MEMBER
REPORT
Hong Kong, China

**ESCAP/WMO Typhoon Committee
19th Integrated Workshop
Shanghai, China
19 - 22 November 2024**

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I. Overview of tropical cyclones which have affected/impacted Member's area since the last Committee Session

1. Meteorological Assessment (highlighting forecasting issues/impacts)

Six tropical cyclones (TCs) affected Hong Kong, China from 1 January to 16 November 2024, namely Tropical Storm Maliksi (2402) in May – June, Severe Tropical Storm Prapiroon (2404) in July, Super Typhoon Yagi (2411) in September, Typhoon Trami (2420) in October, Super Typhoon Yinxing (2422) and Typhoon Toraji (2423) in November (Figure 1). Super Typhoon Yagi and Typhoon Toraji necessitated the issuance of No. 8 Gale or Storm Signal; whereas Tropical Storm Maliksi, Typhoon Trami and Super Typhoon Yinxing required the issuance of No. 3 Strong Wind Signal. Severe Tropical Storm Prapiroon required Standby Signal No. 1.

After a quiet period of tropical cyclone activities over the South China Sea in August, an area of low pressure over the seas east of the Philippines intensified into a tropical depression on 1 September and was named Yagi. Yagi entered the northern part of the South China Sea on 3 September. Under the favorable conditions of very warm sea water and weak vertical wind shear, Yagi rapidly intensified from a severe tropical storm into a super typhoon in just 24 hours on 4 September. Yagi attained its peak intensity with an estimated maximum sustained wind of 230 km/h near its centre in the small hours on 6 September, making it the second strongest tropical cyclone in the South China Sea since the Observatory's records began in 1950.
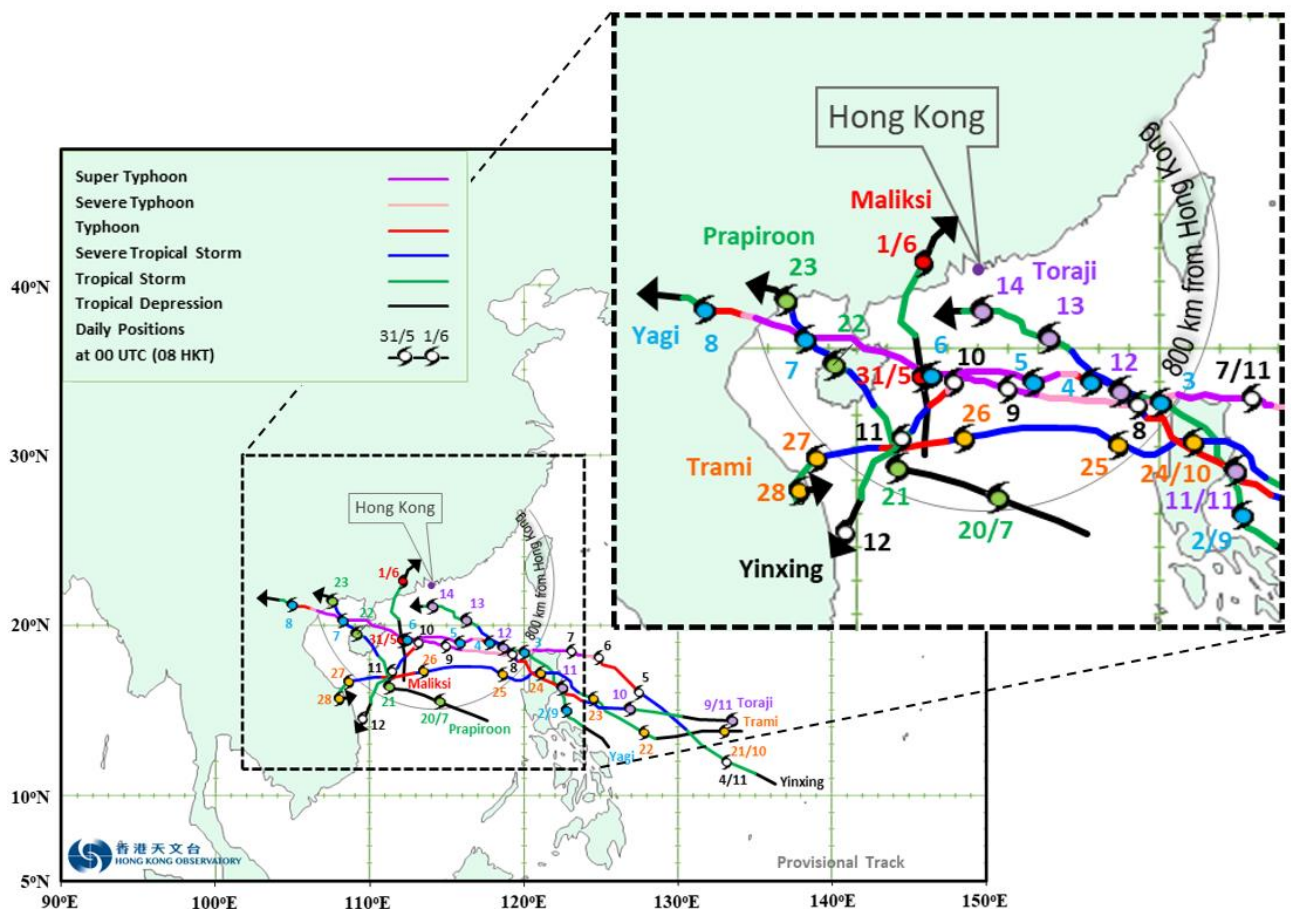

Figure 1 – Provisional tracks of tropical cyclones that affected Hong Kong, China from 1 January to 16 November 2024.

The position errors of forecasts issued by the Hong Kong Observatory (HKO) for these six tropical cyclones are summarized in Table 1. The performance of tropical cyclone forecasts was generally satisfactory with the average errors falling within the "potential track area" (the probable area of tropical cyclone location with a probability above 70%).

	Position forecast error (km) (No. of cases)				
	24-hr	48-hr	72-hr	96-hr	120-hr
Maliksi (2402)	103 (2)	-	-	-	-
Prapiroon (2404)	64 (6)	59 (4)	134 (2)	-	-
Yagi (2411)	55 (12)	83 (10)	86 (8)	177 (6)	285 (4)
Trami (2420)	70 (14)	113 (12)	173 (10)	203 (8)	318 (6)
Yinxing (2422)	42 (16)	91 (14)	152 (12)	245 (10)	301 (8)
Toraji (2423)	46 (10)	77 (8)	90 (6)	131 (4)	139 (2)

Table 1 – Performance summary of track forecasts issued by the HKO at 00 UTC and 12 UTC as verified against HKO's warning positions for the six tropical cyclones that affected Hong Kong, China from 1 January to 16 November 2024.

2. Hydrological Assessment (highlighting water-related issues/impact)

While the six tropical cyclones did not cause significant storm surge impact over Hong Kong, the outer rainbands of Yagi brought heavy showers, violent gusts and thunderstorms to Hong Kong on the night of 5 September and the next two days. More than 100 millimetres of rainfall were recorded over most parts of Hong Kong on 5 – 7 September and rainfall even exceeded 200 millimetres over the northeastern part of the New Territories.

3. Socio-Economic Assessment (highlighting socio-economic and DRR issues/impacts)

During the passage of Maliksi, a female pedestrian was hit by a fallen tree in Ma On Shan and she was sent to hospital for treatment. A broken branch blocked the only lane of Cotton Tree Drive slip road towards Central. During the passage of Yagi, there were at least 581 reports of fallen trees, one report of flooding and one report of landslide in Hong Kong. A total of nine people were injured.

4. Regional Cooperation (highlighting regional cooperation and related activities)

The HKO and the World Meteorological Organization (WMO) updated a Memorandum of Understanding (MOU) on 28 March 2024 to further strengthen meteorological co-operation. The updated MOU was signed by the Director of the HKO and the Permanent Representative of Hong Kong, China with the WMO, Dr Chan Pak-wai, and the Secretary-General of the WMO, Professor Celeste Saulo.

Under the updated MOU, the HKO will continue to develop and operate two WMO global weather information websites, namely the World Weather Information Service (WWIS) and the Severe Weather Information Centre (SWIC). Both websites are core components of the WMO Global Multi-

hazard Alert System framework for increasing the availability of authoritative warnings and information related to extreme and potentially high-impact weather, water, and climate events to contribute to the implementation of the United Nations Early Warnings for All (EW4All) initiative. Through the Regional Specialized Meteorological Centre (RSMC) for Nowcasting, the HKO will continue to support the meteorological and hydrological services in the Asian region on nowcasting hazardous weather and capacity development activities for contributing to the EW4All initiative. Moreover, the HKO will strongly support the WMO Voluntary Cooperation Programme by providing a variety of meteorological training courses to WMO Members through the Meteorological Training Centre for Belt and Road Countries to be set up by the HKO in the year.

Figure 2 –The Director of the HKO, Dr Chan Pak-wai (left) signed the renewed Memorandum of Understanding with the Secretary-General of the World Meteorological Organization, Professor Celeste Saulo (right), on 28 March 2024 to further strengthen meteorological co-operation.

The HKO organised a workshop on "Promoting Technical Exchange of Artificial Intelligence (AI) Applications in Tropical Cyclone Analysis and Forecasting" under the Typhoon Committee on 21 to 22 May 2024.

29 experts from 11 Typhoon Committee Members attended the workshop. The experts engaged in in-depth discussions and technical sharing on the developments and applications of AI in tropical cyclone analysis and forecasting. Their presentations covered objective analysis techniques of tropical cyclone, monitoring and forecasting extreme weather events, applications of data-driven models as well as forecast verification. The workshop also invited leading AI development teams from World Meteorological Centre, academia and information technology company to share the latest advancements in AI applications in weather forecasting. The experts also discussed the requirements for AI technologies and products within the Typhoon Committee region, as well as potential future collaboration projects.

Figure 3 – Group photo of the participants of the Workshop "Promoting Technical Exchange of Artificial Intelligence (AI) Applications in Tropical Cyclone Analysis and Forecasting", at Hong Kong, China, 21 to 22 May 2024.

II. Summary of Progress in Priorities supporting Key Result Areas

1. Tropical cyclone reconnaissance flights

Main text:
The HKO has been collaborating with the Hong Kong Government Flying Service (GFS) on tropical cyclone reconnaissance flights since 2016. Starting in July 2024, the collaboration has been extended by a joint effort with China Meteorological Administration to use multiple aircraft platforms to conduct observations in a coordinated fashion covering the Hong Kong and Sanya flight information regions when situation warrants.

Up to 7 October 2024, a total of 7 dropsonde missions were conducted within the year, respectively for tropical cyclones Maliksi (30 and 31 May), Prapiroon (20 and 21 July), Yagi (4 and 5 September), and a tropical depression (18 September).

The quality-control of dropsonde data was carried out using the ASPEN Software commencing in 2024. With a view to improving dropsonde data usage, in particular for numerical weather prediction (NWP) models, measured weather elements at all available levels are contained in the BUFR file produced by ASPEN. These BUFR files are disseminated via GTS to assist subjective analysis by forecasters as well as data assimilation into NWP models. A WMO Operational Newsletter was published on 25 June 2024.
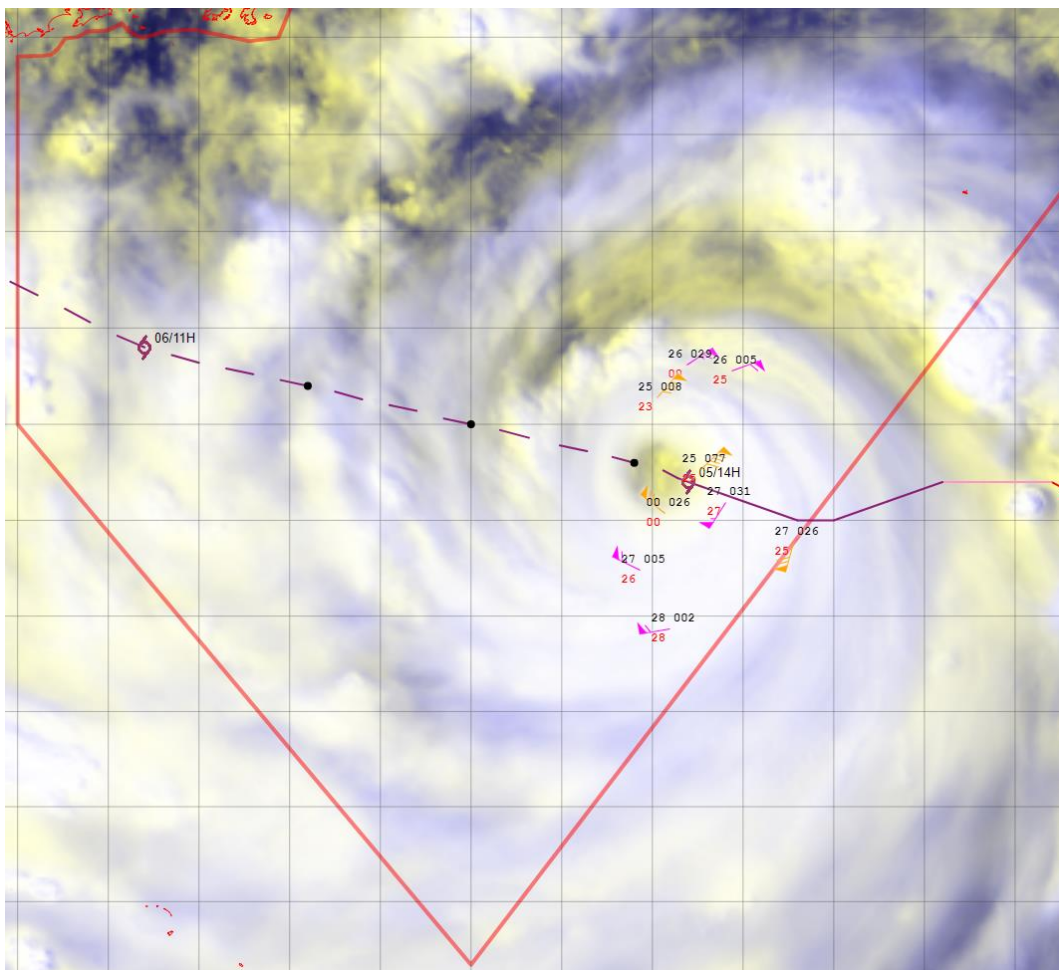

Figure 4 – Near surface winds sampled around Super Typhoon Yagi on 5 September through dropsonde mission of HKO

Identified opportunities/challenges, if any, for further development or collaboration:
Possibility of extending the observations into neighbouring Flight Information Regions (e.g. Manila) could be explored with the respective meteorological services.

Priority Areas Addressed:
Meteorology
▪ Enhance the capacity to monitor and forecast typhoon activities particularly in genesis, intensity and structure change.
▪ Promote communication among typhoon operational forecast and research communities in Typhoon Committee region.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	✓
Warning dissemination and communication	
Preparedness and response capabilities	

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2. Trial operation of Artificial Intelligence (AI) weather forecasting models for TC forecasting

Main Text:

With rapid development of artificial intelligence (AI) medium-range weather forecasting models, the HKO has been running four artificial intelligence (AI) weather forecasting model suites, including Fengwu, Fuxi, Graphcast and Pangu-Weather, as real-time operational trial. The AI models have been producing forecast prognostic charts and various objective guidance as those provided by traditional NWP models, for operational forecasters' reference in preparing weather forecasts and tropical cyclone forecast tracks.

The HKO has also conducted forecast verification of the AI models in alignment with the WMO GDPFS/WIPPS standardized verification procedures, in order to examine and trace the AI models' performance and forecasting skills. The scores of ACC (correlation coefficient between the forecast anomaly and the verifying analysis anomaly) on 500 hPa geopotential up to 15 days ahead during summer 2024 are showed in Figure 5. The AI models generally outperformed traditional NWP models throughout the medium range.
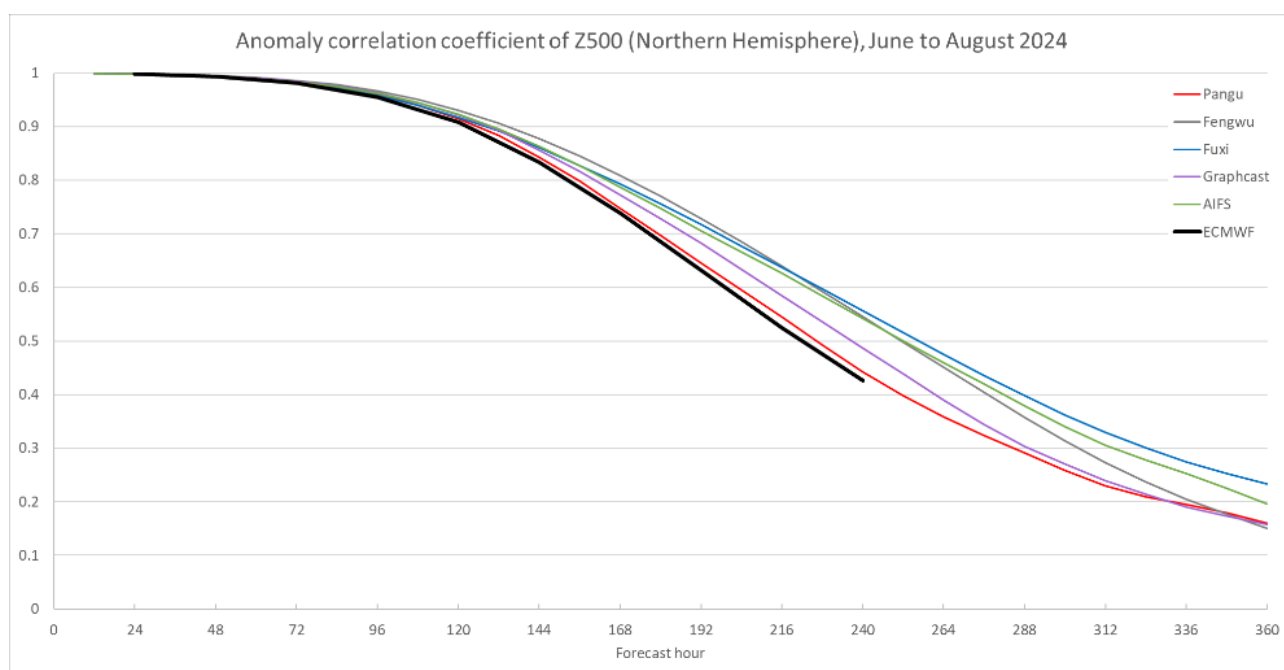

Figure 5 – ACC scores of 500 hPa geopotential forecast by AI models and ECMWF IFS.

Tropical cyclone track forecast errors by AI models and traditional NWP models are shown in Figure 6. It could be seen that the forecast track errors are generally lower from the AI-based models up to about 5 days ahead. Some AI models continued to show advantage over traditional models out to 10 days ahead. It should be noted that, however, the AI models generally underestimated TC intensity through its available forecast lead time.
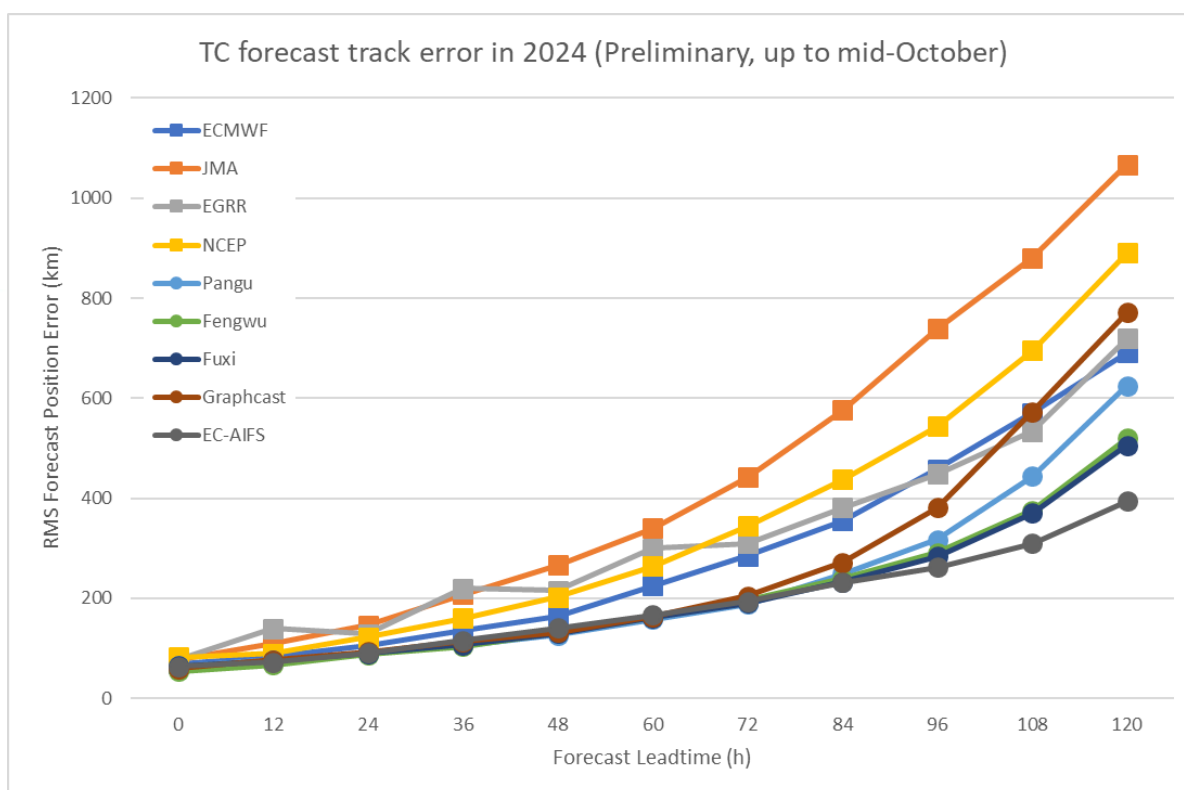
Figure 6 – TC track forecasts verified against positions based on HKO operational analysis tracks.

To further promote the application of AI in meteorology, HKO will continue to work closely with the Typhoon Committee, WMO, and industry experts, in an effort to strengthen the capabilities of tropical cyclone monitoring, forecasting and warning.

Identified opportunities/challenges, if any, for further development or collaboration:
1. Further development of AI models to include more weather elements including precipitation forecast and higher spatial resolution
2. Develop a regional mechanism to facilitate Typhoon Committee Members to exchange ideas and latest technological developments, as well as to share AI applications and data in TC analysis and prediction

Priority Areas Addressed:

Integrated
▪ Strengthen the cooperation between TRCG, WGM, WGH, and WGDRR to develop impact-based forecasts, decision-support and risk-based warning.
▪ Strengthen cross-cutting activities among working groups in the Committee.

Meteorology
▪ Develop and enhance typhoon analysis and forecast techniques from nowcast to medium-range, and seasonal to long-range prediction.
▪ Enhance and provide typhoon forecast guidance based on NWP including ensembles, weather radar and satellite related products, such as QPE/QPF.
▪ Enhance training activities with TRCG, WGH, and WGDRR in accordance with Typhoon Committee forecast competency, knowledge sharing, and exchange of latest development and new techniques.

DRR
▪ Enhance Members' disaster risk reduction techniques and management strategies.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	✓
Warning dissemination and communication	
Preparedness and response capabilities	

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3. Trial run of Delft3D FM model for storm surge forecasting in Hong Kong

Main text:
HKO has been using Sea, Lake and Overland Surges from Hurricanes (SLOSH) model as the operational storm surge model in support of storm surge forecast and alert service in Hong Kong. A circularly symmetric TC parametric model of Jelesnianski was adopted in SLOSH which requires storm size (radius of maximum wind) and central minimum pressure as well as ambient pressure as input parameters. It is computationally economical and efficient to predict storm surge based on the official TC forecast track and intensity. However, it cannot cater for the contribution of northeast monsoon to water level anomaly under the combined effect of TC and northeast monsoon. To address this issue, HKO has developed a data-driven method based on Empirical Orthogonal Functions (EOF) regression to forecast the water level anomaly attributed to the effect northeast monsoon, though the nonlinear effect of the interaction between northeast monsoon and TC cannot be catered for. With ever increasing model resolution and improving model performance, global NWP models now have the capability of forecasting storm structure and intensity with reasonable accuracy. AI models also show competitive performance compared to the traditional NWP models. With the advancement of AI models and the availability of higher resolution model reanalysis data as the training dataset foreseeable in the future, TC intensity and storm structure forecasts by AI models also seem promising in the future. Taking the advantage of these model developments, HKO is experimenting with more sophisticated models including Delft3D Flexible Mesh Suite (Delft3D FM) for storm surge forecasting.

Delft3D FM uses variable grid resolution and allows input of numerical model wind field as the atmospheric forcing besides of TC parametric wind field. HKO has configured a model domain as shown in Figure 7 with the finest resolution over the coastal waters of Hong Kong in the order of 100 m for testing purpose. As illustrated in the case study of Super Typhoon Yagi in 2024, the peak values of water level forecast by Delft3D FM for 5-6 September 2024 based on ECMWF model wind and pressure forecast fields were comparable with those from TC parametric model, and were generally better than the SLOSH model forecast in the run of 00 UTC 4 September 2024 (Figure 8). Delft3D FM is computationally expensive and is tested on the newly acquired high performance computer of HKO. Currently, it takes about 15 minutes to produce a 5-day storm surge forecast using 128 threads on one computational node. Wave effects have not been included in the water level forecast. More systematic model verification and tuning of Delft3D FM will be carried out in the future.
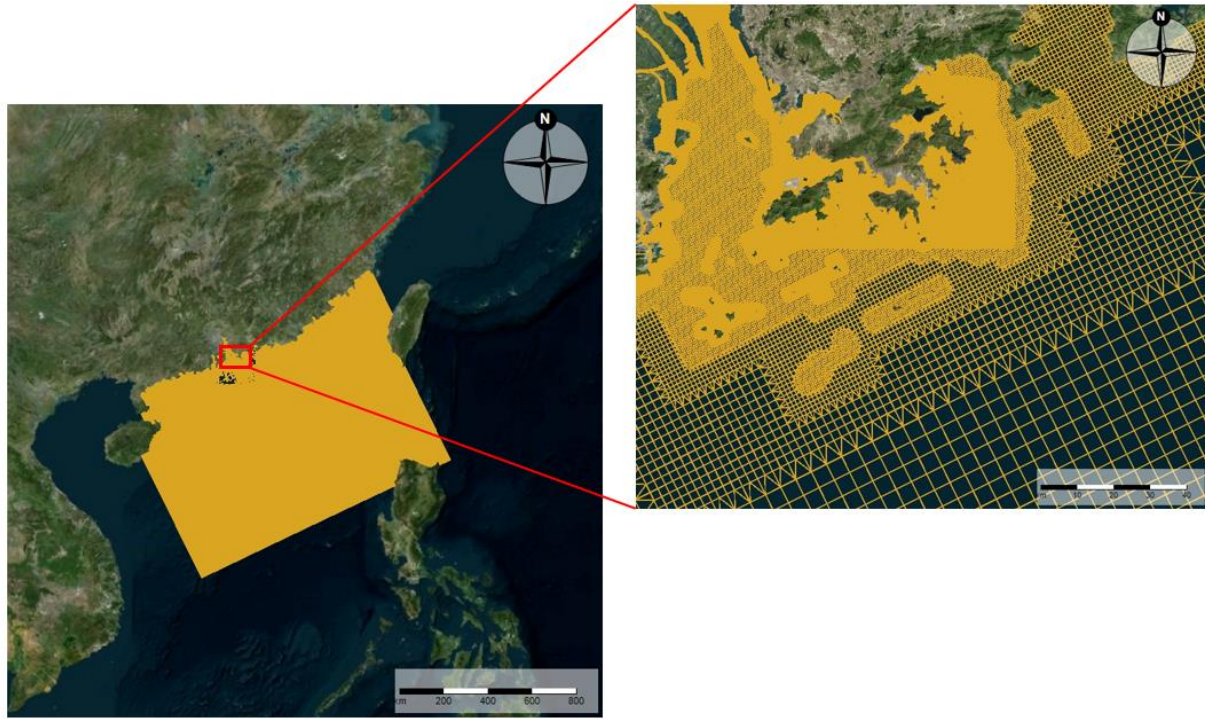
Figure 7 – Model domain of Delft3D-FM with unstructured coarse quadrilateral grids over the northern part of the South China Sea and finer triangular grids over Hong Kong coastal waters.
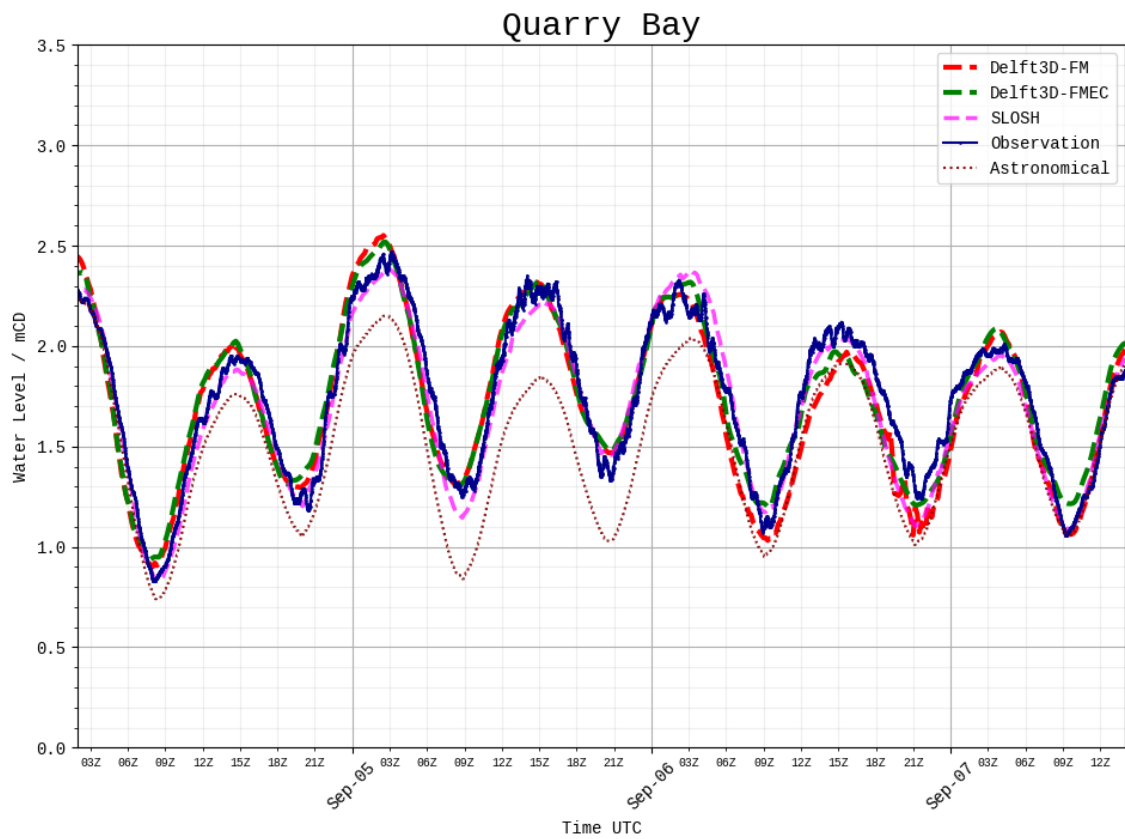

Figure 8 – A comparison of water level forecasts from Delft3D-FM and SLOSH model run at 00 UTC 4 September 2024 against observations at Quarry Bay tide station during the passage of Super Typhoon Yagi. The astronomical tide prediction was produced by harmonic analysis method.

Identified opportunities/challenges, if any, for further development or collaboration:
HKO will continue to tune and test the new storm surge model and develop multi-model forecast strategy to improve storm surge forecast and alert service, contributing to early warning and assessment of storm surge risk and coastal flooding.

Priority Areas Addressed:
Meteorology
- Develop and enhance typhoon analysis and forecast techniques from nowcast to medium-range, and seasonal to long-range prediction.
- Enhance and provide typhoon forecast guidance based on NWP including ensembles, weather radar and satellite related products, such as QPE/QPF.
- Promote communication among typhoon operational forecast and research communities in Typhoon Committee region.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	✓
Warning dissemination and communication	
Preparedness and response capabilities	

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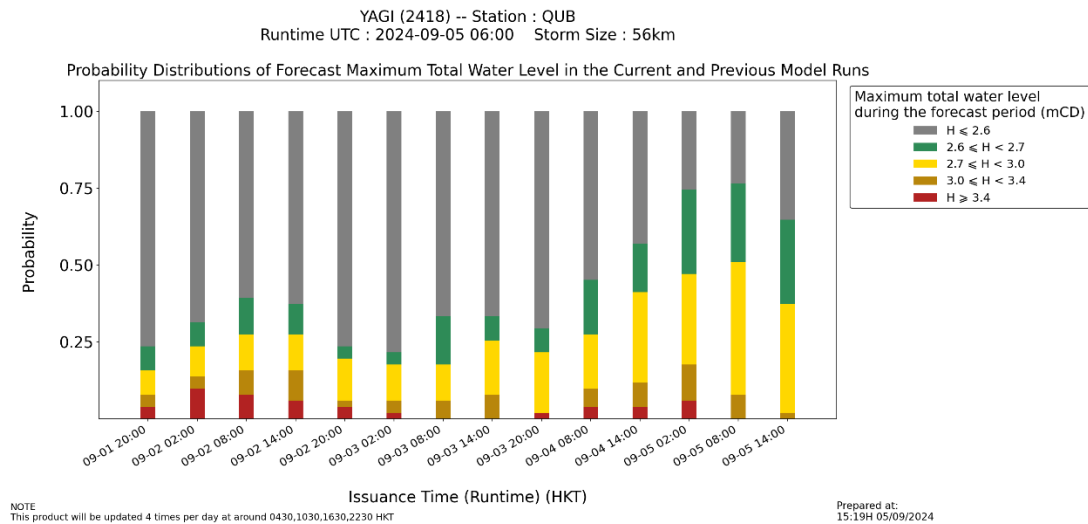# 4. Enhancement of risk-based storm surge forecast products

Main text:

HKO has been providing storm surge forecast and alert service to relevant government departments in Hong Kong through Government Weather Information Server (GOWISE) in support of their decision making on emergency preparedness and response against the threat of coastal flooding. As TC track and intensity forecasts are subject to inevitable uncertainty, it is useful to provide uncertainty information to users to facilitate their risk assessment of coastal flooding due to storm surge. In view of this, new probabilistic storm surge forecast products (Figure 9) were added together with an increase in the number of forecast sites from four to ten on GOWISE in June 2024. A briefing session to introduce the new storm surge products and illustrate their use by a close call of the "super typhoon direct-hit" scenario of Saola in 2023 was conducted for relevant government departments before the launch of the trial products (Figure 10). This enables the users to better appreciate the applicability and limitations of the products, as well as to provide valuable feedback to HKO.

Samples of the storm surge probabilistic forecast products generated based on SLOSH model with input from ECMWF model ensemble TC track forecast and post-processed intensity forecast as well as selected storm size are shown in Figure 9. They include a risk matrix showing the probability of exceeding certain water level for coastal flood risk assessment, probability distribution of forecast maximum water level in the current and previous model runs to facilitate comparison of model forecast changes, water level cumulative exceedance probability plot to help users grasp potential worst-case scenarios and the corresponding probability, and a spaghetti diagram of water level time series forecasts showing the water level prediction from different members of ensemble TC forecast to appreciate the forecast spread and possible timing of water level forecast exceeding the thresholds and for percentiles of 25, 50 and 75%.
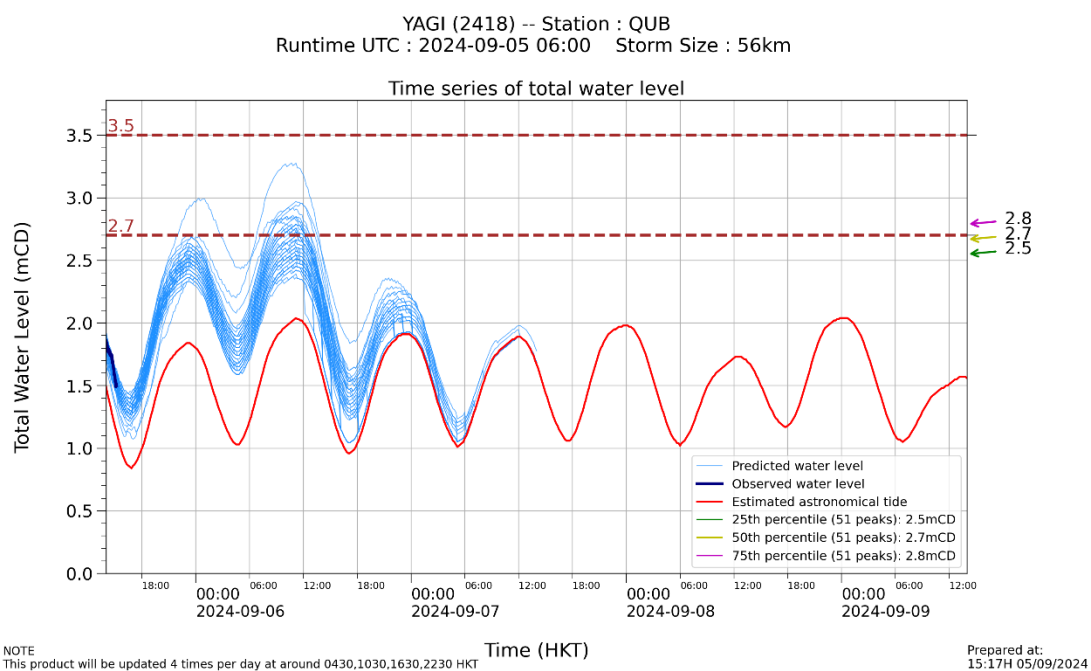

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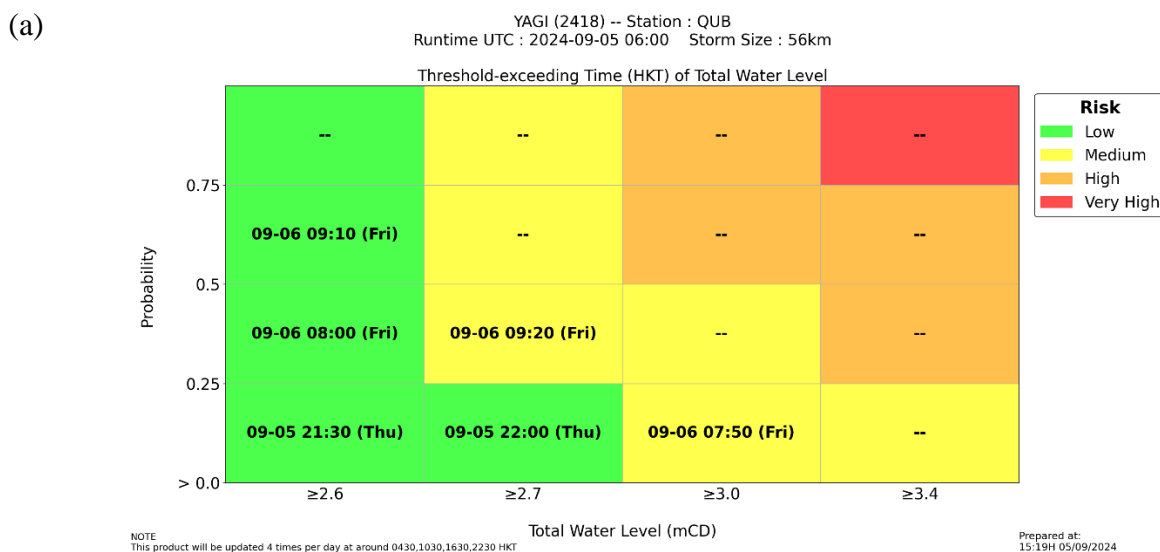
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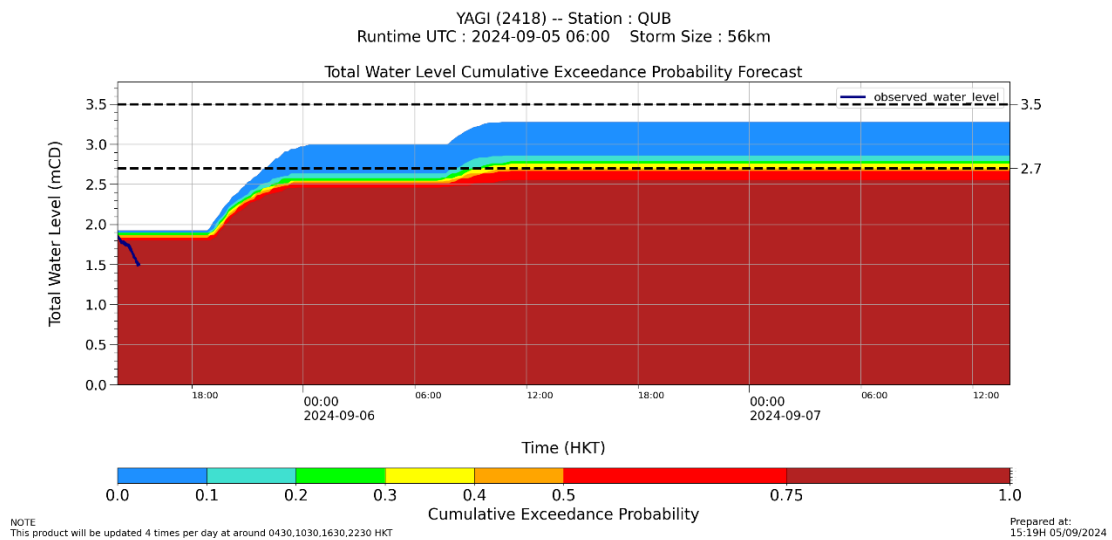
(d)

Figure 9 – Sample graphical products of risk-based storm surge forecasts during the passage of Super Typhoon Yagi in September 2024.

Figure 10 – A briefing session on storm surge forecast and alert service for relevant government departments in Hong Kong.

Identified opportunities/challenges, if any, for further development or collaboration:
HKO will continue to enhance the algorithms for generating storm surge probabilistic forecasts to facilitate risk assessment of coastal flooding during the passage of TCs, and communicate with users to increase the effectiveness of forecast product applications.

Priority Areas Addressed:
Meteorology
- Enhance and provide typhoon forecast guidance based on NWP including ensembles, weather radar and satellite related products, such as QPE/QPF.
- Promote communication among typhoon operational forecast and research communities in Typhoon Committee region.

Hydrology
- Strengthen capacity in effective flood forecasting and impact-based early warning, including hazard mapping and anticipated risk based on methodological and hydrological modelling, and operation system development.
- Increase capacity in utilization of advanced science and technology for typhoon-related flood forecasting, early warning, and management.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	✓
Warning dissemination and communication	
Preparedness and response capabilities	✓

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5. Strengthening Emergency Communication on Extreme Weather

Main text:
In 2023, Hong Kong experienced extreme weather events including close encounter by two super typhoons and serious floodings/landslides resulted from record-breaking rainfall. On 7-8 September 2023, the remnant of Tropical Cyclone Haikui brought unprecedented and prolonged heavy rain to Hong Kong, breaking the one-, two- and twelve-hour rainfall records during the same rainstorm episode. The induced serious floodings and landslides caused a lot of damages and brought the city to a halt. With a view to better alerting the general public of extreme rainfall with intensity far exceeding the usual thresholds set forth by the existing Rainstorm Warning Signals, the HKO has strengthened the dissemination of rainfall information starting from the rain season of 2024.

Figure 11 – When the Black Rainstorm Warning Signal (top amongst the three possible colour-coded signals, meaning widespread and persistent rainfall exceeding 70 mm in an hour) is in force, senior officer of HKO will conduct media briefings every hour to keep the public well informed of the latest rainstorm situation.

Specifically, media briefings would be conducted during the Black Rainstorm Warning Signal (Figure 11) with updates every one hour. Moreover, a "Special Weather Tips" bulletin will be issued to the public through HKO's website and mobile app, highlighting the exceptional circumstances associated with the rainstorm and the need to be on high alert. For this purpose, HKO has introduced two new terminologies, namely "Severe Rainstorm" and "Exceptionally Severe Rainstorm" (Figure 12). An educational article was published in May 2024 as part of the public education effort (link).

Figure 12 – New weather descriptive terms "Severe Rainstorm" and "Exceptionally Severe Rainstorm" introduced in May 2024 to raise public awareness and understanding on extreme rainfall.

In terms of preparedness and emergency response, HKO collaborated with the Geotechnical Engineering Office and formulated a new "Special Landslip Advisory" in 2024 to alert people of

landslide risk that is relatively localized in nature, in addition to the existing Landslip Warning which caters for a high risk of many landslips as a result of persistent heavy rain (link). To help mitigate potential flood impacts, HKO also collaborated closely with the Drainage Services Department (DSD) on flood risk assessment including effective communication of such risk information across different government units with emergency responsibilities via risk maps, email and notifications on mobile application. In support of such, a Flood Risk Assessment System (FRAS) for heavy-rain induced flood risk at district-scale has been set up based on cutting-edge rainfall nowcasting technology and past records of flood incidents. FRAS has been put on trial use by government users since May 2024.

Identified opportunities/challenges, if any, for further development or collaboration:
Balancing early warning with forecast accuracy and information overload is critical for effective communication before and during adverse weather. HKO will continue to conduct research studies and enhance skills in forecasting and communication especially on extreme weather events. Further development of FRAS with the use of AI and big data would be pursued.

Priority Areas Addressed:
Integrated
- Strengthen the cooperation between TRCG, WGM (roles played by HKO), WGH (role played by DSD), and WGDRR (concerned government stakeholders) to develop impact-based forecasts, decision-support and risk-based alerts (FRAS).

Hydrology
- Strengthen capacity in effective flood (risk) forecasting and impact-based early warning, including hazard mapping and anticipated risk based on methodological and hydrological modelling, and operation system development.
- Increase capacity in utilization of advanced science and technology for typhoon-related flood forecasting, early warning, and management.

DRR
- Enhance Members' disaster risk (assessment) reduction techniques and management strategies.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	✓
Detection, observation, monitoring, analysis, and forecasting	✓
Warning dissemination and communication	✓
Preparedness and response capabilities	✓

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6. Pilot Smart Flood Alert System at Shing Mun River

Main text:

Shing Mun River connects to Sha Tin Hoi and Tolo Harbour. Water level of the river may be affected by storm surges, monsoons and astronomical tides. The cycle tracks and pedestrian walkway along the river may be occasionally flooded. In view of this, the DSD has set up a Smart Flood Alert System, comprising display screens and smart poles, next to the four main pedestrian passages near Shing Mun River, and set up QR codes at various places along Shing Mun River to provide weather and water level information to the public.

The display screen and smart poles show real-time water level and images of the river, as well as weather and tidal information from the Hong Kong Observatory. They will also display different messages in response to the change in weather condition and river water level, including "Normal", "Stay Alert", "Warning" and "Danger" mode and let the public to better understand the real-time status of the river.
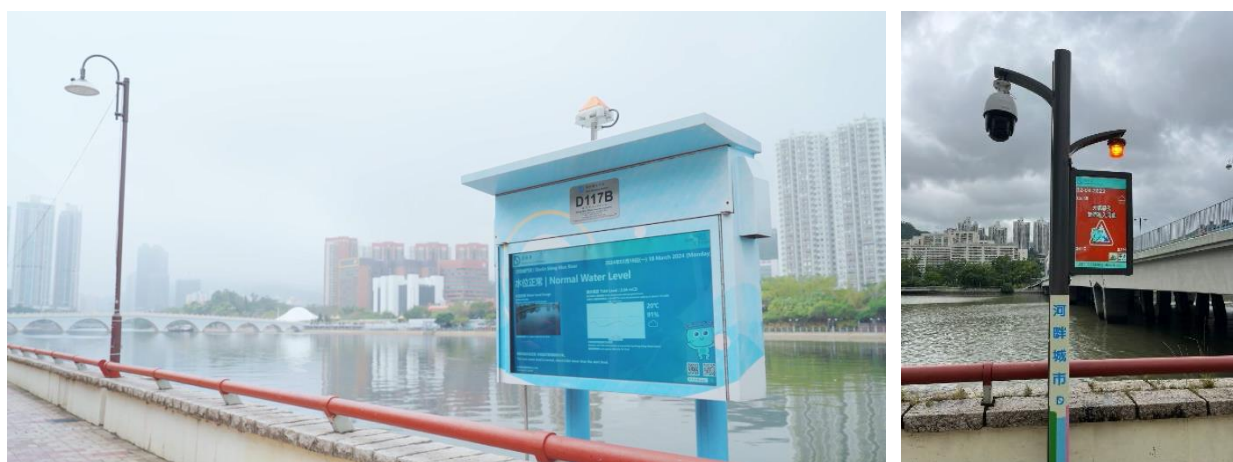

Figure 13 – Display screen and smart pole next to the main pedestrian passage along the river

Figure 14 – Different messages will be displayed, including "Normal", "Stay Alert", "Warning" and "Danger" mode, as the weather condition or river water level changes. Citizens can also use the QR code installed at the subway entrances to better understand the weather and river conditions in advance, so as to stay vigilance, and stay away from the river areas.

Identified opportunities/challenges, if any, for further development or collaboration:
DSD will continue to adopt innovative approaches to flood alert communication. Further development of flood early alerts would be pursued.

Priority Areas Addressed:
Hydrology
▪ Strengthen capacity in effective flood (risk) forecasting and impact-based early warning, including hazard mapping and anticipated risk based on methodological and hydrological modelling, and operation system development.
▪ Improve typhoon-related flood (including riverine flood, flash flood, urban flood, and coastal flood) monitoring, data collection and archiving, quality control, transmission, processing, and sharing framework.
DRR
▪ Enhance Members' disaster risk (assessment) reduction techniques and management strategies.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	✓
Detection, observation, monitoring, analysis, and forecasting	
Warning dissemination and communication	✓
Preparedness and response capabilities	✓

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7. Tropical cyclone strike probability maps based on NWP ensemble predictions

Main text:
The "Tropical Cyclone Track Probability Forecast" (TCTPF) service has been available on the HKO website and MyObservatory mobile app since 2017. The probabilistic forecast of TC movement in the next 9 days is based on data from ensemble prediction systems (EPSs) of several global NWP model centres including ECMWF, JMA, NCEP and UKMO. The TC strike probability map (SPM) of the TCTPF service has been widely utilized by media and various communities, as it provides an effective representation about likelihood of different scenarios and depicting uncertainty of TC movement in the next few days for preparing early actions or precautionary measures in planning of activities.

Continuous enhancements have been implemented to better support the assessment of TC track probability. In the 2024 TC season, EPS data from the Korean Integrated Model (KIM) of KMA has been employed to generate SPM for reference by forecasters (Figure 15). With the rapid development of artificial intelligence (AI) weather model, probabilistic forecast products based on AI weather model ensemble are under active development to enhance supports for TC track forecast and warning operations at HKO.

Furthermore, in order to enhance the assessment of potential TC genesis and subsequent movements, tropical cyclogenesis tracks from NCEP EPS have been utilized to generate SPM during early stage of TC genesis. Combining similar data product from ECMWF EPS for identified low pressure system, forecasters can extract relevant potential TC tracks that pass through a selected area of interest within a given forecast time level for generating the SPMs (Figure 16). This facilitates forecasters to assess the potential TC activity, and impact on weather changes or occurrence of various scenarios in short-term to medium range.
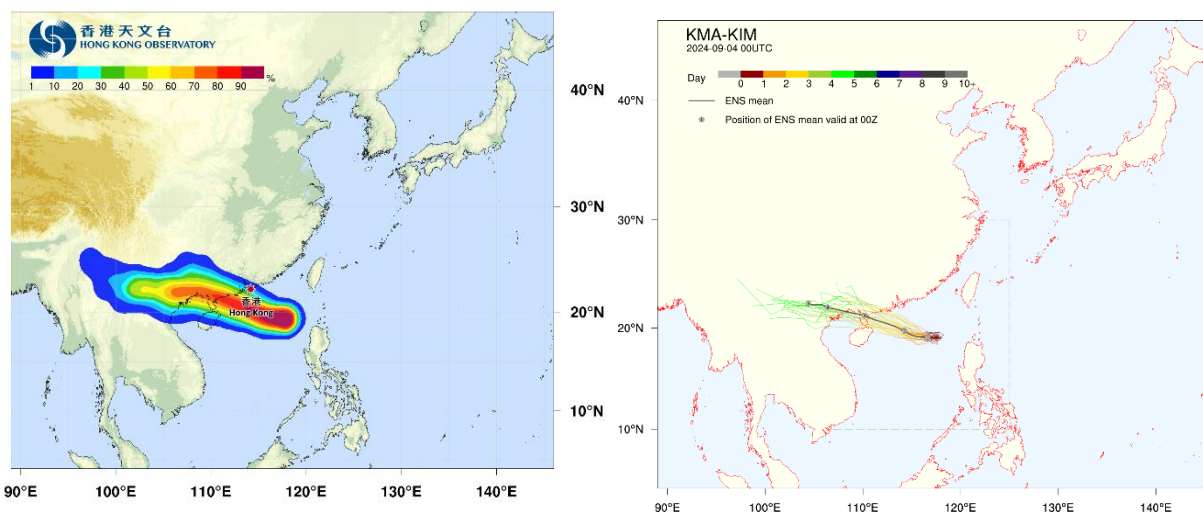

Figure 15 – Strike probability map (left) and forecast tracks (right) for tropical cyclone Yagi based on KMA-KIM EPS model run at 00 UTC 4 September 2024.
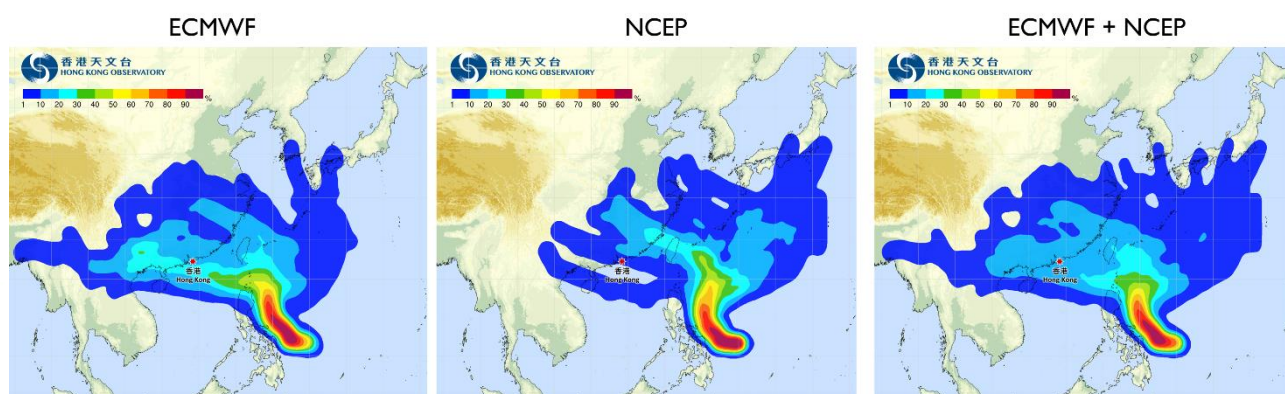
Figure 16 – TC SPMs generated from ECMWF (left panel) and NCEP (middle) EPSs model run at 12 UTC 31 August 2024 prior to formation of tropical cyclone Yagi. The two-model ensemble SPM is depicted on the right panel.

Identified opportunities/challenges, if any, for further development or collaboration:
More NWP EPSs and AI-based model ensemble will be implemented for generating TC SPM to enhance assessment of tropical cyclone genesis and movements for the next few days to a couple of weeks ahead.

Priority Areas Addressed:
Meteorology
▪ Enhance the capacity to monitor and forecast typhoon activities particularly in genesis, intensity and structure change.
▪ Develop and enhance typhoon analysis and forecast techniques from nowcast to medium-range, and seasonal to long-range prediction.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	✓
Warning dissemination and communication	
Preparedness and response capabilities	

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8. Development and verification of AI-STORMVIS

Main text:

The in-house developed AI-STORMVIS (AI-driven Satellite-based Tropical Cyclone Object Recognition, Motion Visualization, and Intensity Estimation System) has been in operational trial since 2023 for providing automatic TC position analysis and intensity estimation. It continuously monitors TC activities over the Western North Pacific (WNP) basin and the South China Sea (SCS) region based on Himawari-9 imagery updated in every 10 minutes, and generates analysis products on a web portal for reference by forecasters to streamline the operations.

AI-STORMVIS has been enhanced in various aspects including re-training of the model with a view to improving the overall accuracy in TC position fix and intensity estimate. Specifically, TC tracks over the Indian Ocean have been utilized to enhance automatic detection when TC is within the western domain. In its visualization web portal (Figure 17), TC's movement speed and direction over the past 1, 3, 6, 12, and 24 hours are provided on top of the current position and intensity estimates that facilitate forecasters' assessment of the latest situation of TC movement and near-term trend.

Based on all TCs in WNP and SCS during 2022-2023, AI-STORMVIS successfully located all their positions and provided an accurate estimate of TC intensity. Notably, TCs with intensities of tropical storm or above displayed a mean absolute track error of less than 0.5° and a small bias in CI (Figure 18). Currently, enhancements of machine learning algorithm in AI-STORMVIS are underway to reduce jumpiness in the results of intensity estimation.
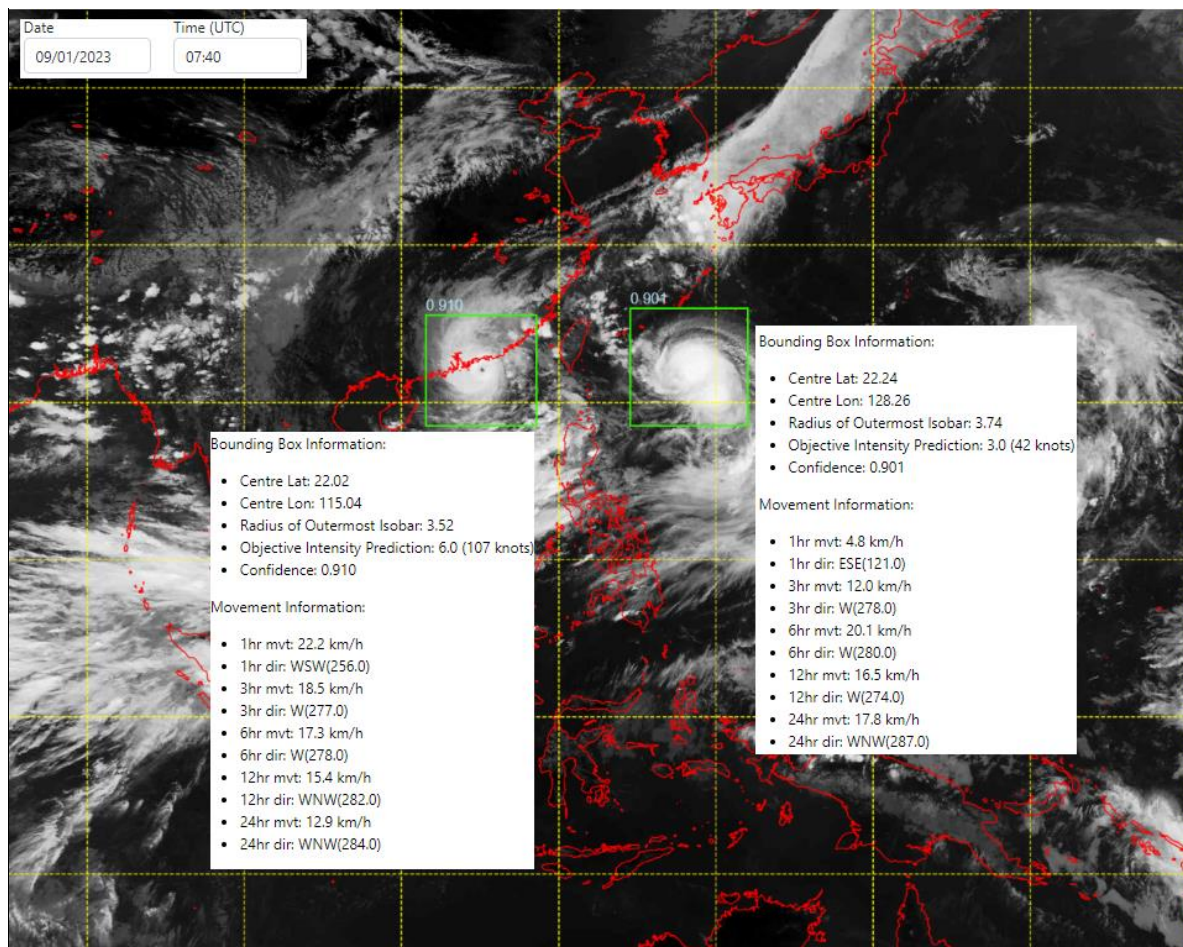

Figure 17 – AI-STORMVIS depicts an initial analysis of the real-time position and intensity of the auto-detected TCs, along with their movements in the past 1 to 24 hours.
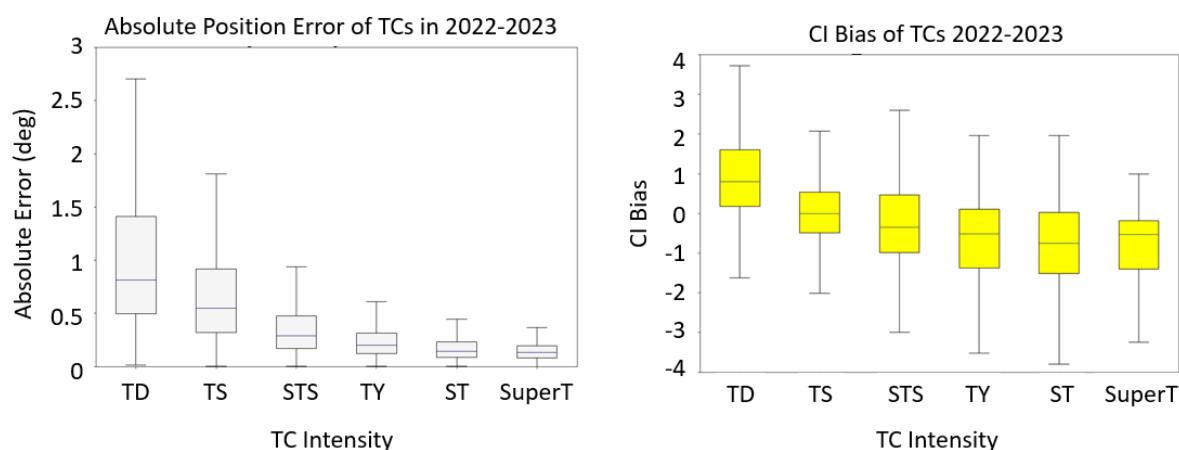
Figure 18 – Error distribution of TC position fix (left) and intensity estimate (right) in 2022-2023.

Identified opportunities/challenges, if any, for further development or collaboration:
1. Utilize additional satellite data such as Feng-yun 4 series to enrich the training and validation datasets in AI-STORMVIS, for improving the overall performance of the AI/ML algorithms in automatic position fixes and intensity estimate.
2. Enhance intensity model to provide maximum wind speed as a more direct assessment on TC intensity. Incorporate functionalities on estimate of the radius of maximum winds and the wind-pressure relationship for enhancing automatic analysis of TC structure.

Priority Areas Addressed:
Meteorology
▪ Enhance the capacity to monitor and forecast typhoon activities particularly in genesis, intensity and structure change.
▪ Develop and enhance typhoon analysis and forecast techniques from nowcast to medium-range, and seasonal to long-range prediction.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	✓
Warning dissemination and communication	
Preparedness and response capabilities	

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9. Enhancements of systems and tools to support tropical cyclone forecast operations

Main Text:

Tropical Cyclone Information Processing System (TIPS), an in-house web-based system integrating meteorological data and forecasting tools related to TCs, continues to be enhanced to provide better support on TC forecasting and warning operations at the HKO.

More forecast TC tracks for computer models were added to TIPS in the 2024 TC season. These include tracks for the ensemble prediction system (EPS) of KMA's Korean Integrated Model (KIM) and tracks for a number of AI-based models, such as "Fuxi", "Fengwu" and "Graphcast" which are run on a trial basis at HKO, as well as "AIFS" from ECMWF. Furthermore, a new track display module was developed to display TC forecast tracks for all ECMWF and NCEP EPS members, including TCs at pre-genesis stage (Figure 19), so as to provide a quick and combined view of potential TC activity in the next ten days for forecasters' awareness and early preparation.

Additional NWP data were also acquired to support forecasting of high winds and heavy rain associated with tropical cyclones, such as outputs from the UKMO Unified Model (UM) at 10-km resolution and outputs from ECMWF's AIFS model. Prognostic charts and time series charts using such data were routinely generated for forecasters' reference (Figure 20).
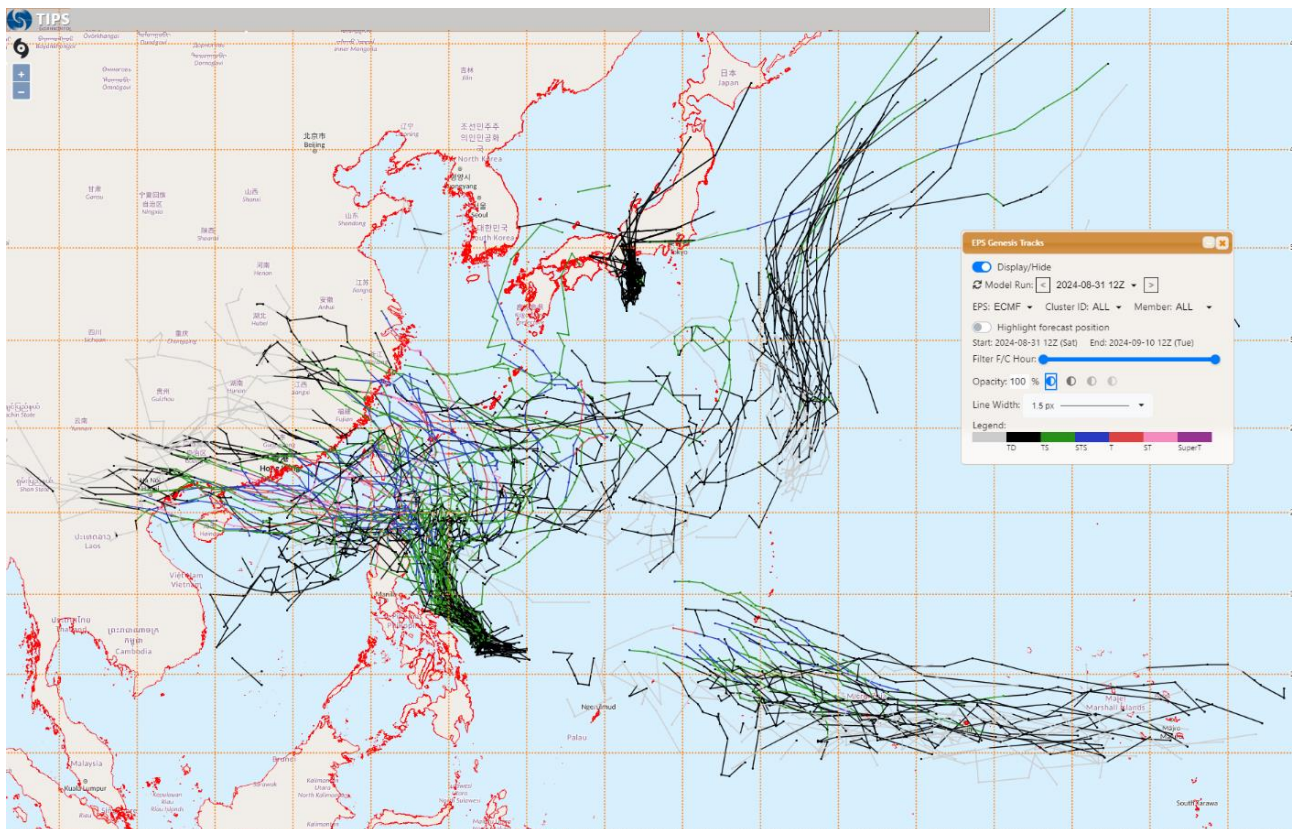

Figure 19 – Sample screenshot of TIPS showing the forecast TC tracks (including those at pre-genesis stage) by individual ECMWF EPS ensemble members for the next ten days. Different TC intensities are indicated by different colours.
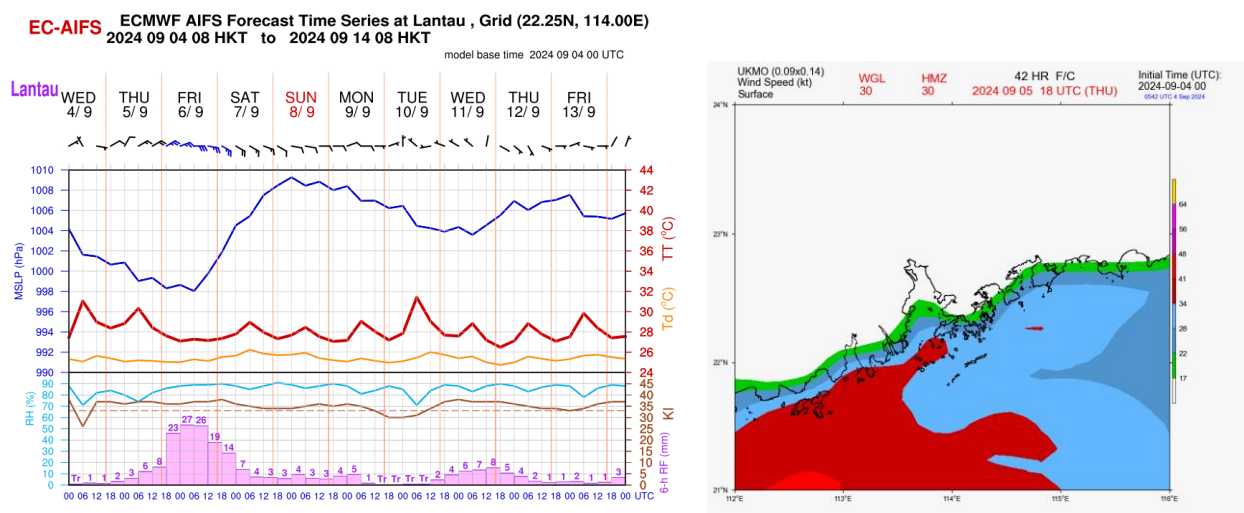
Figure 20 – Time series chart for ECMWF AIFS model (left) and surface wind speed chart based on high-resolution UKMO UM outputs (right) to facilitate assessment of wind and rain impacts associated with TC Yagi (2411).

Identified opportunities/challenges, if any, for further development or collaboration:
More display and analysis functionalities for TIPS will be developed to support tropical cyclone forecast and warning operations.

Priority Areas Addressed:
Meteorology
- Enhance the capacity to monitor and forecast typhoon activities particularly in genesis, intensity and structure change.
- Develop and enhance typhoon analysis and forecast techniques from nowcast to medium-range, and seasonal to long-range prediction.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	✓
Warning dissemination and communication	
Preparedness and response capabilities	

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10. Facelifted Version of Severe Weather Information Centre (SWIC) Website

Main text:

In the 76th Session of the Executive Council (EC-76) of the WMO held in 2023, the SWIC is considered as one of the core components of the Global Multi-hazard Alert System (GMAS) Framework for increasing and enhancing the availability of authoritative warnings and information related to extreme and/or potentially high-impact weather, water and climate events. In contribution to the United Nations' Early Warnings for All (EW4All) initiative, HKO enhanced the SWIC website to make available official warnings in Common Alerting Protocol (CAP) format from more than 130 WMO Members and maritime warning in early 2024. The SWIC website was also upgraded with the latest web technologies to improve responsiveness and enhanced website design to facilitate easier navigation and search for interested information. In addition, it displays the tropical cyclone advisories and warnings from Regional Specialized Meteorological Centres (RSMCs), Tropical Cyclone Warning Centres (TCWCs), and National Meteorological Centres in the Typhoon Committee region in both map and table views.
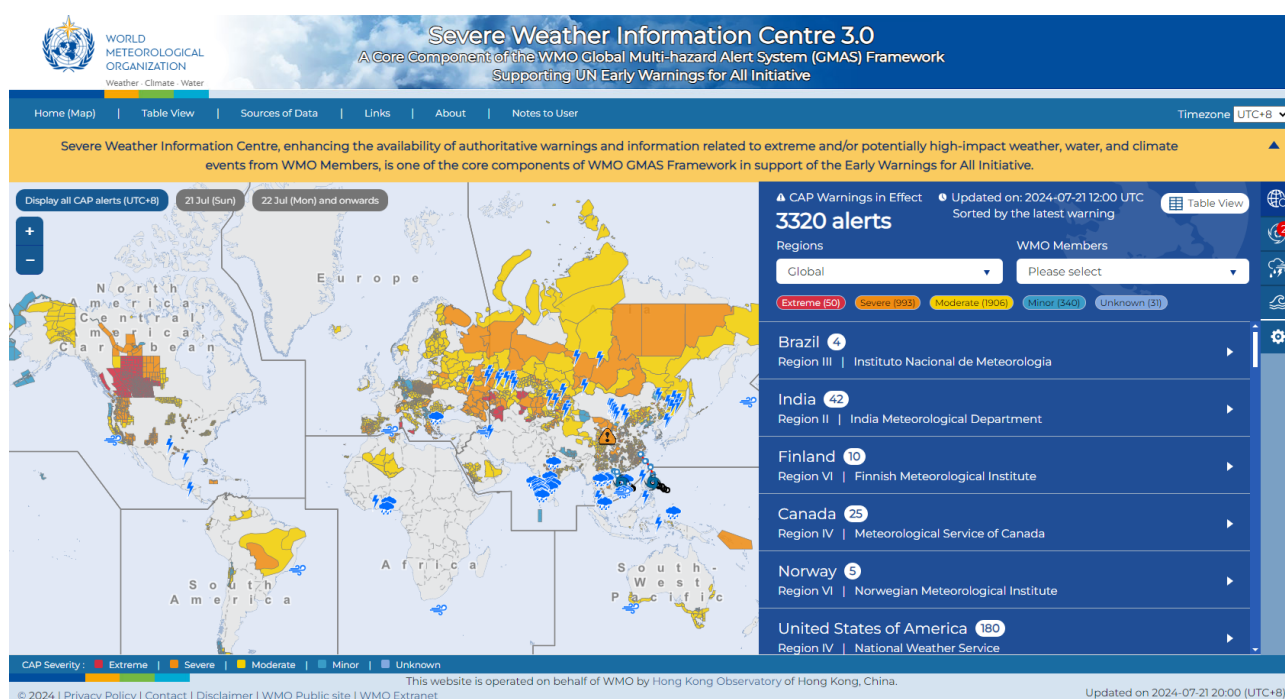

Figure 21 – The facelifted version of SWIC was launched in early 2024, displaying authoritative warnings issued by alerting authorities around the world.
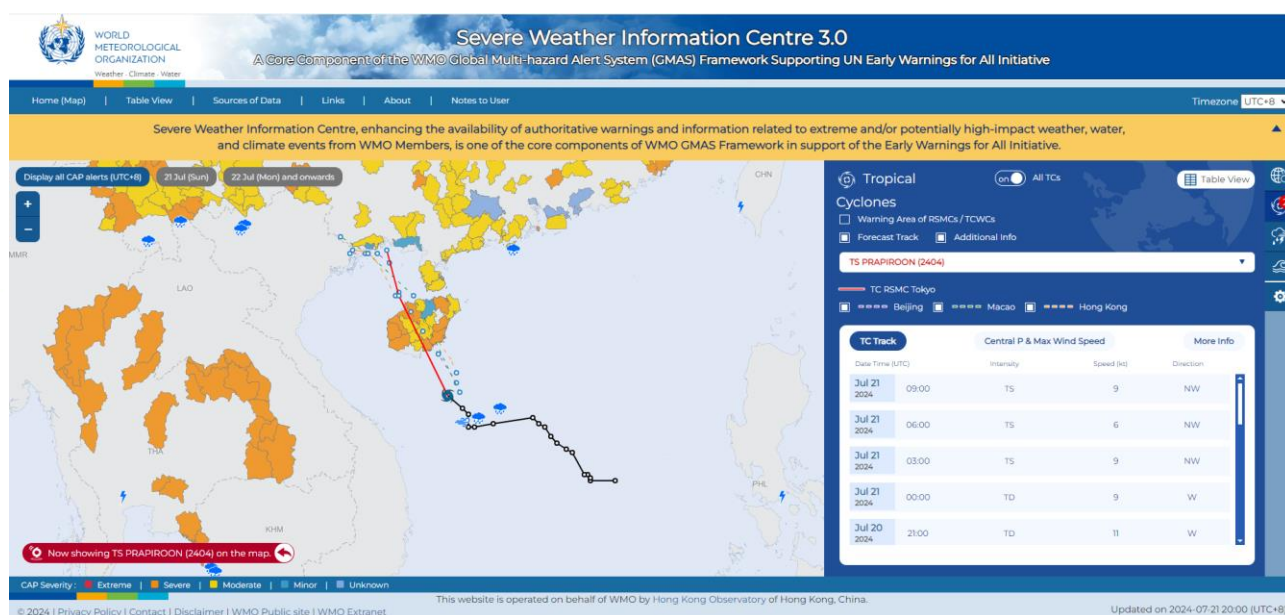
Figure 22 – An example of the SWIC website showing the analysis and forecast information about Tropical Cyclone Prapiroon in July 2024 provided by RSMC Tokyo Typhoon Center and National Meteorological Centers.

Identified opportunities/challenges, if any, for further development or collaboration:
The use of CAP format in the dissemination of weather warnings and alerts from WMO Members should be further promoted.

Priority Areas Addressed:
Meteorology
- Promote communication among typhoon operational forecast and research communities in Typhoon Committee region.
- Enhance RSMC capacity to provide regional guidance including storm surge, responding to Member's needs.

DRR
- Promote international cooperation of DRR implementation project.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	✓
Warning dissemination and communication	✓
Preparedness and response capabilities	

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11. English version of online video course on tropical cyclone

Main text:
The HKO launched the English version of the "Online Video Course on Tropical Cyclone" on its website and YouTube channel in 2024 to educate the public about the formation, structure and movement of tropical cyclones, methods of observing and forecasting the storms, as well as the local effects and hazards including high winds, heavy rain, storm surge and swells. Launched in Chinese in 2022, the course's new English version allowed for reaching a broader audience group. Both Chinese and English versions of the six videos of this series had been enthusiastically received by the public with view counts of around 100,000.
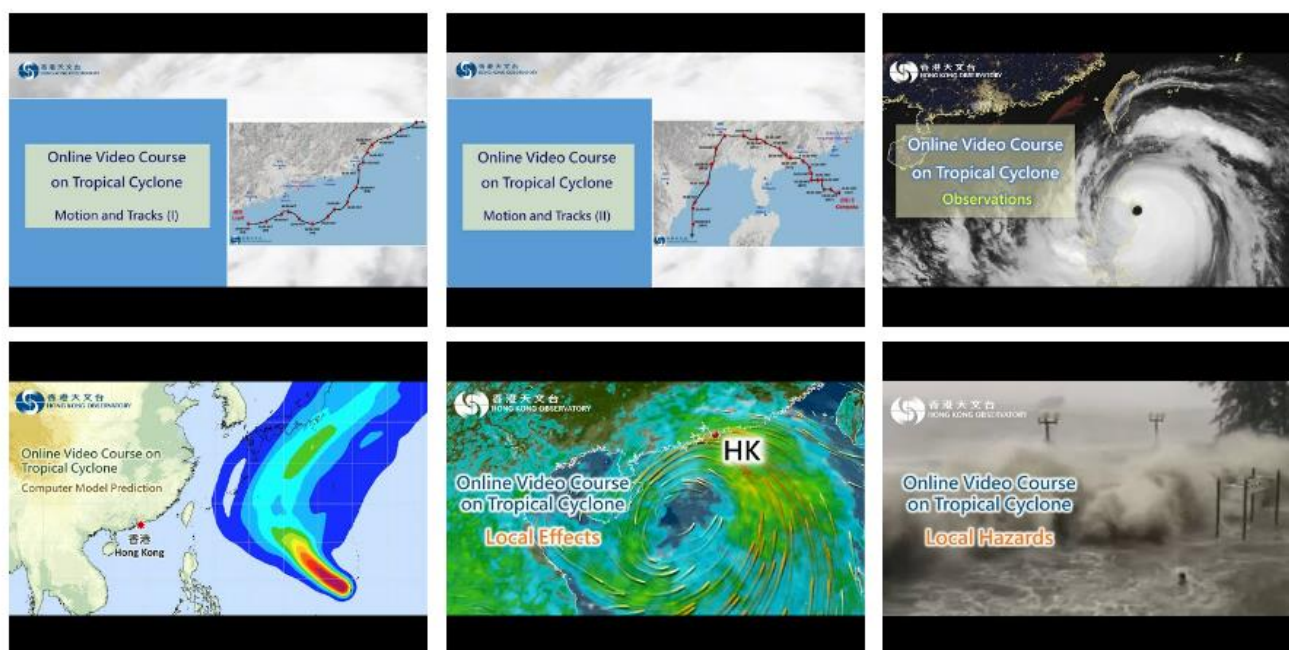

Figure 23 – English version of "Online Video Course on Tropical Cyclone".

Identified opportunities/challenges, if any, for further development or collaboration:
The HKO will continue to develop and enhance public education materials, including online courses focused on weather-related hazards and basic meteorology knowledge, to further enhance public's understanding of disaster preparedness and response.

Priority Areas Addressed:
DRR
- Enhance Members' disaster risk reduction techniques and management strategies.
- Share experience/knowhow of DRR activities including legal and policy framework, community-based DRR activities, methodology to collect disaster-related information.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	✓
Detection, observation, monitoring, analysis, and forecasting	
Warning dissemination and communication	✓
Preparedness and response capabilities	✓

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12. Enhancing public understanding of tropical cyclones and reminding the public on various typhoon hazards

Main Text:

HKO continues to dedicate efforts in raising public awareness on typhoon hazards and provide typhoon-related information through various channels (Figure 24), including timely publication of social media posts on impending tropical cyclones. HKO's official Facebook (FB) page and Instagram (IG) account, launched in March 2018, continued to gain popularity with exceeding 350,000 followers on FB and 96,000 followers on IG.
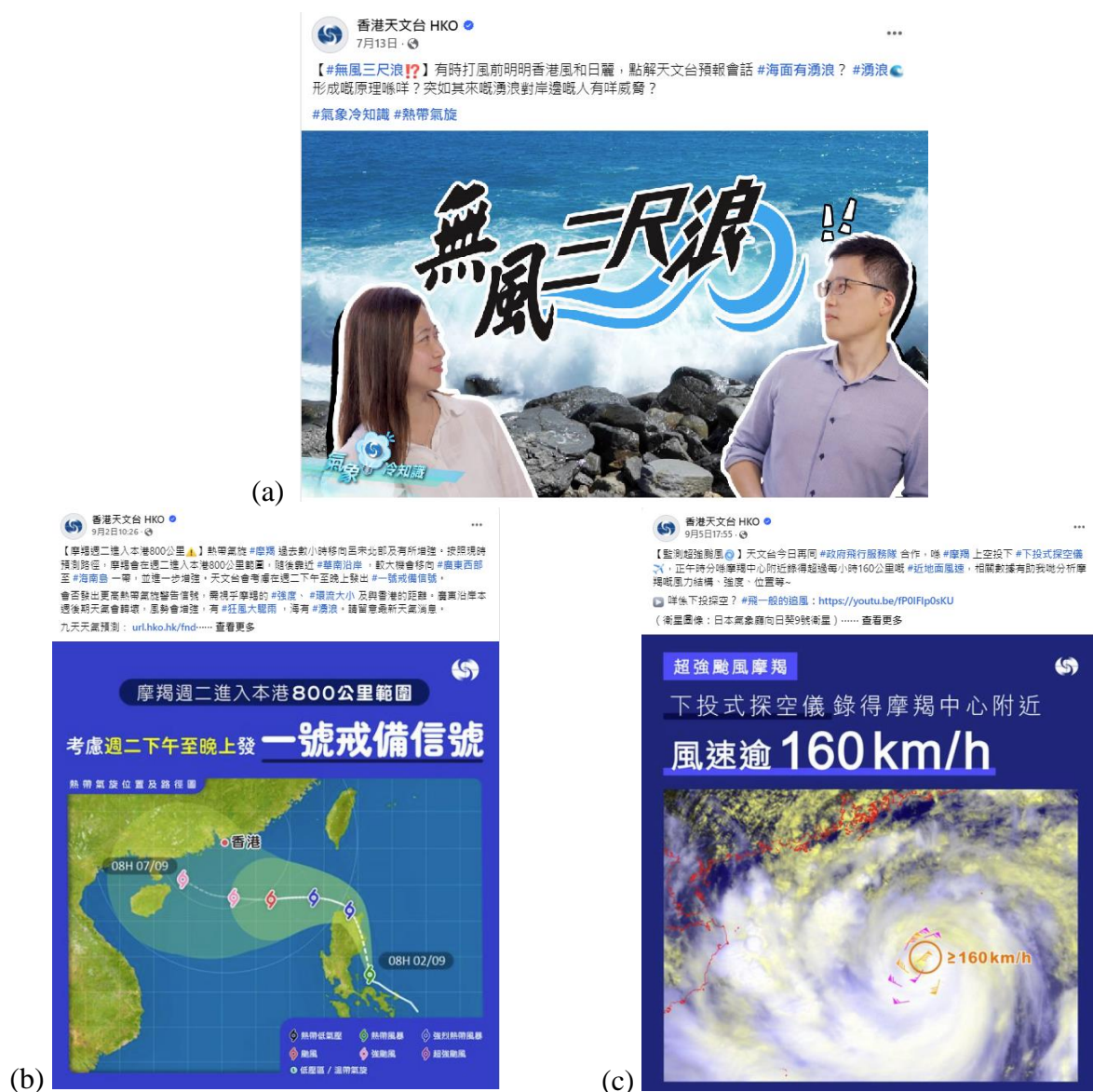

(a)

(b)

(c)

Figure 24 – FB posts showing (a) educational video on hazards from swells before approach of tropical cyclones; (b) forecast track of Tropical Cyclone Yagi; (c) winds data of Tropical Cyclone Yagi collected from the dropsonde measurement in collaboration with Government Flying Service to enhance public's awareness of the approach of tropical cyclones.

The "Tropical Cyclone Name Collection Activity" organised by HKO was concluded successfully in early 2024 with impressive public response of over 20,000 votes during the online voting stage (Figure 25). In addition to raising public awareness and knowledge of tropical cyclone-related hazards,

the activity also expanded the reserve list of tropical cyclone names of Hong Kong, China with the 20 tropical names receiving the most votes.

Figure 25 – FB post announcing the voting results of "Tropical Cyclone Name Collection Activity"

Similar to previous years, HKO continued to contribute tropical cyclone-related educational videos to the Working Group on Disaster Risk Reduction (WGDRR) of the Typhoon Committee. In 2024, a video about the threats of multiple typhoon hazards, including strong winds, heavy rain and high seas, had been translated into English with English subtitle and voice-over (Figure 26). The video was shared with the WGDRR members and uploaded to the Typhoon Committee website to enhance public awareness of multiple hazards caused by tropical cyclones and to adopt corresponding precautionary measures.
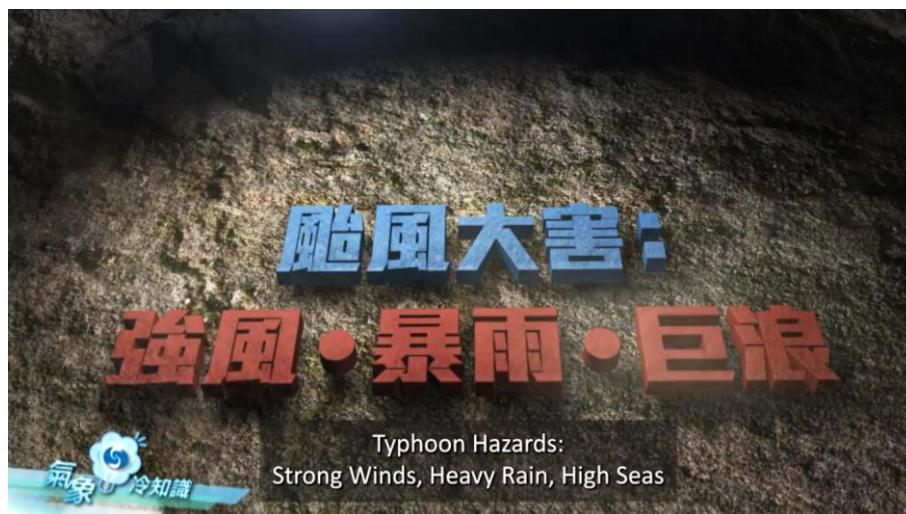

Figure 26 – Educational video to raise public awareness of multiple hazards caused by tropical cyclones and to adopt corresponding precautionary measures
(Video title: Typhoon Hazards: Strong Winds, Heavy Rain, High Seas
Internet access: https://www.typhooncommittee.org/press-14_temp.html).

Identified opportunities/challenges, if any, for further development or collaboration:
HKO will continue to enhance public education materials by developing more infographics and videos on weather related hazards and precautionary measures to be taken by members of the public to further enhance their knowledge of disaster preparedness and response for tropical cyclone.

Priority Areas Addressed:

DRR
- Enhance Members' disaster reduction techniques and management strategies.
- Share experience/know-how of DRR activities including legal and policy framework, community-based DRR activities, methodology to collect disaster-related information.

Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	✓
Detection, observation, monitoring, analysis, and forecasting	
Warning dissemination and communication	✓
Preparedness and response capabilities	✓

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Appendix I - Priority Areas of Working Groups for the Strategic Plan 2022-2026

WG	Priorities
Integrated	1. Strengthen the cooperation between TRCG, WGM, WGH, and WGDRR to develop impact-based forecasts, decision-support and risk-based warning.
	2. Strengthen cross-cutting activities among working groups in the Committee.
	3. Enhance collaborative activities with other regional/international frameworks/organizations, including technical cooperation between TC/AP-TCRC and TC/PTC cooperation mechanism.
Meteorology	4. Enhance the capacity to monitor and forecast typhoon activities particularly in genesis, intensity and structure change.
	5. Develop and enhance typhoon analysis and forecast techniques from nowcast to medium-range, and seasonal to long-range prediction.
	6. Enhance and provide typhoon forecast guidance based on NWP including ensembles, weather radar and satellite related products, such as QPE/QPF.
	7. Promote communication among typhoon operational forecast and research communities in Typhoon Committee region.
	8. Enhance training activities with TRCG, WGH, and WGDRR in accordance with Typhoon Committee forecast competency, knowledge sharing, and exchange of latest development and new techniques.
	9. Enhance RSMC capacity to provide regional guidance including storm surge, in response to Member's needs.
Hydrology	10. Improve typhoon-related flood (including riverine flood, flash flood, urban flood, and coastal flood) monitoring, data collection and archiving, quality control, transmission, processing, and sharing framework.
	11. Enhance capacity in typhoon-related flood risk management (including land-use management, dam operation, etc.) and integrated water resources management and flood-water utilization.
	12. Strengthen capacity in effective flood forecasting and impact-based early warning, including hazard mapping and anticipated risk based on methodological and hydrological modelling, and operation system development.
	13. Develop capacity in projecting the impacts of climate change, urbanization and other human activities on typhoon-related flood disaster vulnerability and water resource availability.
	14. Increase capacity in utilization of advanced science and technology for typhoon-related flood forecasting, early warning, and management.
DRR	15. Provide reliable statistics of mortality and direct disaster economic loss caused by typhoon-related disasters for monitoring the targets of the Typhoon Committee.
	16. Enhance Members' disaster risk reduction techniques and management strategies.
	17. Evaluate socio-economic benefits of disaster risk reduction for typhoon-related disasters.
	18. Promote international cooperation of DRR implementation project.
	19. Share experience/knowhow of DRR activities including legal and policy framework, community-based DRR activities, methodology to collect disaster-related information.