MEMBER REPORT
Hong Kong, China

ESCAP/WMO Typhoon Committee
12th Integrated Workshop
Jeju, Republic of Korea
30 October – 3 November 2017

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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)

Seven tropical cyclones affected Hong Kong, China from 1 January to 31 October 2017 (tracks as shown in Figure 1 and position errors of forecasts issued by the Hong Kong Observatory (HKO) in Table 1): Severe Tropical Storm Merbok (1702) in June, Tropical Strom Roke (1707) in July, Super Typhoon Hato (1713) and Severe Tropical Storm Pakhar (1714) in quick succession over a 5-day period in late August, Severe Tropical Storm Mawar (1716), a tropical depression over the South China Sea in September and Severe Typhoon Khanun (1720) in October. Hato necessitated the issuance of the highest tropical cyclone warning signal, the No.10 Hurricane Signal, in Hong Kong, the first time since Severe Typhoon Vicente in 2012. Merbok, Roke, Pakhar and Khanun necessitated the issuance of the Gale or Storm Signals (and including Hato, the Gale or Storm Signals were raised five times in 2017, a joint record with 1964 and 1999), and Mawar necessitated the issuance of the Strong Wind Signal.

With sea surface temperature warmer than usual, Hato intensified significantly after entering the northeastern part of the South China Sea and developed briefly into a super typhoon over the sea areas south of Hong Kong just before landfall. Figure 2 shows the time series of the estimated maximum sustained wind speed near the centre of Hato and best track of Hato near Hong Kong. A number of follow-up studies on Hato would be pursued, particularly in aspects such as observational, monitoring and warning strategies, intensity change and assessment, as well as the devastating impacts inflicted upon the Pearl River delta region as a result of the storm surge triggered by Hato.

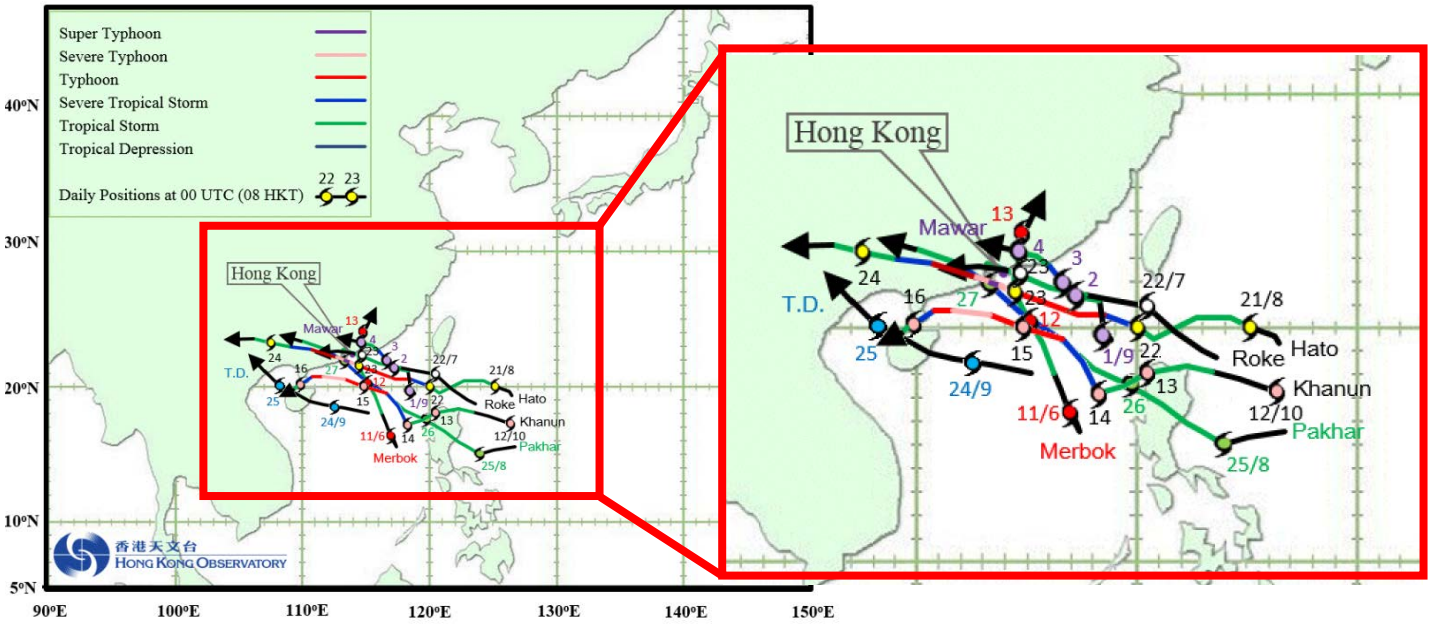

Figure 1 - Tracks of tropical cyclones that affected Hong Kong, China from 1 January to 31 October 2017.

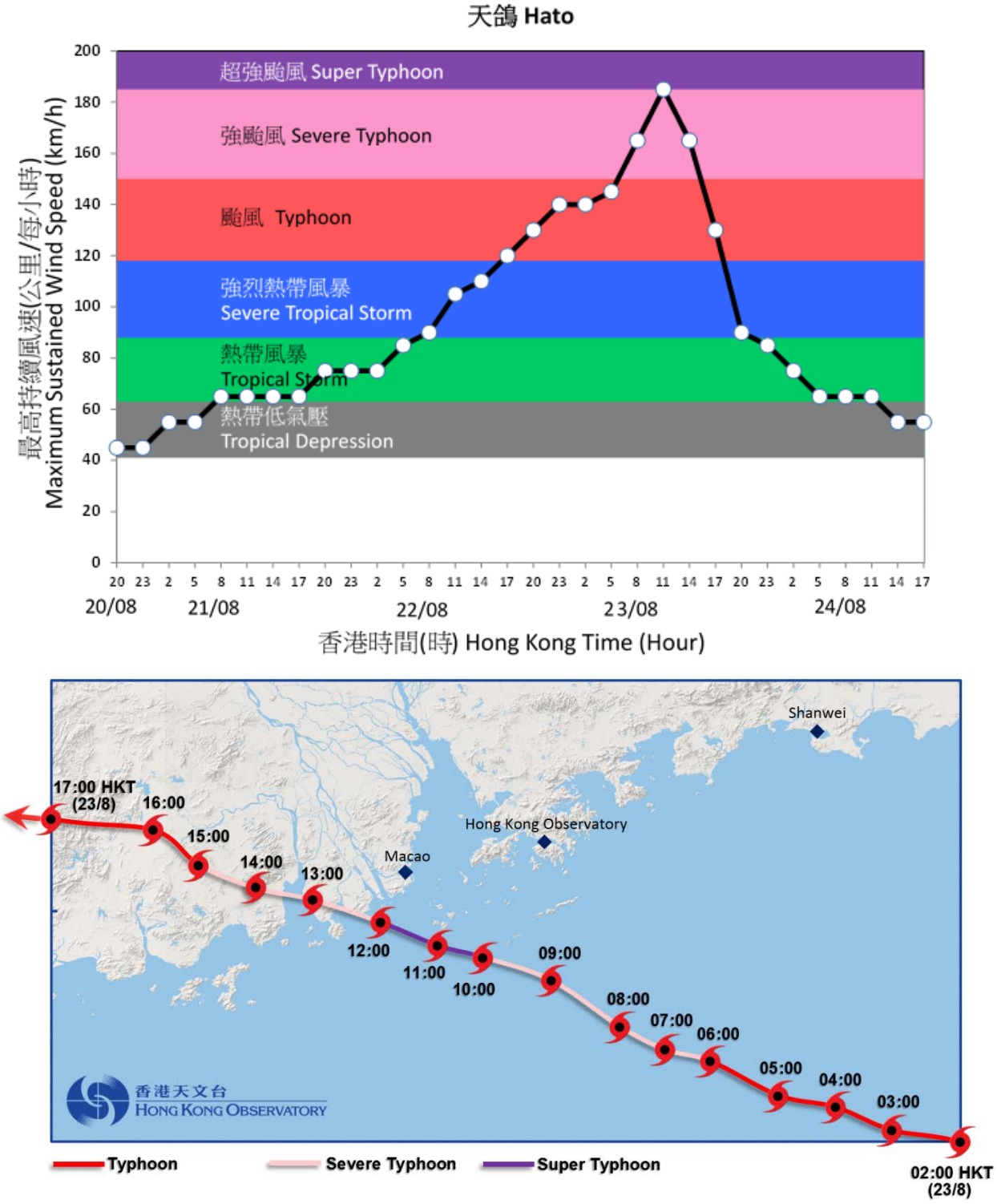

Figure 2 – (Up) Time series of the maximum sustained wind speed near the centre of Hato. (Down) Best track of Hato near Hong Kong

Table 1 Performance summary of track forecasts issued by HKO at 00 UTC and 12 UTC as verified against HKO's warning track for the seven tropical cyclones that affected Hong Kong, China from 1 January to 31 October 2017.

	Position forecast error (km) (No. of cases)				
	24-hr	48-hr	72-hr	96-hr	120-hr
Merbok (1702)	95 (3)	90 (1)			
Roke (1707)*					
Hato (1713)	62 (8)	160 (6)	204 (4)	253 (2)	
Pakhar (1714)	94 (5)	188 (3)	150 (2)		
Mawar (1716)	76 (7)	91 (5)	157 (3)	133 (1)	
Tropical Depression	107 (2)				
Khanun (1720)	89 (7)	132 (5)	167 (3)	150 (1)	

* The lifetime of Roke was less than 24 hours for the track issued at 12 UTC on 22 July 2017

The performance of tropical cyclone forecasts was generally satisfactory with the average errors well within the "potential track area" (the probable area of tropical cyclone location with a probability above 70%).

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

The storm surge brought by Hato raised the water level in Hong Kong generally by about one to two metres. Coinciding with the high water of the astronomical tide (the astronomical high tide was about 2.4 m at Quarry Bay (Figure 3) in the Victoria Harbour that morning), the aggregated effect resulted in the inundation of many low-lying areas in Hong Kong by sea water. The water level at Quarry Bay reached a maximum of 3.57 mCD (metres above Chart Datum), the second highest since records began in 1954 and only lower than the record high of 3.96 mCD set by Super Typhoon Wanda in 1962. A maximum water level of 4.56 mCD was recorded at Tsim Bei Tsui (Figure 3) over the northwestern part of the territory, the highest since records began in 1974. The maximum sea levels recorded at various tide stations in Hong Kong during the passage of Hato are shown in Figure 3.

In terms of rainfall, Hato brought only a meagre amount of about 60 millimetres to Hong Kong generally. In comparison, Merbok and Pakhar each brought more than 250 millimetres of rainfall to parts of Hong Kong. In general, rainfall amounts from Khanun and Mawar were less than 100 millimetres, while from Roke and the tropical depression in September less than 50 millimetres.

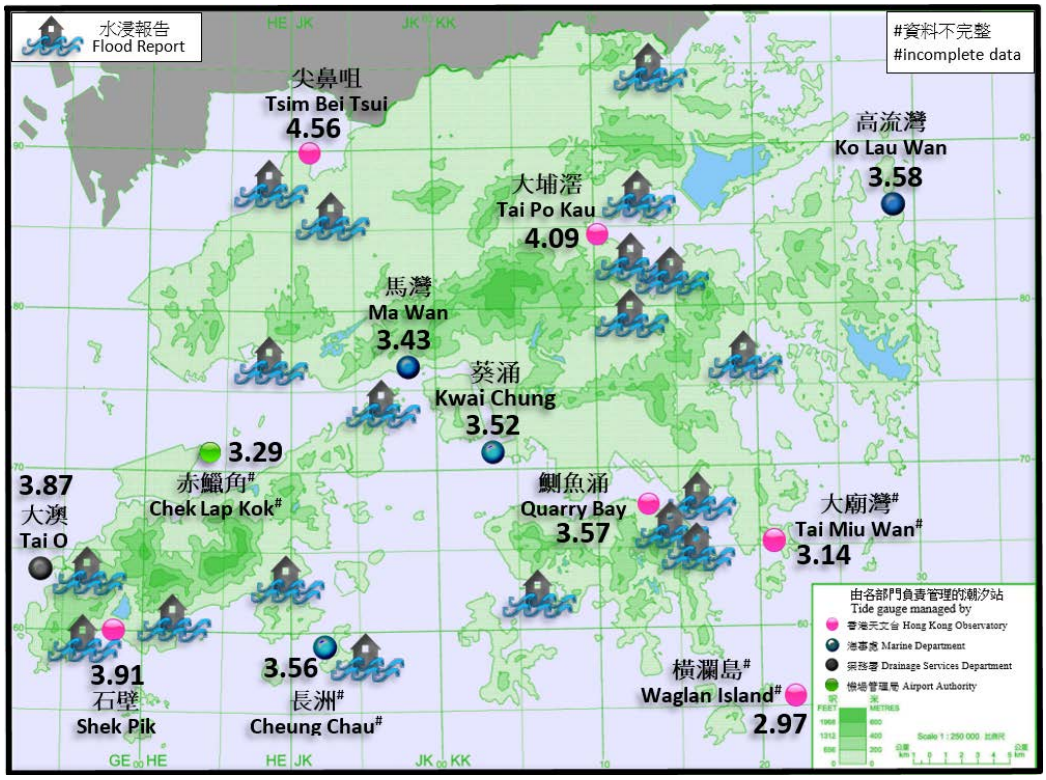

Figure 3 - The maximum sea level recorded at various tide stations in Hong Kong and flood reports from government departments, news and social media during the passage of Hato on 23 August 2017.

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

At least 10 people were injured in Hong Kong during the passage of Merbok. There were more than 600 reports of fallen trees, 20 reports of flooding and two reports of landslide. Traffic was seriously disrupted as many roads were flooded during the rainstorm on the morning of 13 June. A retaining wall collapsed under the heavy rain. About 300 hectares of farmland in the New Territories were affected. More than 500 flights were cancelled or delayed at the Hong Kong International Airport.

In Hong Kong, at least 129 people were injured during the passage of Hato. There were over 5,300 reports of fallen trees, many incidents of falling objects, one report of landslide as well as a number of flooding reports. Transportation services in Hong Kong were seriously affected by Hato. Many roads were closed due to strong winds, fallen trees or flooding. Resumption of ferry services was affected due to the damage of facilities at a number of ferry terminals. More than 480 flights were cancelled and nine flights were diverted at the Hong Kong International Airport.

At least 62 people were injured in Hong Kong during the passage of Pakhar. There were more than 450 reports of fallen trees, 16 reports of flooding and one report of landslide. More than

300 flights were cancelled or delayed, and 30 flights were diverted at the Hong Kong International Airport.

At least 22 people were injured in Hong Kong during the passage of Khanun. There were more than 80 reports of fallen tree. About 470 flights were cancelled or delayed at the Hong Kong International Airport. There was serious traffic congestion on the roads to the airport as a result of the closure of the connecting Tsing Ma Bridge under strong winds.

Roke in July, Mawar and the tropical depression in September did not cause significant damage in Hong Kong.

4. Regional Cooperation Assessment (highlighting regional cooperation success and challenges.

HKO continued to operate the Severe Weather Information Centre (SWIC) (http://severe.worldweather.wmo.int/) and the WMO Tropical Cyclone Forecaster Website (http://severe.worldweather.wmo.int/TCFW/) on behalf of WMO.

To enhance visibility of NMHSs as the authoritative source of warnings at global, regional and national levels, and to facilitate the effective delivery of warning information to decision makers and the public, a pilot project coordinated by HKO and CMA to Enhance the Capability of Meteorological Disaster Risk Reduction in RA II was approved at its 16th Session meeting in February 2017. A regional multi-hazard alert system was being set up to aggregate, display and disseminate official alerts delivered by RA II Members in CAP format. A website with discussion forum for restricted access by RA II Members would also be established to facilitate the sharing of advisory products and operational experience among forecasters.

II. Summary of Progress in Priorities supporting Key Result Areas

1. Tropical cyclone surveillance flights

Main text:

HKO, in collaboration with the Hong Kong Government Flying Service, continued to undertake dropsonde reconnaissance flights for TCs over the South China Sea in 2017. A total of seven missions were conducted up to October 2017 including that for Merbok (12 June), an area of low pressure (15 July) which subsequently developed into Talas, another area of low pressure (28 and 29 July) which later developed into Haitang, Mawar (1 and 2 September), Doksuri (14 September) and Khanun (14 and 15 October; see Figure 4).

In liaison with RSMC Tokyo, the dissemination of dropsonde observations through GTS on a near real-time basis has commenced starting from October 2017.

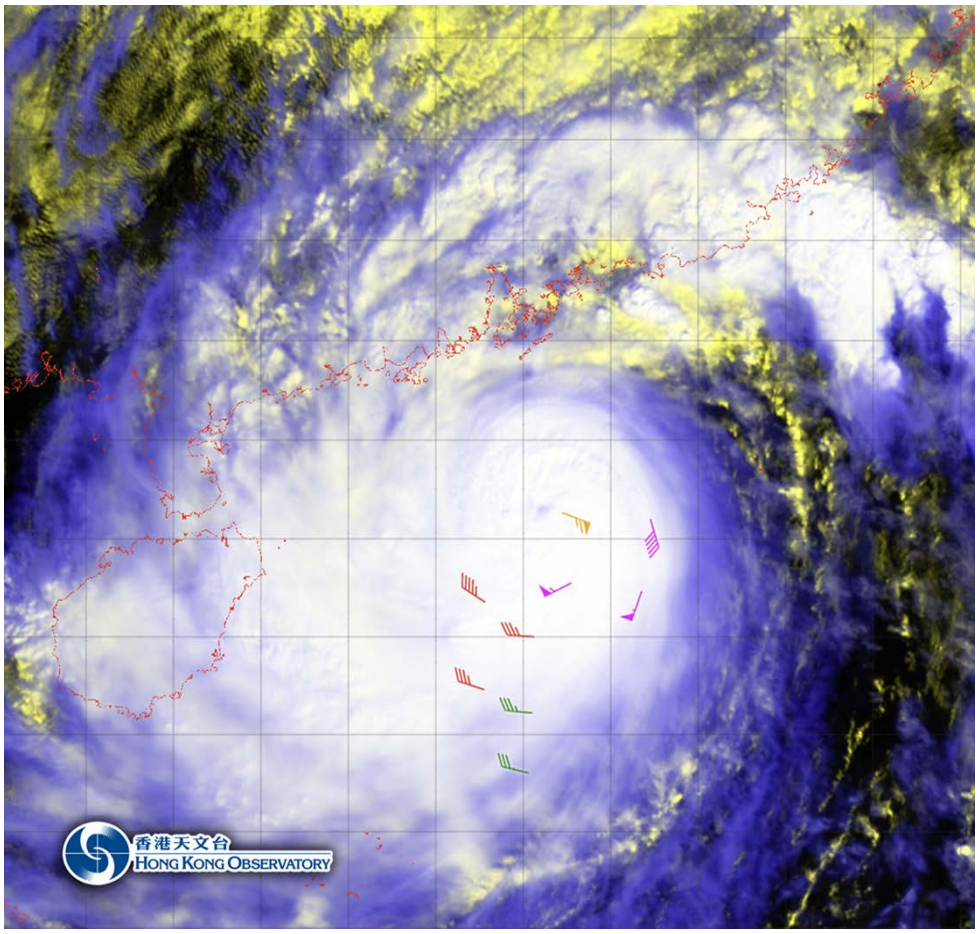

Figure 4 - Near-surface winds sampled within the circulation of Khanun during the dropsonde reconnaissance mission on 15 October. Note in particular the observation of east-southeasterly wind reaching hurricane force (orange wind barb) near the center of Khanun.

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

The assimilation of dropsonde observations into NWP models using advanced ensemble-based techniques, particularly after the commencement of operational exchange of dropsonde observations over GTS in October 2017.

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.

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2. Enhancement of meteorological observation over the South China Sea

Main text:

HKO continued its effort to enhance meteorological observation over the seas. With the support of one of the Hong Kong Voluntary Observing Ships, a drifting buoy equipped with a barometer and temperature sensor was deployed in the South China Sea on 27 July 2017. Hourly observations of sea level pressure and sea surface temperature were transmitted to HKO via Iridium for onward dissemination on GTS until the loss of communication on 20 August 2017, possibly due to vandalism (Figure 5).

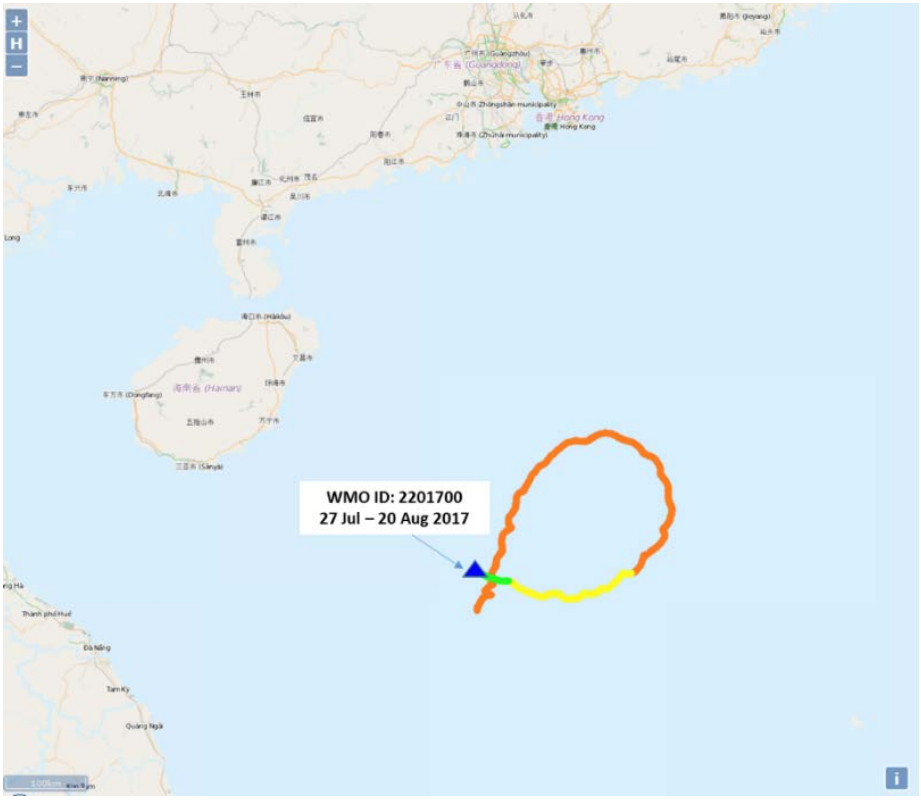

Figure 5 - Track of the drifting buoy since launch. ▲ denotes its last reported position on 20 August 2017 before loss of communication.

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

HKO will continue to support the Barometer Upgrade Scheme of the Global Drifter Programme (GDP), member of Data Buoy Cooperation Panel (DBCP) of JCOMM to deploy more drifting buoys in the South China Sea.

The drifting buoys currently deployed can only take pressure and sea surface temperature measurement. Pending the emergence of more sophisticated buoys in the market, more weather elements may be measured in the future.

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.

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3. Extended outlook on tropical cyclone track probability

Main text:

An experimental version of the "Tropical Cyclone Track Probability Forecast" product (Figure 6), i.e. an extended outlook on the probability of tropical cyclone tracks in the next nine days within HKO's area of responsibility (7-36°N, 100-140°E), was launched in August 2017 to provide authoritative assessment of the trends of tropical cyclone movement for early appraisal by members of the public and for countering the misleading speculation often circulating on the internet and social media these days.

The "Tropical Cyclone Track Probability Forecast" utilizes prognostic information extracted from several Ensemble Prediction Systems (EPS) of global NWP models. The probability information, coded in colour, represents the chance of the tropical cyclone coming within 120 kilometres of that location on the map in the coming nine days.

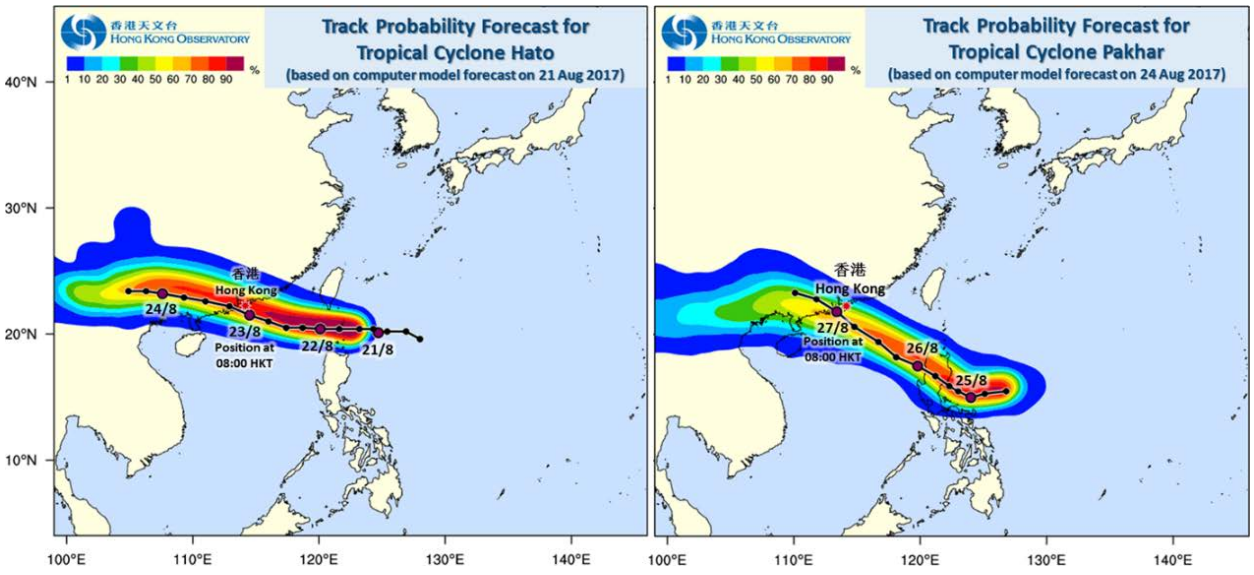

Figure 6 - Track probability forecasts for Hato (1713) on the left and Pakhar (1714) on the right (the actual 6-hourly positions and track of the tropical cyclones are plotted in black dots and line).

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

Development of extended outlook for other elements such as wind, pressure and rainfall will be pursued in phases with a view to strengthening the forecasting services on tropical cyclones and related high-impact weather.

Regional collaboration on the development of probabilistic forecasts for tropical cyclone and post-processing techniques of EPSs and NWP models will be explored.

Priority Areas Addressed:

Integrated
- Enhance activities to develop impact-based forecasts and risk-based warning.

Meteorology
- Develop and enhance typhoon analysis and forecast technique from short- to long-term.
- Enhance and provide typhoon forecast guidance based on NWP including ensembles and weather radar related products, such as QPE/QPF.

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4. Communication of information for strengthening resilience of communities against typhoon-related disasters

Main text:

As an annual exercise, HKO organized briefing seminars for relevant government departments and organizations in preparation for the tropical cyclone and rain season in 2017. HKO also participated in regular exercises and drills on disaster prevention and preparedness. In particular, briefing sessions on emergency response plans were organized for local residents in low-lying areas vulnerable to storm surge, including an inter-departmental rescue and evacuation drill at Tai O, a flood-prone fishing village over the southwestern part of Hong Kong, on 24 July 2017 (Figure 7). A public forum on "Tai O Flood Protection" was organized on 13 August 2017, in collaboration with relevant government departments under the "Science in the Public Service" campaign led by HKO, to enhance public understanding on the impacts of storm surge brought by tropical cyclones.

As it turned out, local storm surge alerts were activated in late August for Hato and Pakhar, and appropriate precautions and responses were effectively undertaken by relevant government departments to mitigate the storm surge impacts and avoid casualties, particularly in the face of extreme sea levels generated during the passage of Hato on 23 August 2017 (Figure 8).

Figure 7 - Inter-departmental rescue and evacuation drill at Tai O on 24 July 2017 (photo courtesy of the Information Services Department, Hong Kong Speical Administrative Region Government).

Figure 8 - Response plans put into effective action at Tai O during the passage of Hato on 23 August 2017 (photo courtesy of Civil Aid Service).

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

HKO will continue to collaborate with communication and social science experts to enhance the effectiveness in communication with the media and the public on the impacts of tropical cyclones and the necessary precautionary measures, taking into account forecast uncertainties in extreme or high-impact weather situations.

More community engagement opportunities will be explored to enhance public preparedness and response in tropical cyclone situations.

Priority Areas Addressed:

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

DRR
- 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. System and product development to support tropical cyclone operation

Main text:

To assist forecasters in assessing the likelihood of anomalous or extreme weather, including those caused by tropical cyclones, new sets of products based on EPS of global NWP models are generated for operational use in HKO. These include maps, summary tables and time series plots of ECMWF Extreme Forecast Index (EFI), Shift of Tails (SOT) and threshold exceedance probabilities for wind, gust and precipitation (Figure 9).

"Integrated Meteorological Information Display" (MET-GIS), a GIS-powered data analysis and visualization system developed in-house at HKO, was enhanced with additional buoy and coastal station data from neighbouring weather services, particularly useful for tracking the movement and development of tropical cyclones. It also displays impact-related events from tropical cyclones, including the locations of reported flooding and fallen trees, among others (Figure 10).

A new version of SLOSH, the underpinning model of HKO "Operational Storm Surge Prediction System", was acquired from NOAA with the capability to apply tidal constituents extracted from an external global tide model for computing the storm tide in addition to storm surge at every grid point. The new feature was under evaluation using the tropical cyclone cases in 2017.

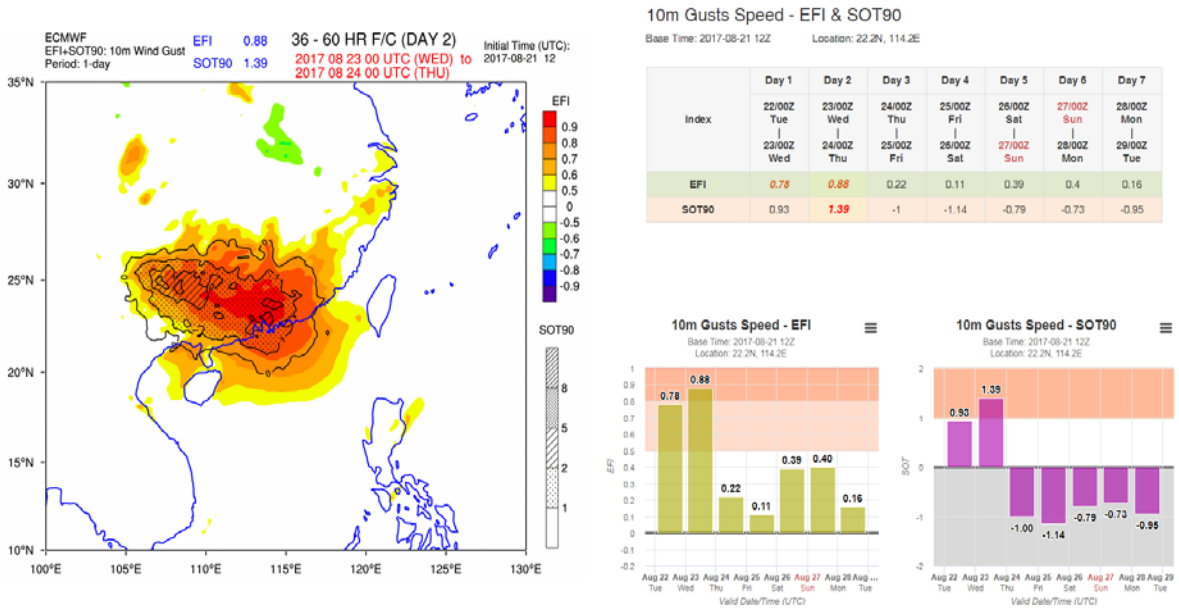

Figure 9 - Maps and time series charts showing ECMWF Extreme Forecast Index (EFI) and Shift of Tails (SOT) for 90th-percentile for wind gust for the period from 00 UTC 23 August to 00 UTC 24 August 2017, based on the model run of 12 UTC 21 August during the approach of Hato. The EFI was higher than +0.8 in the vicinity of Hong Kong, indicating the possibility of anomalously high wind gust in the region.

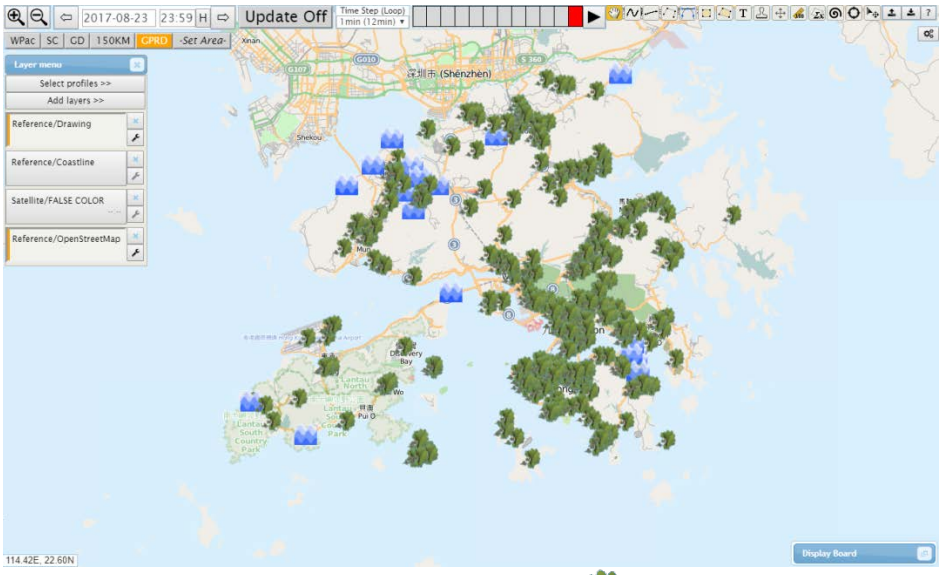

Figure 10 - MET-GIS display of reported fallen trees ( ) and flooding ( ) in Hong Kong during the passage of Hato on 23 August 2017.

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

Development of storm surge risk maps and/or inundation maps will be explored using the new SLOSH feature together with local terrain information.

Priority Areas Addressed:

Meteorology
- Enhance and provide typhoon forecast guidance based on NWP including ensembles and weather radar related products, such as QPE/QPF.

Hydrology
- Enhance capacity in impact-based and community-based operational flood forecasting and early warning, including methodology research, hydrological modelling, and operation system development.
- Enhance capacity in flood risk (hazard, inundation) information, mapping and its application.

DRR
- Provide reliable statistics of mortality and direct disaster economic loss caused by typhoon-related disasters for monitoring the targets of the Typhoon Committee.

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6. Community version of "Short-range Warning of Intense Rainstorms in Localized Systems" (SWIRLS)

Main text:

To support capacity building in tropical cyclone rainfall nowcast and related high-impact weather assessment, HKO nowcasting system "SWIRLS" was made available to NMHSs through a user-registered website (http://swirls.hko.gov.hk/). Through the Typhoon Committee Research Fellowship scheme and WMO workshops over the past few years, a community version of SWIRLS (a.k.a. Com-SWIRLS) was supporting the operation or development of rainfall nowcasting in Malaysia, China (Zhuhai) and South Africa. Collaboration with the Philippines, Myanmar and India on the adaptation of Com-SWIRLS was in progress.

A new algorithm, useful for tropical cyclone rainfall nowcast, for the retrieval of equivalent radar reflectivity using Himawari-8 data based on artificial neural network to generate QPE/QPF products was developed and put into operational use (Figures 11 and 12).

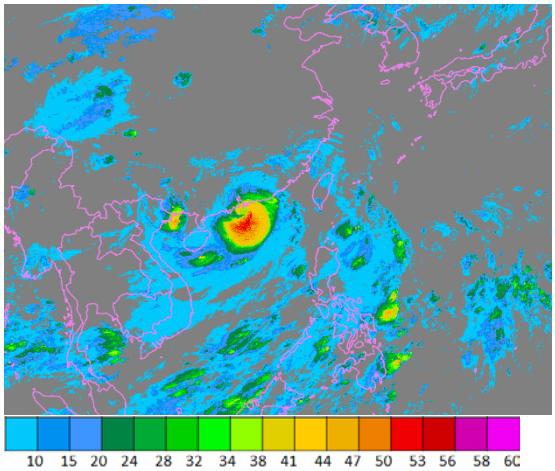

Figure 11 - Retrieved equivalent radar reflectivity in dBZ based on Himawari-8 at 00 UTC 23 August 2017 during the passage of Hato.

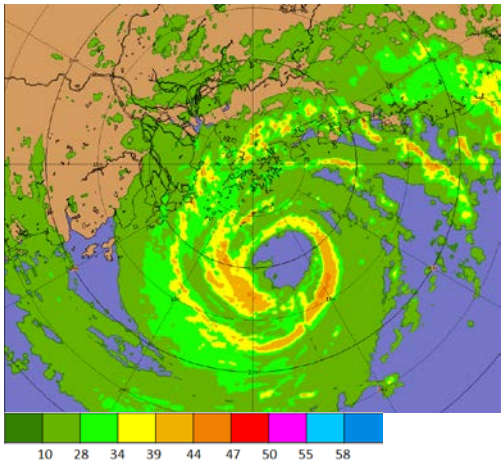

Figure 12 - 1-hour forecast radar reflectivity in dBZ based on multi-sensor data at 00 UTC 23 August 2017 during the passage of Hato.

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

A new version of Com-SWIRLS in the form of a virtual appliance will be developed to support research activities and to facilitate sharing of SWIRLS applications more effectively. The new Com-SWIRLS software system, installation-free and cloud-ready, incorporates standard programming interface and user-friendly web-based interface in manual / demonstration mode.

Training on Com-SWIRLS will be arranged to promote capacity building and regional co-operation.

Priority Areas Addressed:

Meteorology
- Enhance and provide typhoon forecast guidance based on NWP including ensembles and weather radar related products, such as QPE/QPF.
- Enhance, in cooperation with TRCG, training activities in accordance with Typhoon Committee forecast competency, knowledge sharing, and exchange of latest development and new techniques.

Hydrology
- Enhance capacity in advanced technology (including satellite data, GIS, RS, QPE/QPF, ensemble, parallel computing) utilization in typhoon-related flood forecasting and early warning, and hydrological modeling.

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7. Mesoscale and high-resolution regional prediction systems for tropical cyclones

Main text:

HKO operates a mesoscale numerical prediction suite, the Atmospheric Integrated Rapid-cycle (AIR) forecast system based on the Non-hydrostatic Model, providing forecasts over East Asia and the western North Pacific at 10-km resolution up to 72 hours ahead (Meso-NHM), as well as over southern China and the northern part of the South China Sea at 2-km resolution up to 15 hours ahead (RAPIDS-NHM). HKO also operates a fine-scale Aviation Model (AVM) continues to provide hourly-updated aviation-specific forecasts for the Hong Kong International Airport at horizontal resolution down to 200 m.

In 2017, effort was undertaken to study the impact of assimilating satellite data into Meso-NHM with a view to improving tropical cyclone forecasts (Figure 13). Additionally, the 200-m resolution inner domain of the AVM was expanded to provide full coverage of the Hong Kong territory, paving the way to location-specific wind nowcast down to the urban level.

Meanwhile, near real-time trial of an in-house mesoscale EPS continued for aiding probabilistic assessment of tropical cyclone evolution (Figure 14), with performance shown to be comparable to major global models over the South China Sea basin.

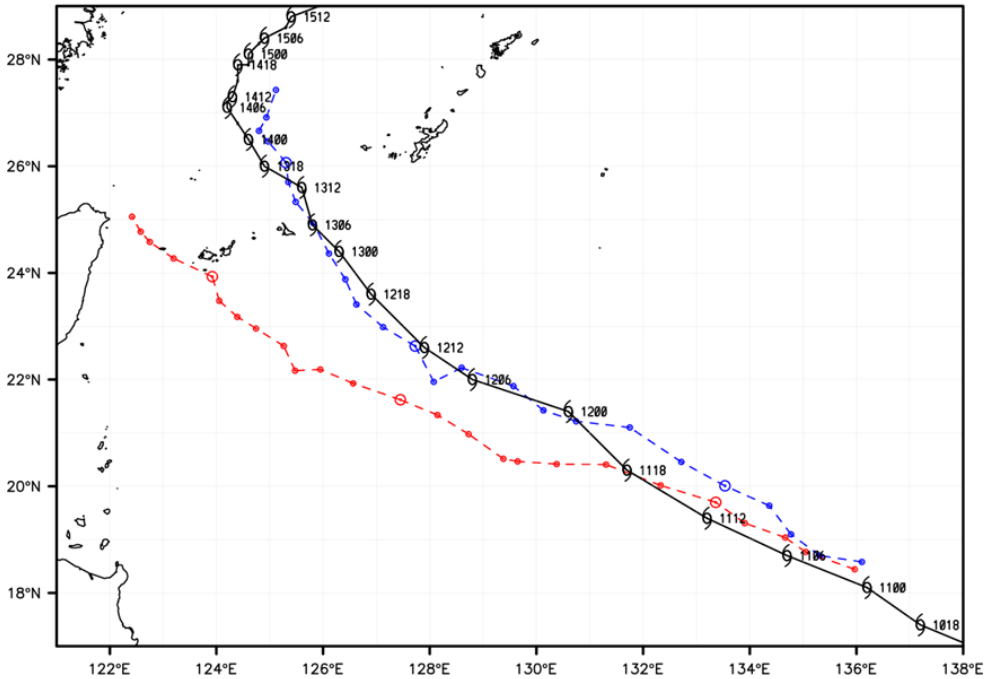

Figure 13 - Forecast track for Talim by Meso-NHM before (red) and after (blue) incorporation of clear sky radiance assimilation, with the actual track in black.

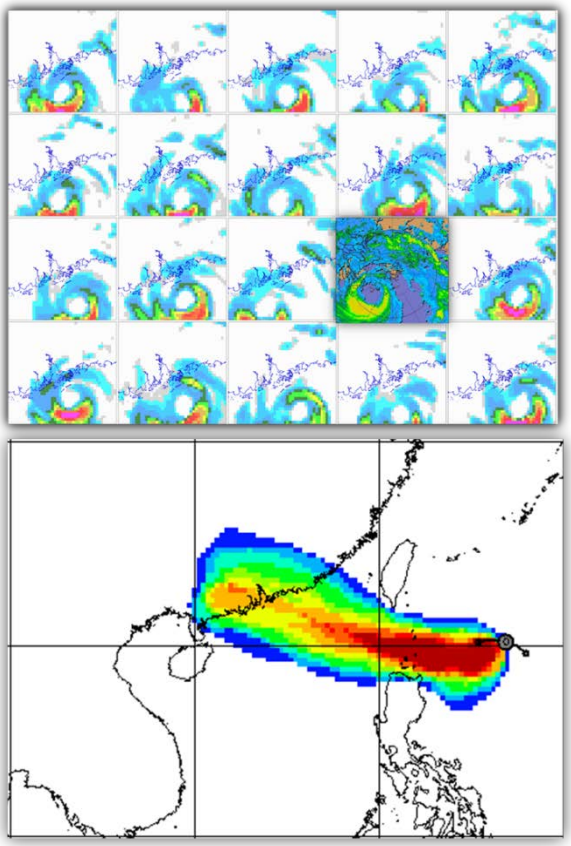

Figure 14 - Mesoscale EPS stamp maps of forecast hourly rainfall (top) against verifying radar observation of Hato (inset); and EPS-derived strike probability map for Hato (bottom) about 72 hours before landfall.

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

Regional exchange of mesoscale model output will continue with a view to fostering closer collaboration.

Priority Areas Addressed:

Meteorology
- Develop and enhance typhoon analysis and forecast technique from short- to long-term.
- Enhance and provide typhoon forecast guidance based on NWP including ensembles and weather radar related products, such as QPE/QPF.

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8. Commemoration of the 100th anniversary of numbered tropical cyclone signal system in Hong Kong

Main text:

2017 marks the 100th anniversary of the introduction of numbered tropical cyclone warning signals in Hong Kong. To commemorate the occasion, HKO arranged a series of activities that would help foster public understanding of tropical cyclone-related hazards and enhance disaster prevention awareness. To promote public understanding of the history of the tropical cyclone warning system, a special media event was arranged on 7 June 2017 at the Cheung Chau Meteorological Station, the last tropical cyclone signal station decommissioned in Hong Kong, where the refurbished signals were on full display and a history room was set up to re-tell the stories of damaging typhoons in the past (Figure 15).

Apart from producing a special series of public education videos on tropical cyclones, HKO in collaboration with the Radio Television Hong Kong also launched a campaign to crowdsource historical materials from the public including articles, photos, audio recordings and videos, especially those showing damages caused by tropical cyclones in Hong Kong. In partnership with the Hongkong Post, special commemorative stamps on the numbered tropical cyclone signal system were also issued (Figure 16).

Figure 15 - Mr. SHUN Chi-ming Director of the Hong Kong Observatory (fourth from right), pictured with officiating guests at the Cheung Chau Meteorological Station during the media event on 7 June 2017. Behind them were the signal mast and the tropical cyclone warning signals on display at the station.

Figure 16 - Special commemorative stamps on the numbered tropical cyclone signal system in Hong Kong issued on 13 June 2017.

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

Nil

Priority Areas Addressed:

DRR
- Share experience/know-how of DRR activities including legal and policy framework, community-based DRR activities, methodology to collect disaster-related information.
- Evaluate socio-economic benefits of disaster risk reduction for typhoon-related disasters.

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9. Typhoon Committee Research Fellowship

Main text:

Considerable effort has been focused on tropical cyclone track and intensity research, but relatively few on tropical cyclone size. HKO hosted a 2-month Typhoon Committee Research Fellowship study on "Tropical Cyclone Size Climatology" from December 2016 to January 2017. Mr HONG Wei from the Fujian Meteorological Observatory of the China Meteorological Administration undertook the research project (Figure 17) and compared the tropical cyclone size parameters documented in the best track datasets with those determined using QuikSCAT. The spatial, monthly and long-term variations of tropical cyclone size over the western North Pacific and the South China Sea were also studied.

Figure 17 - Mr. HONG Wei (centred) with HKO colleagues during his fellowship attachment in Hong Kong, China.

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

The period of QuikSCAT data was rather limited, while the coverage of ASCAT data was not good enough for the estimation of tropical cyclone size. Strategies and opportunities for further research development on the topic need to be identified.

Priority Areas Addressed:

<u>Meteorology</u>
- 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.
- Enhance, in cooperation with TRCG, training activities in accordance with Typhoon Committee forecast competency, knowledge sharing, and exchange of latest development and new techniques.

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