



以氣象署全球模式系集資料同化分析場初始化 人工智慧天氣預報模型之系集預報評估

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中央氣象署科技發展組

(特別感謝：王志嘉)

2024/09/04

113 年天氣分析與預報研討會

大綱

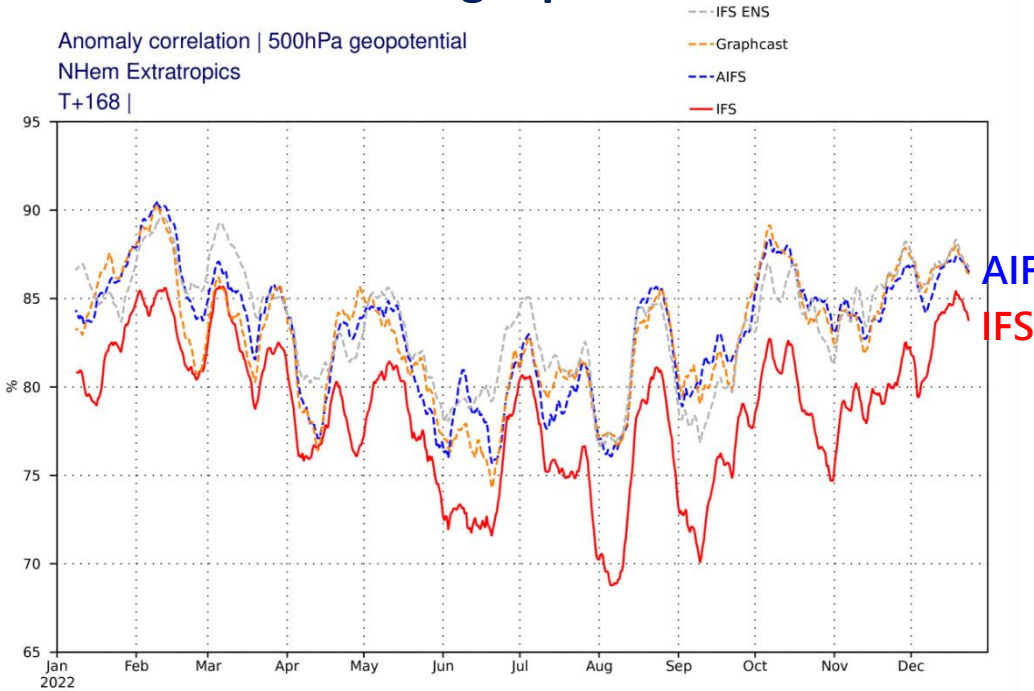
- 動機
- 實驗方法
- 實驗設計
- 結果
 - 綜觀尺度校驗
 - 颱風路徑校驗
- 結論



動機 - Lang et al. (2024, arXiv)



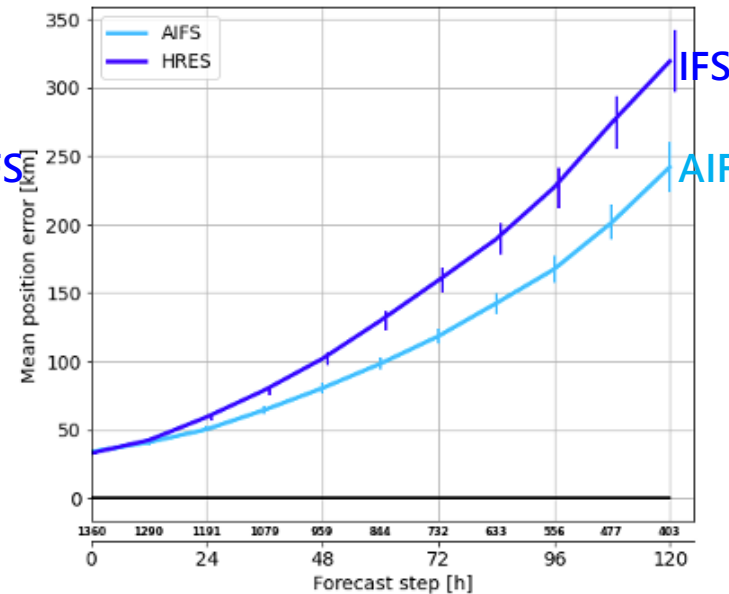
500 hPa geopotential



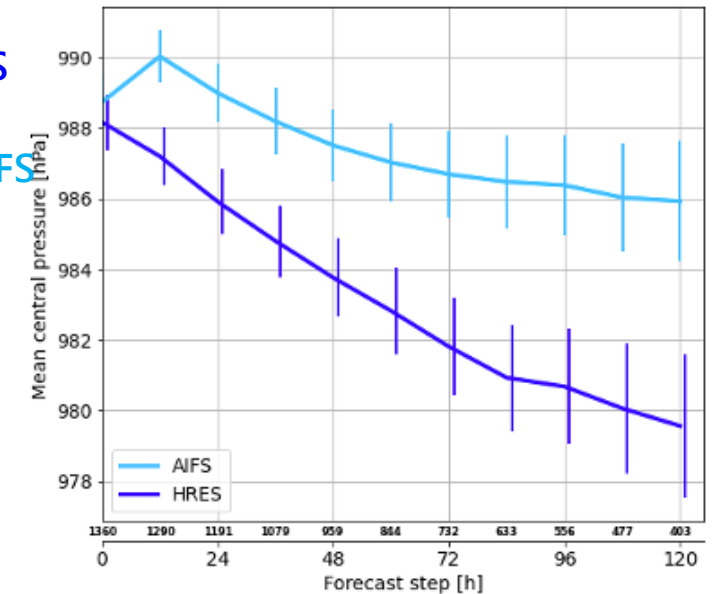
January 2022 to December 2022

- AIFS forecasts show higher skill than IFS forecasts when measured by a range of standard forecast scores.

mean track forecast error



mean central pressure



January 2022 to December 2023

- AIFS exhibits substantially lower tropical cyclone (TC) position forecast errors than IFS.
- AIFS produces less intense TCs than IFS on average, which manifests in a larger TC intensity bias.

動機

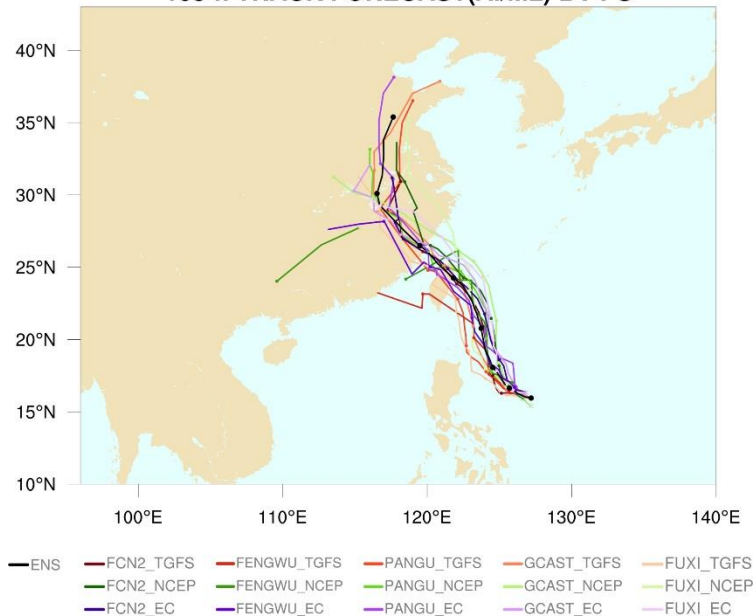


5 different AI global models
×
3 different NWP initial conditions (CWA TGFS, NCEP GFS, ECMWF IFS)
= 15 different AI model tracks

(Liu et al. 2024, under review)

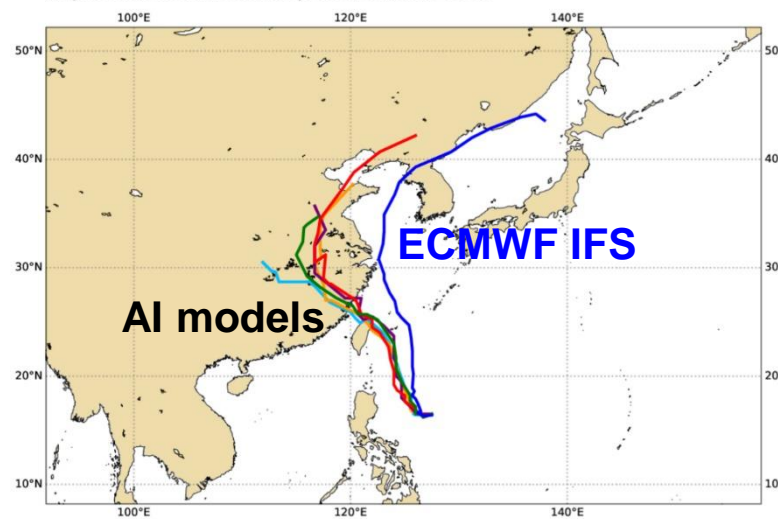
15 AI model tracks run by CWA

TYPHOON GAEMI (24/07/20/12UTC)
168-h TRACK FORECAST(AI/ML) BY PS



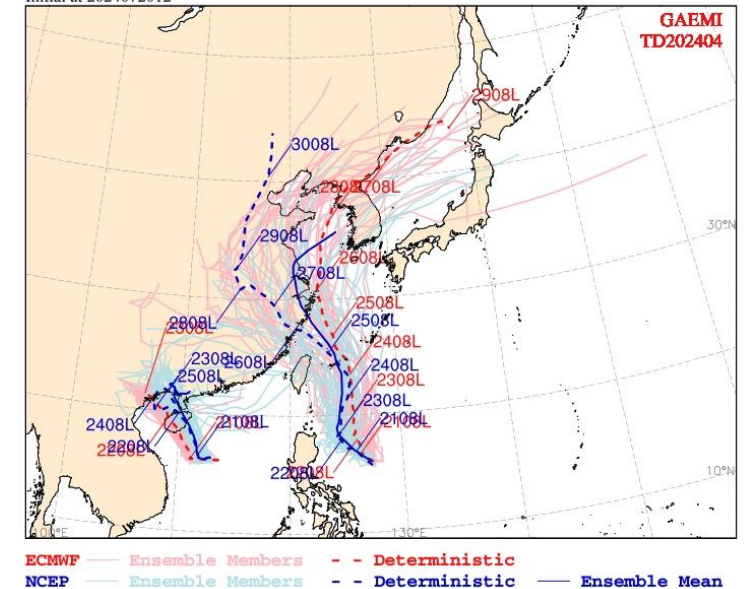
AI model + IFS tracks run by ECMWF

Date 20240720 12 UTC @ECMWF
Individual trajectories for GAEMI during the next 240 hours
tracks in solid: AIFS SFNO FUXI PGUW DMGC IFS
[reported minimum central pressure (hPa) 1002]



NCEP and ECMWF global ensemble tracks

ECMWF/EPS & NCEP/GEPS Typhoon Track Forecast
Initial at 2024072012



實驗方法



TGFS Deterministic Analysis (IC)

TGFS Analysis



Deterministic Forecast

AI Forecast

TGFS ENS Analysis (IC)

Member Analysis 1

Member Analysis 2

:

Member Analysis 32

AI_MODEL

AI_MODEL

AI_MODEL

Ensemble Forecast

AI Forecast Member 1

AI Member Forecast 2

:

AI Member Forecast 32

實驗設計



Experiment	IC	model	stochastic
NCEPGEFS	NCEP_EnKF	NCEPGFS	V
TGFS_ens	TGFS_EnKF	TGFS	V
TGFS_ens_nopt		TGFS	X
AI_Gcast		GraphCast	X
AI_FCNet		FourCastNet v2	X

- **FourCastNet** : developed by NVIDIA and based on Fourier Neural Operators (FNO) with a vision transformer architecture.
- **GraphCast** : developed by Google DeepMind and based on graph neural networks.

層場	變數
50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 850, 925, 1000 hPa (13 levels)	U、V風場 (m/s) ,溫度 (K) ,比濕 (kg/kg) , 重力位高度 (gpm) ,相對溼度 (%) ,垂直速度 (Pa/s)
100 m above ground	U、V風場 (m/s)
10 m above ground	U、V風場 (m/s)
2 m above ground	溫度 (K)
surface	氣壓 (Pa)
mean sea level	平均海平面氣壓 (Pa)

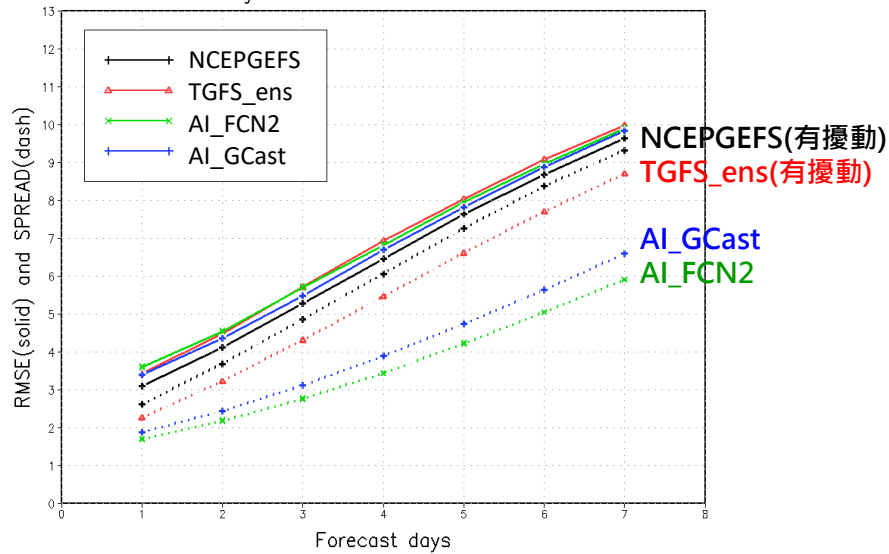
綜觀尺度校驗 - 250 hPa U 風場 (RMSE & SPREAD)



實線 : RMSE ; 虛線: SPREAD

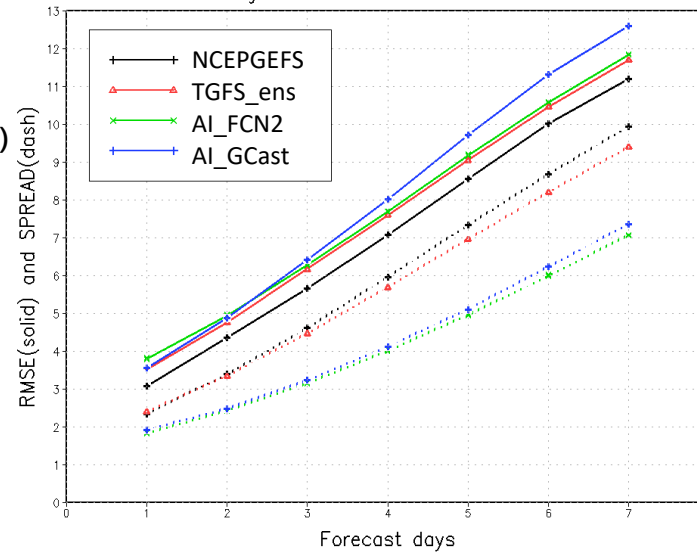
NH

Northern Hemisphere 250hPa U Wind
Ensemble Mean RMSE and Ensemble SPREAD
Average For 2023090500 - 2023100600



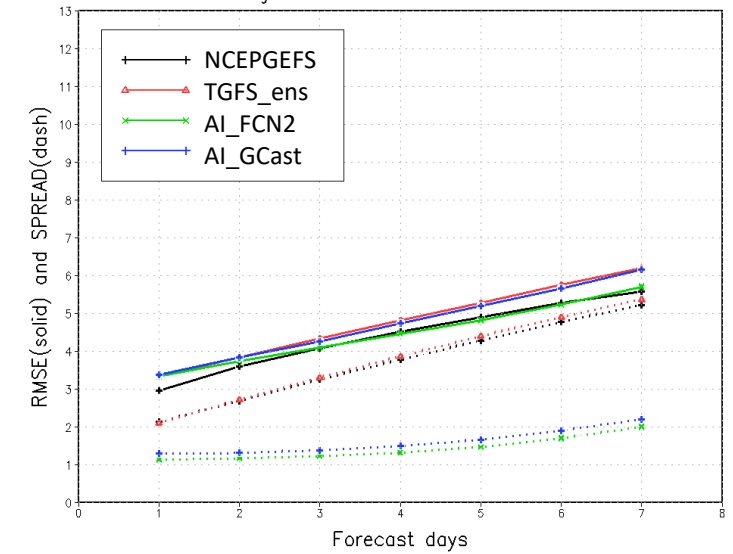
SH

Southern Hemisphere 250hPa U Wind
Ensemble Mean RMSE and Ensemble SPREAD
Average For 2023090500 - 2023100600



TP

Tropical 250hPa U Wind
Ensemble Mean RMSE and Ensemble SPREAD
Average For 2023090500 - 2023100600



綜觀尺度校驗 - 250 hPa U 風場 (RMSE & SPREAD)

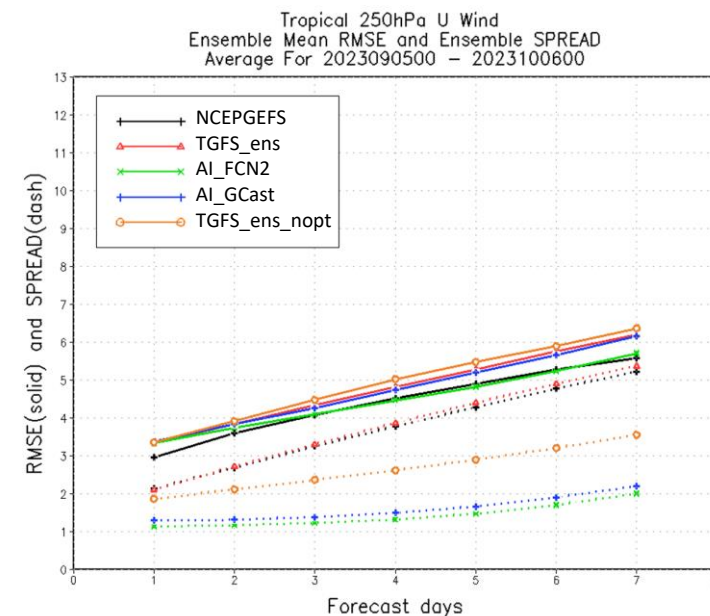
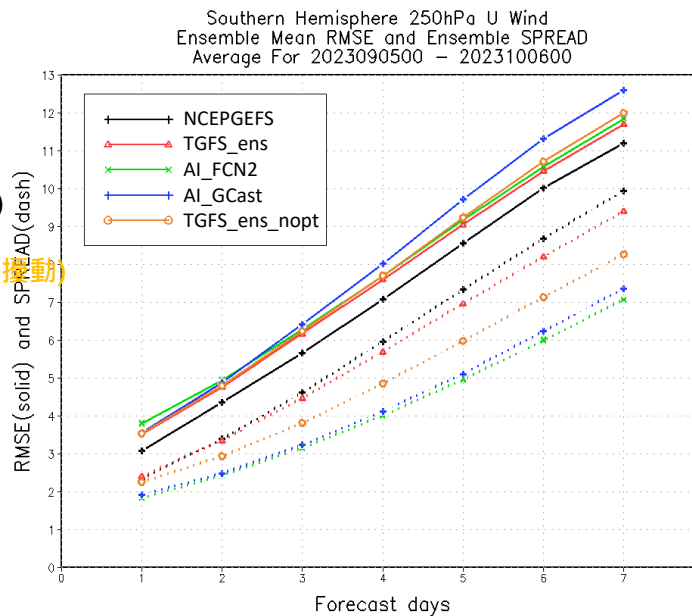
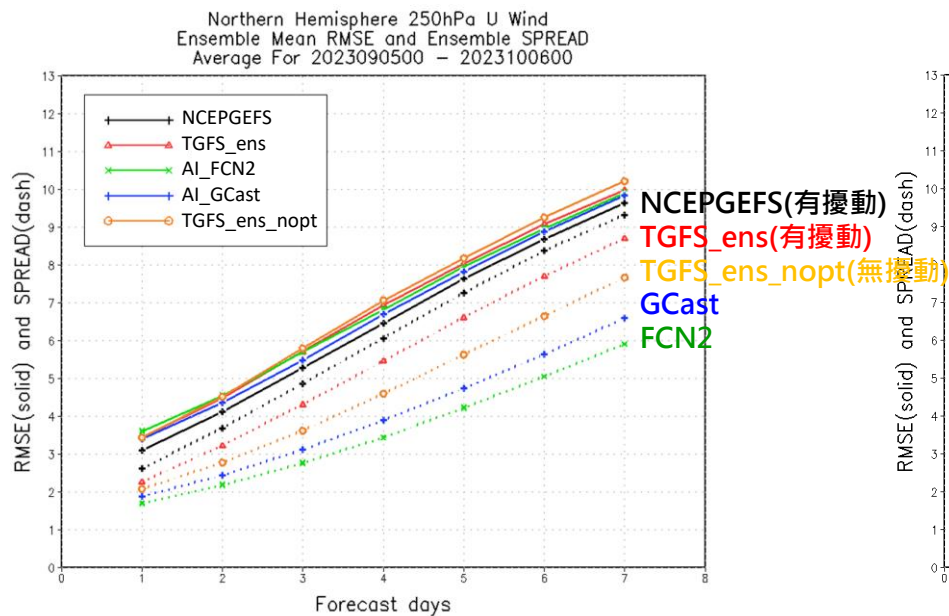


實線 : RMSE ; 虛線: SPREAD

NH

SH

TP



- NWP模式使用**隨機物理參數趨勢法 (Stochastic physics)** 來提供額外的系集離散度。
- 模式特性：AI天氣預測模式為一種平滑過程。
NWP模式為非線性，誤差成長較快速。

綜觀尺度校驗

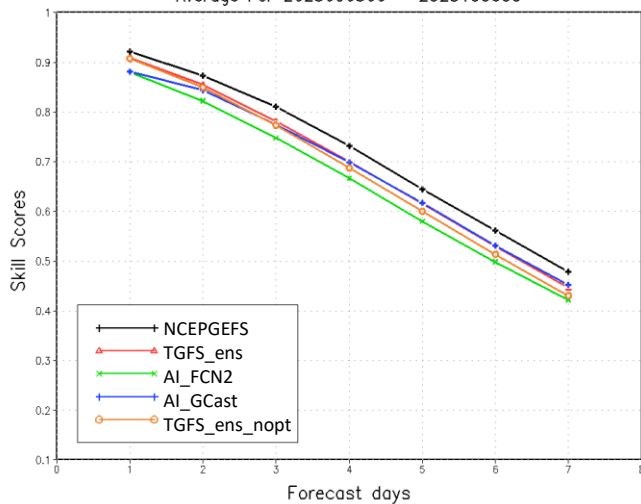
- CRPSS (Continuous Ranked Probability Skill Score)



500 hPa 高度場

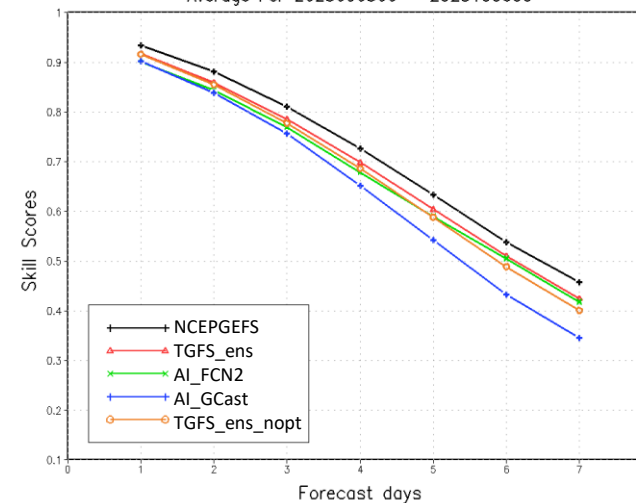
NH

Northern Hemisphere 500hPa Height
Continous Ranked Probability Skill Scores
Average For 2023090500 - 2023100600



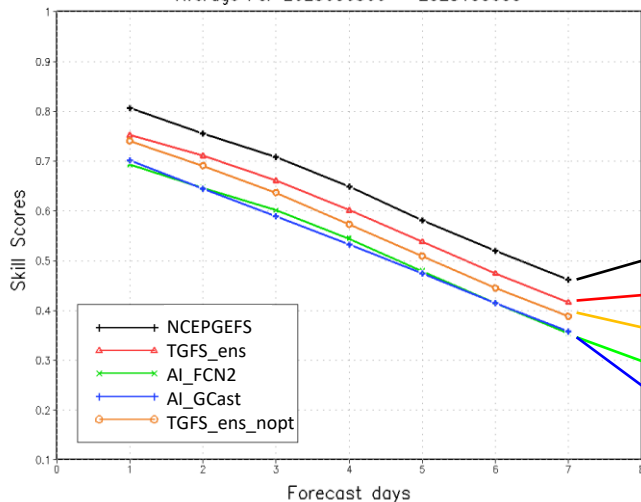
SH

Southern Hemisphere 500hPa Height
Continous Ranked Probability Skill Scores
Average For 2023090500 - 2023100600



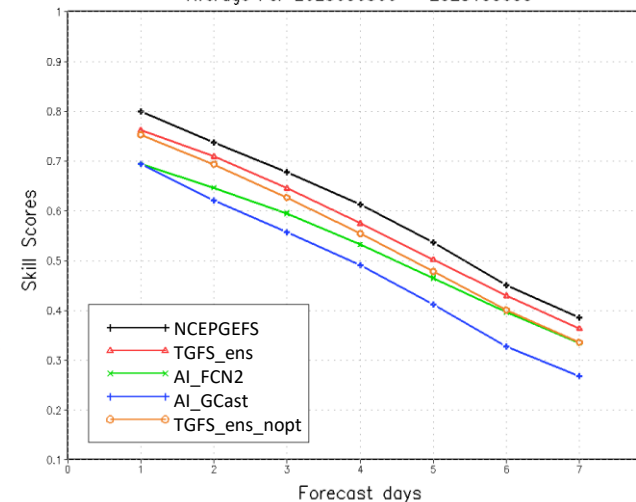
850 hPa 溫度場

Northern Hemisphere 850hPa Temp.
Continous Ranked Probability Skill Scores
Average For 2023090500 - 2023100600



NCEPGEFS
TGFS_ens
TGFS_ens_nopt
AI_FC2
AI_Gcast

Southern Hemisphere 850hPa Temp.
Continous Ranked Probability Skill Scores
Average For 2023090500 - 2023100600

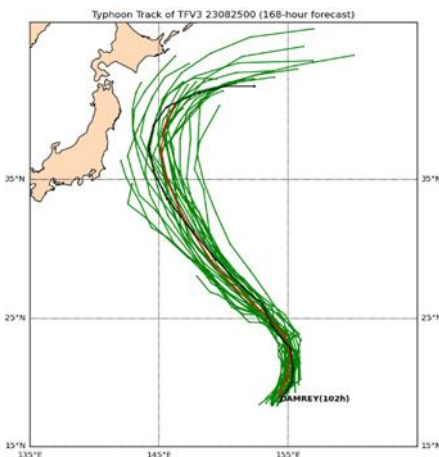


颱風系統校驗 - TYPHOON TRACK

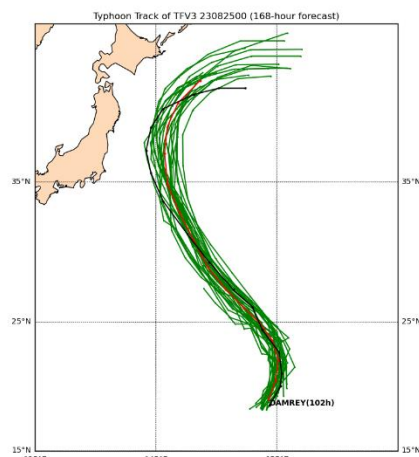
- CWA官方颱風定位路徑
- 系集平均
- 各系集成員路徑

丹瑞(DAMREY)
(2023-08-25 00Z)

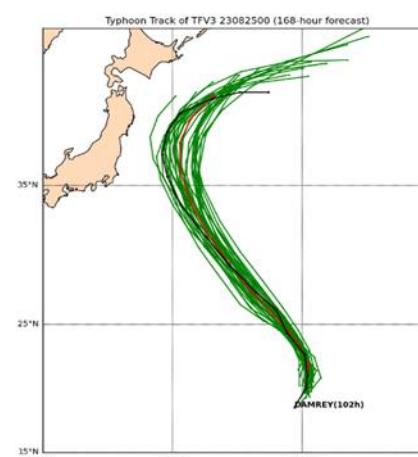
TGFS_ens



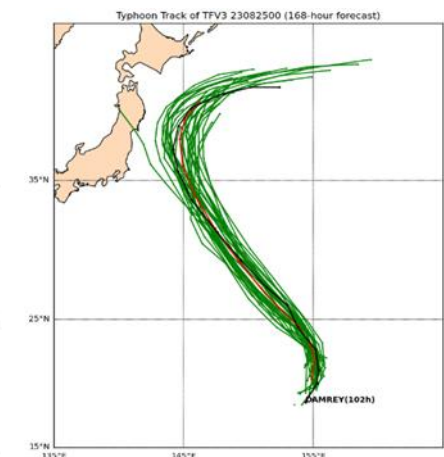
TGFS_ens_nopt



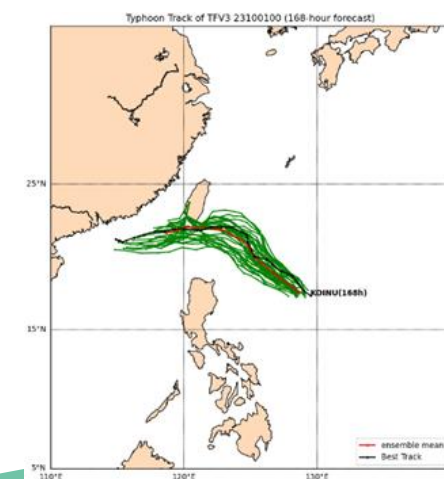
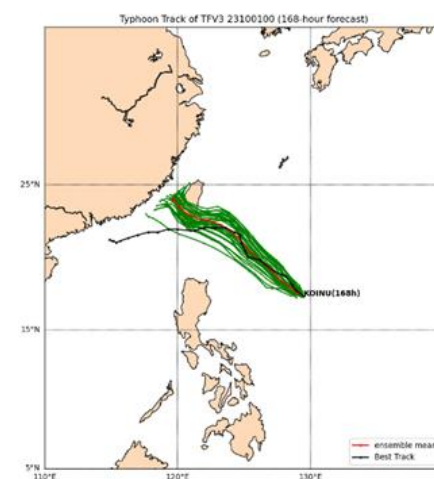
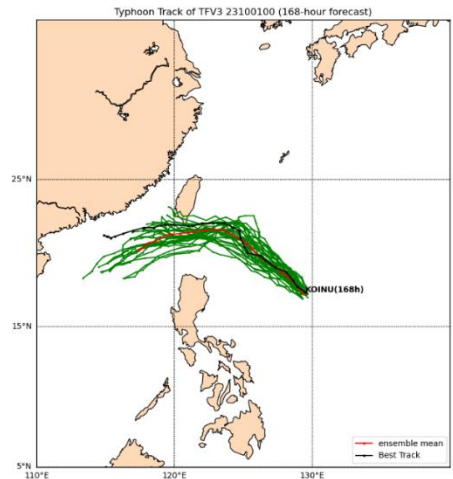
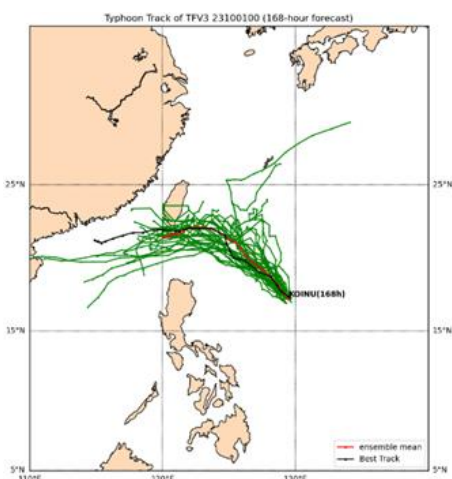
AI_FCN2



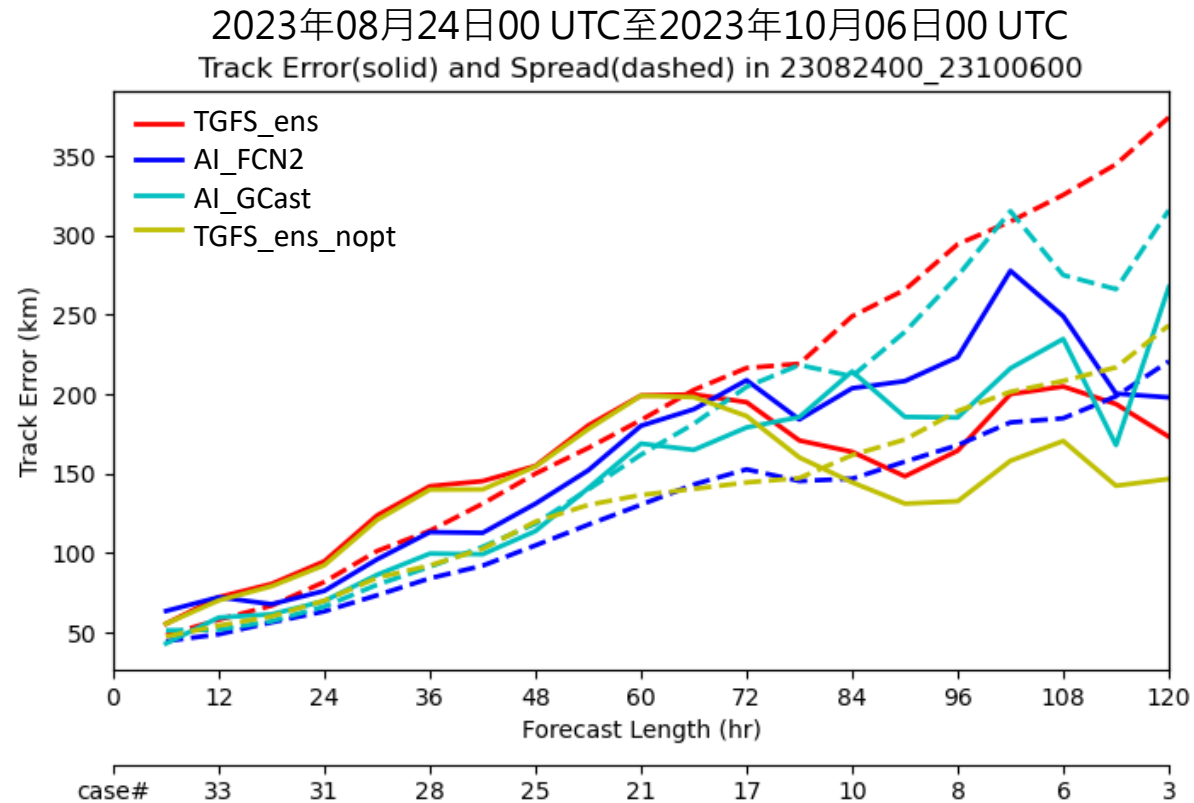
AI_GCAST



小犬(KIONU)
(2023-10-01 00Z)



颱風系統校驗 - TRACK ERROR & SPREAD



- AI_GCAST有較小路徑誤差，系集路徑散度與誤差接近，顯示其散度數值可涵蓋路徑誤差的不確定性。

結論

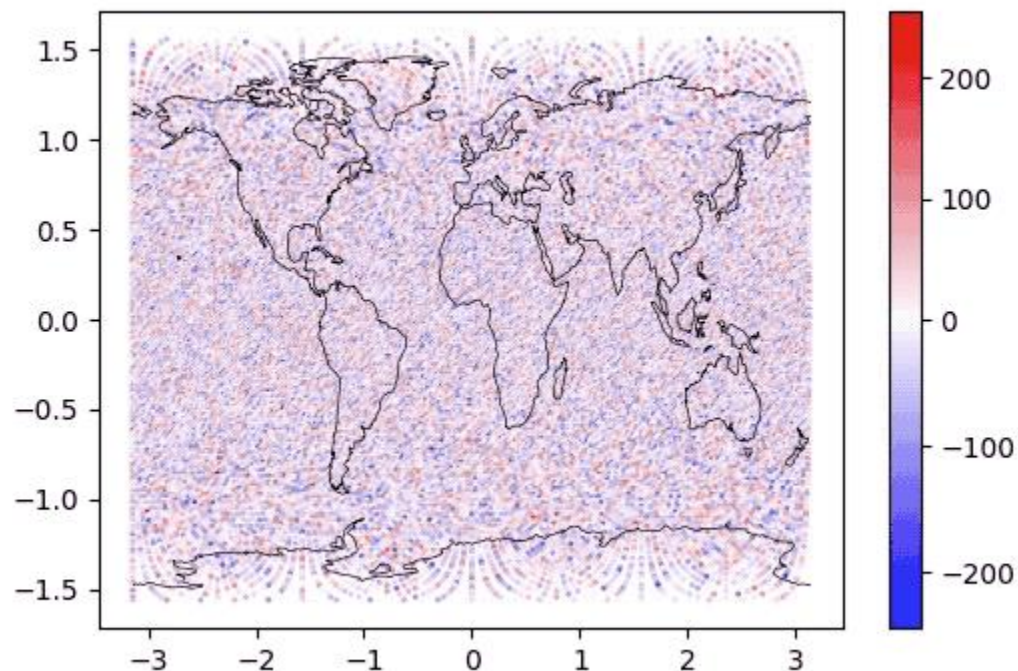


- 以傳統全球NWP模式 (TGFS) 的系集分析場作為初始場，啟動人工智慧模式進行系集預報是可行的。
- AI模式的層場驗證顯示其系集的離散度明顯不足。分析顯示：
 - 目前我們使用的AI模式不像NWP模式具備模式擾動的功能。
 - 但也可能AI模式本身與NWP模式固有的不同誤差成長特性有關。

ECMWF AIFS系集預報



- 歐洲中期天氣預報中心 (ECMWF) 的AIFS系集預報已經實現了AI模式擾動功能，我們將持續關注這一領域的發展。



<https://www.ecmwf.int/en/about/media-centre/aifs-blog/2024/enter-ensembles>



The End

- Thank you for your attention