

評估使用 IAU 策略與地面觀測資料同化策略 對極短期劇烈天氣預報系統的影響

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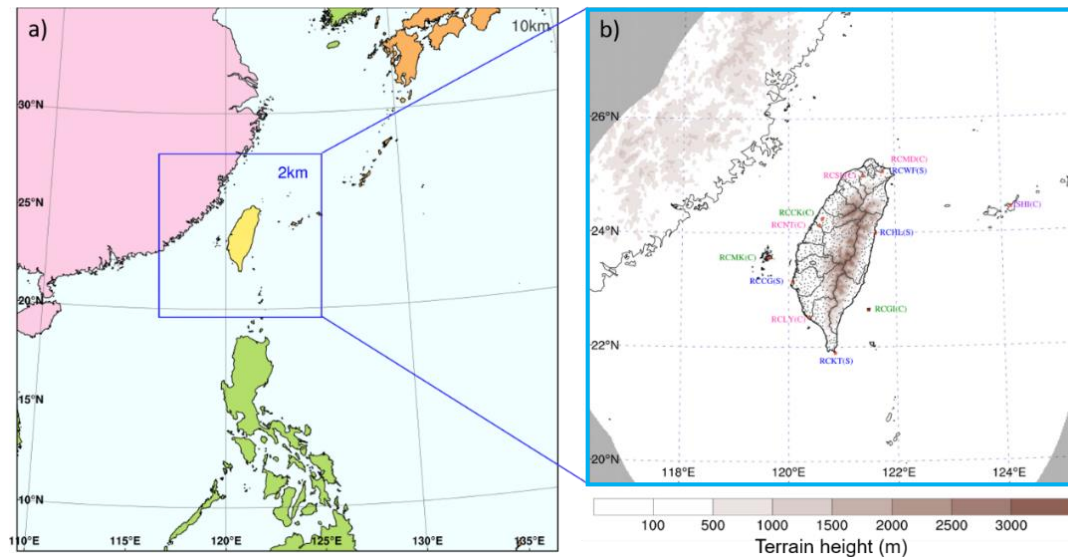
Outline

- Model Configuration
- Case Studies (20250602 00 UTC ~ 20250613 06 UTC)
- Strategy Updates
 - IAU
 - Diffusion Schemes in WRF + **Data Assimilation Methods for Surface Observations**
- Summary

Model Configuration

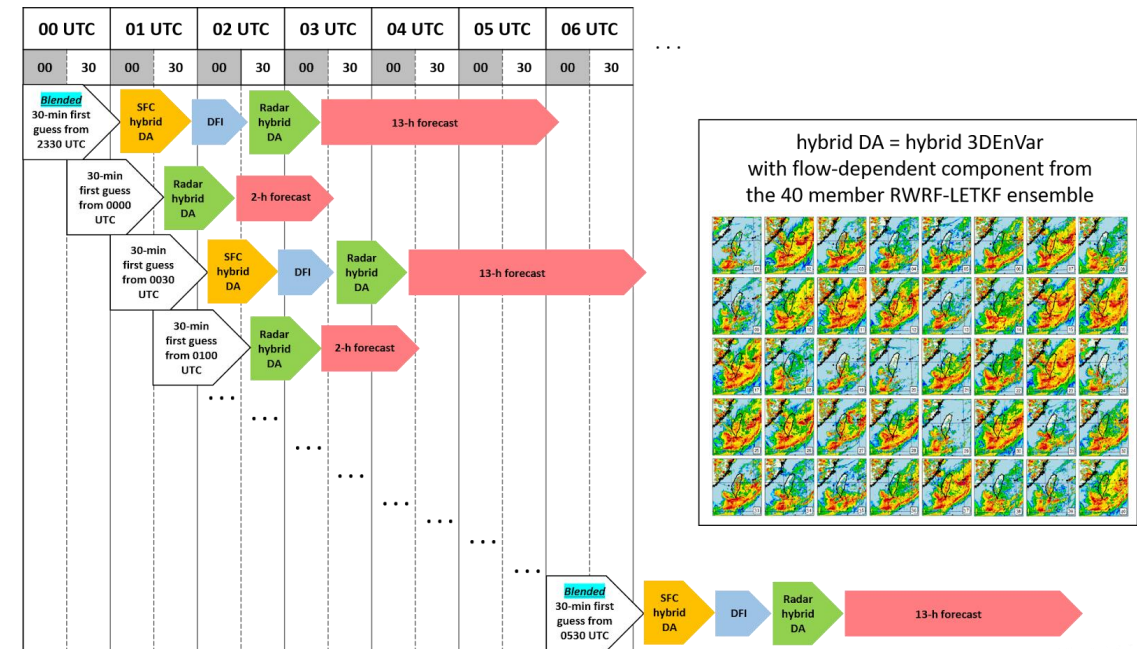
✓ Configuration:

- 10-km mesh:
 - Downscale run from NCEP GFS
 - Drive 2-km mesh by IC & BC
- **2-km mesh:**
 - *RWRF-EnVar* / *RWRF-LETKF* / *CEPS*
 - Provide next **13 hours** model forecast



✓ RWRF-EnVar Assimilation strategy:

- 30-min continuous cycling of Hybrid 3DEnVar (cv7)
- 1-hourly sfc DA: updates U, V, T, Ps, pseudo RH
- 30-min radar Vr DA: updates U, V, T, QVAPOR, P, PSFC, MU
- 30-min radar Ref DA: updates Qr, Qs, & Qg

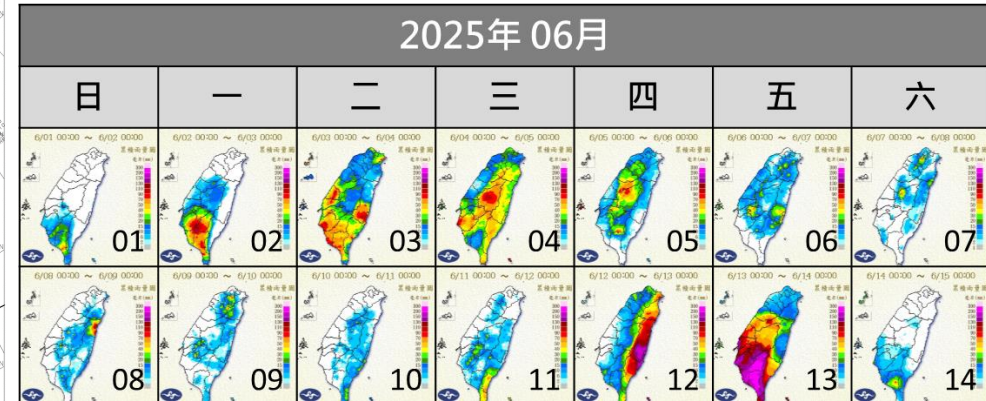
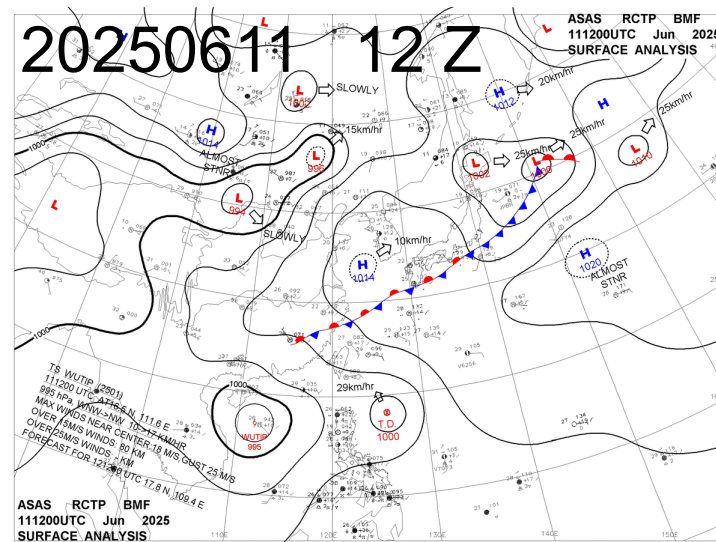
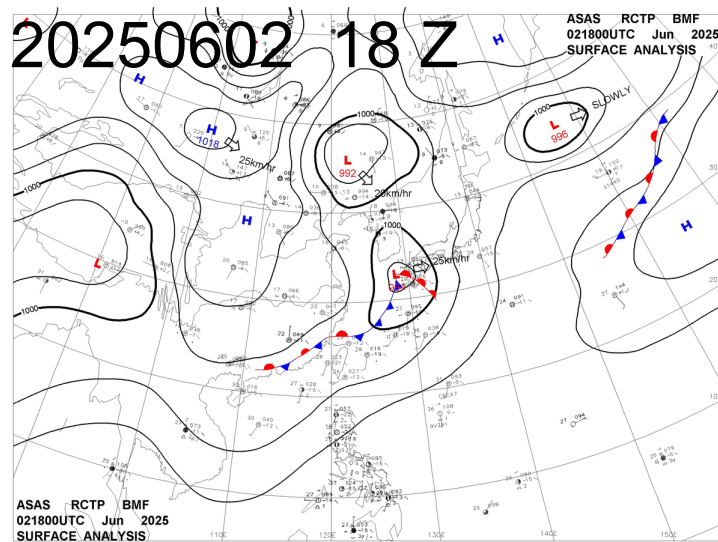


TCWA1微物理參數法 / Noah LSM / YSU邊界層參數法 /

NOAH土壤模式/RRTMG長波及短波輻射參數法

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Case Selection: 20250602 00 – 20250613 06



1. 全台梅雨強降雨高峰期 (6月2日 — 4日)

- 天氣系統：主要受滯留鋒面與西南季風共同影響 (對照 6/2 地面分析圖，滯留鋒面橫跨台灣地區)。
- 天氣特徵：全台經歷大範圍、連續性的強降雨，為天氣最為悶熱且不穩定的梅雨高峰期。

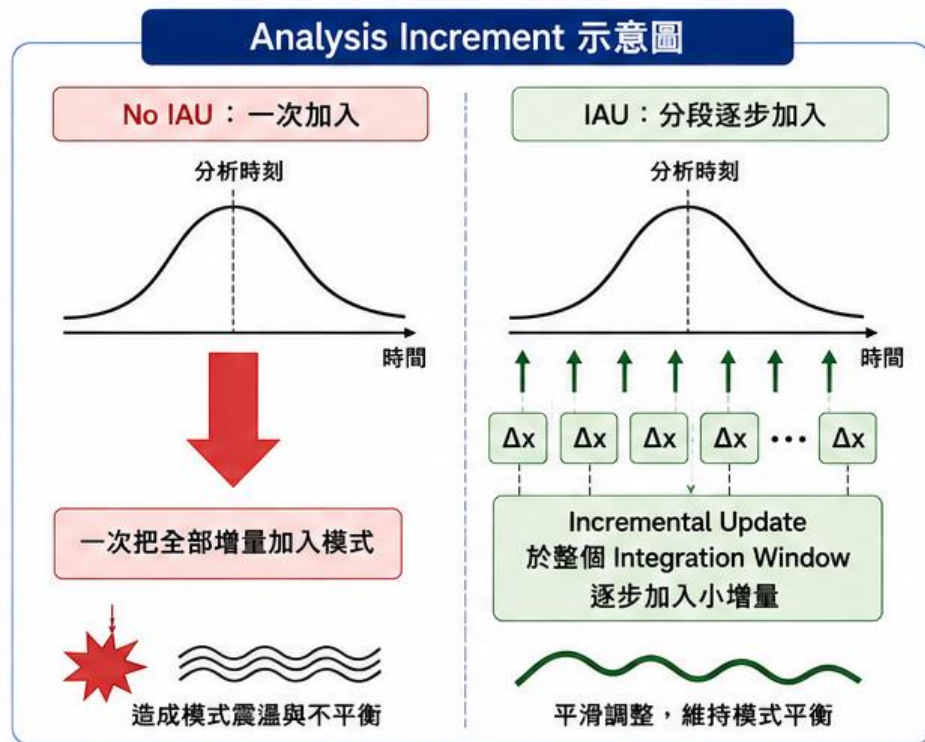
2. 鋒面北抬與午後對流發展期 (6月5日 — 10日)

- 天氣系統：鋒面略微北抬，台灣周圍被暖濕空氣包裹。同時太平洋熱帶洋面轉趨活躍，南海有熱帶低壓 (TD) 形成。
- 天氣特徵：降雨模式轉為以午後對流發展為主，易有局部強降雨；整體天氣格局開始轉向受熱帶低壓外圍環流水氣影響。

3. 颱風與熱帶低壓影響期 (6月11日 — 13日)

- 天氣系統：蝴蝶颱風 (TS WUTIP) 生成 (對照 6/11 地面分析圖，位於南海 16.6°N 111.6°E)，隨後減弱為熱帶性低氣壓 (TD) 並向東移動通過台灣鄰近海域；原梅雨鋒面則大幅北抬至日本一帶。
- 天氣特徵：原梅雨鋒面的影響減弱，但在颱風與熱帶低壓環流夾擊下，降雨區域顯著轉移，東半部與南部地區降雨再次轉趨明顯。

Incremental Analysis Update



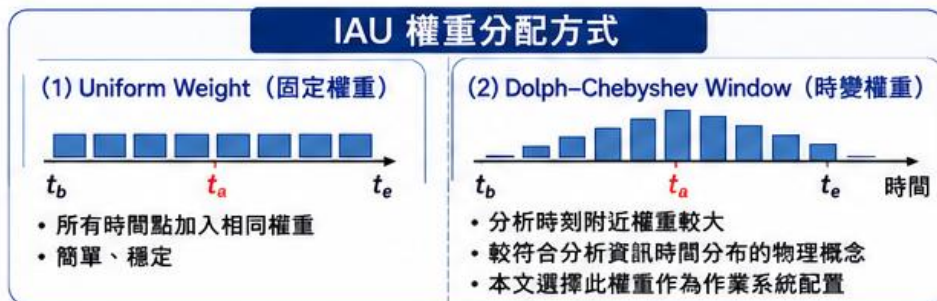
$$\left(\frac{\partial \phi}{\partial t}\right)^n = \left(\frac{\partial \phi}{\partial t}\right)_{dynamics}^n + \left(\frac{\partial \phi}{\partial t}\right)_{physics}^n + \lambda(t) \frac{\delta \phi_{ana}}{\Delta t_c}$$
$$\int_0^{\Delta t_c} \lambda(t) dt = 1, \lambda(t) \geq 0$$

n : each model integration step
 $\delta \phi_{ana}$: analysis increment

Δt_c : time span of IAU integration
 $\lambda(t)$: time-weighted coefficient

Bloom et al. (1996)

An incremental analysis update (IAU) scheme is successfully implemented into a WRF/WRFDA-based **hourly cycling** data assimilation system with the goal to **reduce the imbalance** introduced by the high-frequency intermittent data assimilation, especially when radar data are included. (Chen et al. 2023)

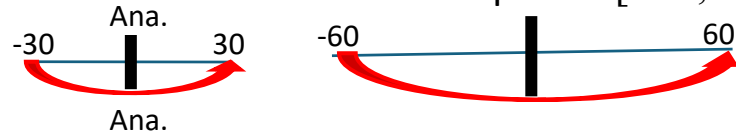


Sensitivity Tests of IAU Time Span and Time-Weighted Coefficients

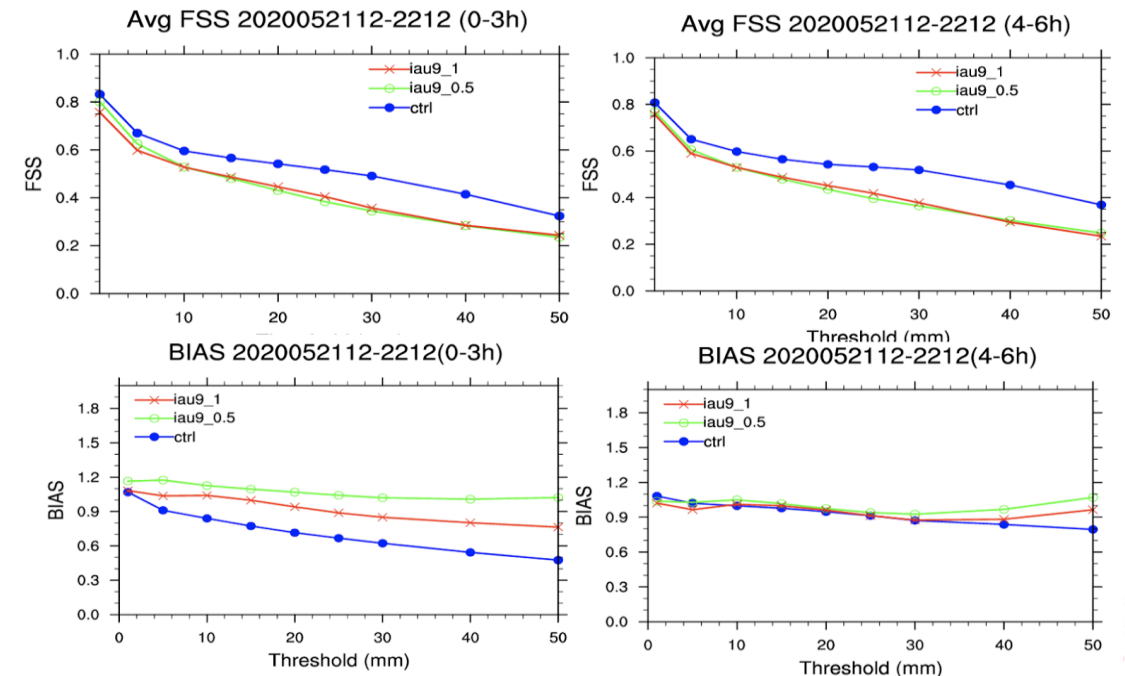
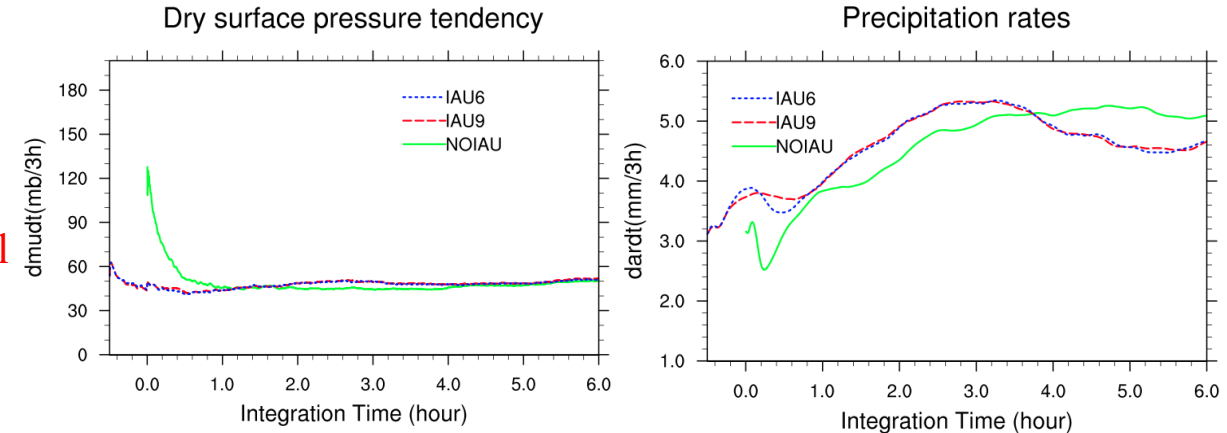
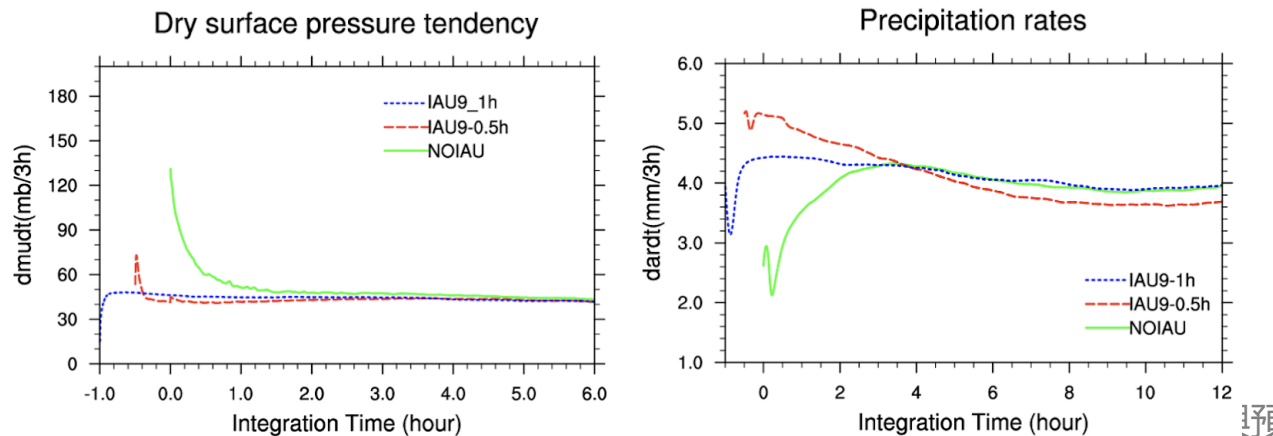
- Ran WRF forecast with and without IAU, and IAU time span is $t=[-0.5,0.5h]$

- Iau6: iau_nfilt = 6 (the Dolph-Chebyshev window filter)
- Iau9: iau_nfilt = 9 (the constant of the reciprocal of the total forecast steps)

- Run iau9 with different time span. $t=[-0.5,0.5h]$ and $t=[-1,1h]$

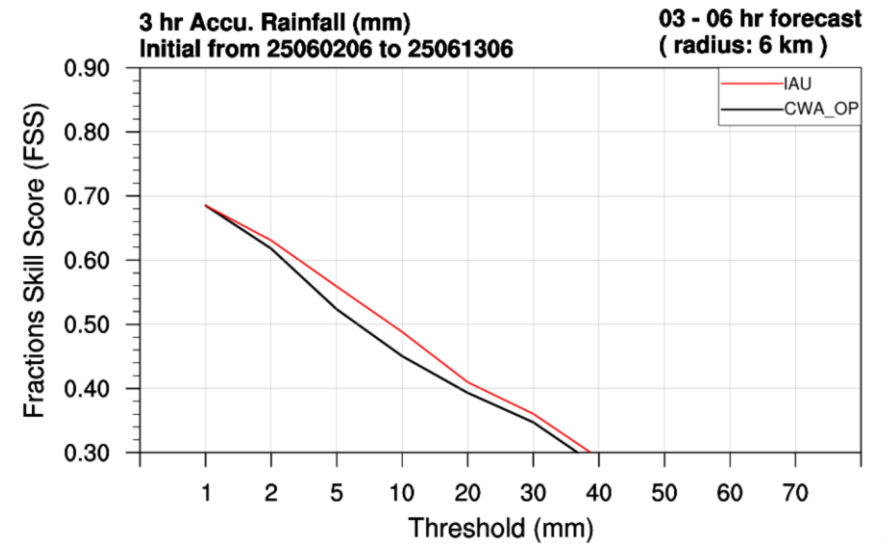
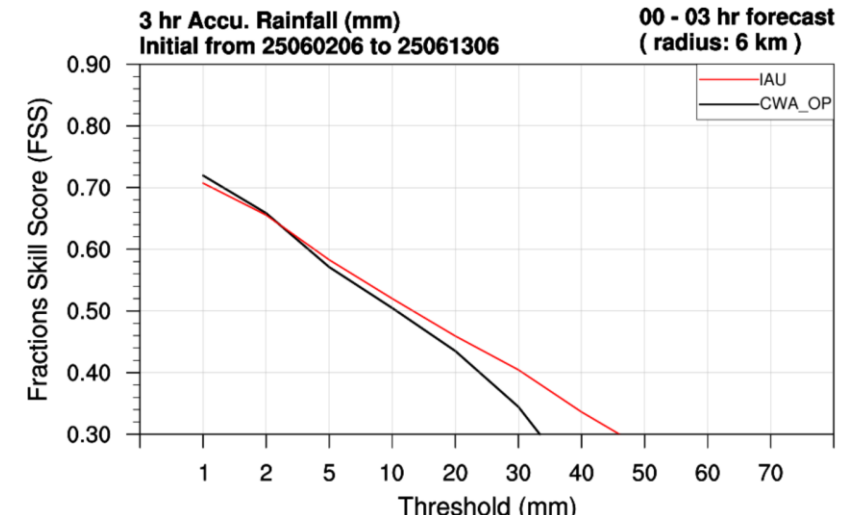
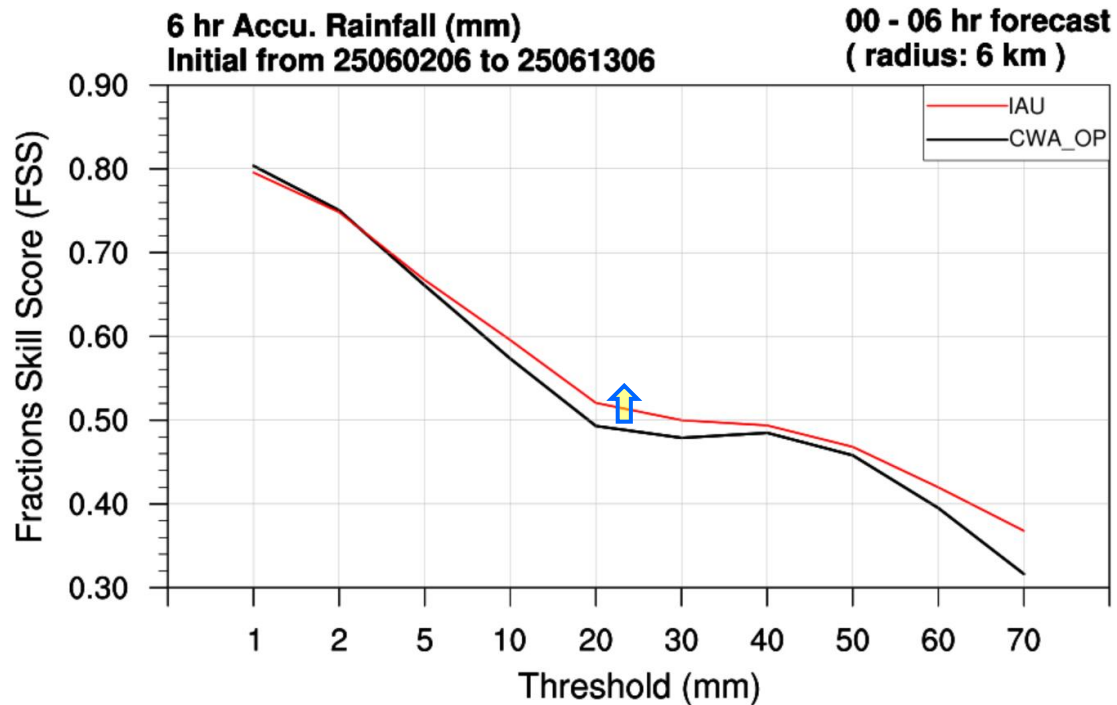


Domain-average dry surface pressure tendency and precipitation rates
Over 25 forecasts

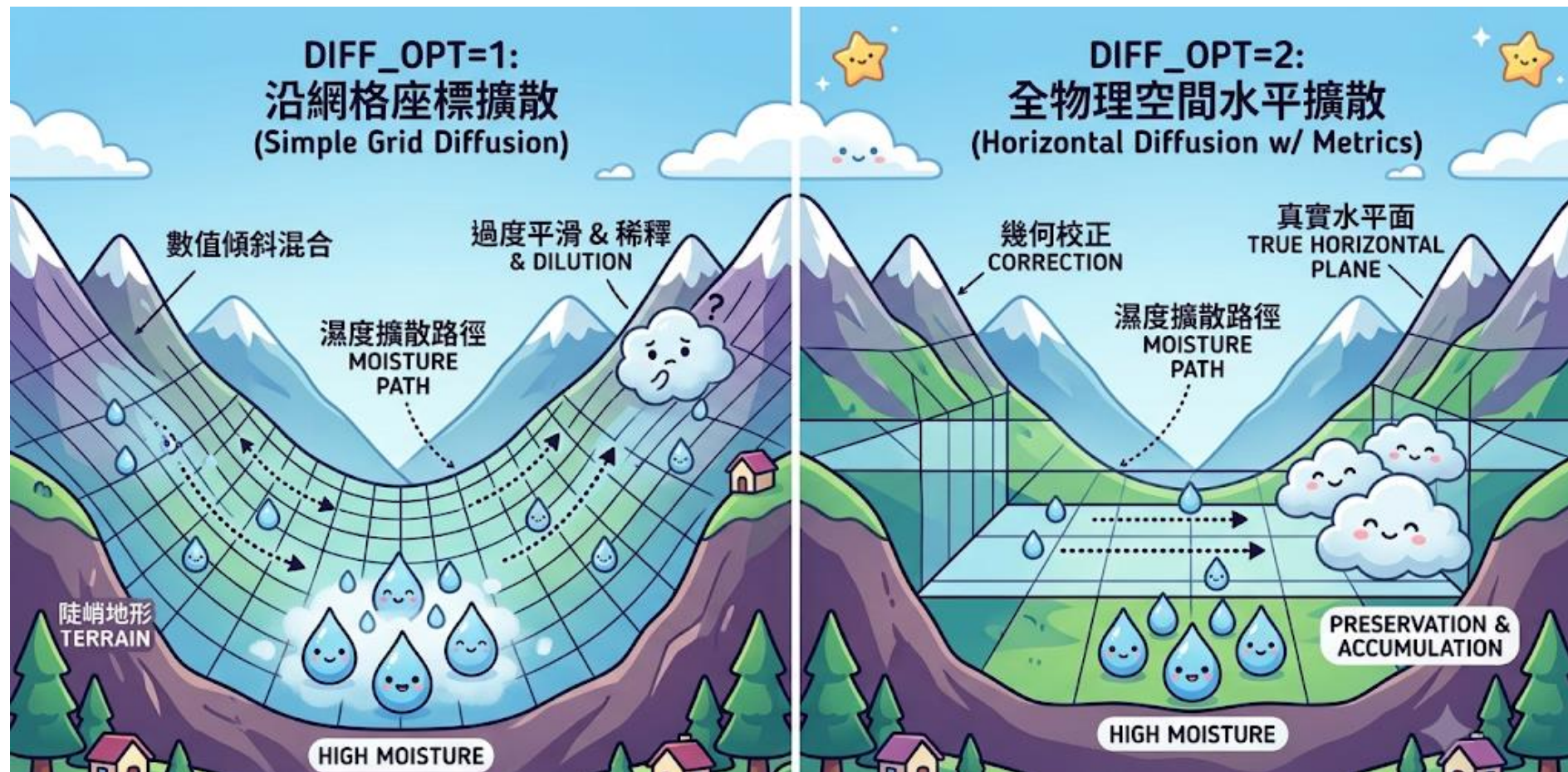


Precipitation Verification Results

Name of experiment	IAU	Window
CWA_OP	No	N/A
IAU	Yes	[-30min,30min]



Diffusion Schemes in WRF



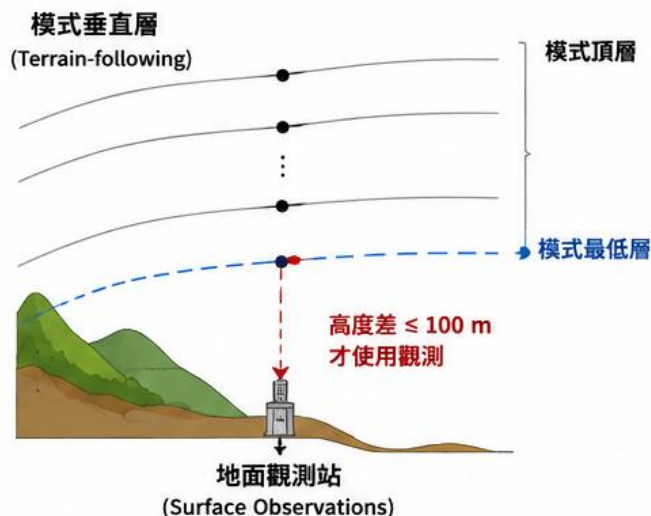
diff_opt=2可改進diff_opt=1的非物理性垂直方向擴散的問題，因此可抑制垂直混合過強的問題。
水氣：減少高層乾空氣向下混合，改進乾偏差 溫度：減少溫度混合，改變溫度垂直結構

Data Assimilation Methods for Surface Observations

地面觀測資料 (Surface Observations) 同化方式比較

sfc_assi_options = 1 (預設值 / Default)

直接基於模式最底層網格 (lowest model level) 進行同化



同化流程

觀測資料



直接與模式
最低層比較



創新值 (Innovation)
計算並同化



高度限制

觀測站與模式最低層
高度差 > 100 m
則剔除不使用



物理考量

不考慮近地面
邊界層物理
計算較直接簡單



優點

方法簡單
計算效率高

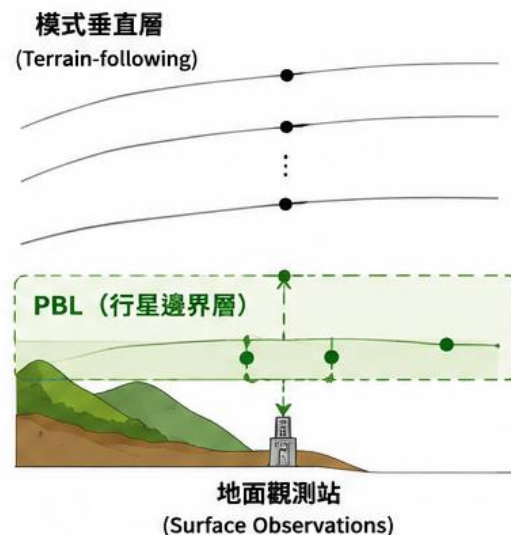


限制

受模式最低層高度
與觀測高度不一致
影響較大

sfc_assi_options = 2

基於行星邊界層 (PBL) 中的地表相似理論進行同化



同化流程

觀測資料



利用地表相似理論
(Surface Similarity Theory)

診斷近地面變數



與觀測比較



創新值 (Innovation)
計算並同化



高度限制

不依最低層高度
直接比對, 無 100 m
高度差限制



物理考量

考慮 PBL 與地表
相似理論, 符合
近地面物理特性



優點

更符合觀測的物理定義
可減少高度不一致
造成的誤差



適用情況

複雜地形、穩定邊界層
或高度差較大的區域
表現較佳

Experiment Design

Name of experiment	sfc_assi_options	diff_opt
OP	1	1
OP51s1	1	2
OP51	2	2

sfc_assi_options

Option 1: assimilates surface observations using the lowest model level

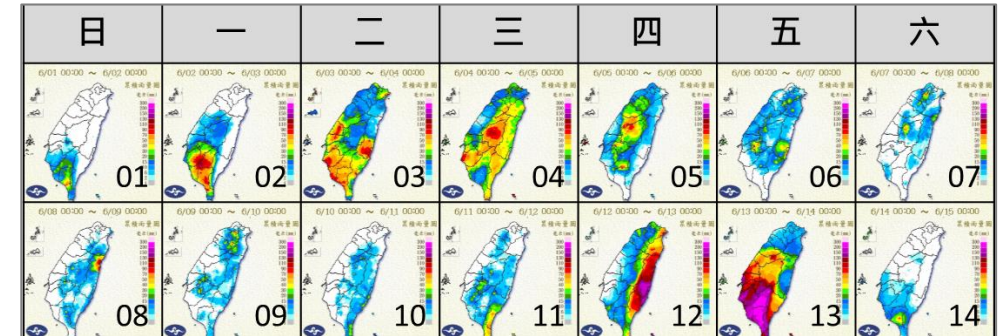
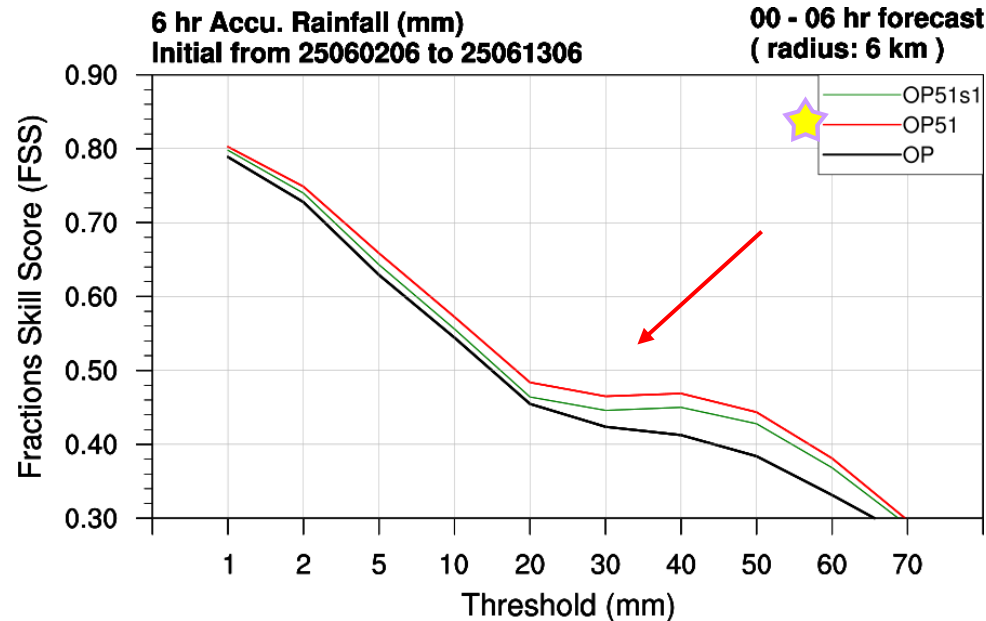
Option 2: applies surface-layer similarity theory to diagnose variables at actual observation heights for assimilation.

diff_opt

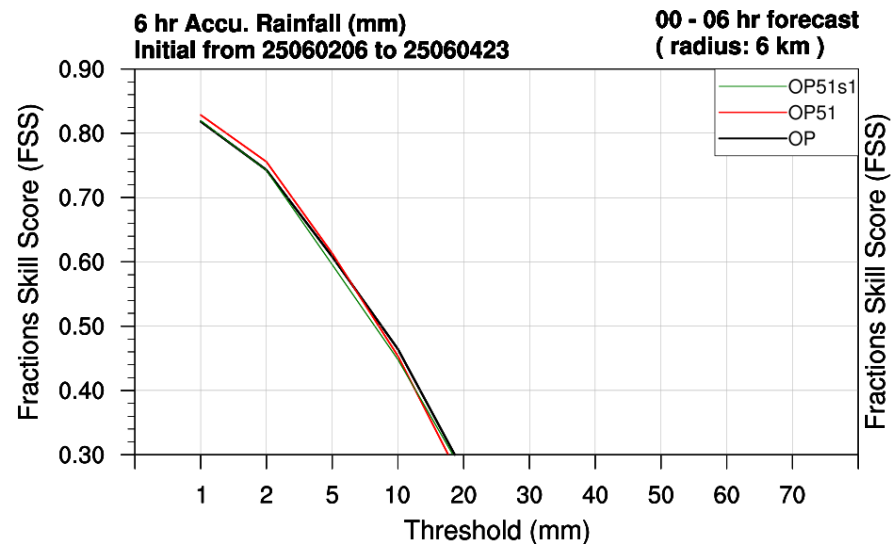
Option 1: computes diffusion along model grid surfaces

Option 2: calculates full 3D diffusion in physical space to evaluate gradients accurately over complex terrain.

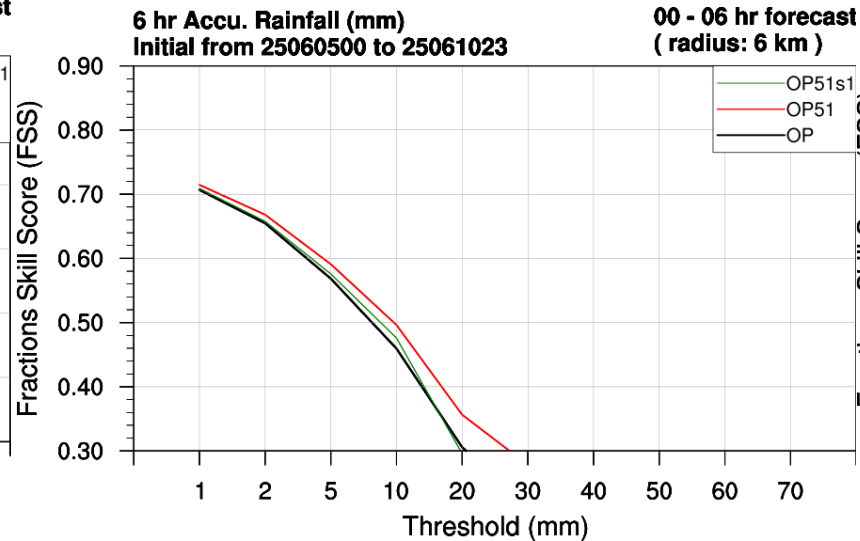
Precipitation Verification Results



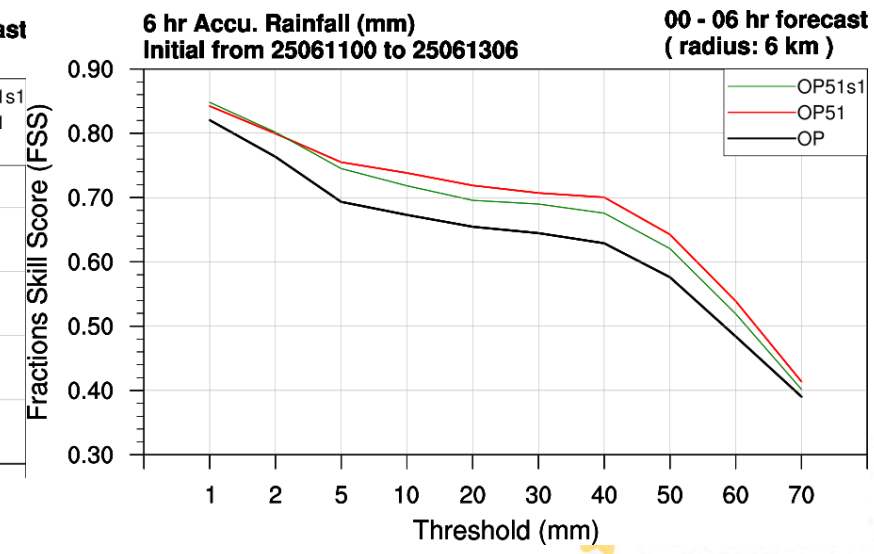
1. 全台梅雨強降雨高峰期



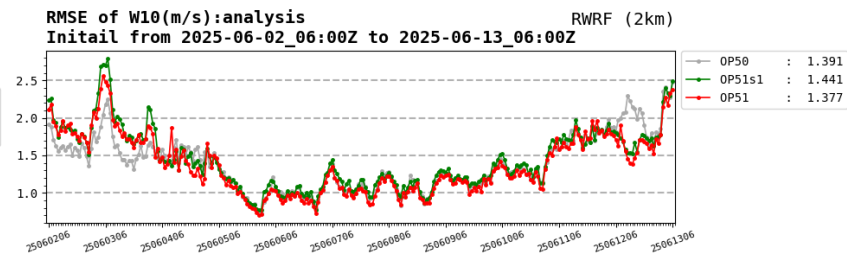
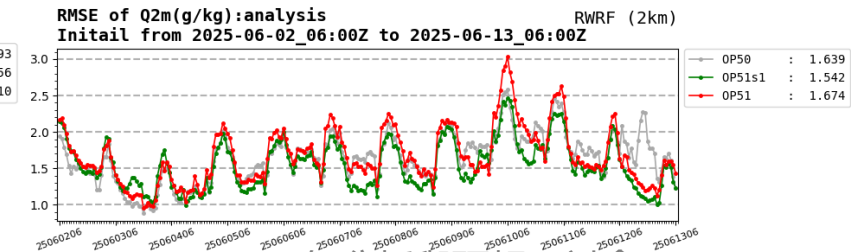
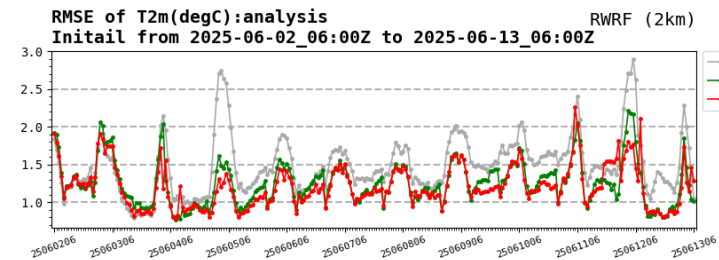
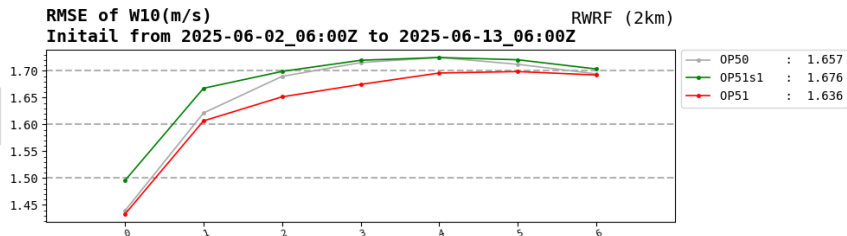
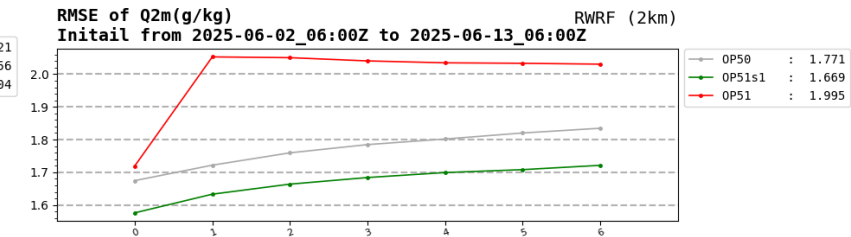
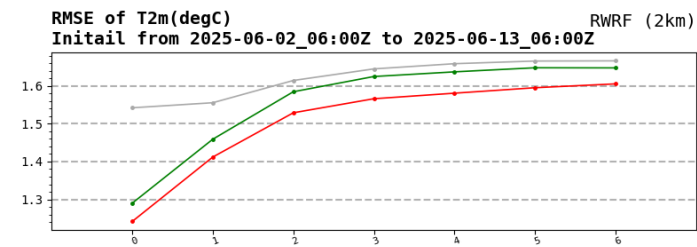
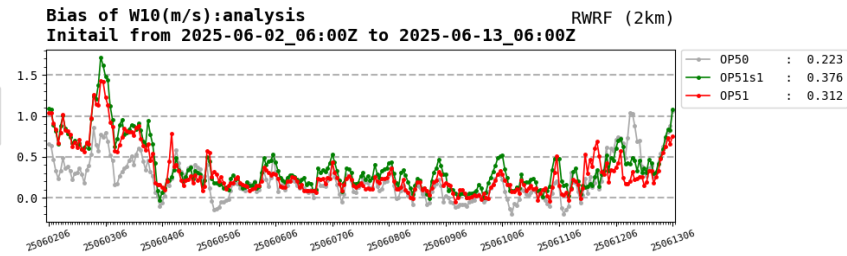
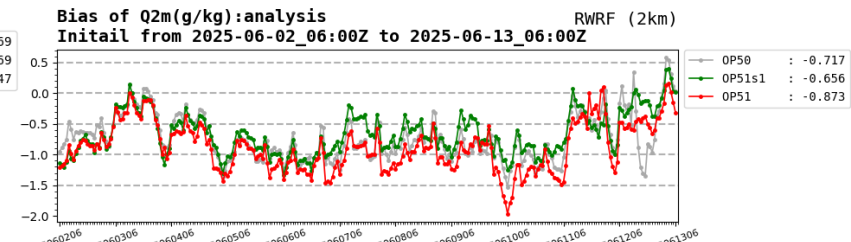
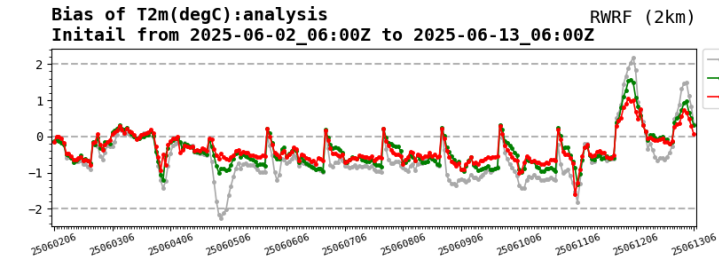
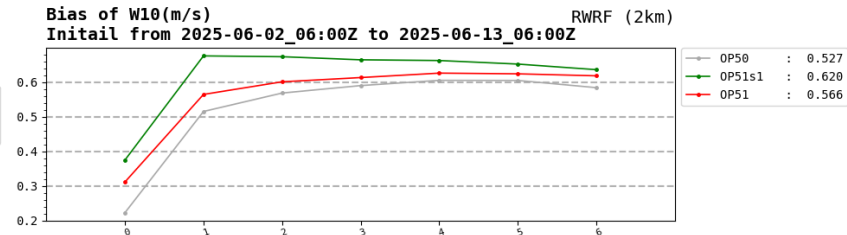
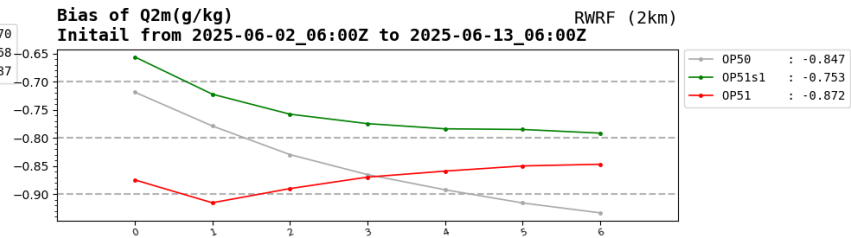
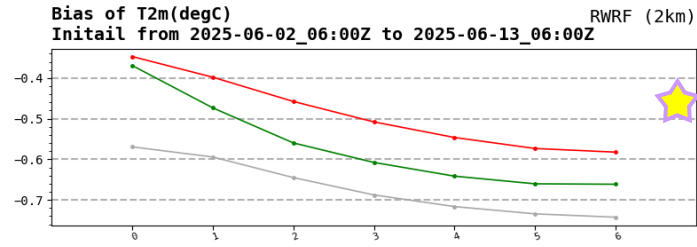
2. 鋒面北抬與午後對流發展期



3. 颱風與熱帶低壓影響期



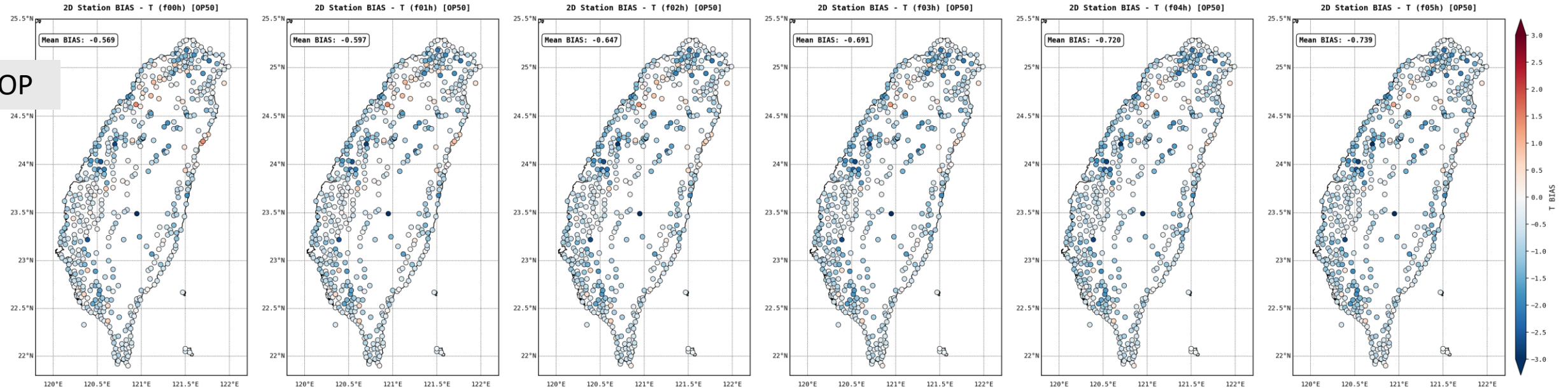
Surface Verification Results



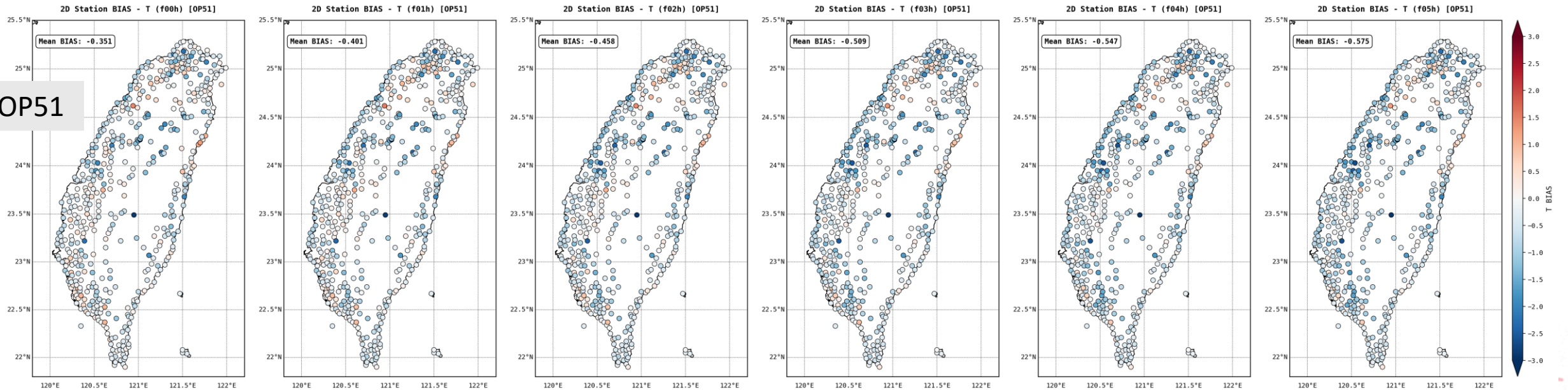
Mitigating of Cold Bias

Surface Verification Results

OP

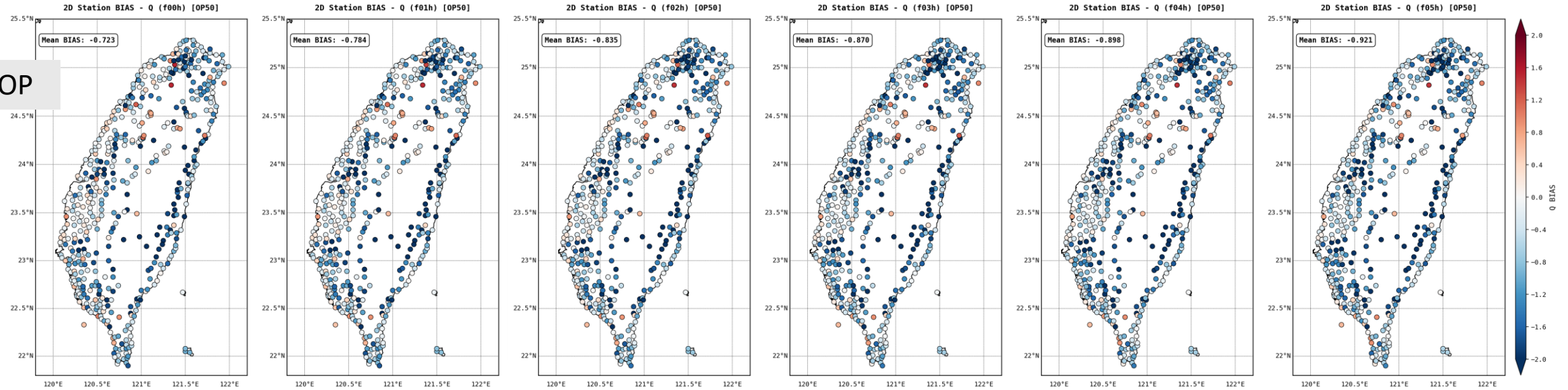


OP51

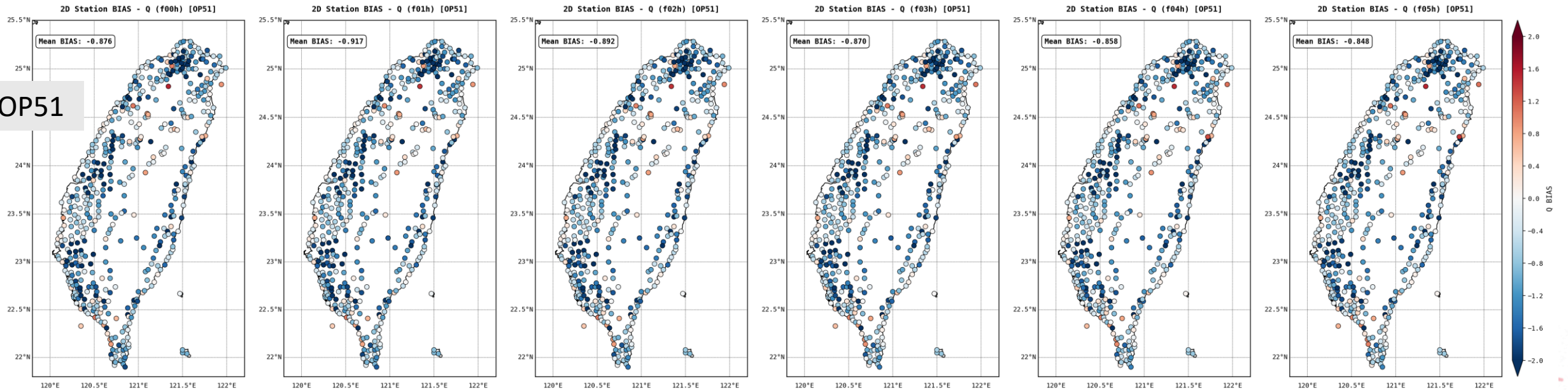


Surface Verification Results

OP

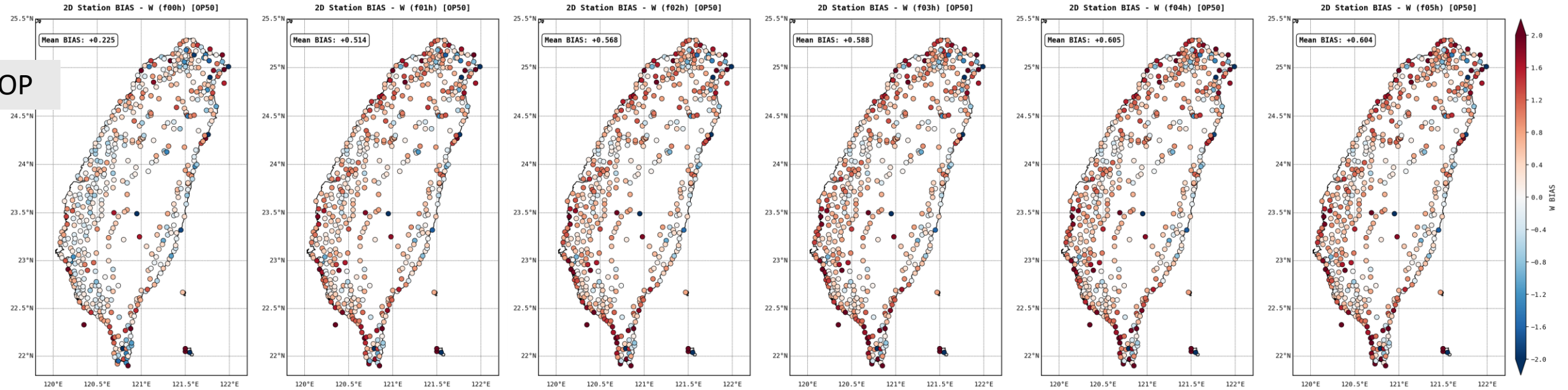


OP51

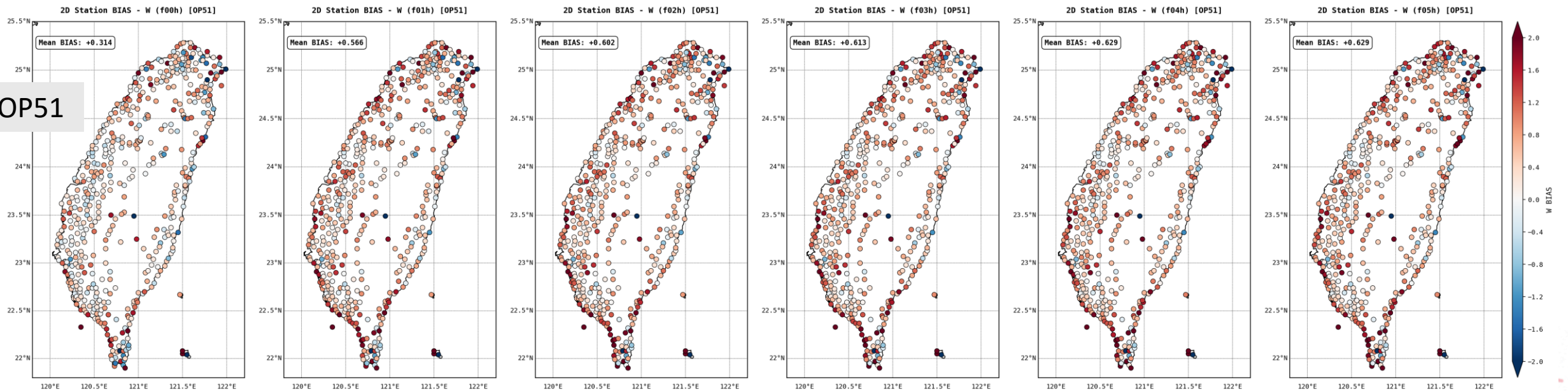


Surface Verification Results

OP



OP51

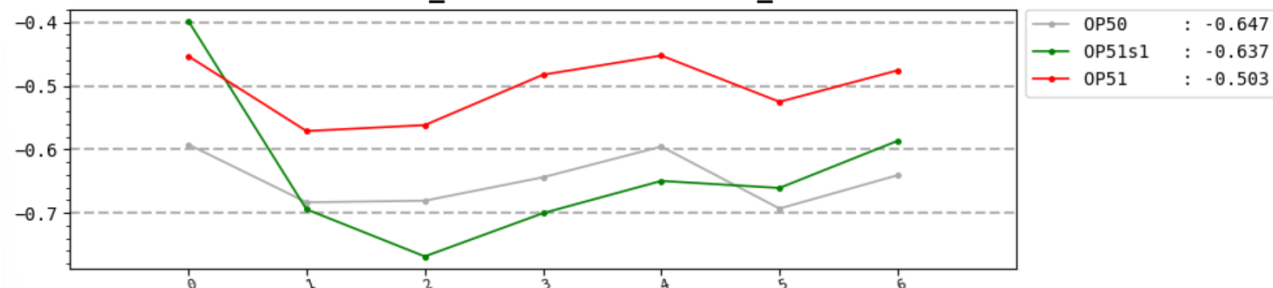


Surface Verification Results

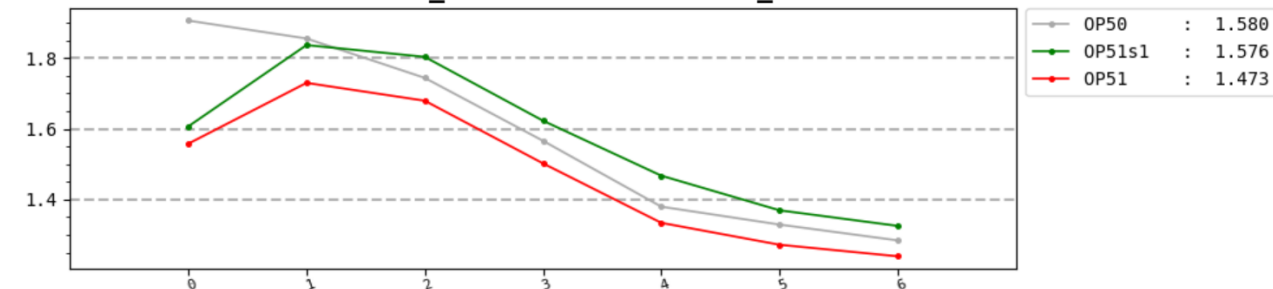
- 單元測試— Diffusion實驗：diffopt=2 (改善Q2預報表現)；小玲
- 單元測試— NOAH土壤參數法調整 (改善urban之T2預報表現)；伯勳
- ✓ OP51整合測試 (改善Q2夜間乾偏差及T2日間冷偏差)；小玲

00 RUN

Bias of T2m(degC)
Initail from 2025-06-02_06:00Z to 2025-06-13_06:00Z RWRf (2km)



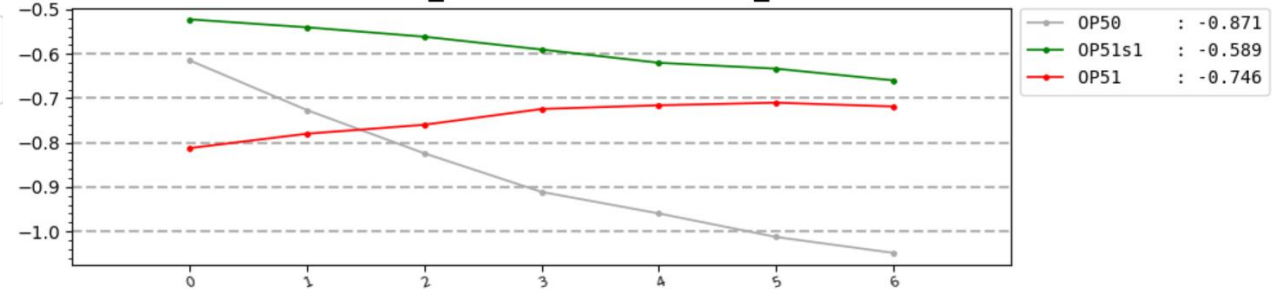
RMSE of T2m(degC)
Initail from 2025-06-02_06:00Z to 2025-06-13_06:00Z RWRf (2km)



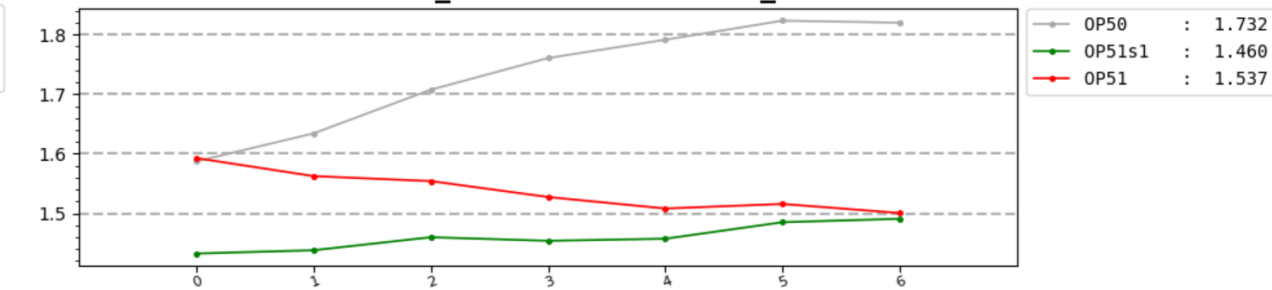
改進冷偏差

12 RUN

Bias of Q2m(g/kg)
Initail from 2025-06-02_12:00Z to 2025-06-12_12:00Z RWRf (2km)



RMSE of Q2m(g/kg)
Initail from 2025-06-02_12:00Z to 2025-06-12_12:00Z RWRf (2km)



改進乾偏差

Summary

- **Incremental Analysis Updates (IAU)**
 - Coupled IAU into the WRF/WRFDA hourly rapid cycling system
 - Mitigated initial model shock and high-frequency gravity wave noise compared to traditional 3D-Var impulsive updates.
 - Achieved higher Fractions Skill Scores (FSS) for 00–06 h accumulated rainfall across all thresholds.
- **Diffusion Schemes & Surface Data Assimilation**
 - **Optimal Rainfall Skill:** Combining updated surface data assimilation with optimized diffusion and PBL schemes yielded the highest precipitation verification scores.
 - **Surface Bias Correction:** Significantly **mitigated daytime cold bias** (temperature) and night-time **dry bias** (moisture).

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天氣分析與預報研討會
40th Conference on Weather Analysis and Forecasting

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四十不惑、研研領航

研討會主題

- 大風區研究分析
- 文島風災後復興
- 氣象局與民間
- 風能利用與發展
- 文島風災後復興
- 文島風災後復興
- 本文型氣象資料分析
- 文島風災後復興

Thank You
for Your Attention!

115 天氣分析
研討會