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National Taiwan University Ocean Center

交通部中央氣象署 Central Weather Administration

IONTU

CODA Lab

應用海洋資料同化於全球海氣耦合模式展期預報之初步評估

謝銘恩[1] 曾喜絃[13] 李崇瑋[13] 邵允銓[12] 曾于恒[12] 陳建河[13]

[1] 國立臺灣大學海洋中心 [2]國立臺灣大學海洋研究所 [3]中央氣象署海象氣候組

中央氣象署114年天氣分析與預報研討會

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大綱

- 研究目的
- 模式簡介
- 實驗結果校驗
- 總結與未來工作

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研究緣起

中央氣象署「智慧海象環境災防服務」計畫（110-115年）

四大目標：

(一) 精進海域海象監測，增進海上災害之分析與預警能力

(二) 強化沿岸海氣象監測，擴大海域海氣象變化監測範圍

(三) **發展海域海象預報技術**，打造臺灣地區較安全的海域活動環境

(四) 推動智慧海象服務，建立一站整合式科技智慧雲端海象服務

(1) **發展動力耦合降尺度海象氣候預報系統**

(2) 建構環島異常波浪預警系統

(3) 完善海域風能預報系統

國際海象氣候預報系統發展趨勢： 全球至區域尺度整合各預報系統以提高準確度作業化海氣耦合模式

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新一代海氣耦合模式

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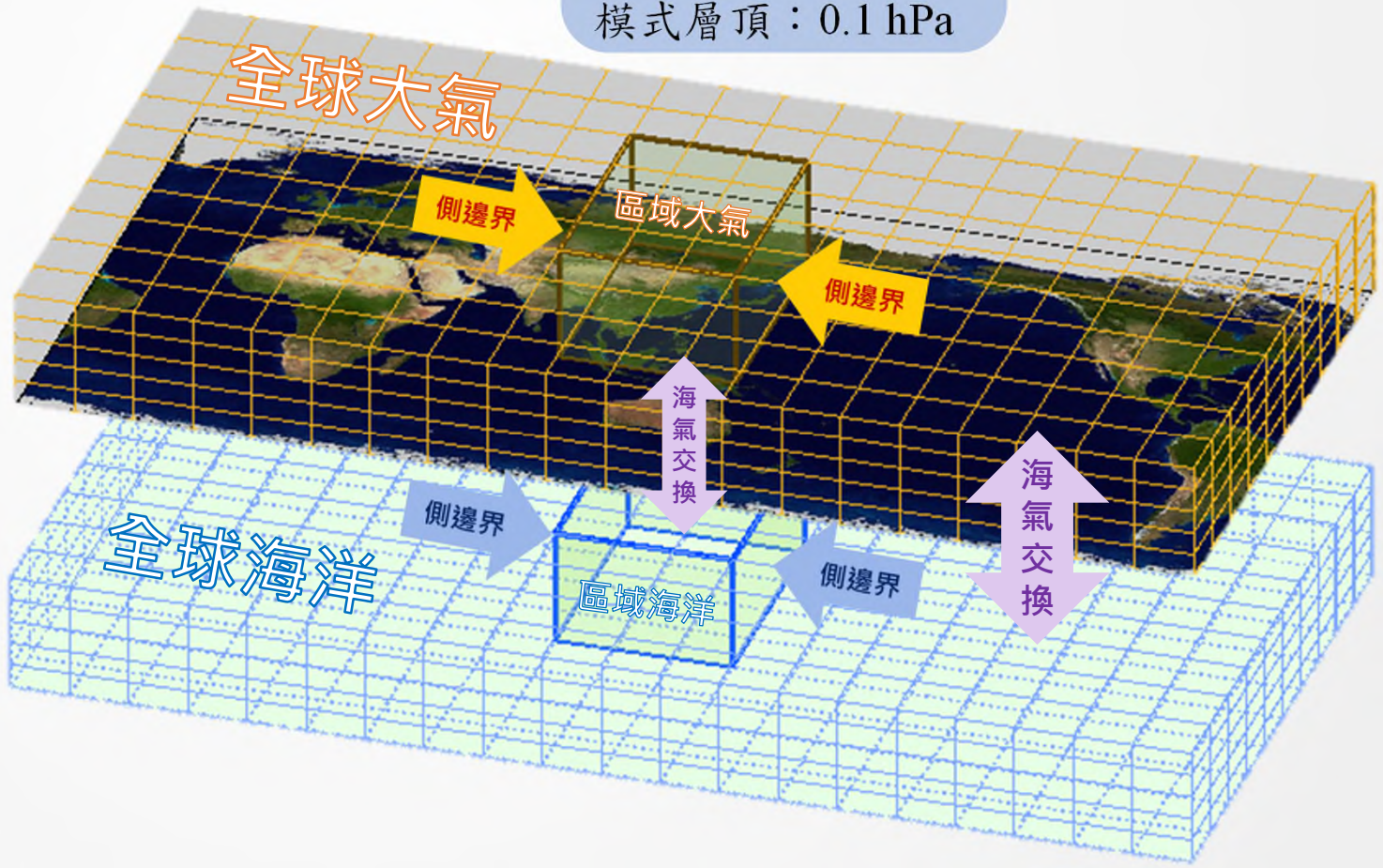
全球大氣模式
CWAGFS-Tco383L72
解析度：**28 km**
垂直層：72
模式層頂：0.1 hPa

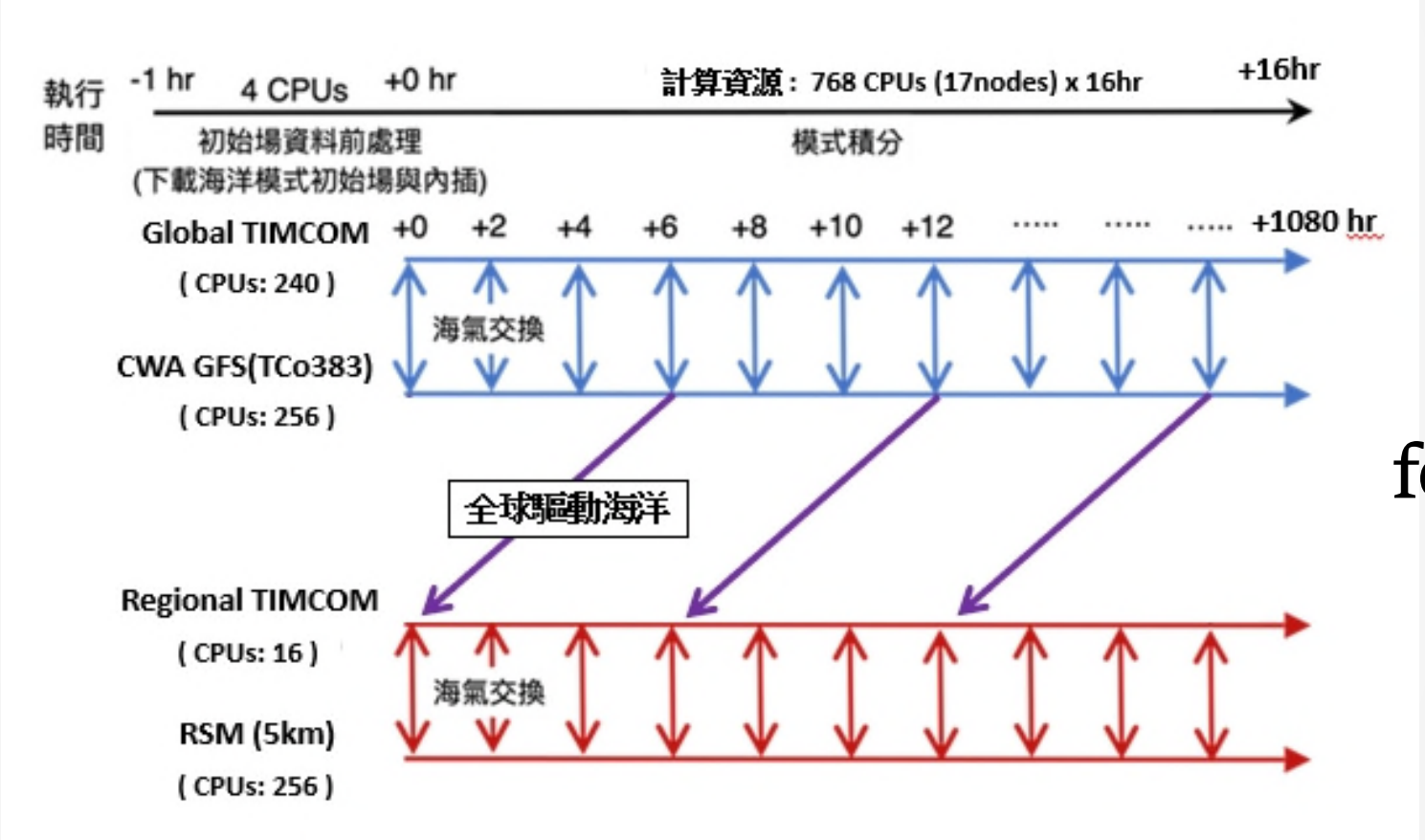
全球/區域海洋模式
TIMCOM
解析度：**25/5 km**
垂直層：55

區域大氣模式
RSM
解析度：**5 km**
垂直層：72
模式層頂：0.1 hPa



作業化耦合系集預報

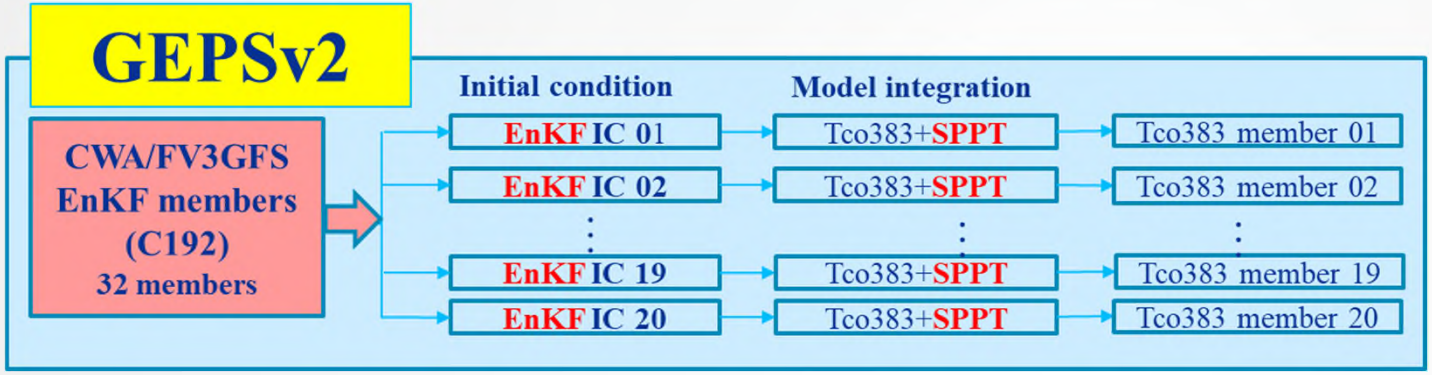
Global Ensemble Prediction System (GEPS)

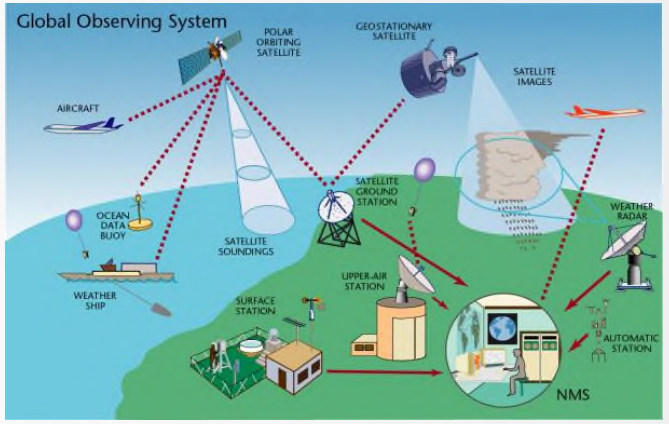


45-d forecast

系集初始化（大氣）

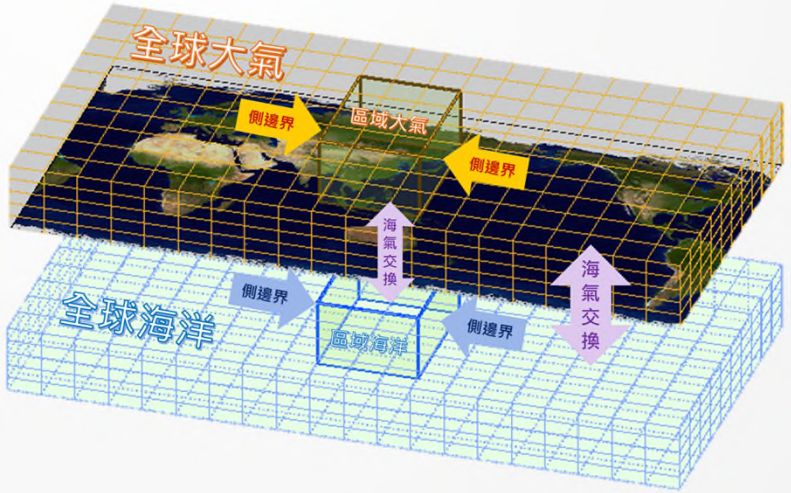
(ATM only)

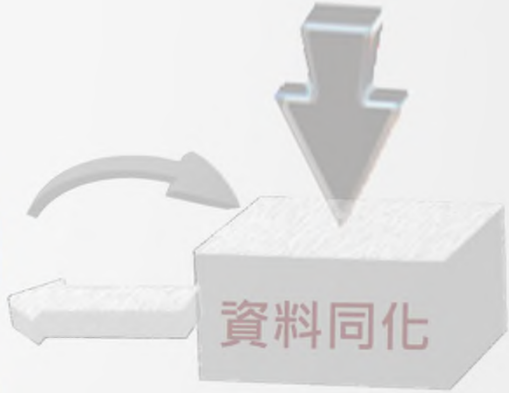




TGFS: operational deterministic 16-d forecast

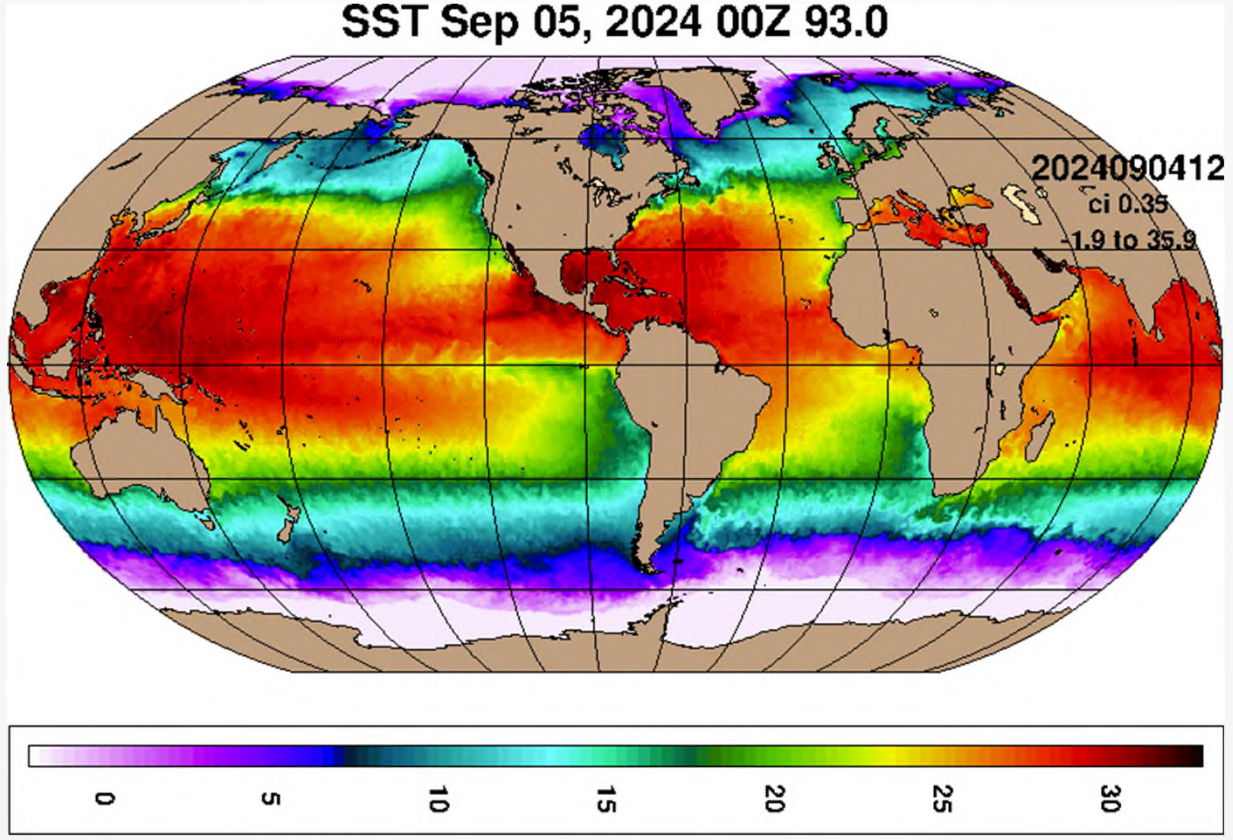
DA: GSI hybrid 4DEnVar





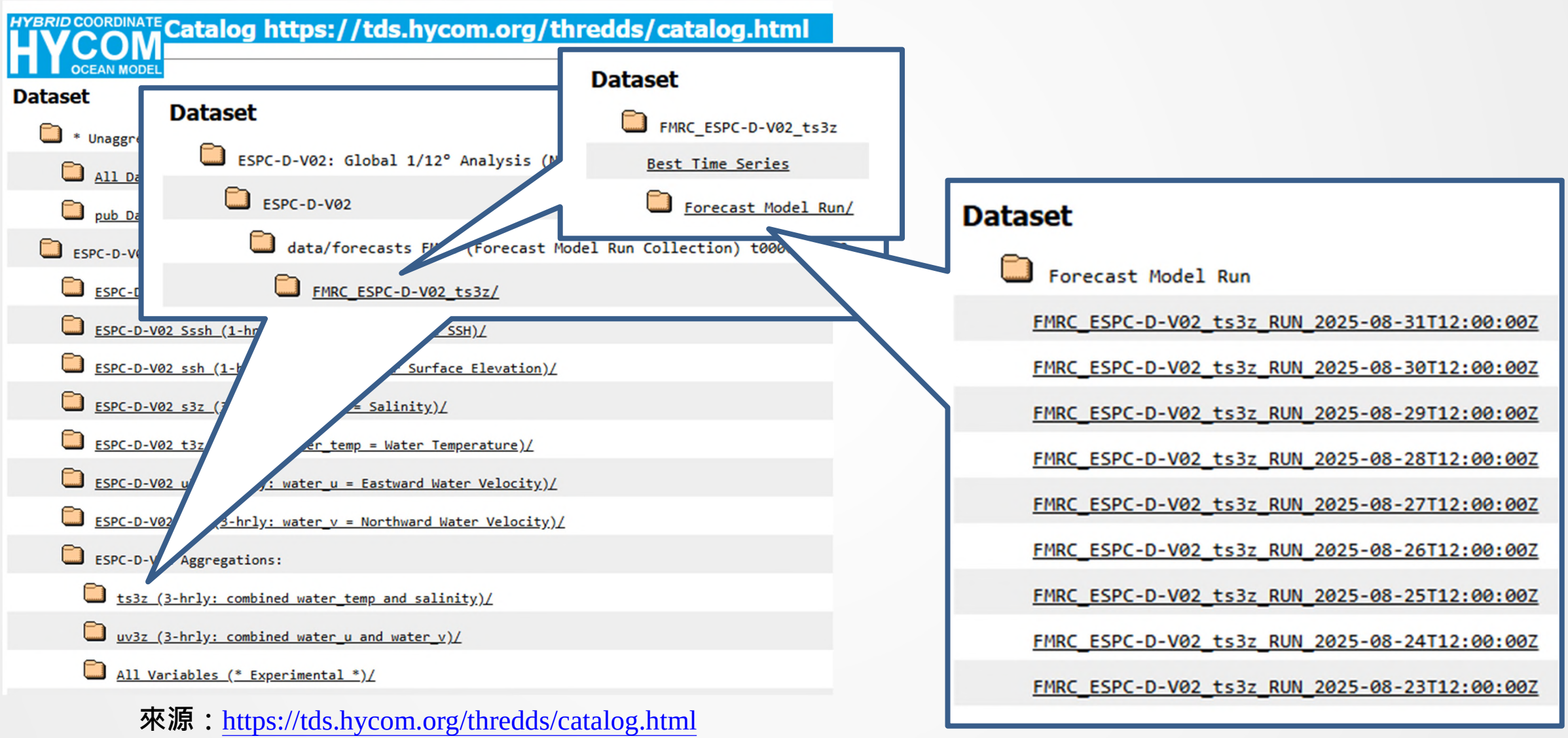
系集初始化（海洋）

HYBRID COORDINATE OCEAN MODEL



來源：https://www.hycom.org/

系集初始化（海洋）



來源：https://tds.hycom.org/thredds/catalog.html

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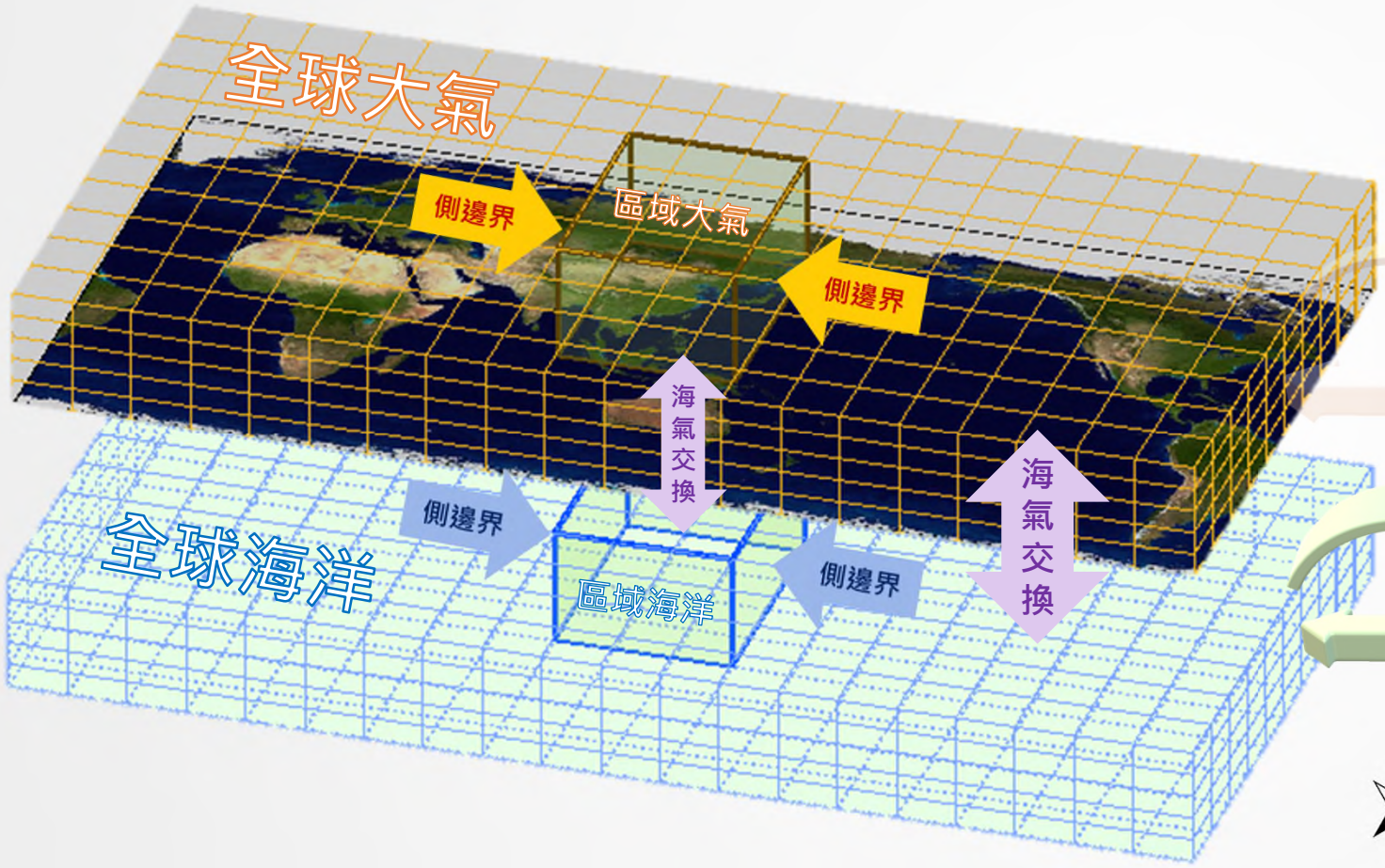
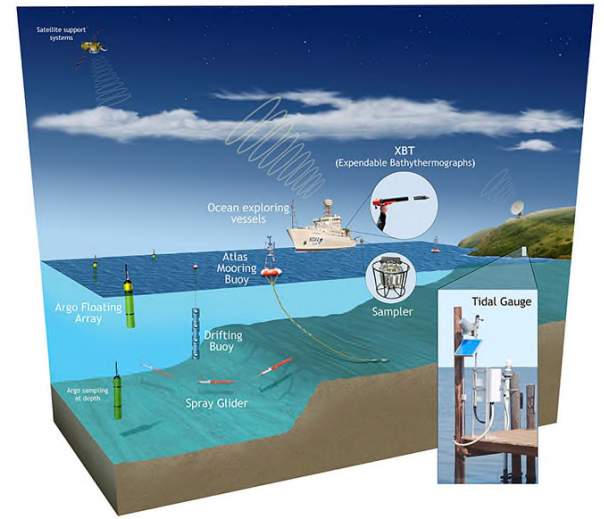
海洋資料同化



資料同化



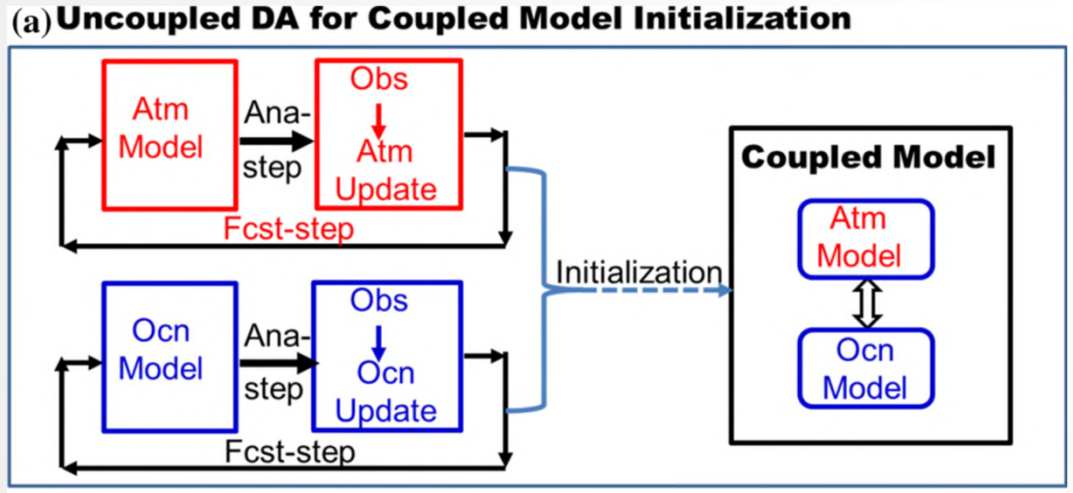
資料同化

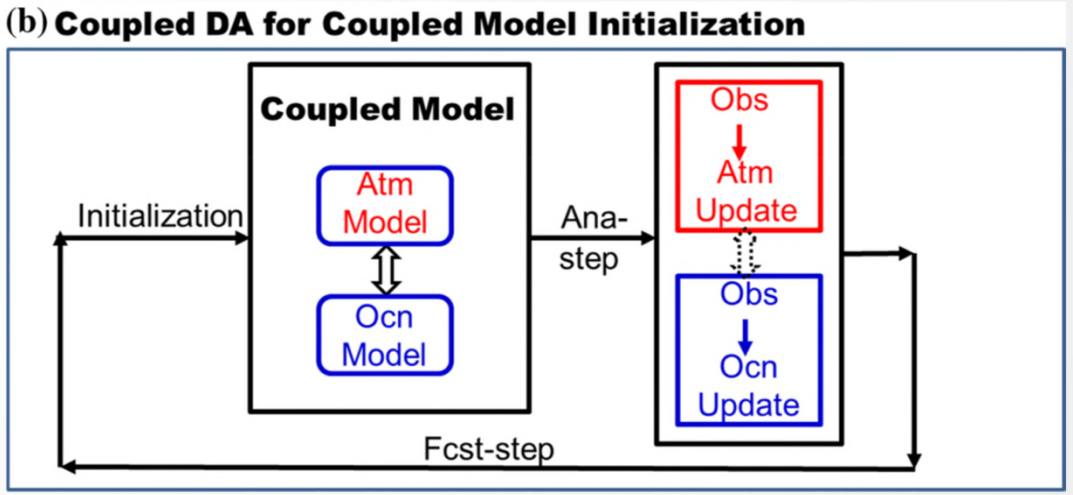
- 改進海洋模式初始場
  建置海洋資料同化系統

耦合模式資料同化方法

Weakly coupled DA

Strongly coupled DA





Zhang et al. (2020)

海洋資料同化

模式	同化方法	同化窗區
NCEP-CFSv3	3D-Var (O)	6h (A/O)、24h (L)
JMA MOVE/MRI.COM-G3	4D-Var(O)、3D-Var (I)	5d (O/I)
EWMWF IFS/SEAS5: NEMOVAR	3D-Var ➠ 3D-Var+EnKF (O)	5d (O)
BOM ACCESS-S1: NEMOVAR ACCESS-S2: EnKF-C	3D-Var ➠ EnOI (O)	24h (O)

各機構的作業同化仍以弱耦合為主，而CWATCO本身無同化（及循環），故 EnKF-C、EnOI為一適當選項

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EnKF-C (https://github.com/sakov/enkf-c)

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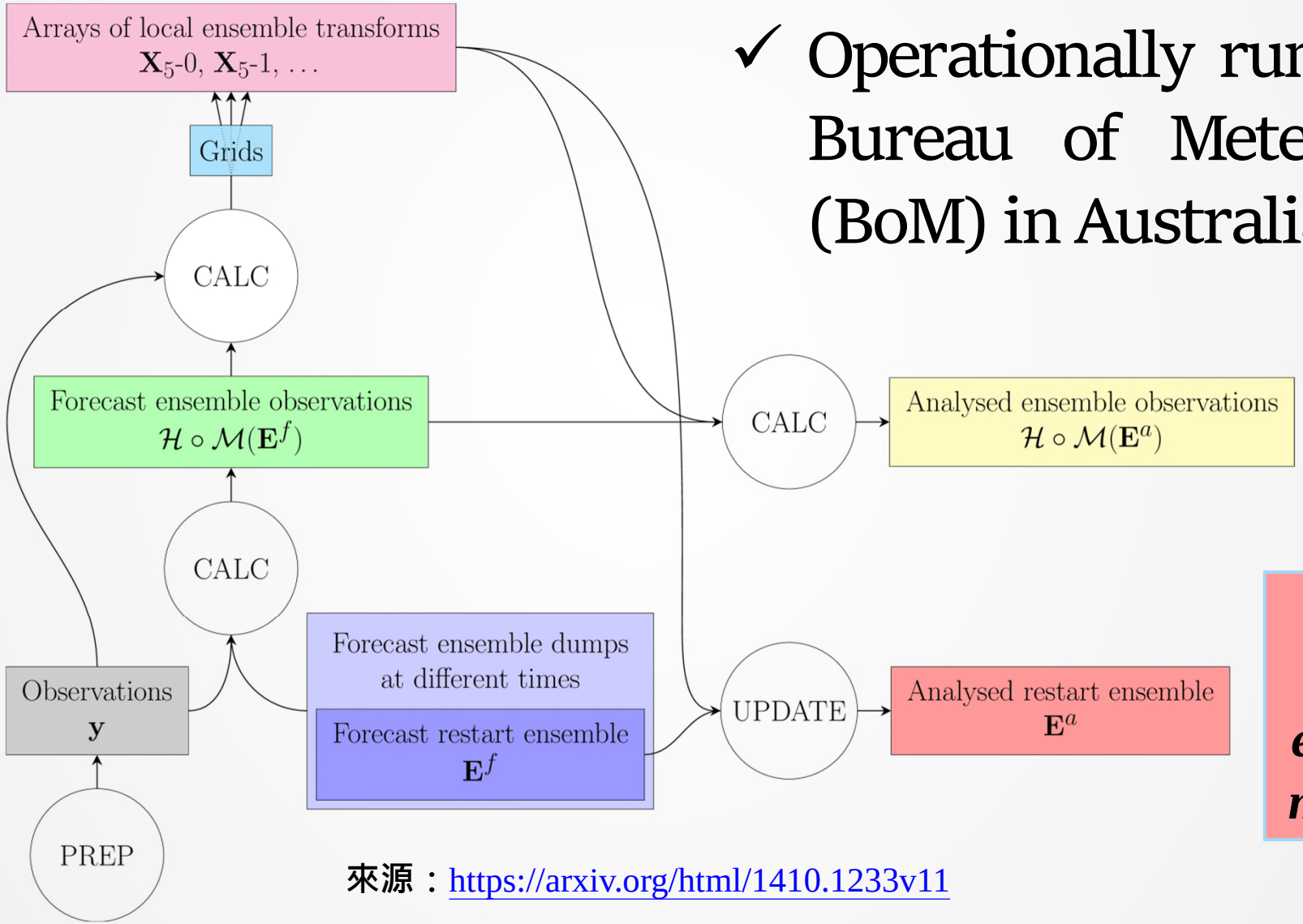
- ✓ Operationally run at the Bureau of Meteorology (BoM) in Australia

Calculates ensemble transforms



Observation processing

Updating forecast ensemble of model states

來源：https://arxiv.org/html/1410.1233v11

EnKF-C (https://github.com/sakov/enkf-c)

$$\mathbf{x}^a = \mathbf{x}^f + \mathbf{K}\left[\mathbf{y} - \mathcal{H}(\mathbf{x}^f)\right]$$

$$\mathbf{E} = \mathbf{x}\mathbf{1}^T + \mathbf{A}, \quad \mathbf{x} = \frac{1}{m}\mathbf{E}\mathbf{1}$$

$$\mathbf{P} = \frac{1}{m-1}\mathbf{A}\mathbf{A}^T$$

EnOI

$$\mathbf{B} \equiv \frac{1}{m-1}\mathbf{A}\mathbf{A}^T$$

$$\mathbf{K} = \mathbf{B}\mathbf{H}^T\left(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R}\right)^{-1}$$

deterministic EnKF

(Sakov and Oke, 2008)

$$\mathbf{A}^a = \mathbf{A}^f - \frac{1}{2}\mathbf{K}\mathbf{H}\mathbf{A}^f$$

$$\mathbf{K} = \mathbf{P}^f\mathbf{H}^T\left(\mathbf{H}\mathbf{P}^f\mathbf{H} + \mathbf{R}\right)^{-1}$$

歷史個案及設定

- 1080-h forecasts initialized at 00UTC in Jan. 2024
- Ensemble members provided by hindcasts from Dec. 2023 to Jan. 2024
- Assimilating observations within 24-h
  - satellite: GHRSST AVHRR MetOp-C L3U SST products
  - T/S profiles: EN4 (https://www.metoffice.gov.uk/hadobs/en4/download-en4-2-2.html)

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同化資料分布

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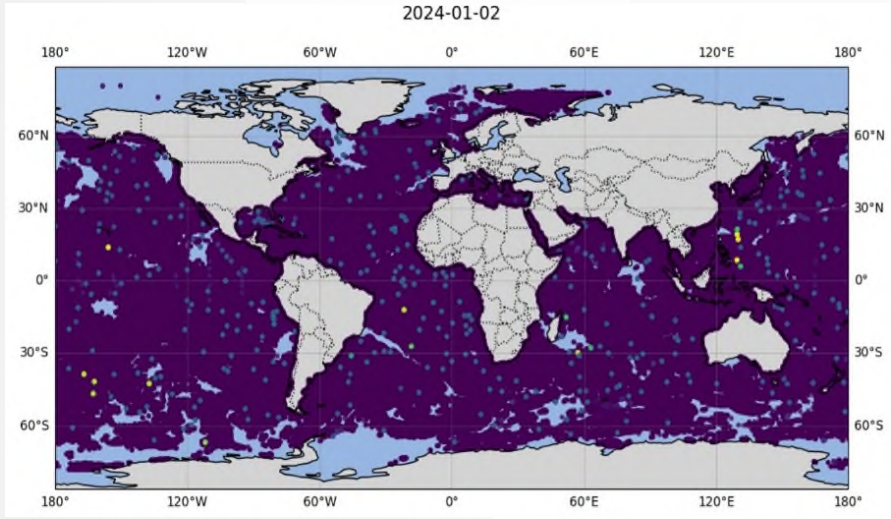
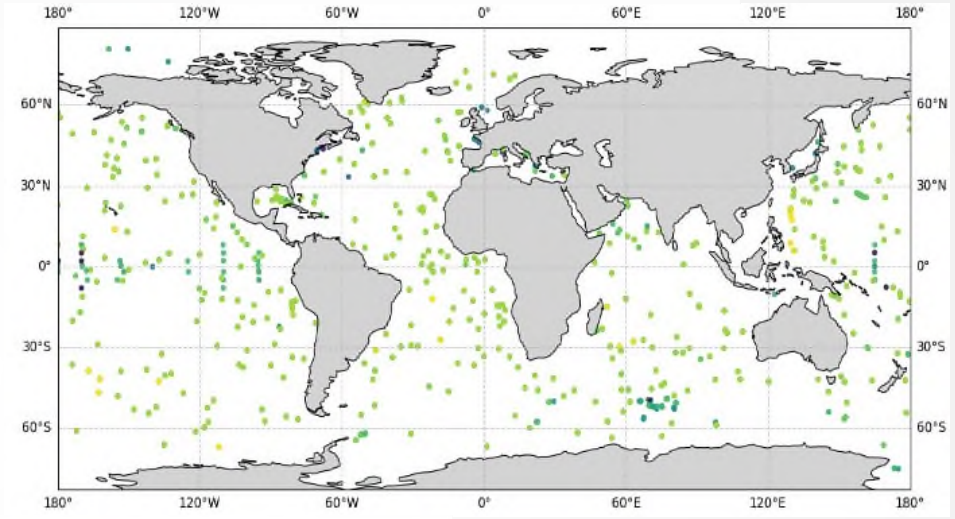
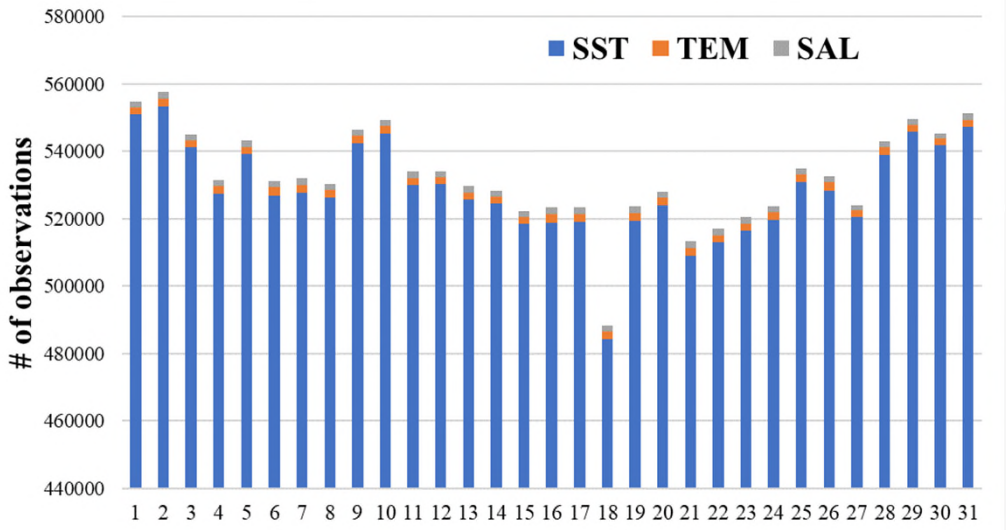
All OBS



T/S Profiles





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校驗：海洋預報（全球）

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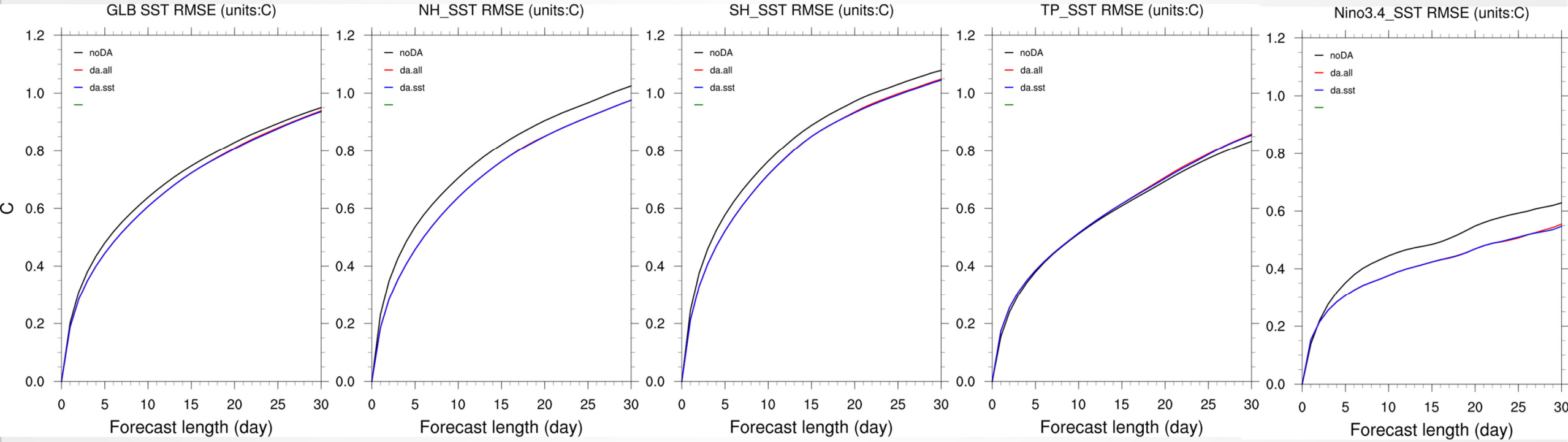

noDA ：無資料同化

DA.sst：僅同化 GHRSST 資料

DA.all ：同化 GHRSST與EN4資料

有作資料同化後的海表溫預報表現較好

DA.sst與DA.all 對海表溫預報的差異不大

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校驗：大氣預報

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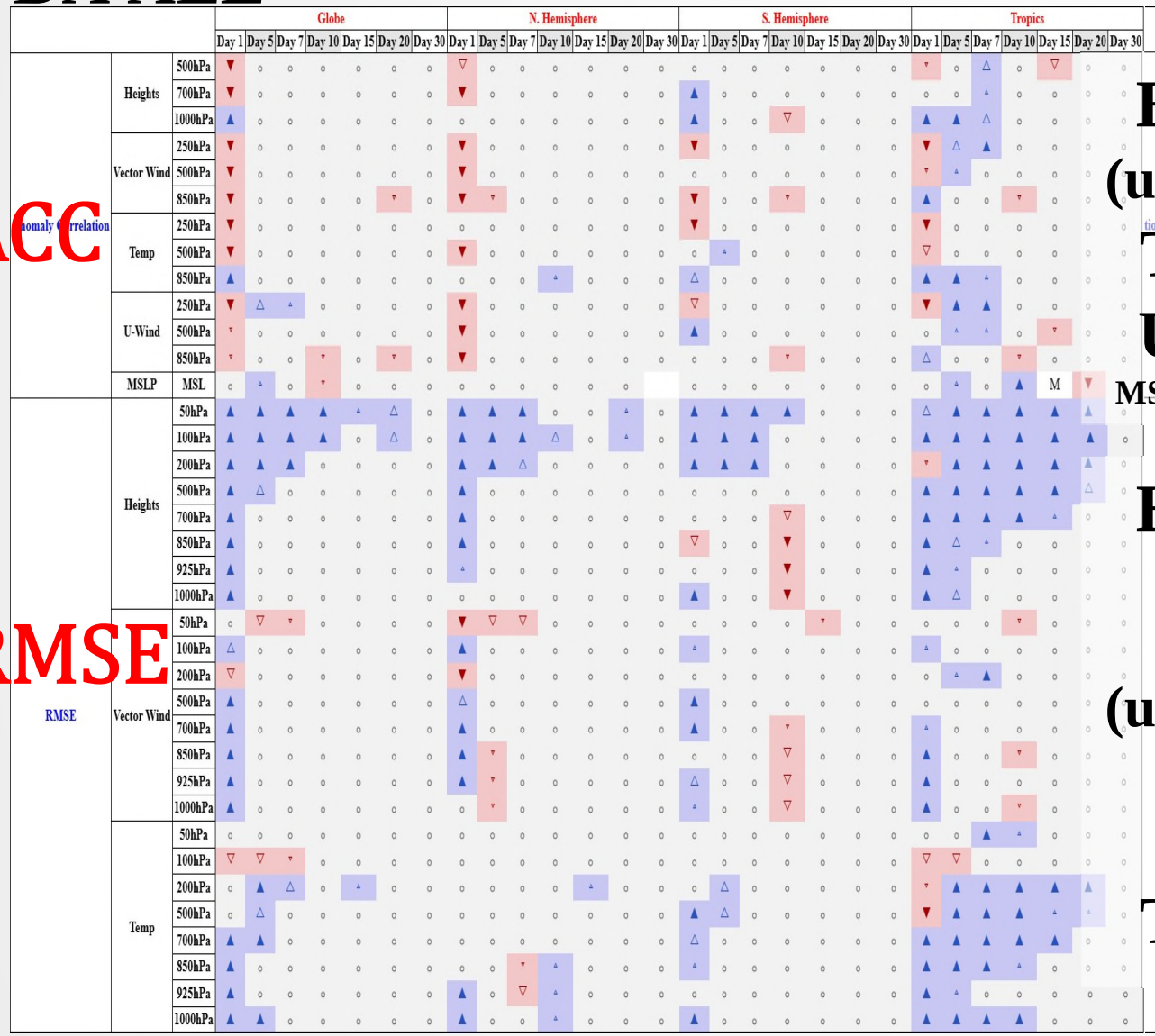
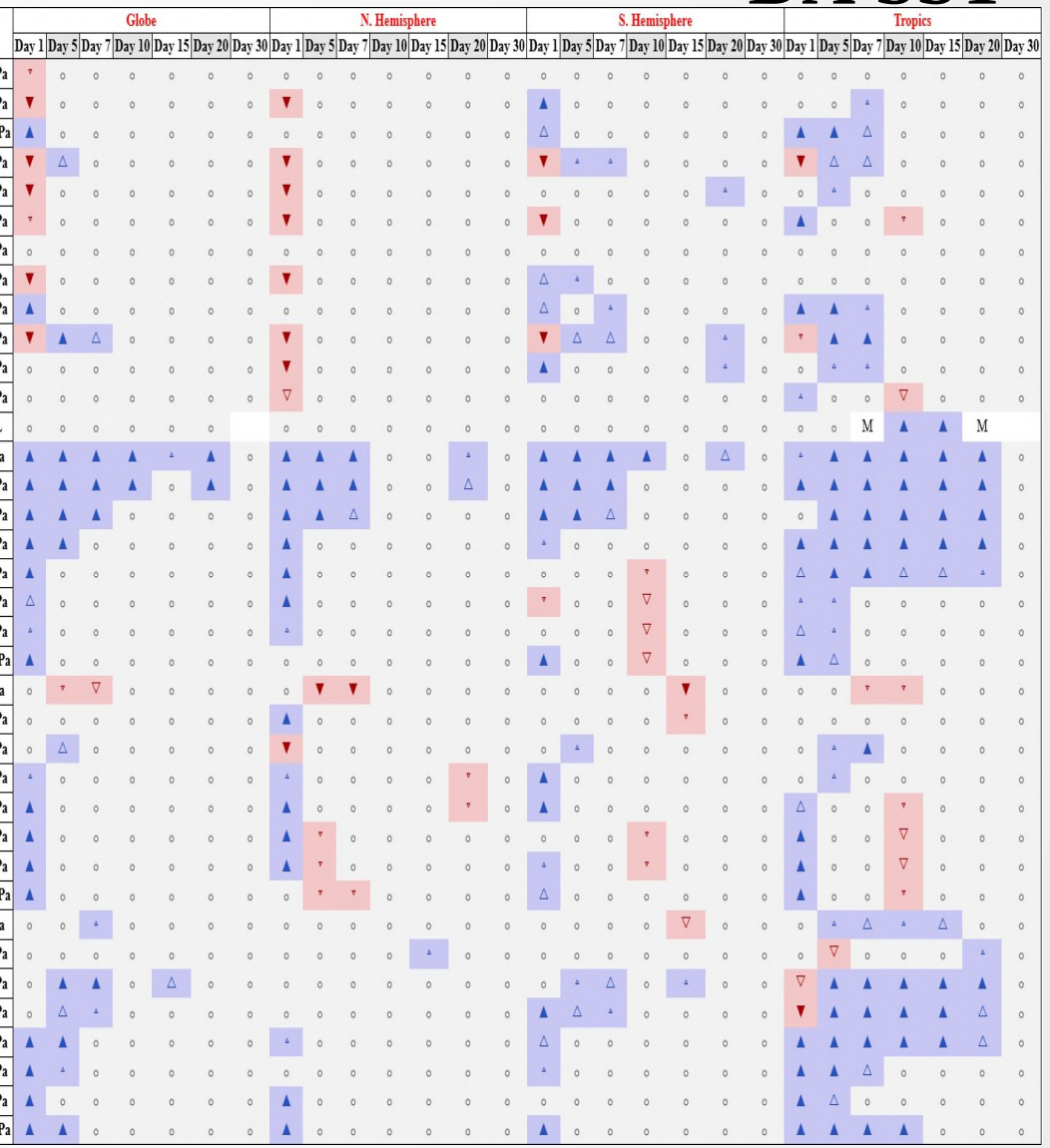
DA ALL



DA SST



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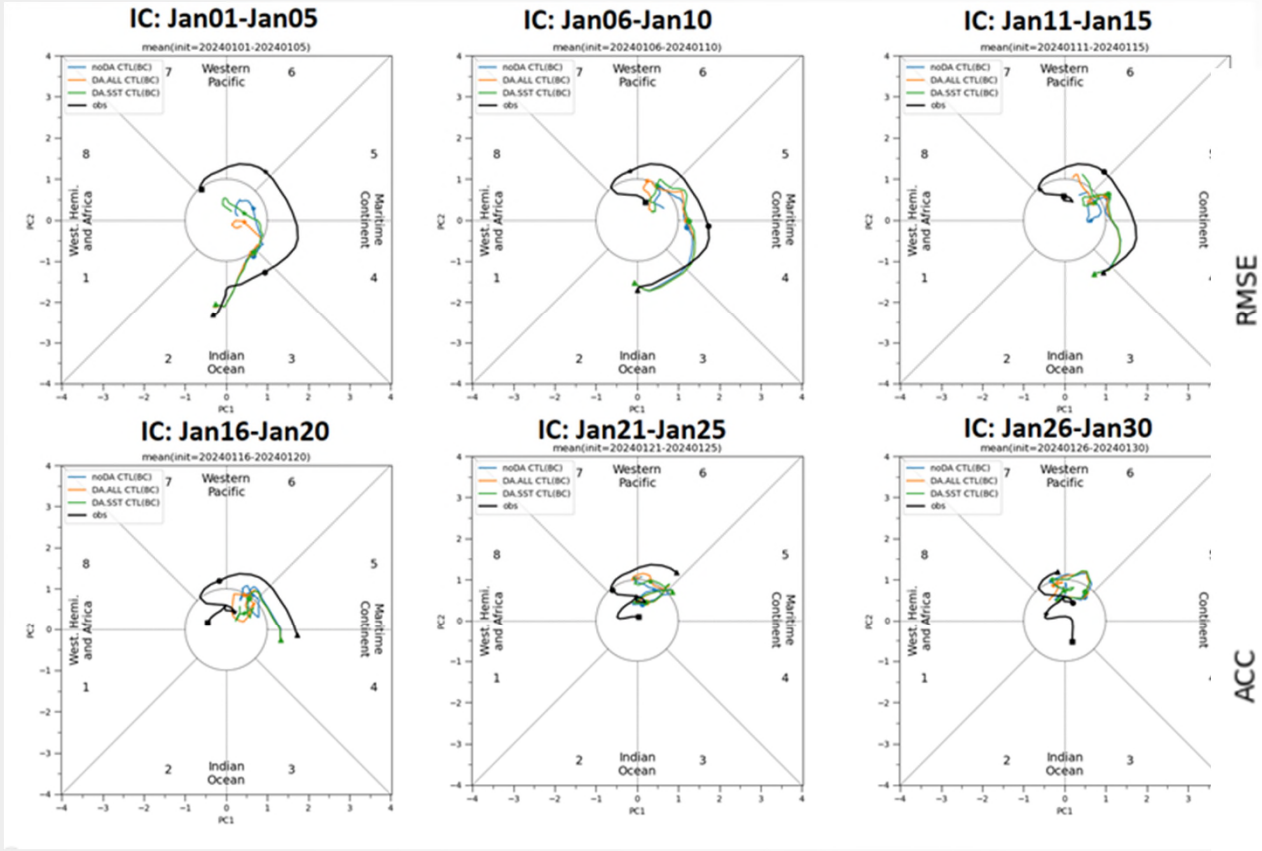
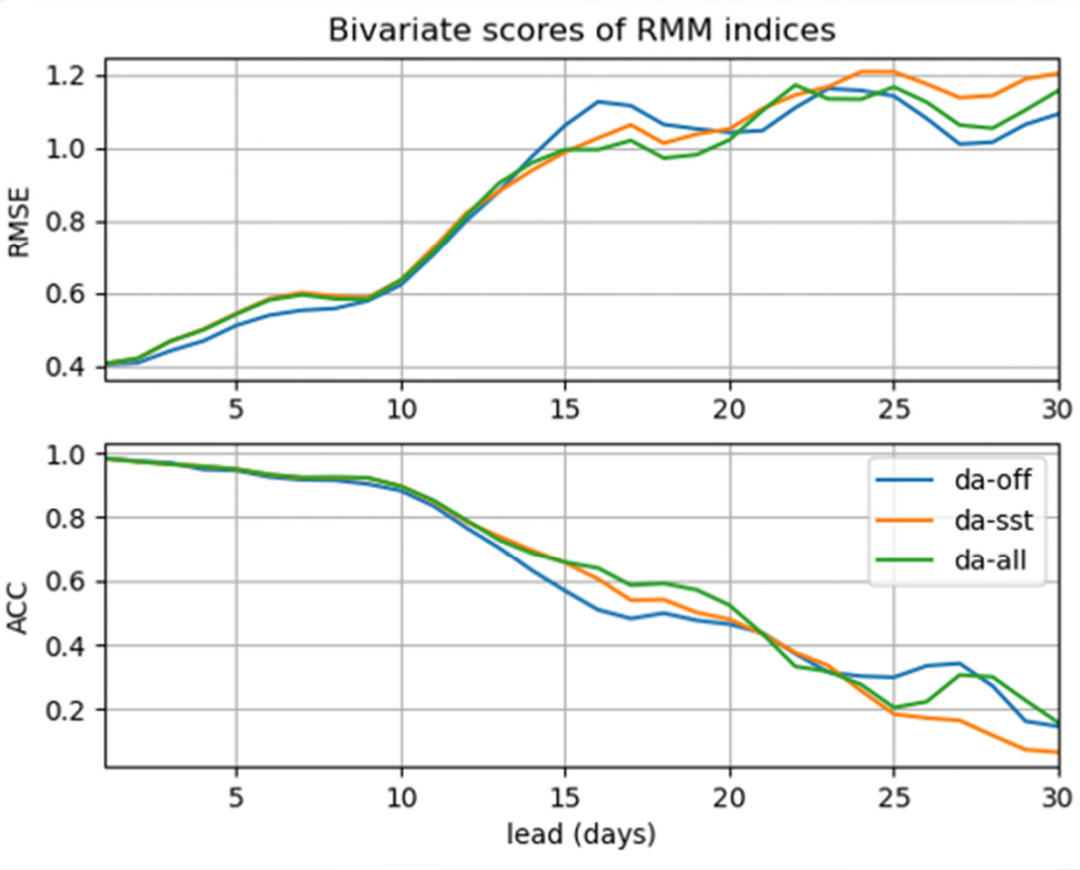
校驗：MJO



OBS **DA all**

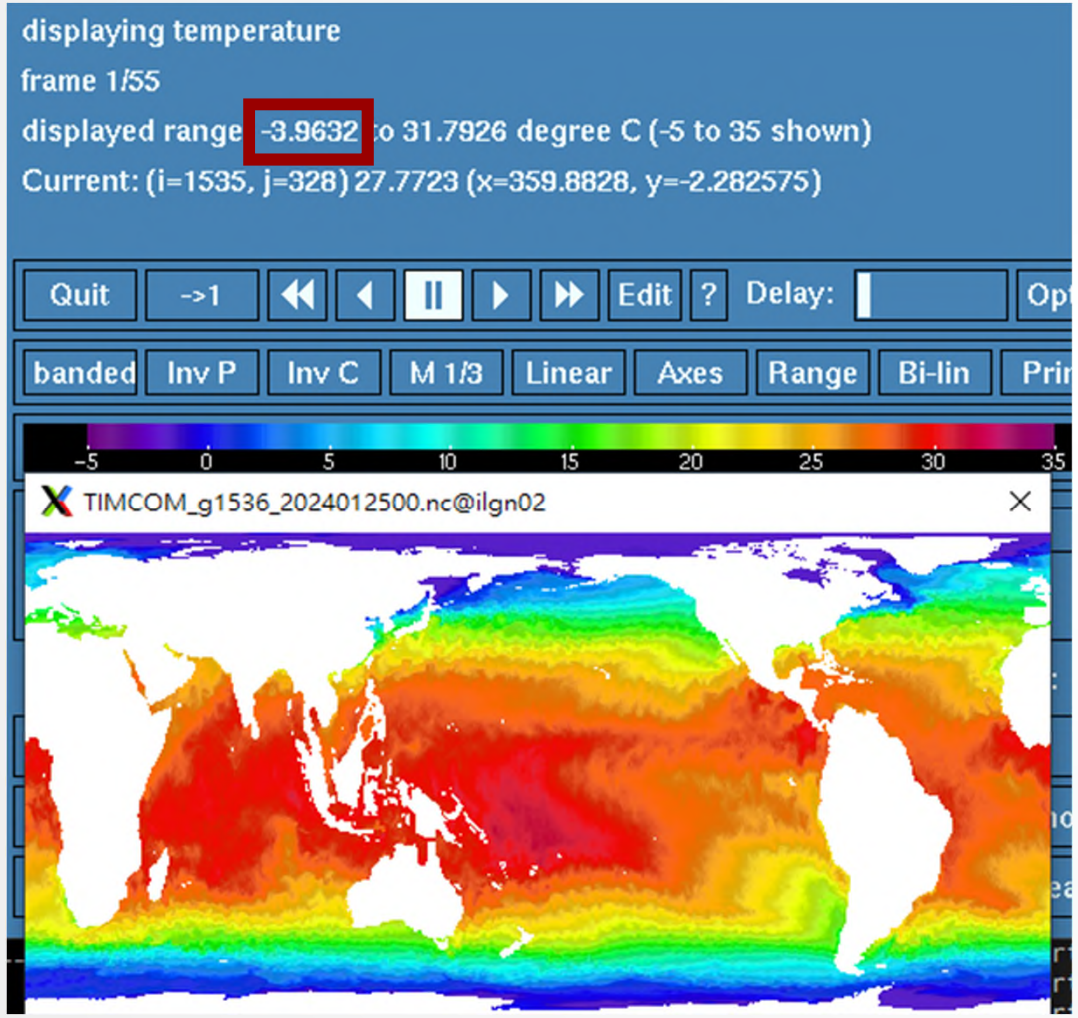
no DA **DA sst**

✓ Smaller RMSE for 13-20 lead

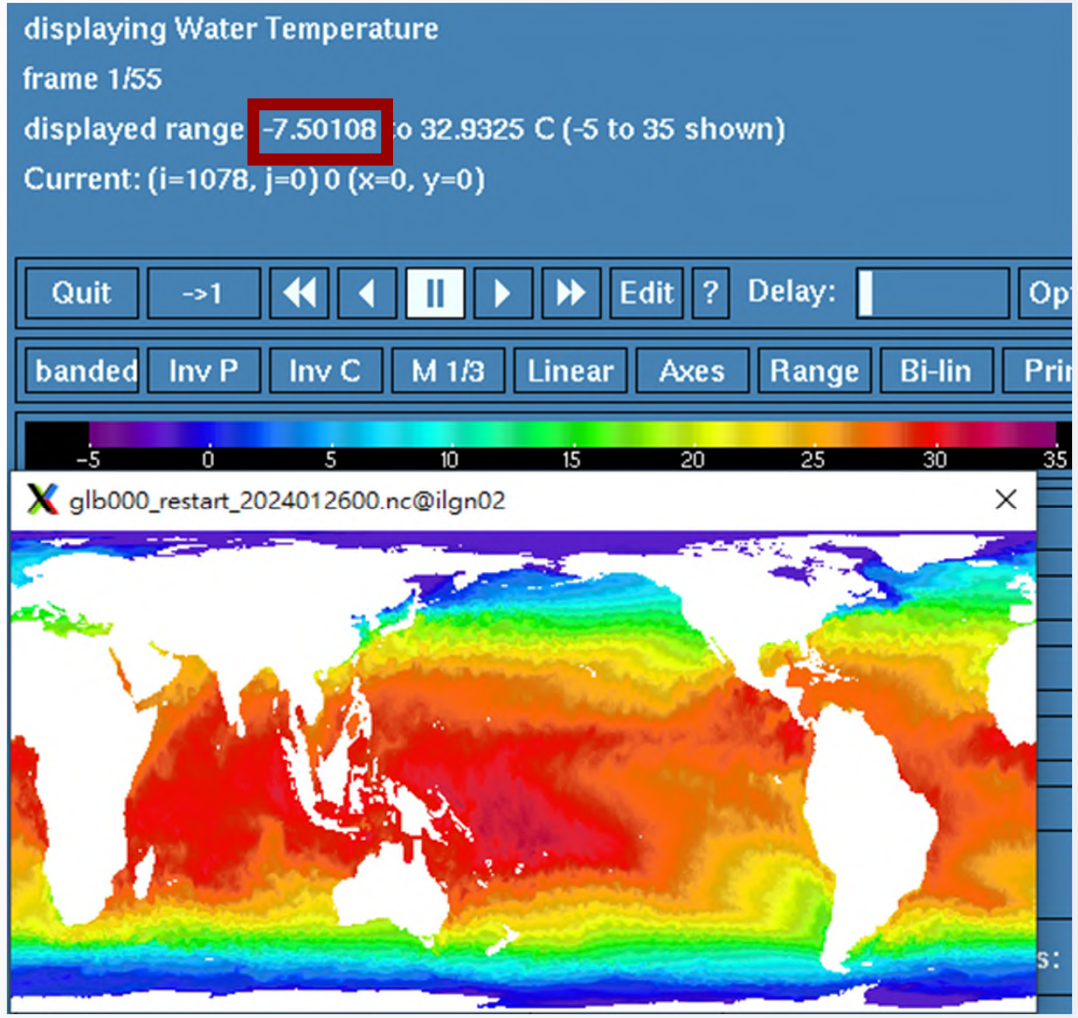


✓ Predictability up to 20-d

IC for the previous 24-h run (DA once)



24-h restart with DA (DA twice)



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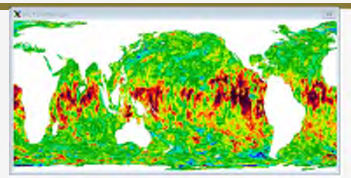
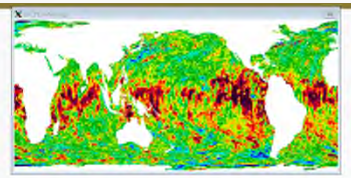
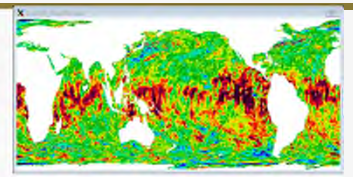
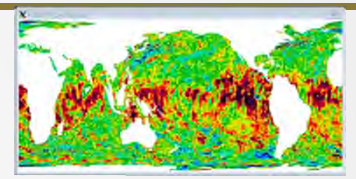
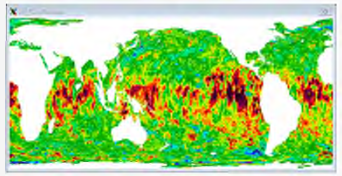
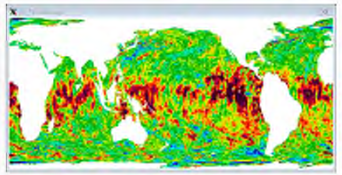
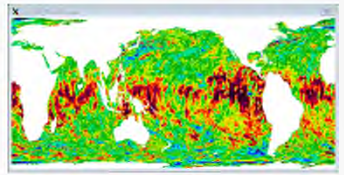
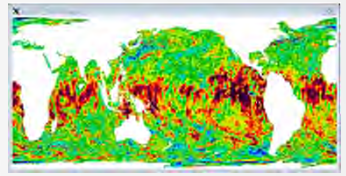
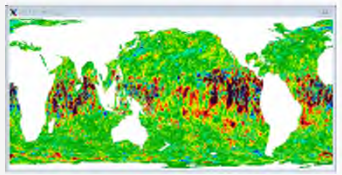
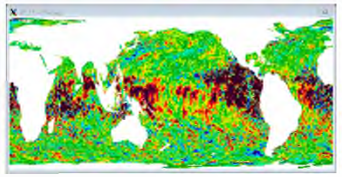
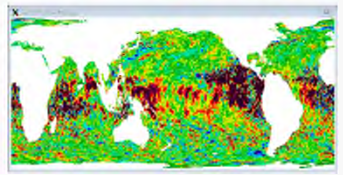
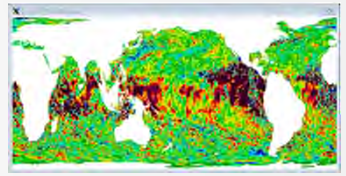
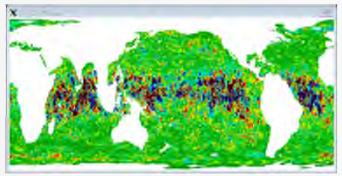
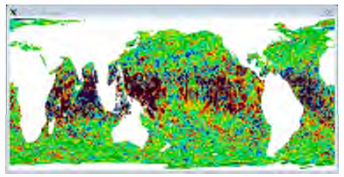
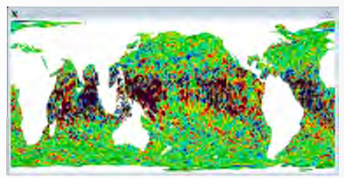
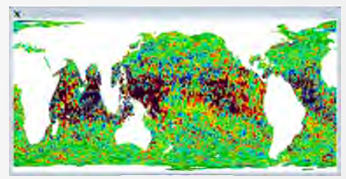
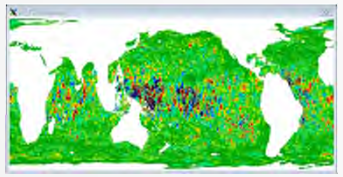
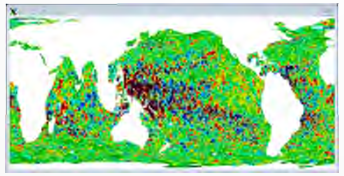
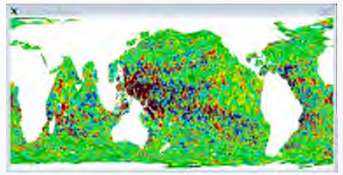
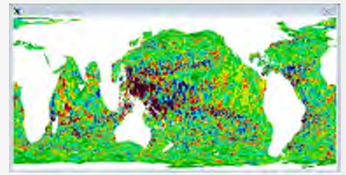
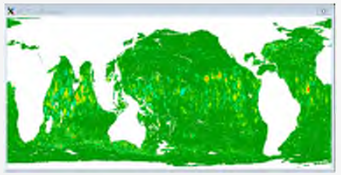
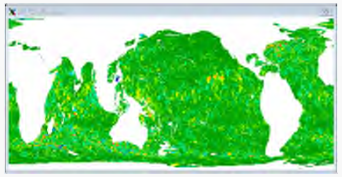
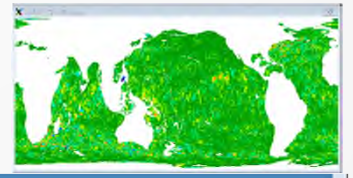
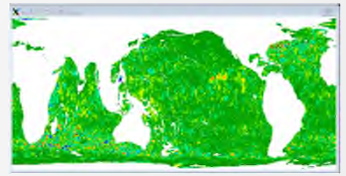
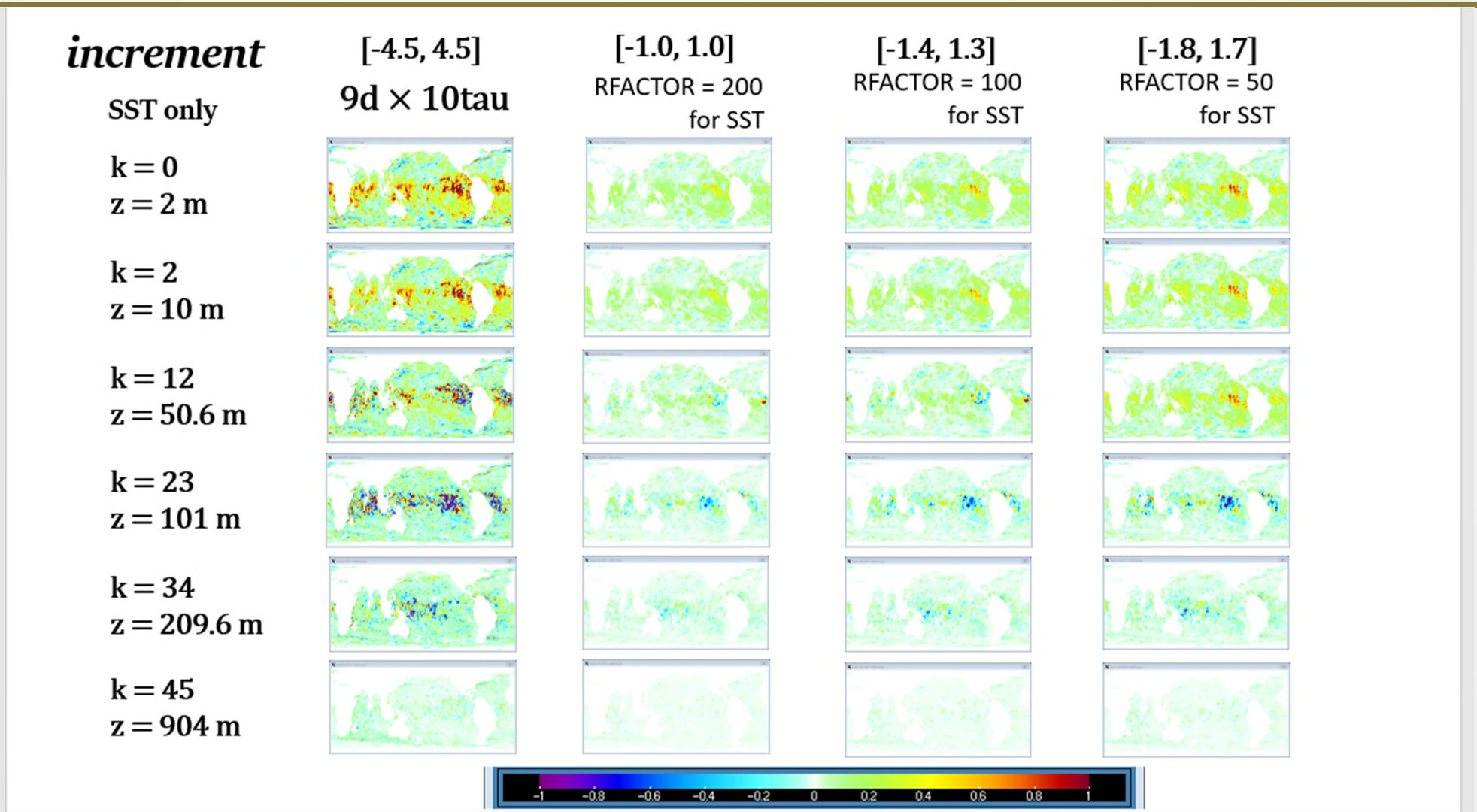
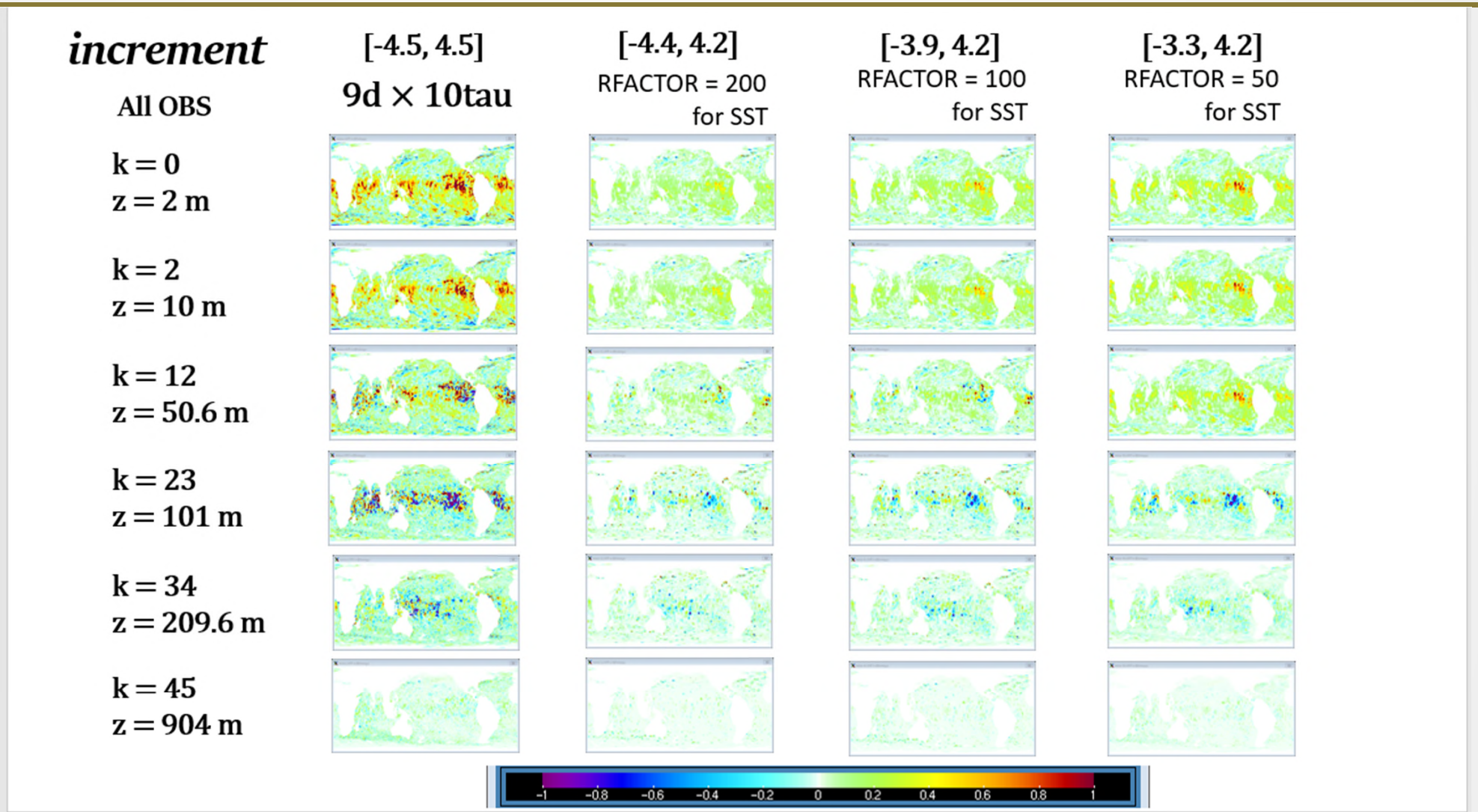
increment

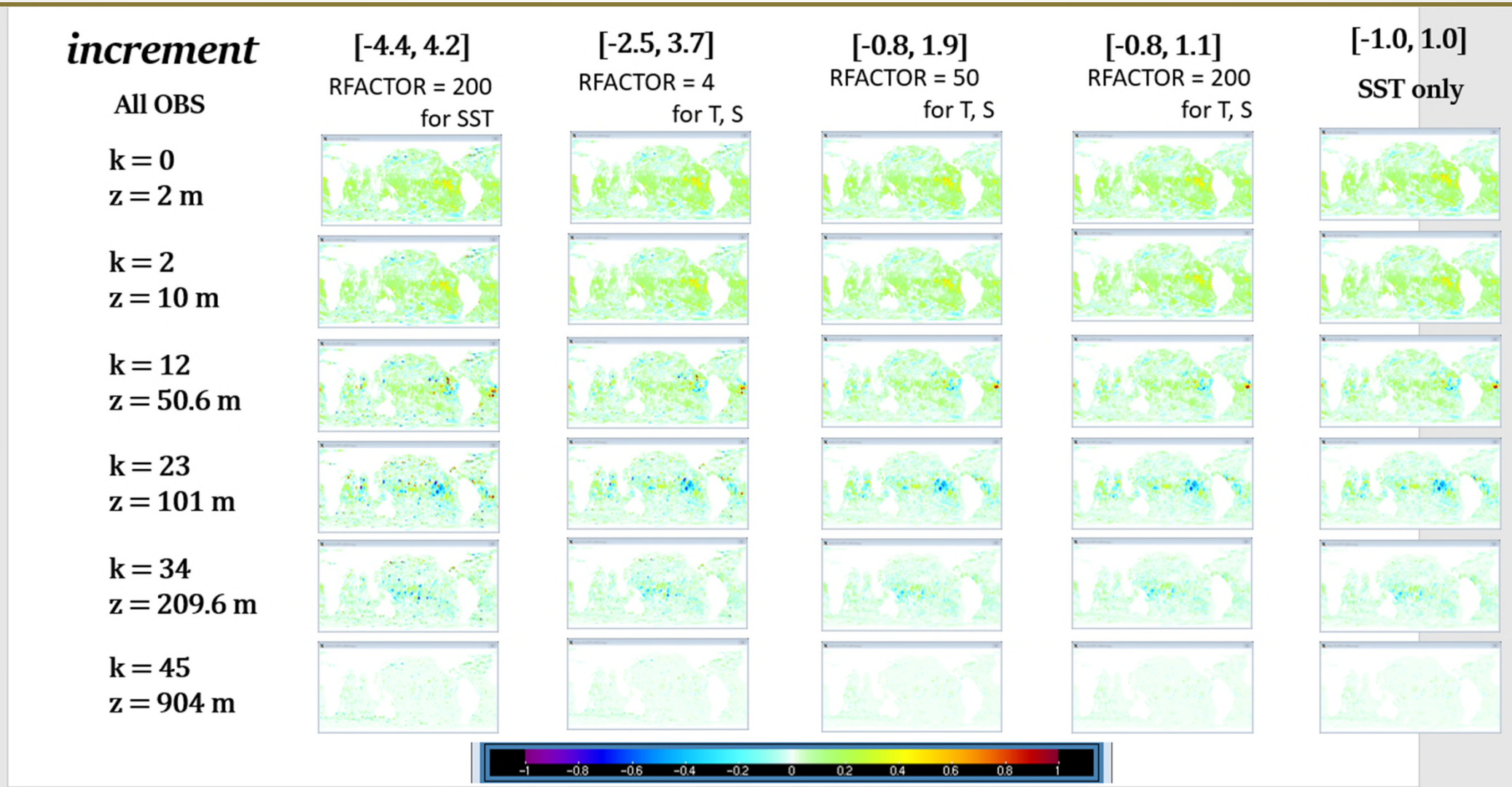
	Lag9 SST	Ens20 SST	20yr × 2tau	20yr × 2date
k = 0 z = 2 m				
k = 2 z = 10 m				
k = 12 z = 50.6 m				
k = 23 z = 101 m				
k = 34 z = 209.6 m				
k = 45 z = 904 m				



Testa 9d2 × 10tau Tmin = -3.10
Testa inc3 9d2 × 10tau Tmin = -1.97
Testa inc5 9d2 × 10tau Tmin = -1.97
Testa inc4 9d2 × 10tau Tmin = -1.97



Testa Tmin = -3.10
Testa.2 Tmin = -2.82
Testa.4 Tmin = -2.56
Testa.3 Tmin = -2.35



Testa.2 Tmin = -2.82
Testa.22 Tmin = -2.07
Testa.23 Tmin = -1.97
Testa.24 Tmin = -1.97

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校驗：海洋預報（全球）

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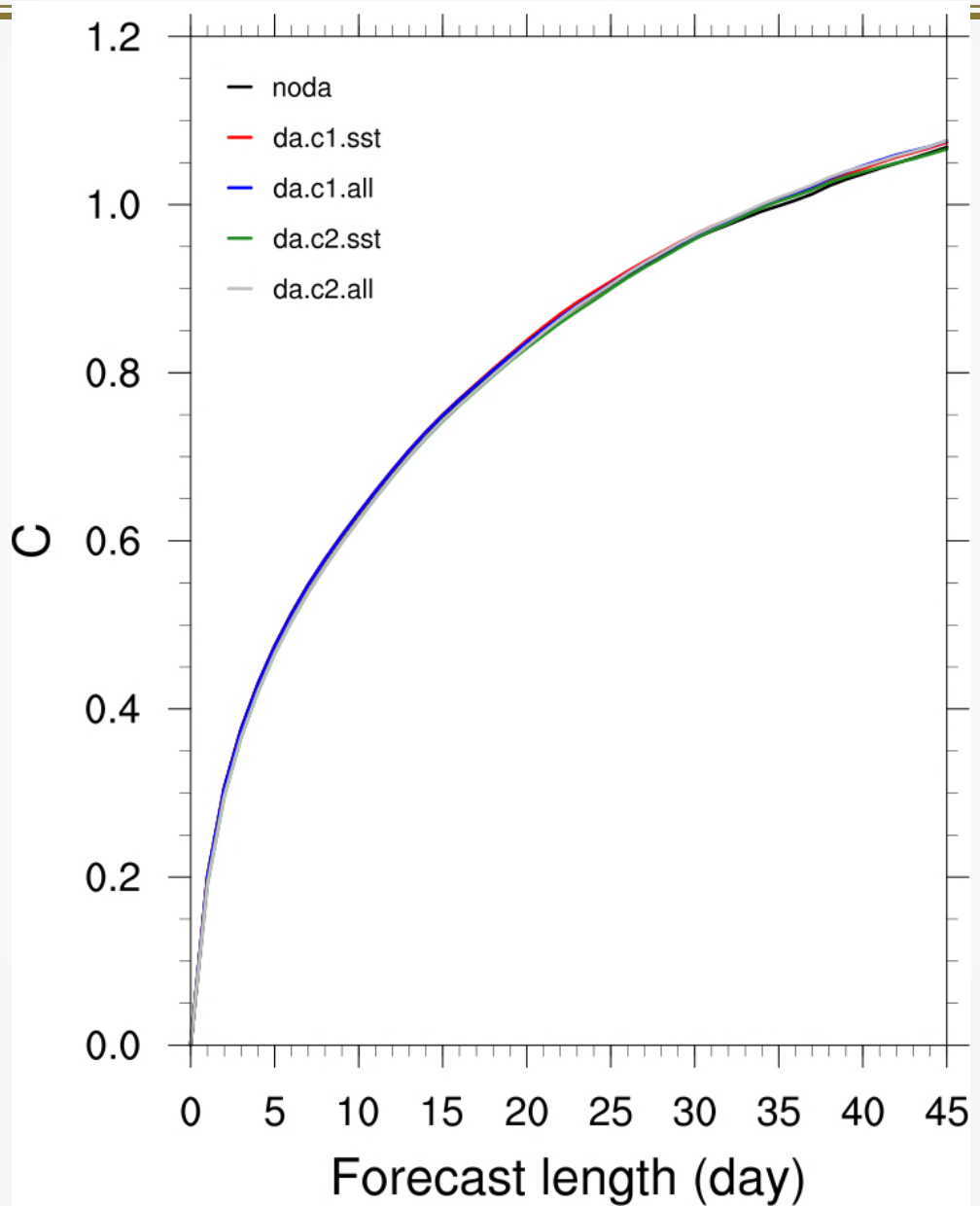
RMSE

against

OISST



No DA

C1 sst

C1 all

C2 sst

C2 all

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校驗：海洋預報（分區）

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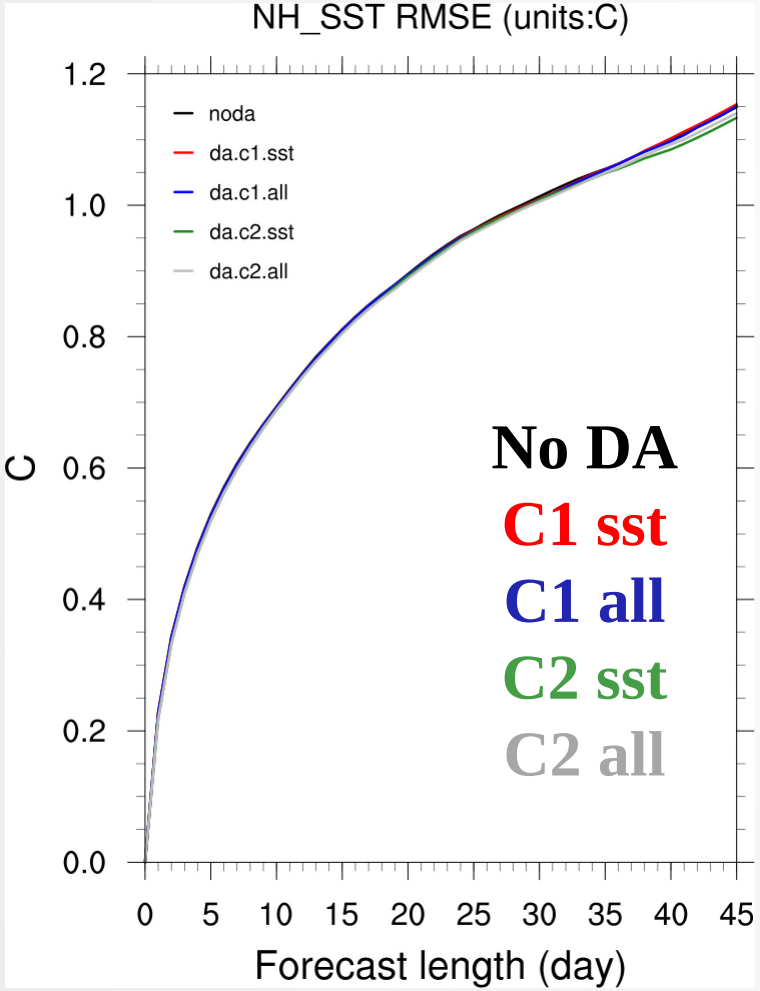
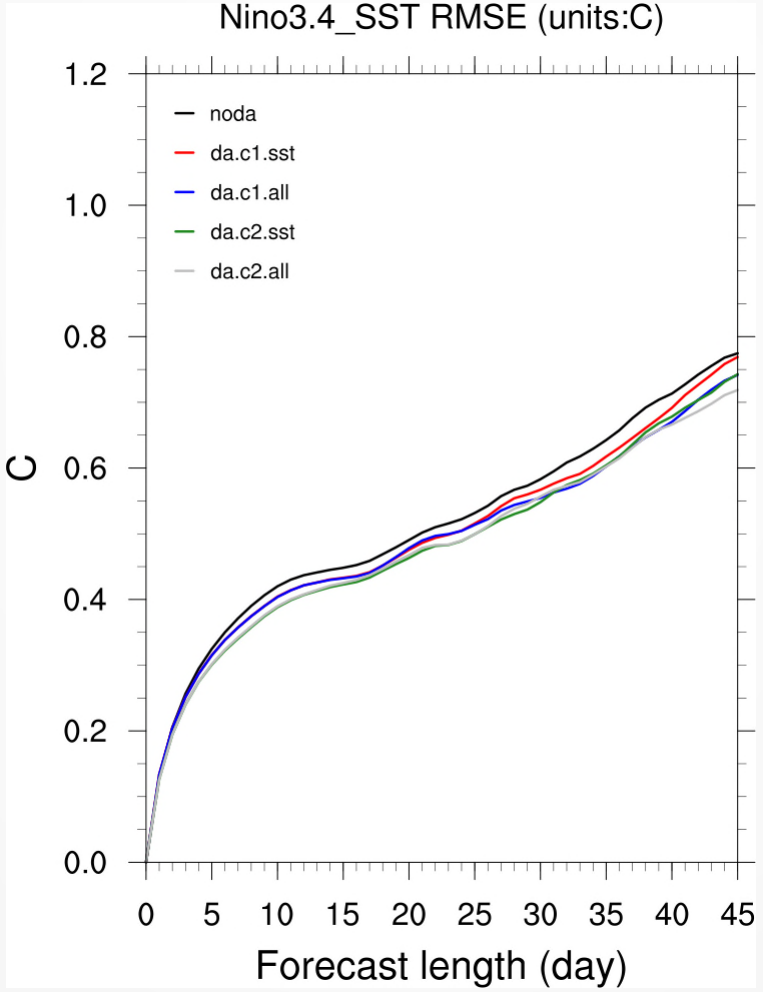
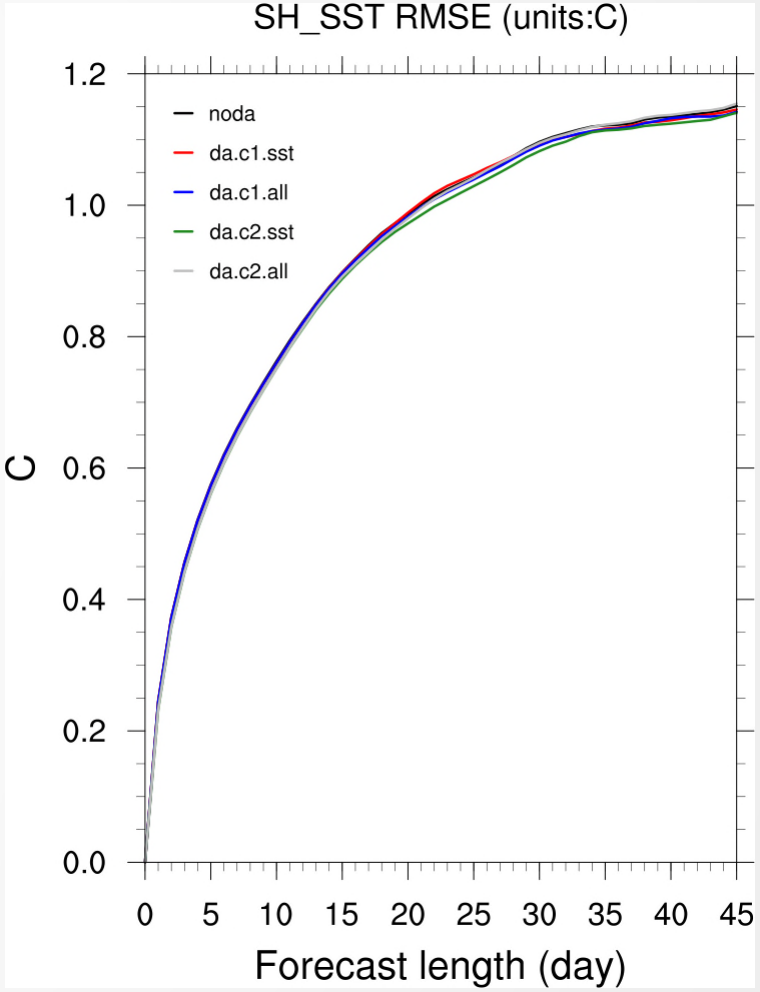
NH



Niño 3.4



SH



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校驗：大氣預報

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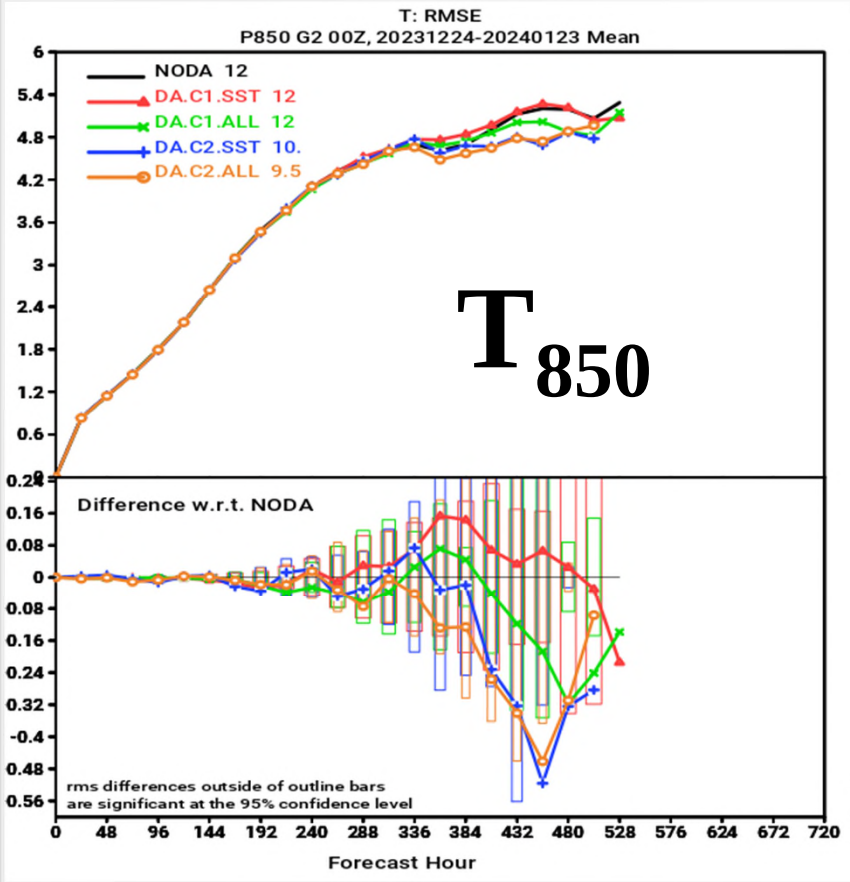
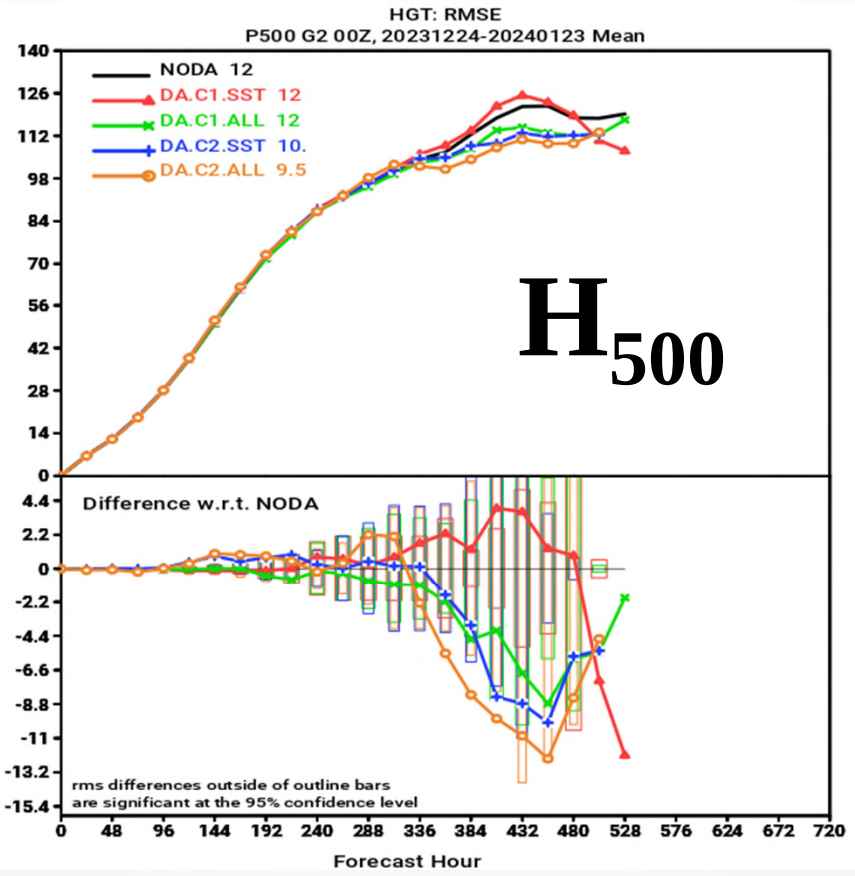
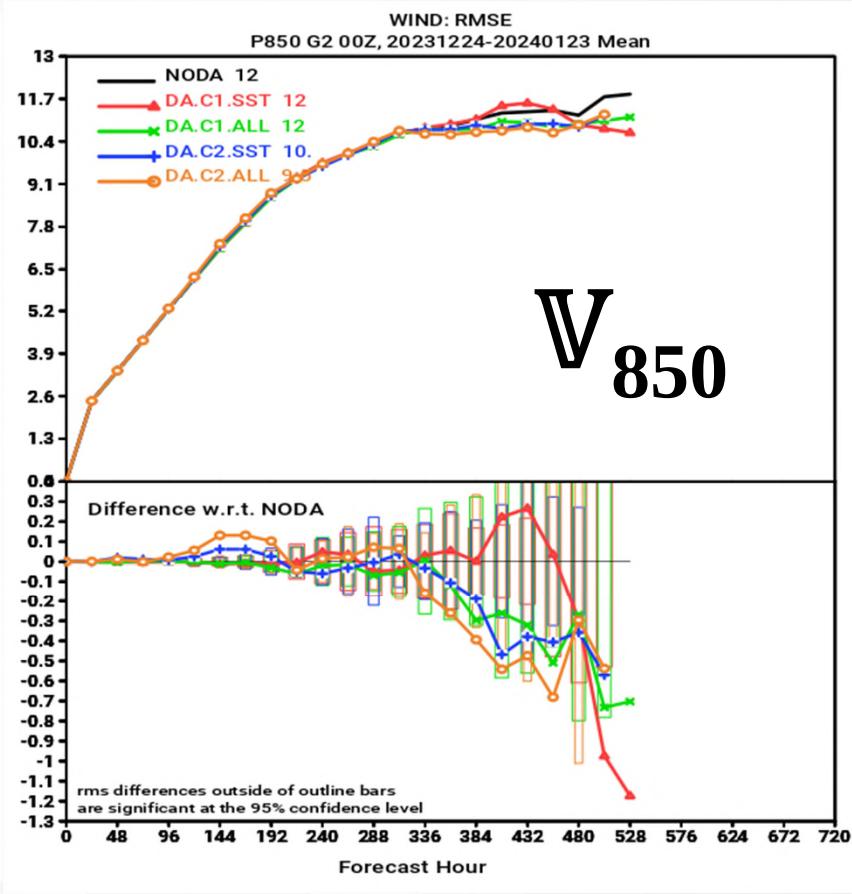
Processing…



T_{850}



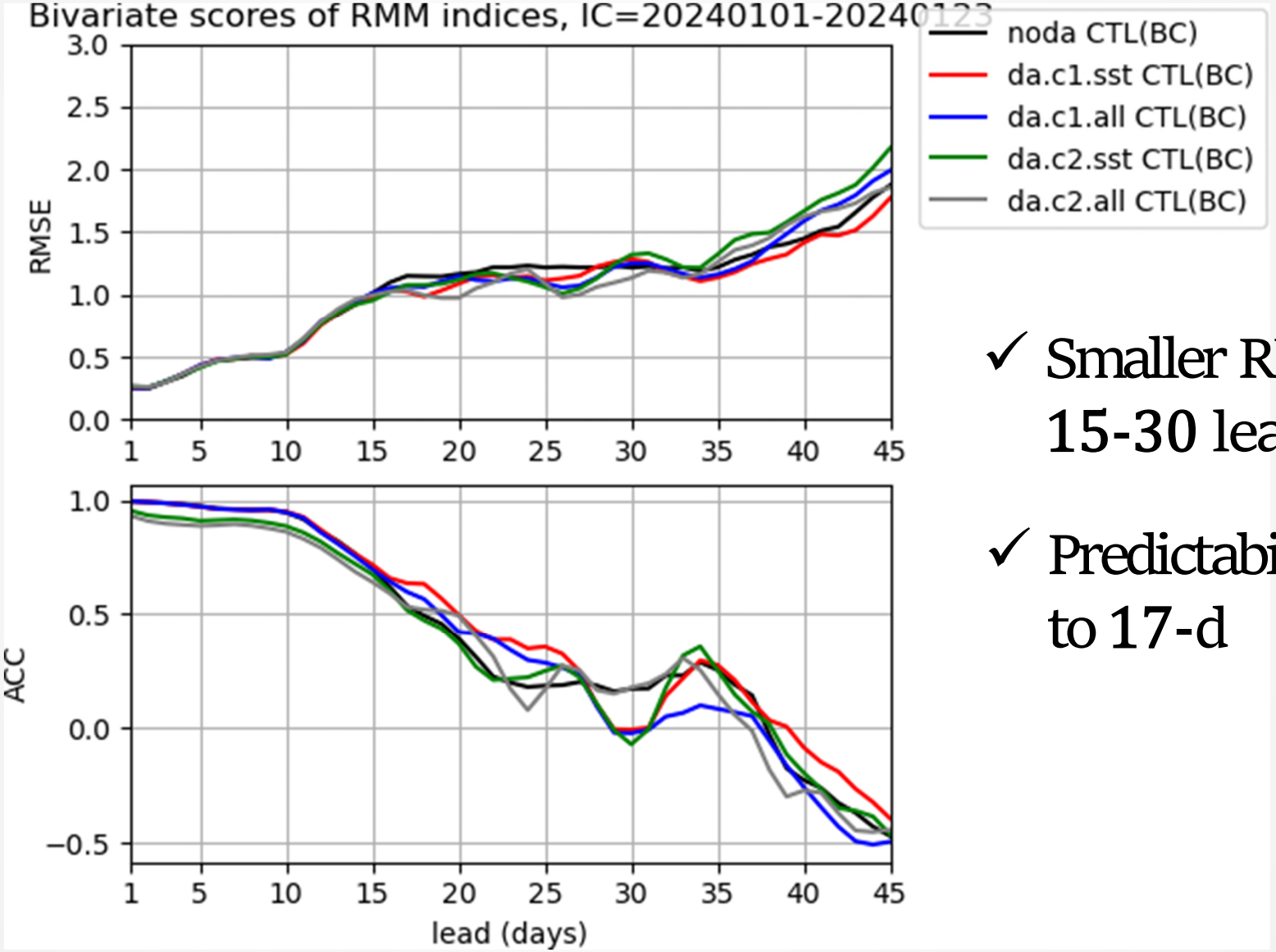
H_{500}



$\mathbb{V}_{850}$

校驗：MJO

No DA
C1 sst
C1 all
C2 sst
C2 all



- ✓ Smaller RMSE for 15-30 lead
- ✓ Predictability up to 17-d

階段成果

- 引進澳洲 **EnKF-C** 資料同化系統
- 使用現有後報資料組成延遲系集，進行同化-預報實驗
- 經單次同化大致可改善海溫預報及大氣重力位高度預報
- 調整參數之第二次循環效益不明顯

未來工作

- 系集資料
  - 其他資料組合
  - 更多個案之長期積分
- 同化參數調整
  - 隨循環次數逐步修正

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敬 請 指 導

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補 充 資 料

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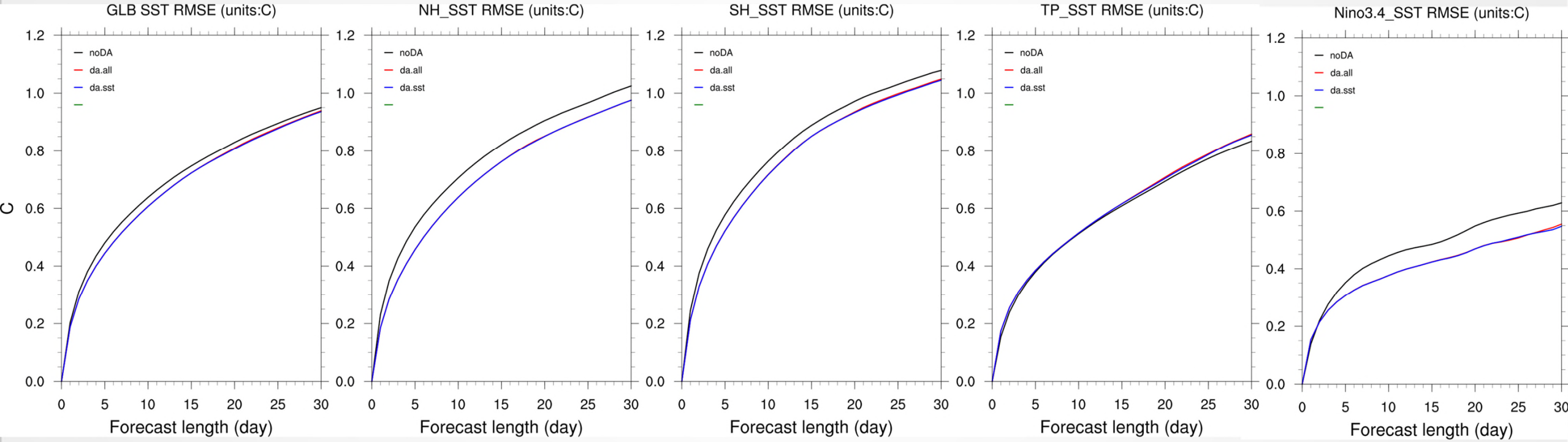
耦合預報系統升級前置作業

SST 校驗



noDA ：無資料同化

DA.sst：僅同化 GHRSST資料

DA.all ：同化 GHRSST與EN4資料

有作資料同化後的海表溫預報表現較好

DA.sst與DA.all 對海表溫預報的差異不大

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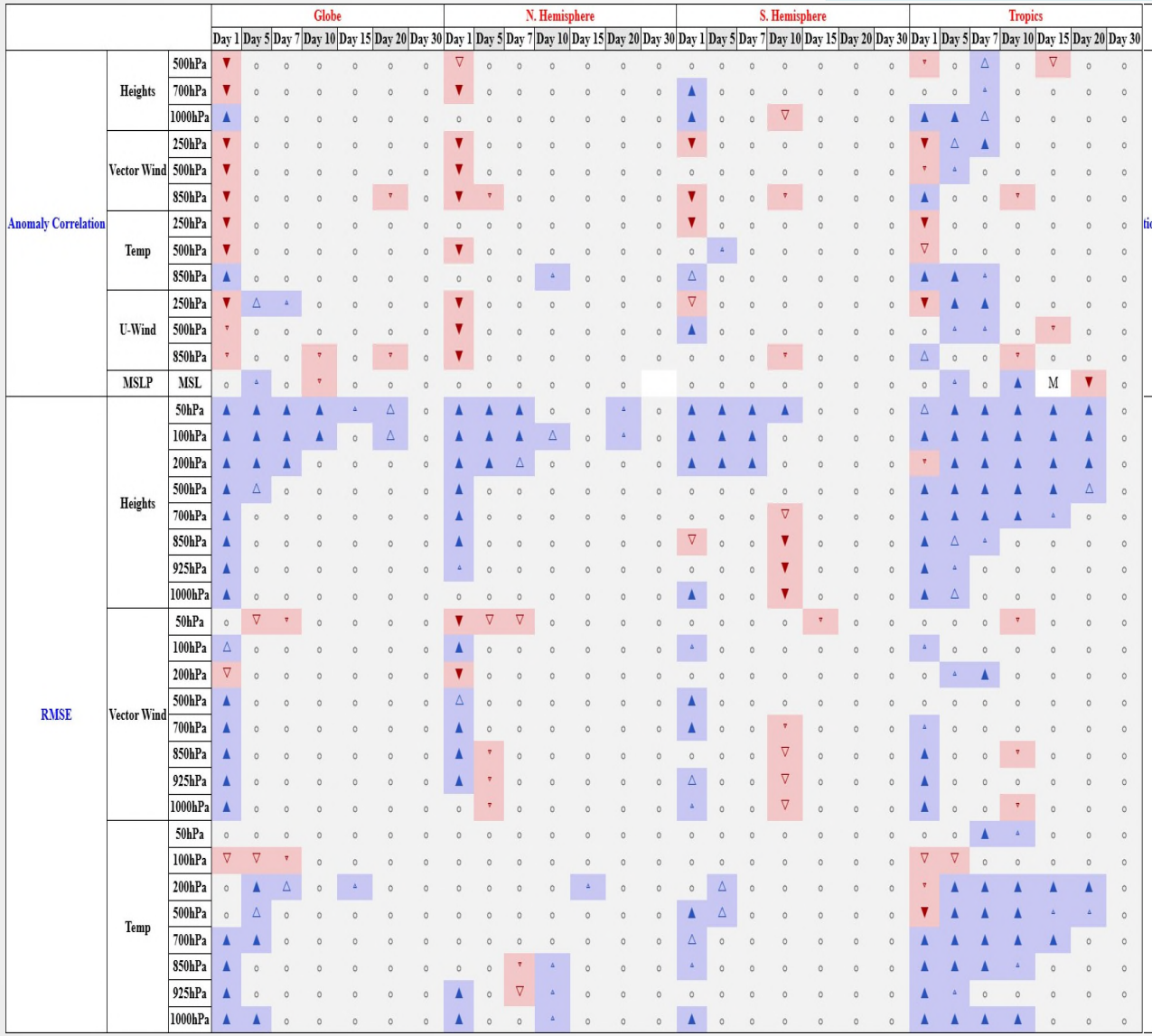
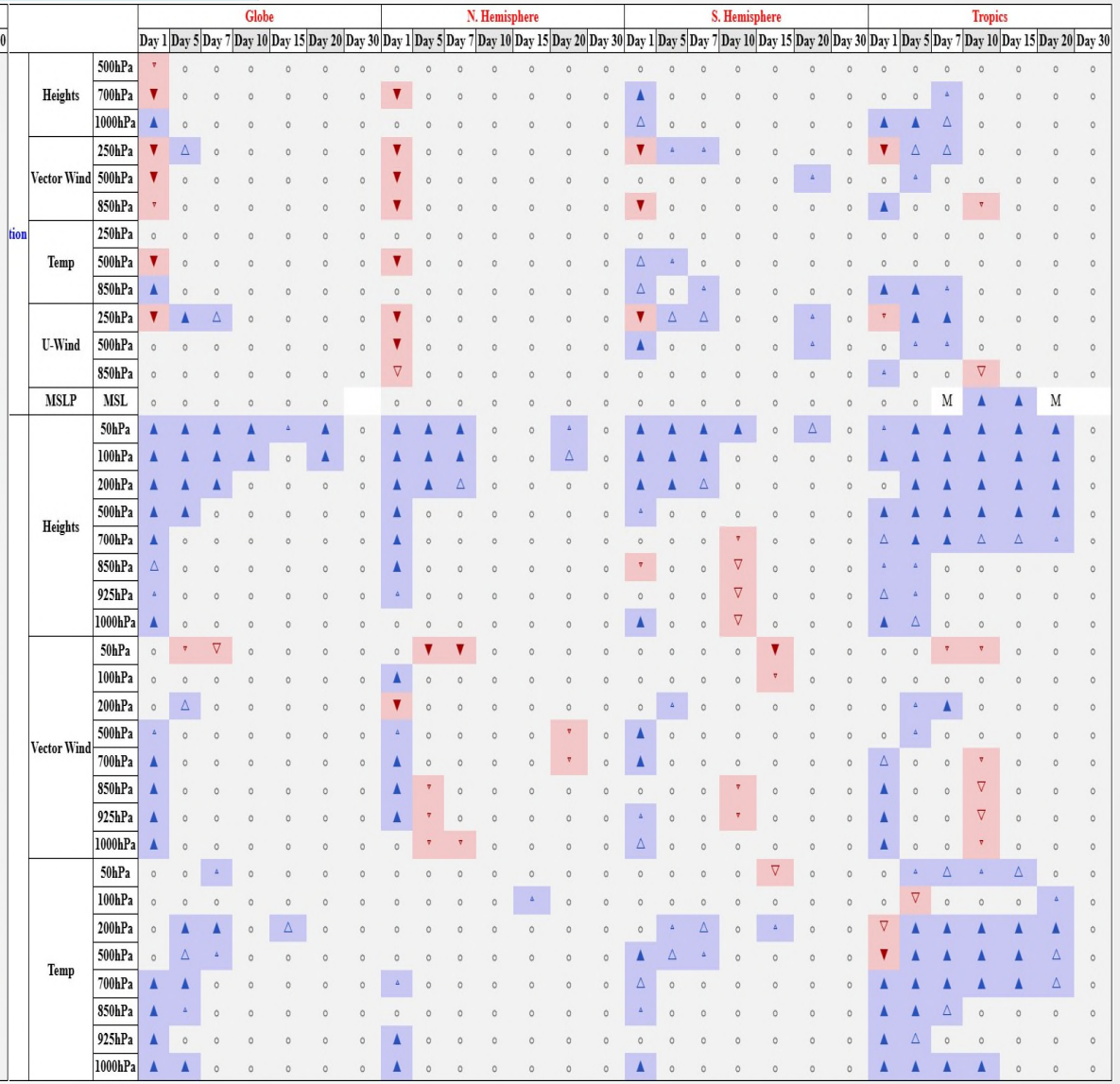
大氣校驗

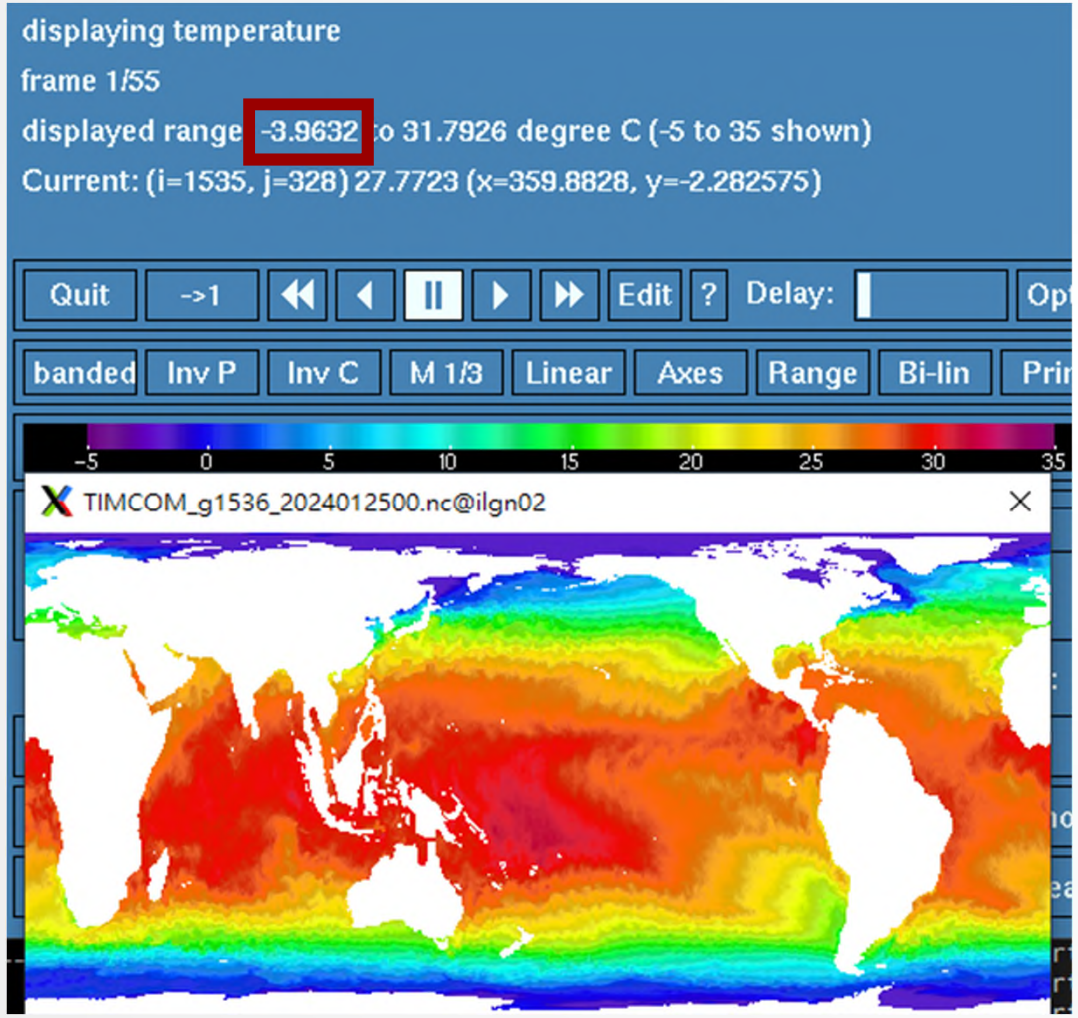
DA ALL



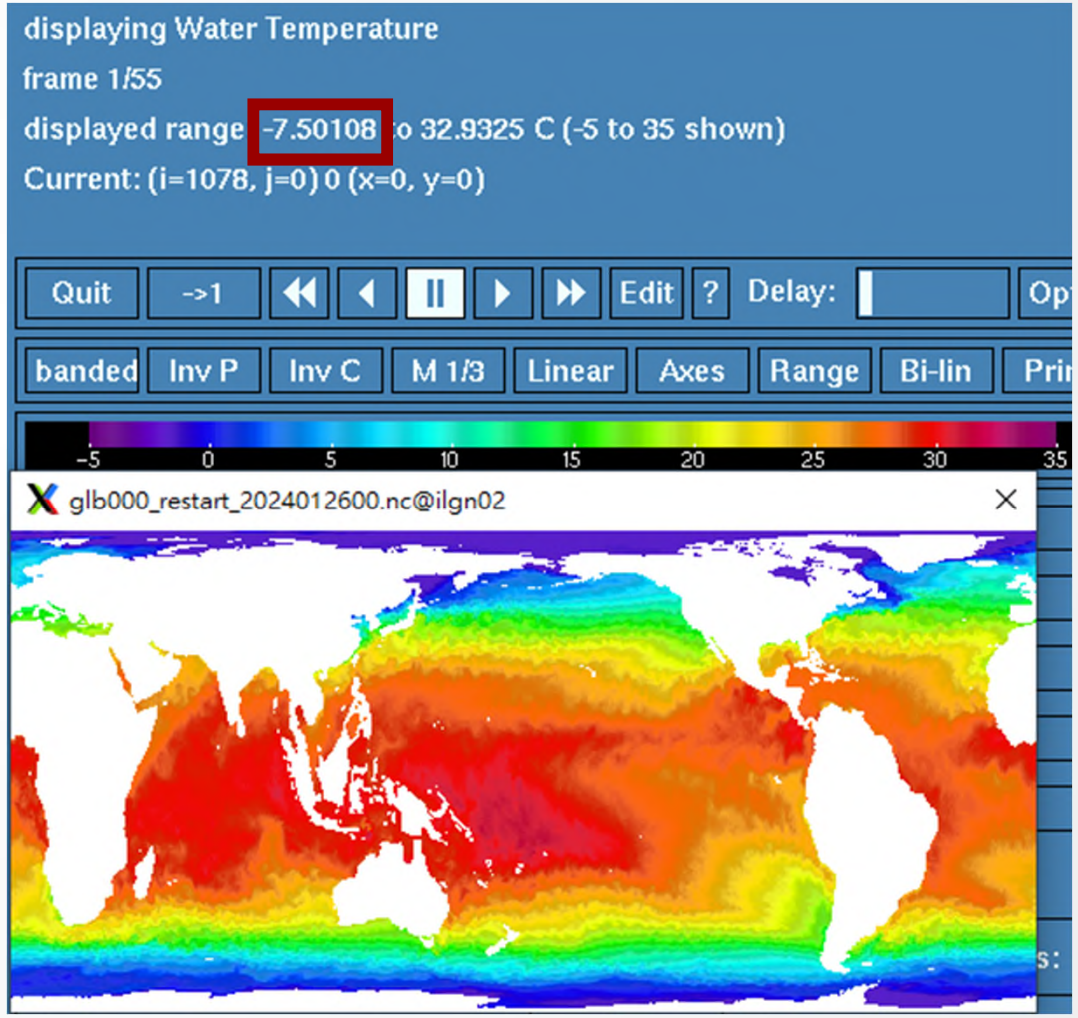
DA SST



IC for the previous 24-h run (DA once)



24-h restart with DA (DA twice)



耦合模式資料同化方法

EnKF-C (https://github.com/sakov/enkf-c)

- Display of model data DA result - **mem001_temp.nc**