



極短期劇烈天氣預報系統之發展： 於 RWRF 系統使用 IAU 之策略與影響評估

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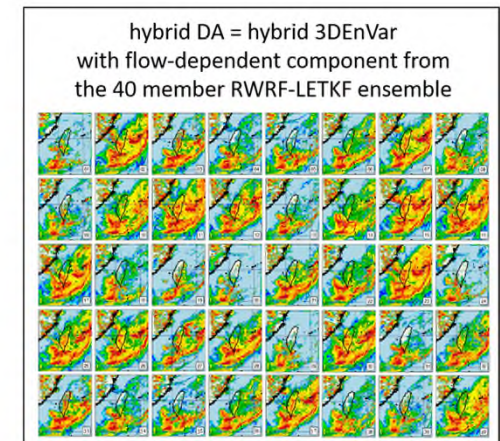
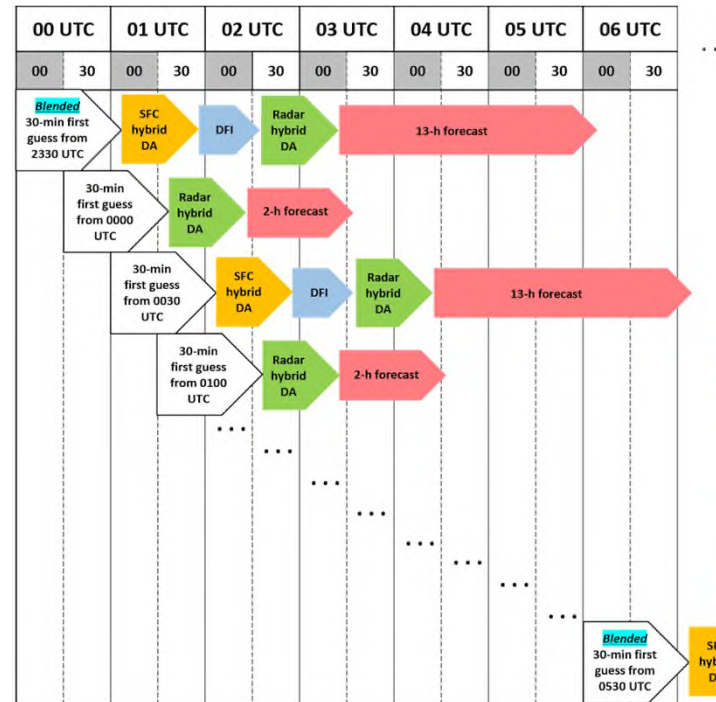
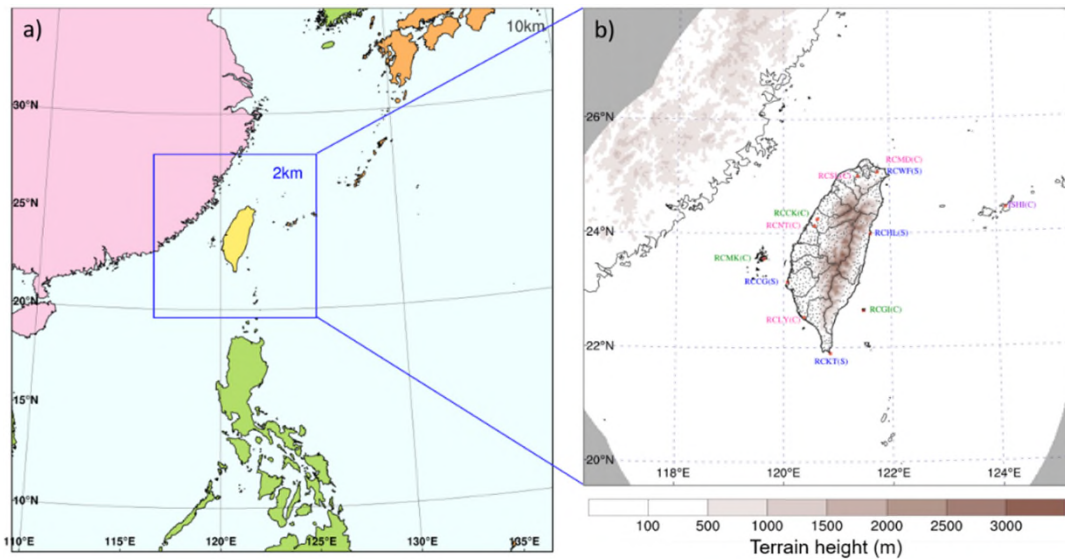
Model Configuration

✓ Configuration:

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

✓ RWRF-VAR Assimilation strategy:

- 30-min continuous cycling of Hybrid 3DVar (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



Incremental Analysis Update

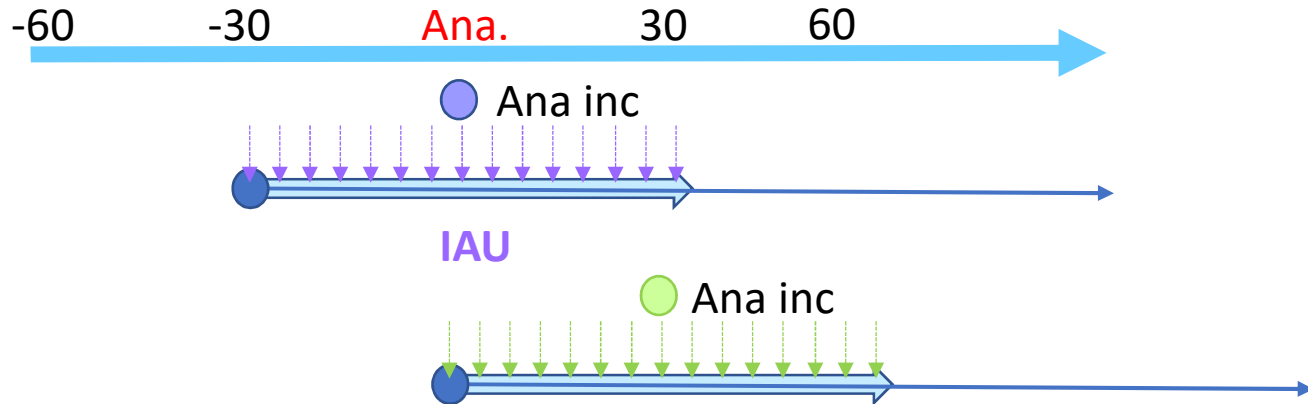
$$\left(\frac{\partial\phi}{\partial t}\right)^n = \left(\frac{\partial\phi}{\partial t}\right)_{dynamics}^n + \left(\frac{\partial\phi}{\partial t}\right)_{physics}^n + \lambda(t) \frac{\delta\phi_{ana}}{\Delta t_c}$$

$$\int_0^{\Delta t_c} \lambda(t) dt = 1, \lambda(t) \geq 0$$

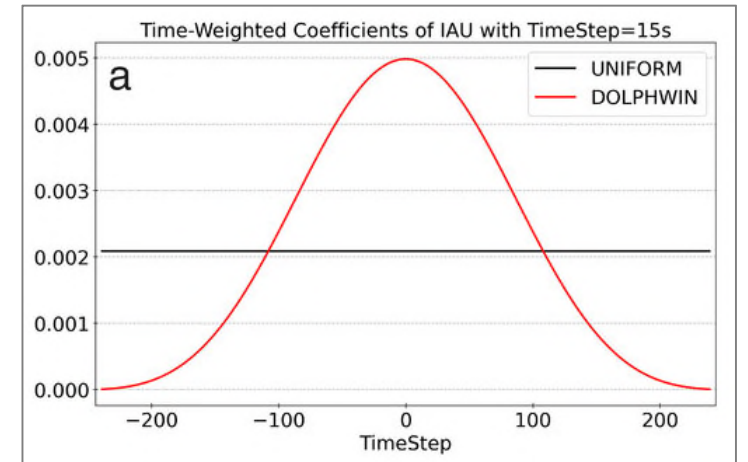
n: each model integration step
 $\delta\phi_{ana}$: analysis increment

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

Bloom et al. (1996)

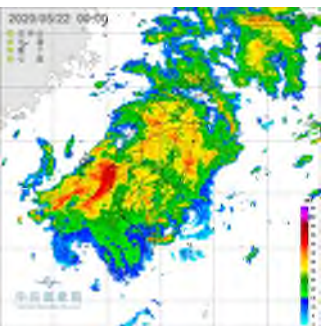
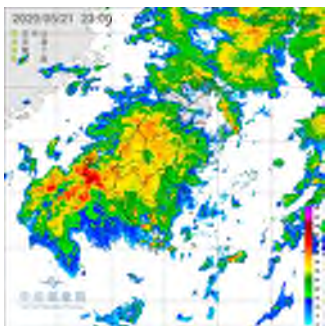
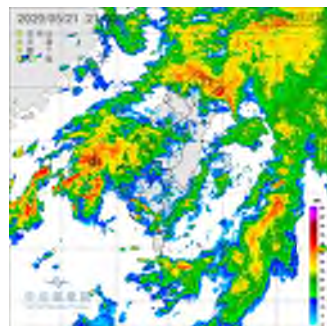
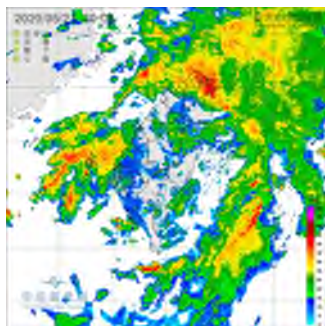


An incremental analysis update (IAU) scheme is successfully implemented into a WRF/WRFDA-based **hourly cycling** data assimilation system with the goal to reduce the imbalance introduced by the high-frequency intermittent data assimilation, especially when radar data are included. (Chen et al. 2023)

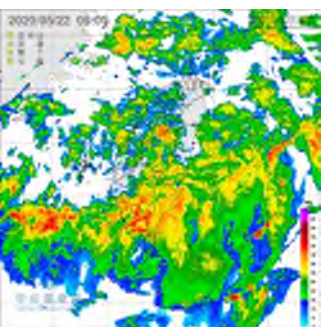
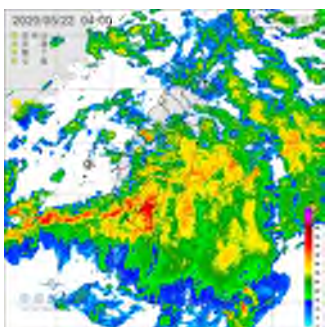
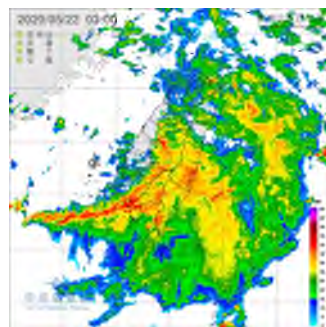
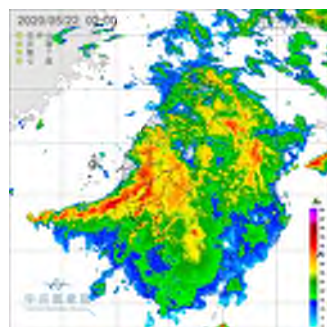
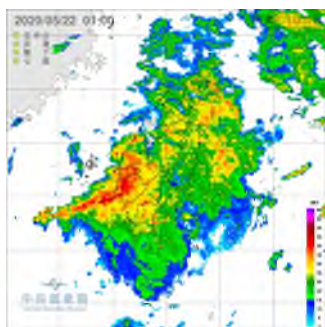


Experiment Time 1 : 2020052112 ~ 2020052212 UTC

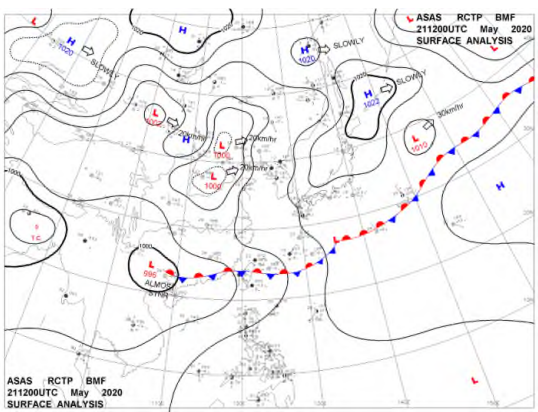
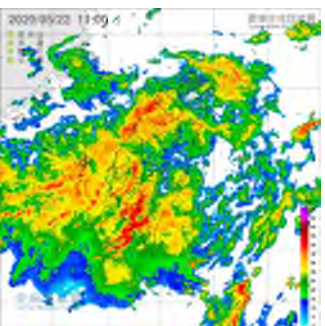
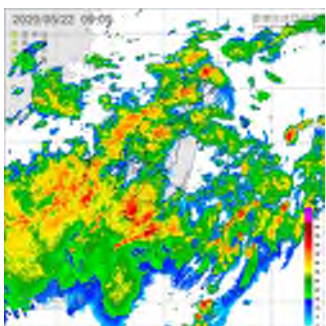
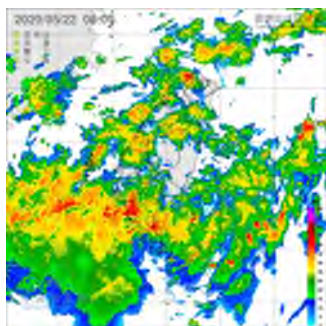
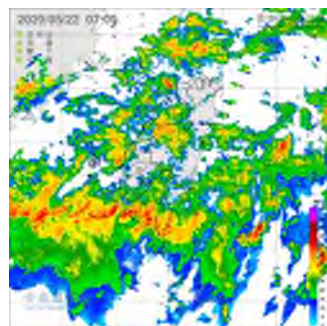
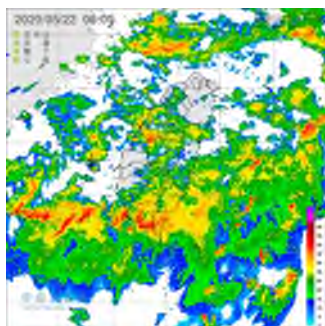
2025/06/12
(0100 – 0600 UTC)



2025/06/12
(0700 – 1200 UTC)



2025/05/12
1300 UTC – 1800 UTC



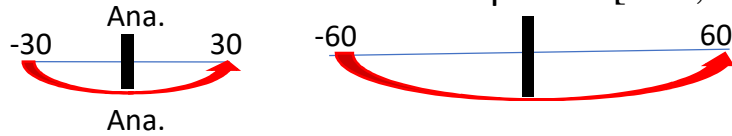
Sensitivity Tests of IAU Time Span and Time-Weighted Coefficients

➤ Ran WRF forecast with and without IAU, and IAU time span is

$t=[-0.5,0.5h]$

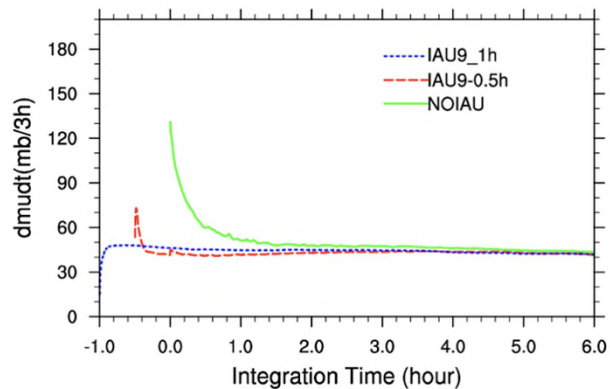
- Iau6: iau_nfilt = 6 (the Dolph-Chebyshev window filter)
- Iau9: iau_nfilt = 9 (the constant of the reciprocal of the total forecast steps)

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

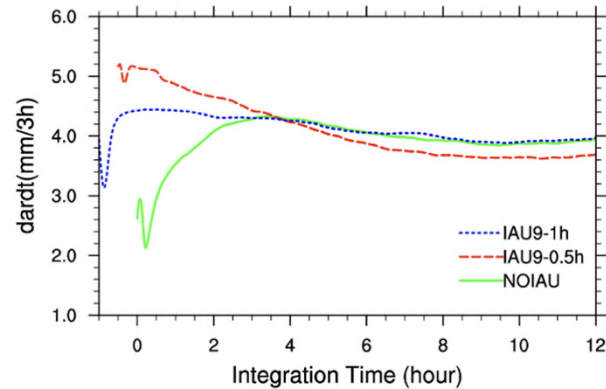


Domain-average dry surface pressure tendency and precipitation rates Over 25 forecasts

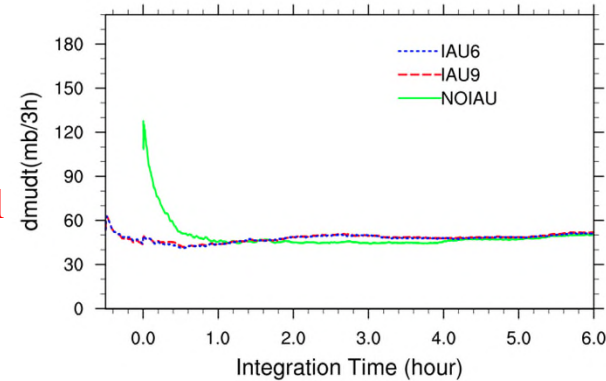
Dry surface pressure tendency



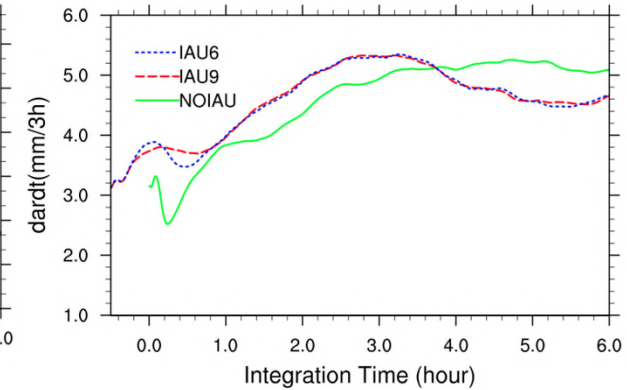
Precipitation rates



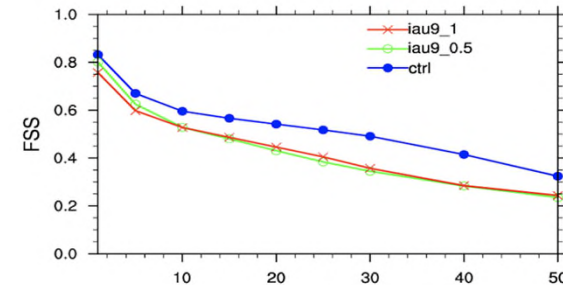
Dry surface pressure tendency



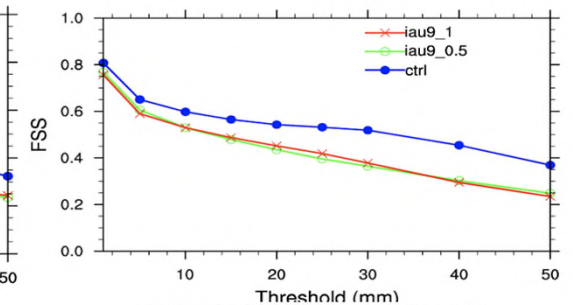
Precipitation rates



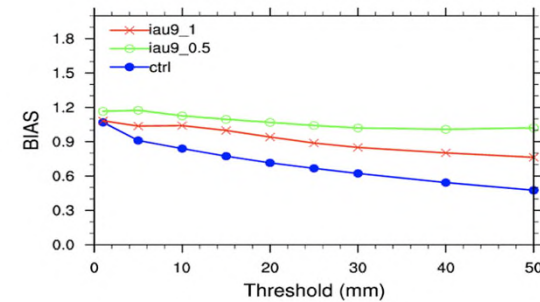
Avg FSS 2020052112-2212 (0-3h)



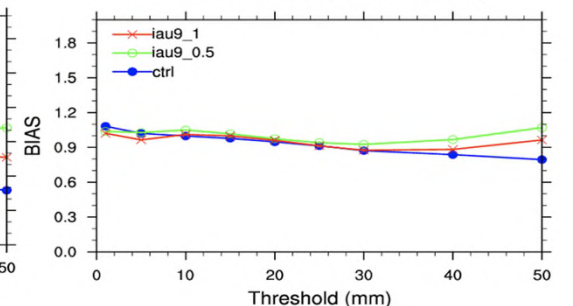
Avg FSS 2020052112-2212 (4-6h)



BIAS 2020052112-2212(0-3h)

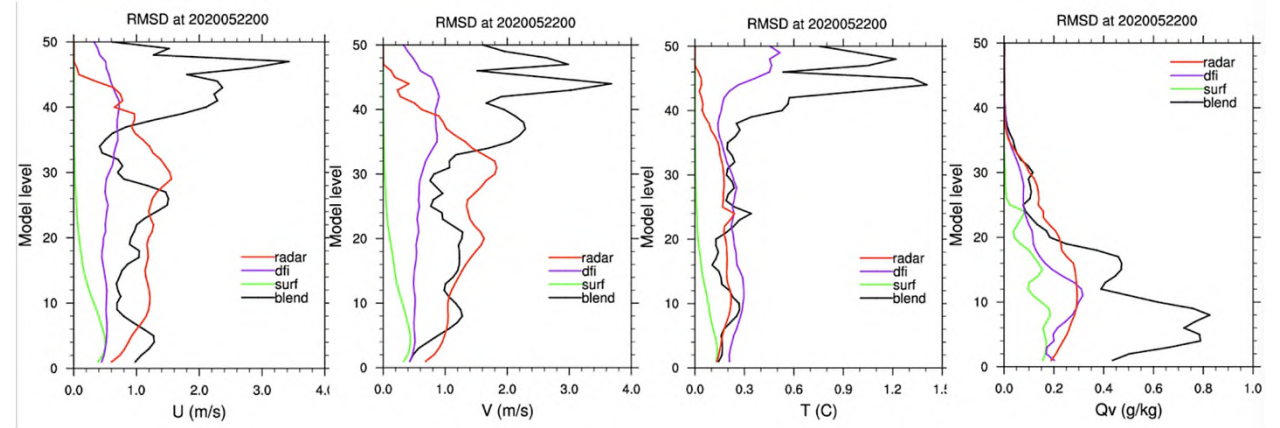
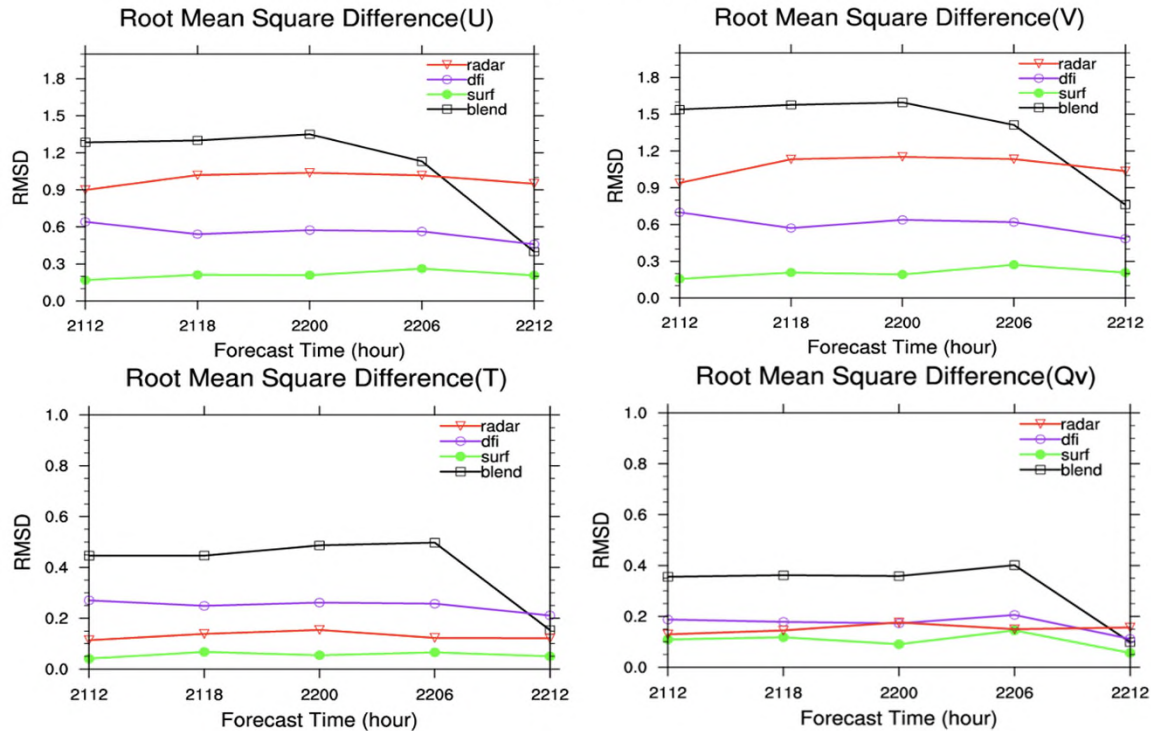


BIAS 2020052112-2212(4-6h)



Increment Contributions at Blending Times

RMSD between analysis and first guess at each step
at the blending times (every six hour)

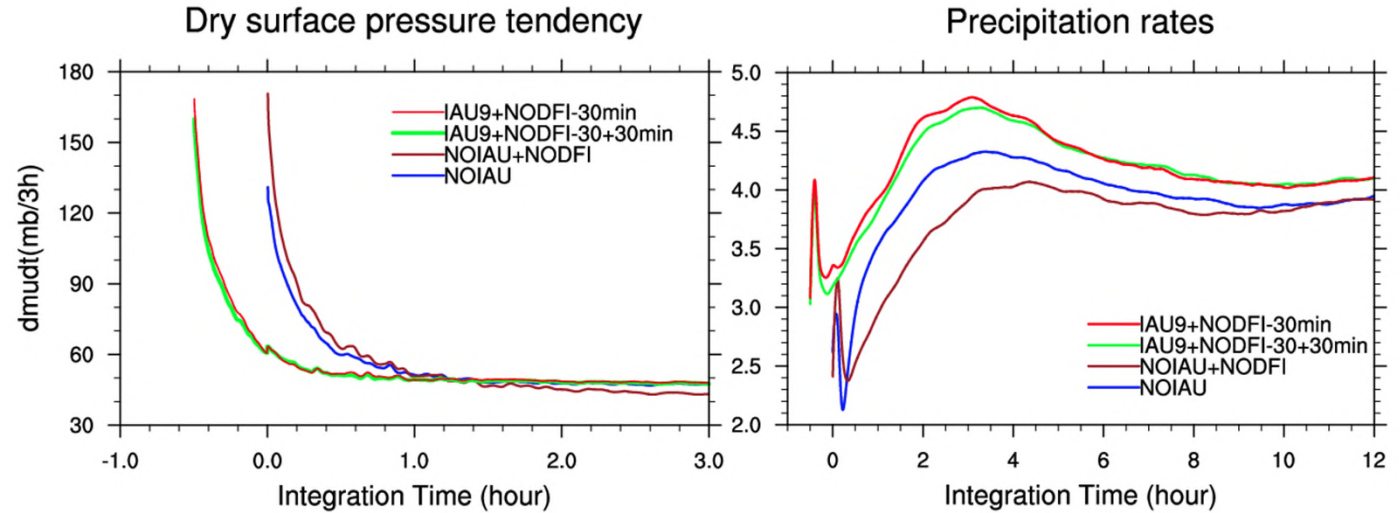


- **Surface DA** had effects limited to the **lower levels**
 - **Blending** major corrections at **upper levels** for **u, v, and T**, significantly affected low-level humidity
 - **DFI** influenced **all vertical levels**
- ➔ **Testing** without DFI

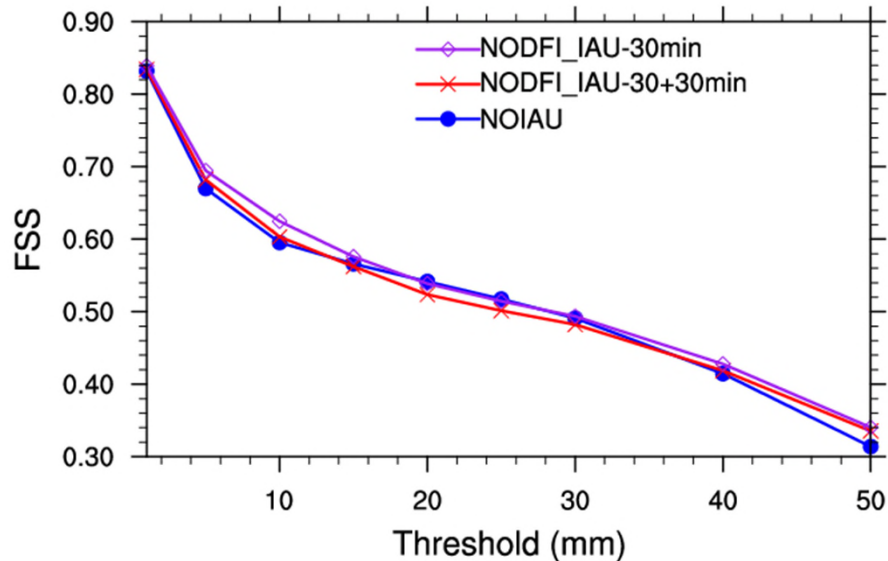
blending > radar DA > DFI > surface DA

Experimental Design 1

Experiment	IAU	IAU Window
NOIAU	No IAU	N/A
NOIAU+NODFI	No IAU	N/A
IAU9+NODFI-30+30min	with IAU	Ana. -30 30
IAU9+NODFI-30min	with IAU	Ana. -30



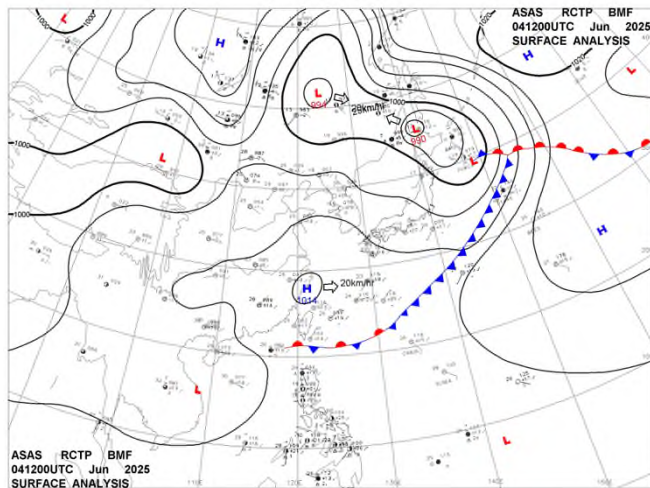
Avg FSS 20200521 12-2212 (0-3h)



- **IAU reduced initial precipitation spin-down as in NOIAU and NOIAU+NODFI.**
- **IAU slightly improved skills**

Experiment Time 2 : 20250612 00 ~ 18 UTC

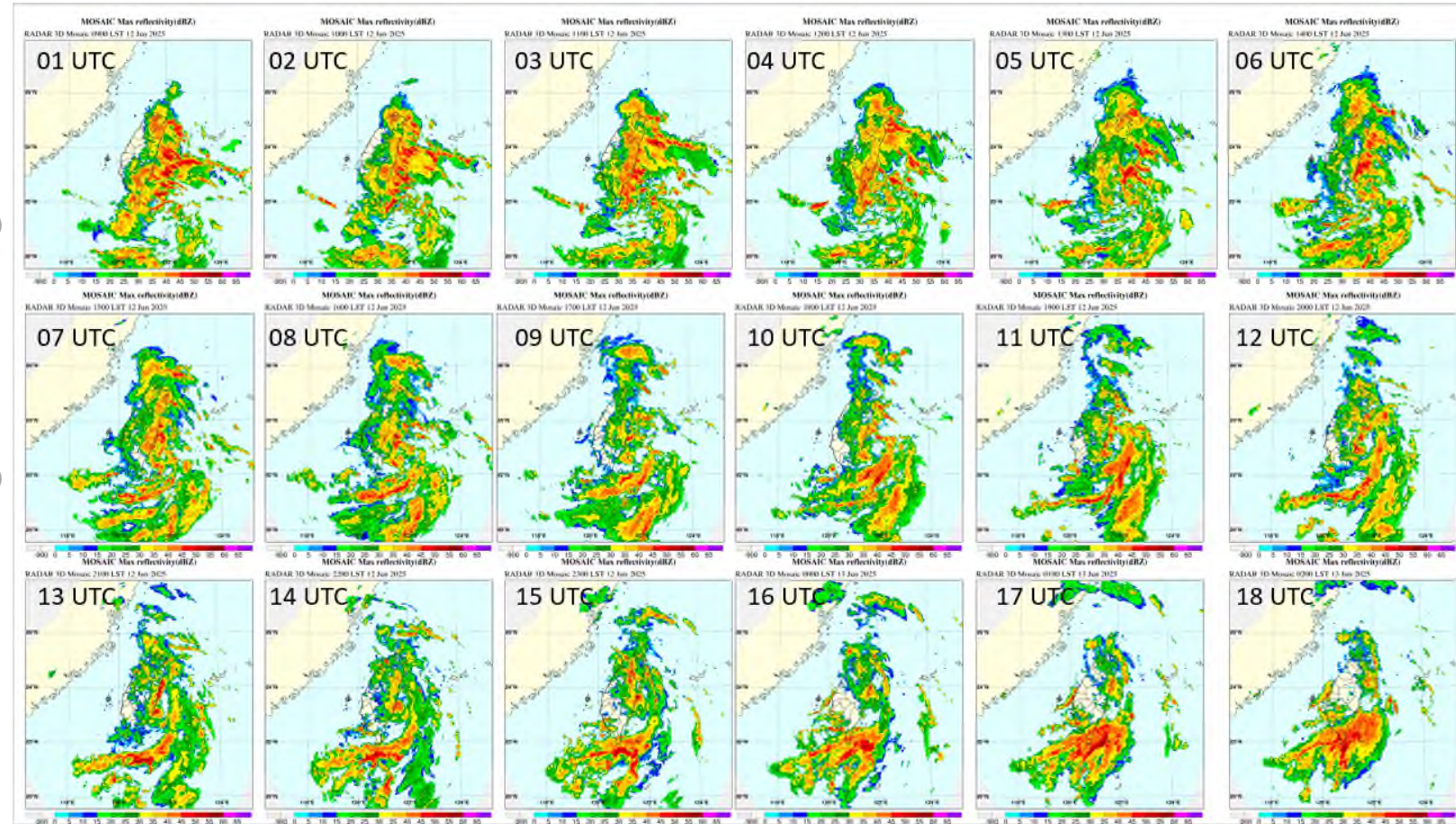
Hourly Radar Observed Maximum Reflectivity (dBZ)



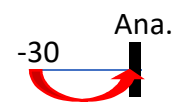

2025/06/12
0900 – 1400 LST
(0100 – 0600 UTC)

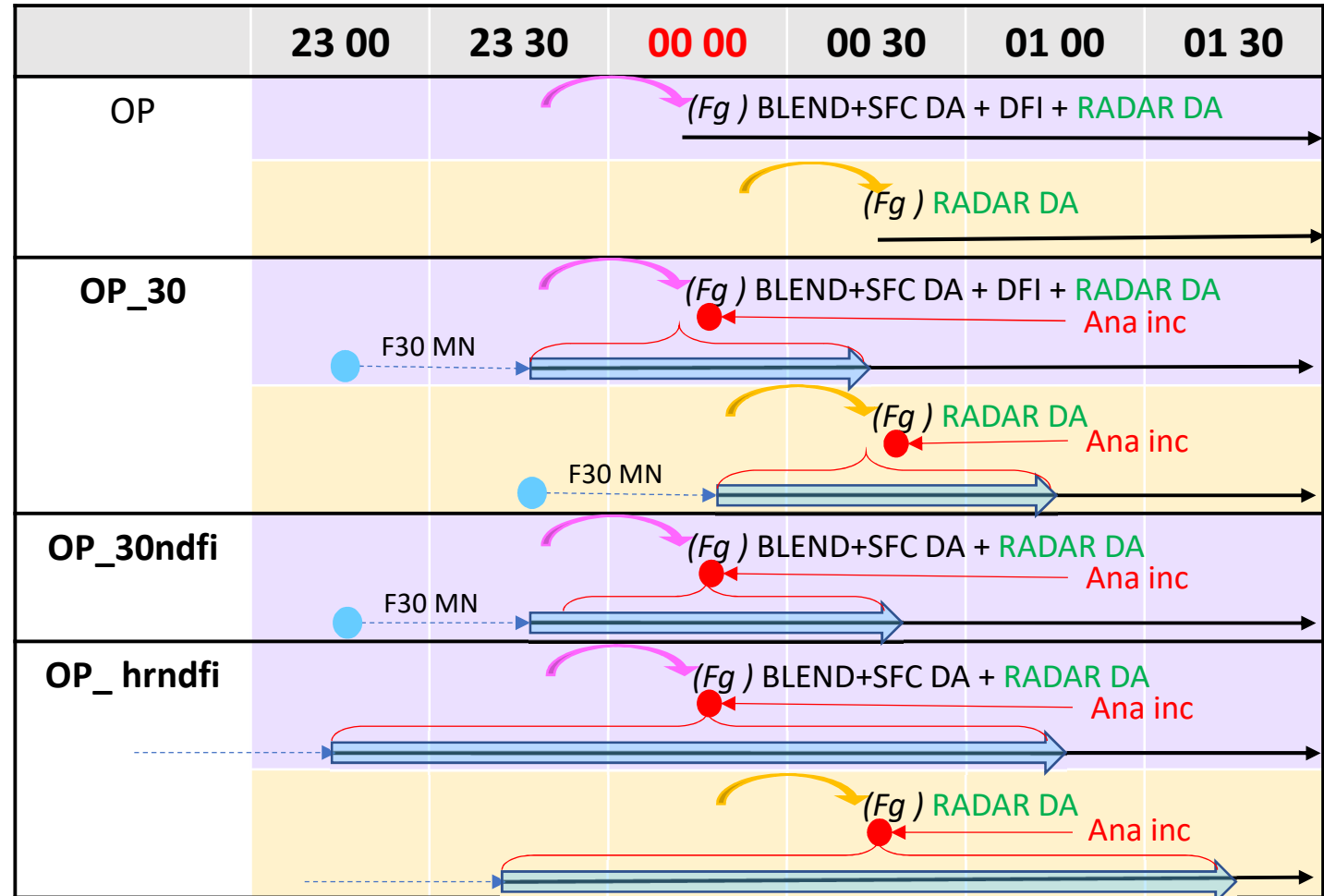
2025/06/12
1500 – 2000 LST
(0700 – 1200 UTC)

2025/06/12 2100 LST –
2025/06/13 0200 LST
(2025/06/12
1300 UTC – 1800 UTC)



Experimental Design 2

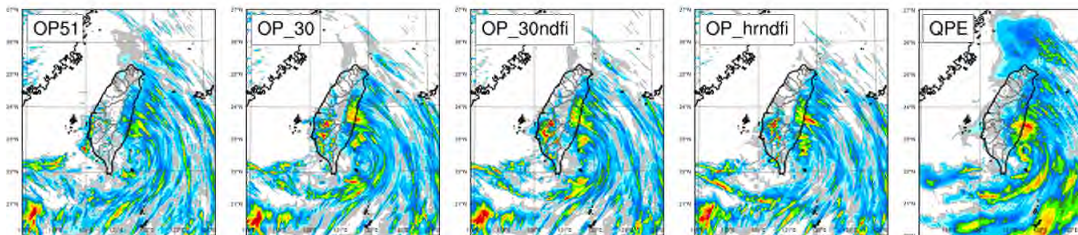
Experiment	IAU	IAU Window
OP (OP51)	No IAU	N/A
OP_30	with IAU	
OP_30ndfi	with IAU	
OP_hrndfi	with IAU	



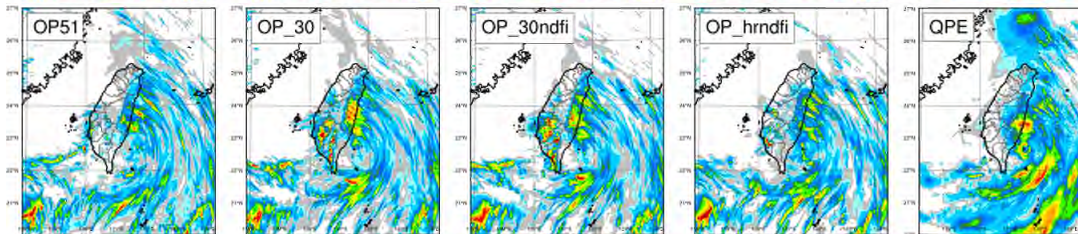
OP OP_30 OP_30ndfi OP_hrndfi OBS

3-hr Accu. Rainfall (mm) @ 00 - 03 hr forecast
Initial at 0600 UTC 12 Jun 2025 / Valid at 2025061206 - 2025061209 UTC

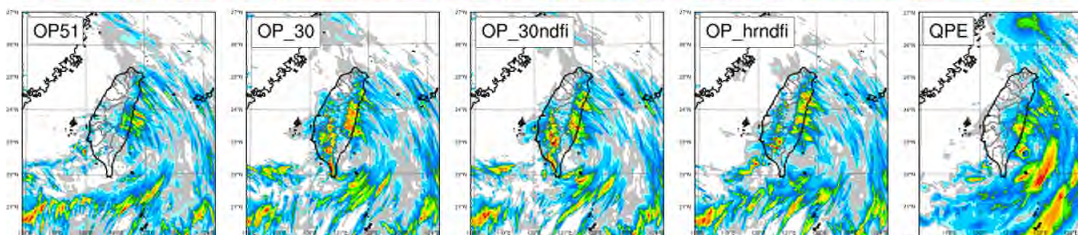
20250612 06 UTC



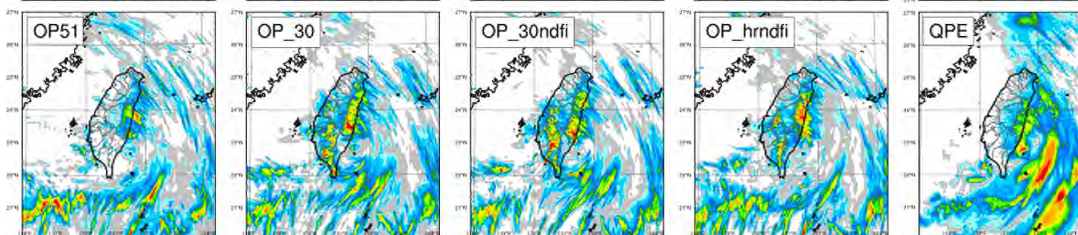
20250612 07 UTC



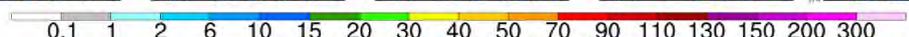
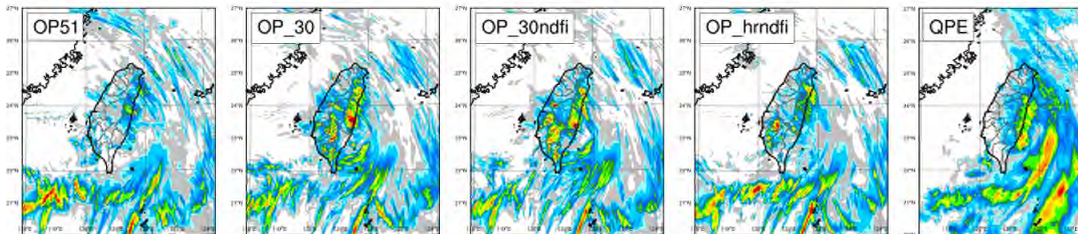
20250612 08 UTC



20250612 09 UTC

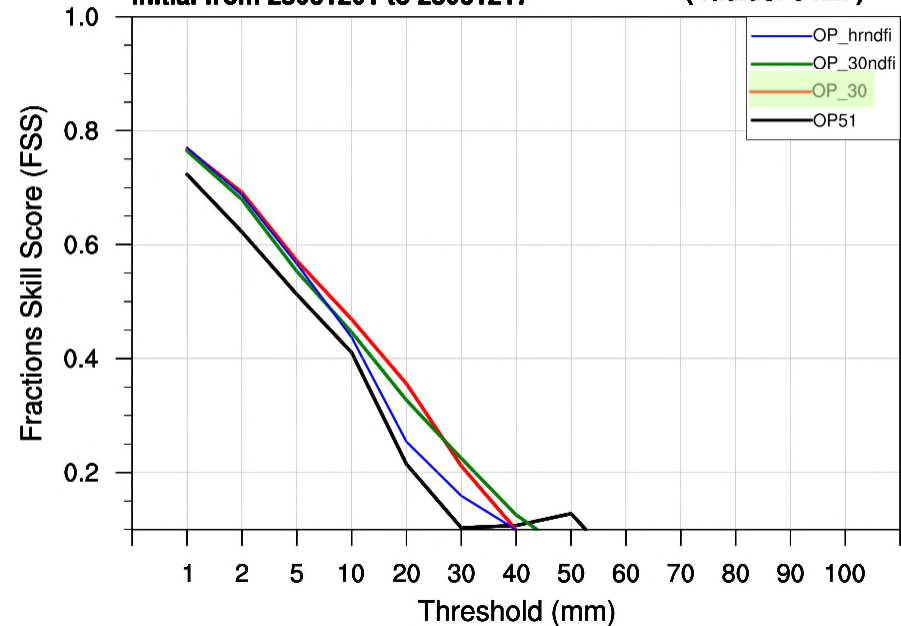


20250612 10 UTC



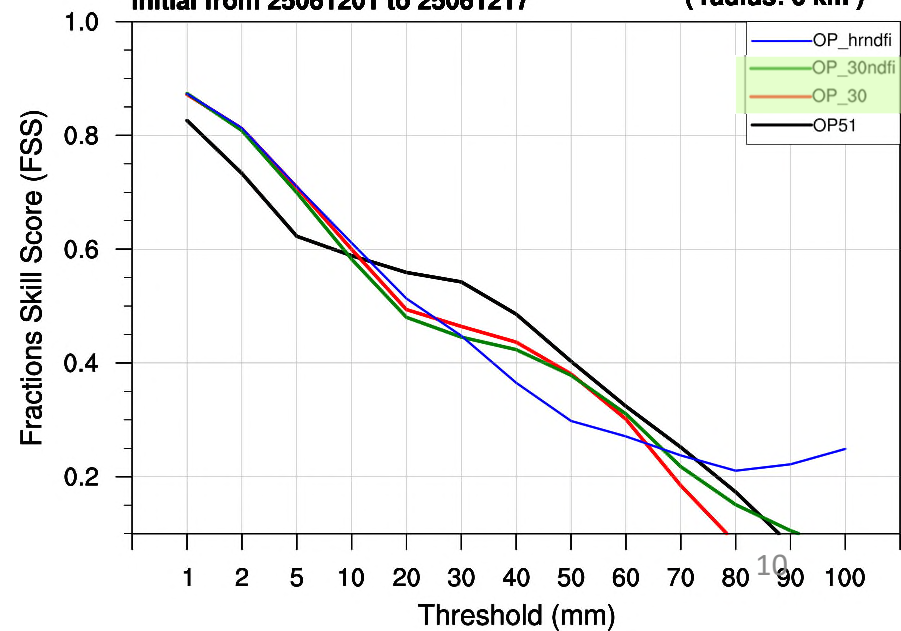
3 hr Accu. Rainfall (mm)
Initial from 25061201 to 25061217

00 - 03 hr forecast
(radius: 6 km)

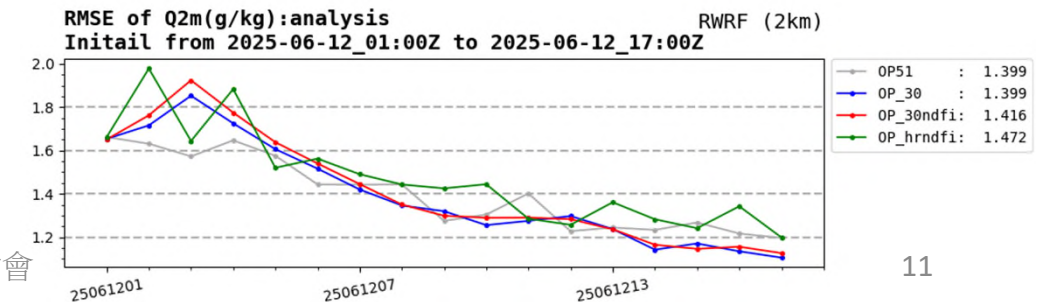
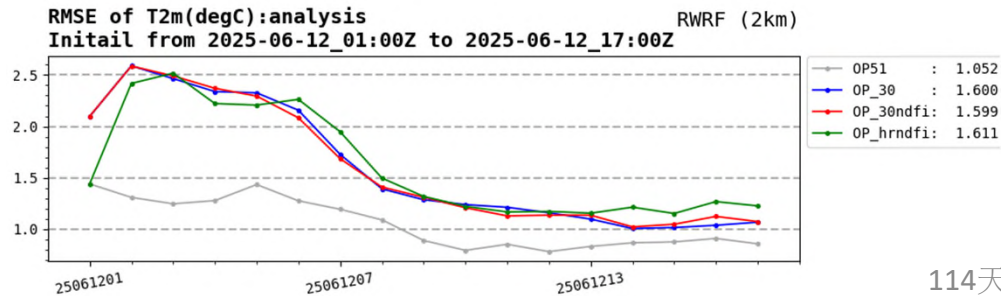
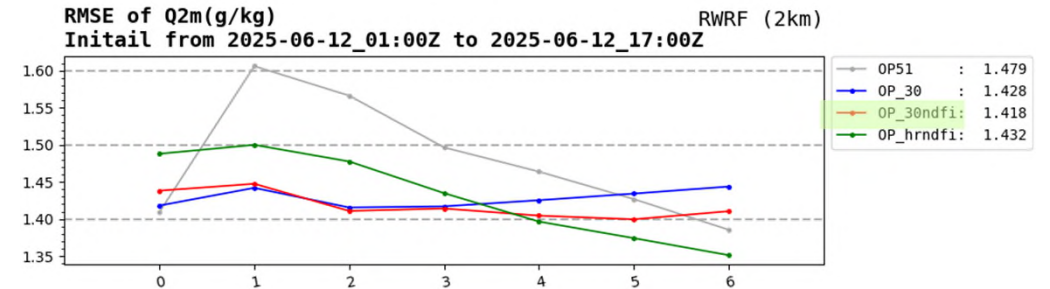
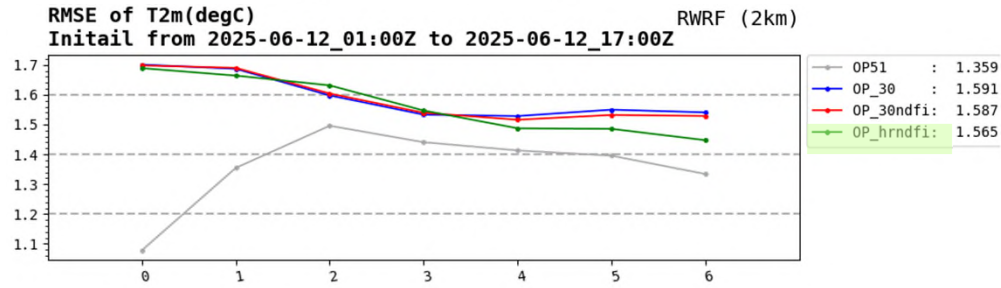
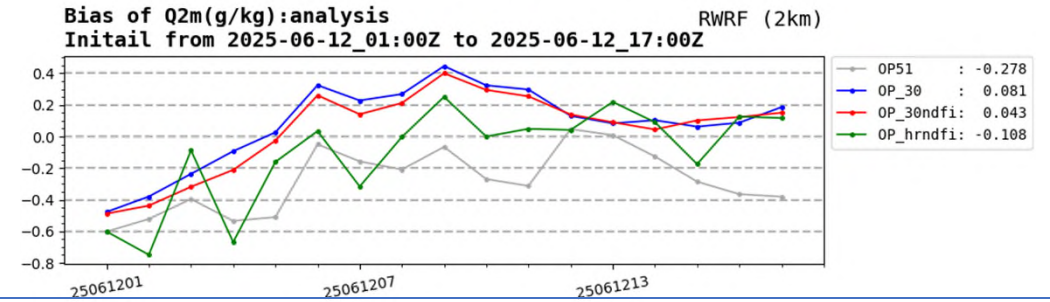
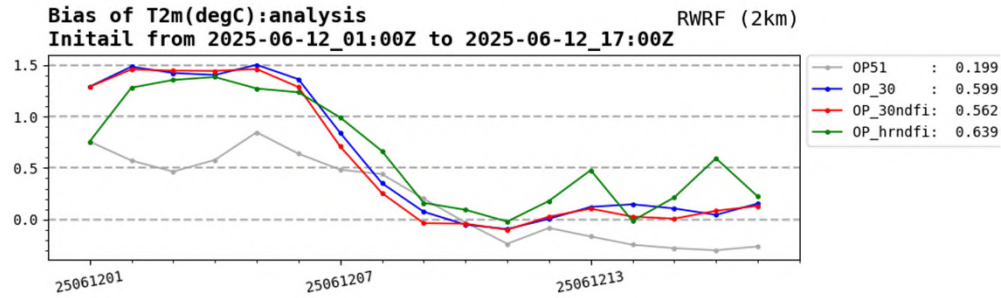
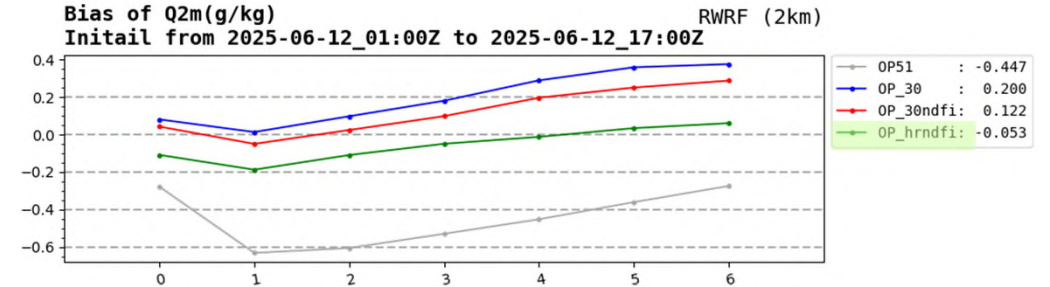
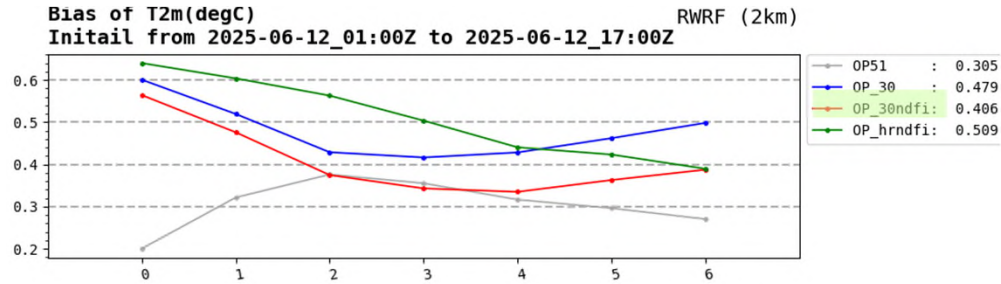


6 hr Accu. Rainfall (mm)
Initial from 25061201 to 25061217

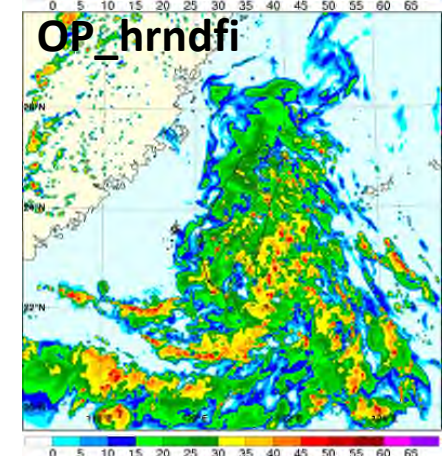
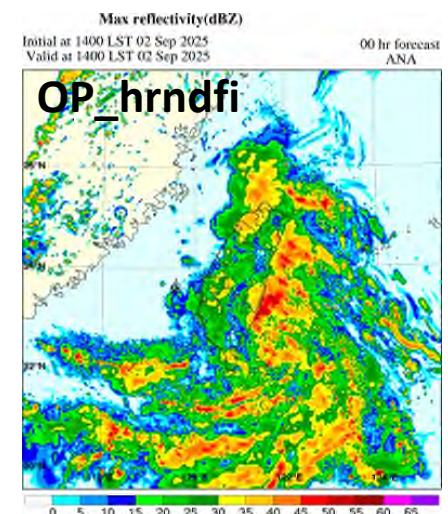
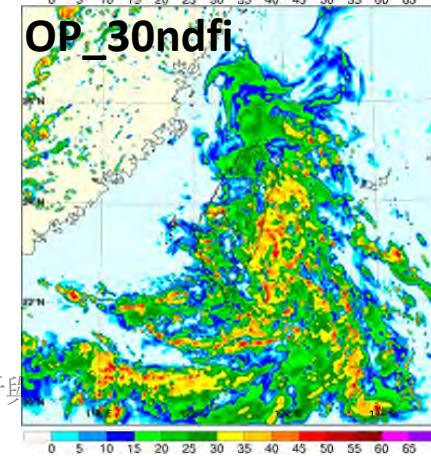
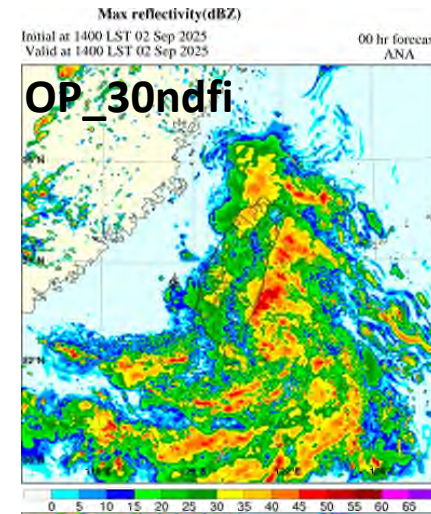
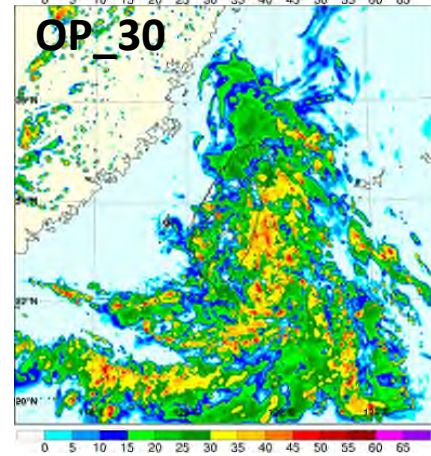
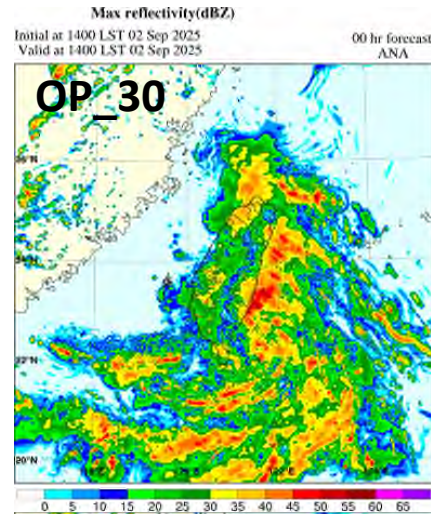
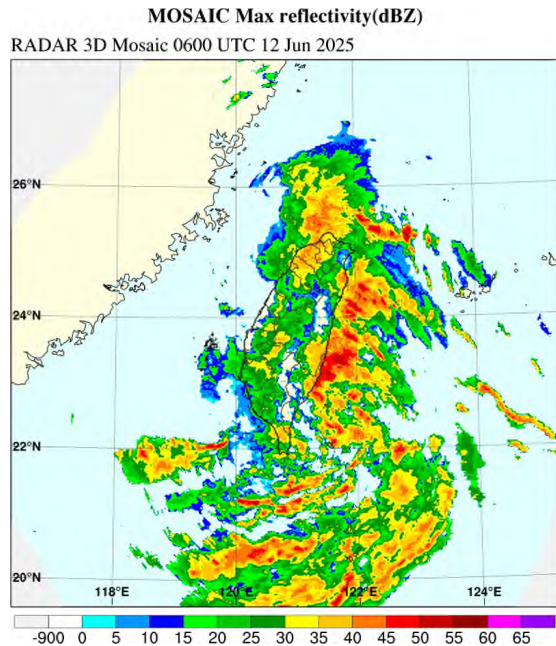
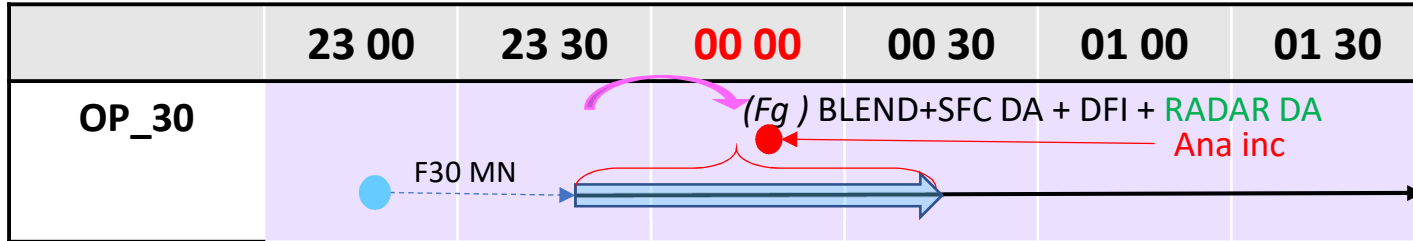
00 - 06 hr forecast
(radius: 6 km)



Surface Verification



Experimental Design 2



Conclusions & Future Work

- **Forecast performance** showed **little sensitivity** to variations in *time-weighted coefficients*
- **Blending** contributed the **largest increments**, affecting:
 - **Upper-level** wind (u, v) and temperature (T)
 - **Low-level humidity** (important for convection)
- **DFI** introduced **excessive smoothing** across all vertical levels
 - **Recommendation:** *Remove DFI* from the analysis cycle
- **30-minute *time window*** produced **better forecasts** in sensitivity experiments
 - Supports use of **shorter IAU time span**
- More Experiments (cases and strategy)

