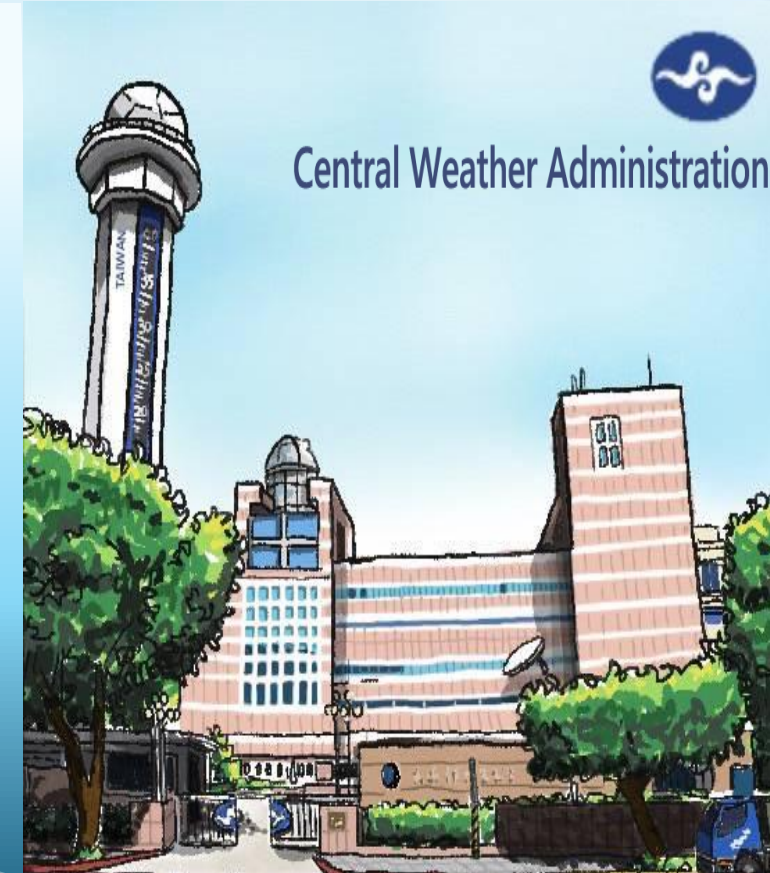


# Integration of Typhoon Track Forecasts Based on Machine Learning Weather Prediction (MLWP) Models into the Ensemble-based Precipitation Forecast Model for Super Typhoon Gaemi (202403)

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## I. Introduction

### Motivation

- Various MLWP models trained on ERA5 are continuously being proposed, and some of these MLWP models (e.g., GraphCast, AIFS) have shown better forecast performance (e.g., Typhoon track forecast) within a ten-day period than traditional numerical weather prediction (NWP) models.
- Many limitations and challenges have been identified and must be addressed and improved (Bonavita, 2024).

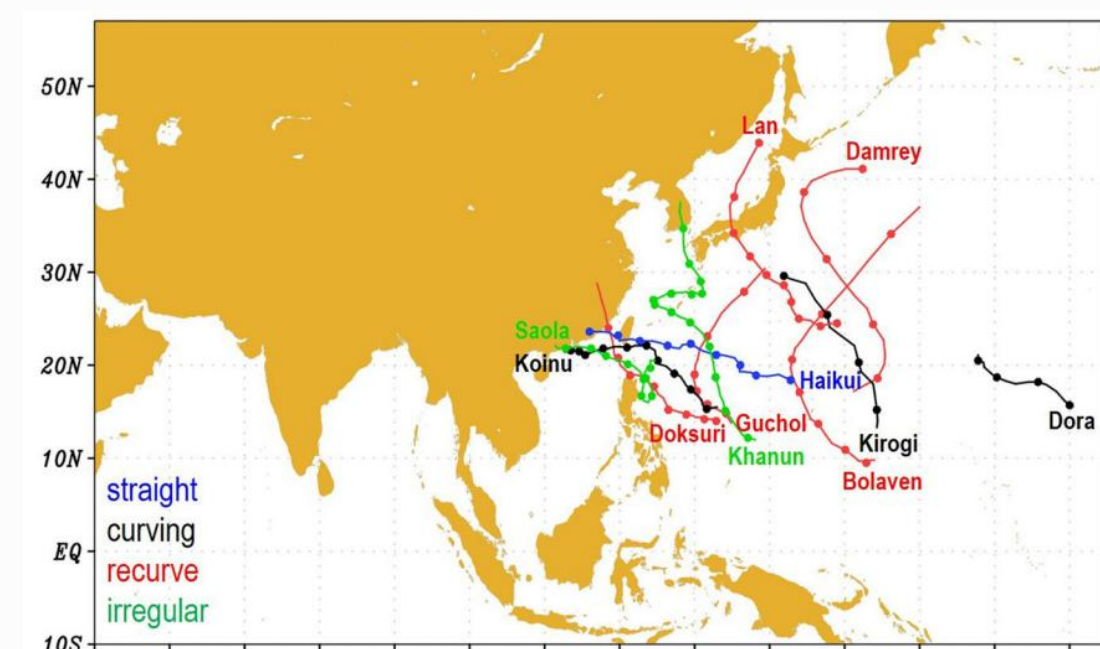
### Target

- Evaluation the performance of MLWP models that focus on the Asia region and their potential for operational use.
- Introduce MLWP typhoon track to Central Weather Administration (CWA) ensemble typhoon quantitative precipitation forecasts (ETQPF) system to generate higher resolution precipitation for typhoon events.

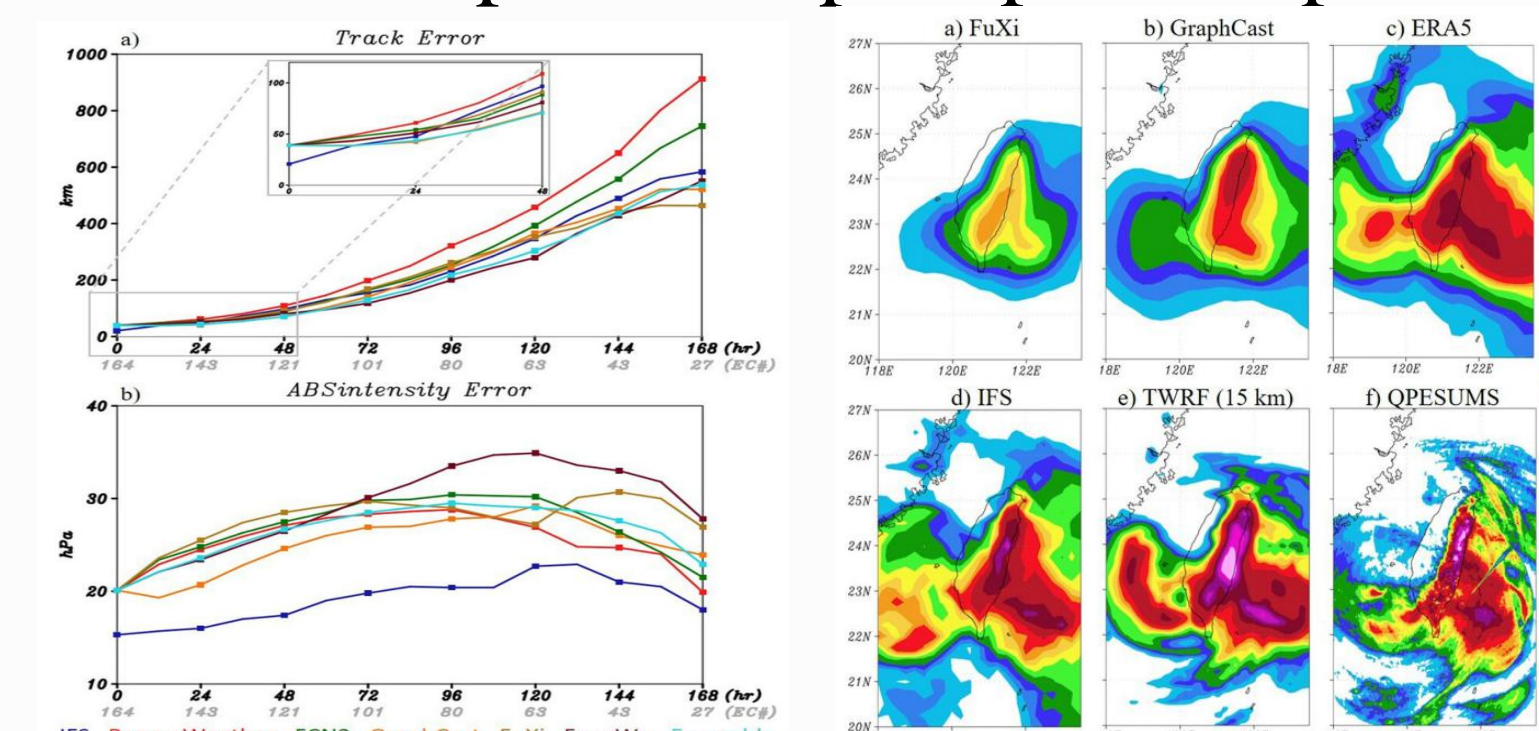
## II. MLWP Evaluation

- Evaluate the forecast performance of five MLWP models in Eastern Asia and Western Pacific. The evaluation period is from June to November 2023.

Model	Algorithm	Vertical pressure levels (excluding surface)	Frequency Options (h)	Time scale (days)	Variables (short name of ECMWF grb2 Table)	
					On pressure levels (in addition to u, v, 10, 20, 25)	At surface or specific height (in addition to ms1, 10 u, 10 v, 20)
Pangu-Weather	3D Earth-specific transformer (Swi Transformer v2 with Earth-specific positional bias)	13	a) 1 b) 6 c) 24	q	-----	
FourCastNet v2	ViT-Mamba Graph neural network	13	6	r	100 u, 100 v, sp, low	
GraphCast	Multi-Mamba Graph neural network	a) 13 b) 37	6	q, w	tp*	
FuXi	U-Transformer (Swi Transformer v2 with cube embedding)	13	6	0 - 5* 6 - 10* 11 - 15	f	tp*
FengWu	Transformer based on Cross model fusion	a) 13 b) 37	6	q	-----	



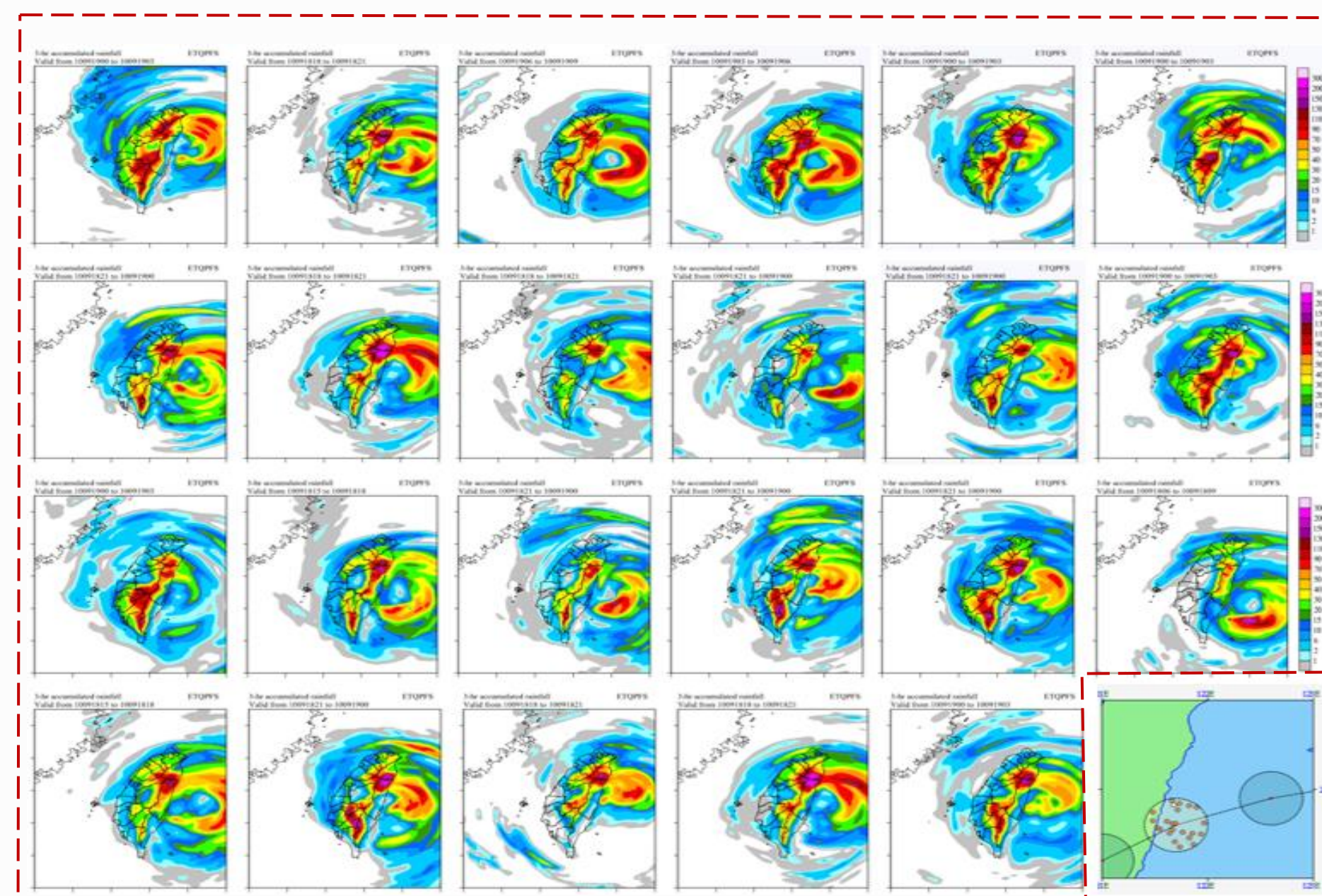
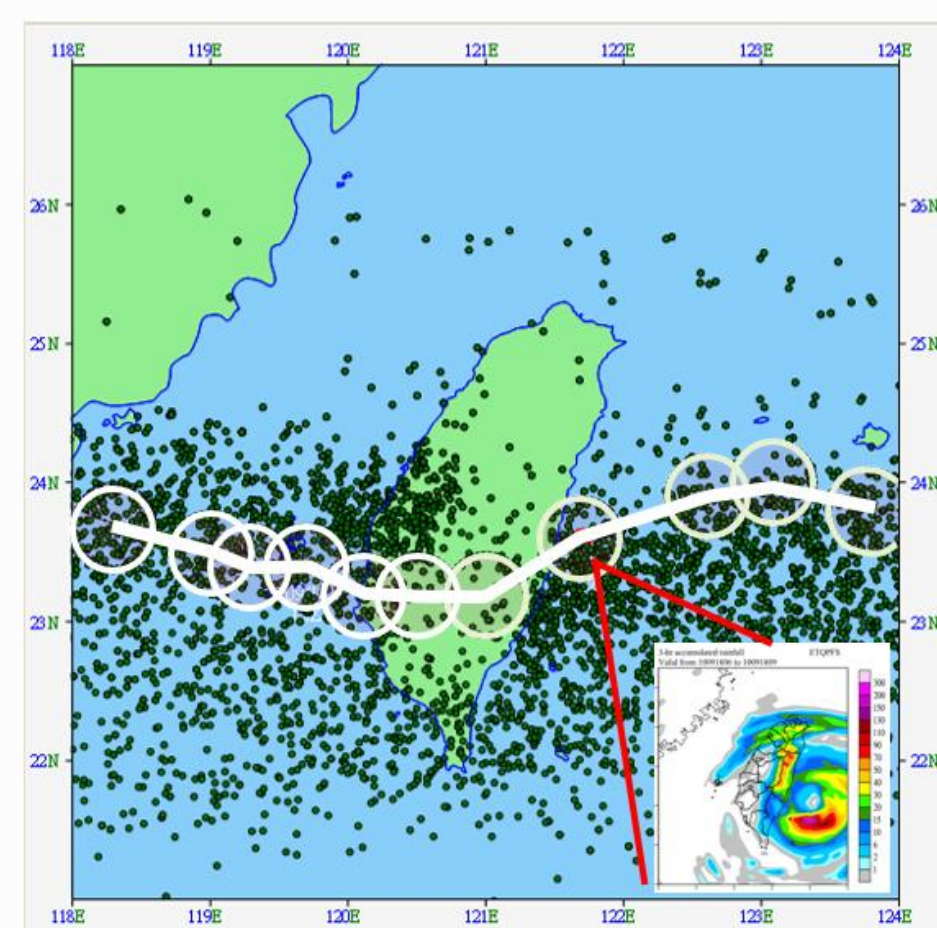
- MLWP models perform well in typhoon track forecast but worse in typhoon intensity forecast. MLWP models underestimate precipitation but can capture the precipitation pattern.



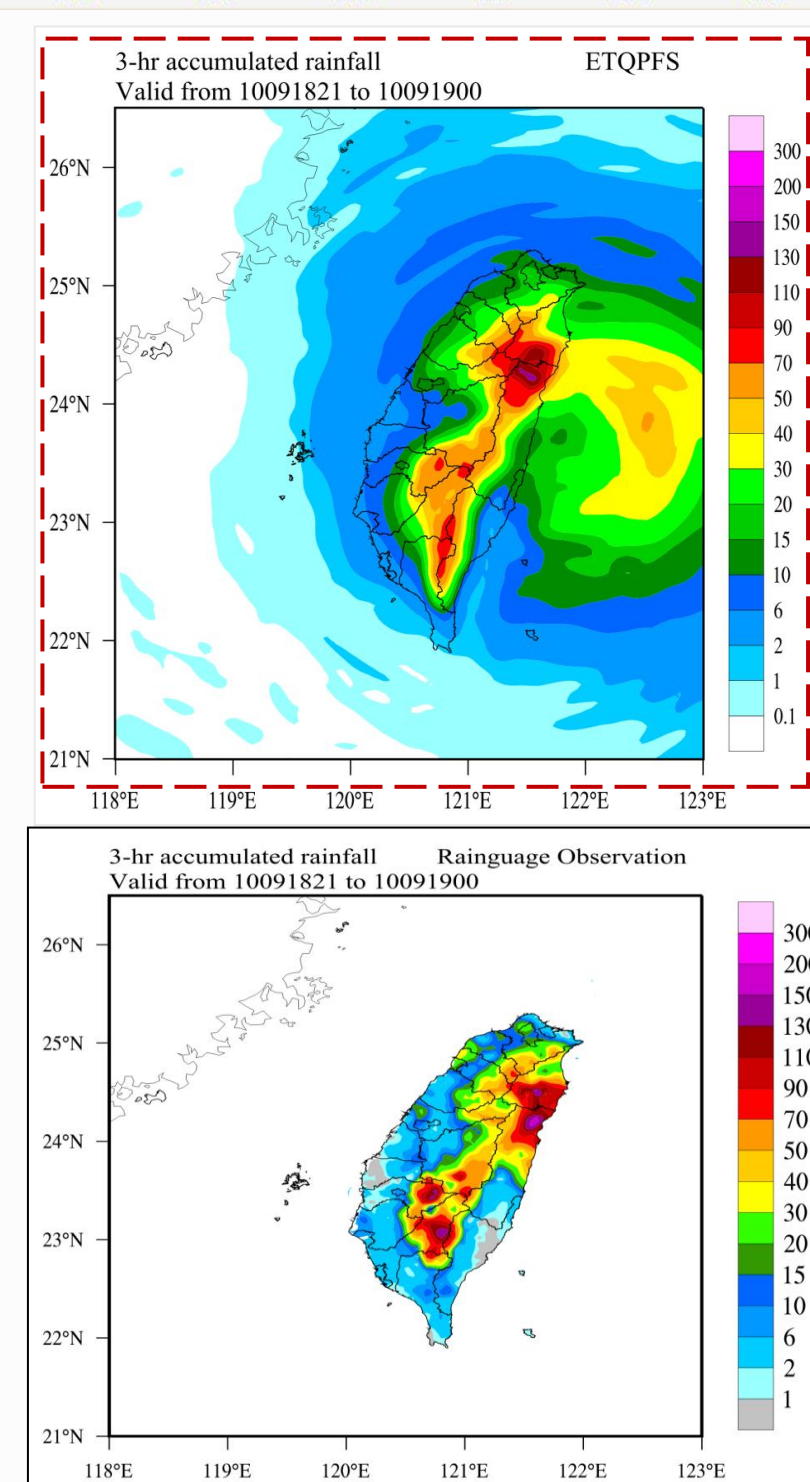
Simple ensemble mean of MLWP typhoon tracks combined CWA ETQPF system may a method to provide sufficient precipitation information for disaster prevention.

## III. ETQPF system

- Predicted typhoon positions with 3-hr intervals (ensemble cases) were given by the ensemble prediction systems (EPS) from CWA and National Science and Technology Center for Disaster Reduction (NCDR). It is the total uncertainties from the EPS
- Each ensemble case is associated with a 3-hr accumulated rainfall map.
- Screen out the ensemble cases according to the prior estimate of the typhoon position. This is a kind of the "QPF scenario" based on the given typhoon track. We are trying to reduce the uncertainties according to the prior estimate of the track



Rainfall terrain locking effect



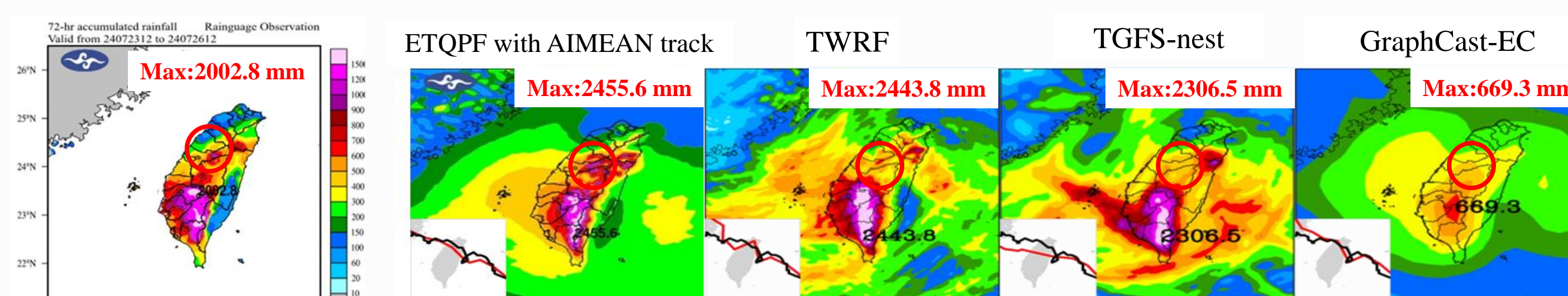
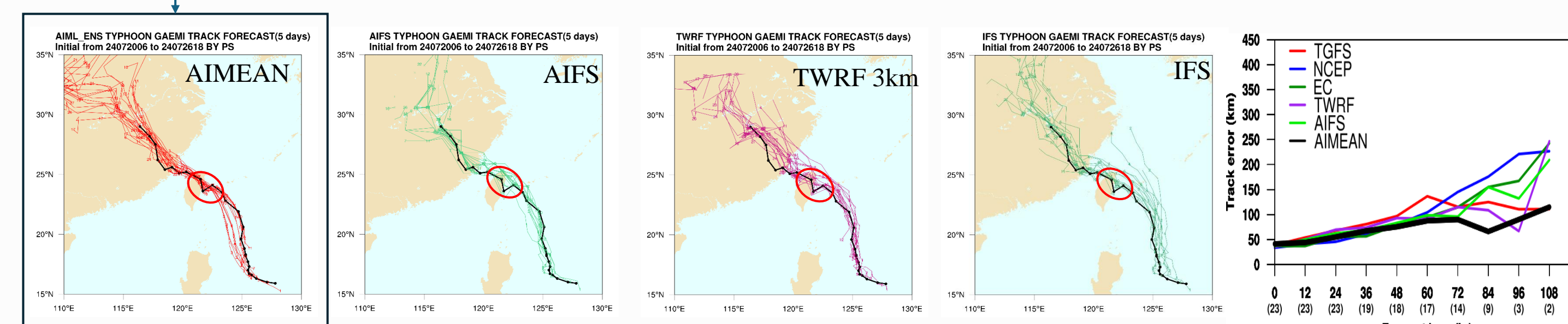
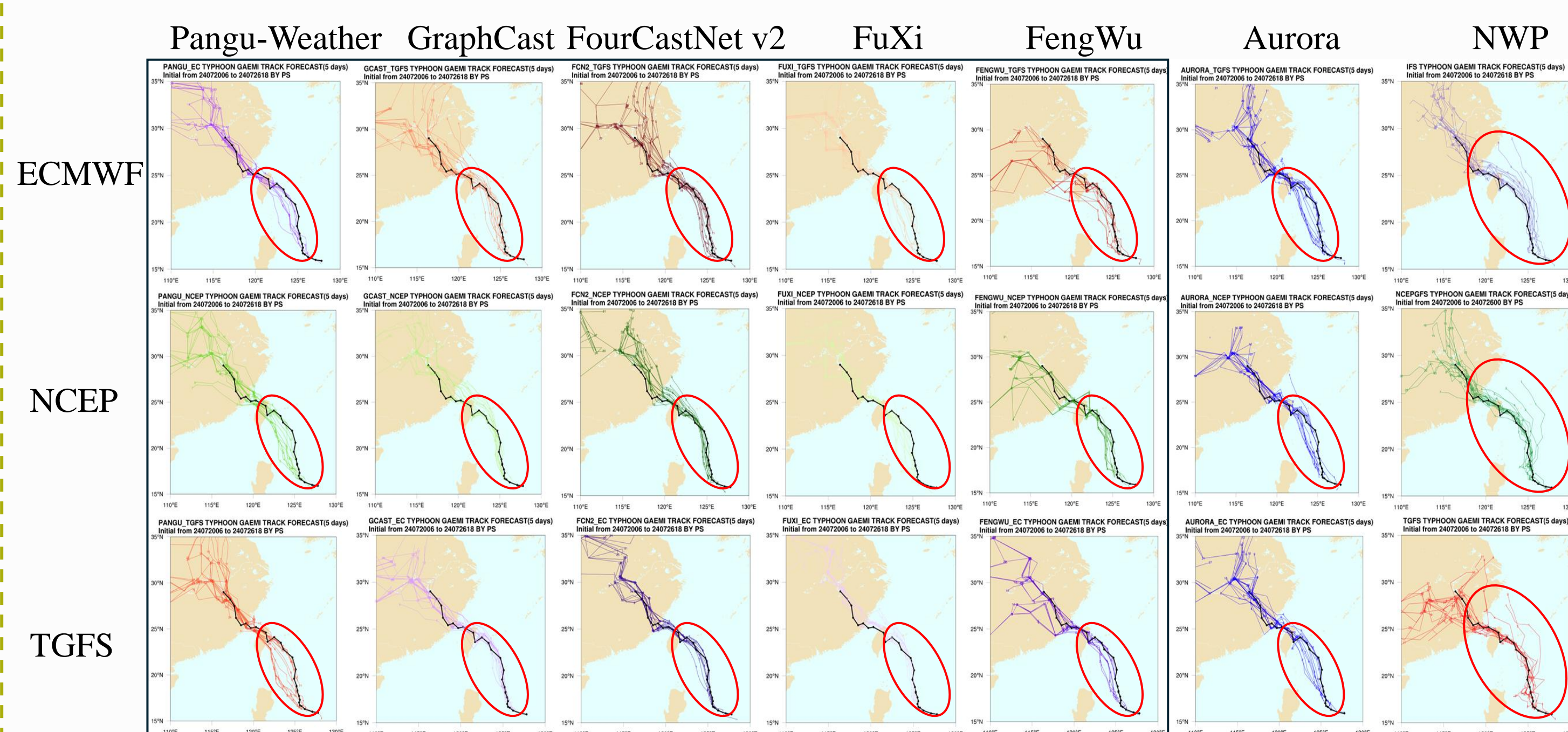
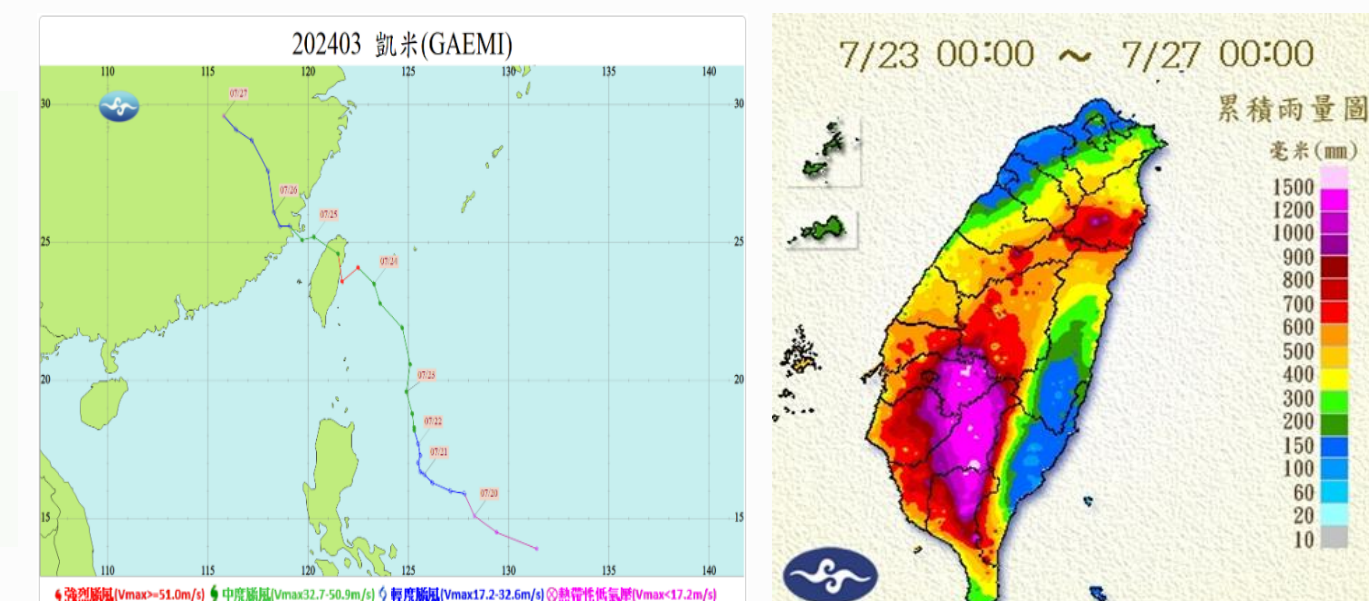
## IV. Case Study

The actions after confirming the MLWP models have potential for operational use:

- Provide typhoon track of MLWP models to CWA weather forecast center during typhoon warning period. The initial condition field are from ECMWF IFS, NCEP GFS, and Taiwan GFS (TGFS).
- Evaluation MLWP typhoon tracks and introduce simple ensemble mean of MLWP typhoon tack (AIMEAN) to CWA ETQPF system.

### Super Typhoon Gaemi (202403)

Formed- July 20 00 UTC, 2024  
Dissipated- July 26 18 UTC, 2024  
Landfall Taiwan- July 24 16 UTC, 2024



- Simple ensemble mean of MLWP models with 3 different NWP initial conditions have best typhoon track forecast.
- Introducing the AIMEAN typhoon track into the ETQPF system successfully generated high-resolution precipitation forecasts and provide the effective information for the mountainous regions of central Taiwan.

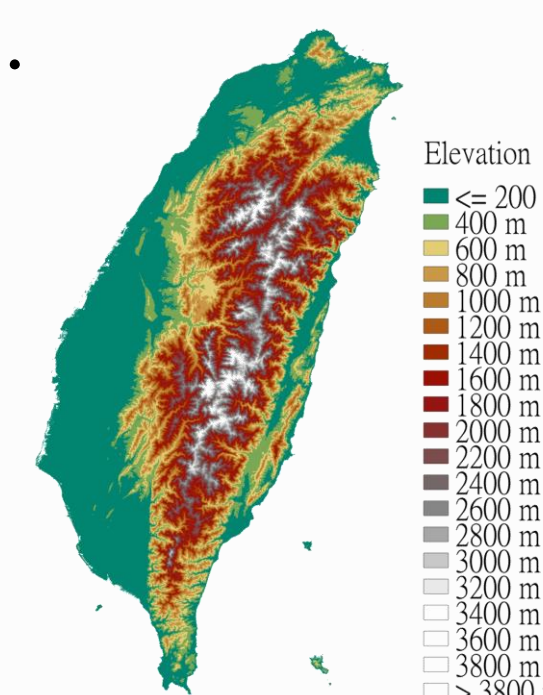
## V. Remark and future work

### Remark

- The MLWP models provided promising typhoon track forecasts for Typhoon Gaemi. In particular, all MLWP models indicated a higher possibility that typhoon Gaemi impacts Taiwan compared to traditional NWP models when the typhoon just formed.
- Integration MLWP typhoon track and CWA ETQPF can generate considerable precipitation more details than MLWP models.

### Future work

- Proposed a strategy to well apply the MLWP models from muti-model ensemble to ensemble.
- Limited area MLWP model for Taiwan.



## VI. Reference

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