MEMBER REPORT

Hong Kong, China

ESCAP/WMO Typhoon Committee
18th Integrated Workshop
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28 November – 1 December 2023

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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)

Five tropical cyclones affected Hong Kong, China from 1 January to 20 October 2023, namely Typhoon Talim (2304), Super Typhoon Doksuri (2305) in July, Super Typhoon Saola (2309) in August-September, Severe Typhoon Haikui (2311) in September and Severe Typhoon Koinu (2314) in October (Figure 1). With a maximum sustained wind of 230 km/h near its centre, Saola is the second most intense tropical cyclone affecting the South China Sea since 1950.

The position errors of forecasts issued by the Hong Kong Observatory (HKO) for these five 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 Haikui in longer hour forecasts was mainly due to the fact that global models generally predicted that Haikui would re-curve and move northwards across the East China Sea. Yet, this prediction failed to materialize as the western North Pacific subtropical high extended more westwards than model prediction and resulted in Haikui making landfall over the southeastern China.

Super Typhoon Saola necessitated the issuance of the Hurricane Signal No. 10, the highest tropical cyclone warning in Hong Kong, again since Super Typhoon Mangkhut hitting Hong Kong in September 2018. Severe Typhoon Koinu necessitated the issuance of Increasing Gale or Storm Signal No. 9. Typhoon Talim necessitated the issuance of No.8 Gale or Storm Signal. Super Typhoon Doksuri and Severe Typhoon Haikui necessitated the issuance of Standby Signal No. 1.

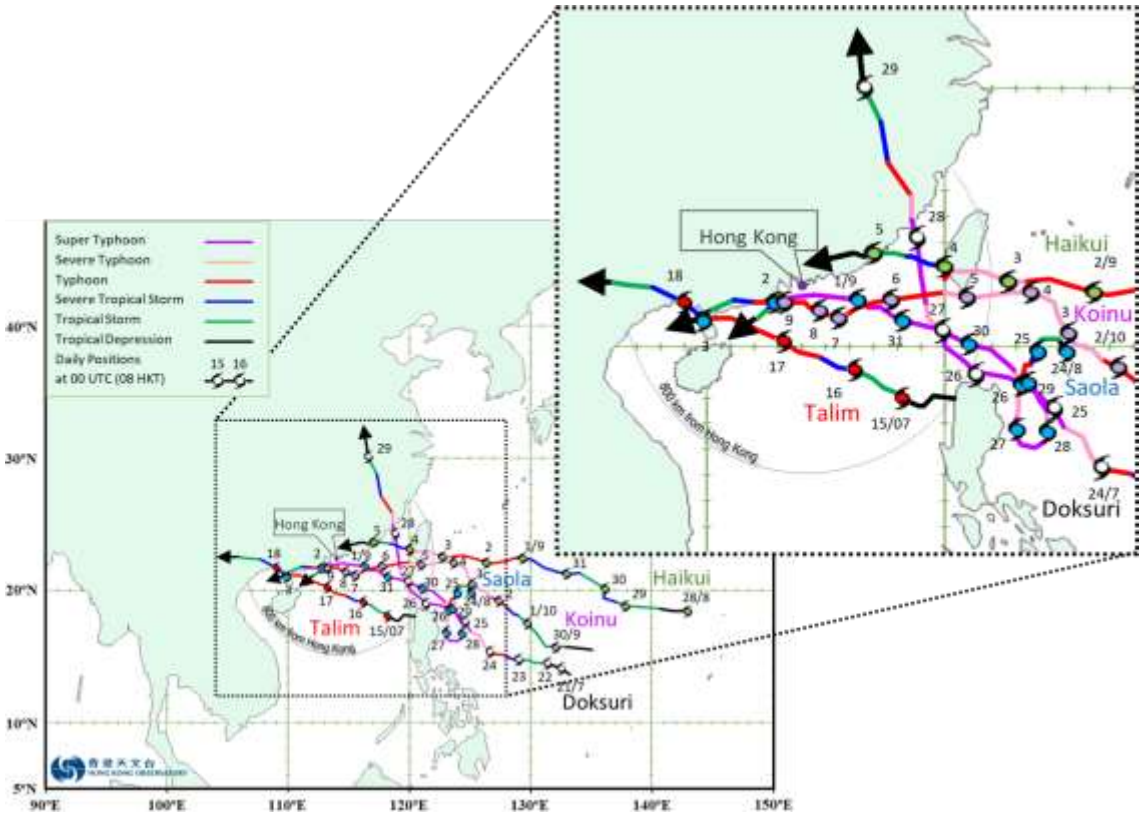

Figure 1 – Tracks of tropical cyclones that affected Hong Kong, China from 1 January to 20 October 2023.

	Position forecast error (km) (No. of cases)				
	24-hr	48-hr	72-hr	96-hr	120-hr
Talim (2304)	51 (9)	98 (8)	116 (8)	183 (6)	316 (4)
Doksuri (2305)	55 (16)	79 (14)	114 (12)	161 (11)	166 (9)
Saola (2309)	66 (19)	120 (17)	168 (15)	235 (13)	324 (11)
Haikui (2311)	141 (16)	238 (14)	397 (12)	629 (10)	964 (8)
Koinu (2314)	58 (19)	109 (17)	125 (15)	125 (13)	140 (11)

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 five tropical cyclones that affected Hong Kong, China from 1 January to 17 October 2023.

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

In terms of rainfall, Haikui was the wettest tropical cyclone affecting Hong Kong by far in 2023. A trough of low pressure associated with the remnant of tropical cyclone Haikui brought a record-breaking rainstorm to Hong Kong on 7 and 8 September 2023.

During the torrential rain, the HKO Headquarters registered a record-breaking hourly rainfall of 158.1 mm from 11 p.m. to midnight on 7 September 2023, the highest since records began in 1884. The 2-hour total rainfall of 201.0 mm and 12-hour total rainfall of 605.8 mm recorded at the Observatory Headquarters during this rainstorm also broke their respective records. The highest rainstorm warning, Black Rainstorm Warning Signal, was issued and lasted for 16 hours and 35 minutes, setting the longest record since the introduction of the rainstorm warning system in 1992.

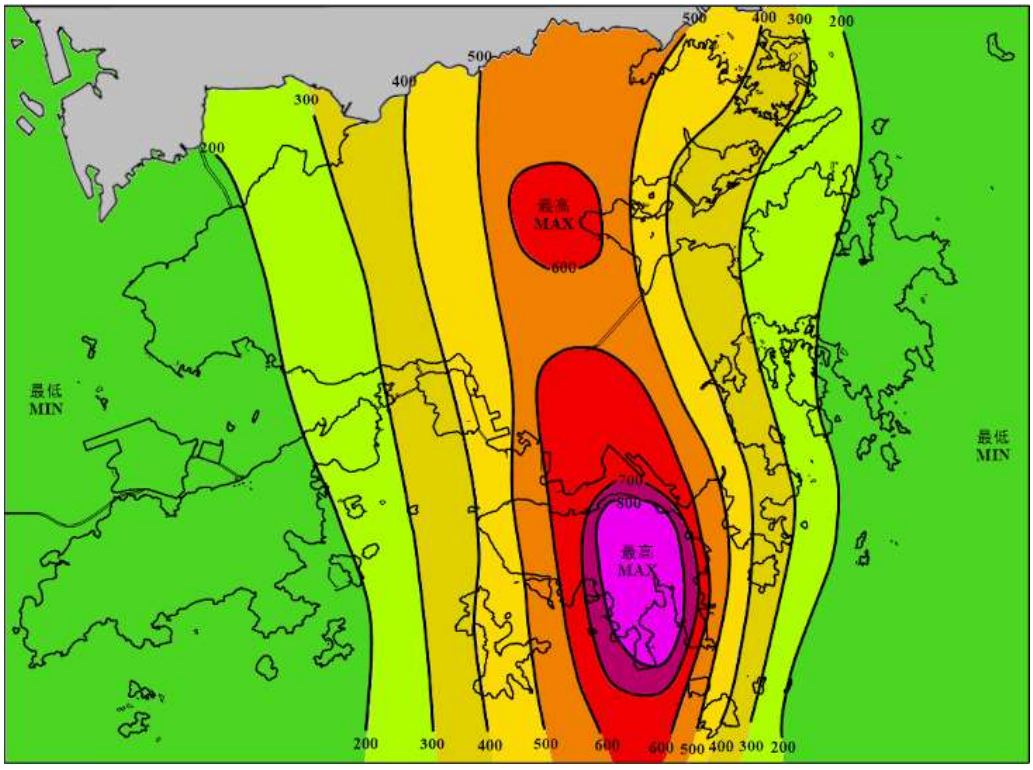

Figure 2 – 24-hour rainfall distribution map of Hong Kong (from 16:00 on 7 September 2023 to 16:00 on 8 September 2023) .

In terms of storm surge, Saola also resulted in flooding in some low-lying coastal areas of Hong Kong, including Sha Tin, Tai Po, and Tai O. The water level at Sai Kung rose to about 4.5 mCD at midnight on 1 Sep.

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

During the passage of Saola, destructive high winds, storm surge and squally heavy rain associated with Saola affected Hong Kong on 1 and 2 September 2023. According to preliminary reports, there were over 3,000 reports of fallen trees, 21 reports of flooding and 2 reports of landslides in Hong Kong. There were also about 40 reports of damaged scaffolding, signboards and windows. Power supply was temporarily interrupted in some places. 460 flights were cancelled at the Hong Kong International Airport. While more than 80 people were injured, there was no fatality in Hong Kong during the passage of Saola.

The record-breaking heavy rain brought by the trough of low pressure associated with the remnant of tropical cyclone Haikui caused flash floods and landslides over many parts of Hong Kong, resulting in widespread traffic disruption and damages to infrastructure. According to preliminary reports, there were 60 reports of flooding and over 200 reports of landslides. Power and water supply were temporarily interrupted in some places. At least two people were killed and more than 140 were injured during the rainstorm.

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

A number of memoranda of understanding (MoUs) were established/renewed between the HKO and overseas official meteorological services in the year. The HKO signed 4 MoUs on meteorological co-operation with the Thai Meteorological Department (TMD), the Agency for Meteorology, Climatology, and Geophysics of the Republic of Indonesia (BMKG), the Papua New Guinea National Weather Service (PNGNWS) and the China Meteorological Administration (CMA) in May, July, August and September 2023 respectively. The synergy of the collaboration will enable all the parties to better cope with the challenges of climate change and various weather hazards.

Figure 3 – The Director of the HKO, Dr Chan Pak-wai (right), and the Director-General of the TMD, Dr Chomparee Chompurat (left), signed the renewed memorandum of understanding to further strengthen meteorological collaboration on 31 May 2023 (Geneva time).

Figure 4 –The Director of the HKO, Dr Chan Pak-wai (right), and the Director of the PNGNWS, Mr Jimmy Gomoga (left), signed a memorandum of understanding via videoconferencing on 3 August 2023 to enhance collaboration and exchange in aeronautical meteorological science and technologies.

Figure 5 – Dr Chan Pak-wai, Director of the HKO (right) and Dr Chen Zhenlin, Administrator of the CMA (left), signed an expanded "Arrangement in Long-term Co-operation in Meteorological Science and Technology" at the HKO Headquarters on 13 September 2023 to further expand its scope to cover the Belt and Road initiatives and to enhance Guangdong-Hong Kong-Macao Greater Bay Area cooperation.

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.

Up to October 2023, a total of 8 dropsonde missions were conducted within the year, respectively for tropical cyclones Talim (15, 16 and 17 July), Doksuri (27 July morning and afternoon), Saola (31 August, see Figure 6), and Koinu (6 October morning and night).

To allow more frequent update of the evolution of the tropical cyclone, dropsonde flights would be carried out more than once in a day when situation permits. The quality-controlled data are converted to BUFR format and disseminated via GTS to facilitate subjective analysis by forecasters as well as data assimilation into NWP models.

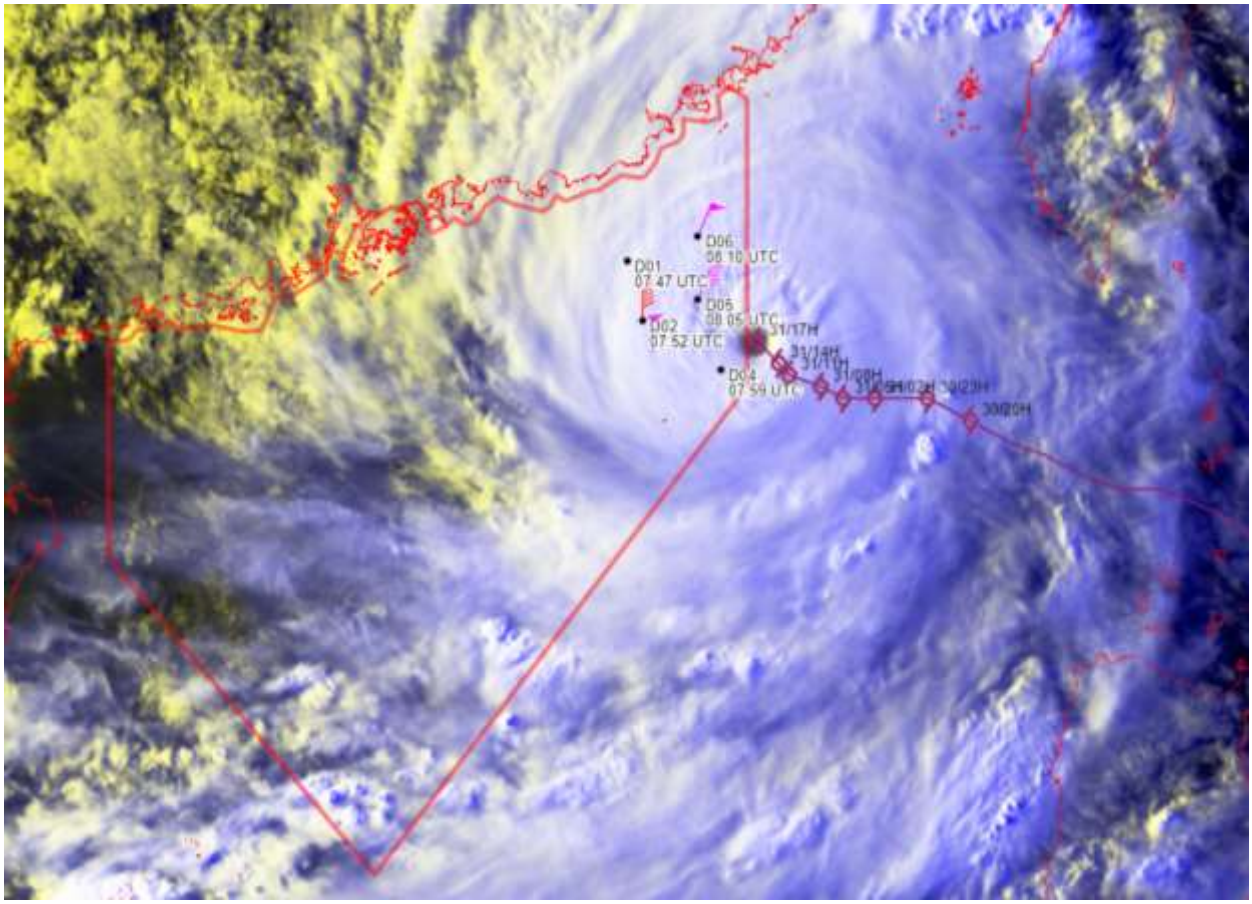

Figure 6 - Near surface winds sampled around the centre of Saola on 31 August by dropsonde missions of HKO

Identified opportunities/challenges, if any, for further development or collaboration:
Possibility of extending the dropsonde reconnaissance flights into 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.

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

Main Text:

Five drifting buoys under the Barometer Upgrade Program of the WMO/IOC Data Buoy Cooperation Panel (DBCP) were deployed in the South China Sea and the western North Pacific during the period of mid-June to late September of 2023 with the assistance of five Hong Kong Voluntary Observing Ships (HKVOS) for tropical cyclone monitoring over the region. Hourly observations of sea level pressure and sea surface temperature were transmitted to the Observatory via Iridium satellite for dissemination on the GTS.

Apart from two drifting buoys that went aground in the vicinity of Luzon in September 2023, three drifting buoys were still operating over the northern part of the South China Sea as of early October 2023 (Figure 7). They collected valuable observations during the passage of several tropical cyclones. In particular, drifting buoys "AMOHK33" and "AMOHK34" were within the circulation of Severe Tropical Storm Talim (2304) in July, and together with "AMOHK35" in the vicinity of Super Typhoon Saola (2309) in August (Figure 8), as well as "AMOHK36" and "AMOHK37" had close encounter with Severe Typhoon Koinu (2314) in October 2023 (Figure 9). Their recorded low pressures during the period are shown in Figures 10 - 14.

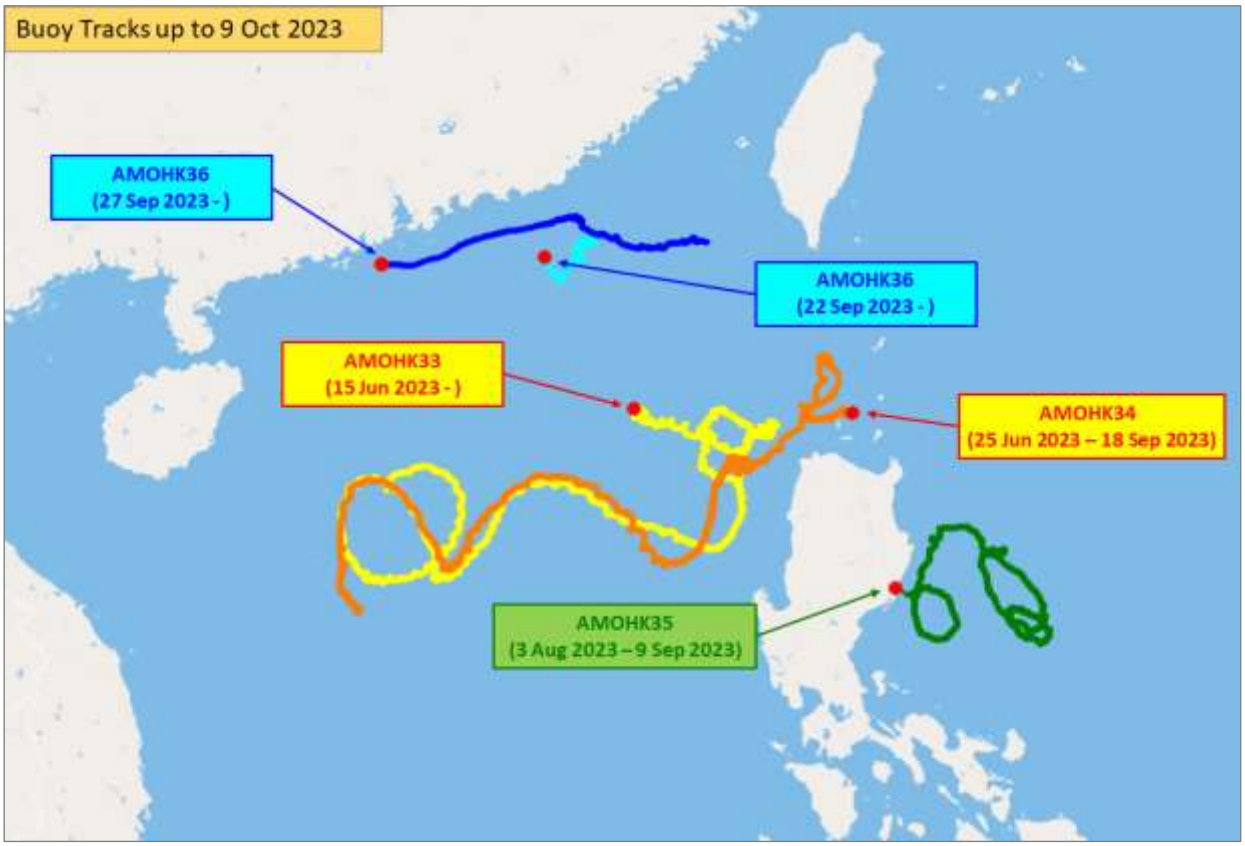

Figure 7 – Tracks of the five drifting buoys deployed in the South China Sea and the western North Pacific in 2023. The red dots denote their latest reported position on 9 October 2023.

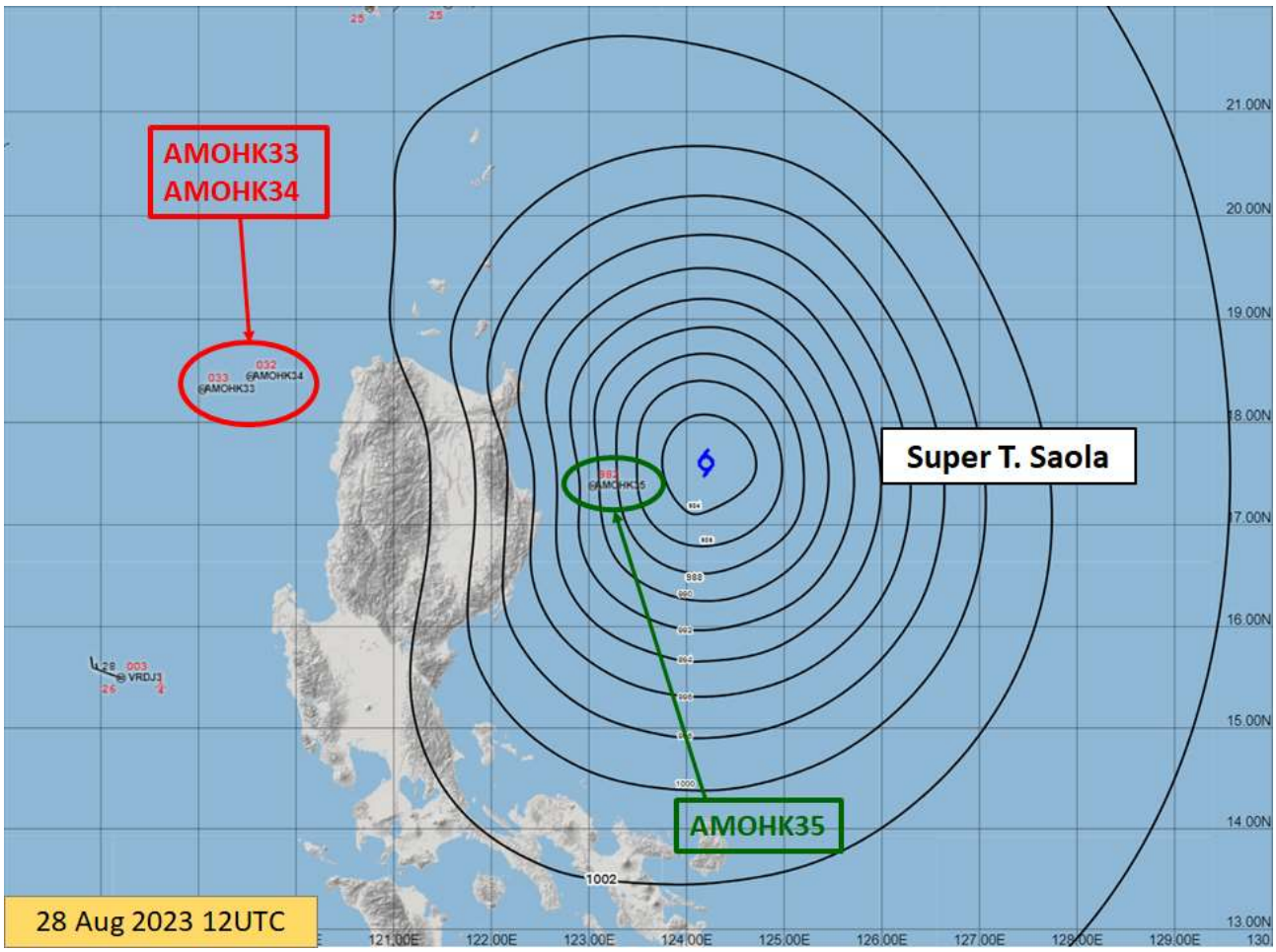

Figure 8 – Super Typhoon Saola (2309) captured by "AMOHK35" over the western North Pacific at 12 UTC on 28 August 2023.

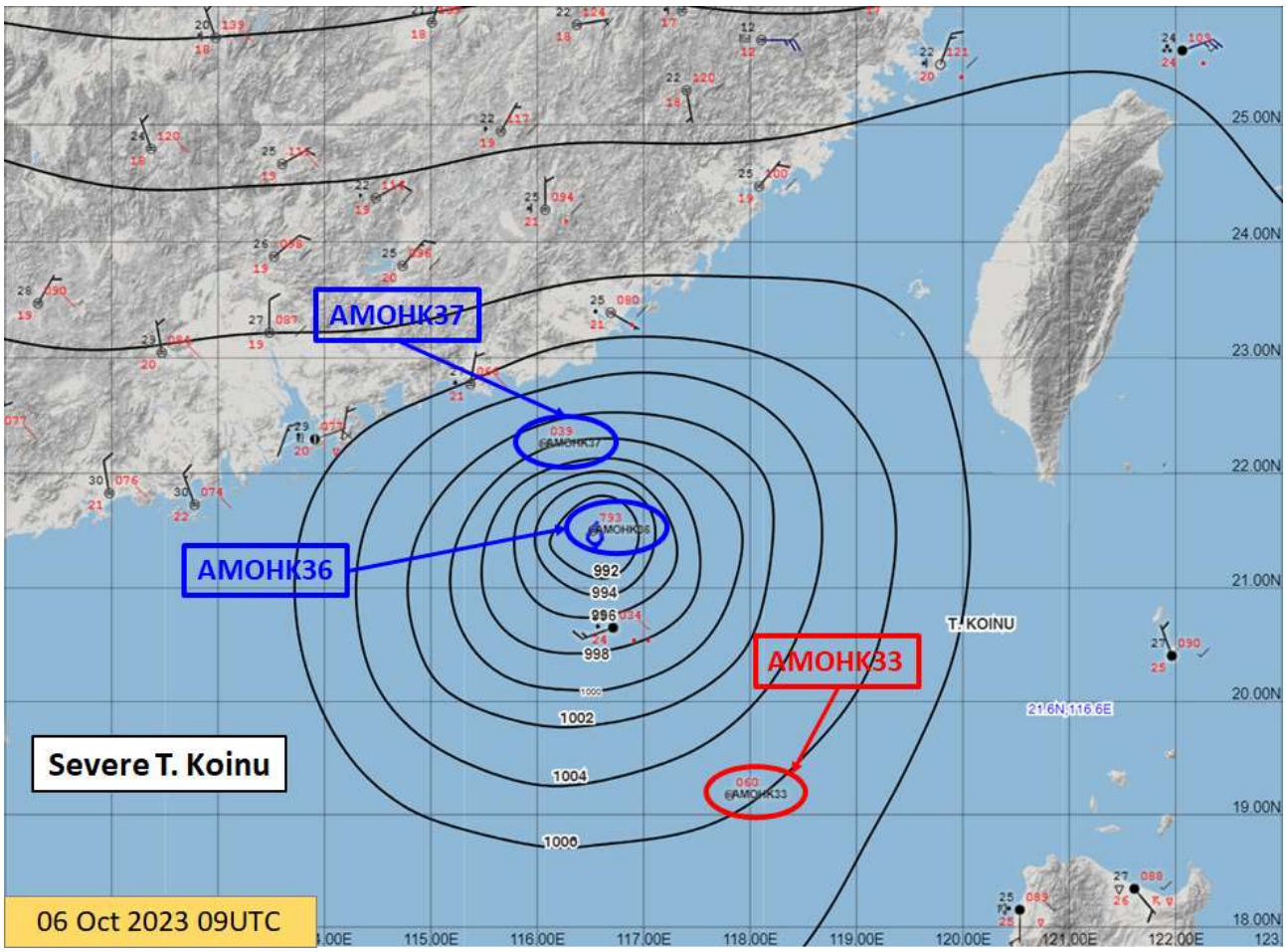

Figure 9 – Close encounter of both "AMOHK36" and "AMOHK37" with Severe Typhoon Koinu (2314) over the South China Sea at 09 UTC on 6 October 2023.

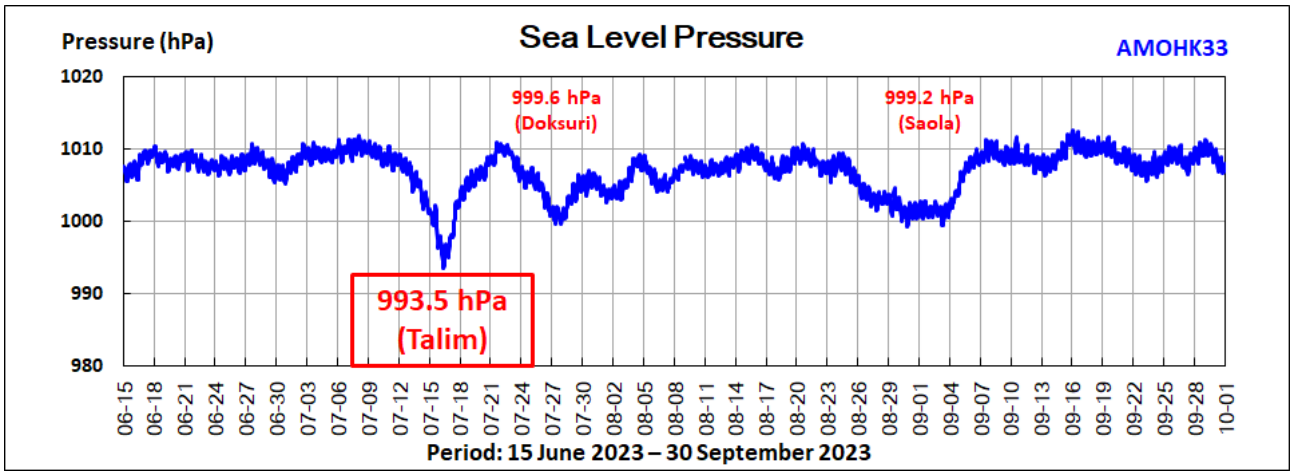

Figure 10 – Time series of sea level pressure measured by "AMOHK33" capturing the low pressures of Talim (2304), Doksuri (2305) and Saola (2309) with a minimum of 993.5 hPa near the centre of Talim on 16 July 2023.

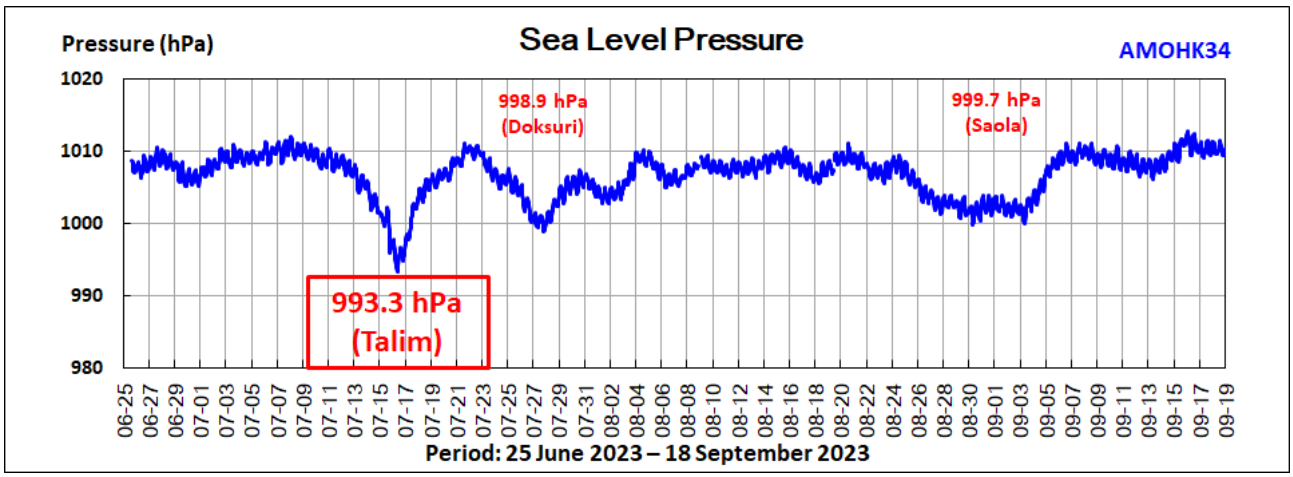

Figure 11 – Time series of sea level pressure measured by "AMOHK34" capturing the low pressures of Talim (2304), Doksuri (2305) and Saola (2309) with a minimum of 993.3 hPa near the centre of Talim on 16 July 2023.

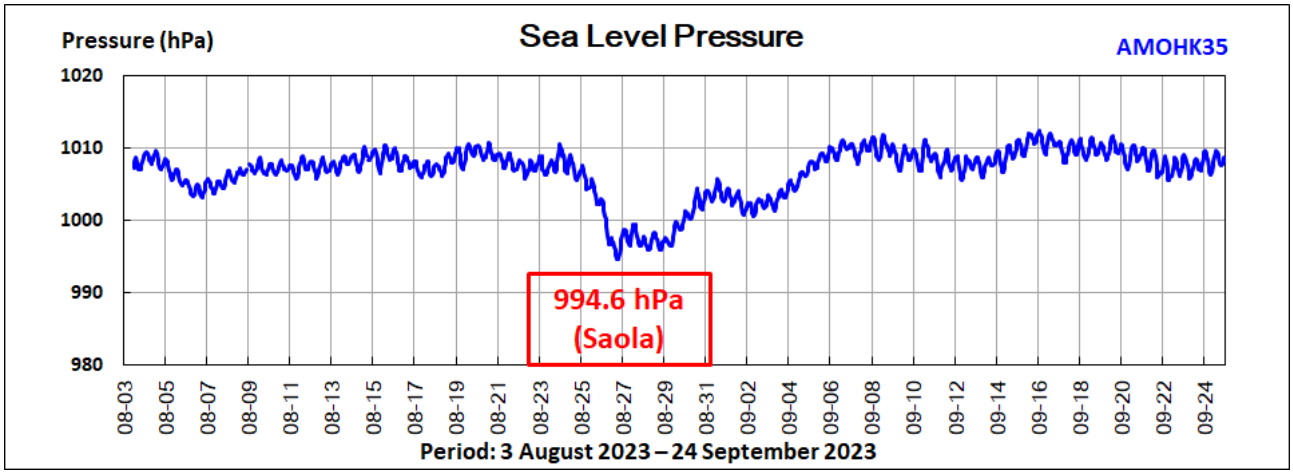

Figure 12 – Time series of sea level pressure mesaured by "AMOHK35" capturing the low pressure of Saola (2309) and recording the lowest pressure of 994.6 hPa near the centre on 26 August 2023.

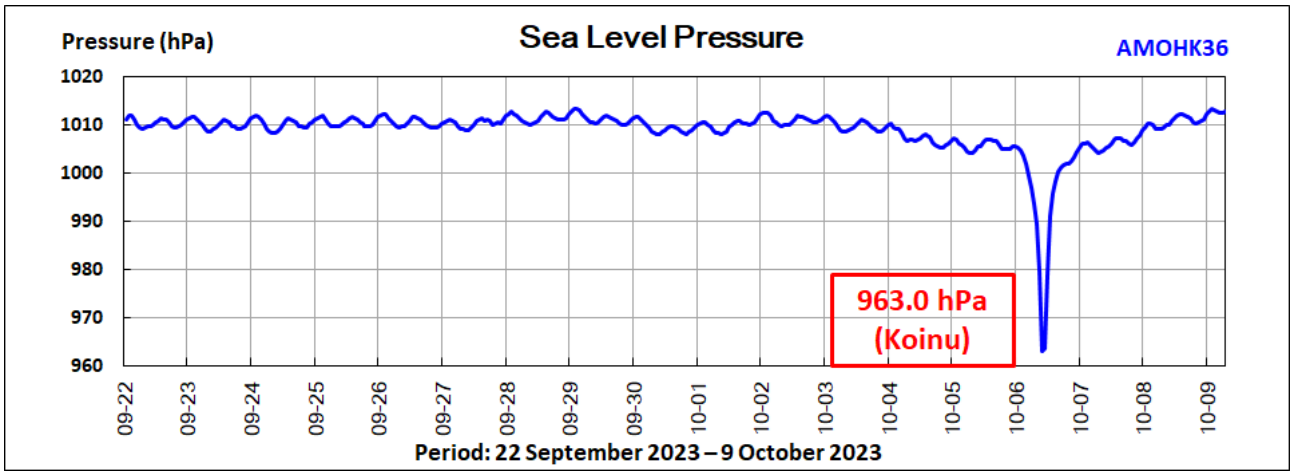

Figure 13 – Time series of sea level pressure measured by "AMOHK36" recording the lowest pressure of 963 hPa in close proximity to the centre of Koinu (2314) on 6 October 2023.

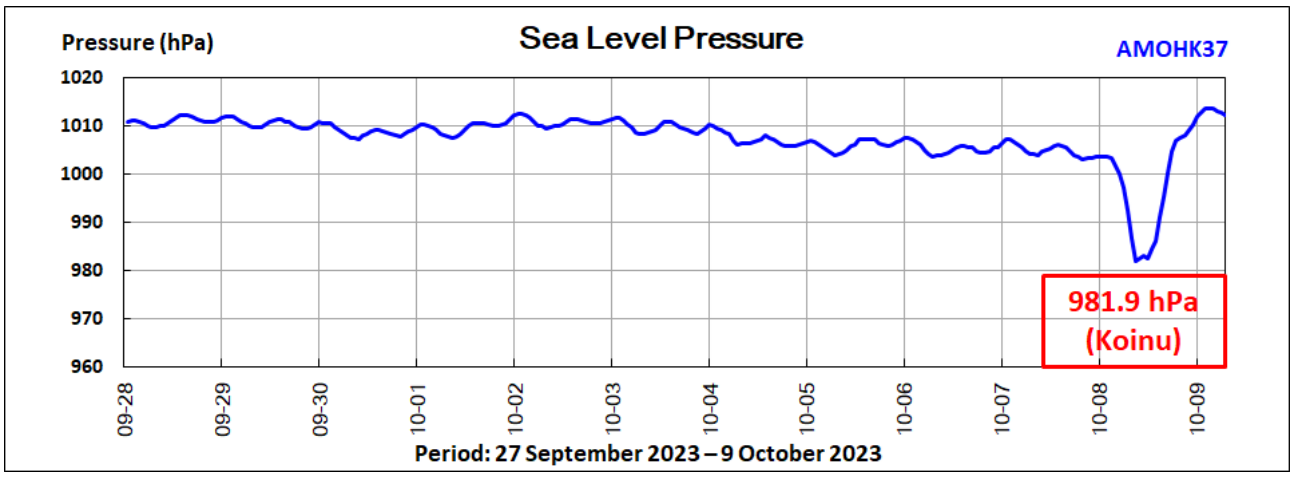

Figure 14 – Time series of sea level pressure measured by "AMOHK37" recording the lowest pressure of 981.9 hPa near the centre of Koinu (2314) on 8 October 2023.

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 2024.

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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3. Development of an Automated Storm Tide Forecast System

Main Text:

The HKO has been operating a storm surge model "Sea, Lake, and Overland Surges from Hurricanes" (SLOSH) in support of storm surge forecast and alert service since 1994, and various enhancements have been made since then. With ever increasing model resolution and improving parametrisation schemes as well as better data assimilation, global models now have the capability of forecasting storm structure and intensity with reasonable accuracy. An automated storm tide prediction system has recently been developed based on the European Centre for Medium-Range Weather Forecasts (ECMWF) global model and SLOSH model to provide weather forecasters with an early reference on the possible occurrence of significant storm surge in Hong Kong during the passage of tropical cyclones. The automated forecast would be particularly useful to forecasters before the first issuance of the Observatory's forecast of tropical cyclone track and intensity for the public, or even as early as before the genesis of tropical cyclones in some cases. In the system, the SLOSH model input parameters, including the radius of maximum wind, central minimum pressure and tropical cyclone positions, are extracted from the ECMWF model forecasts at 0.125-degree resolution. The storm surge model forecast generated from SLOSH will then be added to the astronomical tide prediction together with an "EOF offset" (forecast of sea level anomaly induced by meteorological factors other than the TC such as the effect of northeast monsoon) to automatically produce the total water level forecast at selected reference stations in Hong Kong.

Figure 15 shows the ECMWF model track (purple color) of Tropical Cyclone Kompasu in 2021 initialised at 00 UTC on 10 October, three days before the closest approach to Hong Kong. At that time, Kompasu was still about 1,600 km away from Hong Kong and outside the Shipping Warning area of HKO. Figure 16 shows the sea level forecast by automatic storm tide forecast system. Verification results showed that the ECMWF forecast generally agreed with the actual (track comparison in Figure 15), and thus the automated storm tide forecast could successfully capture the peak water level at Tai O exceeding the alert threshold of 3 mCD around three days in advance in this case. Verification of more tropical cyclone cases will be conducted to evaluate the performance of the automated storm tide forecast system.

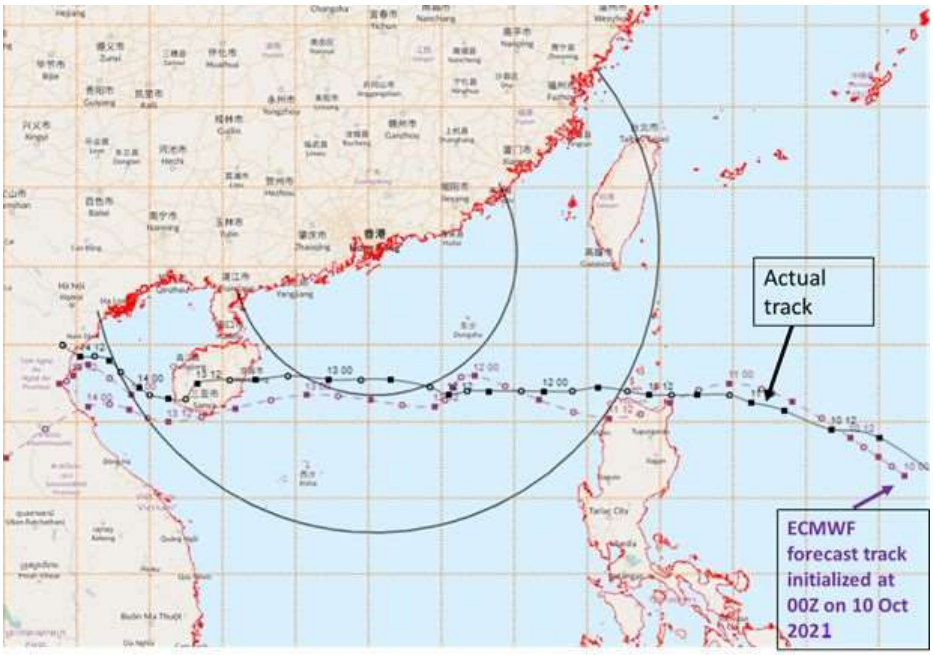

Figure 15 – ECMWF model forecast track (purple) based on the model run initialized at 00 UTC 10 October 2021 generally agreed with the actual track (black) of Kompasu.

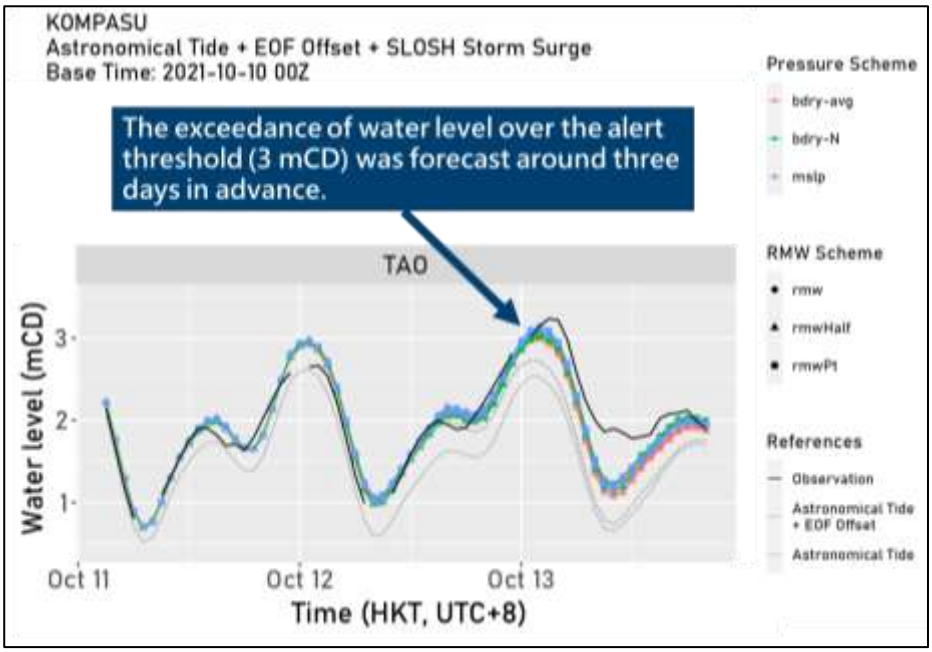

Figure 16 – Comparison of sea level forecast output by automatic storm tide forecast system against water level observation at Tai O in the case of Kompasu in 2021.

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

The HKO will continue the development of the automated storm tide forecast system by using model ensemble system outputs to produce probabilistic forecast of storm tide.

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.

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

Main text:
HKO continues to raise public awareness on typhoon hazards and provide typhoon-related information through various channels, including timely publication of Facebook (FB) posts about the impending tropical cyclones (Figure 17). HKO's official FB page and Instagram (IG) platforms, launched in March 2018, continued to gain popularity with exceeding 320,000 followers on FB and 74,000 followers on IG.

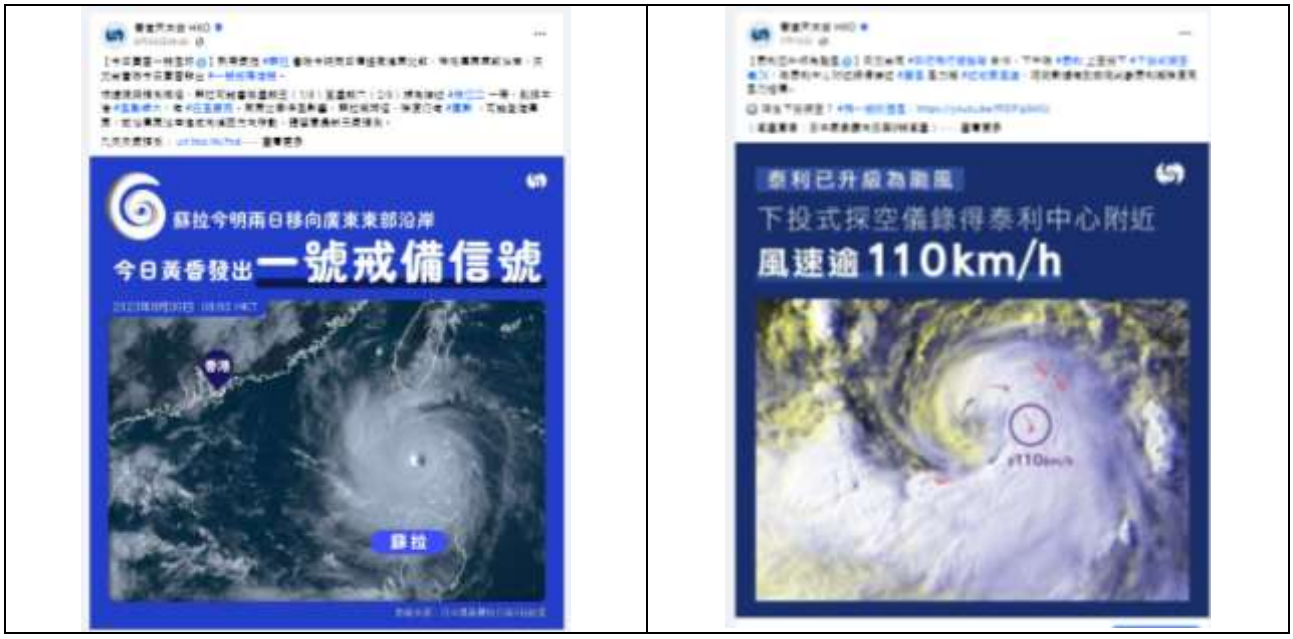

Figure 17 – FB posts showing satellite pictures of Super Typhoon Saola (left) and winds data of Typhoon Talim collected from the dropsonde measurement in collaboration with Government Flying Service (right) to raise public's awareness of the approach of tropical cyclones.

In 2023, HKO organised an online public activity, "Tropical Cyclone Name Collection Activity", (Figure 18) to identify suitable names with Hong Kong characteristics to expand the reserve list of tropical cyclone names of Hong Kong, China, and take the opportunity to raise public awareness and knowledge of hazards caused by tropical cyclones.

Figure 18 – An online activity "Tropical Cyclone Name Collection Activity" was organised in 2023.

Moreover, HKO continued to contribute tropical cyclone-related educational videos to the Working Group on Disaster Risk Reduction (WGDRR) of the Typhoon Committee. In 2023, a video about the threats of concurrence of inclement weather events, such as high winds, storm surges and prolonged heavy rain, had been translated into English version with subtitle and voice over (Figure

19). The video was shared with the WGDRR members and uploaded to the Typhoon Committee website to enhance public awareness of multi-hazard combined effect and to adopt multiple precautionary measures.

Figure 19 – Educational video to raise public awareness of multi-hazard combined effect and to adopt multiple precautionary measures (Video title: Multi-Hazard Combined Effect).

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
- 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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5. Tropical cyclone outlook briefing

Main text:
The HKO continued to conduct bi-weekly online briefings on potential tropical cyclone activities over the western North Pacific and the South China Sea for special users. The aim of the briefing service was to facilitate their early preparation of high-impact weather conditions associated with tropical cyclones as well as manpower arrangement. In 2023, the briefing service was extended to 19 government bureaux/departments and more than 50 organizations from various sectors, including aviation, shipping, utilities and construction etc.

As in previous years, the briefing covered the outlook of TC activity for the coming 2 weeks based on the latest NWP model products and EPS forecasts (Figure 20), with a focus of impacts on local weather. A general overview of potential TC activity in weeks 3 and 4 based on extended EPS outputs was also given to facilitate longer-term planning. Other relevant information, such as prevailing climate patterns affecting TC activity, as well as limitations of NWP models, were included as appropriate. In response to user feedback, potential impacts of TC on weather in major travel destinations, which are of particular concern for the aviation sector, were also discussed in the briefings this year.

In addition to the scheduled briefings, in 2023 an ad-hoc briefing was conducted three days prior to the approach of Super Typhoon Saola (Figure 21) to provide users the latest information of the TC, explanation of forecast uncertainties at that time as well as the potential impacts to the local weather under different track scenarios, including high winds, heavy rain and storm surge, so that they could carry out preparation work before tropical cyclone warning signals for the public were issued.

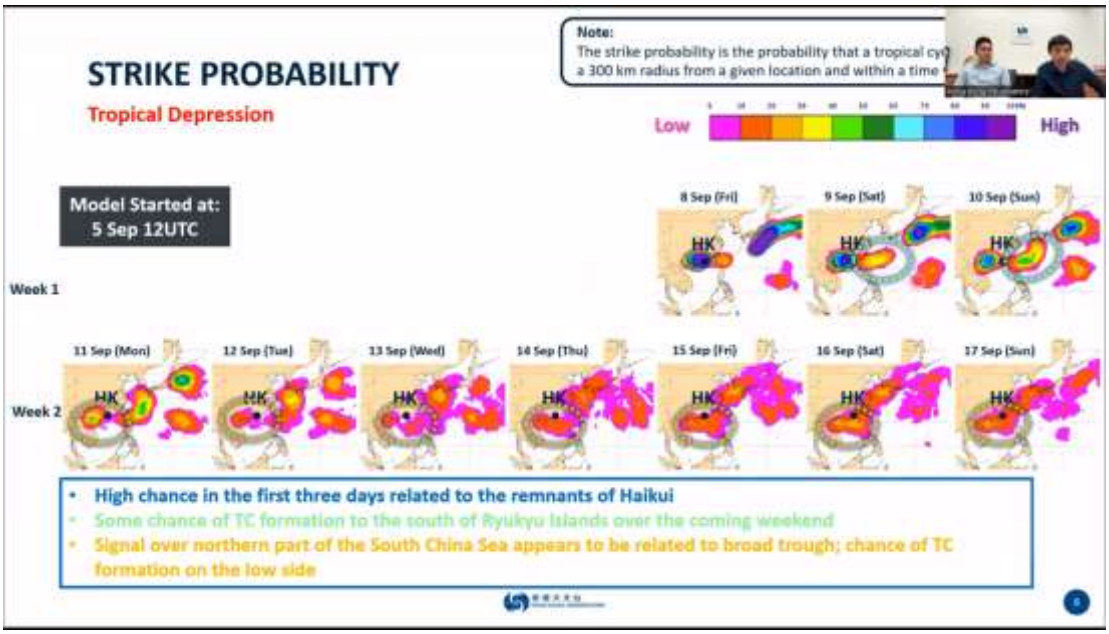

Figure 20 – TC outlook briefing on 6 September 2023 with a 2-week outlook of TC activity over the western North Pacific and South China Sea.

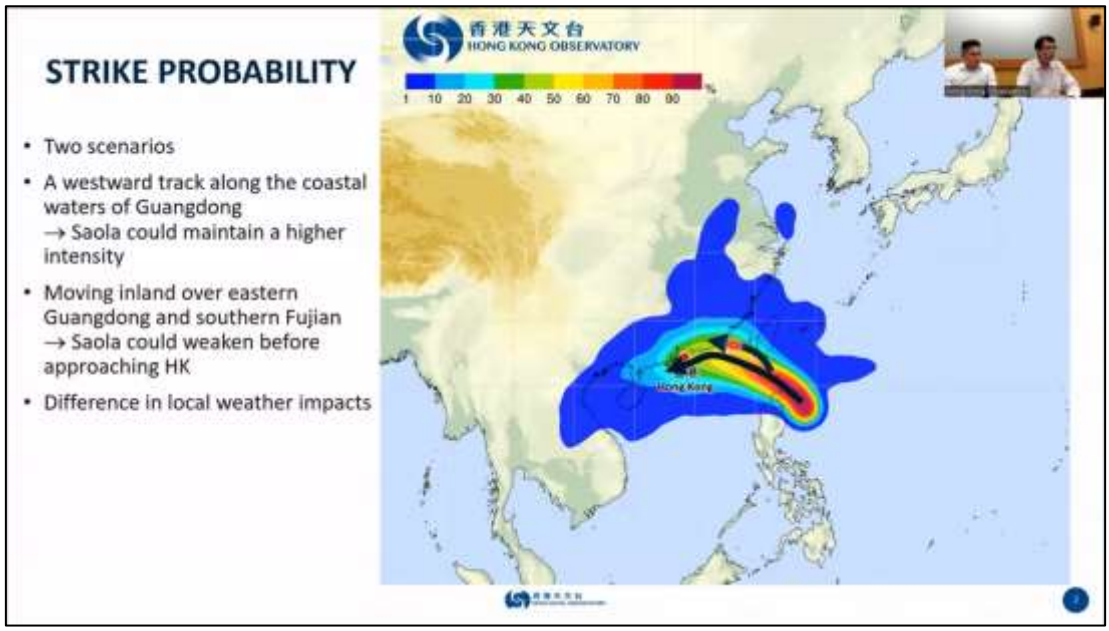

Figure 21 – Ad-hoc TC outlook briefing on Super Typhoon Saola conducted on 29 August 2023.

Identified opportunities/challenges, if any, for further development or collaboration:
More government bureaux/departments and special users will be invited to join the briefing service. It was planned to extend the service to the general public. However, the information has to be further tailored to facilitate public consumption.

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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6. A New Deep Learning Model for Radar and Satellite Nowcast using Generative Adversarial Network

Main text:

In recent years, HKO has been actively developing deep learning nowcast algorithms to improve prediction of movement and intensity of significant convection such as rain bands associated with tropical cyclone (TC). Real-time trial of deep learning nowcast models using radar imagery has revealed a higher forecast skill for the next one or two hours compared to the traditional optical flow technique. However, the deep learning methods (such as TrajGRU) tend to generate considerable blurry nowcast images beyond one hour.

To overcome this limitation, a new deep learning nowcast model called ResConvLSTM-GAN has been developed that enhances the Convolutional Long-Short-Term Memory (ConvLSTM) algorithm using residual connection, the Generative Adversarial Network (GAN) pipeline, style transfer technique, and a dynamically balanced loss function. More realistic and reliable radar nowcast of radar reflectivity can be generated. Additionally, ResConvLSTM-GAN is applied to geostationary satellite imagery to enhance rainfall or significant convection nowcasts over a larger geographical coverage for the next four hours. Verification based on the Critical Success Index and perceptual similarity indicates that ResConvLSTM-GAN is more capable of maintaining and generating small-scale features for both radar and satellite nowcasts compared to previous deep learning methods. Trial operation of ResConvLSTM-GAN commenced in early 2023 to support the Central Forecasting Office and Airport Meteorological Office of HKO in nowcasting convective weather.

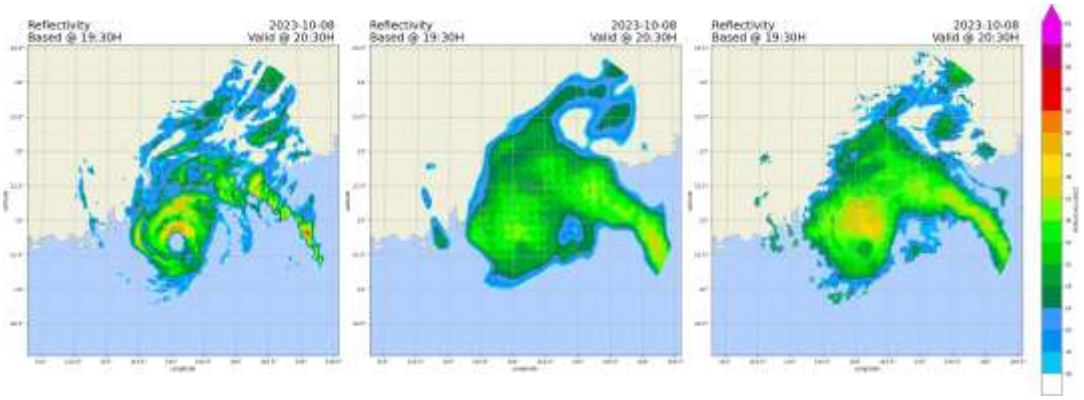

Figure 22 – 1-hour radar reflectivity nowcasts from extrapolation using optical flow field (left), TrajGRU (middle) and ResConvLSTM-GAN (right) for TC Koinu (2326) at 2030 HKT (1230 UTC) on 8 October 2023.

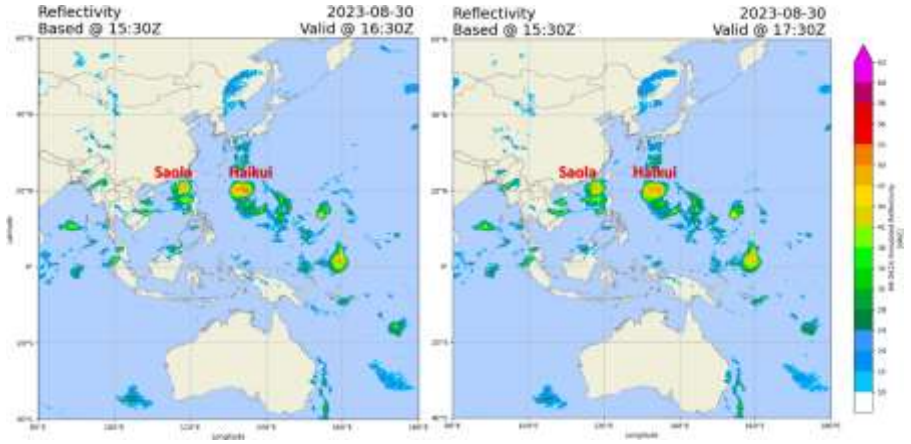

Figure 23 – 1 and 2-hour satellite-derived reflectivity nowcasts from ResConvLSTM-GAN for TC Saola (2318) and Haikui (2320) on at 1630 UTC and 1730 UTC on 30 August 2023 respectively.

Reference:
WK Wong, 2022: How machine learning can improve tropical cyclone forecasts – Perspectives from rainfall nowcasting and intensity prediction. TRCG Special Session, 17th Integrated Workshop of the Typhoon Committee (online), November 2022. (link)

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

1. Expand the geographical coverage of radar nowcasts by utilizing radar mosaic products and extend duration of satellite nowcast beyond 4 hours.
2. Deploy the nowcast products generated by ResConvLSTM-GAN to the RSMC for Nowcasting website, providing real-time nowcasting information for other NMHSs in Asia.

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.

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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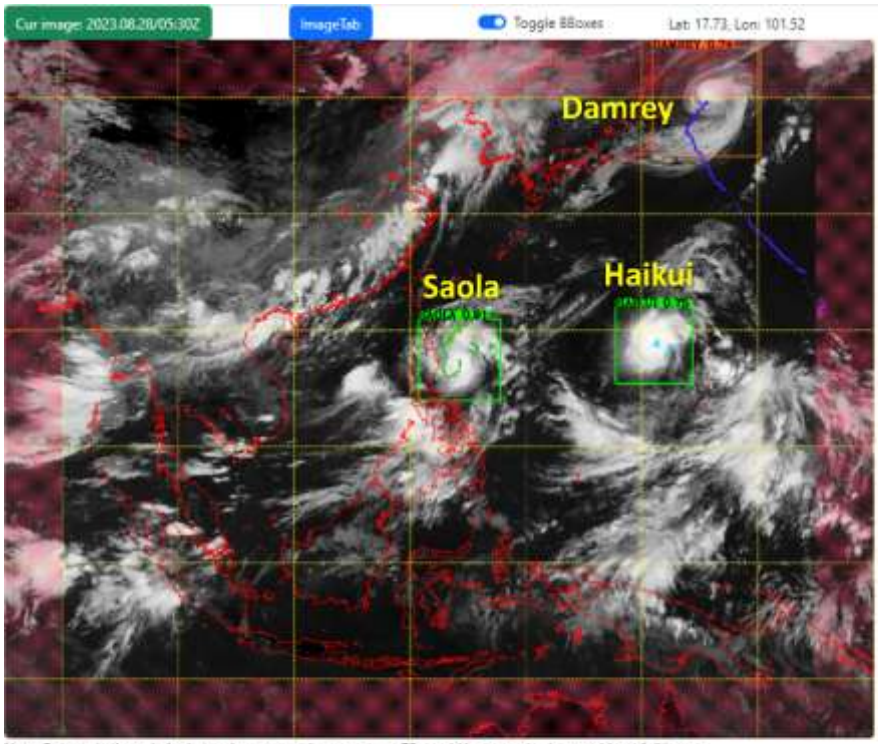
7. Automating Tropical Cyclone Position Analysis and Intensity Estimation from Satellite Images by Artificial Intelligence (AI)

Main text:

A new automatic tropical cyclone (TC) analysis tool, namely AI-STORMVIS (AI-driven Satellite-based TC Object Recognition, Motion Visualization, and Intensity Estimation System), has been developed to perform real-time TC position analysis and intensity estimation based on Himawari-9 infrared satellite images. AI-STORMVIS employs an ensemble approach of three pre-trained YOLOv6 object detection models to detect TC location and a Convolutional Neural Network (CNN) for current intensity (CI) estimation. AI-STORMVIS was trained with satellite images and TC information from 2015 to 2021. A verification of the automatically detected positions for 15 TCs in the western North Pacific in 2022 showed a hit-rate of around 70% within 0.5° absolute position error (APE) for all cases and a mean APE of 0.25° for typhoon or stronger TCs. The trend in TC intensity change can be generally captured with a mean error in CI within 1 but a systematic underestimation for strong TCs was noted. In view of its promising performance that can help streamline operations of TC analysis with reliable and timely estimates of TC position and intensity, AI-STORMVIS was put into trial operation during the 2023 TC season with examples shown in the figures below. Moreover, AI-STORMVIS has demonstrated the ability in providing early indication on developing low-pressure area or potential location of TC genesis.



Note: Outputs in the red-shaded region may not be accurate as TCs could be recognised even without full image.

#	2319 DAMREY	2318 SAOLA	2320 HAIKUI
Pos	39.66°N 145.50°E	17.54°N 124.24°E	18.78°N 141.00°E
CI	3.0 (42 knots)	4.0 (60 knots)	3.9 (59 knots)
Rad	4.7°	3.5°	3.3°
T-1 mvt	24.5 km/h 13 kt NNE (28)	11.0 km/h 5 kt N (11)	26.4 km/h 14 kt SW (227)

Figure 24 – Three TCs, namely Saola (2318), Damrey (2319) and Haikui (2320), detected by AI-STORMVIS based on Himawari-9 infrared satellite image at 0530 UTC on 28 August 2023. Information on automatically analysed positions, intensities, sizes and past movements are provided in the table.

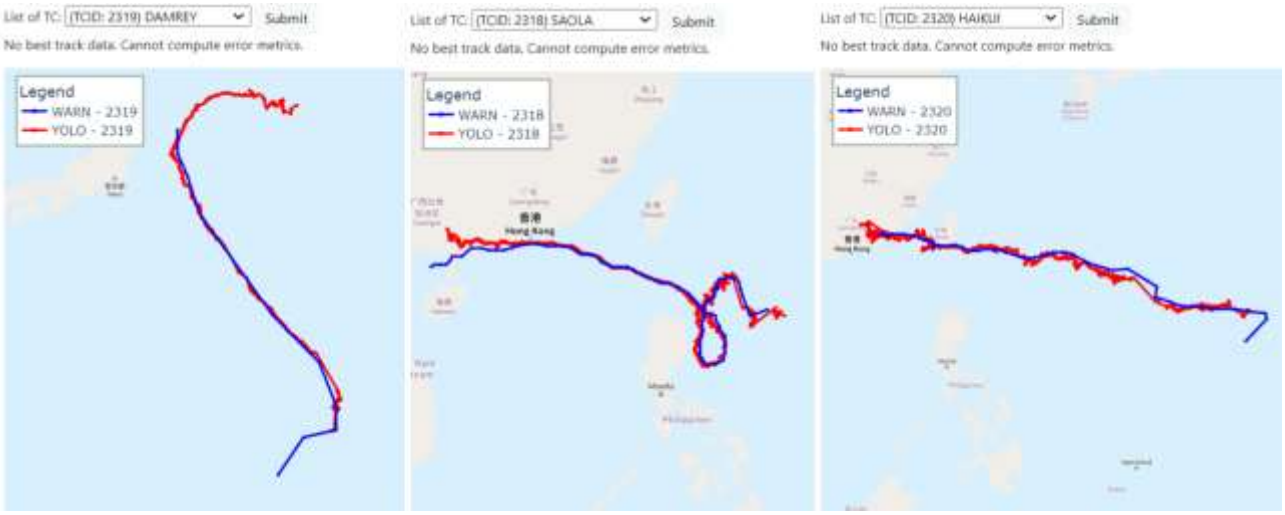


Figure 25 – Comparison of the automatically detected TC tracks (red line) for Saola (2318), Damrey (2319) and Haikui (2320) by AI-STORMVIS against HKO warning positions (blue).

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

1. Perform annual verification and continue to improve the accuracy of the automatic tropical cyclone analysis, especially in intensity determination, by increasing the amount of data used in model training and employing more advanced deep learning algorithms.
2. Explore the feasibility of nowcasting the movement of the tropical cyclone in the next few hours based on automatically detected tropical cyclone track from AI-STORMVIS, analysis field of the environmental steering and forecast from numerical weather prediction models.

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

Main text:
Tropical Cyclone Information Processing System (TIPS), an in-house web-GIS based system integrating meteorological information and forecasting tools related to tropical cyclones (TC), continues to be enhanced to provide better support on TC forecast and warning operations at the HKO.

More TC forecast tracks for computer models were added to TIPS in the 2023 TC season for forecasters' reference, including the Korean Integrated Model (KIM) of KMA, the Hurricane Analysis and Forecasting Model (HAFS) of NOAA, as well as AI-based "Pangu" models which were run on a trial basis at the HKO. Furthermore, the track display module for model ensemble prediction system (EPS) tracks was enhanced to allow users to display TC tracks for individual EPS members with forecast intensity indicated by different colours, giving a combined view of TC forecasts by members (Figure 26).

The suit of NWP products related to tropical cyclone wind impacts was also enhanced. Webpages were developed to provide summary tables showing changes in wind direction and speed in the vicinity of Hong Kong predicted by different NWP models, as well as hourly probability of high winds based on EPS outputs (Figure 27). Such information serves as reference for forecasters to appreciate local wind strength predicted by models and assess the need for issuance of local tropical cyclone warning signals.

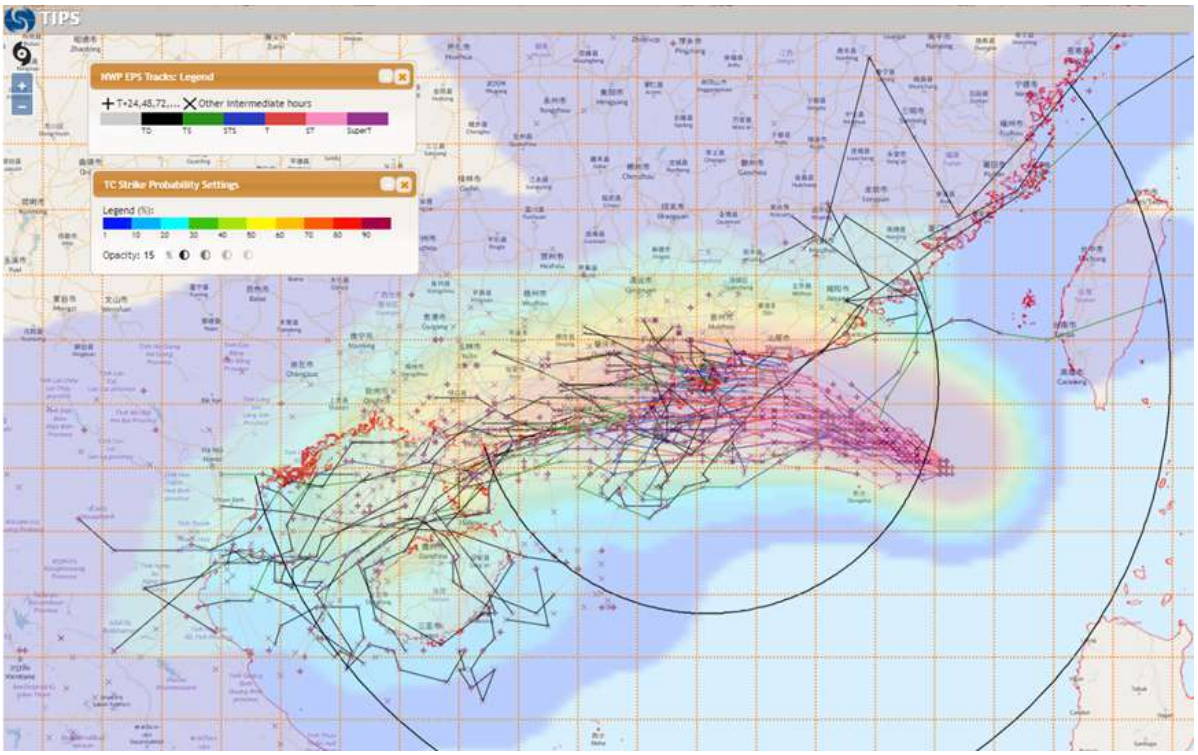

Figure 26 – Sample screenshot of TIPS showing the forecast tracks (colour lines) of Tropical Cyclone Saola by different model ensemble members and track probability forecast (colour contour shading) of ECMWF EPS.

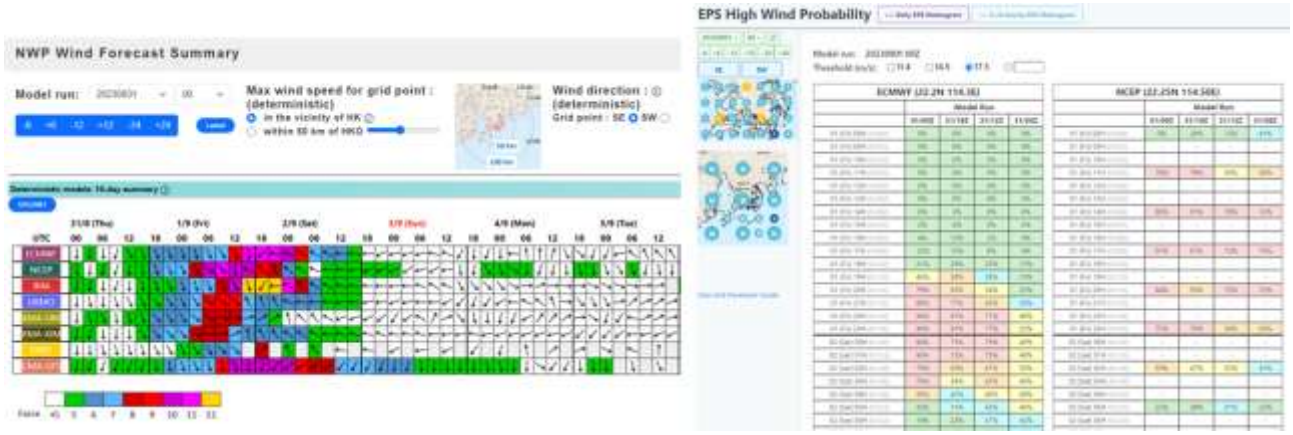

Figure 27 – Webpages of summary tables showing changes in wind direction and wind speed in the vicinity of Hong Kong predicted by various NWP models, as well as hourly probability of high winds based on EPS outputs of ECMWF and NCEP.

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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9. Training Workshop on Public Communication and Media Handling

Main Text:
An in-house Training Workshop on Public Communication and Media Handling was commissioned on 14 April 2023 to enhance the communication skills of HKO staff in handling media and public enquiries arising from high-impact weather events such as tropical cyclones. The workshop comprised lectures and mock sessions, aimed at strengthening participants' social and political sensitivities when dealing with various difficult situations.

Figure 28 – Participants practicing their responses to media enquiries in a mock-up press conference

Identified opportunities/challenges, if any, for further development or collaboration:
More media and communication experts will be engaged to provide training for weather forecasters and presenters to enhance their skills in delivering advisory and warning messages on high-impact weather.

Priority Areas Addressed:
DRR
16. Enhance Members' disaster risk reduction techniques and management strategies.
19. 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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10. Smart Flood Prevention System

Main Text:
The Drainage Services Department (DSD) utilizes smart systems to provide weather information and flood warnings to members of the public. Located in the vicinity of Sha Tin Hoi and Tolo Harbour, the water level of Shing Mun River is susceptible to storm surge, monsoon and high tide, which floods the adjacent low-lying cycle track and pedestrian walkway. Smart flood prevention system have been installed at the riparian area of Shing Mun River, which includes display panel/smart pole installed at locations near the main pedestrian passages alongside Shing Mun River, and QR code installed at the riverside as well as the subways' entrances.

The system allows members of the public to obtain real-time water level images, weather and tidal information announced by Hong Kong Observatory and flood warning messages, to enhance the alertness of members of the public at low-lying locations to stay safe. The smart pole also has smart cameras to detect the flooding and pedestrian condition in order to strengthen public's awareness of flood risk.

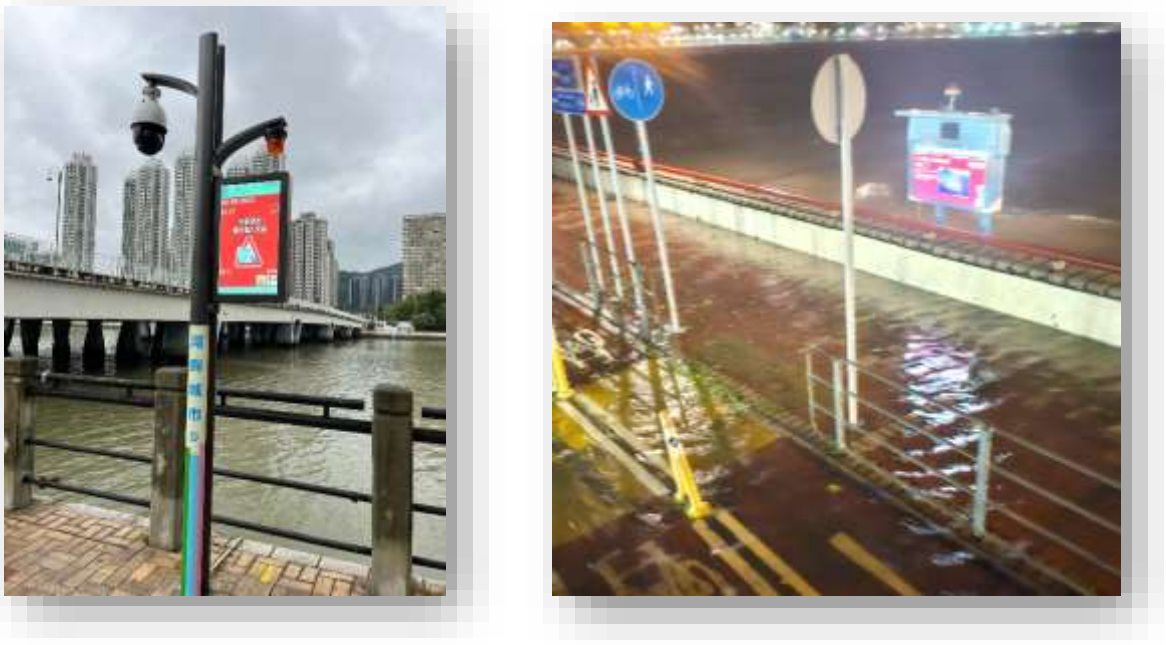

Figure 29 – Display panel/smart pole located alongside Shing Mun River during the passage of Super Typhoon Saola (2309).

Figure 30 – QR code installations at the riverside and the subways' entrances.

Priority Areas Addressed:

Integrated

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

Hydrology

- Enhance capacity in typhoon-related flood risk management (including land-use management, dam operation, etc.) and integrated water resources management and flood-water utilization.
- 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.

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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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.