MEMBER REPORT

Hong Kong, China

ESCAP/WMO Typhoon Committee
17th Integrated Workshop
(Video conferencing)
29-30 November 2022

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

1. Meteorological Assessment

Six tropical cyclones affected Hong Kong, China from 1 January to 25 November 2022 (tracks as shown in Figure 1): Typhoon Chaba (2203) in July, Tropical Depression, Tropical Storm Mulan (2207) and Typhoon Ma-on (2209) in August, Typhoon Nesat (2220) in October and Severe Tropical Storm Nalgae (2222) in November.

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%). The relatively large error of Ma-on (2209) in longer hour forecasts was mainly due to the fact that global models in general predicted that Ma-on would make landfall over the coast of southeastern China. Yet, this prediction failed to materialize and Ma-on made landfall over the western part of Guangdong and moved faster than model expected.

Chaba, Ma-on and Nalgae necessitated the issuance of the No.8 Gale or Storm Wind Signals in Hong Kong. In particular, Nalgae moved very close to Hong Kong in early November 2022, necessitating the issuance of Gale or Storm Wind Signal in November again since 1972. Mulan and Nesat necessitated the issuance of Strong Wind Signal, No. 3.

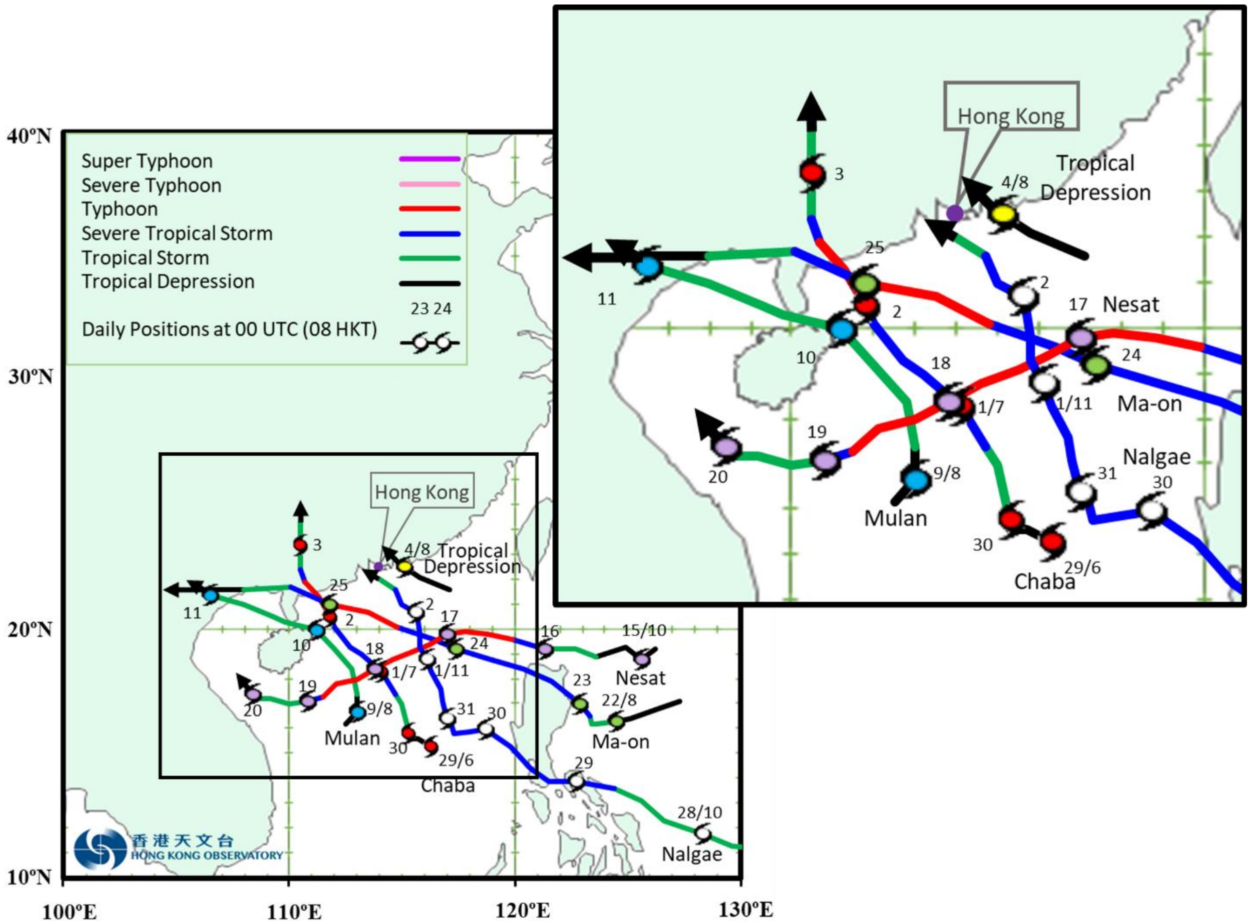

Figure 1 – Tracks of tropical cyclones that affected Hong Kong, China from 1 January to 25 November 2022.

	Position forecast error (km) (No. of cases)				
	24-hr	48-hr	72-hr	96-hr	120-hr
Chaba (2203)	98 (7)	74 (5)	100 (3)	233 (1)	
Tropical Depression (3 – 4 Aug 2022)	88 (1)				
Mulan (2207)	105 (5)	99 (5)	90 (4)	84 (2)	
Ma-on (2209)	102 (9)	230 (7)	402 (5)	615 (3)	890 (1)
Nesat (2220)	52 (10)	96 (8)	186 (6)	268 (4)	400 (2)
Nalgae (2222)	87 (13)	105 (11)	142 (9)	204 (7)	352 (5)

Table 1 Performance summary of track forecasts issued by 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 25 November 2022.

2. Hydrological Assessment

During the passage of Chaba, over 150 mllimetres of rainfall were recorded over most parts of Hong Kong and rainfall even exceeded 250 millimetres in some places.

More than 100 millimetres of rainfall were generally recorded over Hong Kong during the passages of the tropical depression over the northeastern part of the South China Sea in August 2022 and Mulan. More than 50 millimetres of rainfall were recorded over many places in Hong Kong during the passage of Ma-on, Nesat and Nalgae.

3. Socio-Economic Assessment

At least 3 persons were injured in Hong Kong during the passage of Chaba. There were 595 reports of fallen trees and two reports of flooding. The fallen trees in Tai Wai and Central damaged two taxis. Some scaffoldings at Central, Sham Shui Po and Sha Tin collapsed. An advertisement banner at Wong Tai Sin and a flower plaque at Ma Liu Shui were also blown down by strong winds.

During the passage of Mulan, a number of fallen trees were reported in Hong Kong. A hoarding in Tsim Sha Tsui was blown down under violent gusts. There were toppled trees at Chai Wan and Wan Chai, damaging six minibuses and a street lamp. The fallen trees at Kwun Tong and Happy Valley also blocked traffic lanes, resulting in disruption of traffic.

One person was injured in Hong Kong during the passage of Ma-on. There were 279 reports of fallen trees and one report of flooding. An aluminium window was blown down by strong winds and fell to a pedestrian crossing place in Hung Hom.

During the passage of Nesat, 7 passengers were injured when a double-decker bus travelling on the Peak was hit by a fallen tree (Figure 2). Tram service was also disrupted due to a fallen tree in Central.

One people was injured during the passage of Nalgae. There were 448 reports of fallen trees.

Figure 2 - A double-decker bus travelling on the Peak was hit by a fallen tree during passage of Nesat (Source: RTHK).

4. Regional Cooperation

In response to AOP7 of the 16th working meeting of the Working Group on Disaster Risk and Reduction (WGDRR) under ESCAP/WMO Typhoon Committee, HKO hosted an online seminar to share experience on the concept and methodology of obtaining TC crowd-sourcing high density non-conventional weather data for impact analysis and micro-climate study, particularly for monitoring of impacts from tropical cyclones, for Typhoon Committee members on 5 July 2022. During the seminar, two talks on the Pilot Crowd Sourcing Scheme and the establishment of microclimate station network in Hong Kong were delivered by HKO.

Figure 3 - Group photo of WGDRR Online Seminar for TC Crowd-sourcing High Density Non-Conventional Weather Data.

II. Summary of Progress in Priorities supporting Key Result Areas

1. Tropical cyclone reconnaissance flights

Main text:
The HKO had been collaborating with the Government Flying Service (GFS) on tropical cyclone reconnaissance flights since 2016.

Up to November 2022, a total of 12 dropsonde missions were conducted for tropical cyclones Chaba (30 June and 01 July), Mulan (08, 09 and 10 August, see Figure 4), the tropical depression over the South China Sea (16 August), Ma-on (24 August), Noru (26 September), Nesat (17 and 18 October) and Nalgae (1 and 2 November).

The data processing method had been re-engineered for operational implementation in September 2022 to enable a timelier dissemination of dropsonde data on additional vertical levels. A set of data containing weather elements at 16 pressure levels in BUFR format would now be disseminated to GTS immediately after the launch of each sonde unit, whereas previously, the whole set of data was sent in one batch only after the operation was completed and with weather elements at just 10 pressure levels. Together with real-time data relay via satellite and automated data quality checking, the revamped workflow had expedited the data dissemination process to facilitate timely subjective analysis by forecasters and data assimilation into NWP models.

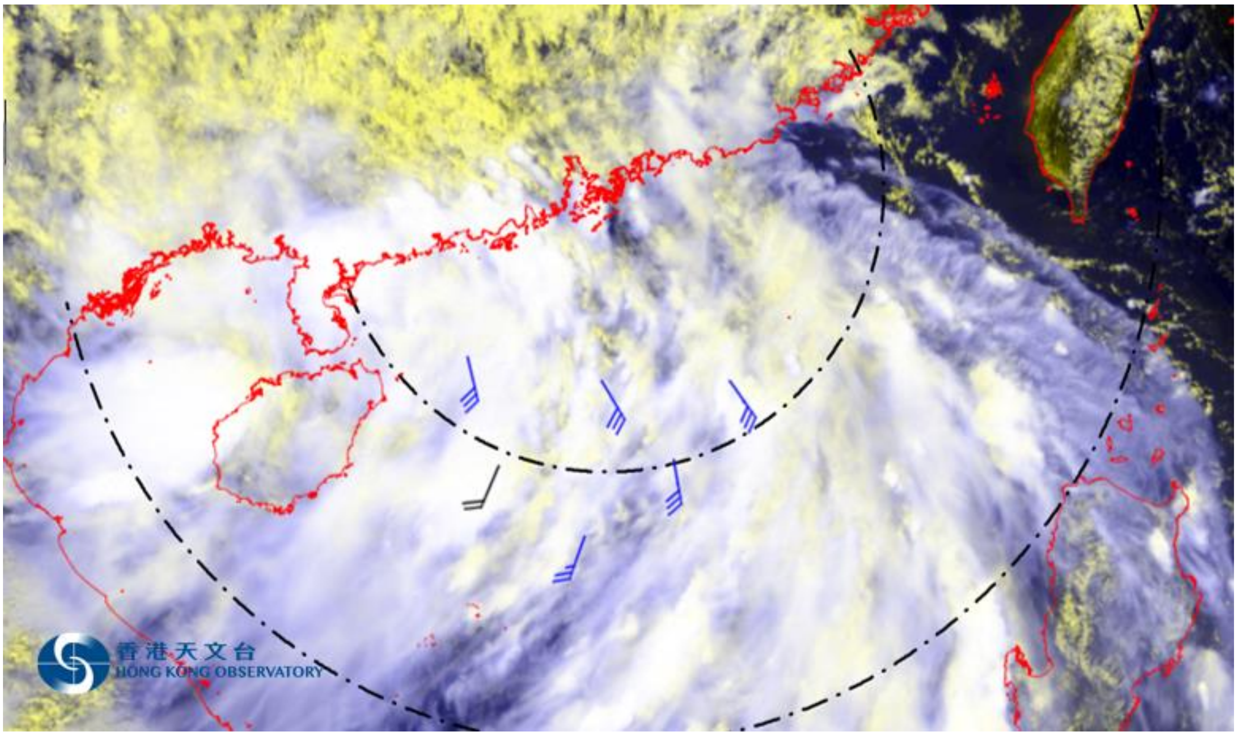

Figure 4 – Near surface winds sampled around the centre of Mulan on 10 August by dropsonde missions of HKO.

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

Priority Areas Addressed:

Meteorology

4. Enhance the capacity to monitor and forecast typhoon activities particularly in genesis, intensity and structure change.
7. Promote communication among typhoon operational forecast and research communities in Typhoon Committee region.

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2. Deployment of drifting buoys in the South China Sea for tropical cyclone monitoring

Main Text:
Two drifting buoys were deployed in the South China Sea in July 2022 with the assistance of a Hong Kong Voluntary Observing Ship (HKVOS) for tropical cyclone monitoring over the region. Hourly observations of sea level pressure and sea surface temperature have been transmitting to the Observatory via satellite for dissemination on the GTS.

The buoys were drifting over the South China Sea as at mid-November 2022 (Figure 5). They collected valuable observations during the passage of several tropical cyclones over the South China Sea during August and September 2022 (Figures 6-8). Both drifting buoys were within the circulation of Mulan and Ma-on in August, and Noru in September, capturing the low pressures associated with the storms (Figures 9 and 10).

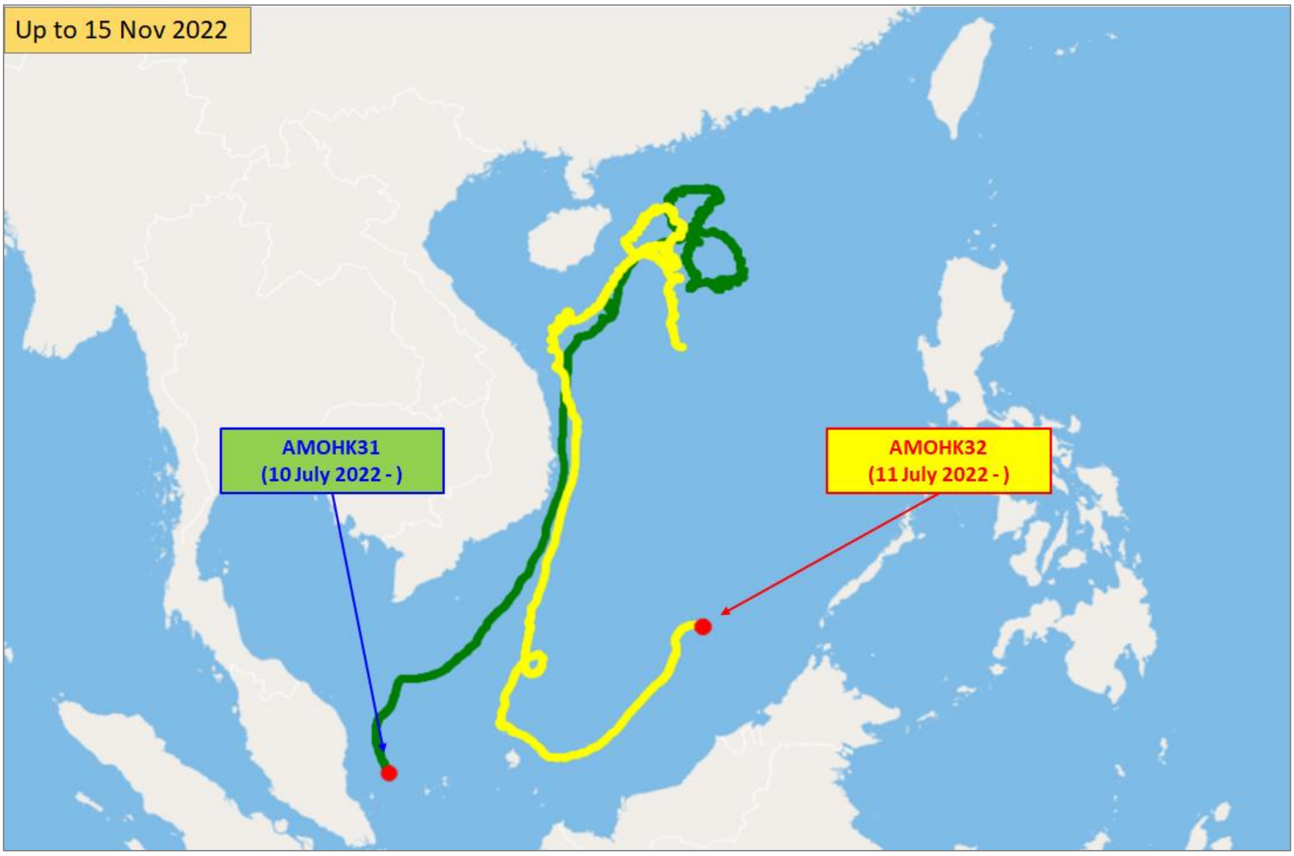

Figure 5 – Tracks of the two drifting buoys deployed in the South China Sea since mid-July 2022. The red dots denote their latest reported position as at mid-November 2022.

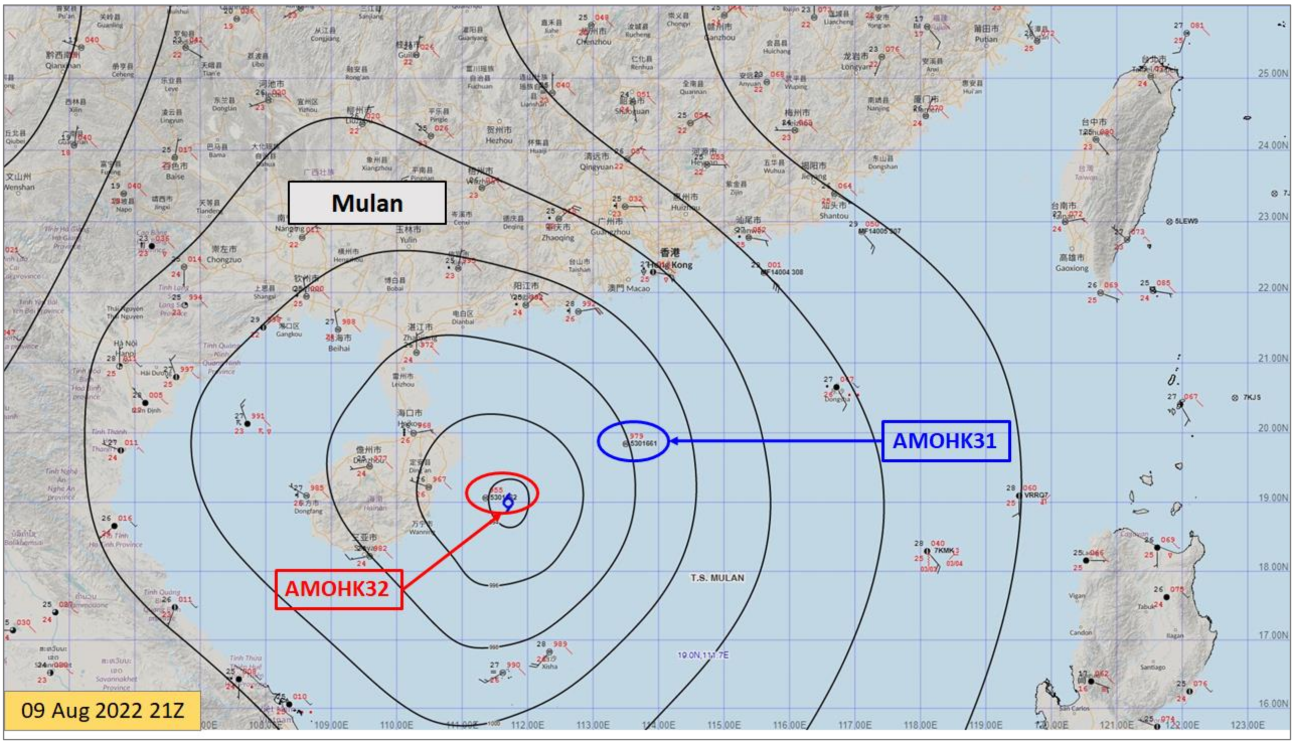

Figure 6 – Close encounter of "AMOHK32" with Mulan in the South China Sea, and "AMOHK31" within the circulation of Mulan at 21 UTC on 9 August 2022.

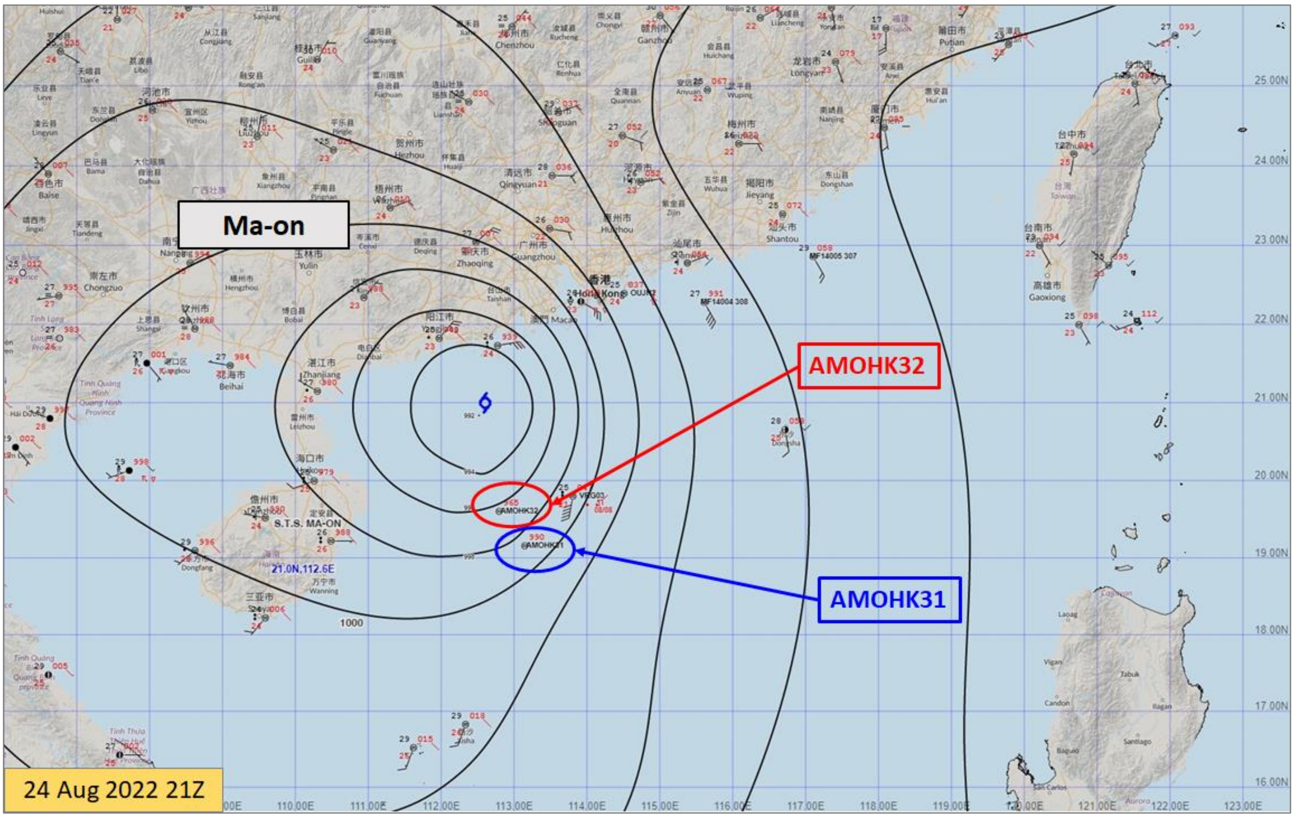

Figure 7 – Ma-on registered by both "AMOHK31" and "AMOHK32" over the South China Sea at 21 UTC on 24 August 2022.

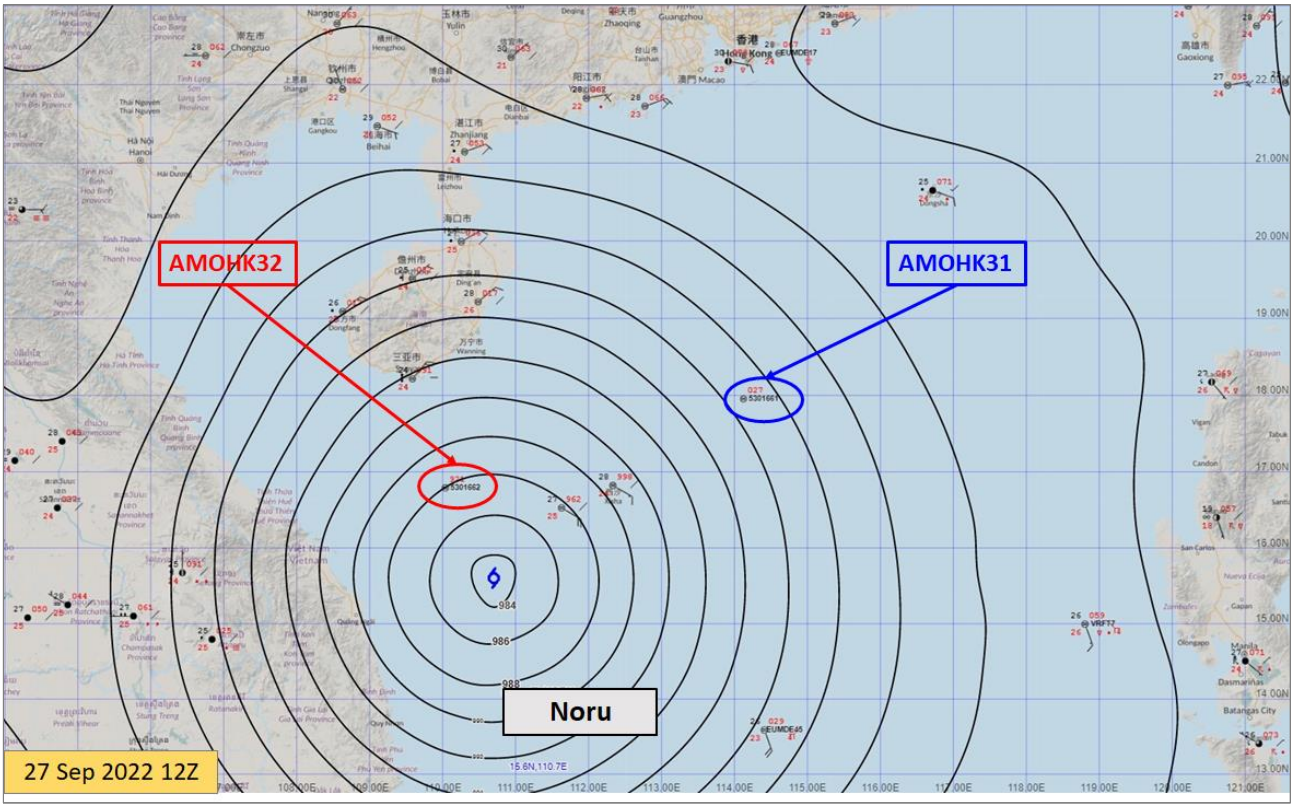

Figure 8 – Noru captured by both "AMOHK31" and "AMOHK32" over the South China Sea at 12 UTC on 27 September 2022.

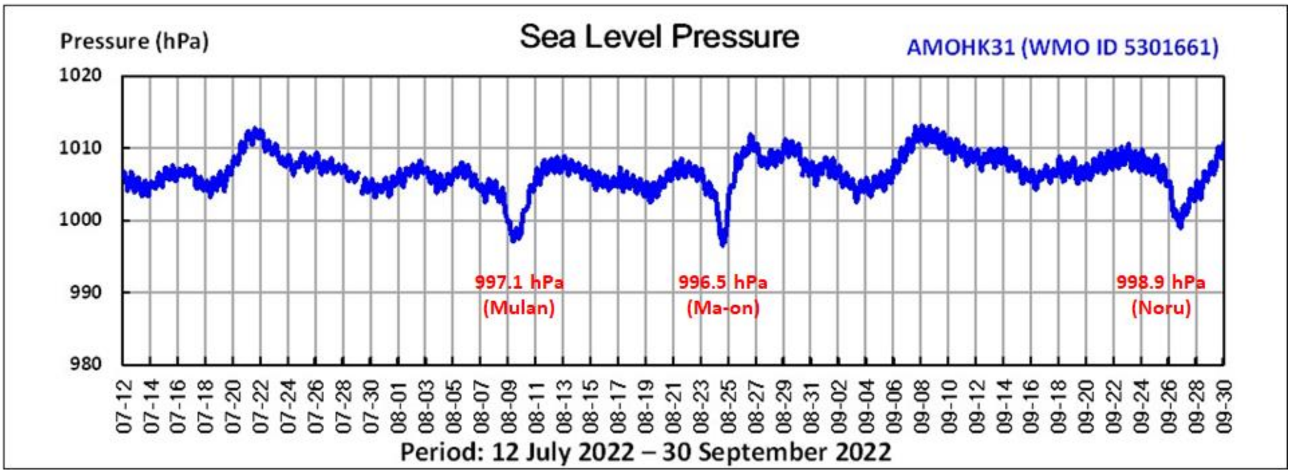

Figure 9 – Time series of sea level pressure measured by "AMOHK31" capturing the low pressures of Mulan, Ma-on and Noru at a minimum of 996.5 hPa near the centre of Ma-On on 24 August 2022.

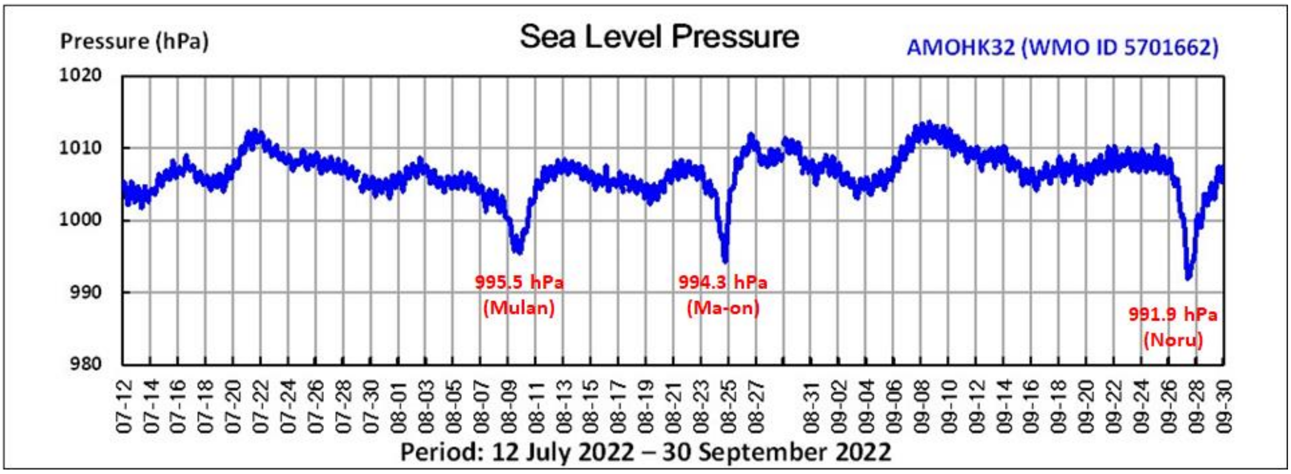

Figure 10 – Time series of sea level pressure mesaured by "AMOHK32" capturing the low pressures of Mulan, Ma-on and Noru, and recording the lowest pressure of 991.9 hPa near the centre of Noru on 27 September 2022.

Identified opportunities/challenges, if any, for further development or collaboration:

The HKO will continue the deployment activities in the South China Sea and the western North Pacific in 2023.

Priority Areas Addressed:

Meteorology

4. Enhance the capacity to monitor and forecast typhoon activities particularly in genesis, intensity and structure change.
7. Promote communication among typhoon operational forecast and research communities in Typhoon Committee region.

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3. Enhancing monitoring and forecasting of multi-hazard combined effect related to tropical cyclones

Main text:

HKO enhanced its services on tropical cyclones in June 2022 including the monitoring and forecasting of the combined effect due to tropical cyclone and prolonged rainstorm. When significant wind-rain combined effect is expected, HKO will make announcement to the public through Tropical Cyclone Warning bulletins and media briefings. This is to ensure that members of the public can take early protective measures against personal security and family safety.

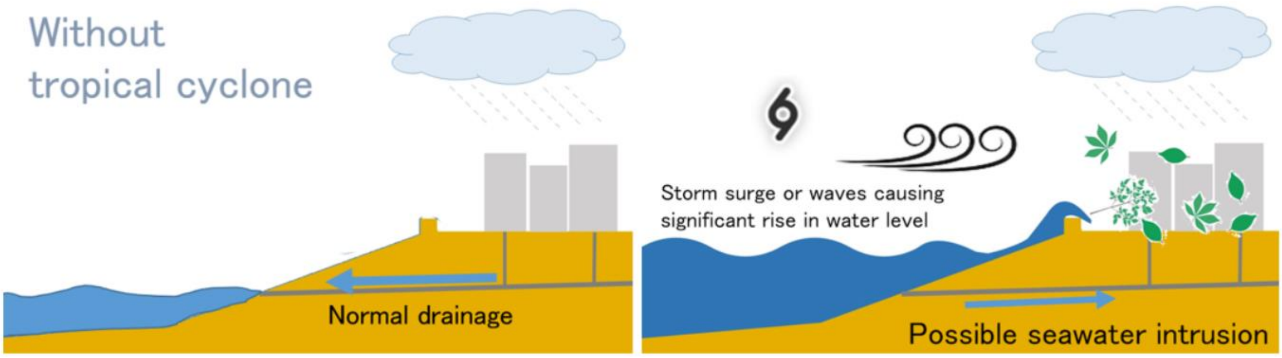

Figure 11 – Similar rainstorm situations with (right) and without tropical cyclone (left). Effects from tropical-cyclone-induced high winds, storm surge, pounding waves, etc., can add up and degrade drainage.

One example of combined effect was the case of Tropical Cyclone Lionrock (2117). Under the combined effect of Lionrock and the northeast monsoon, local winds were up to gale force near the sea level with occasional storm force winds offshore and even hurricane force occasionally on high ground. A maximum storm surge (above astronomical tide) of 0.60 m was recorded. Moreover, it brought squally heavy showers and set a new record for the highest daily rainfall for the month of October. There were over 1,100 reports of fallen trees, 6 reports of flooding and 3 reports of landslip.

To ensure public understanding, HKO promoted the knowledge via social media (link), educational article (link), public talks and "Cool Met Stuff" videos (link of video 1, link of video 2) jointly with the Drainage Services Department (local hydrological authority).

Figure 12 – Shots of "Cool Met Stuff" videos on combined effect and the corresponding alerting message in the Tropical Cyclone Warning bulletin.

Identified opportunities/challenges, if any, for further development or collaboration:
The idea may still be relatively new. It is necessary to develop forecasting tools for supporting the early warning system for TC-rainstorm combined effect. In the long run, multi-hazard in other aspects will be considered.

Priority Areas Addressed:

<u>Hydrology</u>

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.
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

<u>DRR</u>

19. Share experience/knowhow of DRR activities including legal and policy framework, community-based DRR activities, methodology to collect disaster-related information.

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4. Tropical cyclone outlook briefing

Main text:

HKO continued to conduct biweekly online weather briefings on potential tropical cyclone activities over the western North Pacific and the South China Sea to invited government bureaux/departments and special users. The briefing aimed to provide information to those parties to assist their manpower allocation and early preparation for high-impact weather conditions due to tropical cyclones.

After the tropical cyclone season of 2021, an opinion survey was conducted to evaluate the overall performance of the briefings and collect users' feedbacks for possible service enhancement. The reply rate was around 90%. All respondents considered that the forecasts provided in the briefings were accurate/very accurate, and agreed that the briefings were useful for their organizations.

The briefing focuses were fine-tuned in 2022 according to the feedback from the opinion survey. The main focus was still local weather impacts due to tropical cyclones in short to medium range (within 10 to 14 days), particularly those potential tropical cyclones that would come within 800 km from Hong Kong and bring high winds or significant rainfall remained the utmost concern. Other tropical cyclone-related impacts such as extreme hot weather associated with tropical cyclone's outer subsidence, severe thunderstorms, high storm tides etc. were also mentioned if appropriate. More emphasis on introduction of meteorological knowledge, such as tropical cyclone-related climatology and prevailing or developing climate conditions, as well as NWP limitations, was placed so as to facilitate their understanding of the messages delivered in the briefing and formulate better action plans.

In 2022, the briefing service was extended to 16 government bureaux/departments and over 40 organizations from different sectors, e.g. aviation, shipping, utilities, construction etc. The number of engaged users was increased by more than 3-fold comparing to the figure in 2021.

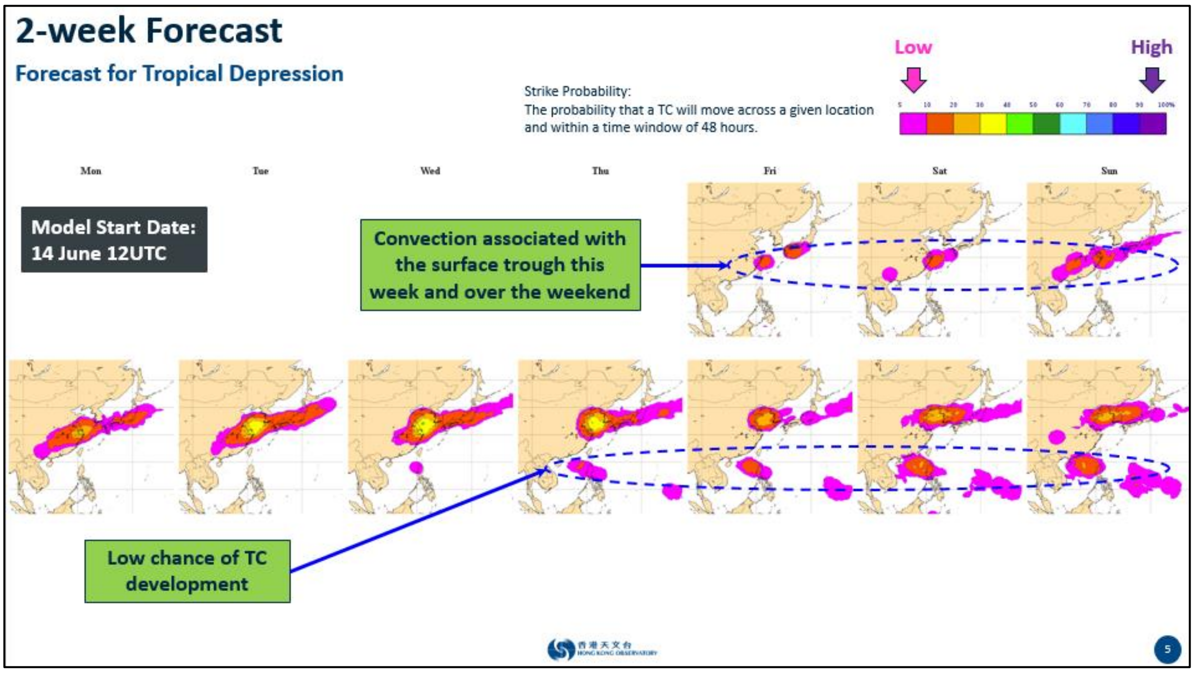

Figure 13 - Sample products presented in the Tropical Cyclone Outlook Briefing - ECMWF's daily tropical cyclone strike probabilistic forecast (up to 2 weeks).

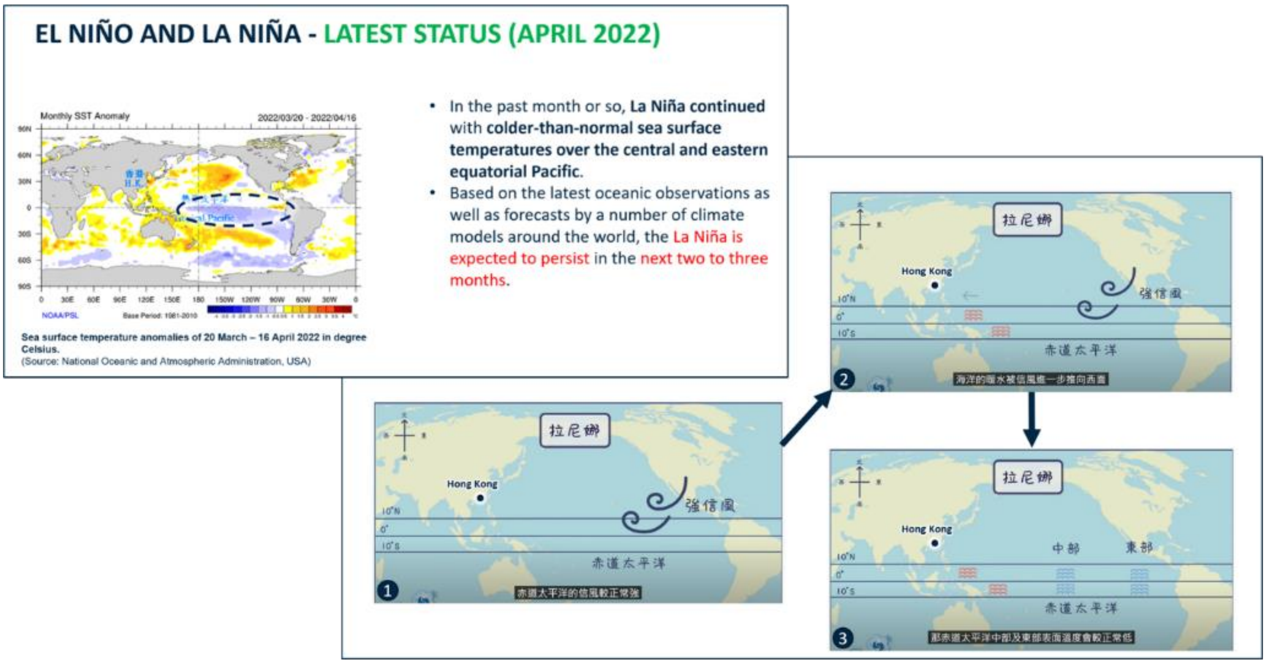

Figure 14 - Sample products presented in the Tropical Cyclone Outlook Briefing - Update the latest status of El Niño and La Niña and explain impact to tropical cyclone activities.

Identified opportunities/challenges, if any, for further development or collaboration:
It was planned to engage more government bureaux/departments and special users and eventually promote the briefing service to the public in the future.

Priority Areas Addressed:
<u>DRR</u>
16. Enhance Members' disaster reduction techniques and management strategies.
19. Share experience/know-how of DRR activities including legal and policy framework, community-based DRR activities, methodology to collect disaster-related information.

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5. Innovation on Hydrometric Information System

Main Text:

The Drainage Services Department (DSD) has deployed various devices on site (other than those installed by HKO and other relevant departments) to collect data of rainfall, tide and water levels of major rivers and channels over the territory in real time in order to identify locations of high flood risks as early as possible for the purpose of implementing appropriate flood prevention measures. DSD has developed a Hydrometric Information System (HIS) to facilitate monitoring of real-time hydrometric data and analysis of flooding situations through mobile phones and computer systems in a timely manner so that DSD can coordinate with the relevant departments to prepare for rescue and evacuation operations when necessary.

Recent innovative development on HIS is its automatic detection of potential flooding cases by setting logic in terms of weather condition and real-time water levels in DSD's drainage facilities, especially at flood prone locations. This innovation enables automatic arrangement of immediate drainage inspection and just-in-time clearance and helps not only optimize manpower resources deployment in handling potential flooding cases at night time, but also minimize the flood risks at different locations in a systematic manner.

With this innovation on HIS, the reliability and robustness of our drainage system and flood control strategy in Hong Kong to deal with upcoming challenges such as climate change and extreme weather events could be reinforced.

DSD also participated at the International Exhibition of Inventions of Geneva for the first time earlier in 2022 and got a silver medal for the above innovation on HIS.

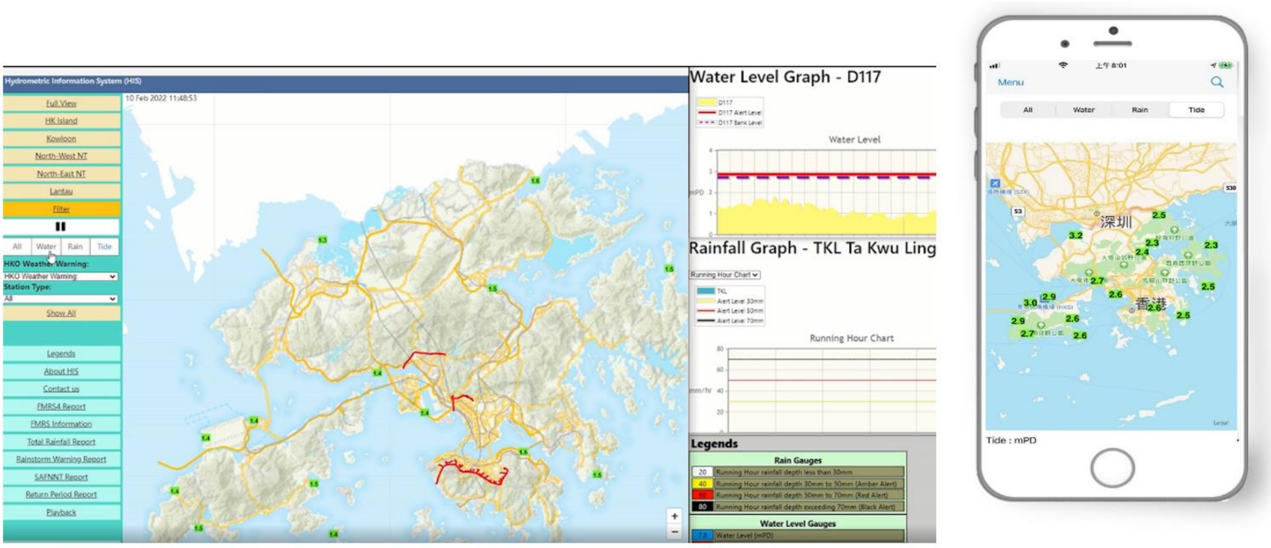

Figure 15 – Real-time information display in HIS.


inventions Geneva

SALON INTERNATIONAL DES INVENTIONS GENÈVE

Après examen, le Jury a décidé

de remettre à: Drainage Services Department of the Government of Hong Kong SAR of the People's Republic of China

pour l'invention: Innovative Hydrometric Information System for Smart Drainage Management and Preventive Flood Control in Hong Kong

MÉDAILLE D'ARGENT
SILVER MEDAL
SILBERMEDAILLE

Genève, le 28 mars 2022

Le Président du Jury: David Taji

Le Président du Salon: Jean-Luc Vincent

Figure 16 – DSD was awarded a silver medal in the International Exhibition of Inventions of Geneva for the innovation on HIS.

Identified opportunities/challenges, if any, for further development or collaboration:

Looking ahead, DSD will continue improving drainage services to deal with upcoming challenges such as climate change and extreme weather events.

Priority Areas Addressed:

Integrated

1. Strengthen the cooperation between TRCG, WGM, WGH, and WGDRR to develop impact-based forecasts, decision support and risk-based warnings.

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.
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

19. Share experience/knowhow of DRR activities including legal and policy framework, community-based DRR activities, and methodology to collect disaster-related information.

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6. Trial of image-based flooding analytics

Main text:

To assist in monitoring and detecting potential coastal flooding due to storm surges associated with the passage of tropical cyclones, an artificial intelligence (AI) analytics tool was developed to analyse real-time camera images of coastal areas (Figure 17). Based on deep learning image segmentation technique, the analytics tool could return detailed information about the water surface, exposed sea wall and water level mark in the images. By taking such information into account, the heights of water level in the images could be estimated in a real-time manner.

Meanwhile, the analytics tool could also provide alerts of possible occurrence of flooding when the estimated water level and its short-term trend reached prescribed thresholds. Analysed outputs and alerts by the tool were visualized on a web-based Geographic Information System (GIS) platform for easy reference by weather forecasters (Figure 18).

The AI analytics tool improved the efficiency and effectiveness in utilising the large number of real-time images of different flood-prone locations. Its outputs and alerts enhanced the situational awareness of weather forecasters, which in turn benefited the overall forecasting and alerting services of the HKO on high-impact weather hazards.

Real-time images

Images analysed by AI analytics tool

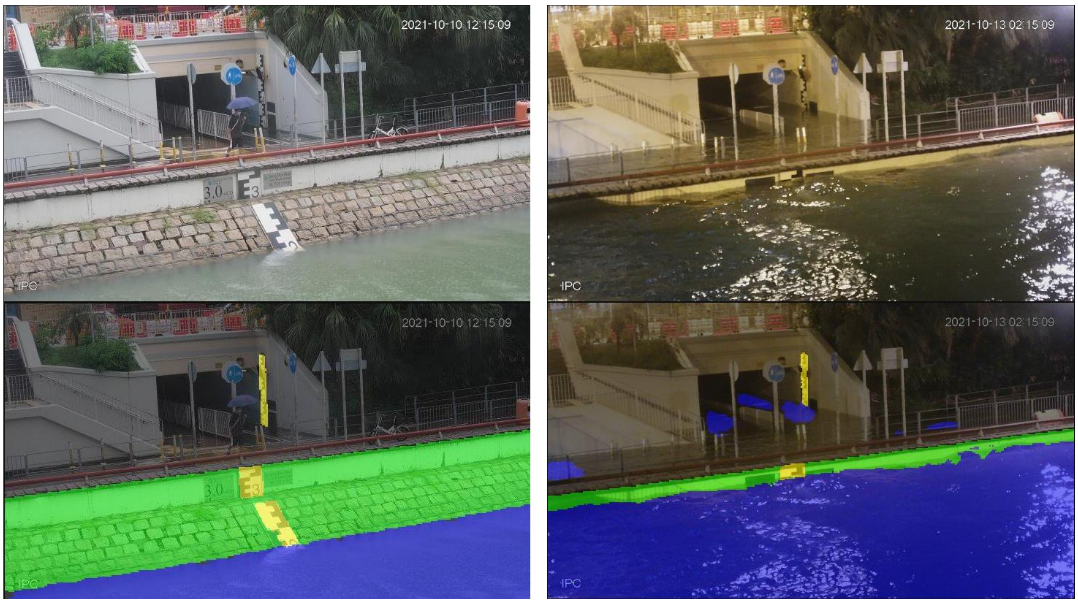

Figure 17 – Exposed sea wall (green area) and water surface (blue area) detected by AI analytics tool.

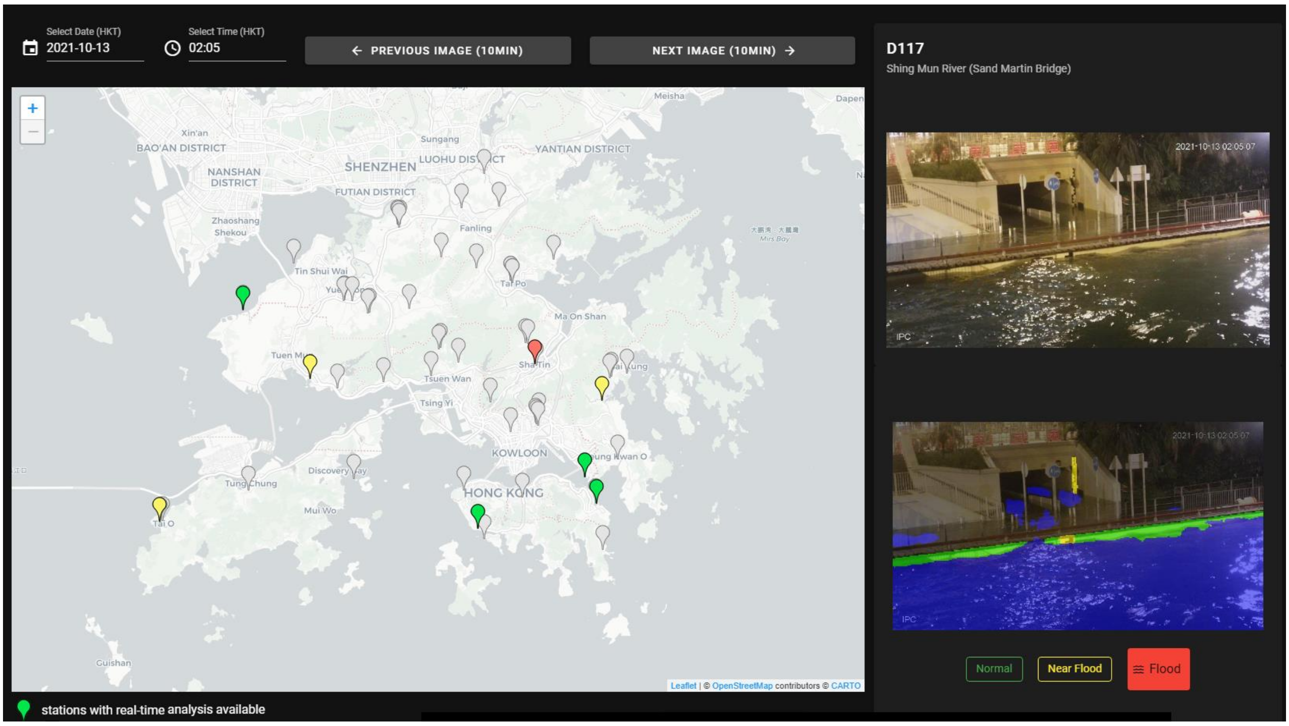

Figure 18 – An integrated view of real-time analysed results and alert status at different locations on GIS platform.

Identified opportunities/challenges, if any, for further development or collaboration:
The analytics tool will be enhanced further to cover more flood-prone locations. A short-term prediction of water level height based on recent analysis results can also be explored, with a view to allowing early warning of flooding.

Priority Areas Addressed:

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.
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.
14. Increase capacity in utilization of advanced science and technology for typhoon-related flood forecasting, early warning, and management.

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7. Generation of nighttime visible imagery to aid tropical cyclone monitoring during nighttime

Main text:
To facilitate weather forecasters to determine the centre of a tropical cyclone during nighttime, virtual visible satellite imageries were generated using the conditional generative adversarial networks (CGAN) model. The CGAN model was trained with visible (0.64 μm), IR1 (10.4μm), IR2 (12.4μm) and water vapour (6.2μm) channels of Himawari-8 satellite imageries taken in three 6-month periods of April to September in 2019-2021.

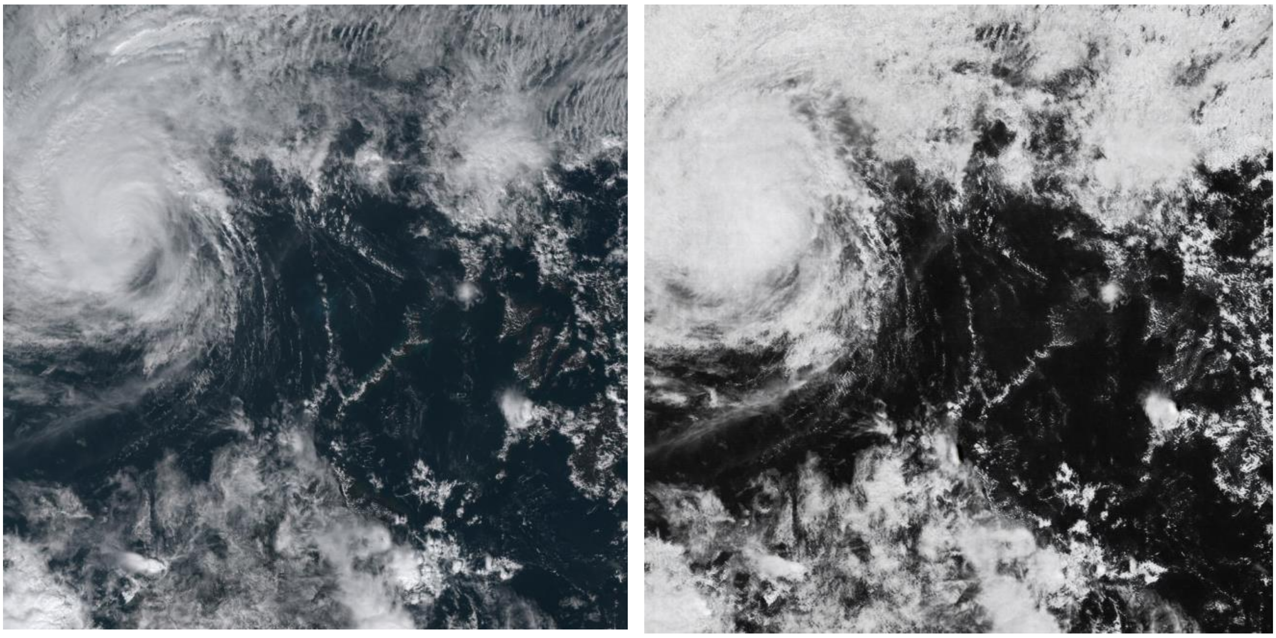

Figure 19 - Himawari-8 true colour image at 0430UTC on 19 December 2021 showing the banding features of clouds associated with tropical cyclone Rai (2122) when it was over the central part of the South China Sea (Left). Virtual visible image at the same time generated from the CGAN model using IR and WV channel data only (Right).

Identified opportunities/challenges, if any, for further development or collaboration:

Further fine-tuning of the CGAN model using different training datasets for possible improvement in depicting the clouds' banding features of tropical cyclones in different seasons.

Priority Areas Addressed:

Meteorology

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.

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8. Verification of wind structure forecast of ECMWF model

Main Text:

Forecasting wind structure of tropical cyclone (TC) is essential for assessment of impacts due to high winds using Numerical Weather Prediction (NWP) model. Under the Typhoon Committee Research Fellowship (TCRF) programme in 2021, a joint study by HKO and the Shanghai Typhoon Institute (STI) was conducted to investigate the performance of TC wind structure forecasts from ECMWF high-resolution deterministic (HRES) model and ensemble prediction system (ENS). The Method for Object-Based Diagnostic Evaluation (MODE) has been implemented for the first time in verification of TC wind structure. The TC wind field forecast of ECMWF HRES and ENS over the western North Pacific (WNP) and the South China Sea (SCS) in 2020 were evaluated. A MODE score of 0.5 is considered as a threshold value to represent a good or skillful forecast. It was found that the radius of 34 knots (R34) in wind field structure forecasts within 72 hours are good in HRES and ENS. The performance of R50 and R64 forecasts is slightly worse but the R50 forecast within 48 hours remains skillful with MODE exceeded 0.5. The R64 forecast within 48 hours is worth for reference as well with MODE of around 0.5. The study reveals that the TC wind field structure forecast by ECMWF is skillful for TCs over WNP and SCS. More details of the study and results are presented in Lu *et al.* (2022).

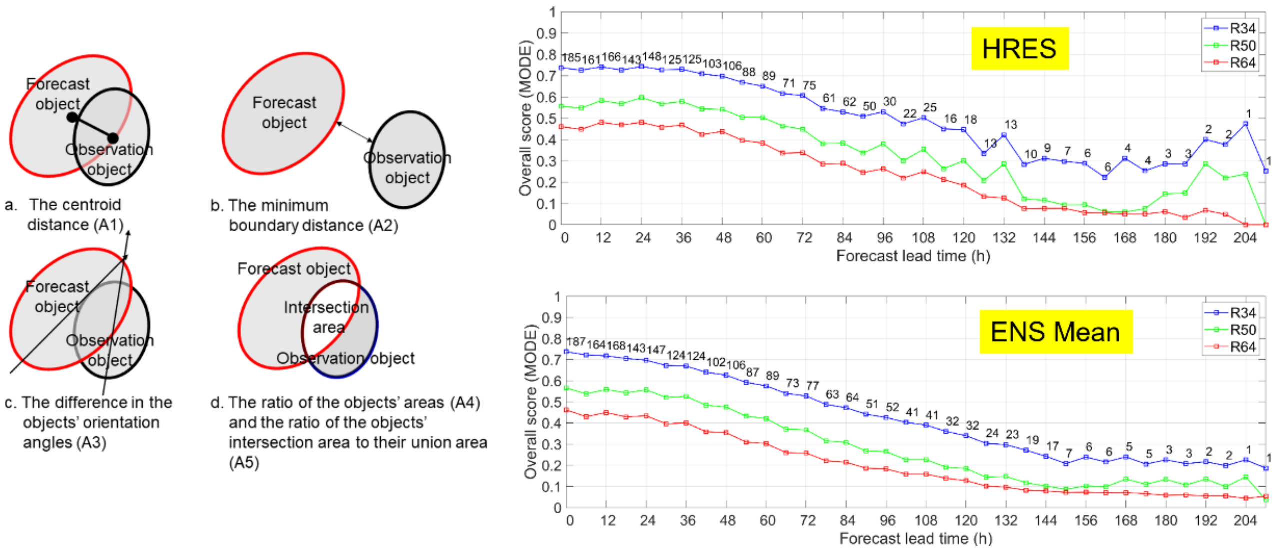

Figure 20 – Schematic of MODE object-based verification method (left). MODE scores of R34 (blue), R50 (green) and R64 (red) in different forecast lead time (x-axis in hour) for ECMWF HRES (upper panel on right) and ENS mean (lower right). The numbers above the blue line show the number of verifying forecasts.

Reference:

Lu X., WK Wong, KC Au-Yeung, CW Choy, H Yu, 2022: Verification of tropical cyclones (TC) wind structure forecasts from global NWP models and ensemble prediction systems (EPSs), Tropical Cyclone Research and Review, 11 (2), https://doi.org/10.1016/j.tcrr.2022.07.002.

Identified opportunities/challenges, if any, for further development or collaboration:

1. Verification of TC wind structure forecasts from ECMWF HRES and ENS will continue to evaluate model performance and identify strength / weakness for different TC cases.
2. The verification methodology can also be applied and fine-tuned in other (global or regional) NWP model forecasts upon their availability. Benchmark of different NWP models regarding TC wind structure predictions may contribute towards enhancement of model physical process in TC intensity forecast.

3. Application of wind structure forecasts from NWP models for supporting impact-based forecast services and risk-based warning due to high winds would also be explored in future.

Priority Areas Addressed:

Integrated

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.

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9. Probabilistic and deterministic regional prediction systems supporting tropical cyclone impact assessment

Main text:

HKO's operational numerical weather prediction suite, the Atmospheric Integrated Rapid-cycle (AIR) forecast system, provides mesoscale forecasts over East Asia and the western North Pacific up to about 3 days ahead, and convective-scale forecasts over southern China and the northern part of the South China Sea up to about 15 hours ahead.

In January 2022, the 10-km resolution AAMC-WRF, an extended-domain prediction system covering (20ºS – 60ºN, 45ºE – 160ºE) in support of the Asian Aviation Meteorological Centre (AAMC) initiative, replaced the Meso-NHM as the mesoscale component of the AIR forecast system, alongside its convective-scale counterpart, the 2-km RAPIDS-NHM. In addition, the 200-m resolution Aviation Model (AVM) provides hourly-updated urban-scale forecasts over Hong Kong as well as aviation-specific products for the Hong Kong International Airport.

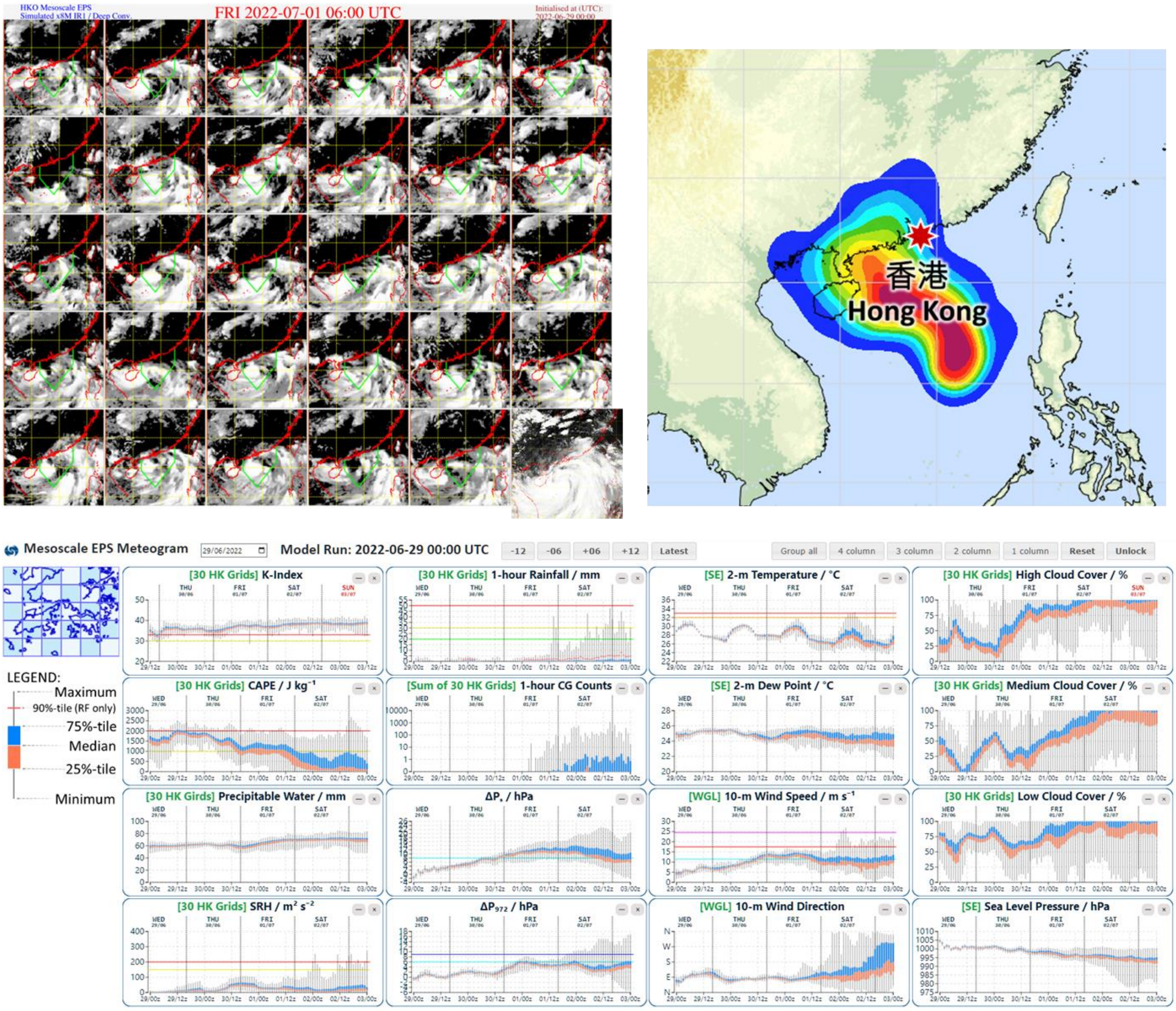

Figure 21 – Stamp map (top left) of simulated satellite imagery by the MEPS of HKO during the passage of Chaba (actual satellite observations shown in lower right) in the morning of 1 July 2022, together with its strike probability map (top right) and multi-parameter ensemble meteogram (bottom).

Furthermore, the 10-km resolution, 30-member experimental Mesoscale EPS (MEPS) has been extended to T+120 hours ahead. The resultant probabilistic forecast products, at up to hourly output intervals, support impact assessment of a variety of meteorological hazards.

Identified opportunities/challenges, if any, for further development or collaboration:

1. Research and development of advanced assimilation techniques, including ensemble-based methods for regional radar composites and new-generation satellite observations, would continue.
2. Moreover, regional exchange of model output products would be explored with a view to fostering closer collaboration.

Priority Areas Addressed:

Integrated

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.

DRR

16. Enhance Members' disaster risk reduction techniques and management strategies.

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10. Development of multi-sensor quantitative precipitation estimation and forecast

Main Text:

A new multi-sensor quantitative precipitation estimation (QPE) is under active development in HKO to improve regional rainfall nowcast with longer forecast hours. The new algorithm utilizes observations from rain gauges, single radar and regional radar mosaic, as well as infra-red channel of Himawari-8 (H-8) data to generate hourly rainfall estimate using optimal interpolation method. It allows blending of the above input observations in the most statistical optimal basis, while retaining rainfall intensity and spatial variation of respective input sources. Furthermore, tracking and extrapolation of successive multi-sensor QPE fields, say in every 6 minutes of time interval, can allow generation of quantitative precipitation forecast (QPF) more directly for the following few hours. This could improve the existing satellite derived reflectivity using artificial neural network and only H-8 data, where conversion from satellite derived reflectivity to rainfall amount is required.

Fine-tuning of the new QPE algorithm is underway to verify and improve rainfall intensity estimates for landfalling TC cases. Meanwhile, deep learning models are being incorporated to enhance rainfall nowcast over an extended geographical domain in support of NMHSs under RSMC for Nowcasting.

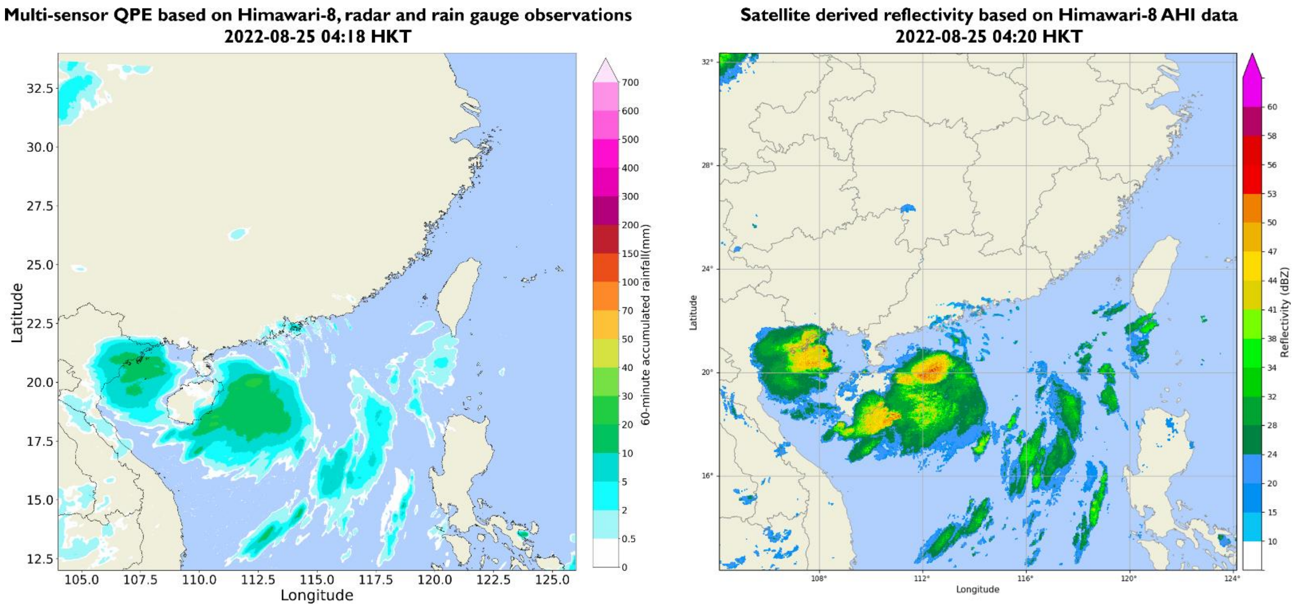

Figure 22 – Multi-sensor QPE (left) and satellite derive reflectivity (right) during 04 HKT on 25 August 2022, where Ma-on moved across the northern part of the South China Sea.

Identified opportunities/challenges, if any, for further development or collaboration:

1. Enhancement of multi-sensor QPE and QPF would continue. Trial rainfall nowcast products would be made available on RSMC for Nowcasting website. The nowcast product will benefit NMHSs in rainfall nowcast and heavy rain prediction where radar data is unavailable, or coverage of good quality radar data is limited. In that case, the availability of more rain gauge data from NMHSs would improve the overall accuracy of multi-sensor QPE.
2. Joint research activities with interested NMHSs such as through the Typhoon Committee Research Fellowship programme to develop the multi-sensor QPE / QPF technique are highly welcomed.

Priority Areas Addressed:

Integrated

3. Enhance collaborative activities with other regional/international frameworks/organizations, including technical cooperation between TC/AP-TCRC and TC/PTC cooperation mechanism.

Meteorology

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.

Hydrology

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.

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11. Objective storm surge forecast under the combined effect of tropical cyclone and the northeast monsoon in autumn season

Main Text:

An objective method to forecast sea level anomalies brought about by the meteorological components unaccountable in the parametric storm surge model utilising numerical weather prediction model forecast fields.

HKO has been operating the SLOSH model to support its storm surge forecast and alert service in tropical cyclone (TC) operation since 1994. SLOSH is a parametric storm surge model with input parameters including TC forecast position, intensity and storm size. The model could predict accurate storm surge heights in Hong Kong induced by TCs that are well represented by parameterised symmetric storm in normal circumstances. However, when the northeast monsoon affects the coastal areas of southern China in the autumn season, its combined effect with the TC in the northern part of the South China Sea will enhance the storm surge in the coastal areas of Guangdong, resulting in higher water levels than those of the SLOSH model predictions.

In order to account for the effect of the meteorological component in the model, namely the northeast monsoon, on the sea level rise in TC situation, an objective method using empirical orthogonal function (EOF) analysis and regression has been developed to supplement the SLOSH model prediction. An "EOF offset" is computed based on ECMWF model forecast fields after vortex removal, transformation of wind fields to the EOF amplitudes, and application of the trained regression to each tide station. This location specific and time dependent offset is then superimposed to the SLOSH model output and astronomical tide prediction to generate the storm tide forecast. Preliminary verification results using TC cases during September to November in 2000-2021 showed significant improvement in reducing the underestimation bias of storm surge forecasts during the period.

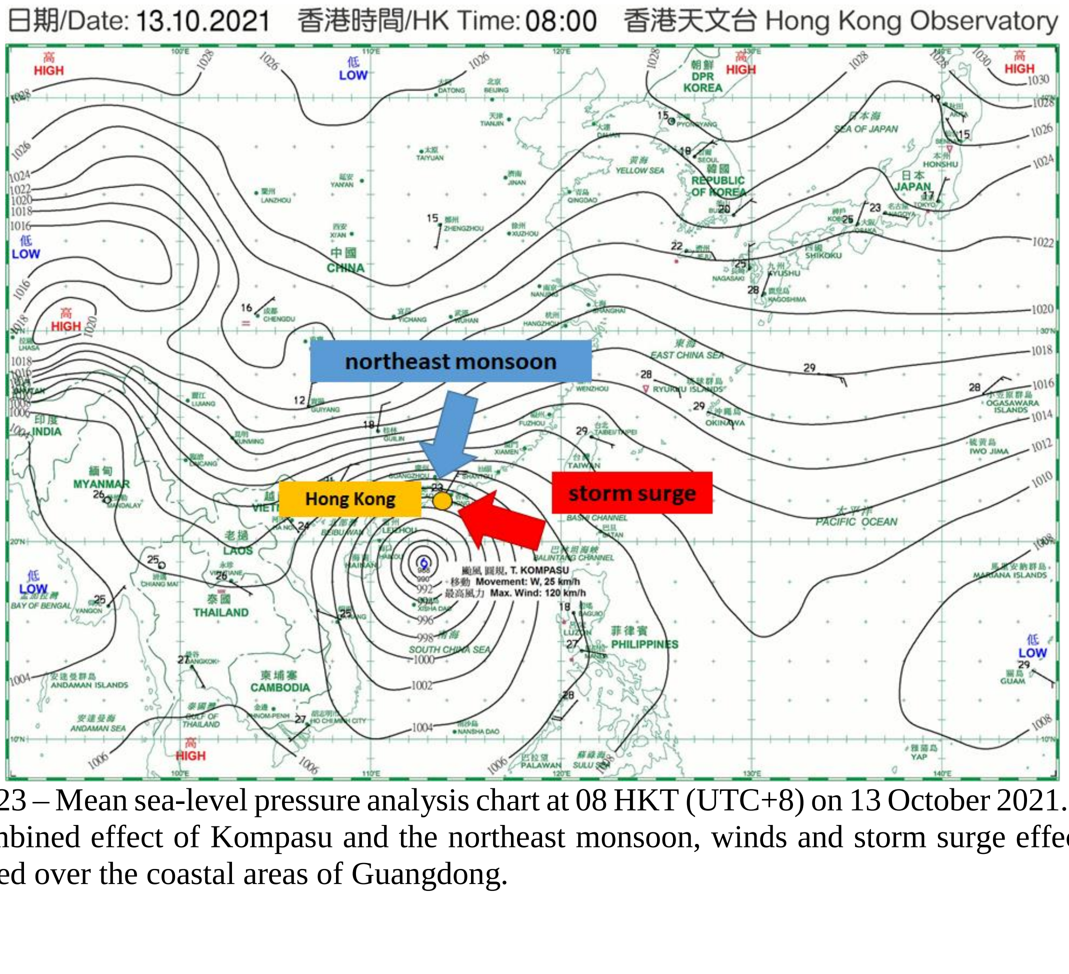

Figure 23 – Mean sea-level pressure analysis chart at 08 HKT (UTC+8) on 13 October 2021. Under the combined effect of Kompasu and the northeast monsoon, winds and storm surge effect were enhanced over the coastal areas of Guangdong.

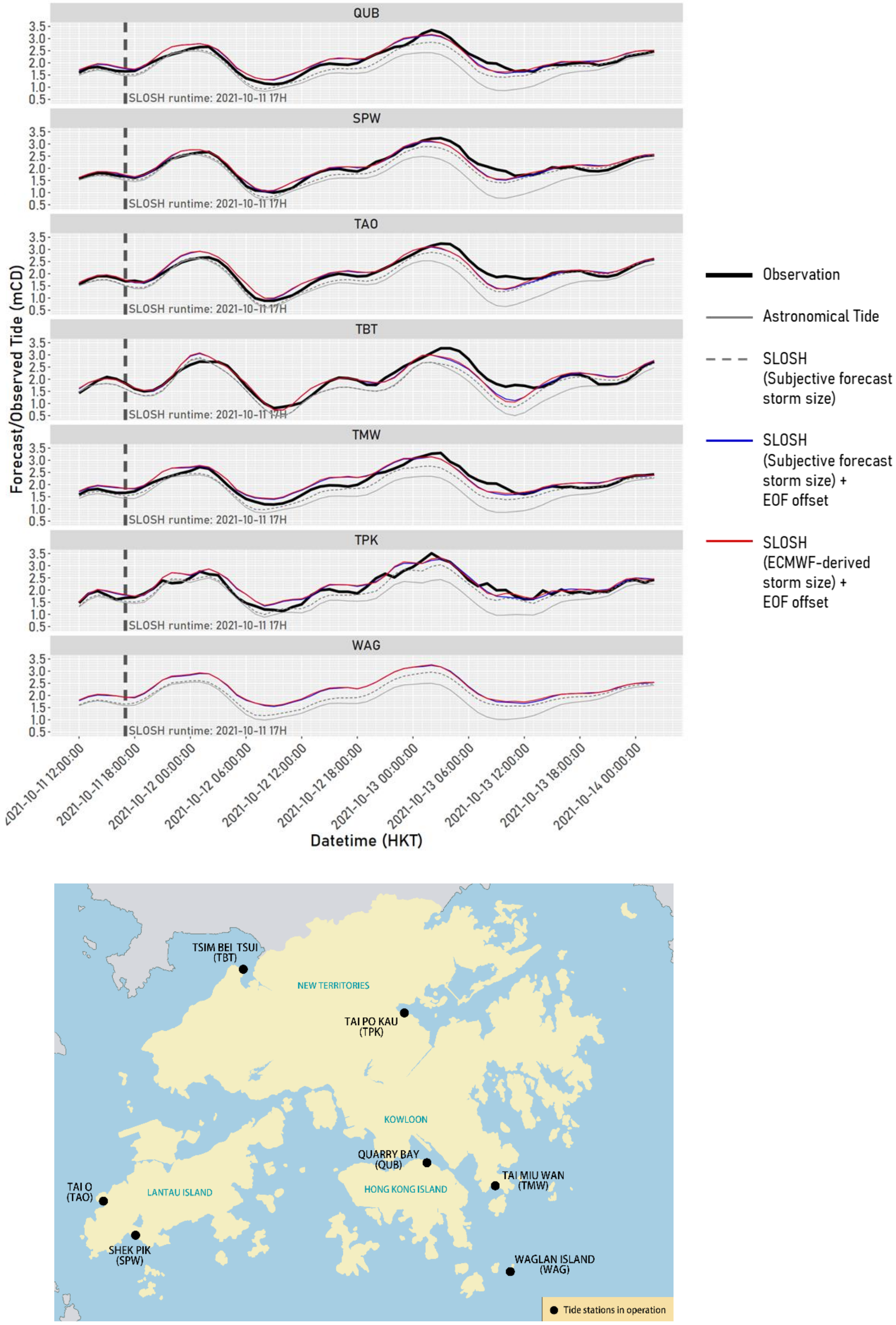

Figure 24 – With the forecast start time at 17 HKT (UTC+8) on 11 October 2021, a hindcast of sea level forecast for different tide stations (QUB, SPW, TAO, TBT, TMW, TPK, and WAG) in Hong Kong under the combined effect of the northeast monsoon and Kompasu. The closest approach of Kompasu to Hong Kong was at around 02 HKT (UTC+8) on 13 October 2021. The addition of "EOF offset" reduced the forecast errors in general, and especially at the peak sea level. The forecasts with SLOSH input of storm size automatically derived from the ECMWF wind field

forecast and subjective forecast from HKO show comparable results. The location of the tide stations can be found in the bottom figure.

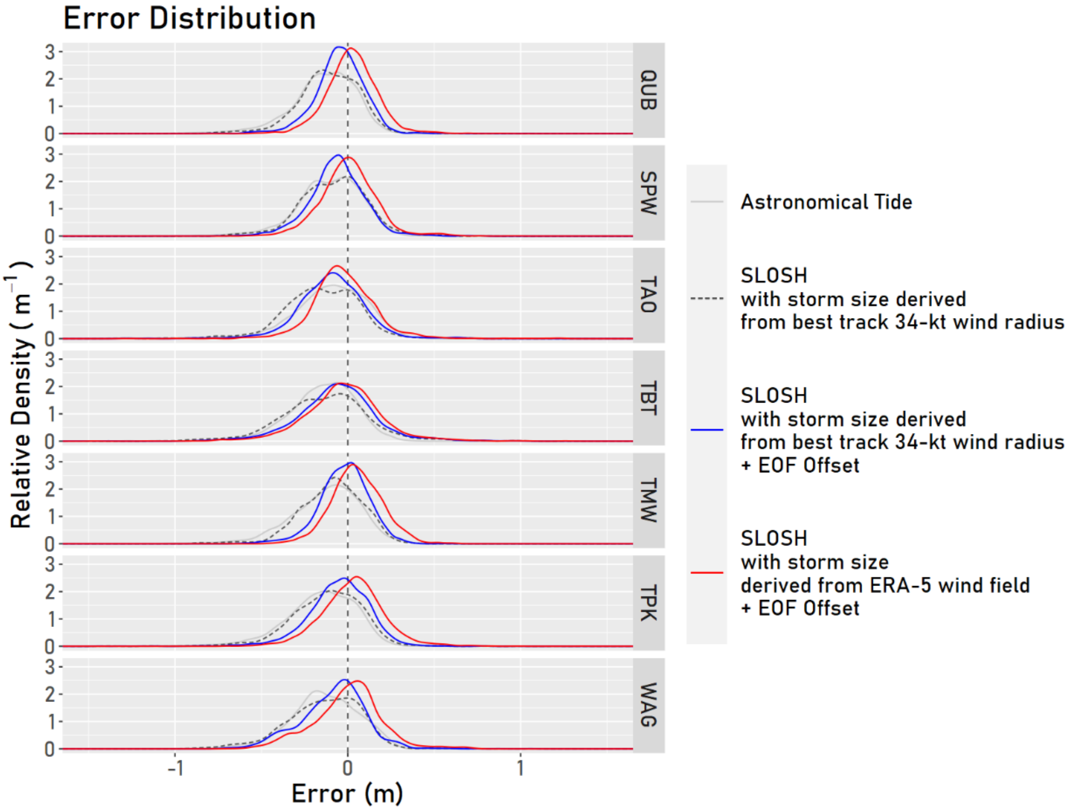

Figure 25 – Error distributions of sea level forecast for tide stations (QUB, SPW, TAO, TBT, TMW, TPK, and WAG) in Hong Kong during the TC episodes during September to November in 2000–2021, using ERA-5 reanalysis instead of ECMWF model forecast to eliminate the effect of model wind forecast error. The addition of "EOF offset" significantly reduced the underestimation bias. The forecasts with the storm size derived from ERA-5 wind field show slightly better results as compared with that derived from the gale wind radius of HKO's best-track data.

Identified opportunities/challenges, if any, for further development or collaboration:

The HKO will further enhance the objective tool for storm surge forecasting by extending it to other seasons, catering for sea level anomalies due to non-TC-induced effects and atypical TCs that are not well parameterised in the storm surge model. Probabilistic forecast of storm surge will also be enhanced by applying the algorithms to model forecasts from ensemble prediction system.

Priority Areas Addressed:

Meteorology

7. Promote communication among typhoon operational forecast and research communities in Typhoon Committee region.
9. Enhance RSMC capacity to provide regional guidance including storm surge, in response to Member's needs.

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

Main text:

The HKO continued to raise public awareness on tropical cyclone hazards and provide relevant information through various social media channels, including Facebook (FB) and Instagram (IG). HKO's official FB page and IG platforms, launched in March 2018, continued to gain popularity, exceeding 290,000 followers on FB and 60,000 followers on IG.

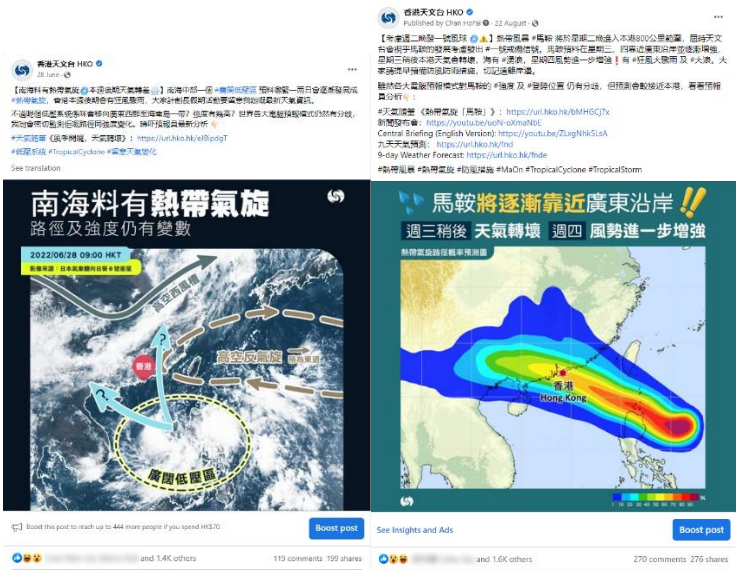

Figure 26 – FB posts showing the development and forecast movement of tropical cyclones.

In 2022, HKO continued to produce educational videos on tropical cyclone hazards and necessary precautionary measures (Figure 26). The videos were broadcasted on local TV stations and HKO's social media platforms.

Figure 27 – Educational video to remind the public on tropical cyclone-related hazards. (Video title: Be alert to storm surge!).

Moreover, HKO continued to contribute tropical cyclone-related educational videos to the Working Group on Disaster Risk Reduction (WGDRR) under ESCAP/WMO Typhoon Committee. In 2022, a video about the potential threats brought by a relatively distant tropical cyclone had been translated into English version with subtitle and voice over. The video was shared with the WGDRR members and had been uploaded to the Typhoon Committee website to enhance public understanding on tropical cyclones.

Identified opportunities/challenges, if any, for further development or collaboration:

The 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

16. Enhance Members' disaster reduction techniques and management strategies.
17. Evaluate socio-economic benefits of disaster risk reduction for typhoon-related disasters.
19. Share experience/know-how of DRR activities including legal and policy framework, community-based DRR activities, methodology to collect disaster-related information.

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13. Online video course on tropical cyclone

Main text:

The HKO launched an "Online Video Course on Tropical Cyclone" on its website in 2022 to introduce the basic scientific knowledge on tropical cyclones to members of the public and to raise their awareness of disaster preparedness and response. The online course comprises six short videos which explain 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. The online course was well received with an ever increasing number of views in YouTube channel.

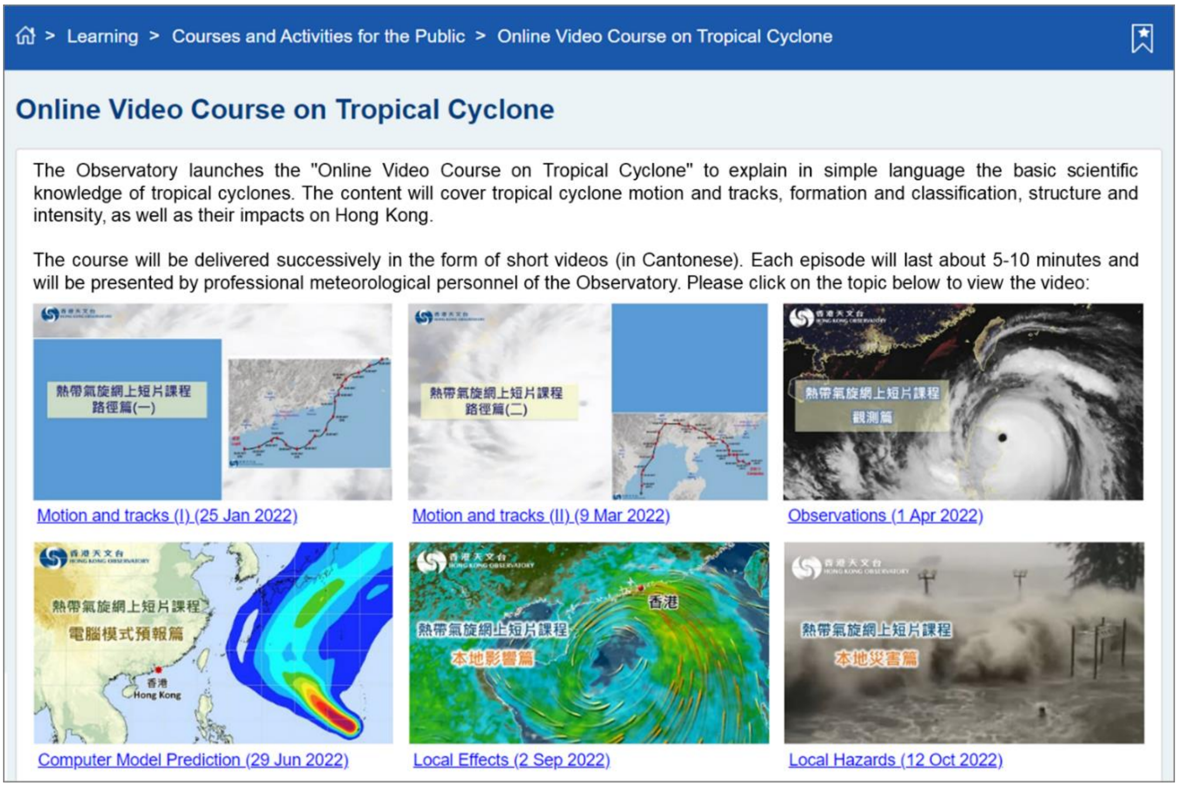

Figure 28 – Online video course on tropical cyclone.

Identified opportunities/challenges, if any, for further development or collaboration:

The HKO will continue to enhance public education materials by developing more infographics and online courses on weather related hazards to further enhance public knowledge of disaster preparedness and response.

Priority Areas Addressed:

DRR

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

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

Main text:

The new web-based version of Tropical Cyclone Information Processing System (TIPS), which supports tropical cyclone forecast and warning operations at the HKO, became fully operational in the 2022 TC season. In addition to its existing track display functionalities, more weather observations and NWP products had been integrated into TIPS. For example, a new NWP chart overlay module was introduced for users to overlay wind speed and rainfall prognostic charts of various NWP models (Figure 29), facilitating easy appreciation of the spatial extent of high winds and heavy rain associated with the tropical cyclone of interest.

The range of location-based NWP products related to tropical cyclone wind impacts was also enhanced. Time cross-section charts of low-level winds, derived from ECMWF's 137 model-level outputs (Figure 30), were routinely generated to support assessment of wind trends over high ground as well as aviation weather forecasting.

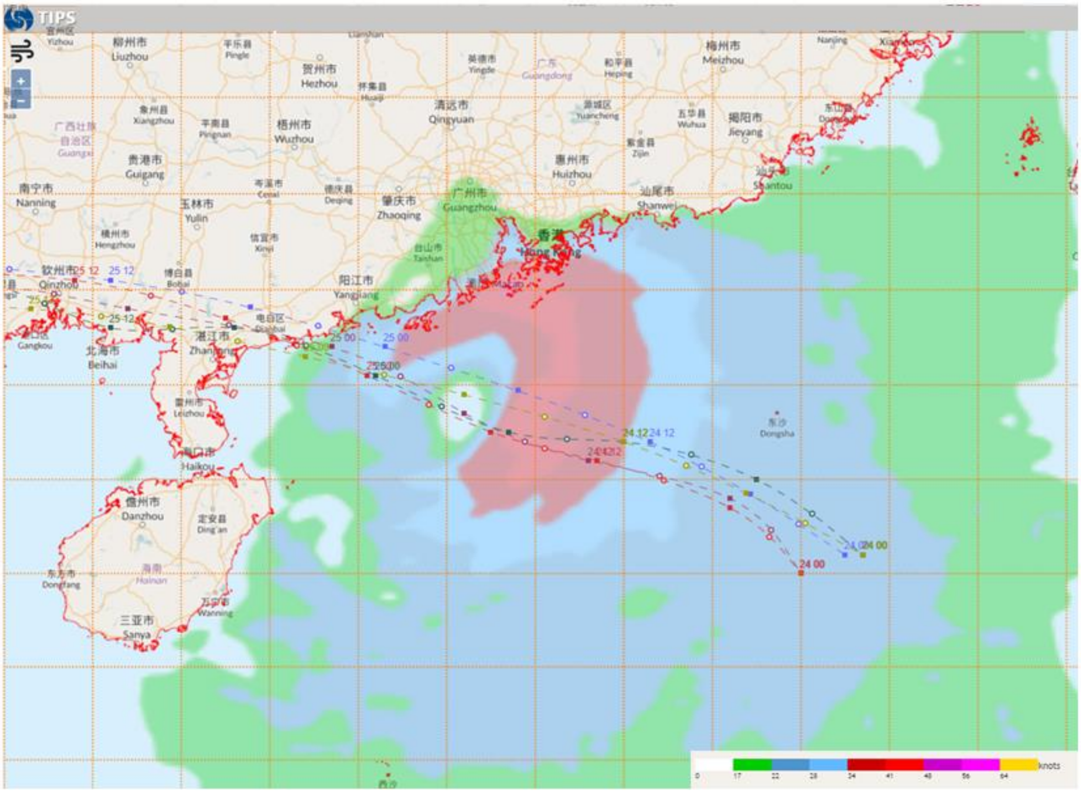

Figure 29 – Sample screenshot of TIPS showing the forecast tracks of Ma-on by various NWP models (dashed lines) and the forecast wind speed by ECMWF (coloured areas).

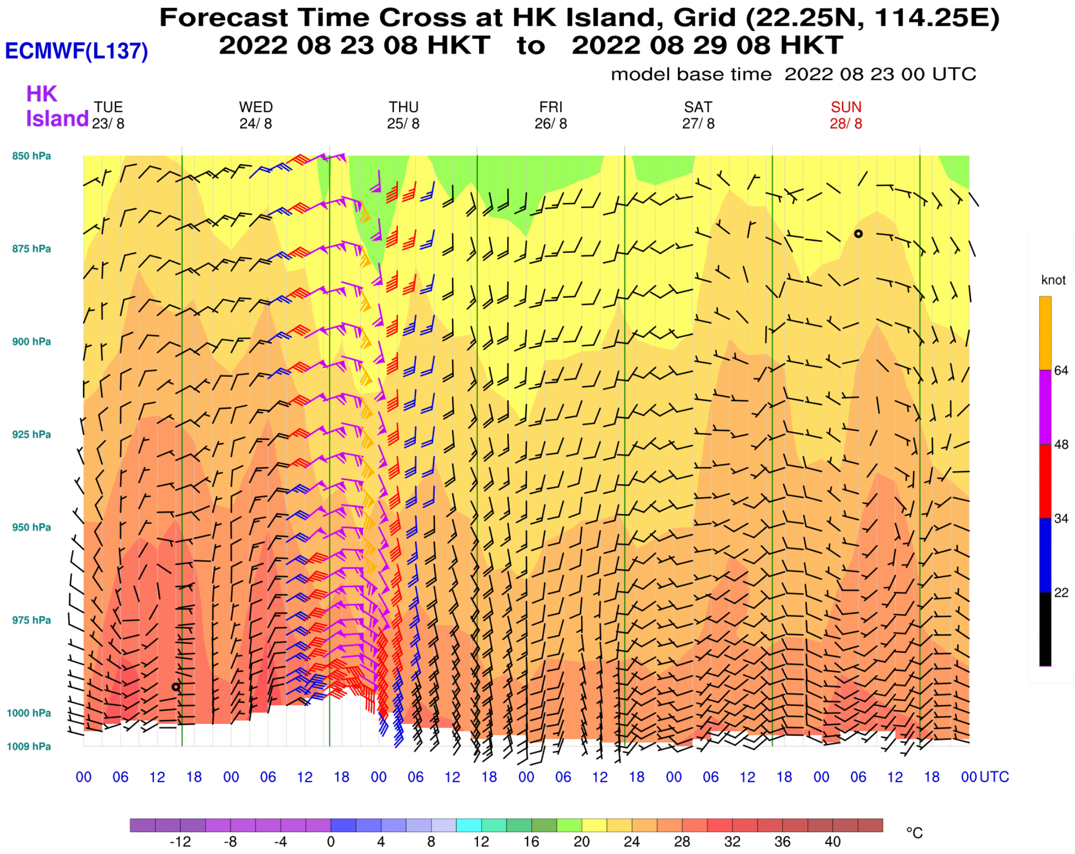

Figure 30 – A sample ECMWF forecast time cross-section chart of low-level winds, showing the vertical extent of high winds associated with Ma-on which were expected to affect Hong Kong on 24 and 25 August 2022.

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
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.

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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.