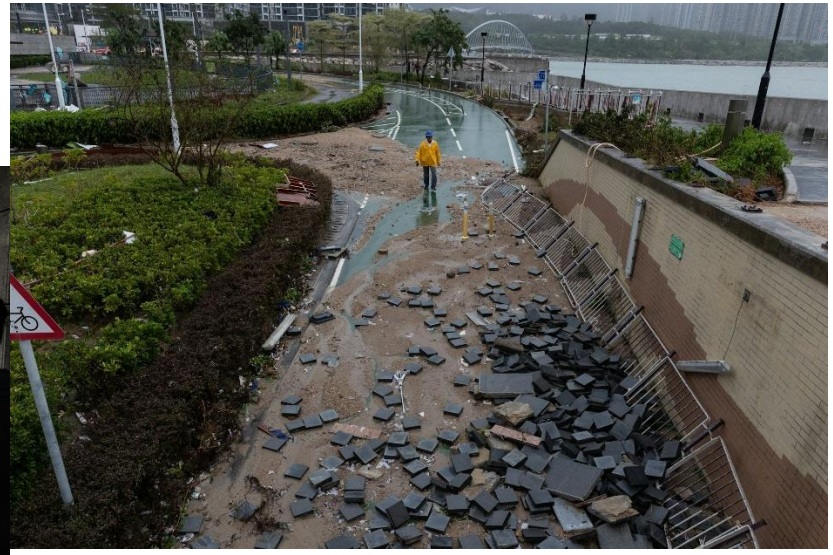
Super Typhoon Ragasa *Hong Kong / Law and Crime*

2 women arrested in Hong Kong over endangering child on Ragasa selfie trip

Secretary for Security Chris Tang vows to review existing legislation addressing storm chasing and consider enacting new laws



Source: HK01



Source: HK01

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Source: Hong Kong Police Facebook

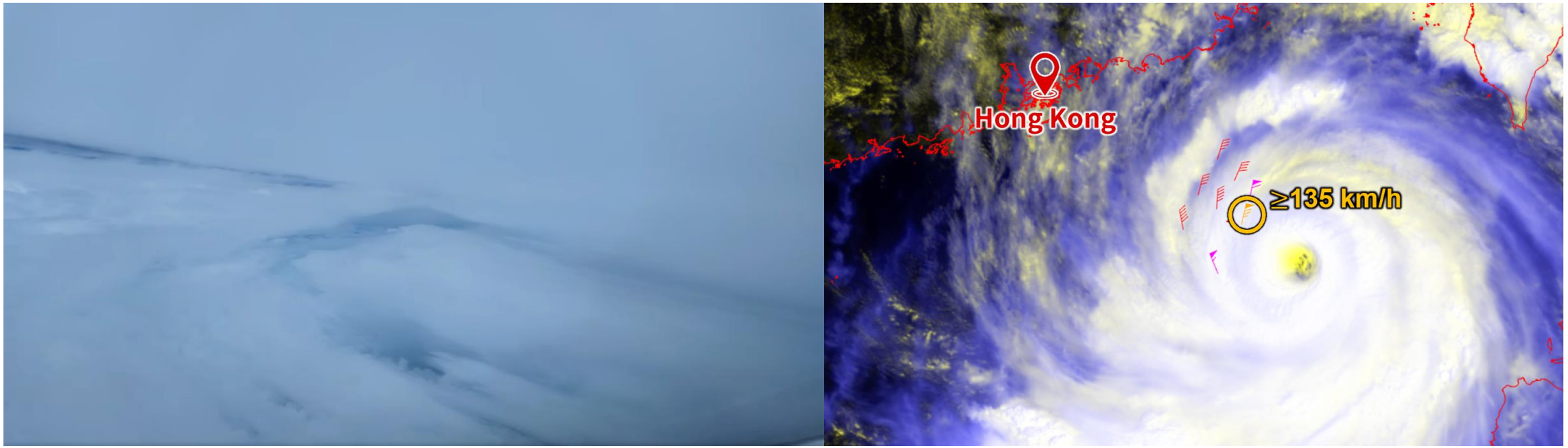
HKO's services and actions in support of Early Warnings for All (1)

Detection, observations, monitoring, analysis and forecasting of hazards

OPERATION

DROPSONDE

- During the passage of Ragasa across the northern part of the South China Sea, the Observatory collaborated with the Government Flying Service for dropsonde operations over the northwestern part of Ragasa on 23 September.
- Hurricane force winds of at least 135 km/h near sea level were recorded 120 kilometres from the centre of Ragasa, indicating that its hurricane force winds were extensive.



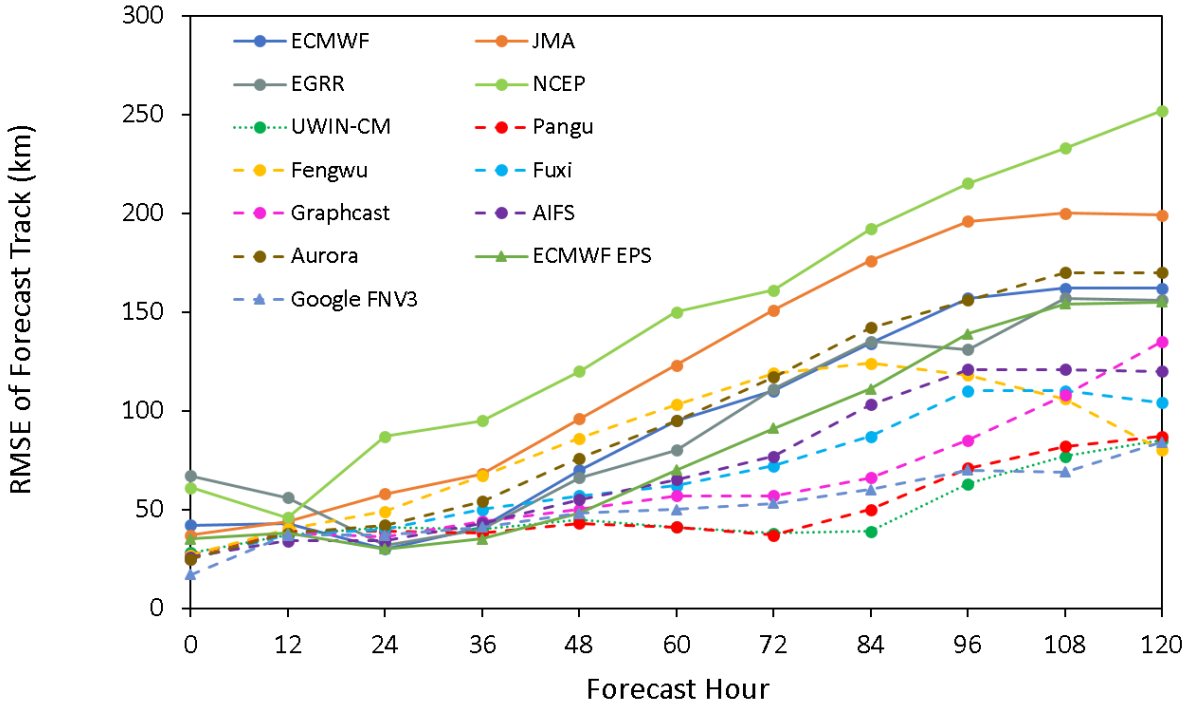
The Hong Kong Government Flying Service captured the eye of Ragasa on the afternoon of 23 September.

RECENT ADVANCE IN TROPICAL CYCLONE FORECASTING

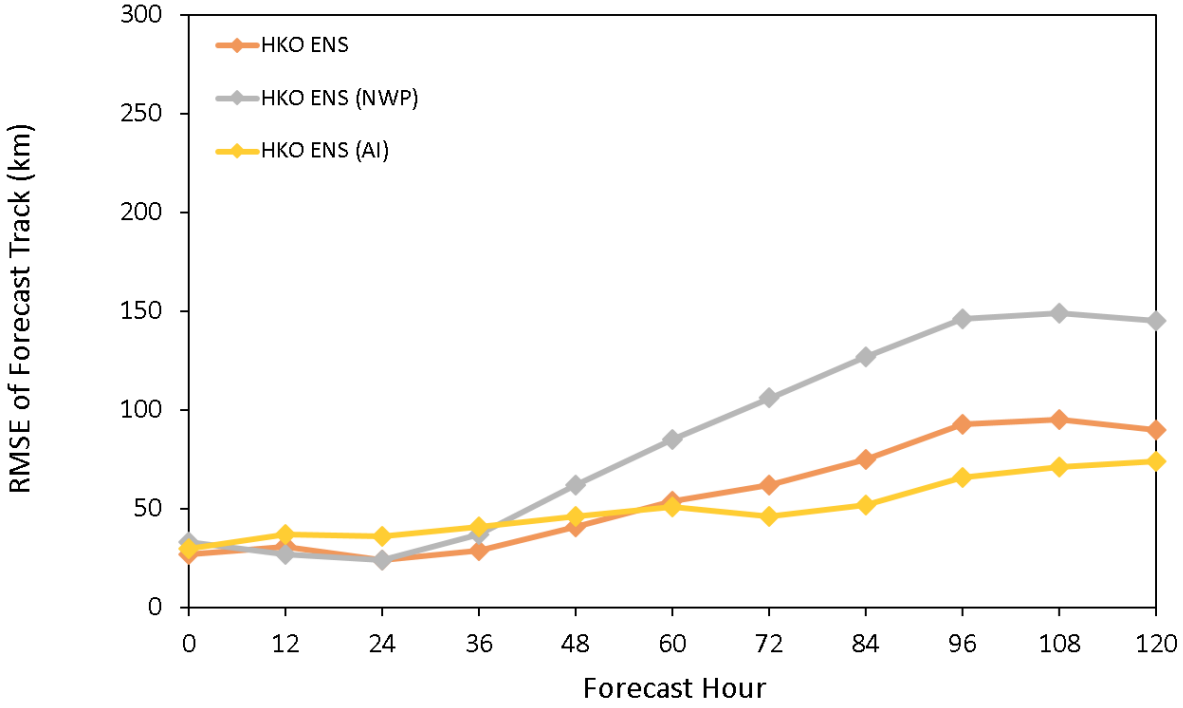
TC TRACK FORECAST USING A ENSEMBLE OF NWP AND AI MODELS

HKO began operational trials of several AI weather prediction models in real-time since mid-2023 to support its daily weather forecast including TC cases.

HKO introduced AI models into the operational ensemble consensus in 2025.



RMSE of forecast tracks by different global, mesoscale NWP and AI models for TC Ragasa

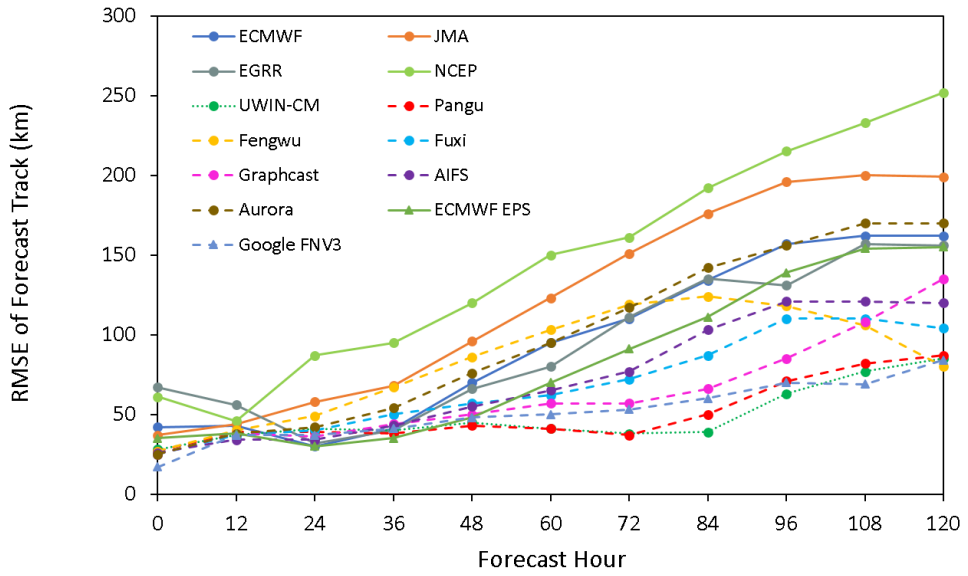


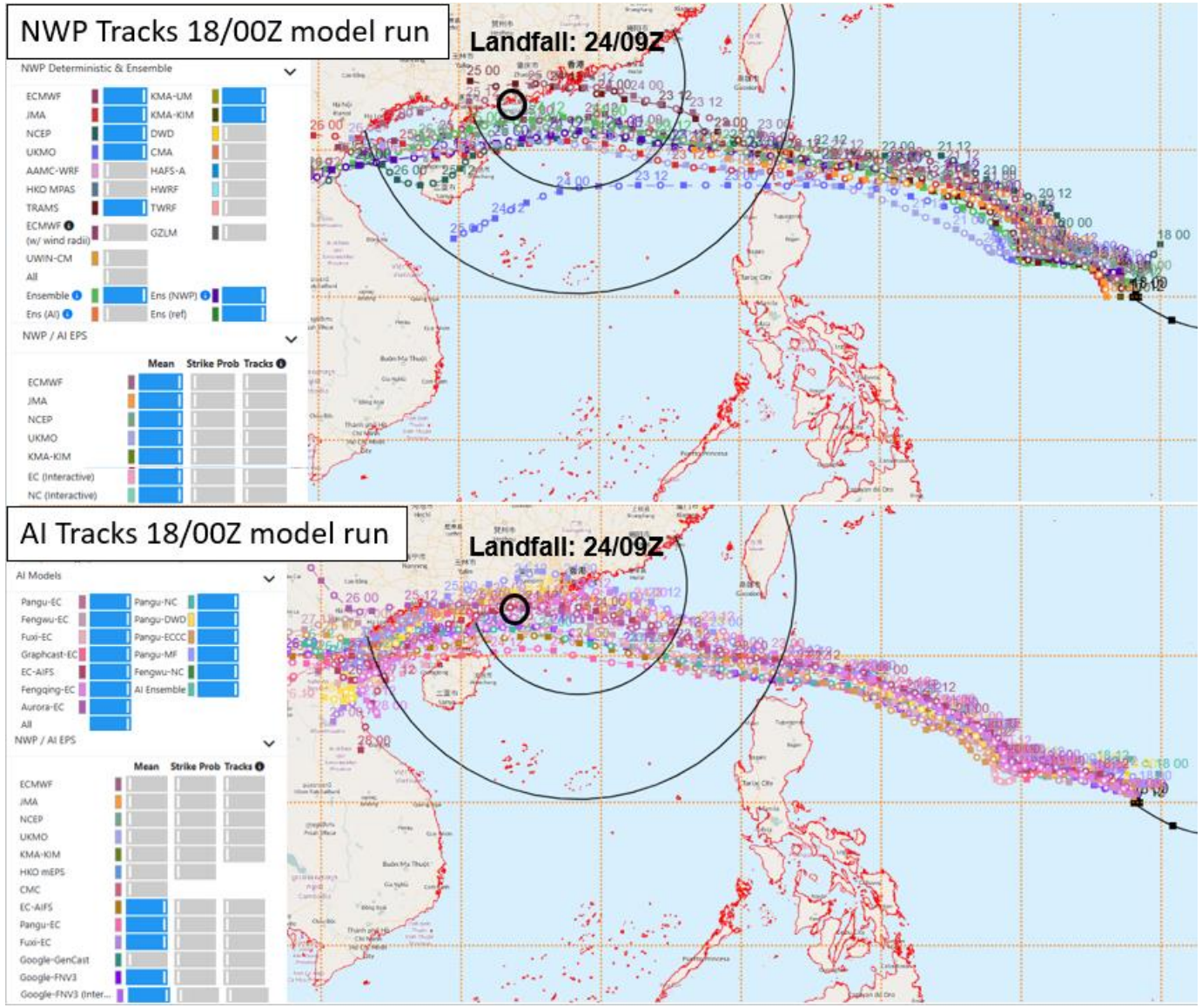
RMSE of forecast tracks by HKO's NWP ensemble, AI ensemble and NWP+AI ensemble for TC Ragasa

RECENT ADVANCE IN TROPICAL CYCLONE FORECASTING

TC TRACK FORECAST USING AI MODELS

AI models generally have better consistency and higher accuracy on forecast track in earlier model runs up to about a week before the approach of Ragasa.





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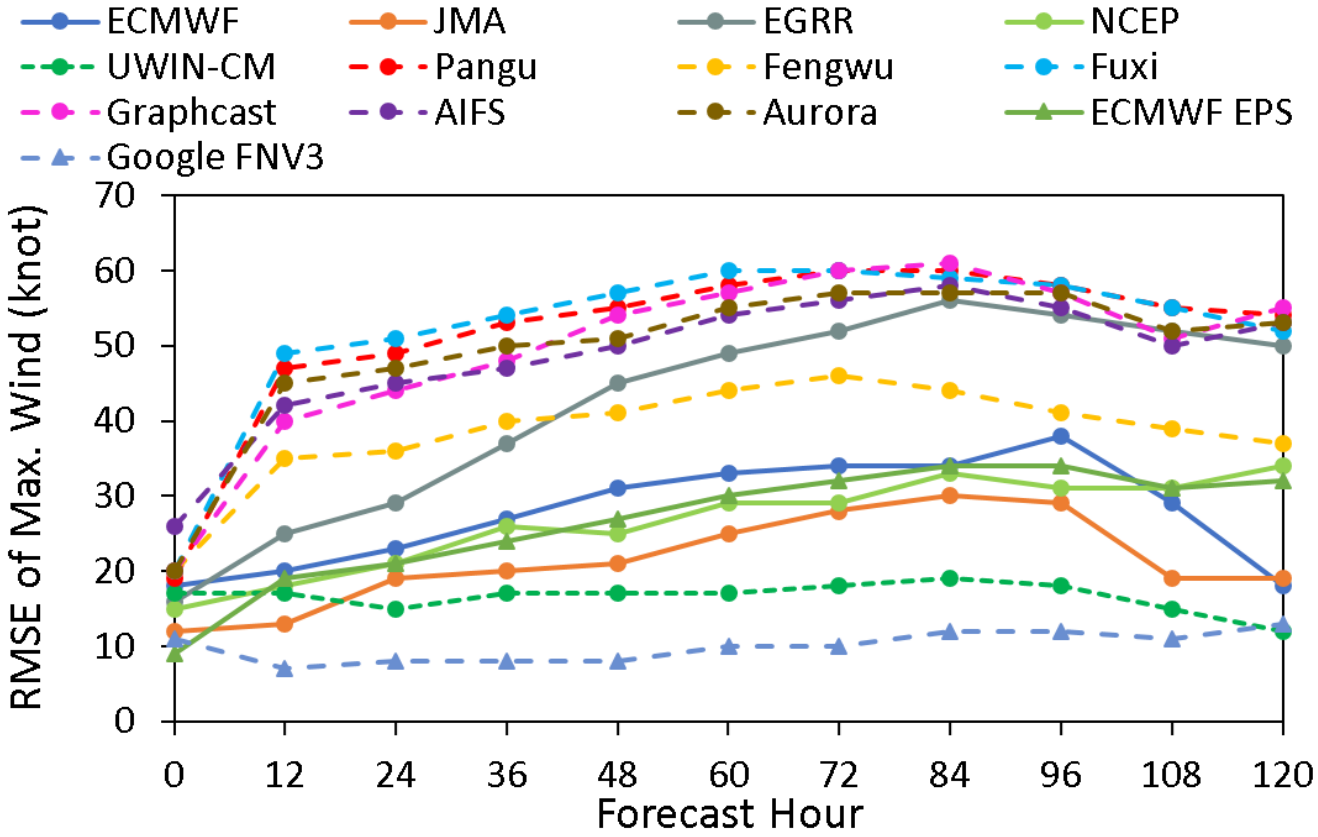
RECENT ADVANCE IN TROPICAL CYCLONE FORECASTING

TC INTENSITY FORECAST

Note that Google's experimental FNv3 predicted the intensity of Ragasa reasonably well, while other AI models tended to underestimate the intensity.

However, for TC Matmo, Google's FNv3 had largely overestimated the intensity for Matmo, with consistent bias of about 30-40 knots for its peak intensity.



RMSE of forecast intensity by different NWP, mesoscale and AI models for TC Ragasa

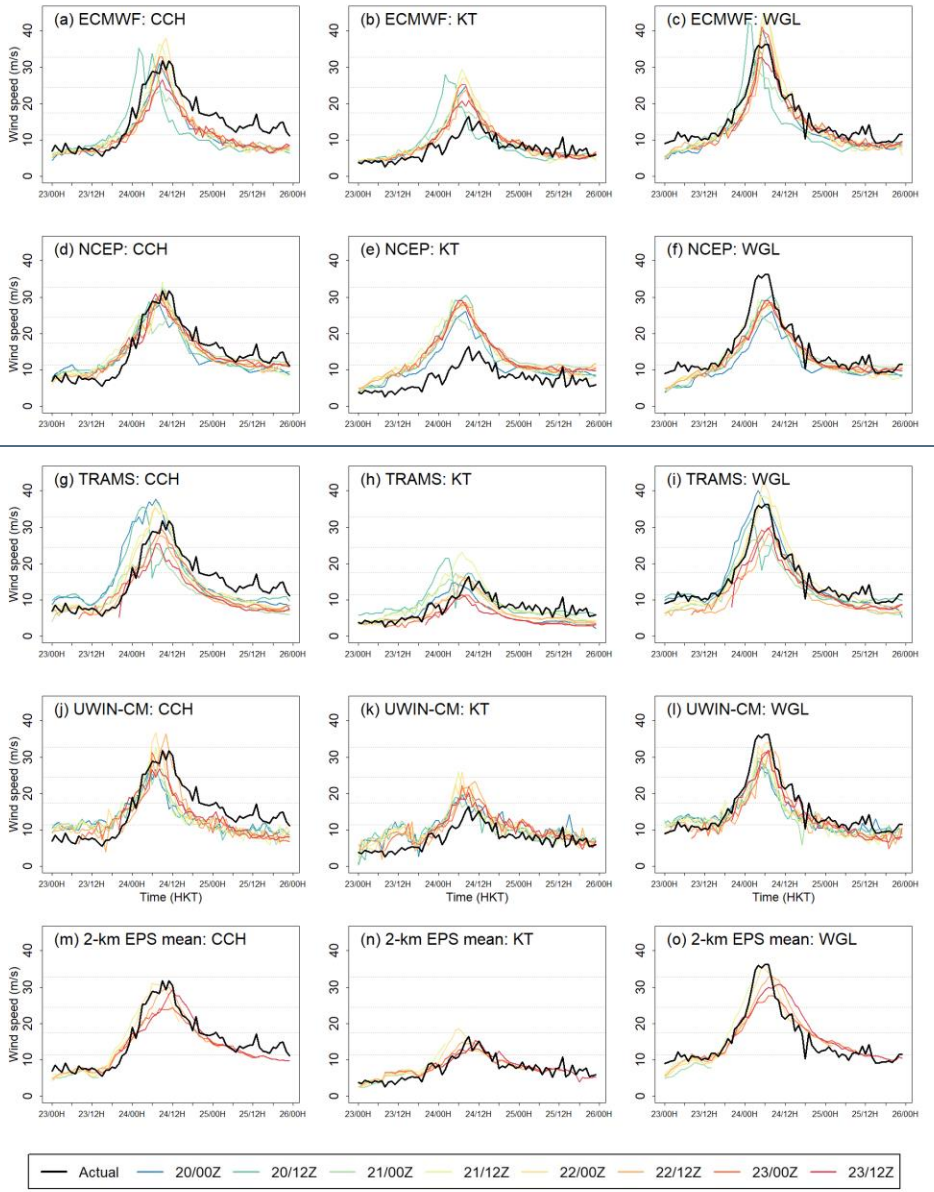
RECENT ADVANCE IN TROPICAL CYCLONE FORECASTING

WIND FORECAST

The global models captured the peak wind speed at CCH / WGL reasonably well. Same applies to the mesoscale and coupled models as well

It is noted that for this particular case, HKO's 2-km regional EPS captured the decreasing trend of wind speed at CCH better than other models

Source: HK01



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RECENT ADVANCE IN TROPICAL CYCLONE FORECASTING

STORM SURGE FORECAST

Storm surge predictions for government bureaux and departments to assist their decision in flood prevention works

Source: HK01

Source: The Collective HK

Source: Environmental Protection Department Facebook

Estimated Maximum Sea Level and Expected Time of Occurrence of Maximum Sea Level

(based on HKO Forecast for Ragasa at 08H 24/9)

HKO's services and actions in support of Early Warnings for All (2-3)

Warning dissemination and communication

&

Disaster risk knowledge

WARNING COMMUNICATION

WEATHER NOTES & SPECIAL WEATHER TIPS

Heads-up to the public days before the approach of Ragasa (even before it was named)

> Weather > Weather Forecast > Special Weather Tips

Special Weather Tips

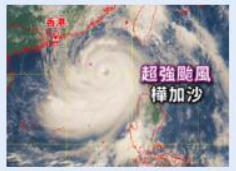
The area of low pressure near Luzon has intensified into a tropical depression. It will move across the vicinity of Luzon today and tomorrow (16 and 17 September) and enter within 800 kilometres of Hong Kong. The Observatory will consider issuing the Standby Signal, No. 1 between Wednesday night and early Thursday (18 September).

The tropical cyclone is expected to move in the general direction of the coast of Guangdong and intensify gradually. However, under the influence of the northeast monsoon, there are uncertainties in its movement and intensity. As its circulation is relatively small, the tropical cyclone will only bring significant impact to local weather when it gets relatively close to Hong Kong. Depending on the intensity of the tropical cyclone, the distance of its strong winds from Hong Kong and the change in local wind conditions, the Observatory will assess the need for issuing higher Tropical Cyclone Warning Signals on Friday (19 September).

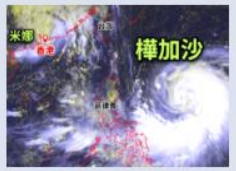
Under the influence of the outer rainbands associated with the tropical cyclone, the local weather will become unsettled on Friday. It will be windier with showers and squally thunderstorms over the weekend. There will be swells. Members of the public should pay attention to the latest weather information from the Observatory.

Observatory HKO @ObservatoryHK · Sep 16

16 Sep 8PM:The area of low pressure near Luzon has intensified into a tropical depression. ... more url.hko.hk/swte

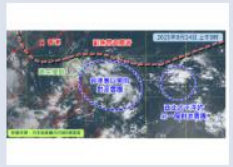


樺加沙帶來的十號風球
2025年9月24日

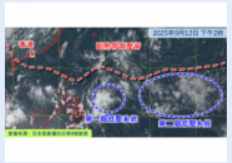


米娜遠離，樺加沙接力
2025年9月20日

一個接一個
2025年9月17日



9月中下旬的低壓系統
2025年9月14日



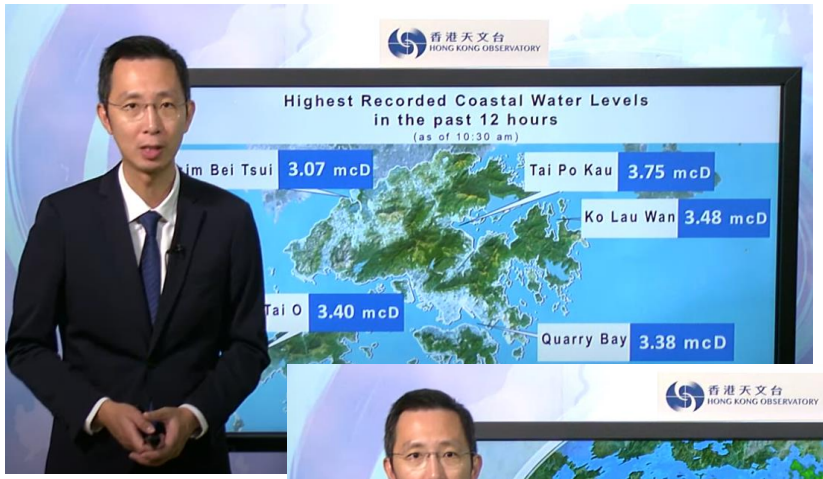
低壓系統三重奏
2025年9月12日

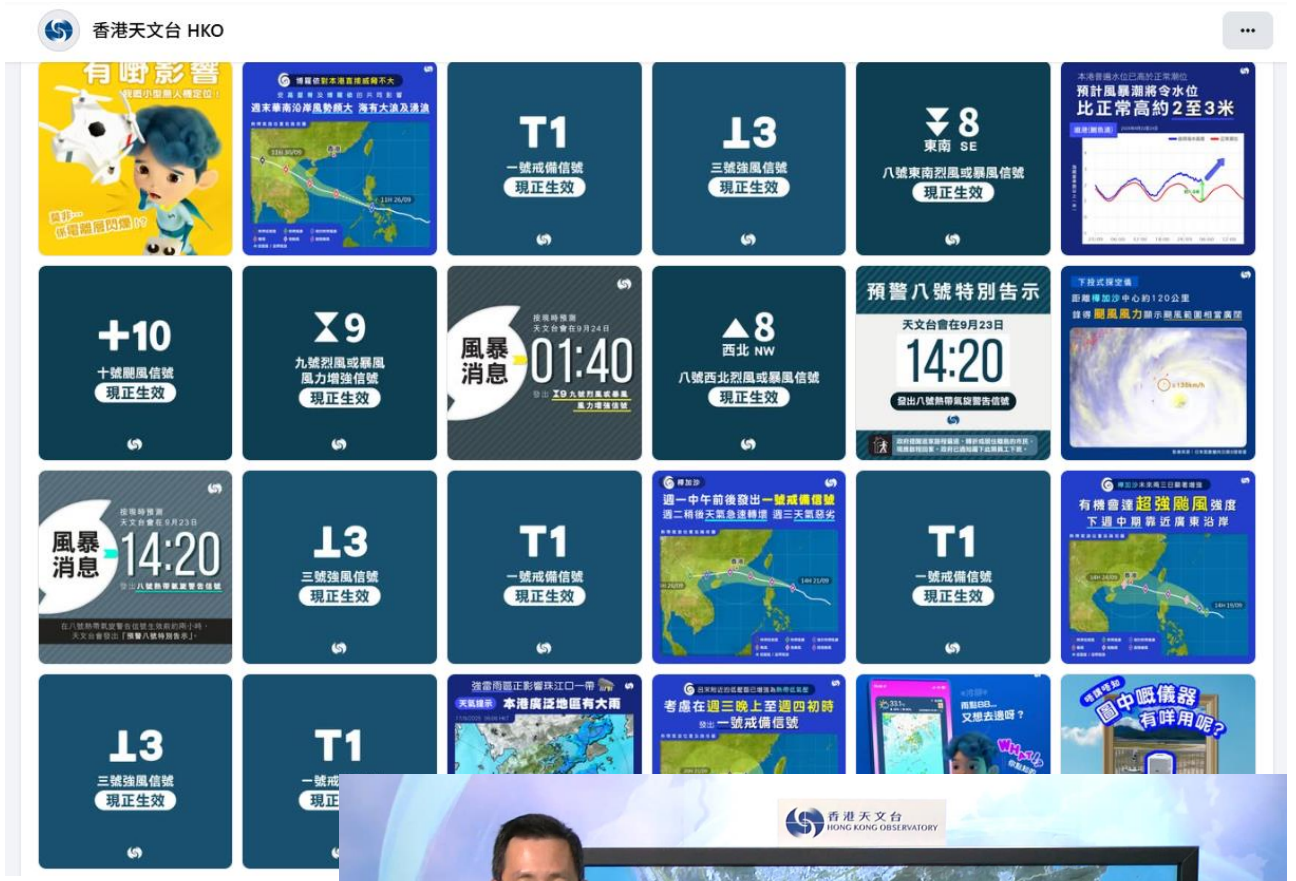
WARNING COMMUNICATION

MEDIA

Instant Facebook & Instagram posts updating latest forecast and warning information.

Hourly Central Briefings for the public while No. 8 TC Warning or above is in force.





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DISASTER RISK KNOWLEDGE

Closest on Wed morning
Time for astronomical high tide

Super Typhoon Intensity when Ragasa is closest to HK on Wed

HKO stated that storm surge is similar to Hato and Mangkhut

Aware of destructive winds if your windows are facing east

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HKO's services and actions in support of Early Warnings for All (4)

Preparedness & Response

HKO'S COORDINATION WITH B/DS

STEERING COMMITTEE

The Chief Executive, Mr John Lee (first left), inspects the operation of the Emergency Monitoring and Support Centre of the Security Bureau on September 22 to steer the comprehensive and adequate preparations and response efforts across departments to address the possible threats that Super Typhoon Ragasa may pose to Hong Kong. Also pictured are the Chief Secretary for Administration, Mr Chan Kwok-ki (first right), and the Secretary for Security, Mr Tang Ping-keung (second right).

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GovHK 香港政府一站通 繁體版 简体版

CS chairs meeting of steering committee on handling GO

CS chairs meeting of steering committee on handling extreme weather (with photos)

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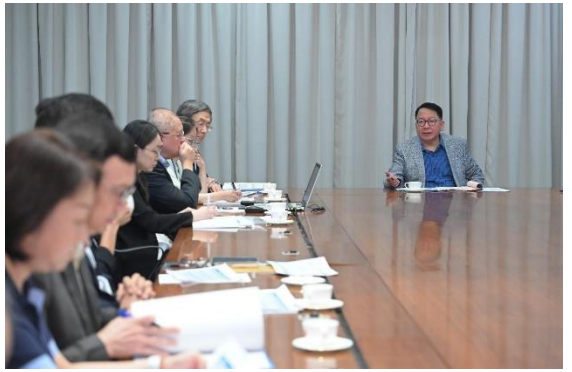
With Super Typhoon Ragasa edging closer to the coast of Guangdong midweek this week, the Chief Secretary for Administration, Mr Chan Kwok-ki, chaired a meeting of the steering committee on handling extreme weather today (September 21) to holistically review and further steer and co-ordinate cross-departmental thorough and adequate preparations and response efforts to address the possible threats that Ragasa may pose to Hong Kong. The Deputy Chief Secretary for Administration, Mr Cheuk Wing-hing; the Secretary for Development, Ms Bernadette Linn; the Under Secretary for Transport and Logistics, Mr Liu Chun-san; the Under Secretary for Security, Mr Michael Cheuk; the Under Secretary for Environment and Ecology, Miss Diane Wong; and representatives from relevant bureaux and departments attended the meeting.

At the meeting, members were briefed by the Director of the Hong Kong Observatory on the latest assessment on Ragasa. According



The Chief Secretary for Administration, Mr Chan Kwok-ki (first right), chaired a meeting of the steering committee on handling extreme weather on September 21 to holistically review and further steer and co-ordinate cross-departmental thorough and adequate preparations and response efforts to address the possible threats that Ragasa may pose to Hong Kong.

HKO'S COORDINATION WITH B/DS

RECOVERY

Mr Chan visited a site in the Central and Western District affected by fallen trees and a landslide to inspect the clean-up and recovery progress by departments such as the Fire Services Department (FSD), the Highways Department (HyD), and the Geotechnical Engineering Office (GEO).

He then chaired a meeting of the steering committee on handling extreme weather to receive updates from the heads of relevant bureaux and departments and comprehensively review emergency response and recovery efforts of various government departments.

DSD's mobile powerful pumping robots "Water-pumping Dragon"

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