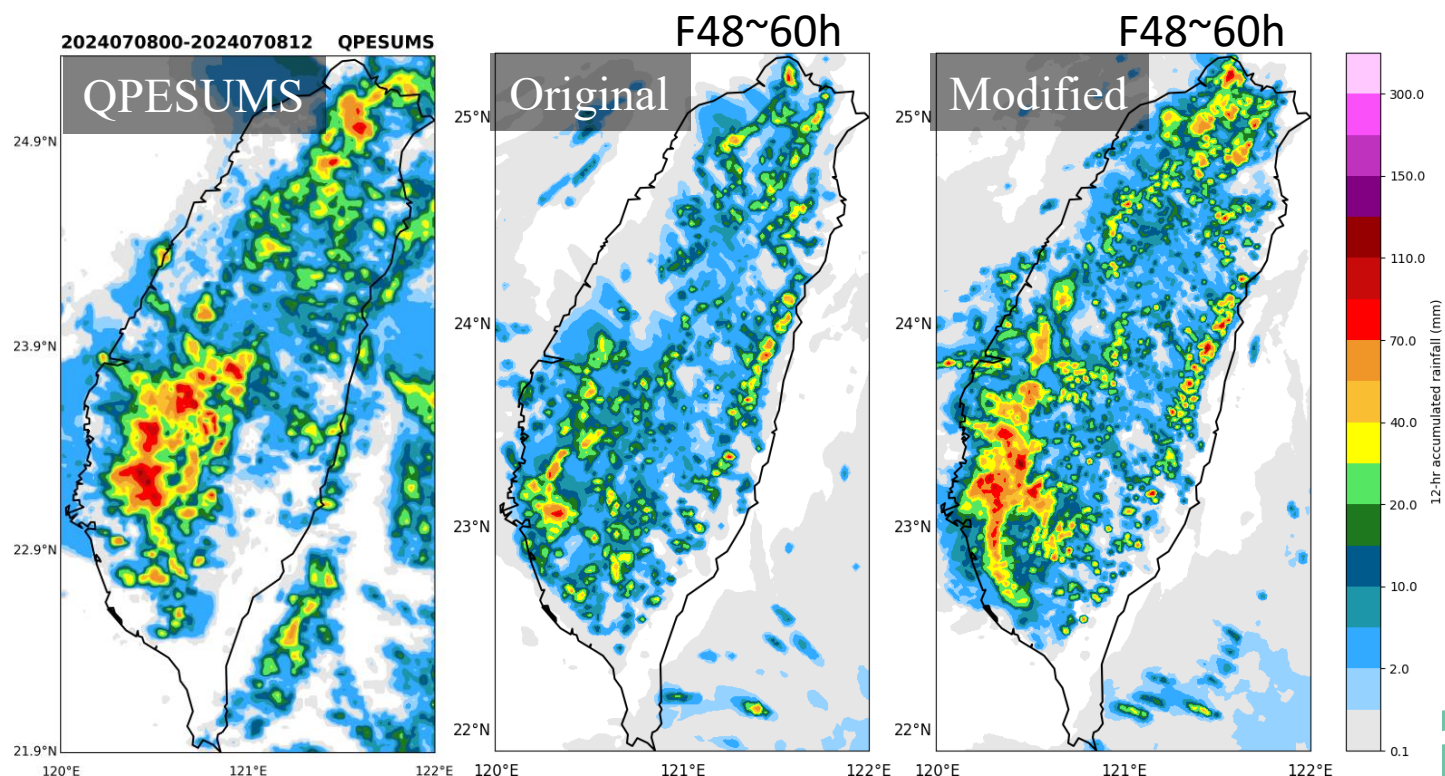


新一代區域模式TW-MPAS之午後對流預報評估與改進研究

林昌鴻 吳英璋 蕭玲鳳

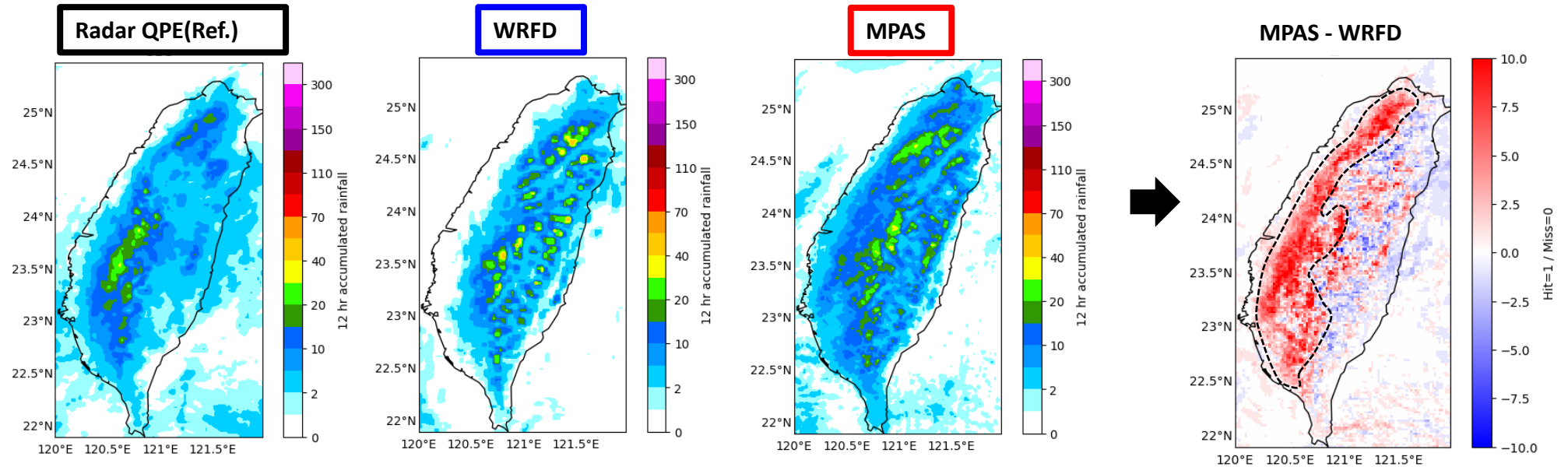
中央氣象署科技發展組



Rainfall Analysis of Afternoon thunderstorm

By 英璋

Composite
rainfall



June 2024

July 2024

August 2024

SUN	MON	TUE	WED	THU	FRI	SAT
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

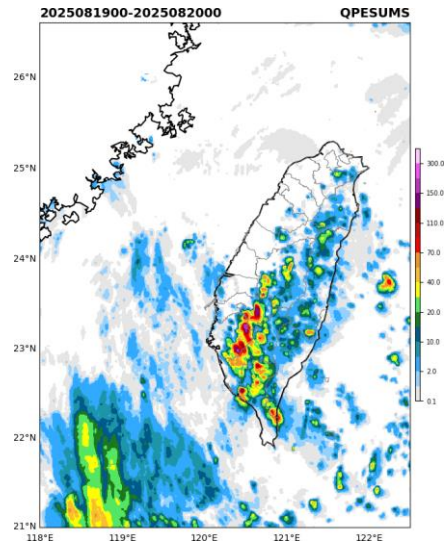
SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

- The MPAS-simulated rainfall area extends farther into the foothills and corresponds more closely to the quantitative precipitation estimate (QPE)

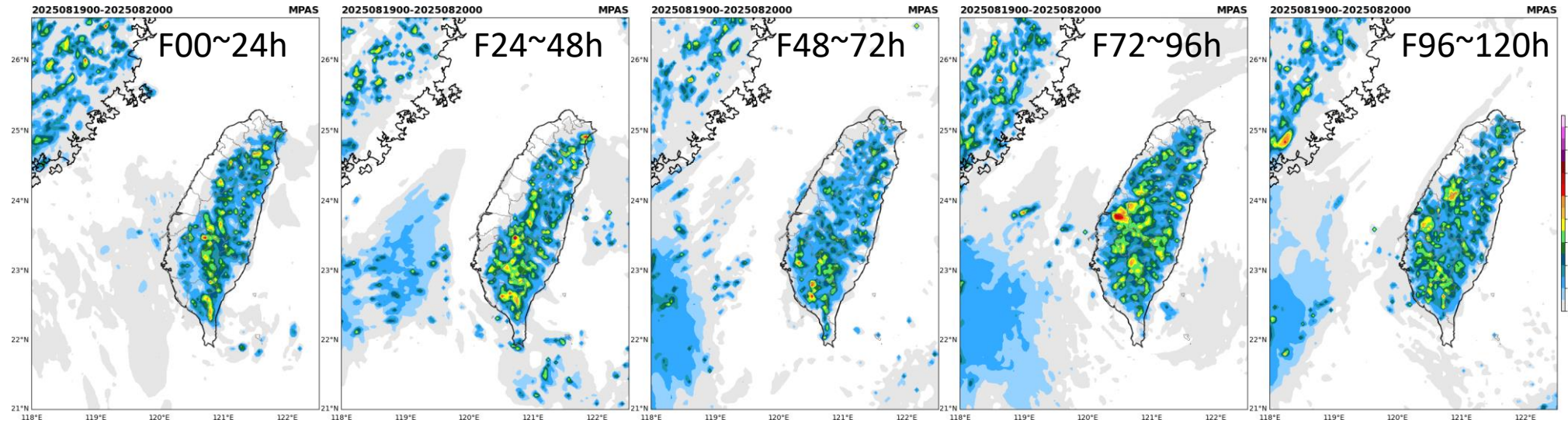
Motivation

- MPAS tends to underestimate rainfall intensity
- Conduct sensitivity experiments of physics schemes (convection)

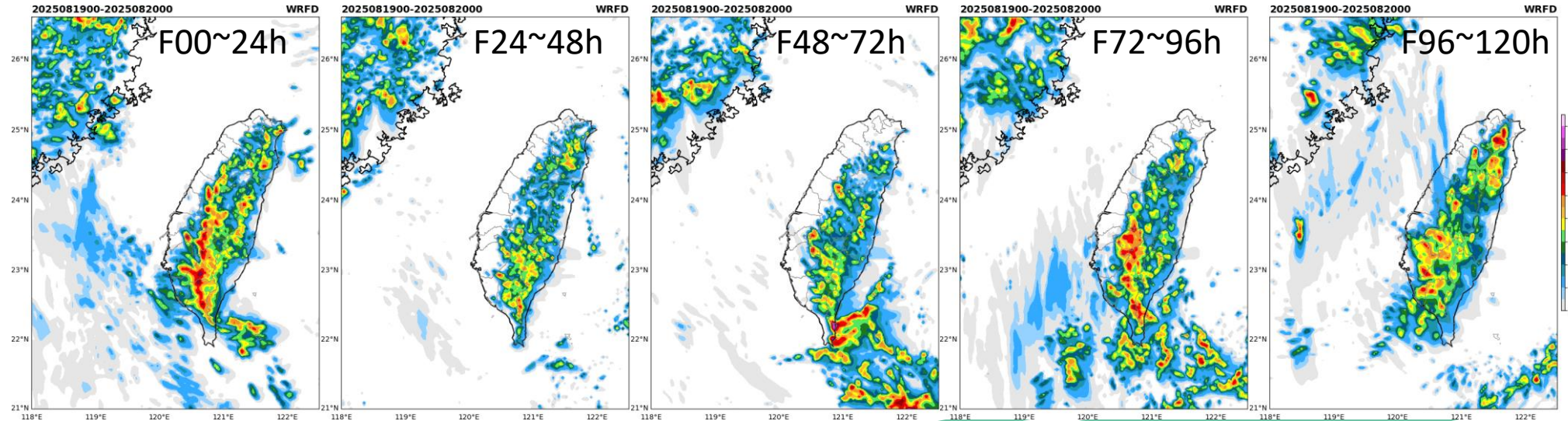
QPESUMS



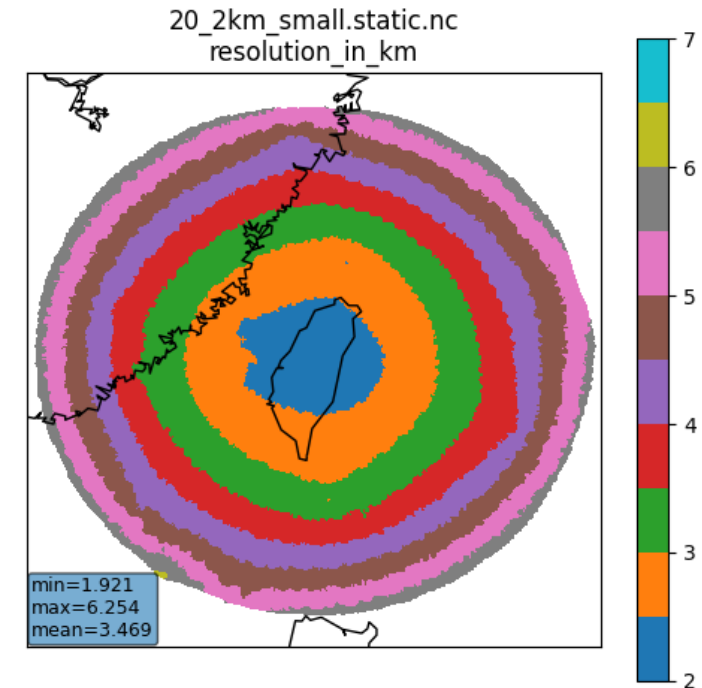
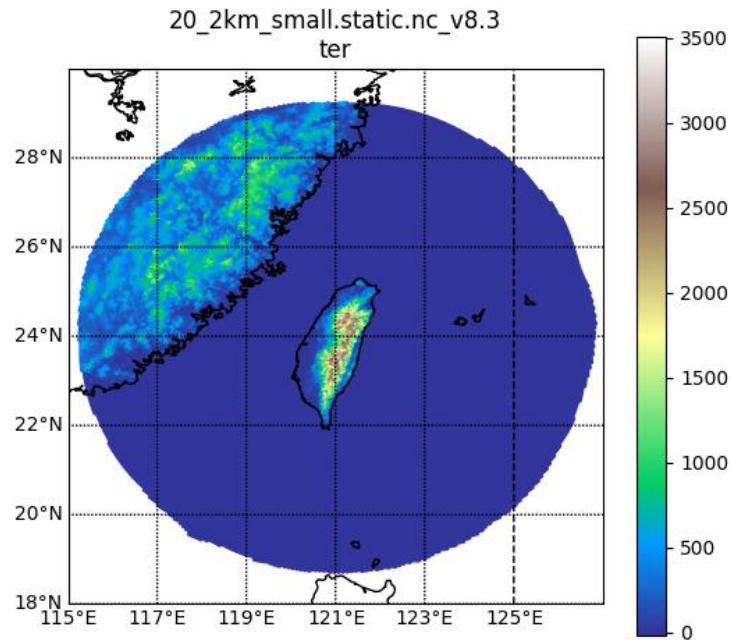
MPAS



WRFD



Model configuration



- Initial condition: ECMWF
- Finest grid spacing: 2km (variable mesh)
- PBL: YSU
- Convection: Tiedtke-Bechtold
- Microphysics: TCWA1

**Single
2 km variable-resolution mesh
(2026)**



List of experiments

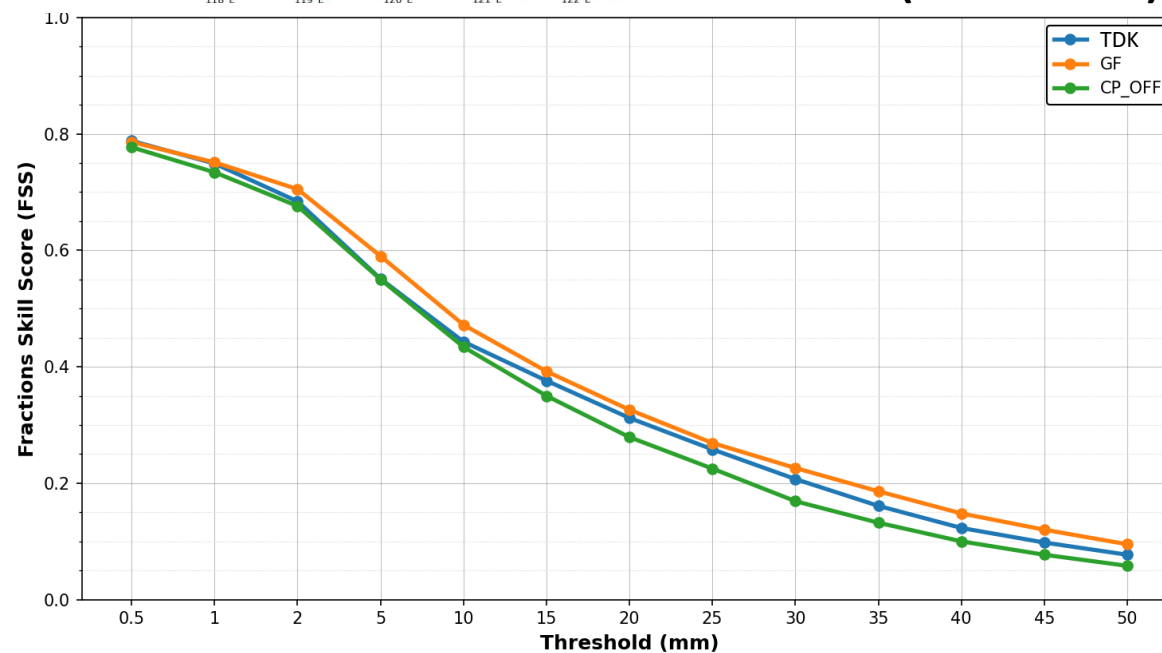
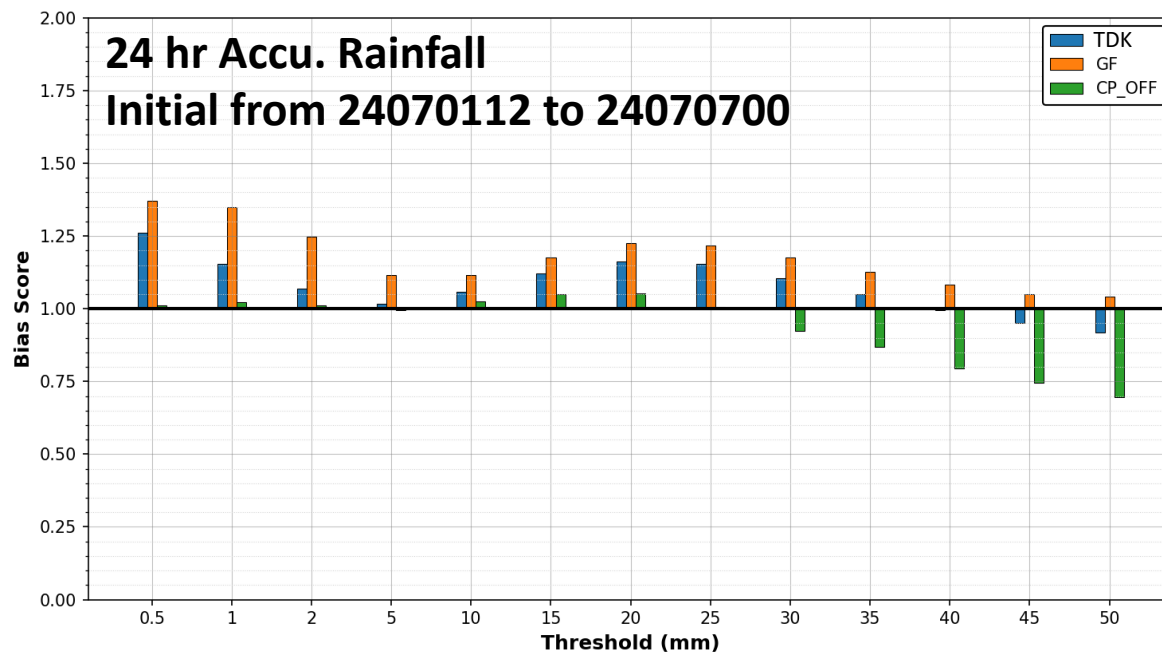
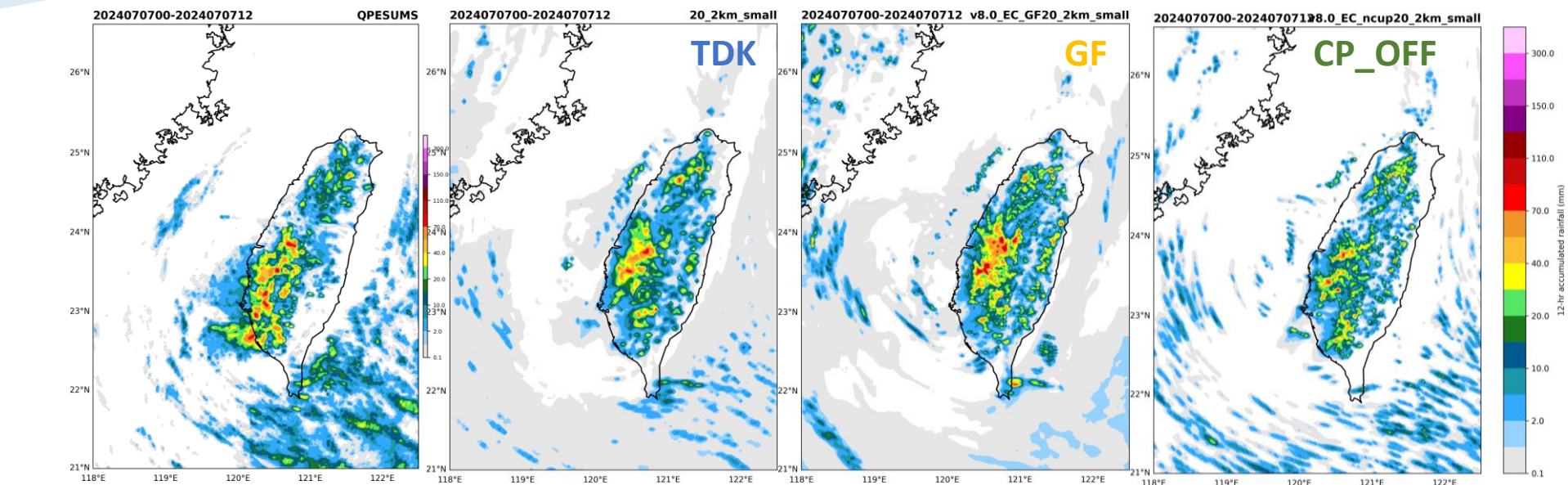
	Convection	Microphysics	PBL/Surface layer
TDK	Tiedtke-Bechtold	TCWA1	YSU/rMO
GF	Grell-Freitas	TCWA1	YSU/rMO
CP_OFF	None	TCWA1	YSU/rMO

rMO: Revised Monin–Obukhov Scheme (Jimenez et al., 2012)

- **Afternoon thunderstorms:**
 - initialized at 00 and 12Z each day from 2024070112~2024070700
(12 cases in total)
- Sensitivity experiments utilizing **alternative microphysics and PBL schemes** were evaluated, revealing an overall **degradation in forecast skill** (not shown).

QPESUMS
2024070700-2024070712

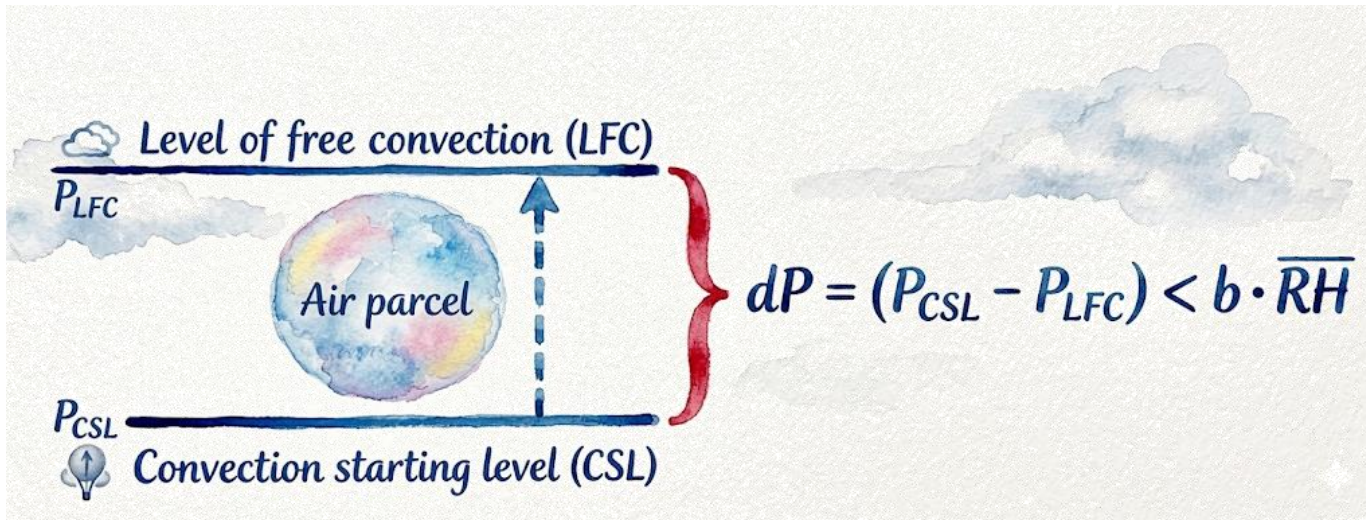
Init: 2024070412; F60-72h



- Convection schemes still play an important role in the 2-km variable-mesh MPAS model.
- The physical configuration with the Tiedtke-Bechtold scheme shows overall better precipitation forecast performance compared to the others.
- Modifications to the Tiedtke-Bechtold scheme are made to mitigate the dry bias for heavy rainfall during afternoon thunderstorms.

Modification to Tiedtke-Bechtold convection scheme

- Implement a **moisture-based trigger condition** (Han et al. 2020)
- **Suppress early triggered convection to accumulate CAPE and moisture** for stronger updrafts



$$\sigma_1 = 1 - \frac{1}{\pi} \left\{ \sigma_{\text{con}} \left[(\Delta x - 5000) + \frac{\pi}{2} \right] \right\}$$

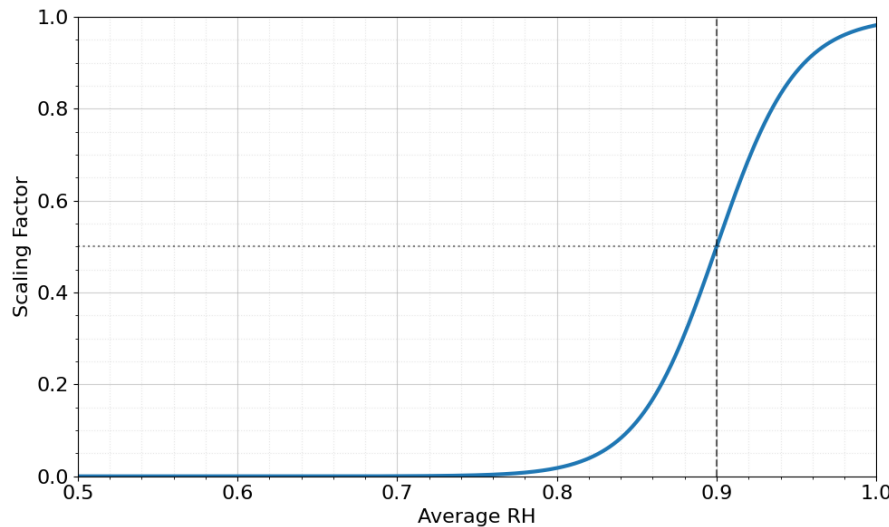
$$\sigma_{\text{con}} = \tan(0.4\pi) / (5000 - 1000)$$

$$b = 120 + 60 \cdot (1 - \sigma_1)$$

$\overline{RH}$: RH averaged from CSL to LFC

Enhanced suppression

- **Rapidly reduce the scaling factor** when the $\overline{\text{RH}}$ falls below a specific threshold

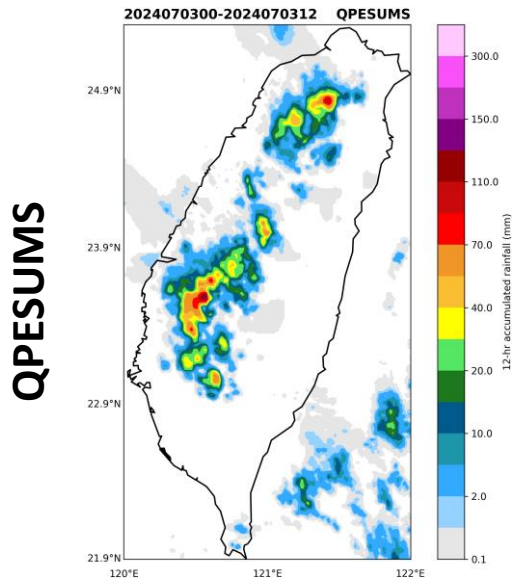


$$dP < b \cdot f(\overline{\text{RH}})$$

$$f(\overline{\text{RH}}) = \frac{1}{2} [1 + \tanh(20 \cdot (\overline{\text{RH}} - 0.9))]$$

- Similar restriction in NCEP GFSv17: Convection is not triggered if $\overline{\text{RH}} < 75\%$. (Han et al. 2021)

12-h accumulated precipitation valid at 2024070300~2024070312

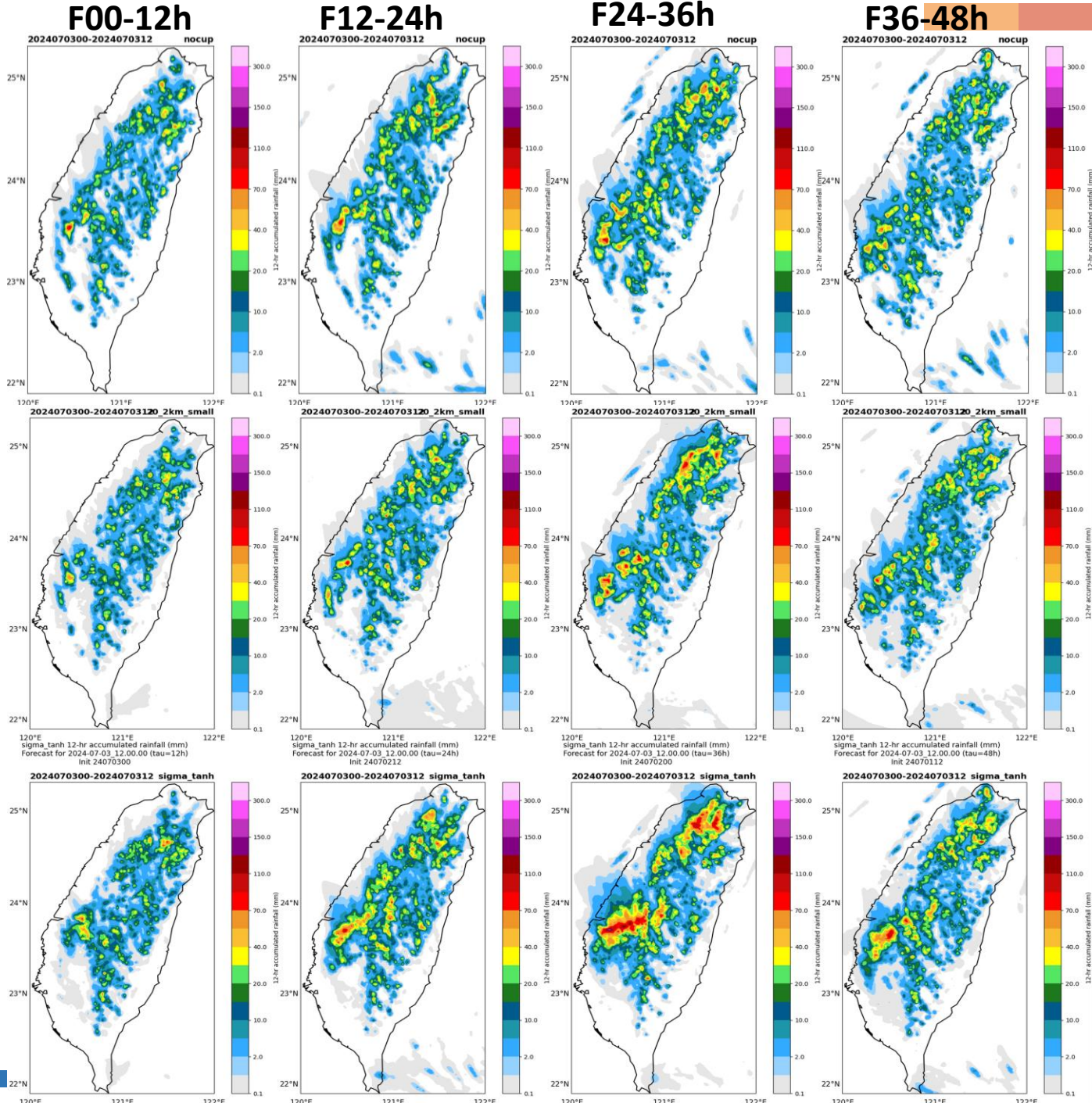


Experiment	Description
CP_ORF	Without convection scheme
CTRL	Tiedtke-Bechtold convection scheme (TDK)
TRIG_RH	Implement moisture-based trigger function in TDK

CP_ORF

CTRL

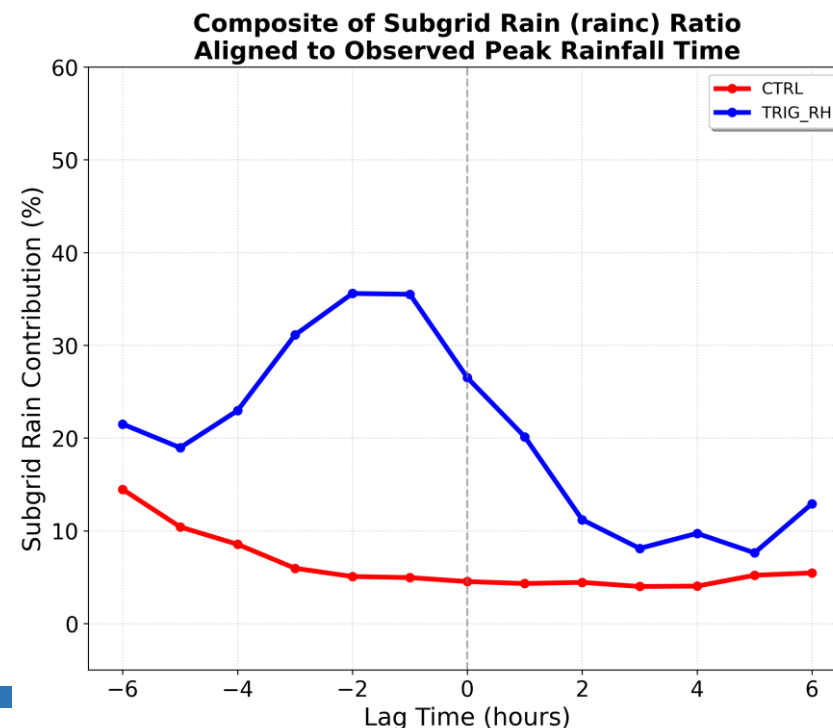
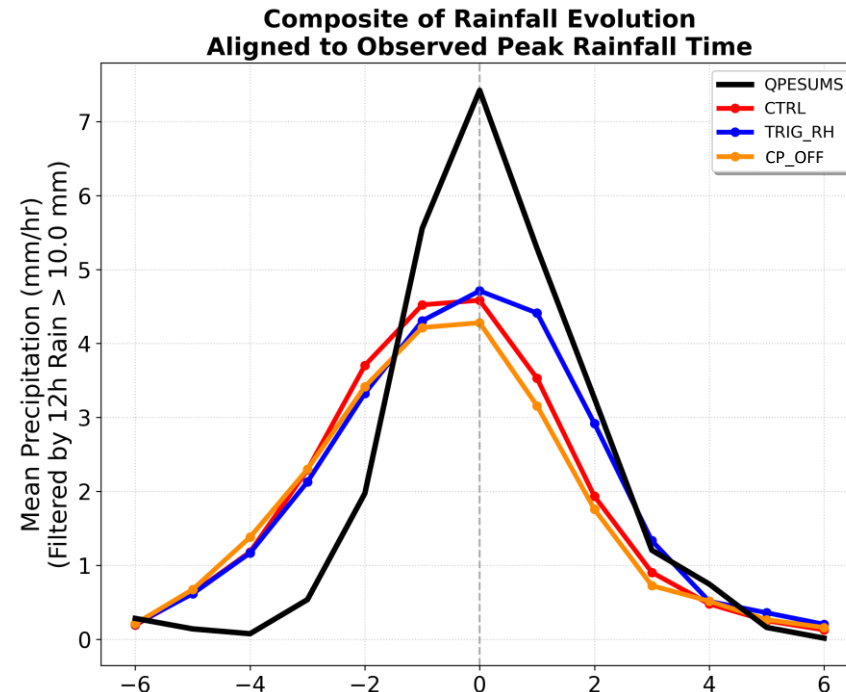
TRIG_RH



5-Case Composite Analysis

Rainfall & Subgrid Rain Ratio

- Initialized daily at 00Z from **2024070200** to **2024070600**
- **Method (Becker et al. 2021):**
 1. interpolation
 2. **land area** only
 3. rain events: **24~36-hr** forecast window
 4. 12-hr accumulated precipitation **>10.0 mm**
- **TRIG_RH:**
 - Suppresses convection in early stage
 - Enhances rainfall intensity at the peak
 - Extends rainfall duration
 - Increases contribution from convection scheme

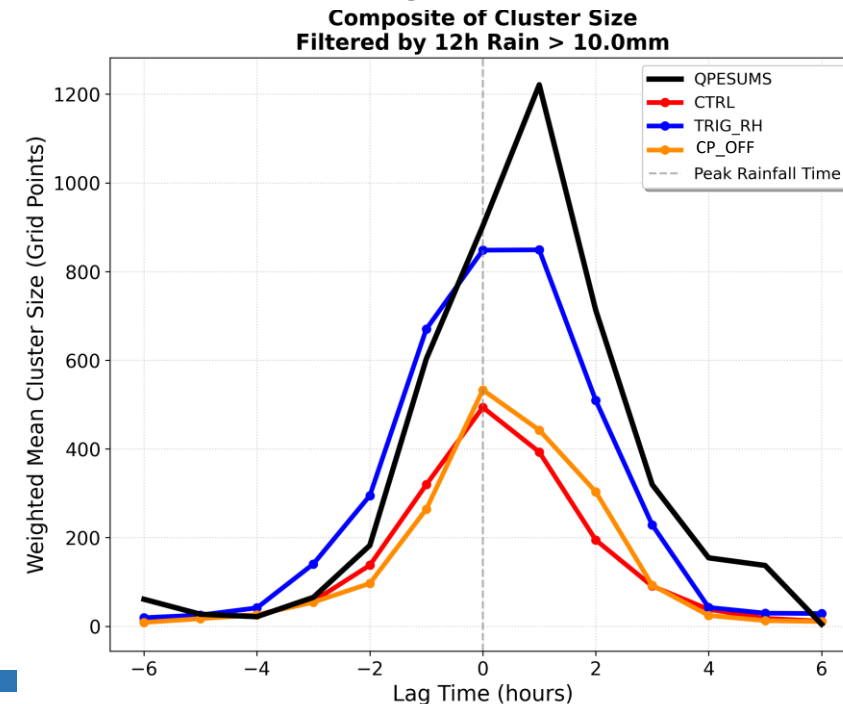
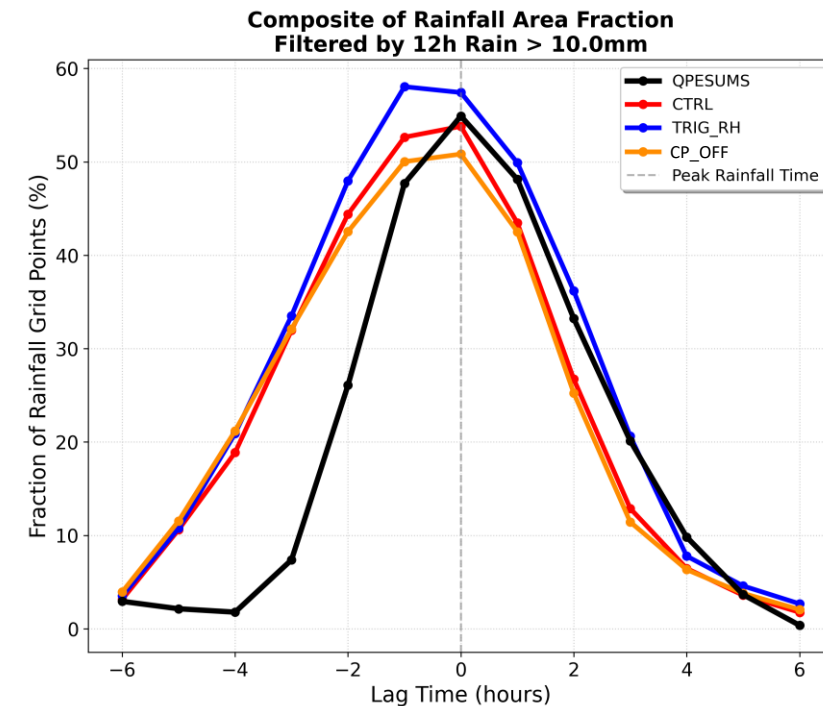




5-Case Composite Analysis

Rainfall Area Fraction & Precipitation Cluster Size

- Method (Becker et al. 2021):
 1. event filter
 2. precipitation clusters: **four-point connectivity**
(N_i : number of grid points per cluster)
 3. Weighted mean: $\frac{\sum N_i^2}{\sum N_i}$
- TRIG_RH:
 - Extends rainfall coverage but show more organized convection before the peak

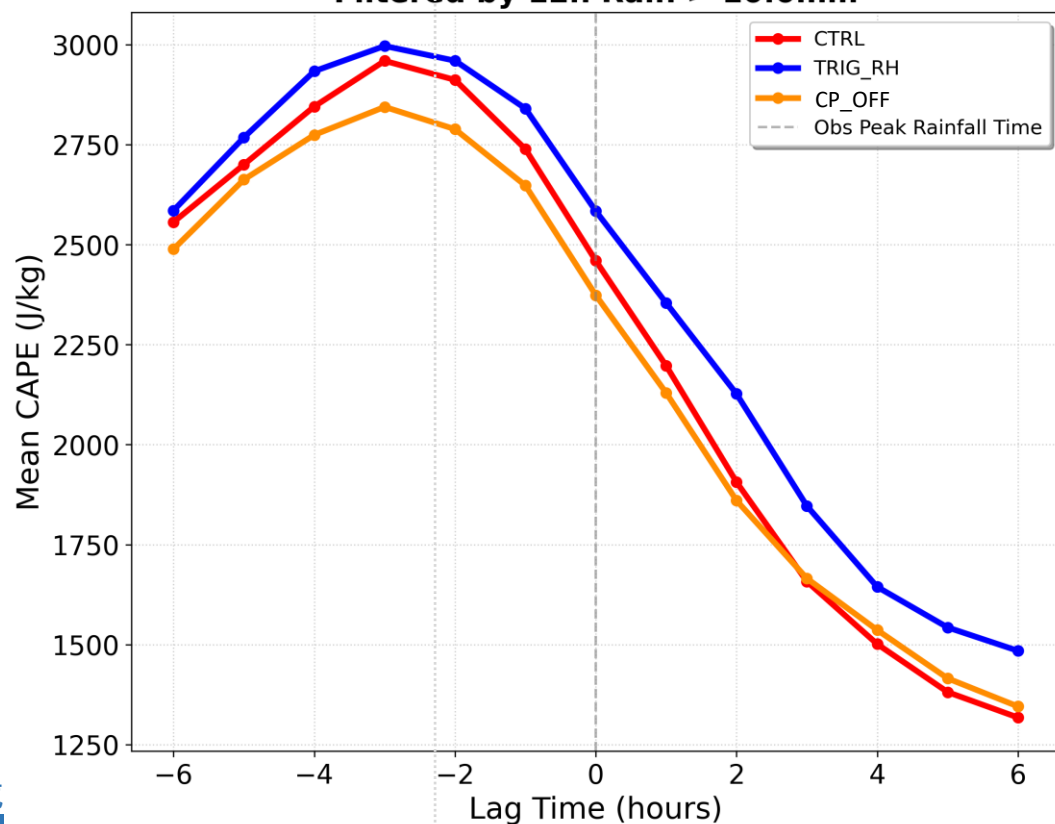




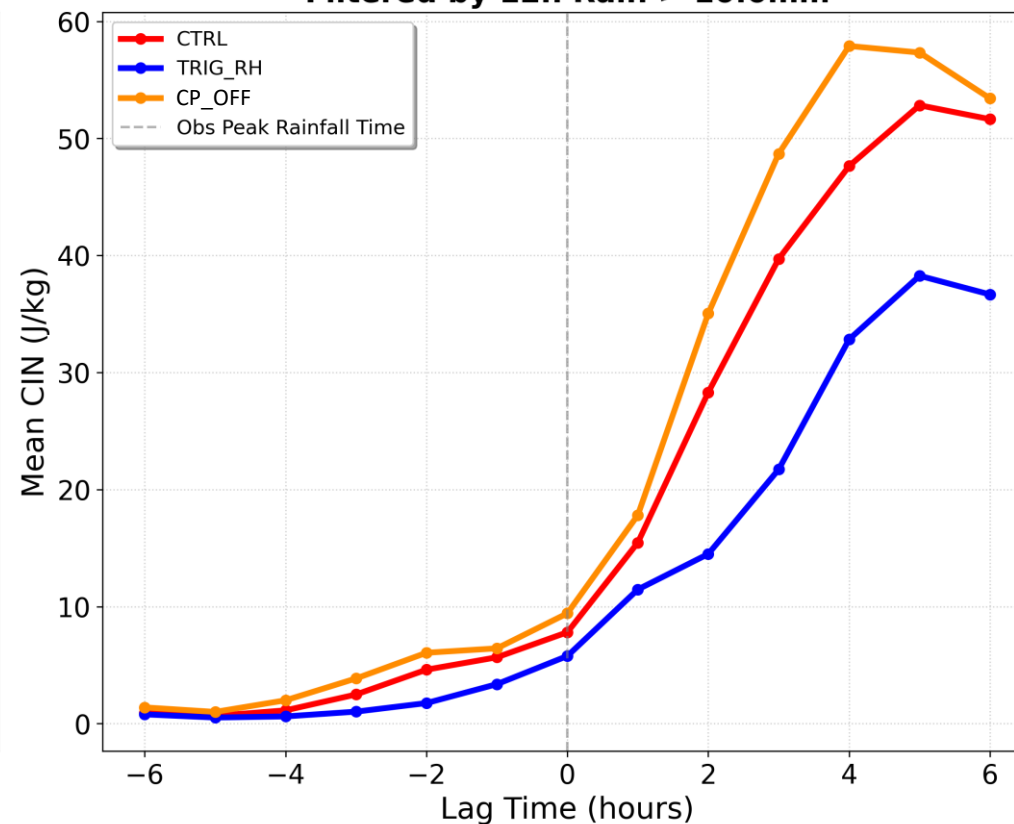
5-Case Composite Analysis: CAPE and CIN

- **TRIG_RH:**
 - Greater **CAPE** accumulation
 - Slower **CAPE depletion** and **CIN enhancement**

Composite of CAPE Evolution (24-36h Forecasts)
Filtered by 12h Rain > 10.0mm



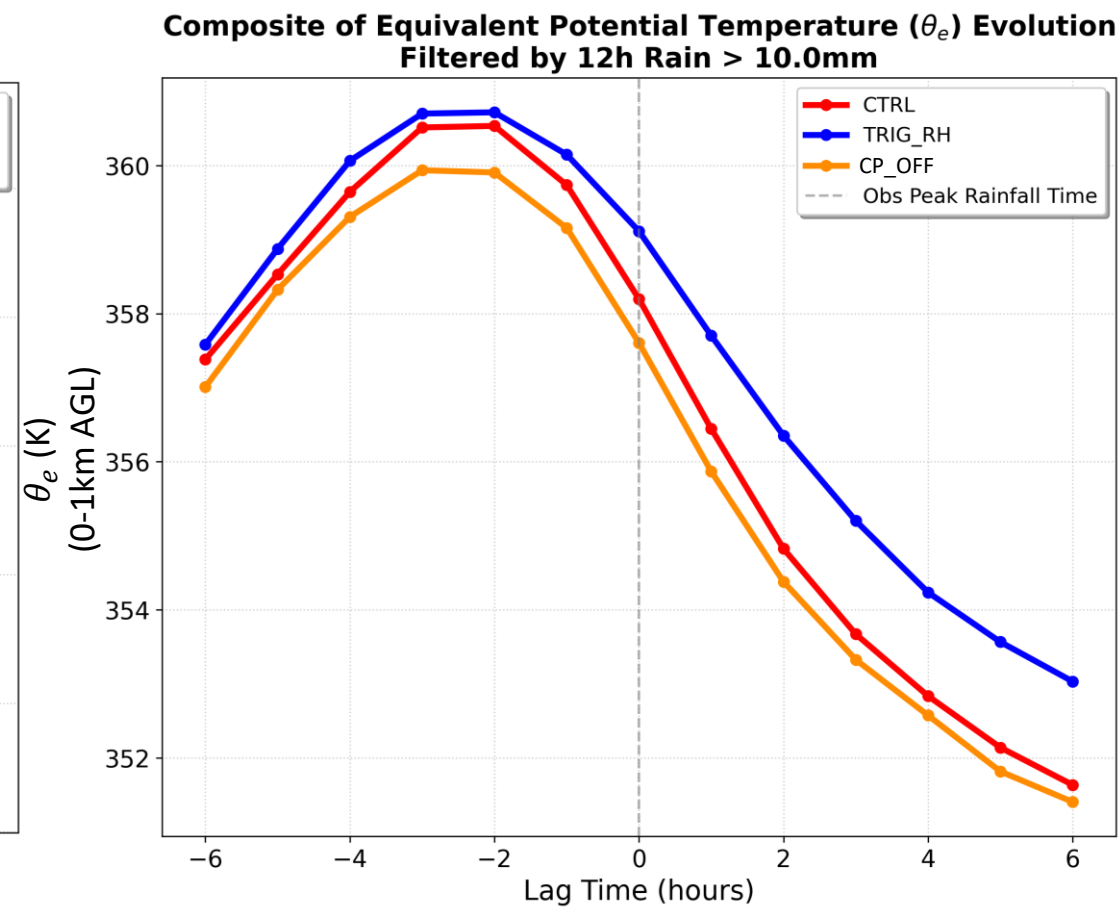
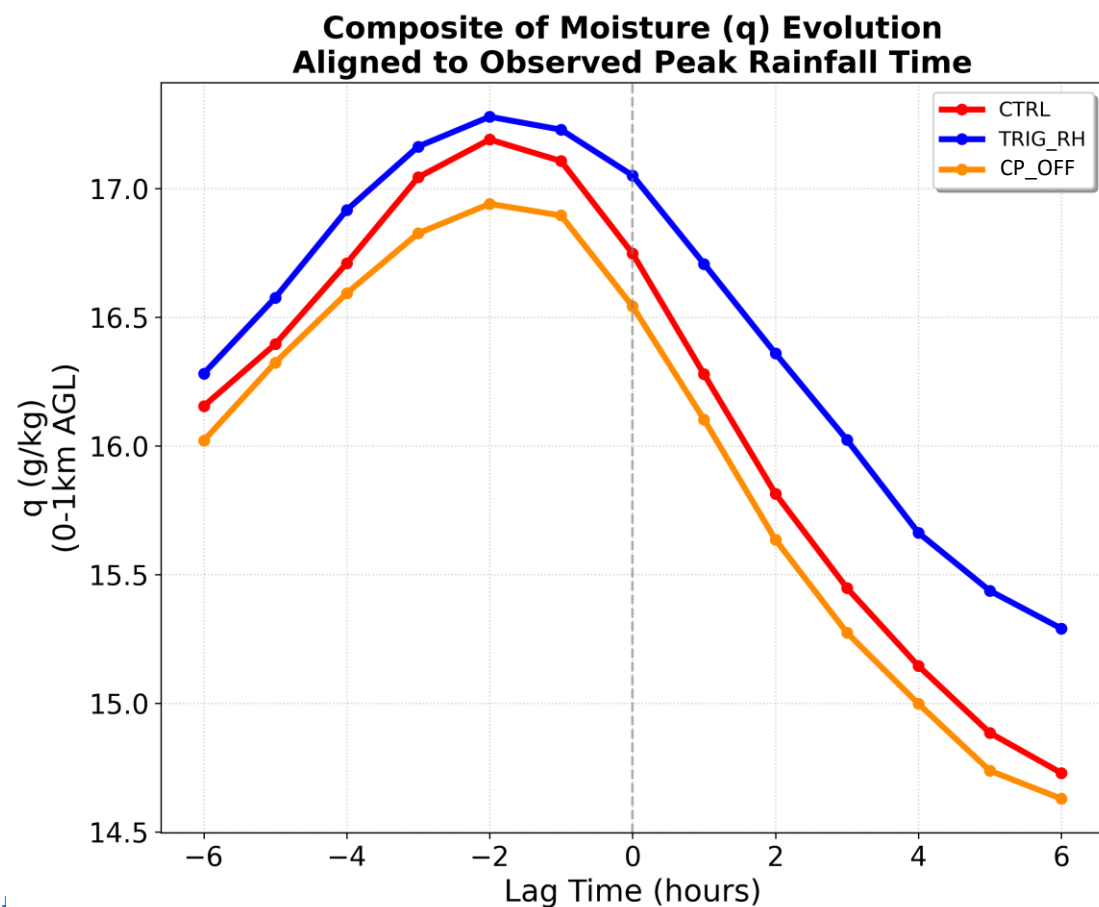
Composite of CIN Evolution (24-36h Forecasts)
Filtered by 12h Rain > 10.0mm





5-Case Composite Analysis: q and θ_e

- TRIG_RH:
 - Preserves moisture and enhance moisture supply
 - Drying and cooling effects driven by Convective downdrafts



Summary

Moisture-based
trigger function

Suppression of early
initiated convection

Accumulated moisture &
CAPE

Active & organized
convection

Longer rainfall
duration



Performance diagram (48 cases)

