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HONG KONG OBSERVATORY

HKO'S RECENT DEVELOPMENTS IN SUPPORT OF TROPICAL CYCLONE WARNING SERVICES

Hong Kong, China

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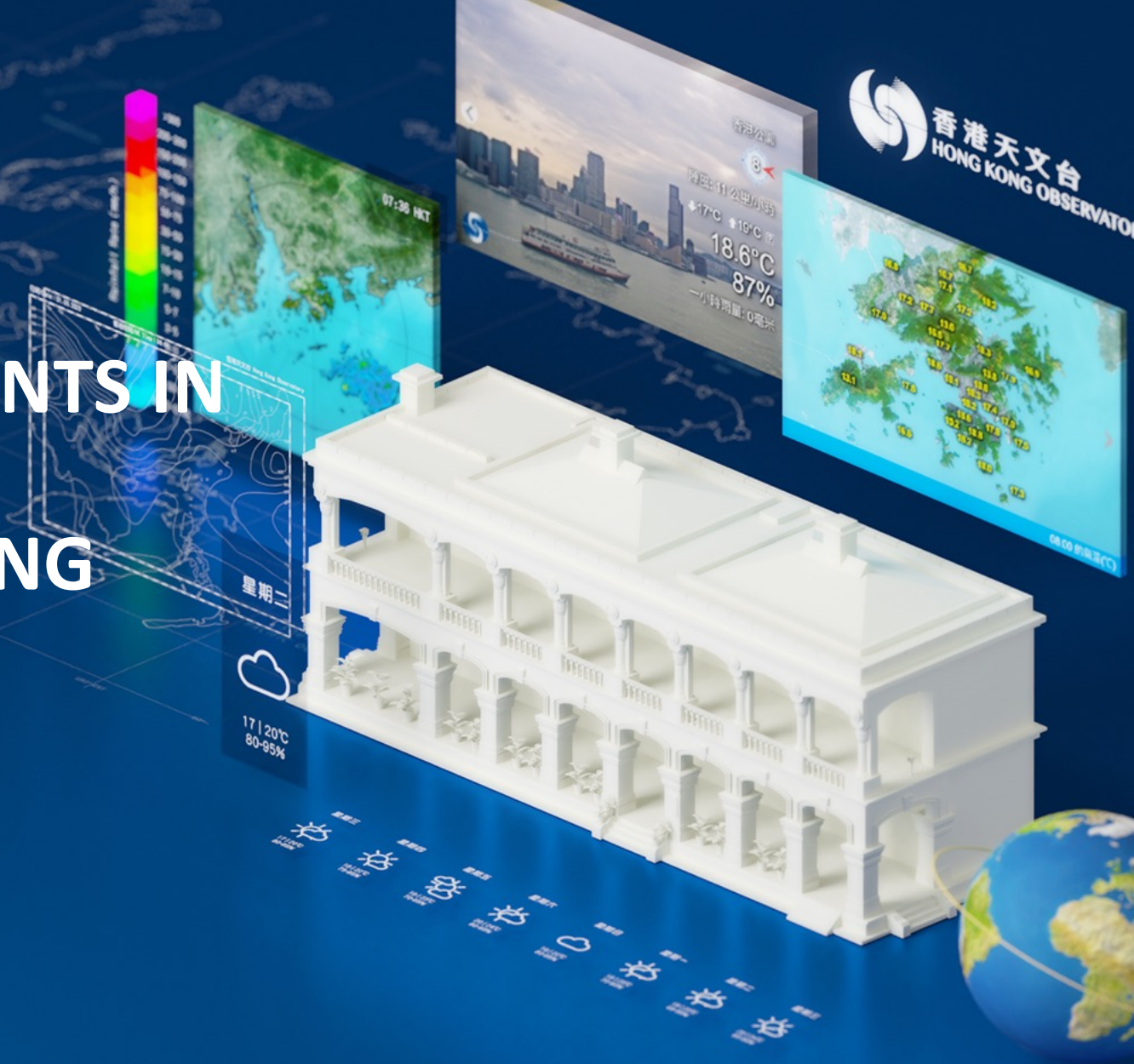

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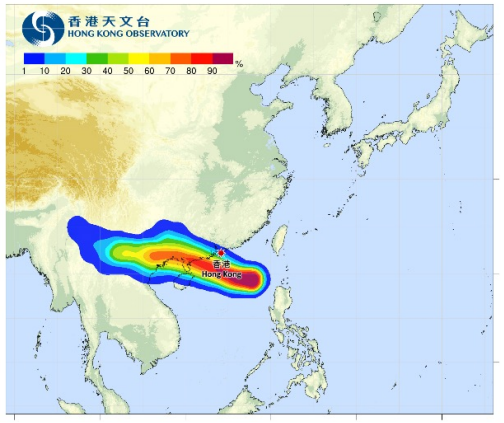
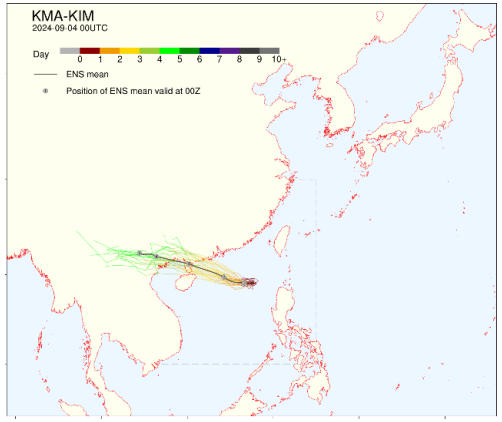
1. Tropical cyclone strike probability maps based on NWP ensemble predictions

- Tropical Cyclone Track Probability Forecast service on HKO website and MyObservatory mobile app provides the probability that a tropical cyclone (TC) will pass over a given location in the next 9 days based on EPS data products from ECMWF, NCEP, JMA and UKMO. The TC strike probability map (SPM) has been widely utilized by media and various communities, as it is an effective representation about likelihood of different scenarios and depicting uncertainty of TC movement.

- In 2024, EPS data from the Korean Integrated Model (KIM) of KMA has been employed to generate SPM for reference by forecasters



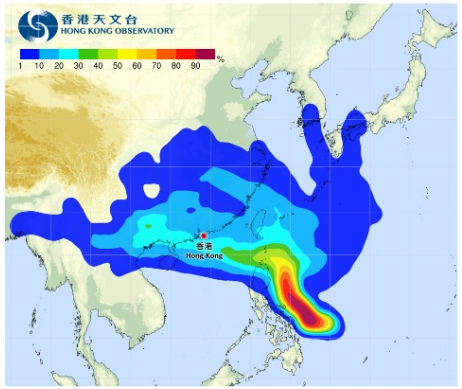


- With rapid development of AI weather model, the probabilistic forecast products based on AI weather model ensemble are under active development to enhance supports for TC track forecast and warning operations at HKO.

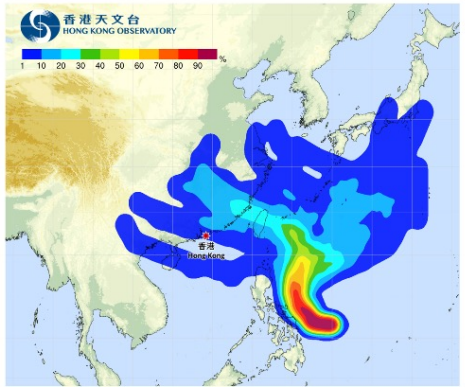
- To enhance the assessment of potential TC genesis and subsequent movements, tropical cyclogenesis tracks from NCEP EPS have been utilized to generate SPM during early stage of TC genesis.

- Combining similar data product from ECMWF EPS for identified low pressure system, forecasters can extract relevant potential TC tracks that pass through a selected area of interest within a given forecast time level for generating the SPMs

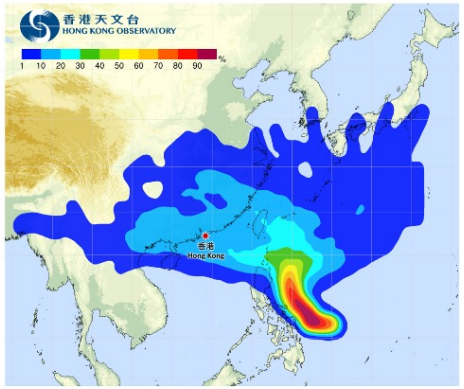
ECMWF



NCEP



ECMWF + NCEP



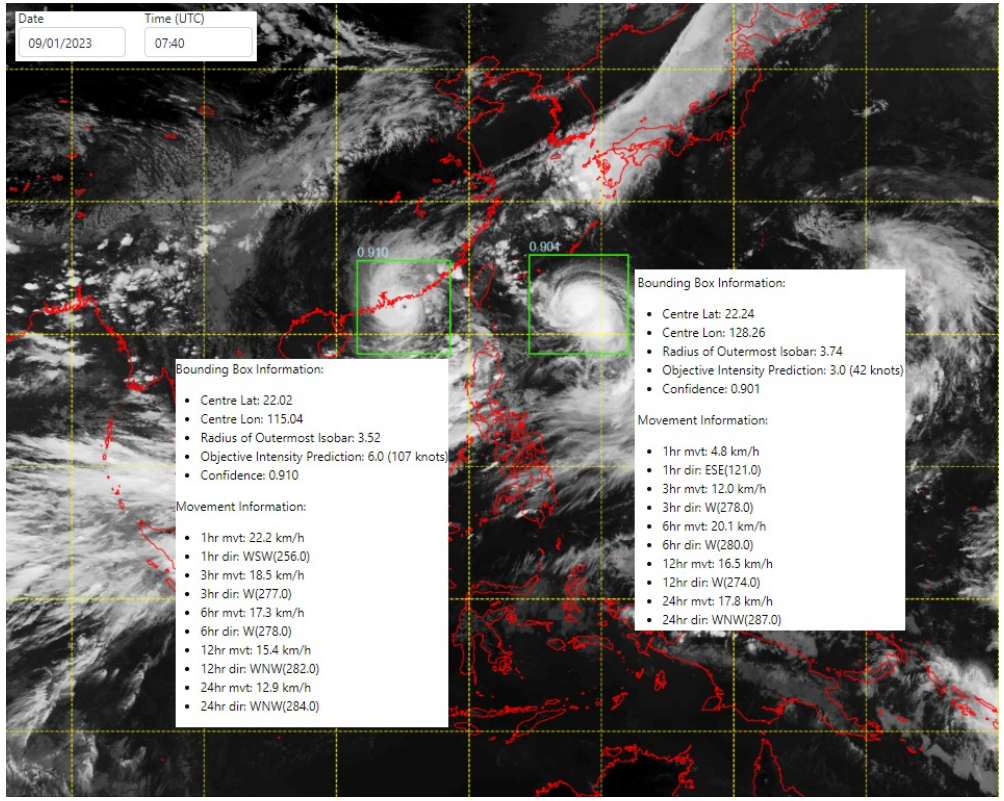
2. Development and Verification of AI-STORMVIS

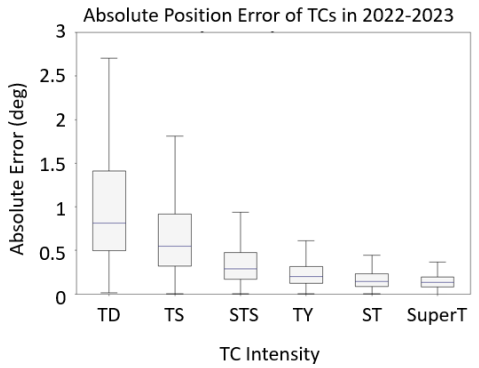
- AI-STORMVIS (AI-driven Satellite-based Tropical Cyclone Object Recognition, Motion Visualization, and Intensity Estimation System) has been in operational trial since 2023 for providing automatic tropical cyclone (TC) position analysis and intensity estimation. It continuously monitors TC activities over the Western North Pacific (WNP) basin and the South China Sea (SCS) region based on Himawari-9 imagery updated in every 10 minutes

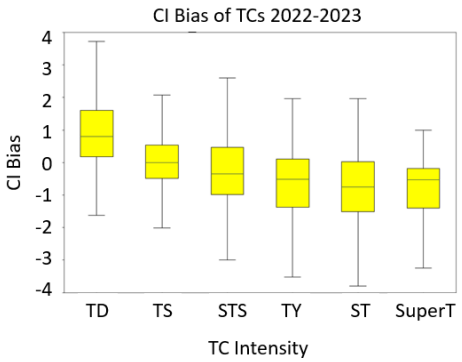
- Recent enhancements in AI-STORMVIS including:
  - re-training of the model with a view to improving the overall accuracy in TC position fix and intensity estimation.
  - TC tracks over the Indian Ocean have been utilized to enhance automatic detection when TC is within the western domain.
  - The visualization web portal provides TC's movement speed and direction over the past 1, 3, 6, 12, and 24 hours on top of the current position and intensity estimates.

- AI-STORMVIS successfully located all TC positions and provided an accurate estimate of intensity for all TC cases in 2022-2023:
  - TCs with intensities of tropical storm or above showed a mean absolute track error of less than 0.5° and a small bias in CI.

- Enhancements of machine learning algorithm in AI-STORMVIS are underway to reduce jumpiness in the results of intensity estimation







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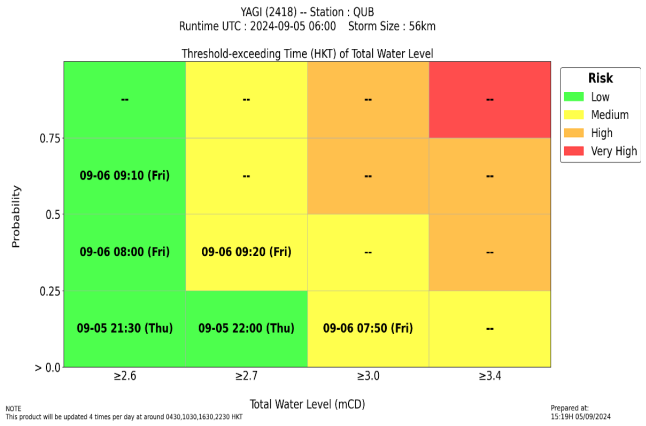
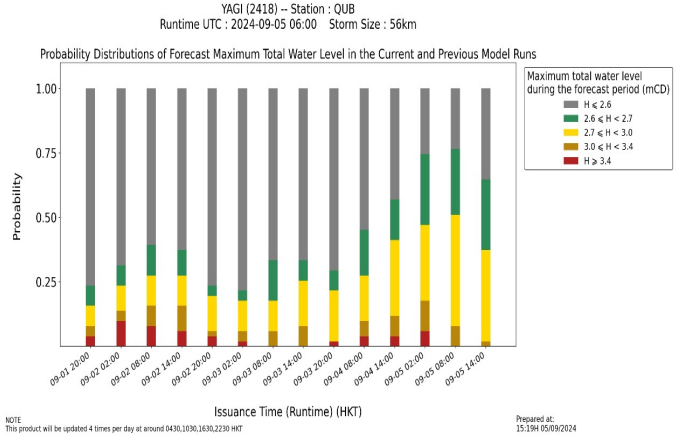
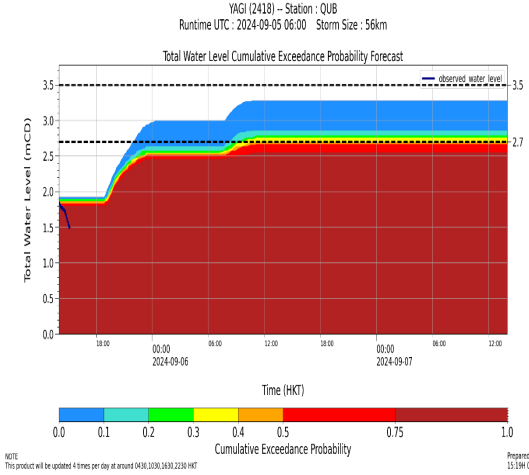
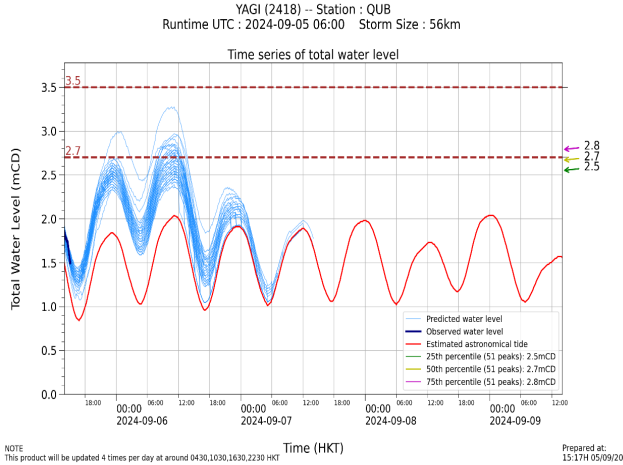
3. STORM SURGE FORECAST PRODUCTS

- HKO has been providing storm surge forecast and alert service to relevant government departments in Hong Kong in support of their decision making on emergency preparedness and response against the threat of coastal flooding.
- New probabilistic storm surge forecast products were added together with an increase in the number of forecast sites from 4 to 10 in 2024.
- The storm surge probabilistic forecast products generated based on SLOSH model with input from ECMWF model ensemble TC track forecast and post-processed intensity forecast as well as selected storm size.









risk matrix showing the probability of exceeding certain water level for coastal flood risk assessment

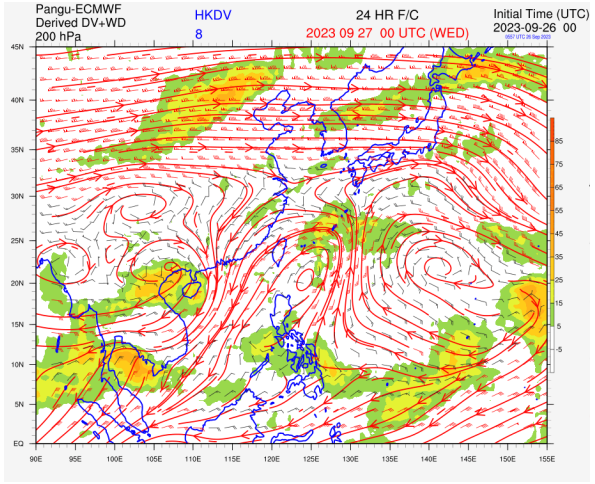
probability distribution of forecast maximum water level in the current and previous model runs to facilitate comparison of model forecast changes

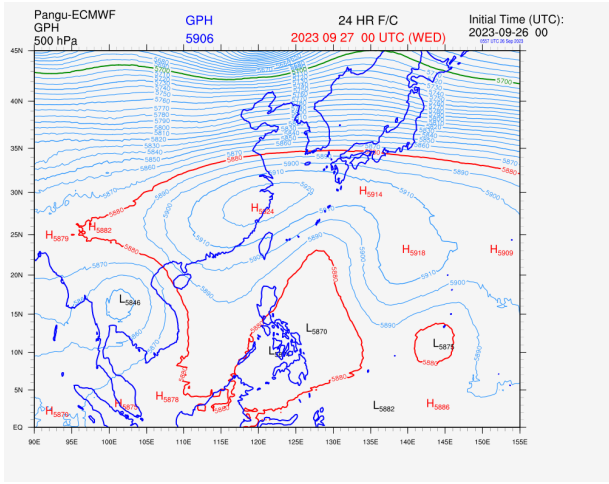
water level cumulative exceedance probability plot to help users grasp potential worst-case scenarios , and the corresponding probability

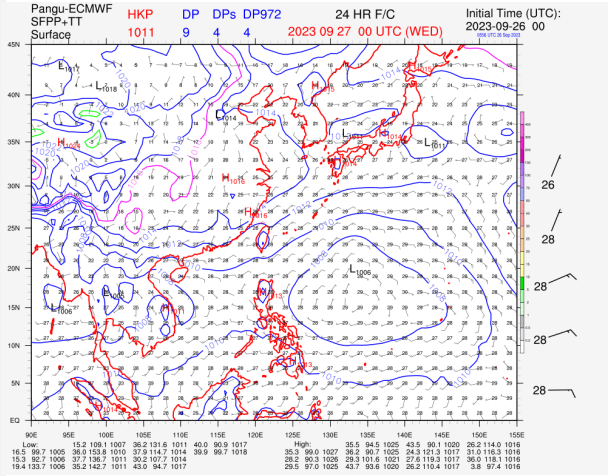
a spaghetti diagram of water level time series forecasts showing the water level prediction from different members of ensemble TC forecast

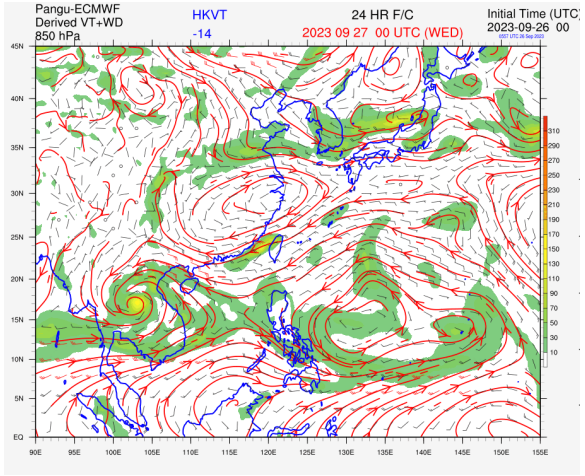
4. HKO has been running some AI models in real time since mid-2023 as an internal trial for operational forecasting.

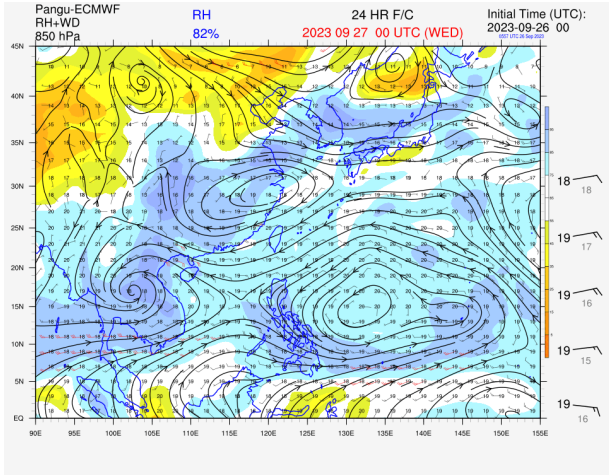
- FengWu
- FuXi
- Graphcast
- Pangu-Weather
- Initialized by the operational analysis of ECMWF IFS



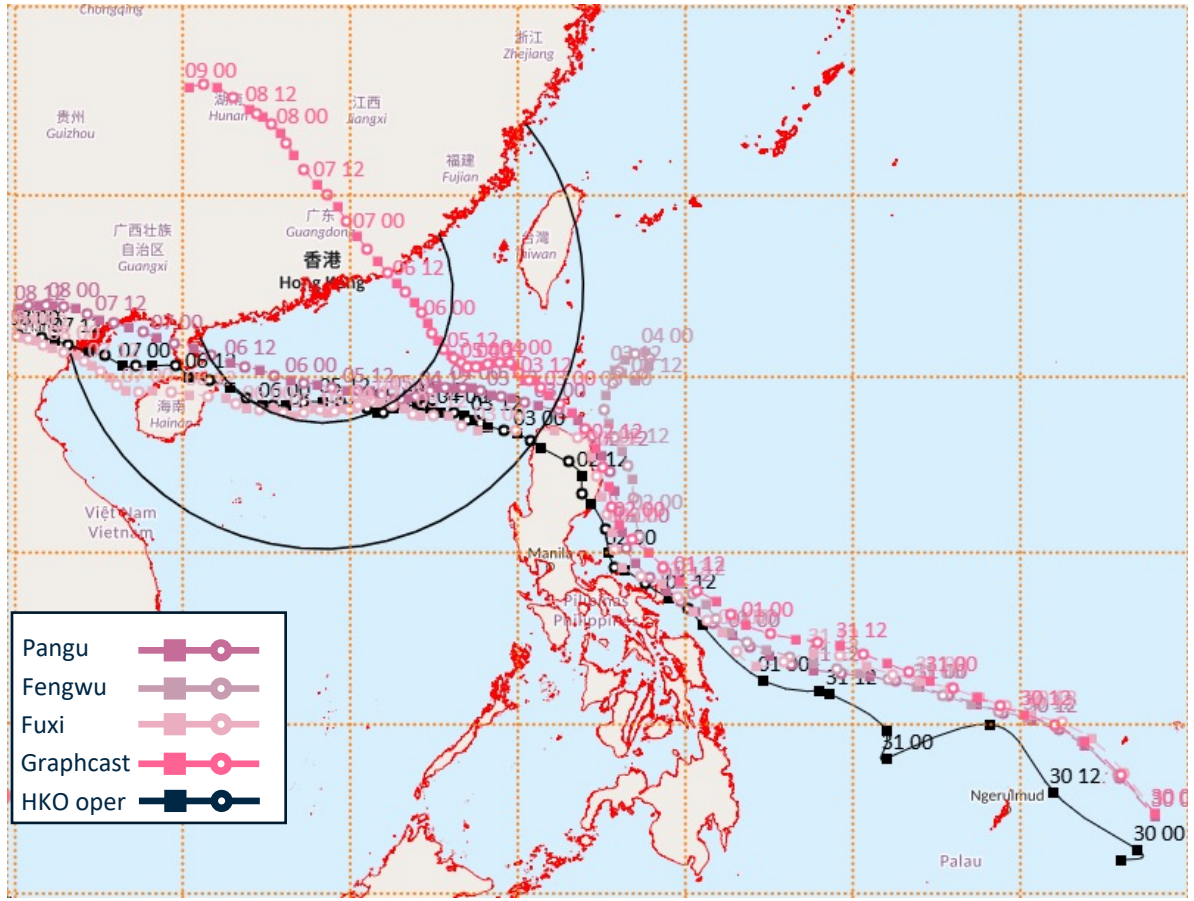


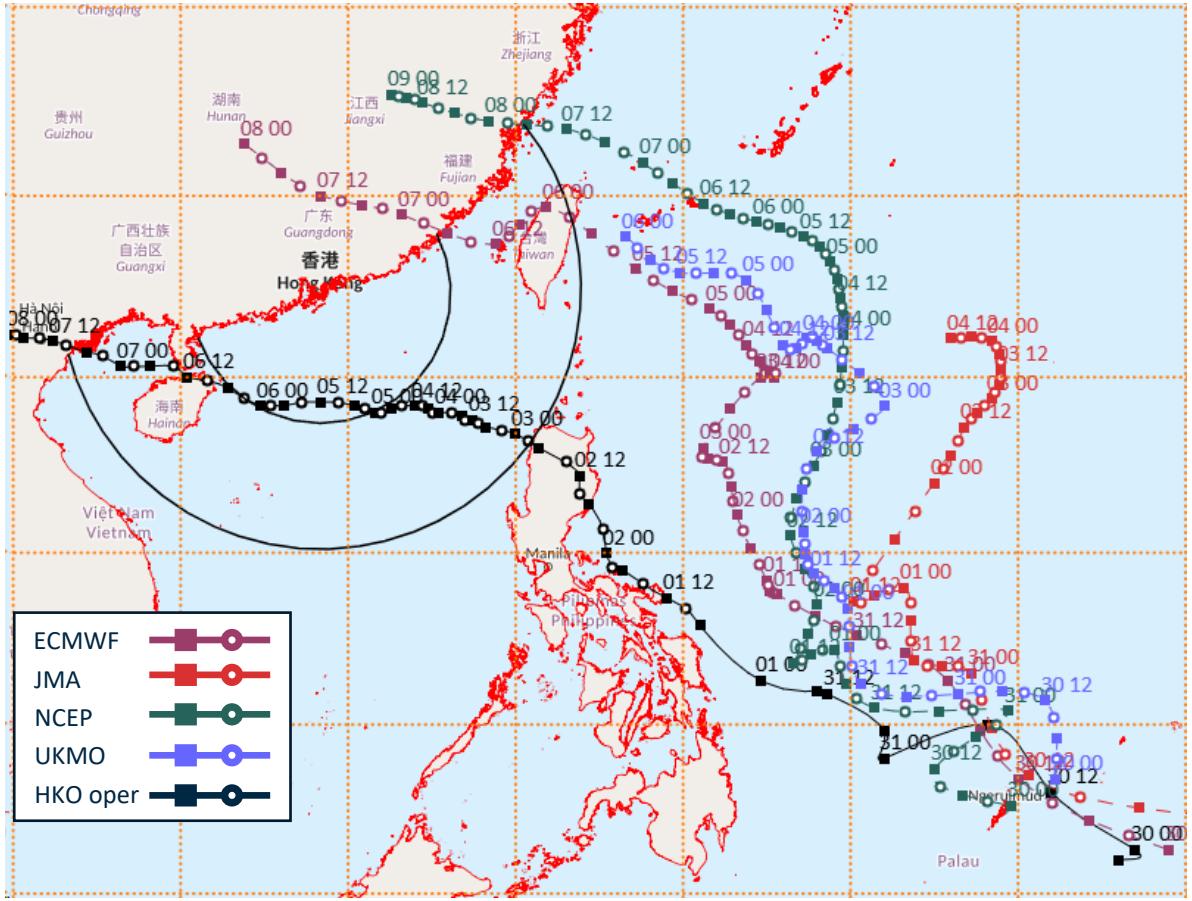






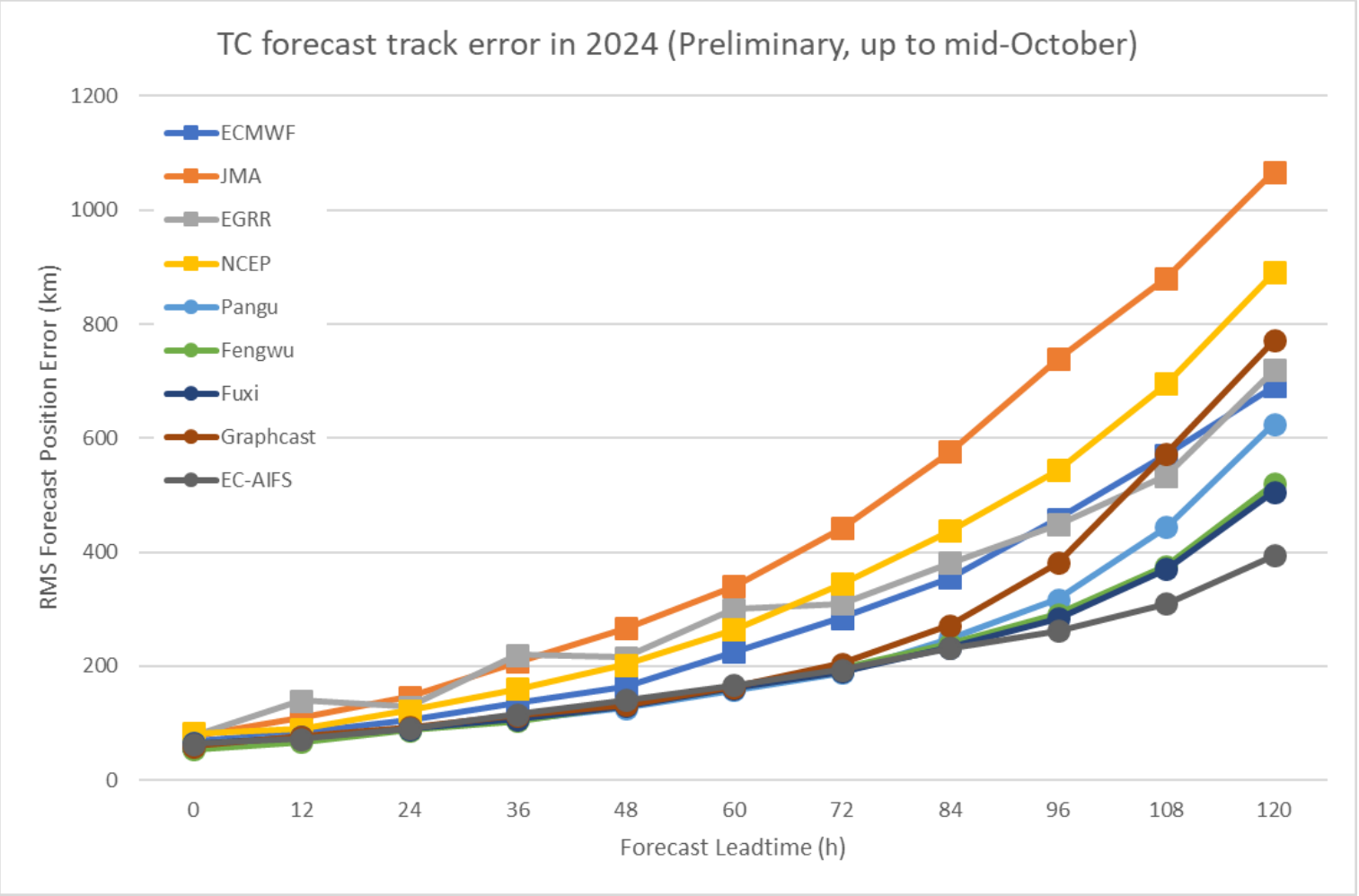
TC TRACK FORECAST





Forecast for Super Typhoon Yagi, initialized at 00Z 30 August 2024.

TC TRACK FORECAST



The AI models generally outperformed traditional NWP up to 5 days ahead.

HKO is also exploring the use of an ensemble approach among the various different AI models.

* Forecasts are verified against analysis positions based on HKO operational warning track and homogenized to have a common data set among models.

TC INTENSITY FORECAST

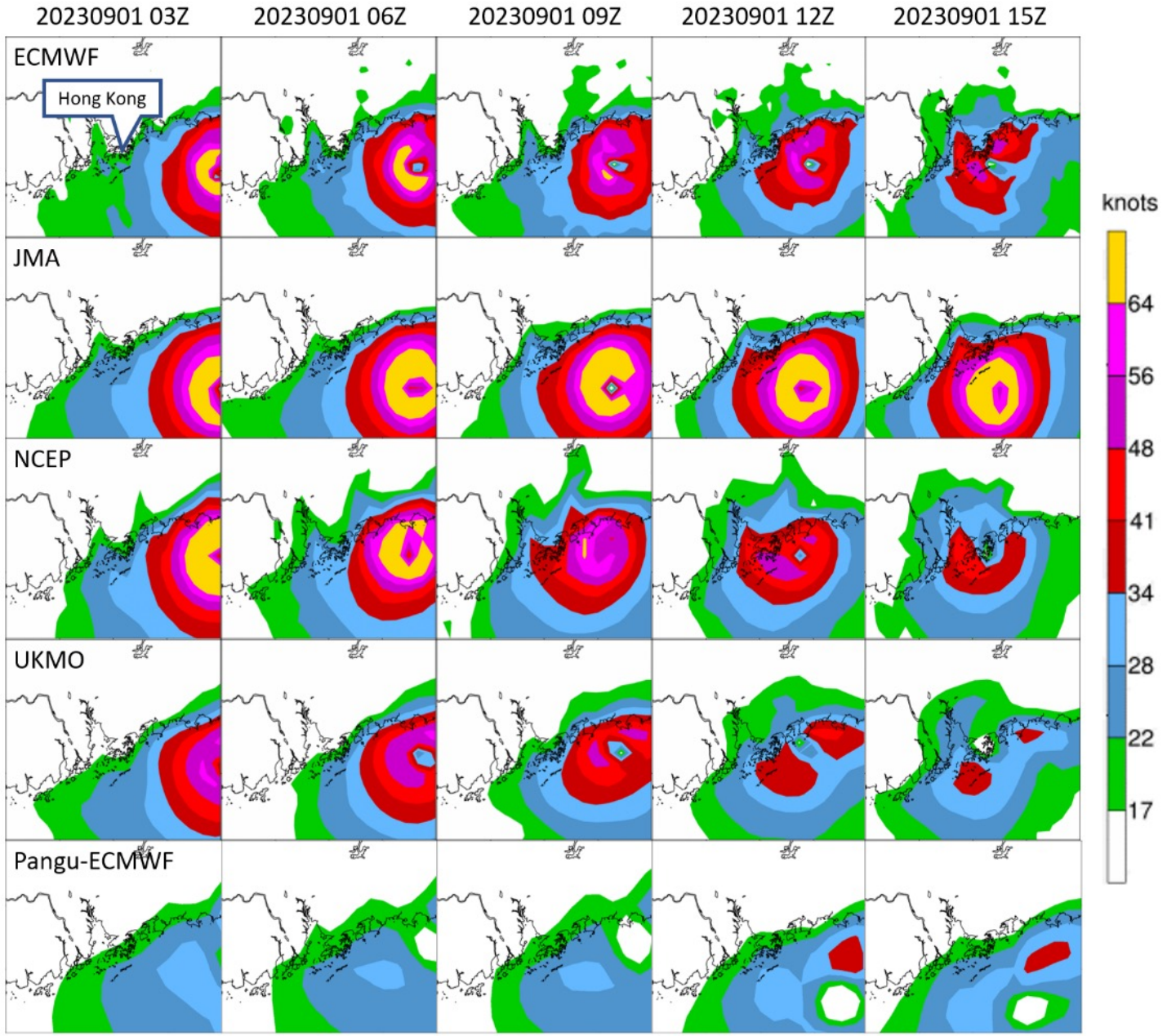
Super Typhoon Saola (Sep 2023)

Models' short-term 10-m wind forecasts, before Saola approached Hong Kong. Winds of hurricane force were colored yellow.

Hurricane force winds were recorded at many places at Hong Kong.

The AI model Pangu-Weather could not properly forecast Saola's wind structure. Pangu-Weather gave significantly weaker winds.

AI models tended to underestimate TC intensity.



Chan, P.W., He, Y.H. and Lui, Y.S. (2024), Forecasting Super Typhoon Saola and its effects on Hong Kong. Weather. https://doi.org/10.1002/wea.4569

EMERGING POTENTIALS AND NEEDS

- AI models in the past one to two years have demonstrated enormous potential for operational weather forecasting, and showed undeniable skill on TC track forecasting.
- AI models is very promising to further enhance our capacity on TC forecasting and warning.

- TC intensity forecast remains a challenge for the AI models.
- Most AI models are not outputting all essential variables (e.g. lack of precipitation), and only available at relatively coarse spatial/temporal resolutions.
- Some models tend to output overly smoothed forecasts in the longer lead times.
- AI models have been evolving very rapidly, with new models (upgrades) coming out from various development teams (by big tech or academia).
- How could we operationally use AI models for TC forecasting?

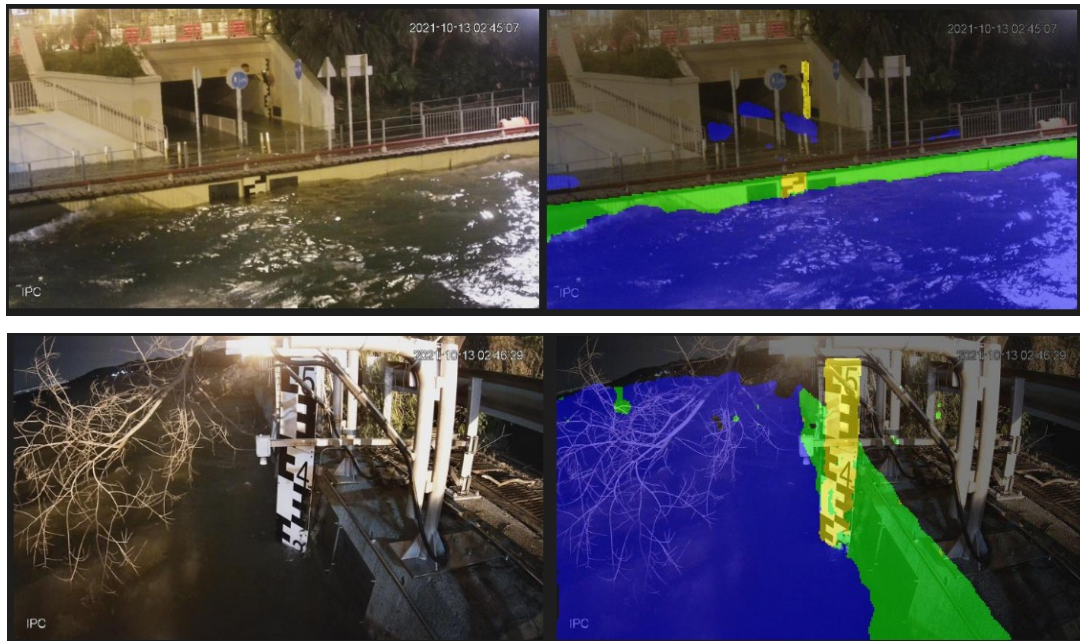
5. AI-BASED FLOODING ANALYTICS

DETECT POTENTIAL FLOODING BASED ON CAMERA IMAGES

- The tool was developed to monitor the impacts associated with storm surge at low lying coastal areas in Hong Kong, in addition to the water level monitoring measurements.

- The real-time analysis results were incorporated to an HKO in-house alarm system to alert forecasters of the possible occurrence of flooding at these locations. Quality checking steps were adopted to improve reliability and avoid flip-flopping signals.

- The tool was enhanced with newly trained models with enhanced performance and extended to detect potential flooding at more low lying coastal areas in Hong Kong.



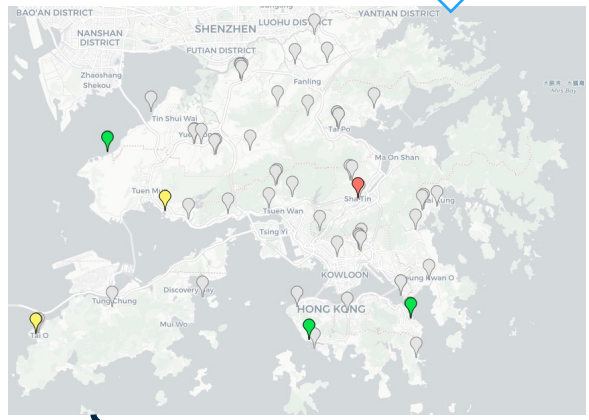
Camera images over low lying coastal areas

AI analysis

Water level mark

Sea wall

Water



Alert signals on maps and via audio

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