



中央氣象署全球展期天氣與短期氣候 系集預報系統發展現況

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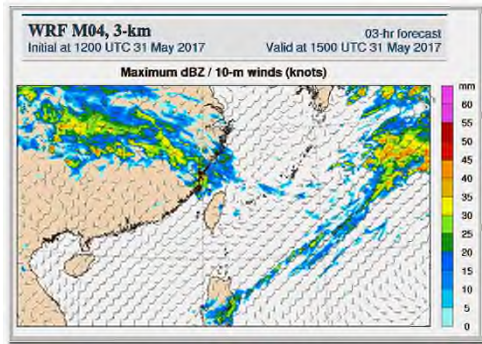
114年第三十九屆天氣分析與預報研討會 交通部中央氣象署 2025.09.04

大綱



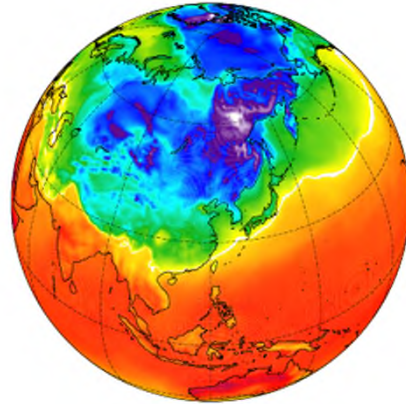
- CWAGEPS & CWACFS現況
 - 模式架構
 - 校驗表現
- 未來規劃及工作
- 總 結

Current modeling systems in CWA



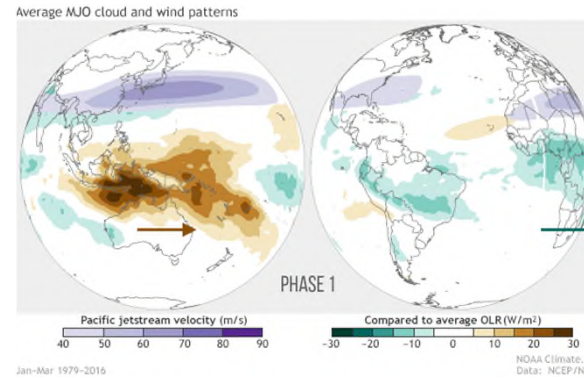
Regional weather

- CWA WRFD (5 days)
- CWA TWRF
- CWA WEPS
- CWA RWRF (13 hours)
- CWA CEPS



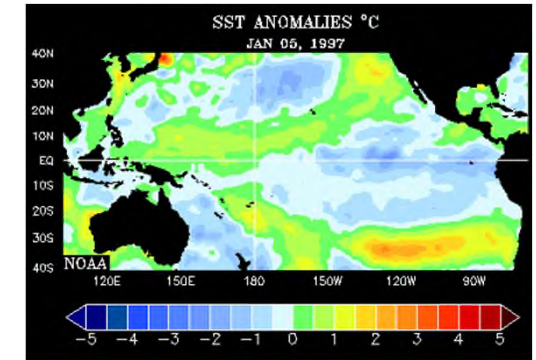
Global weather

- TGFS (16 days)



Extended weather (S2S)

- CWA GEPS (45 days)



Short-term climate

- CWA CFS (9~12months)

Climate Simulation Section

科長: 李明營

GEPS: 劉邦彥, 陳奕安, 郭珮萱, 黃崇惟, 吳佳瑩, 吳蔚琳, 曾喜絃, 李崇璋, 李尚恩

CFS: 胡志文, 吳子榆, 陳薇鈞, 朱芸霆

全球展期系集預報系統

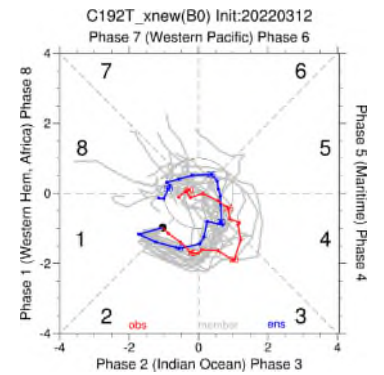
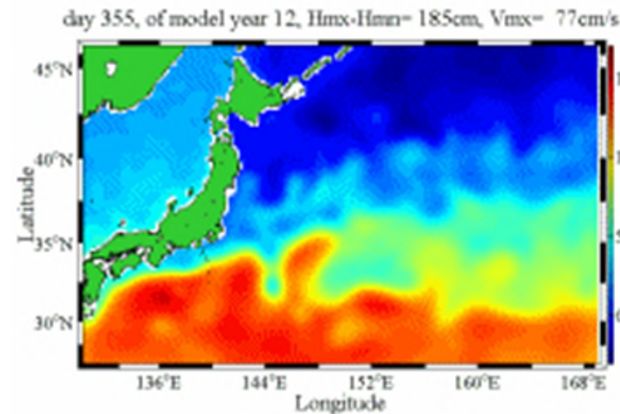
CWAGEPS V3 (will be operational in 2025Q4)

Atmosphere

- Model: **CWAGFS-TCO(global)**
 - Resolution: ~28 km, 72 layers (T_{Co} 383L72)
 - Dy-core: Semi-Lagrangian+Semi-implicit 2 time level
 - Grid system: Octahedral reduced Gaussian grid
 - Stochastic physics: SPPT with 5 scales+SKEB
 - Initial condition: LETKF members
- Model: **RSM(regional)**
 - Resolution: ~5 km, 72 layers
 - Dy-core: Semi-Lagrangian+Semi-implicit 3 time level



(figure from <https://confluence.ecmwf.int/display/FCST/Introducing+the+octahedral+reduced+Gaussian+grid>)



Ocean

- Model: **TIMCOM(global/regional)**
- Resolution: ~25/5 km, 55 layers

Frequency: once per day (00 UTC)

Number of Member: 20 members + 1 deterministic

Forecast length: 45 days

Re-forecast: yes (2006-2020 total 15 years)

(Initial condition from NCEP CFSR)

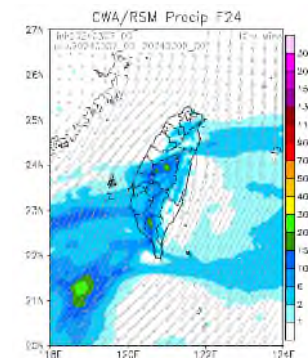
Users

Internal:

氣候預報科、氣候研析科、資料管理科、氣象綠能營運中心

External:

農業部農業試驗所、農業部水產試驗所、經濟部水利署、臺電綜合研究所、中華民國海軍



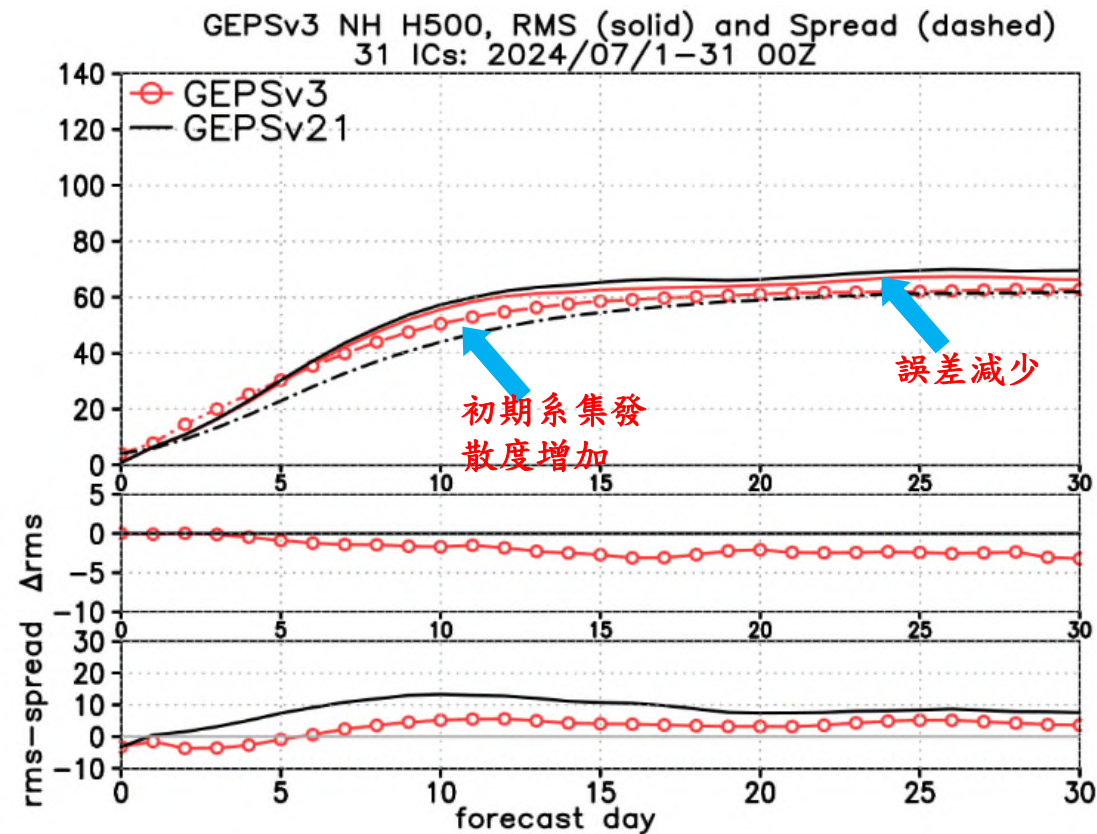
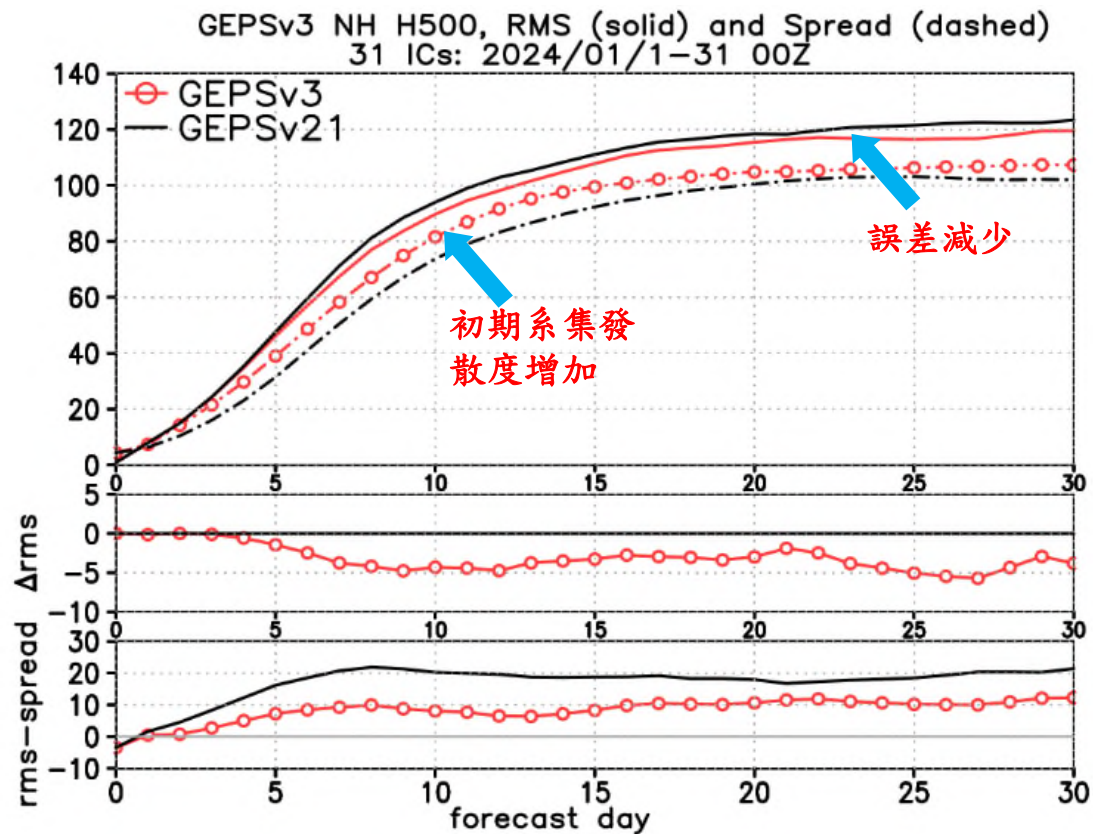
CWAGEPS V3 作業性表現評估-系集RMSE & Spread



500hPa GeoHGT Northern Hemisphere (20S-80S, 0E-360E)

冬季

夏季



CWAGEPS V3 作業性表現評估-MJO相關層場比較

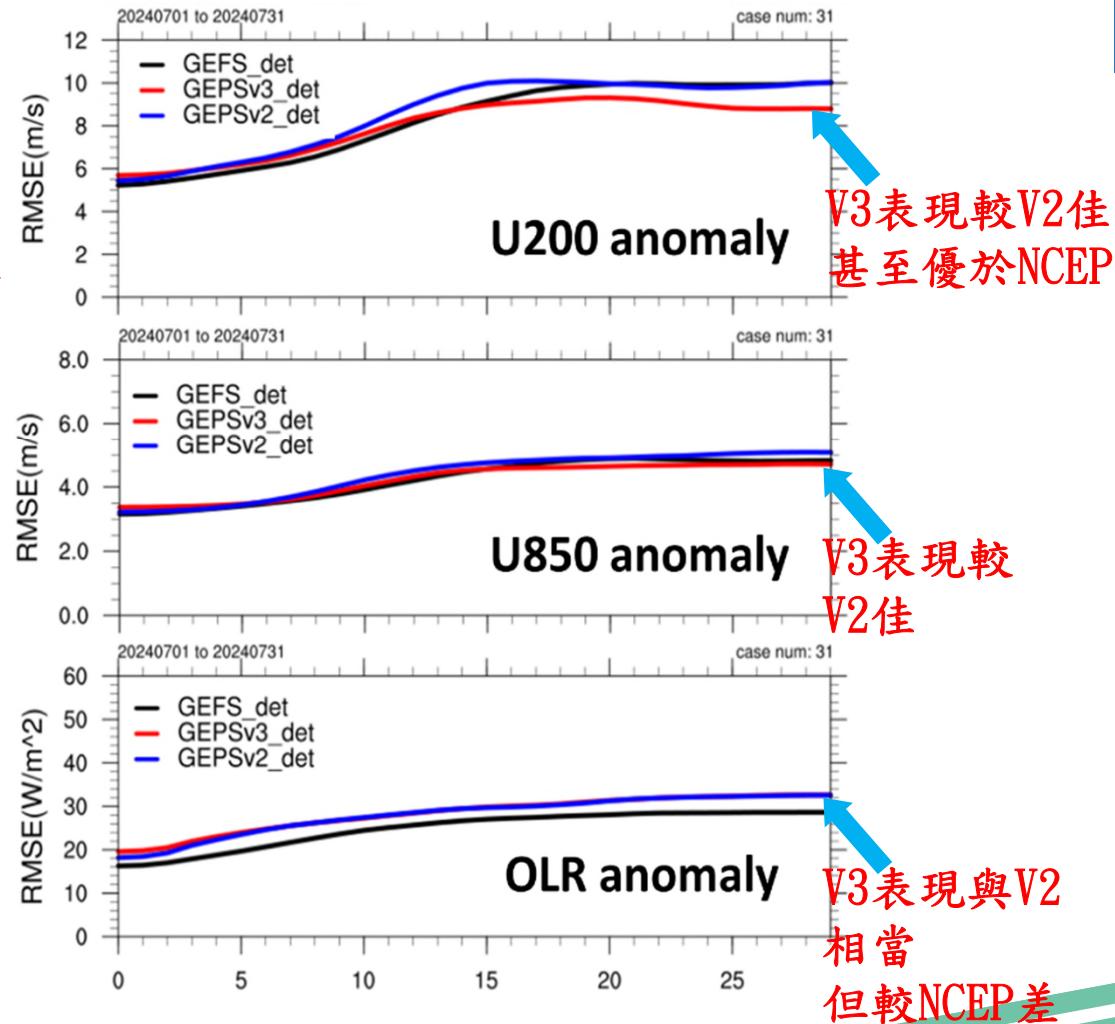
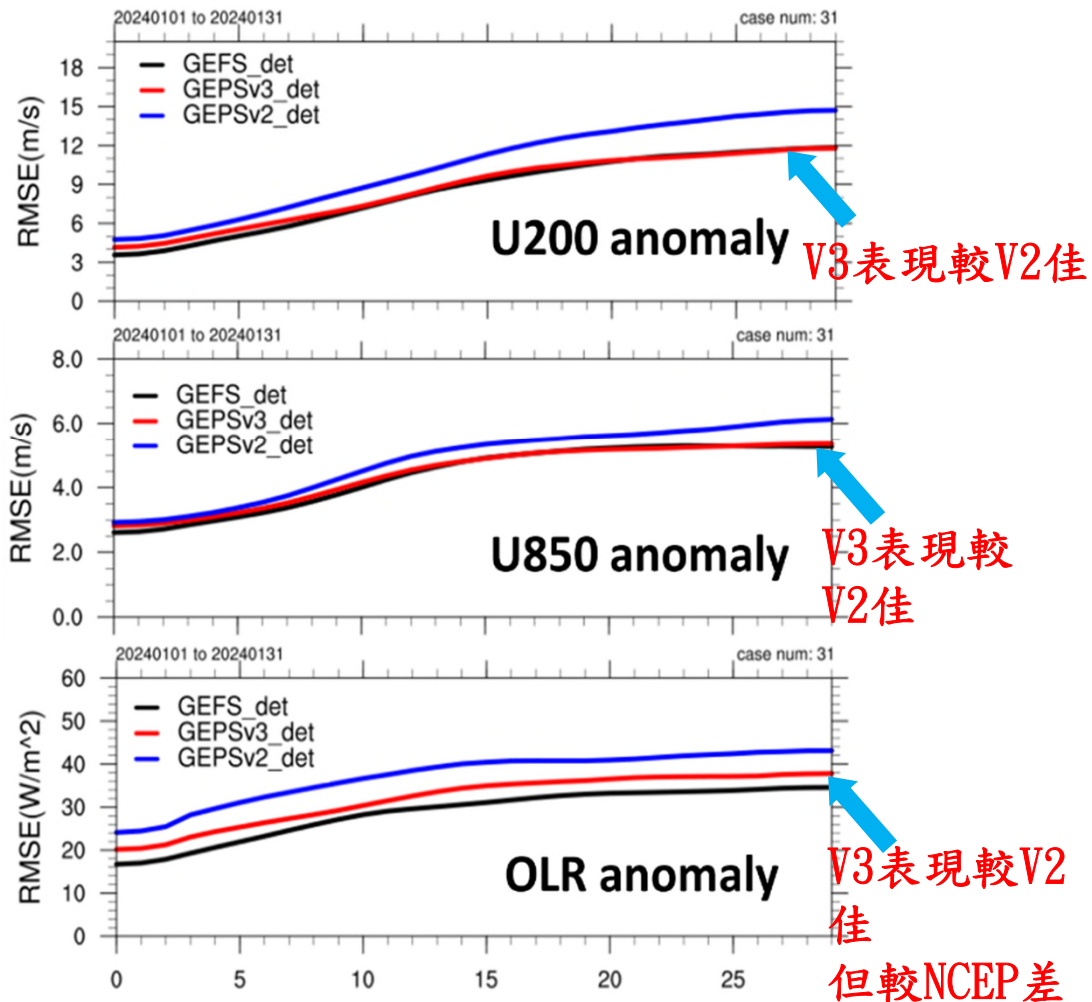


冬季

2024/01/01 to 2024/01/31 (15°S-15°N)

夏季

2024/07/01 to 2024/07/31 (15°S-15°N)



全球短期氣候預報系統



CWACFS V2 (operational in 2023Q2)

Atmosphere

- Model: **CWAGFS(global)**
- Resolution: ~60 km, 60 layers (TL359L60)
- Dy-core: Semi-Lagrangian+Semi-implicit
- Grid system: reduced Gaussian grid
- Initial condition: NCEP CDAS
- Model: **RSM(regional)**
- Resolution: ~12 km, 40 layers
- Dy-core: Semi-Lagrangian+Semi-implicit 3 time level

Ocean:

- Model: **NOAA GFDL MOM5**
- Resolution: ~60 km, 40 layers
- Initial condition: NCEP CDAS

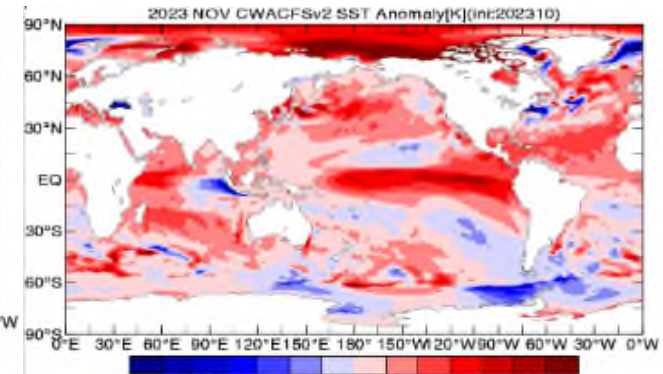
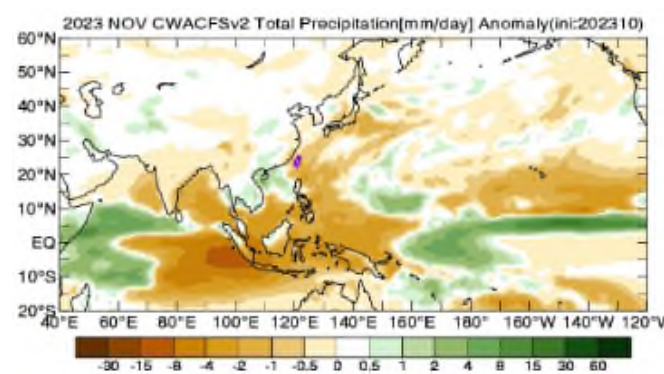
Frequency: once per day (00 UTC)

Number of Member: 30 members/month

Forecast length: 9 months (12 months in
Feb, May, Aug, Nov and Dec)

Re-forecast: 1991-2020 (00UTC)

(Initial condition from NCEP CFSR)



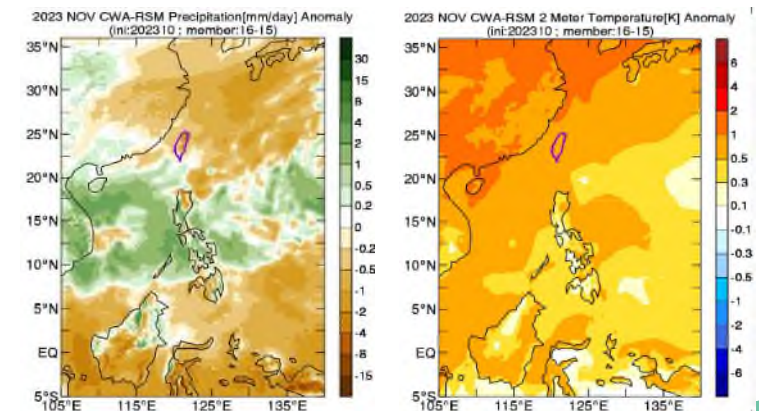
Users

Internal:

氣候預報科、氣候研析科、資料管理科

External:

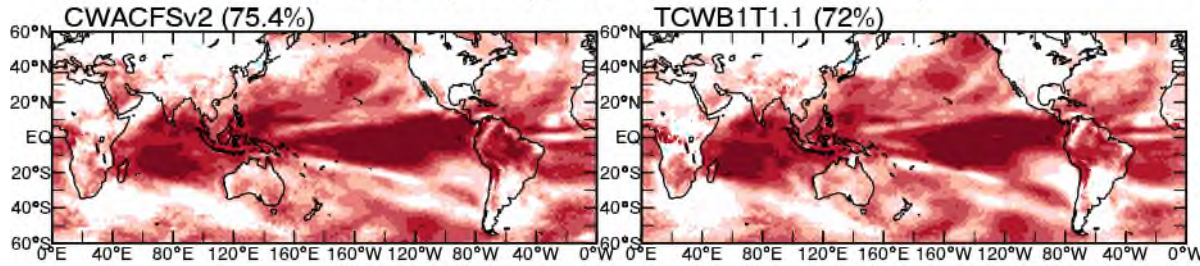
APCC、PAGASA、農業部水產試驗所、
經濟部水利署



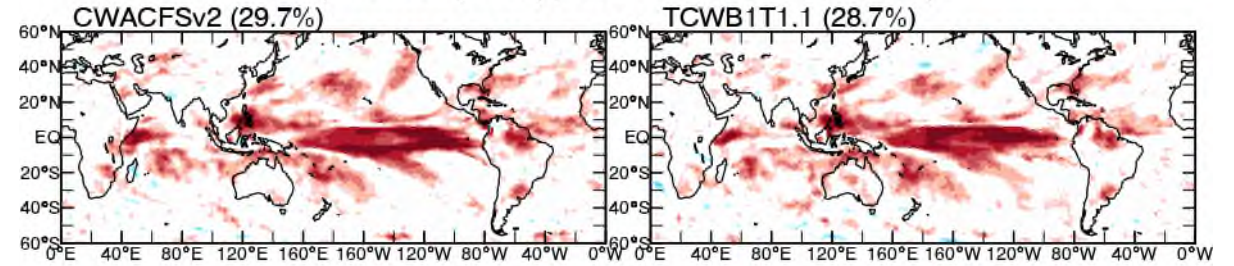
距平相關性



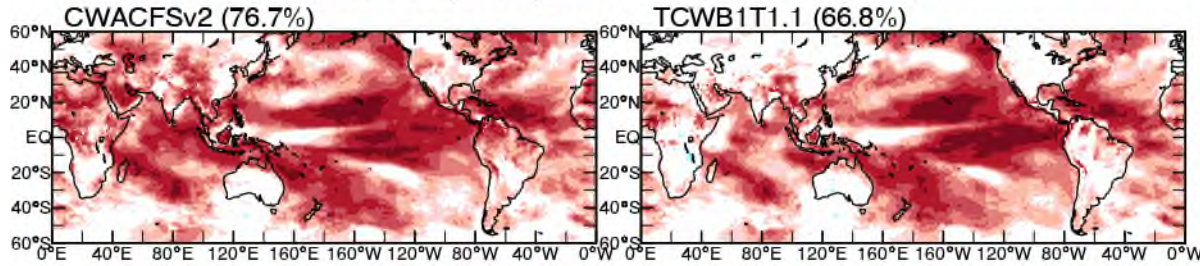
T2M Corr between ERA5& model
(Lead:0(DJF), ini:NOV, 1991-2020)



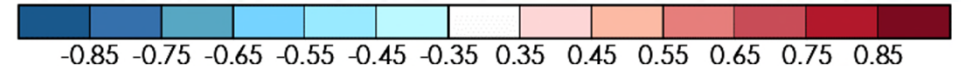
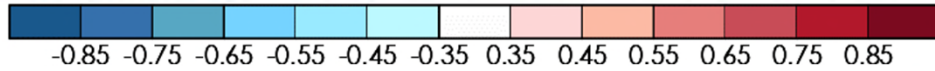
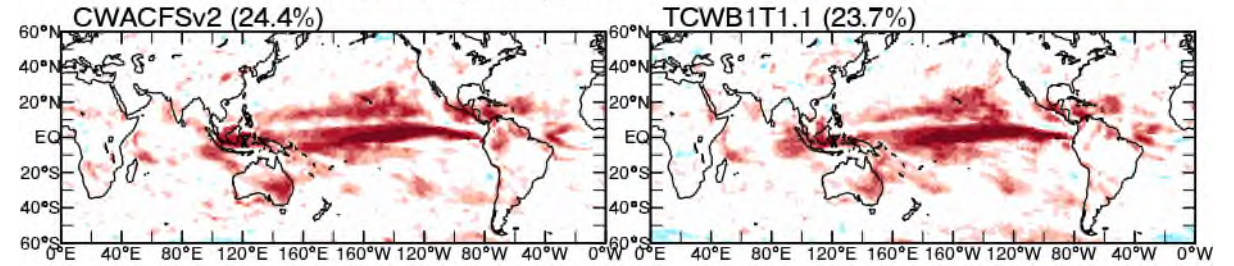
Precipitation Corr between GPCP& model
(Lead:0(DJF), ini:NOV, 1991-2020)



T2M Corr between ERA5& model
(Lead:0(JAS), ini:JUN, 1991-2020)

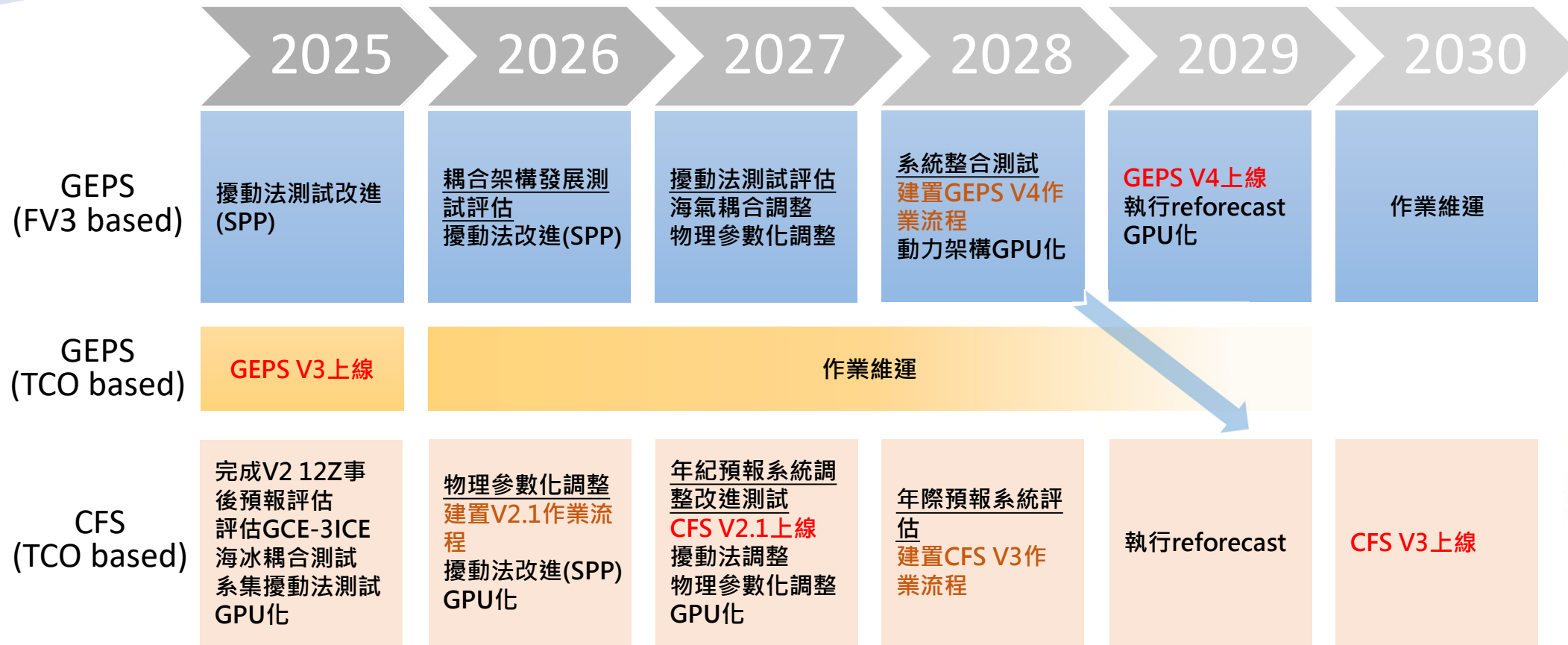


Precipitation Corr between GPCP& model
(Lead:0(JAS), ini:JUN, 1991-2020)



(氣候預報科提供)

未來規劃及工作



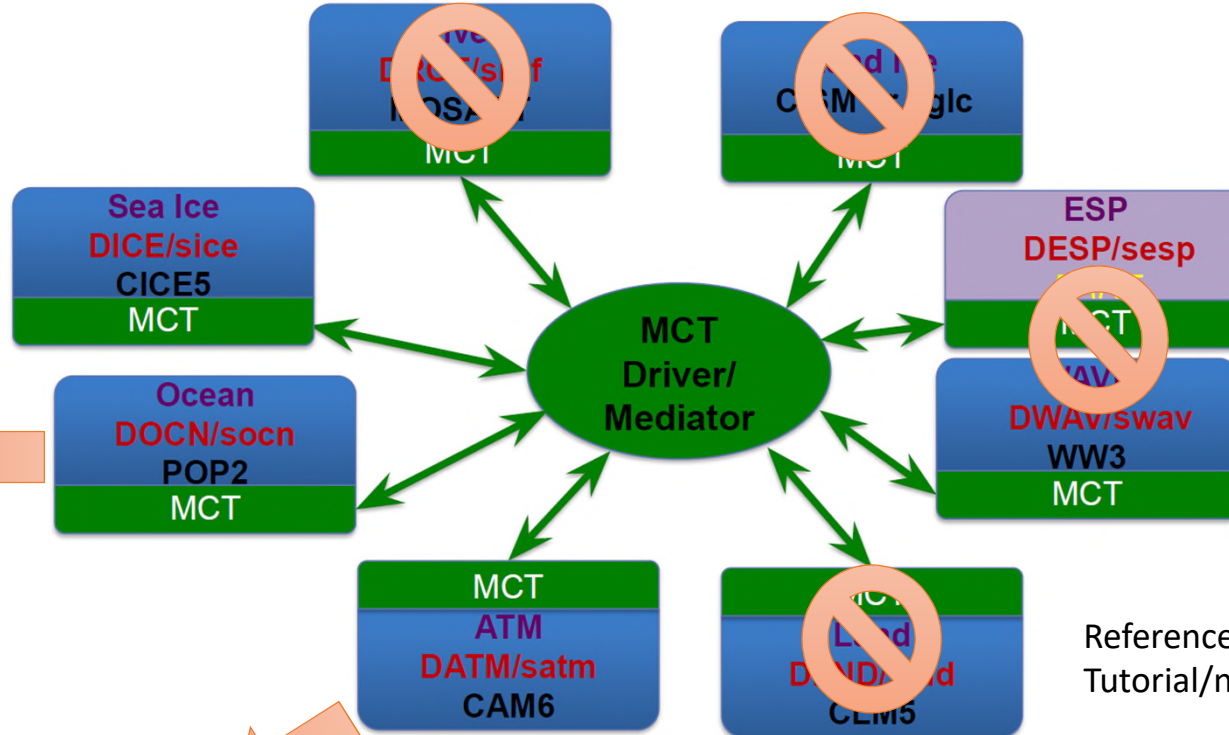
CFS V3 發展思路

- TaiESM2(基於CESM3開發) – 尚在開發中
- CESM3 – 已於fx1000進行測試，但需耗費大量運算資源，主因為記憶體需求較大
- GEPS V4(預計基於CESM2架構進行發展) – 尚在開發中，開發完成穩定後可作為CFS V4發展基礎
- TCO+TIMCOM+CICE6(GPU) – 目前TCO+TIMCOM已成功於署內A100 GPU上運行 ✓

未來規劃及工作：CWAGEPS V4 (~2029)



**Global
MOM6**
Resolution : ~0.25°
Vertical : 75 layers



**Global
TGFS-C384L64**
Resolution : 25 km
Vertical : 64 layers
Model top : 0.2 hPa

Reference: <https://ncar.github.io/CESM-Tutorial/notebooks/intro/coupling.html>

未來規劃及工作：CWACFS V3 (~2030)



Global CWAGFS-T_{C0}199L72

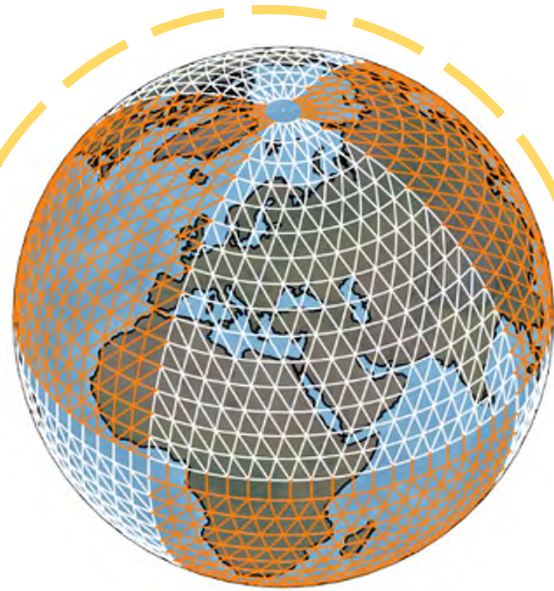
Resolution : 55 km
Vertical : 72 layers
Model top : 0.1 hPa

GCE-3ICE
Noah-MP
GOCART Aerosol model(dust)

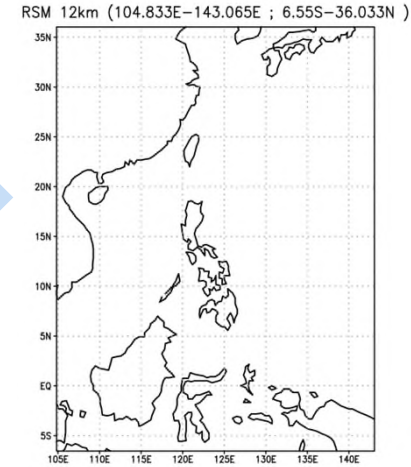
Taiwan Multi-scale Community
Ocean Model (TIMCOM) was
developed by Institute of
Oceanography, NTU

Global TIMCOM

Resolution : ~0.25°
Vertical : 55 layers



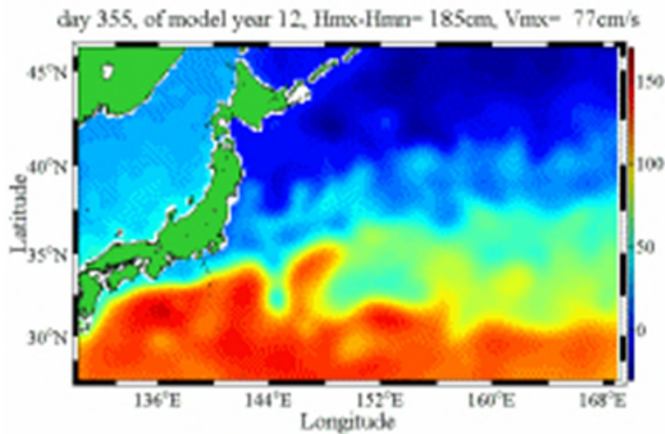
Every 6 hours



Regional 動力降尺度 / CorrDiff

Resolution : 12/2 km
Vertical : 72 layers
Model top : 0.1 hPa

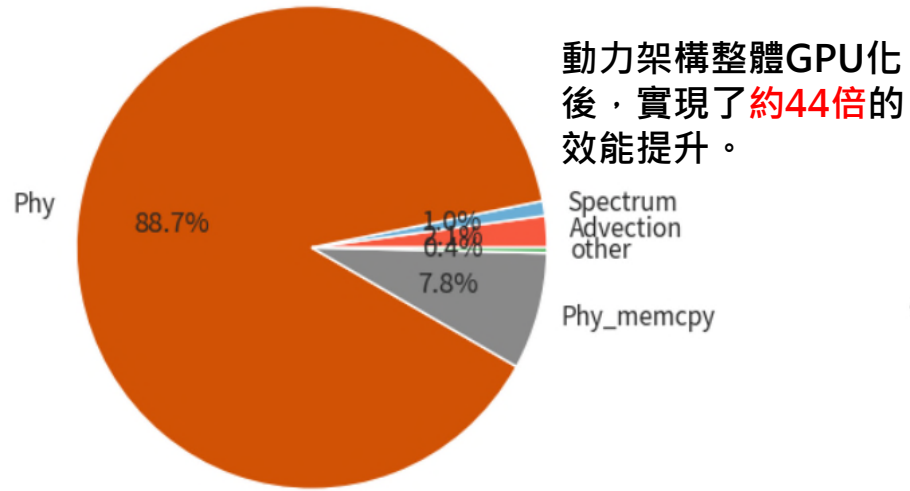
Every 2 hours



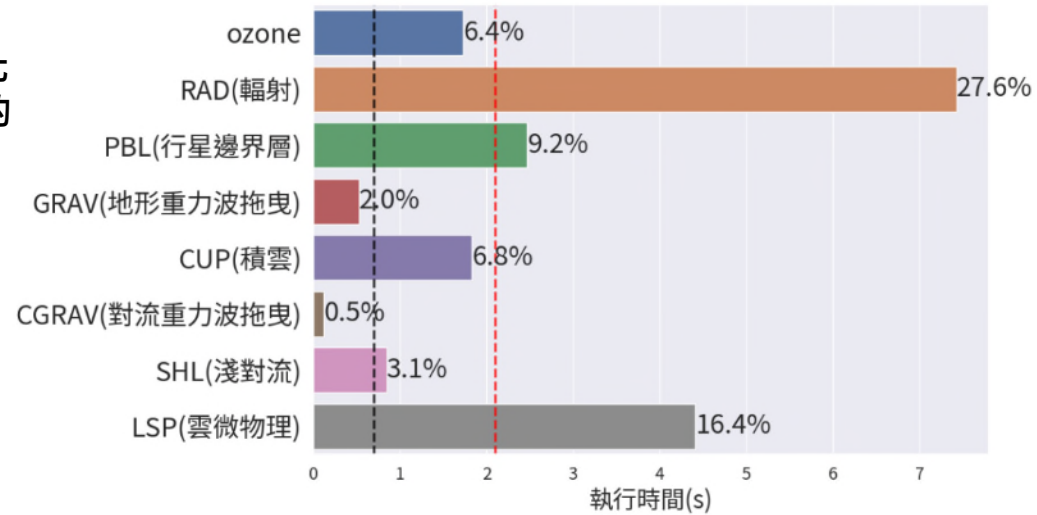
Sea Ice Model CICE6

Resolution : ~0.25°
Vertical : 5 layers

未來規劃及工作：數值模式GPU化



動力架構整體GPU化後，實現了約44倍的效能提升。



物理參數化執行時間占比

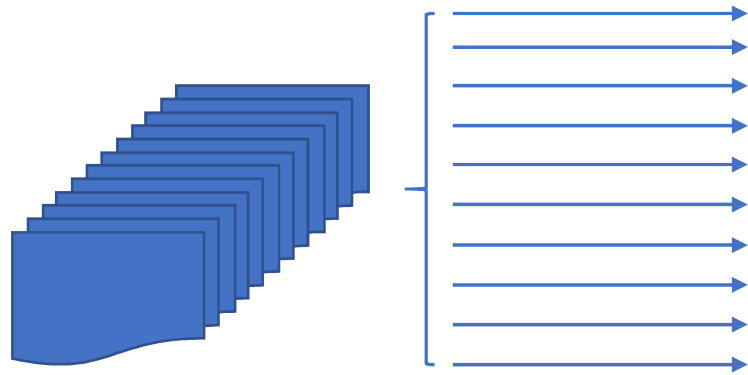
動力架構GPU化後，全模式整體執行時間占比

在單元測試環境，相同的8張 NVIDIA A100 GPU 相較於傳統雙路32核心 CPU (Intel Xeon Gold 6326)平台分別實現了：

- 臭氧(OZONE) 302x
- 行星邊界層及陸表模式(PBL_NOAH) 52.8x
- 地形重力波拖曳(GRAV) 56.6x
- 深對流積雲參數化(CUP) 45.3x
- 對流重力波拖曳(CGRAV) 17x
- 淺對流積雲參數化(SHL) 38.8x
- 雲微物理參數化(LSP) 92.3x

為延續過去的測試標準，個案測試使用高解析度(TCo383L72)，未來將會針對氣候預報系統(TCo199L72+TIMCOM 0.25°)進行評估

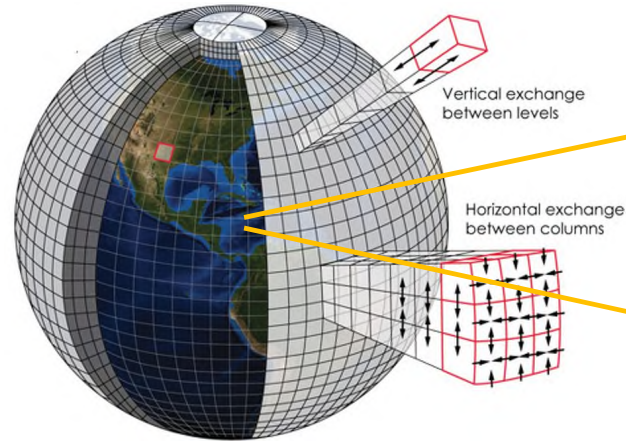
未來規劃及工作：AI技術運用



初始擾動

系集預報

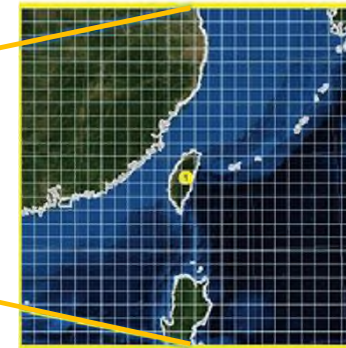
透過AI-ENS/GenCast
產生初始擾動



數值模式

物理參數化模擬器

1. Aerosol Radiation Interaction
2. Sub-grid scale air sea interaction



降尺度系統

Corrdiff 降尺度



- 第二代短期氣候預報系統(CWACFS V2)現已穩定作業，事後預報的表現優於第一代短期氣候預報系統，尤其是在夏季兩米溫度的表現更是顯著提升。
- 第三代展期天氣系集預報系統(CWAGEPS V3)除了透過提升隨機擾動法來改善系集發散度之外，更考慮海氣耦合過程來提升熱帶地區季內震盪的表現。
- 第四代展期天氣系集預報系統(CWAGEPS V4)將以FV3大氣模式作為主要發展基礎，並延續TGFS在天氣預報上的改進，持續精進預報表現。
- 第三代短期氣候預報系統(CWACFS V3)的發展路徑，考量到外部社群預報系統在本署硬體環境的合適性尚未成熟，為滿足作業預報需求，選擇可穩定運作的預報模式系統來進行發展，目前將採用TCO+TIMCOM作為發展基礎，未來將加上海冰耦合過程，甚至將預報系統GPU化來提升效能。
- AI運用於氣候預報作業上則會嘗試透過
 - AI系集預報產製事後預報所需初始擾動場
 - 氣溶膠輻射過程模擬器
 - 次網格海氣耦合過程調整參數法模擬器
 - Corrdiff提供降尺度預報



~The End~
感謝聆聽

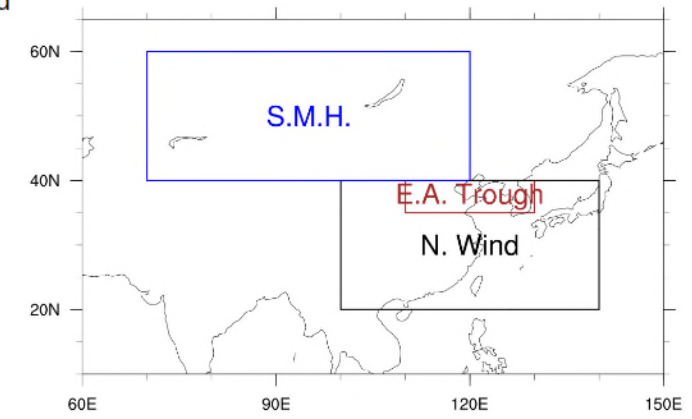
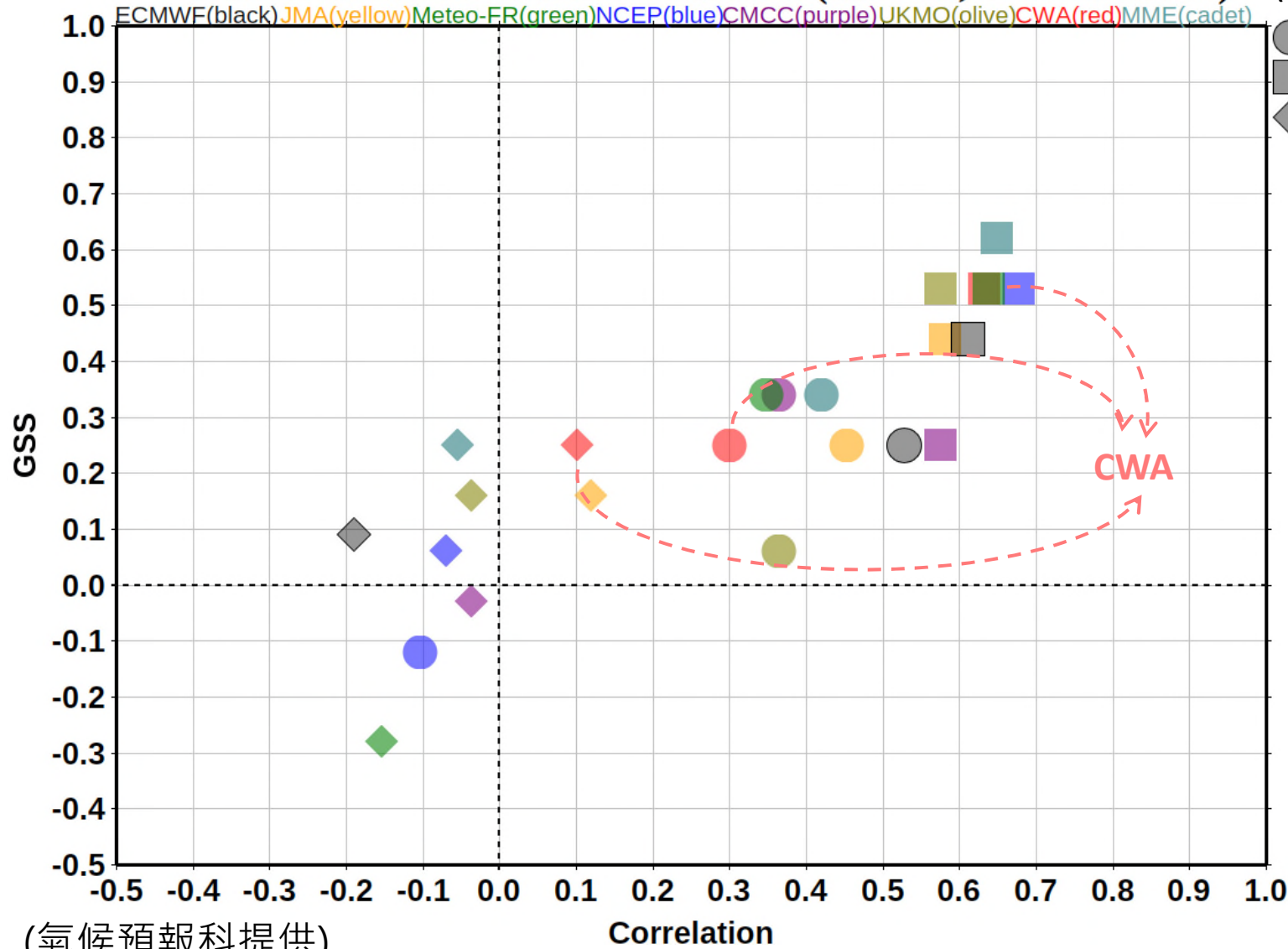




冬季季風指數: Lead 0 season



Winter Monsoon Index CORR-GSS (ini:Oct., Forecast:NDJ) (1993-2016)



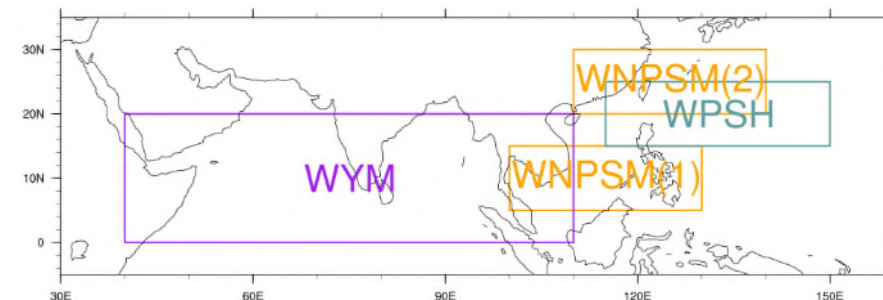
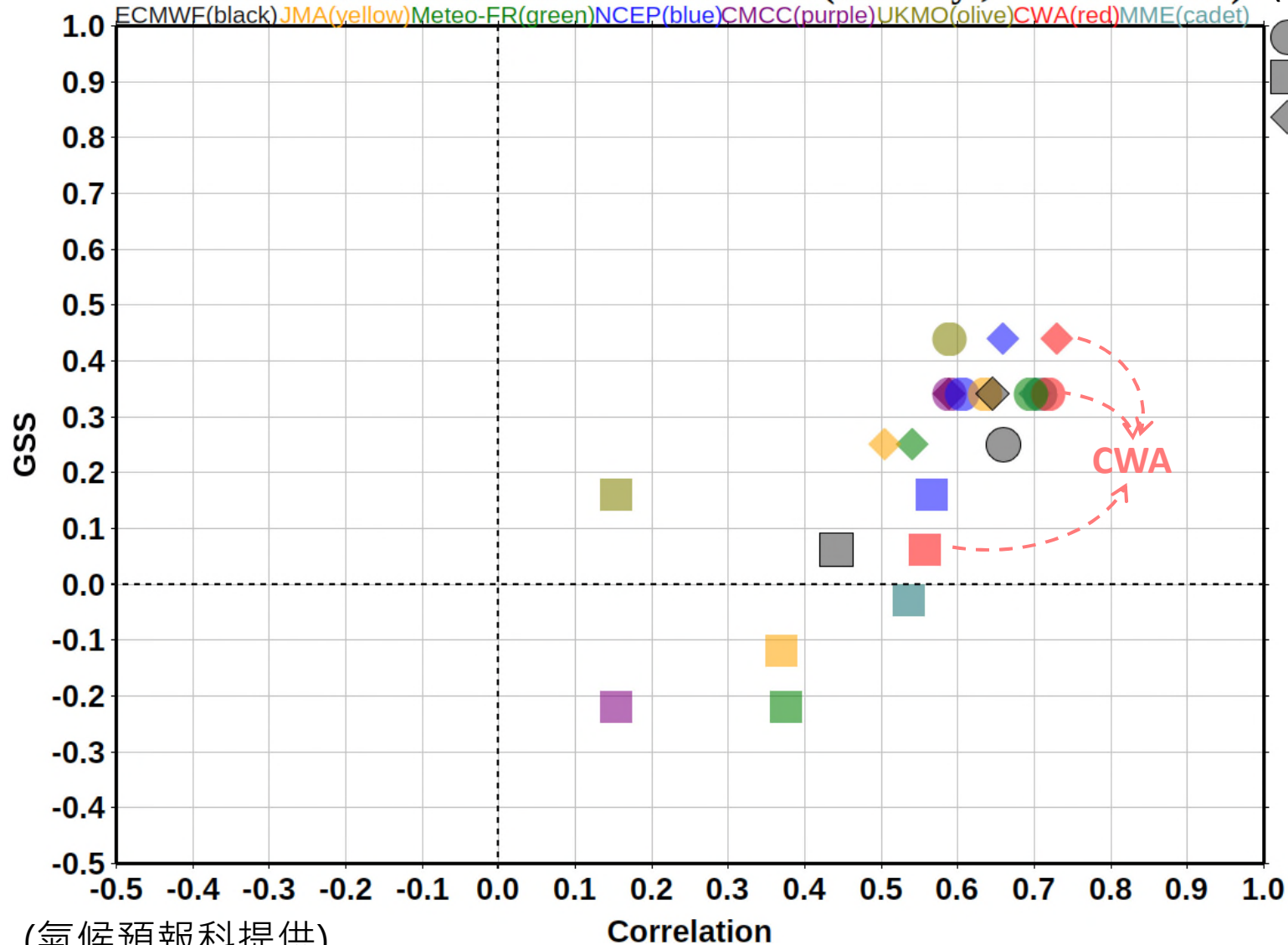
| Index | Definition |
|--|--|
| East Asia Trough (E.A.T.) Cui And Sun (1999) | 500hPa GeoHGT $H_{500}[110^{\circ}-130^{\circ}E, 35^{\circ}-40^{\circ}N]$ area mean |
| Northerly Wind (N. Wind) Yang et al. (2002) | 850hPa V-wind $V_{850}[100^{\circ}-140^{\circ}E, 20^{\circ}-40^{\circ}N]$ area mean |
| Siberian-Mongolian High (S.M.H.) Gong et al. (2001) | Sea Level Pressure $SLP[70^{\circ}-120^{\circ}E, 40^{\circ}-60^{\circ}N]$ area mean |

(氣候預報科提供)

夏季季風指數: Lead 0 season



Summer Monsoon Index CORR-GSS (ini:May., Forecast:JJA) (1993-2016)



| Index | Definition |
|---|--|
| Western North Pacific Summer Monsoon(WNPSM) Wang et al. (2001) | 850hPa U-wind $U_{850}[100^{\circ}\text{-}130^{\circ}\text{E}, 5^{\circ}\text{-}15^{\circ}\text{N}] - U_{850}[110^{\circ}\text{-}140^{\circ}\text{E}, 20^{\circ}\text{-}30^{\circ}\text{N}]$ |
| Webster and Yang Monsoon(WYM) | Difference of U-wind at 850hPa & 200hPa $U_{850}[0^{\circ}\text{-}20^{\circ}\text{N}, 40^{\circ}\text{E}\text{-}110^{\circ}\text{E}] - U_{200}[0^{\circ}\text{-}20^{\circ}\text{N}, 40^{\circ}\text{E}\text{-}110^{\circ}\text{E}]$ |
| West Pacific Subtropical High(WPSH) | 850hPa Geopotential Height $H_{850}[15^{\circ}\text{N}\text{-}25^{\circ}\text{N}, 115^{\circ}\text{E}\text{-}150^{\circ}\text{E}]$ |

(氣候預報科提供)