以氣象署全球模式系集分析場初始化「AIFS ENS」全球系集機器學習天氣預報模型之預報表現評估

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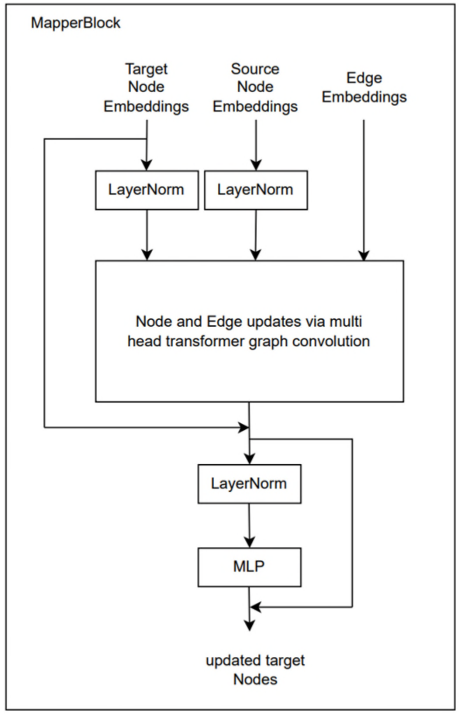
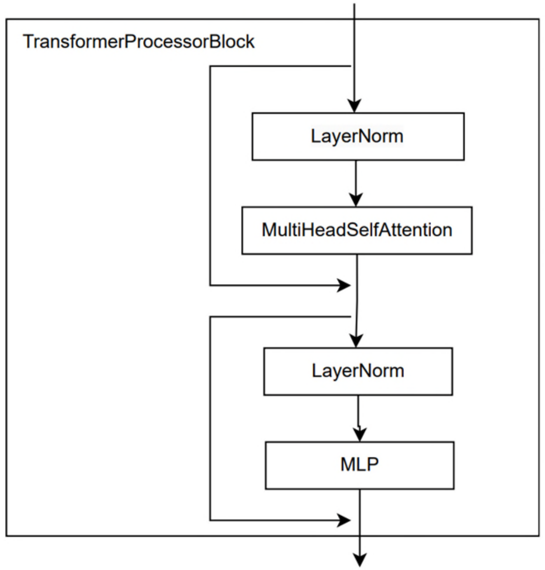
114 年天氣分析與預報研討會

大綱

- 系統簡介
- 實驗設計
- 綜觀尺度校驗與分析
- 結論與未來規劃

AIFS-ENS系統簡介
-Lang et al. (2024, arXiv)





Field	Level type
Geopotential (z) Specific humidity (q) Temperature (t) U component of wind (u) V component of wind (v) Vertical velocity (w)	Pressure level: 50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 850, 925, 1000
2 metre dewpoint temperature (2d) 2 metre temperature (2t) 10 metre U wind component (10u) 10 metre V wind component (10v) Mean sea level pressure (msl) Skin temperature (skt) Surface pressure (sp) Total column water (tcw)	Surface
Soil temperature (sot), at solid depth 1 and 2	Soil layer level
Total precipitation (tp) 100 metre U wind component (100u) 100 metre V wind component (100v) Surface short-wave (solar) radiation downwards (ssrd) Surface long-wave (thermal) radiation downwards (strd) Cloud variables (tcc, hcc, mcc, lcc), Runoff water equivalent (surface plus subsurface) (rowe) Snowfall water equivalent (sf)	Surface
Standard deviation of sub-gridscale orography (sdor) Slope of sub-gridscale orography (slor) Land-sea mask (lsm), orography, insolation, latitude/longitude, time of day/day of year	Surface

- 左側的圖神經網路 (GNN) 區塊用於編碼器和解碼器，負責不同網格解析度間的資料轉換。
- 右側的處理器區塊則在編碼器和解碼器之間，進行潛在狀態的深度處理。

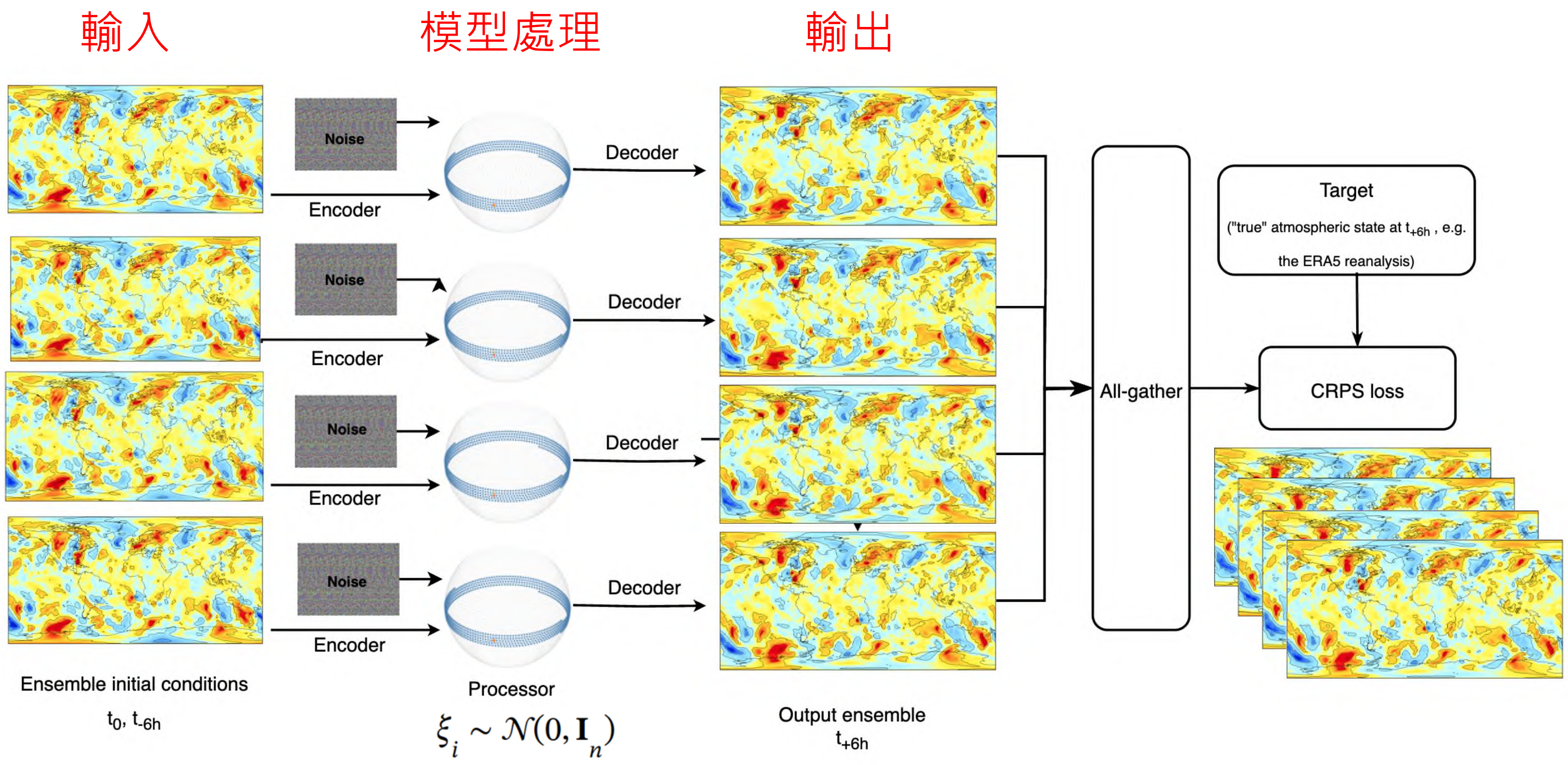
AIFS-ENS系統流程

-Lang et al. (2024, arXiv)

- AIFS-CRPS 架構，於每個系集成員中將不同的隨機高斯雜訊加入到 Transformer 處理器中，供 AIFS-CRPS 學習不確定型態的模式預報結果。

- 除了模式本身的平行化處理外，AIFS 程式碼還可以將系集成員分佈在多個圖形處理單元 (GPU) 上；如此能夠以更高的空間解析度來訓練更大的集合。

- 以 ERA5 的再分析資料為校驗資料(亦即視為真實大氣狀態)。



實驗設計

過去實驗(第一代模型)

Experiment	IC	model	stochastic	member
NCEPGEFS	NCEP_EnKF	NCEPGFS	V	30
TGFS_ens	TGFS_EnKF	TGFS	V	32
TGFS_ens_nopt		TGFS	X	32
AI_Gcast		GraphCast	X	32
AI_FCN2		FourCastNet v2	X	32

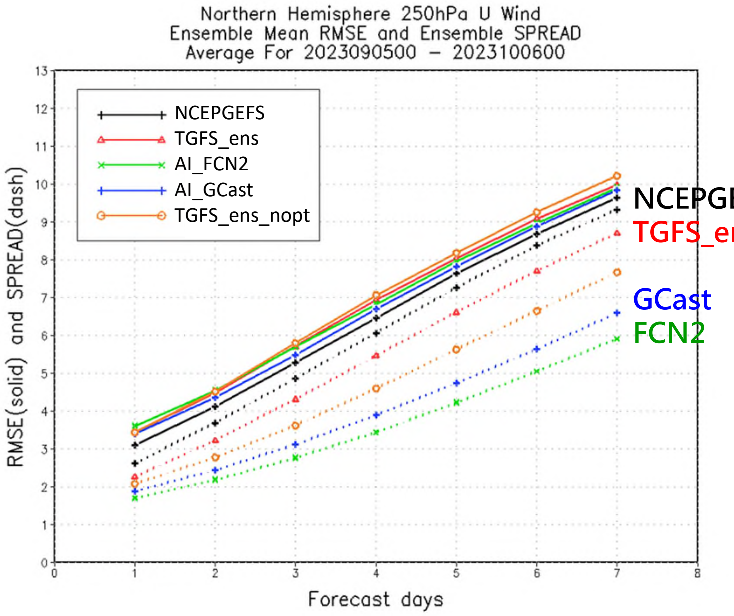
現在實驗(第二代模型)

Experiment	IC	model	random noise (stochastic)	member
EC-ENS	EC_EDA	AIFS_ENS	V	32
TGFS-ENS	TGFS_EnKF		V	32

綜觀尺度校驗
- 250 hPa U 風場 (RMSE & SPREAD)

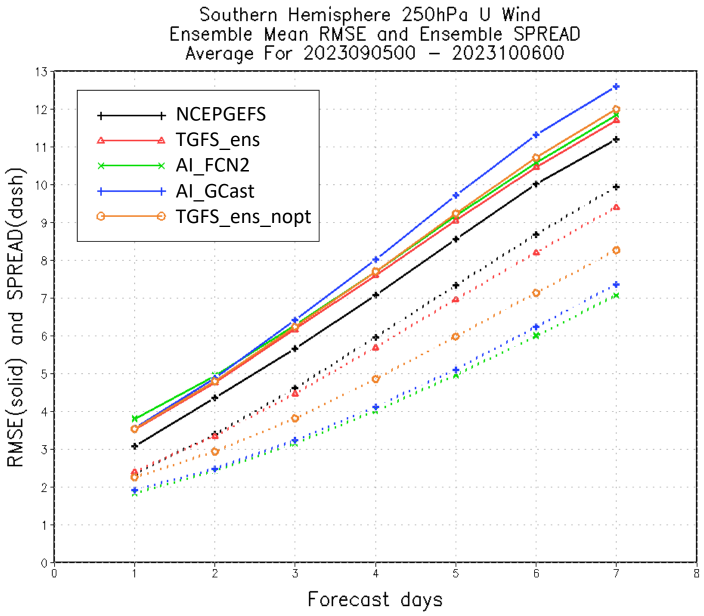
實線 : RMSE ；虛線: SPREAD

NH

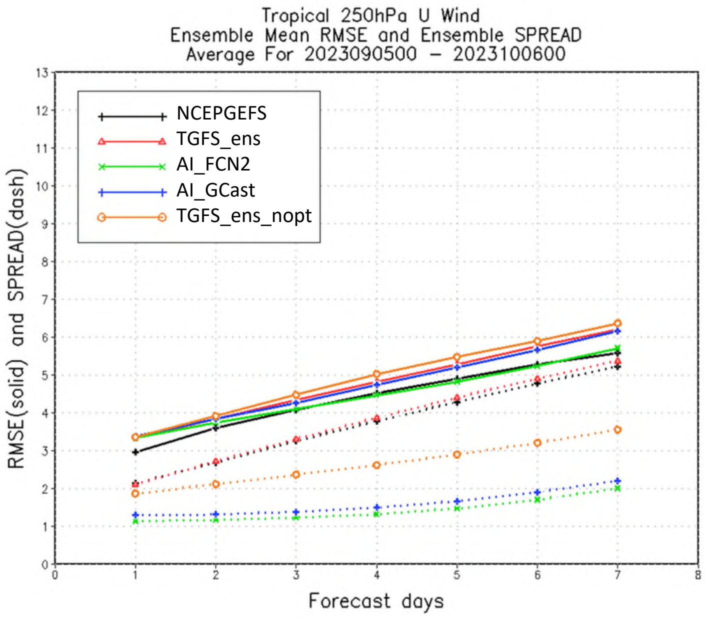


NCEPGEFS(有擾動)
TGFS_ens(有擾動)
GCast
FCN2

SH



TP



* 去年我們嘗試過用第 1 代模型 (GraphCast 等) 介接 TGFS 系集初始場做系集預報，
結果顯示系集離散度不足，無法產製品質良好的系集預報。

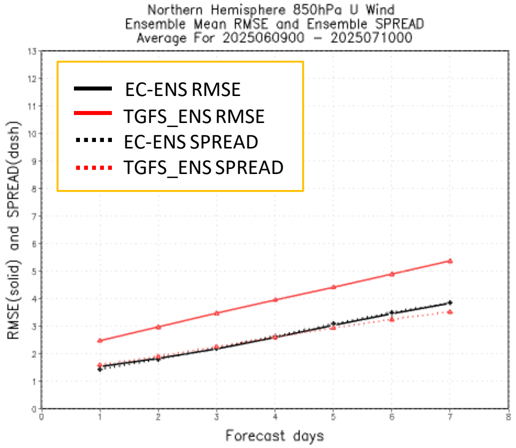
趙子瑩等人：以氣象署全球模式系集資料同化分析場初始化人工智慧天氣預報模型之系集預報評估。

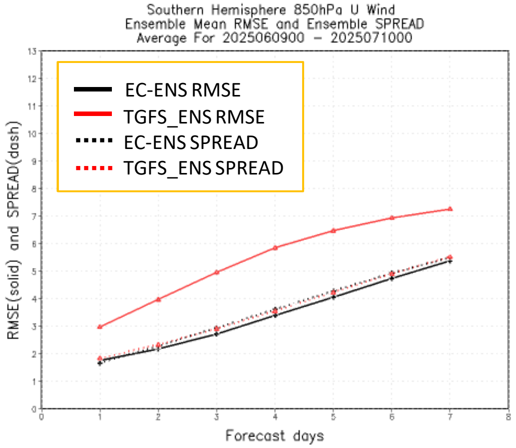
113年天氣分析與預報研討會。

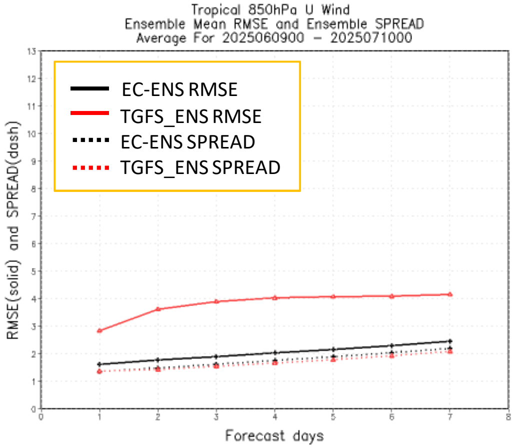
綜觀尺度校驗
- 850 hPa (RMSE & SPREAD)

NH　SH　TP

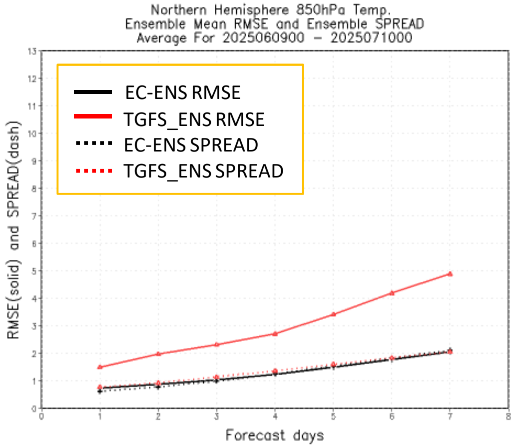
U 風場

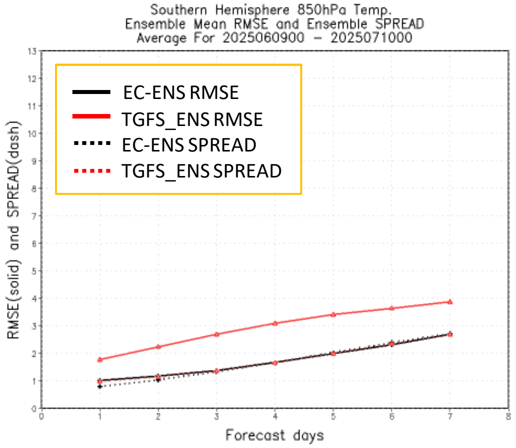


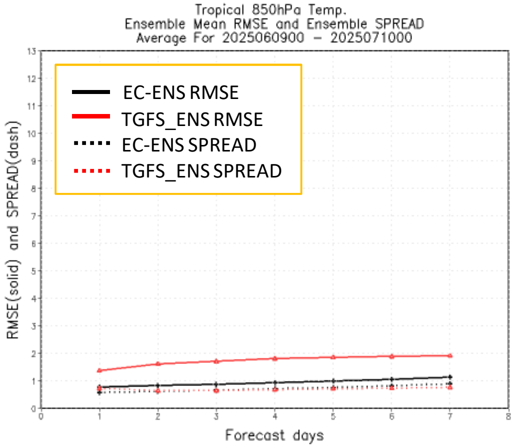




溫度場



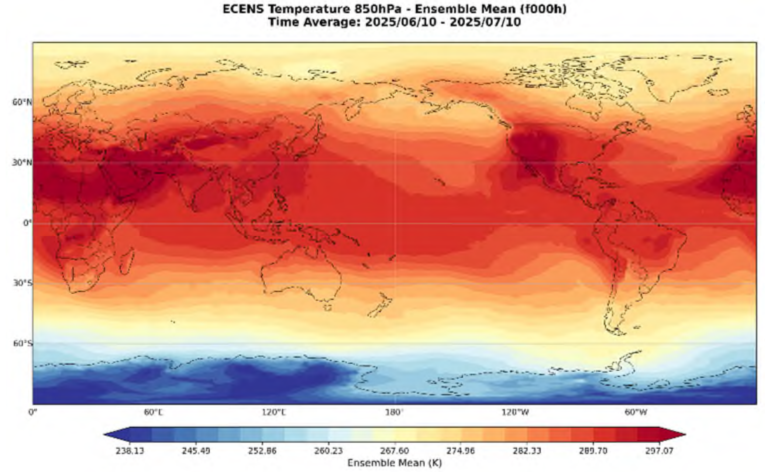


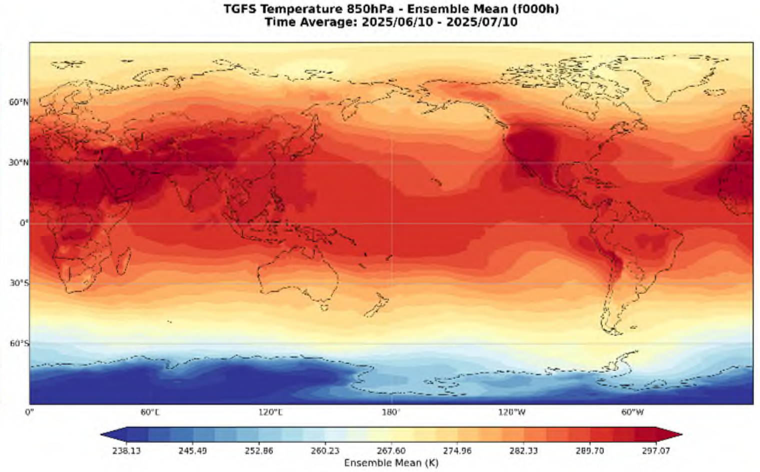


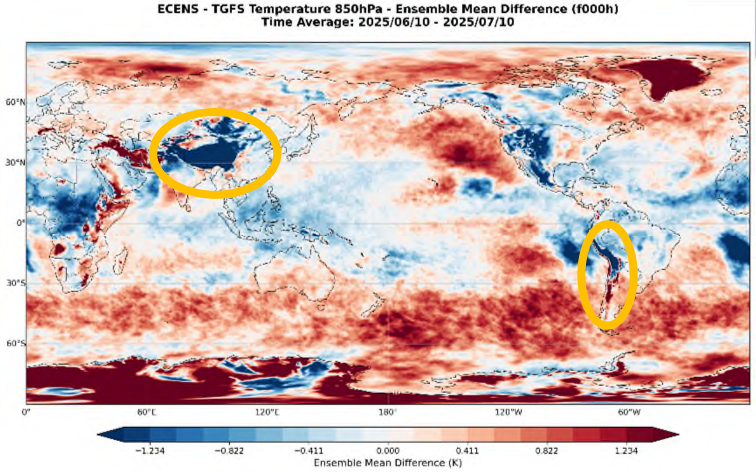
綜觀尺度分析
- ENS MEAN F000

EC-ENS　　TGFS-ENS　　DIFF

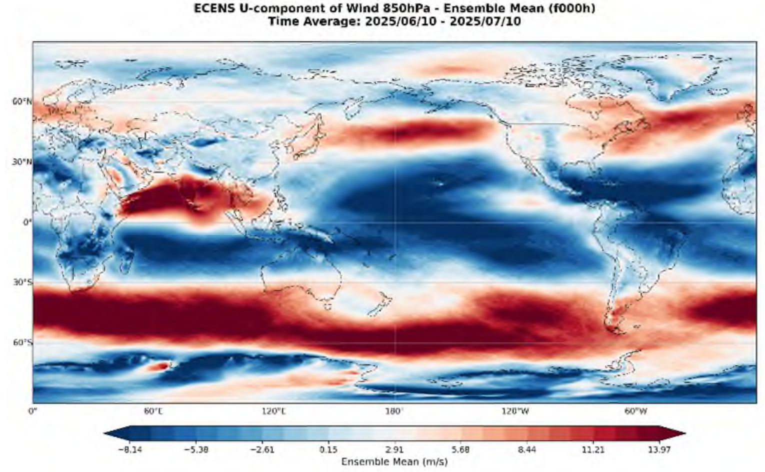
T850

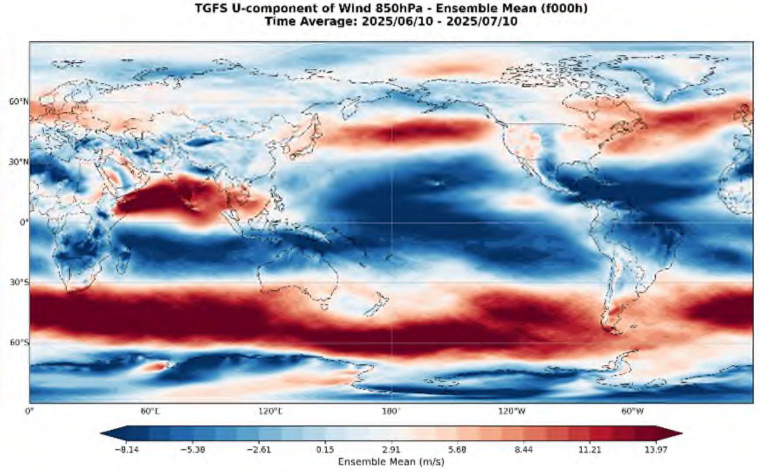


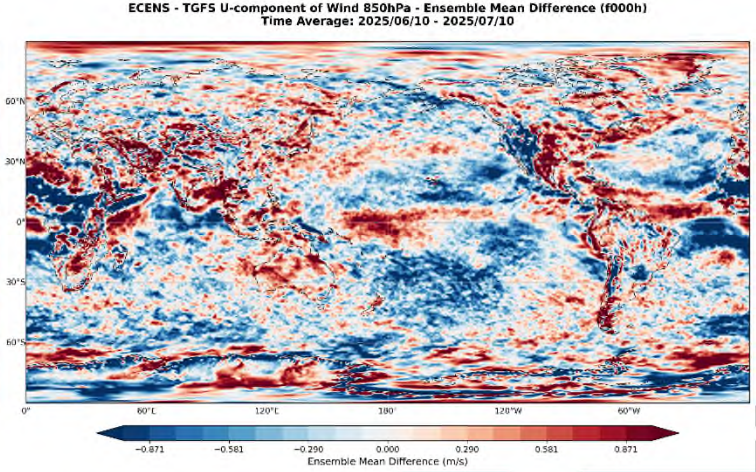




U850





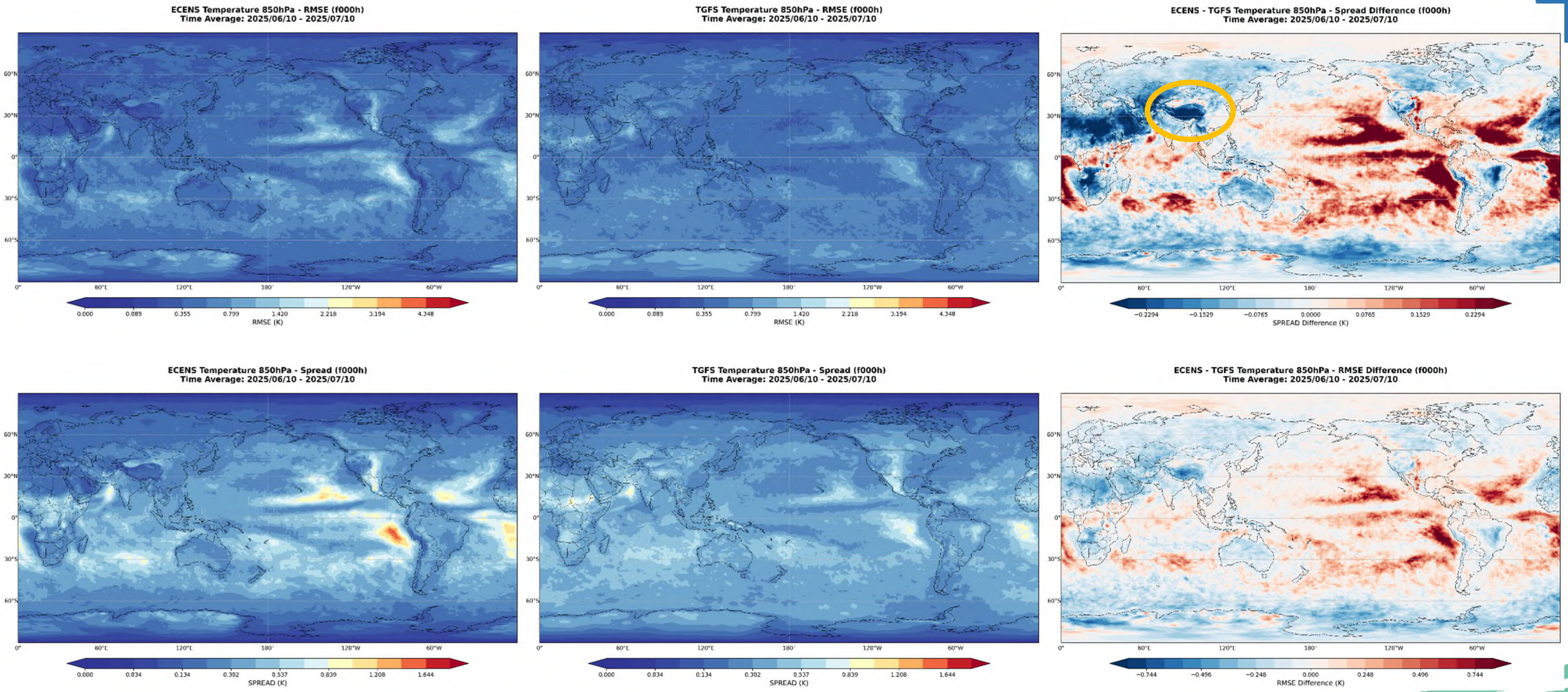


綜觀尺度分析
- RMSE&SPRD T850 F000

EC-ENS TGFS-ENS DIFF

RMSE

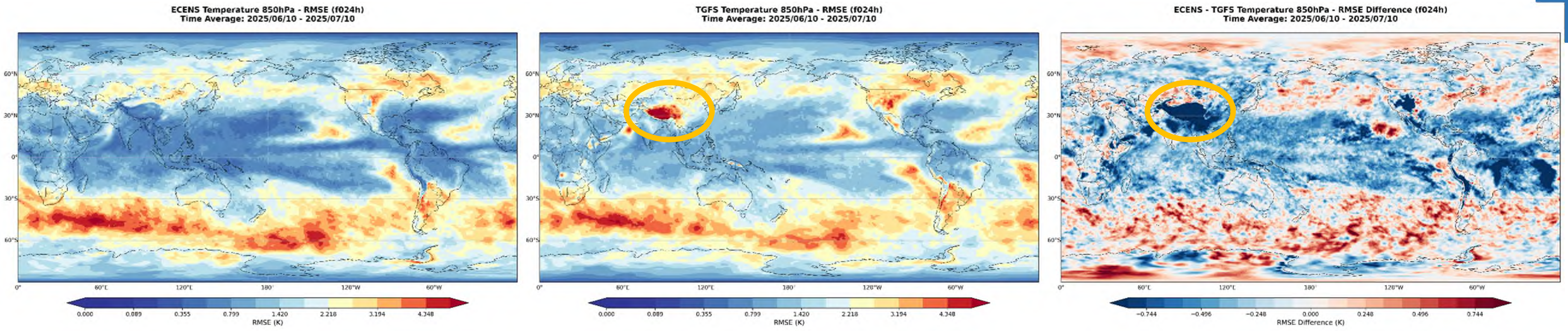
SPREAD



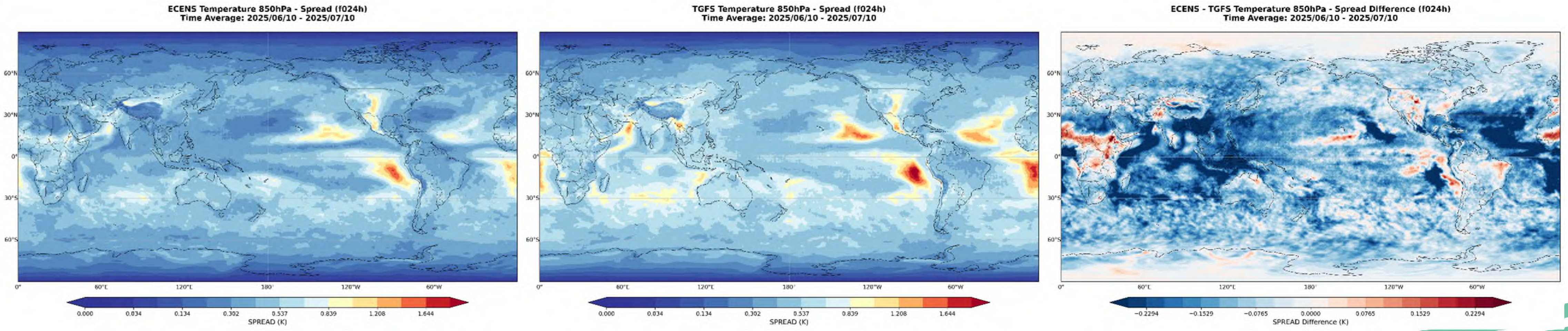
綜觀尺度分析
- RMSE&SPRD T850 F024

EC-ENS | TGFS-ENS | DIFF

RMSE



SPREAD



綜觀尺度分析
- RMSE&SPRD T850 F168

EC-ENS

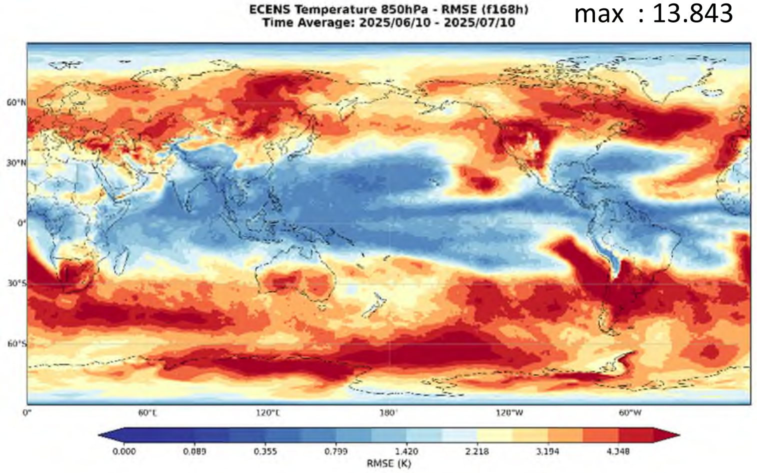
max : 13.843

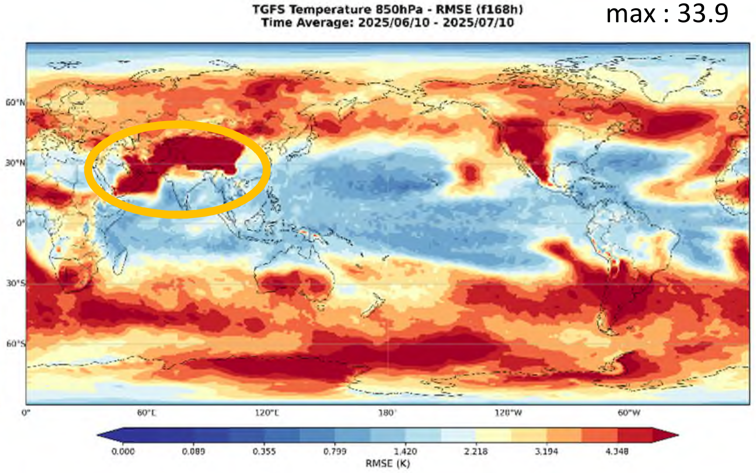
TGFS-ENS

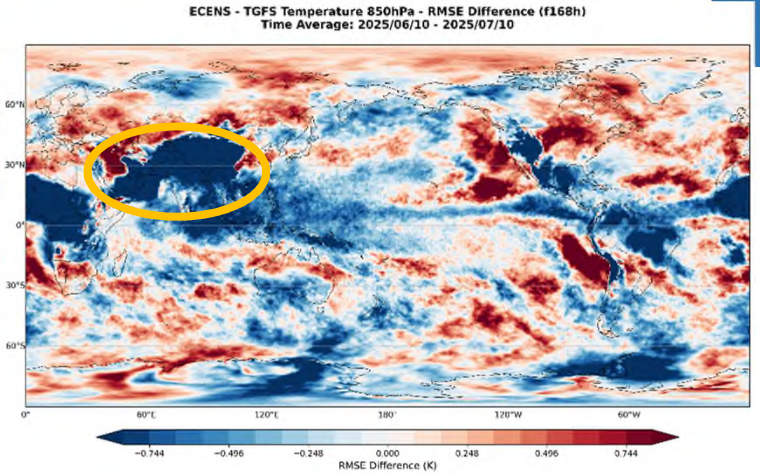
max : 33.9

DIFF

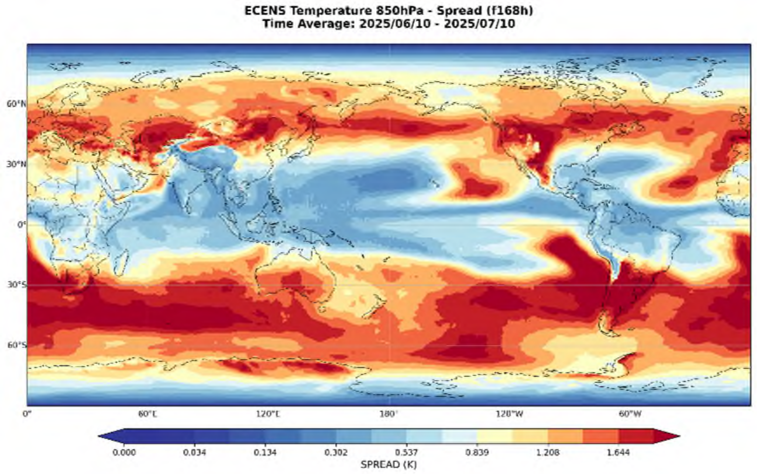
RMSE

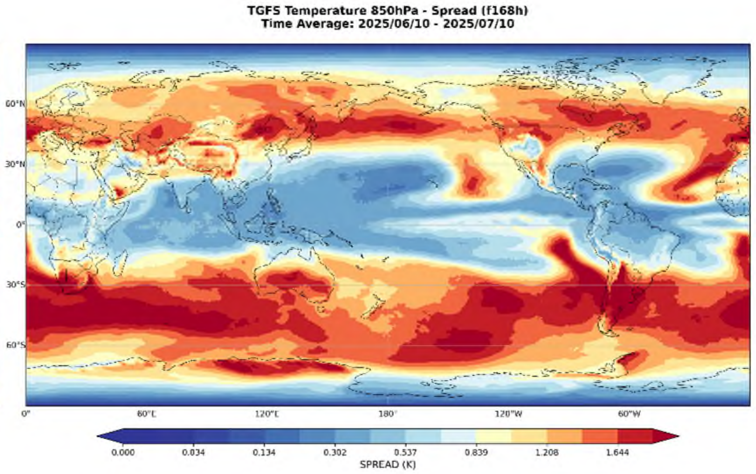


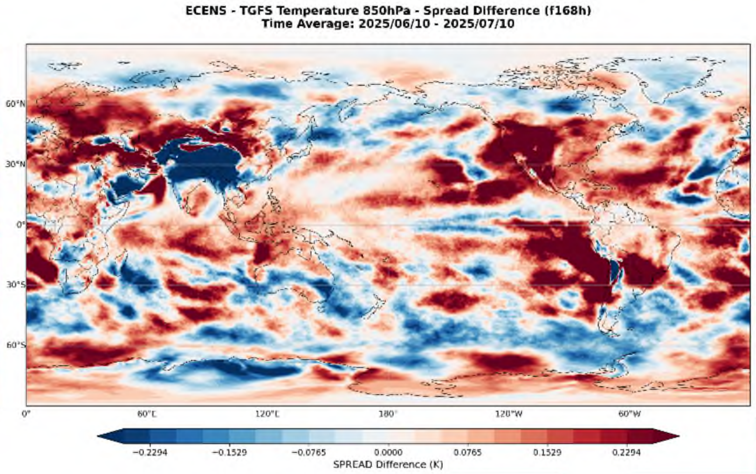




SPREAD







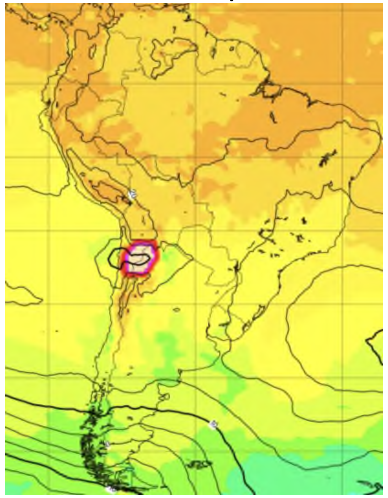
結論與未來規劃

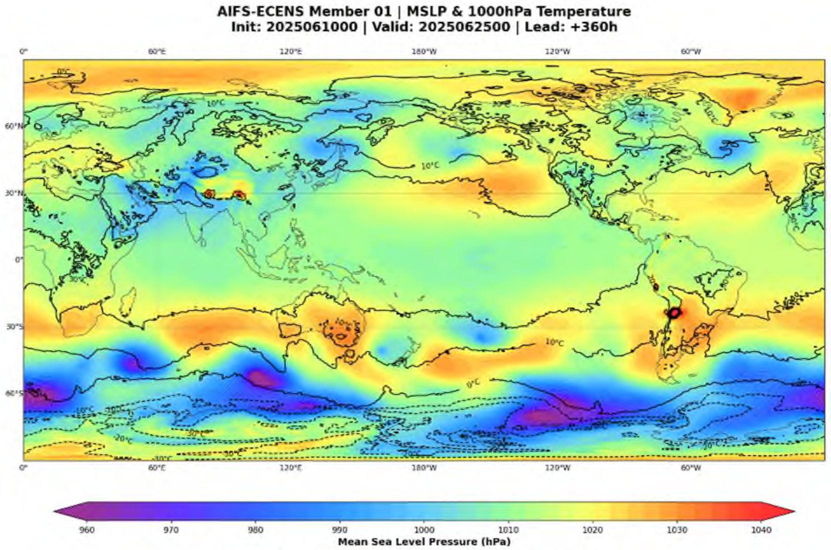
- 分析與小結
  - 目前AIFS-ENS使用TGFS系集初始場的實驗可能存在的問題
    - EC模式初始場和TGFS模式初始場中地形下外插的處理方式不同，導致地形下初始資料有很大的差異。
    - 部分輸入變數，需再檢查其正確性，例如： total column water、soil temperature。
- 未來規劃：
  - 發展基於第 2 代模型的 MLWP 全球系集預報系統。
  - 持續評估使用 TGFS 系集資料同化分析場作為初始場。
  - 妥善介接本署既有作業環境、後處理流程。
  - 跟隨國際發展，嘗試涵蓋展期 (3 ~ 6 週) 預報。

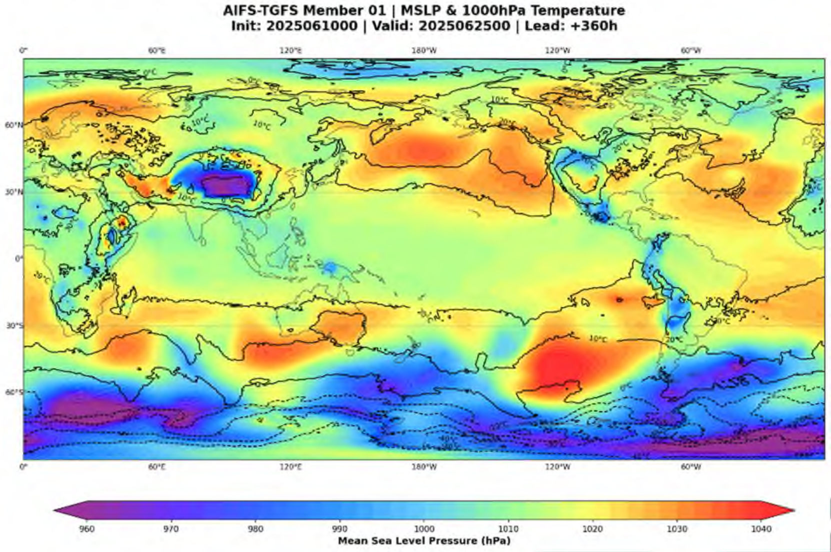
The End

- Thank you for your attention

Known AIFS ENS Forecasting Issues

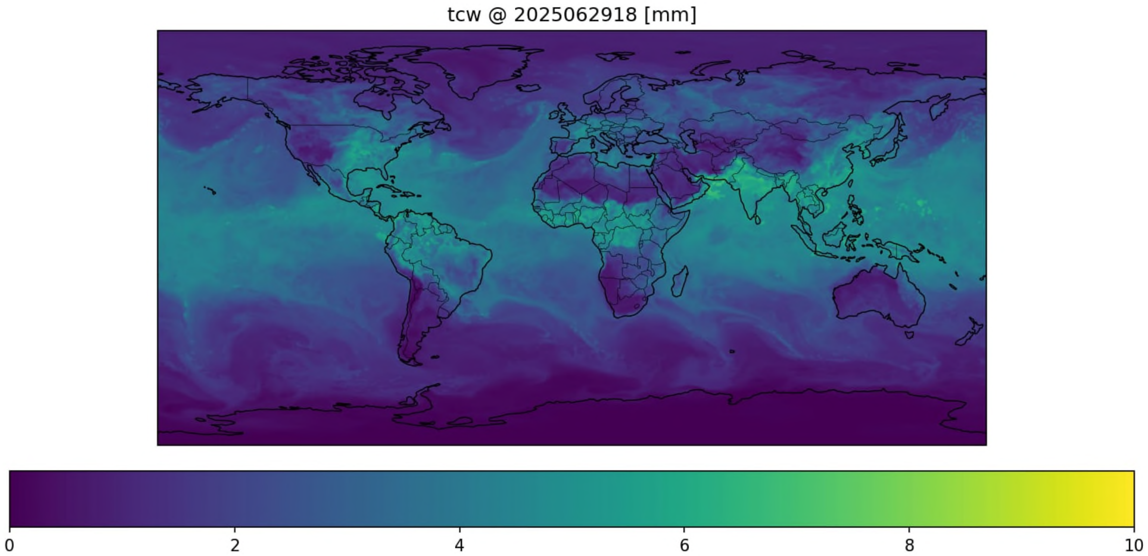
Field /title	G1. Artefacts at long lead times
Description	At long lead times, particularly beyond 10 days, unphysical artefacts can emerge in the model, particularly under areas of high elevation. These are particularly visible for mean sea level pressure and temperature at 1000hPa.  1000hPa temperature artefact beneath the surface of the Andes at 360 hours into the forecast. https://confluence.ecmwf.int/display/FCST/Known+AIFS+ENS+Forecasting+Issues



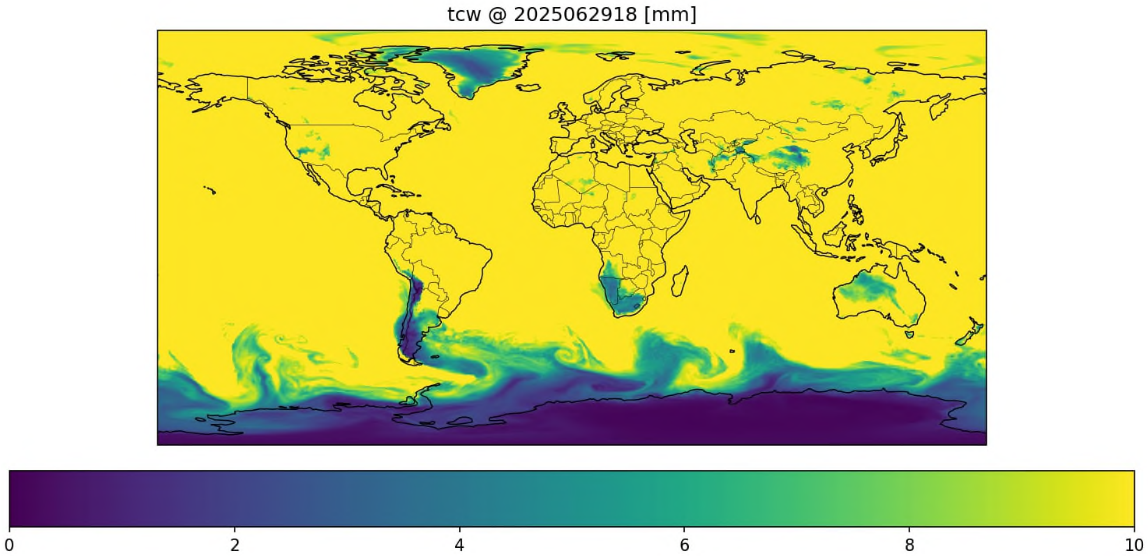


total column water

EC-ENS



TGFS-ENS

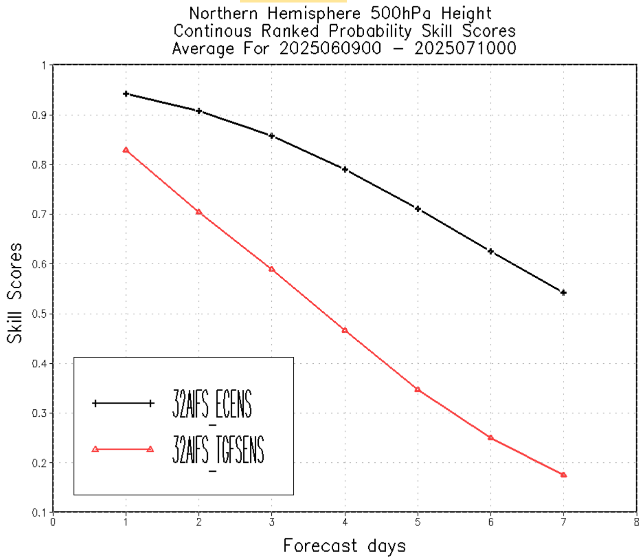


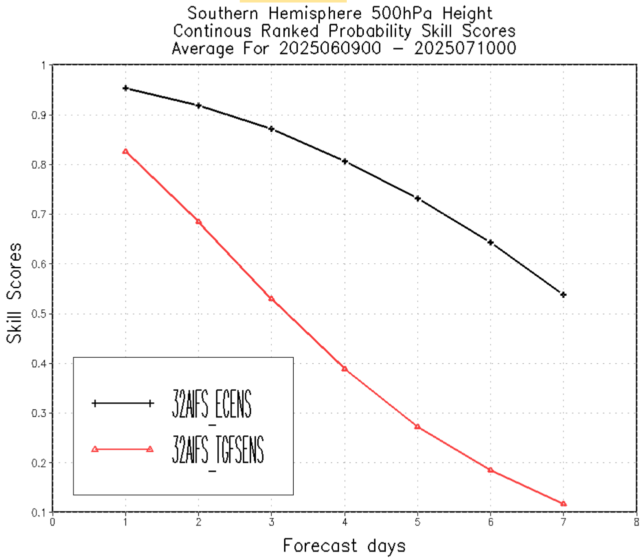
綜觀尺度校驗
- CRPSS (Continuous Ranked Probability Skill Score)

NH

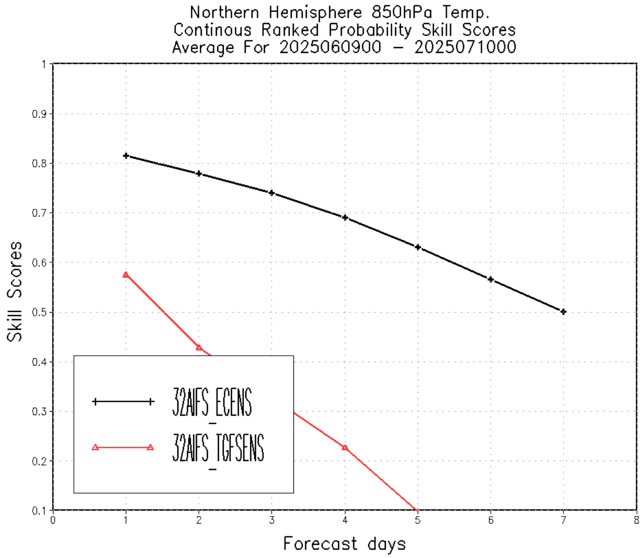
SH

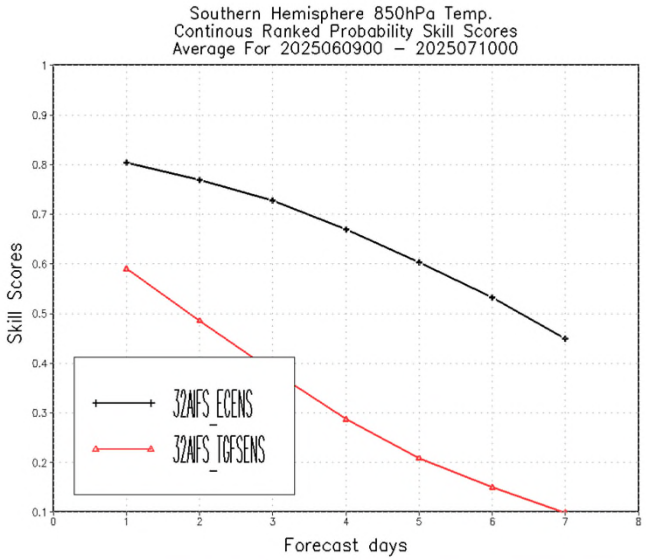
500 hPa 高度場





850 hPa 溫度場





綜觀尺度分析
- RMSE&SPRD U850 F000

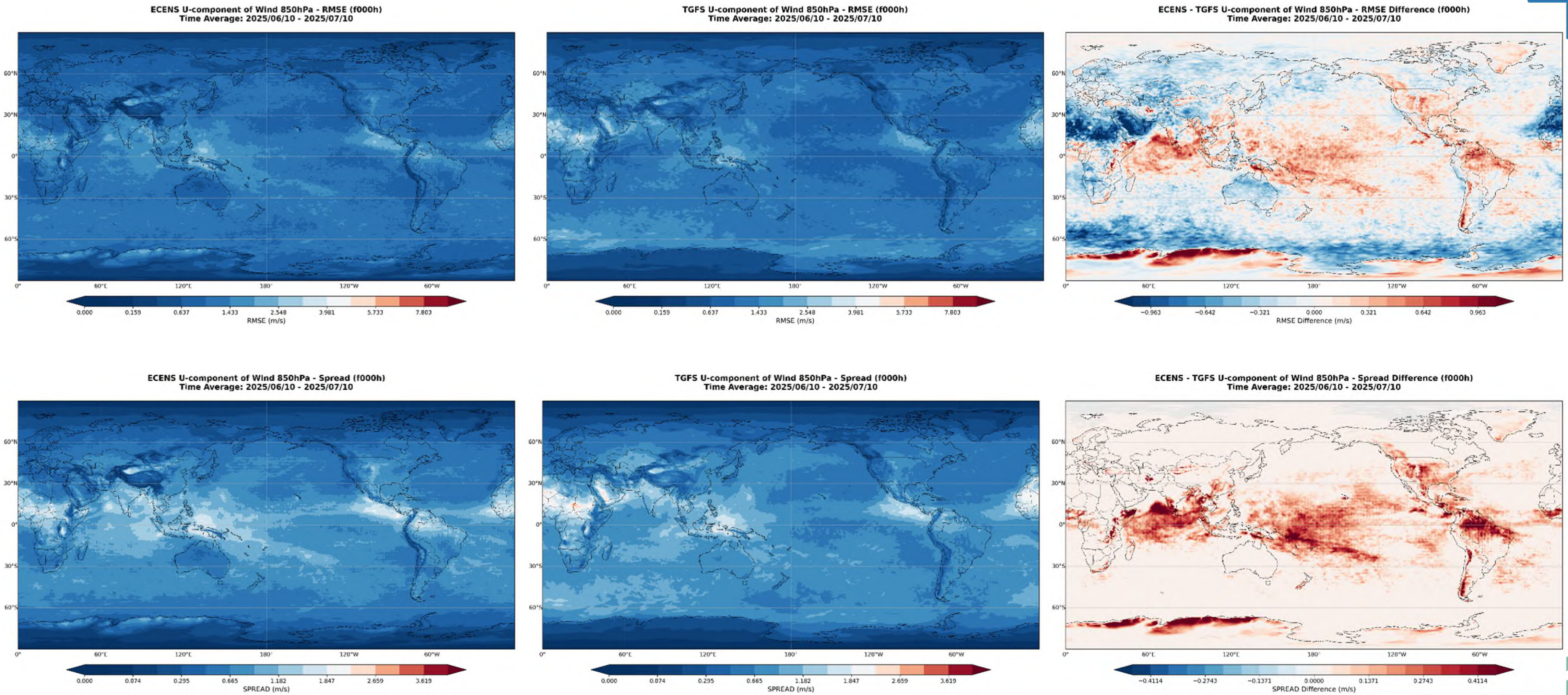
EC-ENS

TGFS-ENS

DIFF

RMSE

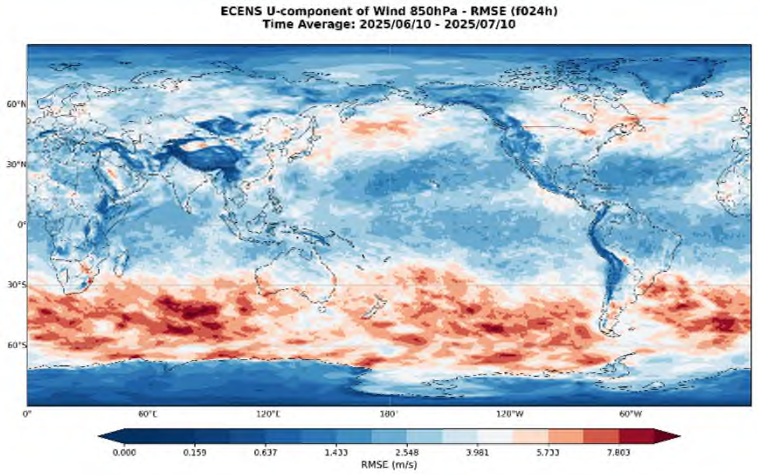
SPREAD

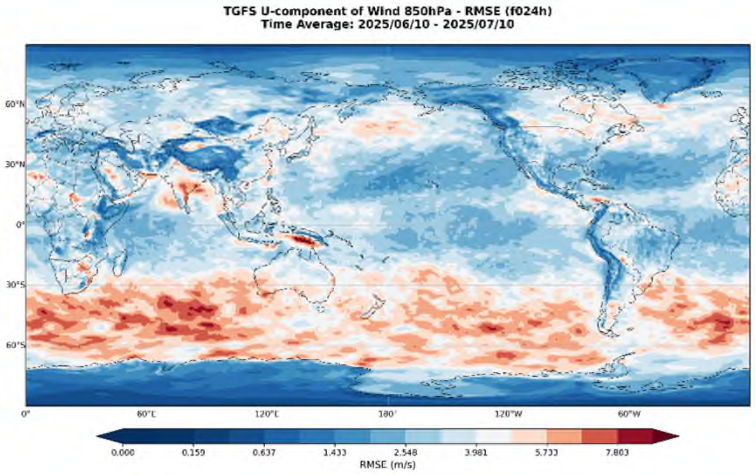


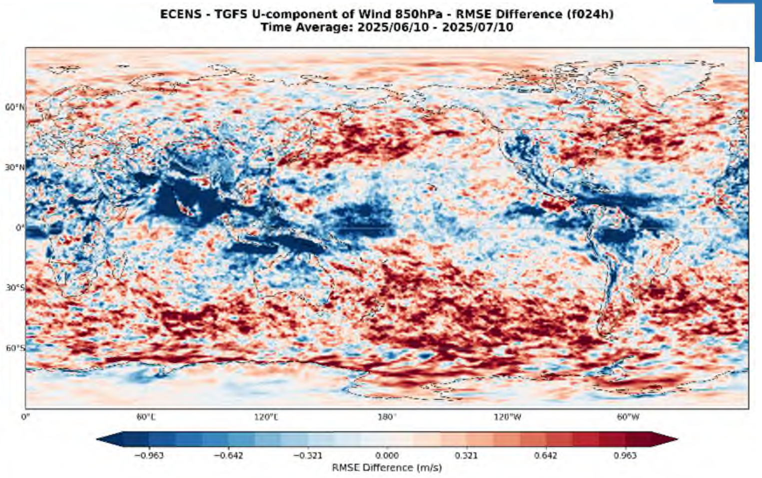
綜觀尺度分析
- RMSE&SPRD U850 F024

EC-ENS | TGFS-ENS | DIFF

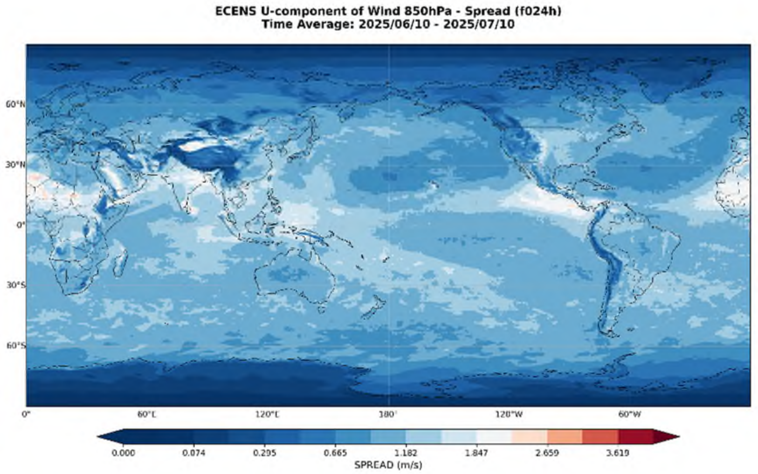
RMSE

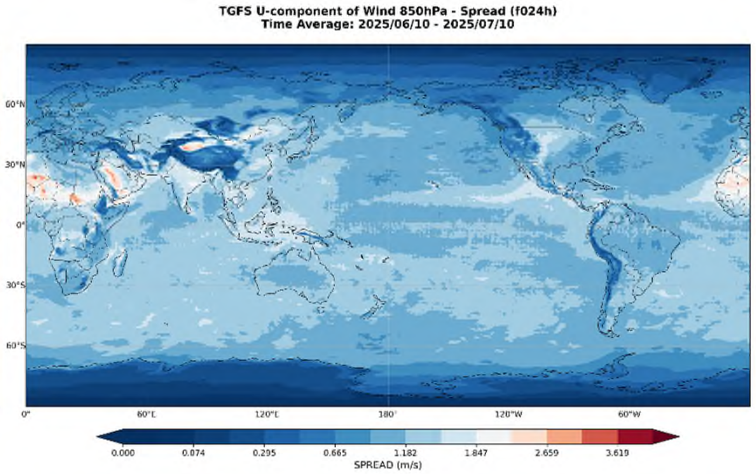


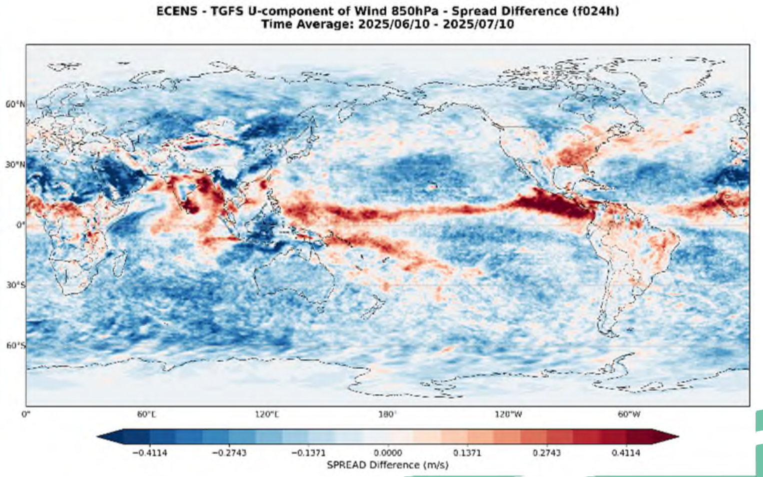




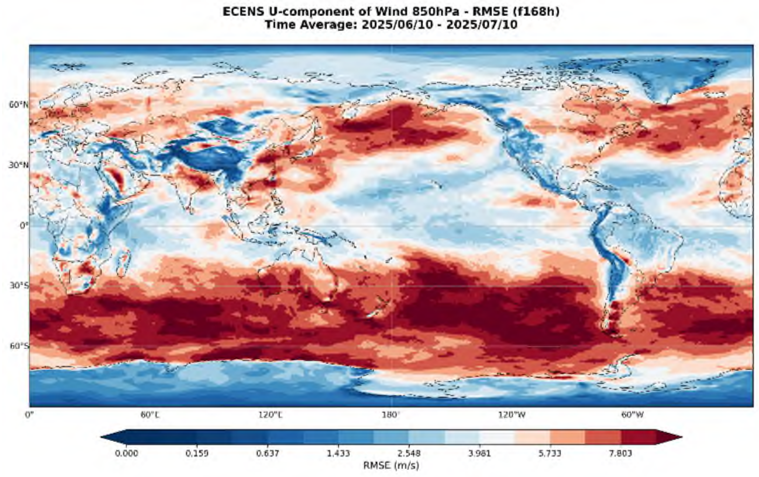
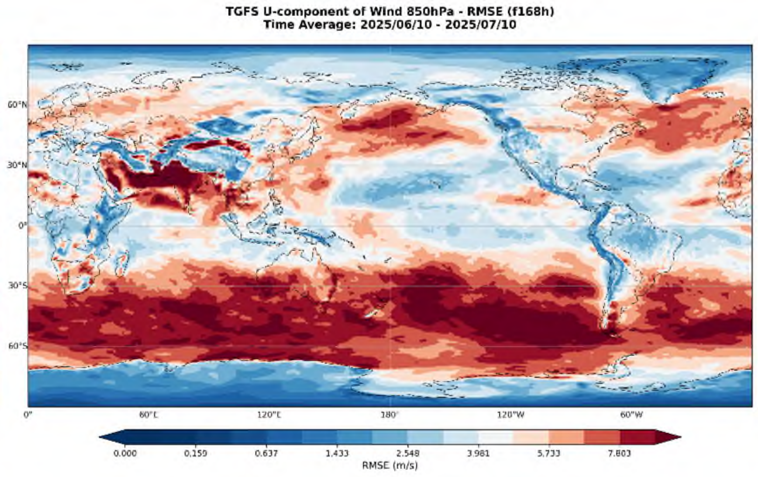
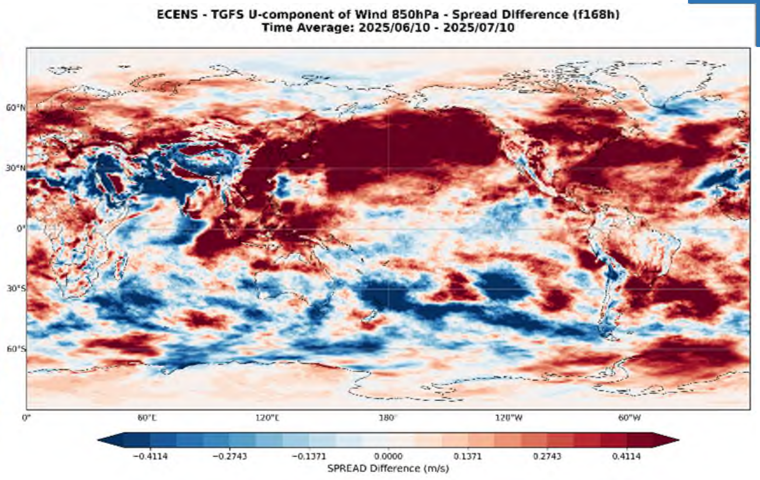
SPREAD







綜觀尺度分析
- RMSE&SPRD U850 F168

	EC-ENS	TGFS-ENS	DIFF
RMSE			
SPREAD